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Geotechnical Report

(Douglas Partners)

Douglas Partners
Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on
Geotechnical Investigation

Proposed Residential Development
Lots 487, 611 & 615 Arnold Road, Serpentine, WA

Prepared for
MALF Corp Pty Ltd

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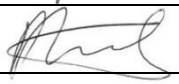
Reviewer		17 September 2020

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Report on Geotechnical Investigation
Proposed Residential Development
Lots 487, 611 & 615 Arnold Road, Serpentine, WA

1. Introduction

This report presents the results of a geotechnical investigation undertaken for a proposed residential development at Lots 487, 611 & 615 Arnold Road, Serpentine, WA. The investigation was commissioned in an email dated 3 March 2020 by Phil Cuttone of Cuttone Property Group on behalf of MALF Corp Pty Ltd and was undertaken in accordance with Douglas Partners' proposal PER200065 dated 25 February 2020.

It is understood that the development of the site will include subdividing the land to create 52 new residential lots of approximately 1 ha each, with construction of new roads to service the lots and a central drainage swale.

The aim of the investigation was to assess the subsurface soil and groundwater conditions across the site and provide comments on:

- The soil conditions underlying the site.
- The depth to groundwater, if encountered.
- Comments on the suitability of the site for effluent disposal and recommendations on a suitable system types for on-site effluent disposal in accordance with AS/NZS 1547.
- Site classification in accordance with the requirements of AS 2870-2011.
- Suitable foundation systems for house construction.
- Site preparation requirements for house pads and pavement construction.
- A subgrade CBR for use in pavement design.
- Suitable pavement thickness design for the proposed subdivision roads.
- The infiltration rate of soils along the proposed drainage swale.

The investigation included the excavation of 32 test pits, the performance of eight in-situ infiltration tests and laboratory testing of selected samples. The details of the field work are presented in this report, together with comments and recommendations on the items listed above.

2. Site Description

The site is approximately 60 ha and is identified as Lots 487, 611 & 615 Arnold Road in Serpentine, Western Australia (Refer to Drawing 1, Appendix A). It is bounded by South Western Highway to the east, existing rural residential lots to the west and open paddocks to the north and south. The site comprises of parcels of land that lie on the north and south of Arnold Road. Vegetation across the site

mainly comprised grass. Wire and wooden pole fences separated the several existing paddocks and formed the boundary of the site.

Based on information obtained from publicly available LiDAR, the site surface levels range from approximately 31.5 m relative to Australian height datum (AHD) near the northern site boundary and rises to levels of approximately between RL 40 m AHD and RL 45 m AHD along the southern site boundary.

The Serpentine 1:50 000 Environmental Geology sheet suggests that shallow sub surface conditions in the western part of the site comprise sandy clay of the Guildford Formation. The eastern part of the site is shown to be underlain by gravelly sandy clay of colluvial origin with lenses of silt and gravel and quartz sand.

3. Field Work Methods

Field work was carried out on 10 to 12 March 2020 and comprised:

- Excavation of 32 test pits together with dynamic cone penetrometer (DCP) tests adjacent to the test pits; and
- In-situ infiltration testing at eight locations using both the constant head and falling head method.

The test pits (1 to 32) were excavated using an 8 tonne backhoe to depths of between 0.8 m and 2.5 m below existing site levels. The test pits were logged in general accordance with AS 1726-2017 by an experienced engineer from Douglas Partners. Samples were recovered at selected locations for material identification and subsequent geotechnical laboratory testing.

Dynamic cone penetrometer testing was carried out adjacent to each test pit location in accordance with AS 1289.6.3.2, to assess the in-situ density of the shallow soils.

The infiltration tests were performed using the constant head method within hand auger boreholes drilled adjacent to test locations 4, 8, 17, 19, 25, 27 and 32, at depths of 0.3 m and 0.35 m below the existing surface level, respectively. A falling head infiltration test was undertaken at a depth of 0.4 m within a borehole drilled adjacent to test location 28.

Test locations were determined using a hand-held GPS and are marked on Drawing 1 in Appendix A. Surface elevations at the test locations were obtained from LiDAR data and should be considered approximate. Levels on the test pit logs in Appendix B are quoted relative to the Australian Height Datum (AHD).

4. Field Work Results

4.1 Ground Conditions

Detailed logs of the ground conditions are presented in Appendix B, and should be read in conjunction with the notes defining descriptive terms and classification methods provided in Appendix A.

The ground conditions beneath the topsoil can be summarised as comprising thin and localised covers of silty sand colluvium, generally less than about 0.2 m thickness, overlying various clayey sandy gravelly colluvial soils of varied thicknesses, generally thicker in the eastern part of the site with thicknesses in excess of 2.5 m, in turn overlying various gravelly sandy clayey soils of the Guildford Formation. Both the colluvium and the ground from the Guildford Formation are locally laterised (both lateritic gravel and strongly indurated zones). The ground conditions across the site are generally hard and resulted in test pitting refusal at several locations when using an 8 tonne excavator. Owing to similarities between the Guildford Formation and the Colluvium, the ground conditions are further described below per soil type (rather than geological units), and selected soil units are shown on Drawing 2, Appendix B, for clarity of the description:

- **Unit 1 - TOPSOIL/ Silty SAND SM, occasionally Sandy SILT ML:** fine to medium grained sand content, dark grey-brown, varied low plasticity silt content, with rootlets, encountered to a depth of between 50 mm and 100 mm at most test locations.
- **Unit 2 - Silty SAND SM and Sandy SILT SM (Colluvium):** fine to medium grained sand, light grey-brown, low plasticity silt, varied gravel content encountered to depths of up to 0.35 m though generally to depths of between 0.15 m and 0.25 m at most test locations in the northern part of the site and occasionally elsewhere.
- **Unit 3 - SAND SP-SM, Sandy GRAVEL GP-GM (Colluvium):** fine to medium grained, light brown, generally trace of or with silt and/or clay, varied gravel content (gravel was laterite), generally dense to very dense, encountered to depths of between approximately 0.3 m and 0.8 m at test locations predominantly in the central southern part of the site (test locations 10, 13, 14, 28, 30 and 31 as shown on Drawing 2, Appendix A).
- **Unit 4 - Clayey SAND SC, Gravelly clayey SAND SC, Sandy CLAY CI, Clayey sandy GRAVEL GC (Colluvium and Guildford Formation):** fine to medium sand, generally medium plasticity fines, varied fine to coarse gravel content (gravel was laterite), with cobbles in some locations, various colours, dense to very dense or very stiff to hard, encountered underlying Unit 2 and Unit 3 at all locations, to the extent of the investigation except where underlain by the strata described below. Firm to stiff sandy clay was encountered between depths of 0.8 m and 1.8 m at test location 28.
- **Unit 5 - CLAY CH:** high plasticity, generally light grey or red-brown, with sand, hard, encountered from depths of between 0.5 m and 2.3 m at test locations 2, 5, 6, 12 and 18, all located on the eastern side of the site.
- **Unit 6 - LATERITE:** excavated as gravel and red-brown high strength cobbles from depths of 1.2 m at test location 8 and 0.6 m at test location 15. Gravel and cobbles of iron cemented laterite were encountered at numerous locations within a matrix of sandy clay and gravel. In most cases, the test pit encountered refusal due to hard digging within the lateritic material.

4.2 Groundwater

Groundwater was observed at test location 28 only at a depth of approximately 2.3 m (approximately RL 38.6 m AHD) during the field work undertaken on 10 and 11 March 2020.

The test pits were immediately backfilled following sampling, which precluded longer-term monitoring of groundwater levels from these locations.

It should be noted that groundwater levels are affected by climatic conditions and land usage, and will therefore vary with time.

4.3 Results of Infiltration Testing

Eight in situ infiltration tests were carried out: seven using the constant head method (test locations 4, 8, 17, 19, 25, 27 and 32) and one using the falling head method (test location 28). An estimated permeability value has been derived using the analytical method included in AS 1547-2012 for the constant head infiltration test data and using an analysis based on Hvorslev (1951) for the falling head infiltration test data.

Table 1 below summarises the permeability results.

Table 1: Summary of Permeability Analysis

Test Location	Depth (m)	Measured Permeability		In situ Conditions of Tested Material
		(m/s)	(m/day)	
4 [2]	0.35	0.4×10^{-5}	0.3	Dense silty sandy GRAVEL
8 [2]	0.3	8.3×10^{-5}	7	Very dense sandy CLAY/clayey SAND, trace silt
17 [2]	0.3	1.3×10^{-5}	1	Dense to very dense clayey SAND
19 [2]	0.3	14.4×10^{-5}	12	Dense clayey SAND
25 [2]	0.3	4.6×10^{-5}	4	Medium dense to dense clayey SAND, trace gravel
27 [2]	0.3	5.4×10^{-5}	4.5	Very dense gravelly, clayey SAND
28 [1]	0.4	4.2×10^{-5}	3.5	Medium dense SAND, with silt
32 [2]	0.3	5.3×10^{-5}	4.5	Dense clayey sandy GRAVEL

Notes: [1]: Falling head test
[2]: Constant head test

5. Laboratory Testing

A geotechnical laboratory testing programme has been scheduled with a NATA registered laboratory and comprises the determination of:

- the particle size distribution of ten samples;
- the Atterberg limits of six samples;
- the shrink swell index of three samples;
- the maximum modified dry density and California bearing ratio of four samples
- the Emerson class of three samples; and
- pH, electrical conductivity, cation exchange capacity, and phosphorus retention index of four samples.

The detailed test certificates are presented in Appendix C, with the results summarised in Tables 2 to 4.

Table 2: Results of Laboratory Testing for Soil Identification and Site Classification

Test	Depth (m)	Gravel (%)	Sand (%)	Fines (%)	LL (%)	PL (%)	PI (%)	LS (%)	Iss (%)	Material
2	0.5	7	44	49	30	14	16	11	-	Sandy CLAY, trace gravel
2	0.6-0.7	-	-	-	-	-	-	-	0.8	Sandy CLAY, trace gravel
2	1.2	6	22	72	64	20	44	14.0	-	CLAY, with sand, trace gravel
10	0.7	4	38	58	38	15	23	8.5	-	Sandy CLAY, trace gravel
11	0.9-1.0	-	-	-	-	-	-	-	1.7	Clayey GRAVEL, with sand
11	1.1	55	25	20	46	19	27	9.0	-	Clayey GRAVEL, with sand
13	0.4	1	89	10	-	-	-	-	-	SAND, with silt, trace clay, trace gravel
17	0.3	0	85	15	-	-	-	-	-	Clayey SAND
25	0.3	1	70	29	30	15	15	5.5	-	Clayey SAND, trace gravel

Test	Depth (m)	Gravel (%)	Sand (%)	Fines (%)	LL (%)	PL (%)	PI (%)	LS (%)	Iss (%)	Material
27	0.5	36	43	21	40	18	22	8.0	-	Gravelly clayey SAND
28	0.8-0.9	-	-	-	-	-	-	-	1.2	Sandy CLAY
30	0.6	39	36	25	-	-	-	-	-	Clayey sandy GRAVEL
32	0.3	9	67	24	-	-	-	-	-	Clayey SAND, trace gravel

Notes The % fines is the amount of particles smaller than 75 µm.
The % sand is the amount of particles smaller than 2.36 mm and larger than 75 µm.
The % gravel is the amount of particles smaller than 63 mm and larger than 2.36 mm.
LL – Liquid Limit PL – plastic limit PI – plasticity index
LS – linear shrinkage Iss – shrink-swell index

Table 3: Results of Compaction and CBR Testing

Test Location	Depth (m)	Max. Dry Density (t/m^3)	Optimum Moisture Content (%)	CBR (%)	CBR Swell (%)	Material
10	0.7	2.03	11.0	11	0.0	Sandy CLAY, trace gravel
13	0.4	1.94	11.0	30	0.0	SAND, with silt, trace clay, trace gravel
25	0.3	1.89	10.5	15	1.0	Clayey SAND, trace gravel
30	0.6	2.08	10.5	25	1.0	Clayey sandy GRAVEL

Table 4: Summary of Laboratory Testing Results for Effluent Disposal

Test	Depth (m)	pH	EC (dS/m)	CEC (meq/100g)	PRI	Emerson Class	Material
3	0.8	5.0	0.11	3	1,090.0	6	Sandy CLAY, trace gravel
19	0.3	5.0	0.04	<1	1,080.0	5	Clayey SAND
22	0.4	5.1	0.01	<1	23.3		SAND, with clay
30	0.6	5.7	0.08	2	8.1	6	Clayey, sandy GRAVEL

Notes:
- pH and EC tests are carried out in 1:5 (soil:water) solution.
- EC: Electrical conductivity
- CEC: Cation exchange capacity in meq/100g.
- PRI: Phosphorous retention index

6. Proposed Development

It is understood that the development of the site will include subdividing the land to create 52 new residential lots of approximately 1 ha each, with construction of new roads to service the lots and a central drainage swale.

7. Geotechnical Comments

7.1 Site Suitability

Results of the investigation indicate that below the topsoil the site is generally underlain by a layer of silty or sandy soil (though this is absent in places), overlying clayey soils. Strong cemented laterite and lateritic gravel were encountered at several test locations.

Groundwater was encountered at test location 28 during the field work undertaken on 10 to 11 March 2020 at a depth of approximately 2.3 m (approximately RL 38.6 m AHD). Groundwater was not encountered at the other test locations. Aerial photographs indicate that the area around test location 28 is a local drainage low point and that surface water is frequently present. The seepage may be the result of perched groundwater resulting from infiltration of ponded water after recent rainfall.

From a geotechnical standpoint, the land is physically capable of development for the proposed development, provided that the provisions outlined in the subsequent subsections of the report are taken into consideration, and recommendations are implemented.

The main geotechnical constraints identified at this site, in relation to the proposed development as described in Section 6, include:

- The site has a general site classification of “Class S” in current condition. However, high plasticity clay (Unit 5, see Section 4.1) with higher reactivity than the sandy clay and clayey sand generally underlying the site, was encountered on the north eastern boundary of the site, as indicated on Drawing 2, Appendix A. A site classification of “Class M” is considered appropriate for that part of the site in current condition, as indicated on Drawing 3, Appendix A.
- Soft to firm clayey soils, and groundwater at a depth of 2.3 m, were encountered at test location 28. Aerial photographs indicate that the area around test location 28 is a local drainage low point and that surface water is often present in this area. The surface elevation of this area may need to be raised, or drainage into the area intercepted to avoid waterlogging of lots in that area.
- The presence of clayey soil and laterite may result in perched groundwater during the wet periods of the year, particularly in the area around test location 28, potentially impacting excavations below existing ground level.
- The site has several limitations for on-site disposal of sewage, including relatively low permeability in situ soils, potentially shallow perched groundwater, shallow hard pan (i.e. effectively impermeable horizon) and low cation exchange capacity and phosphorus retention index. These features will need to be taken into account when designing the onsite effluent disposal systems, as described in Section 8 below.
- The occurrence of locally cemented lateritic materials should be considered in the selection of excavation equipment during the earthworks.

7.2 Site Classification

The site is generally underlain by shallow sandy clay and clayey sand of low plasticity, generally with a thin surface layer of sandy or silty soils. High plasticity clay was encountered at some test locations along the eastern boundary of the site.

A general site classification of "Class S" in accordance AS2870-2011 is considered appropriate for the site in current condition, with characteristic surface movement (y_s) up to 20 mm.

However, high plasticity clay (Unit 5, see Section 4.1) with higher reactivity than the sandy clay and clayey sand generally underlying the site, was encountered on the north eastern boundary of the site, as indicated on Drawing 2, Appendix A. A site classification of "Class M" is considered appropriate for that part of the site in current condition, as indicated on Drawing 3, Appendix A. A site classification of "Class S" would be considered appropriate for such locations if a sand pad of 0.8 m thickness is created above the existing surface elevation beneath the proposed building envelopes.

A minimum thickness of 1.8 m of clean, non-reactive granular soil overlying the clayey soils (sand with clay, clayey sand, sandy clay, clay), including fill and natural soil, is required if a site classification of "Class A" is targeted. The depth to the clayey layer from the existing surface elevation, and therefore the thickness of non-reactive, granular fill required to amend the site classification, is variable across the area. Note that sand with a trace of clay or with clay should be regarded as reactive for the purposes of determining required fill thickness.

It should be noted that AS 2870-2011 applies to single houses, townhouses and the like classified as Class 1 and 10a under the Building Code of Australia. It also applies to light industrial and commercial buildings if they are similar in size, loading and superstructure flexibility to those designs included in AS 2870-2011. Advice on footings outside the application of AS2870-2011 is provided in Section 7.5 below.

7.3 Excavation Conditions

The encountered ground conditions generally comprise sand, silt, and hard clayey soils. Laterite was encountered in some locations, as summarised in Section 4.1.

Powerful conventional earthmoving equipment, such as 15 to 20 t excavator, is recommended for excavations across the site within the shallow soils, which were generally hard.

Laterite was encountered at several locations (discussed in Section 4.1), and the presence of laterite elsewhere below the site cannot be precluded. Excavation of lateritic ground generally resulted in hard digging and caused refusal in several test pits excavated using the 8 tonne excavator during the geotechnical investigation. Therefore, excavation of lateritic material, if required, may necessitate larger equipment such as a 20 tonne excavator with toothed bucket, ripping by a D9 dozer or breaking it up using a rock breaker or a ripping tyne.

Groundwater was encountered at a depth of 2.3 m at test location 28, which is located in a local drainage low point. If is considered that this water is perched infiltration water resulting from recent rains, and subsequent surface drainage into the area. It is possible that perched groundwater may occur generally across the site on low permeability layers, as is typical in Guildford Formation strata. Therefore, while

groundwater is generally unlikely to impact excavations up to 3 m during the dry months of the year, provision for dewatering should be considered for deeper excavation below the existing ground elevation, for excavation in the drainage low point around test location 28 and during the winter period.

7.4 Site Preparation

7.4.1 Site Stripping

All deleterious material, including (if encountered) waste, debris and vegetation should be stripped from the proposed development areas of the site.

Any tree roots remaining from clearing operations within the proposed development area should be completely removed to a depth of 0.6 m, and the excavation backfilled with material of similar geotechnical properties to the surrounding ground and suitably compacted.

7.4.2 Proof Rolling and Compaction

Following removal of unsuitable material, it is recommended that the exposed subgrade below house pads and pavements be proof rolled with a smooth drum roller of at least 12 tonnes deadweight in vibrating mode on sand subgrade or a pad foot roller on clay subgrade.

Any areas that show signs of excessive deformation during compaction should be compacted until deformation ceases or, alternatively, the poor quality material should be excavated and replaced with suitable structural filling and compacted. This may be particularly expected to occur in the drainage area around test location 28, where firm to stiff clayey soils were encountered.

Earthworks should be supervised by a Geotechnical Engineer.

7.4.3 Geotechnical Suitability for Re-use of In Situ Soils

Based on the nature of the material encountered during the investigation, it is anticipated that in situ sand excavated from the site should be generally geotechnically suitable for reuse as structural fill provided it is free from organic matter and particles greater than 150 mm in size. However, it should be noted that sand occurrence beneath the site is relatively limited, both in lateral extent and thickness, and therefore might not be practical for reuse owing to both limited volume and possible contamination during extraction by underling clayey soils and overlying topsoil. The sand typically contained some clay and therefore, would not be suitable for use to improve site classification, if required as discussed in Section 7.2 above.

The thin surficial silty sand and sandy silt may be suitable for reuse of fill. However, the material has a low permeability which may impact drainage design, and use of this material should be confined to deeper parts of fill areas, say below 2 m from finished surface, if any.

The laterite, clayey sand, sandy clay and clay, are not recommended for re-use as structural filling. Consideration may be given to using this material in landscaping areas, though the impact on permeability due to the fines content in these soils should be taken into consideration.

7.4.4 Imported Filling

If required, imported filling should comprise free draining, cohesionless, well graded sand that:

- contains less than 5% by weight of particles less than 75 microns in size;
- contains no particles greater than 150 mm in size; and
- is free of organic and other deleterious materials.

It is recommended that test certificates are reviewed and approved by the geotechnical engineer prior to importing material to site. Other materials than specified above may be suitable, following review and acceptance by a geotechnical engineer.

7.4.5 Fill Placement

Any fill should be placed in layers not exceeding 300 mm loose thickness and compacted near optimum moisture content with a roller of say 12 tonne deadweight. Care should be taken not to run heavy plant immediately adjacent to existing structures and services. It is recommended that earthworks be carried out with regular inspections by a geotechnical engineer.

7.4.6 Compaction Testing

Compaction control of the sand fill could be carried out using a Perth sand penetrometer (PSP) test in accordance with test method AS 1289.6.3.3. Fill within development areas (i.e. below house pads and pavements) should be compacted to achieve a minimum blow count of 8 blows per 300 mm penetration to a depth of not less than 1.0 m below foundation level.

The top 300 mm in the base of excavation in granular soils should be re-compacted using a vibratory plate compactor prior to construction of footings. Inspection of footing excavations by a geotechnical engineer is also recommended.

7.5 Shallow Foundations

Shallow foundation systems comprising slab, pad and strip footings should be suitable to support the proposed structures. Footings of buildings covered by AS 2870-2011 should be designed to satisfy the requirements of this standard for the suitable site classification discussed in Section 7.2, provided that site preparation is carried out as detailed in Section 7.4.

For structures not covered by AS 2870-2011, a presumptive maximum allowable bearing pressure of 150 kPa is suggested for pad footings up to 1.5 m wide and 120 kPa for strip footings up to 1.0 m wide founded at a minimum depth of 0.5 m, provided that site preparation is carried out as discussed in Section 7.4.

7.6 Culvert Foundations

It is understood that culverts will be required for the crossing of roads over the proposed drainage swale. Three culverts will be required, located approximately at test locations 10, 13 and 22.

The encountered ground conditions at all three test locations, from depths of between 0.5 m and 0.8 m to the extent of the investigation at a depth of 2.5 m, comprised hard sandy clay. A presumptive maximum allowable bearing pressure of 150 kPa is suggested for the culvert foundations.

As the formation will be within clayey soils, it is recommended that the culverts are constructed during the dry period of the year and that the base of the foundation excavations be inspected by a geotechnical engineer prior to footing construction.

7.7 Pavement Design Parameters

Based on observation of the shallow soils underlying the site (sand, silt, clayey sand, sandy clay), results of laboratory testing, and Douglas Partners' experience, and assuming the recommendations in Section 7.4 are implemented, a subgrade California bearing ratio (CBR) of 4% is suggested for pavement design for subgrades in these natural soils, provided that the subgrade is compacted to not less than 95% of modified maximum dry density. Although lower than the values suggested by the laboratory testing, this recommended design value is consistent with the variability of the encountered ground conditions and our experience with similar subgrade.

For subgrades comprising sand fill complying with the specification provided in Section 7.4.4, a subgrade California bearing ratio (CBR) of 10% is suggested provided the thickness of sand fill is at least 0.5 m below formation level and the subgrade is compacted to not less than 95% of modified maximum dry density.

The clay encountered on the eastern boundary of the site was at depth and would not impact pavement design in the current site condition. However, if earthworks expose the clay and it subsequently forms the subgrade for pavement, as may be the case at some locations (e.g. near test location 6 where the clay was at only 0.5 m depth), a subgrade California bearing ratio (CBR) of 2% is recommended from our experience with similar materials in the area assuming the recommendations in Section 7.4 are implemented.

7.8 Design Pavement Thickness

Traffic loading for the pavements has been determined in accordance with Austroads Guide to Pavement Technology – Part 2: Structural Pavement Design (2017). With consideration of the road layout of the proposed development, a street category of 'Local Access with Buses' (Austroads, 2017 – Figure 12.1) has been selected for the proposed pavements. In line with this street type and the Austroads (2017) guidelines, a design traffic of 1.5×10^5 Equivalent Standard Axles (ESA) has been assumed, based on a 40 year design life.

The thickness design has been undertaken in accordance with Austroads Guide to Pavement Technology – Part 2: Structural Pavement Design (2017), and also taking into account the minimum pavement thickness suggested in IPWEA (2017) Local Government Guidelines for Subdivisional Development.

The results of the analysis indicating the minimum total pavement thickness and minimum thickness of basecourse quality material for the proposed pavements are presented in Table 5 below, assuming site

preparation is carried out as outlined in Section 7.4. Two scenarios of subgrade were assessed: the subgrade consists of in situ natural materials with a CBR of no less than 4%, and the pavement subgrade comprises at least 0.5 m thickness of sand fill above the natural ground with an equivalent CBR of 10%.

Table 5: Design Pavement Thicknesses

Subgrade Scenario	Pavement Design Life	Total Granular Thickness (mm)	Minimum Basecourse Thickness (mm)	Sub Base Thickness (mm)
Natural Subgrade CBR=4%	40 years	360	110	250
Sand Fill, CBR=10%, 0.5 m thick minimum	40 years	260	110	150

Dense graded asphalt is suggested as bituminous surfacing, although other surfacing treatments (e.g. sprayed seal) can be considered. A minimum asphalt thickness of 25 mm is suggested. A prime or primer seal should be placed on the prepared basecourse prior to laying the asphalt.

A suitable pavement basecourse material could consist of a granitic crushed rock base (CRB). A suitable sub-base could be formed using crushed limestone. Alternatively, the total granular thickness could comprise laterite, although such option increases the risk of asphalt cracking in the long term, and therefore a sprayed seal surfacing treatment (rather than asphalt) would be recommended as surfacing treatment. MRWA Specification 501 should be consulted for suitable pavement material specifications.

The basecourse should be compacted to achieve a dry density ratio of not less than 99% relative to modified compaction for CRB, and be dried back to a moisture content of less than 60% of OMC, prior to application of the prime or primerseal. If a lateritic basecourse is selected, it should be compacted to not less than 98% relative to modified compaction and dried back to 70% or drier prior to placing the bituminous surfacing.

The sub base should be compacted to achieve a dry density ratio of not less than 94% relative to modified compaction. The sub base should be dried back to 85% or less prior to placing the basecourse.

It is also recommended that adequate surface and subsoil drainage be implemented in order to direct water away from the pavement to avoid saturation of the proposed pavement that could result in developing pore pressure under trafficking and subsequent pavement failure. No water should be allowed to pond under the pavement.

With boxed construction, if utilised, the provision of adequate drainage, during construction and during service life, is particularly important. The provision of adequate cross falls on the surfaces of the subgrade and subsequent pavement layers will facilitate run-off of both surface water during construction and water subsequently trapped in the pavement, hence minimising the potential for softening of the materials (Austroads, 2017).

Owing to the variability of ground conditions across this site, it is recommended that the subgrade be inspected during construction by a geotechnical engineer prior to pavement construction, in order to identify possible weak soils that do not meet the design assumptions.

7.9 Stormwater Disposal and Drainage

The shallow ground conditions generally comprise a thin sandy/silty layer overlying clayey soils, with these clayey soils at or near the surface in some locations. Laterite were encountered at two test locations and may be present elsewhere.

Groundwater was encountered at test location 28 during the investigation undertaken on 10 and 11 March 2020. The area around test location 28 appears, from aerial photographs, to be a local drainage low point in the current site condition.

Eight in situ infiltration tests were undertaken, as described in Section 4.2 above, in predominantly sandy or gravelly soils (including clayey sand and clayey sandy gravel). The estimated permeability values arising from the tests ranged between 0.4 m/day and 12 m/day.

The site is underlain by a range of variable soils (e.g. various sands and silts, clayey sand, sandy clay, clay and laterite). A permeability value of 5 m/day is suggested for sand described as light grey or grey, with a trace of silt. A permeability of 0.1 m/day is estimated for the encountered sand, silt and clayey sand allowing for potential variability in the materials and reduction of permeability following compaction operations.

The encountered sandy clay, clay and laterite should be considered impermeable for the purposes of drainage design. The encountered occurrence of laterite and clay is indicated in Drawing 2, Appendix A.

On-site stormwater disposal using soakwells, sumps and drainage basins is not considered suitable at this site in current condition due to the presence of near surface, low permeability soils and the potential for shallow perched groundwater during the wet period of the year. However, if the site is filled to sufficient elevation with clean sand above maximum groundwater levels then on-site stormwater disposal using soakwells, sumps and drainage basins could be considered, provided proximity of the groundwater table, the presence of low permeability soils, water mounding on low permeability layers and lateral flow of infiltrated water within the placed sand fill and possible impact on adjacent land, are considered in the design.

8. Site and Soil Effluent Disposal Preliminary Assessment

8.1 Site and Soil Characteristics

Site characteristics observed during the field work and soil properties determined during subsequent laboratory testing have been assessed in relation to the anticipated limitations that they pose to onsite disposal of domestic effluent.

For this assessment, reference has mostly been made to AS1547-2012 and the Government Sewerage Policy, State Government of Western Australia, September 2019, amongst other documents whose references are listed in Section 8 of this report.

Site and soil characteristics, including any encountered limitations for effluent disposal within the site, are discussed below.

8.1.1 Soil Permeability

Saturated hydraulic conductivity (permeability) is a measure of the ability of soil to transmit water based on soil properties such as structure, texture and porosity. The soil types noted within the test pits and boreholes were interbedded layers of sand, silt, clayey sand and sandy clay, generally very stiff to hard or dense to very dense.

Infiltration testing at the site, using the constant head method in accordance with AS1547-2012, indicate generally low soil permeability with between approximately 0.3 m/day approximately 2 m/day and 12 m/day recorded in the shallow, surficial sandy and gravelly soils (including clayey sand and clayey sandy gravel).

Given the interbedding of the shallow mixed soils, including low permeability clayey soils, with no persistent strata discernible, it is suggested that a soil permeability category Group 4 (weakly structured) (with reference to AS 1547-2012 Tables 5.1 and E1) is assumed and a preliminary design permeability of 0.1 m/day is adopted for the natural sand, silt, clayey sand and clayey sandy gravel ground underlying site.

The relatively low permeability of permeability category Group 4 soils should be taken into account in designing the size of the irrigation area. The encountered soils were generally dense to very dense and or very stiff to hard.

If the required area of infiltration is too large, based on the in situ soils, a layer of imported sand could be placed either above the current ground surface. The permeability of clean sand meeting the specification in Section 7.4.4 above could typically be assumed to be approximately 5 m/day. However, the actual permeability would depend on the properties of the imported material and should be determined once a source of material is established.

A soil permeability category Group 5 (massive) is considered suitable for sandy clay, clay and laterite encountered along the eastern boundary of the site. These soils should be regarded as impermeable for drainage or sewage disposal design, as discussed in Section 7.8.2 below. Where sandy clay, clay or laterite is present within 0.5 m of the ground surface, consideration may be given to replacing the shallow soils, or raising the existing ground surface, with more permeable fill material, as further discussed in Sections 8.1.2 and 8.2 below.

8.1.2 Depth to Hardpan

The encountered sandy clay (part of Unit 5), clay (Unit %) and laterite (Unit 6) are regarded as hardpan and impermeable for drainage or sewage disposal design.

To allow on-site disposal of sewage where shallow sandy clay, clay or laterite is currently present within 0.5 m of the ground surface, either:

- the sandy clay, clay or laterite should be excavated and replaced with sand; or
- the elevation of the site should be raised using sand to provide sufficient depth of soil above the clay or sandy clay for drainage to occur.

8.1.3 Depth to Groundwater

Groundwater was encountered at test location 28 (which lies within a local drainage low point) during the field work undertaken on 10 and 11 March 2020, but not elsewhere.

However, It is possible that perched groundwater will collect on the lower permeability materials such as sandy clay and clay in the winter period. Therefore, the groundwater table is considered a moderate limitation for on-site disposal of sewage. Investigation of groundwater levels at the end of winter is suggested to further assess possible impacts of groundwater levels for on-site sewage disposal, particularly the low lying areas of the site such as around test location 28. Groundwater levels are affected by climatic conditions and soil permeability and groundwater levels higher than those encountered during the field work may occur.

8.1.4 Coarse Fragments

Coarse fragments are defined as particles greater than 2 mm in AS 1547-2012. The abundance of coarse fragments in the soils encountered underlying the site is generally few to common, though rising to many in some places, with the coarse fragments being fine to coarse gravel, in accordance with Table E2, AS 1547-2012.

The abundance of gravel-sized coarse fragments is not considered a limitation at this site, and has been taken into account in the assessment of the excavatability of the site in Section 7.3 and the soil permeability categories described in Section 7.8.1 above.

8.1.5 Slope

The site slopes generally slopes gently from south to north, with gradients estimated to be less than 5%. Slopes of this gradient are not considered a limitation to on-site disposal of sewage.

8.1.6 Dispersivity

Laboratory testing of soil samples taken from the site indicate an Emerson class of 5 or 6. Therefore, the soils generally have a low potential for dispersion and dispersivity does not form a limitation for on-site sewage disposal at the site.

8.1.7 pH

Laboratory testing indicates a pH values of between 5 and 5.7. Therefore, pH is not considered a constraint for on-site sewage disposal at the site.

8.1.8 Electrical Conductivity

Laboratory testing indicates that the electrical conductivity of soils underlying the site is less than 0.11 dS/m and therefore electrical conductivity is not a limitation to on-site sewage disposal.

8.1.9 Cation Exchange Capacity

The cation exchange capacity (CEC) is the total number of cations a soil can retain on its absorbent complex at a given pH, and is therefore a good measure of a soil ability to retain specific pollutants. The laboratory tests carried out on the samples collected the site, indicate CEC values of less than 3 meq/100g or cmol+/kg. A cation exchange capacity of less than 5 cmol+/kg is considered as a major limitation for on-site effluent disposal and a value of more than 15 cmol+/kg Is typically recommended. Therefore secondary treatment of effluent, using equipment such as aerobic treatment units (ATU) is required. Alternatively, an elevated mound constructed from amended soil could be adopted, as described in Section 8.2 below.

8.1.10 Phosphorus Retention Index

The laboratory test carried out on samples collected from the site indicate a highly variable phosphorus retention index (PRI) of between 8 and 1,090 for the variable soils underlying the site, indicating the phosphorus sorption rate varies considerably across the site. It is suggested that the PRI is considered a major limitation for on-site primary sewage disposal. Therefore secondary treatment of effluent, using equipment such as aerobic treatment units (ATU) is recommended at this stage. Investigations within designated irrigation areas once these have been determined may indicate that the PRI in some locations is acceptable. Alternatively, an elevated mound constructed from amended soil could be adopted, as described in Section 8.2 below.

8.2 On-site Wastewater Management Options

Owing to the occurrence of soils with the limitations on permeability, perched ground water, hard pan, Cation Exchange Index and Phosphorus Retention Index mentioned above, it is suggested at this preliminary that the treatment of the primary effluent is undertaken to produce secondary quality effluent, prior to on-site disposal over the land surface.

Several treatment options are possible and include the following:

- Aerobic Treatment Unit (ATU);
- sand filters; and
- closed cell (amended soil) evapo-transpiration systems.

The effluent treatment system selected for use should be approved by the WA Department of Health.

Site specific investigations within irrigation areas, once these have been determined, could be undertaken to potentially re-evaluate the need for an ATU or similar, though it is considered likely that an ATU or similar will generally still be required.

As noted in Section 7.1.1 the soil permeability adopted for design could be increased if a layer of clean sand fill is either placed above the existing ground level, or some of the in situ soil is removed and replaced with clean sand.

Alternatively, an elevated mound could be used, raising the infiltration above existing surface level, constructed with amended soil, which is a material designed to have the capability to accommodate primary effluent. The elevated mound system should be designed by an experienced on-site sewage system designer.

8.3 Conclusions on Site Suitability for Effluent Disposal

The site is considered suitable for the disposal of domestic effluent in general accordance with AS1547-2012, local government conditions and WA Department of Health, provided that the limitations described in Section 8.1 are addressed during the design and selection of the effluent treatment systems and that treatment of primary effluent is undertaken.

As there are a variety of Department of Health WA approved proprietary systems available, the choice of system is ultimately made by the purchaser of the properties within the guidelines of AS 1547:2012, local government authorities, the WA Department of Health and the site characteristics described above.

9. References

1. Australian Standard AS 1289-2000, Methods of Testing Soils for Engineering Purposes.
2. Australian Standard AS 1289.6.3.3-1999, Soil Strength and Consolidation Tests-Determination of the Penetration Resistance of a Soil – Perth Sand Penetrometer Test.
3. Australian Standard AS 1726-2017, Geotechnical Site Investigation.
4. Australian Standard AS 2870-2011, Residential Slabs and Footings.
5. Department of Environment, Perth Groundwater Atlas, Second Edition, December 2004.
6. Code of Practice for the Design, Manufacture, Installation and Operation of Aerobic Treatment Unit (ATUs) - November 2001.
7. Environment & Health Protection Guidelines: On-site Sewage Management for Single Households - January 1998.
8. Australian Standard AS 1547-2012, On-site Domestic-wastewater Management.
9. Government Sewerage Policy, September 2019.
10. Designing and Installing On-site Wastewater Systems, Sydney Catchment Authority, 2012.

11. Code of Practice for Onsite Sewage Management, Consultation Draft, November 2012.

10. Limitations

Douglas Partners (DP) has prepared this report for this project at Lots 487, 611 and 615 Arnold road, Serpentine, WA in accordance with DP's proposal dated 25 February 2020 and acceptance received from Phil Cuttone of Cuttone Property Group on behalf of MALF Corp Pty Ltd dated 3 March 2020. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Cuttone Property Group and MALF Corp Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The scope for work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of filling of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively

of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About This Report
Drawing

About this Report

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Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Sampling

Sampling is carried out during drilling or test pitting to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are generally based on Australian Standard AS1726:2017, Geotechnical Site Investigations. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	19 - 63
Medium gravel	6.7 - 19
Fine gravel	2.36 – 6.7
Coarse sand	0.6 - 2.36
Medium sand	0.21 - 0.6
Fine sand	0.075 - 0.21

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

The proportions of secondary constituents of soils are described as follows:

In fine grained soils (>35% fines)

Term	Proportion of sand or gravel	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	>30%	Sandy Clay
With	15 – 30%	Clay with sand
Trace	0 - 15%	Clay with trace sand

In coarse grained soils (>65% coarse)
- with clays or silts

Term	Proportion of fines	Example
And	Specify	Sand (70%) and Clay (30%)
Adjective	>12%	Clayey Sand
With	5 - 12%	Sand with clay
Trace	0 - 5%	Sand with trace clay

In coarse grained soils (>65% coarse)
- with coarser fraction

Term	Proportion of coarser fraction	Example
And	Specify	Sand (60%) and Gravel (40%)
Adjective	>30%	Gravelly Sand
With	15 - 30%	Sand with gravel
Trace	0 - 15%	Sand with trace gravel

The presence of cobbles and boulders shall be specifically noted by beginning the description with ‘Mix of Soil and Cobbles/Boulders’ with the word order indicating the dominant first and the proportion of cobbles and boulders described together.

Soil Descriptions

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	VS	<12
Soft	S	12 - 25
Firm	F	25 - 50
Stiff	St	50 - 100
Very stiff	VSt	100 - 200
Hard	H	>200
Friable	Fr	-

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	Density Index (%)
Very loose	VL	<15
Loose	L	15-35
Medium dense	MD	35-65
Dense	D	65-85
Very dense	VD	>85

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Extremely weathered material – formed from in-situ weathering of geological formations. Has soil strength but retains the structure or fabric of the parent rock;
- Alluvial soil – deposited by streams and rivers;
- Estuarine soil – deposited in coastal estuaries;
- Marine soil – deposited in a marine environment;
- Lacustrine soil – deposited in freshwater lakes;
- Aeolian soil – carried and deposited by wind;
- Colluvial soil – soil and rock debris transported down slopes by gravity;
- Topsoil – mantle of surface soil, often with high levels of organic material.
- Fill – any material which has been moved by man.

Moisture Condition – Coarse Grained Soils

For coarse grained soils the moisture condition should be described by appearance and feel using the following terms:

- Dry (D) Non-cohesive and free-running.
- Moist (M) Soil feels cool, darkened in colour.
  Soil tends to stick together.
  Sand forms weak ball but breaks easily.
- Wet (W) Soil feels cool, darkened in colour.
  Soil tends to stick together, free water forms when handling.

Moisture Condition – Fine Grained Soils

For fine grained soils the assessment of moisture content is relative to their plastic limit or liquid limit, as follows:

- ‘Moist, dry of plastic limit’ or ‘w <PL’ (i.e. hard and friable or powdery).
- ‘Moist, near plastic limit’ or ‘w ≈ PL (i.e. soil can be moulded at moisture content approximately equal to the plastic limit).
- ‘Moist, wet of plastic limit’ or ‘w >PL’ (i.e. soils usually weakened and free water forms on the hands when handling).
- ‘Wet’ or ‘w ≈LL’ (i.e. near the liquid limit).
- ‘Wet’ or ‘w >LL’ (i.e. wet of the liquid limit).

Symbols & Abbreviations

Douglas Partners

Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	Pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	Lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

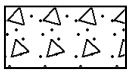
Symbols & Abbreviations

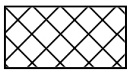
Graphic Symbols for Soil and Rock

General

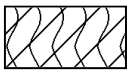

Asphalt

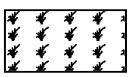

Road base

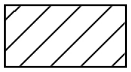

Concrete

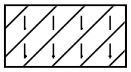

Filling

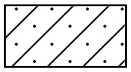
Soils


Topsoil

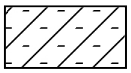

Peat

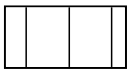

Clay

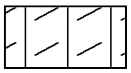

Silty clay

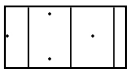

Sandy clay

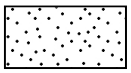

Gravelly clay

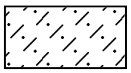

Shaly clay

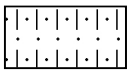

Silt


Clayey silt


Sandy silt

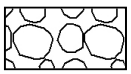

Sand

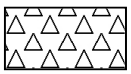

Clayey sand


Silty sand


Gravel

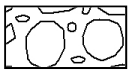

Sandy gravel


Cobbles, boulders

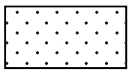

Talus

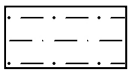
Sedimentary Rocks

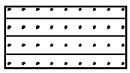

Boulder conglomerate

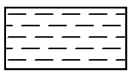

Conglomerate


Conglomeratic sandstone

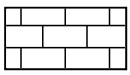

Sandstone


Siltstone

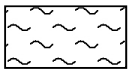

Laminite

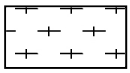

Mudstone, claystone, shale

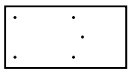

Coal


Limestone

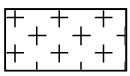
Metamorphic Rocks

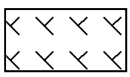

Slate, phyllite, schist

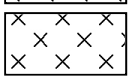

Gneiss

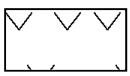

Quartzite

Igneous Rocks

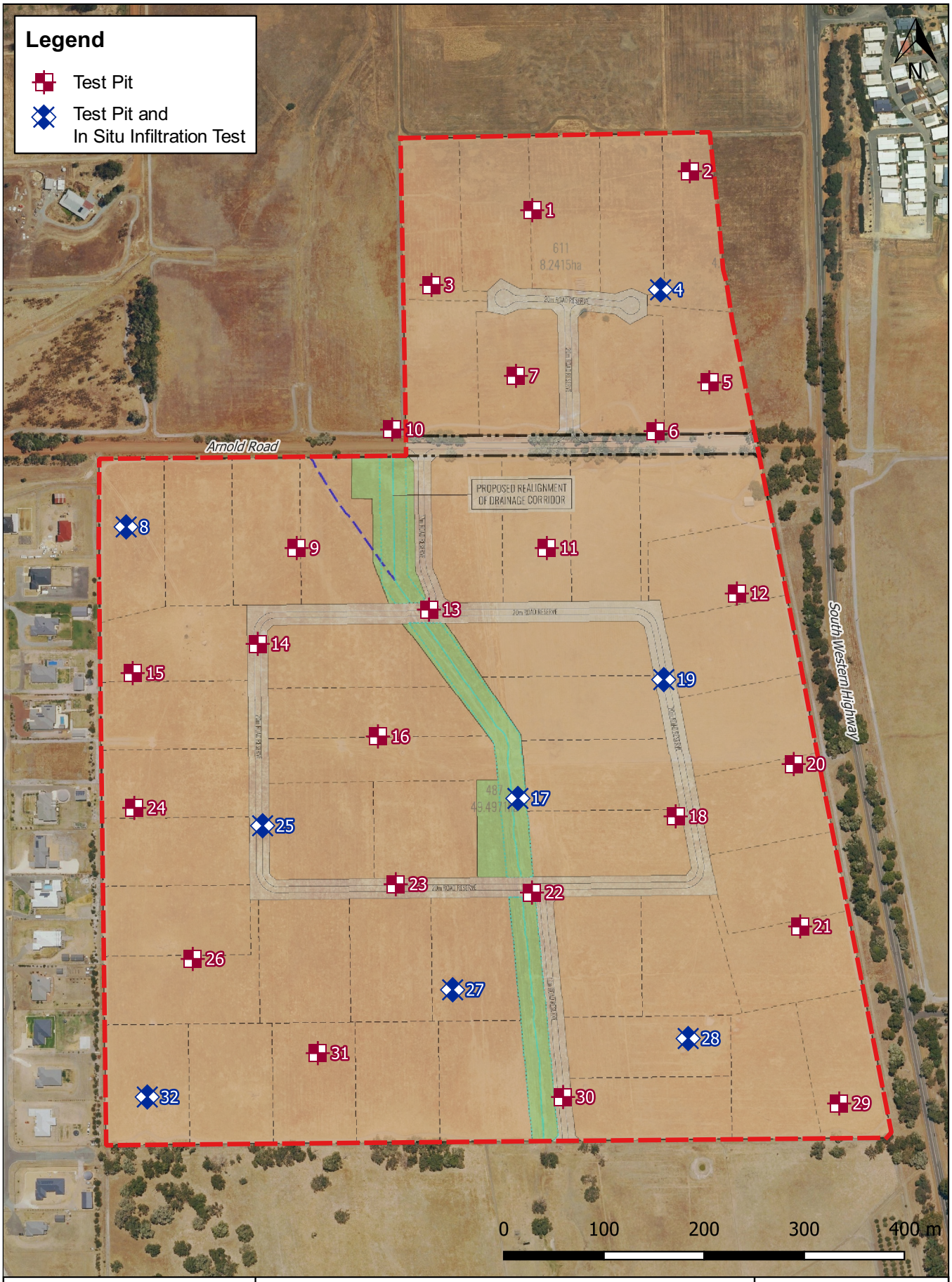

Granite


Dolerite, basalt, andesite

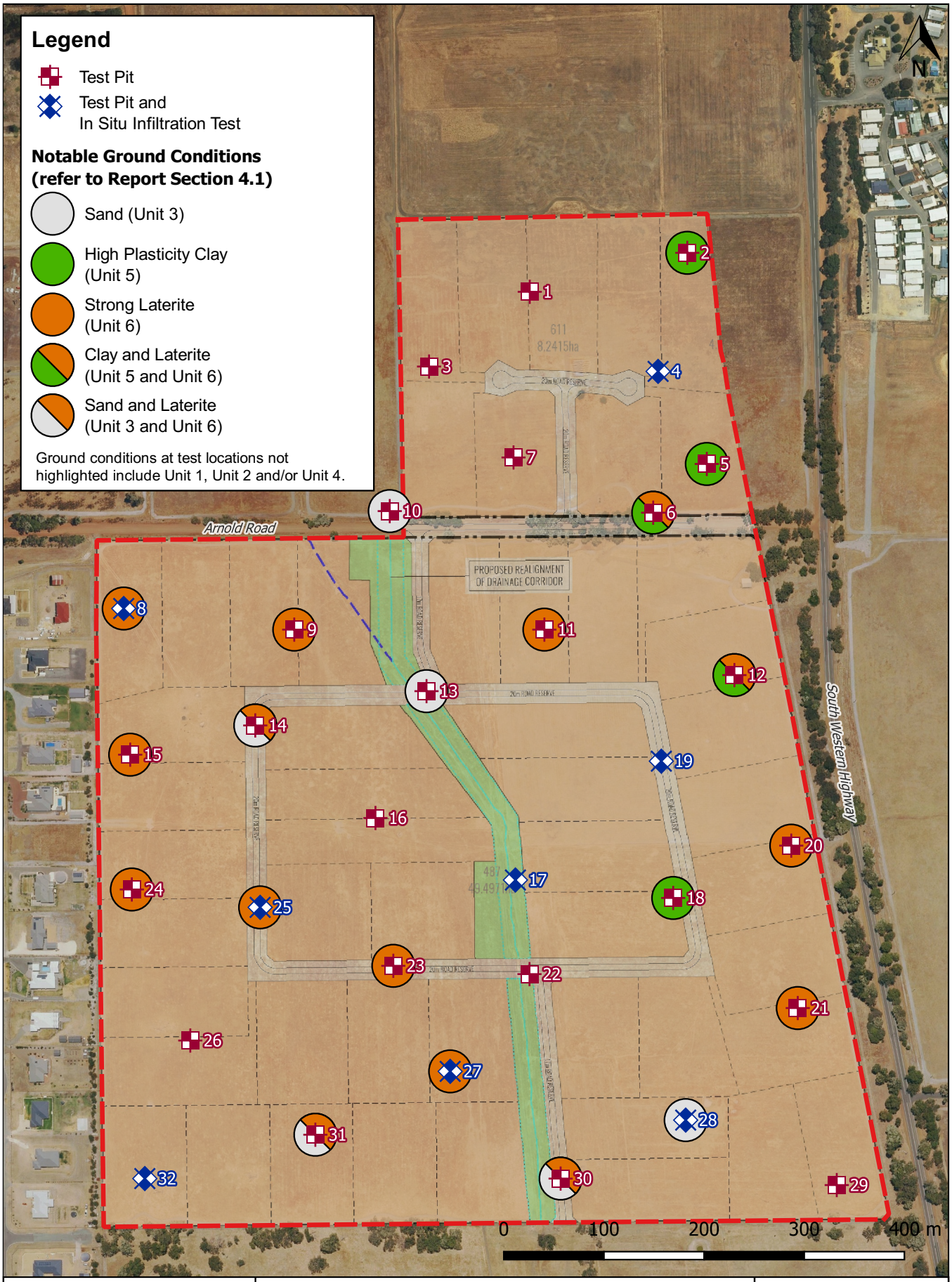

Dacite, epidote


Tuff, breccia

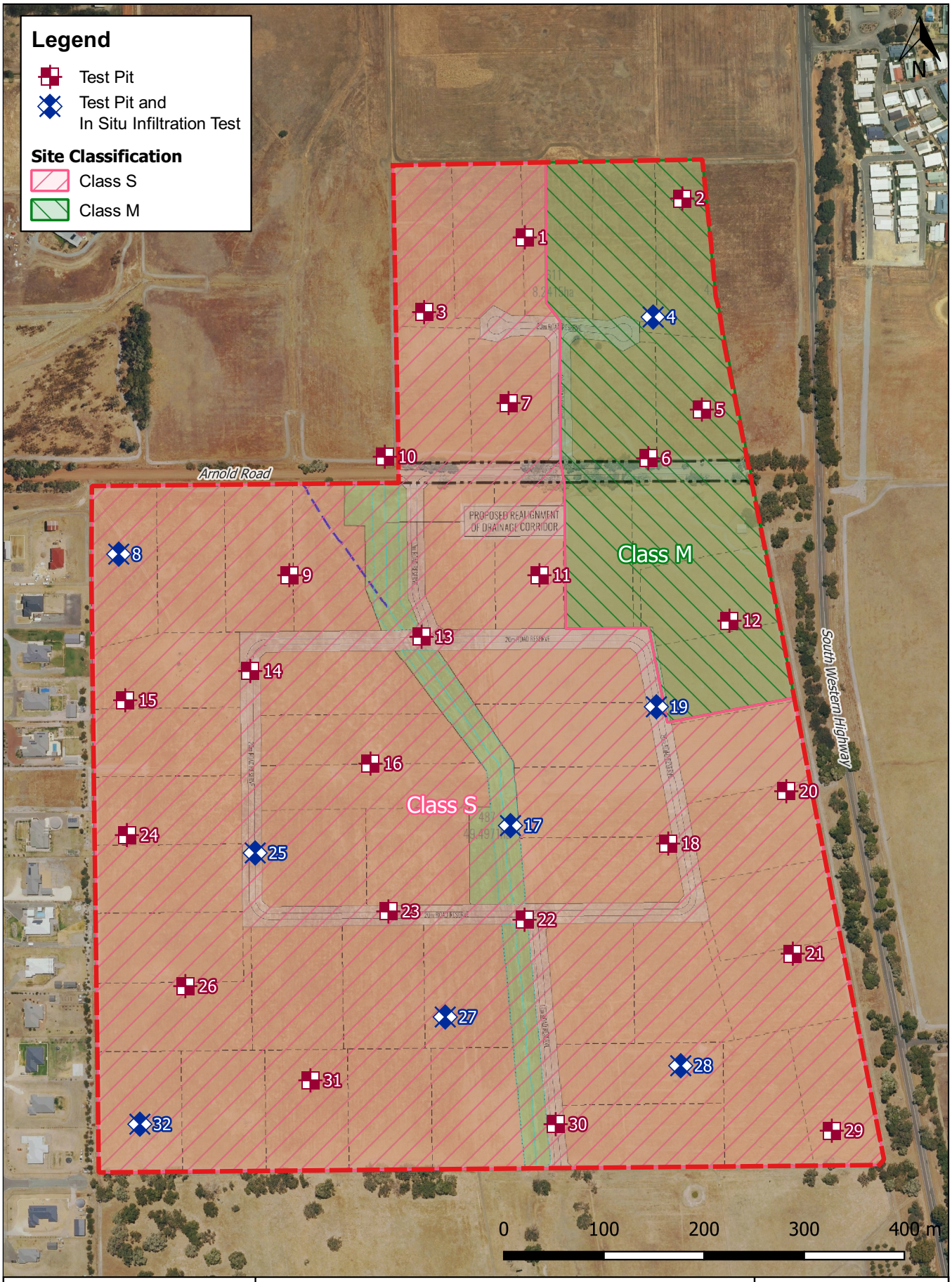

Porphyry



Douglas Partners Geotechnics / Environment / Groundwater	**Test Location Plan** **Proposed Residential Development** **Lots 487, 611 and 615 Arnold Road, Serpentine, WA**	PROJECT: 96660.00 Drawing No: 1 REV: 1
	CLIENT: MALF Corp Pty Ltd	DATE: 17/09/2020



Douglas Partners Geotechnics / Environment / Groundwater	**Test Locations and Encountered Soils** **Proposed Residential Development** **Lots 487, 611 and 615 Arnold Road, Serpentine, WA**	PROJECT: 96660.00 Drawing No: 2 REV: 1
	CLIENT: MALF Corp Pty Ltd	DATE: 17/09/2020



Douglas Partners Geotechnics / Environment / Groundwater	**Test Locations and Interpreted Site Classification** **Proposed Residential Development** **Lots 487, 611 and 615 Arnold Road, Serpentine, WA**	PROJECT: 96660.00 Drawing No: 3 REV: 1
	CLIENT: MALF Corp Pty Ltd	DATE: 17/09/2020

Appendix B

Report of Field Work

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 31.6 m AHD*
EASTING: 404838
NORTHING: 6418237

PIT No: 1
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
31	0.05	TOPSOIL/Sandy SILT ML: low plasticity, dark grey-brown, fine to medium grained sand, with rootlets, moist.							
	0.2	Sandy SILT SM: low plasticity, grey-brown, fine to medium grained sand, dry to moist, very stiff.							
		Sandy CLAY CI: medium plasticity, orange-brown and red-brown mottled light brown, fine to medium grained sand, trace gravel, dry to moist, hard.			1.0		pp = 600		
30	1				1.5		pp = 600		
	1.9	- with gravel and cobbles of iron cemented laterite.							
29	2	Pit discontinued at 1.9m (Hard digging/Refusal)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 31.9 m AHD*
EASTING: 404995
NORTHING: 6418276

PIT No: 2
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
31	0.05	TOPSOIL/Sandy SILT ML: low plasticity, grey-brown, fine to medium grained sand, with rootlets, dry to moist.		D	0.1				
	0.15	Sandy SILT ML: low plasticity, brown, fine to medium grained sand, trace gravel, dry to moist, stiff.							
		Sandy CLAY CI: medium plasticity, yellow-brown, fine to medium grained sand, trace gravel, moist, hard.		D	0.5				
				U	0.6				
					0.73				
	0.9	CLAY CH: high plasticity, brown, with sand, moist, hard.		D	1.2				
	1				1.5		pp = 600		1
30		- becoming red-brown, grey and brown from 1.8 m depth.		D	2.0		pp = 600		
	2								2
	2.5	Pit discontinued at 2.5m (Target depth)							
29									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 31.8 m AHD*
EASTING: 404737
NORTHING: 6418162

PIT No: 3
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
31	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.25	Silty SAND SM: fine to medium grained, grey-brown, low plasticity, with gravel, moist.							
	0.6	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, grey-brown, fine to medium grained sand, medium plasticity clay, dry to moist.							
		Sandy CLAY CI: medium to high plasticity, red-brown, orange-brown and grey-brown, fine to medium grained sand, trace gravel, dry to moist, hard.		B	0.8				
1					1.0		pp = 600		1
		- with gravel and cobbles of iron cemented laterite from 1.5 m depth.			1.5		pp = 600		
30				D	1.9		Rock sample		
2	2.0	Pit discontinued at 2.0m (Hard digging)							2
29									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 33.2 m AHD*
EASTING: 404966
NORTHING: 6418157

PIT No: 4
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
33	0.1	TOPSOIL/Silty Sandy GRAVEL GM: fine to coarse gravel, grey-brown, low plasticity silt, fine to medium grained sand, with rootlets, dry to moist.							
	0.2	Silty Sandy GRAVEL GM: fine to coarse gravel, grey-brown, low plasticity silt, fine to medium grained sand, dry to moist.		B	0.3		2 bulk bags of sample		
	0.5	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, light brown, medium plasticity clay, fine to medium grained sand, dry to moist.							
32	1	Sandy CLAY CI: medium plasticity, yellow-brown and orange-brown, fine to medium grained sand, with gravel, moist, hard.			1.0		pp = 600		1
					1.5		pp = 600		
	1.7	Pit discontinued at 1.7m (Hard digging)							
31	2								





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 33.8 m AHD*
EASTING: 405015
NORTHING: 6418065

PIT No: 5
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
33	0.05	TOPSOIL/Sandy SILT ML: low plasticity, grey-brown, fine to medium grained sand, with rootlets, dry to moist.							
	0.2	Sandy SILT ML: low plasticity, grey-brown, fine to medium grained sand, dry to moist.							
		Sandy CLAY CI: medium plasticity, light brown mottled orange-brown, fine to medium grained sand, trace gravel, dry to moist, hard.		D	1.0				
32	1.5	CLAY CH: high plasticity, light grey-white and brown, with sand, moist, hard.			1.7		pp = 600		
31	2.2	Pit discontinued at 2.2m (Hard digging/Refusal)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20; 1; 2





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 34.5 m AHD*
EASTING: 404961
NORTHING: 6418016

PIT No: 6
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
34	0.2	Gravelly Silty SAND SM: fine to medium grained, brown, low plasticity, fine to coarse lateritic gravel, dry.							
		Sandy CLAY CI: medium plasticity, yellow-brown mottled orange-brown, fine to medium grained sand, with lateritic gravel and cobbles, dry to moist, hard.		B	0.3				
	0.5	CLAY CH: high plasticity, light grey-white mottled red-brown, with sand, dry to moist, hard.							
	1			D	1.0		pp = 600		1
33					1.5		pp = 600		
	1.8	Pit discontinued at 1.8m (Hard digging)							
	2								
32									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 32.5 m AHD*
EASTING: 404822
NORTHING: 6418071

PIT No: 7
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
32	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.		D	0.1				
	0.2	SAND/Silty SAND SP-SM/SM: fine to medium grained, grey-brown, with silt or silty, low plasticity silt, dry to moist.		D	0.3				
	0.4	SAND/Clayey SAND SP-SC/SC: fine to medium grained, light brown, with clay or clayey, medium plasticity clay, dry to moist, very dense.			0.5		pp = 600		
	0.8	Sandy CLAY CI: medium plasticity, orange-brown and light brown, fine to medium grained sand, with gravel, dry to moist, hard.							
31	1	Sandy CLAY CI: medium plasticity, red-brown and orange-brown mottled grey, fine to medium grained sand, dry to moist, hard.			1.0		pp = 600		1
					1.5		pp = 600		
	2								2
30	2.5	Pit discontinued at 2.5m (Target depth)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 33.5 m AHD*
EASTING: 404432
NORTHING: 6417921

PIT No: 8
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
33	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.4	Clayey SAND/Sandy CLAY SC/CI: fine to medium grained, light brown, medium plasticity clay, trace gravel, moist, very dense.							
	1	Sandy CLAY CI: medium plasticity, light brown mottled orange-brown, fine to medium grained sand, trace gravel, moist, hard. Gravel content increasing with depth.			0.8		pp = 600		1
32	1.1	LATERITE: excavated as gravel and high strength cobbles of red-brown iron cemented laterite.							
	1.2	Pit discontinued at 1.2m (Hard digging)							
	2								
31									

5 10 15 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 32.9 m AHD*
EASTING: 404603
NORTHING: 6417900

PIT No: 9
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
32	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.		D	0.15				
	0.2	Sandy SILT ML: low plasticity, grey-brown, fine to medium grained, dry to moist.		D	0.3				
	0.35	Silty SAND SM: fine to medium grained, grey-brown, low plasticity, dry to moist, very dense.							
	1	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, orange-brown, red-brown and brown, medium plasticity clay, fine to medium grained sand, moist, hard.			1.0		pp = 500		1
	1.4	MIXTURE OF Clayey Sandy GRAVEL AND COBBLES GC: fine to coarse gravel, red-brown, fine to medium grained sand, medium plasticity clay, moist. Gravel and cobbles are iron cemented laterite.							
31	1.8	Pit discontinued at 1.8m (Hard digging)							
	2								
30									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 32.8 m AHD*
EASTING: 404698
NORTHING: 6418018

PIT No: 10
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
32	0.2	Silty SAND SM: fine to medium grained, grey-brown, low plasticity, dry to moist.							
		SAND SP-SC: fine to medium grained, light brown, with clay, moist, very dense to dense.		B	0.3				
	0.5	Sandy CLAY CH: medium plasticity, orange-brown, brown and red-brown, fine to medium grained sand, trace gravel, moist, hard.		B	0.7				
	1				1.0		pp = 600		1
					1.5		pp = 450		
31	2				2.0		pp = 450		2
	2.5	Pit discontinued at 2.5m (Target depth)			2.5		pp = 600		
30									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 35.1 m AHD*
EASTING: 404852
NORTHING: 6417900

PIT No: 11
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
35	0.05	TOPSOIL/Silty Sandy GRAVEL GM: fine to coarse gravel, dark grey-brown, fine to medium grained sand, low plasticity silt, with rootlets, dry to moist.							
		Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, light brown, fine to medium grained sand, medium plasticity clay, with cobbles, moist.		D	0.5				
	0.7	Clayey GRAVEL GC: fine to coarse gravel, light brown and orange-brown, medium plasticity clay, with sand, dry to moist, hard/very dense.		U	0.9				
34	1			D	1.03 1.1				1
		- becoming red-brown, grey and brown from 1.4 m depth.							
		- with gravel and cobbles of iron cemented laterite from 1.8 m depth.							
33	2 2.0	Pit discontinued at 2.0m (Hard digging)							2

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 38.3 m AHD*
EASTING: 405042
NORTHING: 6417854

PIT No: 12
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
38	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.2	Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, dry to moist.							
		Sandy CLAY CI: medium plasticity, yellow-brown and orange-brown, fine to medium grained sand, dry to moist, hard.							
	0.7	Gravelly Sandy CLAY CI: medium plasticity, yellow-brown and orange-brown, fine to medium grained sand, fine to coarse lateritic gravel, with cobbles of laterite, dry to moist, hard. Hard digging experienced in this layer.							
37	1.3	CLAY CH: high plasticity, light brown and red-brown, with sand, moist, hard.			1.5		pp = 600		
				D	2.0		pp = 600		
36	2.3	Pit discontinued at 2.3m (Boom obstructed by hard upper layers)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 34.4 m AHD*
EASTING: 404735
NORTHING: 6417838

PIT No: 13
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
34	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.							
		SAND SP-SM: fine to medium grained, light brown, with silt, trace clay, moist, dense.		B	0.4				
	0.6	Sandy CLAY CI: medium plasticity, orange-brown mottled red-brown and brown, fine to medium grained sand, trace gravel, moist, hard.							
33	1								1
		- becoming red-brown and brown from 1.7 m depth.			1.7		pp = 600		
32	2								2
	2.5	Pit discontinued at 2.5m (Target depth)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 34.2 m AHD*
EASTING: 404564
NORTHING: 6417804

PIT No: 14
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
34	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.							
		SAND SP-SM: fine to medium grained, light brown, with silt, moist, dense to very dense. Possibly silty.		D	0.3				
	0.5	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, orange-brown, brown and red-brown, fine to medium grained sand, medium plasticity clay, moist, dense.		B	0.6				
	1				1.0		pp = 600		1
33		- becoming brown and red-brown, with cobbles from 1.2 m depth.							
	2								2
	2.1	Sandy CLAY CI: medium plasticity, red-brown and grey, fine to medium grained sand, moist.							
32	2.5	Pit discontinued at 2.5m (Target depth)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 34.7 m AHD*
EASTING: 404439
NORTHING: 6417775

PIT No: 15
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
34	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.2	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, trace gravel, moist, medium dense to dense.							
	0.5	MIXTURE OF Clayey Sandy GRAVEL AND COBBLES: fine to coarse gravel, red-brown and light brown, fine to medium grained sand, medium plasticity clay, with cobbles, moist, dense. Gravel and cobbles are iron cemented laterite.							
	0.8	LATERITE: excavated as gravel and high strength cobbles of red-brown iron cemented laterite.							
33	1	Pit discontinued at 0.8m (Hard digging)							
32	2								

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 35.3 m AHD*
EASTING: 404684
NORTHING: 6417712

PIT No: 16
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
35	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.4	Sandy CLAY CI: medium plasticity, grey-brown, fine to medium grained sand, dry to moist, hard.							
		Sandy CLAY CI: medium plasticity, orange-brown, brown and red-brown, fine to medium grained sand, with gravel, dry to moist, hard.			0.5		pp = 600		
34	1			D	1.0		pp = 600		1
		- becoming red-brown mottled grey from 1.5 m depth.			1.5		pp = 600		
	2								2
33	2.2	Pit discontinued at 2.2m (Hard digging)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 36.4 m AHD*
EASTING: 404824
NORTHING: 6417650

PIT No: 17
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
36	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, dry to moist.							
		Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist, dense to very dense.		D	0.3				
	0.7	Sandy CLAY CI: medium plasticity, orange-brown and red-brown, fine to medium grained sand, with gravel, moist, hard.		D	1.0				
35	1	- with gravel and cobbles of iron cemented laterite from 1.7 m depth.							
	2								
34	2.2	Pit discontinued at 2.2m (Hard digging)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 39.4 m AHD*
EASTING: 404981
NORTHING: 6417632

PIT No: 18
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
39	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.4	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist, medium dense.							
	0.7	Sandy GRAVEL GP-GC: fine to coarse lateritic gravel, light brown, fine to medium grained sand, with clay, moist.							
	1	Sandy CLAY CI: medium plasticity, light brown and orange-brown, fine to medium grained sand, with gravel, moist, hard.							
38		- trace gravel from approximately 1.3 m depth.							
	2								
	2.3	CLAY CH: high plasticity, light grey mottled orange-brown, with sand, moist.							
37	2.5	Pit discontinued at 2.5m (Target depth)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 38.5 m AHD*
EASTING: 404969
NORTHING: 6417768

PIT No: 19
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
38	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.1	Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, dry to moist.		D	0.3				
	0.5	Clayey SAND SC: fine to medium grained, grey-brown, medium plasticity, dry to moist, dense.							
		Sandy CLAY CI: medium plasticity, light brown, fine to medium grained sand, dry to moist, hard.							
	0.9	Sandy CLAY CI: medium plasticity, brown mottled red-brown and orange-brown, with iron cemented lateritic gravel, dry to moist.							
37	1.5	Sandy CLAY CI: medium to high plasticity, light grey mottled red-brown, fine to medium grained sand, with cobbles, moist. - appears there are no cobbles from 1.8 m depth.							
	2.3	Pit discontinued at 2.3m (Boom obstructed by hard upper layers)							
36									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20; 1; 2





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 41.1 m AHD*
EASTING: 405099
NORTHING: 6417684

PIT No: 20
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
41	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.2	Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, moist.							
	0.5	Clayey SAND SC: medium plasticity, light brown, fine to medium grained sand, moist, dense.							
		Sandy CLAY CI: medium plasticity, light brown mottled orange-brown, fine to medium grained sand, trace gravel, moist, hard.							
40	1.0	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, red-brown and orange-brown, fine to medium grained sand, medium plasticity clay, with cobbles, moist. Hard digging experienced in this layer.		D	1.4				
	1.6	Sandy CLAY CI: medium plasticity, light yellow-brown, fine to medium grained sand, with gravel and cobbles of laterite, moist.							
39	2.1	Pit discontinued at 2.1m (Boom obstructed by hard upper layers)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20; 1, 2





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 42.3 m AHD*
EASTING: 405105
NORTHING: 6417522

PIT No: 21
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
42	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.3	Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, moist, medium dense.		D	0.2				
	0.5	Clayey SAND SC: medium plasticity, light brown, fine to medium grained sand, moist, dense.							
41	1	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, light yellow-brown mottled red-brown and orange-brown, fine to medium grained sand, medium plasticity clay, with cobbles, moist.							1
	1.6	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist.		D	1.8				
40	2								2
	2.5	Pit discontinued at 2.5m (Target depth)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 37.5 m AHD*
EASTING: 404838
NORTHING: 6417556

PIT No: 22
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
37	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, dry to moist.							
		Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist, dense to very dense.		B	0.4				
	0.8	Sandy CLAY CI: medium plasticity, orange-brown and red-brown, fine to medium grained sand, with gravel, moist, hard.			1.0		pp = 600		
36	1				1.5		pp = 600		
		- with gravel and cobbles of iron cemented laterite from 1.8 m depth.							
35	2								
	2.5	Pit discontinued at 2.5m (Target depth)							

5 10 15 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 37.2 m AHD*
EASTING: 404702
NORTHING: 6417564

PIT No: 23
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
37	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.4	Clayey Sandy GRAVEL GC: fine to medium gravel, light grey-brown, medium plasticity clay, fine to medium grained sand, moist, dense.							
	1	Gravelly Clayey SAND SC: fine to medium grained, light brown and orange-brown, medium plasticity clay, fine to coarse gravel, moist, hard.							
36		- with cobbles and gravel of iron cemented laterite from 1.1 m depth.							
	1.3	Pit discontinued at 1.3m (Hard digging)							
	2								
35									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20; 1





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 35.8 m AHD*
EASTING: 404441
NORTHING: 6417640

PIT No: 24
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
35	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
		Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist, medium dense.							
		- becoming light brown mottled orange-brown from 0.6 m depth.		D	1.0				
34	1.3	MIXTURE OF Clayey Sandy GRAVEL AND COBBLES GC: fine to coarse lateritic gravel, red-brown and light brown, fine to medium grained sand, medium plasticity clay, moist.							
	1.9	Sandy CLAY CI: medium plasticity, brown mottled orange-brown, fine to medium grained sand, trace gravel, moist, hard.							
33	2.2	Pit discontinued at 2.2m (Hard digging/Refusal)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 36.1 m AHD*
EASTING: 404569
NORTHING: 6417622

PIT No: 25
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
36	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
		Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, trace gravel, moist, medium dense to dense.		B	0.3				
	0.5	Clayey Sandy GRAVEL GC: fine to medium lateritic gravel, orange-brown and red-brown, medium plasticity clay, fine to medium grained sand, dry to moist, dense.							
35	1								1
	1.3	Sandy CLAY CI: medium plasticity, brown and orange-brown, fine to medium grained sand, with gravel, moist.							
34	2								2
	2.3	Pit discontinued at 2.3m (Boom obstructed by hard upper layers)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 37.9 m AHD*
EASTING: 404499
NORTHING: 6417489

PIT No: 26
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
37	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.3	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, dry to moist, medium dense.		D	0.4				
	0.6	Gravelly Clayey SAND SC: fine to coarse grained sand, light brown, medium plasticity clay, fine to coarse gravel, dry to moist.							
	1	Gravelly Sandy CLAY CI: medium plasticity, orange-brown and brown, fine to medium gravel, fine to medium grained sand, dry to moist, hard.							1
	1.2	- with gravel and cobbles of iron cemented laterite.							
36		Pit discontinued at 1.2m (Hard digging/Refusal)							
	2								
35									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 38.7 m AHD*
EASTING: 404758
NORTHING: 6417459

PIT No: 27
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.4	Clayey Sandy GRAVEL GC: fine to medium gravel, light grey-brown, medium plasticity clay, fine to medium grained sand, moist, dense.		D	0.3				
38		Gravelly Clayey SAND SC: fine to medium grained, light brown and orange-brown, medium plasticity clay, fine to coarse gravel, moist, very dense/hard.		D	0.5				
	1								1
37	1.9	- with gravel and cobbles of iron cemented laterite from 1.8 m depth.							
	2	Pit discontinued at 1.9m (Hard digging)							
36									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 40.9 m AHD*
EASTING: 404993
NORTHING: 6417410

PIT No: 28
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.							
		SAND SP-SM: fine to medium grained, light grey, with silt, moist, medium dense.		D	0.5				
	0.6	Sandy CLAY CI: medium to high plasticity, brown, orange-brown and grey, fine to medium grained sand, moist, hard.							
		- becoming firm from 0.8 m depth.		U	0.8				
40	1				0.9				
					1.0		pp = 100		1
		- becoming stiff from approximately 1.3 m depth.		D	1.5		pp = 150		
39	2	- becoming light grey with higher sand content from 1.8 m depth.			2.0		pp = 500		2
		- becoming hard from approximately 1.8 m depth.							
		- becoming stiff to very stiff from approximately 2.3 m depth.						11-03-20	
	2.5	Pit discontinued at 2.5m (Target depth)			2.5		pp = 200		
38									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: Groundwater observed at 2.3 m depth.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 45.1 m AHD*
EASTING: 405144
NORTHING: 6417345

PIT No: 29
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
45	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.							
		Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, light brown, medium plasticity clay, moist, dense.							
		- becoming light yellow-brown, with cobbles from 0.6 m depth.		D	1.0				
44	1								1
	1.4	Sandy CLAY CI: medium plasticity, light brown mottled red-brown, fine to medium grained sand, trace gravel, moist.							
43	2								2
	2.5	Pit discontinued at 2.5m (Target depth)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 40.0 m AHD*
EASTING: 404869
NORTHING: 6417352

PIT No: 30
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
40	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.4	Sandy GRAVEL GP-GM: fine to coarse lateritic gravel, grey-brown, fine to medium grained sand, with silt, moist.							
		Clayey Sandy GRAVEL GC: fine to coarse gravel, light brown mottled red-brown, fine to medium grained sand, medium plasticity clay, moist, very dense/hard.		B	0.5 0.6		pp = 600		
39	1.0	Sandy CLAY CI: medium plasticity, brown mottled red-brown, fine to medium grained sand, trace gravel, moist, hard.			1.5		pp = 600		1
	1.9	- with cobbles of iron cemented laterite from 1.8 m depth.							
38	2	Pit discontinued at 1.9m (Hard digging)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 39.2 m AHD*
EASTING: 404624
NORTHING: 6417395

PIT No: 31
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
39	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.3	SAND SP-SC: fine to medium grained, light grey-brown, with clay, moist, medium dense.							
		Sandy CLAY CI: medium plasticity, light brown mottled orange-brown, with gravel, moist, hard. Gravel content increasing with depth.							
	1								1
38	1.1	MIXTURE OF Clayey Sandy GRAVEL AND COBBLES GC: fine to coarse gravel, light brown and orange-brown, medium plasticity clay, moist. Gravel and cobbles are iron cemented laterite.		D	1.4				
	1.8	Sandy CLAY CI: medium plasticity, light grey mottled brown and orange-brown, fine to medium grained sand, moist.							
	2			D	2.1		Rock sample		2
37	2.2	Pit discontinued at 2.2m (Refusal on rock)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 39.3 m AHD*
EASTING: 404454
NORTHING: 6417352

PIT No: 32
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
39	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.		D	0.2				
	0.3	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, trace gravel, dry to moist, medium dense.							
		Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, yellow-brown and brown, fine to medium grained sand, medium plasticity clay, dry to moist, dense.							
38	1.0	Clayey SAND SC: fine to medium grained, yellow-brown, medium plasticity clay, moist.		D	1.5				
	1.7	Pit discontinued at 1.7m (Hard digging)							
37									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Appendix C

Results of Laboratory Testing

WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

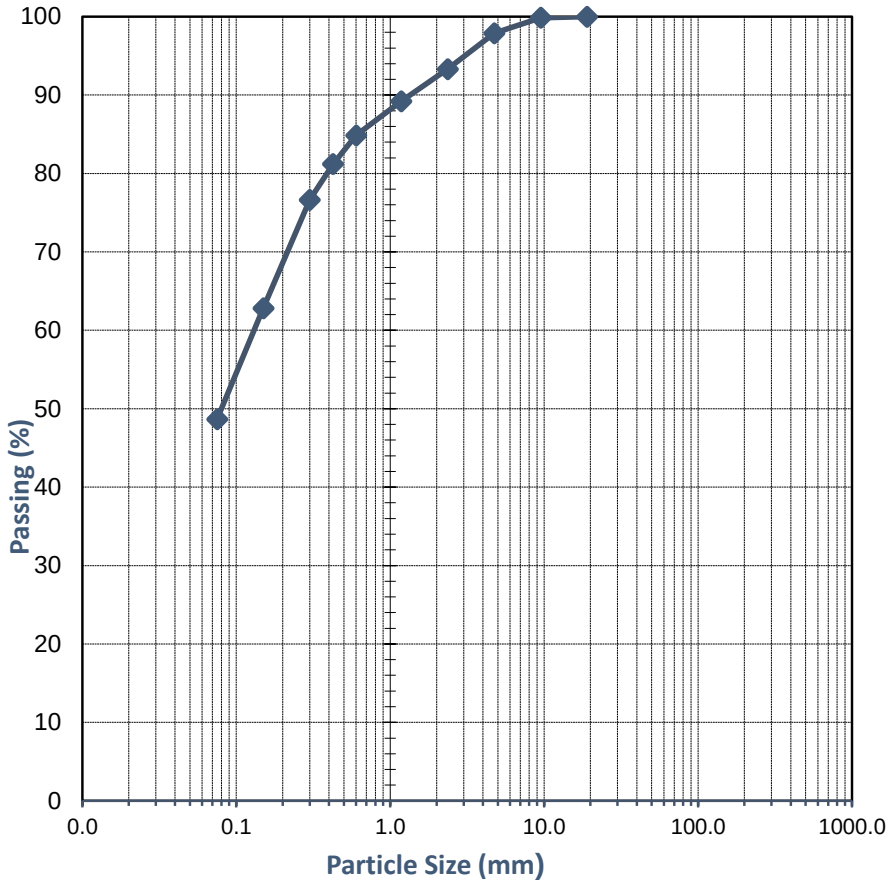
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4147_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4147
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 0.5m	*Date Tested:*	18/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	100
9.5	100
4.75	98
2.36	93
1.18	89
0.600	85
0.425	81
0.300	77
0.150	63
0.075	49



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

Accreditation No. 20599
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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4147_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4147
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 0.5m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**30**
AS 1289.3.2.1	**Plastic Limit (%)**	**14**
AS 1289.3.3.1	**Plasticity Index (%)**	**16**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**11.0**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked, Curled**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.7.7.1

Client:	Malf Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4148_1_SSI
Project:	Proposed Residential Development	*Sample No.*	WG20/4148
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 0.6-0.73m	*Date Tested:*	19-23/03/2020

TEST RESULTS - SHRINK SWELL INDEX

Sampling Method: Sampled by Client, Tested as Received

Material Description: Brown Clay, with Gravel

SWELL SPECIMEN	
Moisture Content Initial (%):	15.8
Dry Density - Initial (t/m^3):	1.84
Moisture Content Final (%):	17.6
Estimated Inert Inclusions (%):	2

SHRINK SPECIMEN	
Moisture Content Initial (%):	16.1
Extent of Crumbling:	Nil
Length/Diameter Ratio:	2.7
Extent of Cracking:	Slight

SHRINK SWELL INDEX	
Shrink Swell Index (I_{SS})	**0.8**

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4149_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4149
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 1.2m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**64**
AS 1289.3.2.1	**Plastic Limit (%)**	**20**
AS 1289.3.3.1	**Plasticity Index (%)**	**44**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**14.0**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

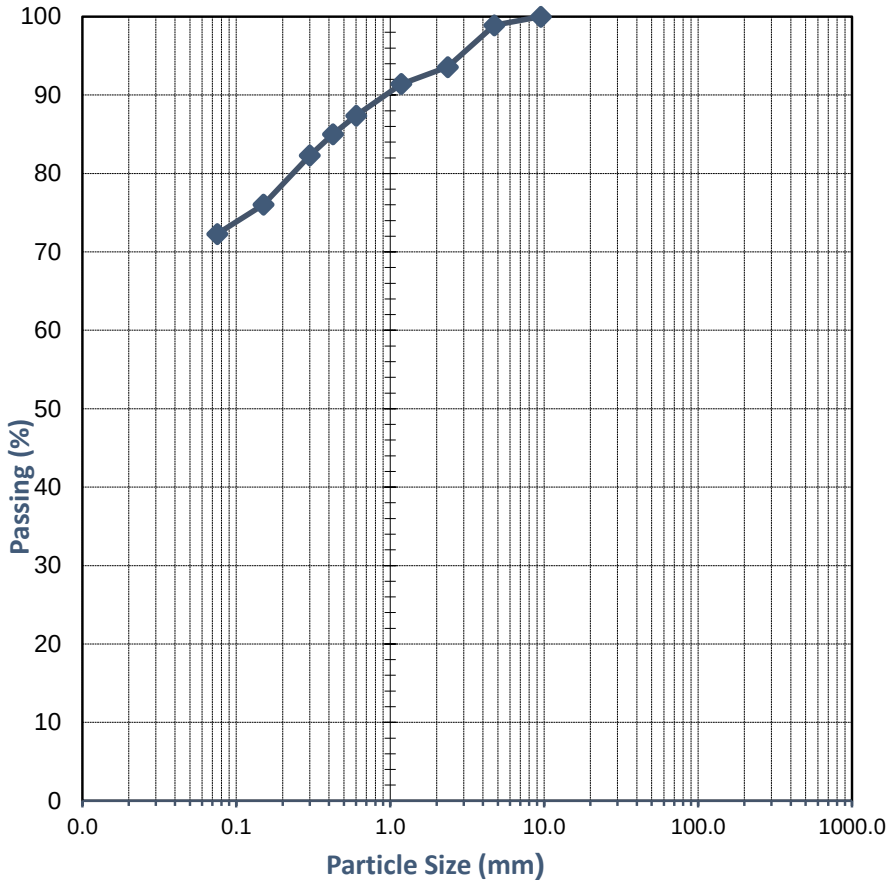
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4149_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4149
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 1.2m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	99
2.36	94
1.18	91
0.600	87
0.425	85
0.300	82
0.150	76
0.075	72



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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TEST REPORT - AS 1289.3.8.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4150_1_ECN
Project:	Proposed Residential Development	*Sample No.*	WG20/4150
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP3, 0.8m	*Date Tested:*	19/03/2020

TEST RESULTS - Emerson Class Number

Sampling Method:	**Sampled by Client, Tested as Received**
Source of Material:	**Not Specified**
Soil Description:	**Silty Clay, with Gravel**
Water Used:	**Distilled**

EMERSON CLASS NUMBER

6

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

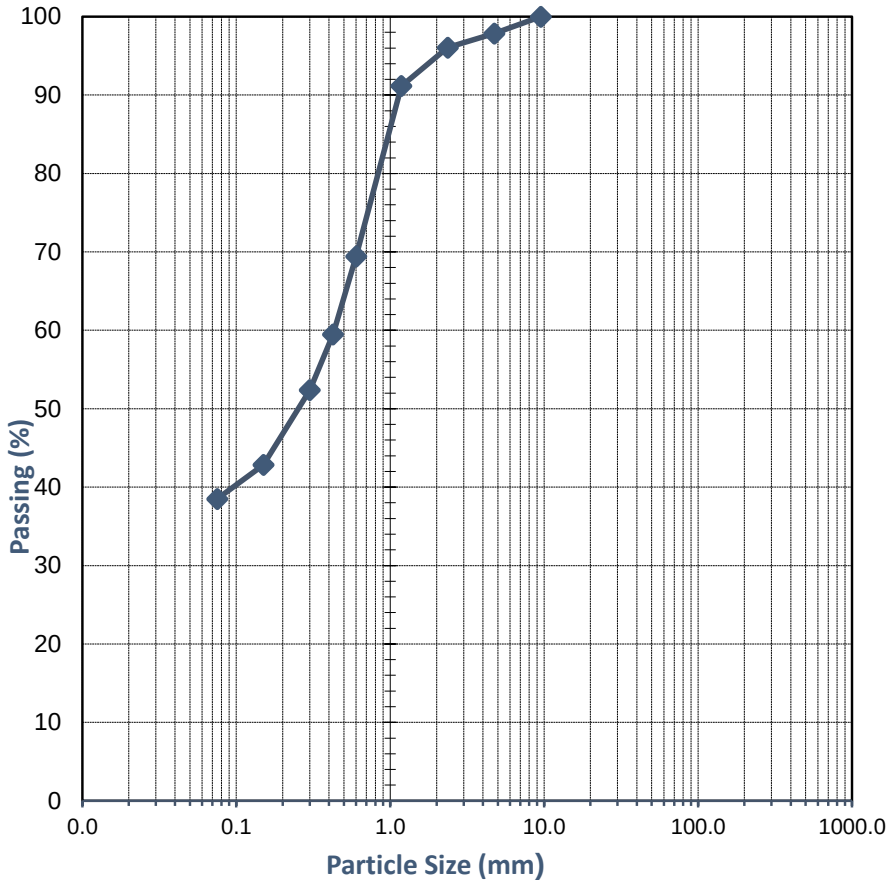
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4151_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4151
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP10, 0.7m	*Date Tested:*	18/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	98
2.36	96
1.18	91
0.600	69
0.425	59
0.300	52
0.150	43
0.075	38



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4151_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4151
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP10, 0.7m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**38**
AS 1289.3.2.1	**Plastic Limit (%)**	**15**
AS 1289.3.3.1	**Plasticity Index (%)**	**23**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**8.5**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.5.2.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4151_1_MMDD
Project:	Proposed Residential Dvelopment	*Sample No.*	WG20/4151
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP10, 0.7m	*Date Tested:*	18/03/2020

TEST RESULTS - Modified Maximum Dry Density

Sampling Method: Sampled by Client, Tested as Received

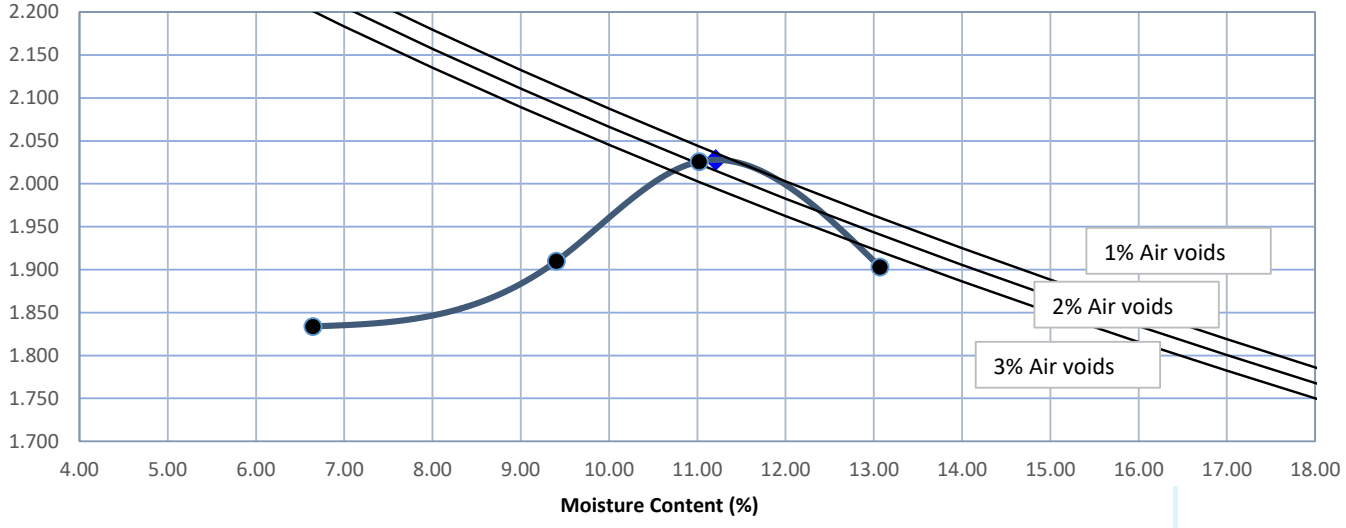
Sample Curing Time: 24 Hours

Method used to Determine Liquid Limit: Visual / Tactile Assessment by Competent Technician

Material + 19.0mm (%): 0 **Material + 37.5mm (%)** -

Moisture Content (%)	**6.6**	**9.4**	**11.0**	**13.1**	
Dry Density (t/m³)	**1.834**	**1.910**	**2.026**	**1.903**	

Dry Density (t/m³)



Modified Maximum Dry Density (t/m³) **2.03**

Optimum Moisture Content (%) **11.0**

Comments: ***The above air void lines are derived from a calculated apparent particle density of 2.672 t/m³***

Approved Signatory:

Name: Kirk McConachy
Function: Laboratory Manager
Date: 19/March/2020

NATA WORLD RECOGNISED ACCREDITATION

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.6.1.1

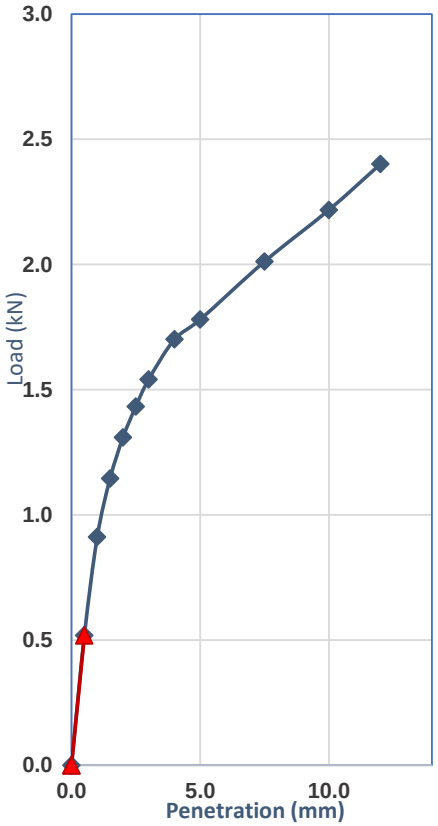
Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4151_1_SCBR
Project:	Proposed Residential Development	*Sample No.*	WG20/4151
Location:	Lots 487, 611 & 615 Arnold Road Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP10, 0.7m	*Date Tested:*	23/03/2020

TEST RESULTS - CALIFORNIA BEARING RATIO

Sample Description: Sandy Clay, trace Gravel

Sampling Method: Sampled by Client, Tested as Received

Load Penetration Curve



Compaction Details			
Compaction Method	AS 1289.5.2.1	Hammer Type	Modified
Plasticity Determined by	Estimated	Curing Time (Hours)	28.0
% Retained 19.0mm	0	Excluded/Replaced	Excluded
Maximum Dry Density (t/m^3)	2.03	Optimum Moisture (%)	11.0
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100

Specimen Conditions At Compaction			
Dry Density (t/m3)	1.93	Moisture Content (%)	11.2
Density Ratio (%)	95.0	Moisture Ratio (%)	100.5

Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.93	Dry Density Ratio (%)	95.0
Moisture Content (%)	13.2	Moisture Ratio (%)	118.0

Specimen Conditions After Test			
Top 30mm Moisture (%)	14.3	Remaining Depth (%)	13.0

Correction applied to Penetration: 0mm

Determined at a Penetration of: 2.5mm

California Bearing Ratio (CBR): 11%

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 24/March/2020

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.7.7.1

Client:	Malf Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4152_1_SSI
Project:	Proposed Residential Development	*Sample No.*	WG20/4152
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP11, 0.9-1.03m	*Date Tested:*	19-23/03/2020

TEST RESULTS - SHRINK SWELL INDEX

Sampling Method: Sampled by Client, Tested as Received

Material Description: Gravelly Clay

SWELL SPECIMEN	
Moisture Content Initial (%):	15.8
Dry Density - Initial (t/m^3):	1.82
Moisture Content Final (%):	17.3
Estimated Inert Inclusions (%):	12

SHRINK SPECIMEN	
Moisture Content Initial (%):	15.3
Extent of Crumbling:	Nil
Length/Diameter Ratio:	2.7
Extent of Cracking:	Slight

SHRINK SWELL INDEX	
Shrink Swell Index (I_{SS})	**1.7**

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

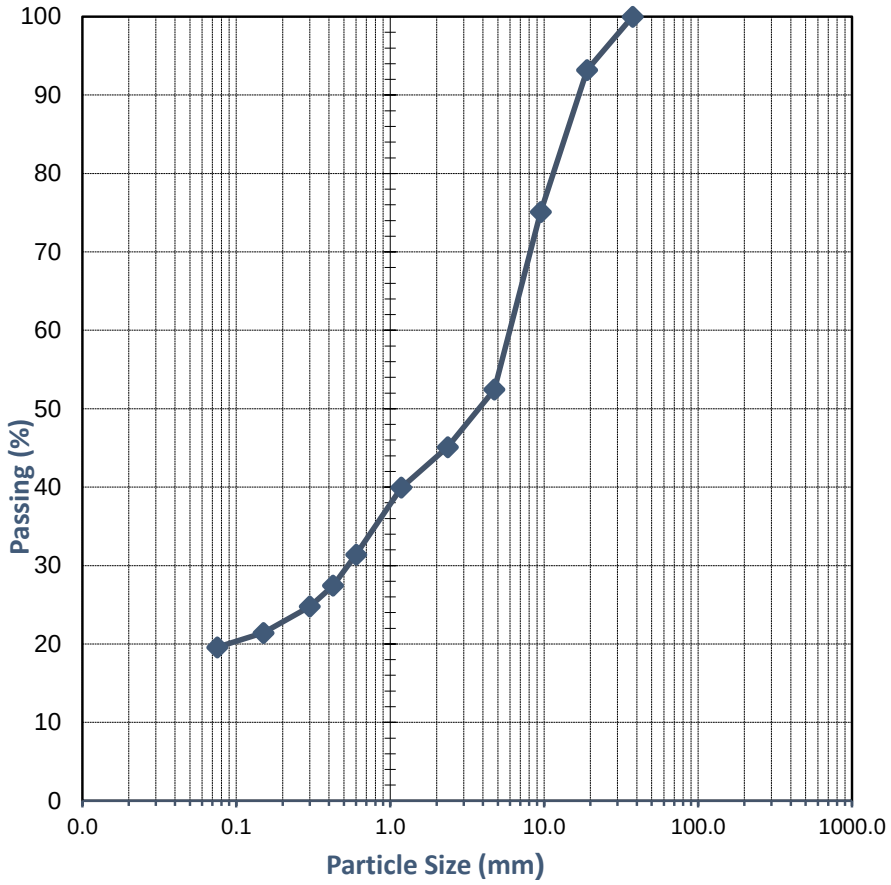
TEST REPORT - AS 1289.1.1 & 3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4153_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4153
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP11, 1.1m	*Date Tested:*	18/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	100
19.0	93
9.5	75
4.75	52
2.36	45
1.18	40
0.600	31
0.425	27
0.300	25
0.150	21
0.075	20



Comments: *AS 1289.1.1- Deviation from standard: Insufficient sample according to test method requirements. NATA accreditation does not cover the performance of this service.

Approved Signatory:

Name: Blank
Function: Blank
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4153_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4153
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP11, 1.1m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**46**
AS 1289.3.2.1	**Plastic Limit (%)**	**19**
AS 1289.3.3.1	**Plasticity Index (%)**	**27**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**9.0**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

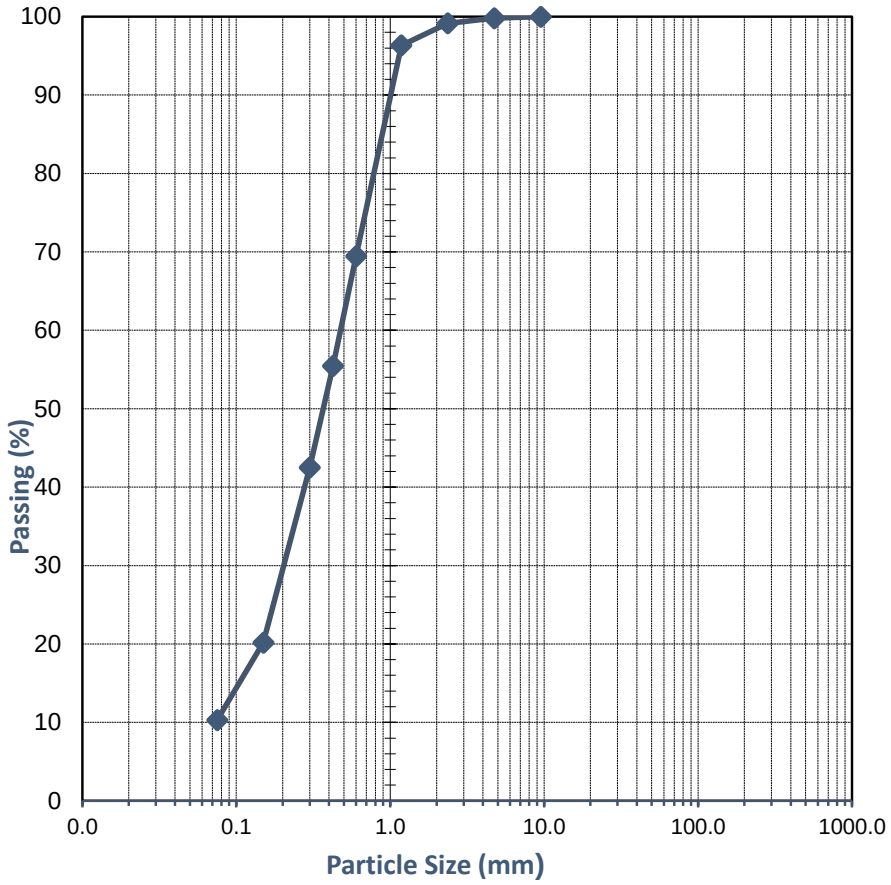
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4154_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4154
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP13, 0.4m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	100
2.36	99
1.18	96
0.600	69
0.425	55
0.300	43
0.150	20
0.075	10



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.5.2.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4154_1_MMDD
Project:	Proposed Residential Dvelopment	*Sample No.*	WG20/4154
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP13, 0.4m	*Date Tested:*	17/03/2020

TEST RESULTS - Modified Maximum Dry Density

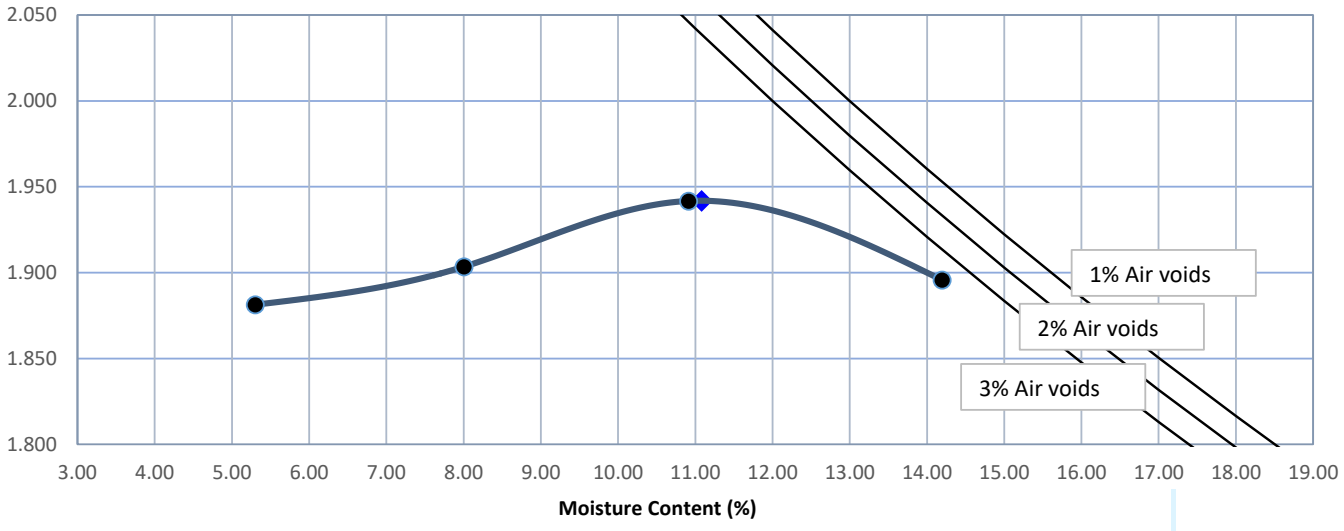
Sampling Method: Sampled by Client, Tested as Received

Sample Curing Time: 2.5 Hours

Method used to Determine Liquid Limit: Visual / Tactile Assessment by Competent Technician

Material + 19.0mm (%): 0 **Material + 37.5mm (%)** -

Moisture Content (%)	**5.3**	**8.0**	**10.9**	**14.2**	
Dry Density (t/m³)	**1.881**	**1.903**	**1.942**	**1.896**	



Modified Maximum Dry Density (t/m³) **1.94**

Optimum Moisture Content (%) **11.0**

Comments: ***The above air void lines are derived from a calculated apparent particle density of 2.74 t/m³***

Approved Signatory:

Name: Kirk McConachy
Function: Laboratory Manager
Date: 19/March/2020

NATA WORLD RECOGNISED ACCREDITATION

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.6.1.1

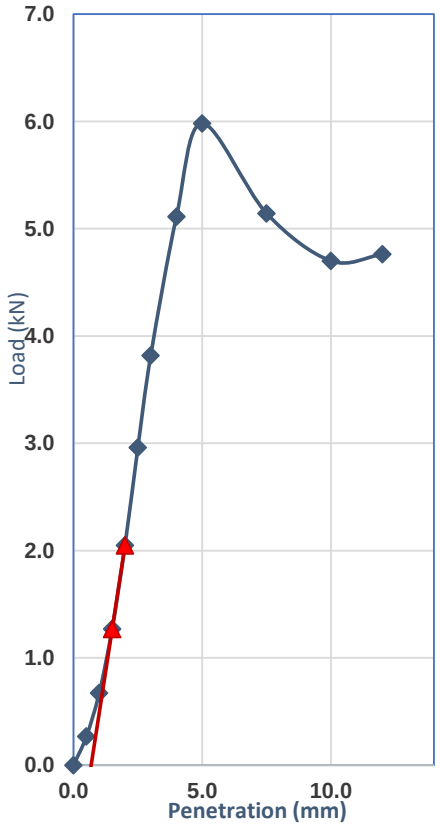
Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4154_1_SCBR
Project:	Proposed Residential Development	*Sample No.*	WG20/4154
Location:	Lots 487, 611 & 615 Arnold Road Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP13, 0.4m	*Date Tested:*	23/03/2020

TEST RESULTS - CALIFORNIA BEARING RATIO

Sample Description: Sand

Sampling Method: Sampled by Client, Tested as Received

Load Penetration Curve



Compaction Details			
Compaction Method	AS 1289.5.2.1	Hammer Type	Modified
Plasticity Determined by	Estimated	Curing Time (Hours)	2.0
% Retained 19.0mm	0	Excluded/Replaced	Excluded
Maximum Dry Density (t/m^3)	1.94	Optimum Moisture (%)	11.0
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100

Specimen Conditions At Compaction			
Dry Density (t/m3)	1.85	Moisture Content (%)	11.0
Density Ratio (%)	95.0	Moisture Ratio (%)	99.0

Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.85	Dry Density Ratio (%)	95.0
Moisture Content (%)	11.3	Moisture Ratio (%)	101.5

Specimen Conditions After Test			
Top 30mm Moisture (%)	11.1	Remaining Depth (%)	10.0

Correction applied to Penetration: 0.7mm

Determined at a Penetration of: 2.5mm

California Bearing Ratio (CBR): 30%

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 24/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

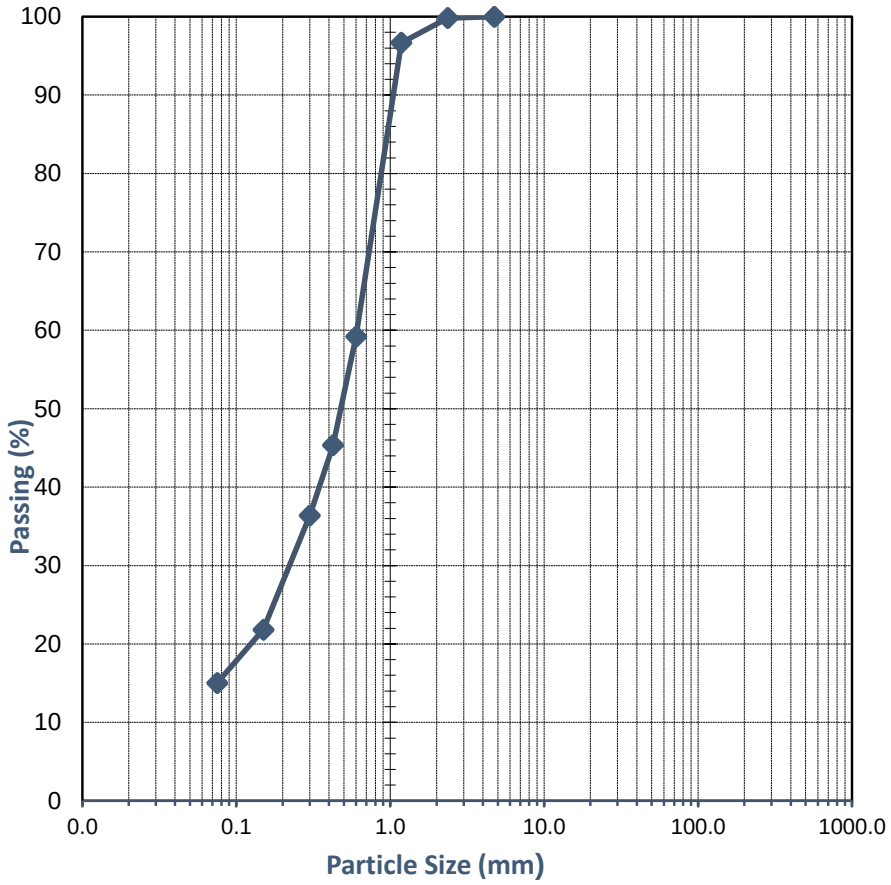
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4155_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4155
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP17, 0.3m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	
4.75	100
2.36	100
1.18	97
0.600	59
0.425	45
0.300	36
0.150	22
0.075	15



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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TEST REPORT - AS 1289.3.8.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4156_1_ECN
Project:	Proposed Residential Development	*Sample No.*	WG20/4156
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP19, 0.3m	*Date Tested:*	19/03/2020

TEST RESULTS - Emerson Class Number

Sampling Method:	**Sampled by Client, Tested as Received**
Source of Material:	**Not Specified**
Soil Description:	**Silty Sand**
Water Used:	**Distilled**

EMERSON CLASS NUMBER

5

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

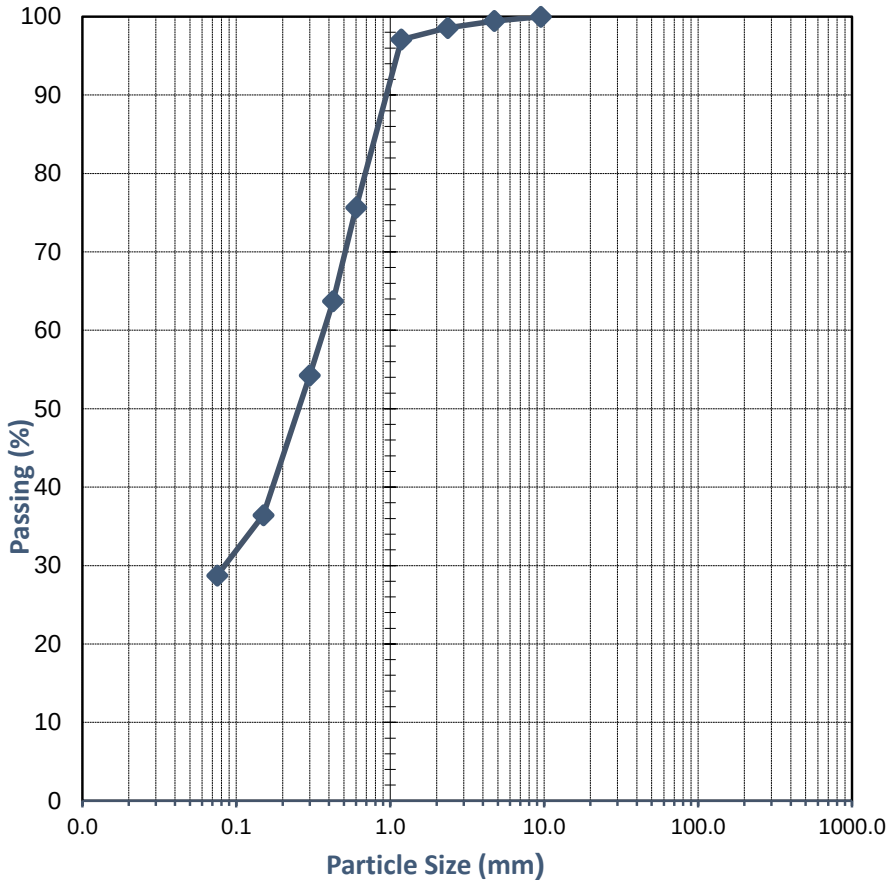
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4157_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4157
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP25, 0.3m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	99
2.36	99
1.18	97
0.600	76
0.425	64
0.300	54
0.150	36
0.075	29



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4157_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4157
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP25, 0.3m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**30**
AS 1289.3.2.1	**Plastic Limit (%)**	**15**
AS 1289.3.3.1	**Plasticity Index (%)**	**15**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**5.5**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.5.2.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4157_1_MMDD
Project:	Proposed Residential Dvelopment	*Sample No.*	WG20/4157
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP25, 0.3m	*Date Tested:*	17/03/2020

TEST RESULTS - Modified Maximum Dry Density

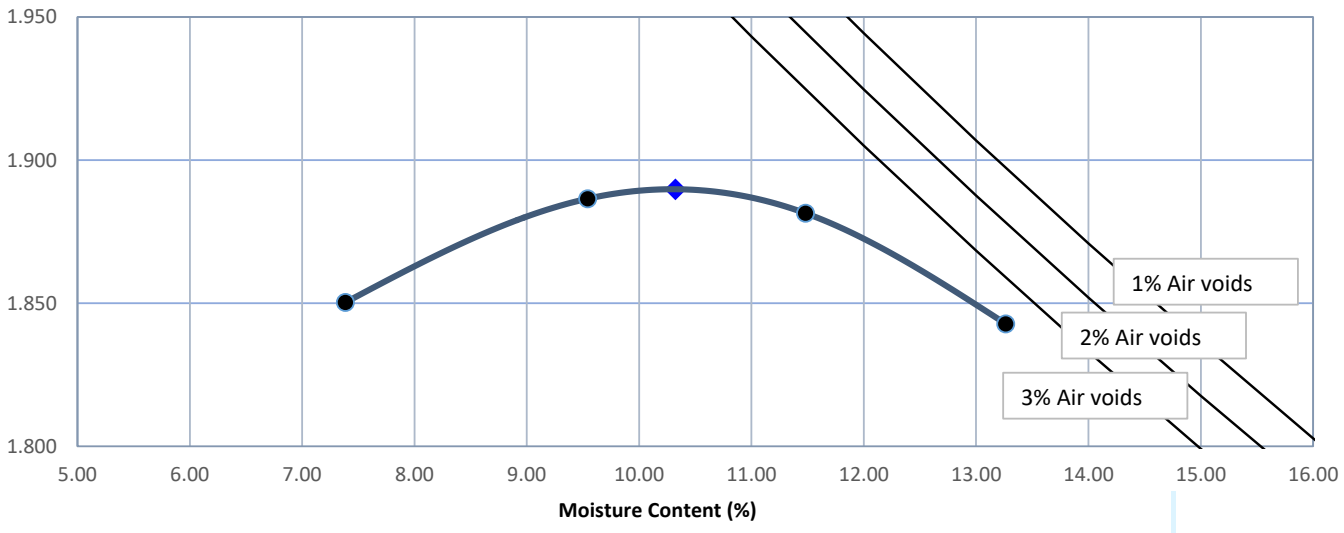
Sampling Method: Sampled by Client, Tested as Received

Sample Curing Time: 6 Hours

Method used to Determine Liquid Limit: Visual / Tactile Assessment by Competent Technician

Material + 19.0mm (%): 0 **Material + 37.5mm (%)** -

Moisture Content (%)	7.4	9.5	11.5	13.3	
Dry Density (t/m³)	1.850	1.887	1.881	1.843	



Modified Maximum Dry Density (t/m³) **1.89**

Optimum Moisture Content (%) **10.5**

Comments: *The above air void lines are derived from a calculated apparent particle density of 2.57 t/m³*

Approved Signatory:

Name: Kirk McConachy
Function: Laboratory Manager
Date: 19/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.6.1.1

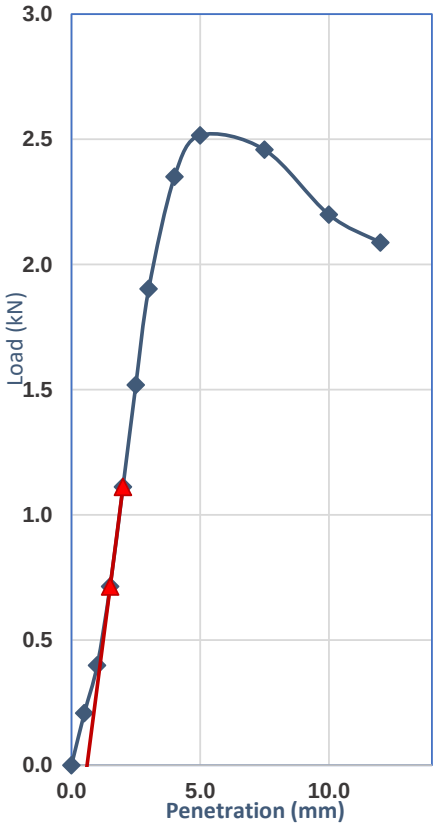
Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4157_1_SCBR
Project:	Proposed Residential Development	*Sample No.*	WG20/4157
Location:	Lots 487, 611 & 615 Arnold Road Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP25, 0.3m	*Date Tested:*	23/03/2020

TEST RESULTS - CALIFORNIA BEARING RATIO

Sample Description: Clayey Sand

Sampling Method: Sampled by Client, Tested as Received

Load Penetration Curve



Compaction Details			
Compaction Method	AS 1289.5.2.1	Hammer Type	Modified
Plasticity Determined by	Estimated	Curing Time (Hours)	26.0
% Retained 19.0mm	0	Excluded/Replaced	Excluded
Maximum Dry Density (t/m^3)	1.89	Optimum Moisture (%)	10.5
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100

Specimen Conditions At Compaction			
Dry Density (t/m3)	1.80	Moisture Content (%)	10.2
Density Ratio (%)	95.5	Moisture Ratio (%)	98.5

Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	1.0
Dry Density (t/m³)	1.78	Dry Density Ratio (%)	94.0
Moisture Content (%)	15.2	Moisture Ratio (%)	147.5

Specimen Conditions After Test			
Top 30mm Moisture (%)	12.2	Remaining Depth (%)	14.6

Correction applied to Penetration: 0.6mm

Determined at a Penetration of: 2.5mm

California Bearing Ratio (CBR): 15%

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 24/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

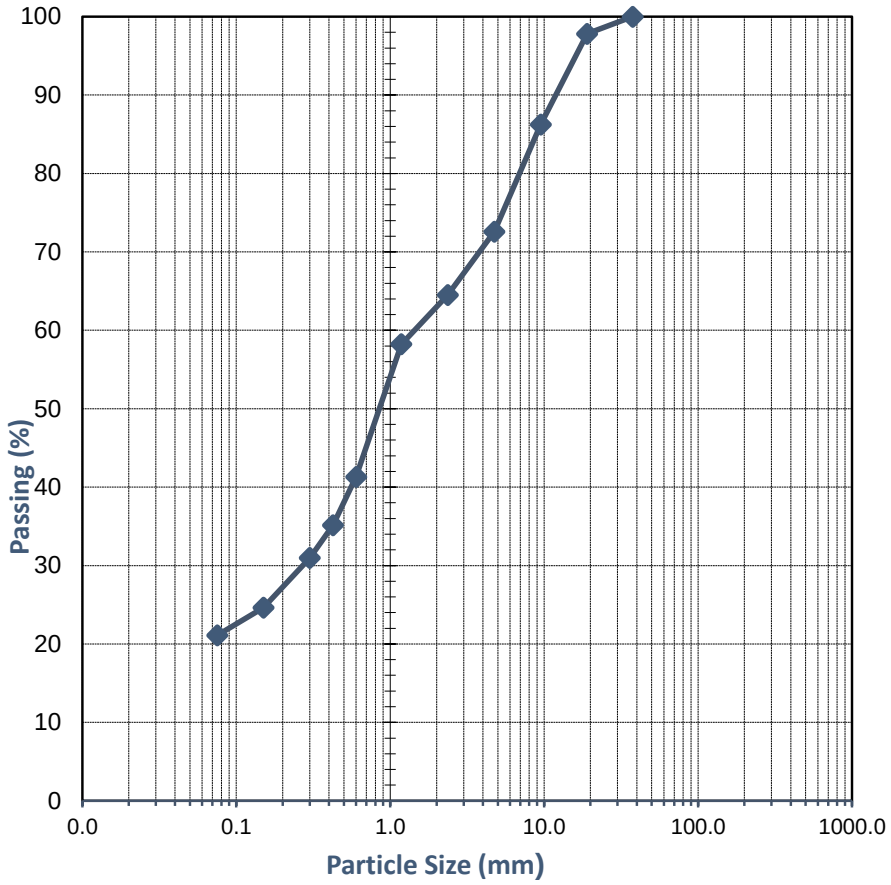
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4158_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4158
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP27, 0.5m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	100
19.0	98
9.5	86
4.75	73
2.36	64
1.18	58
0.600	41
0.425	35
0.300	31
0.150	25
0.075	21



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4158_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4158
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP27, 0.5m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**40**
AS 1289.3.2.1	**Plastic Limit (%)**	**18**
AS 1289.3.3.1	**Plasticity Index (%)**	**22**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**8.0**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.7.7.1

Client:	Malf Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4159_1_SSI
Project:	Proposed Residential Development	*Sample No.*	WG20/4159
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP28, 0.8-0.9m	*Date Tested:*	19-23/03/2020

TEST RESULTS - SHRINK SWELL INDEX

Sampling Method: Sampled by Client, Tested as Received

Material Description: Sandy Clay

SWELL SPECIMEN	
Moisture Content Initial (%):	20.9
Dry Density - Initial (t/m^3):	1.68
Moisture Content Final (%):	20.8
Estimated Inert Inclusions (%):	0

SHRINK SPECIMEN	
Moisture Content Initial (%):	20.4
Extent of Crumbling:	Nil
Length/Diameter Ratio:	2.6
Extent of Cracking:	Nil

SHRINK SWELL INDEX	
Shrink Swell Index (I_{SS})	**1.2**

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

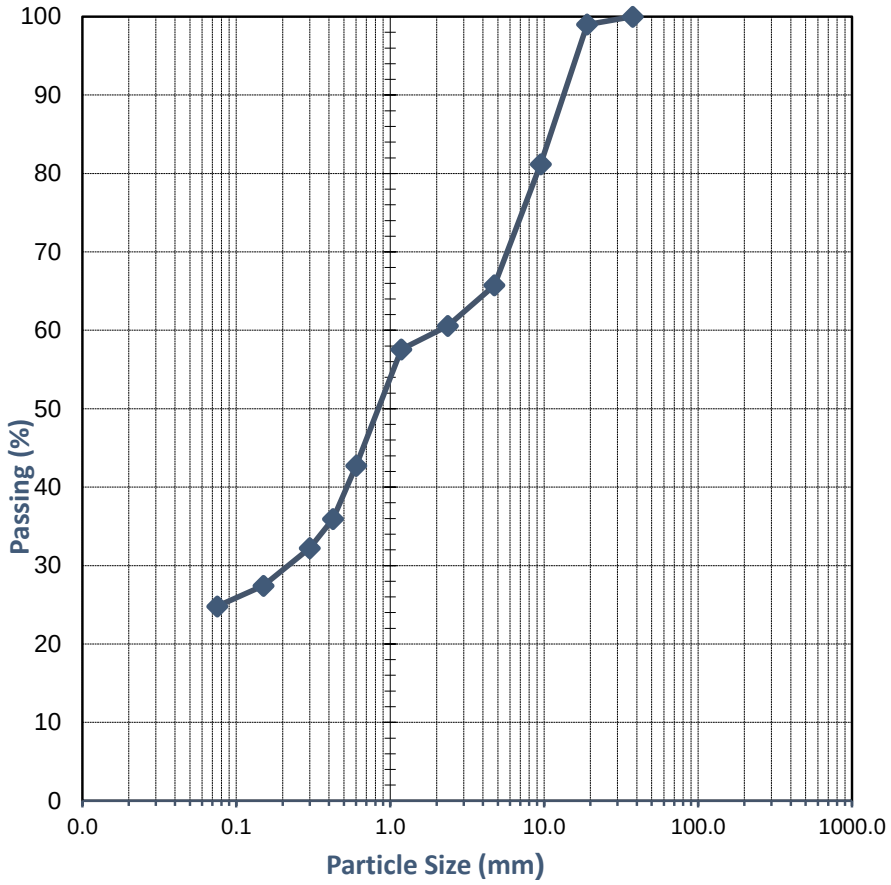
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4160_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4160
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP30, 0.6m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	100
19.0	99
9.5	81
4.75	66
2.36	61
1.18	58
0.600	43
0.425	36
0.300	32
0.150	27
0.075	25



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.8.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4160_1_ECN
Project:	Proposed Residential Development	*Sample No.*	WG20/4160
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP30, 0.6m	*Date Tested:*	19/03/2020

TEST RESULTS - Emerson Class Number

Sampling Method:	**Sampled by Client, Tested as Received**
Source of Material:	**Not Specified**
Soil Description:	**Clayey Sand, with Gravel**
Water Used:	**Distilled**

EMERSON CLASS NUMBER

6

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.5.2.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4160_1_MMDD
Project:	Proposed Residential Dvelopment	*Sample No.*	WG20/4160
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP30, 0.6m	*Date Tested:*	18/03/2020

TEST RESULTS - Modified Maximum Dry Density

Sampling Method: Sampled by Client, Tested as Received

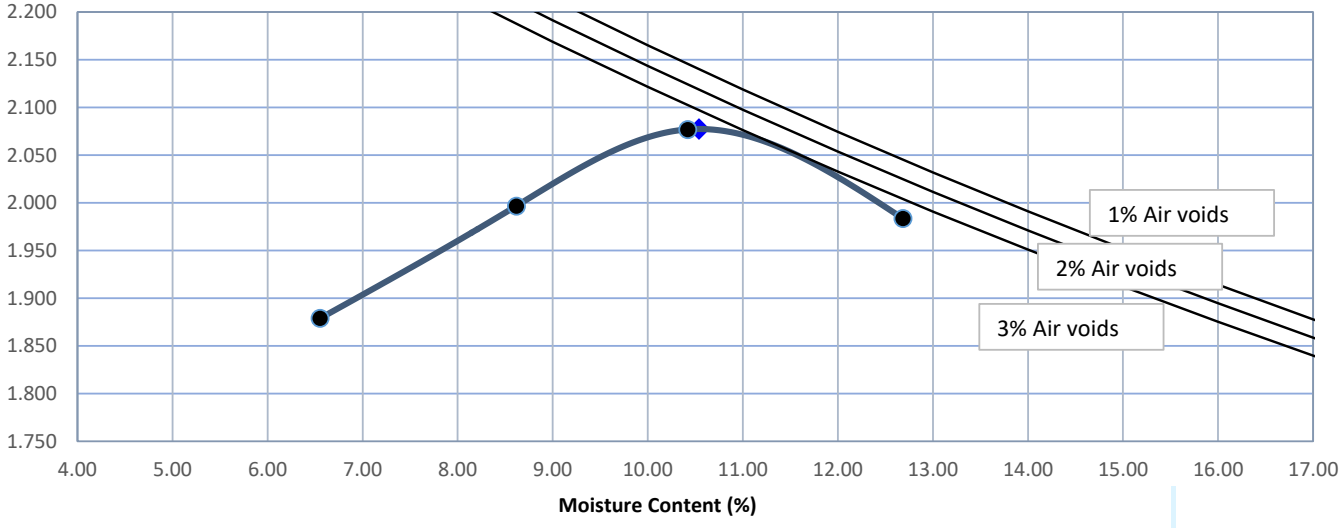
Sample Curing Time: 2 Hours

Method used to Determine Liquid Limit: Visual / Tactile Assessment by Competent Technician

Material + 19.0mm (%): 1 **Material + 37.5mm (%)** -

Moisture Content (%)	**6.6**	**8.6**	**10.4**	**12.7**	
Dry Density (t/m³)	**1.879**	**1.997**	**2.077**	**1.984**	

Dry Density (t/m³)



Modified Maximum Dry Density (t/m³) **2.08**

Optimum Moisture Content (%) **10.5**

Comments: ***The above air void lines are derived from a calculated apparent particle density of 2.799 t/m³***

Approved Signatory:

Name: Kirk McConachy
Function: Laboratory Manager
Date: 19/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.6.1.1

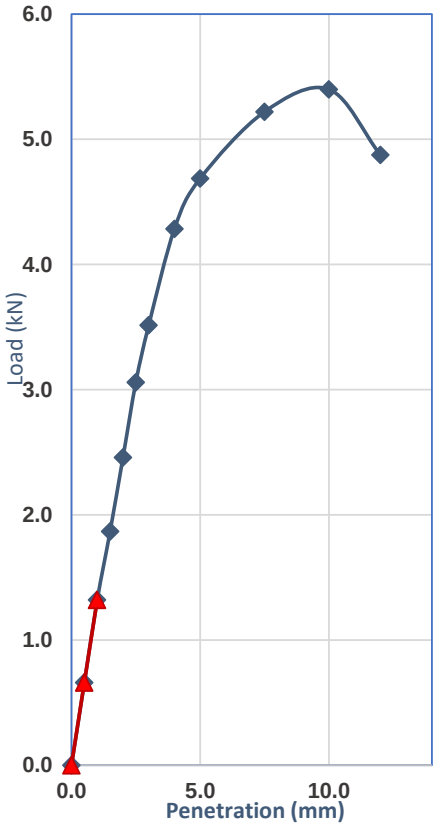
Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4160_1_SCBR
Project:	Proposed Residential Development	*Sample No.*	WG20/4160
Location:	Lots 487, 611 & 615 Arnold Road Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP30, 0.6m	*Date Tested:*	23/03/2020

TEST RESULTS - CALIFORNIA BEARING RATIO

Sample Description: Sandy Clay, with Gravel

Sampling Method: Sampled by Client, Tested as Received

Load Penetration Curve



Compaction Details			
Compaction Method	AS 1289.5.2.1	Hammer Type	Modified
Plasticity Determined by	Estimated	Curing Time (Hours)	27.0
% Retained 19.0mm	1	Excluded/Replaced	Excluded
Maximum Dry Density (t/m^3)	2.08	Optimum Moisture (%)	10.5
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100

Specimen Conditions At Compaction			
Dry Density (t/m3)	1.97	Moisture Content (%)	10.5
Density Ratio (%)	95.0	Moisture Ratio (%)	100.5

Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	1.0
Dry Density (t/m³)	1.95	Dry Density Ratio (%)	94.0
Moisture Content (%)	12.8	Moisture Ratio (%)	121.5

Specimen Conditions After Test			
Top 30mm Moisture (%)	12.1	Remaining Depth (%)	12.0

Correction applied to Penetration: 0mm

Determined at a Penetration of: 5.0mm

California Bearing Ratio (CBR): 25%

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 24/March/2020

NATA WORLD RECOGNISED ACCREDITATION

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

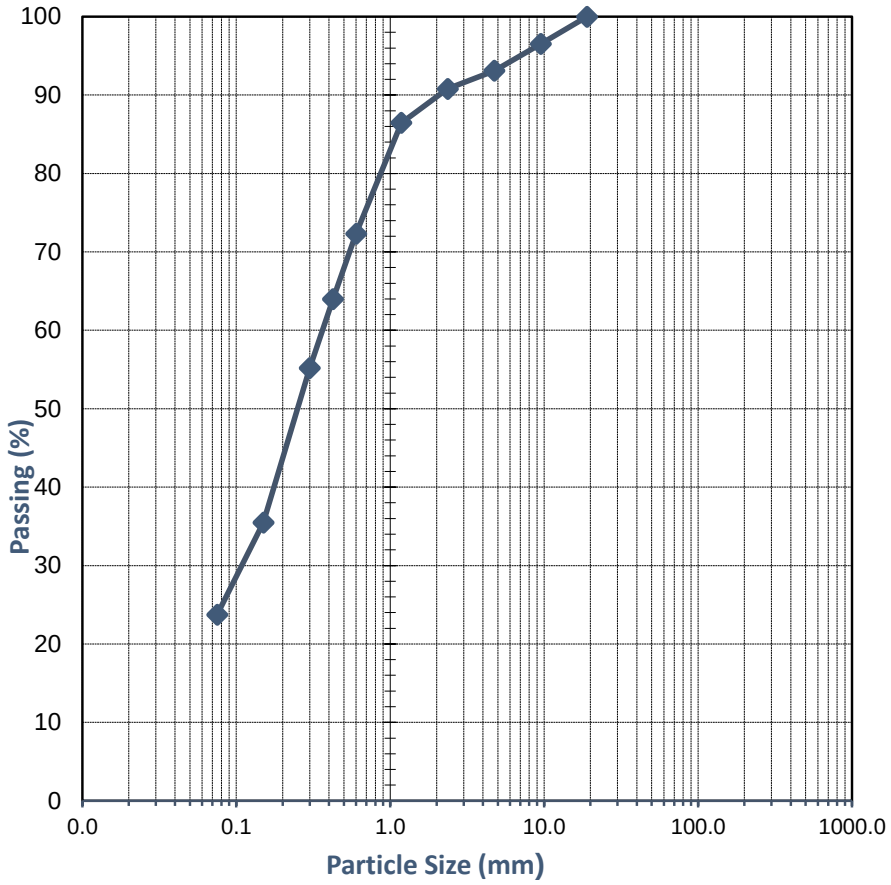
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4161_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4161
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP32, 0.2m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	100
9.5	97
4.75	93
2.36	91
1.18	86
0.600	72
0.425	64
0.300	55
0.150	35
0.075	24



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

Accreditation No. 20599
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Envirolab Services (WA) Pty Ltd trading as MPL Laboratories
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lab@mpl.com.au
www.mpl.com.au

CERTIFICATE OF ANALYSIS 241972

Client Details

Client	Douglas Partners Perth
Attention	Yujun Chen
Address	36 O'Malley St, Osborne Park, WA, 6017

Sample Details

Your Reference	**96660 - Lots 487, 611 & 615**
Number of Samples	4 Soil
Date samples received	17/03/2020
Date completed instructions received	17/03/2020
Location	Arnold Road, Serpentine

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Please refer to the last page of this report for any comments relating to the results.

Report Details

Date results requested by	23/03/2020
Date of Issue	23/03/2020

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Results Approved By
Heram Halim, Operations Manager
Stacey Hawkins, Acid Soils Supervisor

Authorised By



Michael Kubiak, Laboratory Manager

Miscellaneous Inorg - soil					
Our Reference		241972-1	241972-2	241972-3	241972-4
Your Reference	UNITS	TP3, 0.8	TP19, 0.3	TP22, 0.4	TP30, 0.6
Date Sampled		10/03/2020	10/03/2020	10/03/2020	10/03/2020
Type of sample		Soil	Soil	Soil	Soil
Date prepared	-	20/03/2020	20/03/2020	20/03/2020	20/03/2020
Date analysed	-	20/03/2020	20/03/2020	20/03/2020	20/03/2020
pH	pH Units	5.0	5.0	5.1	5.7
Electrical Conductivity (EC)	µS/cm	110	36	13	84

ESP/CEC					
Our Reference		241972-1	241972-2	241972-3	241972-4
Your Reference	UNITS	TP3, 0.8	TP19, 0.3	TP22, 0.4	TP30, 0.6
Date Sampled		10/03/2020	10/03/2020	10/03/2020	10/03/2020
Type of sample		Soil	Soil	Soil	Soil
Date digested	-	20/03/2020	20/03/2020	20/03/2020	20/03/2020
Date analysed	-	20/03/2020	20/03/2020	20/03/2020	20/03/2020
Calcium	mg/kg	180	56	<50	78
Potassium	mg/kg	<50	<50	<50	<50
Magnesium	mg/kg	230	<50	<50	220
Sodium	mg/kg	<50	<50	<50	<50
Aluminium	mg/kg	<10	<10	<10	<10
Exchangeable Ca	meq/100g	0.9	0.3	<0.25	0.4
Exchangeable K	meq/100g	<0.13	<0.13	<0.13	<0.13
Exchangeable Mg	meq/100g	1.9	<0.41	<0.41	1.8
Exchangeable Na	meq/100g	<0.22	<0.22	<0.22	<0.22
Exchangeable Al	meq/100g	<0.07	<0.07	<0.07	<0.07
Cation Exchange Capacity	meq/100g	3	<1	<1	2

Phosphorus Retention Index					
Our Reference		241972-1	241972-2	241972-3	241972-4
Your Reference	UNITS	TP3, 0.8	TP19, 0.3	TP22, 0.4	TP30, 0.6
Date Sampled		10/03/2020	10/03/2020	10/03/2020	10/03/2020
Type of sample		Soil	Soil	Soil	Soil
Phosphorus Retention Index		1,090	1,080	23.3	8.81

Method ID	Methodology Summary
AGRI-003	Phosphorous Retention index (PBI) is equilabration of a sample with a solution containing P in CaCl solution at a soil: solution ratio of 1:10. A portion of the leachate is centrifuged, then an aliquot is diluted with DI water and the resultant solution is analysed for P by DA.
INORG-001	pH - Measured using pH meter and electrode base on APHA latest edition, Method 4500-H+. Please note that the results for water analyses may be indicative only, as analysis can be completed outside of the APHA recommended holding times. Soils are reported from a 1:5 water extract unless otherwise specified.
INORG-002	Conductivity and Salinity - measured using a conductivity cell at 25°C based on APHA latest edition Method 2510. Soils reported from a 1:5 water extract unless otherwise specified.
METALS-009	Determination of exchangeable cations and cation exchange capacity in soils using 1M Ammonium Chloride exchange and ICP-AES analytical finish.
METALS-009	Determination of exchangeable cations and cation exchange capacity in soils using 1M Ammonium Chloride exchange and ICP-AES analytical finish.
METALS-020	Determination of various metals by ICP-AES.

QUALITY CONTROL: Miscellaneous Inorg - soil					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date prepared	-			20/03/2020	[NT]	[NT]	[NT]	[NT]	20/03/2020	[NT]
Date analysed	-			20/03/2020	[NT]	[NT]	[NT]	[NT]	20/03/2020	[NT]
pH	pH Units		INORG-001	[NT]	[NT]	[NT]	[NT]	[NT]	102	[NT]
Electrical Conductivity (EC)	µS/cm	1	INORG-002	<1	[NT]	[NT]	[NT]	[NT]	104	[NT]

QUALITY CONTROL: ESP/CEC						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	241972-2
Date digested	-			20/03/2020	1	20/03/2020	20/03/2020		20/03/2020	20/03/2020
Date analysed	-			20/03/2020	1	20/03/2020	20/03/2020		20/03/2020	20/03/2020
Calcium	mg/kg	50	METALS-020	<50	1	180	170	6	103	#
Potassium	mg/kg	50	METALS-020	<50	1	<50	<50	0	101	#
Magnesium	mg/kg	50	METALS-020	<50	1	230	230	0	105	#
Sodium	mg/kg	50	METALS-020	<50	1	<50	<50	0	100	#
Aluminium	mg/kg	10	METALS-020	<10	1	<10	<10	0	97	#

QUALITY CONTROL: Phosphorus Retention Index						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Phosphorus Retention Index			AGRI-003	[NT]	[NT]	[NT]	[NT]	[NT]	106	[NT]

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

The recommended maximums for analytes in urine are taken from “2018 TLVs and BEIs”, as published by ACGIH (where available). Limit provided for Nickel is a precautionary guideline as per Position Paper prepared by AIOH Exposure Standards Committee, 2016.

Guideline limits for Rinse Water Quality reported as per analytical requirements and specifications of AS 4187, Amdt 2 2019, Table 7.2

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals (not SPOCAS); 60-140% for organics/SPOCAS (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

Samples for Microbiological analysis (not Amoeba forms) received outside of the 2-8°C temperature range do not meet the ideal cooling conditions as stated in AS2031-2012.

Report Comments

Matrix spike recovery was outside recommended acceptance criteria, however an acceptable recovery was achieved for the LCS. This indicates a sample matrix interference.

ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix b

Environmental Assessment & Management Strategy

(Emerge Associates)

Environmental Assessment and Management Strategy

Lot 487, 611 & 615 Arnold Road Serpentine

Project No: EP20-020(01)

Prepared for MALF Corp Pty Ltd
September 2020



Document Control

Doc name:	Environmental Assessment and Management Strategy Lot 487, 611 & 615 Arnold Road Serpentine				
Doc no.:	**EP20-020(01)--003**				
Version	**Date**	**Author**		**Reviewer**	
1	March 2020	Bianca Bertelli	BRB	Chrystal King	CKK
	Submitted to client for review.				
A	April 2020	Bianca Bertelli	BRB	Chrystal King	CKK
	Document updated in response to client comments.				
B	September 2020	Bianca Bertelli	BRB	Chrystal King	CKK
	Document updated with revised structure plan layout.				

Executive Summary

This *Environmental Assessment and Management Strategy* (EAMS) has been prepared on behalf of MALF Corp Pty Ltd ('the proponent') to support a Structure Plan (SP) to enable future rural-residential development. Located within the Shire of Serpentine - Jarrahdale, the proposed Arnold Road SP applies to an area primarily comprised of Lot 487, 611 & 615 Arnold Road Serpentine (an area referred to as 'the site').

This EAMS has been prepared to address the requirements of the Western Australian Planning Commission's (WAPC) *Structure Plan Framework* (WAPC 2015b) to support the preparation and implementation of the structure plan. This report provides a synthesis of information from a range of sources regarding the environmental features, attributes and values of the site.

The site comprises a total area of 61.80 hectares (ha) and is zoned 'Rural Living A' under the Shire of Serpentine-Jarrahdale Town Planning Scheme No. 2 (TPS 2) and 'Rural' and 'Primary Regional Roads' under the Metropolitan Region Scheme (MRS). The site is generally bound by privately owned land to the north, South Western Highway to the east, land proposed as an extension of Maidstone View to the south, adjoining privately owned land, and private residential and future residential landholdings to the west. The site is divided by Arnold Road.

The relevant environmental attributes and values of the site are summarised as follows:

- The majority of the site has been historically cleared to allow for agricultural activities.
- Topography across the site is relatively uniform, with elevation ranging from 32 m Australian Height Datum (m AHD) in the north western portion of the site to 46 m AHD in the south eastern portion of the site
- The entire site is classified as having a moderate to low risk of acid sulfate soils (ASS) occurring within 3 m of the natural soil surface.
- Given historic clearing and associated agricultural land uses, flora and vegetation within the site has been significantly modified, with the entirety of the site identified as being in 'completely degraded' condition in accordance with the Keighery (1994) vegetation condition scale.
- One native plant community was identified within the site '**parkland/cleared'** which comprises a small number of scattered native and non-native trees and shrubs over non-native grassland.
- No threatened ecological communities (TECs) were identified within the site, nor are any likely to occur based on the degraded nature of vegetation within the site.
- No threatened or priority flora species have been identified within the site, nor are any likely to occur based on the degraded nature of vegetation within the site.
- Due to the degraded nature of vegetation within the site, the extent of functional fauna habitat within the site is constrained to a small stand of native marri trees extending over 0.38 ha which is not considered significant habitat due to the limited extent. Vegetation in nearby, adjacent land is considered to provide higher fauna habitat values than that within the site. A total of seven habitat trees were recorded in the site, of which none were observed to contain hollows suitable for nesting by black cockatoos.
- Based on the existing *Geomorphic Wetlands of the Swan Coastal Plain* mapping, one multiple use wetland (MUW) is identified within the site.

- One registered Aboriginal Heritage site has been identified within the site 'Serpentine River' (ID 3582). However, the Department of Planning, Lands and Heritage (DPLH) has advised that while the boundary intersects with the site, the actual boundary of site 3582 does not impinge on the site. Therefore, approval under AH Act is not required in relation to this site.
- Areas of extensive permanent bushfire hazard are located to the north, east and south of the site boundary. These hazards will be retained in the future and therefore need to be considered.

The structure plan design has responded to site-specific environmental considerations where necessary and possible, including accommodation of stormwater management requirements consistent with the Local Water Management Strategy (LWMS). The structure plan design does not specifically provide for the future retention of existing flora, vegetation or fauna habitat values, due to the determined significance of these values through detailed surveys, the small size and fragmented nature of these areas and the ability for vegetation to be retained on lots, given the proposed rural residential development.

This document provides an environmental management strategy to be implemented across the site for future subdivision and development stages. The key components of this management strategy are summarised as follows.

- Acid sulfate soils: completion of an ASS self-assessment form, and if necessary, the preparation of an Acid Sulfate Soil and Dewatering Management Plan (ASSDMP). However, given the depth to groundwater within the site, ASS investigations and management considerations for the site are unlikely to be required at subdivision.
- Native vegetation: completing a detailed analysis of the final development design and bulk earthworks requirements, to confirm any potential retention opportunities. Where clearing of vegetation is proposed, a clearing permit will need to be attained pursuant to Part V of the *Environmental Protection Act 1986* (unless a valid exemption applies).
- Hydrology: stormwater management requirements as outlined within the LWMS will be implemented through an Urban Water Management Plan (UWMP) for each stage of future subdivision.
- Bushfire risks: To respond to the known bushfire hazards within and surrounding the site future development will be in accordance with the currently prepared BMP (Emerge Associates 2020) This assumed that public open space (POS) and the Hardy's Creek Main Drainage corridor within the site will be classified as Grassland (Class G) vegetation in the post development scenario and that areas of 'extreme' bushfire hazard surrounding the site with environmental values area fully retained in the future.

Overall, the environmental attributes and values of the site can be accommodated within the structure plan design, or can be managed appropriately through the future subdivision and development phases in line with the relevant state and local government legislation, policies and guidelines and best management practices.

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Appendices

Appendix A

Proposed Structure Plan (CDP Town Planning & Urban Design 2020)

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1 Introduction

1.1 Background

MALF Corp Pty Ltd (the proponent) have prepared the Arnold Road Proposed Structure Plan (SP) to guide rural-residential across Lots 487, 611 & 615 Arnold Rd, Serpentine (the 'site'). The proposed SP is provided in **Appendix A** and features 52 rural-residential lots ranging in size from 1 to 1.28 hectares (ha). The site is located within the Shire of Serpentine-Jarradale, approximately 45 km to the south-east of the Perth Central Business District (CBD), as shown in **Figure 1**.

The site comprises a total area of 61.80 hectares (ha) and is zoned 'Rural Living A' under the Shire of Serpentine-Jarrahdale Town Planning Scheme No. 2 (TPS 2) and 'Rural' and 'Primary Regional Roads' under the Metropolitan Region Scheme (MRS). The site contains a portion of the South Western Highway road reservation along the north-eastern boundary. The site is bounded to the west, north and east by mixed land uses including broadacre grazing, small rural lots and rural residential lots. The Serpentine townsite is located approximately 300 m to the west, while the Serpentine Falls Lifestyle Village is located approximately 160 m to the north-east. The site is divided by Arnold Road. The land immediately west of the site is planned for residential development as part of the draft Serpentine Town Site Structure Plan (Department of Planning, 2014). The land use zoning of the site and surrounding locality is shown in **Plate 1** below.

The site is currently used for broadacre cattle grazing and has historically been cleared of native vegetation, with a review of aerial imagery indicating that this clearing occurred prior to 1965 for agricultural uses, including grazing. A small stand of trees surrounding an existing shed within the eastern portion of the site adjacent to South Western Highway and Arnold Road has been retained.

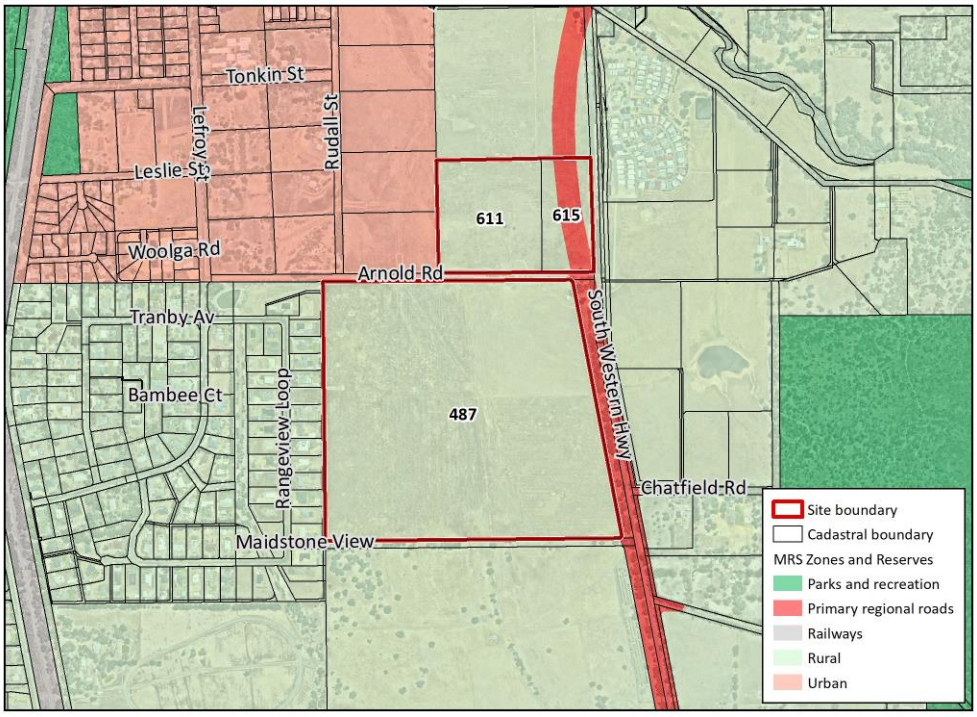

Plate 1: Region scheme zones and reserves surrounding the site (DPLH 2018)

1.2 Purpose of this report

The purpose of this Environmental Assessment and Management Strategy (EAMS) is to provide a synthesis of information regarding the environmental values and attributes of the site. Specifically, this report:

- Identifies the existing environmental values and attributes of the site (**Section 2**)
- Discusses the land use planning context and the proposed SP (**Section 3**)
- Discusses how the SP design responds to the existing environment and outlines the future environmental management framework (**Section 4**)
- Outlines how the environmental management framework will be implemented (**Section 5**)

The EAMS is the key supporting environmental document for the SP process, to ultimately facilitate the consideration of any environmental issues by the various local and state government agencies and authorities. It is consistent with the Western Australian Planning Commission's *Structure Plan Framework* (WAPC 2015b).

1.3 Scope of work

Emerge Associates (Emerge) were engaged by the proponent to undertake an environmental assessment to document the existing environmental attributes and values of the site and ensure any relevant environmental values can be accommodated within the SP. This involved utilising a range of information sources including local and regional reports, databases, mapping and site-specific investigations. The outcomes of these findings include information on the following attributes:

- Landforms, topography and soils
- Flora and vegetation
- Terrestrial fauna
- Hydrology
- Aboriginal and non-indigenous heritage
- Historical and existing land uses within and surrounding the site
- Bushfire hazards.

In addition to the preparation of this EAMS, Emerge have prepared or commissioned the following documentation to support the proposed SP:

- Reconnaissance Flora, Vegetation and Fauna survey, included within this EAMS
- Bushfire Management Plan (Emerge Associates 2020).

The proponent has also commissioned several documents to support the proposed SP:

- Local Water Management Strategy (Bayley Environmental Services 2016)
- Local Water Management Strategy Addendum (RPS 2020)
- Acoustic Assessment (Herring Storer Acoustics 2020).

2 Existing Environment

2.1 Landform and soils

2.1.1 Topography

The site is generally flat, with elevation ranging from 32 m Australian Height Datum (m AHD) in the north western portion of the site to 46 m AHD in the south eastern portion of the site (DoW 2008). The topographical characteristics of the site are shown in **Figure 1.**

2.1.2 Landform, soils and geology

Regional soil association mapping indicates that the entirety of the site occurs within the Pinjarra Zone (Churchward and McArthur 1980). Based on regional landform mapping of the Swan Coastal Plain (Gozzard 2011), the majority of the site is located in within the Pinjarra Plain with the southern portion located within the Forrestfield Complex.

The Geological Survey of Western Australia, as documented in *Perth Metropolitan Region 1: 50,000 Environmental Geology Series Armadale Part Sheets 2033 I & 2133 IV* (Jordan 1986) indicates the majority of the site is comprised of 'Semi-wet soil' (213Pj__P1a) and 'Duplex sandy gravel' (213Fo__F2b). The general descriptions of these soil units are provided in **Table 1** and their extent is shown in **Figure 2.**

Table 1: Environmental geology of the site

Map unit	Description
213Pj__P1a	Flat to very gently undulating plain with deep acidic mottled yellow duplex soils. Shallow pale sand to sandy loam over clay; imperfect to poorly drained and generally not susceptible to salinity
213Pj__P4	Poorly drained flats, sometimes with Gilgai microrelief and with moderately deep to deep black and grey cracking clays, less commonly non-cracking friable clays with acid subsoils.
213Fo__F2b	Low slopes and foot slopes up to 5-10% with well drained moderately deep to deep, gravelly acidic yellow duplex soils and rare laterite.

2.1.3 Acid sulfate soils

Acid sulfate soils (ASS) is the name commonly given to naturally occurring soils and sediment containing iron sulphide (iron pyrite) materials. In their natural state, ASS are generally present in waterlogged anoxic conditions and do not present any risk to the environment. ASS can present issues when oxidised, producing sulphuric acid, which can impart a range of impacts on the surrounding environment, infrastructure and human health. Projects involving the disturbance of ASS must therefore assess the risk associated with disturbance by considering potential impacts.

The Department of Water and Environment Regulation (DWER) provides broad-scale mapping indicating areas of potential ASS risk (DWER 2018). A review of the DWER mapping indicates that the majority of the site is classified as having a moderate to low risk of ASS occurring within 3 m of the natural soil surface, as shown in **Figure 3.**

2.2 Biodiversity and natural assets

2.2.1 Flora and vegetation

2.2.1.1 Regional context

Native vegetation is described and mapped at different scales in order to illustrate patterns in its distribution. At a continental scale the *Interim Biogeographic Regionalisation of Australia* (IBRA) divides the Swan Coastal Plain into two floristic subregions (Environment Australia 2000).

The site is contained within the Perth subregion of the Swan Coastal Plain, which is characterised as mainly containing *Banksia* low woodland on leached sands with *Melaleuca* swamps where ill-drained; and woodland of *Eucalyptus gomphocephala* (tuart), *E. marginata* (jarrah) and *Corymbia calophylla* (marri) on less leached soils (Beard 1990).

At a regional scale, vegetation complex mapping undertaken by Heddle *et al.* (1980) indicates the majority of the site occurs within the Forrestfield Complex with a small portion within the Guildford Complex, the description of which is detailed in **Table 2**. In 2018, there was 12.29% of the pre-European extent of the Forrestfield Complex and 5.09% of the Guildford Complex remaining on the Swan Coastal Plain (Government of Western Australia 2019).

Table 2: Regional vegetation complex descriptions (Heddle et al. 1980)

Complex	Description
Forrestfield Complex	Open forest *of Corymbia calophylla*, *Eucalyptus wandoo*, *E. marginata* to open forest of *E. marginata*, *Corymbia calophylla*, *Allocasuarina fraseriana* and *Banksia* spp. Fringing woodland of *E. rudis* in the gullies that dissect this landform.
Guildford Complex	A mixture of open forest to tall open forest of *Corymbia calophylla*, *Eucalyptus wandoo*, *E. marginata* and woodlands of *E. wandoo.* Minor occurrences of *E. rudis and Melaleuca rhaphiophylla.*

2.2.1.2 Site specific surveys and investigations

A Reconnaissance Flora and Vegetation Assessment was carried out by an environmental consultant from Emerge Associates on the 12 March and 1 April 2020.

2.2.1.3 Plant communities

One plant community was identified within the site. Plant community **Parkland/cleared** exists over the entire site. This community comprises a small number of scattered native and non-native trees and shrubs such as *Corymbia calophylla* (marri) and *Ficus* sp. over non-native grassland.

A description and the total extent of the plant community identified within the site is provided in **Table** 3 with representative photograph provided in **Plate 2**.

Table 3: Plant communities identified within the site

Plant community	Description	Area (ha)
Parkland/ cleared	Heavily disturbed areas comprising weeds with occasional native trees and planted vegetation (**Plate 2).**	61.79



*Plate 2: Plant community **parkland/cleared** in 'completely degraded' condition*

2.2.1.4 Vegetation condition

The vegetation condition was assessed using methods from Keighery (1994). The entire site supports primarily non-native vegetation in 'completely degraded' condition due to the low number and cover of native species.

The extent of vegetation by condition category is detailed in **Table 4** and shown in **Figure 5**.

Table 4: Vegetation condition categories within the site

Condition category (Keighery (1994))	Size (ha)
Pristine	0
Excellent	0
Very Good	0
Good	0
Degraded	0
Completely Degraded	61.79

2.2.1.5 Threatened and Priority Ecological Communities

Generally, ecological communities can be described as groups of native plants, animals and other organisms that occur together in a particular type of habitat. An ecological community's structure, composition and distribution are determined by a range of environmental factors. 'Threatened ecological communities' (TECs) are ecological communities that are recognised as rare or under threat and therefore warrant special protection.

Selected TECs are afforded statutory protection at a Commonwealth level under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). TECs listed under the EPBC Act are categorised as either 'critically endangered', 'endangered' or 'vulnerable'. Any action likely to have a significant impact on a TEC listed under the EPBC Act requires approval from the Commonwealth Minister for the Environment.

Within Western Australia, TECs are protected under the BC Act and the BC Regulations. TECs are determined by the Western Australian Threatened Ecological Communities Scientific Advisory Committee and endorsed by the Minister for the Environment. Somewhat confusingly no TECs have been formally listed under the BC Act and so, while protected under legislation, the significance of TECs is currently best acknowledged through other State environmental approval processes such as the Environmental Impact Assessment pursuant to Part IV of the *Environmental Protection Act 1986* (EP Act) and the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004* pursuant to Part V of the EP Act.

An ecological community under consideration for listing as a TEC in Western Australia, but which does not yet meet survey criteria or has not been adequately defined, or which is rare but not currently threatened, is referred to as a 'priority ecological community' (PEC). Whilst PECs are not afforded statutory protection in Western Australia, they are considered during the approval process.

A search of State and Commonwealth TEC and PEC databases was completed prior to the reconnaissance flora and vegetation survey. These database searches indicated that multiple TECs and PECs have previously been recorded within 10 km of the site. However, in consideration of the existing environment of the site, none of these TECs or PECs occur within the site.

2.2.1.6 Significant flora

Certain flora taxa that are considered to be rare or under threat warrant special protection under Commonwealth and/or State legislation. At a Commonwealth level, flora taxa may be listed as 'threatened' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Threatened flora species listed under the EPBC Act are assigned a conservation status according to attributes such as population size and geographic distribution. Any action likely to have a significant impact on a taxon listed under the EPBC Act requires approval from the Commonwealth Minister for the Environment and Energy.

In Western Australia flora species may also be classed as 'threatened' under the *Biodiversity Conservation Act 2016* (BC Act). It is an offence to 'take' or 'disturb' threatened flora listed under the BC Act without Ministerial approval.

Flora species that do not currently meet the criteria for listing as threatened but are potentially rare or threatened may be added to the DBCA's *Priority Flora List*. These species are classified into 'priority' levels based on threat. Whilst priority species are not under direct statutory protection, they are considered during State approval processes.

A search of State and Commonwealth listed threatened and priority flora databases was completed prior to the reconnaissance flora and vegetation survey. These database searches indicated that multiple species of conservation significance have the potential to occur within 10 km of the site. However, in consideration of the existing environment of the site, none of these species were identified as potentially occurring within the site.

2.2.2 Terrestrial fauna

2.2.2.1 Site specific surveys and investigations

A Level 1 Fauna Survey in combination with a targeted black cockatoo assessment was carried out by personnel from Emerge Associates on the 12 March and 1 April 2020, to determine the fauna values within the site.

2.2.2.2 Species of conservation significance

Certain fauna taxa that are considered to be rare or under threat warrant special protection under Commonwealth and/or State legislation. At a Commonwealth level, fauna taxa may be listed as 'threatened' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Any action likely to have a significant impact on a taxon listed under the EPBC Act requires approval from the Commonwealth Minister for the Environment and Energy.

In Western Australia fauna species may also be classed as 'threatened' under the *Biodiversity Conservation Act 2016* (BC Act). It is an offence to 'take' or 'disturb' threatened fauna without Ministerial approval.

Threatened fauna species listed under the EPBC Act and/or BC Act are assigned a conservation status according to attributes such as population size and geographic distribution.

Fauna species that do not currently meet the criteria for listing as threatened but are potentially rare or threatened may be added to the Department of Biodiversity, Conservation and Attractions (DBCA) *Priority Fauna List*. These species are classified into 'priority' levels based on threat. Whilst priority species are not under direct statutory protection, they are considered during State approval processes.

Migratory fauna species that migrate to Australia and its external territories, or pass though or over Australian waters during their annual migrations warrant special protection under Commonwealth and State legislation. At a Commonwealth level, migratory fauna taxa may be listed as 'migratory' under *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Any action likely to have a significant impact on a taxon listed under the EPBC Act requires approval from the Commonwealth Minister for the Environment and Energy.

In Western Australia migratory fauna taxa may be listed as 'specially protected species' and classed as 'migratory' under the *Biodiversity Conservation Act 2016* (BC Act).

The term 'pest fauna' can refer to any animal that requires some form of action to reduce its effect on the economy, the environment, human health and amenity. Many non-native fauna species and some fauna species native to Australia but not Western Australia are considered to be pest fauna.

A particularly invasive or detrimental pest species may be listed as a 'declared pest' pursuant to Western Australia's *Biosecurity and Agriculture Management Act 2007* (BAM Act), indicating that it warrants special management to limit its spread. At a National level, pest fauna may be listed as 'Established Pests and Diseases of National Significance' (EPDNS) under the *Australian Pest Animal Strategy (2017-2027) (DoA 2017)*.

A search of State and Commonwealth listed threatened, priority and other conservation significant fauna databases was completed prior to the field survey.

Based on these desktop results and taking into account the habitat requirements of individual fauna species, the following eleven fauna species of conservation significance were considered 'likely' or 'possible' to occur within the site:

- *Apus pacificus* (Pacific swift)
- *Calyptorhynchus banksii naso* (forest red-tailed black cockatoo)
- Calyptorhynchus baudinii (Baudin's cockatoo)
- Calyptorhynchus latirostris (Carnaby's cockatoo)
- *Falco peregrinus* (peregrine falcon)
- Isoodon fusciventer (quenda)

None of these species or any other conservation significant fauna were recorded within the site during the field survey. With the exception of the three species of black cockatoo mentioned above (from herein referred to collectively as 'black cockatoos' and further discussed in **Section 2.2.2.4** below) the site is likely to be primarily utilised by common and widespread native and non-native fauna species. The likelihood that the site would provide important habitat for any fauna species of conservation significance is low, given the site primarily comprises cleared areas and non-native vegetation which support low fauna habitat values.

2.2.2.3 Fauna habitat

As part of the fauna assessment, fauna habitats were described according to the dominant flora species and vegetation type present. While the majority of the site currently comprises cleared areas used for grazing, a total of two fauna habitats were identified within the site as listed and described in **Table 5** and shown in **Figure 6**.

The highest natural fauna habitat value within the site is associated with '**Scattered native and non-native trees and shrubs**' which contains a small stand of native marri trees. However, habitat value is still low given the limited extent of this vegetation within the site (0.38 ha) and the lack of understorey plant species. The remainder of the site (61.42 ha) comprises '**parkland/ cleared**' areas which support very low fauna habitat values due to the removal most or all native vegetation. Much

of the canopy mapped as **Scattered native and non-native trees and shrubs** is also associated with trees that are located outside. These trees would not be impacted by development within the site.

Table 5: Fauna habitats identified within the site.

Fauna habitat classification	Description	Area (ha)
Scattered native and non-native trees and shrubs	Isolated *Corymbia calophylla* trees over non-native shrubs (or absent) and non-native grassland.	0.38
Parkland/ cleared	Heavily disturbed areas comprising primarily non-native grassland, as well as, bare and sealed areas including tracks and building structures.	61.42

2.2.2.4 Black cockatoo habitat

Breeding habitat

Trees of species known to support breeding by black cockatoos that are located within the known range of black cockatoos and either have a suitable nest hollow or are of a suitable diameter at breast height (DBH) to support future hollow formation, are considered breeding habitat trees (from herein referred to as 'habitat trees'). A total of seven habitat trees were recorded in the site, of which none were observed to contain hollows suitable for nesting by black cockatoos as shown in **Figure 6**.

No confirmed Carnaby's cockatoo breeding sites, as mapped by DEC (2011) with a 12 km buffer, are located near the site. The closest confirmed Carnaby's cockatoo breeding site buffer is located approximately 20 km north-east of the site.

Roosting habitat

The site contains only a very limited number of trees that could provide potential roosting habitat for black cockatoos. No evidence of roosting was observed.

Records of black cockatoo roosting sites across south-west Western Australia are maintained by Birdlife Australia, utilising annual community surveys as part of the *Great Cocky Count* (GCC). Based on the most recently published 2019 GCC report, the site does not contain any confirmed black cockatoo roosting sites.

A number of potential roost sites are mapped as occurring near the site. However, no birds have been recorded at most of these sites. The closest known roost sites where birds have been recorded are located approximately 1.5 km and 2 km north of the site. These roost sites are associated with forest red-tailed black cockatoos. The closest roost site where Carnaby's and/or Baudin's cockatoos were recorded is located approximately 5 km south-east of the site.

It is considered unlikely that roosting would occur, given there is no historical roosting and that only a small extent of potential roosting habitat is present.

Foraging habitat

Foraging habitat within the site is generally limited and patchily distributed throughout the site. The areas mapped as foraging habitat within the site primarily relate to vegetation containing marri trees which are consumed by all three species of black cockatoo. The foraging habitat extends over approximately 0.38 ha including canopy that over hangs into the site form trees that occur outside of the site boundary and is shown in **Figure 6**. It is not considered that the site provides important foraging habitat, given its small extent and presence of extensive areas of higher quality foraging habitat near the site within the Darling Scarp.

2.2.3 Bush Forever

The Government of Western Australia's Bush Forever policy is a strategic plan for conserving regionally significant bushland within the Swan Coastal Plain portion of the Perth Metropolitan Region. The objective of Bush Forever is to protect comprehensive representations of all original ecological communities by targeting a minimum of 10% of each vegetation complex for protection (Government of WA 2000). The Bush Forever policy is only applicable within the boundary of the Metropolitan Region Scheme (MRS).

Bush Forever Site 468 'Serpentine National Park and Adjacent Bushland' is located 470 m to the east of the site and Bush Forever site 375 'Byford to Serpentine Rail/Road Reserves' is located 600 m to the north west of the site, as shown in **Figure 8.**

2.2.4 Ecological linkages

Ecological or biodiversity linkages are described as areas of native vegetation which provide a corridor or linkage (typically linear) between patches of vegetation to allow movement of flora and fauna and their genetic material through the landscape, helping to maintain metapopulations. Ecological linkages are often continuous or near-continuous as the more fractured a linkage is, the less ease flora and fauna have in moving within the corridor (Alan Tingay and Associates 1998).

The Perth Biodiversity Project, supported by the Western Australia Local Government Association (WALGA), has identified and mapped regional ecological linkages within the Perth Metropolitan Region (PBP 2007).

There are no ecological linkages mapped as occurring within the site, however two regional ecological linkages are mapped as occurring adjacent to the east and west, as shown in **Figure 8.** These ecological linkages extend in a north – south direction and includes several Bush Forever sites. The site is not considered to contribute to or provide any significant ecological linkages functionality, particularly due to the lack of environmental values within the broader site.

2.2.5 Environmentally sensitive areas

Within Western Australia, the clearing of native vegetation can only be undertaken once a Clearing Permit has been attained under Part V of the EP Act, or if the clearing activity is in accordance with a valid exemption, including:

- Exemptions listed in Schedule 6 of EP Act. These include, but are not limited to:
  - Clearing undertaken in accordance with a subdivision approval
  - Clearing that is required under other laws (for example, Local Governments may require landholders to establish and maintain firebreaks under the *Bush Fires Act 1954*).
- Exemptions listed in the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004* (the Regulations). These are associated with low impact land management practices and include, but are not limited to:
  - Clearing to allow for the construction of fence-lines
  - Clearing for vehicular and walking tracks
  - Burning to reduce fire hazards
  - The collection of firewood.

'Environmentally sensitive areas' (ESAs) are prescribed under the Regulations to protect native vegetation values in proximity to significant threatened flora, ecological communities, wetlands or ecosystems. Within ESAs, exemptions listed in the Regulations (i.e. those associated with low impact land management practices) do not apply and a Clearing Permit is required to undertake such clearing activities. The relevance of ESAs is limited to this specific context.

One ESA intersects with the eastern portion of the site, and extends to the east of the site. This is likely to be associated with Bush Forever Site 468, in addition to the mapped extent of a Threatened Ecological Community (TEC). The extent of the ESA is shown in **Figure 8.** The portion of the site mapped as occurring within an ESA is not considered to contribute to or provide any significant environmental values of retention significance.

2.3 Shire of Serpentine – Jarrahdale Local Biodiversity Strategy

The *Shire of Serpentine – Jarrahdale Local Biodiversity Strategy* (Ironbark Environmental 2008) was prepared to to protect local areas of bushland, wetlands and vegetated waterways, especially where they have significant ecological features within the *Shire of Serpentine – Jarrahdale*. The Strategy's main vision is to; '*retain, protect and manage a connected network of over 5800 hectares of natural areas throughout the Shire so that these areas are found to be healthy and resilient in 2050*'. This vision would be achieved through the following four goals:

- Prevent the further loss of Local Natural Areas. This goal aims to retain at least 4000 hectares of Local Natural Areas in the Shire.
- Protect and manage a portion of each basic type of vegetation and ecosystem typical of the Shire. Approximately 1690 hectares of Local Natural Area would be protected to meet this goal.
- Protect specific ecological features and processes including rare species, threatened ecological communities, wetland vegetation and ecological linkages throughout the Shire.
- Manage and restore Local Natural Areas and revegetate new areas to increase native fauna habitat.

The Strategy focuses on the protection and management of natural areas as the foundation of protecting biodiversity. In this report the term 'natural areas' is used to describe an area that contains native species or communities in a relatively natural state and hence these areas comprise

'biodiversity'. To complement the protection of natural areas, the Shire revegetation of waterways, retention of mature trees and other sustainable land development practices.

The site is not mapped as occurring with a Shire of Serpentine- Jarrahdale 'Local Natural Area' and the entirety of the site comprises parkland cleared vegetation in 'completely degraded' condition which was not considered to support a high level of biodiversity.

2.4 Hydrology

2.4.1 Groundwater

The site is within the Serpentine Groundwater Management Area and the Serpentine 3 Sub-area. Information on the regional groundwater resources obtained from DWER (2019) indicates that the site is underlain by a multi-layered aquifer system comprised of the following resources:

- Perth - Superficial Swan (unconfined)
- Perth – Cattamarra Coal Measures (confined)
- Perth - Leederville (confined).

There are currently no publicly available regional groundwater contours covering the site. The characteristics of groundwater underlying the site are documented in the *Report on Geotechnical Investigation* (Douglas Partners 2020) prepared to support the proposed SP and summarised below.

Groundwater levels have been measured at multiple locations within the site and surrounds and groundwater quality analysis was performed during March 2020. Groundwater was observed at test location 28 within the southern portion of the site at a depth of approximately 2.3 m (approximately RL 38.6 m AHD) during the field work undertaken on 10 and 11 March 2020.

Much of the subject land is subject to surface saturation and in some cases inundation in winter, due to either groundwater rise, perching or surface ponding. The regional groundwater flow is to the north-west but local flows and levels are likely to be influenced by the Serpentine River and, in winter, by the drains that flow through and near the site.

2.4.2 Surface water

The site is within the catchment of the Serpentine River, which flows from east to west about 450 m north-east of the site and discharges into the Peel Inlet.

The site is intersected by the Water Corporation drain, the Hardy's Creek Main Drain (HCMD), which extends 1.2 km to the south-east of the site and flows north across Lot 487 before joining the Serpentine River approximately 940 m north west of the site, as shown in **Figure 9.** The drain is seasonal, flowing in winter and drying up in summer. The drain consists of an eroded channel approximately 0.5 to 1 m deep and 2 m to 10 m wide with a narrow, flat sandy bottom. The banks are partly stabilised by pasture grasses but are continuing to erode where disturbed by cattle and occasional vehicles.

The proposed stormwater management system post development is summarised in the LWMS (Bayley Environmental Services 2016) and the LWMS addendum (RPS 2020). The LSP's response to the need to manage an altered stormwater regime is described further in **Section 4.4.**

2.4.3 Wetlands

Wetlands are areas which are permanently, seasonally or intermittently waterlogged or inundated with water. Naturally occurring wetland features are common across the Swan Coastal Plain and can contain fresh or salty water, which may be flowing or still.

DBCA maintains the *Geomorphic Wetlands of the Swan Coastal Plain* dataset (DBCA 2018), which categorises geomorphic wetland features into types and management categories to guide land use and conservation. Wetland types are based on landform shape and water permanence (hydro-period) and management categories of wetlands are determined based on hydrological, biological and human use features. The three management categories are described in **Table 6**.

Table 6: Management categories defined in the Geomorphic Wetlands of the Swan Coastal Plain (DBCA 2017)

Management category	Description of wetland	Management objectives
Conservation (CCW)	Support high levels of attributes	Preserve wetland attributes and functions through reservation in national parks, crown reserves and state owned land. Protection provided under environmental protection policies.
Resource enhancement (REW)	Modified or degraded but still supporting substantial attributes and functions	Restore wetland through maintenance and enhancement of wetland functions and attributes. Protection via crown reserves, state or local government owned land, environmental protection policies and sustainable management on private properties.
Multiple use (MUW)	Few remaining important wetland attributes and functions but still provide important hydrological functions	Use, development and management considered in the context of water, town and environmental planning through land care.

A review of the *Geomorphic Wetlands, Swan Coastal Plain* dataset (DBCA 2018) indicated that one 'multiple use' category wetland (MUW) feature (UFI 16,021) occurs across the majority of the site, and is shown in **Figure 9**. This feature is classified as a 'Palusplain' wetland. The wetland extends beyond the site and is adjacent to a 'resource enhancement' (REW) that lies to the west of Hardy Road (UFI 15,364).

Given the general absence of remnant vegetation within the site and the regional landforms and soils mapping (described in **Section 2.2**), the extent of this mapped MUW is unlikely to be reflective of wetland conditions on the ground.

MUWs do not require specific conservation or protection measures, and the hydrological characteristics of these wetlands (i.e. groundwater levels and surface water flows) can be suitably addressed through the standard water management approaches.

2.4.4 Public Drinking Water Source Areas

PDWSAs are proclaimed by the DWER to protect identified drinking water sources, which can be surface water or groundwater sources (DoW 2009). They are proclaimed under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* or the *Country Areas Water Supply Act 1947* as Water Reserves, Catchment Areas or Underground Water Pollution Areas. PDWSAs provide Western Australia with the majority of its drinking water supplies and can be vulnerable to contamination from a range of land uses and water-based activities.

The site is not located within or in proximity to any proclaimed or proposed Public Drinking Water Source Areas (PDWSAs).

2.5 Heritage

2.5.1 Aboriginal heritage

The *Aboriginal Heritage Inquiry System* (AHIS) is maintained pursuant to Section 38 of the *Aboriginal Heritage Act 1972* (AH Act) by the Department of Planning, Lands and Heritage (DPLH), containing information on Registered Aboriginal Heritages Sites and Other Heritage Places throughout Western Australia.

In accordance with the *Aboriginal Heritage Due Diligence Guidelines* (DAA 2013), a search of the AHIS online database (DPLH 2018) was undertaken to support preparation of the SP, which did not identify any Aboriginal heritage sites as being mapped by DPLH within the site.

One registered Aboriginal Heritage site has been identified within the site 'Serpentine River' (ID 3582), a mythological site, which extends over the area to the north of Arnold Road, as shown in **Figure 7**. A Registered Site inquiry of the site was submitted to DPLH to determine if the site intersects with the known location of the 'Serpentine River' registered site (C. Rodrigues, 2014). The Department of Aboriginal Affairs has advised that while the boundary intersects with the site, the actual boundary of site 3582 does not impinge on the site. Therefore, approval under AH Act is not required in relation to this site.

Although no Aboriginal heritage sites were identified within the site, it is important to note that if during construction Aboriginal artefacts or sites are uncovered, these are protected under the AHA and works should cease and a suitably qualified expert should be brought in to survey the potential site. If required based on the outcome of the survey, permission under the AHA to manage and disturb sites should be sought.

2.5.2 Non-indigenous heritage

In order to determine the actual or potential presence of sites or features of non-indigenous heritage significance within the site, a review of readily available information at a federal, state and local government level was undertaken to determine if any of the following occur within the site:

- World Heritage Sites
- National Heritage Places
- Commonwealth Heritage Places

- Sites listed in the State Register of Heritage Places
- Sites listed in the City of Armadale Heritage Register.

A review of the above registers did not identify any heritage features as being mapped within the site.

2.6 Land use considerations

2.6.1 Historical land uses

2.6.1.1 Changes in land use

A review of historical aerial imagery for the site between 1953 to present (Landgate 2020) was completed to understand temporal changes in land use. Historical Landgate aerial photography shows that the land has been cleared and grazed since at least 1965 and that no other land uses have occurred on the property since that time.

2.6.1.2 Potential contamination

A review of the *Contaminated Sites Database* has indicated the site is not recorded on the database, nor are there any registered sites within 2 km of the site (DER 2018).

Whilst the site is not identified in the Contaminated Sites Database, a review of historical aerial photography indicates there is no visual or other evidence on site or on aerial photographs of any contamination or potentially contaminating land uses.

2.6.2 Surrounding land uses

The site is bounded to the north, east and south by mixed land uses including broadacre grazing, small rural lots and rural residential lots. The land immediately to the north west of the site is planned for residential development as part of the Serpentine townsite expansion and is zoned 'Urban' under the MRS. Immediately abutting the eastern boundary of the site is South Western Highway, which is identified under the MRS as a 'primary regional road'. Acoustic impacts associated with the South Western Highway are discussed further in **Section 4.6.**

A review of available information and consideration of nearby land uses indicates that no land uses have been identified within at least 1000 m of the site that are likely to impact on future residential land uses or require separation distances to be accommodated in order to mitigate potential impacts on health and/or amenity.

2.7 Bushfire hazard

The entirety of the site is located within a 'bushfire prone area' under the state-wide Map of Bush Fire Prone Areas prepared by the Office of Bushfire Risk Management (OBRM 2019) as shown in **Plate 3**. Strategic planning proposals, including local structure plans require a bushfire hazard level

assessment under the *Guidelines for Planning in Bushfire Prone Areas Version 1.3* (the Guidelines) (WAPC and DFES 2017).

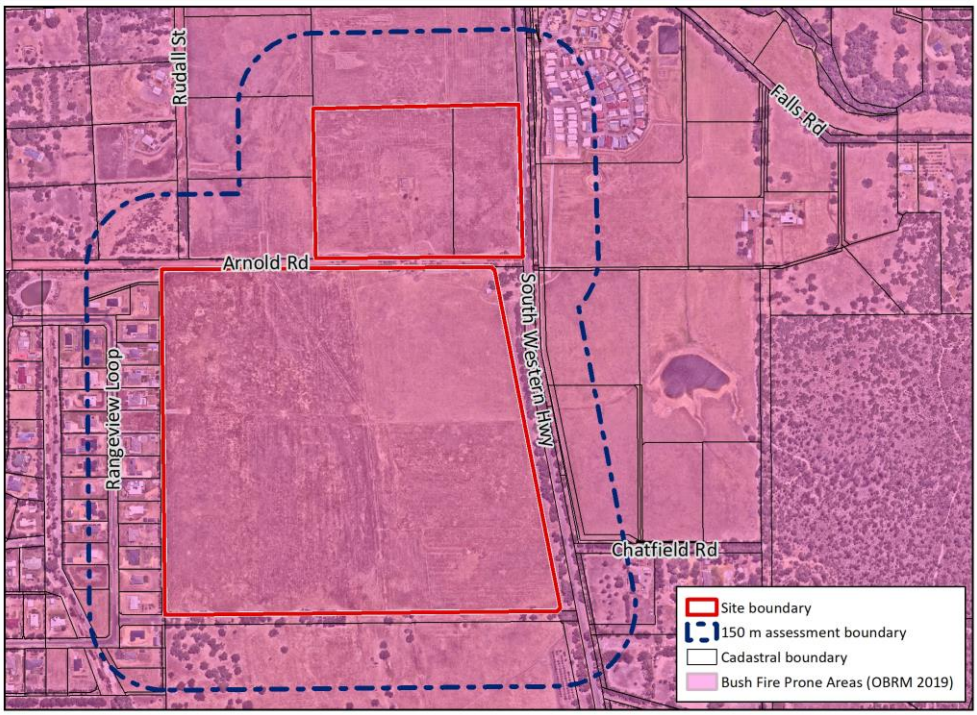

Plate 3: Areas within and surrounding the site identified as 'bushfire prone areas' (as indicated in purple) under the state-wide Map of Bush Fire Prone Areas (OBRM 2019).

A Bushfire Management Plan (BMP) has been prepared by Emerge Associates (2020) to support the SP, which includes an assessment of vegetation within and surrounding the site to determine applicable bushfire hazards, in accordance with *Australian Standard 3959:2018 Construction of buildings in bushfire-prone areas (AS 3959),* and an assessment of the bushfire protection criteria outlined in the Guidelines. The BMP has determined that the SP can satisfy the requirements of SPP 3.7 and the Guidelines.

As part of the BMP, a post-development vegetation classification scenario has been determined to assist in understanding whether the proposed urban development can satisfy SPP 3.7, and whether any separation distances to achieve a bushfire attack level of BAL-29 or less will need to be accommodated within the SP area. The bushfire hazards likely to affect residential development within the site (in the post-development scenario) will largely be associated with existing rural-residential land uses to surrounding the site in addition to the South Western Highway road reserve and the Harvey's Creek Main Drainage Corridor, however overall the site will be subject to low or moderate bushfire hazards.

The anticipated environmental impacts of the SP, as outlined in **Section 4** have specifically considered any bushfire management requirements. No further environmental impacts (such as clearing of vegetation) beyond those outlined in **Section 4** will be required in order to implement urban development across the site, consistent with the SP.

This is discussed further in the BMP (Emerge Associates 2020).

2.8 Acoustic impacts

South Western Highway is reserved as a 'Primary Regional Road' under the MRS and is situated adjacent to the eastern boundary of the site. In order to understand the potential acoustic impacts on the site associated with vehicular noise emissions extending from South Western Highway, a *Acoustic Impact Assessment* has been undertaken by Herring Storer Acoustics (2020). South Western Highway may, in the future, undergo a re-alignment, which would affect noise levels onto the development. Therefore, *Acoustic Impact Assessment* considers noise level associated with the current road alignment and the proposed future road alignment.

The *Acoustic Impact Assessment* involved onsite monitoring of noise emissions from South Western Highway, in addition to modelling of future noise emissions based on future road usage data provided by Main Roads WA. The results of the *Acoustic Impact Assessment* in the context of the proposed future residential development of the site are discussed in **Section 4.6**.

2.9 Summary of relevant environmental factors

Table 7 provides a summary of the environmental factors that have been investigated for the site and those that will require further specific consideration as part of the future development within the site. These considerations are discussed further in **Section 4**.

Table 7: Relevant environmental factors and considerations for the proposed SP

Environmental factor	Relevant considerations
Landform and soils	No issues posed and therefore no further consideration of this factor is required.
Flora and vegetation	Due to the degraded nature of the site, no significant flora or vegetation values have been identified within the site that require specific spatial responses from the SP. This is discussed further in **Section 4.2**.
Terrestrial fauna	No issues posed and therefore no further consideration of this factor is required.
Bush Forever	Whilst Bush Forever Site 468 'Serpentine National Park and Adjacent Bushland' is located 470 m to the east of the site, the residential development of the site is not likely to impact on the site and no further consideration of this factor is required.
Ecological linkages	No ecological linkages have been identified within the site. No further consideration of this factor is required.
Environmentally sensitive areas	The eastern portion of the site is mapped as occurring within an ESA. As the portion of the site mapped as occurring within an ESA is not considered to contribute to or provide any significant environmental values of retention significance, no further consideration of this factor is required.
Groundwater	The depth to groundwater was measured at approximately 2.3 m (approximately RL 38.6 m AHD) across the drainage low point within the southern portion of the site. This is discussed further in **Section 4.4**.
Surface water	The Hardy's Creek Main Drain has been identified within the site. The management the drain and associated stormwater will be a consideration for future development and is discussed further in **Section 4.4.**
Wetlands	A Multiple Use Wetland (Unique Feature Identifier (UFI) 16,02) has been identified over the majority of the site. The presence of a multiple use wetland (MUW) within the site does not require

Environmental factor	Relevant considerations
	a specific spatial response within the SP as this category contains few wetland attributes and is suitable for development if hydrological considerations are addressed appropriately. The standard urban water management process (applied through the planning process) will address the hydrological considerations and is considered in **Section 4.4** and **Section 4.5**.
Aboriginal heritage	One registered Aboriginal Heritage site has been identified within the site 'Serpentine River' (ID 3582), a mythological site, which extends over the area to the north of Arnold Road. However the actual boundary of site 3582 does not impinge on the site. Therefore no further consideration of this factor is required.
Non-indigenous heritage	No non-indigenous heritage values have been identified within, or in close proximity to the site and therefore no further consideration of this factor is required.
Historic land uses	The site is largely cleared of native vegetation and while it has supported a range of rural and agricultural land uses, including cattle grazing, no specific contamination has been identified as requiring management. No further consideration of this factor is provided as part of this EAMS.
Surrounding land uses	There are no existing land uses in proximity to the site which are incompatible with the proposed residential land use of the site, therefore no further consideration of this factor is required.
Bushfire hazard	Classified vegetation has been identified as affecting the site in the post development scenario and is further considered in **Section 4.5** and within the BMP (Emerge Associates 2020)
Acoustic impacts	The site is exposed to vehicular noise emissions from South Western Highway. This is discussed further in **Section 4.6.**

3 Planning Framework and Proposal

3.1 Historical planning context

The site is currently zoned 'Rural' under the Metropolitan Region Scheme (MRS), and was rezoned from 'Rural' to 'Rural Living A' through Amendment No. 193 to the Shire of Serpentine-Jarrahdale Town Planning Scheme No. 2 (TPS 2), gazetted 29 January 2019. As part of this process Amendment No. 193 was referred to the Environmental Protection Authority (EPA) and deemed 'scheme not assessed: advice given (no appeals).'

The corresponding EPA advice, dated 23 November 2015, identified one environmental factor relevant to the scheme amendment: hydrological processes. Specifically, the EPA noted that the subject area is within the Peel Harvey Catchment and the draft Local Water Management Strategy (LWMS) (Bayley Environmental Services, 2016) states the subject area currently significantly exceeds the phosphorus concentration and load targets set by the Water Quality Improvement Plan (WQIP) for the Rivers and Estuary of the Peel Harvey System - Phosphorus Management (EPA, 2008).

On this basis, the EPA concluded that Amendment No. 193 could be managed to meet the EPA's environmental objectives through '*the implementation of scheme provisions including the requirement for the use of alternative domestic waste water systems with a phosphorous retention capacity, adequate mechanisms to control future residents' fertiliser application practices, and finalisation and endorsement of the LWMS by Department of Water to manage and protect hydrological processes.'*

The proposed stormwater management system post development is summarised in the LWMS (Bayley Environmental Services 2016). The LWMS addendum (RPS 2020) provides additional information in relation to stormwater management and is described further in **Section 4.4.**

3.2 Proposed Local Structure Plan

The site covers approximately 61.80 hectares (ha) and is proposed to be developed for rural residential purposes. The Arnold Rd Proposed Structure Plan has been prepared for the site on behalf of MALF Corp Pty Ltd by CDP Town Planning & Urban Design (2020) and is included in **Appendix A**.

The land uses within the site are proposed to include residential lots; public open space (POS); an interconnected road network and services such as power associated with residential development as well as a reserve for the future South Western Highway. A total of 0.88 ha of POS is proposed within the site, which serves a number of functions including:

- The provision of active and passive recreation.
- Incorporation of the Hardy's Creek Main Drain including a 5 m wide vegetated buffer on each side of the channel to provide a safety margin for extreme (>100-year ARI) flood events. The drain will be redeveloped as a living stream with a varying profile to accommodate minor and major flows.
- Treatment and flood detention of stormwater runoff prior to discharge from the site.

This are discussed in detail in **Section 4**.

3.3 Future planning approvals and environmental management framework

The SP will be submitted to the Shire of Serpentine-Jarrahdale for consideration, with final approval to be given by the WAPC.

A key component of implementing the future subdivision and development of the site is the environmental management framework. Where required, the majority of environmental management requirements to be implemented will be addressed through applicable subdivision conditions. The future environmental management framework is discussed further in **Section 4**.

4 Environmental Assessment and Management Framework

This section outlines how the SP has been designed to accommodate the environmental attributes and values associated with the site and details the environmental management considerations that will be required as part of future planning stages. Only those environmental values and attributes that require specific consideration based on their presence within the site, and/or applicable legislation and policy requirements are assessed.

4.1 Acid sulfate soils

4.1.1 Policy framework, site context and management objectives

The Department of Water and Environmental Regulation (DWER), through the WAPC, ensures ASS are adequately managed during the land use planning and development process. The objective of the DWER's ASS policy framework is to manage ASS appropriately to prevent the release of metals, nutrients and acidity into the soil and groundwater system that may adversely affect the natural and built environment and human health.

The principal management objective for acid sulfate soils within the site is to ensure that any future development that may disturb acid sulfate soils is appropriately managed to avoid impacts on the environment.

4.1.2 Structure plan layout considerations for acid sulfate soils

A review of the DWER mapping indicates that the majority of the site is classified as having a moderate to low risk of ASS occurring within 3 m of the natural soil surface. The nearest mapped high ASS risk area is a small wetland located 850 m west of the site. As part of the *Local Water Management Strategy* (Bayley Environmental Services 2016), water samples were taken from eight bores on and near the site and found some evidence of the presence of soil acidity (elevated Total Acidity, Acidity/Alkalinity ratio and/or low pH).

The development of the site is expected to involve little excavation or dewatering (required for installation of underground power, water and communications only). ASS is therefore not considered to be a significant issue on the site.

Therefore, ASS management does not require any spatial consideration within the structure plan, and any ASS risk can be appropriately managed through future development planning.

4.1.3 Future acid sulfate soils management requirements

The WAPC includes a standard condition on all subdivision applications (model subdivision condition EN8, WAPC 2017) which states:

An acid sulphate soils self-assessment form and, if required as a result of the self-assessment, an acid *sulphate soils report and an acid sulphate soils management plan shall be submitted to and approved by the Department of Water and Environmental Regulation before any subdivision works or*

development are commenced. Where an acid sulphate soils management plan is required to be submitted, all subdivision works shall be carried out in accordance with the approved management plan. (Department of Water and Environmental Regulation).

4.2 Flora and vegetation

4.2.1 Policy framework and management objective

In the context of environmental impact assessment, the EPA objective for flora and vegetation is '*to protect flora and vegetation so that biological diversity and ecological integrity are maintained*'. Where a proposal may potentially impact upon flora and vegetation values, the following mitigation hierarchy should be applied to minimise potential impacts:

1. **Avoid** impacts
2. **Minimise** impacts
3. **Offset** impacts.

The site is largely dominated by areas of 'Parkland Cleared' vegetation with scattered remnant native trees, as well as planted endemic and non-endemic species. No vegetation within the site has been identified as conservation significant (i.e. TEC or threatened flora) or of regional or local significance.

Given this, the impact of future development within the site is likely to be minimal on flora and vegetation values. Therefore, the objective for future management of flora and vegetation within the site will be principally focussed around opportunistically retaining areas of vegetation and/or individual trees within future POS or on lots where this is practical.

4.2.2 SP considerations for flora and vegetation

Due to the degraded nature of the site, no significant flora or vegetation values have been identified within the site that require specific spatial responses from the SP.

Native vegetation, and in particular existing scattered paddock trees, can be retained within areas of POS, road reserve or on lots within the site, however will need to respond to site constraints such as level changes (i.e. the provision or removal of fill material) and health/longevity considerations.

4.2.3 Future flora and vegetation management requirements

Should bulk earthworks or any other works be commenced within the site that requires clearing of native vegetation before subdivision approvals are gained, a clearing permit pursuant to Part V of the EP Act will be required. Otherwise, subdivision approval and associated authorised subdivision works will provide an exemption from the requirements for a clearing permit.

In addition, and as part of subdivision, the WAPC may include a standard condition (model subdivision condition EN2, WAPC 2017), which requires:

Measures being taken to ensure the identification and protection of any vegetation on the site worthy of retention that is not impacted by subdivisional works, prior to commencement of subdivisional works. (Local Government)

This can be used to ensure that where possible in POS vegetation retention is considered as part of the subdivision works process. It is recommended that this be considered as part of the subdivision design process, so that the subdivision layout responds to existing vegetation where possible.

4.3 Terrestrial fauna

4.3.1 Policy framework and management objectives

In the context of environmental impact assessment, the EPA's objective for terrestrial fauna is *'to protect fauna so that biological diversity and ecological integrity are maintained'.* The application of the mitigation hierarchy should be applied to avoid or minimise impacts to terrestrial fauna where possible.

The EPBC Act also provides protection for listed 'threatened' species, including black cockatoos, which may potentially use habitat within the site. Any proposed action which is considered likely to result in a 'significant' impact upon these species, identified by the DoEE as Matters of National Environmental Significance (MNES), should be referred to the Commonwealth Department of Environment and Energy.

Based on the degraded condition of vegetation within the site, there are limited fauna habitat values remaining. Two potential habitat trees, one of which has a hollow has been identified within the site, however the hollow is considered too small to be utilised by black cockatoos, and no roosting or breeding activity has been identified.

Opportunities to facilitate the retention of fauna habitat within the site are limited due to the small areas of vegetation within the site, and the proposed layout of the future development.

4.3.2 SP considerations for terrestrial fauna

Due to the cleared and degraded nature of vegetation within the site, limited fauna habitat values exist. No specific spatial response to fauna habitat values within the site has been provided for in the structure plan.

4.3.3 Future terrestrial fauna management requirements

Given the limited fauna habitat values within the site it is unlikely that a Fauna Management Plan will be required for this site.

Due to the degraded nature of vegetation within the site, and as no threatened species were identified as utilising the site, there is no requirement for a referral to the DoEE as a Matter of national Environmental Significance (MNES).

4.4 Hydrology

4.4.1 Policy framework and management objective

In the context of environmental impact assessment, the EPA's objective for inland waters is *'to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected'.*

The *State Water Strategy for Western Australia* (Government of WA 2003) and *Better Urban Water Management* (WAPC 2008) endorse the promotion of integrated water cycle management and application of water sensitive urban design (WSUD) principles to provide improvements in the management of stormwater, and to increase the efficient use of other existing water supplies. Of particular relevance to the wetland habitat that occurs adjacent to the site is the *Better Urban Water Management* criteria for ecological protection, which requires development to maintain or restore desirable environmental flows and/or hydrological cycles.

The Government Sewerage Policy (DPLH 2019) requires that land used for effluent disposal must have a minimum clearance of 0.5m from the natural ground surface to the highest water table. Under the policy, the required clearance can be achieved by properly engineered drainage and effluent disposal systems.

The Department of Water (DoW, 2006) advises that nutrient-removing effluent disposal systems should be located at least 30m from watercourses in all soil types.

4.4.2 SP considerations for hydrology

An addendum to the previously approved Local Water Management Strategy (LWMS) has been prepared by RPS (2020) to support the preparation of the structure plan and this addendum in conjunction with the 2016 LWMS (Bayley Environmental Services 2016). It provides a framework for the future delivery of a best practice approach to integrated water cycle management utilising WSUD principles. The structure plan responds to the requirements for flood mitigation, flow management and treatment of surface water within road reserves and public open space, as discussed in further detail below.

The Hardy's Creek Main Drain will be realigned and revegetated as part of the proposed residential development of the site as shown in **Figure 10**. The drain will be redeveloped as a living stream incorporating a 5 m wide vegetated buffer on each side of the channel to provide for extreme (>100-year ARI) flood events. Approximately 400 m of the central drainage corridor located north of Arnold Road will be realigned 100 m to the east, adjacent to the site boundary. The proponent will recontour the drain to slow and broaden the flow path and improve its ability to retain sediment, nutrients and other contaminants entering it from the site and areas upstream.

It is proposed that a setback of 20 m on each side of the Hardy's Creek Main Drain centreline be adopted, giving a total drainage corridor width of 40 m. This will give an effective setback of approximately 18 m from the 1.5-year ARI level. The drain corridor will be designated as public open space and ceded to the Shire of Serpentine-Jarrahdale. These modifications are further detailed in

the Local Water Management Strategy (Bayley Environmental Services 2016) and the LWMS addendum (RPS 2020).

The drainage characteristics of most of the site will be unchanged by the development. The road drainage system has been designed to minimise disturbance to the existing site drainage in terms of flow paths, volumes and peak flows. All road runoff from storms up to 1-year ARI, 1 hour duration (about 17.5mm) will be retained and infiltrated in swale drains built into one or both sides of the road embankment. The ultimate destination of all overland runoff from the site is the Hardy's Creek Main Drain, either directly or via roadside swales and drains.

All lots in the subdivision will employ on-site effluent disposal. The land capability assessment detailed in the LWMS (Bayley Environmental Services 2016) and the geotechnical assessment (Douglas Partners 2020) showed that the majority of the site is suitable for onsite effluent disposal in terms of soil permeability, slope and setbacks from watercourses. Constraints posed by groundwater clearance may be addressed by a combination of filling and drainage.

The LWMS should be referred to for further detailed information regarding the groundwater and surface water strategy.

4.4.3 Future management requirements

The LWMS provides for the environmental management framework for groundwater and surface water within the site.

It is anticipated that environmental condition D2 of the WAPC's *Model Subdivision Conditions Schedule* 2017 will be attached to all subdivision approvals, requiring the preparation of an Urban Water Management Plan (UWMP) which states:

Prior to the commencement of subdivisional works, an urban water management plan is to be prepared and approved, in consultation with the Department of Water, consistent with any approved Local Water Management Strategy. (Local Government).

Furthermore, it is anticipated that a memorial will be included on the title notifying purchasers that reticulated sewerage will not be provided to lots and an onsite effluent disposal system is required.

Landowners will also be required to submit an 'Application' to construct or install an apparatus for the treatment of sewage' to the Shire of Serpentine Jarrahdale.

4.5 Bushfire management

4.5.1 Policy framework and management objective

State Planning Policy 3.7 Planning in Bushfire Prone Areas (WAPC 2015a) stipulates that any development proposal which occurs partly or wholly within a bushfire prone area is required to be accompanied by a bushfire management plan. The preparation of the BMP is required to incorporate the following tasks:

- Classification of existing vegetation types within the site and surrounding 100 m, in accordance with *Australia Standard 3959 Construction of buildings in bushfire-prone areas* (AS 3959) (Standards Australia 2018).
- Assessment of bushfire hazard levels within the site and surrounding 100 m, in accordance with the *Guidelines for Planning in Bushfire Prone Areas* (WAPC and DFES 2015).
- Assessment of effective slope under areas of classified vegetation.
- Completion of an indicative Bushfire Attack Level (BAL) assessment and preparation of an associated BAL contour plan.
- Assessment of the SP design against the bushfire protection criteria, in accordance with the *Guidelines for Planning in Bushfire Prone Areas* (WAPC and DFES 2015).

4.5.2 SP considerations for bushfire management

Based on the outcomes of the BAL assessment and the BAL contour plan (Emerge Associates 2020) all future lots will be subject to a BAL rating less than BAL-29, due to setbacks provided by public roads and in-lot setbacks, ensuring that development (i.e. future habitable buildings) within the site will be able to achieve a BAL rating of BAL-29 or less.

Areas of public open space, roadside swales, roadside verges and the Harvey's Creek Main Drainage channel will be designed and maintained to achieve a Grassland (Class G) classification. The Harvey's Creek Main Drainage corridor will be classified as Grassland in the post development scenario based on the future planting of grasses and sedge species growing to a maximum height of 1 m within the channel with scattered large native trees with a minimum 4 m separation distance from each other.

Further discussion in this regard is provided in the BMP (Emerge Associates 2020).

4.5.3 Future bushfire management requirements

A BMP (Emerge Associates 2020) has been prepared to support the SP, and outlines the key considerations that will need to be accommodated as part of future subdivision, detailed design and implementation in order to satisfy SPP 3.7 and the associated bushfire protection criteria. These include:

- *Element 1 Location:* future habitable buildings can be located in an area that will, on completion, be subject to a low or moderate bushfire hazard.
- *Element 2 Siting and Design*: all future habitable buildings should be sited within the proposed development so that BAL-29 or less can be achieved, through the provision of appropriate separation distances based on the location of public roads and/or in lot setbacks. Areas of public open space (including the Hardy Main Drain corridor) will be designed to achieve a Grassland (Class G) classification in the post development scenario.
- *Element 3 Vehicular Access*: The proposed structure plan provides for two access roads that will service the lots within the site. The northern lots will connect onto Arnold Road via a cul-de-sac road. Arnold Road provides egress options to east and west and connects onto South Western Highway which provides further egress to the north and south.

- *Element 4 Water*: the development should be provided with an adequate water supply to support fire-fighting activities, which is addressed through the provision of a permanent and reticulated water supply to support onsite firefighting requirements.

Further consideration of bushfire will be required for those areas of the SP designated as 'bushfire prone areas' (within the *Map of Bush Fire Prone Areas*, as published) at the time of subdivision. This will include the preparation of an updated/new BMP to support future subdivision applications, and a model subdivision condition will likely be applied requiring the implementation the approved BMP as well as the certification of BAL ratings predicted as part of subdivision in order to support the appropriate the construction of habitable buildings in accordance with AS 3959.

4.6 Acoustic impacts

4.6.1 Policy framework and management objective

SPP 5.4 (WAPC 2009) recognises that excessive noise has the potential to affect the health and amenity of a community as a whole, as well as the wellbeing of individuals. The policy aims to protect people from unreasonable levels of transport noise by establishing a standardised set of criteria to be used in the assessment of development proposals.

Table 8 outlines the SPP 5.4 *Outdoor noise criteria*, which apply at any point one metre from a habitable façade of a noise-sensitive premise and in one outdoor living area.

Table 8: SPP 5.4 Outdoor noise criteria (WAPC 2009b)

Time of Day	Noise Target	Noise Limit
Day (6 am – 10 pm)	55 dB $L_{Aeg(Day)}$	60 dB $L_{Aeg(Day)}$
Night (10 pm – 6 am)	50 dB $L_{Aeg(Night)}$	55 dB $L_{Aeg(Night)}$

The objective of the outdoor noise criteria is for all noise sensitive developments to be subject to no more than the *limit* and preferably no more than the *target*.

4.6.2 SP considerations for acoustic impacts

In order to understand the potential acoustic impacts on the site associated with vehicular noise emissions extending from South Western Highway, an *Acoustic Impact Assessment* has been undertaken by Herring Storer Acoustics (2020). Information provided is that the South Western Highway may, in the future, undergo a re-alignment, which would affect noise levels onto the development. Therefore, this report considers noise level associated with the current road alignment and the proposed future road alignment.

The results of the acoustic assessment indicate that without any noise amelioration, noise received at the residences in the future would exceed the "Noise Targets" as outlined in the Western Australian Planning Commission (WAPC) Planning Policy 5.4 "Road and Rail Noise" by up to 3-8 dB(A) during the night period.

A number of development measures can be implemented as part of future phases of development to appropriately respond to the findings of the acoustic assessment and reduce noise levels to acceptable levels.

4.6.3 Future acoustic impact management requirements

As part of the future residential subdivision process and associated detailed design, the following development measures could be implemented to control noise impacts to acceptable levels (Herring Storer Acoustics 2020):

- Provision of a building envelope set-back for the first row of houses located adjacent to South West Highway. This setback to the edge of the buildings envelopes, which is approximately 60 metres from the road, provides sufficient distance to reduce noise levels to allow the internal noise criteria to be met.
- For any proposed lots which exceed the noise target:
    - Constructed dwellings should incorporate 'Package A' or 'Package B' architectural treatments, as detailed and specified in the acoustic assessment (Herring Storer Acoustics 2020). This generally included treatments relating to glazing, doors, walls, roofing, eaves, mechanical ventilation and siting of outdoor living areas.
    - A notification will be placed on the lot title, likely to be WAPC model subdivision condition T24 (WAPC and DPLH 2019), which states:
      A notification, pursuant to Section 70A of the Transfer of Land Act 1893 is to be placed on the certificate(s) of title of the proposed lot(s). Notice of this notification is to be included on the diagram or plan of survey (deposited plan). The notification is to state as follows: "The lot/s is/are situated in the vicinity of a transport corridor and is currently affected, or may in the future be affected by transport noise." (Local Government)

These mitigation measures will be dependent upon final subdivision layout and detailed design. Should double-story dwellings be proposed for subdivided lots in the southern portion of the site, different architectural packages may be required.

5 Implementation

A summary of the SP responses to the environmental values and attributes within the site is provided in **Table 9**: Environmental management framework implementation table

Factor	SP phase	Subdivision phase	Development phase
Acid sulfate soils	• Preparation of Acid Sulfate Soil Site Assessment.	• Preparation of an Acid Sulfate Soil and Dewatering Management Plan, as required.	• Implementation of an Acid Sulfate Soil and Dewatering Management Plan, as required
Flora and Vegetation	• Assessment of flora and vegetation values and preliminary consideration of potential retention opportunities.	• Detailed analysis of final subdivision layout to determine tree retention opportunities. • Consideration of potential requirement for Clearing Permit.	• If areas of retention are proposed, accommodate these as part of construction and landscaping works.
Terrestrial Fauna	• Assessment of fauna habitat and preliminary consideration of potential retention opportunities	• Detailed analysis of final subdivision layout to determine potential habitat	• If areas of retention are proposed, accommodate these as part of construction and landscaping works. •
Hydrology	• Preparation of a Local Water Management Strategy. • Assessment of the suitability of the site for onsite effluent disposal	• Preparation of an Urban Water Management Plan. • Notification on title notifying for the requirement for onsite effluent disposal	• Implementation of the UWMP. • Landowners to seek approval from Shire for construction/installation of effluent disposal system.
Aboriginal heritage	• No response required.	• No response required.	• No response required.
Acoustics	• Preparation of Acoustic Impact Assessment	• Incorporation of South Western Highway setbacks in subdivision design. • Notification of titles of noise-affected subdivision lots. • Detailed acoustic assessment of final subdivision design.	• Dwellings to incorporate architectural treatments specified in acoustic assessment.
Bushfire management	• Preparation of a Bushfire Management Plan. • Provision of public open space and road reserves to accommodate appropriate setbacks. • Determining a spatial layout that reduces the bushfire hazard to future development.	• Complete detailed BAL assessment to support dwelling construction.	• Dwellings within 100 m of bushfire threat to demonstrate compliance with AS 3959.

. The table also outlines the proposed future management required as part of the subdivision and development process.

Table 9: Environmental management framework implementation table

Factor	SP phase	Subdivision phase	Development phase
Acid sulfate soils	• Preparation of Acid Sulfate Soil Site Assessment.	• Preparation of an Acid Sulfate Soil and Dewatering Management Plan, as required.	• Implementation of an Acid Sulfate Soil and Dewatering Management Plan, as required
Flora and Vegetation	• Assessment of flora and vegetation values and preliminary consideration of potential retention opportunities.	• Detailed analysis of final subdivision layout to determine tree retention opportunities. • Consideration of potential requirement for Clearing Permit.	• If areas of retention are proposed, accommodate these as part of construction and landscaping works.
Terrestrial Fauna	• Assessment of fauna habitat and preliminary consideration of potential retention opportunities	• Detailed analysis of final subdivision layout to determine potential habitat	• If areas of retention are proposed, accommodate these as part of construction and landscaping works. •
Hydrology	• Preparation of a Local Water Management Strategy. • Assessment of the suitability of the site for onsite effluent disposal	• Preparation of an Urban Water Management Plan. • Notification on title notifying for the requirement for onsite effluent disposal	• Implementation of the UWMP. • Landowners to seek approval from Shire for construction/installation of effluent disposal system.
Aboriginal heritage	• No response required.	• No response required.	• No response required.
Acoustics	• Preparation of Acoustic Impact Assessment	• Incorporation of South Western Highway setbacks in subdivision design. • Notification of titles of noise-affected subdivision lots. • Detailed acoustic assessment of final subdivision design.	• Dwellings to incorporate architectural treatments specified in acoustic assessment.
Bushfire management	• Preparation of a Bushfire Management Plan. • Provision of public open space and road reserves to accommodate appropriate setbacks. • Determining a spatial layout that reduces the bushfire hazard to future development.	• Complete detailed BAL assessment to support dwelling construction.	• Dwellings within 100 m of bushfire threat to demonstrate compliance with AS 3959.

6 Conclusions

This EAMS has been prepared on behalf of the proponent for the Arnold Road Structure Plan (see **Appendix A**). This EAMS has been prepared to support the structure plan, together with:

- Local Water Management Strategy (Bayley Environmental Services 2016)
- Local Water Management Strategy Addendum (RPS 2020)
- Bushfire Management Plan (Emerge Associates 2020)
- Acoustic Impact Assessment (Herring Storer Acoustics 2020)

The structure plan design has responded to site-specific environmental considerations where necessary and possible, including accommodation of stormwater management requirements consistent with the LWMS. The structure plan design does not specifically provide for the future retention of existing flora, vegetation or fauna habitat values, due to the determined significance of these values through detailed surveys the small size and fragmented nature of these areas and the ability to retain vegetation within lots given the rural residential development. Notwithstanding this, all seven potential black cockatoo habitat trees that were identified within the site, none of which contain hollows, will be retained as part of the proposed development.

This document provides an environmental management strategy to be implemented across the site for future subdivision and development stages. The key components of this management strategy are summarised as follows.

- Acid sulfate soils: completion of an ASS self-assessment form, and if necessary, the preparation of an Acid Sulfate Soil and Dewatering Management Plan (ASSDMP). However, given the depth to groundwater within the site, ASS investigations and management considerations for the site are unlikely to be required at subdivision.
- Native vegetation: completing a detailed analysis of the final development design and bulk earthworks requirements, to confirm any potential retention opportunities. Where clearing of vegetation is proposed, a clearing permit will need to be attained pursuant to Part V of the *Environmental Protection Act 1986* (unless a valid exemption applies).
- Hydrology: stormwater management requirements as outlined within the Local Water Management Strategy (LWMS) will be implemented through an Urban Water Management Plan (UWMP) for each stage of future subdivision. The requirement for onsite effluent disposal systems will be specified as a condition of subdivision and landowners will need to seek approval from the Shire for construction and installation of these systems.
- Bushfire risks: To respond to the known bushfire hazards within and surrounding the site future development will be in accordance with the currently prepared BMP. This assumed that public open space (POS) and the Hardy's Creek Main Drainage corridor within the site will be classified as Grassland (Class G) vegetation in the post development scenario and that areas of 'extreme' bushfire hazard surrounding the site with environmental values area fully retained in the future.

Overall, the environmental attributes and values of the site can be accommodated within the structure plan design, or can be managed appropriately through the future subdivision and development phases in line with the relevant

7 References

7.1 Legislation

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Biodiversity Conservation Act 2016

Bush Fires Act 1954

Contaminated Sites Act 2003

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Figures

Figure 1: Site Location and Topographic Contours

Figure 2: Environmental Geology

Figure 3: Acid Sulfate Soil Mapping

Figure 4: Plant Communities

Figure 5: Vegetation Condition

Figure 6: Fauna Habitat

Figure 7: Aboiginal Heritage Sites

Figure 8: Environmental Features

Figure 9: Wetlands and Surface Water Features

Figure 10: Structure Plan Response to Environmental Attributes

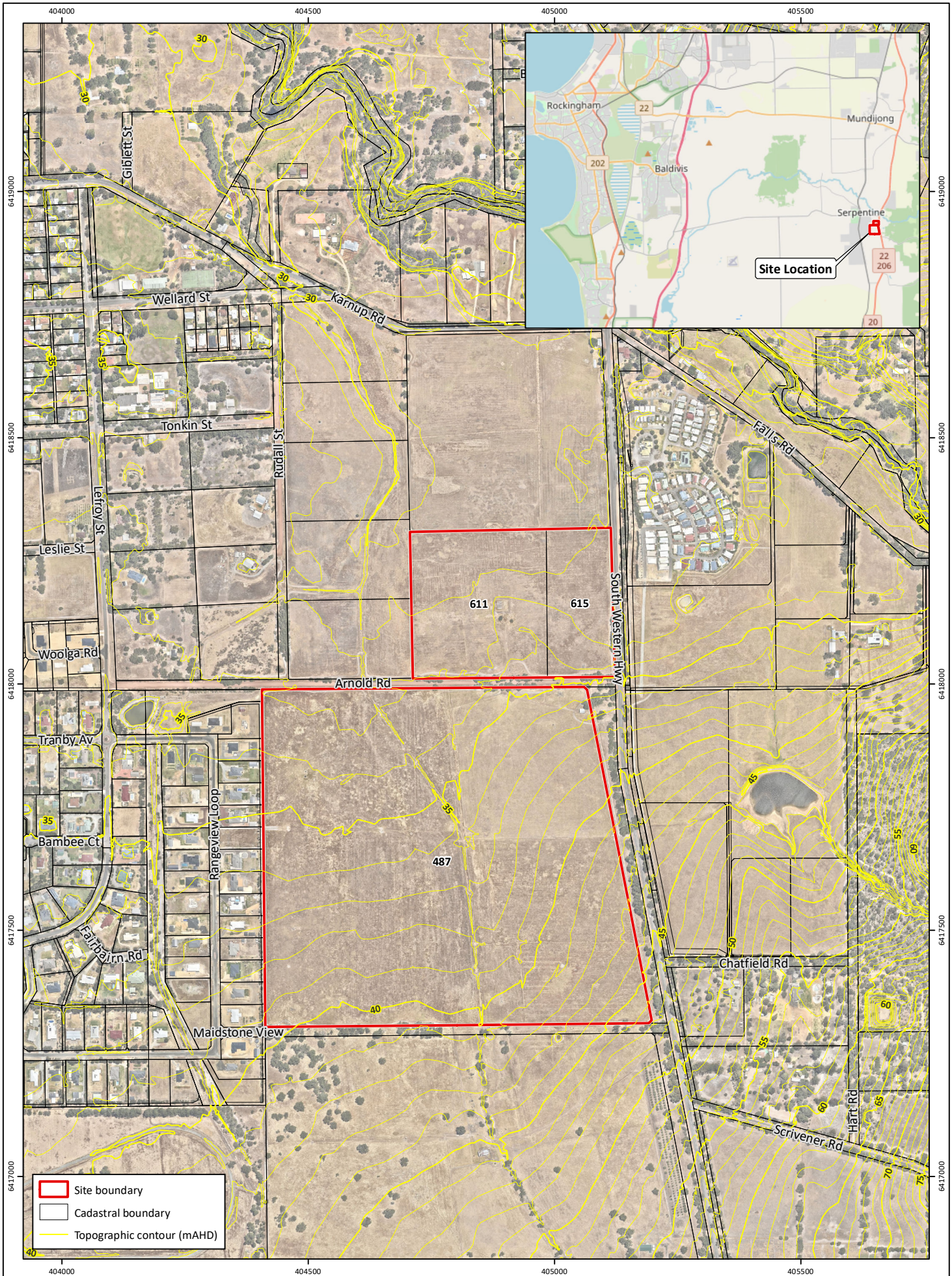

Figure 1: **Site Location and Topographic Contours**

Project:	Environmental Assessment Management Strategy Lots 487, 611 & 615 Arnold Rd, Serpentine
Client:	MALF Corp Pty Ltd

Plan Number:
EP20-020(01)--F10

Drawn:	GAR
Date:	06/04/2020
Checked:	BRB
Approved:	CKK
Date:	08/04/2020

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Metres

Scale: 1:10,000@A4

GDA 1994 MGA Zone 50

emerge ASSOCIATES

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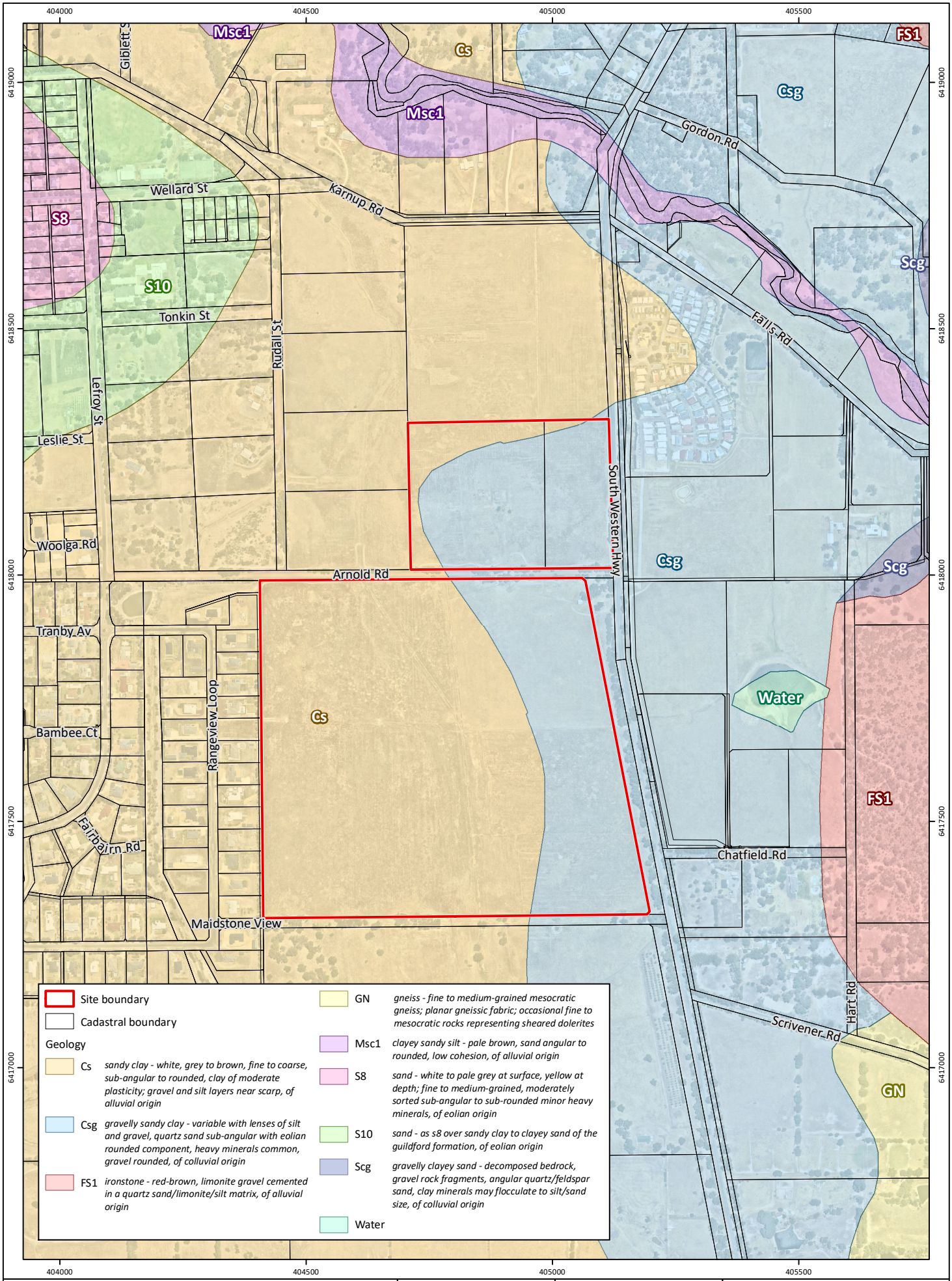

Figure 2: Environmental Geology

Project: Environmental Assessment Management Strategy
Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number: EP20-020(01)--F11

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Date:	06/04/2020
Checked:	BRB
Approved:	CKK
Date:	08/04/2020

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GDA 1994 MGA Zone 50

emerge ASSOCIATES

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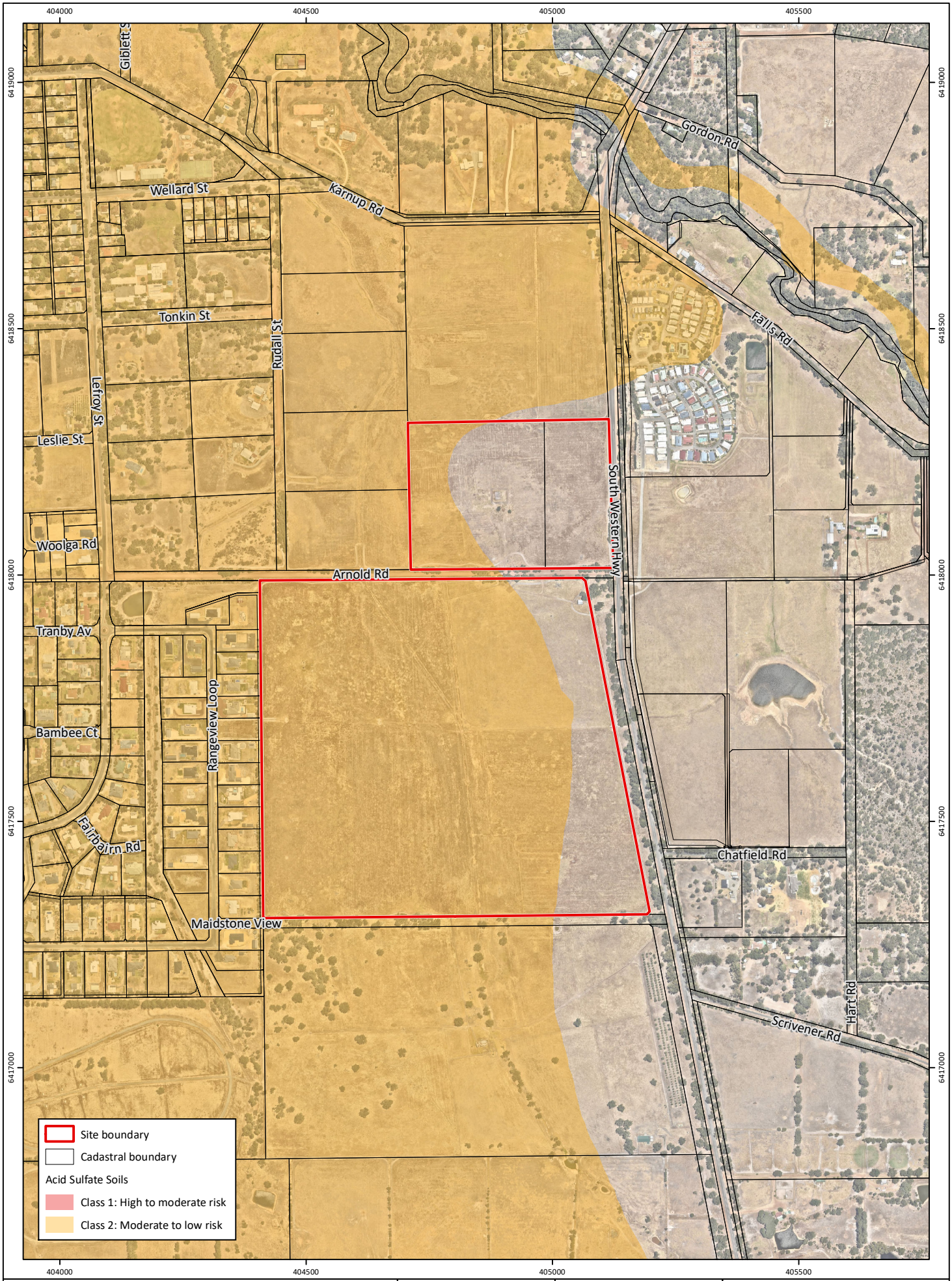

Figure 3: Acid Sulfate Soil Mapping

Project: Environmental Assessment Management Strategy
Lots 487, 611 & 615 Arnold Rd, Serpentine
Client: MALF Corp Pty Ltd

Plan Number: EP20-020(01)--F12
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Date: 06/04/2020
Checked: BRB
Approved: CKK
Date: 08/04/2020

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emerge ASSOCIATES

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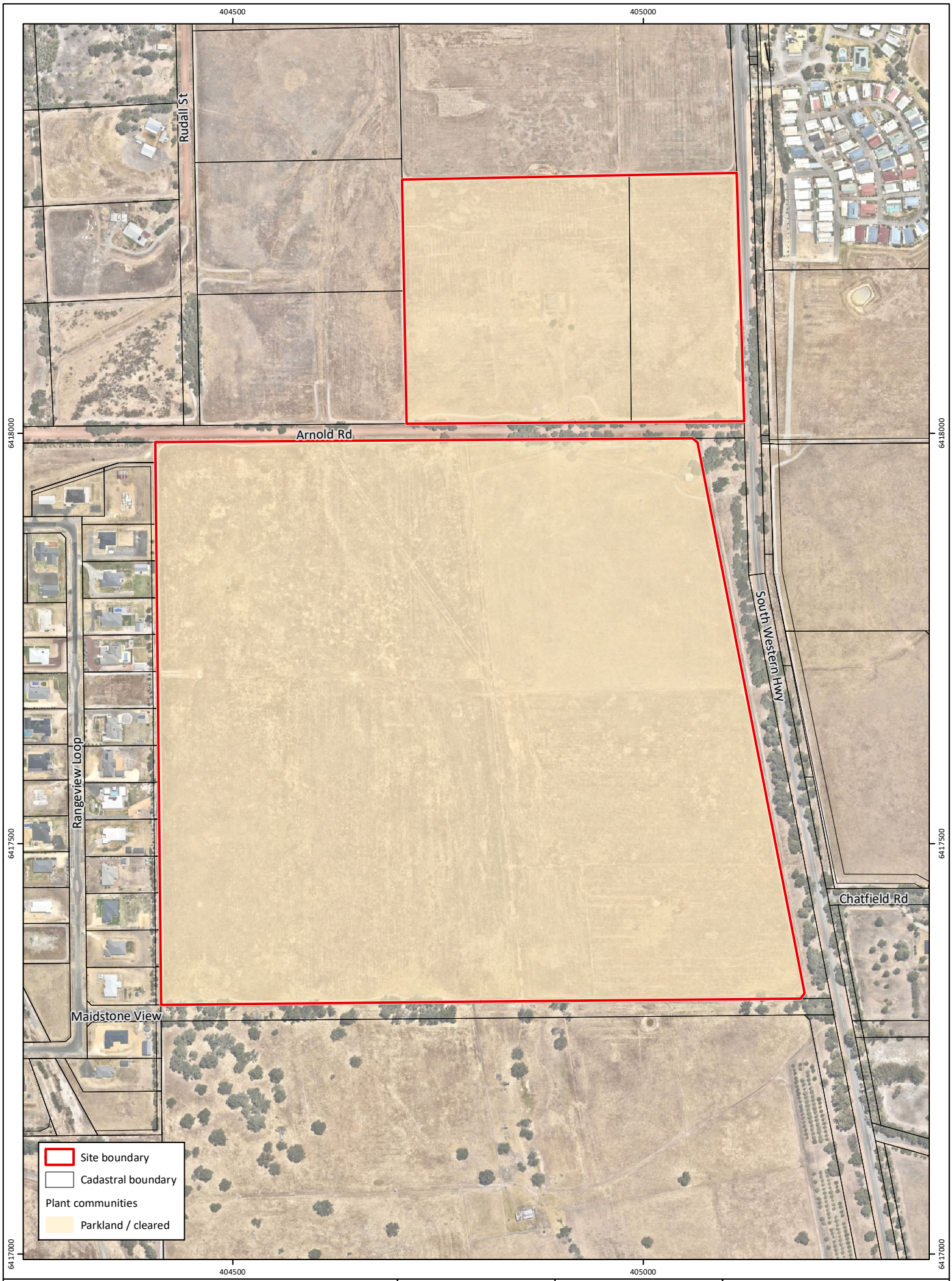

Figure 4: Plant Communities

Project:	Environmental Assessment Management Strategy Lots 487, 611 & 615 Arnold Rd, Serpentine
Client:	MALF Corp Pty Ltd

Plan Number:	**EP20-020(01)--F13**
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Date:	06/04/2020
Checked:	BRB
Approved:	CKK
Date:	08/04/2020

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GDA 1994 MGA Zone 50

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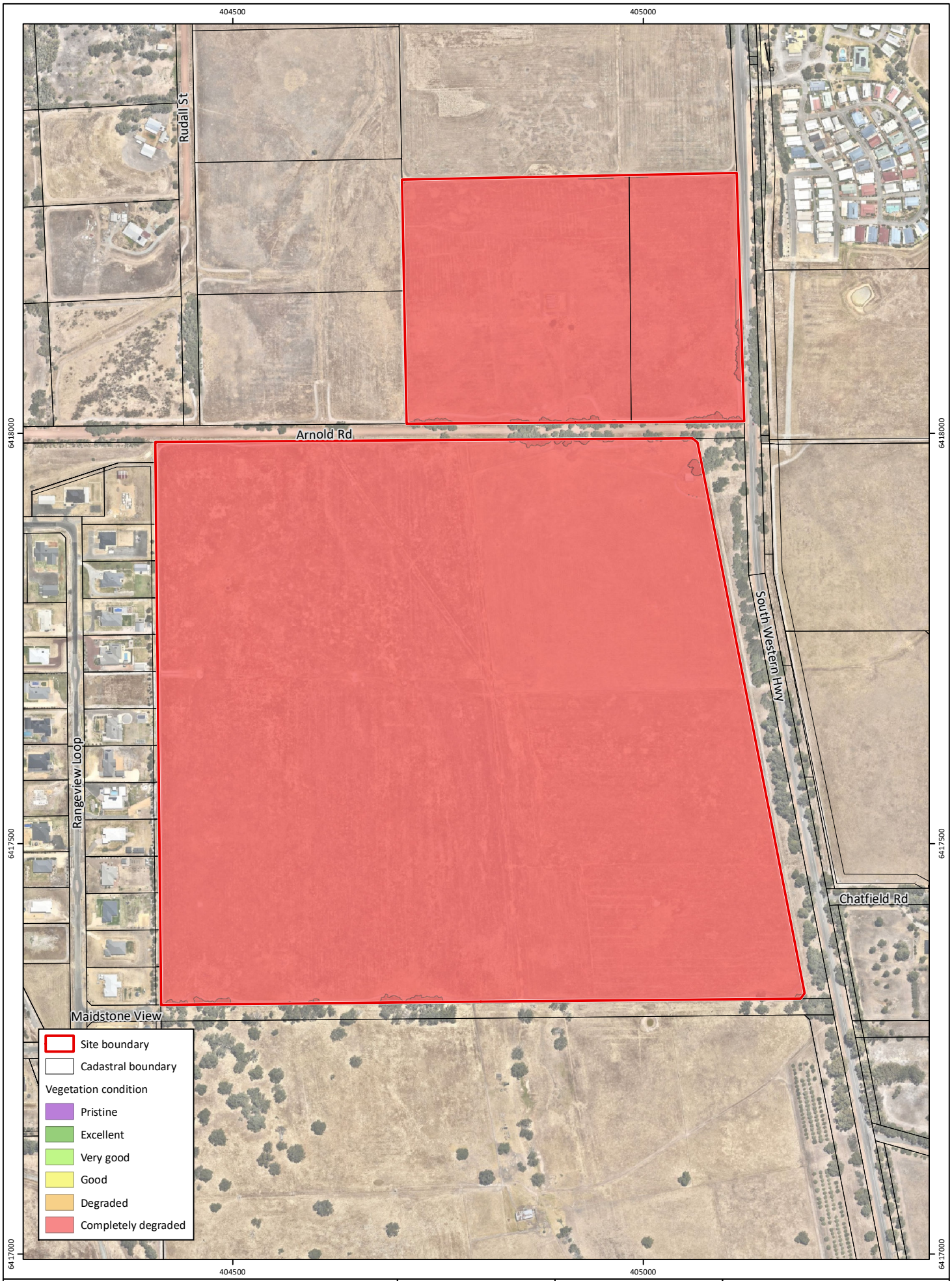

Figure 5: Vegetation Condition

Project: Environmental Assessment Management Strategy
Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number: EP20-020(01)--F14

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Date:	06/04/2020
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Approved:	CKK
Date:	08/04/2020

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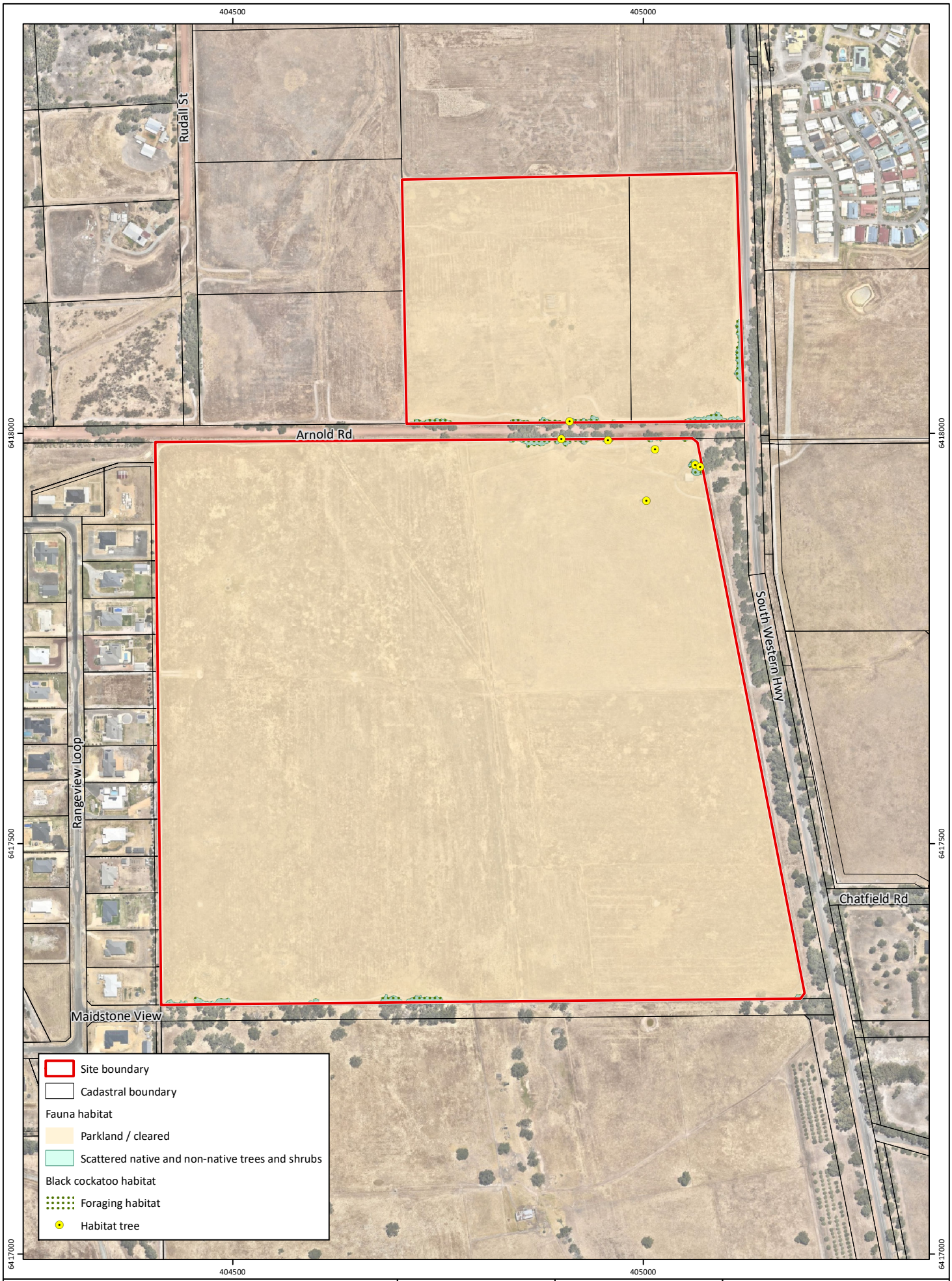

Figure 6: Fauna Habitat

Project: Environmental Assessment Management Strategy
Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number: EP20-020(01)--F15

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Date:	06/04/2020
Checked:	BRB
Approved:	CKK
Date:	08/04/2020

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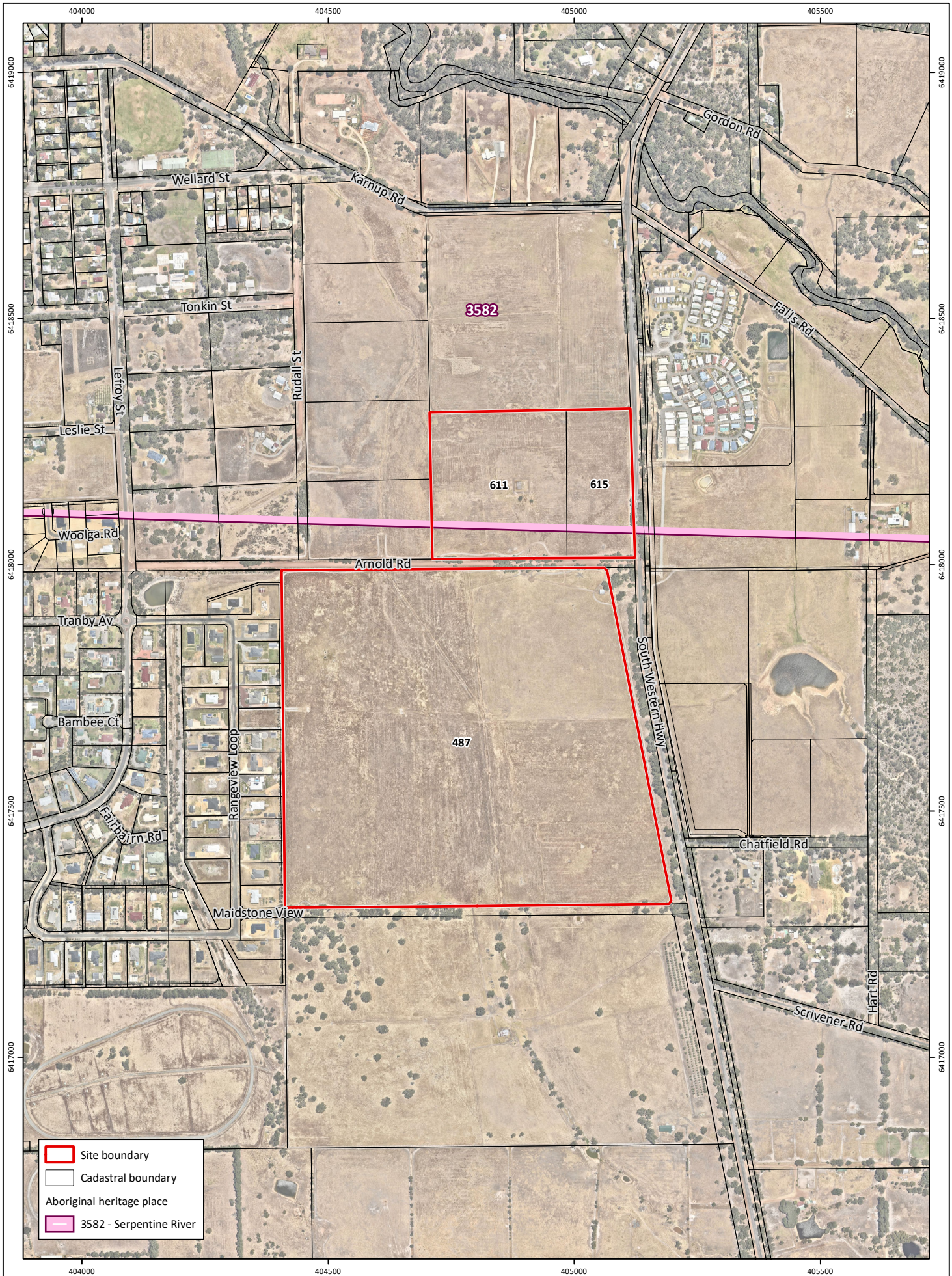

Figure 7: Aboriginal Heritage Sites

Project:	Environmental Assessment Management Strategy Lots 487, 611 & 615 Arnold Rd, Serpentine
Client:	MALF Corp Pty Ltd

Plan Number:
EP20-020(01)--F16

Drawn:	GAR
Date:	06/04/2020
Checked:	BRB
Approved:	CKK
Date:	08/04/2020

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Scale: 1:10,000@A4

GDA 1994 MGA Zone 50

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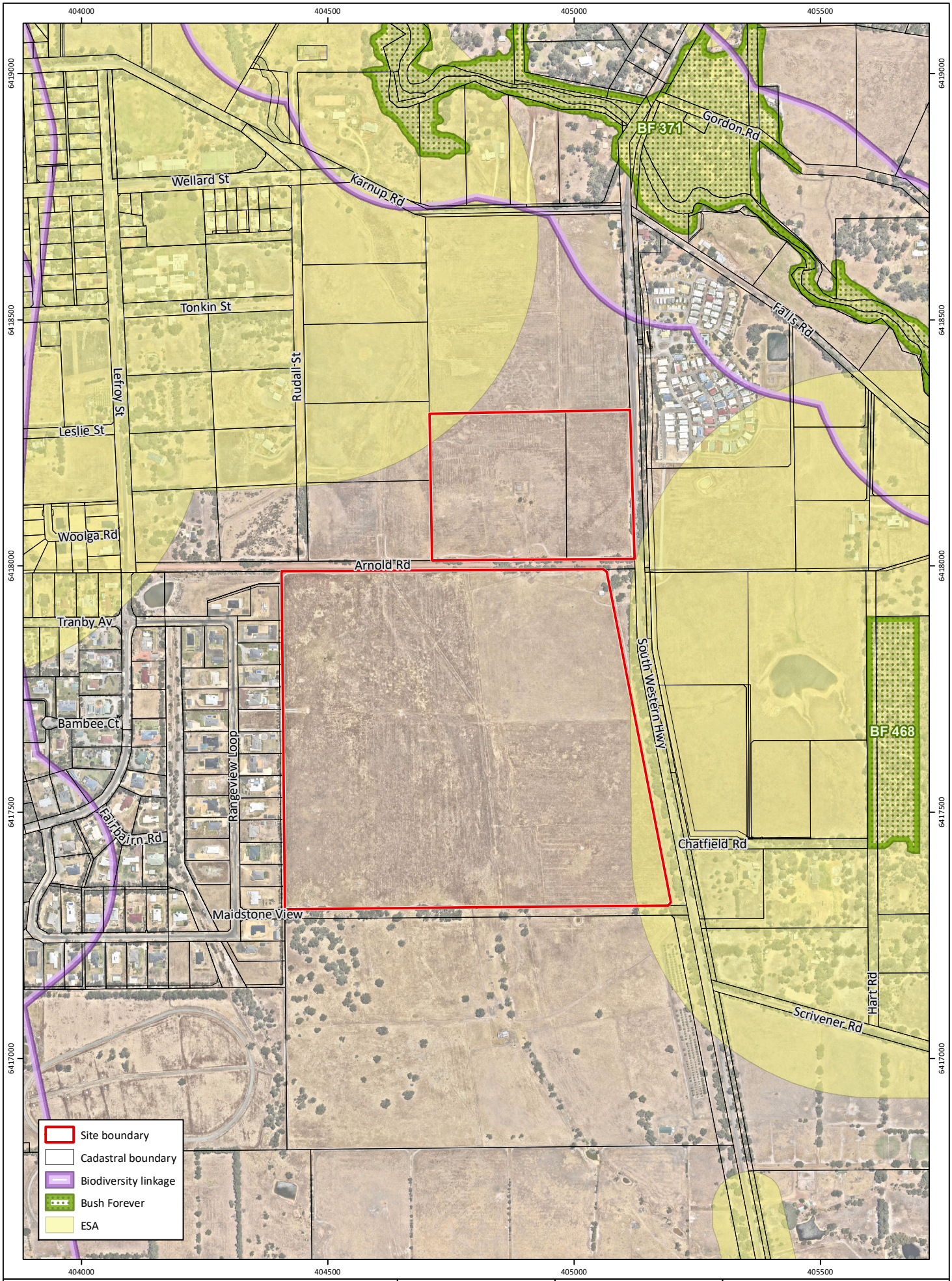

Figure 8: Environmental Features

Project: Environmental Assessment Management Strategy
Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number: EP20-020(01)--F17

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Date:	06/04/2020
Checked:	BRB
Approved:	CKK
Date:	08/04/2020

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Scale: 1:10,000@A4

GDA 1994 MGA Zone 50

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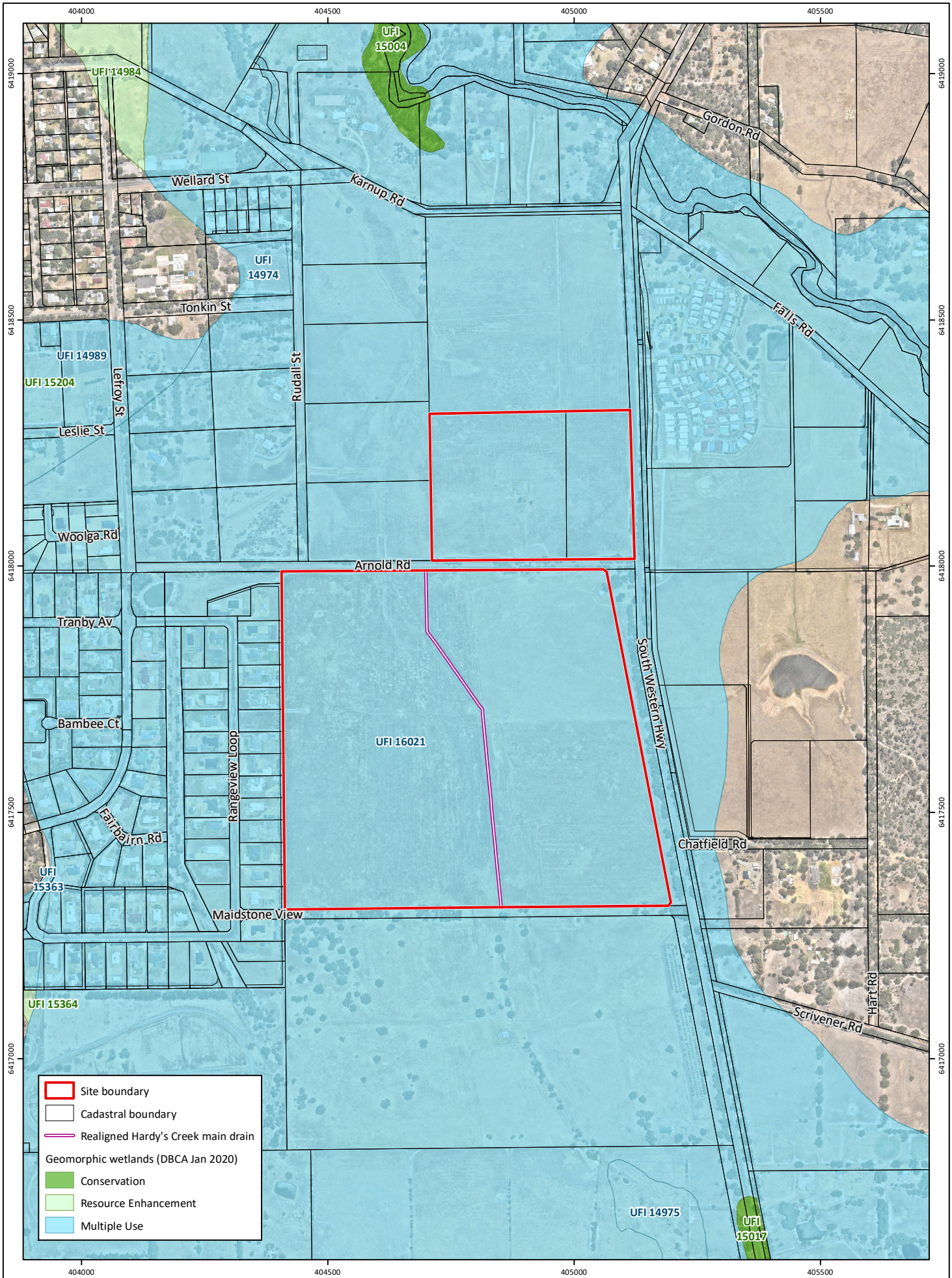

Figure 9: Wetlands and Surface Water Features

Project:	Environmental Assessment Management Strategy Lots 487, 611 & 615 Arnold Rd, Serpentine
Client:	MALF Corp Pty Ltd

Plan Number:
EP20-020(01)--F18

Drawn:	GAR
Date:	06/04/2020
Checked:	BRB
Approved:	CKK
Date:	08/04/2020

N

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Metres

Scale: 1:10,000@A4

GDA 1994 MGA Zone 50

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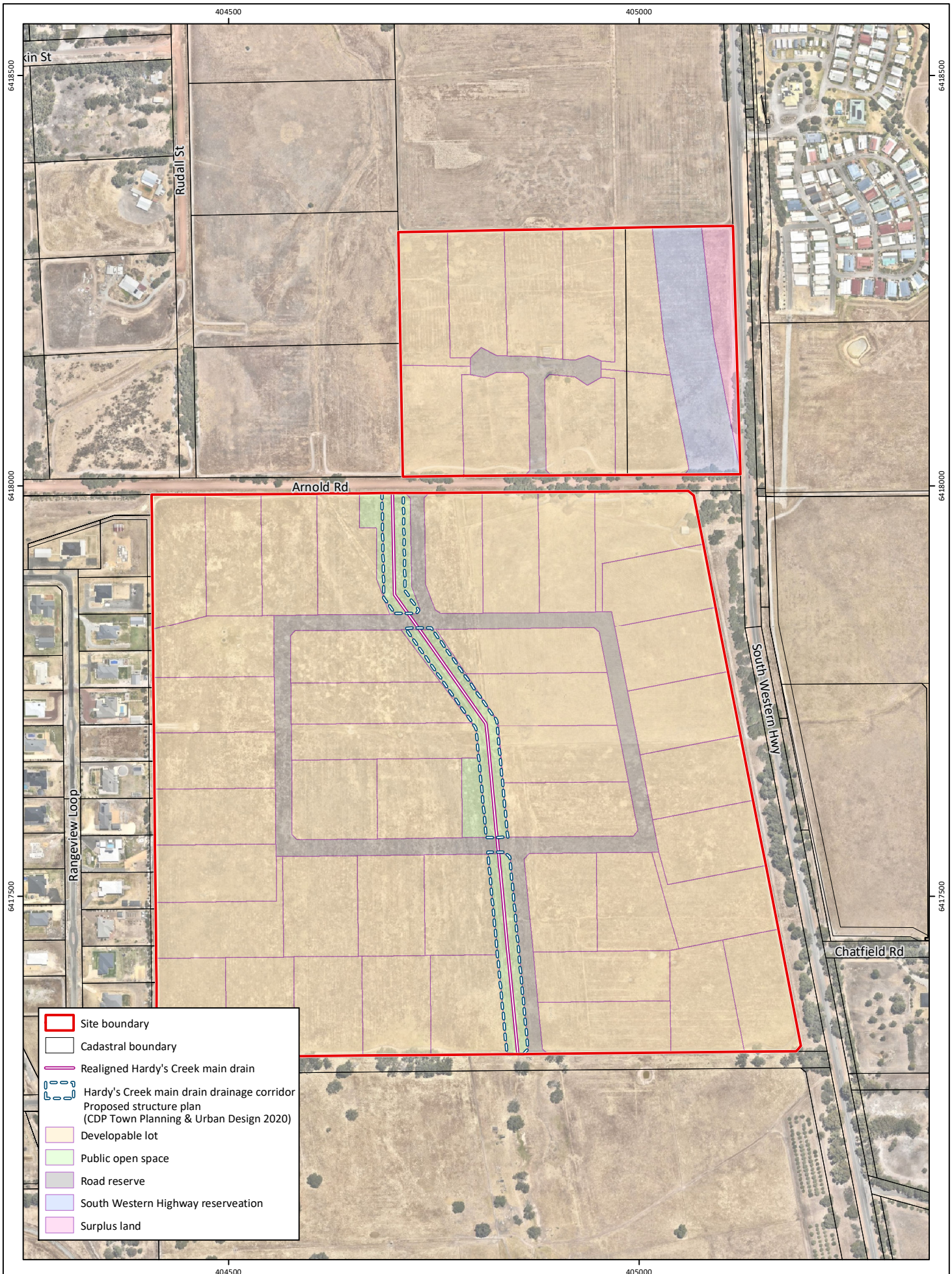

Figure 10: **Structure Plan Response to Environmental Attributes**

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Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number:
EP20-020(01)--F19a

Drawn:	AFF
Date:	17/09/2020
Checked:	BRB
Approved:	CKK
Date:	17/09/2020

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Scale: 1:6,000@A4

GDA 1994 MGA Zone 50

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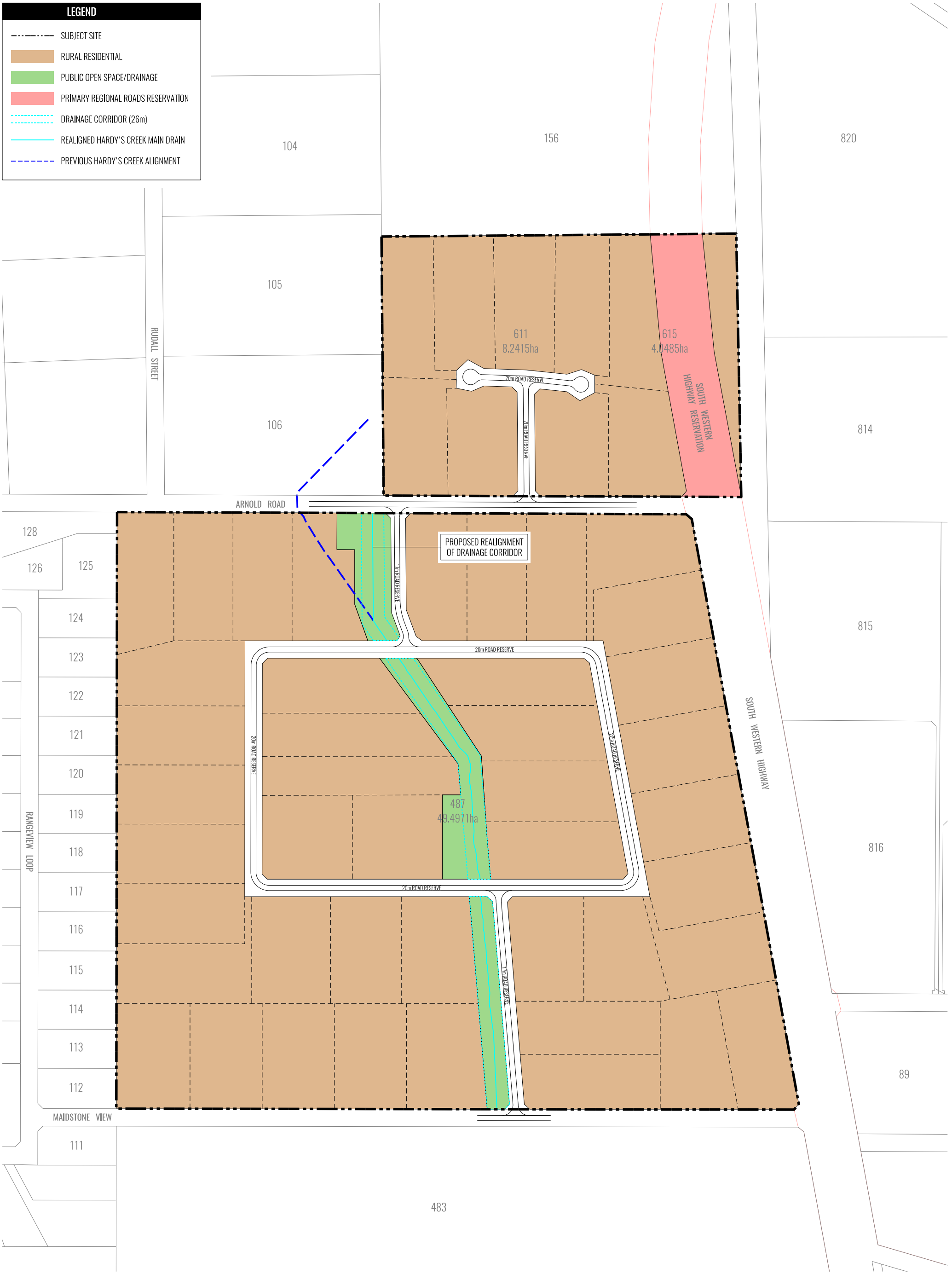
Appendix A

Proposed Structure Plan (CDP Town Planning & Urban Design 2020)



CONCEPT PLAN

Lots 487, 611 & 615 Arnold Rd, SERPENTINE

A Malf Corp Pty Ltd. Project

NORTH

Scale: 1:4000 @ A3

0 40 80 120m

PLAN: MALAR-5-001A REVISION: A
DATE: 21/07/2020 DRAWN: JDP
PROJECTION: PCG 94 PLANNER: MT
DATUM: AHD CHECK: KB

cdp
Town Planning & Urban Design

Unit 2, 464 Murray Street
Perth WA 6000
(08) 6333 1888
info@cdpaus.com.au
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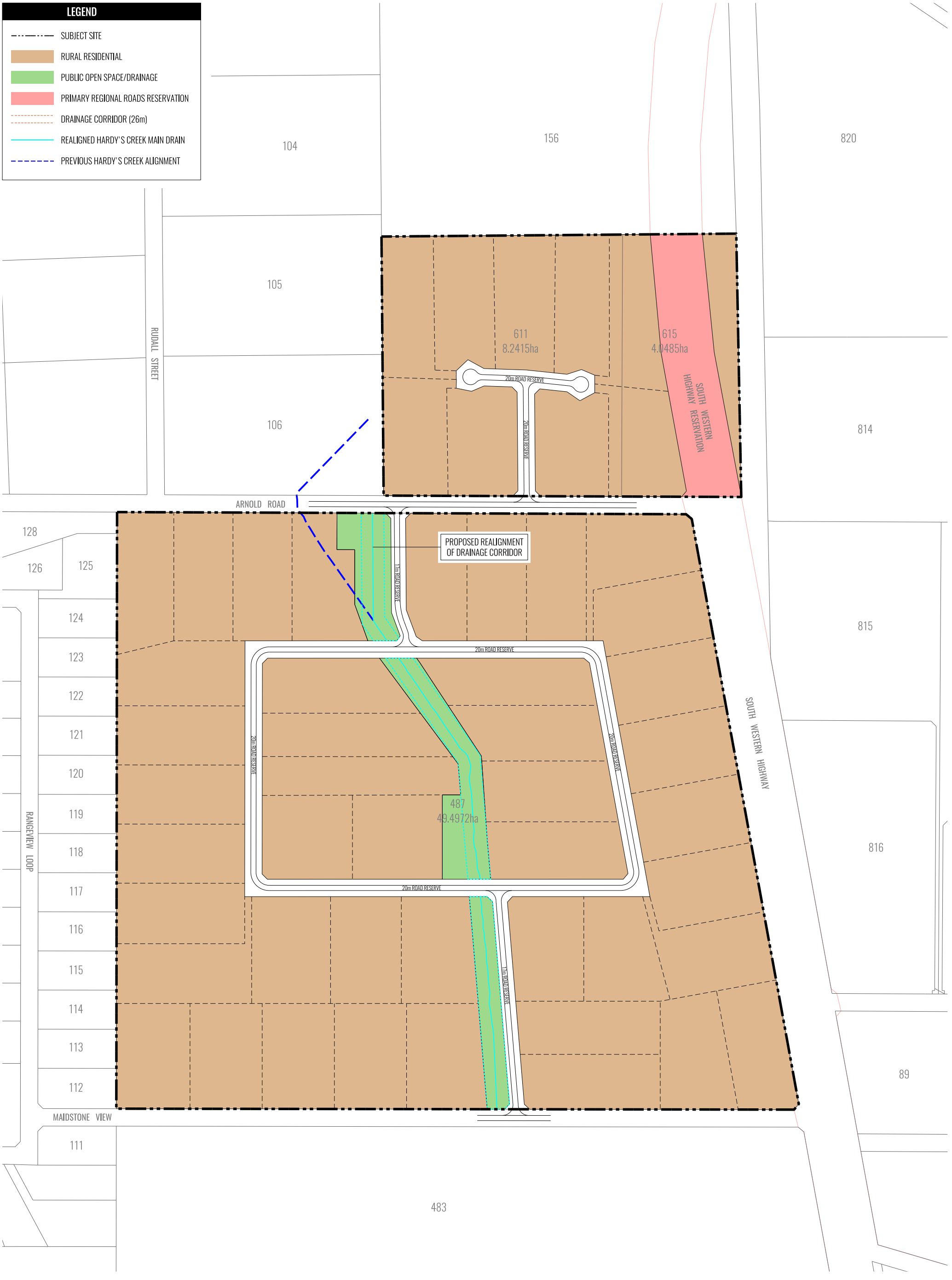
ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix c

Concept Plan

(RobertsDay)



CONCEPT PLAN

Lots 487, 611 & 615 Arnold Rd, SERPENTINE

A Malf Corp Pty Ltd. Project

NORTH

Scale: 1:4000 @ A3

0 40 80 120m

PLAN: MALAR-5-001A REVISION: A
DATE: 21/07/2020 DRAWN: JDP
PROJECTION: PCG 94 PLANNER: MT
DATUM: AHD CHECK: KB

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ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix d

Landscape Masterplan

(Plan/e Landscape Architects)

ARNOLD ROAD, SERPENTINE – LANDSCAPE & REVEGETATION STRATEGY REPORT

The objective of the landscape proposals for the Arnold Road development is to establish an attractive, functional landscape that is sympathetic with the rural character of the area, and meets environmental and fire management objectives.

The components of the public realm are the drainage corridor traversing south to north through the central portion of the site, and the streetscapes. The proposed landscape treatment of each is described in more detail below.

DRAINAGE CORRIDOR

The existing drainage line that runs from south to north through the site will form a central open space corridor. Currently cleared pasture land, the corridor will be landscaped to form an attractive green spine through the site. The existing drainage line will be reshaped where required to assist water conveyance, with logs and boulders strategically placed along its length to moderate water flow in storm events, assisting in erosion control. Stormwater collection and conveyance will be managed through roadside swales and the central drainage channel, with no stormwater storage proposed for the public open space nodes.

A key feature of the green spine will be a 4m wide bridle path, constructed of compacted roadbase, which will form part of a regional bridle trail. Two open space nodes are proposed adjoining the drainage corridor, strategically located at key intersections to visually enhance these entry points. These open space nodes will be developed as rest areas along the trail for horses and their riders, as well as pedestrians and cyclists using the trail. These resting nodes will have an informal, low-key character sympathetic with the rural setting, featuring compacted roadbase paving and a mulched open area, with logs and boulders strategically placed to provide informal seating, and also act as "mounting steps" for riders. There will also be post and rail tie up spots provided for horses. These break-out spaces along the bridle path will be framed and softened with planting comprising low native grasses and groundcovers, and scattered trees to comply with fire management requirements (to achieve BAL 12.5), while still providing visual and environmental amenity.

Planting within the drainage channel will also comprise low native grasses and sedges to maximum 1.0m height, with scattered planting of native trees not exceeding 10% canopy cover at maturity, to comply with bushfire management criteria, whilst ensuring erosion control is managed within the drain. Proposed plant species are derived from the Shire of Serpentine Jarrahdale recommended species list, which are adapted to the wet, waterlogged winter soils and dry summer soils. The list includes deep rooted perennial plants which will utilise water stored in the soil over long periods of the year. Low understorey planting will also assist with passive surveillance within the green spine to meet CPTED principles (Crime Prevention Though Environmental Design).

STREETSCAPES

The streetscapes are proposed to have a rural character, with informal spaced groupings of native trees and an understorey of low-growing native grasses and groundcovers, in order to comply with fire management requirements (to achieve BAL 12.5) while assisting with erosion control within roadside swales, which are located on one side of the road. The roads will be unkerbed, with 1.2m wide sealed shoulders, to reflect a rural character.

LOTS

All lots will be planted with endemic tree species to achieve 3% canopy coverage on the lots when the trees reach maturity. Tree planting will be scattered and generally concentrated towards the perimeter of lots, especially along rear boundaries, to assist in providing screening and visual containment. The scattered tree planting will meet Asset Protection Zone (APZ) standards in order to comply with bushfire management requirements.

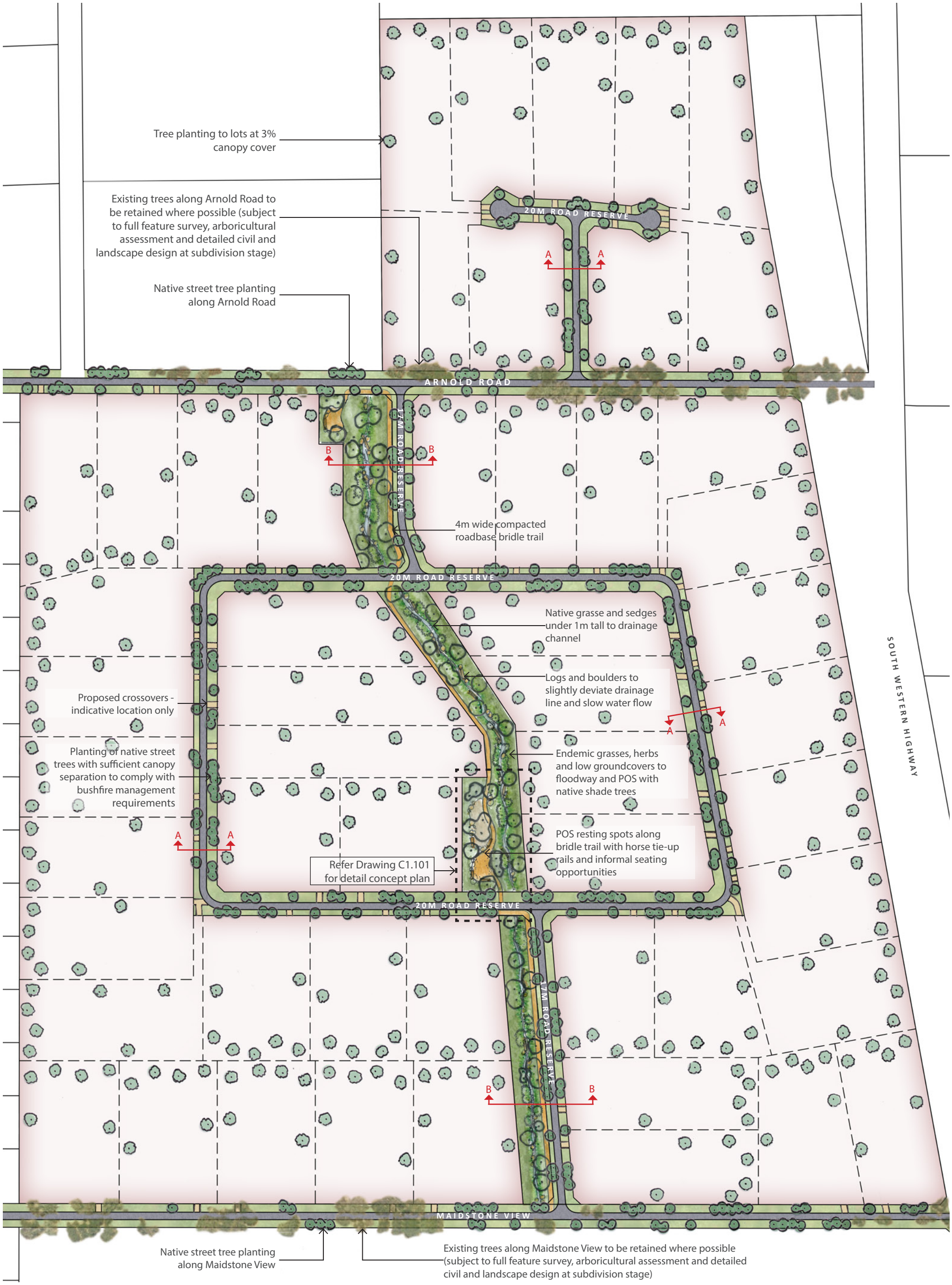
PROPOSED VEGETATION COVER TO SITE

The total vegetation cover proposed for the site following completion of subdivision development can be summarised as follows:

REVEGETATION & TREE CANOPY COVER		
ZONE	AREA OF VEGETATION COVER	PERCENTAGE OF DEVELOPMENT AREA *(59.2547ha)
POS (including drainage channel) *Excludes bridle trail, resting spots and mulch only area*	1.9887ha	3.35%
Streetscape *Excludes road and road shoulders*	2.499ha	4.22%
Lots *3% tree canopy cover to lots*	1.5844ha	2.67%
TOTAL	6.0721ha	10.24%

**NOTE: The Development Area comprises 49.4971ha for Lot 487, 8.2415ha for Lot 611 and 1.5161ha for Lot 615 (this excludes the land area for South Western Highway and the wedge of land on Lot 615 east of the highway)*

It is noted that the above calculations do not include the additional proposed planting along Arnold Road and Maidstone View which would increase the total revegetation provided by the development.



ARNOLD ROAD, SERPENTINE

LANDSCAPE & REVEGETATION STRATEGY

AUGUST 2020

JOB NO. 2002001

1:3000 @ A3

C1.101

REV E

0 15 30 60 90 150m

PLAN E

LANDSCAPE ARCHITECTS

414 ROKEBY RD SUBIACO WA 6008

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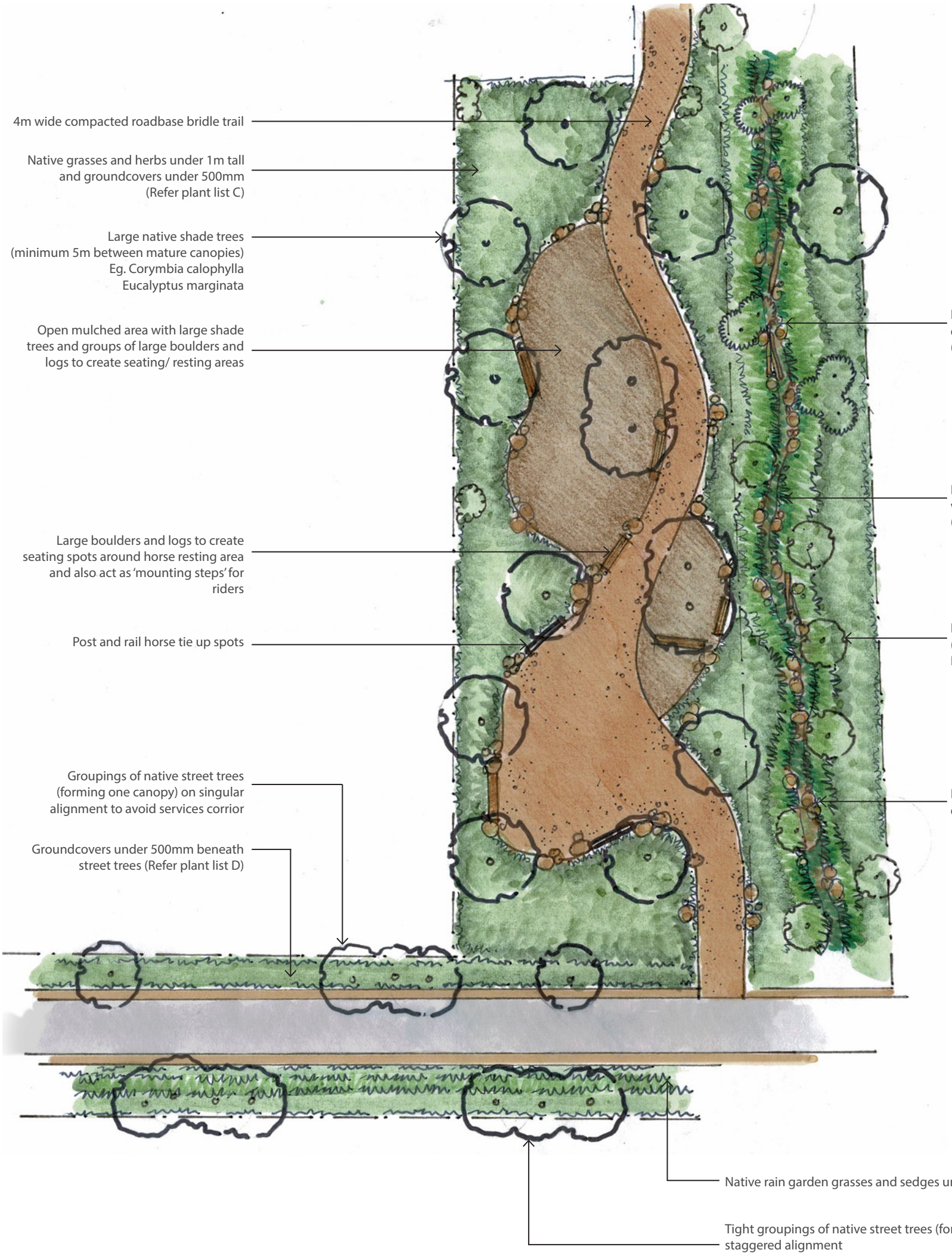

ARNOLD ROAD, SERPENTINE

INDICATIVE LANDSCAPE CONCEPT PLAN - POS AREAS
AUGUST 2020

JOB NO. 2002001
1:500 @ A3

C1.102
REV B

0 5 10 15 25m

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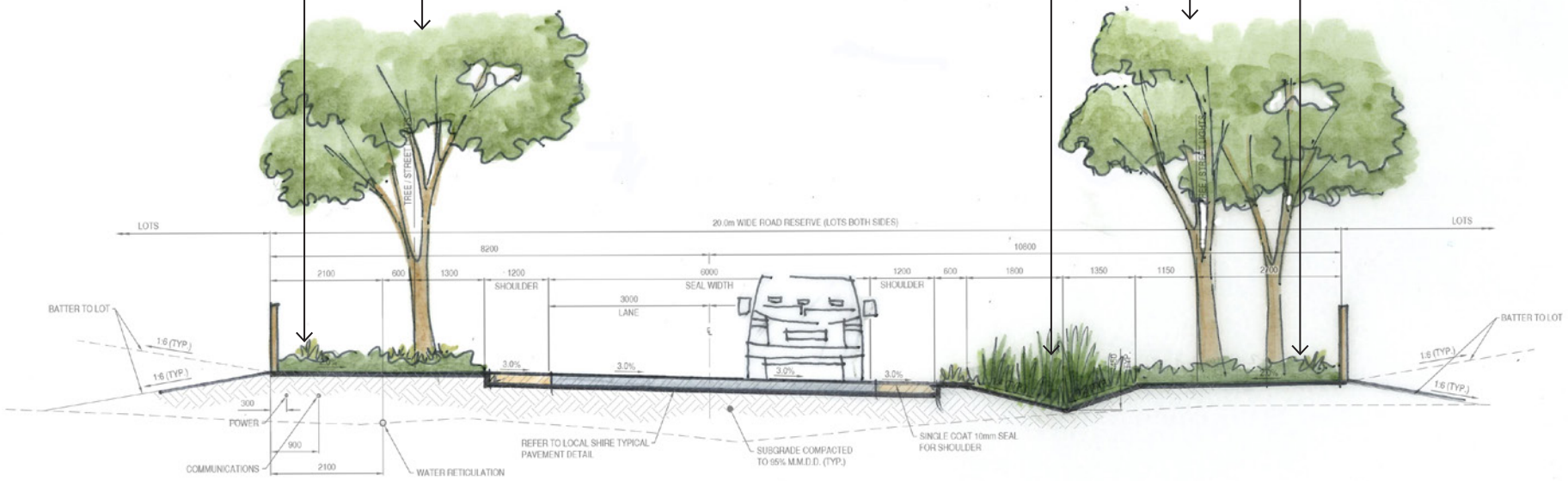
Groupings of native street trees on singular alignment to avoid services corrior (approx 20m gap between group canopies)

Low native herb and groundcover planting to verge (under 500mm h) with minimum 3m between understory and tree canopy

Native rain garden grasses and sedges to swale (under 1m tall)

Groupings of native street trees on staggered alignment (approx 20m between group canopies)

Low native herb and groundcover planting to verge (under 500mm h) with minimum 3m between understory and tree canopy



SECTION A-A TYPICAL CROSS SECTION 20m ROAD RESERVE TO COMPLY WITH COUNCIL COMMENTS

SCALE 1:50

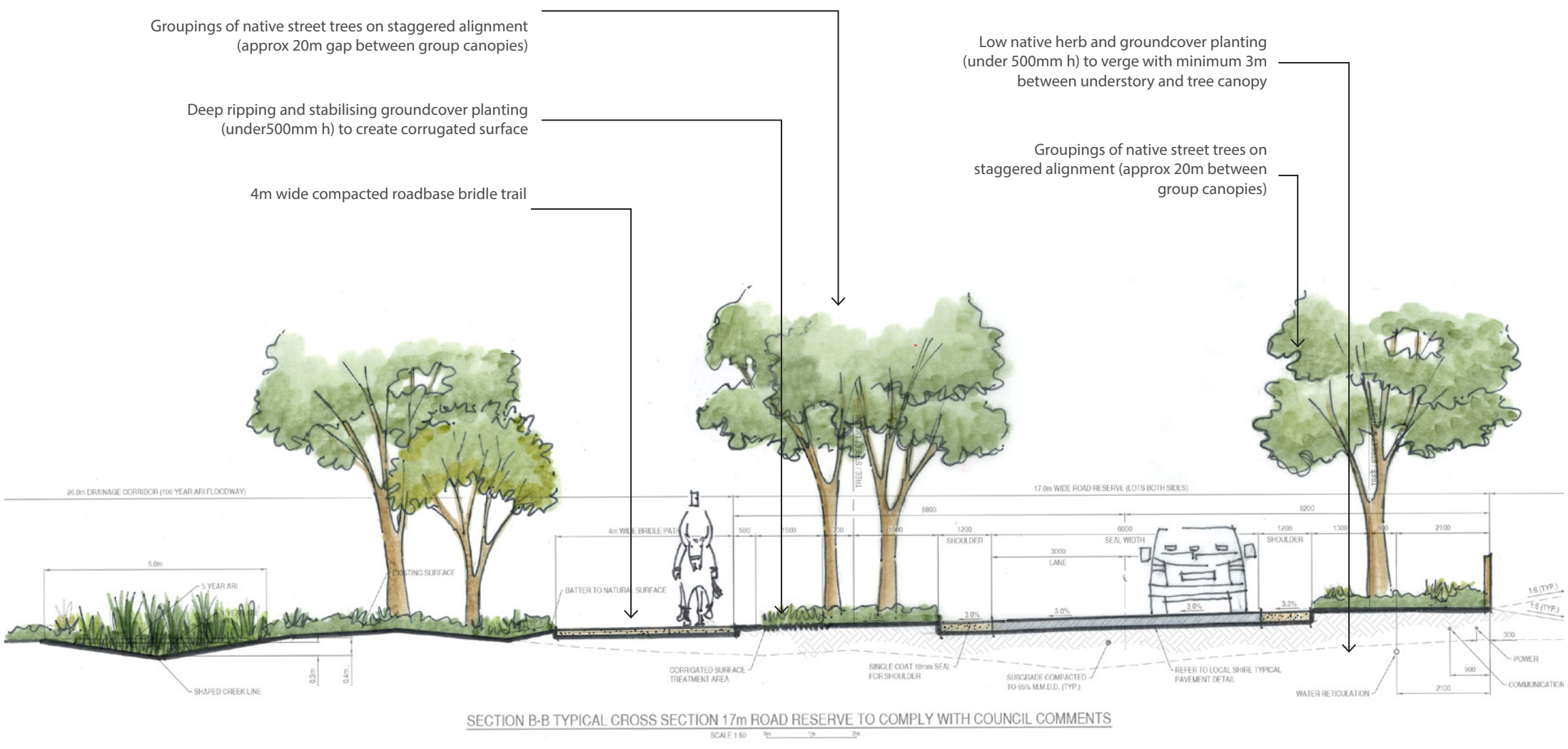
Groupings of native street trees on staggered alignment (approx 20m gap between group canopies)

Deep ripping and stabilising groundcover planting (under500mm h) to create corrugated surface

4m wide compacted roadbase bridle trail

Low native herb and groundcover planting (under 500mm h) to verge with minimum 3m between understory and tree canopy

Groupings of native street trees on staggered alignment (approx 20m between group canopies)



SECTION B-B TYPICAL CROSS SECTION 17m ROAD RESERVE TO COMPLY WITH COUNCIL COMMENTS

SCALE 1:50

ARNOLD ROAD, SERPENTINE

INDICATIVE LANDSCAPE CONCEPT SECTIONS

AUGUST 2020

JOB NO. 2002001

1:100 @ A3

C1.103

REV C

0 1 2 3 5m

PLAN E

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DRAINAGE CHANNEL BASE
(WET IN WINTER/DAMP IN SUMMER. REEDS, SEDGES & GRASSES UNDER 1M HIGH WITH GRAVEL MULCH)

BAUMEA JUNCEA
JUNCUS PALLIDUS
JUNCUS SUBSECUNDUS
LEPIDOSPERMA LONGITUDINALE



DRAINAGE CHANNEL SIDES
(DAMP IN WINTER/DRY IN SUMMER. REEDS, SEDGES & GRASSES UNDER 1M HIGH)

EUCALYPTUS RUDIS
MELALEUCA RHAPHIOPHYLLA

CAREX APRESSA
FICINIA NODOSA
JUNCUS PALLIDUS
JUNCUS SUBSECUNDUS

JUNCUS SUBSECUNDUS
LEPIDOSPERMA SQUAMMATUM
MEEBOLDINA SCARIOSA



UPPER FLOODWAY & POS
(GRASSES & HERBS UNDER 1M HIGH WITH LOW FLAMMABILITY AND GROUNDCOVERS UNDER 500MM)

ALLOCASUARINA FRASERIANA
CORYMBIA CALOPHYLLA
EUCALYPTUS MARGINATA

ACACIA LASIOCARPA PROSTRATE
ANIGOZANTHOS HUMILIS
ANIGOZANTHOS VIRIDUS
BRACHYSCOMBE IBERIDIFOLIA

CAREX APRESSA
CONOSTYLIS ACULEATA
DAMPIERA ALATA
DAMPIERA LINEARIS
DASYPOGON BROMELIIFOLIS
DIANELLA REVOLUTA
ERAGROSTIS ELONGATA
FICINIA NODOSA
GREVILLEA BIPINNATIFIDA
HEMIANDRA PUNGENS
HIBBERTIA HUEGELII
LOMANDRA 'VERDAY'

HOVEA TRISPERMA
LEPIDOSPERMUM SQUAMMATUM
LOBELIA ANCEPS
PATERSONIA OCCIDENTALIS
POA POIFORMIS
ORTHROSANTHUS LAXUS
SCAEVOLA GLANDULIFERA



STREETSCAPE
(LOW FLAMMABILITY RATED GROUNDCOVERS OR HERBS UNDER 500MM HIGH)

CORYMBIA CALOPHYLLA
EUCALYPTUS LANE POOLEI
EUCALYPTUS WANDOO

ACACIA LASIOCARPA PROSTRATE
ACACIA SALIGNA PROSTRATE
DAMPIERA LINEARIS
GREVILLEA BIPINNATIFIDA
HEMIANDRA PUNGENS



ROADSIDE DRAINAGE
SWALES
(GRASSES/REEDS/HERBS UNDER 1M HIGH WITH GRAVEL MULCH & OCCASIONAL ROCK PITCHING)

CAREX APRESSA
CONOSTYLIS ACULEATA
DIANELLA REVOLUTA
FICINIA NODOSA
LEPIDOSPERMA SQUAMMATUM
LOMANDRA 'SHARA'
PATERSONIA OCCIDENTALIS



RESIDENTIAL LOTS
(TREES PLANTED IN ACCORDANCE WITH APZ STANDARDS)

CORYMBIA CALOPHYLLA
EUCALYPTUS LANE POOLEI
EUCALYPTUS WANDOO



ARNOLD ROAD, SERPENTINE

PROPOSED LANDSCAPE PLANT MIXES
AUGUST 2020

JOB NO. 2002001 C3.101 REV D
1:3000 @ A3

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ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix e

Transport Impact Assessment

(GTA Consultants)

Lot 487, 611 & 615 Arnold Road

Transport Impact Assessment



Prepared by: GTA Consultants (WA) Pty Ltd for MALF Corp Pty Ltd

on 11/11/21

Reference: W188080

Issue #: D

GTAconsultants

Lot 487, 611 & 615 Arnold Road

Shire of Serpentine - Jarrahdale
Transport Impact Assessment

Client: MALF Corp Pty Ltd

on 11/11/21

Reference: W188080

Issue #: D

Quality Record

Issue	Date	Description	Prepared By	Checked By	Approved By	Signed
A-Dr	06/04/2020	Draft	Aaron MacNish	Tim Judd		
A	14/04/2020	Revision A - Final	Aaron MacNish	Tim Judd	Tim Judd	
B	05/05/2020	Minor amendment to path network	Aaron MacNish	Tim Judd	Tim Judd	
C	22/07/2020	Minor wording speed zoning, updated road cross sections	Aaron MacNish	Tim Judd	Tim Judd	
D	03/12/2021	Updates to address DPLH requested modifications	Aaron MacNish	Tim Judd	Tim Judd	

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1. INTRODUCTION

01

1.1. Background & Proposal

The Serpentine-Jarrahdale Town Planning Scheme 2 (TPS2) was successfully amended in 2019 which resulted in lots 487, 611 & 615 Arnold Road being zoned as Rural Living A under the scheme.

Subsequent to this, CDP Town Planning & Urban Design are preparing a Structure Plan covering lots 487, 611 & 615 Arnold Road with the aim of subdividing these lots into approximately 1Ha rural residential lots consistent with the lands zoning.

GTA Consultants (GTA) has been engaged by MALF Corp Pty Ltd to undertake a transport impact assessment of the proposed Structure Plan.

1.2. Purpose of this Report

Volume 2 of the Western Australian Planning Commission Transport Assessment Guidelines (WAPC Guidelines) provide direction on the preparation of a Transport Impact Assessment (TIA) for Planning Schemes and Structure Plans. The WAPC Guidelines identify that a TIA for a Structure Plan is to provide a broad-brush assessment.

The current WAPC policy requires structure plans to be supported by a transport assessment.

In accordance with the WAPC Guidelines, this TIA outlines:

- Existing transport conditions proximate to the site
- Suitability of the proposed parking provision within the site
- The adequacy of the proposed site layout
- The traffic generating characteristics of the proposed development
- The anticipated impact of the proposed development on the surrounding road network.

1.3. Summary of key issues

From a traffic and transport point of view, the following key provisions are immediately identified for this TIA:

- South Western Highway is under the care and control of Main Roads WA and runs adjacent to the eastern boundary of the structure plan area, the form and function of the intersection of South Western Highway and Arnold Road will be a key component of this TIA.

1.4. Previous Studies

The following studies were previously prepared and are relevant to the subject sites due to their proximity:

- Transport Assessment Lots 487, 611 & 615 Arnold Road, Serpentine (Opus, July 2016)

1.5. References

In preparing this report, reference has been made to the following:

- Shire of Serpentine-Jarrahdale Town Planning Scheme No.2 (TPS 2)
- Liveable Neighbourhoods Guidelines
- WAPC Transport Assessment Guidelines for Development
- plans for the proposed structure plan dated 21 July 2020 prepared by CDP Town Planning & Urban Design

- traffic and car parking surveys undertaken by GTA Consultants as referenced in the context of this report
- various technical data as referenced in this report
- other documents as nominated.

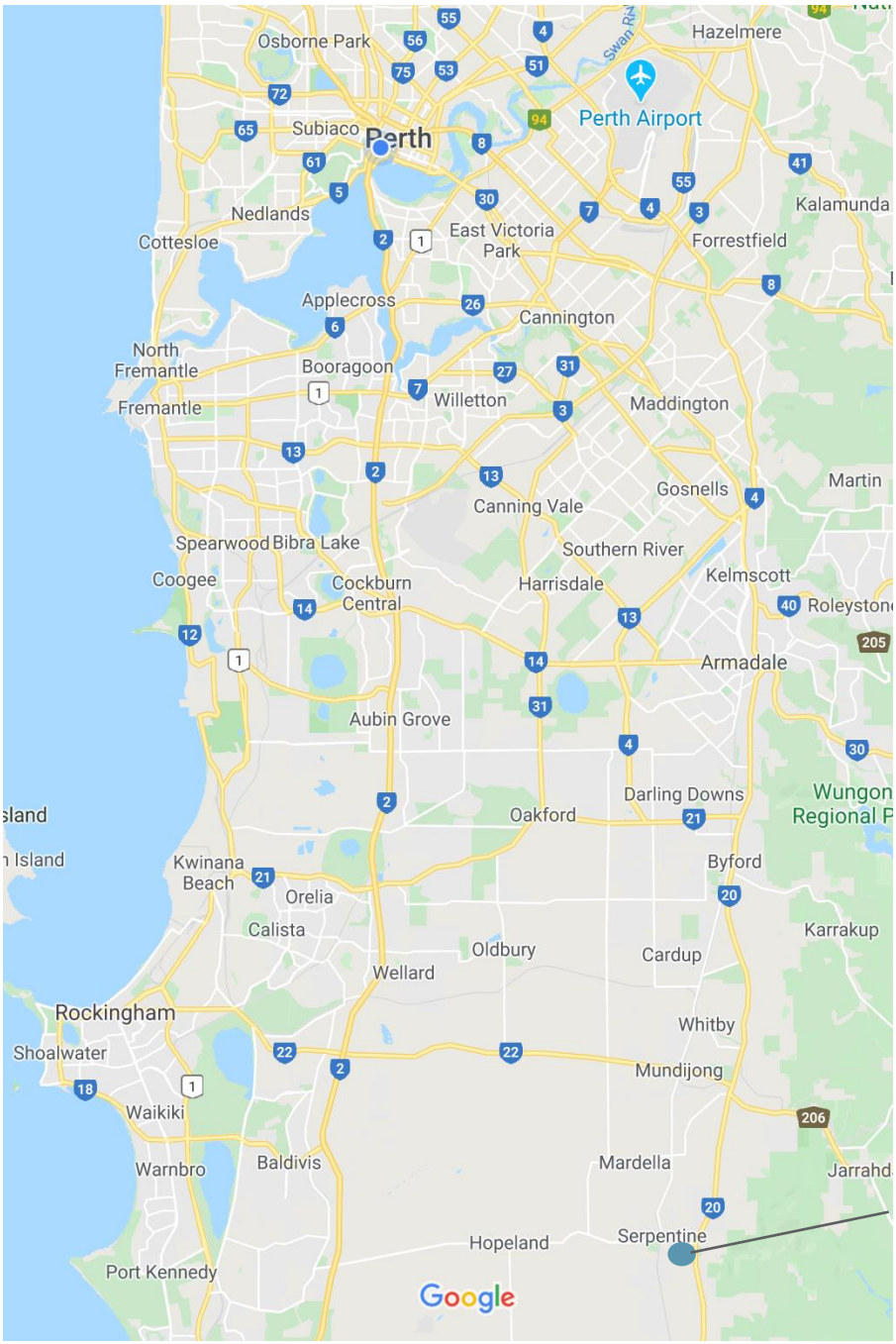
2. STRUCTURE PLAN OUTLINE

02

2.1. Regional Context

The subject site is located in the suburb of Serpentine, within the Shire of Serpentine-Jarrahdale. The site is approximately 47km south-east of the Perth CBD, immediately west of the South West Highway and approximately 1.2km south-east of the Serpentine Town Centre.

Figure 2.1: Location Map



(PhotoMap courtesy of Google Maps)

2.2. Proposed Land Uses

The structure plan proposes 52 rural residential lots, with public open space adjacent the drainage reserve that runs north - south through the site. The land uses are summarised in Table 2.1.

Table 2.1: Land Uses

Land Use	Yield / Area
Rural Residential	52 lots / 53.0449ha
Public Open Space	0.876ha
Road Reserve (Local)	3.8127ha
South Western Hwy Reserve	1.8489ha
Drainage Reserve	1.5151ha
Surplus Land	0.6869ha
Total	**61.7871ha**

2.3. Attractors or Generators of Traffic (non-residential)

The structure plan does not include any traffic generators except the rural residential lots.

2.4. Specific issues

As South Western Highway is under the care and control of Main Roads WA the intersection form and function at Arnold Road & South Western Highway will be subject to endorsement from Main Roads WA. Given the status of South Western Highway as a Primary Distributor the treatment of this intersection may be of a higher standard than would typically be warranted given the low volumes of predicted traffic.

3. EXISTING SITUATION

03

3.1. Subject Site

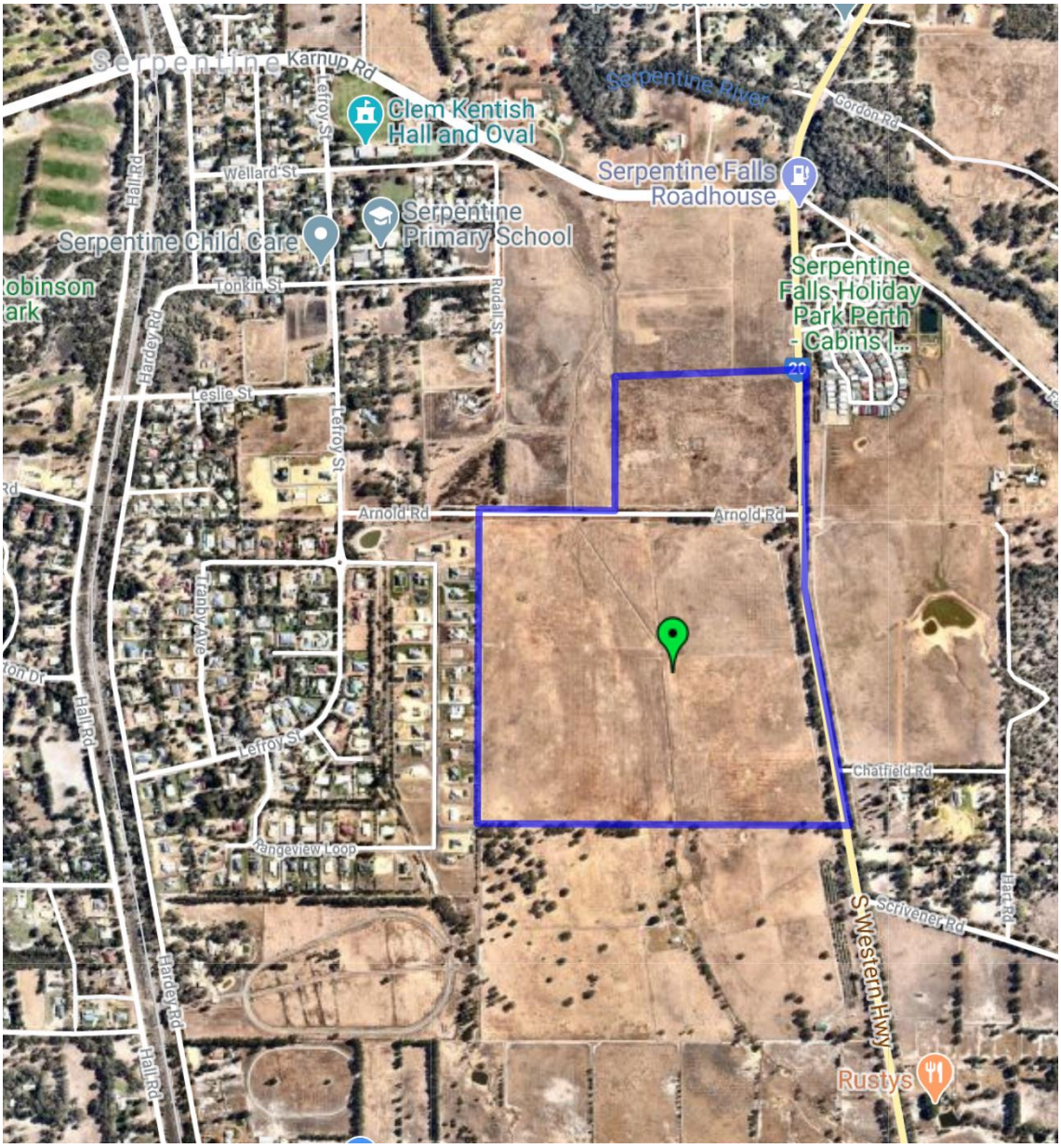
The subject site comprises of lots 487, 611 & 615 Arnold Road, Serpentine. The site area is bound by South Western Highway to the east, existing residential development to the west, and other land currently zoned Rural Living A under the City's TPS 2.

TPS 2 states that the Lots 487, 611 & 615 Arnold Road require a structure plan to guide subdivision and development of the land.

The surrounding properties include a mix of zones including the Rural Living A and Residential Zones.

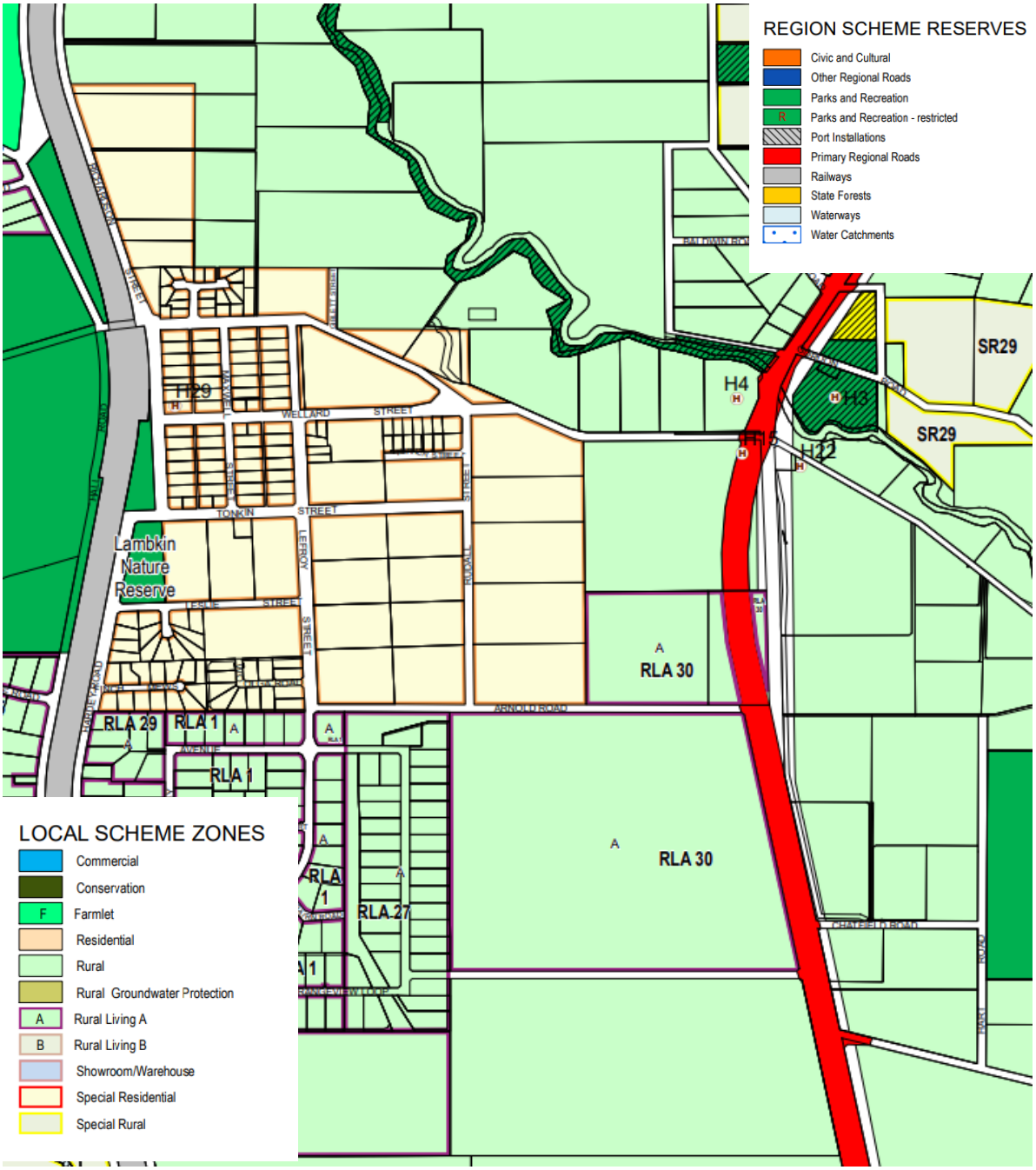
The location of the subject site and the surrounding environs is shown in Figure 3.1, and the land zoning is shown in Figure 3.2.

Figure 3.1: Subject Site and its Environs



(PhotoMap courtesy of Nearmap Pty Ltd)

Figure 3.2: Land Zoning Map



(Reproduced from Shire of Serpentine-Jarrahdale TPS No. 2 Map)

3.2. Existing Movement Network

3.2.1. Roads (inc RAV Networks)

The urban development of the Serpentine area is limited, and the land is currently largely rural.

South Western Highway

South Western Highway runs north-south along the eastern boundary of the subject area and is identified as a "Primary Regional Road" under the Metropolitan Region Scheme (MRS). It is a Primary Distributor Road with a posted speed limit of 110km/h as per the Main Roads Western Australia (MRWA) Functional Road Hierarchy and Road Information Mapping System.

MRWA has indicated that while there are long term plans for the upgrade of South Western Highway adjacent to the site these works are currently unplanned and unfunded. Therefore, the intersection design of Arnold Road and South Western Highway will be treated as the ultimate design for the foreseeable future.

Arnold Road

Arnold Road runs east-west through the centre of the structure plan area and is identified as an Access Road with a default speed limit of 110km/h by the MRWA Road Information Mapping System. It is envisaged that Arnold Road will have a reduced posted speed by Main Roads WA upon subdivision likely reducing the speed to 60km/h. Arnold Road is currently an unsealed gravel track that connects to South Western Highway and an uncontrolled T-intersection.

3.2.2. Pedestrian and Cyclist Network

Given the predominantly rural nature of the area there is little in the way of formalised cycling infrastructure. There is a 1.5m concrete path that runs the full length of Lefroy Street, approximately 600m west of the subject site. There is no pedestrian or cycling network along Arnold Road or South Western Highway.

3.2.3. Public Transport

Serpentine Train Station (Australind Line) is 1.9km north west of the site which provides residence with access to Perth and Bunbury city centres. There are no other public transport facilities in the area.

3.3. Existing Road Network (Within 2km)

In addition to Arnold Road and South Western Highway there are a number of lower order roads within 2km of the subject site. Lefroy Street is a local access road with a default speed limit of 50km/h, Lefroy Street connects the development site to the existing town centre via Arnold Road.

Karnup Road runs east west to the north of the site connecting South Western Highway to the Kwinana Freeway. Karnup Road is classed as a Regional Distributor in the MRWA Functional Road Hierarchy and is a two-lane single carriageway with 4.0m traffic lanes and a posted speed limit of 70km/h.

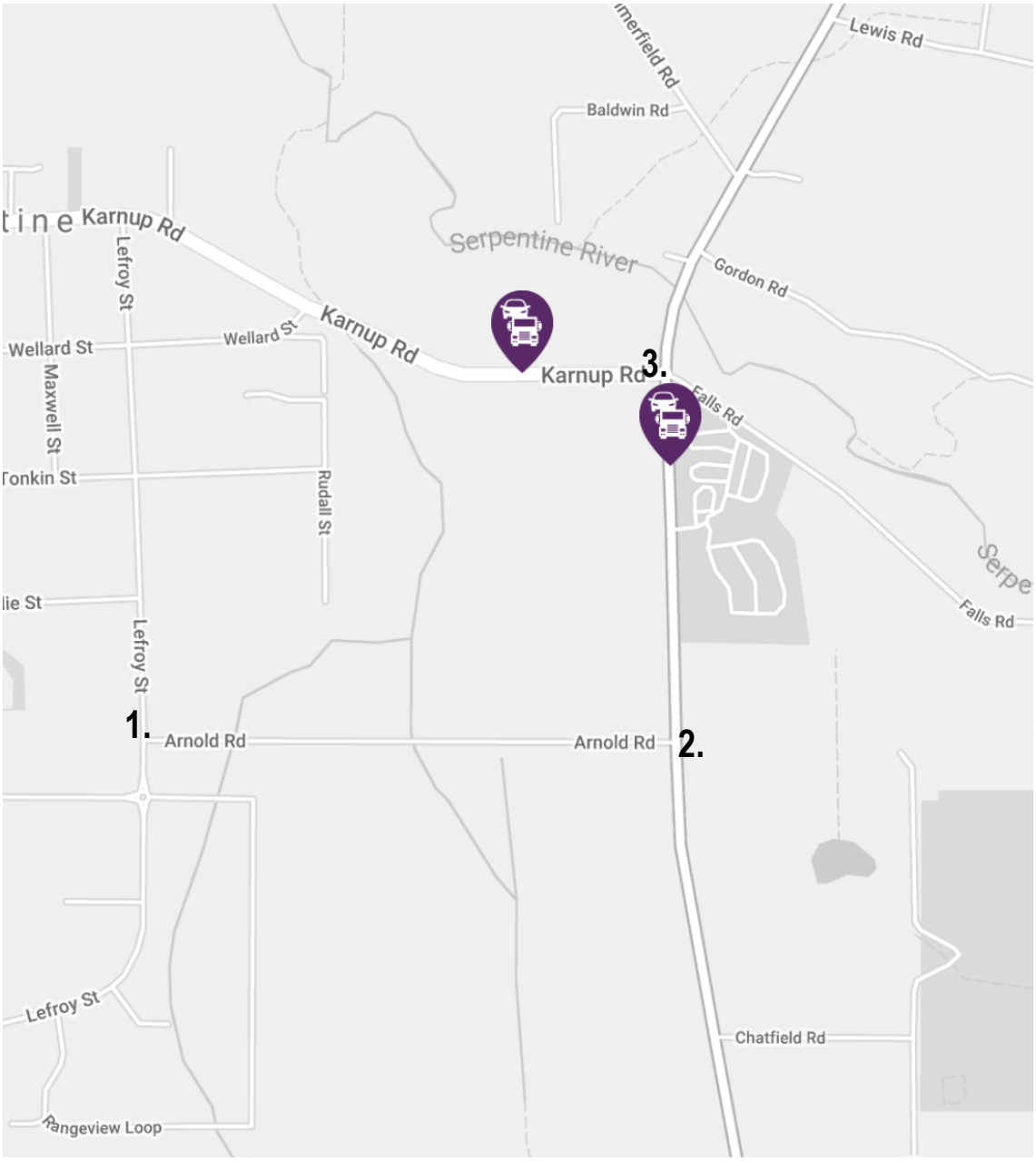
3.4. Traffic Counts (within 2km)

In addition to traffic counts sourced from Main Roads WA TrafficMap data GTA commissioned video counts at the following locations:

1. Arnold Road & Lefroy Street
2. Arnold Road & South Western Highway
3. Karnup Road & Southern Western Highway & Falls Road

These counts were undertaken by Austraffic on 18th of March 2020, the AM peak was 7:45 to 8:45am and the PM peak was 14:15 to 15:15.

Figure 3.3: Location of Counters



	Location	2016/17 Monday to Friday Average	% Cars	% Trucks
1	Karnup Road west of South Western Highway	1,973	87.1	12.9
2	South Western Highway south of Karnup Road	2,841	79.5	20.5

4. PROPOSED INTERNAL TRANSPORT NETWORKS

04

4.1. Changes to Existing Road Network

Arnold Road is proposed to be upgraded to a sealed two-lane single carriageway including an upgrade of the intersection of South Western Highway and Arnold Road consisting of an auxiliary right turn lane on Southern Western Highway to enable southbound vehicles to safely overtake a stationary vehicle turning right into Arnold Road. In addition to the upgrade of Arnold Road, there are several new access roads proposed as part of the structure plan. A copy of the current proposed structure plan can be seen in Appendix A.

4.2. Proposed Road Hierarchy, Road Reserve Widths and Speed Limits

4.2.1. Primary Distributor

South Western Highway is proposed to remain as a Primary Distributor Road along its current alignment. South Western Highway sits within a 60m wide road reserve and has a posted speed limit of 110km/h. The posted speed limit on South Western Highway drops to 80km/h just north of Arnold Road. Discussions should be had with Main Roads WA to move the decrease in speed limit south to include the intersection of Arnold Road. Given the change in land use adjacent this section of South Western Highway to Rural Residential it would support a lower speed limit through the intersection.

4.2.2. Local Access Streets

The structure plan area comprises largely of local access streets due to its residential nature. The local streets proposed as part of this structure plan are detailed below and consider guidance from Austroads Guide to Road Design Part 3 and Liveable Neighbourhoods. Access roads within the structure plan area will be constructed within 17m or 20m road reserves. The Local Access Streets within the development area, including Arnold Road will have residential development extending along at least 90% of the road frontage of both sides of the road. AS1742.4-2008 *Manual of uniform traffic control devices Part 4: Speed controls* stipulates such an environment would typically have an appropriate speed limit of 60km/h.

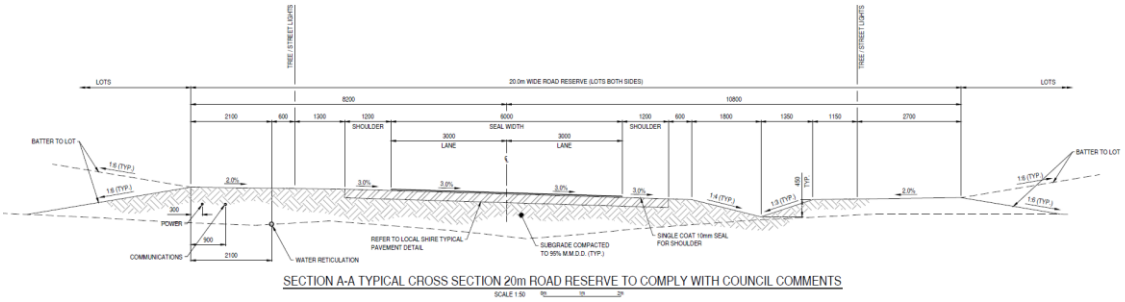
Maidstone View is currently unconstructed along the southern boundary of the structure plan area. As this road is not proposed to form a connection with South Western Highway it is only anticipated to carry a low volume of development traffic. Maidstone View is proposed to be constructed as a rural standard road with the intention of retaining existing trees where possible, subject to a full feature survey, arboriculture assessment and detailed civil and landscape design at the relevant stage of subdivision.

4.3. Road Cross Sections

Given the predominantly rural nature of the structure plan area it is appropriate that the road cross sections take guidance from Table 4.5 of Austroads Guide to Road Design – Part 3, Rural Road Widths.

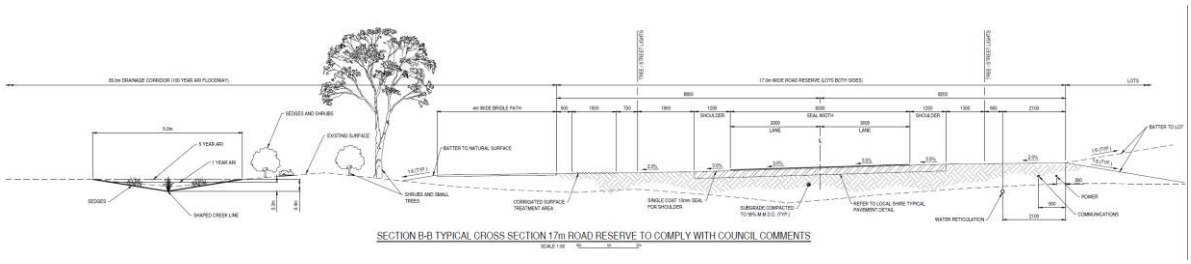
Road cross sections consisting of 3.0m traffic lanes and 1.2m sealed shoulders are deemed appropriated for these low volume's rural roads.

Figure 4.1: Proposed Road Cross Section – 20m Reserve



Source: Typical cross section details, Pritchard Francis DRW 19009-C9-SK-05 REV B

Figure 4.2: Proposed Road Cross Section – 17m Reserve



Source: Typical cross section details, Pritchard Francis DRW 19009-C9-SK-05 REV B

4.4. Intersection Controls

Given the low volume rural road environment all internal intersections within the structure plan are proposed to be priority-controlled t-intersections.

The only exception to this is the intersection of Arnold Road and South Western Highway. Given the high percentage of heavy vehicles and 110km/h speed limit a higher degree of protection is required for vehicles turning from South Western Highway onto Arnold Road.

Main Roads WA were consulted as part of the rezoning of lots 487, 611 & 615 Arnold Road with MRWA endorsing the transport impact assessment findings that the intersection of Arnold Road and South Western Highway should be upgraded with an Auxiliary Right Turn lane (AUR) and a Basic Left Turn (BAL) due to the high speed and high volume of RAV vehicles past the intersection. A typical AUR & BAL intersection configuration is shown in MRWA Drawing No. 20 0131-0082-2 included as Appendix B.

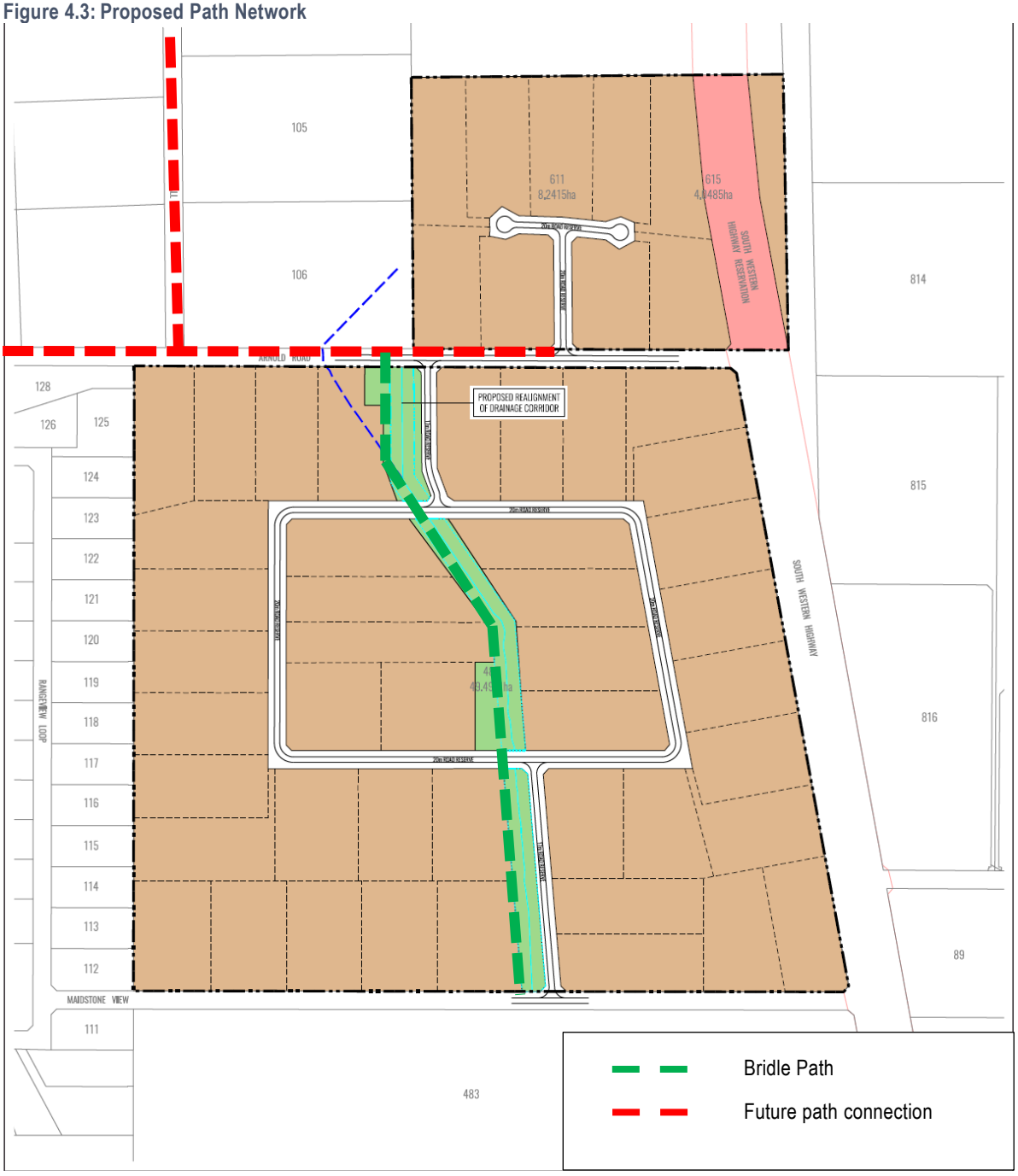
4.5. Pedestrian/Cycle Networks and Crossing Facilities

On April 27, 2016, WA's laws were changed to allow cyclists of all ages to use footpaths, unless otherwise signed. The amendment to the *Road Traffic Code 2000* brought WA's bicycle laws into line with the rest of Australia, making it legal for parents to cycle alongside their children on footpaths, improving safety.

Given the rural-residential nature of the development the demand for dedicated pedestrian/cycling facilities within the site are limited, however the development has proposed several possible pedestrian connections between the Arnold Road structure plan and the townsite, these are represented by the dashed red lines in Figure 4.3. The construction of these path connections is not solely the responsibility of the developer and discussion will occur with the Shire to determine the final

alignment and implementation of the path network. In addition, a 4.0m wide bridle trail (shown as a green dashed line) is proposed along the full length of the open drain that runs north - south through the development area. This bridal trail will provide excellent amenity for local residents and residents of Serpentine for recreational walks and exercise.

Figure 4.3: Proposed Path Network



4.6. Public Transport Routes

Due to the nature of the development, there is no proposed public transport within the structure plan area.

5. INTEGRATION WITH SURROUNDING AREAS

05

5.1. Surrounding Attractors

The structure plan area is consistent with the zoning for the area. However, the majority of the land surrounding the subject area is currently still rural and has not been developed. Given this, there are limited attractors within the structure plan area.

5.2. Trip Attractors/Generators within 800m

The existing Serpentine townsite is situated to the north-west of the structure plan area, just outside of the 800m catchment. The Serpentine townsite is primarily residential with one childcare facility and a local primary school (188 students in 2018). The remainder of the land surround the structure plan area is predominantly rural in nature.

5.3. Proposed Changes to Land Uses within 800m

There are no current proposed changes to the land use within 800m of the Structure plan area.

5.4. Travel Desire Lines from Structure Plan to these Attractors/Generators

Travel desire lines to local attractors such as the school, community facilities and local centre will be well catered for when developed as they all lie on direct road routes which will cater for motor vehicles, pedestrians, and cyclists. There are no other trip attractors/generators within 800m of the structure plan areas as the surrounding land is predominantly Rural and/or Residential.

5.5. Adequacy and Deficiencies in External Transport Networks

Arnold Road currently intersects South Western Highway as an uncontrolled priority t-intersection. South Western Highway caters for a high number of large multicombination heavy vehicles, travelling at 100km/h past the intersection of Arnold Road. With this in mind the current unprotected turning arrangements for vehicles entering Arnold Road from South Western Highway will not be suitable with future growth of traffic along South Western Highway and the addition of development traffic.

5.6. Remedial Measures to Address Deficiencies

Proposed upgrade to South Western Highway and Arnold Road to a Type B intersection represented MRWA Drawing No. 200131-0082-2 included as Appendix B as previously endorsed by MRWA in correspondence dated 9th August 2016.

6. ANALYSIS OF INTERNAL TRANSPORT NETWORKS

06

6.1. Assessment Year(s) and Time Period(s)

The WAPC Transport Impact Assessment Guidelines state that the analysis of the transport networks should be undertaken for the (assumed) year of full development, which for this development is 2026. Nevertheless, it has been agreed with Main Roads WA that a design assessment of the year 2031 would be more appropriate given the need for access to South Western Highway. The traffic assessment has considered the AM and PM Peaks for the purpose of intersection analysis, as all-day traffic volumes generated by the structure plan area are low all internal roads are proposed as Access Roads and no further all-day analysis has been completed.

6.2. Structure Plan Generated Traffic

6.2.1. Trip Generation Rate

The trip generation rates used for this structure plan were taken from the WAPC Transport Assessment Guidelines: Volume 2 – Planning Schemes, Structure Plans and Activity Centre Plans (2016).

The trip generation rates for the proposed structure plan can be seen in Table 6.1.

Table 6.1: Trip Generation Rates

Land Use	Unit	AM Trip Rate		PM Trip Rate	
		In	Out	In	Out
Residential	Dwellings	0.2	0.6	0.5	0.3

6.2.2. Trip Generation of Site

Based on the trip generation rates in Table 6.1, the total in/out traffic generation for the AM and PM peak hours have been calculated and presented below in Table 6.2.

Table 6.2: Traffic Generation

Lot	Land Use	AM Trip Rate		PM Trip Rate	
		In	Out	In	Out
52 Lots	Residential	10	31	27	14

6.3. Traffic Distribution

Due to the nature of the development, it is assumed all trips generated by the development will have an origin or destination outside of the structure plan area. No internal – internal trips have been calculated for this structure plan.

It is assumed that 50% of trips will be to/from the Serpentine Townsite to the west of the structure plan, with the remaining 50% of trips being distributed to South Western Highway in the east.

The structure plan area is serviced by two roads, Arnold Road in the north and the future extension of Maidstone View in the south. Due to the structure plan configuration traffic is anticipated to distribute 80% to Arnold Road and 20% to Maidstone View. Trips to/from South Western Highway are split 80% north and 20% south taken from existing intersection movements in 2020.

This results in a traffic distribution summarised below:

- Arnold Road West = 40%

- Maidstone View West = 10%
- South Western Highway North = 40%
- South Western Highway South = 10%

6.4. Extraneous (Through) Traffic

Given the layout of the structure plan area there are no through trips expected within the structure plan site.

6.5. Design Traffic Flows (i.e. Total Traffic)

6.5.1. South Western Highway

A growth factor of 5% per annum has been applied to the background traffic flow on South Western Highway between 2020 and 2031. This 5% growth has been obtained from MRWA ROM24 modelling of the area and is consistent with the 4% growth per annum previously applied in 2016. This can be considered conservative as the growth may be much less with the extension of Tonkin Highway to Byford scheduled to begin construction in 2020. The forecast peak hour volumes on South Western Highway can be seen in Table 6.3.

Table 6.3: Forecast Peak Traffic Flows on South Western Highway

2031 Vehicles per hour	Northbound	Southbound	Total
AM Peak	188	172	361
PM Peak	246	193	438

6.5.2. Arnold Road

Arnold Road already provides a connection to South Western Highway in the form of a priority-controlled intersection, the upgrade of this intersection as part of the proposed development will likely attract a portion of residential traffic from the existing developments to the west of the structure plan area. However, the road can be seen to have sufficient capacity to cater for any additional traffic attracted to it based on current land use planning in the area.

To obtain these figures existing traffic counts were taken in March 2020 and a 5% annual growth over 10 years was applied, the traffic volumes from the development traffic was then added to the background traffic to determine the total traffic volumes in 2031.

Table 6.4: Forecast Peak Traffic Flows on Arnold Road

2031 Vehicles per hour	Eastbound	Westbound	Total
AM Peak	26	9	35
PM Peak	18	20	38

6.5.3. Maidstone View

Maidstone View is not proposed to connect through to South Western Highway, it will serve as an access to the structure plan area. If Maidstone View does ever connect through to South Western Highway traffic volumes along this road are likely to be substantially higher because of additional background traffic from the existing residential developments to the west of the structure plan area.

As this road is not proposed to connect to South Western Highway no external through traffic has been applied to this road, thus the total traffic in 2031 is expected to consist solely of development traffic. If in the future Maidstone View is to connect to South Western Highway a new analysis should be completed to determine the new traffic volumes.

Table 6.5: Forecast Peak Traffic Flows on Maidstone View

2031 Vehicles per hour	Eastbound	Westbound	Total
AM Peak	1	4	5
PM Peak	4	2	6

6.6. Intersection Controls

Given the very low volumes of traffic on the internal roads all internal intersections are proposed as priority-controlled t-intersections with give-way or stopped sign controls as appropriate.

6.7. Access Strategy

Access to the structure plan area from the east will be facilitated by an upgrade full movement t-intersection at South Western Highway and Arnold Road. Western access to the site will be split between the intersections of Arnold Road / Lefroy Street (T-intersection) and Maidstone View / Rangeview Loop (T-intersection).

6.8. Pedestrian / Cycle Networks

Due to the rural – residential nature of the structure plan there is a low demand for dedicated pedestrian and cycling networks. A bridal trail will run for the full length of the drain that runs north – south through the structure plan area and a pedestrian connection to the existing townsite is still for discussion with the Shire and subject to detailed design.

This arrangement is considered acceptable given the low volume rural nature of the internal street network.

6.9. Safe Routes to Schools

The local primary school is located within the existing Serpentine townsite to the north west of the structure plan area. A pedestrian connection to the existing townsite is still for discussion with the Shire and subject to detailed design.

6.10. Access to Public Transport

Residents will be able to access the Serpentine train station via Arnold Road and Lefroy Street. It is assumed there will be a low demand for public transport given the rural – residential nature of the development in this location.

7. ANALYSIS OF EXTERNAL TRANSPORT NETWORKS

07

7.1. Extent of Analysis

The proposed structure plan generates a very low amount of traffic (408 vpd and 41 vph). Therefore, the extent of analysis for the external transport network has been limited to the intersection of Great Southern Highway and Arnold Road.

7.2. Impact Assessment

7.2.1. Trip Distribution

As discussed in Chapter 6 the distribution of traffic access to the Arnold Road / South Western Highway intersection is 50% of the total structure plan traffic. This traffic is then further distributed 80% northbound on South Western Highway and 20% southbound.

7.2.2. Traffic Impact of Development Traffic

As a general guide an increase in traffic of less than 10 per cent of capacity would be unlikely to have any material impact on the performance of an intersection. The transport impact assessment completed in 2016 for the rezoning of the structure plan undertook a SIDRA analysis on the intersection of Arnold Road and South Western Highway resulting in a typical Type B intersection with auxiliary right turn lane and basic left turn treatment.

Volumes assessed in 2016 were significantly higher than the volumes of this proposed structure plan (115 lots previously proposed, 52 lots currently proposed). A sensitivity analysis was completed in the 2016 transport impact assessment and distributed 100% of the development traffic onto the intersection of Arnold Road & South Western Highway. The results concluded that the intersection would still operate with a Degree of Saturation of 0.165, Level of Service A with a 95% queue of 2.5m.

As such no further operational modelling is proposed at this intersection as it has already been concluded the operational performance will be acceptable long past the design year for this structure plan.

7.2.3. Traffic Impact of Development on Local Area

Based on the above assessment it is concluded that the development will have an acceptable impact on the surrounding roads and intersections with the only change required being the upgrade of Arnold Road / South Western Highway.

7.3. Intersection Layouts & Controls

The intersection of Arnold Road and South Western Highway has been assessed in accordance with Main Roads WA Supplement to Austroads Guide to Road Design Part 4 A.8.

The assessment shown in Figure 7.1 and Figure 7.2 shows that in 2031 (5 years after the year of full development) the intersection of South Western Highway and Arnold Road only requires an Auxiliary Right (AUR) and Basic Left (BAL) treatment, consistent with the previous assessment in 2016 for the scheme amendment.

Figure 7.1: Warrants for Turn Treatments on Major Road – 2031 AM Peak

INTERSECTION WARRANTS

Main Roads WA Supplement to Austroads Guide to Road Design - Part 4 A.8

DESIGN SPEED =	110km/h
SPLITTER ISLAND YES / NO =	No
DUAL CARRIAGEWAY YES / NO =	No

MOVEMENT	COUNT (v/h)	HV (%)
Q_{T1} =	172	16
Q_R =	5	0
Q_{T2} =	188	16
Q_L =	4	0

RIGHT TURN ASSESSMENT

Q_m =	364
% HV =	15.824
x =	0.99
TREATMENT =	BAR

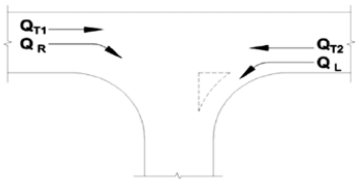
LEFT TURN ASSESSMENT

Q_m =	188
% HV =	16.000
x =	0.49
TREATMENT =	BAL

Source: Austroads GTM Part 6 - 2017

Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings

Figure 2.27: Calculation of the major road traffic volume Q_M



Road type	Turn type	Splitter island	Q_M (veh/h)
Two-lane two-way	Right	No	= $Q_{T1} + Q_{T2} + Q_L$
		Yes	= $Q_{T1} + Q_{T2}$
	Left	Yes or no	= Q_{T2}
Four-lane two-way	Right	No	= 50% x $Q_{T1} + Q_{T2} + Q_L$
		Yes	= 50% x $Q_{T1} + Q_{T2}$
	Left	Yes or no	= 50% x Q_{T2}
Six-lane two-way	Right	No	= 33% x $Q_{T1} + Q_{T2} + Q_L$
		Yes	= 33% x $Q_{T1} + Q_{T2}$
	Left	Yes or no	= 33% x Q_{T2}

Source: TMR (2016a).

Figure 7.2: Warrants for Turn Treatments on Major Road – 2031 PM Peak

INTERSECTION WARRANTS

Main Roads WA Supplement to Austroads Guide to Road Design - Part 4 A.8

DESIGN SPEED =	110km/h
SPLITTER ISLAND YES / NO =	No
DUAL CARRIAGEWAY YES / NO =	No

MOVEMENT	COUNT (v/h)	HV (%)
Q_{T1} =	193	14
Q_R =	13	0
Q_{T2} =	246	15
Q_L =	7	0

RIGHT TURN ASSESSMENT

Q_m =	446
% HV =	14.332
x =	1.74
TREATMENT =	AUR

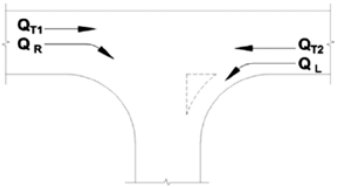
LEFT TURN ASSESSMENT

Q_m =	246
% HV =	15.000
x =	0.79
TREATMENT =	BAL

Source: Austroads GTM Part 6 - 2017

Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings

Figure 2.27: Calculation of the major road traffic volume Q_M



Road type	Turn type	Splitter island	Q_M (veh/h)
Two-lane two-way	Right	No	= $Q_{T1} + Q_{T2} + Q_L$
		Yes	= $Q_{T1} + Q_{T2}$
	Left	Yes or no	= Q_{T2}
Four-lane two-way	Right	No	= 50% x $Q_{T1} + Q_{T2} + Q_L$
		Yes	= 50% x $Q_{T1} + Q_{T2}$
	Left	Yes or no	= 50% x Q_{T2}
Six-lane two-way	Right	No	= 33% x $Q_{T1} + Q_{T2} + Q_L$
		Yes	= 33% x $Q_{T1} + Q_{T2}$
	Left	Yes or no	= 33% x Q_{T2}

Source: TMR (2016a).

8. CONCLUSION

08

CONCLUSION

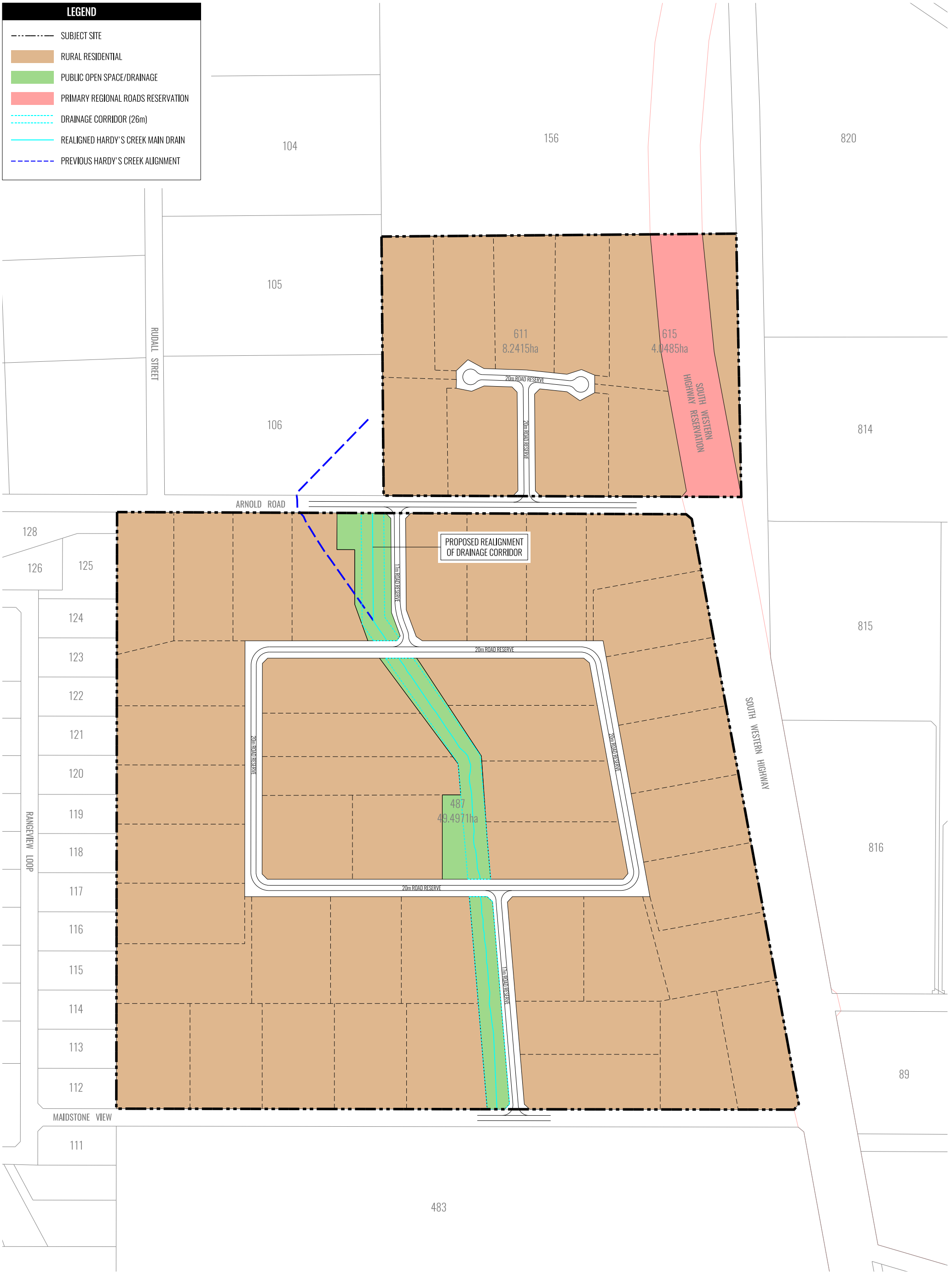
As a result of the transport analysis undertaken for the proposed structure plan of Lot 487, 611 & 615 Arnold Road the following findings and recommendations are made:

- The structure plan will produce 52 residential lots generating 408 vehicle trips per day and 41 trips in the peak hour.
- The low demand for pedestrian and cycling movements is adequately catered for via a proposed bridal trail that runs north – south through the site and a possible connection between the Structure Plan and existing townsite to be discussed with the Shire.
- The intersection of Arnold Road & South Western Highway will function with ample operational capacity in 2031 and should be constructed with an auxiliary right turn treatment & basic left turn treatment on South Western Highway.

The WAPC checklist is included in Appendix C.

A. STRUCTURE PLAN

A



CONCEPT PLAN

Lots 487, 611 & 615 Arnold Rd, SERPENTINE

A Malf Corp Pty Ltd. Project

NORTH

Scale: 1:4000 @ A3

0 40 80 120m

PLAN: MALAR-5-001A REVISION: A
DATE: 21/07/2020 DRAWN: JDP
PROJECTION: PCG 94 PLANNER: MT
DATUM: AHD CHECK: KB

cdp
Town Planning & Urban Design

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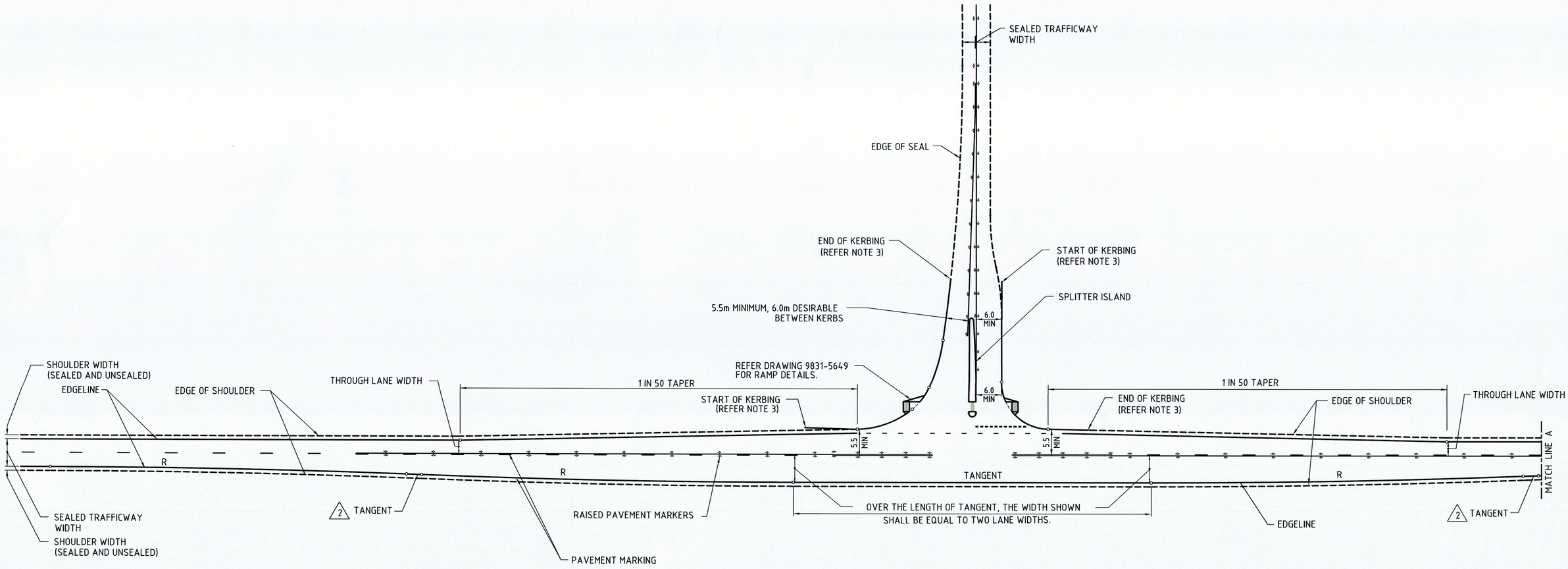
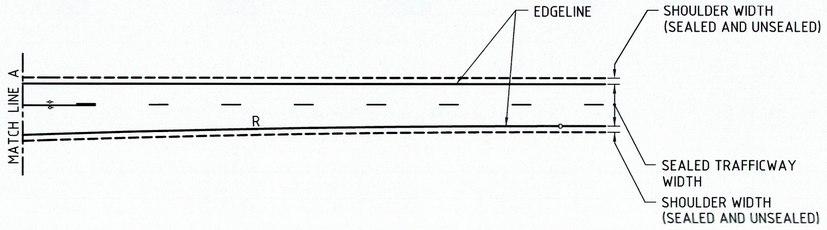
B. INTERSECTION LAYOUT

B





NOTES

1. THIS DRAWING SHOWS AN EXAMPLE 'T' INTERSECTION TREATMENT, IT SHOULD BE READ IN CONJUNCTION WITH DRAWINGS 200131-081, 200131-083, 200131-084, 200131-085, 200131-086, 200431-065 AND 200431-066.
   EACH TURN MOVEMENT SHOWN ON THIS SET OF DRAWINGS IS INTERCHANGABLE DEPENDING ON THE DESIGN WARRANT OF THE PARTICULAR INTERSECTION.
   INTERSECTION CURVE RADII SHALL BE DESIGNED FOR EACH INDIVIDUAL LOCATION USING THE TURNING TEMPLATE OF THE DESIGN VEHICLE.
   EACH ELEMENT OF THE DESIGN NOT SPECIFIED ON THIS DRAWING SHALL BE DETERMINED FROM:
   (a). THE MAIN ROADS SUPPLEMENTS TO AUSTROADS GRD PART 4A: UNSIGNALISED AND SIGNALISED INTERSECTIONS AND GRD PART 4: INTERSECTIONS AND CROSSINGS: GENERAL.
   (b). AUSTROADS GRD PART 4A: UNSIGNALISED AND SIGNALISED INTERSECTIONS AND GRD PART 4: INTERSECTIONS AND CROSSINGS: GENERAL.
   IN THAT ORDER. 2
2. THE PAVEMENT MARKING (LINE AND RAISED PAVEMENT MARKERS) SHOWN ON THIS DRAWING ARE INDICATIVE ONLY. DETAILS OF PAVEMENT MARKING REQUIREMENTS SHALL BE OBTAINED FROM THE MAIN ROADS STANDARD CONTRACT DRAWINGS AND, AS 1742.2 AND THE FOLLOWING DRAWINGS:-
   201031-0026 RAISED PAVEMENT MARKER GENERAL APPLICATIONS IN URBAN AREAS.
   201031-0027 RAISED PAVEMENT MARKER GENERAL APPLICATIONS IN RURAL AND OUTER METROPOLITAN AREAS.
   9931-0198 PAVEMENT MARKING LINE TYPES.
   200331-182 PAVEMENT MARKINGS AND RRPMs AT TYPE "BA" AND TYPE "AUR" INTERSECTIONS.
   200331-184 SPLITTER ISLANDS - LINE MARKING AND RRPM's.
   200431-002 STOP AND GIVE WAY LINES.
3. FOR DETAILS OF KERB DESIGN REFER TO MAIN ROADS SUPPLEMENT TO AUSTROADS GRD PART 3, CLAUSE 4.6.4.
4. DIMENSIONS SHOWN AS MINIMUMS ARE DESIRABLE MINIMUMS.
5. FOR LATERAL MOVEMENT GEOMETRY INCLUDING 'R' REFER TO MAIN ROADS SUPPLEMENT TO AUSTROADS GRD PART 4, SECTION A.6. 2
6. WARRANTS FOR THE PROVISION OF BARRIER LINES AT TYPE "BA" AND TYPE "AUR" INTERSECTIONS ARE GIVEN ON DRAWING 200331-182.

2

SCALES N.T.S.

A1

No.	DESCRIPTION	APPROVED & DATE
2.	REFERENCES TO AUSTROADS GUIDES UPDATED, TITLEBLOCK UPDATED.	CM 20/11/19
1.	REFERENCES TO AUSTROADS GUIDES UPDATED, TGSI's ADDED, RRPM's AMENDED.	CM 20/11/12

AMENDMENTS

AMENDMENTS

PLANNING AND TECHNICAL SERVICES DIRECTORATE
ROAD AND TRAFFIC ENGINEERING BRANCH
WATERLOO CRESCENT EAST PERTH 6004
Telephone (08) 9323 4111

DESIGNED	
DRAWN	E. FINDLATER
VERIFIED	T. FREEMAN 06/09/06
APPROVED	R. GROVE 06/09/06
FILE NUMBER	67-08-3

GUIDELINE DRAWING

MAIN ROADS RIGHT TURN TYPE "AUR"
MAIN ROADS LEFT TURN TYPE "BAL" (WIDENED TO 5.5m)
SIDE ROAD SINGLE TURN LANE

INTERSECTIONS AT GRADE

SHEET 2 OF 8

MRWA DRAWING NUMBER
200131-0082-2

C. WAPC GUIDELINES CHECKLIST

C

CONCLUSION

Item	Provided	Comments/Proposals
Summary	✓	
Introduction/Background	✓	
Structure plan proposal	✓	
regional context	✓	
proposed land uses	✓	
table of land uses and quantities	✓	
major attractors/generators	✓	
specific issues	✓	
Existing situation		
existing land uses within structure plan	✓	
existing land uses within 800 metres of structure plan area	✓	
existing road network within structure plan area	✓	
existing pedestrian/cycle networks within structure plan area	✓	
existing public transport services within structure plan area	✓	Minimal due to the semi-rural nature of the surrounding area.
existing road network within 2 (or 5) km of structure plan area	✓	
traffic flows on roads within structure plan area (PM and/or AM peak hours)	✓	
traffic flows on roads within 2 (or 5) km of structure plan area (AM and/ or PM peak hours)	✓	
existing pedestrian/cycle networks within 800m of structure plan area	✓	
existing public transport services within 800m of structure plan area	✓	
Proposed internal transport networks		
changes/additions to existing road network or proposed new road network	✓	
road reservation widths	✓	
road cross-sections & speed limits	✓	
intersection controls	✓	
pedestrian/cycle networks and crossing facilities	✓	
public transport routes	✓	
Changes to external transport networks		
road network	✓	
intersection controls	✓	
pedestrian/cycle networks and crossing facilities	N/A	Not applicable due to such low demand in the area.
public transport services	✓	
Integration with surrounding area		
trip attractors/generators within 800 metres	✓	

proposed changes to land uses within 800 metres	✓	
travel desire lines from structure plan to these attractors/generators	✓	
adequacy of external transport networks	✓	
deficiencies in external transport networks	✓	
remedial measures to address deficiencies	✓	
Analysis of internal transport networks		
assessment year(s) and time period(s)	✓	
structure plan generated traffic	✓	
extraneous (through) traffic	✓	
design traffic flows (that is, total traffic)	✓	
road cross-sections	✓	
intersection controls	✓	
access strategy	✓	
pedestrian/cycle networks	✓	
safe routes to schools	✓	
pedestrian permeability & efficiency	✓	
access to public transport	✓	
Analysis of external transport networks		
extent of analysis	✓	
base flows for assessment year(s)	✓	
total traffic flows	✓	
road cross-sections	✓	
intersection layouts & controls	✓	
pedestrian/cycle networks	✓	
Conclusions		

Proponent's Name: Lara Iozzi

Company: MALF Corp Pty Ltd Date: 11/11/2021

Transport Assessor's Name: Aaron MacNish

Company: GTA Consultants Date: 11/11/2021

GTAconsultants

www.gta.com.au

ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix f

Addendum to Local Water Management Strategy

(RPS Group)

Our ref: EWP20068.001

Level 2, 27-31 Troode Street
West Perth WA 6005
T +61 8 9211 1111

Date: 14 April 2021

Shire of Serpentine Jarrahdale
6 Paterson Street
Mundijong WA 6123

To whom it may concern,

Lots 611, 615 and 487 Arnold Road, Serpentine – Addendum to the Local Water Management Strategy

This letter has been prepared as an addendum to the Local Water Management Strategy (LWMS), Lots 611, 615 and 487 Arnold Road (Bayley Environmental Services 2016). This addendum has been prepared to support the submission of the Structure Plan (SP) that has been recently prepared for Lots 611, 615 and 487 Arnold Road (from herein referred to as 'the site') (Appendix A).

This addendum also provides updated details on water management proposed within the site and should be read in conjunction with the following water management reports:

- Local Water Management Strategy Lots 611, 615 and 487 Arnold Road, Serpentine (Bayley Environmental Services 2016) (Appendix B)
- Arnold Road Flood Modelling Redesign (Coterra Environment 2019) (Appendix C)
- Lots 102 to 106 Rudall Street, Serpentine: Townsite Flood Modelling Report – Summary of Results Rev 2 (Coterra Environment 2017) (Appendix D)
- Shire of Serpentine Jarrahdale Engineering Services – Letter of Acceptance for Coterra Environment (2017) Townsite Flood Modelling Report Rev 2 (Appendix E)

The documents below were all recently prepared to support the SP submission and should also be read in conjunction with this addendum to the LWMS:

- Geotechnical Report, Lots 611, 615 and 487 Arnold Road (Douglas Partners 2020) (Appendix F)
- Landscape and Revegetation Strategy, Lots 611, 615 and 487 Arnold Road (Plan E 2021) (Appendix G)
- Desktop Engineering Servicing Report, Lots 611, 615 and 487 Arnold Road (Pritchard Francis 2020) (Appendix H)
- Bioretention treatment correspondence with Department of Water and Environmental Regulation (DWER), and the Shire of Serpentine Jarrahdale (the Shire) (Appendix I)
- LWMS checklist (Appendix J)
- Septic setback correspondence with DWER (Appendix K)

- Arnold Road Creek Crossing Typical Table Drain Treatment Details (Pritchard Francis 2021) (Appendix L)

Background

A draft LWMS was prepared for the Serpentine Outline Plan Area (also referred to as the Serpentine Townsite Local Structure Plan) which is located immediately downstream of the site and includes Lots 102 to 106 Rudall Street was prepared by GHD in February 2013 (herein referred to as the Serpentine Outline Plan Area LWMS). This LWMS was prepared to support a SP called the "Serpentine Townsite Local Structure Plan" on behalf of the Department of Planning, Land and Heritage (DPLH) and has not been endorsed by the Shire or DWER. A revised submission which focuses on realignment of the Hardy Creek Main Drain (HCMD) within Lots 102 to 106 Rudall Street was later submitted and received support from the Western Australian Planning Commission (WAPC). It's understood that the Shire is now modifying the Serpentine Townsite Local Structure Plan (along with a long list of other changes) so that it is consistent with the realignment of the HCMD and plan to re-advertise it in the second half of 2020.

A LWMS (from herein referred to as 'the LWMS') was prepared for the site by Bayley Environmental Services in 2016 (Appendix B). This document was prepared based on a Subdivision Concept Plan with average lot sizes of 0.44 ha and takes into consideration the Serpentine Outline Plan Area Plan LWMS. The LWMS accompanied a metropolitan regional scheme amendment application for a landuse change from "Rural" to "Rural Living A" which was approved in 2019.

In 2017 Coterra Environment prepared a technical flood modelling report addendum (from herein referred to as 'the modelling report') to support the realignment of the HCMD within the Serpentine Outline Plan Area (Appendix D). The modelling report provides details on hydraulic and hydrological modelling undertaken to support realignment of the HCMD located on the northern side of Arnold Road. It also provides stormwater modelling details of the HCMD within the subject site. It is understood that the modelling report was prepared in consultation with DWER and the Shire. A letter of acceptance from the Shire's Engineering Services department to this technical report was issued in 2017 (Appendix E). As the modelling report has been approved by the Shire it therefore supplements any modelling details presented in the LWMS (2016) in Appendix B.

In 2019 Coterra Environment undertook a flood modelling exercise on a redesigned HCMD (from herein referred to as the 'modelling redesign report') for the site (Appendix C). For this investigation, the approved hydraulic model was modified with a realignment of the HCMD approximately 80 m east either side of Arnold Road consistent with the SP and demonstrates that this can be achieved without increasing flood risk or peak flows.

LWMS addendum for the site

The purpose of this addendum to the LWMS is to provide additional water management details relating to changes in the proposed SP. The main differences between the current proposed SP and the Subdivision Concept Plan which was used to inform the original LWMS and the modelling report include:

- The alignment of lots and roads has changed, with an increase in the average lot size from around 0.44 ha to 1 ha and a decrease in the total road reserve area from approximately 9.53 ha to approximately 4.2 ha. This has resulted in a reduction of the total impervious area.
- A portion of the HCMD located immediately to the south and north of Arnold Road has been realigned approximately 80 m to the east (Figure 1).
- Bioretention treatment of the first 15 mm of runoff will be provided in linear swales located within a buffer strip adjacent to the HCMD instead of roadside swales as agreed by DWER and the Shire (Appendix I). Further bioretention swale details are provided in the Landscape Concept Master Plan (Appendix G) and Engineering Servicing Report (Appendix H).
- Arnold Road creek crossing typical drain treatment details are also included in Appendix L.

As there has been a reduction in total impervious area, the peak discharge rates from the site into the HCMD will be less than peak flow rates presented in the previously approved modelling report.

The realignment of the HCMD within the site proposed is consistent with the SP and has been designed with a cross-sectional shape, length and volume storage that is similar to the modelling redesign report and the approved modelling report (Figures 2 and 3). The online flood detention portion of the HCMD immediately south of the Arnold Road culverts (for a 117 m length south of the culvert) will generally have a 1 in 3 side, with opportunities for sections of 1:6 side slopes to allow for maintenance vehicles to enter the drain if required. The conceptual drain profile at this short stretch and the drivers (flood storage requirements) have been discussed with the Shire and provisionally accepted subject to further information at the detailed design stage. The modelling redesign report results demonstrate the proposed drainage infrastructure's ability to maintain pre-development flow rates and not increase flood risk. The hydraulic information detailed in the LWMS and addendum are in line with the Water Corporations drainage planning requirements.

The direction of surface water flow within the road drainage network and into the HCMD is presented in Figure 4 and is generally consistent with the LWMS and flood modelling report accepted by the Shire.

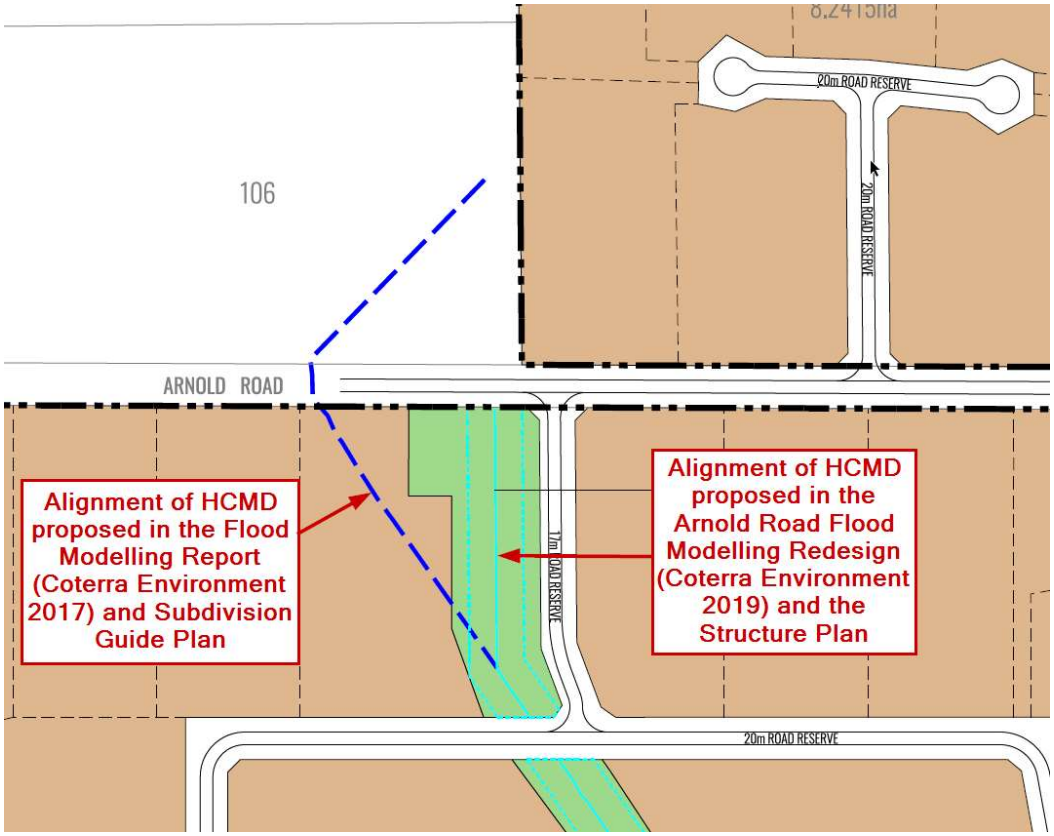


Figure 1. Proposed realignment of the Hardy Creek Main Drain.

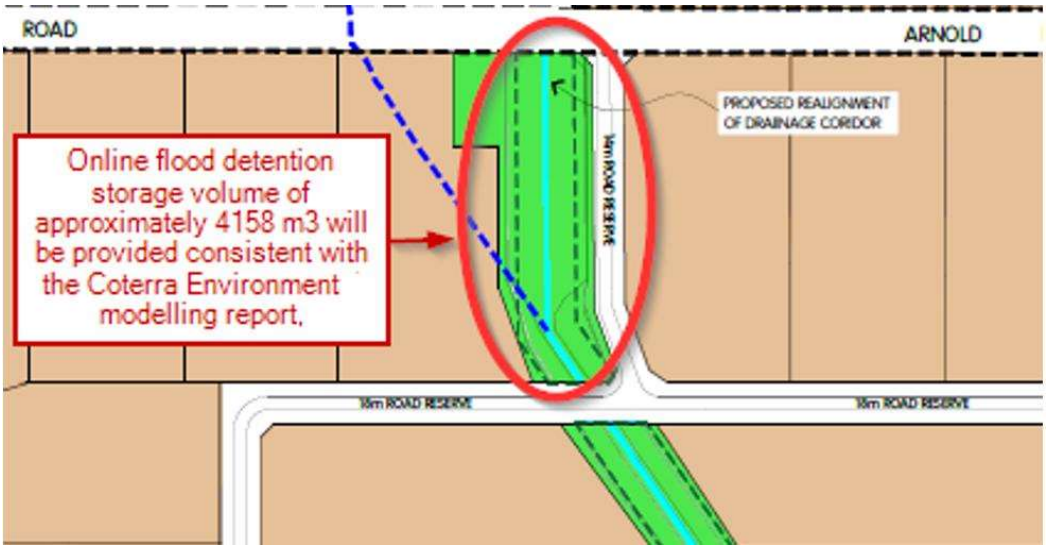


Figure 2. Proposed online flood detention area within the HCMD immediately south of Arnold Road.

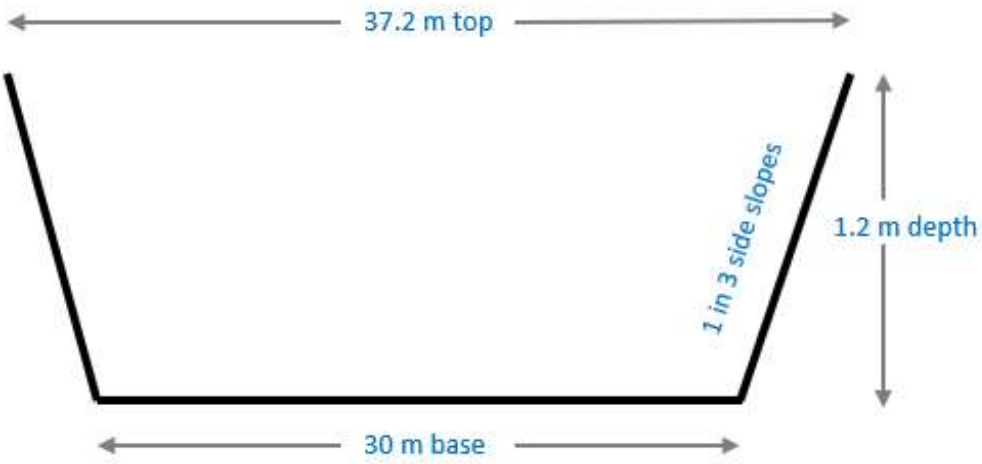


Figure 3. Indicative cross section of the proposed online flood detention area within the HCMD adjacent to Arnold Road culverts.

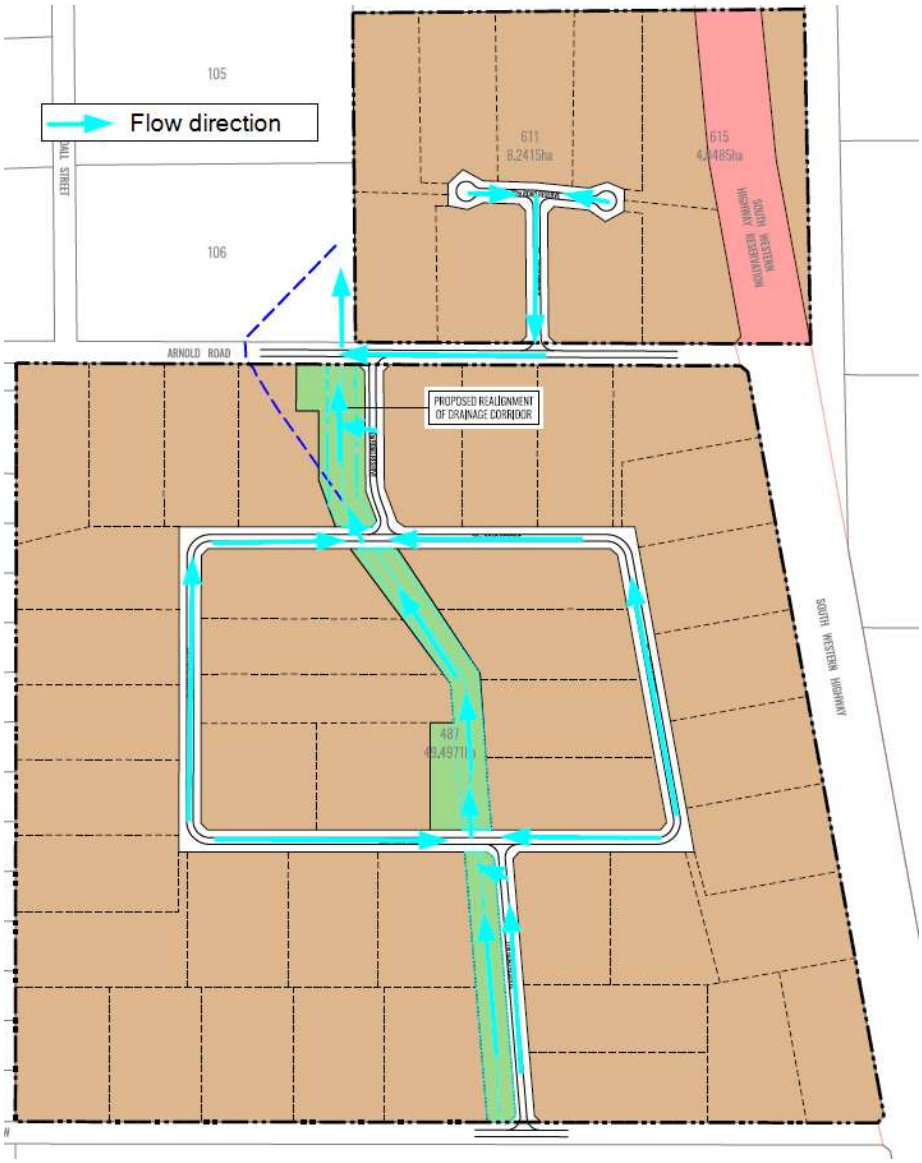


Figure 4. Indicative surface water flow direction within the road drainage network.

Table 1 provides a summary of the water management strategies proposed in the LWMS, the modelling report (2017), the modelling redesign report (2019) and this addendum. From the table it is evident that the key water management strategies presented in this addendum are generally consistent with the LWMS, the modelling report and the modelling redesign report.

Table 1: Proposed water management and amendments

Considerations	The LWMS (Bayley Environmental Services 2016)	Flood modelling report (Coterra Environment 2017)	Flood modelling redesign report (Coterra Environment 2019)	This LWMS addendum
• Lot layout	• Original Subdivision Concept Plan with an average lot size of 0.44 ha.	• Consistent with the LWMS.	• Consistent with the LWMS.	• Revised draft SP with an average lot size of 1 ha.

Considerations	The LWMS (Bayley Environmental Services 2016)	Flood modelling report (Coterra Environment 2017)	Flood modelling redesign report (Coterra Environment 2019)	This LWMS addendum
• Landuse areas	• Total area 62 ha. • Road reserve 9.53 ha. • 115 rural residential lots with an average size of 0.44 ha, totalling approximately 50 ha.	• Consistent with the LWMS.	• Consistent with the LWMS.	• Total area 62 ha. • Road reserve 4.2 ha. • 52 rural residential lots with an average size of approximately 1ha and totalling 53.13 ha.
• Alignment of the HCMD	• As per existing alignment.	• Consistent with the LWMS on the south side of Arnold Road. Realignment of the HCMD on the north side of Arnold Road.	• Further realignment of the existing HCMD approximately 80 m to the east of Arnold Road, on both the northern and the southern sides (Figure 1).	• Consistent with the modelling redesign report. • The hydraulic information is in line with the Water Corporations drainage planning requirements.
• Surface Water Management	• 1 year ARI – Retain and infiltrate all flows as close to source as possible. Maintain pre-development flow rates and volumes. Minimise export of nutrients and sediments. • 5 year ARI - Detain water prior to discharge. Maintain pre-development flow rates and volumes. Maintain amenity and serviceability. Prevent scouring and damage. • 100 year ARI - Maintain pre-development flow rates and volumes. Prevent flooding and damage.	• Consistent with the LWMS.	• Consistent with the LWMS.	• Consistent with the LWMS.
• Road drainage	• The road drainage system has been designed to minimise disturbance to the existing site drainage in terms of flow paths, volumes and peak flows. All road runoff from storms up to 1-year ARI, 1 hour duration (about 17.5mm)	• Consistent with the LWMS.	• Consistent with the LWMS.	• Generally consistent with the LWMS. However, the first 15 mm of runoff from road reserves will be retained and treated in bioretention swales located adjacent to the HCMD and not in roadside swales as accepted by the

Considerations	The LWMS (Bayley Environmental Services 2016)	Flood modelling report (Coterra Environment 2017)	Flood modelling redesign report (Coterra Environment 2019)	This LWMS addendum
	will be retained and infiltrated in swale drains built into one or both sides of the road embankment. • Runoff from storms greater than 1-year ARI will discharge into either roadside drains along Arnold Road or the Hardy's Creek Main Drain.			Shire and DWER (Appendix I). • The peak flows from the site into the HCMD are expected to be less than previously reported also due to a reduction in impervious areas. • Cross sections of the bioretention swale have been provided in the Engineering Servicing Report (Appendix H). • Arnold Road creek crossing typical drain treatment details are also included in Appendix L.
• Lot drainage	• Runoff from lots will be managed within the boundary and peak discharge rates will be similar to predevelopment rates. • Houses within the subdivision will be required to retain the roof runoff from a 20-year ARI 5-minute storm (about 12.5mm) in soakwells.	• Consistent with the LWMS.	• Consistent with the LWMS.	• Generally consistent with the LWMS with runoff from lots to be managed within the boundary. The use of soakwells may not be suitable unless filled in some areas as detailed in the Geotechnical Report (Appendix F). Note however that as the lot sizes have increased, the impervious areas will decrease and peak flows from the lots are expected to be similar to previously reported even without soakwells.
• HCMD culverts under Arnold Road	• Two sets of 1200mm diameter culverts.	• Two sets of 900 x 1500 mm rectangular culverts consistent with survey of the existing culverts.	• Two sets of 900 x 1500 mm rectangular culverts consistent with survey of the existing culverts.	• Replacement culvert on Arnold Road for realigned crossing will be consistent with existing culverts, the flood modelling report and the

Considerations	The LWMS (Bayley Environmental Services 2016)	Flood modelling report (Coterra Environment 2017)	Flood modelling redesign report (Coterra Environment 2019)	This LWMS addendum
				modelling redesign report.
• HCMD flood modelling and design adjacent to Arnold Road	• Predevelopment peak flow rate of 10.71 m^3/s in the 100 year ARI event. • Post development maintain 100 year ARI peak flow rate 9.72 m^3/sec.	• Predevelopment peak flow rate of 11.03 m^3/s under Arnold Rd in the 100 year ARI event. • Post development peak flow rate 10.79 m^3/sec in the 100 year ARI event. • Flood storage provided in Link 10 which is 117 m long and immediately upstream of Arnold Road of 4158 m^3 in the 100 year ARI event.	• Peak flows under Arnold Road in the 100 year ARI event consistent with the modelling report. • Flood storage provided in Link 10 which is maintained at 117 m long and immediately upstream of Arnold Road of 4427 m^3 in the 100 year ARI event.	• No modelling undertaken but accepting pre-development modelling from the modelling redesign report. • Peak flow rates, maximum flood depth and provision of 4427 m^3 flood storage immediately upstream of Arnold Road consistent with the modelling redesign report. • Maximum top width of the channel may be wider than the modelling report in some locations. But storage volume will be maintained to maintain pre-development hydrology and flow rates and to not increase any flood risk downstream.
• HCMD design upstream of the flood storage area which is located adjacent to Arnold Road	• A low-flow channel (1-5 year ARI) measuring about 0.4mm deep and 5m wide, with 1:6 (17%) side slopes. • A major flood channel (100-year ARI) measuring about 0.4m deep and 25m wide, with 1:33 (3%) side slopes with 2609 m^3 of storage. • A 5m wide upland buffer on each side of the channel. • Total drainage corridor width of 40 m. • Widened sections of 'broad pools'	• No 'broad pools' or riffles. • HCMD channel designed with low flow and high flow areas upstream of the flood storage area shown as Link 11 in the model. • Drainage corridor width of less than 32 m required to convey flows. • 2609 m^3 of flood storage provided in the 100 year ARI event.	• Generally consistent with the modelling report. • 2531 m^3 of flood storage provided in the 100 year ARI event.	• HCMD channel designed with low flow and high flow areas generally consistent with the flood modelling report and modelling redesign report. • 2531 m^3 of flood storage will be provided consistent with the modelling redesign report. • A drainage corridor width of less than 32 m will be provided.

Considerations	The LWMS (Bayley Environmental Services 2016)	Flood modelling report (Coterra Environment 2017)	Flood modelling redesign report (Coterra Environment 2019)	This LWMS addendum
	every 100 m, with riffles every 50 m.			
• On-Site Effluent disposal	• All lots required to employ alternative effluent disposal systems with high phosphorus removal capability. Suitable systems include modified leach drain systems and ATUs with amended-soil irrigation areas • Proposed effluent disposal systems are able to be located at least 30m from watercourses in soils with PRI of 5.5 or higher.	• NA	• NA	• The Geotechnical Report (Appendix F) confirms the use of on-site effluent disposed and treatment systems are acceptable. • For effluent systems to operate efficiently, a clean layer of sand should be placed above the existing ground beneath the treatment system to increase permeability. Alternatively, the cells could be placed in a mound above the existing ground which would allow infiltration to accommodate the primary effluent. This will need to be designed as part of the house build. • Proposed effluent disposal systems can be located at least 30m from watercourses in soils with PRI of 5.5 or higher • The requirements and locations of ATU will be assessed through future Building Licensing process at the Shire. • The project team has prepared an site and soil evaluation (SSE) in accordance with Australian Standard 1547 (AS/NZS 1547). The SSE has been submitted to the Shire and Department of Health and will outline justification

Considerations	The LWMS (Bayley Environmental Services 2016)	Flood modelling report (Coterra Environment 2017)	Flood modelling redesign report (Coterra Environment 2019)	This LWMS addendum
				for the proposed ATU in line with DWER advice (Appendix K)
• Water supply	• The development will be supplied with potable water provided by the Water Corporation.	• NA	• NA	• As per the Engineering Servicing Report (Appendix H) there is an existing potable water supply system servicing the existing development to the west of the site that can be extended to service the new lots.
• Surface Water Quality Management	• Provided that the permeability of the soil is adequate, the native soils can be used for infiltration swales without modification. If imported fill is required for the swales, suitable High-PRI materials include crushed laterite, limesand, crushed limestone, some yellow sands and sandy loams.	• NA	• NA	• Generally consistent with the LWMS. The first 15 mm of runoff from road reserves will be retained and treated in bioretention swales located adjacent to the HCMD as accepted by the Shire and DWER (Appendix I)
• Groundwater Levels	• Drainage swales and subsoil drains will be set at or above the MGL.	• NA	• NA	• Consistent with the LWMS.
• Monitoring and response	• Water quality monitoring from the commencement of subdivision until two years after the completion of the last stage of subdivision works and contingency actions if required. • Preparation of a monitoring report for the Shire at completion of monitoring.	• NA	• NA	• Consistent with the LWMS.
• Geotechnical report	• NA	• NA	• NA	• Prepared consistent with the proposed SP and

Considerations	The LWMS (Bayley Environmental Services 2016)	Flood modelling report (Coterra Environment 2017)	Flood modelling redesign report (Coterra Environment 2019)	This LWMS addendum
				attached as Appendix F.
• Landscape Concept Master Plan	• NA	• NA	• NA	• Prepared consistent with the proposed SP and attached as Appendix G.
• Desktop Engineering Servicing Report	• NA	• NA	• NA	• Prepared consistent with the proposed SP and attached as Appendix H.

Conclusion

In summary, the key water management strategies presented in this addendum have been prepared to support the SP and are generally consistent with the LWMS (Bayley Environmental Services 2016), the Shire accepted flood modelling report (Coterra Environment 2017) and the modelling redesign report (Coterra Environment 2019). The proposed landuse change will not result in an increase in peak flows from the site or flood risk as impervious areas will be reduced and a flood storage volume will be provided in the HCMD within the site consistent with the modelling redesign report. Runoff in minor storm events will be managed within lots and runoff from roads will be retained and treated in bioretention swales located adjacent to the HCMD.

A completed LWMS checklist has also been provided as Appendix J and shows that all the required deliverables have now been provided.

Further water management details will also be provided at detailed design stage and documented in future Urban Water Management Plan(s) to support subdivision application.

Yours sincerely,
for RPS Australia West Pty Ltd

Gerard Edwards
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+61 8 6315 0341

Our ref: EWP20068.Q01

Enc:

Proposed Structure Plan, Lots 487, 611 and 615 Arnold Rd Serpentine (CDP Town Planning and Urban Design 2020) (Appendix A)

Local Water Management Strategy Lots 611, 615 and 487 Arnold Road, Serpentine (Bayley Environmental Services 2016) (Appendix B)

Arnold Road Flood Modelling Redesign (Coterra Environment 2019) (Appendix C)

Lots 102 to 106 Rudall Street, Serpentine: Townsite Flood Modelling Report – Summary of Results Rev 2 (Coterra Environment 2017) (Appendix D)

Shire of Serpentine Jarrahdale Engineering Services – Letter of Acceptance for Coterra Environment (2017) Townsite Flood Modelling Report Rev 2 (Appendix E)

Geotechnical Report, Lots 611, 615 and 487 Arnold Road (Douglas Partners 2020) (Appendix F)

Landscape and Revegetation Strategy, Lots 611, 615 and 487 Arnold Road (Plan E 2021) (Appendix G)

Desktop Engineering Servicing Report, Lots 611, 615 and 487 Arnold Road (Pritchard Francis 2020) (Appendix H)

Bioretention treatment correspondence with DWER and the Shire (Appendix I)

LWMS checklist (Appendix J)

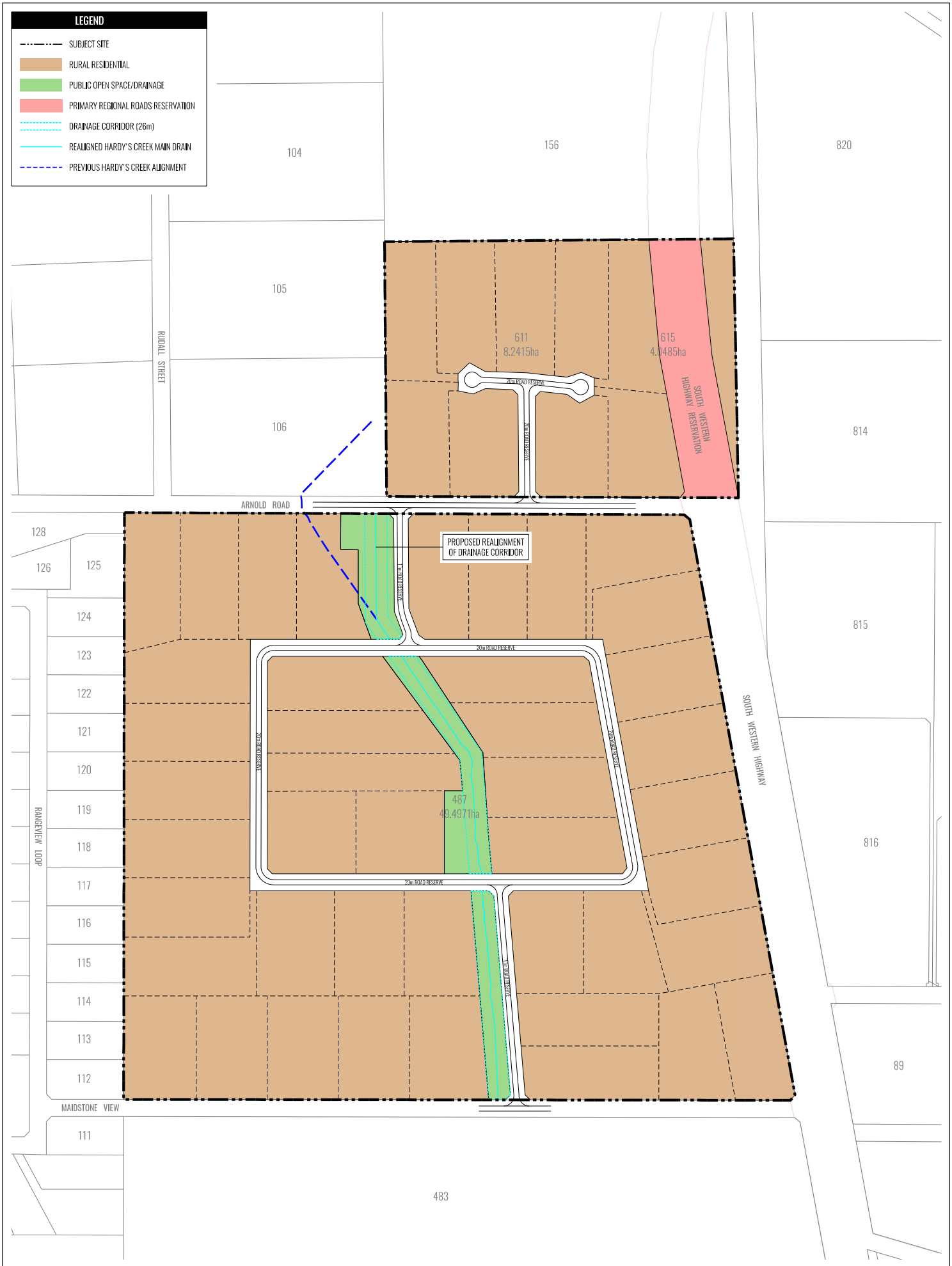
Septic setback correspondence with DWER (Appendix K)

Arnold Road Creek Crossing Typical Table Drain Treatment Details (Pritchard Francis 2021) (Appendix L)

cc:

Jane Sturgess, Department of Water and Environmental Regulation

Appendix A
Proposed Structure Plan, Lots 487, 611 and 615 Arnold Road Serpentine



CONCEPT PLAN

Lots 487, 611 & 615 Arnold Rd, SERPENTINE

A Malf Corp Pty Ltd. Project

NORTH

Scale: 1:4000 @ A3

0 40 80 120m

PLAN: MALAR-5-001A REVISION: A

DATE: 21/07/2020 DRAWN: JDP

PROJECTION: PCG 94 PLANNER: MT

DATUM: AHD CHECK: KB

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Appendix B
Local Water Management Strategy Lots 611, 615 and 487 Arnold Road, Serpentine

LOTS 611, 615 AND 487 ARNOLD ROAD SERPENTINE

LOCAL WATER MANAGEMENT STRATEGY

Prepared for

MALF Corporation Pty Ltd
Lot 2489 South Western Highway
SERPENTINE WA 6125

Report No. J14006
21 March 2016

BAYLEY ENVIRONMENTAL SERVICES
30 Thomas Street
SOUTH FREMANTLE WA 6162

Sundowner Nominees Pty Ltd as trustee for the Bayley Cook Family Trust ABN 20 822 598 897
trading as Bayley Environmental Services

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1.0 INTRODUCTION

1.1 Background

MALF Corporation Pty Ltd proposes to subdivide and develop Lots 611, 615 and 487 Arnold Road, Serpentine (the subject land) for rural-residential use. The subject land covers a total of 62.157 hectares. Figure 1 shows the proposed subdivision layout.

The proposed subdivision features 115 lots ranging in size from 4,000m^2 to 5,988m^2. The lots will be supplied with scheme water, underground telecommunications and power and will employ on-site effluent disposal.

MALF Corporation has submitted an application to the Shire of Serpentine-Jarrahdale to amend the zoning of the subject land from Rural to Rural Living in order to facilitate the subdivision. The Shire of Serpentine-Jarrahdale advertised the Amendment (no. 193), including a draft Local Water Management Strategy (LWMS), in January and February 2016. Submissions were received from eleven government agencies and two individuals. The comments from government agencies (Dept of Water, Water Corporation and Environmental Protection Authority) relevant to the draft LWMS have been addressed and reflected in this final LWMS.

1.2 Relevant Statutes, Policies and Guidelines

1.2.1 State Planning Policy 2.9

State Planning Policy 2.9: *Water Resources* (WAPC, 2006) lists the following key principles for total water cycle management:

- Consideration of all water sources (including wastewater) in water planning, maximising the value of water resources.
- Integration of water and land use planning.
- Sustainable and equitable use of all water sources, having consideration of the needs of all water users including the community, industry and the environment.
- Integration of water use and natural water processes.
- A whole-of-catchment integration of natural resource use and management.

SPP 2.9 also lists the following general objectives for water-sensitive urban design:

- To manage a water regime.
- To maintain and, where possible, enhance water quality.
- To encourage water conservation.
- To enhance water-related environmental values.
- To enhance water-related recreational and cultural values.

1.2.2 Liveable Neighbourhoods

Element 5 of *Liveable Neighbourhoods* Edition 3 (WAPC, 2004) identifies specific objectives and requirements for Urban Water Management. These are based on Best Planning Practices which are defined as the best practical approach for achieving water resource management objectives within an urban framework.

1.2.3 Better Urban Water Management

Better Urban Water Management (WAPC, 2008) sets out the following objectives for water sensitive urban design:

Water Conservation

- Consumption of 100kL/p/yr including less than 40-60 kL/p/yr scheme water.

Water Quantity

- Ecological Protection – Maintain pre-development flow rates and volumes for the 1 year ARI event. Maintain or restore desirable environmental flows and/or hydrological cycles.

- Flood Management – Maintain pre-development flow rates and volumes for the 100 year ARI event.

Water Quality

- Maintain pre-development nutrient outputs (if known) or meet relevant water quality guidelines (e.g. ANZECC & ARMCANZ, 2000).

- Treat all runoff in the drainage network prior to discharge consistent with the Stormwater Management Manual.

- As compared to a development that does not actively manage stormwater quality, achieve:
  - at least 80% reduction of Total Suspended Solids;
  - at least 60% reduction of Total Phosphorus;
  - at least 45% reduction of Total Nitrogen; and
  - at least 70% reduction of gross pollutants.

Mosquitoes and Midges

- Design detention structures so that, between the months of November and May, stormwater is fully infiltrated within 96 hours.

- Design permanent water bodies (where accepted by DoW) to maximise predation of mosquito larvae by native fauna.

1.2.4 Peel-Harvey EPP 1992

The estate is located within the Swan Coastal Plain catchment of the Peel-Harvey Estuary, which has a history of poor water quality. The objective of the *Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992* (Peel-Harvey EPP) is to reduce the input of nutrients, particularly phosphorus, into the Peel-Harvey Estuary through a number of means, which includes appropriate land management by landowners in the policy area.

The Peel Harvey EPP establishes statutory targets for phosphorus export from each part of the coastal catchment of the Peel-Harvey estuary. For the Serpentine River catchment, which includes the subject land, the target is 21 tonnes per annum.

1.2.5 Peel-Harvey WQIP

Based on the load targets for the estuary set out in the Peel-Harvey EPP, the Water Quality Improvement Plan (WQIP) for the Peel-Harvey (EPA, 2008) has undertaken predictive modelling of phosphorus exports at each of 216 catchment outflows and has produced interim phosphorus load targets for 17 "reporting catchments" to meet a concentration target of 0.1 mg/L at each catchment outlet. The subject land is within Outlet 28 of the Upper Serpentine reporting catchment. The WQIP phosphorus parameters for Outlet 28 are:

Current Condition	
Winter Median TP Concentration:	0.558 mg/L
Winter Median TP Load:	2.17 tpa
Targets	
Target TP Concentration:	0.1 mg/L
TP Concentration Reduction Required:	82%
Target TP Load:	0.39 tpa
TP Load Reduction Required:	82%.

The above shows that the Outlet 28 subcatchment is significantly exceeding the phosphorus concentration and load targets set by the WQIP. Therefore the management objective for the subject land is that development should aim to significantly reduce phosphorus exports from the site.

1.2.6 State Planning Policy 2.1

The objectives of the WAPC's *Statement of Planning Policy No. 2.1 – The Peel-Harvey Coastal Plain Catchment* (the SPP) reflect the environmental objectives of the Peel-Harvey EPP and aim to ensure that changes to land use within the catchment are controlled so as to avoid and minimise environmental damage.

The SPP contains a number of general and specific policy provisions relating to drainage. The policy states that subdivision proposals shall make provision for a

drainage system which maximises the consumption and retention of drainage on site. Biological wetland filters or other means of drainage water retention or treatment approved by the EPA are to be incorporated into drainage designs, possibly by amendment of the soils in drainage basins or by the provision of wetland filters with nutrient retentive soil amendments. Conservation reserves are not considered appropriate biological wetland filters. Development near conservation reserves may require special constraints to protect and preserve them.

In addition, the SPP imposes a moratorium on new clearing and drainage within the Peel Harvey catchment. This does not affect the maintenance of existing drains.

The SPP seeks to ensure that emphasis is given to the preservation of remnant vegetation along the fringes of surface water drainage channels. The SPP also establishes a target of achieving least a 50% cover of deep-rooted native vegetation over the catchment.

1.3 Scope of This Report

The scope of this report is to:

- Document the existing environment of the site in relation to soils, drainage, erosion, watercourses, groundwater and water-dependent ecosystems.
- Demonstrate the capability of the site to support on-site effluent disposal.
- Examine the potential environmental impacts of the proposal.
- Briefly describe the proposed development in relation to water management.
- Address relevant regulatory requirements and design criteria for setbacks to watercourses, foreshore management, groundwater management and drainage.
- Describe the strategies to be implemented for water conservation, watercourse protection, groundwater management and stormwater drainage.
- Outline the proposed water monitoring program.

2.0 PRE-DEVELOPMENT ENVIRONMENT

2.1 Climate

2.1.1 Rainfall

Serpentine has a strongly seasonal rainfall, with most of the annual rain falling between May and September in association with winter cold fronts. Occasional heavy falls may occur from summer thunderstorms. The long-term average annual rainfall for Mandurah, the closest Bureau of Meteorology weather station in a similar geographical setting, is 882mm, of which over 80% falls between the months of May and September.

Figure 2 shows a rainfall occurrence chart for Mandurah. Figure 3 and Table 2.1 show rainfall intensity and frequency for the Serpentine vicinity.

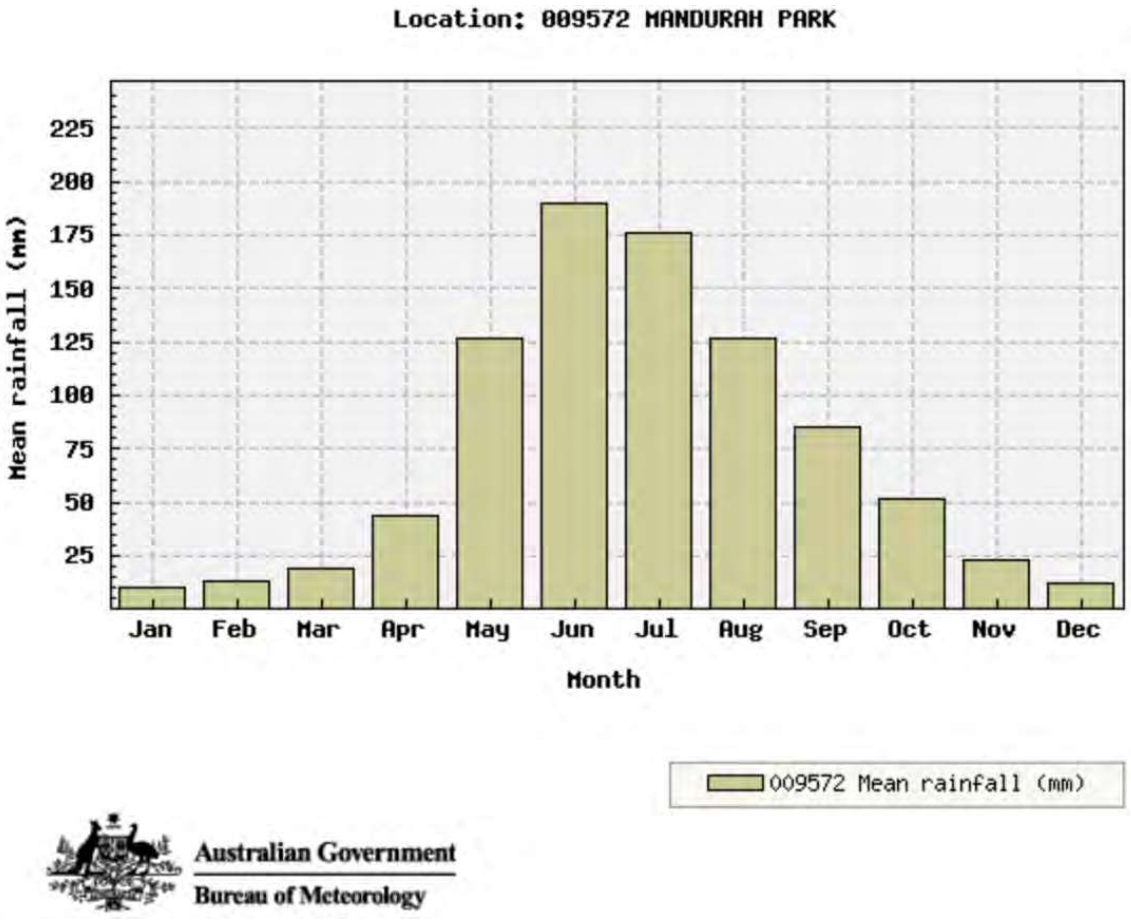

Figure 2 Mandurah Mean Rainfall

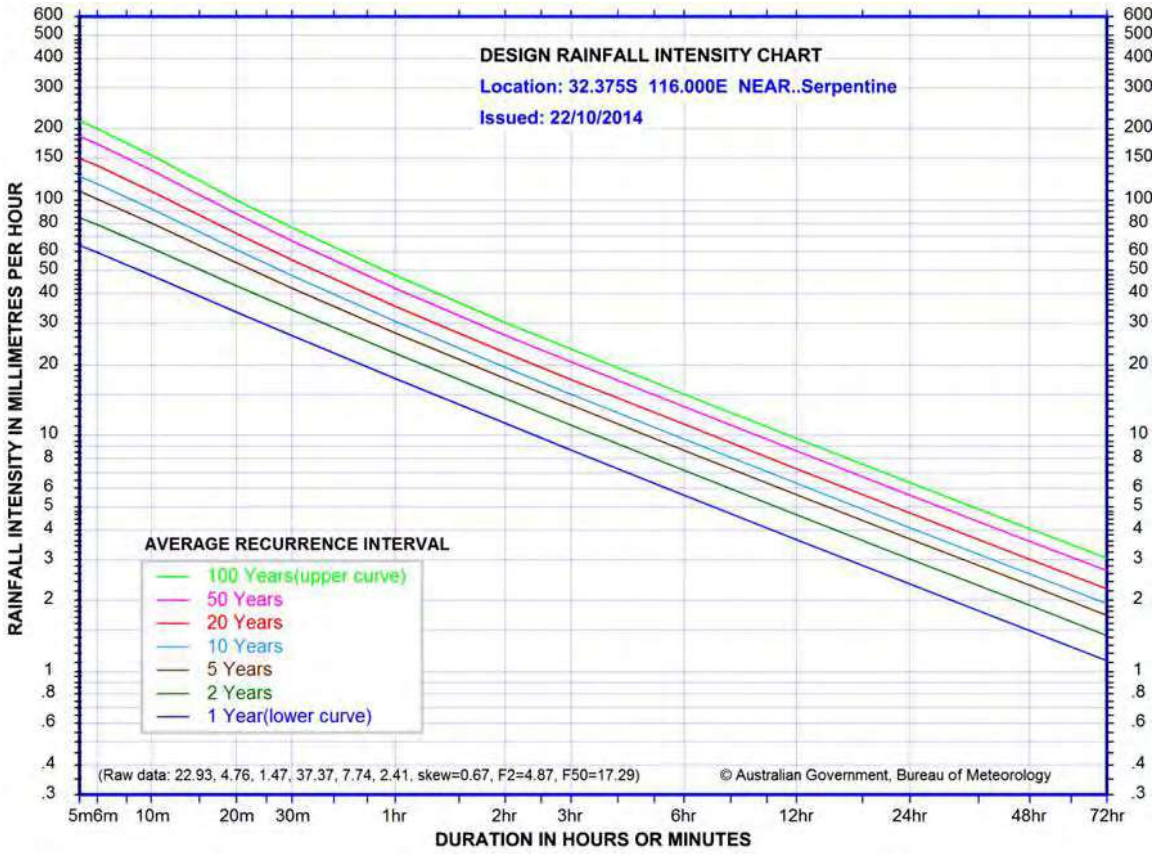

Figure 3 Rainfall Intensity Chart for Serpentine

Intensity-Frequency-Duration Table

Location: 32.375S 116.000E NEAR.. Serpentine Issued: 22/10/2014

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

	Average Recurrence Interval						
Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	64.3	84.2	109	126	150	186	217
6Mins	59.9	78.6	101	117	140	173	201
10Mins	47.9	62.6	79.9	91.9	109	134	155
20Mins	33.5	43.3	54.2	61.6	72.2	87.5	100
30Mins	26.6	34.2	42.3	47.8	55.7	67.1	76.5
1Hr	17.5	22.4	27.3	30.6	35.4	42.2	47.9
2Hrs	11.3	14.4	17.5	19.5	22.5	26.7	30.2
3Hrs	8.70	11.1	13.5	15.0	17.3	20.6	23.3
6Hrs	5.59	7.14	8.67	9.69	11.2	13.3	15.0
12Hrs	3.62	4.62	5.62	6.29	7.24	8.62	9.75
24Hrs	2.35	3.00	3.65	4.07	4.70	5.59	6.33
48Hrs	1.49	1.91	2.32	2.59	2.99	3.56	4.03
72Hrs	1.11	1.42	1.73	1.94	2.24	2.68	3.03

(Raw data: 22.93, 4.76, 1.47, 37.37, 7.74, 2.41, skew=0.67, F2=4.87, F50=17.29) © Australian Government, Bureau of Meteorology

Table 2.1 Rainfall Intensity for Serpentine

2.1.2 Evaporation

Like rainfall, evaporation is also strongly seasonal, ranging from an average of under 2mm/day in June and July to over 8mm/day in January. Figure 4 shows average daily pan evaporation for Medina, the closest site for which records are available.

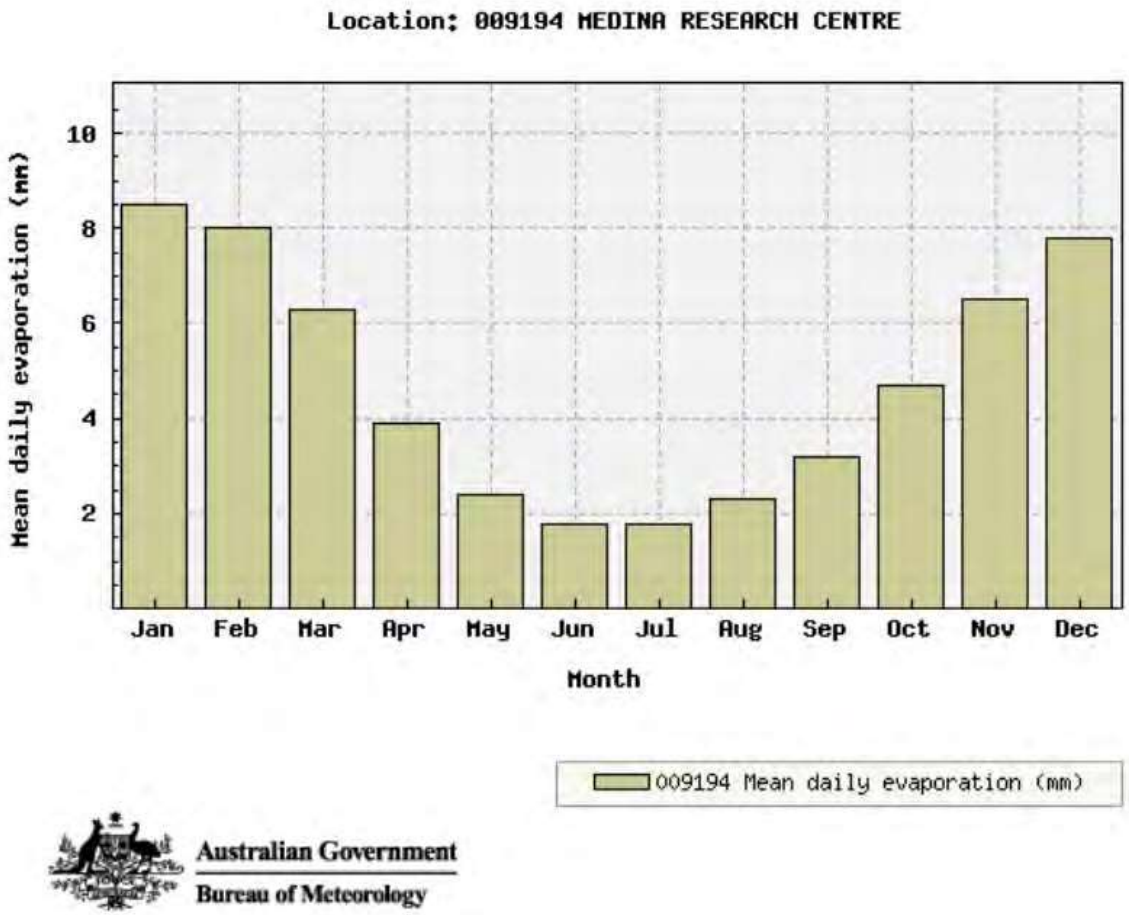

Figure 4 Daily Pan Evaporation for Medina

2.1.3 Wind

Wind data from Mandurah shows that the prevailing winds tend to be north-easterly to south-easterly in the mornings and south-westerly in the afternoons. The south-westerly is much more dominant in early to mid summer under the influence of the sea breeze. In winter, occasional strong north-westerlies occur with the passage of cold fronts. Figure 5 shows annual 9am and 3pm wind roses for Mandurah.

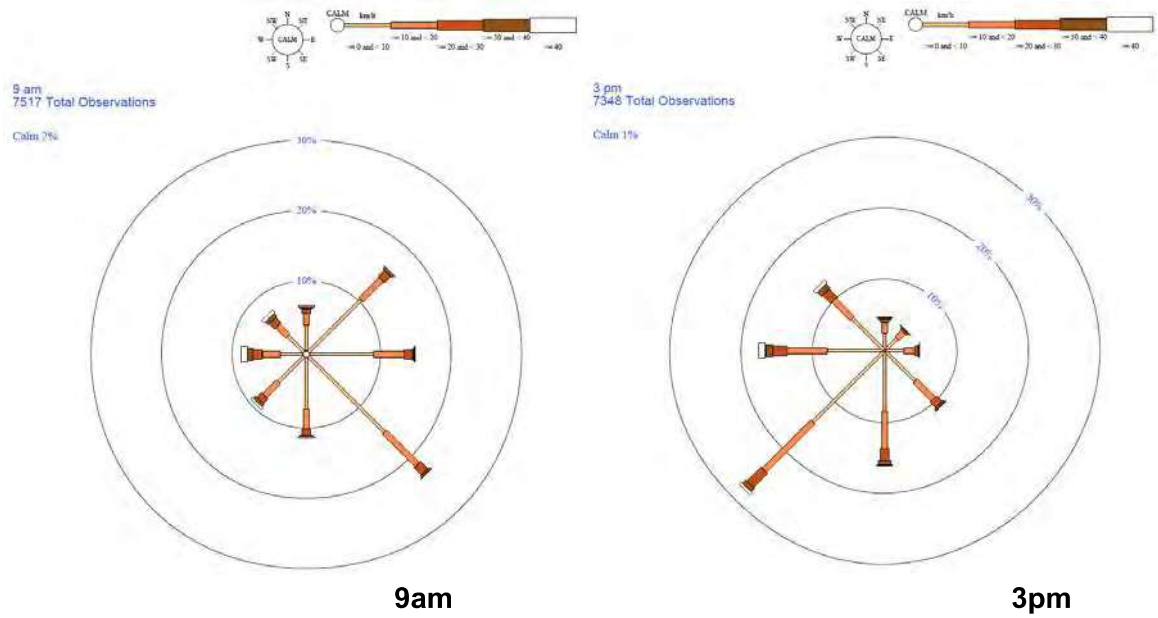

Figure 5 **Wind Roses for Mandurah** (BoM, 2013)

2.2 Physiography

2.2.1 Topography

The subject land slopes gently to the north-northwest, from a maximum elevation of 47m AHD at the south-east corner to 33m at the north-west corner. The slope of the land is mostly between 1% and 2%, reaching a maximum of less than 4% in the south-east corner.

2.2.2 Geology and Soils

The subject land is situated on the Pinjarra Plain and the Ridge Hill Shelf. The Pinjarra Plain consists of shallow sandy soils overlying alluvial silty clays. The Geological Survey of Western Australia (GSWA, 1978) mapped the western side of the subject land as Guildford Formation (Qpa) with sandy clay soils (Cs). The Ridge Hill Shelf consists of low foothills of the Darling Scarp. The GSWA mapped the eastern part of the subject land as Colluvium (Qc) with gravelly sandy clay soils (Csg).

Drilling at eight locations across and to the north and west of the subject land (Figure 6) found soil profiles that generally match the GSWA mapping. Soil logs are attached in Appendix A. Figure 6 shows the geology and soils of the subject land.

2.2.3 Land Units

The Department of Agriculture mapped most of the subject land as Pinjarra Plan (P1a, P4), with the east and south-west as Ridge Hill Shelf (Foothills) (F2b). These land units are described by Wells (1989) as follows:

Pinjarra Plain
Broad low-relief plan west of the foothills, on mostly Pleistocene fluvial sediments and some Holocene alluvium associated with major active drainage systems. Major soils are naturally poorly drained and many swamps occur.

P1a Gently undulating plain with deep acid mottled yellow duplex soils having sand to sandy loam surface and generally shallow topsoil over clay subsoil.
P4 Poorly drained flats, sometimes with Gilgai microrelief and with moderately deep to deep black and grey cracking clays, less commonly non-cracking friable clays with acid subsoils.

Ridge Hill Shelf (Foothills)
Lateritised, low relief foothills of the Darling Scarp comprising fossil shoreline bench sediments, Holocene colluvium and narrow bands of alluvial deposits. Slopes are very gently to gently inclined (1-10%) and soils are moderately well to well drained.

F2b Very gently to gently inclined slopes (2-5%) with moderately deep to deep, gravelly acid yellow duplex soils and rare laterite.

Figure 6 shows the Department of Agriculture mapping over the subject land.

2.2.4 Phosphorus Retention Index

Soil analyses at 0.5m depth at six sites across and north of the subject land (Figure 6) returned high to very high PRI values ranging from 42.9 to 2089.1. These results indicate that the soils have a high to very high capacity to retain phosphorus.

Table 2.2 PRI Analysis Results

Sample Location (see Figure 6)	PRI at 0.5m depth
SB2	2089
SB4	1780
SB5	64
SB6	43
SB7	276
SB8	410

2.2.5 Acid Sulphate Soils

The DPAW maps most of the subject land as having a moderate risk of acid sulphate soils and the south-eastern part as low risk. The nearest mapped high ASS risk area is a small wetland located 850m west of the subject land. Water samples from the eight bores on and near the subject land found some evidence of the presence of soil acidity (elevated Total Acidity, Acidity/Alkalinity ratio and/or low pH) (Appendix B).

The development of the subject land is expected to involve little excavation or dewatering (required for installation of underground power, water and communications only). ASS is therefore not considered to be a significant issue on the site. If significant dewatering were proposed, it would be prudent to monitor the abstracted water and treat with lime before disposal if necessary.

2.3 Hydrology

2.3.1 Surface Drainage

The subject land is within the catchment of the Serpentine River, which flows from east to west about 450m north-east of the subject land and discharges into the Peel Inlet.

Drainage within the site occurs not in defined pathways but as dispersed sheet flow across the saturated ground surface. The topography of the site results in a general overland flow direction from south-east to north-west. The runoff coefficient before development will vary from close to zero in dry soil conditions to almost 100% in saturated areas.

Substantial areas of the subject land are subject to waterlogging by groundwater rise and/or surface ponding during winter, with the extent depending on the seasonal rainfall. This is discussed further in Section 2.3.2.

The subject land is drained by a Water Corporation drain, the Hardy's Creek Main Drain (HCMD), which rises on the Darling Scarp about 1,200m south-east of the subject land and flows north across Lot 487 before joining the Serpentine River about 940m north-west of the subject land. The drain is seasonal, flowing in winter and drying up in summer.

The HCMD has a catchment of 104ha upstream of the subject land and an additional internal catchment within Lot 487 of 49.6ha. The upstream catchment consists of cleared palusplain (36%), cleared uplands (10%) and forested hills (54%). The internal catchment consists entirely of cleared palusplain.

Section 5.3 presents details of proposed management of flows in the HCMD.

2.3.2 Groundwater

Groundwater Occurrence and Flows

Groundwater occurs at shallow depth throughout the subject land. The regional groundwater flow is to the north-west but local flows and levels are likely to be influenced by the Serpentine River and, in winter, by the drains that flow through and near the site.

The groundwater regime in the Serpentine area is complex, due at least partly to the low and variable permeability of the soils. The groundwater levels measured on the subject land vary significantly across the site in a way that does not always reflect the topography; for example, the greatest depth to groundwater was measured in Bore SB2, near the lowest point of the site. Further south, bores SB5 and SB6, although surrounded by dry ground, recorded piezometric groundwater levels almost 0.2m above the ground surface, indicating that an upward head was present. Such upward heads have previously been observed on a site about 350m west of the subject land, and may be related to the area's position at the base of the Darling Scarp, where considerable recharge of the superficial aquifer occurs.

The variability of groundwater levels across the site indicates that considerable perching of groundwater occurs on low-permeability clay layers in the soil profile.

Figure 7 shows late winter groundwater level contours based on measurements in September 2014. Given the complexity and variability of the local groundwater regime it is not possible to accurately model the maximum groundwater levels by the usual means (extrapolation from measured levels using a known reference bore). However, it can be reasonably assumed that groundwater levels will be at or near the ground surface over most of the site during wet winters.

Groundwater Availability

The subject land is located in the Serpentine 3 sub-area of the Serpentine groundwater area. The most readily available groundwater resource is the superficial aquifer, which extends from near the surface to about 15m depth. The superficial aquifer is underlain by the Leederville Formation, Cattamarra Coal Measures and Yarragadee Formation. The superficial formation is the only one that is likely to be considered for non-potable water supply on the subject land.

The DoW has not yet prepared an allocation plan for the Serpentine groundwater area.

2.3.3 Wetlands

The Department of Parks & Wildlife (DPAW) maps all of the subject land and its immediate surroundings as Multiple Use Category palusplain.

2.4 Water Quality

2.4.1 Surface Water

The drains crossing the subject land were sampled at their entry to and exit from the site in late June and early September 2014. The results of the analysis are shown in Appendix B. The results show that the water in the drains was fresh (<400 mg/L TDS), with neutral acidity (pH 6.4 – 7.3) and reasonable clarity (TSS 16 – 51 mg/L). The levels of most chemical contaminants was low. Of note was that the concentration of

Total Phosphorus was consistently between 190% and 320% of the target for the Serpentine River set by the Peel-Harvey WQIP. In late June, when flow in the drains was minimal, the TP concentration at the outflow from the site was higher than at the inflows, but in September, when the drains were flowing strongly, the concentration at the outflow was lower than at the inflows or at the midpoint of the site. Nitrogen followed a similar pattern. This suggests that water flowing into the site from upstream is being diluted by higher-quality groundwater and runoff from within the site.

2.4.2 Groundwater

Groundwater sampling in late June and early September 2014 showed that the groundwater is neutral to moderately acidic (pH 3.4 – 6.8) and fresh to slightly brackish (102 – 2,400 mg/L TDS). The higher salinities occur in the east of the site.

The groundwater quality is generally good, with only one phosphate level exceeding 0.02mg/L and total nitrogen at 2.7mg/L or less. Appendix B shows the full groundwater quality results.

2.5 Vegetation

The subject land is entirely cleared of native vegetation.

Heddle *et al.* (1980) mapped the original vegetation of the northern part of the subject land as 32: Guildford Complex, and the southern part (the majority of the site) as 29: Forrestfield Complex. No remnant of either of these complexes remains on the subject land.

2.6 Fauna and Habitats

The subject land provides no significant fauna habitat except for those species able to utilise open cleared paddocks. Species observed during site works included Maned Ducks, Magpies and Straw-Necked Ibis. It is unlikely that any native mammals would use the site.

2.7 Land Uses

2.7.1 Current and Previous Land Uses

The subject land is currently used for broadacre cattle grazing. Historical Landgate aerial photography shows that the land has been cleared and grazed since at least 1965 and that no other land uses have occurred on the property since that time.

There is no visual or other evidence on site or on aerial photographs of any contamination or potentially contaminating land uses.

2.7.2 Neighbouring Land Uses

The subject land is bounded to the west, north and east by mixed land uses including broadacre grazing, small rural lots and rural residential lots. The Serpentine townsite is located about 300m to the west, while the Serpentine Falls Lifestyle Village is located about 160m across South-Western Highway to the north-east. Broadacre grazing adjoins to the south.

The land immediately west of the northern part of the subject land is planned for residential development as part of the Serpentine townsite expansion.

There are no land uses in the vicinity that would affect or be affected by the proposed development of the subject land.

2.7.3 Aboriginal and European Heritage

The Department of Aboriginal Affairs' online database shows one registered Aboriginal Heritage site on the subject land. This is 3582: Serpentine River, a mythological site, which covers the area north of Arnold Road.

The boundaries shown in the public DAA database are deliberately vague and inaccurate so as to protect the listed sites. The Department of Aboriginal Affairs has advised (C. Rodrigues, 2014) that the actual boundary of site 3582 does not impinge on the subject land.

3.0 LAND CAPABILITY ASSESSMENT

3.1 Capability for On-Site Effluent Disposal

3.1.1 Published Land Capability Ratings

The proposed building envelopes are located on land mapped by the Department of Agriculture as Pinjarra Plain (P1a, P4) and Ridge Hill Shelf Foothills (F2b). Wells (1989) rated the capability of these units for on-site effluent disposal as follows:

P1a Low (limited by soil absorption ability)
P4 Low (limited by soil absorption ability)
F2b Fair (limited by soil absorption ability)

The limitations reported by the Department of Agriculture may be overcome by proper system design or site engineering. For example:

- Low soil adsorption ability may be overcome by the use of a larger than normal leach drain or ATU irrigation area, subsoil drains and/or excavation of soil and replacement with permeable soil. Soil permeability testing (see below) indicated that all soil types on the site had sufficient permeability for on-site effluent disposal.

- Pollution risk by overland flow and flood risk may be overcome by the use of filling and inverted (mounded) modified leach drain systems or ATU irrigation areas.

3.1.2 Soil Permeability

Australian Standard AS1947:2000 advocates a minimum hydraulic conductivity of 0.06m/day for on-site effluent disposal without special design.

Six constant-head permeability tests (two on each major land unit) were carried out on the subject land in January 2015 at 0.5m depth in accordance with the method set out in AS1947:2000. Figure 6 shows the test locations. The test results are detailed in Appendix C and summarised in Table 3.1.

All of the locations tested more than met the AS1947:2000 permeability standard for on-site effluent disposal.

Table 3.1 Permeability Test Results

Test Site (see Figure 6)	*Land Unit (see Section 2.2.3)*	*Saturated Hydraulic Conductivity (m/day)*
S1	F2b	3
S2	F2b	2.7
S3	P1a	0.4
S4	P1a	6
S5	P4	2.5
S6	P4	1

3.1.3 Phosphorus Retention Index

The six soil analyses carried out at the site all returned high to very high PRI values (43 - 2089), indicating that all of the site soils have adequate PRI for on-site effluent disposal. No soil modification will be necessary to improve PRI.

Provided that effluent disposal systems are correctly sited and constructed so that infiltration through the soil profile occurs, there is not expected to be any significant export of phosphorus from these systems for the foreseeable future.

3.1.4 Depth to Groundwater

The Government Sewerage Policy (GSP) requires that land used for effluent disposal must have a minimum clearance of 0.5m from the natural ground surface to the highest water table. Under the policy, the required clearance can be achieved by properly engineered drainage.

Much of the subject land is subject to surface saturation and in some cases inundation in winter, due to either groundwater rise, perching or surface ponding. This suggests that in-ground effluent disposal systems are unlikely to be effective over much of the site. Within these areas, filling and local subsoil drainage of building pads will be required to provide the necessary clearance to the water table. The height of filling required may be minimised by using aerobic treatment units with subsoil irrigation of effluent rather than leach drains.

Given the high water tables and the location of the site within the Peel-Harvey catchment, all lots in the development will be required to employ alternative effluent disposal systems with high phosphorus removal capability. Suitable systems include modified leach drain systems and ATUs with amended-soil irrigation areas.

3.1.5 Slope

The GSP forbids on-site effluent disposal on land with a slope of more than 1 in 5 (20%), in order to prevent runoff of effluent.

The subject land is mostly flat and contains no areas with more than 20% slope. There is therefore no constraint due to slope for on-site effluent disposal.

3.1.6 Watercourse Setbacks

The Department of Water (DoW, 2006) advises that nutrient-removing effluent disposal systems should be located at least 30m from watercourses in all soil types.

The conceptual subdivision guide plan for the subject land shows all building envelopes but one to be located at least 30m from watercourses. The one exception is Lot 112 in the south-east of the site, where the building envelope is adjacent to a small seasonal drain. In this case, a special effluent disposal envelope will be created on the side of the building envelope away from the drain, to ensure that the effluent disposal system is located at least 30m from the drain. Figure 1 conceptually shows the envelope.

3.1.7 Conclusion

This analysis has found that the majority of the subject site is physically suitable for on-site effluent disposal. Specifically:

- The risks of microbial contamination and water pollution identified by Wells (1989) have been or can be overcome by correct siting and design of effluent systems.
- The soils have adequate permeability and phosphorus retention index for infiltration systems to operate efficiently.
- Limitations posed by shallow depth to groundwater and surface inundation can be resolved by a combination of filling, drainage and use of high-performance effluent disposal systems.
- The slope of the site is suitable for effluent disposal.
- Proposed effluent disposal systems are able to be located at least 30m from watercourses in soils with PRI of 5.5 or higher.

4.0 WATER USE SUSTAINABILITY

4.1 Water Supply

The development will be supplied with potable water provided by the Water Corporation.

Groundwater is available at shallow depth within the subject land, although its yield, quality and suitability for irrigation may vary. Over much of the site, groundwater of suitable salinity for irrigation of gardens will be available.

In accordance with the amended *Building Regulations 1989*, all new homes within the development will incorporate the following features:

- Minimum 4 stars WELS rated tap fittings, except bath outlets and garden taps.
- Minimum 3 stars WELS rated shower heads.
- Minimum 4 stars WELS rated dual flush toilets.
- Covers on all private swimming pools.
- All internal hot water pipes installed in accordance with AS/NZS 3500:2003.
- Maximum run of pipe from hot water system to outlet not exceeding 20 metres length or 2 litres of internal volume.

The design and installation of water wise initiatives such as rainwater tanks, grey water reuse systems and water efficient fixtures and fittings will be promoted as part of the marketing of the estate to ensure such initiatives can be implemented by homeowners.

4.2 POS Irrigation

The public open space bordering the Hardy's Creek Main Drain, totalling about 3ha, will be planted with native sedges, shrubs and small trees. These may be irrigated by tanker or temporary drip lines for one or two years after planting but will thereafter be unirrigated. Some small areas of irrigated grass may be maintained to provide for passive recreation.

Depending on the presence of grassed areas, water for irrigation may be drawn from scheme water or from a bore within the POS. The details of planting, irrigation and water supply will be set out in a Landscaping Plan to be prepared at the subdivision design stage. If irrigation from a bore is proposed, an applications for a groundwater licence will be submitted to the Department of Water.

4.3 Wastewater Management

All lots in the subdivision will employ on-site effluent disposal. The land capability assessment detailed in Section 3.1 of this report showed that all proposed building

envelopes are suitable, in terms of soil permeability, slope and setbacks from watercourses, for on-site effluent disposal. Constraints posed by groundwater clearance may be addressed by a combination of filling and drainage.

All lots within the subdivision will be required to employ alternative effluent disposal systems with high phosphorus removal capability.

Greywater reuse may be implemented by individual lot owners. Any person wishing to install a greywater reuse system must lodge an Application to Construct or Install an Apparatus for the Treatment of Sewage with the Shire of Serpentine-Jarrahdale.

5.0 SURFACE WATER MANAGEMENT

5.1 Principles and Objectives

The subdivision guide plan aims to comply with the principles and objectives for stormwater management identified in the *Stormwater Management Manual for WA* (DoE, 2004) and *Better Urban Water Management* (WAPC, 2008).

The drainage system will be designed to maintain surface flow rates and volumes within and from the developed site at or below their pre-development levels, and as far as possible to maintain the existing flow paths. The priorities for managing the various sizes of flow event will be as follows:

- 1 year ARI — Retain and infiltrate all flows as close to source as possible. Maintain pre-development flow rates and volumes. Minimise export of nutrients and sediments.
- 5 year ARI — Detain water prior to discharge. Maintain pre-development flow rates and volumes. Maintain amenity and serviceability. Prevent scouring and damage.
- 100 year ARI — Maintain pre-development flow rates and volumes. Prevent flooding and damage.

The drainage design presented here is conceptual and will be refined during the subdivision design stage.

5.2 Drainage Management System

5.2.1 Road Drainage

The internal roads will generally be built on elevated embankments with a 6m wide sealed pavement. The roads will be flush-kerbed or unkerbed except at intersections, where semi-mountable kerbs will be installed. Culverts will be installed beneath the roads where necessary to maintain existing overland drainage paths.

The road drainage system has been designed to minimise disturbance to the existing site drainage in terms of flow paths, volumes and peak flows. All road runoff from storms up to 1-year ARI, 1 hour duration (about 17.5mm) will be retained and infiltrated in swale drains built into one or both sides of the road embankment. The bases of the swales will be set above the maximum groundwater level (MGL) which, for preliminary design purposes, is assumed to coincide with the natural ground level. Figure 8 shows a conceptual layout and cross-section of the roadside swales.

Road reserves will occupy an estimated 9.53ha within the development (15.3% of the total area). The paved area of the internal road network will constitute about 5% of the total site area. Much of this will be in areas where runoff rates in winter are already high. The presence of the roads will therefore have a minor effect on the volume and rate of runoff under 5-year to 100-year ARI conditions.

The roadside swales will follow the grade of the roads and will be built with a series of low (approx. 200mm high) internal weirs that will ensure that flows up to 1-year ARI are retained and infiltrated locally. Runoff from storms greater than 1-year ARI will progressively overflow the weirs and flow along the swales into either the roadside drains along Arnold Road or the Hardy's Creek Main Drain, from where it will eventually flow into the Serpentine River.

The preliminary drainage design divides the road network into seven catchments, as shown on Figure 8. Catchments A and B will overflow into the Hardy's Creek Main Drain (HCMD) within the site. Overflow from Catchments C and D will overflow into roadside drains along Arnold Road and then into the HCMD downstream of the subject land. Catchment E will overflow into the HCMD downstream of the subject land. Catchments F and G will overflow into roadside drains along the new southern boundary road, which will then flow into the western branch of the HCMD (Catchment F) and the HCMD upstream of the subject land (Catchment G).

Appendix D.1 presents detailed flow calculations for the internal roads. The drainage and swale sizing calculations are summarised in Table 5.1.

Table 5.1 Preliminary Road Runoff and Swale Sizing

Storm Event (critical duration)	*Rain Intensity (mm/hr)*	*Peak Inflow Rate (L/sec)*		*Storage Required (m^3)*	*Effective Storage Including Infiltration (m^3)*	*Top Surface Area (m^2)*	*Water Depth (m)*
		Pre-Dev	*Post-Dev*				
1 year ARI (1 hour)	17.5	232	394	415	1,420	4,133	0.2
5 year ARI (30 min)	42.3	662	1,037	60	128	579	0.2
100 year ARI (30 min)	76.5	1,202	1,894	123	241	1,212	0.2

5.2.2 Overall Site Drainage

The drainage characteristics of most of the site will be unchanged by the development. Lot owners will fill house pads and other development areas within their building envelopes but these will represent a small percentage of each lot. Flow that is obstructed by a filled house pad will simply flow around the filling and continue on its way. Scheme provisions will ensure that lot owners do not fill outside building envelopes without development approval.

Where road embankments interrupt the general overland flow direction, culverts will be used to maintain drainage though the embankment. In order to ensure that flows are not interrupted, the developer will install all driveway crossovers, with adequate culverting, at the subdivision stage.

Two small drains enter the subject land in the south-east via culverts under South Western Highway. The southern of these will flow along the road reserve of the new southern boundary road into the HCMD. The more northerly crosses one proposed lot before entering a road reserve and flowing into the HCMD. Where it crosses the lot, this drain will be realigned slightly to follow the lot boundary and protected by a drainage easement. Figure 8 shows the conceptual alignment of the easement.

The ultimate destination of all overland runoff from the site is the Hardy's Creek Main Drain, either directly or via roadside swales and drains. Section 5.3.4 presents details of the flows from the site to the HCMD.

5.3 Hardy's Creek Main Drain

5.3.1 Overview

The subject land is within Region 2 of the Water Corporation's Mundijong Drainage District. The *Rural Drainage Criteria for the Mundijong Drainage District* (Water Corporation, 2000) sets out the Corporation's recommended limits on drainage discharge rates from adjacent lands to the Hardy's Creek Main Drain and proposes flood storage areas (FSAs) to compensate runoff to the drain. The recommended 100-year ARI discharge limit for land in Region 2 is 12 litres/sec/ha (K. Kanagaratnam, August 2015 pers. comm.).

The estimated 100-year ARI peak flow from the subject land to the HCMD at Arnold Road in its current (pre-development) state is 119 litres/sec/ha. Therefore, to meet the Water Corporation's recommended limit, the post-development discharge rate would have to be reduced by nearly 90% from the pre-development rate. This represents a radical departure from the current hydrology of the subject land, and is considered both unachievable and undesirable.

The excavated channel of the HCMD within Lot 487 is designed to carry a flow of up to 0.9 m^3/sec (K. Kanagaratnam, 2016 pers. comm.). The total pre-development flow in the HCMD at Arnold Road (including upstream and internal catchments) is estimated at 11.4 m^3/sec (see Table 5.4). The excess flow will break out from the central channel of the drain and spread across the nearby land, providing temporary storage and detention as well as additional flow area. The Water Corporation terms this temporary detention "regional flood storage". Due to the topography of the subject land, this flood storage would be confined to the area alongside the drain.

In order to maintain the functionality of the HCMD, it is necessary to maintain the flood storage capacity within the subject land. This can be achieved by dedicating a corridor through the site centred on the drain, with the width of the corridor determined by the expected flow in the drain. In addition, it is necessary to limit 100-year ARI flows from the site to the HCMD at or below their pre-development levels.

The Water Corporation's approach to development adjacent to the HCMD may be interpreted from its comments in relation to a previous Scheme amendment for Lot 8 Arnold Road, Serpentine (Serpentine Downs Estate), located immediately west of the subject land, in 2011 when the Corporation wrote in its submission on the amendment:

> "Developments within this catchment are required to contain the flows from a one in one hundred year storm event on site. Discharge to the Water Corporation drains must be compensated to pre-development levels."
> (Source: Shire of Serpentine-Jarrahdale, 2011).

Following discussions and meetings with the Water Corporation and Shire of Serpentine-Jarrahdale, the requirements for the subject land in terms of the HCMD have been identified as:

- Maintain 100-year ARI flows from the subject land to the HCMD at or below their pre-development levels.
- Convey 100-year ARI upstream flows in the HCMD through the subject land without obstruction.
- Maintain the existing flood storage capacity alongside the HCMD within the subject land.
- Maintain 100-year ARI water heights at upstream and downstream culverts at or below their pre-development levels.

The means by which these objectives will be achieved are detailed below. The Water Corporation has endorsed the hydrological aspects of the proposed management strategy for the HCMD. The Corporation's advice to this effect is attached in Appendix E.

5.3.2 Drain Profile

The HCMD follows an existing low point in the landscape but has been excavated to improve its drainage characteristics. The drain consists of an eroded channel about 0.5-1m deep and 2m to 10m wide with a narrow, flat sandy bottom. The banks are partly stabilised by pasture grasses but are continuing to erode where disturbed by cattle and occasional vehicles.

The drain will be redeveloped as a living stream with a varying profile to accommodate minor and major flows. The profile is shown conceptually on Figure 9 and will consist of:

- A low-flow channel (1-5 year ARI) measuring about 0.4mm deep and 5m wide, with 1:6 (17%) side slopes.
- A major flood channel (100-year ARI) measuring about 0.4m deep and 25m wide, with 1:33 (3%) sideslopes.
- A 5m wide upland buffer on each side of the channel.

This profile is based on advice from the Water Corporation (K. Kanagaratnam, 2016 pers. comm.) and is broadly consistent with the profile shown in the LWMS for the Serpentine Townsite LSP (GHD, 2013).

The low-flow channel will incorporate straight sections, meanders, riffles and broad pools to slow the water flows, promote nutrient uptake and provide a diversity of habitats. The high-flow channel will be kept in its existing straight alignment to efficiently convey flood flows through the site. The high-flow channel will provide the flood storage for major floods required by the Water Corporation.

Figure 10 shows a conceptual layout plan of the living stream.

5.3.3 Drain Corridor

A vegetated buffer will be established along both sides of the HCMD to provide room for flood flows/storage, protect against erosion, intercept nutrients in direct drainage to the HCMD, create a visually pleasing landscape element and protect nearby land uses from flooding.

The Department of Water's *Stormwater Management Manual for Western Australia* (DoE, 2004) recommends a minimum native vegetated buffer for constructed waterways in urban areas of 10m to 20m from the edge of the "bank full channel" (as defined as the 1.5 – year ARI flow level).

In this case, it is proposed that a setback of 20m on each side of the centreline of the drain be adopted, giving a total drainage corridor width of 40m. This will give an effective setback of about 18m from the 1.5-year ARI level, which is close to the maximum recommended by the DoW. The 100-year ARI floodway will extend about 15m into the vegetated buffer, with the remaining 5m providing an additional upland buffer and a safety margin for extreme (>100-year ARI) flood events. Figure 9 shows a conceptual profile of the buffer.

The living stream and buffer zone will be planted with local native sedges, shrubs and small trees. The species will be selected to suit each part of the stream profile:

predominantly sedges for the 1-year ARI low-flow channel, sedges and shrubs for the 5-year ARI medium-flow channel, shrubs and small trees (e.g. paperbarks) for the 100-year ARI major flood channel, and upland shrubs and small trees in the outer buffer. Figure 9 shows this conceptual zoning. All species planted will need to be tolerant of summer drought, seasonal saturation and/or occasional inundation. A detailed planting plan will be prepared prior to construction of the living stream.

The drain corridor will be designated as public open space and ceded to the Shire of Serpentine-Jarrahdale. The Shire will assumed ownership of the HCMD from the Water Corporation, which will no longer manage the HCMD as a rural drain.

5.3.4 Flows from the Subject Land to the HCMD

Road Runoff
Section 5.2.1 described the proposed road drainage system and presented details of flows and sizing of roadside swales.

Table 5.1 showed that the storage provided in the swales for a 1-year ARI 1-hour storm is considerably greater than that required to compensate the runoff from a critical (30 minute) 5-year or 100-year ARI storm. This means that the net runoff from the internal road network to the HCMD in all storms up to 100-year ARI will be reduced following the development of the site.

Buildings
In accordance with the Building Code of Australia (BCA), houses within the subdivision will be required to retain the roof runoff from a 20-year ARI 5-minute storm (about 12.5mm) in soakwells. Other hardened surfaces within lots including shed roofs, driveways and paths will generate increased runoff, which has been included in the runoff calculations. Elsewhere on the lots, the establishment of gardens and trees will reduce and delay runoff somewhat. This reduction has been ignored in the calculation of overall drainage flows.

Table 5.2 summarises overall 100-year ARI pre-development and post-development flows from the site, including road reserves, to the HCMD. The areas of houses, sheds and other hardened areas within lots have been estimated by measurement of a number of similarly-sized developed lots in Serpentine. Detailed calculations of the overall site runoff are presented in Appendix D.2.

Table 5.2 Overall Site Runoff

Storm Event	*Peak Flow (L/s)*	
	Pre Development	*Post Development*
1 yr ARI	2,589	1,868
5 yr ARI	4,105	3,363
100 yr ARI	7,391	6,663

Table 5.3 presents a breakdown of runoff generation, storage and net flows to the HCMD from the subject land before and after development. The table shows that the peak and total discharge from the subject land to the HCMD from a 100-year ARI 1-hour storm will decrease following development.

Table 5.3 100-yr ARI Discharge to HCMD

PRE DEVELOPMENT			
Storm duration	60	minutes	
Storm intensity	47.9	mm/hr	
Paddock	Area	62.9	ha
	Cr	0.6	
	100 yr peak flow	**5022**	**L/s**
	100 yr total flow	18079	m3
	Effective Storage	0	m3
	Net total flow	**18079**	**m3**
POST DEVELOPMENT			
Storm duration	60	minutes	
Storm intensity	47.9	mm/hr	
Paddock, lawn, garden, POS	Area	39.7	ha
	Cr	0.6	
	100 yr peak flow	3166	L/s
	100 yr total flow	11398	m3
	Effective Storage	0	m3
	Net total flow	11398	m3
Road reserves	Area	8.9	ha
	Cr	0.85	
	100 yr peak flow	1005	L/s
	100 yr total flow	3617	m3
	Effective Storage	1420	m3
	Net total flow	2197	m3
Houses	Area	5.3	ha
	Cr	1	
	100 yr peak flow	702	L/s
	100 yr total flow	2526	m3
	Effective Storage	659	m3
	Net total flow	1867	m3
Sheds	Area	0.8	ha
	Cr	1	
	100 yr peak flow	107	L/s
	100 yr total flow	387	m3
	Effective Storage	0	m3
	Net total flow	387	m3
Driveways etc.	Area	5.2	ha
	Cr	0.8	
	100 yr peak flow	551	L/s
	100 yr total flow	1985	m3
	Effective Storage	0	m3
	Net total flow	1985	m3
Catchment Totals	**100 yr Peak Flow**	**5531**	**L/s**
	Total Flow	19912	m3
	Effective Storage	2080	m3
	Net total flow	**17833**	**m3**

5.3.5 Flows in the HCMD

GHD (2013), in the Serpentine Townsite Local Structure Plan LWMS, modelled the current 100-year ARI peak flow in the HCMD 184m downstream of the Arnold Road culvert (immediately above the junction with the western arm of the drain) as 10.96m^3/sec with a depth of 1.076m and a flow velocity of 1.368m/s.

Calculations for this LWMS based on the Rational Method estimated the 100-year ARI pre-development peak flow in the HCMD as 11.37m^3/s at Arnold Road and 4.66m^3/s at the upstream boundary of the subject land.

Following development of the subject land, the 100-year flow at the upstream boundary is expected to increase by about 12% to 5.23m^3/s due to the interception of some overland flows (which would previously have entered the HCMD within the subject land) by the southern boundary road. The 100-year flow in the HCMD at Arnold Road is expected to decrease by about 10% to 10.33m^3/s, due in part to the redirection of flows by the new southern boundary road and partly to the reduction in flows from within the site. Figure 11 shows the upstream and internal catchments of the HCMD before and after development. Details of the flow calculations are attached in Appendix D.3.

Calculations of 100-yr ARI flows in the HCMD before and after development were made using Manning's Equation for open channel flow above the upstream boundary, at the mid-point of the subject land and at the Arnold Road culvert. Table 5.4 summarises the input parameters and the results of the calculations.

Table 5.4 HCMD 100 yr ARI Flows

	Upstream		***Mid Point***		***Arnold Rd***	
	Pre-Dev	*Post-Dev*	*Pre-Dev*	*Post-Dev*	*Pre-Dev*	*Post-Dev*
Inputs						
Gradient (m/m)	0.016	0.016	0.008	0.008	0.007	0.007
Side Slope	1:8	1:8	1:8	1:33[1]	1:8	1:33[1]
Invert (m AHD)	40.25	40.25	35.7	35.7	32.35	32.35
Bottom Width (m)	1	1	1	0	1	0
Roughness (Manning's n)	0.03[3]	0.03	0.03	0.033[4]	0.03	0.033[4]
Flow (m^3/s)	4.72	5.30	7.72[2]	7.51[2]	10.71	9.72
Outputs						
Flow Depth (m)	0.51	0.54	0.73	0.47	0.85	0.53
Velocity (m/s)	1.8	1.9	1.6	1.0	1.6	1.0
Top Water Level (m AHD)	40.8	40.8	36.4	36.2	33.2	32.9
Top Water Width (m)	9.2	9.6	12.6	31.1	14.6	35.3

1. For simplicity, the post-development drain has been modelled as a single 1:33 channel; in reality it will have a varying profile as described in Section 5.3.2. The profile may be modified to achieve the optimum water depth and width.
2. Flows at the mid-point are estimated as the average of flows at the upstream boundary and Arnold Road, on the assumption that water enters the drain progressively as it crosses the site.
3. Manning's n for "slightly winding excavated channel with some grass and weeds" (Chow, 1959)
4. Manning's n for "excavated channel with dense aquatic plants" (Chow, 1959)

Table 5.4 shows that:

- The 100-year top water width upstream of the site will increase marginally (less than 5%) following development, as a result of the slight increase to the upstream catchment of the HCMD.

- The 100-year flow depth, velocity and top water level at the mid-point and at Arnold Road will decrease following development, due partly to the reduced flow volumes and partly to the broadening of the high-flow channel

- The 100-year water width within the subject land will increase following development as a result of the broadening of the high-flow channel. The profile of the channel can be modified as necessary to optimise the water depth and width and to maintain the flows through the Arnold Rd culvert.

The above preliminary calculations demonstrate that flows in the HCMD can be conveyed through the site both before and after development without adverse impacts on the development or on neighbouring landholdings. A detailed engineering design of the drain will be undertaken at the pre-subdivision stage, at which time the hydraulic calculations described above will be refined.

5.3.6 Water Levels at Culverts

The HCMD passes beneath Arnold Road in a culvert consisting of two 1200mm diameter concrete pipes with an invert of 32.15m AHD. As part of the development, another culvert will be installed beneath the road on the southern boundary.

Flow volume through a culvert is proportional to the diameter of the pipe and the water level in the pipe. Flow velocity is proportional to the water level and inversely proportional to the pipe diameter. Flow restriction can occur if the diameter of the culvert is not sufficient to convey the flow in the drain at the prevailing water depth. If the flow is restricted, the water level immediately upstream of the culvert will increase until the flow through the culvert increases to match the flow in the drain. Downstream scouring can occur if an increased water level causes increased flow velocity through the culvert.

Flows through the Arnold Road culvert and the proposed upstream boundary culvert were calculated using Manning's Equation for open-channel flow for the pre-development and post-development scenarios. Table 5.5 shows the results of the calculations.

Table 5.5 HCMD 100-yr ARI Culvert Flows

	Upstream (no Pre-Dev)	*Arnold Rd*	
	Post-Dev	*Pre-Dev*	*Post-Dev*
Inputs			
Pipe no. x Diameter (mm)	2 x 1200	2 x 1200	2 x 1200
Gradient	0.01	0.01	0.01
Invert (m AHD)	40.15	32.15	32.15
Roughness (Manning's n)	0.011[1]	0.011[1]	0011[1]
Flow (m^3/s)	5.3	10.71	9.72
Outputs			
Water Depth (m)	0.66	1.23[2]	1.06
Flow Velocity (m/s)	4.2	4.7	4.6
Top Water Level (m AHD)	40.8	33.4[2]	33.2

1 Manning's n for "culvert, straight and free of debris" (Chow, 1959)

2 Water depth greater than pipe diameter indicates ponding upstream of the culvert.

Table 5.5 shows that:

- A culvert consisting of two 1200mm pipes will be sufficient to convey the upstream flow in the HCMD under the new southern road with no increase in upstream water levels.

- The velocity of water exiting the new culvert will be less than that occurring in the Arnold Rd culvert before and after development, but will be greater than that existing pre-development in the absence of a culvert. Erosion protection may be necessary in the drain immediately downstream of the new culvert to prevent scouring.

- The water depth, flow velocity and top water level at the Arnold Road culvert will decrease following development, due largely to the decreased flow in the drain and, to a lesser extent, to the broadening of the high-flow channel.

The new culvert will be subject to detailed engineering design at the pre-subdivision stage. The preliminary calculations above are sufficient to demonstrate that the flows through both the new and existing culverts can be managed without adverse impacts within the development area or on neighbouring landholdings.

5.4 Surface Water Quality Management

Nutrient concentrations and loads in water leaving the site will be managed to meet the targets of the Peel-Harvey WQIP (EPA, 2008) as follows:

- Winter median TP concentration: 0.1 mg/L
- Winter median TN concentration: 1.0 mg/L
- Annual TP yield: 0.3 kg/ha
- Annual TN yield: 2.4 kg/ha.

Surface flow from saturated ground surfaces is likely to be the major route for export of nutrients from fertilisers and animal manure from the site in its current state. The development of the site will cause little change to the overall drainage but will introduce opportunities to improve the quality of water draining from the site, including:

- use of high-PRI soil in the construction of roadside swales;
- revegetation of the Hardy's Creek Main Drain;
- land use changes including removal of stock, reduced fertiliser use and increased deep-rooted vegetation; and
- converting surface runoff to groundwater seepage via infiltration swales and sand building pads.

Infiltration Swales
The natural soils of the project area have a high to very high capacity to adsorb phosphorus (PRI 43 – 2089). The DoW advocates a minimum PRI for 15 for infiltration swales. Provided that the permeability of the soil is adequate, the native soils can be used for infiltration basins without modification. If imported fill is required for the swales, suitable High-PRI materials include crushed laterite, limesand, crushed limestone, some yellow sands and sandy loams

The swales will be densely planted with native sedges and low shrubs to maximise the take-up of nitrogen from the stormwater.

Drain Rehabilitation
The Hardy's Creek Main Drain is vegetated only with grass with a loose sandy bed where it flows through the project area. The drain has been excavated and straightened over the years to make it carry water more efficiently. Cattle trampling is causing ongoing erosion and sedimentation in the drain.

The developer will recontour the HCMD within the subdivision to slow and broaden the flow path and improve its ability to retain sediment, nutrients and other contaminants entering it from the project area and areas upstream. These modifications are detailed in Sections 5.3.2 and 5.3.3.

A detailed rehabilitation and landscaping plan for the HCMD within the subject land will be prepared at the subdivision stage.

Land Use Changes

The current land use of broadacre grazing on fertilised pastures, coupled with the high runoff rates in winter, is a potential source of nutrient export to the Peel Inlet. The change to small Rural Living lots (almost all of which will be too small for the keeping of horses or cattle) will effectively remove stock from the site. With the removal of stock there will be no need for fertilisation of pastures or importation of feed, and no mobilisation of nutrients from pasture in manure. This will potentially reduce the export of nutrients, especially phosphorus, by a significant amount.

Houses and gardens developed on the site will be a source of nutrient inputs to the soil. However, the use of nutrient-retentive effluent disposal systems, coupled with the widespread availability of phosphate-free garden fertilisers and the very high PRI of the site soils, means that little phosphorus will reach the groundwater from these sources. With low-phosphorus garden fertilisers being strongly promoted under the State government's Fertiliser Action Plan, most garden fertilisers for sale in hardware and garden stores contain little or no phosphorus.

The planting of deep-rooted trees and shrubs by lot owners, together with screening planting along roadsides by the developer, will reduce runoff rates from the site and further limit nutrient exports.

Conversion of Runoff to Seepage

The runoff coefficient of the site would be very high in winter-wet conditions due to the large areas of saturated ground. In some areas the runoff could be as high as 90% under late winter conditions.

Construction of houses on the site will involve the creation of elevated building pads on most lots, which will have the effect of increasing the area of dry sandy ground where infiltration of rainfall can occur. On an average-sized 4,400m^2 block in a low-lying area, a 250m^2 house on an 800m^2 sand pad could reduce the runoff-generating area of the block by 18% (roof runoff will be infiltrated by soakwells and so is counted as infiltration). The net runoff from the roads in smaller storms will also decrease, as the road runoff from storms up to 1-year ARI will be captured and infiltrated in swales.

Given that the major route of nutrient export from the site is surface flow, this reduction in surface runoff from small storms has the potential to significantly reduce nutrient export from the site as a whole.

5.5 Maintenance

The drainage system has been designed to require little maintenance. The principal maintenance required to ensure that the system continues to function as designed will be periodic mowing and/or maintenance of roadside swales and other vegetated drainage features to remove trash, control weeds and encourage the growth of native species.

6.0 GROUNDWATER MANAGEMENT

6.1 Groundwater Levels

Maximum groundwater levels at the site are currently regulated by the site topography and drains. Development of the site will have little effect on the winter groundwater levels, although abstraction of groundwater during summer for irrigation of lawns and gardens may draw down groundwater levels in summer and may lead to lower groundwater levels in the early part of winter.

Subsoil drains may be employed beneath house pads and road embankments to prevent groundwater rise into the filled areas. Drainage swales and subsoil drains will be set at or above the MGL (approximately the existing ground surface), thereby minimising the impact of the development on maximum groundwater levels.

6.2 Groundwater Quality

Groundwater quality at the site is generally high (see Section 2.4.2), with reactive phosphorus, the nutrient of most concern in the Peel-Harvey catchment, exceeding a concentration of 0.2mg/L at only one bore on one occasion. This is considered to be largely due to the high to very high PRI of the site soils (Section 2.2.4).

The high PRIs mean that development of the site is not expected to significantly change the quality of groundwater beneath the site.

7.0 SUBDIVISION WORKS

The construction of the subdivision will involve minimal earthworks due to the large size of the lots. Subdivision works will be mainly confined to the construction of roads and fences and the installation of water, power and telecommunications.

The project site is within 50m of houses on some neighbouring lots, so careful management of noise and dust during construction will be essential. A conservative approach will be taken in order to minimise the potential for nuisance.

The very low slopes over the site mean that water erosion and sedimentation are unlikely to occur anywhere except in close proximity to the drain.

The developer will implement a Construction Management Plan for the development dealing with dust management, erosion and sediment control, containment of environmental hazardous materials (chiefly fuel and oils) and spill response. The key elements of the Construction Management Plan will include the following:

Dust Minimisation

- No topsoil stripping will occur when the wind speed is greater than 25km/hr. No earthworks will occur in winds of greater than 40km/hr.
- Dust will be suppressed on any disturbed ground and stockpiles by watering, hydromulching, wind fencing and/or covering.
- An adequate supply of water for dust suppression will be kept on site at all times.
- Ground to be disturbed will be wetted prior to soil disturbance.
- Any soil stockpiles will be limited in height to minimise dust generation and facilitate watering.
- Other dust minimisation measures will include minimising areas of disturbance, limiting the volume and speed of construction traffic and instructing site workers in dust minimisation.

Erosion and Sedimentation

- Drains and bunds will be constructed where necessary to capture and direct all runoff from disturbed areas into settling ponds prior to discharge.
- Drains, bunds and ponds will be appropriately designed and sized.
- Vehicles and machinery will be kept to designated roads, tracks and work areas.

Water Conservation

- Water consumption during construction will be minimised by:
  - limiting dust suppression watering to prevent ponding and runoff
  - use of non-water dust control methods such as wind fencing and hydromulching.

Hazardous Materials

- All environmentally hazardous materials will be stored in their original labelled containers (or labelled jerrycans in the case of petroleum products) in a ventilated

sea container equipped with appropriate signage, fire extinguishers and a spill response kit.

- Petroleum products will be held in a bunded enclosure.
- Material Safety Data Sheets (MSDS) and a chemical register for all hazardous materials on the site will be maintained by the site supervisor in the site office.

Complaints Register

- Signs at the construction manager's office will provide a manned telephone number for members of the public to contact in case of dust or noise problems.
- The construction manager will maintain a record of any public complaints and the actions taken in response.

8.0 MONITORING AND RESPONSE

8.1 Monitoring Programme

The developer will monitor water quality on the site from the commencement of subdivision until two years after the completion of the last stage of subdivision works. The monitoring points will include those used for pre-development monitoring, as shown on Figure 7. Any bores that are lost or damaged during construction will be reinstalled or replaced.

Water monitoring will be carried out nominally once each year in late winter. The monitoring parameters will include:

- Depth to water (in bores).
- Physical parameters – temperature, pH, conductivity, salinity, pH, TDS, TSS, hardness, acidity, alkalinity.
- Major ions – chloride, sulphate.
- Nutrients – Total P, FRP, Total N, TKN, NO_X.
- Metals – Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Zn.

8.2 Criteria

The monitoring results will be compared with water quality criteria based on the two rounds of monitoring carried out in 2014 (as detailed in Section 2.4) and any other monitoring carried out before development. The criteria have been designed to ensure that the water quality within and downstream of the site will be at least as good after development as before development. The criteria will be reviewed after the second round of post-development monitoring to confirm their applicability and to assess the need for any revision.

Bore Criteria

- Target - Median of bore values for each parameter should not exceed the median of all pre-development bore values by more than 20%.
- Limit - No parameter in any bore should exceed twice the maximum of all pre-development bore values.

Downstream Watercourse Criteria

- Target - Median of all post-development values should not exceed the median of all pre-development values by more than 20%.
- Limit - No post-development value should exceed twice the maximum of all pre-development values.

pH (all sites)

- Target
  - The median pH in the bores should be within 20% of the median of all pre-development bore values.
  - The median pH in downstream watercourses should be within 20% of the pre-development values or the range of values given in the ANZECC freshwater aquatic ecosystems guidelines.

8.3 Contingency Response

The results of each round of water monitoring will be compared with the criteria. If any limit is breached, the developer will respond as follows:

1. Initially, resample to confirm that the exceedence was not due to sample contamination or natural variation.

2. Inform the Shire of Serpentine-Jarrahdale.

3. Determine whether the exceedence is an isolated, project or regional occurrence.

4. Determine whether the exceedence is attributable to the development or to external factors.

5. Take appropriate contingency action(s) in consultation with the Shire and the Department of Water. These may include:

   - Identify and remove or mitigate any point sources of contamination.
   - Review operational and maintenance (e.g. fertiliser) practices.
   - Modify the stormwater system including enlarge or modify infiltration basins.
   - Reinforce community education/awareness programs.

6. Record the exceedence and the action taken.

7. If necessary, inform residents of any required actions and their purpose.

8.4 Recording and Reporting

The developer will keep a record of the results of all monitoring, including any breaches of criteria and actions taken. Any breaches and contingency actions will be reported immediately to the Shire of Serpentine-Jarrahdale.

At the end of the post-development maintenance period, the developer will prepare a report to the Shire containing all of the recorded data and records of any breaches and contingency actions taken.

9.0 IMPLEMENTATION

The developer will implement and fund the monitoring and management activities outlined in this LWMS for two years after the completion of the final stage of subdivision works. At the end of this time, the responsibility for implementation will pass to the Shire of Serpentine-Jarrahdale, subject to the Shire's acceptance of the works.

As part of the handover, the Shire will assume ownership of and responsibility for the Hardy's Creek Main Drain from the Water Corporation.

10.0 REFERENCES

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Figures



Figure 1

SUBDIVISION GUIDE PLAN

Source: Harley Dykstra, 2015

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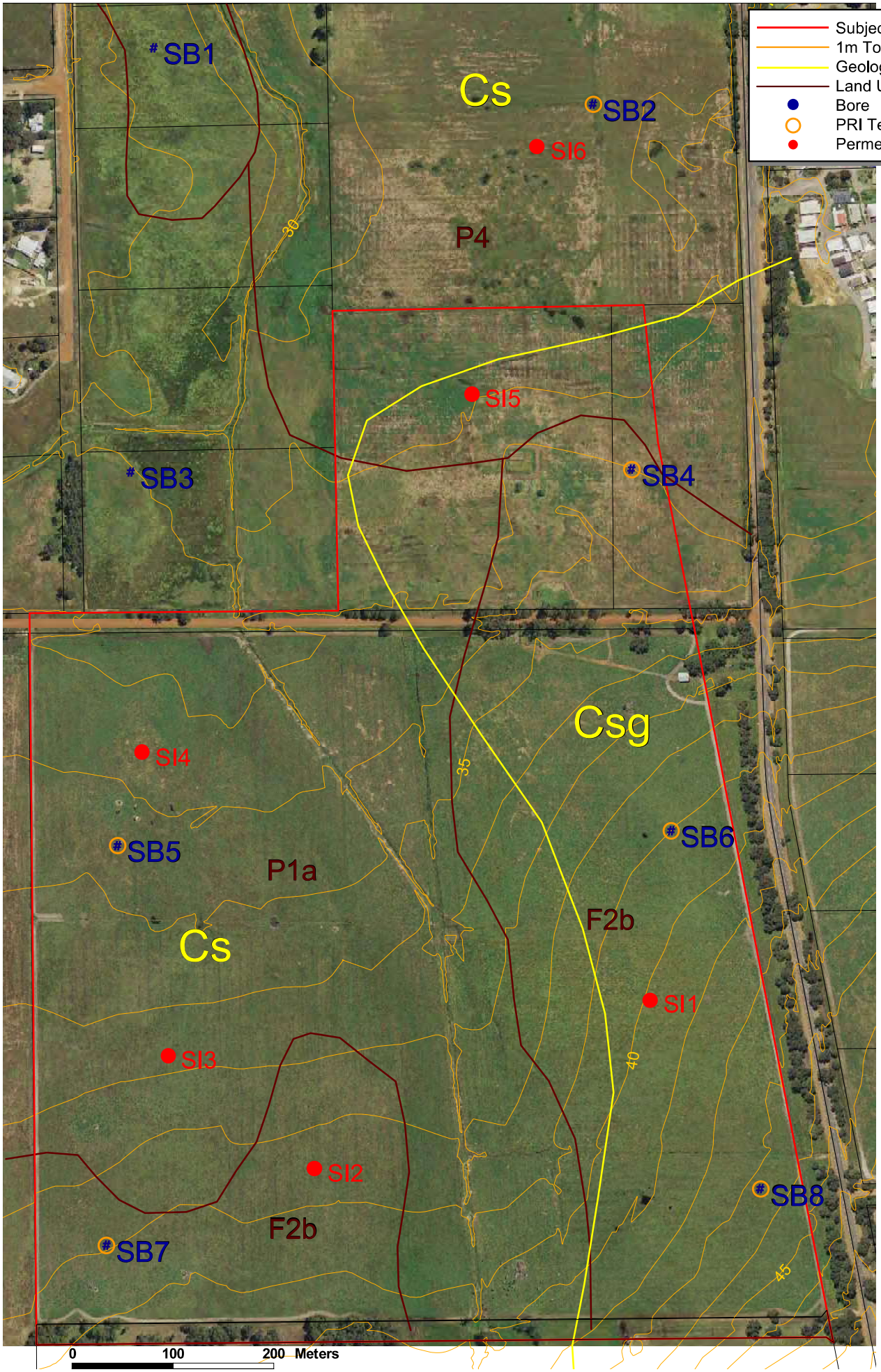

Figure 6

PHYSIOGRAPHY

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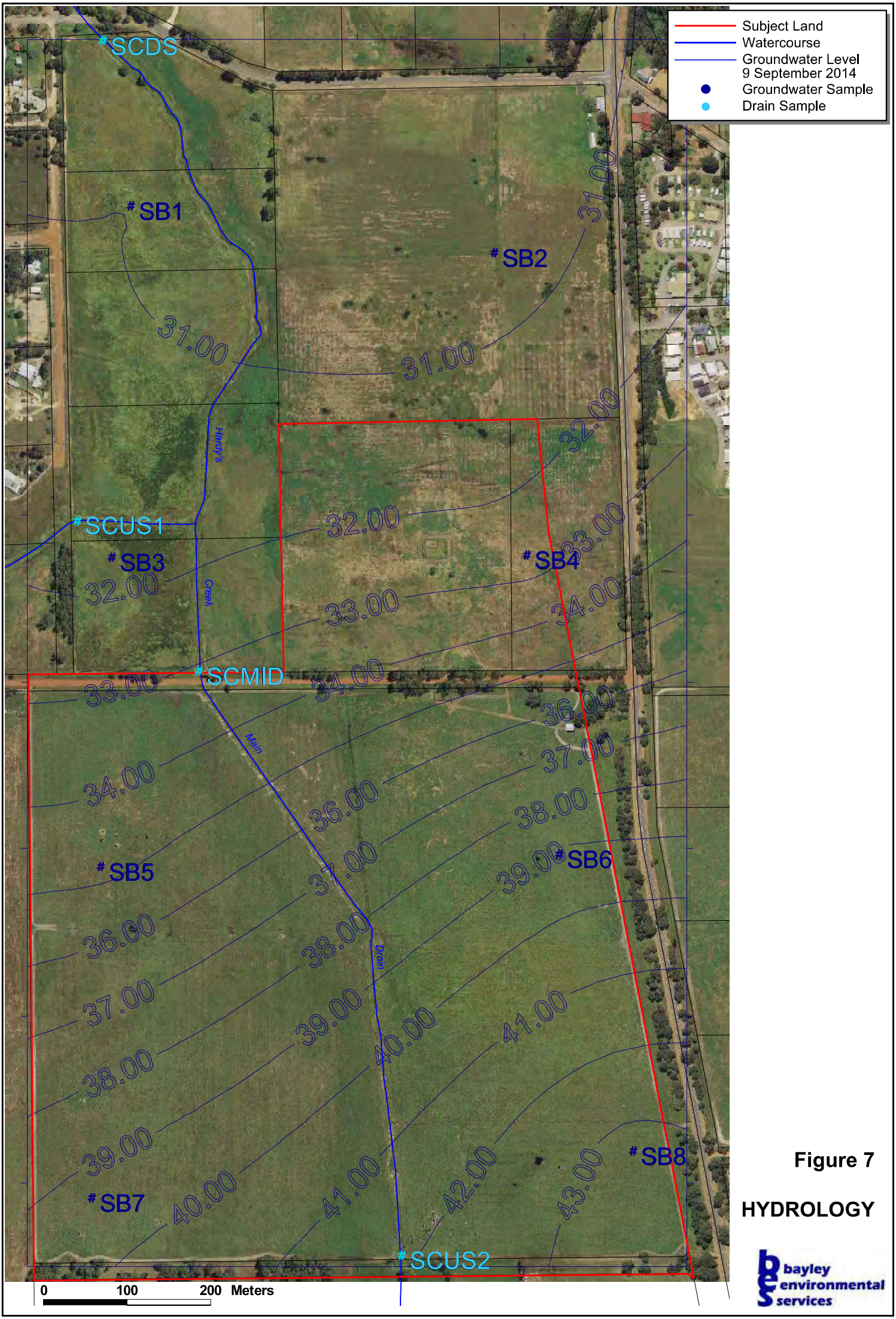

Figure 7

HYDROLOGY

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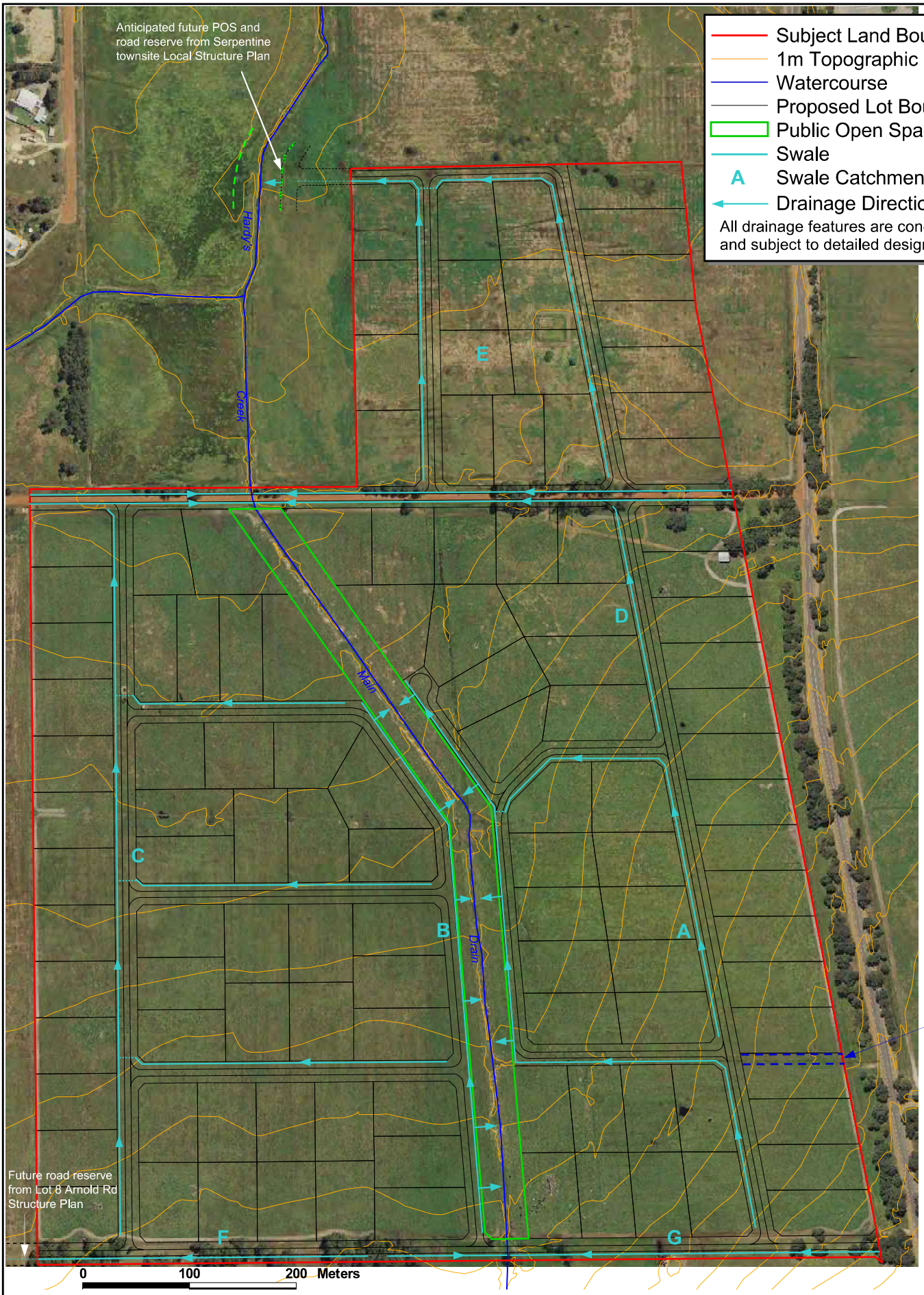
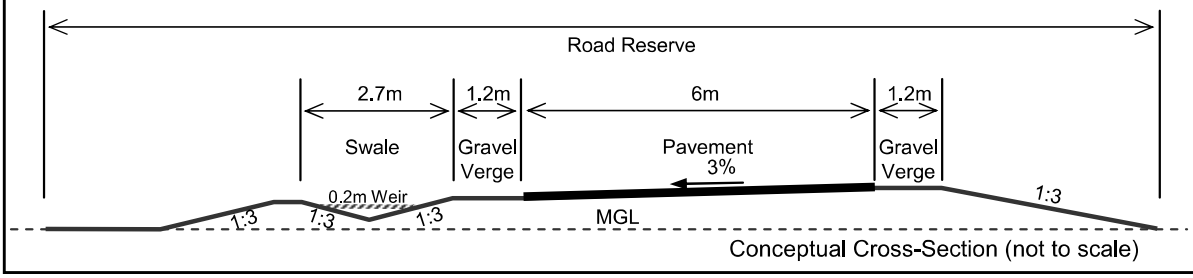


Figure 8



DRAINAGE CONCEPT

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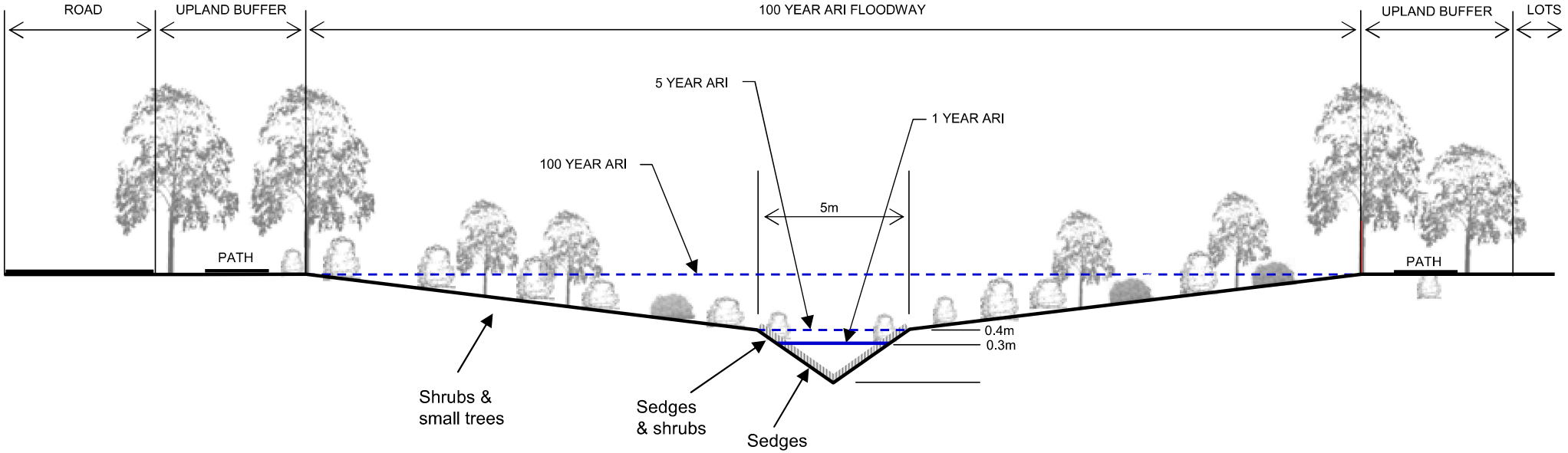

Figure 9

HARDY'S CREEK MAIN DRAIN
CONCEPTUAL LIVING
STREAM PROFILE



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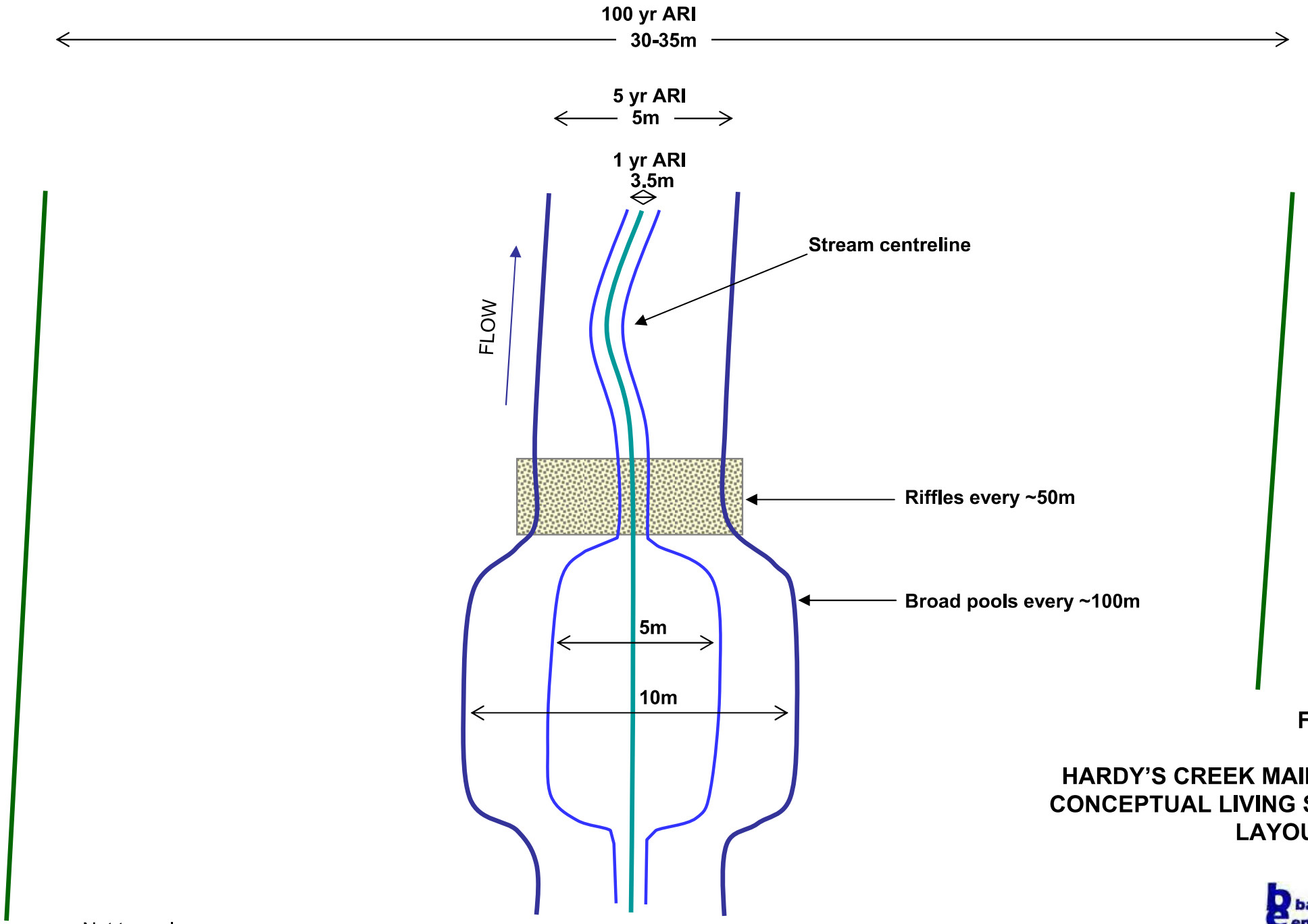

Not to scale

Figure 10

HARDY'S CREEK MAIN DRAIN
CONCEPTUAL LIVING STREAM
LAYOUT PLAN

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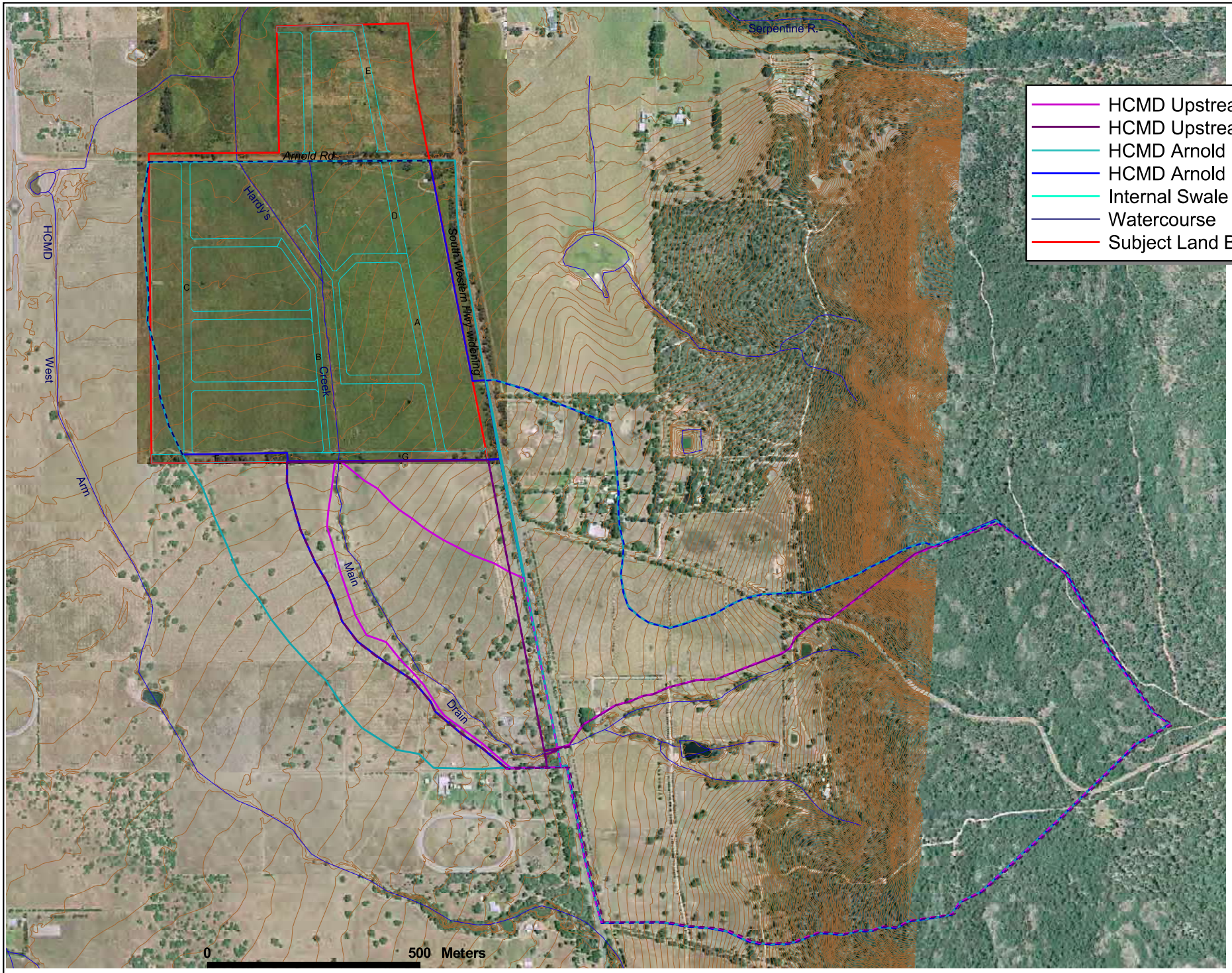

Figure 11

HARDY'S CREEK MAIN DRAIN CATCHMENTS

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Appendix A

Soil Logs

SOIL PROFILE LOG

PROJECT NUMBER:	J14006
SITE ID:	**SB1**
EASTING:	404529
NORTHING:	6418570
METHOD:	Auger Rig
TOTAL DEPTH (mbgl):	5.0
REFUSAL (Y/N):	N
DATE:	28/05/2014
DEPTH TO WATER (mbgl)	

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0	Dark brown silty sand		
0.5	Dark brown silty sand		
1	Orange-brown gravelly clayey silt with pebbles to 10mm		
1.5	Yellow-brown coarse gravelly clay/silt/saprocol with quartz pebbles to 10mm		
2	Orange-brown coarse gravelly clay/silt/saprocol with quartz pebbles to 10mm		
2.5	Brown coarse gravelly clay/silt/saprocol with quartz pebbles to 10mm		
3	Red/brown/grey mottled silty clay		
3.5	Yellow-brown silty clay, weakly structured		
4	Yellow-brown silty clay, weakly structured, stiff		
4.5	Pale brown gravelly clayey silt, very wet		
5	Pale brown gravelly clayey silt, very wet		



SOIL PROFILE LOG

PROJECT NUMBER:	J14006
SITE ID:	**SB2**
EASTING:	404965
NORTHING:	6418514
METHOD:	Auger Rig
TOTAL DEPTH (mbgl):	6.0
REFUSAL (Y/N):	N
DATE:	28/05/2014
DEPTH TO WATER (mbgl)	

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0 - 3	Orange silty clay		
3.5 - 5	Brown silty clay, stiff		
5.5 - 5	Red-brown gritty clay with laterite pebbles to 5mm		





SOIL PROFILE LOG

PROJECT NUMBER:	J14006
SITE ID:	**SB3**
EASTING:	404506
NORTHING:	6418149
METHOD:	Auger Rig
TOTAL DEPTH (mbgl):	4.5
REFUSAL (Y/N):	N
DATE:	28/05/2014
DEPTH TO WATER (mbgl)	

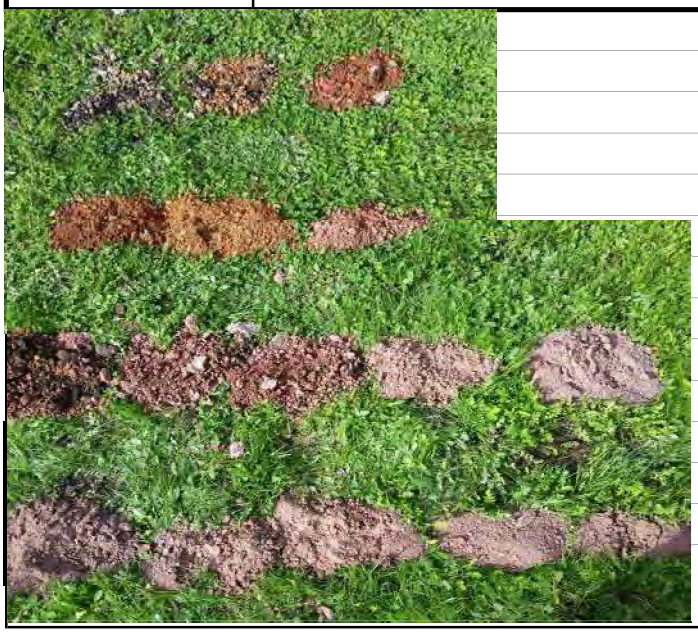
SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0 - 2	Brown silty gravel with stones to 25mm		
2.5	Brown gravelly silt with stones to 25mm, wet		
3 - 4.5	Pale brown silt, very wet		



SOIL PROFILE LOG

PROJECT NUMBER:	J14006
SITE ID:	**SB4**
EASTING:	405003
NORTHING:	6418152
METHOD:	Auger Rig
TOTAL DEPTH (mbgl):	7.5
REFUSAL (Y/N):	N
DATE:	28/05/2014
DEPTH TO WATER (mbgl)	

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0	Dark brown silty sand		
0.5	Orange-brown clayey gravelly silt		
1 - 1.5	Red-brown gravelly clay		
2	Orange/white mottled silty clay		
2.5	Red/white mottled silty clay		
3	Red/white mottled silty clay with lateritic stones to 40mm		
3.5 - 4	Red/white mottled silty clay		
4.5 - 7.5	Red gravelly clay with occ white mottles		



SOIL PROFILE LOG

PROJECT NUMBER:	J14006
SITE ID:	**SB5**
EASTING:	404493
NORTHING:	6417779
METHOD:	Auger Rig
TOTAL DEPTH (mbgl):	6.0
REFUSAL (Y/N):	N
DATE:	28/05/2014
DEPTH TO WATER (mbgl)	

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0	Grey silty sand		
0.5	Brown-grey silty sand with pebbles to 15mm		
1	Red-brown gravelly silty sand with pebbles to 10mm		
1.5	Red-brown gravelly silty sand with pebbles to 15mm		
2	Red gravelly silt with pebbles to 5mm		
2.5 - 3	Red gravelly silt with pebbles to 10mm		
3.5 - 5	Red/white mottled gravelly clay with quartz pebbles to 10mm		
5.5 - 6	Grey clay weakly structured, wet		



SOIL PROFILE LOG

PROJECT NUMBER:	J14006
SITE ID:	**SB6**
EASTING:	405042
NORTHING:	6417793
METHOD:	Auger Rig
TOTAL DEPTH (mbgl):	7.5
REFUSAL (Y/N):	N
DATE:	28/05/2014
DEPTH TO WATER (mbgl)	

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0	Brown-grey silty sand, moist		
0.5 - 1	Grey-brown clayey sand, moist		
1.5	Light brown sandy clay, moist		
2	Pink-brown sandy clay, moist		
2.5	Pink sandy clay, dry		
3 - 4	Red-brown silty clay with pebbles to 5mm, moist		
4.5	Red/brown mottled silty clay, moderately structured, moist		
5	Brown silty clay, weakly structured, moist		
5.5 - 7.5	Brown-grey clay, massive, wet		



SOIL PROFILE LOG

PROJECT NUMBER:	J14006
SITE ID:	**SB7**
EASTING:	404482
NORTHING:	6417382
METHOD:	Auger Rig
TOTAL DEPTH (mbgl):	5.0
REFUSAL (Y/N):	Y
DATE:	28/05/2014
DEPTH TO WATER (mbgl)	

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0	Dark grey-brown silty sand		
0.5	Orange-brown-red gravelly silt, moist		
1 - 1.5	Orange-brown clayey silt, moist		
2	Red-brown sandy silt with gravel to 10mm		
2.5	Brown-red sandy silt with gravel to 10mm		
3	Red gravelly clayey silt with gravel to 10mm		
3.5 - 4	Red-brown gravelly sandy clay with gravel to		
4.5 - 5	Red-brown silty clay weakly structured, moist		
5	Red-brown silty clay weakly structured, moist		



SOIL PROFILE LOG

PROJECT NUMBER:	J14006
SITE ID:	**SB8**
EASTING:	405131
NORTHING:	6417438
METHOD:	Auger Rig
TOTAL DEPTH (mbgl):	6.0
REFUSAL (Y/N):	N
DATE:	28/05/2014
DEPTH TO WATER (mbgl)	

SOIL PROFILE		SAMPLE DATA	
DEPTH (m)	SOIL DESCRIPTION	SAMPLE ID	INTERVAL (m)
0	Grey silty sand		
0.5 - 1	Brown-grey silty gravelly sand with stones to 20mm		
1.5	Brown silty gravel with pebbles to 15mm		
2 - 2.5	Brown silty clay gravel with stones to 20mm		
3	Red/brown mottled clay moderately structured, moist		
3.5	Yellow-brown clay with occasional pebbles to 5mm		
4	Brown-grey clay, moist		
4.5	Pale brown silt, liquid		
5 - 6	Very pale brown silt, slightly gritty, very wet		





Appendix B

Water Analysis Results

Analytical Reference Laboratory

LABORATORY REPORT

Job Number: 14-4750
Revision: 00
Date: 24 July 2014

ADDRESS: **Bayley Environmental Services**
30 Thomas Street
South Fremantle WA 6162

ATTENTION: Phil Bayley

DATE RECEIVED: 11/07/2014

YOUR REFERENCE: J14006 Serpentine

PURCHASE ORDER: N/A

APPROVALS:

Kim Rodgers	Leigh Bermingham	Sam Becker
General Manager	Senior Inorganic Chemist	Inorganic Supervisor

REPORT COMMENTS:

Samples are analysed on an as received basis unless otherwise noted.
Arsenic speciation not covered by scope of NATA accreditation.

METHOD REFERENCES:

ARL No. 040	Arsenic by Hydride Atomic Absorption
ARL No. 29/402/403	Metals in Water by AAS/ICPOES/ICPMS
ARL No. 039	Mercury by Cold Vapour Atomic Absorption
ARL No. 029	Metals in Water by AAS
ARL No. 305	Chloride in Water by Discrete Analyser
ARL No. 301	Sulphate in Water by Discrete Analyser
ARL No. 309	Filterable Reactive Phosphorus in Water by Discrete Analyser
ARL No. 313	NOx in Water by Discrete Analyser
ARL No. 021	Acidity in Water
ARL No. 037	Alkalinity in Water
ARL No. 316	Hexavalent Chromium in Water by Discrete Analyser
ARL No. 014	pH in Water
ARL No. 019	Conductivity and Salinity in Water
ARL No. 016	Total Suspended Solids
ARL No. 330	Persulphate Method for Simultaneous Determination of TN & TP
ARL No. 308	Total Phosphorus in Water by Discrete Analyser

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WORLD RECOGNISED ACCREDITATION
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NATA Accreditation No. 2377

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LABORATORY REPORT

Bayley Environmental Services

ARL Job No: 14-4750 *Revision: 00* *Date:* 24 July 2014

8 Heavy Metals in Water Sample No: Sample Description:	LOR	UNITS	14-4750-1 SB1	14-4750-2 SB2	14-4750-3 SB3	14-4750-4 SB4	14-4750-5 SB5
Arsenic (V)	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic - (III)	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium - Dissolved	0.002	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Copper - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	0.01	<0.01
Mercury - Dissolved	0.0002	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Lead - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	0.02	0.05

8 Heavy Metals in Water Sample No: Sample Description:	LOR	UNITS	14-4750-6 SB6	14-4750-7 SB7	14-4750-8 SB8	14-4750-9 SCDS	14-4750-10 SCMID
Arsenic (V)	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic - (III)	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium - Dissolved	0.002	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Copper - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury - Dissolved	0.0002	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Lead - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc - Dissolved	0.01	mg/L	0.01	0.05	<0.01	<0.01	<0.01

8 Heavy Metals in Water Sample No: Sample Description:	LOR	UNITS	14-4750-11 SCUS1	14-4750-12 SCUS2
Arsenic (V)	0.001	mg/L	<0.001	<0.001
Arsenic - (III)	0.001	mg/L	<0.001	<0.001
Cadmium - Dissolved	0.002	mg/L	<0.002	<0.002
Chromium - Dissolved	0.01	mg/L	<0.01	<0.01
Copper - Dissolved	0.01	mg/L	<0.01	<0.01
Mercury - Dissolved	0.0002	mg/L	<0.0002	<0.0002
Nickel - Dissolved	0.01	mg/L	<0.01	<0.01
Lead - Dissolved	0.01	mg/L	<0.01	<0.01
Zinc - Dissolved	0.01	mg/L	<0.01	<0.01

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LABORATORY REPORT

Bayley Environmental Services

ARL Job No: 14-4750 Revision: 00 Date: 24 July 2014

Metals in Water Sample No: Sample Description:	LOR	UNITS	14-4750-1 SB1	14-4750-2 SB2	14-4750-3 SB3	14-4750-4 SB4	14-4750-5 SB5
Calcium - Dissolved	0.1	mg/L	0.4	12	1.9	4.8	4.4
Iron - Dissolved	0.01	mg/L	0.03	<0.01	0.13	9.3	<0.01
Potassium - Dissolved	0.1	mg/L	0.6	4.4	3.3	1.7	0.8
Magnesium - Dissolved	0.1	mg/L	3.6	39	4.1	33	5.8
Sodium - Dissolved	0.1	mg/L	140	450	36	610	67

Metals in Water Sample No: Sample Description:	LOR	UNITS	14-4750-6 SB6	14-4750-7 SB7	14-4750-8 SB8	14-4750-9 SCDS	14-4750-10 SCMID
Calcium - Dissolved	0.1	mg/L	2.3	2.1	0.5	4.4	9.4
Iron - Dissolved	0.01	mg/L	4.4	<0.01	0.21	0.01	0.17
Potassium - Dissolved	0.1	mg/L	4.1	1.3	1.0	1.9	5.3
Magnesium - Dissolved	0.1	mg/L	19	3.5	3.2	5.1	11
Sodium - Dissolved	0.1	mg/L	300	19	74	36	91

Metals in Water Sample No: Sample Description:	LOR	UNITS	14-4750-11 SCUS1	14-4750-12 SCUS2
Calcium - Dissolved	0.1	mg/L	9.0	9.1
Iron - Dissolved	0.01	mg/L	0.02	0.27
Potassium - Dissolved	0.1	mg/L	3.6	3.2
Magnesium - Dissolved	0.1	mg/L	9.3	7.5
Sodium - Dissolved	0.1	mg/L	71	71

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	14-4750-1 SB1	14-4750-2 SB2	14-4750-3 SB3	14-4750-4 SB4	14-4750-5 SB5
Chloride	5	mg/L	160	690	43	940	130
Sulphate	3	mg/L	90	110	27	240	28
Filterable Reactive Phosphorus	0.01	mg/L	<0.01	0.02	<0.01	0.02	<0.01
NOx-N	0.01	mg/L	0.03	<0.01	1.9	0.95	0.10

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	14-4750-6 SB6	14-4750-7 SB7	14-4750-8 SB8	14-4750-9 SCDS	14-4750-10 SCMID
Chloride	5	mg/L	520	35	150	79	150
Sulphate	3	mg/L	55	8	<3	23	48
Filterable Reactive Phosphorus	0.01	mg/L	<0.01	<0.01	<0.01	0.02	0.02
NOx-N	0.01	mg/L	0.29	0.50	0.02	1.2	0.24

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LABORATORY REPORT

Bayley Environmental Services

ARL Job No: 14-4750 *Revision: 00* *Date:* 24 July 2014

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	14-4750-11 SCUS1	14-4750-12 SCUS2
Chloride	5	mg/L	120	110
Sulphate	3	mg/L	35	44
Filterable Reactive Phosphorus	0.01	mg/L	0.02	0.01
NOx-N	0.01	mg/L	1.7	<0.01

Physical Parameters Sample No: Sample Description:	LOR	UNITS	14-4750-1 SB1	14-4750-2 SB2	14-4750-3 SB3	14-4750-4 SB4	14-4750-5 SB5
Acidity	5	mgCaCO3/L	66	22	12	100	17
Alkalinity	5	mgCaCO3/L	22	120	11	<5	<5
Chromium (VI)	0.002	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002
pH	0.1	pH units	5.6	6.8	6.0	3.8	5.4
Conductivity	0.01	mS/cm	0.80	2.6	0.26	3.4	0.47
Total Suspended Solids	5	mg/L	960	42	670	1,400	650

Physical Parameters Sample No: Sample Description:	LOR	UNITS	14-4750-6 SB6	14-4750-7 SB7	14-4750-8 SB8	14-4750-9 SCDS	14-4750-10 SCMID
Acidity	5	mgCaCO3/L	64	<5	15	<5	<5
Alkalinity	5	mgCaCO3/L	7	<5	9	12	12
Chromium (VI)	0.002	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002
pH	0.1	pH units	5.2	6.0	5.6	6.7	6.9
Conductivity	0.01	mS/cm	1.7	0.17	0.45	0.29	0.66
Total Suspended Solids	5	mg/L	280	340	330	32	24

Physical Parameters Sample No: Sample Description:	LOR	UNITS	14-4750-11 SCUS1	14-4750-12 SCUS2
Acidity	5	mgCaCO3/L	<5	<5
Alkalinity	5	mgCaCO3/L	26	20
Chromium (VI)	0.002	mg/L	<0.002	<0.002
pH	0.1	pH units	7.3	7.3
Conductivity	0.01	mS/cm	0.54	0.51
Total Suspended Solids	5	mg/L	51	24

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	14-4750-1 SB1	14-4750-2 SB2	14-4750-3 SB3	14-4750-4 SB4	14-4750-5 SB5
Total Nitrogen	0.2	mg/L	<0.2	<0.2	2.7	1.3	0.3
TKN	0.2	mg/L	<0.2	<0.2	0.8	0.4	0.2

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	14-4750-6 SB6	14-4750-7 SB7	14-4750-8 SB8	14-4750-9 SCDS	14-4750-10 SCMID
Total Nitrogen	0.2	mg/L	0.3	1.6	0.2	2.1	3.4
TKN	0.2	mg/L	<0.2	1.1	0.2	0.9	3.2

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LABORATORY REPORT

Bayley Environmental Services

ARL Job No: 14-4750 *Revision: 00* *Date:* 24 July 2014

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	14-4750-11 SCUS1	14-4750-12 SCUS2
Total Nitrogen	0.2	mg/L	2.7	1.5
TKN	0.2	mg/L	1.0	1.5

Total Phosphorus in Water Sample No: Sample Description:	LOR	UNITS	14-4750-1 SB1	14-4750-2 SB2	14-4750-3 SB3	14-4750-4 SB4	14-4750-5 SB5
Total Phosphorus	0.01	mg/L	1.0	0.27	0.65	19	0.43

Total Phosphorus in Water Sample No: Sample Description:	LOR	UNITS	14-4750-6 SB6	14-4750-7 SB7	14-4750-8 SB8	14-4750-9 SCDS	14-4750-10 SCMID
Total Phosphorus	0.01	mg/L	0.55	3.2	0.57	0.32	0.25

Total Phosphorus in Water Sample No: Sample Description:	LOR	UNITS	14-4750-11 SCUS1	14-4750-12 SCUS2
Total Phosphorus	0.01	mg/L	0.20	0.19

Result Definitions

LOR Limit of Reporting
[NT] Not Tested
[ND] Not Detected at indicated Limit of Reporting
[NR] Analysis Not Requested
(SS) Surrogate Standard Compound - Used for QC purposes. Acceptance Criteria is 60-120%.

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ARL
Analytical Reference Laboratory

LABORATORY REPORT

Job Number: 14-6360
Revision: 00
Date: 3 October 2014

ADDRESS: **Bayley Environmental Services**
30 Thomas Street
South Fremantle WA 6162

ATTENTION: Phil Bayley

DATE RECEIVED: 16/09/2014

YOUR REFERENCE: J14006

PURCHASE ORDER:

APPROVALS:

Douglas Todd
Laboratory Manager

Sam Becker
Inorganic Supervisor

REPORT COMMENTS:

Samples are analysed on an as received basis unless otherwise noted.
AsIII and AsV are not covered by ARL's NATA scope of accreditation.

METHOD REFERENCES:

ARL No. 040	Arsenic by Hydride Atomic Absorption
ARL No. 29/402/403	Metals in Water by AAS/ICPOES/ICPMS
ARL No. 039	Mercury by Cold Vapour Atomic Absorption
ARL No. 029	Metals in Water by AAS
ARL No. 330	Persulphate Method for Simultaneous Determination of TN & TP
ARL No. 308	Total Phosphorus in Water by Discrete Analyser
ARL No. 305	Chloride in Water by Discrete Analyser
ARL No. 301	Sulphate in Water by Discrete Analyser
ARL No. 309	Filterable Reactive Phosphorus in Water by Discrete Analyser
ARL No. 313	NOx in Water by Discrete Analyser
ARL No. 021	Acidity in Water
ARL No. 037	Alkalinity in Water
ARL No. 316	Hexavalent Chromium in Water by Discrete Analyser
ARL No. 014	pH in Water
ARL No. 019	Conductivity and Salinity in Water
ARL No. 016	Total Suspended Solids

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NATA Accreditation No. 2377

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LABORATORY REPORT

Bayley Environmental Services

ARL Job No: 14-6360 *Revision: 00* *Date:* 3 October 2014

8 Heavy Metals in Water Sample No: Sample Description:	LOR	UNITS	14-6360-1 SB1	14-6360-2 SB2	14-6360-3 SB3	14-6360-4 SB4	14-6360-5 SB5
Arsenic III - Dissolved	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic V - Dissolved	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium - Dissolved	0.002	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Copper - Dissolved	0.01	mg/L	<0.01	<0.01	0.07	0.04	<0.01
Mercury - Dissolved	0.0002	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Lead - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc - Dissolved	0.01	mg/L	0.04	<0.01	<0.01	0.03	0.07

8 Heavy Metals in Water Sample No: Sample Description:	LOR	UNITS	14-6360-6 SB6	14-6360-7 SB7	14-6360-8 SB8	14-6360-9 SCDS	14-6360-10 SCMID
Arsenic III - Dissolved	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic V - Dissolved	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium - Dissolved	0.002	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Copper - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury - Dissolved	0.0002	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Lead - Dissolved	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc - Dissolved	0.01	mg/L	<0.01	0.07	0.09	<0.01	<0.01

8 Heavy Metals in Water Sample No: Sample Description:	LOR	UNITS	14-6360-11 SCUS1	14-6360-12 SCUS2
Arsenic III - Dissolved	0.001	mg/L	<0.001	<0.001
Arsenic V - Dissolved	0.001	mg/L	<0.001	<0.001
Cadmium - Dissolved	0.002	mg/L	<0.002	<0.002
Chromium - Dissolved	0.01	mg/L	<0.01	<0.01
Copper - Dissolved	0.01	mg/L	<0.01	<0.01
Mercury - Dissolved	0.0002	mg/L	<0.0002	<0.0002
Nickel - Dissolved	0.01	mg/L	<0.01	<0.01
Lead - Dissolved	0.01	mg/L	<0.01	<0.01
Zinc - Dissolved	0.01	mg/L	<0.01	0.06

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Metals in Water Sample No: Sample Description:	LOR	UNITS	14-6360-1 SB1	14-6360-2 SB2	14-6360-3 SB3	14-6360-4 SB4	14-6360-5 SB5
Aluminium - Dissolved	0.1	mg/L	<0.1	<0.1	<0.1	1.4	<0.1
Calcium - Dissolved	0.1	mg/L	1.2	2.1	1.3	3.3	1.3
Iron - Dissolved	0.01	mg/L	0.02	<0.01	0.08	3.7	0.15
Potassium - Dissolved	0.1	mg/L	1.0	0.6	2.7	1.4	1.4
Magnesium - Dissolved	0.1	mg/L	4.5	15	4.0	42	4.1
Sodium - Dissolved	0.1	mg/L	140	260	31	800	47

Metals in Water Sample No: Sample Description:	LOR	UNITS	14-6360-6 SB6	14-6360-7 SB7	14-6360-8 SB8	14-6360-9 SCDS	14-6360-10 SCMID
Aluminium - Dissolved	0.1	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Calcium - Dissolved	0.1	mg/L	1.3	3.5	0.6	7.6	8.1
Iron - Dissolved	0.01	mg/L	5.1	<0.01	1.7	0.14	0.02
Potassium - Dissolved	0.1	mg/L	3.3	2.8	1.2	3.1	2.8
Magnesium - Dissolved	0.1	mg/L	13	7.1	4.1	9.0	9.2
Sodium - Dissolved	0.1	mg/L	180	36	67	54	57

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Metals in Water Sample No: Sample Description:	LOR	UNITS	14-6360-11 SCUS1	14-6360-12 SCUS2
Aluminium - Dissolved	0.1	mg/L	<0.1	<0.1
Calcium - Dissolved	0.1	mg/L	6.4	9.7
Iron - Dissolved	0.01	mg/L	0.29	0.44
Potassium - Dissolved	0.1	mg/L	5.1	4.7
Magnesium - Dissolved	0.1	mg/L	8.1	7.3
Sodium - Dissolved	0.1	mg/L	53	49

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	14-6360-1 SB1	14-6360-2 SB2	14-6360-3 SB3	14-6360-4 SB4	14-6360-5 SB5
Total Nitrogen	0.2	mg/L	<0.2	<0.2	0.4	<0.2	<0.2
TKN	0.2	mg/L	<0.2	<0.2	0.2	<0.2	<0.2

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	14-6360-6 SB6	14-6360-7 SB7	14-6360-8 SB8	14-6360-9 SCDS	14-6360-10 SCMID
Total Nitrogen	0.2	mg/L	<0.2	<0.2	<0.2	0.8	0.8
TKN	0.2	mg/L	<0.2	<0.2	<0.2	0.4	0.3

Total Nitrogen in Water Sample No: Sample Description:	LOR	UNITS	14-6360-11 SCUS1	14-6360-12 SCUS2
Total Nitrogen	0.2	mg/L	1.2	1.6
TKN	0.2	mg/L	1.2	1.6

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Total Phosphorus in Water Sample No: Sample Description:	LOR	UNITS	14-6360-1 SB1	14-6360-2 SB2	14-6360-3 SB3	14-6360-4 SB4	14-6360-5 SB5
Total Phosphorus	0.01	mg/L	1.8	2.0	0.51	1.9	0.71

Total Phosphorus in Water Sample No: Sample Description:	LOR	UNITS	14-6360-6 SB6	14-6360-7 SB7	14-6360-8 SB8	14-6360-9 SCDS	14-6360-10 SCMID
Total Phosphorus	0.01	mg/L	2.0	0.30	0.48	0.21	0.28

Total Phosphorus in Water Sample No: Sample Description:	LOR	UNITS	14-6360-11 SCUS1	14-6360-12 SCUS2
Total Phosphorus	0.01	mg/L	0.28	0.24

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	14-6360-1 SB1	14-6360-2 SB2	14-6360-3 SB3	14-6360-4 SB4	14-6360-5 SB5
Chloride	5	mg/L	130	260	47	960	81
Sulphate	3	mg/L	85	200	23	280	16
Filterable Reactive Phosphorus	0.01	mg/L	0.02	0.02	0.02	0.20	0.01
NOx-N	0.01	mg/L	0.07	<0.01	0.18	0.01	<0.01

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Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	14-6360-6 SB6	14-6360-7 SB7	14-6360-8 SB8	14-6360-9 SCDS	14-6360-10 SCMID
Chloride	5	mg/L	130	70	350	110	110
Sulphate	3	mg/L	<3	17	28	24	25
Filterable Reactive Phosphorus	0.01	mg/L	0.03	<0.01	<0.01	0.02	0.02
NOx-N	0.01	mg/L	<0.01	0.17	<0.01	0.38	0.53

Ions by Discrete Analyser Sample No: Sample Description:	LOR	UNITS	14-6360-11 SCUS1	14-6360-12 SCUS2
Chloride	5	mg/L	120	69
Sulphate	3	mg/L	17	14
Filterable Reactive Phosphorus	0.01	mg/L	0.03	0.02
NOx-N	0.01	mg/L	0.03	0.02

Physical Parameters Sample No: Sample Description:	LOR	UNITS	14-6360-1 SB1	14-6360-2 SB2	14-6360-3 SB3	14-6360-4 SB4	14-6360-5 SB5
Acidity	5	mgCaCO3/L	60	23	28	170	29
Alkalinity	5	mgCaCO3/L	17	97	10	<5	<5
Chromium (VI)	0.002	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002
pH	0.1	pH units	5.1	6.3	5.2	3.4	4.7
Conductivity	0.01	mS/cm	0.88	1.5	0.25	4.0	0.33
Total Suspended Solids	5	mg/L	1,000	520	120	630	280

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Physical Parameters Sample No: Sample Description:	LOR	UNITS	14-6360-6 SB6	14-6360-7 SB7	14-6360-8 SB8	14-6360-9 SCDS	14-6360-10 SCMID
Acidity	5	mgCaCO3/L	170	40	47	5	<5
Alkalinity	5	mgCaCO3/L	<5	19	6	31	36
Chromium (VI)	0.002	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002
pH	0.1	pH units	4.5	5.3	4.9	6.4	6.8
Conductivity	0.01	mS/cm	1.2	0.32	0.45	0.46	0.45
Total Suspended Solids	5	mg/L	770	63	150	21	23

Physical Parameters Sample No: Sample Description:	LOR	UNITS	14-6360-11 SCUS1	14-6360-12 SCUS2
Acidity	5	mgCaCO3/L	9	11
Alkalinity	5	mgCaCO3/L	24	32
Chromium (VI)	0.002	mg/L	<0.002	<0.002
pH	0.1	pH units	6.4	6.0
Conductivity	0.01	mS/cm	0.42	0.40
Total Suspended Solids	5	mg/L	18	16

Misc. Inorganics in Water Sample No: Sample Description:	LOR	UNITS	14-6360-1 SB1	14-6360-2 SB2	14-6360-3 SB3	14-6360-4 SB4	14-6360-5 SB5
Hardness	5	mgCaCO3/L	22	67	20	180	20

Misc. Inorganics in Water Sample No: Sample Description:	LOR	UNITS	14-6360-6 SB6	14-6360-7 SB7	14-6360-8 SB8	14-6360-9 SCDS	14-6360-10 SCMID
Hardness	5	mgCaCO3/L	57	38	18	56	58

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Misc. Inorganics in Water Sample No: Sample Description:	LOR	UNITS	14-6360-11 SCUS1	14-6360-12 SCUS2
Hardness	5	mgCaCO3/L	49	54

Result Definitions

LOR Limit of Reporting
[NT] Not Tested
[ND] Not Detected at indicated Limit of Reporting
[NR] Analysis Not Requested
(SS) Surrogate Standard Compound - Used for QC purposes. Acceptance Criteria is 60-120%.

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Appendix C

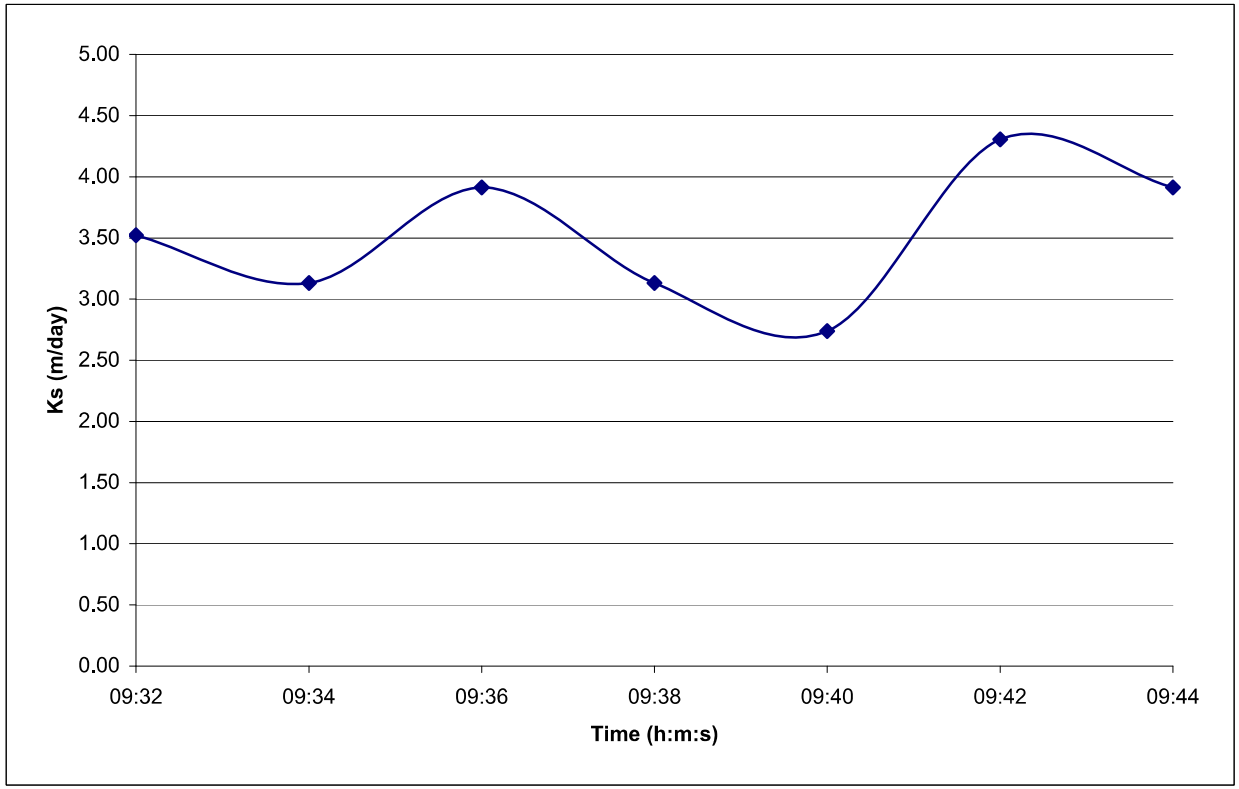
Permeability Test Results

SOIL PERMEABILITY TEST

Site No.	SI1
Date	21/01/15
Easting	405021
Northing	6417627

Time (h:m:s)	Weight (kg)	Change in Weight (kg)	Ks (m/d)
09:30:00	44.7		
09:32:00	43.8	0.9	**3.52**
09:34:00	43	0.8	**3.13**
09:36:00	42	1	**3.91**
09:38:00	41.2	0.8	**3.13**
09:40:00	40.5	0.7	**2.74**
09:42:00	39.4	1.1	**4.30**
09:44:00	38.4	1	**3.91**
		38.4	

H =	25
r =	**5**

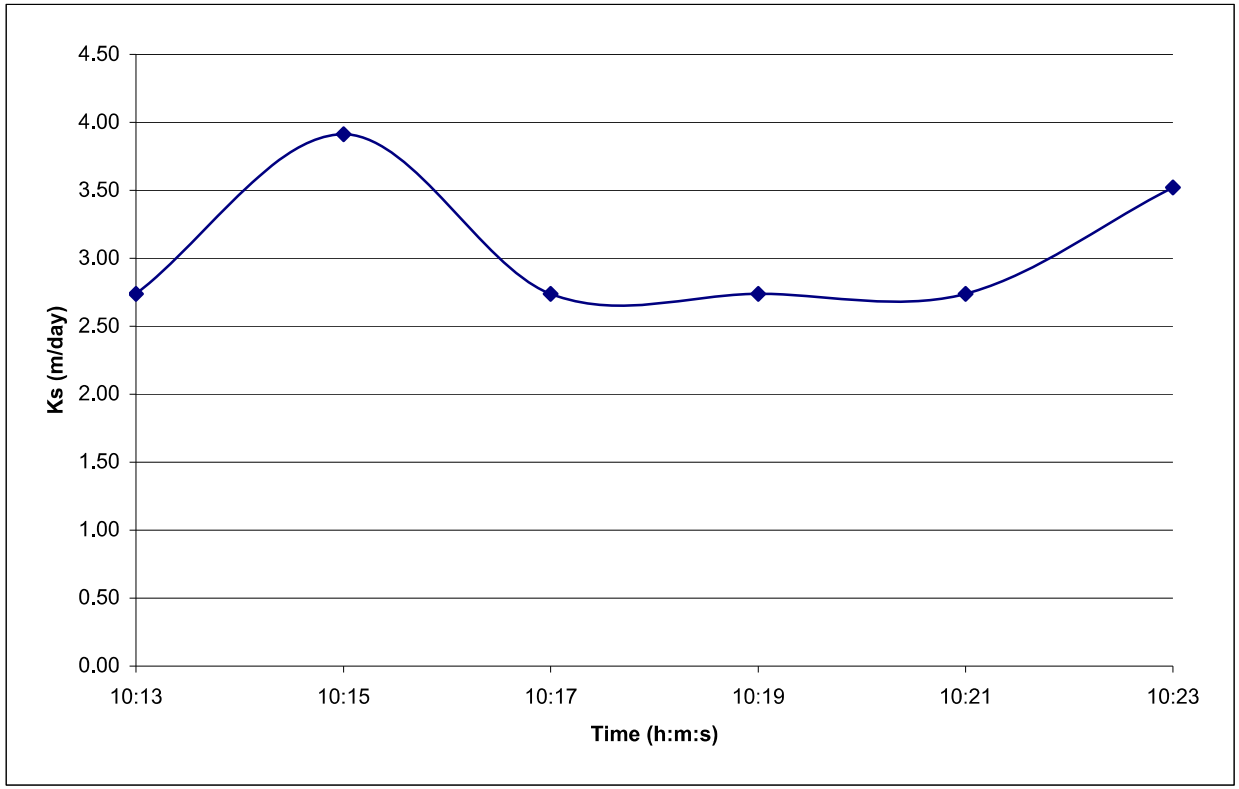


SOIL PERMEABILITY TEST

Site No.	SI2
Date	21/01/15
Easting	404688
Northing	6417459

Time (h:m:s)	Weight (kg)	Change in Weight (kg)	Ks (m/d)
10:11:00	27.9		
10:13:00	27.2	0.7	**2.74**
10:15:00	26.2	1	**3.91**
10:17:00	25.5	0.7	**2.74**
10:19:00	24.8	0.7	**2.74**
10:21:00	24.1	0.7	**2.74**
10:23:00	23.2	0.9	**3.52**
		23.2	

H =	25
r =	**5**

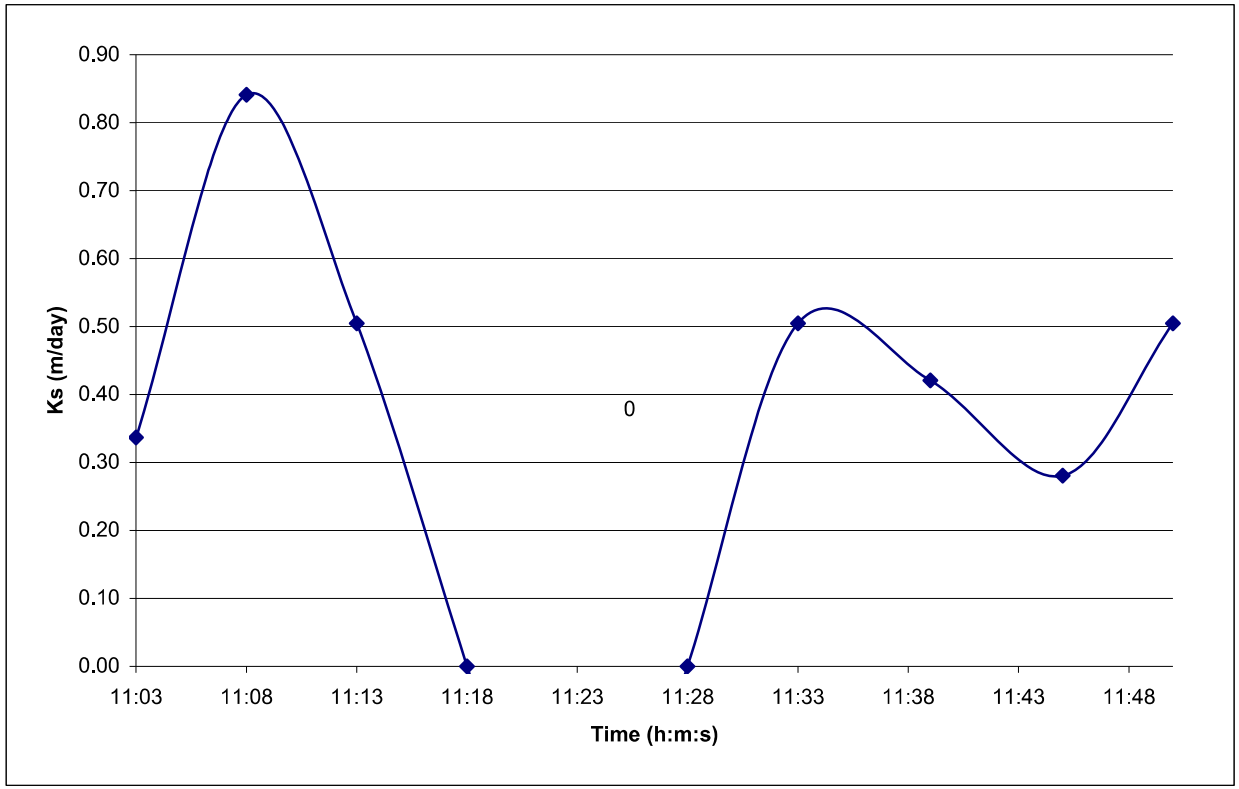


SOIL PERMEABILITY TEST

Site No.	SI3
Date	21/01/15
Easting	404543
Northing	6417571

Time (h:m:s)	Weight (kg)	Change in Weight (kg)	Ks (m/d)
10:58:00	38.8		
11:03:00	38.6	0.2	**0.34**
11:08:00	38.1	0.5	**0.84**
11:13:00	37.8	0.3	**0.50**
11:18:00	37.8		
11:23:00	38.1	-0.3	**-0.50**
11:28:00	38.1		
11:33:00	37.8	0.3	**0.50**
11:39:00	37.5	0.3	**0.42**
11:45:00	37.3	0.2	**0.28**
11:50:00	37	0.3	**0.50**
		37	

H =	25
r =	**4.5**

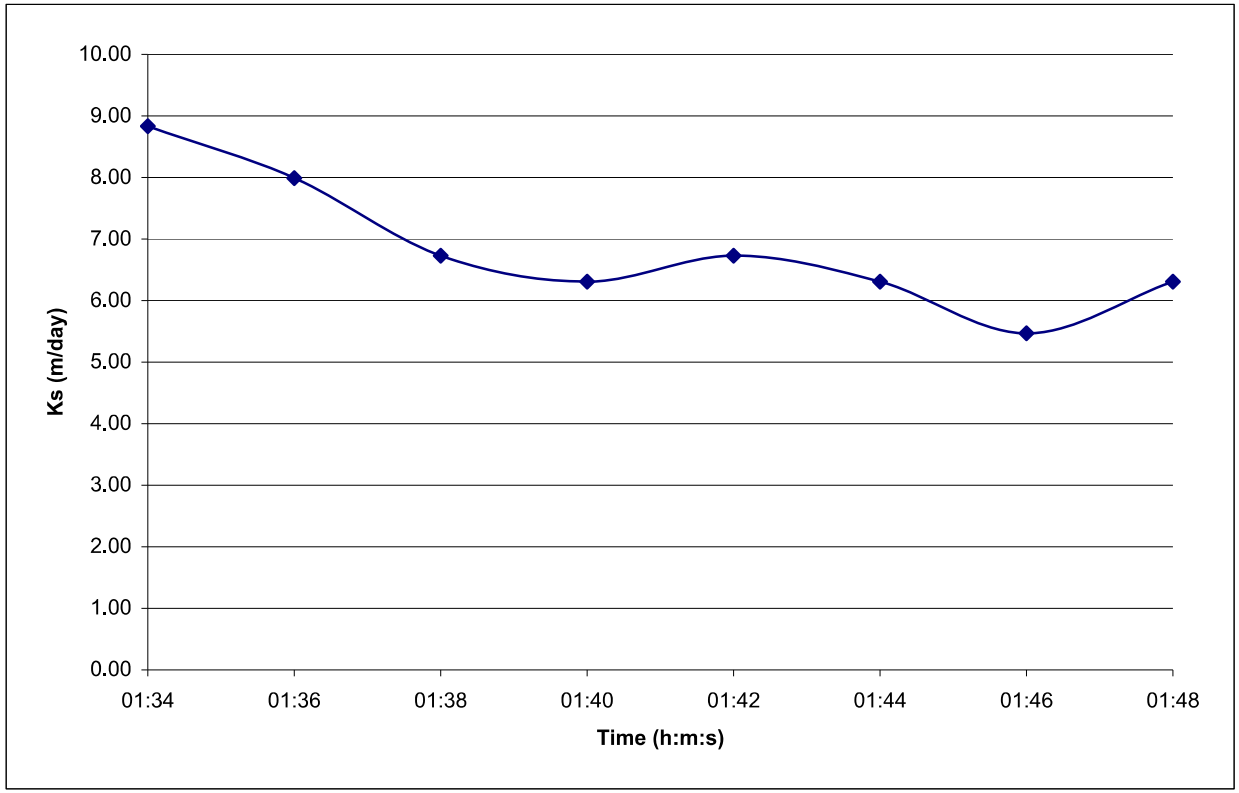


SOIL PERMEABILITY TEST

Site No.	SI4
Date	21/01/15
Easting	404516
Northing	6417872

Time (h:m:s)	Weight (kg)	Change in Weight (kg)	Ks (m/d)
01:32:00	38.4		
01:34:00	36.3	2.1	**8.83**
01:36:00	34.4	1.9	**7.99**
01:38:00	32.8	1.6	**6.73**
01:40:00	31.3	1.5	**6.31**
01:42:00	29.7	1.6	**6.73**
01:44:00	28.2	1.5	**6.31**
01:46:00	26.9	1.3	**5.47**
01:48:00	25.4	1.5	**6.31**
		25.4	

H =	25
r =	**4.5**

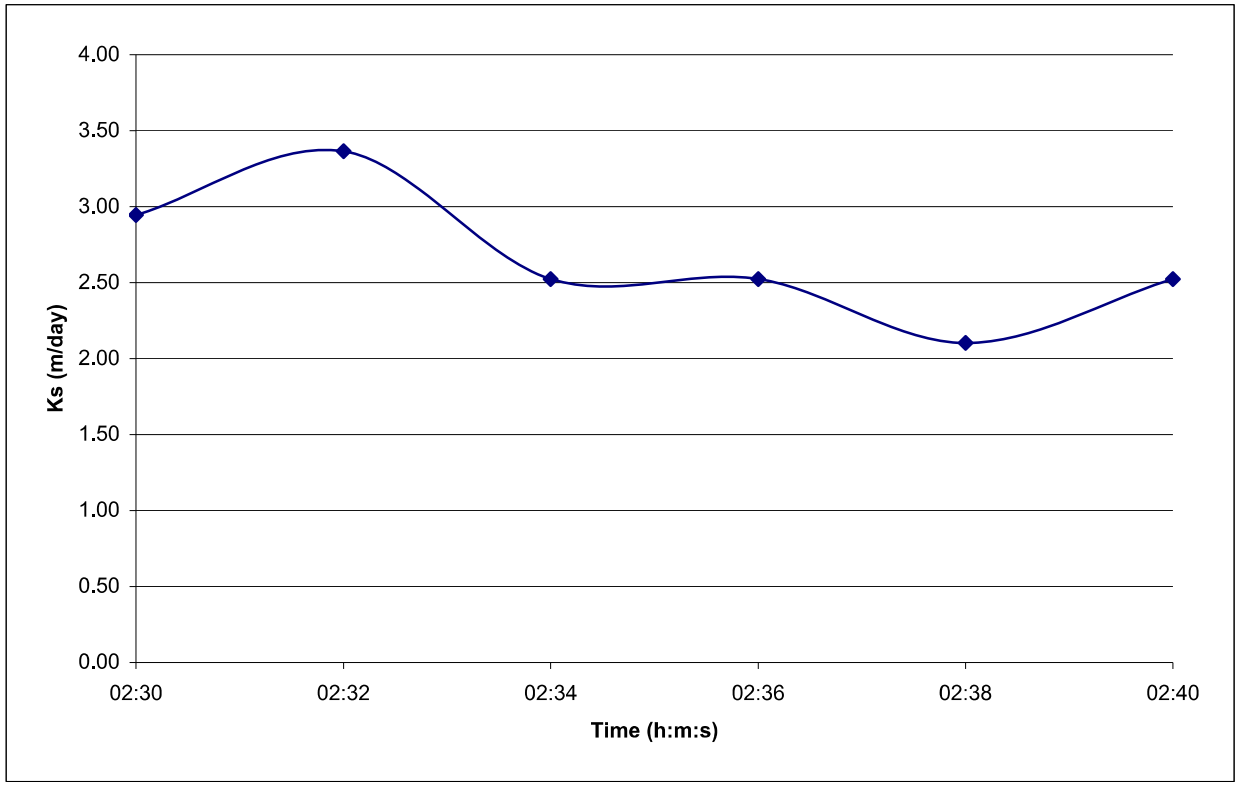


SOIL PERMEABILITY TEST

Site No.	SI5
Date	21/01/15
Easting	404845
Northing	6418228

Time (h:m:s)	Weight (kg)	Change in Weight (kg)	Ks (m/d)
02:26:00	34.1		
02:30:00	32.7	1.4	**2.94**
02:32:00	31.9	0.8	**3.37**
02:34:00	31.3	0.6	**2.52**
02:36:00	30.7	0.6	**2.52**
02:38:00	30.2	0.5	**2.10**
02:40:00	29.6	0.6	**2.52**
		29.6	

H =	25
r =	**4.5**

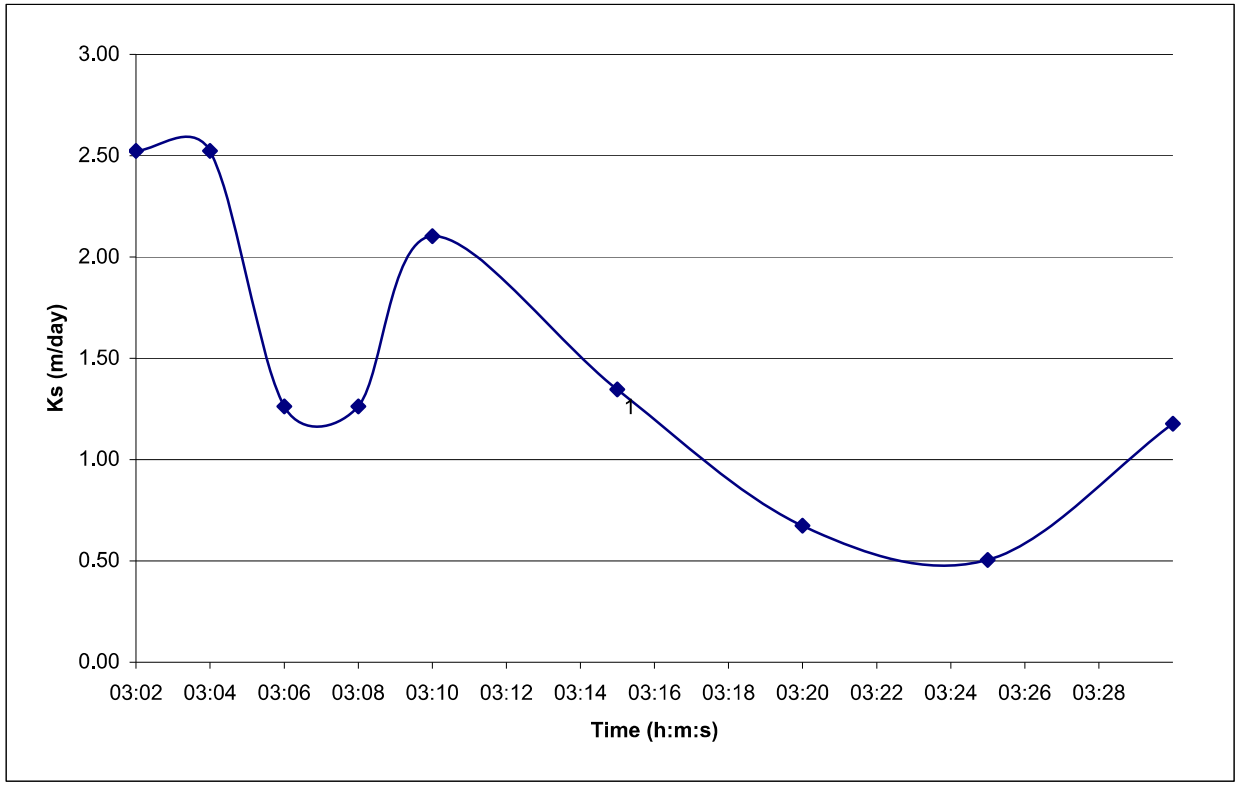


SOIL PERMEABILITY TEST

Site No.	SI6
Date	21/01/15
Easting	404909
Northing	6418474

Time (h:m:s)	Weight (kg)	Change in Weight (kg)	Ks (m/d)
03:00:00	26.9		
03:02:00	26.3	0.6	**2.52**
03:04:00	25.7	0.6	**2.52**
03:06:00	25.4	0.3	**1.26**
03:08:00	25.1	0.3	**1.26**
03:10:00	24.6	0.5	**2.10**
03:15:00	23.8	0.8	**1.35**
03:20:00	23.4	0.4	**0.67**
03:25:00	23.1	0.3	**0.50**
03:30:00	22.4	0.7	**1.18**
		22.4	

H =	25
r =	**4.5**



Appendix D

Drainage Calculations

D.1
Road and Swale Runoff

1 YEAR ARI 1 HOUR FLOWS

Rainfall Intensity i (mm/h)	17.5	(1 Yr, 1 Hr Storm)
Runoff Coefficient Road Rese	0.85	
Runoff Coefficient Lots	0.5	
Runoff Coefficient OS	0.5	
Permeability k (m/hr)	0.1700	

Catchment	Road/Verge Area (m2)	Lot Area (m2)	OS Area (m2)	Ai	Q (L/s)	Vinflow (m3)
A	22620	0	0	19227.00	93.54	337
B	7897	0	0	6712.45	32.66	118
C	29731	0	0	25271.35	122.95	443
D	4512	0	0	3835.20	18.66	67
E	14595	0	0	12405.75	60.35	217
F	6472	0	0	5501.20	26.76	96
G	9476	0	0	8054.60	39.19	141

Swale Sizing

Catchment	Storm Event	Depth	Slope 1:x	Base Width	Base Length	Volume	Effective Volume (including infiltration)	Surface Area (m2)	Volume check	2% Area	Base Length Available
A	1	0.2	3	0	817	98	337	982	ok	452	1170
B	1	0.2	3	0	284	34	118	342	ok	158	519
C	1	0.2	3	0	1075	129	443	1291	ok	595	1472
D	1	0.2	3	0	161	20	67	195	ok	90	221
E	1	0.2	3	0	526	63	217	633	ok	292	769
F	1	0.2	3	0	232	28	97	280	ok	129	318
G	1	0.2	3	0	341	41	141	411	ok	190	462

5 YEAR ARI DRAINAGE PROPERTIES

CATCHMENT	AREAS (m2)				EFFECTIVE AREAS (m2)		TIME OF CONCENTRATION PRE-DEVELOPMENT					TIME OF CONCENTRATION POST-DEVELOPMENT					CRITICAL STORM INTENSITY (mm/h)	
	Roads	Lots	OS	Total	Pre-Dev	Post-Dev	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope (m/km)	TC (mIn)	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope	TC (mIn)	Pre-Dev	Post-Dev
A	22620	0	0	22620	13572	19227	739	44	35	12.18	40.0	739	44	35	12.18	38.6	37.32	38.00
B	7897	0	0	7897	4738	6712	520	40.5	34.5	11.54	31.6	520	40.5	34.5	11.54	30.5	41.51	42.05
C	29731	0	0	29731	17839	25271	836	40	33	8.37	47.4	836	40	33	8.37	45.8	33.59	34.40
D	4512	0	0	4512	2707	3835	223	38.5	35	15.70	13.5	223	38.5	35	15.70	13.0	70.99	72.17
E	14595	0	0	14595	8757	12406	487	34.5	31.2	6.78	30.9	487	34.5	31.2	6.78	29.9	41.83	42.44
F	6472	0	0	6472	3883	5501	318	41.1	39.5	5.03	23.3	318	41.1	39.5	5.03	22.5	50.32	51.27
G	9476	0	0	9476	5686	8055	347	47	41	18.73	18.8	347	47	41	18.73	18.1	57.33	58.98

Runoff Coefficients	**Pre-Dev**	**Post-Dev**
Roads	0.6	0.85
Lots	0.6	0.5
OS	0.6	0.5

Rainfall IFD

Event	**Duration (mins)**	**Intensity (mm/hr)**
5 min	5	109
6 min	6	101
10 min	10	79.9
20 min	20	54.2
30 min	30	42.3
1 hr	60	27.3
2 hr	120	17.5
3 hr	180	13.5
6 hr	360	8.67
12 hr	720	5.62
24 hr	1440	3.65
48 hr	2880	2.32
72 hr	4320	1.73

5 YEAR ARI FLOWS

Storm Duration (mins)	Catchment A				Catchment B				Catchment C				Catchment D			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
5	140.69	582.15	441.47	-114.63	54.63	203.24	148.61	-28.52	166.46	765.16	598.70	-178.24	53.38	116.12	62.74	-3.69
6	140.69	539.42	398.74	-97.29	54.63	188.32	133.69	-22.85	166.46	709.00	542.55	-154.65	53.38	107.60	54.22	-1.47
10	140.69	426.73	286.05	-46.77	54.63	148.98	94.35	-6.71	166.46	560.88	394.43	-84.96	53.38	85.12	31.74	3.51
20	140.69	289.47	148.79	11.08	54.63	101.06	46.43	9.78	166.46	380.47	214.02	-0.44	53.38	57.74	4.36	2.09
30	140.69	225.92	85.23	30.50	54.63	78.87	24.24	12.90	166.46	296.94	130.48	33.90	53.38	45.06	-8.32	-7.28
60	140.69	145.80	5.12	6.99	54.63	50.90	-3.73	-6.10	166.46	191.64	25.19	30.56	53.38	29.08	-24.30	-52.66
120	140.69	93.46	-47.22	-175.38	54.63	32.63	-22.00	-91.00	166.46	122.85	-43.61	-151.63	53.38	18.64	-34.74	-172.48
180	140.69	72.10	-68.58	-430.79	54.63	25.17	-29.46	-201.16	166.46	94.77	-71.69	-428.27	53.38	14.38	-39.00	-308.22
360	140.69	46.31	-94.38	-1374.54	54.63	16.17	-38.47	-592.98	166.46	60.86	-105.59	-1487.34	53.38	9.24	-44.14	-754.40
720	140.69	30.02	-110.67	-3579.66	54.63	10.48	-44.15	-1486.17	166.46	39.45	-127.00	-4014.27	53.38	5.99	-47.39	-1717.62
1440	140.69	19.49	-121.19	-8445.44	54.63	6.81	-47.83	-3429.64	166.46	25.62	-140.83	-9654.19	53.38	3.89	-49.49	-3745.87
2880	140.69	12.39	-128.29	-18795.88	54.63	4.33	-50.31	-7530.31	166.46	16.29	-150.17	-21732.21	53.38	2.47	-50.91	-7938.98
4320	140.69	9.24	-131.45	-29435.72	54.63	3.23	-51.41	-11731.33	166.46	12.14	-154.31	-34186.21	53.38	1.84	-51.54	-12193.60

Storm Duration (mins)	Catchment E				Catchment F				Catchment G			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
5	101.75	375.62	273.87	-50.85	54.28	166.56	112.28	-15.63	90.54	243.88	153.34	-15.96
6	101.75	348.05	246.30	-40.43	54.28	154.34	100.06	-11.41	90.54	225.98	135.44	-10.30
10	101.75	275.34	173.59	-10.86	54.28	122.10	67.82	0.06	90.54	178.77	88.23	4.30
20	101.75	186.78	85.02	18.98	54.28	82.82	28.54	9.04	90.54	121.27	30.73	11.90
30	101.75	145.77	44.02	24.14	54.28	64.64	10.36	6.92	90.54	94.64	4.10	3.11
60	101.75	94.08	-7.67	-12.75	54.28	41.72	-12.56	-23.19	90.54	61.08	-29.46	-58.53
120	101.75	60.31	-41.45	-173.03	54.28	26.74	-27.54	-122.94	90.54	39.15	-51.39	-240.65
180	101.75	46.52	-55.23	-379.91	54.28	20.63	-33.65	-244.09	90.54	30.20	-60.34	-454.78
360	101.75	29.88	-71.87	-1113.62	54.28	13.25	-41.03	-659.71	90.54	19.40	-71.14	-1175.26
720	101.75	19.37	-82.38	-2782.98	54.28	8.59	-45.69	-1584.66	90.54	12.57	-77.97	-2757.10
1440	101.75	12.58	-89.17	-6411.23	54.28	5.58	-48.70	-3569.09	90.54	8.17	-82.37	-6123.08
2880	101.75	7.99	-93.76	-14061.75	54.28	3.55	-50.73	-7720.02	90.54	5.19	-85.35	-13128.02
4320	101.75	5.96	-95.79	-21897.47	54.28	2.64	-51.64	-11955.20	90.54	3.87	-86.67	-20258.15

Permeability 0.17 m/hr

SWALE SIZING - 5 YR CRITICAL STORM

Catchment	Storm Event	Depth	Slope 1:x	Base Width	Base Length	Volume	Effective Volume (including infiltration)	Surface Area (m2)	Volume check
A	5	0.2	3	0	123	15	31	149.04	ok
B	5	0.2	3	0	50	6	13	61.44	ok
C	5	0.2	3	0	80	10	34	97.44	ok
D	5	0.2	3	0	20	3	4	25.44	ok
E	5	0.2	3	0	100	12	25	121.44	ok
F	5	0.2	3	0	43	6	9	53.04	ok
G	5	0.2	3	0	58	7	12	71.04	ok

100 YEAR ARI DRAINAGE PROPERTIES

CATCHMENT	AREAS (m2)				EFFECTIVE AREAS (m2)		TIME OF CONCENTRATION PRE DEVELOPMENT					TIME OF CONCENTRATION POST-DEVELOPMENT					CRITICAL STORM INTENSITY (mm/h)	
	Roads	Lots	OS	Total	Pre-Dev	Post-Dev	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope (m/km)	TC (mIn)	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope	TC (mIn)	Pre-Dev	Post-Dev
A	22620	0	0	22620	13572	19227	739	44	35	12.18	40.0	739	44	35	12.18	38.6	67.00	68.30
B	7897	0	0	7897	4738	6712	520	40.5	34.5	11.54	31.6	520	40.5	34.5	11.54	30.5	74.99	76.02
C	29731	0	0	29731	17839	25271	836	40	33	8.37	47.4	836	40	33	8.37	45.8	59.90	61.44
D	4512	0	0	4512	2707	3835	223	38.5	35	15.70	13.5	223	38.5	35	15.70	13.0	135.92	138.46
E	14595	0	0	14595	8757	12406	487	34.5	31.2	6.78	30.9	487	34.5	31.2	6.78	29.9	75.60	76.78
F	6472	0	0	6472	3883	5501	318	41.1	39.5	5.03	23.3	318	41.1	39.5	5.03	22.5	92.34	94.21
G	9476	0	0	9476	5686	8055	347	47	41	18.73	18.8	347	47	41	18.73	18.1	106.69	110.23

Runoff Coefficients	**Pre-Dev**	**Post-Dev**
Roads	0.6	0.85
Lots	0.6	0.5
OS	0.6	0.5

Rainfall IFD

Event	**Duration (mins)**	**Intensity (mm/hr)**
5 min	5	217
6 min	6	201
10 min	10	155
20 min	20	100
30 min	30	76.5
1 hr	60	47.9
2 hr	120	30.2
3 hr	180	23.3
6 hr	360	15
12 hr	720	9.75
24 hr	1440	6.33
48 hr	2880	4.03
72 hr	4320	3.03

100 YEAR ARI FLOWS - CRITICAL STORM

Storm Duration (mins)	Catchment A				Catchment B				Catchment C				Catchment D			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
5	252.59	1158.96	906.37	-185.56	98.70	404.61	305.91	-44.79	296.80	1523.30	1226.50	-288.64	102.21	231.18	128.96	-5.81
6	252.59	1073.51	820.92	-151.79	98.70	374.78	276.08	-33.67	296.80	1410.98	1114.18	-242.83	102.21	214.13	111.92	-1.40
10	252.59	827.83	575.24	-61.33	98.70	289.01	190.31	-4.76	296.80	1088.07	791.27	-118.27	102.21	165.13	62.91	7.35
20	252.59	534.08	281.50	29.49	98.70	186.46	87.76	20.29	296.80	701.98	405.18	15.53	102.21	106.53	4.32	1.95
30	252.59	408.57	155.99	57.45	98.70	142.64	43.94	23.45	296.80	537.02	240.22	67.61	102.21	81.50	-20.72	-17.01
60	252.59	255.83	3.24	4.25	98.70	89.31	-9.39	-14.81	296.80	336.25	39.45	46.34	102.21	51.03	-51.18	-104.25
120	252.59	161.29	-91.29	-326.22	98.70	56.31	-42.39	-169.24	296.80	212.00	-84.80	-284.38	102.21	32.17	-70.04	-330.62
180	252.59	124.44	-128.15	-781.60	98.70	43.44	-55.26	-367.03	296.80	163.56	-133.24	-774.69	102.21	24.82	-77.39	-587.10
360	252.59	80.11	-172.47	-2466.10	98.70	27.97	-70.73	-1071.02	296.80	105.30	-191.50	-2653.38	102.21	15.98	-86.23	-1432.15
720	252.59	52.07	-200.51	-6409.76	98.70	18.18	-80.52	-2678.50	296.80	68.44	-228.36	-7144.27	102.21	10.39	-91.83	-3261.65
1440	252.59	33.81	-218.78	-15117.11	98.70	11.80	-86.90	-6178.16	296.80	44.44	-252.37	-17173.01	102.21	6.74	-95.47	-7119.20
2880	252.59	21.52	-231.06	-33648.06	98.70	7.51	-91.19	-13565.19	296.80	28.29	-268.51	-38658.72	102.21	4.29	-97.92	-15101.10
4320	252.59	16.18	-236.40	-52730.74	98.70	5.65	-93.05	-21144.04	296.80	21.27	-275.53	-60854.03	102.21	3.23	-98.99	-23210.70

Storm Duration (mins)	Catchment E				Catchment F				Catchment G			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Storage (m3)
5	183.91	747.79	563.89	-79.47	99.60	331.60	232.00	-24.32	168.51	485.51	317.01	-24.65
6	183.91	692.65	508.75	-59.03	99.60	307.15	207.55	-16.00	168.51	449.72	281.21	-13.45
10	183.91	534.14	350.23	-6.06	99.60	236.86	137.25	4.56	168.51	346.80	178.29	12.69
20	183.91	344.60	160.70	39.08	99.60	152.81	53.21	17.11	168.51	223.74	55.23	21.00
30	183.91	263.62	79.72	43.79	99.60	116.90	17.30	11.27	168.51	171.16	2.65	1.93
60	183.91	165.07	-18.84	-30.19	99.60	73.20	-26.41	-46.64	168.51	107.17	-61.33	-115.84
120	183.91	104.07	-79.84	-321.88	99.60	46.15	-53.46	-229.38	168.51	67.57	-100.94	-452.77
180	183.91	80.29	-103.61	-693.54	99.60	35.60	-64.00	-449.89	168.51	52.13	-116.37	-847.43
360	183.91	51.69	-132.22	-2012.49	99.60	22.92	-76.68	-1207.24	168.51	33.56	-134.94	-2177.37
720	183.91	33.60	-150.31	-5018.24	99.60	14.90	-84.71	-2896.05	168.51	21.81	-146.69	-5103.77
1440	183.91	21.81	-162.09	-11554.68	99.60	9.67	-89.93	-6521.98	168.51	14.16	-154.34	-11336.53
2880	183.91	13.89	-170.02	-25342.56	99.60	6.16	-93.45	-14110.47	168.51	9.02	-159.49	-24315.61
4320	183.91	10.44	-173.46	-39484.32	99.60	4.63	-94.97	-21863.72	168.51	6.78	-161.73	-37544.20

Permeability 0.17 m/hr

SWALE SIZING - 100 YR CRITICAL STORM

Catchment	Storm Event	Storm Duration (minutes)	Depth	Slope 1:x	Base Width	Base Length	Volume	Effective Volume (including infiltration)	Surface Area (m2)	Volume check
A	5	30	0.2	3	0	233	28	58	281.04	ok
B	5	30	0.2	3	0	94	12	24	114.24	ok
C	5	30	0.2	3	0	275	33	68	331.44	ok
D	5	10	0.2	3	0	35	5	9	43.44	ok
E	5	30	0.2	3	0	177	22	44	213.84	ok
F	5	20	0.2	3	0	84	10	17	102.24	ok
G	5	20	0.2	3	0	104	13	21	126.24	ok

100 YEAR ARI FLOWS - 1 HR STORM

Storm Duration (mins)	Catchment A				Catchment B				Catchment C				Catchment D			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Total Excess Flow (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Total Excess Flow (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Total Excess Flow (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Total Excess Flow (m3)
60	180.58	255.83	75.24	270.87	63.04	89.31	26.27	94.57	237.35	336.25	98.90	356.03	36.02	51.03	15.01	54.03

Storm Duration (mins)	Catchment E				Catchment F				Catchment G			
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Total Excess Flow (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Total Excess Flow (m3)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Total Excess Flow (m3)
60	116.52	165.07	48.55	174.78	51.67	73.20	21.53	77.50	75.65	107.17	31.52	113.48

Permeability 0.17 m/hr

SWALE SIZING - 100 YR 1 HR STORM

Catchment	Storm Event	Storm Duration (minutes)	Depth	Slope 1:x	Base Width	Base Length	Volume	Effective Volume (including infiltration)	Surface Area (m2)	Volume check	1-yr 1-hr Swale Effective Volume
A	100	60	0.2	3	0	657	79	271	789.84	ok	337
B	100	60	0.2	3	0	228	28	95	275.04	ok	118
C	100	60	0.2	3	0	864	104	356	1038.24	ok	443
D	100	60	0.2	3	0	129	16	54	156.24	ok	67
E	100	60	0.2	3	0	423	51	175	509.04	ok	217
F	100	60	0.2	3	0	186	23	78	224.64	ok	97
G	100	60	0.2	3	0	274	33	114	330.24	ok	141

D.2
Site Runoff

1 YEAR ARI DRAINAGE PROPERTIES

CATCHMENT	AREAS (m2)														EFFECTIVE AREA (m2)		TIME OF CONCENTRATION PRE-DEVELOPMENT					TIME OF CONCENTRATION POST-DEVELOPMENT					CRITICAL STORM INTENSITY (mm/h)	
	Houses		Sheds		Driveways etc		Garden, Lawn, Paddock, POS		Palusplain		Road Reserve		Total		Pre Dev	Post Dev	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope (m/km)	TC (mIn)	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope	TC (mIn)	Pre-Dev	Post-Dev
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post														
Internal (above Arnold Rd)	0	43543	0	6668	0	42758	0	333324	531565	0	0	74236	531565	500529	318939	250448	955	47	33	14.66	36.3	1090	47	33	12.84	43.6	24.69	22.48
Internal (below Arnold Rd)	0	9202	0	1409	0	9036	0	63253	97495	0	0	14595	97495	97495	58497	48614	443	35	31	8.58	22.2	489	35	31	7.77	25.5	31.98	29.73

Runoff Coefficients	**Pre-Dev**	**Post-Dev**	
Palusplain	0.6	0.6	
Road Reserves	0.6	0	1 yr 1 hr ARI (17.5mm) retained in roadside swales
Houses	0.6	0.22	Reduced by 78% from 1 to account for capture of 20 yr ARI 5 min runoff (12.5mm) in soakwells
Sheds	0.6	1	
Driveways, paved areas	0.6	0.8	
Gardens, lawns, paddocks, POS	0.6	0.6	

Rainfall IFD

Event	**Duration (mins)**	**Intensity (mm/hr)**
5 min	5	64.3
6 min	6	59.9
10 min	10	47.9
20 min	20	33.5
30 min	30	26.6
1 hr	60	17.5
2 hr	120	11.3
3 hr	180	8.7
6 hr	360	5.59
12 hr	720	3.62
24 hr	1440	2.35
48 hr	2880	1.49
72 hr	4320	1.11

1 YEAR ARI FLOWS

Storm Duration (mins)	Internal (above Arnold Rd)			Internal (below Arnold Rd)		
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)
5	2187.46	4473.28	2285.82	519.63	868.30	348.67
6	2187.46	4167.18	1979.72	519.63	808.88	289.25
10	2187.46	3332.35	1144.89	519.63	646.84	127.21
20	2187.46	2330.56	143.10	519.63	452.38	-67.25
30	2187.46	1850.53	-336.93	519.63	359.20	-160.43
60	2187.46	1217.46	-970.00	519.63	236.32	-283.31
120	2187.46	786.13	-1401.33	519.63	152.59	-367.04
180	2187.46	605.25	-1582.21	519.63	117.48	-402.15
360	2187.46	388.89	-1798.57	519.63	75.49	-444.14
720	2187.46	251.84	-1935.62	519.63	48.88	-470.75
1440	2187.46	163.49	-2023.97	519.63	31.73	-487.90
2880	2187.46	103.66	-2083.80	519.63	20.12	-499.51
4320	2187.46	77.22	-2110.24	519.63	14.99	-504.64
Critical Storm	**2187.46**	**1564.06**	**-623.40**	**401.20**	**303.60**	**-97.61**
Duration (min)	36.29	43.58		36.55	43.79	Same as above Arnold Rd
Intensity (mm/h)	24.69	22.48		24.61	22.42	Same as above Arnold Rd

5 YEAR ARI DRAINAGE PROPERTIES

CATCHMENT	AREAS (m2)														EFFECTIVE AREA (m2)		TIME OF CONCENTRATION PRE-DEVELOPMENT					TIME OF CONCENTRATION POST-DEVELOPMENT					CRITICAL STORM INTENSITY (mm/h)	
	Houses		Sheds		Driveways etc		Garden, Lawn, Paddock, POS		Palusplain		Road Reserve		Total		Pre Dev	Post Dev	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope (m/km)	TC (mIn)	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope	TC (mIn)	Pre-Dev	Post-Dev
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post														
Internal (above Arnold Rd)	0	43543	0	6668	0	42758	0	333324	531565	0	0	74236	531565	500529	318939	283119	955	47	33	14.66	36.3	1090	47	33	12.84	43.0	39.15	35.78
Internal (below Arnold Rd)	0	9202	0	1409	0	9036	0	63253	97495	0	0	14595	97495	97495	58497	55223	443	35	31	8.58	22.2	489	35	31	7.77	25.1	51.58	48.08

Runoff Coefficients	**Pre-Dev**	**Post-Dev**	
Palusplain	0.6	0.6	
Road Reserves	0.6	0.27	Reduced by 68% from 0.85 to account for capture of 1-yr ARI 1-hr runoff (17.5mm) in swales
Houses	0.6	0.51	Reduced by 49% from 1 to account for capture of 20 yr ARI 5 min runoff (12.5mm) in soakwells
Sheds	0.6	1	
Driveways, paved areas	0.6	0.8	
Gardens, lawns, paddocks, POS	0.6	0.6	

Rainfall IFD

Event	**Duration (mins)**	**Intensity (mm/hr)**
5 min	5	109
6 min	6	101
10 min	10	79.9
20 min	20	54.2
30 min	30	42.3
1 hr	60	27.3
2 hr	120	17.5
3 hr	180	13.5
6 hr	360	8.67
12 hr	720	5.62
24 hr	1440	3.65
48 hr	2880	2.32
72 hr	4320	1.73

5 YEAR ARI FLOWS

Storm Duration (mins)	Internal (above Arnold Rd)			Internal (below Arnold Rd)		
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)
5	3468.72	8572.23	5103.50	838.08	1672.04	833.96
6	3468.72	7943.07	4474.35	838.08	1549.32	711.24
10	3468.72	6283.68	2814.95	838.08	1225.65	387.57
20	3468.72	4262.52	793.80	838.08	831.42	-6.66
30	3468.72	3326.65	-142.07	838.08	648.87	-189.20
60	3468.72	2146.99	-1321.74	838.08	418.78	-419.30
120	3468.72	1376.28	-2092.45	838.08	268.45	-569.63
180	3468.72	1061.70	-2407.03	838.08	207.09	-630.99
360	3468.72	681.85	-2786.88	838.08	133.00	-705.08
720	3468.72	441.98	-3026.74	838.08	86.21	-751.87
1440	3468.72	287.05	-3181.67	838.08	55.99	-782.09
2880	3468.72	182.45	-3286.27	838.08	35.59	-802.49
4320	3468.72	136.05	-3332.67	838.08	26.54	-811.54
Critical Storm	**3468.72**	**2813.72**	**-655.01**	**636.20**	**548.82**	**-87.38**
Duration (min)	36.29	43.04		36.29	43.04	Same as above Arnold Rd
Intensity (mm/h)	39.15	35.78		39.15	35.78	Same as above Arnold Rd

100 YEAR ARI DRAINAGE PROPERTIES

CATCHMENT	AREAS (m2)														EFFECTIVE AREA (m2)		TIME OF CONCENTRATION PRE-DEVELOPMENT					TIME OF CONCENTRATION POST-DEVELOPMENT					CRITICAL STORM INTENSITY (mm/h)	
	Houses		Sheds		Driveways etc		Garden, Lawn, Paddock, POS		Palusplain		Road Reserve		Total		Pre Dev	Post Dev	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope (m/km)	TC (mIn)	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope	TC (mIn)	Pre-Dev	Post-Dev
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post														
Internal (above Arnold Rd)	0	43543	0	6668	0	42758	0	333324	531565	0	0	74236	531565	500529	318939	311258	955	47	33	14.66	36.3	1090	47	33	12.84	42.6	70.50	64.45
Internal (below Arnold Rd)	0	9202	0	1409	0	9036	0	63253	97495	0	0	14595	97495	97495	58497	60896	443	35	31	8.58	22.2	489	35	31	7.77	24.9	94.82	88.49

Runoff Coefficients	**Pre-Dev**	**Post-Dev**	
Palusplain	0.6	0.6	
Road Reserves	0.6	0.52	Reduced by 39% from 0.85 to account for capture of 1 yr ARI 1 hr runoff (17.5mm) in swales
Houses	0.6	0.73	Reduced by 28% from 1 to account for capture of 20 yr ARI 5 min runoff (12.5mm) in soakwells
Sheds	0.6	1	
Driveways, paved areas	0.6	0.8	
Gardens, lawns, paddocks, POS	0.6	0.6	

Rainfall IFD

Event	**Duration (mins)**	**Intensity (mm/hr)**
5 min	5	217
6 min	6	201
10 min	10	155
20 min	20	100
30 min	30	76.5
1 hr	60	47.9
2 hr	120	30.2
3 hr	180	23.3
6 hr	360	15
12 hr	720	9.75
24 hr	1440	6.33
48 hr	2880	4.03
72 hr	4320	3.03

100 YEAR ARI FLOWS

Storm Duration (mins)	Internal (above Arnold Rd)			Internal (below Arnold Rd)		
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)
5	6245.86	18761.94	12516.08	1540.73	3670.70	2129.97
6	6245.86	17378.57	11132.71	1540.73	3400.05	1859.32
10	6245.86	13401.38	7155.52	1540.73	2621.93	1081.20
20	6245.86	8646.05	2400.20	1540.73	1691.57	150.83
30	6245.86	6614.23	368.37	1540.73	1294.05	-246.68
60	6245.86	4141.46	-2104.40	1540.73	810.26	-730.47
120	6245.86	2611.11	-3634.75	1540.73	510.85	-1029.88
180	6245.86	2014.53	-4231.33	1540.73	394.14	-1146.60
360	6245.86	1296.91	-4948.95	1540.73	253.74	-1287.00
720	6245.86	842.99	-5402.87	1540.73	164.93	-1375.81
1440	6245.86	547.30	-5698.56	1540.73	107.08	-1433.66
2880	6245.86	348.44	-5897.42	1540.73	68.17	-1472.56
4320	6245.86	261.98	-5983.88	1540.73	51.25	-1489.48
Critical Storm	**6245.86**	**5572.49**	**-673.37**	**1145.56**	**1090.24**	**-55.32**
Duration (min)	36.29	42.64		36.29	42.64	Same as above Arnold Rd
Intensity (mm/h)	70.50	64.45		70.50	64.45	Same as above Arnold Rd

D.3
HCMD 100-yr ARI Flows

100 YEAR ARI DRAINAGE PROPERTIES

CATCHMENT	AREAS (m2)																EFFECTIVE AREA (m2)		TIME OF CONCENTRATION PRE-DEVELOPMENT					TIME OF CONCENTRATION POST-DEVELOPMENT					CRITICAL STORM INTENSITY (mm/h)	
	Houses		Sheds		Driveways etc		Garden, Lawn, Paddock, POS		Palusplain		Cleared Hills		Forested Hills		Road Reserve		Total		Pre Dev	Post Dev	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope (m/km)	TC (min)	Longest Path (m)	RL Top (mAHD)	RL Bottom (mAHD)	Slope	TC (min)	Pre-Dev	Post-Dev
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post													
Upstream	0	0	0	0	0	0	0	0	381464	454433	103000	103000	560000	560000	0	0	1044464	1117433	371778	415560	2444	205	41	67.10	67.5	2444	205	41	67.10	66.7	45.69	45.91
Arnold Rd (inc N&S tribs)	0	43543	0	6668	0	42758	0	333324	1289711	632649	195933	195933	579078	579078	0	74236	2064722	1908189	948422	865443	3213	205	33	53.53	84.5	3213	205	33	53.53	85.3	40.67	40.44
Internal (above Arnold Rd)	0	43543	0	6668	0	42758	0	333324	531565	0	0	0	0	0	0	74236	531565	500529	318939	311258	955	47	33	14.66	36.3	1090	47	33	12.84	42.6	70.50	64.45
Internal (below Arnold Rd)	0	9202	0	1409	0	9036	0	63253	97495	0	0	0	0	0	0	14595	97495	97495	58497	60896	443	35	31	8.58	22.2	489	35	31	7.77	24.9	94.82	88.49

Runoff Coefficients	**Pre-Dev**	**Post-Dev**	
Palusplain	0.6	0.6	
Cleared Hills	0.3	0.3	
Forested Hills	0.2	0.2	
Road Reserves	0.6	0.52	Reduced by 39% from 0.85 to account for capture of 1 yr ARI 1 hr runoff (17.5mm) in swales
Houses	0.6	0.73	Reduced by 28% from 1 to account for capture of 20 yr ARI 5 min runoff (12.5mm) in soakwells
Sheds	0.6	1	
Driveways, paved areas	0.6	0.8	
Gardens, lawns, paddocks, POS	0.6	0.6	

Rainfall IFD

Event	**Duration (mins)**	**Intensity (mm/hr)**
5 min	5	217
6 min	6	201
10 min	10	155
20 min	20	100
30 min	30	76.5
1 hr	60	47.9
2 hr	120	30.2
3 hr	180	23.3
6 hr	360	15
12 hr	720	9.75
24 hr	1440	6.33
48 hr	2880	4.03
72 hr	4320	3.03

100 YEAR ARI FLOWS

Storm Duration (mins)	Upstream			Internal (above Arnold Rd)			Arnold Rd (inc N & S tribs)			Internal (below Arnold Rd)		
	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)	Pre-Dev Flow (l/s)	Post-Dev Flow (l/s)	Excess Flow (l/s)
5	4718.95	25049.02	20330.07	6245.86	18761.94	12516.08	10714.31	52166.97	41452.66	1540.73	3670.70	2129.97
6	4718.95	23202.09	18483.14	6245.86	17378.57	11132.71	10714.31	48320.56	37606.24	1540.73	3400.05	1859.32
10	4718.95	17892.16	13173.21	6245.86	13401.38	7155.52	10714.31	37262.12	26547.81	1540.73	2621.93	1081.20
20	4718.95	11543.33	6824.38	6245.86	8646.05	2400.20	10714.31	24040.08	13325.77	1540.73	1691.57	150.83
30	4718.95	8830.65	4111.70	6245.86	6614.23	368.37	10714.31	18390.66	7676.35	1540.73	1294.05	-246.68
60	4718.95	5529.25	810.31	6245.86	4141.46	-2104.40	10714.31	11515.20	800.89	1540.73	810.26	-730.47
120	4718.95	3486.08	-1232.86	6245.86	2611.11	-3634.75	10714.31	7260.10	-3454.21	1540.73	510.85	-1029.88
180	4718.95	2689.60	-2029.35	6245.86	2014.53	-4231.33	10714.31	5601.34	-5112.97	1540.73	394.14	-1146.60
360	4718.95	1731.50	-2987.45	6245.86	1296.91	-4948.95	10714.31	3606.01	-7108.30	1540.73	253.74	-1287.00
720	4718.95	1125.47	-3593.47	6245.86	842.99	-5402.87	10714.31	2343.91	-8370.40	1540.73	164.93	-1375.81
1440	4718.95	730.69	-3988.25	6245.86	547.30	-5698.56	10714.31	1521.74	-9192.58	1540.73	107.08	-1433.66
2880	4718.95	465.20	-4253.75	6245.86	348.44	-5897.42	10714.31	968.82	-9745.50	1540.73	68.17	-1472.56
4320	4718.95	349.76	-4369.18	6245.86	261.98	-5983.88	10714.31	728.41	-9985.90	1540.73	51.25	-1489.48
Critical Storm	**4718.95**	**5300.10**	**581.15**	**6245.86**	**5572.49**	**-673.37**	**10714.31**	**9721.77**	**-992.54**	**1145.56**	**1090.24**	**-55.32**
Duration (min)	67.48	66.73		36.29	42.64		84.51	85.29		36.29	42.64	Same as above Arnold Rd
Intensity (mm/h)	45.69	45.91		70.50	64.45		40.67	40.44		70.50	64.45	Same as above Arnold Rd

Appendix E

Correspondence from the Water Corporation

From: Kevin Purcher
To: "Phil Bayley"
Subject: RE: Arnold Rd, Serpentine - LWMS
Date: Thursday, 25 February 2016 10:54:36 AM

Hi Phil

The resubmitted LWMS dated 19 February 2016 is acceptable from a hydraulic perspective. The LWMS has also been updated to show an easement for a tributary of the HCMD within the development. As such, the LWMS is acceptable to the WC subject to receiving a letter of intent from the Shire for taking over the drain upstream of Arnold Rd.

Regards

Kevin Purcher
Senior Development Planner
Development Services
Water Corporation
T: (08) 9420 2385

-----Original Message-----
From: Phil Bayley [mailto:bayley@iinet.net.au]
Sent: Friday, 19 February 2016 4:51 PM
To: Kevin Purcher
Subject: Arnold Rd, Serpentine - LWMS

Hi Kevin,

After a phone call from Kanex today, I realised that I'd omitted to show in the amended LWMS how the two minor drainage lines in the south-east were going to be managed. The only real change required is a drainage easement across the top of one lot to protect the part of one drain that isn't in a road reserve. Figure 8 shows the proposed easement. I've also added a paragraph to Section 5.2.2 (p. 21) describing this. Everything else in the LWMS is the same as the one I sent you on 9 February. Please use this version for your review instead.

I am still waiting for advice from the Shire on their assuming ownership of the drain; will send it when it arrives.

Regards,

Phil Bayley
BAYLEY ENVIRONMENTAL SERVICES
30 Thomas Street
SOUTH FREMANTLE 6162
tel: 08 9335 9160
fax: 08 9335 9160
mob: 0427 808 633
www.bayleyenvironmental.com.au

Water Corporation Email - To report spam Click
https://www.mailcontrol.com/sr/MZbqvYs5QwJvpeaetUwhCQ==

This Electronic Mail Message and its attachments are confidential.If you are not the intended recipient, you may not disclose or use the information contained in it. If you have received this Electronic Mail Message in error, please advise the sender immediately by replying to

Appendix C
Arnold Road Flood Modelling Redesign

COTERRA
ENVIRONMENT

Level 3, 25 Prowse Street
West Perth WA 6005

T (08) 9381 5513

www.coterra.com.au
info@coterra.com.au

Our Ref: CUTARN01
Date: 23rd October 2019

Attention: Phil Cuttone
Director

Cuttone Property Group

Via email: phil@cuttoneproperty.com.au

Dear Phil

Arnold Road Flood Modelling Redesign

Method

As per the proposed scope of works, flood modelling was undertaken to make the following changes and to determine the impact on the flood inundation area within the watercourse;

- Assess changing to course of the proposed post development waterway (as per proposed Pritchard Francis realignment) – straightening the living stream alignment in the proximity of Arnold Road and realigning the culvert under Arnold Road.
- Deepen the watercourse in the same location from 400mm to 600mm.

The modelling was undertaken using XPSWMM (by Hyd2o) and involved the following changes;

- Modified channel lengths and cross sections.
- Modified catchment and land use changes.
- Other necessary modifications such as culverts/road crossings.

Please note: The method and remodelling scope did not include any changes to the proposed post development land use or changes to the road layout (ie. Subdivision design changes). It was noted that the new concept plan shows changes to the road layout and larger lots. This could have potential impact on the post development site runoff from the site. The remodelling considered that the site layout remained the same as the original design with the exception of the stream layout modification.

Results

The flood modelling revision indicates that the area of flood inundation in a 100 year event can be contained within the proposed corridor indicated on the revised concept plan (Appendix 1).

The changes to the living stream design have generally resulted in slight reductions in the top water levels (TWLs) within the Stage 2 and townsite areas. These are shown in Table 1. The changes have also resulted in slight variations to the width at the 100 year ARI top water level as detailed in Table 1.

Table 1: Comparative Results

	Original 2016 modelling	2019 Redesign	Difference
Stage 2 living stream (Links 3 – 8)			
100 year ARI TWL (mAHD)	34.37 - 40.14	34.27 - 40.09	0.1 – 0.05m lower
Width at TWL (m)	18 - 33	18.6 – 30.2	0.6 wider at link 4 - 2.8m narrower at link 3.
Online basin upstream of Arnold Road (Link 10)			
100 year ARI TWL (mAHD)	32.58	32.53	0.05m lower
Width at TWL (m)	36	37	1m wider (due to new redesign)
Townsite living stream (Links 12 – 16)			
100 year ARI TWL (mAHD)	30.68 – 32.45	30.65 – 32.39	0.03 – 0.06m lower
Width at TWL (m)	18 - 36	18.2 – 36.3	0.2 – 0.3m wider
Townsite online basin upstream of Wellard Road (Links 17 - 20)			
100 year ARI TWL (mAHD)	30.40 - 30.48	30.40 - 30.48	No difference
Width at TWL (m)	59 - 71	59.4 – 70.9	0.4m wider at link 20 – 0.1m narrower at link 19

A full description of the modelling is provided in Appendix 1 and shape files of the revised flood inundation area has also been provided to the project team.

If you have any queries, please do not hesitate to contact me.

Yours sincerely



REBECCA EPWORTH
Director

cc. Ryan Darby, Robertsday

Philip Paterson, Pritchard Francis

Appendix 1 – Modelling Report (Hyd2o, 2019)

Appendix 1 Modelling Report (Hyd2o, 2019)

Your Ref:
Our Ref: H19063Av2

22 October 2019

Coterra Environment
Level 3, 25 Prowse Street,
West Perth, WA 6005
ATTENTION: Rebecca Epworth

Dear Rebecca,

Arnold Rd Serpentine Revised Stormwater Modelling

As requested, please find below Hyd2o's brief report detailing the results of revised stormwater modelling and reporting for the proposed realignment and reconfiguration of the Hardy Creek Main Dain at Arnold Rd in Serpentine.

The modelling is required to support proposed changes the location and configuration of the post development swale compared to that previously modelled in the Coterra (2016) report, with its depth increased from 400 mm to 600 mm deep.

Changes to the model in accordance with the above are detailed in Figure 1.

Note that this report does not reproduce all background information and modelling parameters and assumptions as in the Coterra (2016) report, which remain the same as previous modelling, but rather provide a supplementary report detailing the updated modelling results only. This report should therefore be read in conjunction with the Coterra (2016) report which details all modelling assumptions.

A copy of the previous XP-SWMM model of the site was provided by Coterra to Hyd2o for use in this study. Hyd2o used XP-Storm to undertake the modelling, which is similarly a model developed by Innovyze and utilises the same hydrological and hydraulic calculation techniques.

Prior to making model changes, the original XP-SWMM models were run in XP-Storm to ensure the modelling results were consistent with previous outputs as detailed in Coterra (2016). This was achieved and no further changes other than specified in Figure 1 were made to the original model for this study.

Modelling results are detailed in Attachment 1 for 1, 5, and 100 year events in comparison to previous results detailed in Coterra (2016) for key links and nodes. Approximate areas of inundation within POS for 1, 5, and 100 year events are detailed in Figure 2.

These results should be considered an update of previous modelling and used as the basis of informing the design of the living stream within the site.

REFERENCES

Coterra Environment (2016). Lots 102 to 106 Rudall Street ('Townsite') and Lots 611, 615 & 487 Arnold Rd ('Stage 2'), Serpentine : Flood Modelling – FINAL Summary of Results, August 2016

Should you have any queries regarding the above report, please do not hesitate to contact Sasha Martens or Suzanne Smart of this office.

Yours sincerely,



Sasha Martens
Managing Director, Hyd2o

Attached
Figure 1: Model Changes & Amendments
Attachment 1: Revised Modelling Results

This document is published in accordance with and subject to an agreement between Hyd2o and the Client for whom it has been prepared, and is restricted to those issues that have been raised by the Client in its engagement of Hyd2o. It has been prepared using the skill and care ordinarily exercised by hydrologists in the preparation of such documents.

Hyd2o recognise site conditions change and contain varying degrees of non-uniformity that cannot be fully defined by field investigation. Measurements and values obtained from sampling and testing in this document are indicative within a limited timeframe, and unless otherwise specified, should not be accepted as conditions on site beyond that timeframe.

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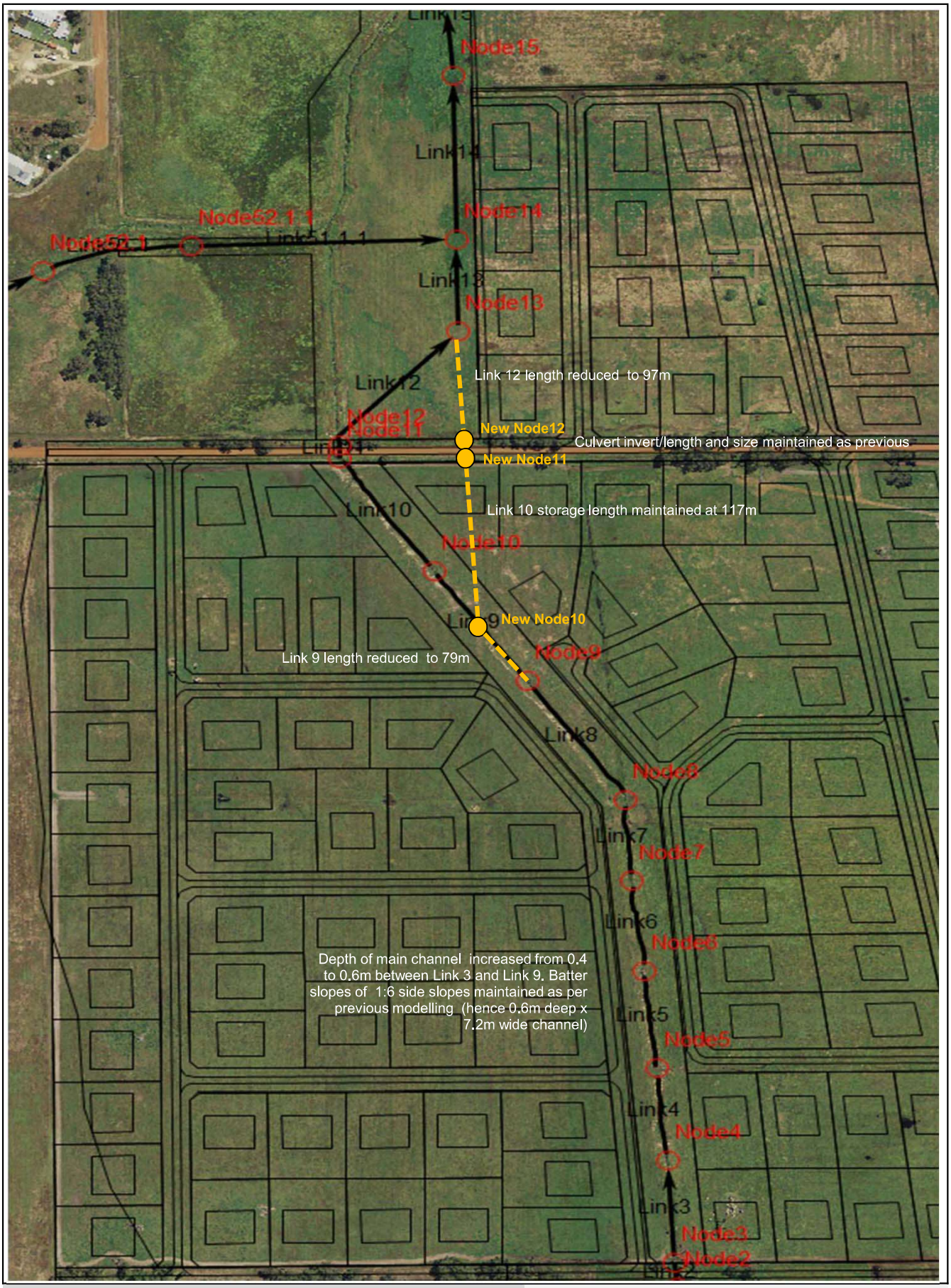
Figures

Date: 10/10/2019 Job No. H19063



Source: Coterra (2016)

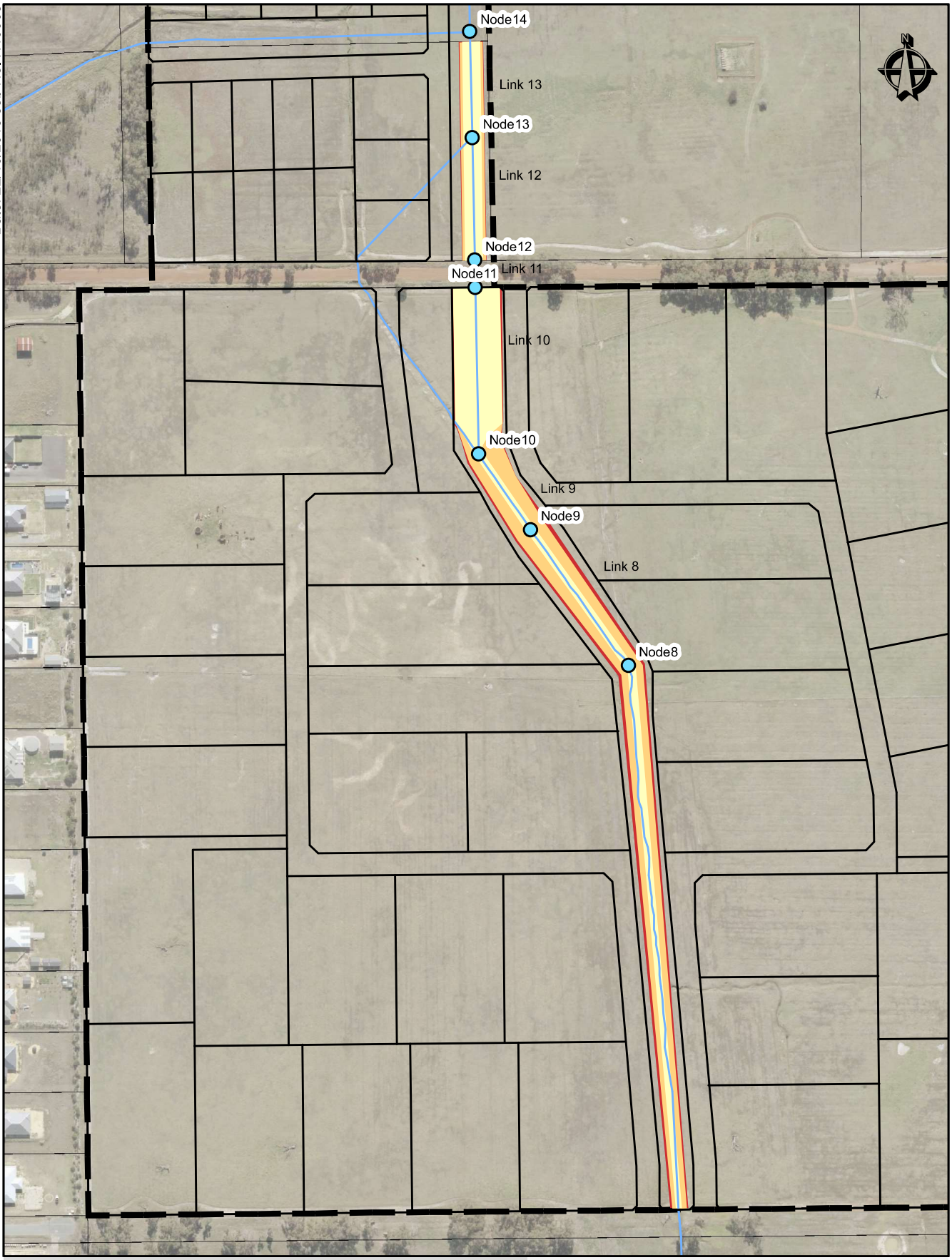
Previous model shown in black/red
Model amendments shown in white/gold

hyd$_2$o

Arnold Rd Serpentine Stormwater Modelling

Model Changes & Amendments

Figure 1



hyd2o

Arnold Rd Serpentine Stormwater Modelling

1,5, & 100 Year ARI Flood Inundation Area

Figure 2

Attachment 1
XP-Storm Updated Modelling Results

ARNOLD RD : POST DEVELOPMENT SCENARIO REMODELLING

(Hyd2o 10/10/2019)

Model Changes : Re-alignment between Node 13 - Node 9, Increase living stream depth of main channel from 0.4 to 0.6m (1:6 side slopes) for Link 3 to Link 9.

ORIGINAL COTERRA MODELLING

Proposed Development Area	Hardy Creek Link	POST-DEVELOPMENT (1D CHANNEL ONLY)									
		Length (m)	1 year ARI			5 year ARI			100 year ARI		
			Peak flow (m^3/s)	Volume (m^3)	Top Width (m)	Peak flow (m^3/s)	Volume (m^3)	Top Width (m)	Peak flow (m^3/s)	Volume (m^3)	Top Width (m)
Stage 2	Link3	87	1.32	26	5	2.66	73	11	5.99	302	33
	Link4	79	1.32	41	5	2.66	92	11	5.99	216	18
	Link5	83	1.73	81	10	3.37	173	15	7.29	390	22
	Link6	78	1.73	144	11	3.36	272	17	7.28	502	25
	Link7	70	1.72	148	12	3.35	257	17	7.27	451	25
	Link8	125	2.69	124	16	5.53	252	23	10.97	482	32
	Link9	115	2.67	18	19	5.51	66	28	10.98	266	37
	Link10	117	2.54	2252	34	5.37	2963	35	10.84	4158	36
Arnold Road	Link11	11	2.51	25	2	5.31	25	2	10.79	25	2
	Link11	n/a	0.00	0	0	0.00	0	0	0.00	0	0
Townsite	Link12	132	2.51	368	15	5.31	644	17	10.79	1018	19
	Link13	78	2.51	285	13	5.30	496	17	10.77	736	18
	Link14	140	3.95	673	16	9.49	1142	18	16.84	1600	19
	Link15	99	4.26	609	26	10.08	1175	33	17.99	1797	35
	Link16	95	4.25	557	21	10.07	1012	29	17.85	1822	36
	Link17	118	4.25	911	32	10.05	1795	47	17.49	4464	61
	Link18	99	4.55	472	28	10.68	1455	42	17.98	4711	65
	Link19	70	4.52	890	54	10.35	2795	63	17.48	6010	71
	Link20	74	4.48	1172	42	10.22	2953	51	17.28	6162	59

Note: Results are for maximum of all storm events simulated

REVISED MODELLING 10/10/2019

Post Dev Area	Hardy Creek Link	Length (m)	1 year ARI			5 year ARI			100 year ARI		
			PeakFlow (m3/s)	Volume (m3)	Top Width (m)	PeakFlow (m3/s)	Volume (m3)	Top Width (m)	PeakFlow (m3/s)	Volume (m3)	Top Width (m)
Stage 2	Link3	87	1.34	26	4.8	2.68	73	11.0	6.02	259	30.2
	Link4	79	1.33	36	4.9	2.67	92	11.2	6.01	231	13.4
	Link5	83	1.74	63	5.6	3.37	173	15.3	7.36	419	18.6
	Link6	78	1.74	111	6.1	3.37	272	17.1	7.35	474	21.1
	Link7	70	1.74	117	6.2	3.35	257	17.3	7.34	450	21.4
	Link8	125	2.75	79	6.6	5.53	252	23.3	11.02	496	28.0
	Link9	79	2.75	19	6.3	5.51	66	27.8	11.05	202	30.0
	Link10	117	2.55	2604	35.0	5.38	2965	35.1	10.91	4427	37.0
Arnold Rd	Link11	11	2.51	25	1.5	5.31	25	1.5	10.79	25	1.5
Townsite	Link12	97	2.52	252	13.5	5.32	644	17.2	10.86	709	18.2
	Link13	78	2.52	286	13.5	5.31	496	16.9	10.85	735	18.2
	Link14	140	3.92	671	16.3	9.50	1142	18.0	16.81	1600	18.8
	Link15	99	4.24	607	25.9	10.09	1176	32.9	17.97	1800	35.2
	Link16	95	4.23	555	21.3	10.08	1013	28.8	17.87	1830	36.3
	Link17	118	4.22	907	32.3	10.06	1801	46.7	17.48	4480	61.0
	Link18	99	4.53	469	27.8	10.70	1463	42.3	18.00	4726	65.0
	Link19	70	4.49	880	54.4	10.38	2807	62.7	17.49	6022	70.9
	Link20	74	4.44	1161	42.4	10.25	2963	50.9	17.30	6159	59.4

ARNOLD RD : POST DEVELOPMENT SCENARIO REMODELLING

(Hyd2o 10/10/2019)

Model Changes : Re-alignment between Node 13 - Node 9, Increase living stream depth of main channel from 0.4 to 0.6m (1:6 side slopes) for Link 3 to Link 9.

ORIGINAL COTERRA MODELLING

Parameter		Stage 2		Townsite	
		Living Stream	Online basin upstream of Arnold Road	Living Stream	Online basin upstream of Wellard Road
		Links 3 – 9	Link 10	Link 12 to 16	Links 17 to 20
Minimum Invert (mAHD)		33.60 – 39.57	31.13	29.42 – 31.37	28.32 – 29.15
1yr ARI event	TWL (mAHD)	34.17 – 39.97	32.18	30.24 – 32.15	29.21 – 29.98
	Max. Depth (m)	0.40 – 0.57	1.03	0.82	0.89
	Max. Storage (m^3)	582	2,252	2,493	3,444
5yr ARI event	TWL (mAHD)	34.26 – 40.10	32.31	30.44 – 32.28	29.72 – 30.16
	Max. Depth (m)	0.53 – 0.66	1.18	1.02	1.40
	Max. Storage (m^3)	1,184	2,963	4,468	8,998
100yr ARI event	TWL (mAHD)	34.37 – 40.14	32.58	30.65 – 32.45	30.40 – 30.48
	Max. Depth (m)	0.57 – 0.77	1.45	1.23	2.08
	Max. Storage (m^3)	2,609	4,158	6,975	21,346

REVISED MODELLING 10/10/2019

Parameter		Stage 2		Townsite	
		Living Stream	Online basin upstream of Arnold Rd	Living Stream	Online basin upstream ofWellard Rd
		Links 3-9	Link 10	Link 12-16	Links 17-20
Minimum Invert (mAHD)		33.40 - 39.37	31.13	29.42 - 31.37	28.32 - 29.15
1 year ARI event	TWL (mAHD)	33.94 - 39.77	32.13	30.24 - 32.12	29.23 - 29.98
	Max Depth (m)	0.40 - 0.55	1.00	0.66 - 0.83	0.71 - 0.88
	Max Storage (m3)	452	2604	2370	3416
5 year ARI event	TWL (mAHD)	34.13 - 39.90	32.27	30.45 - 32.24	29.73 - 30.16
	Max Depth (m)	0.53 - 0.66	1.18	0.82 - 1.03	1.04 - 1.21
	Max Storage (m3)	1185	2965	4472	9034
100 year ARI event	TWL (mAHD)	34.27 - 40.09	32.53	30.65 - 32.39	30.40 - 30.48
	Max Depth (m)	0.74 - 0.91	1.40	0.94 - 1.32	1.53 - 2.08
	Max Storage (m3)	2531	4427	6674	21387

Appendix D
Lots 102 to 106 Rudall Street, Serpentine: Townsite Flood Modelling Report – Summary of Results Rev 2

MEMORANDUM

COTERRA
ENVIRONMENT

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TO:	Harley Dykstra
ATTENTION:	Jason Carr
FROM:	Kristy Chandler
DATE:	15 February 2017
OUR REF:	BAYARN01
SUBJECT:	Lots 102 to 106 Rudall Street, Serpentine: Townsite Flood Modelling – Summary of Results (Rev 2)

Introduction

MALF Corporation (proponent) propose to develop Lots 102 to 106 Rudall Street ('the site'), Serpentine (see Figure 1). The site is currently rural and will be subdivided into residential lots.

The Hardy Creek Main Drain (HCMD) flows in a northerly direction through the site before joining the Serpentine River. A western branch of the creek (HCWB) joins the HCMD within Lot 105.

The development proposal includes the modification of the existing HCMD into a living stream to achieve integrated stormwater management post-development. Preliminary design of the living stream system has been undertaken during structure planning and reported in a Local Water Management Strategy (LWMS) prepared for the site.

The proponent wishes to revisit the conceptual design of the living stream reserve and determine if there are further opportunities to optimise the alignment of the living stream.

This memorandum provides a summary of the hydraulic and hydrological modelling that has been undertaken to assist in the review of the proposed living stream system.

It has been prepared in liaison with the Department of Water and Shire of Serpentine Jarrahdale.

Previous Studies

The LWMS that covers the site was prepared by GHD in February 2013. The site will be filled and subdivided into 2,000 m^2 lots. The existing drain will be converted into a living stream, with an online attenuation basin located immediately upstream of Karnup Road. The basin will provide flood attenuation for the site as well as urban development proposed further west. Modelling using InfoWorks CS and SWMM was undertaken to inform the LWMS. Some model inputs, assumptions and results are presented in the LWMS. No pre-development flood extent was included within the report.

Methodology and Results

Hydrological and hydraulic modelling has been undertaken in this study to assess flooding in the existing creeks, as well as investigate the potential realignment of the proposed living stream.

A pre-development model was generated for the site to assess the current extent of flooding. The pre-development model was updated to represent the post-development scenario summarised in the LWMS (GHD, 2013).

XPSWMM (2016.1) software was used to undertake the hydrological modelling, as summarised in the following sections. The modelling log, schematic and results are appended to this memorandum.

Pre-Development Model

Pre-Development Hydrological Model

A pre-development model was prepared for the site to estimate the peak discharges in the existing HCMD north of Arnold Road during 1 in 1 year ARI (1 EY), 5 year ARI (0.2 EY) and 100 year ARI (100 year AEP) design storm events. Broad cross-sections were included upstream of the site to convey flood hydrographs from upstream catchments (obtained from LiDAR data).

The design storms used in the modelling were derived from the Australian Rainfall and Runoff (AR&R) (Institution of Engineers Australia, 2000) and Bureau of Meteorology Intensity Frequency Duration (IFD) data (BoM, 2016). Design storms were assumed to be spatially uniform across the catchments, and durations ranged from 10 minutes to 72 hours.

Hydrological sub-catchments were obtained from the previous two LWMS studies and verified with aerial photography and topographic contour data. The following hydrological sub-catchments were included in the pre-development model:

- Hardy Creek Main Drain (HCMD):
  - Node 53: 85ha upstream catchment of HCMD – steep, 60% forested, remaining rural (cleared). Limited infrastructure.
  - Node 53.1.1: 19ha rural catchment south of the site.
  - Nodes 3 & 5: 27ha and 24ha catchments south-east of the site, which enter the HCMD via a rural drain. Part-forested, predominantly rural.
  - Node 8: 71ha rural catchment south of the site.
  - Node 15: 20ha catchment east of the site, which includes the portion of land located east of the site.
  - Node 18: 22ha catchment which covers the site. Pre-development model assumes rural state.
  - Node 23: small 6ha catchment north-west of the site which drains to the HCMD at Karnup Road.

- Hardy Creek Western Branch (HCWB):
  - Node 49: 453ha upstream catchment of HCWB – steep, forested, limited clearing or infrastructure.
  - Node 50: 97ha rural catchment south of the proposed development site.
  - Node 51: 85ha catchment south-west of the site. This sub-catchment is currently being developed, with runoff managed in a compensation basin. It

is assumed that the basin has been designed in line with Better Urban Water Management (WAPC, 2008) and is therefore sufficient to attenuate runoff to pre-development flow rates.

- Node 14: 35ha catchment west of the site. The proposed development in this catchment is outlined in the LWMS (GHD, 2013). The pre-development model assumes a pre-development (rural) state.

The Laurenson / Uniform Loss Method was selected to represent the runoff mechanism. Sub-catchments were subdivided into impermeable and permeable areas and losses applied to each land use (forest, rural, roads, lots). Losses were reduced in rural areas adjacent to the HCMD and HCWB to reflect the presence of shallow groundwater.

The model results were verified against the previous LWMS studies undertaken at the site and found to be highly agreeable for the pre-development 100 year ARI at Arnold Road basin and Arnold Road. The peak flow at the downstream extent of the model (Karnup Road) was found to be higher than the previous study which reflects the different hydrological approaches employed and updated modelling assumptions, such as the culvert size at Karnup Road.

Pre-Development Hydraulic Model

A fully hydrodynamic linked 1D-2D hydraulic model was set-up to investigate flood flows within the HCMD north of Arnold Road. The 1D network was extended to cover the HCMD and HCWB up to South West Highway to convey flood flows from upstream catchments. The use of a 1D network within the 2D domain allows a more accurate representation of in-channel flow and flow through structures. The 2D model extent was included in the lower HCMD to represent the area expected to be subject to wide scale inundation. A 4m grid cell size was selected, with global roughness of 0.05 to represent the existing rural surface.

The open channel cross-sections and inverts were defined using 1m LiDAR data supplied by the Department of Water on 07/06/2016. Structure data was obtained from a site survey provided by Harley Dykstra on 06/07/2016. Some discrepancies were noted between the new survey data and assumptions included within the previous LWMS models. In particular the two culverts under Wellard Road were previously assumed to be 1.2m in diameter - however the survey showed them to be 1.3m. Spill levels over roads were taken from survey data as levels in LiDAR data were not representative at crossings.

Manning's values were based on aerial photography, and in line with standard text (typically 0.03).

The downstream boundary was extended into the Serpentine River foreshore. A constant head boundary of 29.20 mAHD was used for the 100 year ARI event as obtained from the Serpentine River Flood Study (WAPC, 2016). A constant head boundary of 28.54 mAHD was used for the 5 year ARI event as assumed in the LWMS (GHD, 2013). This is a conservative approach as it assumes the peak flows on these two watercourses would coincide. A free-flowing outfall was assumed for the 1 year ARI event.

Pre-Development Model Results

The modelled peak flow for the three design runoff events and key locations is summarised in Table 1. Peak discharge from the downstream extent of the site (Wellard Road) was found to range from 4.92 m^3/s in a 1 year ARI event to 20.51 m^3/s in a 100 year ARI event. The

critical duration was determined at downstream extent. Flood hydrographs at Wellard Road (Link 22) are provided in Appendix B.

Modelled pre-development flood extents are depicted in Figure 2 and are consistent with widespread shallow sheet flow expected in this location.

Existing 100 year ARI flood levels are expected to range from 30.87 mAHD immediately upstream of Wellard Road, to 32.44 mAHD immediately downstream of Arnold Road. Flood depths up to 2.55m were modelled in the central channel immediately upstream of Wellard Road.

Table 1 Pre-Development Modelled Peak Flow at Key Locations

Peak Flow (m^3/s)	HCWB at Arnold Road basin	HCMD at Arnold Road culvert	HCMD at Wellard Road
	Link 51	Link 10	Link 22
1 year ARI event	2.30	2.57	4.92
5 year ARI event	5.85	5.53	10.93
100 year ARI event	11.77	11.03	20.51

Post Development Model

Post-Development Hydrological Model

The XPSWMM pre-development model was updated to represent the post-development scenario as described in the LWMS. The following sub-catchments were updated to represent the proposed development:

- Hardy Creek Main Drain (HCMD):
  - Node 8: updated to include the proposed development south of Arnold Road referred to as 'Stage 2' in the LWMS prepared by Bayley Environmental Services in March 2016. This includes 95 lots with soakwells, 4.2km roads and roadside swales sized to retain the 1yr ARI (1 EY) event. Also updated to reflect change in catchment boundary due to the southern boundary road diverting runoff west.
  - Node 15: updated to include the proposed Stage 2 development north of Arnold Road, and a portion of the proposed development at the site including 33 lots with soakwells, 1.7 km roads and water quality treatment areas and/or roadside swales sized to retain the 1yr ARI (1 EY) event.
  - Node 18: updated to include the proposed development at the site adjacent to the living stream including 20 lots with soakwells, 0.4 km road and water quality treatment areas sized to retain the 1yr ARI (1 EY) event.

- Hardy Creek Western Branch (HCWB):
  - Node 14: updated to include proposed Townsite development including 128 lots with soakwells, 3.8 km roads and water quality treatment areas sized to retain the 1yr ARI (1 EY) event.

Sub-catchments were subdivided into impermeable and permeable areas and losses applied to each land use (roads, roofs, open space). Additional losses were added to roads and roofs to reflect the presence of soakwells, roadside swales and water quality treatment areas.

The model results were verified against the previous LWMS studies undertaken at the site and found to be highly agreeable for the post-development 100 year ARI at all key locations.

Post-Development Hydraulic Model

The XPSWMM pre-development hydraulic model was updated to represent the post-development scenario as described in the LWMS.

It should be noted that no new design or optimisation analysis has been undertaken within this study. It is assumed that the work undertaken and approved in the previous LWMS documents is in line with Better Urban Water Management (WAPC, 2008) and achieves the required design criteria for the site. As such, the approved cross-sections included in the LWMS have been modelled with slight adjustments for the purpose of realigning the stream and tying in with the existing landscape.

The following key adjustments were made:

- Updated cross-sections to represent the proposed living stream and western swale as per typical cross-section information included in the LWMS.
- Realign living stream along eastern boundary of the POS. Note: due to shallow groundwater levels, drain inverts have been retained, and the adjusted cross-section has been tied in to existing adjacent ground levels in accordance with the typical cross-section outlined in the LWMS. Channel lengths updated accordingly.
- Upgrade Wellard Road culverts to 2 x 1500mm diameter culverts as per LWMS.
- Inclusion of online flood storage area upstream of Wellard Road culverts to represent Basin 2 within the LWMS. Note: an online basin is proposed instead of an offline basin as it will provide a more naturalised system which is suited to the existing topography in the area. In addition, the inverts of the basin have been varied from those proposed in the LWMS due to the more detailed topographic analysis undertaken in this study.

It is assumed that any minor footbridges included within the landscaping works will not constrict flood flows. No changes were made to the downstream boundary conditions.

Post-Development Model Results

The modelled peak flow for the three design runoff events and key locations is summarised in Table 2. Peak discharge from the downstream extent of the site (Karnup Road) was found to range from 4.47 m^3/s in a 1 year ARI event to 17.25 m^3/s in a 1 in 100 year ARI event. The 100 year ARI event results were found to be consistent with previous studies. As with the pre-development model the 1 year and 5 year ARI events were shown to be higher than previous studies which reflects the different hydrological approaches employed and updated modelling assumptions, such as culvert size at Karnup Road.

The modelled peak flows are all the same or lower that the pre-development state, which reflects the stormwater management strategies employed, as well as the change in timing of runoff hydrographs from the developed portion of the site. Flood Hydrographs for Wellard Road (Link 22) are provided in Appendix C.

Table 2 Post-Development Modelled Peak Flow at Key Locations

Peak Flow (m^3/s)	HCWB at Arnold Road basin	HCMD at Arnold Road culvert	HCMD at Wellard Road
	Link 51	Link 10	Link 22
1 year ARI event	2.24	2.52	4.47
5 year ARI event	5.31	5.37	10.21
100 year ARI event	9.48	10.77	17.25

Indicative post development flood extents for the site are depicted in Figure 3. It should be noted that this is based on typical cross-sections included within the LWMS for the site. It is envisaged that the flood extents will be adjusted in response to detailed earthworks planning and landscape design within the proposed POS. In particular the extent of the 1 year ARI event could be significantly reduced if the proposed low flow channel was increased to convey the full flow. Minor amendments to the cross-section and alignment will not affect model results provided that the cross-sectional area and storage volumes are preserved.

The modification of the drain into a living stream within the site is shown to control the extent of flooding within the site as well as significantly reduced the extent of flooding in the land to the east.

Modelled top water level (TWL), depth, volume and area are summarised in Table 3.

Table 3 Modelled 100 year ARI Flood Storage

Parameter		Living Stream	Online basin upstream of Wellard Road
		Link 12 to 16	Links 17 to 20
Minimum Invert (mAHD)		29.42 – 31.37	28.32 – 29.15
1yr ARI event	TWL (mAHD)	30.24 – 32.15	29.21 – 29.98
	Max. Depth (m)	0.82	0.89
	Max. Volume (m^3)	2,493	3,444
	Indicative Area at TWL (m^2)*	9,850	13,550
5yr ARI event	TWL (mAHD)	30.44 – 32.28	29.72 – 30.16
	Max. Depth (m)	1.02	1.40
	Max. Volume (m^3)	4,468	8,998
	Indicative Area at TWL (m^2)*	12,100	17,850
100yr ARI event	TWL (mAHD)	30.65 – 32.45	30.40 – 30.48
	Max. Depth (m)	1.23	2.08
	Max. Volume (m^3)	6,975	21,346
	Indicative Area at TWL (m^2)*	13,450	23,000

* Subject to change pending detailed earthworks planning and landscape design

Post-development 100 year ARI flood levels are expected to range from 30.40 mAHD upstream of Wellard Road, to 32.44 mAHD at the upstream extent (Arnold Road).

The majority of storage is located in the lower reaches of the living stream (immediately upstream of Wellard Road). Full water level results are summarised in the appended model log.

Existing flooding is expected to range up to 2.08m deep in the flood storage area immediately upstream of Wellard Road. Whilst this is deeper than the design criteria outlined in the LWMS (GHD, 2013), it is an improvement as it is shallower than the existing situation.

The swale entering the living stream from the east has not been specifically analysed in this study, however the model results indicate that the design may require further investigation to ensure that it is of sufficient size to convey the 100 year ARI flood flow. It may be necessary to steepen the proposed batter slopes in the lower reaches to achieve the required base inverts within the designated 15m wide corridor. Alternatively the width of the drainage corridor could be reviewed.

Public Safety

The management of public safety in flooded areas is a key interest of the proponent and the Shire of Serpentine Jarrahdale. The lower reaches of the POS area (Nodes 16 – 21) are expected to be subject to 100 year ARI mid-channel flood depths in excess of 1.2m (see Figure 4). Whilst the maximum flood depths are expected to significantly decrease from the existing situation, it is still necessary to demonstrate that the proposals are acceptable from a public safety perspective.

The Department of Water (Brett Dunn, *pers.comm.*) and Shire of Serpentine Jarrahdale (Ruban Ganeshamoorthy, *pers. comm*) have provided advice for the detailed design of the open space/living stream with respect to public safety. The advice and proponent commitments are summarised in Table 4.

Table 4 Public Safety Recommendations

Department of Water / Shire of Serpentine Jarrahdale Advice	Application to the Site
Apply Velocity x Depth criteria as per Design Standard 66 (Water Corporation) to crossings, boardwalks, bridges and side slopes limited to the edge of the living stream [Department of Water].	The Velocity x Depth equation has been used to assess flood hazard in the living stream. The assessment criteria included in the new ARR 2016 guidelines supersedes that contained within the Water Corporation Design Standard 66. As such, it has been agreed with the Shire of Serpentine Jarrahdale that the criteria included within the ARR 2016 guidelines will be followed. No crossings, boardwalks or bridges have been proposed to date. However the flood hazard criteria will be applied to any of these structures should they be proposed during detailed landscape design. Preliminary analysis indicates that the Velocity x Depth criteria can be achieved along the edge of the living stream for all design events. The analysis will need to be revisited once the detailed design of the living stream is available to
Use Velocity x Depth equation to asses flood hazard at the edge of the living stream during 1, 5 and 100 year ARI events, relative to the criteria outlined in the ARR 2016 guidelines [Shire of Serpentine Jarrahdale]	

Department of Water / Shire of Serpentine Jarrahdale Advice	Application to the Site
	confirm that the flood hazard at the edge of the living stream is still acceptable under the final design. Public access will be restricted in areas which are deemed hazardous (as outlined under the 'Other Commitments' section below).
Locate recreational areas above the minor storm (20% or 10% AEP as applicable) flood level. Any provision for public access below this level should demonstrate that public safety has been adequately addressed.	Current proposed structure plan shows all recreational areas outside of the 100yr ARI (1% AEP) flood event which is in excess of the 20% AEP (~1 in 5yr ARI) event (see Figure 4). Additional information will be presented during detailed design stage should recreational areas be proposed within the 20% AEP (~1 in 5yr ARI) flooded area.
Use vegetation and landscaping (in preference to structures and fences) where feasible to restrict access to hazardous areas.	This will be implemented in the landscape plans during detailed design stage.
Provide recreational access to the water's edge where safe and beneficial to recreational activities.	This will be investigated during the detailed design stage.

The modelling undertaken to date shows that the safety criteria outlined by the Department of Water and Shire of Serpentine Jarrahdale can be achieved. Indicative cross-sections showing flood hazard in accordance with ARR 2016 criteria have been provided for Links 12, 15 and 18 (see Appendix D).

Maximum flood hazard is less than 0.6 for all cross-sections during the 1 year ARI (1 EY) event. Only the low flow channel (not the edge) is expected to contain floodwater which is hazardous to some (0.8 – 1.2) during the 1 in 5 year ARI (0.2 EY) event. As expected, hazardous water would be experienced during a 100 year ARI (1% AEP) event within the centre of the living stream. However the flood hazard is low at the edge of the water as required.

The cross-section analysis is based on conceptual living stream design. It will need to be revisited during the detailed design stage to confirm that the final design is still acceptable from a public safety perspective.

Future Work

The modelling has shown that the drain can be realigned to the eastern boundary of the site and converted into a living stream as part of the development proposals.

Additional analysis will be undertaken in the future to prepare a detailed design of the open space areas including the living stream. The following guidelines will be considered during the detailed design stage:

- River Restoration Manual: A Guide to the Nature, Protection, Rehabilitation and Long-Term Management of Waterways in Western Australia (Water and Rivers Commission, 2003).
- Design Standard No.66 – Urban Main Drainage Standard (Water Corporation, 2011).

- Stormwater Management Manual for Western Australia (Department of Environment, 2004).
- Australian Rainfall and Runoff: A Guide to Flood Estimation (Geoscience Australia, 2016).

The ultimate design of the open space and living stream will be the subject of detailed design by a landscape architect, with input and assistance from hydrological and civil engineering specialists. It will take into account the regional and local drainage requirements, as well as safety, access and recreation requirements, and revegetation / planting measures.

The following will be implemented during the detailed design stage:

- Preparation of detailed design drawings of living stream which includes consideration of the following:
  - Optimisation of the low flow channel for the required design event (1-1.5yr ARI as per River Restoration Manual or as otherwise agreed with Authorities).
  - Inclusion of a baseflow channel to convey events smaller than 1-1.5yr ARI event.
  - Inclusion of meanders, riffles and pools as required from a technical design perspective and where beneficial to create useable open space within the 100yr flood extent.
  - Provision of recreational access to the low flow channel where it is safe and beneficial to do so.
  - Assessing flood hazard in accordance with ARR 2016 criteria to confirm that the detailed design is still considered safe.
- Further examination of 1 year and 5 year ARI events to finalise design hydrographs for detailed design analyses.
- Investigate design immediately south of Arnold Road to enhance pedestrian linkage between two formal POS areas, such as:
  - Provision of a pedestrian crossing to link the two formal POS areas. Any crossing would need to be safe (i.e. culvert type/size and frequency of overtopping to be agreed with the Shire). Other measures such as signage may also be used to manage flood risk.
  - Consolidation the two formal POS areas by realigning the creek further west (note: additional losses which may result from the bend and need for stabilisation would need to be assessed).
  - Extension of the Arnold Road culvert to improve linkage.
  - Minor adjustment of road layout to alter POS configuration (i.e. POS on western bank could be incorporated as an enlarged verge).
- Preparation of detailed landscape plans for the POS including:
  - Selection of local native riparian plant species appropriate for the different living stream zones.
  - Locating recreational areas above the 5 year ARI (0.2 EY / ~20% AEP) flood level (or demonstrate that any recreation areas within the 5 year ARI will be safe).
  - Any crossing, boardwalks or pedestrian bridges to be safe (criteria to be agreed with Shire of Serpentine Jarrahdale).
  - Use of vegetation and landscaping to restrict access to potentially hazardous flood areas (non-recreational areas).
  - Use of signage to warn public of potential hazard during flood conditions.

References

Bayley Environmental Services (2016) Lots 611, 615 and 487 Arnold Road, Serpentine – Local Water Management Strategy. *Prepared for MALF Corporation.*

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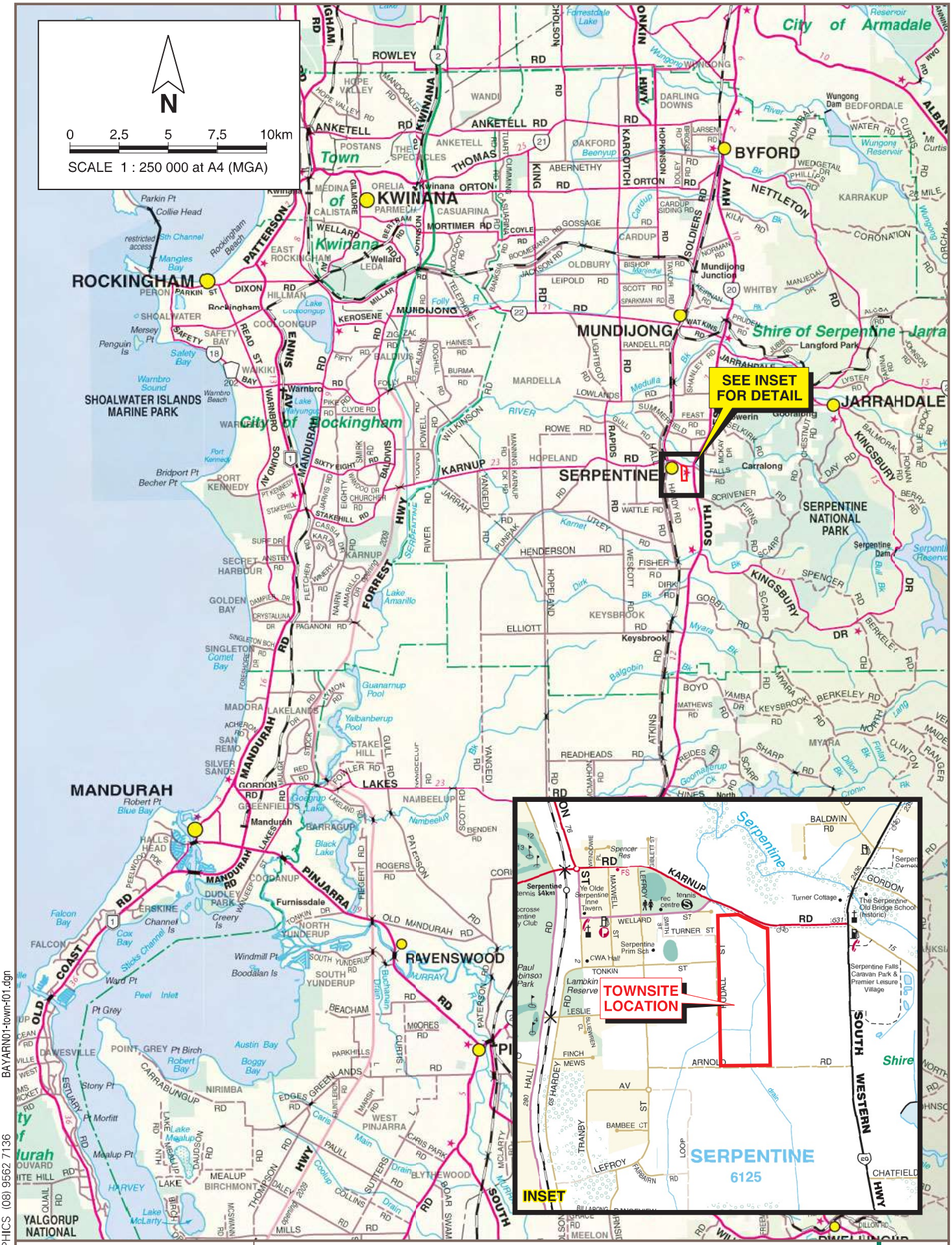
Water Corporation (2011) Design Standard No.66 – Urban Main Drainage Standard (30 June 2011)

Western Australian Planning Commission (WAPC) (2016) 100 Year ARI Flood Level – Points (mAHD) available at https://www2.landgate.wa.gov.au/ (accessed on 14/06/2013)

FIGURES



PINPOINT CARTOGRAPHICS (08) 9562 7136 BAYARN01-town-f01.dgn

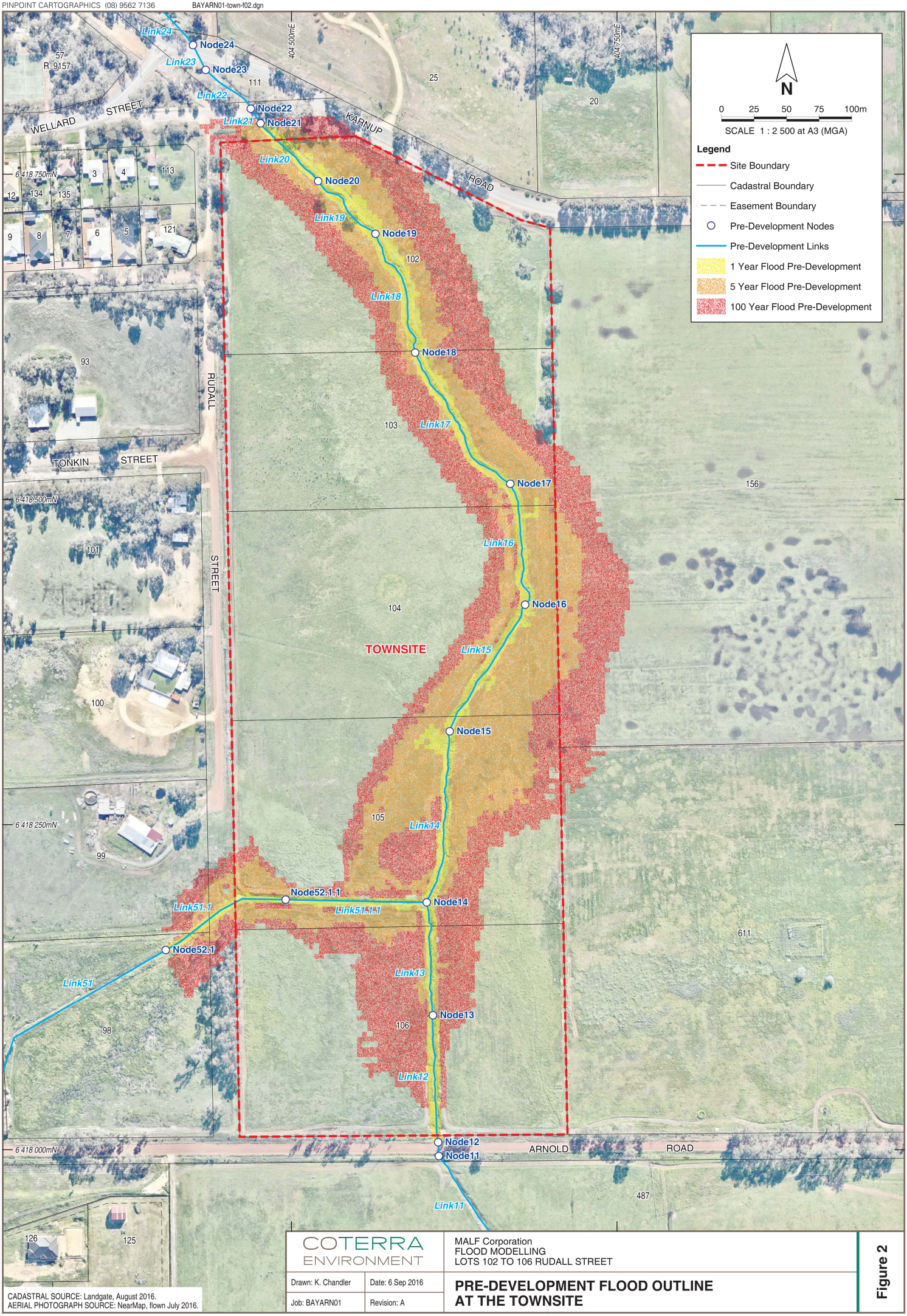
COTERRA ENVIRONMENT

MALF Corporation
FLOOD MODELLING
LOTS 102 TO 106 RUDALL STREET

Drawn: K. Chandler	Date: 6 Sep 2016
Job: BAYARN01	Revision: A

SITE LOCATION

Figure 1



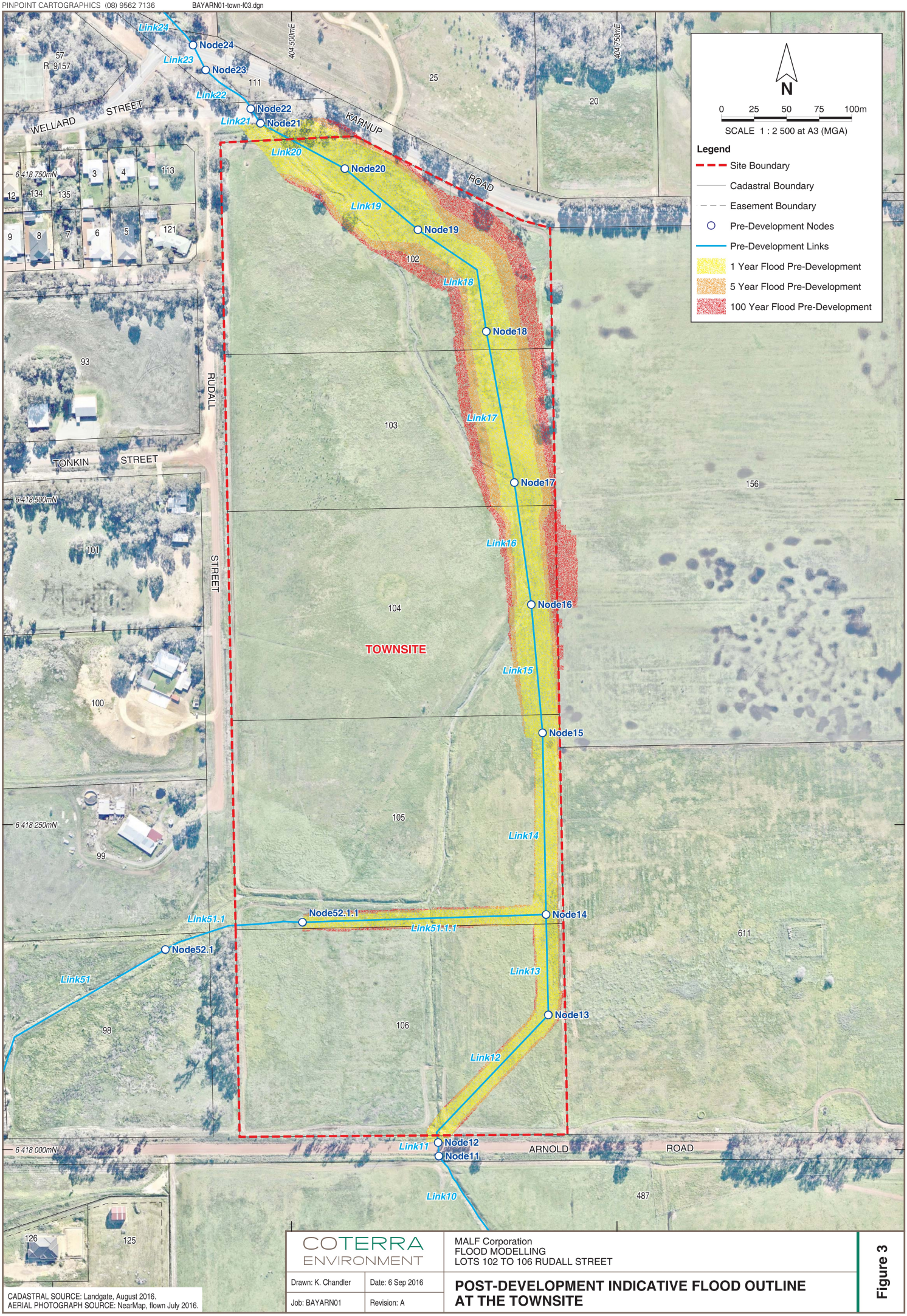
COTERRA ENVIRONMENT

MALF Corporation
FLOOD MODELLING
LOTS 102 TO 106 RUDALL STREET

Drawn: K. Chandler | Date: 6 Sep 2016
Job: BAYARN01 | Revision: A

PRE-DEVELOPMENT FLOOD OUTLINE AT THE TOWNSITE

Figure 2



CADASTRAL SOURCE: Landgate, August 2016.
AERIAL PHOTOGRAPH SOURCE: NearMap, flown July 2016.

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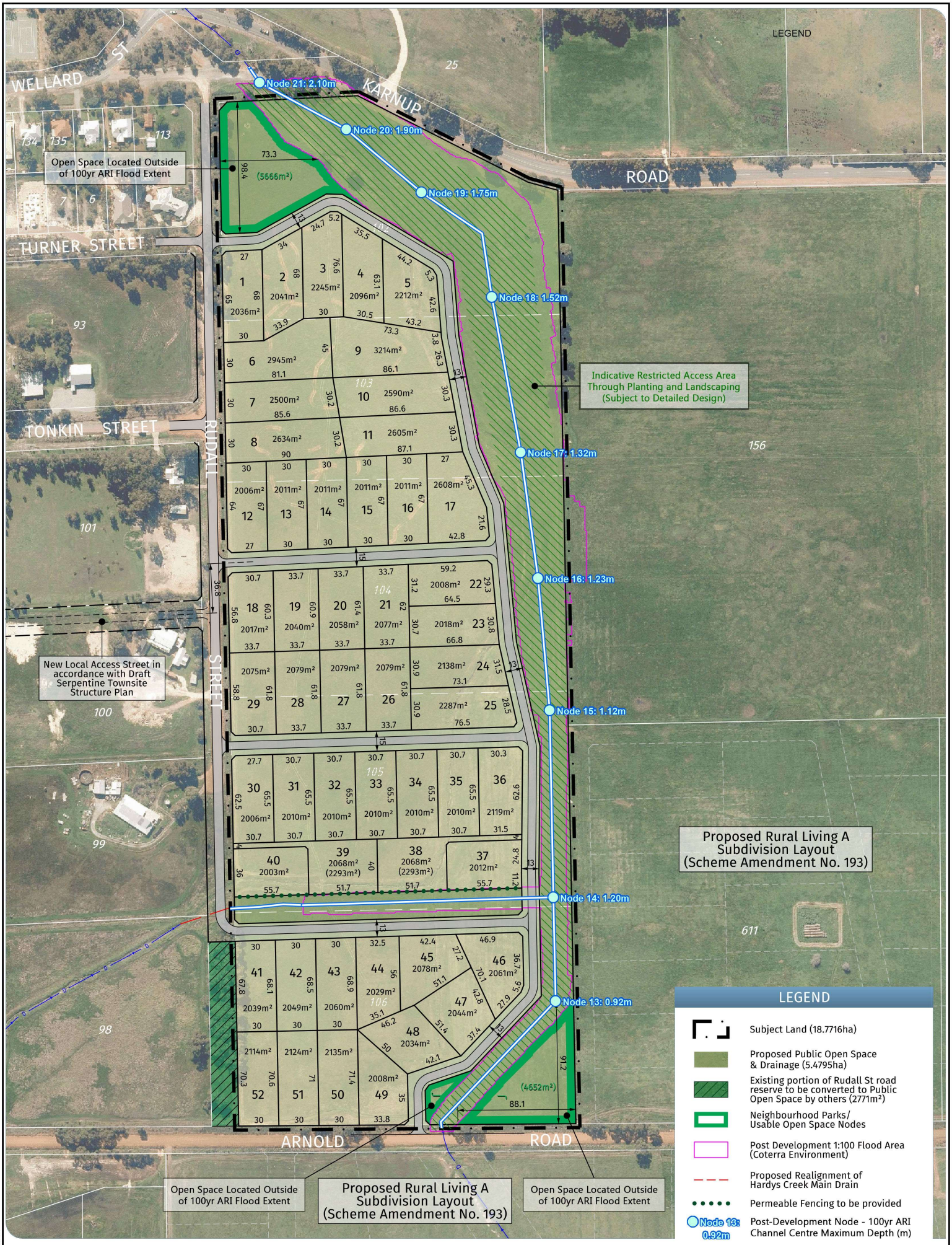
LOTS 102 TO 106 RUDALL STREET

Drawn: K. Chandler	Date: 6 Sep 2016
Job: BAYARN01	Revision: A

POST-DEVELOPMENT INDICATIVE FLOOD OUTLINE AT THE TOWNSITE

Figure 3



Source: Harley Dykstra, D11-866-08A

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MALF Corporation
FLOOD MODELLING
LOTS 102 TO 106 RUDALL STREET

APPROACH TO PUBLIC SAFETY

Figure 4

APPENDIX A – MODEL LOG, RESULTS, SCHEMATIC

COTERRA
ENVIRONMENT

MODEL OVERVIEW

Job Number:	BAYARN01
Job Name:	Arnold Road Flood Modelling
Study overview:	Rural area proposed for urban development. Conversion of existing drain to living stream.
Purpose of technical assessment:	Flood risk in proposed living stream
Model Software (Version):	XPSWMM (2016.1)
Model naming convention:	BAYARN_XXX_XXX_QXXX_XXX

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ENVIRONMENT

IFD CURVE

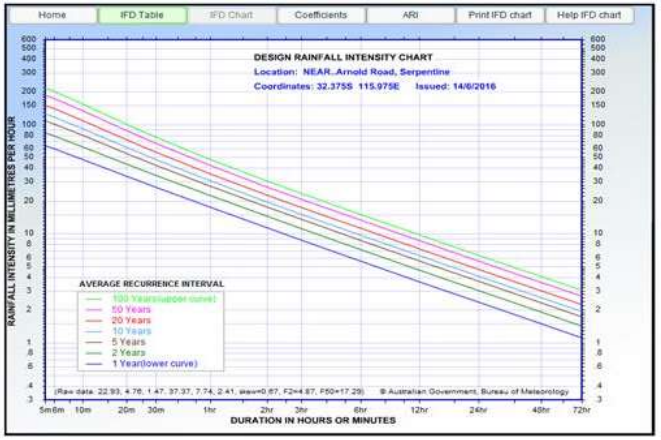
Job Number: BAYARN01
Job Name: Arnold Road Flood Modelling

Source of IFD: BoM website accessed on 14/06/2016
Location: Arnold Road, Serpentine (MGA94 Zone 50 - 404612, 6418002)

OLD 1987 METHOD - IFD Design Rainfall Depth (mm/hr)

DURATION	1 Year	2 years	5 years	10 years	20 years	50 years	100 years
5Mins	64.3	84.2	109.0	126.0	150.0	186.0	217.0
6Mins	59.9	78.6	101.0	117.0	140.0	173.0	201.0
10Mins	47.9	62.6	79.9	91.9	109.0	134.0	155.0
20Mins	33.5	43.3	54.2	61.6	72.2	87.5	100.0
30Mins	26.6	34.2	42.3	47.8	55.7	67.1	76.5
1Hr	17.5	22.4	27.3	30.6	35.4	42.2	47.9
2Hrs	11.3	14.4	17.5	19.5	22.5	26.7	30.2
3Hrs	8.7	11.1	13.5	15.0	17.3	20.6	23.3
6Hrs	5.6	7.1	8.7	9.7	11.2	13.3	15.0
12Hrs	3.6	4.6	5.6	6.3	7.2	8.6	9.8
24Hrs	2.4	3.0	3.7	4.1	4.7	5.6	6.3
48Hrs	1.5	1.9	2.3	2.6	3.0	3.6	4.0
72Hrs	1.1	1.4	1.7	1.9	2.2	2.7	3.0

DURATION	1 Year	2 years	5 years	10 years	20 years	50 years	100 years
5	5.4	7.0	9.1	10.5	12.5	15.5	18.1
6	6.0	7.9	10.1	11.7	14.0	17.3	20.1
10	8.0	10.4	13.3	15.3	18.2	22.3	25.8
20	11.2	14.4	18.1	20.5	24.1	29.2	33.3
30	13.3	17.1	21.2	23.9	27.9	33.6	38.3
60	17.5	22.4	27.3	30.6	35.4	42.2	47.9
120	22.6	28.8	35.0	39.0	45.0	53.4	60.4
180	26.1	33.3	40.5	45.0	51.9	61.8	69.9
360	33.5	42.8	52.0	58.1	67.2	79.8	90.0
720	43.4	55.4	67.4	75.5	86.9	103.4	117.0
1440	56.4	72.0	87.6	97.7	112.8	134.2	151.9
2880	71.5	91.7	111.4	124.3	143.5	170.9	193.4
4320	79.9	102.2	124.6	139.7	161.3	193.0	218.2



Global Storms

Name	mm
1Yr-5min	5.4
1Yr-6min	6.0
1Yr-10min	8.0
1Yr-20min	11.2
1Yr-30min	13.3
1Yr-60min	17.5
1Yr-120min	22.6
1Yr-180min	26.1
1Yr-360min	33.5
1Yr-720min	43.4
1Yr-1440min	56.4
1Yr-2880min	71.5
1Yr-4320min	79.9
5Yr-5min	9.1
5Yr-6min	10.1
5Yr-10min	13.3
5Yr-20min	18.1
5Yr-30min	21.2
5Yr-60min	27.3
5Yr-120min	35.0
5Yr-180min	40.5
5Yr-360min	52.0
5Yr-720min	67.4
5Yr-1440min	87.6
5Yr-2880min	111.4
5Yr-4320min	124.6
100Yr-5min	18.1
100Yr-6min	20.1
100Yr-10min	25.8
100Yr-20min	33.3
100Yr-30min	38.3
100Yr-60min	47.9
100Yr-120min	60.4
100Yr-180min	69.9
100Yr-360min	90.0
100Yr-720min	117.0
100Yr-1440min	151.9
100Yr-2880min	193.4
100Yr-4320min	218.2

COTERRA
ENVIRONMENT

HYDROLOGICAL INPUT DATA AND KEY ASSUMPTIONS

Job Number: BAYARN01
Job Name: Arnold Road Flood Modelling

Summary of methodology: Laurenson method within XPSWMM

Hydrological Model Component	Input data	Method	Key assumptions	Comments
Sub-catchment areas	GIS pre and post dev sub-catchments [BAY | 02/06/2016]	Import into GIS and check against 1m & 5m contour information	Assumed that sub-catchments are up to date and accurate.	
Percentage Impermeable	Aerial Photo [BAY | 02/06/2016]	Pre-Development landuse type based on manual inspection of aerial photography [See EIA Worksheet]		
Catchment slope	LiDAR data [DoW | 07/06/2016] 1m topo [DoW | 14/05/13]	Manual calculation based on available data.	Assumed that topo is accurate.	
Catchment width	Not used in method.	N/A	N/A	N/A
Rainfall	BoM IFD data - 1987 version as still using old temporal patterns [See IFD Worksheet]			
Catchment infiltration / losses	Landuse type based on aerial photography Runoff parameters taken from standard text and compared to GHD LWMS			
Mannings n*	Runoff parameters taken from standard text and compared to GHD LWMS		Not well known. Use of standard values. Verify with observed data.	Engman, E.T., 1986. "Roughness Coefficients for Routing Surface Runoff," Journal of Irrigation and Drainage Engineering, ASCE, Vol. 112, No. 1, pp. 39-53.
Depression storage	Not used in method.	N/A	N/A	N/A
Critical Duration	IFD data and Australian temporal patterns	Ran global storms through model to determine critical duration of each reach		

COTERRA ENVIRONMENT

HYDROLOGICAL CATCHMENTS

Job Number: BAYARN01

Job Name: Arnold Road Flood Modelling

Post-Development Onsite Catchments	Node8	Node 15	Node14	Node18
Post-Dev Total Area (ha)	54.179	19.734	34.887	22.527
Post-Dev Roads Area (ha)	8.442	3.424	7.708	0.840
Post-Dev Roofs (ha)	7.600	2.640	6.400	1.000
Living Stream/POS (ha)	3.000	3.481	2.998	8.455
Gardens (ha)	35.137	10.189	17.781	12.232
CHECK	*0.000*	*0.000*	*0.000*	*0.000*
Effective Impervious / Pervious Areas				
Pervious (ha)	40.670	14.697	23.091	20.939
Impervious Area - swales Stage 2 (ha)	5.909	1.998	0.000	0.000
Impervious Area - WQT (ha)	0.000	0.399	5.396	0.588
Roofs with soakwells (ha)	7.600	2.640	6.400	1.000
CHECK	*0.000*	*0.000*	*0.000*	*0.000*

Land Type	% Impervious
Roads	70%

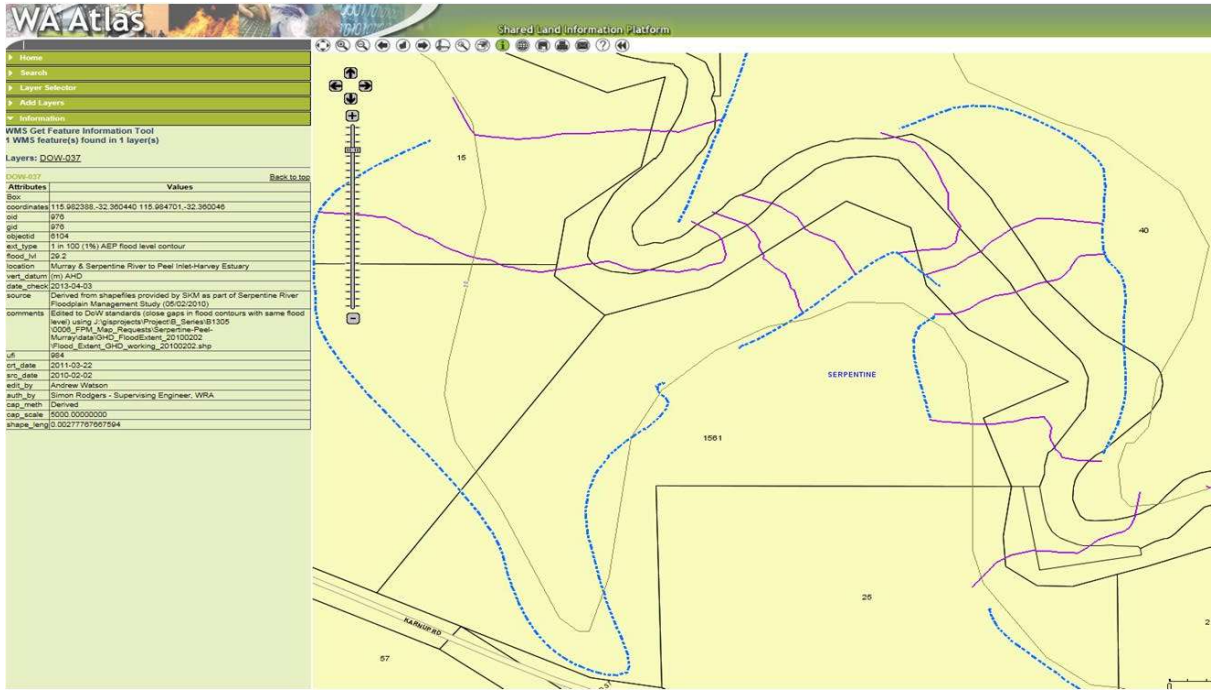
COTERRA
ENVIRONMENT

HYDRAULIC INPUT DATA AND KEY ASSUMPTIONS

Job Number: BAYARN01
Job Name: Arnold Road Flood Modelling

Hydraulic Model Component	Input data [date / source]	Method	Key assumptions	Comments
Background Image	Aerial Photography (Landgate Nov 13.ecw) [BAY / 02.06.2016]		Assumed to accurately reflect current land shape and use, and be georeferenced accurately.	
Channel and floodplain topography	LiDAR data supplied in .xyz format [DoW / 07.06.2016].		Assumed to accurately reflect current land shape and use, and be georeferenced accurately.	Pre-development channel downstream of Karnup Road assumed to be the same as that between Wellard and Karnup Roads.
	Data extracted from GHD LWMS			
Structure details	Data extracted from GHD LWMS			
Structure losses	Standard losses used in absence of measured data	Standard losses as per standard guidance.		
Mannings 'n' values	Data extracted from GHD LWMS and aerial photography (BAY / 02.06.2016)	Reference to standard engineering texts (i.e. Chow). Roughness not modelled as varying with depth.		
	2D digitised from aerial photography [BAY / 02.06.2016]	Manual digitisation. Mannings values from standard literature (i.e. Chow)		
Downstream boundary	Q100 river level in WA Atlas is 29.2mAHD (see below) [WA Atlas / 14.06.2016] Q5 river level from GHD LWMS is 28.543 Q1 assume to be free flowing	Constant head	Assumes peak flow on Arnold Creek and Serpentine River coincide.	This is a conservative assumption as in reality the peaks may not coincide.
Basin infiltration	Data extracted from GHD LWMS - 4mm/hr			

Downstream boundary:



COTERRA ENVIRONMENT

STRUCTURE DETAILS
Job Number: BAYARND1
Job Name: Arnold Road Flood Modelling

Link Name	Location	Physical Description	Modelling Assumptions	Photos: Looking Downstream	Photos: Looking Upstream	Comments
Link23	Kemup Road	2 x 1500 corrugated metal circular culverts [HD Survey - 07/072016]	Mannings n - 0.022 based on 68 x 13mm corrugations (assumed). Average of inverts used.			
Link21C	Wellard Road culverts	2 x 1300 concrete circular culverts [HD Survey - 07/072016]	Average of inverts used.			Previous reports refer to this culvert being 1.2m - however recent survey shows it to be 1.3m NOTE THESE CULVERTS ARE UPGRADED TO 1.5m IN THE POST DEVELOPMENT SCENARIO
Link21W	Wellard Road spill (weir)	Spill over road	Cross-section taken from LIDAR data - verified with survey			
Link11C	Arnold Road (HCMD)	2 x rectangular concrete culverts [HD Survey - 07/072016]	Average of inverts used.			Culverts grade upstream. GHD report states that there are 2 x 1200mm culverts under Arnold Road. However the recent survey states that these are 900 x 1500mm
Link11W	Arnold Road Spill (weir)	Spill over road	Survey level used. Lidar is not accurate in this location.			
Link50C	Arnold Road Basin culvert	1 x rectangular concrete culvert [HD Survey - 07/072016]	Average of inverts used.			
Link50W	Arnold Road Basin spill (weir)	Spill over road	Survey level used.			

HCMD Arnold Road Weir Link11 — THIS CROSS SECTION HAS NOT BEEN USED AS LIDAR DATA APPEARS TO HAVE BEEN EDITED AND IS INCORRECT

Invert of culvert 31.129

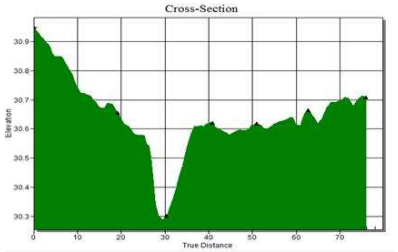
Elevation	Depth	Length	Exponent (3/2 for transverse weir and 5/3 for side-flow weirs)	Discharge	
32.3	1.171	0	1.50	0.7	
32.9	1.771	10	1.50	0.7	
33	1.871	80	1.50	0.7	



HCMD Wellard Road Weir Link11

Invert of culvert 28.318

Elevation	Depth	Length	Exponent (3/2 for transverse weir and 5/3 for side-flow weirs)	Discharge	
30.488	2.17	0	1.50	0.7	
30.58	2.262	10	1.50	0.7	
30.625	2.307	40	1.50	0.7	
30.7	2.382	64	1.50	0.7	
30.8	2.482	80	1.5	0.7	

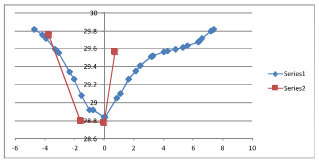


Broad crested (flat topped) weirs

Q	15.00793307
B	80
g	9.81
H	0.244648318
h	0.3
V	4

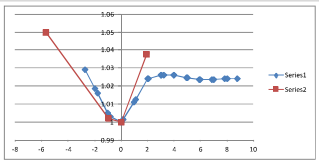
LINK38

-4.739	29.82					97.75	-4.739
-4.143	29.754					98.346	-4.143
-3.942	29.715					98.547	-3.942
-3.31	29.594					99.179	-3.31
-3.146	29.561					99.343	-3.146
-3.094	29.549					99.395	-3.094
-2.349	29.343					100.14	-2.349
-2.045	29.263					100.444	-2.045
-1.553	29.079					100.936	-1.553
-0.996	28.917					101.493	-0.996
-0.756	28.921					101.733	-0.756
0	28.837					102.489	0
0.04	28.834					102.529	0.04
0.053	28.836					102.542	0.053
0.837	29.047					103.326	0.837
1.102	29.102					103.591	1.102
1.633	29.266					104.122	1.633
2.151	29.356					104.64	2.151
2.43	29.412					104.919	2.43
3.2	29.516					105.689	3.2
3.227	29.517					105.716	3.227
3.309	29.521					105.798	3.309
4.023	29.566	-3.7607	29.755	0	0	106.511	4.023
4.249	29.573	-1.6033	28.799	2.1574	2.1574	106.738	4.249
4.82	29.594	0	28.778	1.6033	3.7607	107.309	4.82
5.298	29.614	0.6987	29.568	0.6987	4.4594	107.787	5.298
5.616	29.632					108.105	5.616
6.347	29.678					108.836	6.347
6.413	29.694					108.902	6.413
6.619	29.713					109.108	6.619
7.209	29.797					109.698	7.209
7.396	29.814					109.885	7.396



Link16

-2.742	1.028959093					123.46	30.486
-2.002	1.018597773					124.2	30.179
-1.783	1.015897124					124.419	30.099
-1.001	1.004995275					125.201	29.776
-0.824	1.003071419					125.378	29.719
0	1					126.202	29.628
0.135	1.001215067					126.337	29.664
1.001	1.011070609					127.203	29.956
1.095	1.012353179					127.297	29.994
2.002	1.024065074					128.204	30.341
2.054	1.024233833					128.256	30.346
3.003	1.026225192					129.205	30.405
3.013	1.026225192					129.215	30.405
3.239	1.026225192					129.441	30.405
3.972	1.026258944					130.174	30.406
4.004	1.026157689					130.206	30.403
4.931	1.024841366					131.133	30.364
5.005	1.024638855					131.207	30.358
5.89	1.023828811					132.092	30.334
6.006	1.023828811					132.208	30.334
6.85	1.023693803	-5.6844	1.049640041	0	0	133.052	30.33
7.007	1.023727555	-0.9727	1.001782653	4.7117	4.7117	133.209	30.331
7.809	1.023963818	0	1	0.9727	5.6844	134.011	30.338
8.008	1.024031322	1.9545	1.03791.5667	1.9545	7.6389	134.21	30.34
8.768	1.024335088					134.97	30.349



COTERRA
ENVIRONMENT

PROPOSED LIVING STREAM

Job Number: BAYARN01

Job Name: Arnold Road Flood Modelling

GHD TYPICAL - Link12

Western invert	0	32.5	
0.5m sep to Q100	2	32	Assume 1:4
	3.452	31.956	1to6
	5.852	31.756	Assume 1:2
Low flow channel	6.452	31.456	
Low flow channel	6.752	31.456	
	7.352	31.756	Assume 1:2
	9.752	31.956	1 to 6
0.m sep to Q100	17.804	32.2	1to33
Eastern Invert	19.804	32.7	Assume 1:4

GHD TYPICAL - Node13

Western invert	0	31.8	
0.5m sep to Q100	2	31.3	Assume 1:4
	2.231	31.293	1to6
	4.631	31.093	Assume 1:2
Low flow channel	5.231	30.793	
Low flow channel	5.531	30.793	
	6.131	31.093	Assume 1:2
	8.531	31.293	1 to 6
0.m sep to Q100	23.612	31.75	1to33
Eastern Invert	25.612	32.25	Assume 1:4

GHD TYPICAL - Node14

Western invert	0	31.4	
0.5m sep to Q100	2	30.9	Assume 1:4
	9.062	30.686	1to6
	11.462	30.486	Assume 1:2
Low flow channel	12.062	30.186	
Low flow channel	12.362	30.186	
	12.962	30.486	Assume 1:2
	15.362	30.686	1 to 6
0.m sep to Q100	29.024	31.1	1to33
Eastern Invert	31.024	31.6	Assume 1:4

GHD TYPICAL - Link14

Western invert	0	31	
0.5m sep to Q100	2	30.5	Assume 1:4
	2.99	30.47	1to6
	5.39	30.27	Assume 1:2
Low flow channel	5.99	29.97	
Low flow channel	6.29	29.97	
	6.89	30.27	Assume 1:2
	9.29	30.47	1 to 6
0.m sep to Q100	16.88	30.7	1to33
Eastern Invert	18.88	31.2	Assume 1:4

GHD TYPICAL - Link15

Western invert	0	31.1	
0.5m sep to Q100	2	30.6	Assume 1:4
	18.83	30.09	1to6
	21.23	29.89	Assume 1:2
Low flow channel	21.83	29.59	
Low flow channel	22.13	29.59	
	22.73	29.89	Assume 1:2
	25.13	30.09	1 to 6
0.m sep to Q100	35.36	30.4	1to33
Eastern Invert	37.36	30.9	Assume 1:4

GHD TYPICAL - Link16

Western invert	0	31.4	
0.5m sep to Q100	2	30.9	Assume 1:4
	38.63	29.79	1to6
	41.03	29.59	Assume 1:2
Low flow channel	41.63	29.29	
Low flow channel	41.93	29.29	
	42.53	29.59	Assume 1:2
	44.93	29.79	1 to 6
0.m sep to Q100	48.56	29.9	1to33
Eastern Invert	50.56	30.4	Assume 1:4

GHD TYPICAL - Link17

Western invert	0	30.7	
0.5m sep to Q100	2	30.2	Assume 1:4
	19.49	29.67	1to6
	21.89	29.47	Assume 1:2
Low flow channel	22.49	29.17	
Low flow channel	22.79	29.17	
	23.39	29.47	Assume 1:2
	25.79	29.67	1 to 6
0.m sep to Q100	69.68	31	1to33
Eastern Invert	71.68	31.5	Assume 1:4

GHD TYPICAL - Link18

Western invert	0	30.7	
0.5m sep to Q100	2	30.2	Assume 1:4
	24.44	29.52	1to6
	26.84	29.32	Assume 1:2
Low flow channel	27.44	29.02	
Low flow channel	27.74	29.02	
	28.34	29.32	Assume 1:2
	30.74	29.52	1 to 6
0.m sep to Q100	79.58	31	1to33
Eastern Invert	81.58	31.5	Assume 1:4

GHD TYPICAL - Link19

Western invert	0	30.2	
0.5m sep to Q100	2	29.7	Assume 1:4
	13.55	29.35	1to6
	15.95	29.15	Assume 1:2
Low flow channel	16.55	28.85	
Low flow channel	16.85	28.85	
	17.45	29.15	Assume 1:2
	19.85	29.35	1 to 6
0.m sep to Q100	61.1	30.6	1to33
Eastern Invert	63.1	31.1	Assume 1:4

Link19v2

	28.85
0	30.20
8.1	29.45
37.34	29.15
37.35	28.85
37.65	28.85
37.66	29.15
61.5	29.45
75	31.10

Link20

	28.85
0	30.20
9.42	29.15
29.84	28.93
29.85	28.63
30.15	28.63
30.16	28.93
48.18	29.15
60	30.60

TRAPEZOIDAL CHANNEL

	28.85
0	1.00
6	0.00
9	0.00
15	1.00

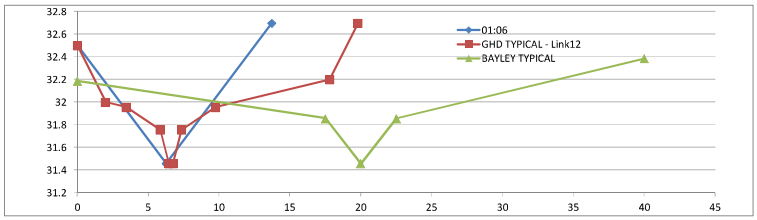
0.044
1.452
8.052
0.244
13.662
0.414
0.03
0.99
17.49
43.89
1.33
0.68
22.44
48.84
1.48
0.35
11.55
41.25
1.25

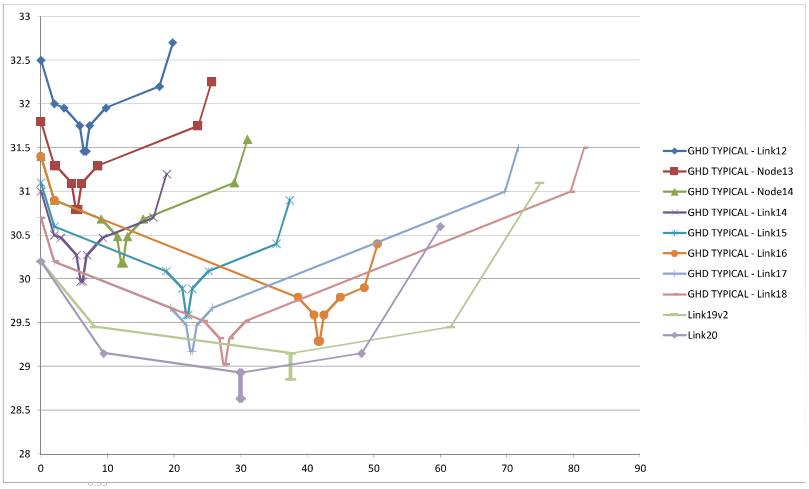
1:6 TYPICAL Link12

Chainage	Elevation
0	32.5
6.264	31.456
6.264	31.456
13.728	32.7

BAYLEY TYPICAL

0	32.19
17.5	31.86
20	31.46
22.5	31.86
40	32.39





COTERRA
ENVIRONMENT

CALIBRATION / VERIFICATION

Job Number: BAYARN01

Job Name: Arnold Road Flood Modelling

Model Iteration: BAYARN01_Townsite_PRE_Q100_D100_009.xp / BAYARN01_Townsite_POST_Q100_D100_012.xp

Event	Study	Peak Flow (m3/s)			
		HCWB	HCMD		
		Arnold Road Basin (Link 51)	U/S Stage 2 (Link 3)	Arnold Road (Link 10)	Karnup Road (Link 22)
Pre-Dev 1yr	Coterra Model				5.01
Pre-Dev 5yr	Coterra Model	5.85	2.64	5.53	10.93
	GHD LWMS Model	6.00	n/a	3.99	8.17
Pre-Dev 100yr	Coterra Model	11.77	5.87	11.03	20.51
	GHD LWMS Model	11.68	n/a	10.96	17.90
	Sepentine Downs Estate Model	12.00	n/a	n/a	n/a
	Byford Townsite Model	11.90	n/a	n/a	n/a
	Bayley Rational Method	n/a	4.66	11.37	n/a
Post-Dev 1yr	Coterra Model	2.24	1.32	2.52	4.47
Post-Dev 5yr	Coterra Model	5.31	2.66	5.37	10.21
	GHD LWMS Model	n/a	n/a	3.99	7.80
Post-Dev 100yr	Coterra Model	9.48	5.93	10.77	17.25
	GHD LWMS Model	n/a	n/a	10.96	17.40
	Bayley Rational Method	n/a	5.23	10.33	n/a

COTERRA
ENVIRONMENT

SUMMARY OF RESULTS

Job Number: BAYARN01
Job Name: Arnold Road Flood Modelling
Models: BAYARN01_Townsite_PRE_Q100_D100_009.xp / BAYARN01_Townsite_POST_Q100_D100_012.xp

Proposed Development Area	Hardy Creek Node	PRE-DEVELOPMENT (1D Channel ONLY)				POST-DEVELOPMENT (1D Channel ONLY)						
		Invert (mAHD)	1 year ARI	5 year ARI	100 year ARI	Invert (mAHD)	1 year ARI		5 year ARI		100 year ARI	
			Maximum Water Levels (mAHD)	Maximum Water Levels (mAHD)	Maximum Water Levels (mAHD)		Maximum Water Levels (mAHD)	Maximum Depth (m)	Maximum Water Levels (mAHD)	Maximum Depth (m)	Maximum Water Levels (mAHD)	Maximum Depth (m)
Townsite	Node12	31.37	32.00	32.21	32.44	31.37	32.15	0.78	32.28	0.91	32.45	1.07
	Node13	30.79	31.55	31.81	31.99	30.79	31.44	0.65	31.56	0.77	31.72	0.93
	Node14	30.19	31.21	31.45	31.60	30.19	30.99	0.81	31.21	1.03	31.41	1.23
	Node15	29.76	30.86	31.09	31.25	29.76	30.56	0.80	30.74	0.97	30.90	1.13
	Node16	29.42	30.43	30.69	31.05	29.42	30.24	0.82	30.44	1.02	30.65	1.23
	Node17	29.15	30.20	30.49	30.97	29.15	29.98	0.83	30.16	1.01	30.48	1.32
	Node18	28.89	29.91	30.28	30.91	28.89	29.74	0.85	29.93	1.04	30.42	1.53
	Node19	28.67	29.70	30.15	30.89	28.67	29.32	0.65	29.74	1.07	30.40	1.74
	Node20	28.52	29.49	30.12	30.88	28.52	29.24	0.72	29.73	1.21	30.40	1.88
	Node21	28.32	29.33	30.09	30.87	28.32	29.21	0.89	29.72	1.40	30.40	2.08

Note: Results are for maximum of all storm events simulated

Proposed Development Area	Hardy Creek Link	POST-DEVELOPMENT (1D CHANNEL ONLY)											
		Length (m)	1 year ARI				5 year ARI				100 year ARI			
			Peak flow (m^3/s)	Volume (m^3)	Top Width (m)	Area at TWL (m^2)	Peak flow (m^3/s)	Volume (m^3)	Top Width (m)	Area at TWL (m^2)	Peak flow (m^3/s)	Volume (m^3)	Top Width (m)	Area at TWL (m^2)
Townsite	Link12	132	2.51	368	15	1926	5.31	644	17	2276	10.79	1018	19	2449
	Link13	78	2.51	285	13	1044	5.30	496	17	1316	10.77	736	18	1414
	Link14	140	3.95	673	16	2272	9.49	1142	18	2511	16.84	1600	19	2627
	Link15	99	4.26	609	26	2565	10.08	1175	33	3258	17.99	1797	35	3486
	Link16	95	4.25	557	21	2020	10.07	1012	29	2726	17.85	1822	36	3435
	Link17	118	4.25	911	32	3826	10.05	1795	47	5508	17.49	4464	61	7191
	Link18	99	4.55	472	28	2757	10.68	1455	42	4168	17.98	4711	65	6417
	Link19	70	4.52	890	54	3835	10.35	2795	63	4407	17.48	6010	71	4992
	Link20	74	4.48	1172	42	3121	10.22	2953	51	3743	17.28	6162	59	4364

Note: Results are for maximum of all storm events simulated

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ENVIRONMENT

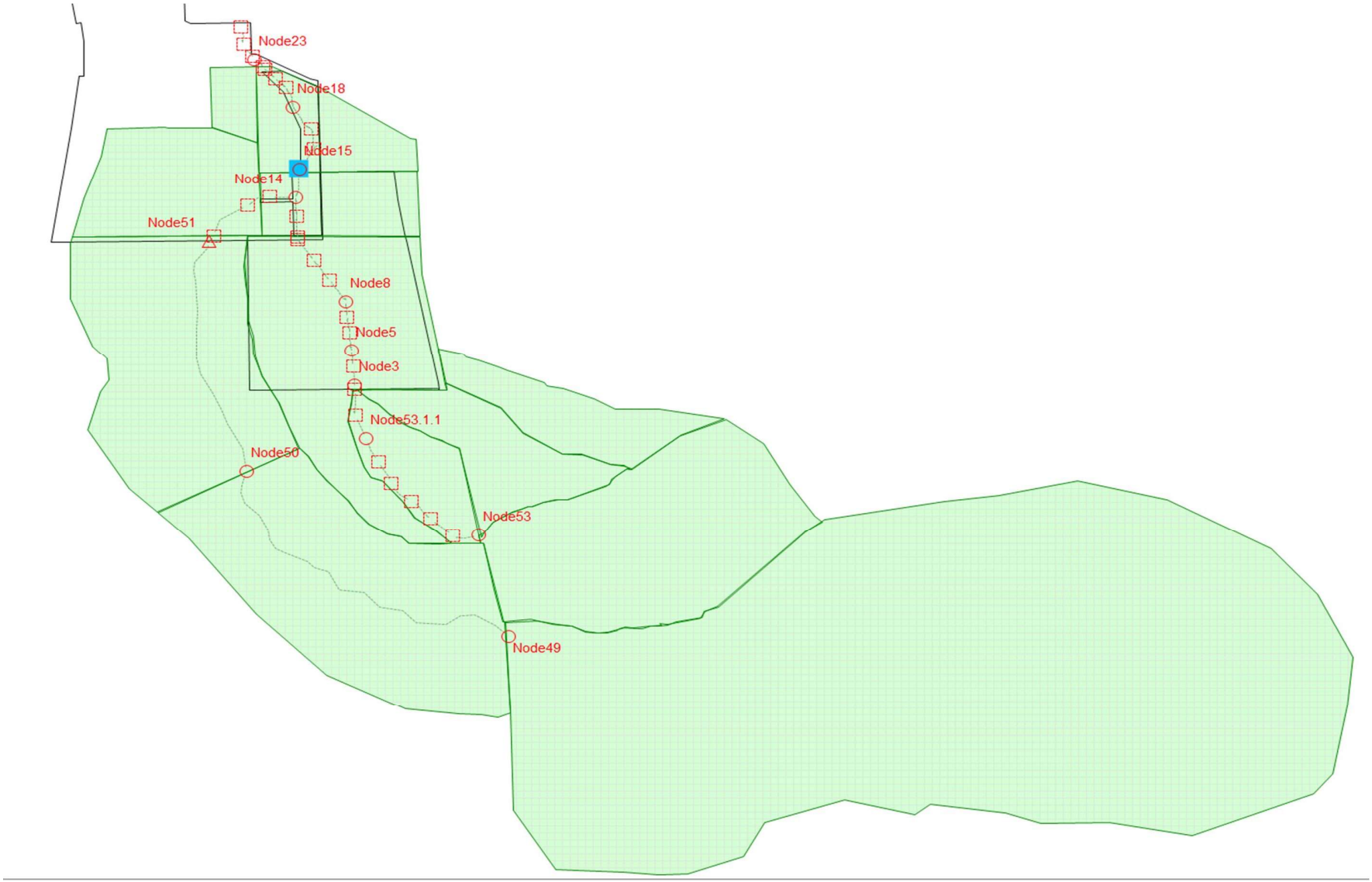
MODEL SCHEMATIC

Job Number: BAYARN01

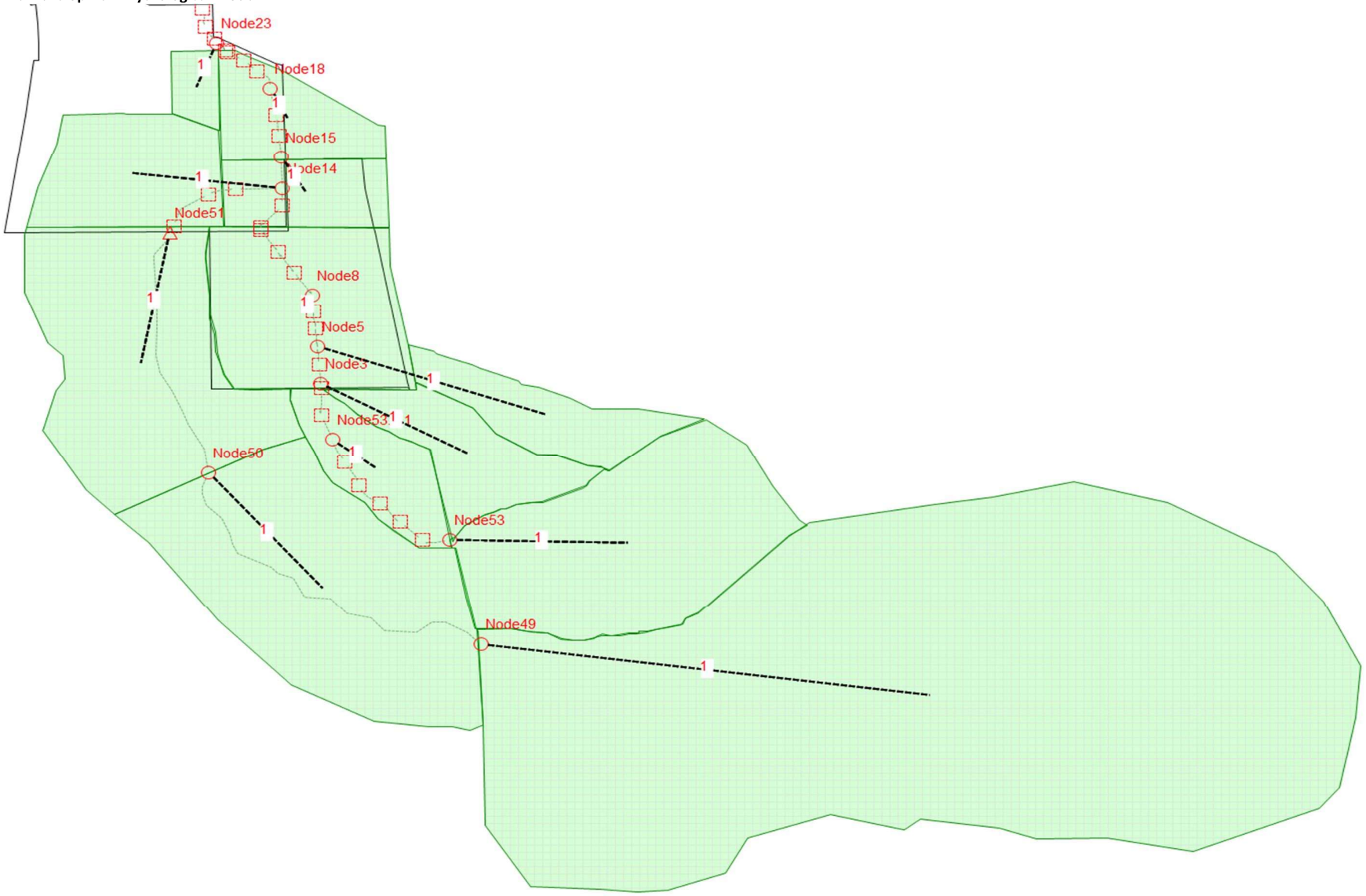
Job Name: Arnold Road Flood Modelling

Models: BAYARN01_Townsite_PRE_Q100_D100_009.xp / BAYARN01_Townsite_POST_Q100_D100_012.xp

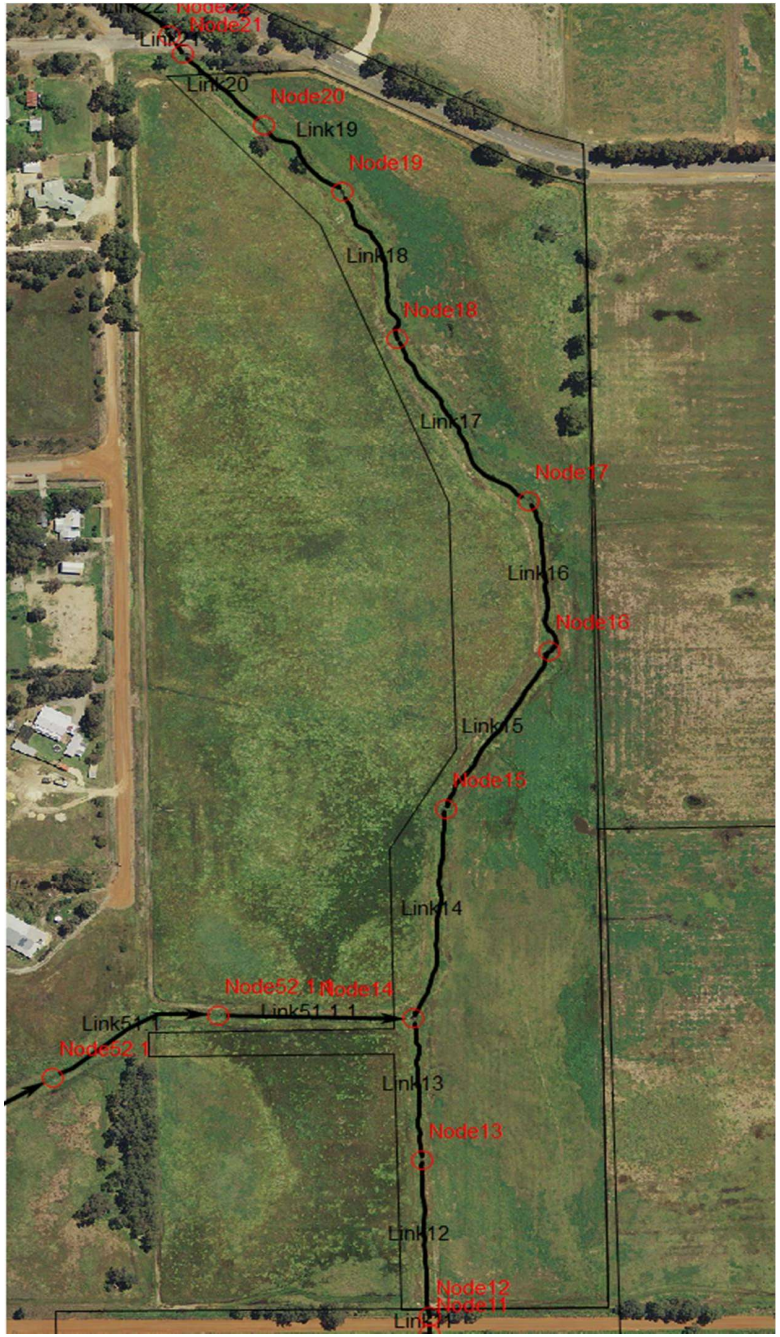
Pre-Development Hydrological Model



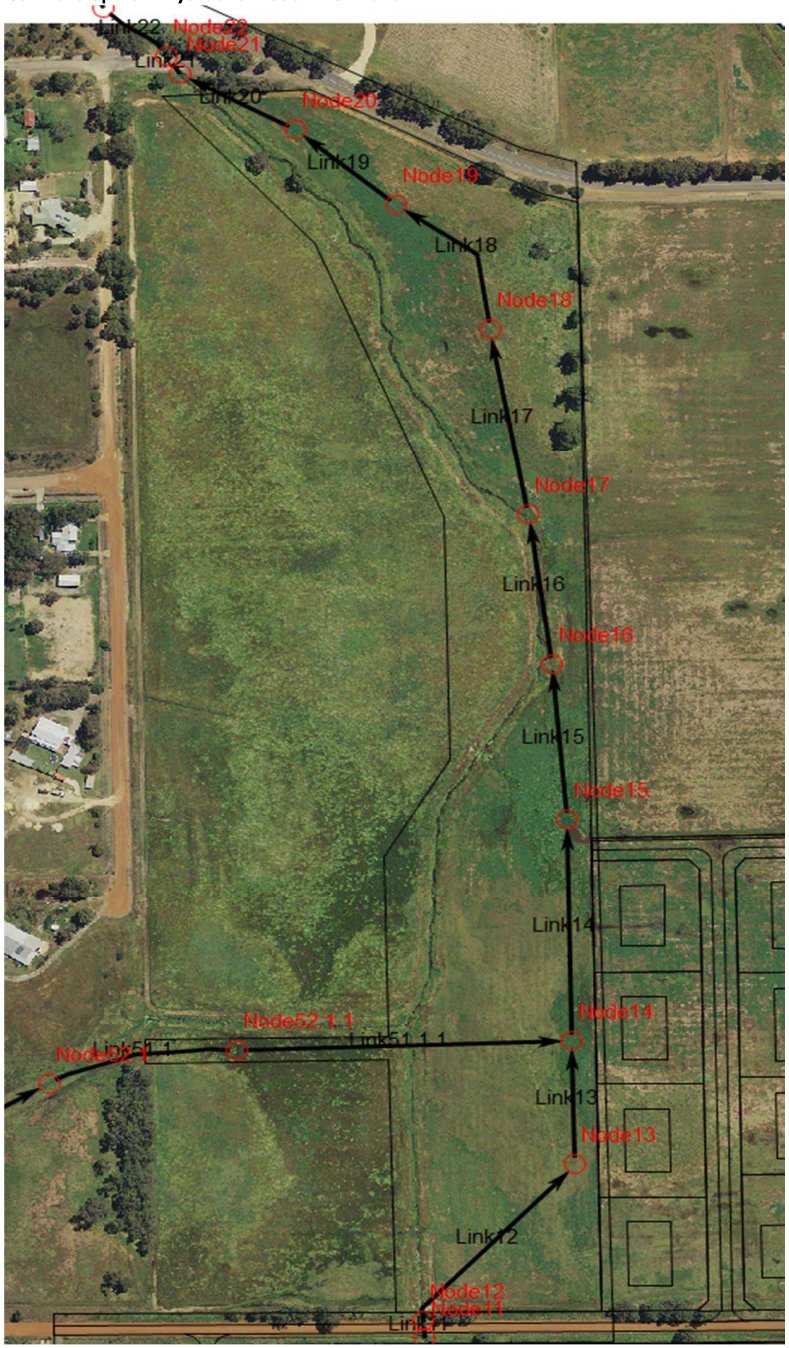
Pre-Development Hydrological Model



Pre-Development Hydraulic Model - Townsite



Post-Development Hydraulic Model - Townsite



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ENVIRONMENT

Q100 Post Development Long and Cross Section Results

Job Number: BAYARN01

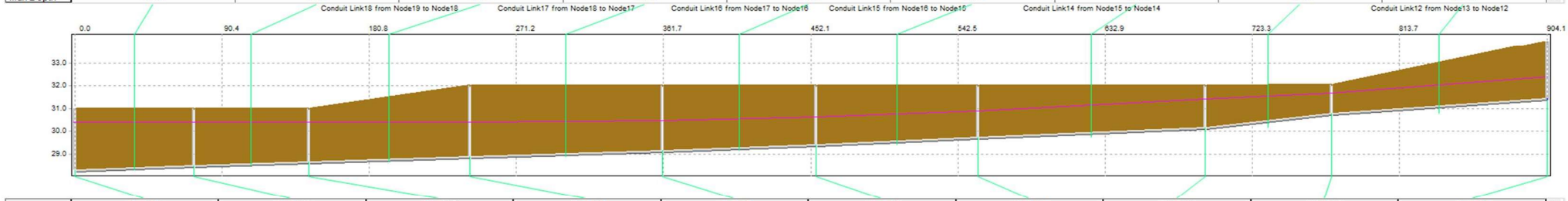
Job Name: Arnold Road Flood Modelling

Models: BAYARN01_Townsite_PRE_Q100_D100_009.xp / BAYARN01_Townsite_POST_Q100_D100_012.xp

Q100 Post-Development LS and XS - Townsite (360min)

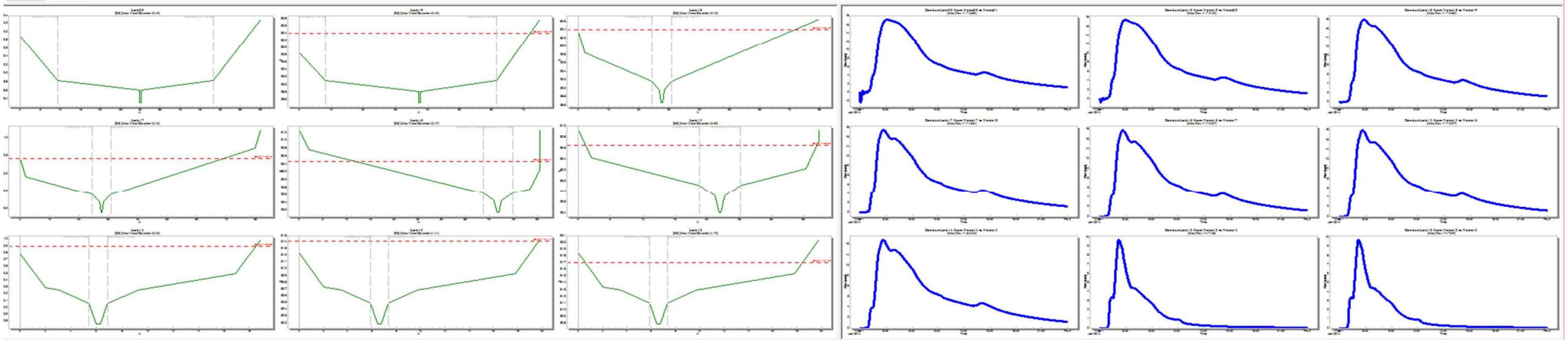
Links

	Link20	Link19	Link18	Link17	Link16	Link15	Link14	Link13	Link12
Storm	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min
Max Flow	17.275	17.478	17.980	17.490	17.851	17.993	16.839	9.741	9.756
Max Velocity	0.280	0.340	0.820	0.760	1.060	1.070	1.380	1.340	1.280
Length	73.550	70.390	98.850	118.080	94.720	98.970	139.560	77.710	132.310
Max Flow	17.275	17.478	17.980	17.490	17.851	17.993	16.839	9.741	9.756
Max Depth	2.081	1.881	1.736	1.532	1.321	1.229	1.225	1.225	0.960



	Node21	Node20	Node19	Node18	Node17	Node16	Node15	Node14	Node13	Node12
Storm	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min
Max Water D	2.081	1.881	1.736	1.532	1.321	1.229	1.134	1.225	0.906	1.044
Max Water El	30.399	30.401	30.402	30.424	30.475	30.650	30.896	31.411	31.699	32.416
Max Volume	2.539	2.294	2.118	1.869	1.612	1.500	1.383	1.495	1.105	1.274
Flood Loss	0.000	0.000	0.000	0.000	0.000	356.172	0.000	0.000	0.000	0.000
Volume of Ou	0.000	0.000	0.000	0.000	0.000	356.172	0.000	0.000	0.000	0.000

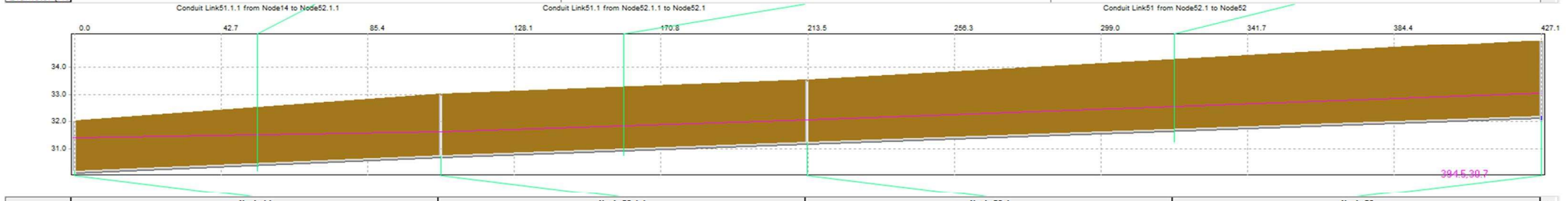
Nodes Hydrology



Q100 Post-Development LS and XS - Swale (360min)

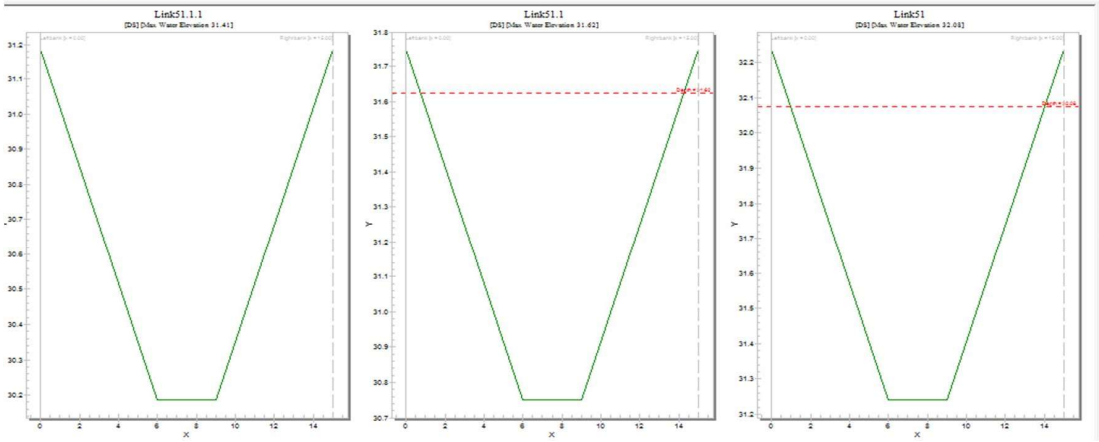
Links

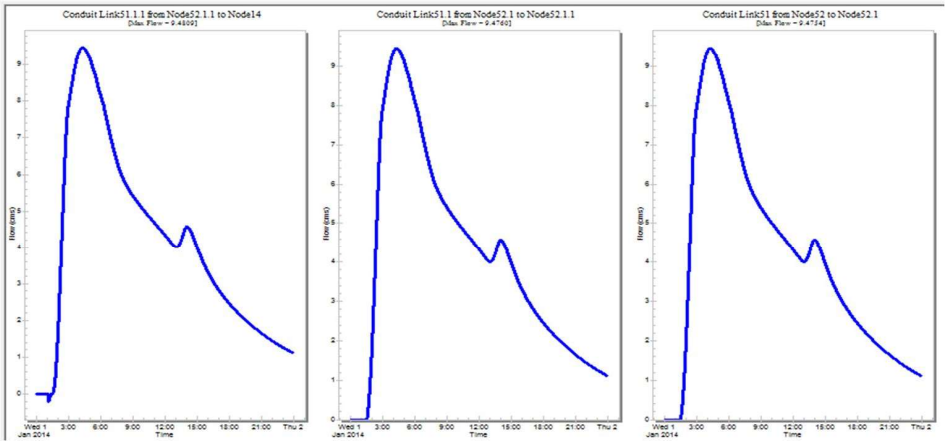
	Link51.1.1	Link51.1	Link51
Storm	100Yr-360min	100Yr-360min	100Yr-360min
Downstream	30.186	30.750	31.240
Upstream Inv	30.750	31.240	32.200
Conduit Slop	0.528	0.459	0.450
Roughness	0.030	0.030	0.030
Diameter (He	0.000	0.000	0.000



	Node14	Node52.1.1	Node52.1	Node52
Storm	100Yr-360min	100Yr-360min	100Yr-360min	100Yr-360min
Max Surface	1.220	1.220	1.220	1.220
Max Water D	1.225	0.873	0.836	0.997
Max Water El	31.411	31.623	32.076	33.033
Max Volume	1.495	1.065	1.020	1.217
Flood Loss	0.000	0.000	0.000	0.000

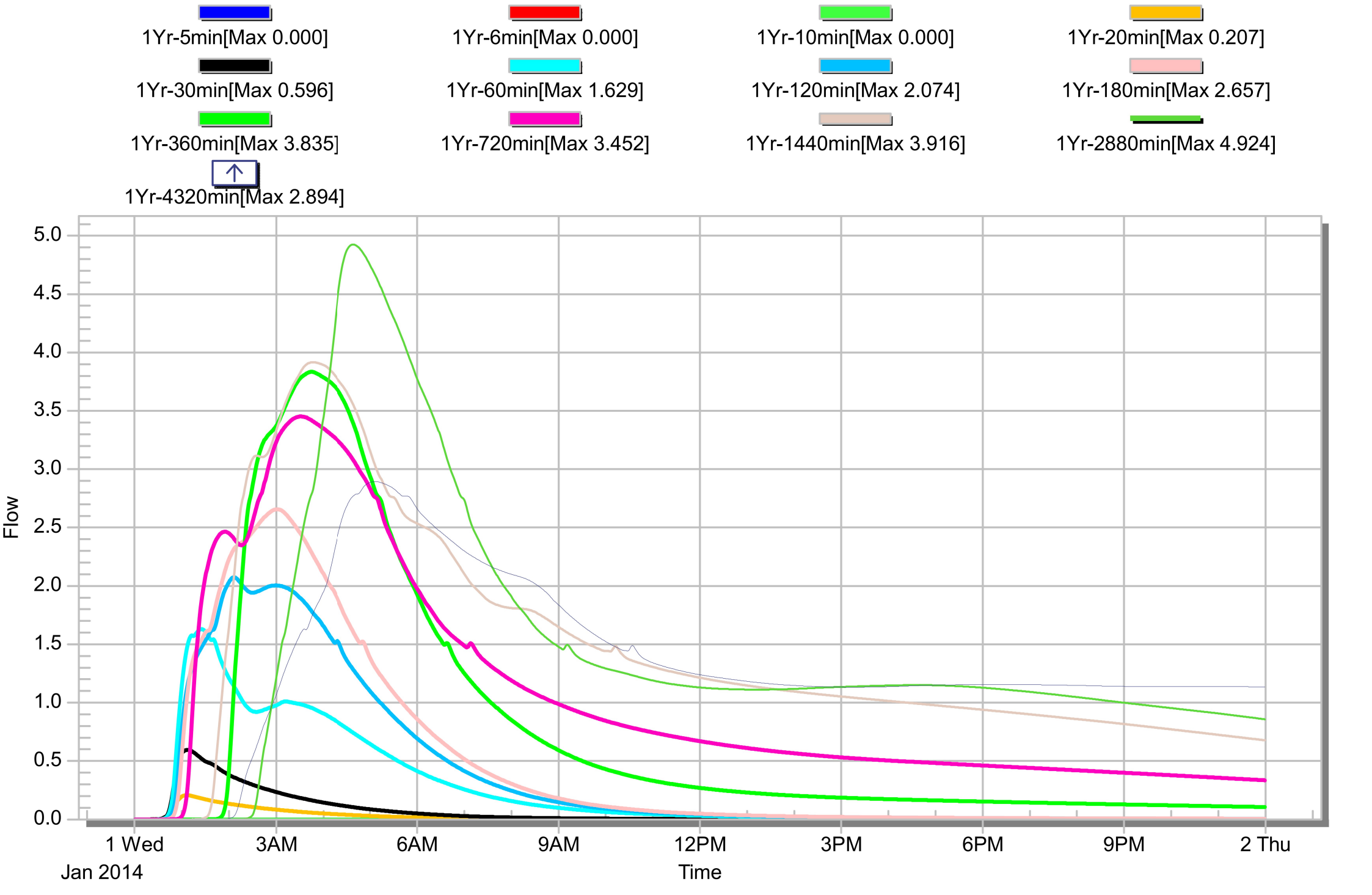
Nodes Hydrology



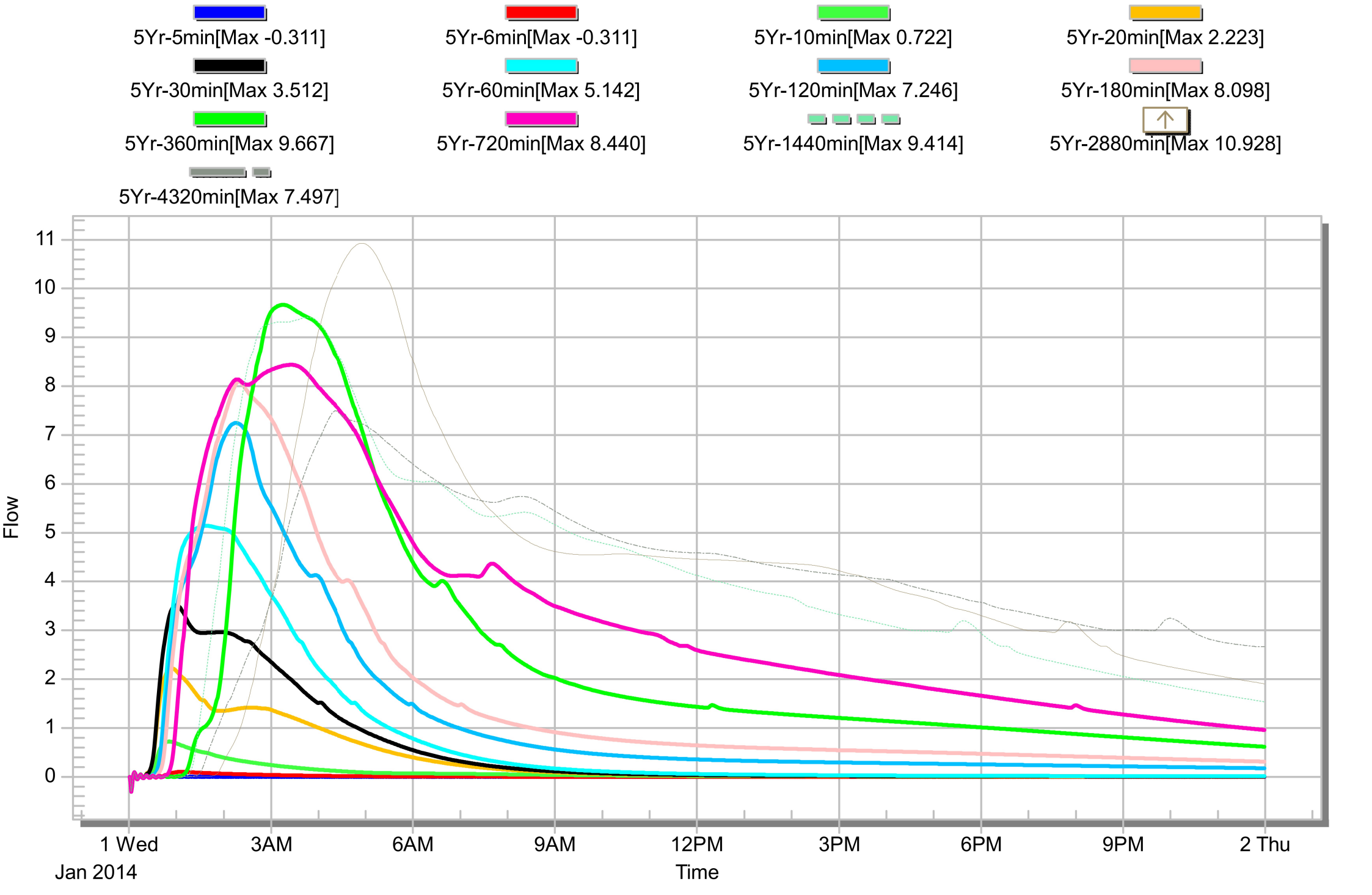


APPENDIX B – PRE-DEVELOPMENT HYDROGRAPHS (LINK 22)

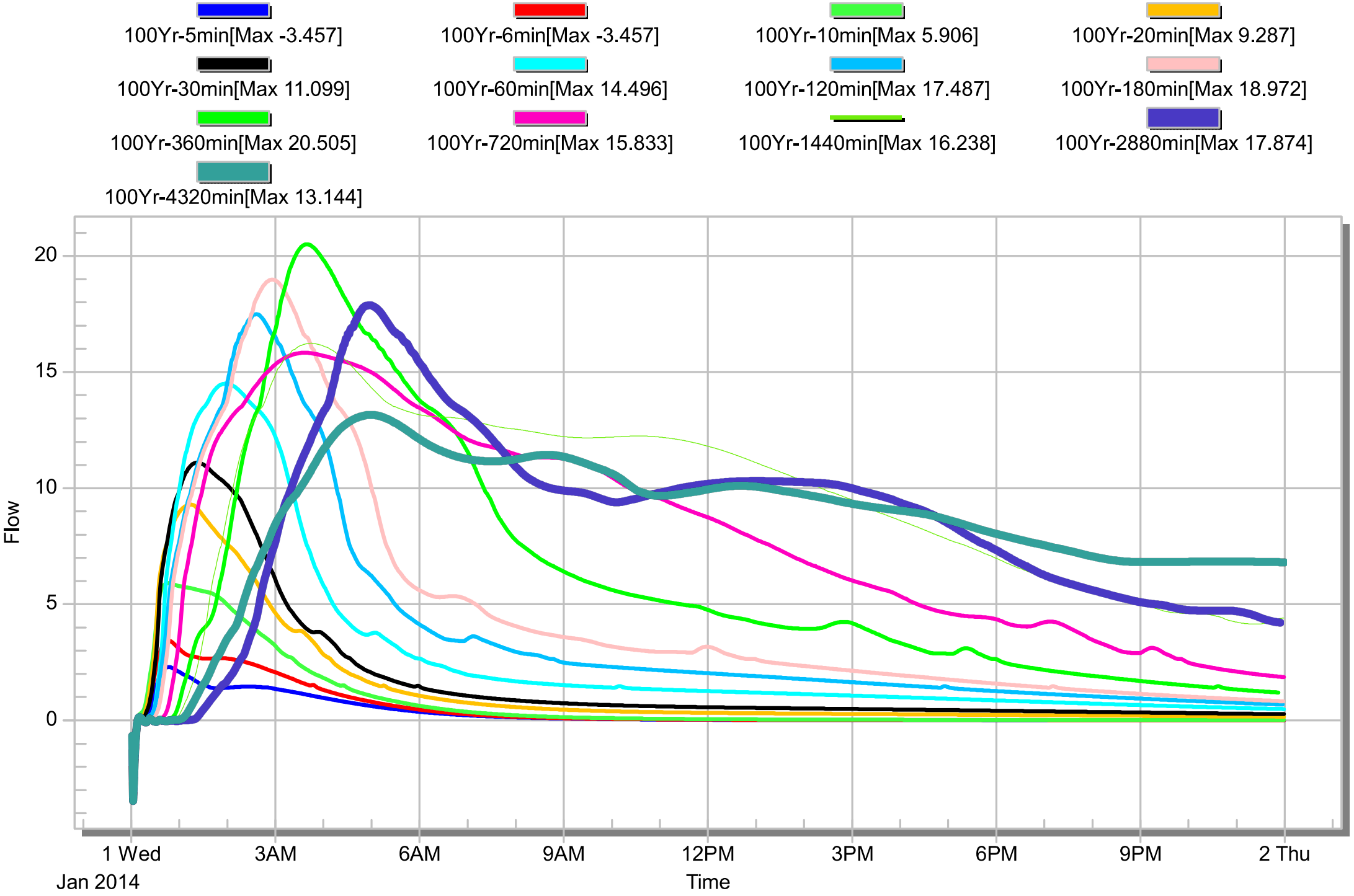
Conduit Link22 from Node22 to Node23



Conduit Link22 from Node22 to Node23

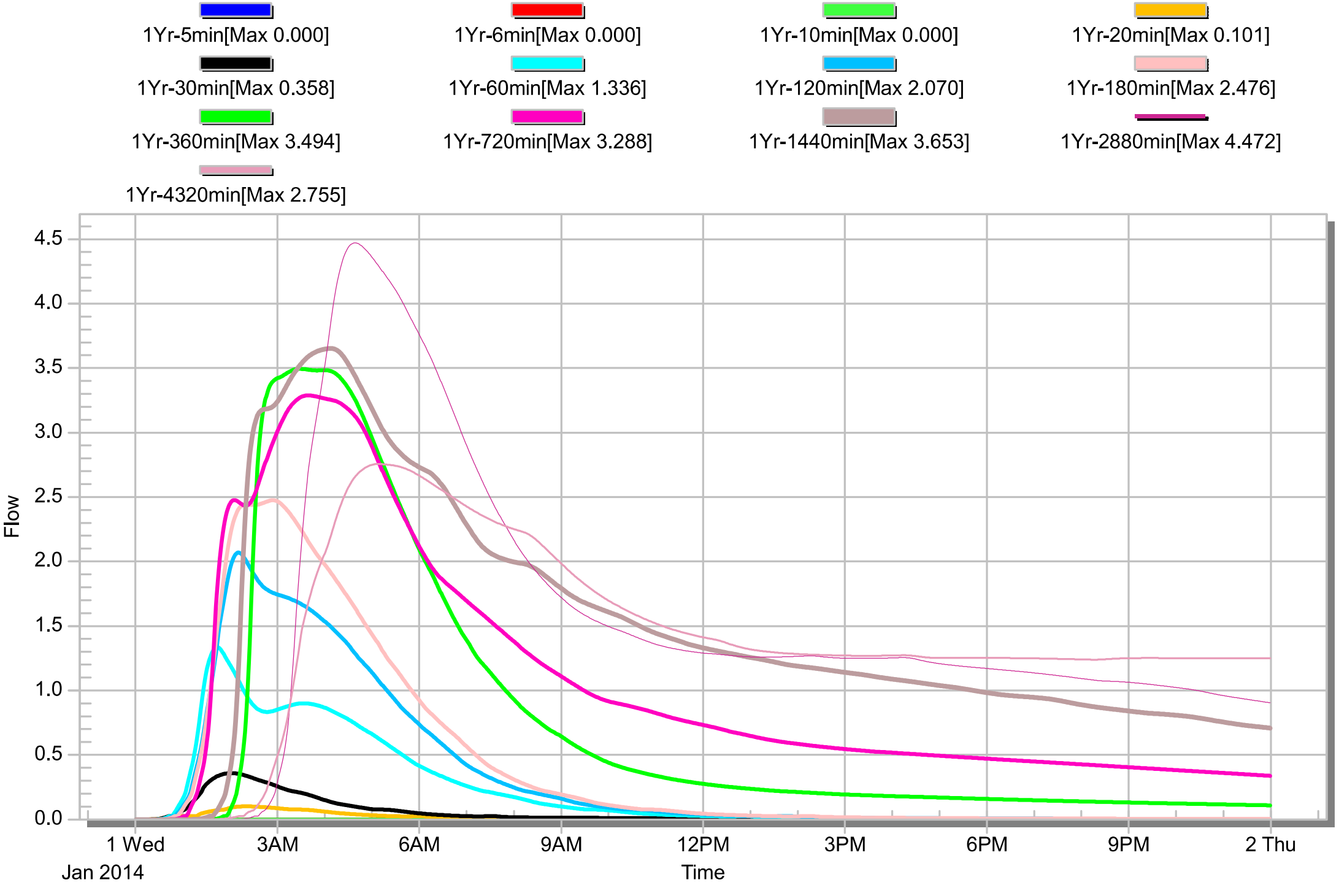


Conduit Link22 from Node22 to Node23

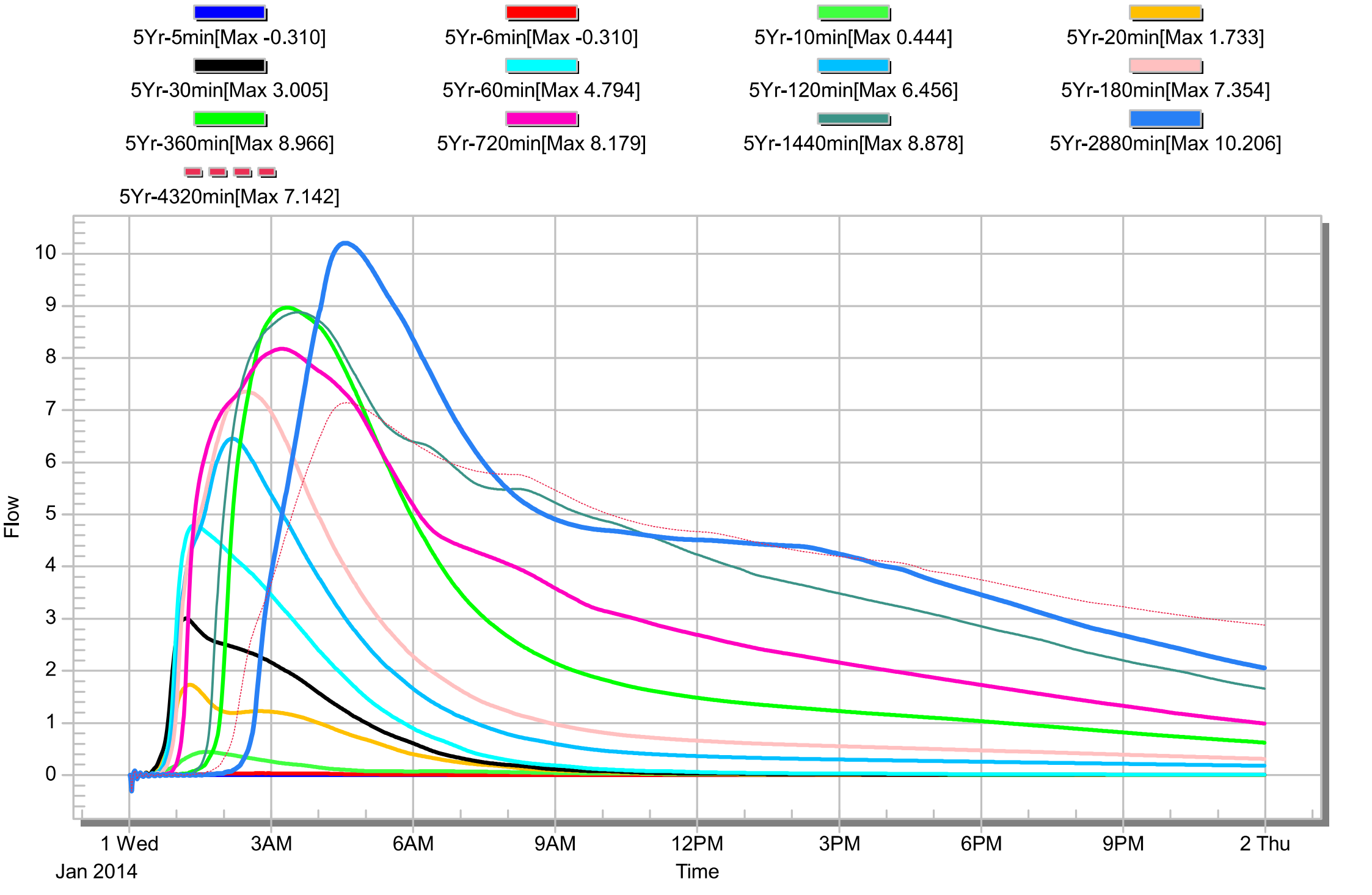


APPENDIX C – POST-DEVELOPMENT HYDROGRAPHS (LINK 22)

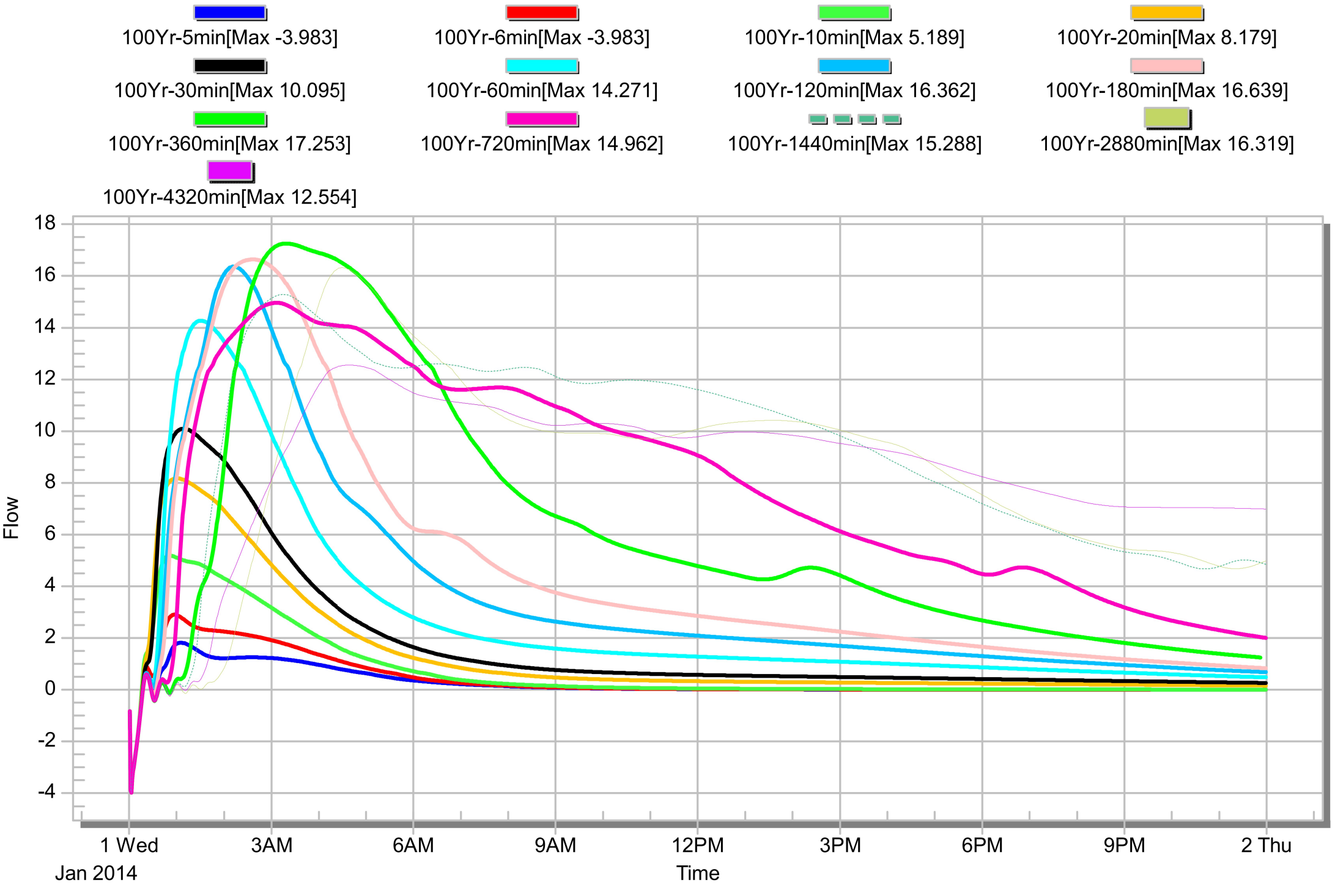
Conduit Link22 from Node22 to Node23



Conduit Link22 from Node22 to Node23



Conduit Link22 from Node22 to Node23



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APPENDIX D – INDICATIVE FLOOD HAZARD CROSS-SECTION ANALYSIS

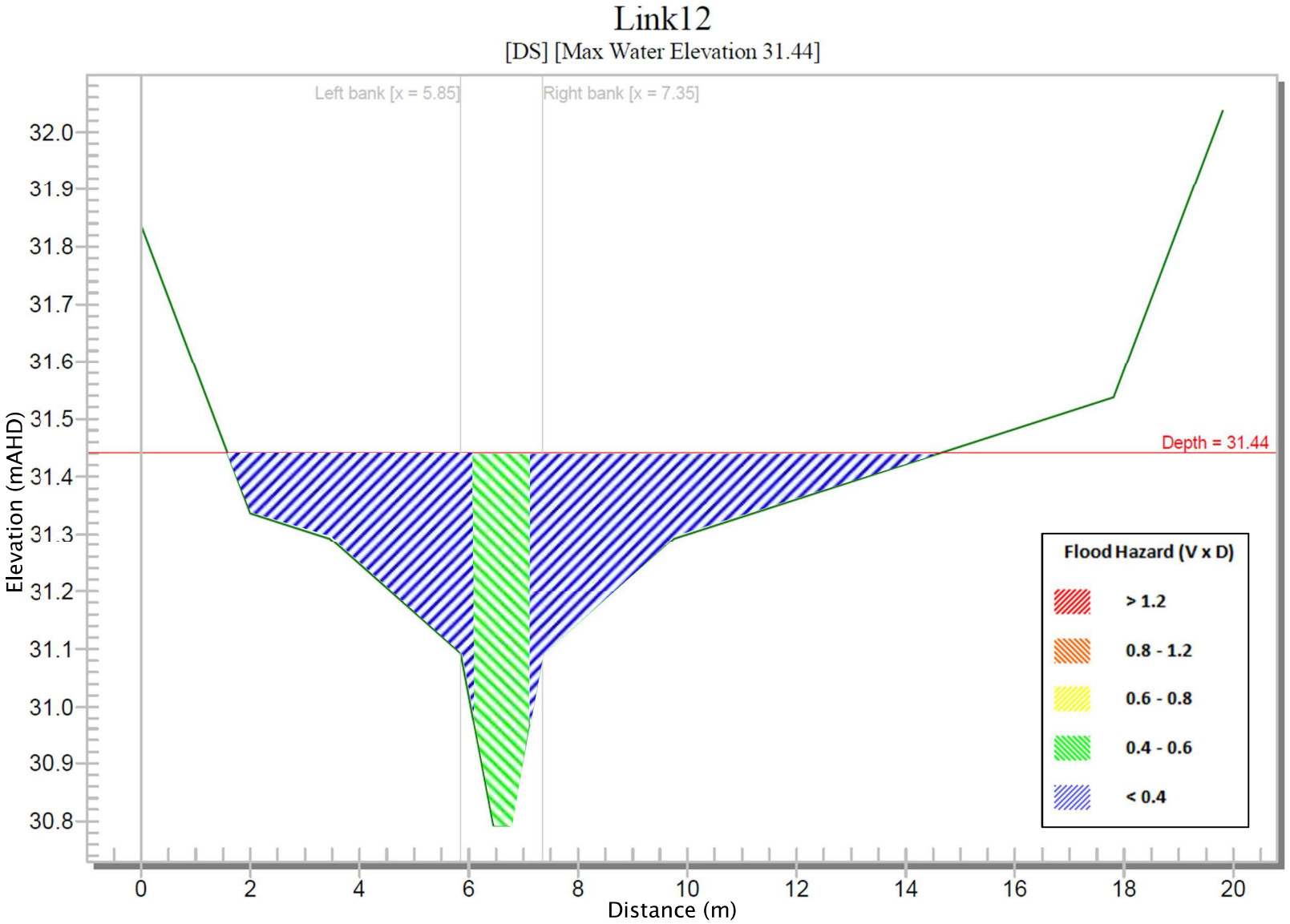


Plate 1: 1 year ARI Post-Development Indicative Hazard Analysis – Link 12 (360 min duration)

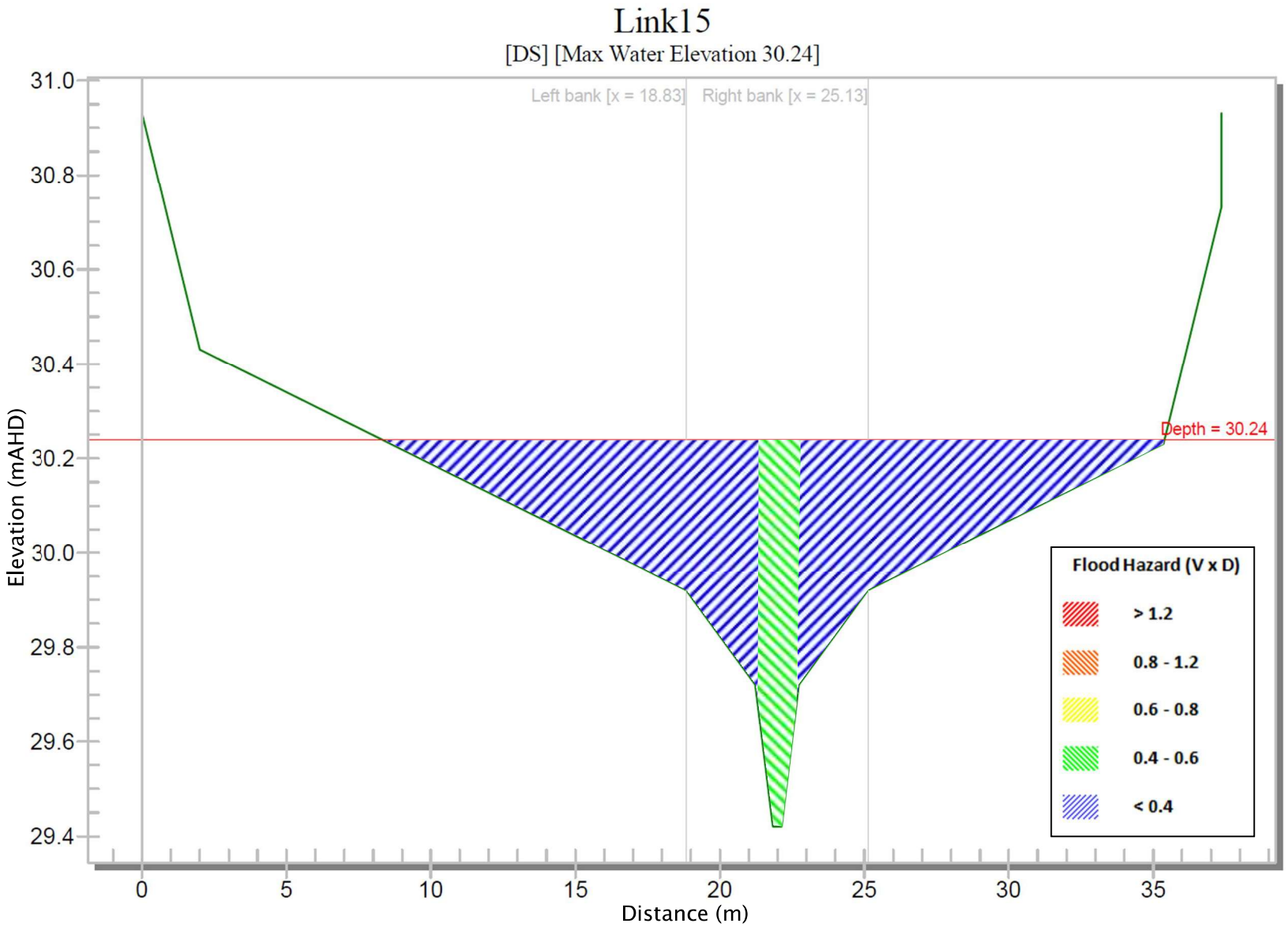


Plate 2: 1 year ARI Post-Development Indicative Hazard Analysis – Link 15 (2880 min duration)

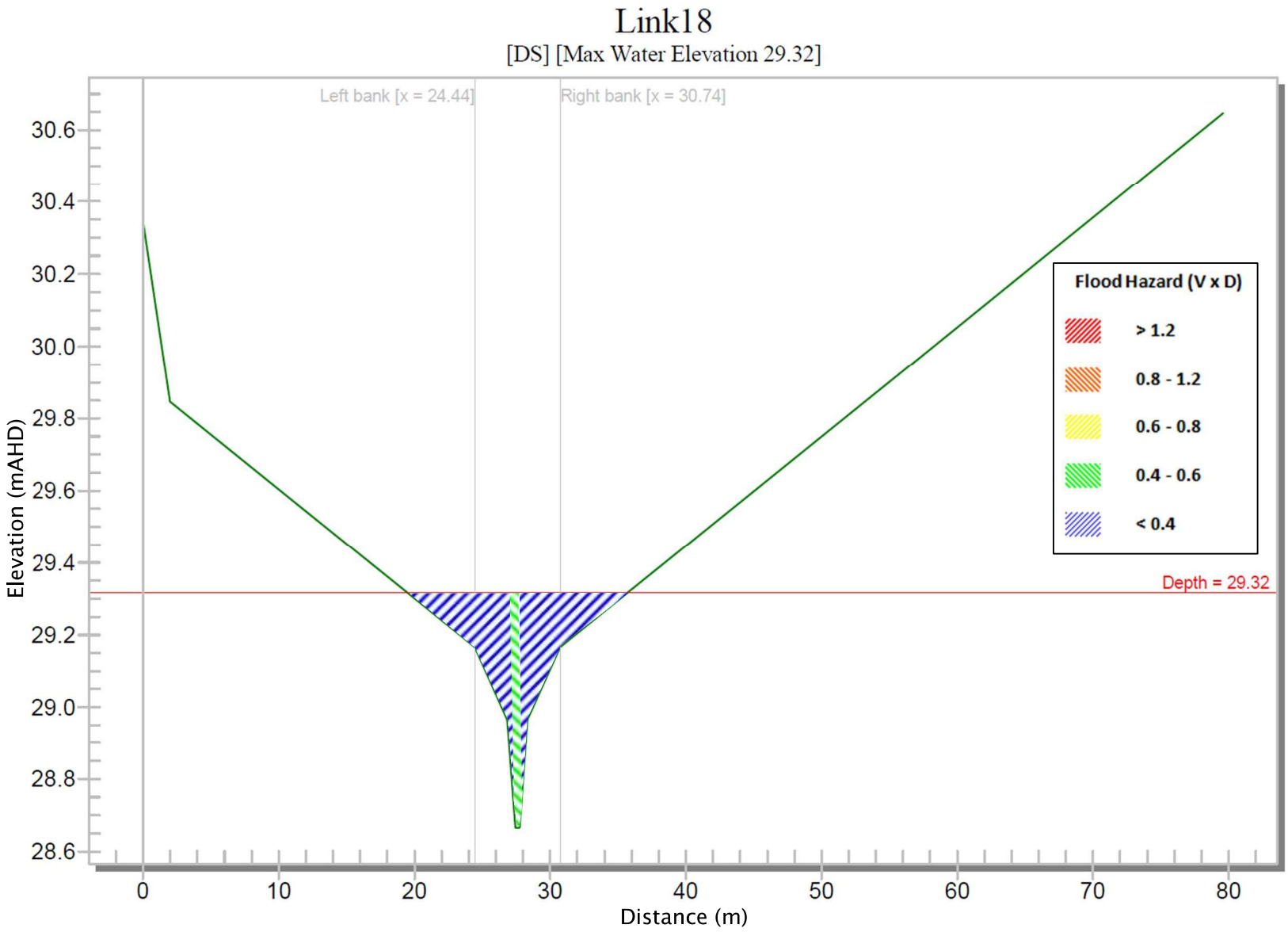


Plate 3: 1 year ARI Post-Development Indicative Hazard Analysis – Link 18 (2880 min duration)

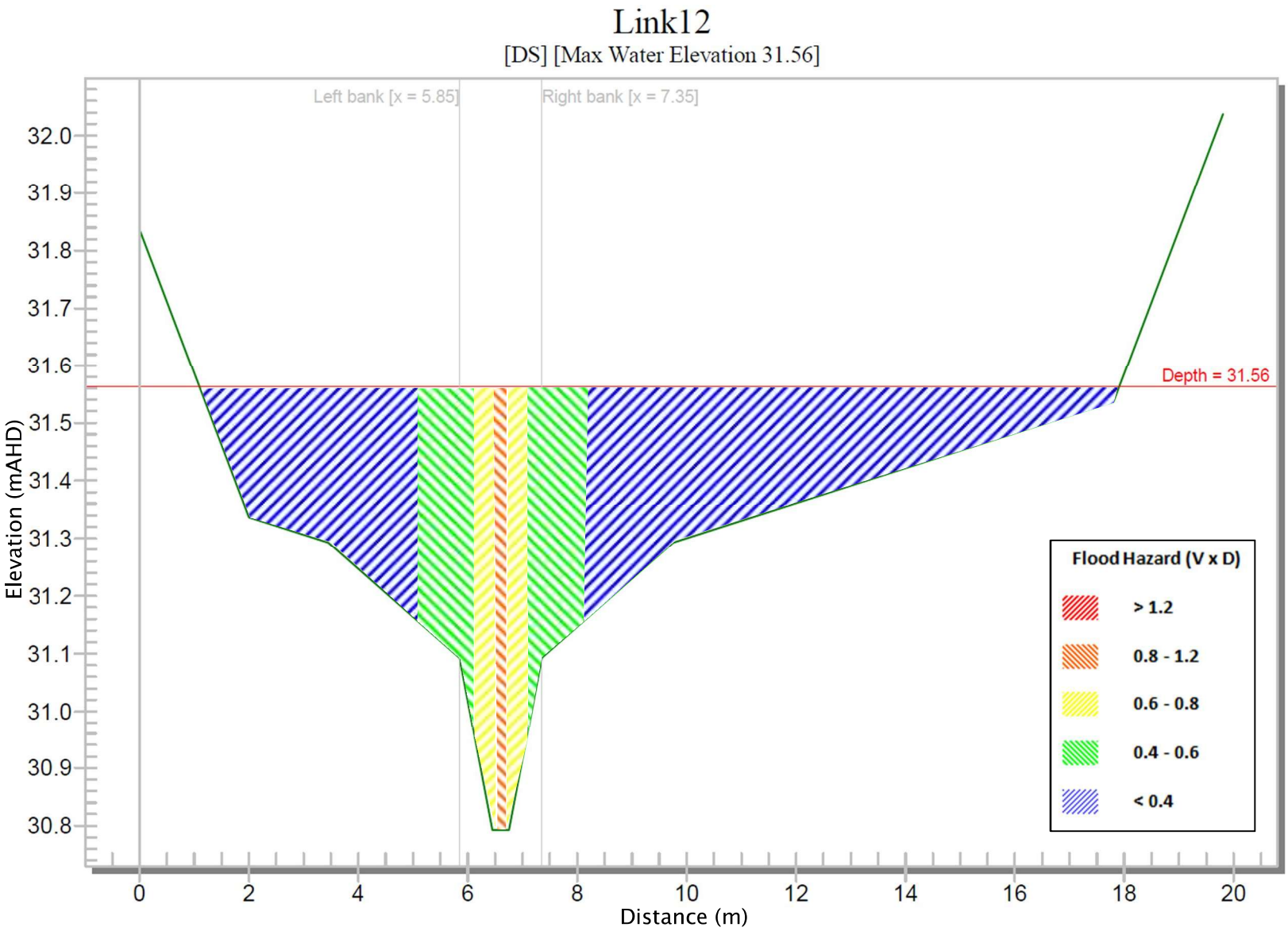


Plate 4: 5 year ARI Post-Development Indicative Hazard Analysis – Link 12 (360 min duration)

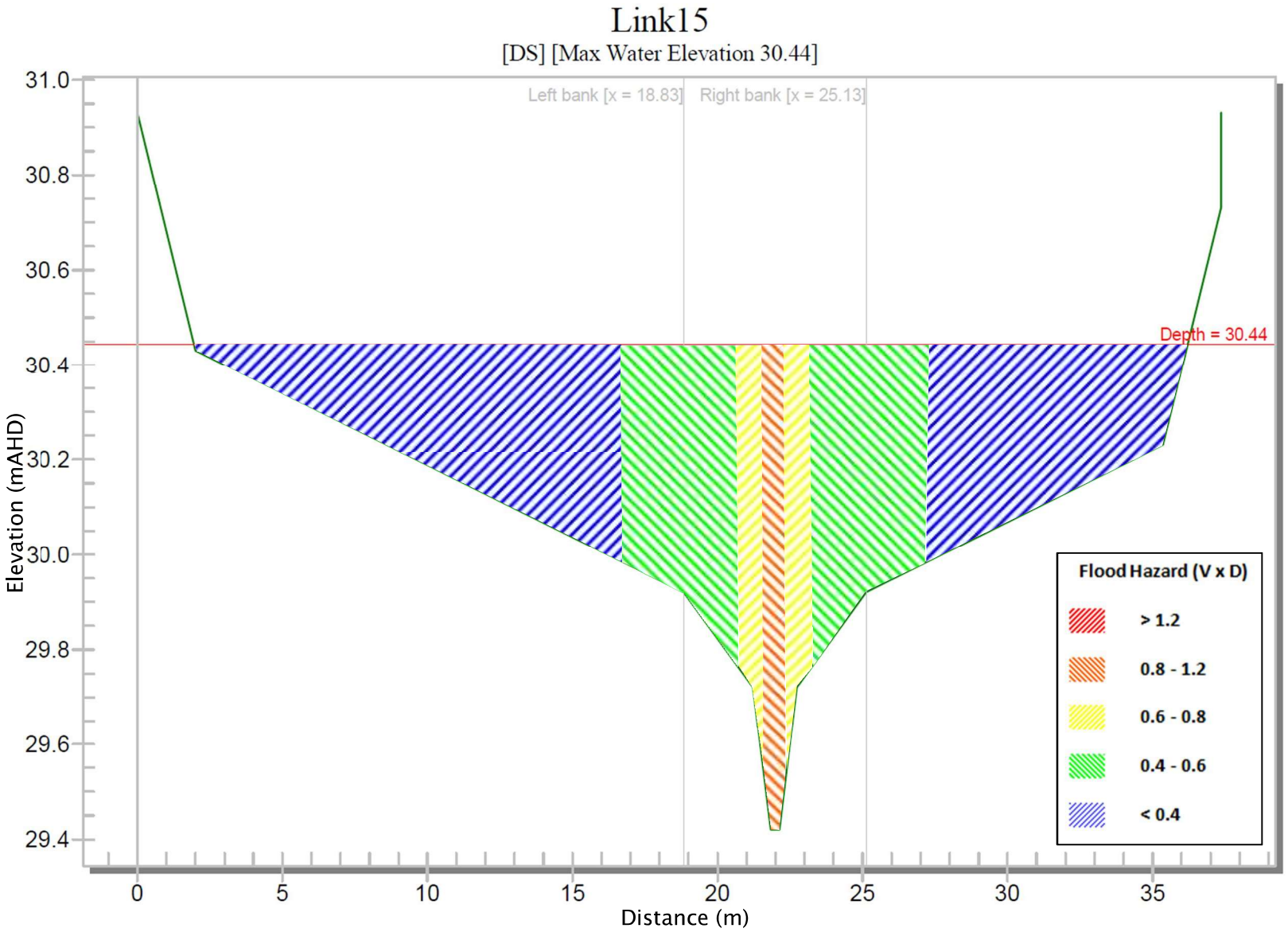


Plate 5: 5 year ARI Post-Development Indicative Hazard Analysis – Link 15 (2880 min duration)

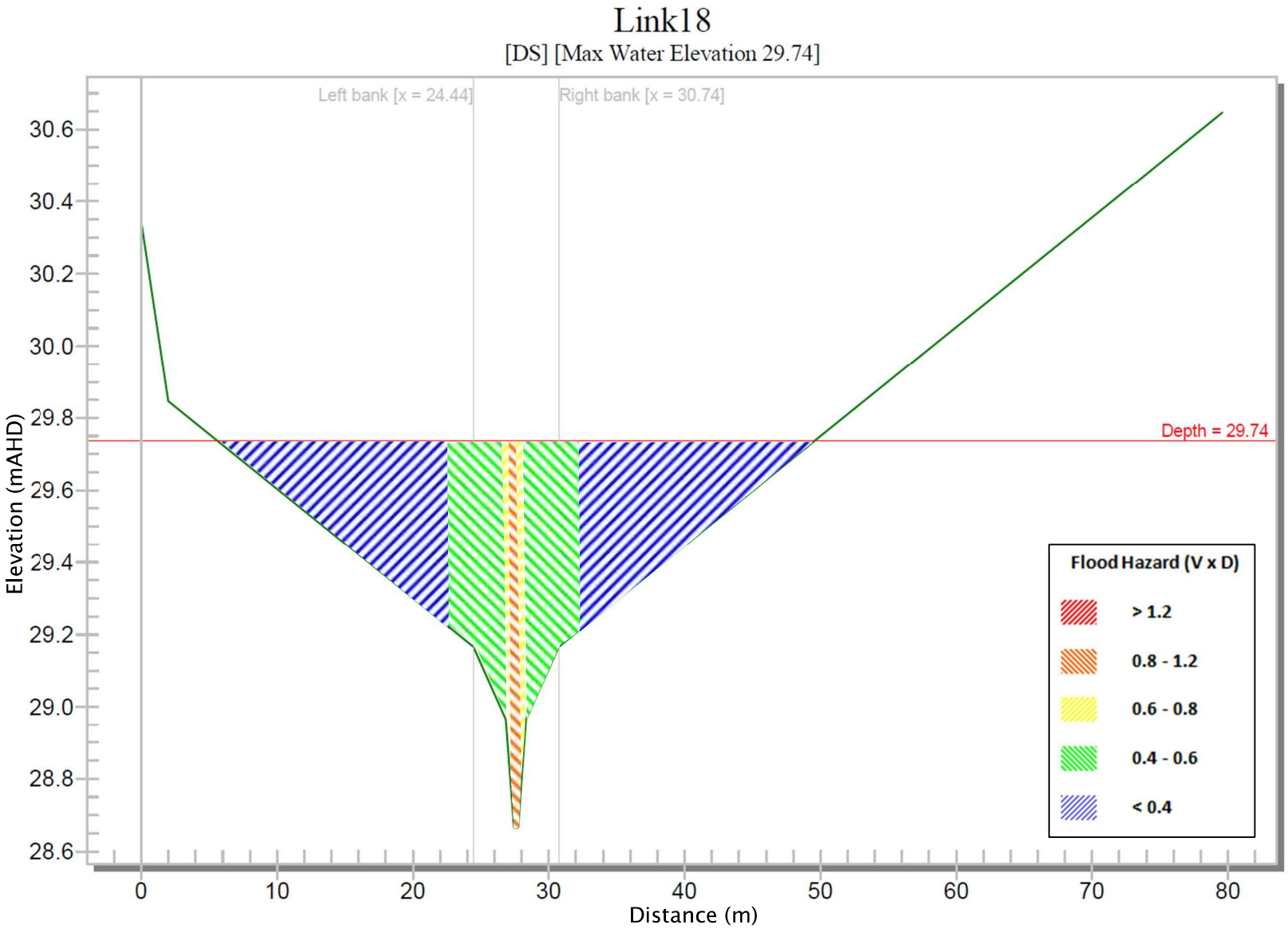


Plate 6: 5 year ARI Post-Development Indicative Hazard Analysis – Link 18 (2880 min duration)

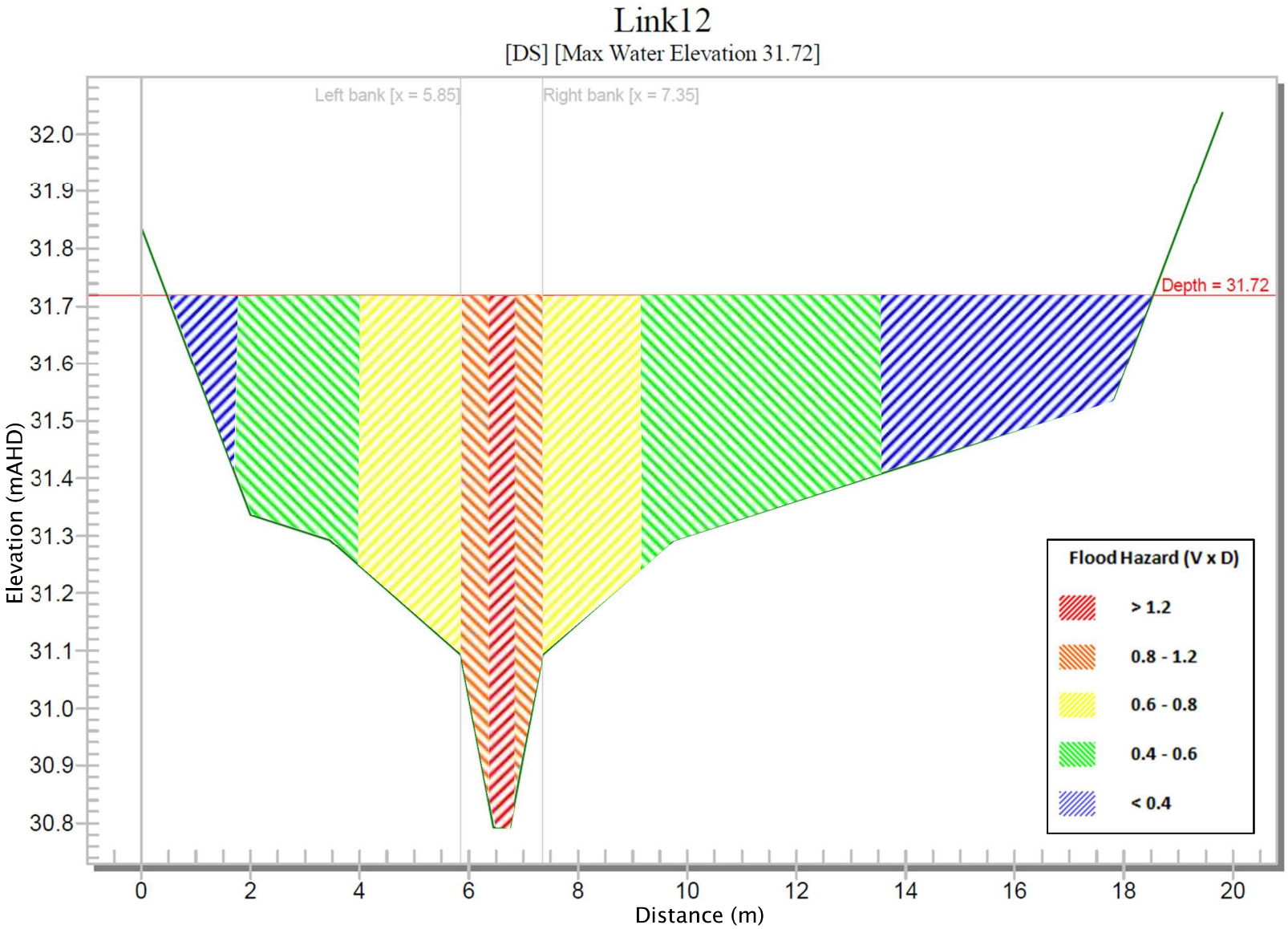


Plate 7: 100 year ARI Post-Development Indicative Hazard Analysis – Link 12 (60 min duration)

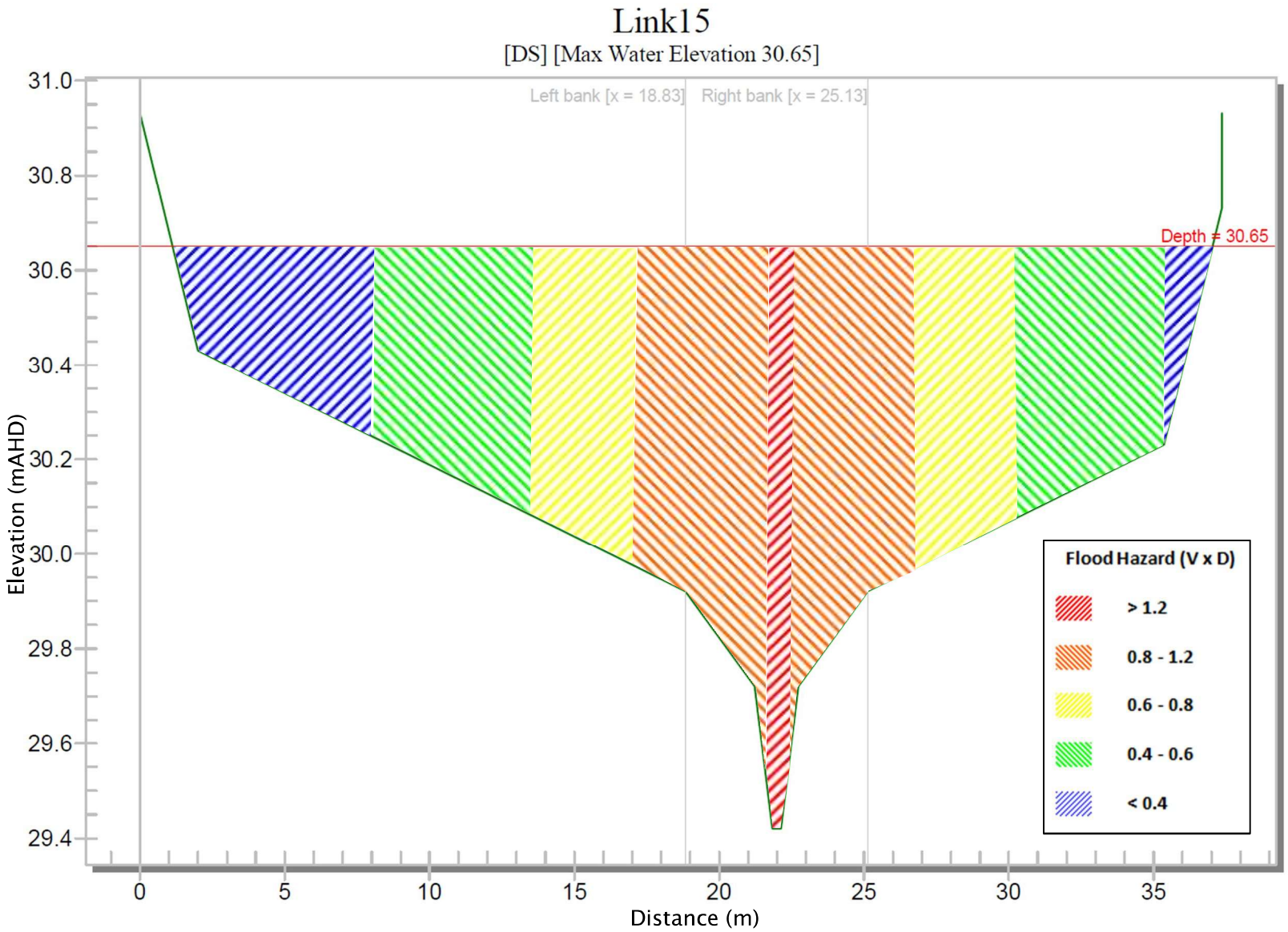


Plate 8: 100 year ARI Post-Development Indicative Hazard Analysis – Link 15 (360 min duration)

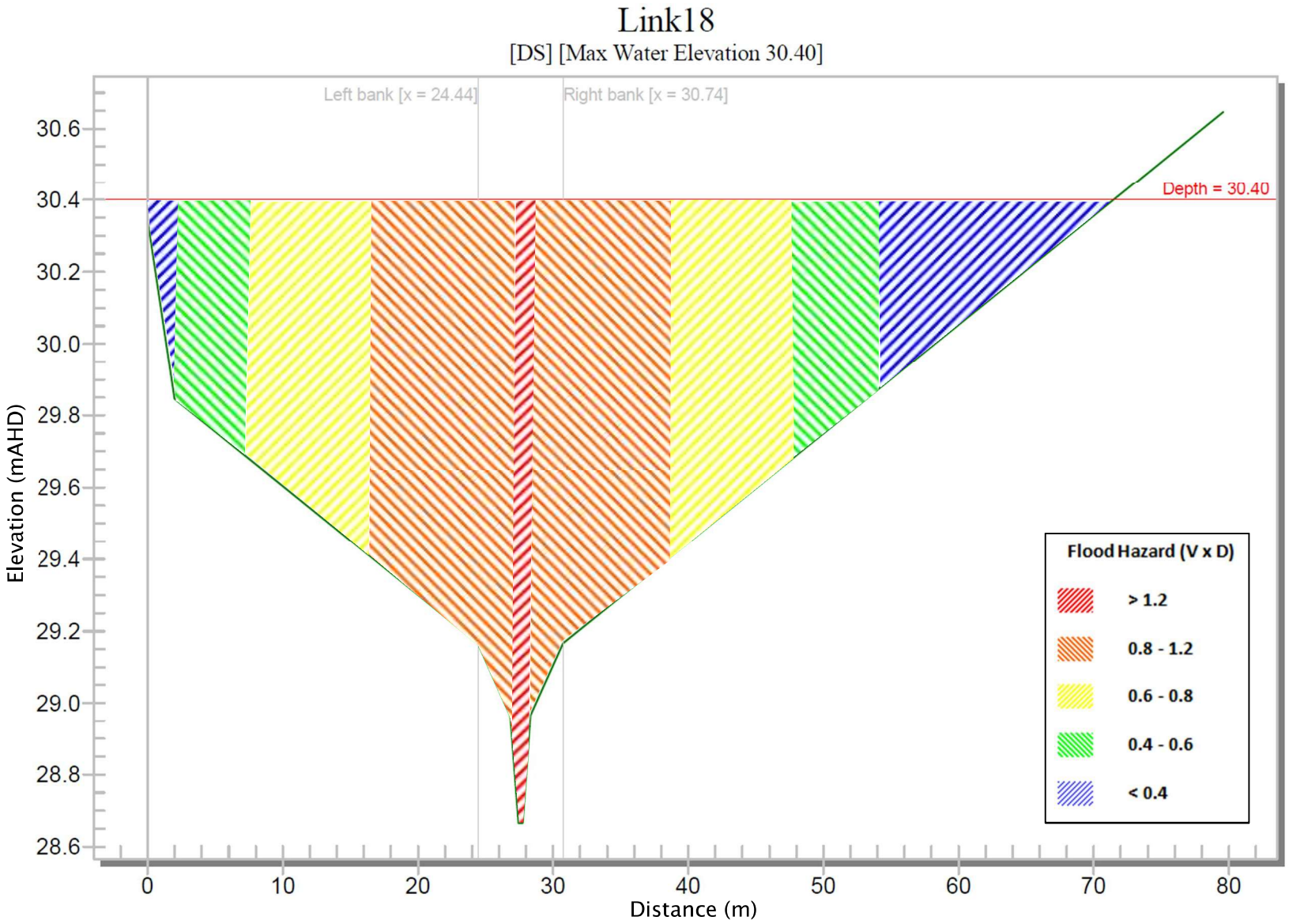


Plate 9: 100 year ARI Post-Development Indicative Hazard Analysis – Link 18 (360 min duration)

Appendix E
Shire of Serpentine Jarrahdale Engineering Services – Letter of Acceptance

All enquiries to Ruban Ganeshamoorthy on 9526 1191
Our ref: SJ993-02: AR:rg
Electronic ref: OC17/3827
Your ref: BAYARN01

Shire of Serpentine Jarrahdale

Sustainable. Connected. Thriving!

1 March 2017

Kristy Chandler
Cottera Environment
Level 3, 25 Prowse Street
West Perth WA 6005

Dear Kristy

Local Structure Plan – Serpentine Townsite – Lot 102 to 106, Rudall Street – Local Water Management Strategy – Technical Addendum - Revision 2 – Shire of Serpentine Jarrahdale Engineering Services – Letter of Acceptance

Thank you for the revised technical addendum for the abovementioned development, received by the Council office on 15 February 2017.

In accordance with the Better Urban Water Management (BUWM) Framework (WAPC, 2008) a Local Structure Plan is required to be supported by an approved LWMS prior to approval.

The Shire of Serpentine Jarrahdale' s Engineering Services wishes to advise that it is satisfied with the technical addendum for the above mentioned property to support the proposed Local structure plan modification.

If you have any questions about this matter please contact Ruban Ganeshamoorthy or the undersigned on (08) 9526 1191.

Yours sincerely

Alan Rajah
Manager Subdivisions

Cc. Jane Sturgess, Department of Water

a 6 Paterson Street, Mundijong WA 6123 t 08 9526 1111 f 08 9525 5441 e info@sjshire.wa.gov.au www.sjshire.wa.gov.au

Appendix F
Geotechnical report, Lots 611, 615 and 487 Arnold Road

Douglas Partners
Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on
Geotechnical Investigation

Proposed Residential Development
Lots 487, 611 & 615 Arnold Road, Serpentine, WA

Prepared for
MALF Corp Pty Ltd

Project 96660.00
September 2020



Douglas Partners
Geotechnics / Environment / Groundwater

Document History

Document details

Project No.	96660.00	Document No.	R.001.Rev1
Document title	Report on Geotechnical Investigation Proposed Residential Development		
Site address	Lots 487, 611 & 615 Arnold Road, Serpentine, WA		
Report prepared for	MALF Corp Pty Ltd		
File name	96660.00.R.001.Rev1.SERPENTINE Lots 487 611 and 615 Arnold Road		

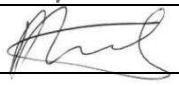
Document status and review

Status	Prepared by	Reviewed by	Date issued
Revision 0	Paul Hutchinson	Fred Verheyde	6 April 2020
Revision 1	Damian Jagoe-Banks	Dan Reaveley	17 September 2020

Distribution of copies

Status	Electronic	Paper	Issued to
Revision 0	1	-	Phil Cuttone, MALF Corp Pty Ltd
Revision 1	1	-	MALF Corp Pty Ltd

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

	Signature	Date
Author		17 September 2020
Reviewer		17 September 2020

bsi. ISO 9001 Quality Management
FS 604853

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36 O'Malley Street
Osborne Park WA 6017
Phone (08) 9204 3511

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Report on Geotechnical Investigation
Proposed Residential Development
Lots 487, 611 & 615 Arnold Road, Serpentine, WA

1. Introduction

This report presents the results of a geotechnical investigation undertaken for a proposed residential development at Lots 487, 611 & 615 Arnold Road, Serpentine, WA. The investigation was commissioned in an email dated 3 March 2020 by Phil Cuttone of Cuttone Property Group on behalf of MALF Corp Pty Ltd and was undertaken in accordance with Douglas Partners' proposal PER200065 dated 25 February 2020.

It is understood that the development of the site will include subdividing the land to create 52 new residential lots of approximately 1 ha each, with construction of new roads to service the lots and a central drainage swale.

The aim of the investigation was to assess the subsurface soil and groundwater conditions across the site and provide comments on:

- The soil conditions underlying the site.
- The depth to groundwater, if encountered.
- Comments on the suitability of the site for effluent disposal and recommendations on a suitable system types for on-site effluent disposal in accordance with AS/NZS 1547.
- Site classification in accordance with the requirements of AS 2870-2011.
- Suitable foundation systems for house construction.
- Site preparation requirements for house pads and pavement construction.
- A subgrade CBR for use in pavement design.
- Suitable pavement thickness design for the proposed subdivision roads.
- The infiltration rate of soils along the proposed drainage swale.

The investigation included the excavation of 32 test pits, the performance of eight in-situ infiltration tests and laboratory testing of selected samples. The details of the field work are presented in this report, together with comments and recommendations on the items listed above.

2. Site Description

The site is approximately 60 ha and is identified as Lots 487, 611 & 615 Arnold Road in Serpentine, Western Australia (Refer to Drawing 1, Appendix A). It is bounded by South Western Highway to the east, existing rural residential lots to the west and open paddocks to the north and south. The site comprises of parcels of land that lie on the north and south of Arnold Road. Vegetation across the site

mainly comprised grass. Wire and wooden pole fences separated the several existing paddocks and formed the boundary of the site.

Based on information obtained from publicly available LiDAR, the site surface levels range from approximately 31.5 m relative to Australian height datum (AHD) near the northern site boundary and rises to levels of approximately between RL 40 m AHD and RL 45 m AHD along the southern site boundary.

The Serpentine 1:50 000 Environmental Geology sheet suggests that shallow sub surface conditions in the western part of the site comprise sandy clay of the Guildford Formation. The eastern part of the site is shown to be underlain by gravelly sandy clay of colluvial origin with lenses of silt and gravel and quartz sand.

3. Field Work Methods

Field work was carried out on 10 to 12 March 2020 and comprised:

- Excavation of 32 test pits together with dynamic cone penetrometer (DCP) tests adjacent to the test pits; and
- In-situ infiltration testing at eight locations using both the constant head and falling head method.

The test pits (1 to 32) were excavated using an 8 tonne backhoe to depths of between 0.8 m and 2.5 m below existing site levels. The test pits were logged in general accordance with AS 1726-2017 by an experienced engineer from Douglas Partners. Samples were recovered at selected locations for material identification and subsequent geotechnical laboratory testing.

Dynamic cone penetrometer testing was carried out adjacent to each test pit location in accordance with AS 1289.6.3.2, to assess the in-situ density of the shallow soils.

The infiltration tests were performed using the constant head method within hand auger boreholes drilled adjacent to test locations 4, 8, 17, 19, 25, 27 and 32, at depths of 0.3 m and 0.35 m below the existing surface level, respectively. A falling head infiltration test was undertaken at a depth of 0.4 m within a borehole drilled adjacent to test location 28.

Test locations were determined using a hand-held GPS and are marked on Drawing 1 in Appendix A. Surface elevations at the test locations were obtained from LiDAR data and should be considered approximate. Levels on the test pit logs in Appendix B are quoted relative to the Australian Height Datum (AHD).

4. Field Work Results

4.1 Ground Conditions

Detailed logs of the ground conditions are presented in Appendix B, and should be read in conjunction with the notes defining descriptive terms and classification methods provided in Appendix A.

The ground conditions beneath the topsoil can be summarised as comprising thin and localised covers of silty sand colluvium, generally less than about 0.2 m thickness, overlying various clayey sandy gravelly colluvial soils of varied thicknesses, generally thicker in the eastern part of the site with thicknesses in excess of 2.5 m, in turn overlying various gravelly sandy clayey soils of the Guildford Formation. Both the colluvium and the ground from the Guildford Formation are locally laterised (both lateritic gravel and strongly indurated zones). The ground conditions across the site are generally hard and resulted in test pitting refusal at several locations when using an 8 tonne excavator. Owing to similarities between the Guildford Formation and the Colluvium, the ground conditions are further described below per soil type (rather than geological units), and selected soil units are shown on Drawing 2, Appendix B, for clarity of the description:

- **Unit 1 - TOPSOIL/ Silty SAND SM, occasionally Sandy SILT ML:** fine to medium grained sand content, dark grey-brown, varied low plasticity silt content, with rootlets, encountered to a depth of between 50 mm and 100 mm at most test locations.
- **Unit 2 - Silty SAND SM and Sandy SILT SM (Colluvium):** fine to medium grained sand, light grey-brown, low plasticity silt, varied gravel content encountered to depths of up to 0.35 m though generally to depths of between 0.15 m and 0.25 m at most test locations in the northern part of the site and occasionally elsewhere.
- **Unit 3 - SAND SP-SM, Sandy GRAVEL GP-GM (Colluvium):** fine to medium grained, light brown, generally trace of or with silt and/or clay, varied gravel content (gravel was laterite), generally dense to very dense, encountered to depths of between approximately 0.3 m and 0.8 m at test locations predominantly in the central southern part of the site (test locations 10, 13, 14, 28, 30 and 31 as shown on Drawing 2, Appendix A).
- **Unit 4 - Clayey SAND SC, Gravelly clayey SAND SC, Sandy CLAY CI, Clayey sandy GRAVEL GC (Colluvium and Guildford Formation):** fine to medium sand, generally medium plasticity fines, varied fine to coarse gravel content (gravel was laterite), with cobbles in some locations, various colours, dense to very dense or very stiff to hard, encountered underlying Unit 2 and Unit 3 at all locations, to the extent of the investigation except where underlain by the strata described below. Firm to stiff sandy clay was encountered between depths of 0.8 m and 1.8 m at test location 28.
- **Unit 5 - CLAY CH:** high plasticity, generally light grey or red-brown, with sand, hard, encountered from depths of between 0.5 m and 2.3 m at test locations 2, 5, 6, 12 and 18, all located on the eastern side of the site.
- **Unit 6 - LATERITE:** excavated as gravel and red-brown high strength cobbles from depths of 1.2 m at test location 8 and 0.6 m at test location 15. Gravel and cobbles of iron cemented laterite were encountered at numerous locations within a matrix of sandy clay and gravel. In most cases, the test pit encountered refusal due to hard digging within the lateritic material.

4.2 Groundwater

Groundwater was observed at test location 28 only at a depth of approximately 2.3 m (approximately RL 38.6 m AHD) during the field work undertaken on 10 and 11 March 2020.

The test pits were immediately backfilled following sampling, which precluded longer-term monitoring of groundwater levels from these locations.

It should be noted that groundwater levels are affected by climatic conditions and land usage, and will therefore vary with time.

4.3 Results of Infiltration Testing

Eight in situ infiltration tests were carried out: seven using the constant head method (test locations 4, 8, 17, 19, 25, 27 and 32) and one using the falling head method (test location 28). An estimated permeability value has been derived using the analytical method included in AS 1547-2012 for the constant head infiltration test data and using an analysis based on Hvorslev (1951) for the falling head infiltration test data.

Table 1 below summarises the permeability results.

Table 1: Summary of Permeability Analysis

Test Location	Depth (m)	Measured Permeability		In situ Conditions of Tested Material
		(m/s)	(m/day)	
4 [2]	0.35	0.4×10^{-5}	0.3	Dense silty sandy GRAVEL
8 [2]	0.3	8.3×10^{-5}	7	Very dense sandy CLAY/clayey SAND, trace silt
17 [2]	0.3	1.3×10^{-5}	1	Dense to very dense clayey SAND
19 [2]	0.3	14.4×10^{-5}	12	Dense clayey SAND
25 [2]	0.3	4.6×10^{-5}	4	Medium dense to dense clayey SAND, trace gravel
27 [2]	0.3	5.4×10^{-5}	4.5	Very dense gravelly, clayey SAND
28 [1]	0.4	4.2×10^{-5}	3.5	Medium dense SAND, with silt
32 [2]	0.3	5.3×10^{-5}	4.5	Dense clayey sandy GRAVEL

Notes: [1]: Falling head test
[2]: Constant head test

5. Laboratory Testing

A geotechnical laboratory testing programme has been scheduled with a NATA registered laboratory and comprises the determination of:

- the particle size distribution of ten samples;
- the Atterberg limits of six samples;
- the shrink swell index of three samples;
- the maximum modified dry density and California bearing ratio of four samples
- the Emerson class of three samples; and
- pH, electrical conductivity, cation exchange capacity, and phosphorus retention index of four samples.

The detailed test certificates are presented in Appendix C, with the results summarised in Tables 2 to 4.

Table 2: Results of Laboratory Testing for Soil Identification and Site Classification

Test	Depth (m)	Gravel (%)	Sand (%)	Fines (%)	LL (%)	PL (%)	PI (%)	LS (%)	lss (%)	Material
2	0.5	7	44	49	30	14	16	11	-	Sandy CLAY, trace gravel
2	0.6-0.7	-	-	-	-	-	-	-	0.8	Sandy CLAY, trace gravel
2	1.2	6	22	72	64	20	44	14.0	-	CLAY, with sand, trace gravel
10	0.7	4	38	58	38	15	23	8.5	-	Sandy CLAY, trace gravel
11	0.9-1.0	-	-	-	-	-	-	-	1.7	Clayey GRAVEL, with sand
11	1.1	55	25	20	46	19	27	9.0	-	Clayey GRAVEL, with sand
13	0.4	1	89	10	-	-	-	-	-	SAND, with silt, trace clay, trace gravel
17	0.3	0	85	15	-	-	-	-	-	Clayey SAND
25	0.3	1	70	29	30	15	15	5.5	-	Clayey SAND, trace gravel

Test	Depth (m)	Gravel (%)	Sand (%)	Fines (%)	LL (%)	PL (%)	PI (%)	LS (%)	Iss (%)	Material
27	0.5	36	43	21	40	18	22	8.0	-	Gravelly clayey SAND
28	0.8-0.9	-	-	-	-	-	-	-	1.2	Sandy CLAY
30	0.6	39	36	25	-	-	-	-	-	Clayey sandy GRAVEL
32	0.3	9	67	24	-	-	-	-	-	Clayey SAND, trace gravel

Notes The % fines is the amount of particles smaller than 75 µm.
The % sand is the amount of particles smaller than 2.36 mm and larger than 75 µm.
The % gravel is the amount of particles smaller than 63 mm and larger than 2.36 mm.
LL – Liquid Limit PL – plastic limit PI – plasticity index
LS – linear shrinkage Iss – shrink-swell index

Table 3: Results of Compaction and CBR Testing

Test Location	Depth (m)	Max. Dry Density (t/m^3)	Optimum Moisture Content (%)	CBR (%)	CBR Swell (%)	Material
10	0.7	2.03	11.0	11	0.0	Sandy CLAY, trace gravel
13	0.4	1.94	11.0	30	0.0	SAND, with silt, trace clay, trace gravel
25	0.3	1.89	10.5	15	1.0	Clayey SAND, trace gravel
30	0.6	2.08	10.5	25	1.0	Clayey sandy GRAVEL

Table 4: Summary of Laboratory Testing Results for Effluent Disposal

Test	Depth (m)	pH	EC (dS/m)	CEC (meq/100g)	PRI	Emerson Class	Material
3	0.8	5.0	0.11	3	1,090.0	6	Sandy CLAY, trace gravel
19	0.3	5.0	0.04	<1	1,080.0	5	Clayey SAND
22	0.4	5.1	0.01	<1	23.3		SAND, with clay
30	0.6	5.7	0.08	2	8.1	6	Clayey, sandy GRAVEL

Notes:
- pH and EC tests are carried out in 1:5 (soil:water) solution.
- EC: Electrical conductivity
- CEC: Cation exchange capacity in meq/100g.
- PRI: Phosphorous retention index

6. Proposed Development

It is understood that the development of the site will include subdividing the land to create 52 new residential lots of approximately 1 ha each, with construction of new roads to service the lots and a central drainage swale.

7. Geotechnical Comments

7.1 Site Suitability

Results of the investigation indicate that below the topsoil the site is generally underlain by a layer of silty or sandy soil (though this is absent in places), overlying clayey soils. Strong cemented laterite and lateritic gravel were encountered at several test locations.

Groundwater was encountered at test location 28 during the field work undertaken on 10 to 11 March 2020 at a depth of approximately 2.3 m (approximately RL 38.6 m AHD). Groundwater was not encountered at the other test locations. Aerial photographs indicate that the area around test location 28 is a local drainage low point and that surface water is frequently present. The seepage may be the result of perched groundwater resulting from infiltration of ponded water after recent rainfall.

From a geotechnical standpoint, the land is physically capable of development for the proposed development, provided that the provisions outlined in the subsequent subsections of the report are taken into consideration, and recommendations are implemented.

The main geotechnical constraints identified at this site, in relation to the proposed development as described in Section 6, include:

- The site has a general site classification of “Class S” in current condition. However, high plasticity clay (Unit 5, see Section 4.1) with higher reactivity than the sandy clay and clayey sand generally underlying the site, was encountered on the north eastern boundary of the site, as indicated on Drawing 2, Appendix A. A site classification of “Class M” is considered appropriate for that part of the site in current condition, as indicated on Drawing 3, Appendix A.
- Soft to firm clayey soils, and groundwater at a depth of 2.3 m, were encountered at test location 28. Aerial photographs indicate that the area around test location 28 is a local drainage low point and that surface water is often present in this area. The surface elevation of this area may need to be raised, or drainage into the area intercepted to avoid waterlogging of lots in that area.
- The presence of clayey soil and laterite may result in perched groundwater during the wet periods of the year, particularly in the area around test location 28, potentially impacting excavations below existing ground level.
- The site has several limitations for on-site disposal of sewage, including relatively low permeability in situ soils, potentially shallow perched groundwater, shallow hard pan (i.e. effectively impermeable horizon) and low cation exchange capacity and phosphorus retention index. These features will need to be taken into account when designing the onsite effluent disposal systems, as described in Section 8 below.
- The occurrence of locally cemented lateritic materials should be considered in the selection of excavation equipment during the earthworks.

7.2 Site Classification

The site is generally underlain by shallow sandy clay and clayey sand of low plasticity, generally with a thin surface layer of sandy or silty soils. High plasticity clay was encountered at some test locations along the eastern boundary of the site.

A general site classification of "Class S" in accordance AS2870-2011 is considered appropriate for the site in current condition, with characteristic surface movement (y_s) up to 20 mm.

However, high plasticity clay (Unit 5, see Section 4.1) with higher reactivity than the sandy clay and clayey sand generally underlying the site, was encountered on the north eastern boundary of the site, as indicated on Drawing 2, Appendix A. A site classification of "Class M" is considered appropriate for that part of the site in current condition, as indicated on Drawing 3, Appendix A. A site classification of "Class S" would be considered appropriate for such locations if a sand pad of 0.8 m thickness is created above the existing surface elevation beneath the proposed building envelopes.

A minimum thickness of 1.8 m of clean, non-reactive granular soil overlying the clayey soils (sand with clay, clayey sand, sandy clay, clay), including fill and natural soil, is required if a site classification of "Class A" is targeted. The depth to the clayey layer from the existing surface elevation, and therefore the thickness of non-reactive, granular fill required to amend the site classification, is variable across the area. Note that sand with a trace of clay or with clay should be regarded as reactive for the purposes of determining required fill thickness.

It should be noted that AS 2870-2011 applies to single houses, townhouses and the like classified as Class 1 and 10a under the Building Code of Australia. It also applies to light industrial and commercial buildings if they are similar in size, loading and superstructure flexibility to those designs included in AS 2870-2011. Advice on footings outside the application of AS2870-2011 is provided in Section 7.5 below.

7.3 Excavation Conditions

The encountered ground conditions generally comprise sand, silt, and hard clayey soils. Laterite was encountered in some locations, as summarised in Section 4.1.

Powerful conventional earthmoving equipment, such as 15 to 20 t excavator, is recommended for excavations across the site within the shallow soils, which were generally hard.

Laterite was encountered at several locations (discussed in Section 4.1), and the presence of laterite elsewhere below the site cannot be precluded. Excavation of lateritic ground generally resulted in hard digging and caused refusal in several test pits excavated using the 8 tonne excavator during the geotechnical investigation. Therefore, excavation of lateritic material, if required, may necessitate larger equipment such as a 20 tonne excavator with toothed bucket, ripping by a D9 dozer or breaking it up using a rock breaker or a ripping tyne.

Groundwater was encountered at a depth of 2.3 m at test location 28, which is located in a local drainage low point. If is considered that this water is perched infiltration water resulting from recent rains, and subsequent surface drainage into the area. It is possible that perched groundwater may occur generally across the site on low permeability layers, as is typical in Guildford Formation strata. Therefore, while

groundwater is generally unlikely to impact excavations up to 3 m during the dry months of the year, provision for dewatering should be considered for deeper excavation below the existing ground elevation, for excavation in the drainage low point around test location 28 and during the winter period.

7.4 Site Preparation

7.4.1 Site Stripping

All deleterious material, including (if encountered) waste, debris and vegetation should be stripped from the proposed development areas of the site.

Any tree roots remaining from clearing operations within the proposed development area should be completely removed to a depth of 0.6 m, and the excavation backfilled with material of similar geotechnical properties to the surrounding ground and suitably compacted.

7.4.2 Proof Rolling and Compaction

Following removal of unsuitable material, it is recommended that the exposed subgrade below house pads and pavements be proof rolled with a smooth drum roller of at least 12 tonnes deadweight in vibrating mode on sand subgrade or a pad foot roller on clay subgrade.

Any areas that show signs of excessive deformation during compaction should be compacted until deformation ceases or, alternatively, the poor quality material should be excavated and replaced with suitable structural filling and compacted. This may be particularly expected to occur in the drainage area around test location 28, where firm to stiff clayey soils were encountered.

Earthworks should be supervised by a Geotechnical Engineer.

7.4.3 Geotechnical Suitability for Re-use of In Situ Soils

Based on the nature of the material encountered during the investigation, it is anticipated that in situ sand excavated from the site should be generally geotechnically suitable for reuse as structural fill provided it is free from organic matter and particles greater than 150 mm in size. However, it should be noted that sand occurrence beneath the site is relatively limited, both in lateral extent and thickness, and therefore might not be practical for reuse owing to both limited volume and possible contamination during extraction by underling clayey soils and overlying topsoil. The sand typically contained some clay and therefore, would not be suitable for use to improve site classification, if required as discussed in Section 7.2 above.

The thin surficial silty sand and sandy silt may be suitable for reuse of fill. However, the material has a low permeability which may impact drainage design, and use of this material should be confined to deeper parts of fill areas, say below 2 m from finished surface, if any.

The laterite, clayey sand, sandy clay and clay, are not recommended for re-use as structural filling. Consideration may be given to using this material in landscaping areas, though the impact on permeability due to the fines content in these soils should be taken into consideration.

7.4.4 Imported Filling

If required, imported filling should comprise free draining, cohesionless, well graded sand that:

- contains less than 5% by weight of particles less than 75 microns in size;
- contains no particles greater than 150 mm in size; and
- is free of organic and other deleterious materials.

It is recommended that test certificates are reviewed and approved by the geotechnical engineer prior to importing material to site. Other materials than specified above may be suitable, following review and acceptance by a geotechnical engineer.

7.4.5 Fill Placement

Any fill should be placed in layers not exceeding 300 mm loose thickness and compacted near optimum moisture content with a roller of say 12 tonne deadweight. Care should be taken not to run heavy plant immediately adjacent to existing structures and services. It is recommended that earthworks be carried out with regular inspections by a geotechnical engineer.

7.4.6 Compaction Testing

Compaction control of the sand fill could be carried out using a Perth sand penetrometer (PSP) test in accordance with test method AS 1289.6.3.3. Fill within development areas (i.e. below house pads and pavements) should be compacted to achieve a minimum blow count of 8 blows per 300 mm penetration to a depth of not less than 1.0 m below foundation level.

The top 300 mm in the base of excavation in granular soils should be re-compacted using a vibratory plate compactor prior to construction of footings. Inspection of footing excavations by a geotechnical engineer is also recommended.

7.5 Shallow Foundations

Shallow foundation systems comprising slab, pad and strip footings should be suitable to support the proposed structures. Footings of buildings covered by AS 2870-2011 should be designed to satisfy the requirements of this standard for the suitable site classification discussed in Section 7.2, provided that site preparation is carried out as detailed in Section 7.4.

For structures not covered by AS 2870-2011, a presumptive maximum allowable bearing pressure of 150 kPa is suggested for pad footings up to 1.5 m wide and 120 kPa for strip footings up to 1.0 m wide founded at a minimum depth of 0.5 m, provided that site preparation is carried out as discussed in Section 7.4.

7.6 Culvert Foundations

It is understood that culverts will be required for the crossing of roads over the proposed drainage swale. Three culverts will be required, located approximately at test locations 10, 13 and 22.

The encountered ground conditions at all three test locations, from depths of between 0.5 m and 0.8 m to the extent of the investigation at a depth of 2.5 m, comprised hard sandy clay. A presumptive maximum allowable bearing pressure of 150 kPa is suggested for the culvert foundations.

As the formation will be within clayey soils, it is recommended that the culverts are constructed during the dry period of the year and that the base of the foundation excavations be inspected by a geotechnical engineer prior to footing construction.

7.7 Pavement Design Parameters

Based on observation of the shallow soils underlying the site (sand, silt, clayey sand, sandy clay), results of laboratory testing, and Douglas Partners' experience, and assuming the recommendations in Section 7.4 are implemented, a subgrade California bearing ratio (CBR) of 4% is suggested for pavement design for subgrades in these natural soils, provided that the subgrade is compacted to not less than 95% of modified maximum dry density. Although lower than the values suggested by the laboratory testing, this recommended design value is consistent with the variability of the encountered ground conditions and our experience with similar subgrade.

For subgrades comprising sand fill complying with the specification provided in Section 7.4.4, a subgrade California bearing ratio (CBR) of 10% is suggested provided the thickness of sand fill is at least 0.5 m below formation level and the subgrade is compacted to not less than 95% of modified maximum dry density.

The clay encountered on the eastern boundary of the site was at depth and would not impact pavement design in the current site condition. However, if earthworks expose the clay and it subsequently forms the subgrade for pavement, as may be the case at some locations (e.g. near test location 6 where the clay was at only 0.5 m depth), a subgrade California bearing ratio (CBR) of 2% is recommended from our experience with similar materials in the area assuming the recommendations in Section 7.4 are implemented.

7.8 Design Pavement Thickness

Traffic loading for the pavements has been determined in accordance with Austroads Guide to Pavement Technology – Part 2: Structural Pavement Design (2017). With consideration of the road layout of the proposed development, a street category of 'Local Access with Buses' (Austroads, 2017 – Figure 12.1) has been selected for the proposed pavements. In line with this street type and the Austroads (2017) guidelines, a design traffic of 1.5 x 10^5 Equivalent Standard Axles (ESA) has been assumed, based on a 40 year design life.

The thickness design has been undertaken in accordance with Austroads Guide to Pavement Technology – Part 2: Structural Pavement Design (2017), and also taking into account the minimum pavement thickness suggested in IPWEA (2017) Local Government Guidelines for Subdivisional Development.

The results of the analysis indicating the minimum total pavement thickness and minimum thickness of basecourse quality material for the proposed pavements are presented in Table 5 below, assuming site

preparation is carried out as outlined in Section 7.4. Two scenarios of subgrade were assessed: the subgrade consists of in situ natural materials with a CBR of no less than 4%, and the pavement subgrade comprises at least 0.5 m thickness of sand fill above the natural ground with an equivalent CBR of 10%.

Table 5: Design Pavement Thicknesses

Subgrade Scenario	Pavement Design Life	Total Granular Thickness (mm)	Minimum Basecourse Thickness (mm)	Sub Base Thickness (mm)
Natural Subgrade CBR=4%	40 years	360	110	250
Sand Fill, CBR=10%, 0.5 m thick minimum	40 years	260	110	150

Dense graded asphalt is suggested as bituminous surfacing, although other surfacing treatments (e.g. sprayed seal) can be considered. A minimum asphalt thickness of 25 mm is suggested. A prime or primer seal should be placed on the prepared basecourse prior to laying the asphalt.

A suitable pavement basecourse material could consist of a granitic crushed rock base (CRB). A suitable sub-base could be formed using crushed limestone. Alternatively, the total granular thickness could comprise laterite, although such option increases the risk of asphalt cracking in the long term, and therefore a sprayed seal surfacing treatment (rather than asphalt) would be recommended as surfacing treatment. MRWA Specification 501 should be consulted for suitable pavement material specifications.

The basecourse should be compacted to achieve a dry density ratio of not less than 99% relative to modified compaction for CRB, and be dried back to a moisture content of less than 60% of OMC, prior to application of the prime or primerseal. If a lateritic basecourse is selected, it should be compacted to not less than 98% relative to modified compaction and dried back to 70% or drier prior to placing the bituminous surfacing.

The sub base should be compacted to achieve a dry density ratio of not less than 94% relative to modified compaction. The sub base should be dried back to 85% or less prior to placing the basecourse.

It is also recommended that adequate surface and subsoil drainage be implemented in order to direct water away from the pavement to avoid saturation of the proposed pavement that could result in developing pore pressure under trafficking and subsequent pavement failure. No water should be allowed to pond under the pavement.

With boxed construction, if utilised, the provision of adequate drainage, during construction and during service life, is particularly important. The provision of adequate cross falls on the surfaces of the subgrade and subsequent pavement layers will facilitate run-off of both surface water during construction and water subsequently trapped in the pavement, hence minimising the potential for softening of the materials (Austroads, 2017).

Owing to the variability of ground conditions across this site, it is recommended that the subgrade be inspected during construction by a geotechnical engineer prior to pavement construction, in order to identify possible weak soils that do not meet the design assumptions.

7.9 Stormwater Disposal and Drainage

The shallow ground conditions generally comprise a thin sandy/silty layer overlying clayey soils, with these clayey soils at or near the surface in some locations. Laterite were encountered at two test locations and may be present elsewhere.

Groundwater was encountered at test location 28 during the investigation undertaken on 10 and 11 March 2020. The area around test location 28 appears, from aerial photographs, to be a local drainage low point in the current site condition.

Eight in situ infiltration tests were undertaken, as described in Section 4.2 above, in predominantly sandy or gravelly soils (including clayey sand and clayey sandy gravel). The estimated permeability values arising from the tests ranged between 0.4 m/day and 12 m/day.

The site is underlain by a range of variable soils (e.g. various sands and silts, clayey sand, sandy clay, clay and laterite). A permeability value of 5 m/day is suggested for sand described as light grey or grey, with a trace of silt. A permeability of 0.1 m/day is estimated for the encountered sand, silt and clayey sand allowing for potential variability in the materials and reduction of permeability following compaction operations.

The encountered sandy clay, clay and laterite should be considered impermeable for the purposes of drainage design. The encountered occurrence of laterite and clay is indicated in Drawing 2, Appendix A.

On-site stormwater disposal using soakwells, sumps and drainage basins is not considered suitable at this site in current condition due to the presence of near surface, low permeability soils and the potential for shallow perched groundwater during the wet period of the year. However, if the site is filled to sufficient elevation with clean sand above maximum groundwater levels then on-site stormwater disposal using soakwells, sumps and drainage basins could be considered, provided proximity of the groundwater table, the presence of low permeability soils, water mounding on low permeability layers and lateral flow of infiltrated water within the placed sand fill and possible impact on adjacent land, are considered in the design.

8. Site and Soil Effluent Disposal Preliminary Assessment

8.1 Site and Soil Characteristics

Site characteristics observed during the field work and soil properties determined during subsequent laboratory testing have been assessed in relation to the anticipated limitations that they pose to onsite disposal of domestic effluent.

For this assessment, reference has mostly been made to AS1547-2012 and the Government Sewerage Policy, State Government of Western Australia, September 2019, amongst other documents whose references are listed in Section 8 of this report.

Site and soil characteristics, including any encountered limitations for effluent disposal within the site, are discussed below.

8.1.1 Soil Permeability

Saturated hydraulic conductivity (permeability) is a measure of the ability of soil to transmit water based on soil properties such as structure, texture and porosity. The soil types noted within the test pits and boreholes were interbedded layers of sand, silt, clayey sand and sandy clay, generally very stiff to hard or dense to very dense.

Infiltration testing at the site, using the constant head method in accordance with AS1547-2012, indicate generally low soil permeability with between approximately 0.3 m/day approximately 2 m/day and 12 m/day recorded in the shallow, surficial sandy and gravelly soils (including clayey sand and clayey sandy gravel).

Given the interbedding of the shallow mixed soils, including low permeability clayey soils, with no persistent strata discernible, it is suggested that a soil permeability category Group 4 (weakly structured) (with reference to AS 1547-2012 Tables 5.1 and E1) is assumed and a preliminary design permeability of 0.1 m/day is adopted for the natural sand, silt, clayey sand and clayey sandy gravel ground underlying site.

The relatively low permeability of permeability category Group 4 soils should be taken into account in designing the size of the irrigation area. The encountered soils were generally dense to very dense and or very stiff to hard.

If the required area of infiltration is too large, based on the in situ soils, a layer of imported sand could be placed either above the current ground surface. The permeability of clean sand meeting the specification in Section 7.4.4 above could typically be assumed to be approximately 5 m/day. However, the actual permeability would depend on the properties of the imported material and should be determined once a source of material is established.

A soil permeability category Group 5 (massive) is considered suitable for sandy clay, clay and laterite encountered along the eastern boundary of the site. These soils should be regarded as impermeable for drainage or sewage disposal design, as discussed in Section 7.8.2 below. Where sandy clay, clay or laterite is present within 0.5 m of the ground surface, consideration may be given to replacing the shallow soils, or raising the existing ground surface, with more permeable fill material, as further discussed in Sections 8.1.2 and 8.2 below.

8.1.2 Depth to Hardpan

The encountered sandy clay (part of Unit 5), clay (Unit %) and laterite (Unit 6) are regarded as hardpan and impermeable for drainage or sewage disposal design.

To allow on-site disposal of sewage where shallow sandy clay, clay or laterite is currently present within 0.5 m of the ground surface, either:

- the sandy clay, clay or laterite should be excavated and replaced with sand; or
- the elevation of the site should be raised using sand to provide sufficient depth of soil above the clay or sandy clay for drainage to occur.

8.1.3 Depth to Groundwater

Groundwater was encountered at test location 28 (which lies within a local drainage low point) during the field work undertaken on 10 and 11 March 2020, but not elsewhere.

However, It is possible that perched groundwater will collect on the lower permeability materials such as sandy clay and clay in the winter period. Therefore, the groundwater table is considered a moderate limitation for on-site disposal of sewage. Investigation of groundwater levels at the end of winter is suggested to further assess possible impacts of groundwater levels for on-site sewage disposal, particularly the low lying areas of the site such as around test location 28. Groundwater levels are affected by climatic conditions and soil permeability and groundwater levels higher than those encountered during the field work may occur.

8.1.4 Coarse Fragments

Coarse fragments are defined as particles greater than 2 mm in AS 1547-2012. The abundance of coarse fragments in the soils encountered underlying the site is generally few to common, though rising to many in some places, with the coarse fragments being fine to coarse gravel, in accordance with Table E2, AS 1547-2012.

The abundance of gravel-sized coarse fragments is not considered a limitation at this site, and has been taken into account in the assessment of the excavatability of the site in Section 7.3 and the soil permeability categories described in Section 7.8.1 above.

8.1.5 Slope

The site slopes generally slopes gently from south to north, with gradients estimated to be less than 5%. Slopes of this gradient are not considered a limitation to on-site disposal of sewage.

8.1.6 Dispersivity

Laboratory testing of soil samples taken from the site indicate an Emerson class of 5 or 6. Therefore, the soils generally have a low potential for dispersion and dispersivity does not form a limitation for on-site sewage disposal at the site.

8.1.7 pH

Laboratory testing indicates a pH values of between 5 and 5.7. Therefore, pH is not considered a constraint for on-site sewage disposal at the site.

8.1.8 Electrical Conductivity

Laboratory testing indicates that the electrical conductivity of soils underlying the site is less than 0.11 dS/m and therefore electrical conductivity is not a limitation to on-site sewage disposal.

8.1.9 Cation Exchange Capacity

The cation exchange capacity (CEC) is the total number of cations a soil can retain on its absorbent complex at a given pH, and is therefore a good measure of a soil ability to retain specific pollutants. The laboratory tests carried out on the samples collected the site, indicate CEC values of less than 3 meq/100g or cmol+/kg. A cation exchange capacity of less than 5 cmol+/kg is considered as a major limitation for on-site effluent disposal and a value of more than 15 cmol+/kg Is typically recommended. Therefore secondary treatment of effluent, using equipment such as aerobic treatment units (ATU) is required. Alternatively, an elevated mound constructed from amended soil could be adopted, as described in Section 8.2 below.

8.1.10 Phosphorus Retention Index

The laboratory test carried out on samples collected from the site indicate a highly variable phosphorus retention index (PRI) of between 8 and 1,090 for the variable soils underlying the site, indicating the phosphorus sorption rate varies considerably across the site. It is suggested that the PRI is considered a major limitation for on-site primary sewage disposal. Therefore secondary treatment of effluent, using equipment such as aerobic treatment units (ATU) is recommended at this stage. Investigations within designated irrigation areas once these have been determined may indicate that the PRI in some locations is acceptable. Alternatively, an elevated mound constructed from amended soil could be adopted, as described in Section 8.2 below.

8.2 On-site Wastewater Management Options

Owing to the occurrence of soils with the limitations on permeability, perched ground water, hard pan, Cation Exchange Index and Phosphorus Retention Index mentioned above, it is suggested at this preliminary that the treatment of the primary effluent is undertaken to produce secondary quality effluent, prior to on-site disposal over the land surface.

Several treatment options are possible and include the following:

- Aerobic Treatment Unit (ATU);
- sand filters; and
- closed cell (amended soil) evapo-transpiration systems.

The effluent treatment system selected for use should be approved by the WA Department of Health.

Site specific investigations within irrigation areas, once these have been determined, could be undertaken to potentially re-evaluate the need for an ATU or similar, though it is considered likely that an ATU or similar will generally still be required.

As noted in Section 7.1.1 the soil permeability adopted for design could be increased if a layer of clean sand fill is either placed above the existing ground level, or some of the in situ soil is removed and replaced with clean sand.

Alternatively, an elevated mound could be used, raising the infiltration above existing surface level, constructed with amended soil, which is a material designed to have the capability to accommodate primary effluent. The elevated mound system should be designed by an experienced on-site sewage system designer.

8.3 Conclusions on Site Suitability for Effluent Disposal

The site is considered suitable for the disposal of domestic effluent in general accordance with AS1547-2012, local government conditions and WA Department of Health, provided that the limitations described in Section 8.1 are addressed during the design and selection of the effluent treatment systems and that treatment of primary effluent is undertaken.

As there are a variety of Department of Health WA approved proprietary systems available, the choice of system is ultimately made by the purchaser of the properties within the guidelines of AS 1547:2012, local government authorities, the WA Department of Health and the site characteristics described above.

9. References

1. Australian Standard AS 1289-2000, Methods of Testing Soils for Engineering Purposes.
2. Australian Standard AS 1289.6.3.3-1999, Soil Strength and Consolidation Tests-Determination of the Penetration Resistance of a Soil – Perth Sand Penetrometer Test.
3. Australian Standard AS 1726-2017, Geotechnical Site Investigation.
4. Australian Standard AS 2870-2011, Residential Slabs and Footings.
5. Department of Environment, Perth Groundwater Atlas, Second Edition, December 2004.
6. Code of Practice for the Design, Manufacture, Installation and Operation of Aerobic Treatment Unit (ATUs) - November 2001.
7. Environment & Health Protection Guidelines: On-site Sewage Management for Single Households - January 1998.
8. Australian Standard AS 1547-2012, On-site Domestic-wastewater Management.
9. Government Sewerage Policy, September 2019.
10. Designing and Installing On-site Wastewater Systems, Sydney Catchment Authority, 2012.

11. Code of Practice for Onsite Sewage Management, Consultation Draft, November 2012.

10. Limitations

Douglas Partners (DP) has prepared this report for this project at Lots 487, 611 and 615 Arnold road, Serpentine, WA in accordance with DP's proposal dated 25 February 2020 and acceptance received from Phil Cuttone of Cuttone Property Group on behalf of MALF Corp Pty Ltd dated 3 March 2020. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Cuttone Property Group and MALF Corp Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The scope for work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of filling of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively

of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

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Appendix A

About This Report
Drawing

About this Report

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Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Sampling Methods

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Sampling

Sampling is carried out during drilling or test pitting to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

Soil Descriptions

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Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are generally based on Australian Standard AS1726:2017, Geotechnical Site Investigations. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	19 - 63
Medium gravel	6.7 - 19
Fine gravel	2.36 – 6.7
Coarse sand	0.6 - 2.36
Medium sand	0.21 - 0.6
Fine sand	0.075 - 0.21

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

The proportions of secondary constituents of soils are described as follows:

In fine grained soils (>35% fines)

Term	Proportion of sand or gravel	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	>30%	Sandy Clay
With	15 – 30%	Clay with sand
Trace	0 - 15%	Clay with trace sand

In coarse grained soils (>65% coarse)
- with clays or silts

Term	Proportion of fines	Example
And	Specify	Sand (70%) and Clay (30%)
Adjective	>12%	Clayey Sand
With	5 - 12%	Sand with clay
Trace	0 - 5%	Sand with trace clay

In coarse grained soils (>65% coarse)
- with coarser fraction

Term	Proportion of coarser fraction	Example
And	Specify	Sand (60%) and Gravel (40%)
Adjective	>30%	Gravelly Sand
With	15 - 30%	Sand with gravel
Trace	0 - 15%	Sand with trace gravel

The presence of cobbles and boulders shall be specifically noted by beginning the description with 'Mix of Soil and Cobbles/Boulders' with the word order indicating the dominant first and the proportion of cobbles and boulders described together.

Soil Descriptions

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	VS	<12
Soft	S	12 - 25
Firm	F	25 - 50
Stiff	St	50 - 100
Very stiff	VSt	100 - 200
Hard	H	>200
Friable	Fr	-

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	Density Index (%)
Very loose	VL	<15
Loose	L	15-35
Medium dense	MD	35-65
Dense	D	65-85
Very dense	VD	>85

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Extremely weathered material – formed from in-situ weathering of geological formations. Has soil strength but retains the structure or fabric of the parent rock;
- Alluvial soil – deposited by streams and rivers;
- Estuarine soil – deposited in coastal estuaries;
- Marine soil – deposited in a marine environment;
- Lacustrine soil – deposited in freshwater lakes;
- Aeolian soil – carried and deposited by wind;
- Colluvial soil – soil and rock debris transported down slopes by gravity;
- Topsoil – mantle of surface soil, often with high levels of organic material.
- Fill – any material which has been moved by man.

Moisture Condition – Coarse Grained Soils

For coarse grained soils the moisture condition should be described by appearance and feel using the following terms:

- Dry (D) Non-cohesive and free-running.
- Moist (M) Soil feels cool, darkened in colour.
  Soil tends to stick together.
  Sand forms weak ball but breaks easily.
- Wet (W) Soil feels cool, darkened in colour.
  Soil tends to stick together, free water forms when handling.

Moisture Condition – Fine Grained Soils

For fine grained soils the assessment of moisture content is relative to their plastic limit or liquid limit, as follows:

- 'Moist, dry of plastic limit' or 'w <PL' (i.e. hard and friable or powdery).
- 'Moist, near plastic limit' or 'w ≈ PL (i.e. soil can be moulded at moisture content approximately equal to the plastic limit).
- 'Moist, wet of plastic limit' or 'w >PL' (i.e. soils usually weakened and free water forms on the hands when handling).
- 'Wet' or 'w ≈LL' (i.e. near the liquid limit).
- 'Wet' or 'w >LL' (i.e. wet of the liquid limit).

Symbols & Abbreviations

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Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	Pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	Lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

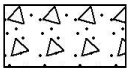
Symbols & Abbreviations

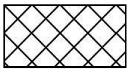
Graphic Symbols for Soil and Rock

General

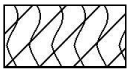

Asphalt

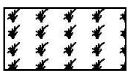

Road base

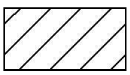

Concrete

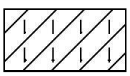

Filling

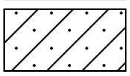
Soils


Topsoil

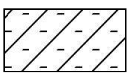

Peat

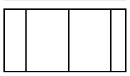

Clay

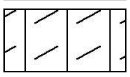

Silty clay


Sandy clay


Gravelly clay


Shaly clay


Silt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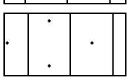
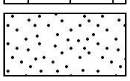
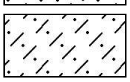
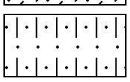
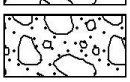

Sandy silt

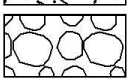

Sand

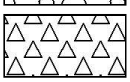

Clayey sand


Silty sand


Gravel


Sandy gravel


Cobbles, boulders

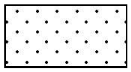

Talus

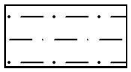
Sedimentary Rocks

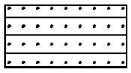

Boulder conglomerate

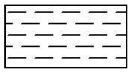

Conglomerate


Conglomeratic sandstone

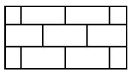

Sandstone


Siltstone

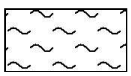

Laminite

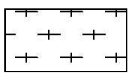

Mudstone, claystone, shale

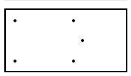

Coal


Limestone

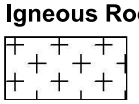
Metamorphic Rocks

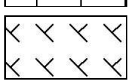

Slate, phyllite, schist

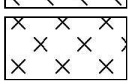

Gneiss

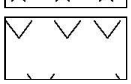

Quartzite

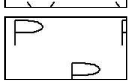
Igneous Rocks

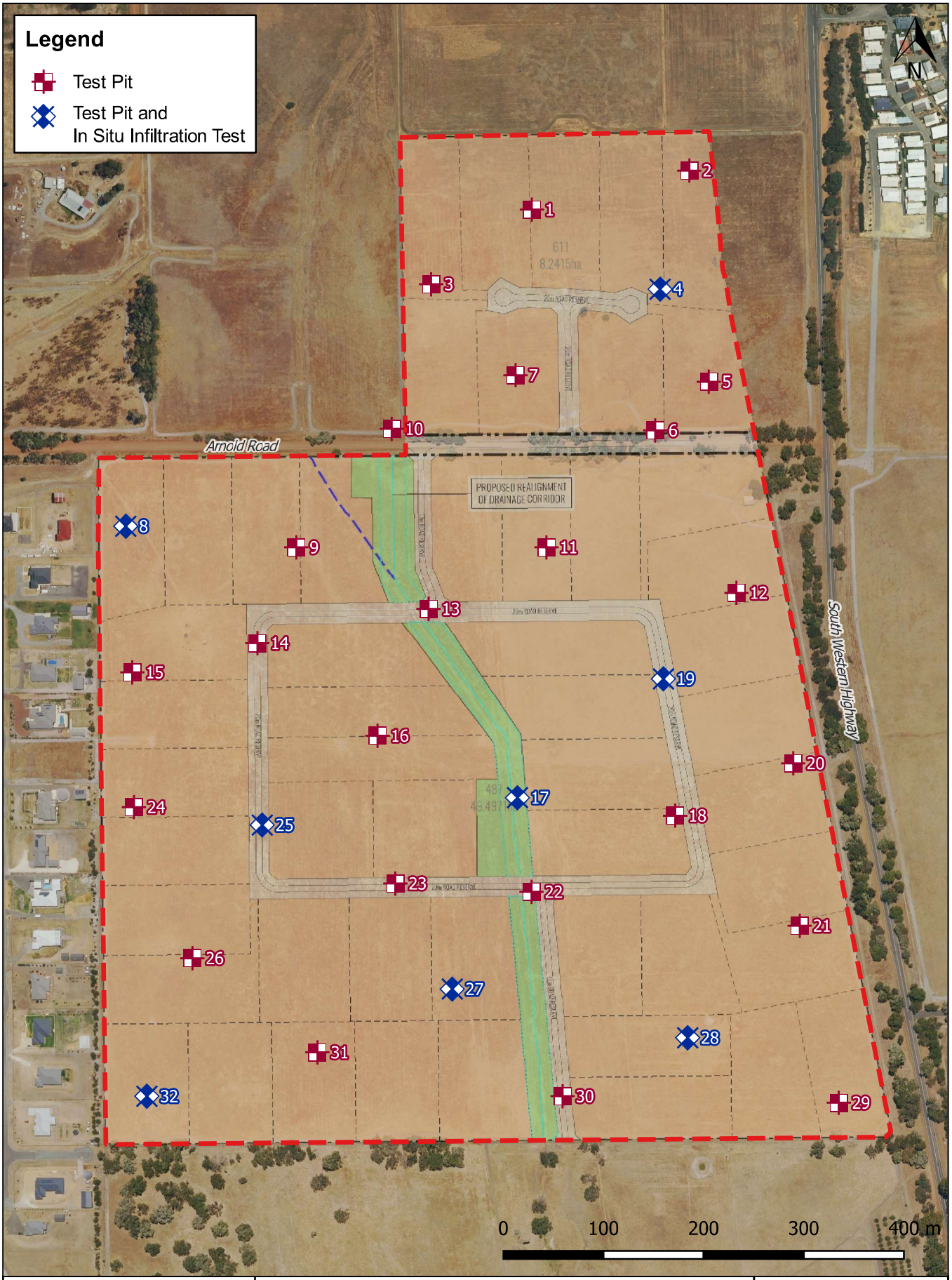

Granite


Dolerite, basalt, andesite

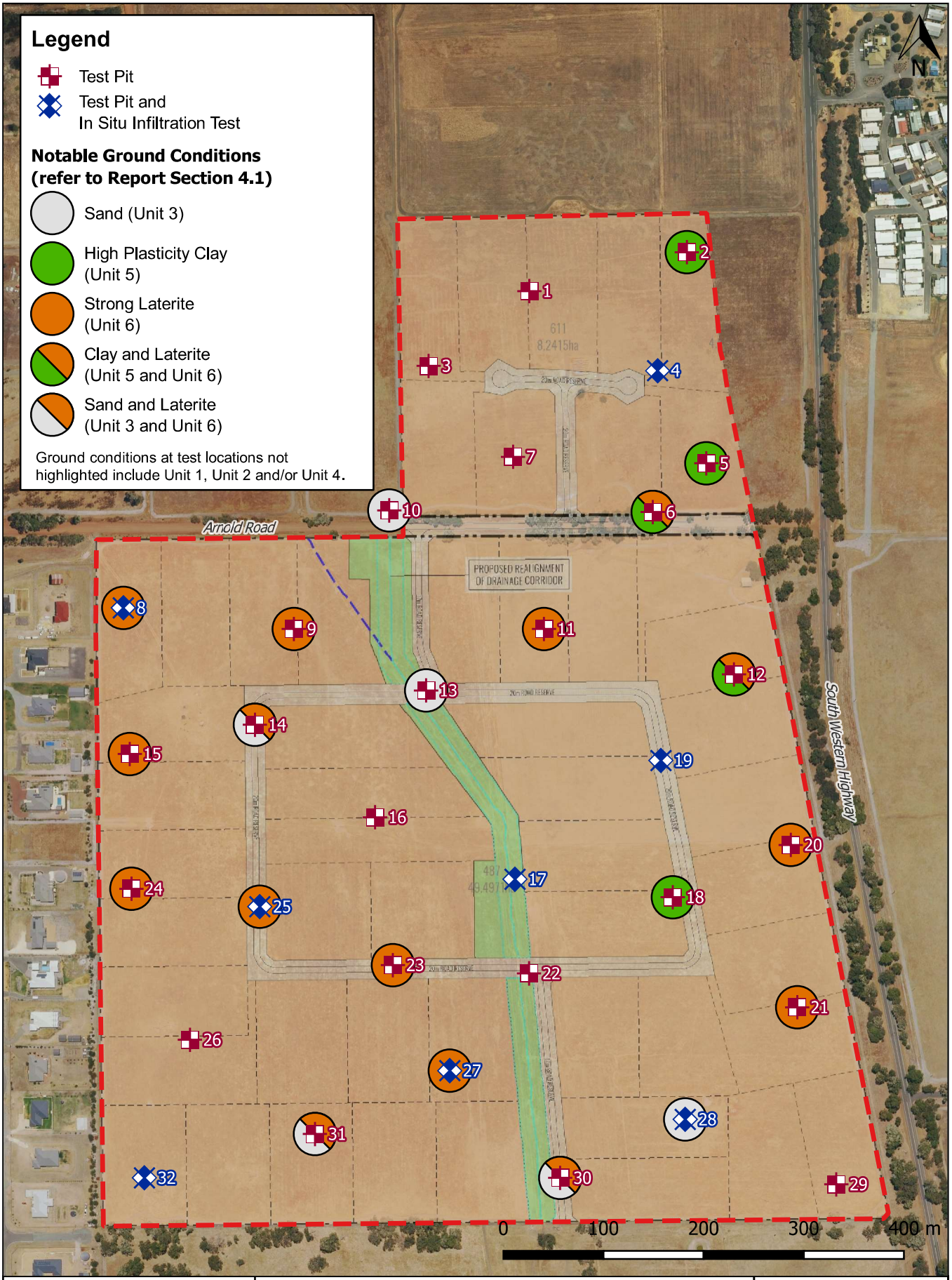

Dacite, epidote


Tuff, breccia

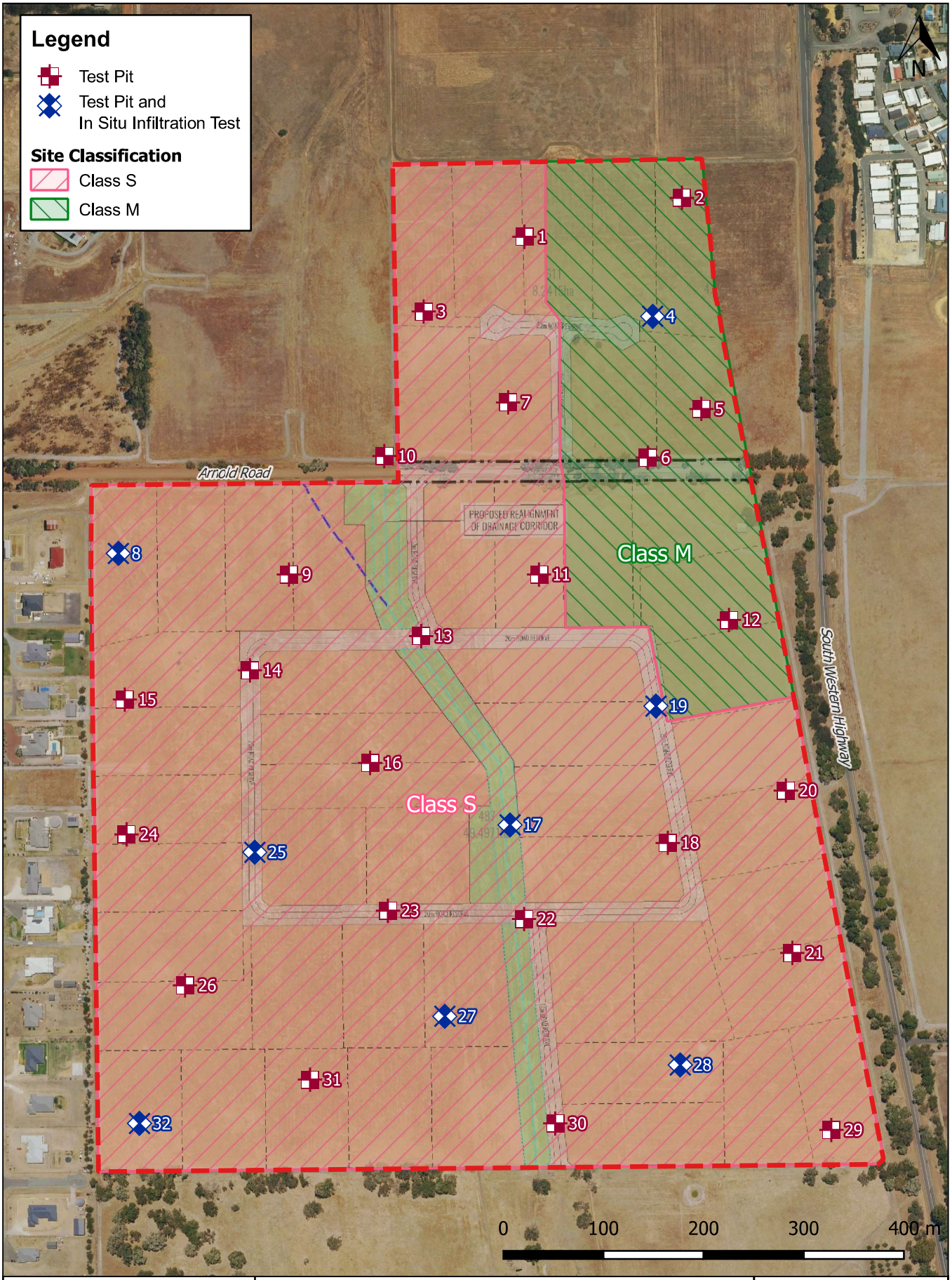

Porphyry



Douglas Partners Geotechnics / Environment / Groundwater	**Test Location Plan** **Proposed Residential Development** **Lots 487, 611 and 615 Arnold Road, Serpentine, WA**	PROJECT: 96660.00 Drawing No: 1 REV: 1
	CLIENT: MALF Corp Pty Ltd	DATE: 17/09/2020



Douglas Partners Geotechnics / Environment / Groundwater	**Test Locations and Encountered Soils** **Proposed Residential Development** **Lots 487, 611 and 615 Arnold Road, Serpentine, WA**	PROJECT: 96660.00 Drawing No: 2 REV: 1
	CLIENT: MALF Corp Pty Ltd	DATE: 17/09/2020



Douglas Partners Geotechnics / Environment / Groundwater	**Test Locations and Interpreted Site Classification** **Proposed Residential Development** **Lots 487, 611 and 615 Arnold Road, Serpentine, WA**	PROJECT: 96660.00 Drawing No: 3 REV: 1
	CLIENT: MALF Corp Pty Ltd	DATE: 17/09/2020

Appendix B

Report of Field Work

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 31.6 m AHD*
EASTING: 404838
NORTHING: 6418237

PIT No: 1
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
31	0.05	TOPSOIL/Sandy SILT ML: low plasticity, dark grey-brown, fine to medium grained sand, with rootlets, moist.							
	0.2	Sandy SILT SM: low plasticity, grey-brown, fine to medium grained sand, dry to moist, very stiff.							
		Sandy CLAY CI: medium plasticity, orange-brown and red-brown mottled light brown, fine to medium grained sand, trace gravel, dry to moist, hard.			1.0		pp = 600		
30	1				1.5		pp = 600		
	1.9	- with gravel and cobbles of iron cemented laterite.							
29	2	Pit discontinued at 1.9m (Hard digging/Refusal)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 31.9 m AHD*
EASTING: 404995
NORTHING: 6418276

PIT No: 2
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
	0.05	TOPSOIL/Sandy SILT ML: low plasticity, grey-brown, fine		D	0.1				
	0.15	to medium grained sand, with rootlets, dry to moist.							
		Sandy SILT ML: low plasticity, brown, fine to medium grained sand, trace gravel, dry to moist, stiff.							
		Sandy CLAY CI: medium plasticity, yellow-brown, fine to medium grained sand, trace gravel, moist, hard.		D	0.5				
					0.6				
				U	0.73				
31	0.9	CLAY CH: high plasticity, brown, with sand, moist, hard.							
	1			D	1.2				1
					1.5		pp = 600		
30		- becoming red-brown, grey and brown from 1.8 m depth.							
	2			D	2.0		pp = 600		2
	2.5	Pit discontinued at 2.5m (Target depth)							
29									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 31.8 m AHD*
EASTING: 404737
NORTHING: 6418162

PIT No: 3
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
31	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.25	Silty SAND SM: fine to medium grained, grey-brown, low plasticity, with gravel, moist.							
	0.6	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, grey-brown, fine to medium grained sand, medium plasticity clay, dry to moist.							
		Sandy CLAY CI: medium to high plasticity, red-brown, orange-brown and grey-brown, fine to medium grained sand, trace gravel, dry to moist, hard.		B	0.8				
1					1.0		pp = 600		1
		- with gravel and cobbles of iron cemented laterite from 1.5 m depth.			1.5		pp = 600		
30				D	1.9		Rock sample		
2	2.0	Pit discontinued at 2.0m (Hard digging)							2
29									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 33.2 m AHD*
EASTING: 404966
NORTHING: 6418157

PIT No: 4
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
33	0.1	TOPSOIL/Silty Sandy GRAVEL GM: fine to coarse gravel, grey-brown, low plasticity silt, fine to medium grained sand, with rootlets, dry to moist.							
	0.2	Silty Sandy GRAVEL GM: fine to coarse gravel, grey-brown, low plasticity silt, fine to medium grained sand, dry to moist.		B	0.3		2 bulk bags of sample		
	0.5	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, light brown, medium plasticity clay, fine to medium grained sand, dry to moist.							
32	1	Sandy CLAY CI: medium plasticity, yellow-brown and orange-brown, fine to medium grained sand, with gravel, moist, hard.			1.0		pp = 600		1
					1.5		pp = 600		
	1.7	Pit discontinued at 1.7m (Hard digging)							
31	2								





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 33.8 m AHD*
EASTING: 405015
NORTHING: 6418065

PIT No: 5
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
33	0.05	TOPSOIL/Sandy SILT ML: low plasticity, grey-brown, fine to medium grained sand, with rootlets, dry to moist.							
	0.2	Sandy SILT ML: low plasticity, grey-brown, fine to medium grained sand, dry to moist.							
		Sandy CLAY CI: medium plasticity, light brown mottled orange-brown, fine to medium grained sand, trace gravel, dry to moist, hard.		D	1.0				
32	1.5	CLAY CH: high plasticity, light grey-white and brown, with sand, moist, hard.			1.7		pp = 600		
31	2.2	Pit discontinued at 2.2m (Hard digging/Refusal)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20; 1; 2





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 34.5 m AHD*
EASTING: 404961
NORTHING: 6418016

PIT No: 6
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
34	0.2	Gravelly Silty SAND SM: fine to medium grained, brown, low plasticity, fine to coarse lateritic gravel, dry.							
	0.5	Sandy CLAY CI: medium plasticity, yellow-brown mottled orange-brown, fine to medium grained sand, with lateritic gravel and cobbles, dry to moist, hard.		B	0.3				
		CLAY CH: high plasticity, light grey-white mottled red-brown, with sand, dry to moist, hard.							
33	1			D	1.0		pp = 600		1
					1.5		pp = 600		
32	1.8	Pit discontinued at 1.8m (Hard digging)							
	2								





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 32.5 m AHD*
EASTING: 404822
NORTHING: 6418071

PIT No: 7
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
32	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.		D	0.1				
	0.2	SAND/Silty SAND SP-SM/SM: fine to medium grained, grey-brown, with silt or silty, low plasticity silt, dry to moist.		D	0.3				
	0.4	SAND/Clayey SAND SP-SC/SC: fine to medium grained, light brown, with clay or clayey, medium plasticity clay, dry to moist, very dense.			0.5		pp = 600		
	0.8	Sandy CLAY CI: medium plasticity, orange-brown and light brown, fine to medium grained sand, with gravel, dry to moist, hard.							
31	1	Sandy CLAY CI: medium plasticity, red-brown and orange-brown mottled grey, fine to medium grained sand, dry to moist, hard.			1.0		pp = 600		1
					1.5		pp = 600		
	2								2
30	2.5	Pit discontinued at 2.5m (Target depth)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▽	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 33.5 m AHD*
EASTING: 404432
NORTHING: 6417921

PIT No: 8
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
33	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.4	Clayey SAND/Sandy CLAY SC/Cl: fine to medium grained, light brown, medium plasticity clay, trace gravel, moist, very dense.							
		Sandy CLAY Cl: medium plasticity, light brown mottled orange-brown, fine to medium grained sand, trace gravel, moist, hard. Gravel content increasing with depth.			0.8		pp = 600		
32	1.1	LATERITE: excavated as gravel and high strength cobbles of red-brown iron cemented laterite.							
	1.2	Pit discontinued at 1.2m (Hard digging)							
31									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 32.9 m AHD*
EASTING: 404603
NORTHING: 6417900

PIT No: 9
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
32	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.		D	0.15				
	0.2	Sandy SILT ML: low plasticity, grey-brown, fine to medium grained, dry to moist.		D	0.3				
	0.35	Silty SAND SM: fine to medium grained, grey-brown, low plasticity, dry to moist, very dense.							
	1	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, orange-brown, red-brown and brown, medium plasticity clay, fine to medium grained sand, moist, hard.			1.0		pp = 500		1
	1.4	MIXTURE OF Clayey Sandy GRAVEL AND COBBLES GC: fine to coarse gravel, red-brown, fine to medium grained sand, medium plasticity clay, moist. Gravel and cobbles are iron cemented laterite.							
31	1.8	Pit discontinued at 1.8m (Hard digging)							
	2								
30									

Dynamic Penetrometer Test (blows per 150mm): 5 10 15 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 32.8 m AHD*
EASTING: 404698
NORTHING: 6418018

PIT No: 10
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
32	0.2	Silty SAND SM: fine to medium grained, grey-brown, low plasticity, dry to moist.							
	0.5	SAND SP-SC: fine to medium grained, light brown, with clay, moist, very dense to dense.		B	0.3				
		Sandy CLAY CH: medium plasticity, orange-brown, brown and red-brown, fine to medium grained sand, trace gravel, moist, hard.		B	0.7				
	1				1.0		pp = 600		1
					1.5		pp = 450		
31	2				2.0		pp = 450		2
	2.5	Pit discontinued at 2.5m (Target depth)			2.5		pp = 600		
30									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 35.1 m AHD*
EASTING: 404852
NORTHING: 6417900

PIT No: 11
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
35	0.05	TOPSOIL/Silty Sandy GRAVEL GM: fine to coarse gravel, dark grey-brown, fine to medium grained sand, low plasticity silt, with rootlets, dry to moist.							
		Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, light brown, fine to medium grained sand, medium plasticity clay, with cobbles, moist.		D	0.5				
	0.7	Clayey GRAVEL GC: fine to coarse gravel, light brown and orange-brown, medium plasticity clay, with sand, dry to moist, hard/very dense.		U	0.9				
34	1			D	1.03 1.1				1
		- becoming red-brown, grey and brown from 1.4 m depth.							
		- with gravel and cobbles of iron cemented laterite from 1.8 m depth.							
33	2 2.0	Pit discontinued at 2.0m (Hard digging)							2

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▽	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 38.3 m AHD*
EASTING: 405042
NORTHING: 6417854

PIT No: 12
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
38	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.2	Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, dry to moist.							
		Sandy CLAY CI: medium plasticity, yellow-brown and orange-brown, fine to medium grained sand, dry to moist, hard.							
	0.7	Gravelly Sandy CLAY CI: medium plasticity, yellow-brown and orange-brown, fine to medium grained sand, fine to coarse lateritic gravel, with cobbles of laterite, dry to moist, hard. Hard digging experienced in this layer.							
37	1.3	CLAY CH: high plasticity, light brown and red-brown, with sand, moist, hard.			1.5		pp = 600		
				D	2.0		pp = 600		
36	2.3	Pit discontinued at 2.3m (Boom obstructed by hard upper layers)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 34.4 m AHD*
EASTING: 404735
NORTHING: 6417838

PIT No: 13
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
34	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.							
		SAND SP-SM: fine to medium grained, light brown, with silt, trace clay, moist, dense.		B	0.4				
	0.6	Sandy CLAY CI: medium plasticity, orange-brown mottled red-brown and brown, fine to medium grained sand, trace gravel, moist, hard.							
33	1								1
		- becoming red-brown and brown from 1.7 m depth.			1.7		pp = 600		
32	2								2
	2.5	Pit discontinued at 2.5m (Target depth)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 34.2 m AHD*
EASTING: 404564
NORTHING: 6417804

PIT No: 14
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
34	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.							
		SAND SP-SM: fine to medium grained, light brown, with silt, moist, dense to very dense. Possibly silty.		D	0.3				
	0.5	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, orange-brown, brown and red-brown, fine to medium grained sand, medium plasticity clay, moist, dense.		B	0.6				
33	1	- becoming brown and red-brown, with cobbles from 1.2 m depth.			1.0		pp = 600		1
	2								2
32	2.1	Sandy CLAY CI: medium plasticity, red-brown and grey, fine to medium grained sand, moist.							
	2.5	Pit discontinued at 2.5m (Target depth)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 34.7 m AHD*
EASTING: 404439
NORTHING: 6417775

PIT No: 15
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
34	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.2	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, trace gravel, moist, medium dense to dense.							
	0.5	MIXTURE OF Clayey Sandy GRAVEL AND COBBLES: fine to coarse gravel, red-brown and light brown, fine to medium grained sand, medium plasticity clay, with cobbles, moist, dense. Gravel and cobbles are iron cemented laterite.							
	0.8	LATERITE: excavated as gravel and high strength cobbles of red-brown iron cemented laterite.							
33	1	Pit discontinued at 0.8m (Hard digging)							
	2								
32									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 35.3 m AHD*
EASTING: 404684
NORTHING: 6417712

PIT No: 16
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
35	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.4	Sandy CLAY CI: medium plasticity, grey-brown, fine to medium grained sand, dry to moist, hard.							
		Sandy CLAY CI: medium plasticity, orange-brown, brown and red-brown, fine to medium grained sand, with gravel, dry to moist, hard.			0.5		pp = 600		
34	1			D	1.0		pp = 600		1
		- becoming red-brown mottled grey from 1.5 m depth.			1.5		pp = 600		
	2								2
33	2.2	Pit discontinued at 2.2m (Hard digging)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 36.4 m AHD*
EASTING: 404824
NORTHING: 6417650

PIT No: 17
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
36	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, dry to moist.							
		Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist, dense to very dense.		D	0.3				
	0.7	Sandy CLAY CI: medium plasticity, orange-brown and red-brown, fine to medium grained sand, with gravel, moist, hard.							
35	1			D	1.0				1
		- with gravel and cobbles of iron cemented laterite from 1.7 m depth.							
	2								2
	2.2	Pit discontinued at 2.2m (Hard digging)							
34									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 39.4 m AHD*
EASTING: 404981
NORTHING: 6417632

PIT No: 18
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
39	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.4	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist, medium dense.							
	0.7	Sandy GRAVEL GP-GC: fine to coarse lateritic gravel, light brown, fine to medium grained sand, with clay, moist.							
	1	Sandy CLAY CI: medium plasticity, light brown and orange-brown, fine to medium grained sand, with gravel, moist, hard.							
38		- trace gravel from approximately 1.3 m depth.							
	2								
	2.3	CLAY CH: high plasticity, light grey mottled orange-brown, with sand, moist.							
37	2.5	Pit discontinued at 2.5m (Target depth)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 38.5 m AHD*
EASTING: 404969
NORTHING: 6417768

PIT No: 19
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
38	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.1	Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, dry to moist.		D	0.3				
	0.5	Clayey SAND SC: fine to medium grained, grey-brown, medium plasticity, dry to moist, dense.							
		Sandy CLAY CI: medium plasticity, light brown, fine to medium grained sand, dry to moist, hard.							
	0.9	Sandy CLAY CI: medium plasticity, brown mottled red-brown and orange-brown, with iron cemented lateritic gravel, dry to moist.							
37	1.5	Sandy CLAY CI: medium to high plasticity, light grey mottled red-brown, fine to medium grained sand, with cobbles, moist. - appears there are no cobbles from 1.8 m depth.							
	2.3	Pit discontinued at 2.3m (Boom obstructed by hard upper layers)							
36									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20; 1; 2





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.
LOGGED: YC
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 41.1 m AHD*
EASTING: 405099
NORTHING: 6417684

PIT No: 20
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
41	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.2	Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, moist.							
	0.5	Clayey SAND SC: medium plasticity, light brown, fine to medium grained sand, moist, dense.							
		Sandy CLAY CI: medium plasticity, light brown mottled orange-brown, fine to medium grained sand, trace gravel, moist, hard.							
40	1.0	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, red-brown and orange-brown, fine to medium grained sand, medium plasticity clay, with cobbles, moist. Hard digging experienced in this layer.		D	1.4				
	1.6	Sandy CLAY CI: medium plasticity, light yellow-brown, fine to medium grained sand, with gravel and cobbles of laterite, moist.							
39	2.1	Pit discontinued at 2.1m (Boom obstructed by hard upper layers)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20; 1; 2





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 42.3 m AHD*
EASTING: 405105
NORTHING: 6417522

PIT No: 21
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
42	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, dry to moist.							
	0.3	Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, moist, medium dense.		D	0.2				
	0.5	Clayey SAND SC: medium plasticity, light brown, fine to medium grained sand, moist, dense.							
41	1	Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, light yellow-brown mottled red-brown and orange-brown, fine to medium grained sand, medium plasticity clay, with cobbles, moist.							1
	1.6	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist.		D	1.8				
40	2								2
	2.5	Pit discontinued at 2.5m (Target depth)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 37.5 m AHD*
EASTING: 404838
NORTHING: 6417556

PIT No: 22
PROJECT No: 96660.00
DATE: 10/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
37	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, dry to moist.							
		Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist, dense to very dense.		B	0.4				
	0.8	Sandy CLAY CI: medium plasticity, orange-brown and red-brown, fine to medium grained sand, with gravel, moist, hard.			1.0		pp = 600		
36	1				1.5		pp = 600		
		- with gravel and cobbles of iron cemented laterite from 1.8 m depth.							
35	2.5	Pit discontinued at 2.5m (Target depth)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20; 1; 2





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 37.2 m AHD*
EASTING: 404702
NORTHING: 6417564

PIT No: 23
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
37	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.4	Clayey Sandy GRAVEL GC: fine to medium gravel, light grey-brown, medium plasticity clay, fine to medium grained sand, moist, dense.							
	1	Gravelly Clayey SAND SC: fine to medium grained, light brown and orange-brown, medium plasticity clay, fine to coarse gravel, moist, hard.							
36		- with cobbles and gravel of iron cemented laterite from 1.1 m depth.							
	1.3	Pit discontinued at 1.3m (Hard digging)							
35	2								

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 35.8 m AHD*
EASTING: 404441
NORTHING: 6417640

PIT No: 24
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
35	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
		Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, moist, medium dense.							
	1	- becoming light brown mottled orange-brown from 0.6 m depth.		D	1.0				1
34	1.3	MIXTURE OF Clayey Sandy GRAVEL AND COBBLES GC: fine to coarse lateritic gravel, red-brown and light brown, fine to medium grained sand, medium plasticity clay, moist.							
	1.9	Sandy CLAY CI: medium plasticity, brown mottled orange-brown, fine to medium grained sand, trace gravel, moist, hard.							2
	2								
	2.2	Pit discontinued at 2.2m (Hard digging/Refusal)							
33									

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 36.1 m AHD*
EASTING: 404569
NORTHING: 6417622

PIT No: 25
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
36	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
		Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, trace gravel, moist, medium dense to dense.		B	0.3				
	0.5	Clayey Sandy GRAVEL GC: fine to medium lateritic gravel, orange-brown and red-brown, medium plasticity clay, fine to medium grained sand, dry to moist, dense.							
35	1								1
	1.3	Sandy CLAY CI: medium plasticity, brown and orange-brown, fine to medium grained sand, with gravel, moist.							
34	2								2
	2.3	Pit discontinued at 2.3m (Boom obstructed by hard upper layers)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 37.9 m AHD*
EASTING: 404499
NORTHING: 6417489

PIT No: 26
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
37	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.3	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, dry to moist, medium dense.		D	0.4				
	0.6	Gravelly Clayey SAND SC: fine to coarse grained sand, light brown, medium plasticity clay, fine to coarse gravel, dry to moist.							
	1	Gravelly Sandy CLAY CI: medium plasticity, orange-brown and brown, fine to medium gravel, fine to medium grained sand, dry to moist, hard.							1
36	1.2	- with gravel and cobbles of iron cemented laterite.							
	2	Pit discontinued at 1.2m (Hard digging/Refusal)							
35									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 38.7 m AHD*
EASTING: 404758
NORTHING: 6417459

PIT No: 27
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
38	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							5 10 15 20
	0.4	Clayey Sandy GRAVEL GC: fine to medium gravel, light grey-brown, medium plasticity clay, fine to medium grained sand, moist, dense.		D	0.3				
		Gravelly Clayey SAND SC: fine to medium grained, light brown and orange-brown, medium plasticity clay, fine to coarse gravel, moist, very dense/hard.		D	0.5				
	1								1
37	1.9	- with gravel and cobbles of iron cemented laterite from 1.8 m depth.							
	2	Pit discontinued at 1.9m (Hard digging)							
36									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 40.9 m AHD*
EASTING: 404993
NORTHING: 6417410

PIT No: 28
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
40	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.							
		SAND SP-SM: fine to medium grained, light grey, with silt, moist, medium dense.		D	0.5				
	0.6	Sandy CLAY CI: medium to high plasticity, brown, orange-brown and grey, fine to medium grained sand, moist, hard.			0.8				
		- becoming firm from 0.8 m depth.		U	0.9				
1					1.0		pp = 100		1
		- becoming stiff from approximately 1.3 m depth.		D	1.5		pp = 150		
39		- becoming light grey with higher sand content from 1.8 m depth.							
2		- becoming hard from approximately 1.8 m depth.			2.0		pp = 500		2
		- becoming stiff to very stiff from approximately 2.3 m depth.						▼ 11-03-20	
	2.5	Pit discontinued at 2.5m (Target depth)			2.5		pp = 200		
38									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: Groundwater observed at 2.3 m depth.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 45.1 m AHD*
EASTING: 405144
NORTHING: 6417345

PIT No: 29
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
45	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.							
		Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, light brown, medium plasticity clay, moist, dense.							
44	1	- becoming light yellow-brown, with cobbles from 0.6 m depth.		D	1.0				1
	1.4	Sandy CLAY CI: medium plasticity, light brown mottled red-brown, fine to medium grained sand, trace gravel, moist.							
43	2								2
	2.5	Pit discontinued at 2.5m (Target depth)							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 40.0 m AHD*
EASTING: 404869
NORTHING: 6417352

PIT No: 30
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
40	0.1	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.4	Sandy GRAVEL GP-GM: fine to coarse lateritic gravel, grey-brown, fine to medium grained sand, with silt, moist.							
		Clayey Sandy GRAVEL GC: fine to coarse gravel, light brown mottled red-brown, fine to medium grained sand, medium plasticity clay, moist, very dense/hard.		B	0.5 0.6		pp = 600		
39	1.0	Sandy CLAY CI: medium plasticity, brown mottled red-brown, fine to medium grained sand, trace gravel, moist, hard.			1.5		pp = 600		
	1.9	- with cobbles of iron cemented laterite from 1.8 m depth.							
38	2	Pit discontinued at 1.9m (Hard digging)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 39.2 m AHD*
EASTING: 404624
NORTHING: 6417395

PIT No: 31
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
39	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, grey-brown, low plasticity silt, with rootlets, moist.							
	0.3	SAND SP-SC: fine to medium grained, light grey-brown, with clay, moist, medium dense.							
		Sandy CLAY CI: medium plasticity, light brown mottled orange-brown, with gravel, moist, hard. Gravel content increasing with depth.							
	1								1
38	1.1	MIXTURE OF Clayey Sandy GRAVEL AND COBBLES GC: fine to coarse gravel, light brown and orange-brown, medium plasticity clay, moist. Gravel and cobbles are iron cemented laterite.		D	1.4				
	1.8	Sandy CLAY CI: medium plasticity, light grey mottled brown and orange-brown, fine to medium grained sand, moist.		D	2.1		Rock sample		
	2								2
37	2.2	Pit discontinued at 2.2m (Refusal on rock)							





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: MALF Corp Pty Ltd
PROJECT: Proposed Residential Development
LOCATION: Lots 487, 611 & 615 Arnold Road, Serpentine, WA

SURFACE LEVEL: 39.3 m AHD*
EASTING: 404454
NORTHING: 6417352

PIT No: 32
PROJECT No: 96660.00
DATE: 11/3/2020
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
39	0.05	TOPSOIL/Silty SAND SM: fine to medium grained, dark grey-brown, low plasticity silt, with rootlets, moist.		D	0.2				
	0.3	Clayey SAND SC: fine to medium grained, light brown, medium plasticity clay, trace gravel, dry to moist, medium dense.							
		Clayey Sandy GRAVEL GC: fine to coarse lateritic gravel, yellow-brown and brown, fine to medium grained sand, medium plasticity clay, dry to moist, dense.							
38	1.0	Clayey SAND SC: fine to medium grained, yellow-brown, medium plasticity clay, moist.		D	1.5				
	1.7	Pit discontinued at 1.7m (Hard digging)							
37									





RIG: JCB 8 tonne backhoe with a 450 mm wide toothed bucket.

LOGGED: YC

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level obtained from publicly available LiDAR.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

Appendix C

Results of Laboratory Testing

WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

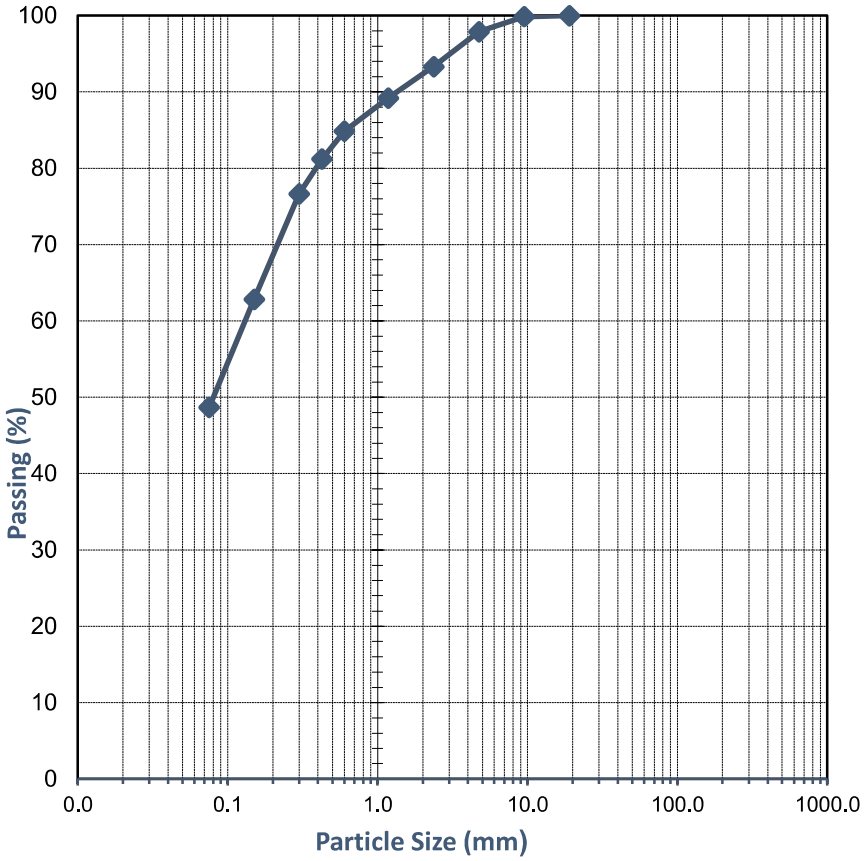
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4147_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4147
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 0.5m	*Date Tested:*	18/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	100
9.5	100
4.75	98
2.36	93
1.18	89
0.600	85
0.425	81
0.300	77
0.150	63
0.075	49



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4147_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4147
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 0.5m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**30**
AS 1289.3.2.1	**Plastic Limit (%)**	**14**
AS 1289.3.3.1	**Plasticity Index (%)**	**16**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**11.0**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked, Curled**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.7.7.1

Client:	Malf Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4148_1_SSI
Project:	Proposed Residential Development	*Sample No.*	WG20/4148
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 0.6-0.73m	*Date Tested:*	19-23/03/2020

TEST RESULTS - SHRINK SWELL INDEX

Sampling Method: Sampled by Client, Tested as Received

Material Description: Brown Clay, with Gravel

SWELL SPECIMEN	
Moisture Content Initial (%):	15.8
Dry Density - Initial (t/m^3):	1.84
Moisture Content Final (%):	17.6
Estimated Inert Inclusions (%):	2

SHRINK SPECIMEN	
Moisture Content Initial (%):	16.1
Extent of Crumbling:	Nil
Length/Diameter Ratio:	2.7
Extent of Cracking:	Slight

SHRINK SWELL INDEX	
Shrink Swell Index (I_{SS})	**0.8**

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4149_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4149
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 1.2m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**64**
AS 1289.3.2.1	**Plastic Limit (%)**	**20**
AS 1289.3.3.1	**Plasticity Index (%)**	**44**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**14.0**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

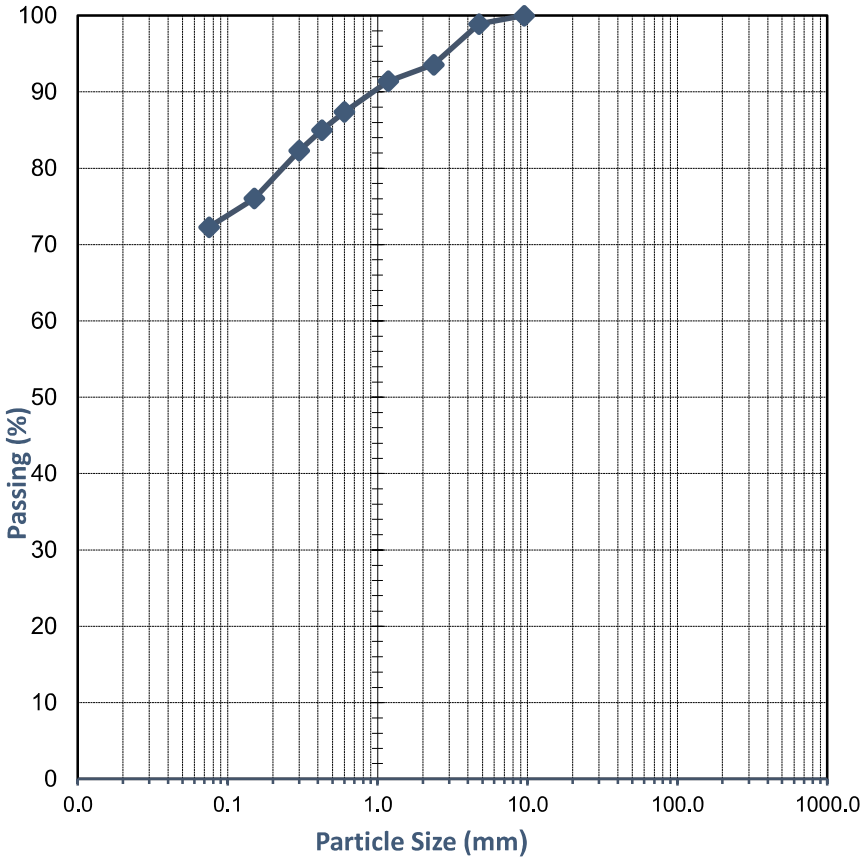
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4149_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4149
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP2, 1.2m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	99
2.36	94
1.18	91
0.600	87
0.425	85
0.300	82
0.150	76
0.075	72



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.8.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4150_1_ECN
Project:	Proposed Residential Development	*Sample No.*	WG20/4150
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP3, 0.8m	*Date Tested:*	19/03/2020

TEST RESULTS - Emerson Class Number

Sampling Method:	**Sampled by Client, Tested as Received**
Source of Material:	**Not Specified**
Soil Description:	**Silty Clay, with Gravel**
Water Used:	**Distilled**

EMERSON CLASS NUMBER

6

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

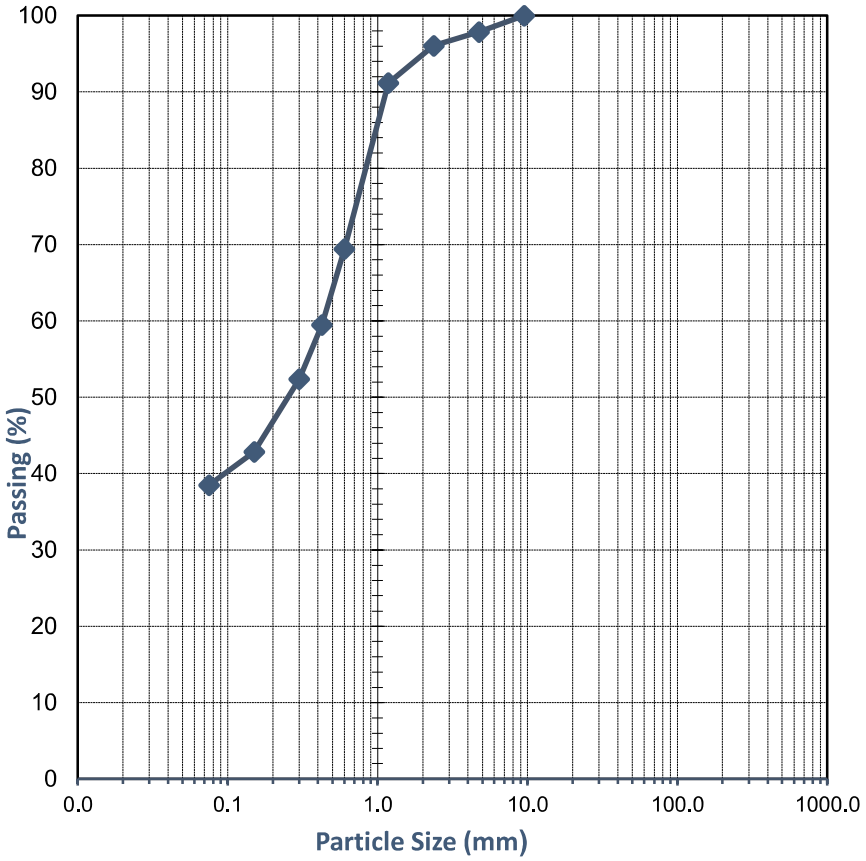
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4151_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4151
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP10, 0.7m	*Date Tested:*	18/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	98
2.36	96
1.18	91
0.600	69
0.425	59
0.300	52
0.150	43
0.075	38



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4151_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4151
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP10, 0.7m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**38**
AS 1289.3.2.1	**Plastic Limit (%)**	**15**
AS 1289.3.3.1	**Plasticity Index (%)**	**23**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**8.5**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.5.2.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4151_1_MMDD
Project:	Proposed Residential Dvelopment	*Sample No.*	WG20/4151
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP10, 0.7m	*Date Tested:*	18/03/2020

TEST RESULTS - Modified Maximum Dry Density

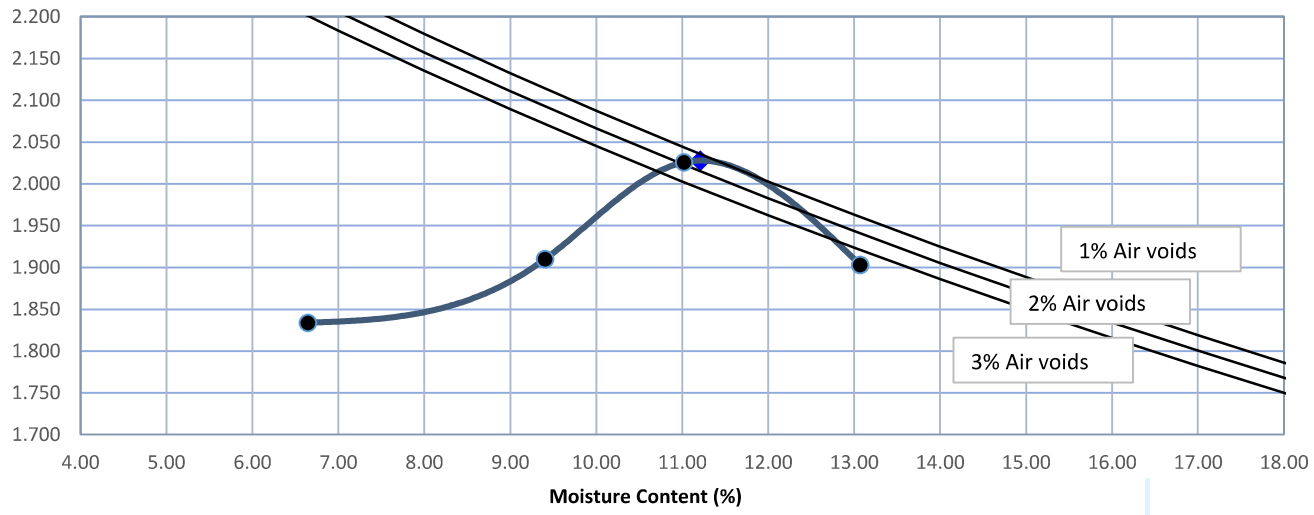
Sampling Method: Sampled by Client, Tested as Received

Sample Curing Time: 24 Hours

Method used to Determine Liquid Limit: Visual / Tactile Assessment by Competent Technician

Material + 19.0mm (%): 0 **Material + 37.5mm (%)** -

Moisture Content (%)	6.6	9.4	11.0	13.1	
Dry Density (t/m³)	1.834	1.910	2.026	1.903	



Modified Maximum Dry Density (t/m³) **2.03**

Optimum Moisture Content (%) **11.0**

Comments: *The above air void lines are derived from a calculated apparent particle density of 2.672 t/m³*

Approved Signatory:

Name: Kirk McConachy
Function: Laboratory Manager
Date: 19/March/2020

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.6.1.1

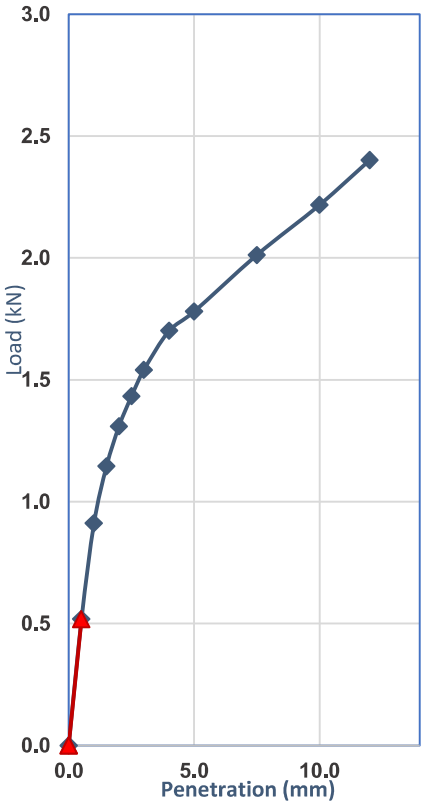
Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4151_1_SCBR
Project:	Proposed Residential Development	*Sample No.*	WG20/4151
Location:	Lots 487, 611 & 615 Arnold Road Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP10, 0.7m	*Date Tested:*	23/03/2020

TEST RESULTS - CALIFORNIA BEARING RATIO

Sample Description: Sandy Clay, trace Gravel

Sampling Method: Sampled by Client, Tested as Received

Load Penetration Curve



Compaction Details			
Compaction Method	AS 1289.5.2.1	Hammer Type	Modified
Plasticity Determined by	Estimated	Curing Time (Hours)	28.0
% Retained 19.0mm	0	Excluded/Replaced	Excluded
Maximum Dry Density (t/m^3)	2.03	Optimum Moisture (%)	11.0
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100

Specimen Conditions At Compaction			
Dry Density (t/m3)	1.93	Moisture Content (%)	11.2
Density Ratio (%)	95.0	Moisture Ratio (%)	100.5

Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.93	Dry Density Ratio (%)	95.0
Moisture Content (%)	13.2	Moisture Ratio (%)	118.0

Specimen Conditions After Test			
Top 30mm Moisture (%)	14.3	Remaining Depth (%)	13.0

Correction applied to Penetration: 0mm

Determined at a Penetration of: 2.5mm

California Bearing Ratio (CBR): 11%

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 24/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.7.7.1

Client:	Malf Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4152_1_SSI
Project:	Proposed Residential Development	*Sample No.*	WG20/4152
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP11, 0.9-1.03m	*Date Tested:*	19-23/03/2020

TEST RESULTS - SHRINK SWELL INDEX

Sampling Method: Sampled by Client, Tested as Received

Material Description: Gravelly Clay

SWELL SPECIMEN	
Moisture Content Initial (%):	15.8
Dry Density - Initial (t/m^3):	1.82
Moisture Content Final (%):	17.3
Estimated Inert Inclusions (%):	12

SHRINK SPECIMEN	
Moisture Content Initial (%):	15.3
Extent of Crumbling:	Nil
Length/Diameter Ratio:	2.7
Extent of Cracking:	Slight

SHRINK SWELL INDEX	
Shrink Swell Index (I_{SS})	**1.7**

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 23/March/2020

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

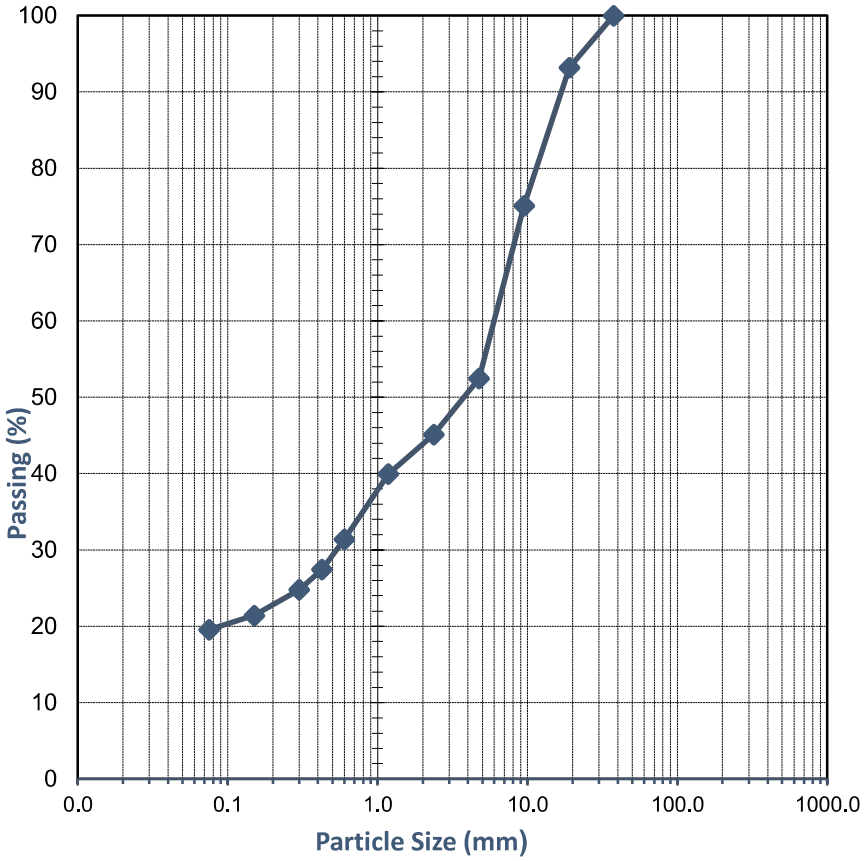
TEST REPORT - AS 1289.1.1 & 3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4153_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4153
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP11, 1.1m	*Date Tested:*	18/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	100
19.0	93
9.5	75
4.75	52
2.36	45
1.18	40
0.600	31
0.425	27
0.300	25
0.150	21
0.075	20



*Comments: *AS 1289.1.1- Deviation from standard: Insufficient sample according to test method requirements. NATA accreditation does not cover the performance of this service.*

Approved Signatory:

Name: Blank
Function: Blank
Date: 21/March/2020

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4153_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4153
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP11, 1.1m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**46**
AS 1289.3.2.1	**Plastic Limit (%)**	**19**
AS 1289.3.3.1	**Plasticity Index (%)**	**27**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**9.0**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

NATA WORLD RECOGNISED ACCREDITATION

Accreditation No. 20599
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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

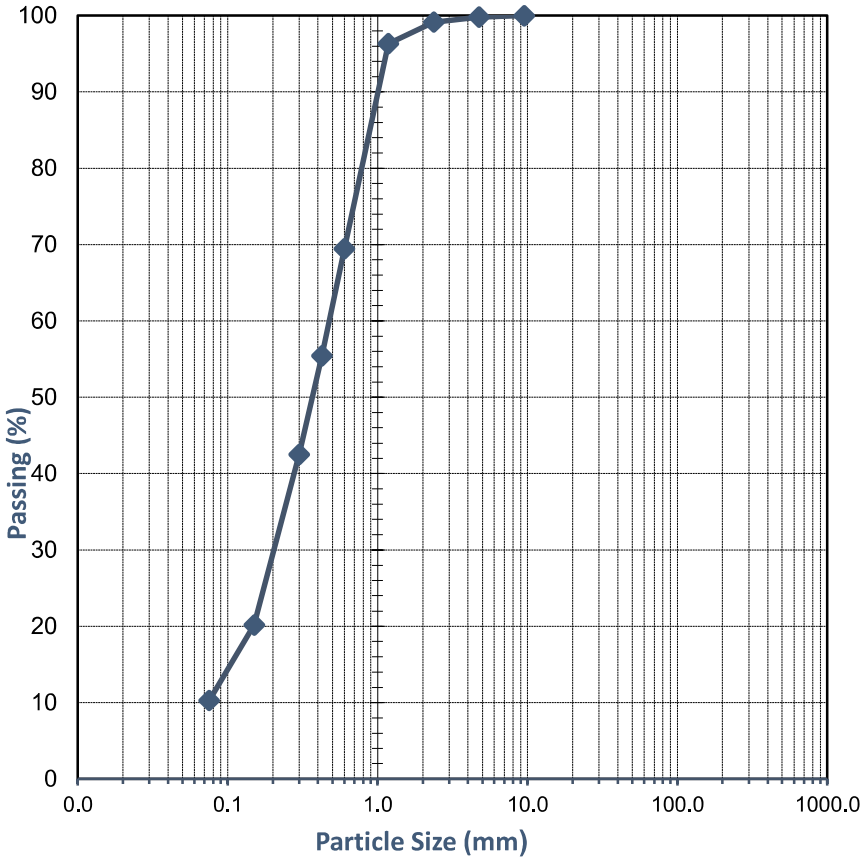
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4154_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4154
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP13, 0.4m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	100
2.36	99
1.18	96
0.600	69
0.425	55
0.300	43
0.150	20
0.075	10



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.5.2.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4154_1_MMDD
Project:	Proposed Residential Dvelopment	*Sample No.*	WG20/4154
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP13, 0.4m	*Date Tested:*	17/03/2020

TEST RESULTS - Modified Maximum Dry Density

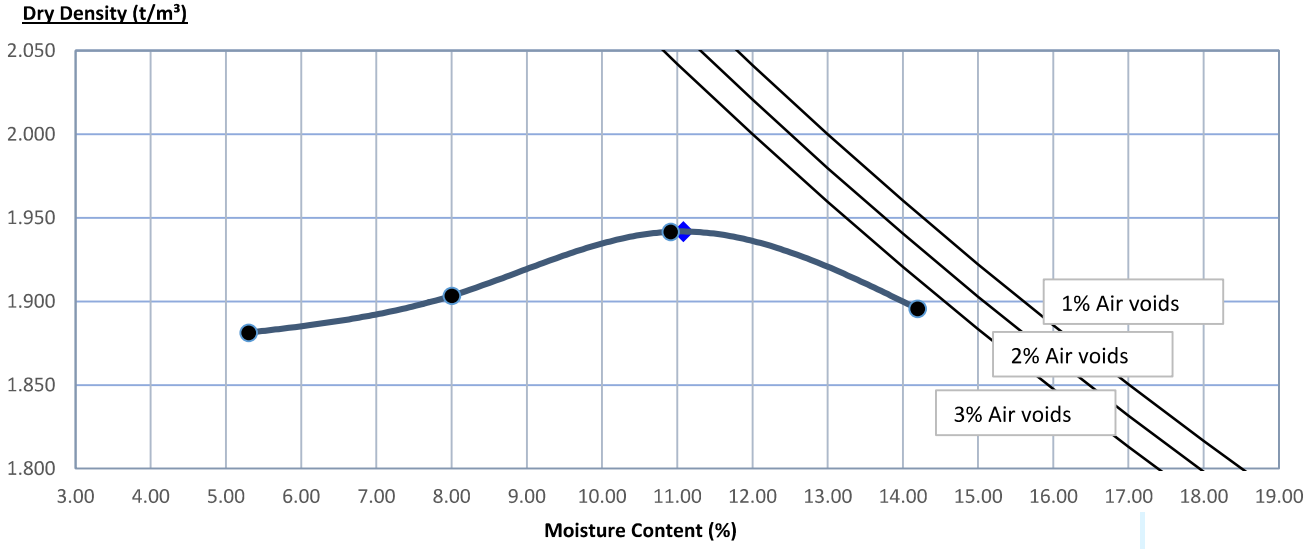
Sampling Method: Sampled by Client, Tested as Received

Sample Curing Time: 2.5 Hours

Method used to Determine Liquid Limit: Visual / Tactile Assessment by Competent Technician

Material + 19.0mm (%): 0 **Material + 37.5mm (%)** -

Moisture Content (%)	5.3	8.0	10.9	14.2	
Dry Density (t/m³)	1.881	1.903	1.942	1.896	



Modified Maximum Dry Density (t/m³) **1.94**

Optimum Moisture Content (%) **11.0**

Comments: *The above air void lines are derived from a calculated apparent particle density of 2.74 t/m³*

Approved Signatory:

Name: Kirk McConachy
Function: Laboratory Manager
Date: 19/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.6.1.1

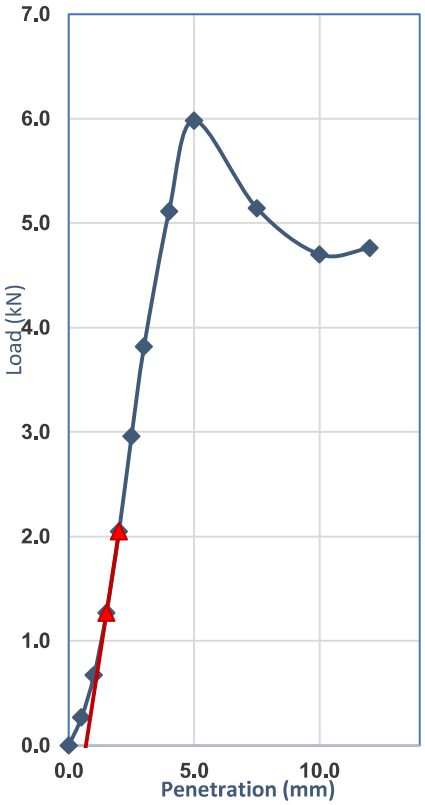
Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4154_1_SCBR
Project:	Proposed Residential Development	*Sample No.*	WG20/4154
Location:	Lots 487, 611 & 615 Arnold Road Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP13, 0.4m	*Date Tested:*	23/03/2020

TEST RESULTS - CALIFORNIA BEARING RATIO

Sample Description: Sand

Sampling Method: Sampled by Client, Tested as Received

Load Penetration Curve



Compaction Details			
Compaction Method	AS 1289.5.2.1	Hammer Type	Modified
Plasticity Determined by	Estimated	Curing Time (Hours)	2.0
% Retained 19.0mm	0	Excluded/Replaced	Excluded
Maximum Dry Density (t/m^3)	1.94	Optimum Moisture (%)	11.0
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100

Specimen Conditions At Compaction			
Dry Density (t/m3)	1.85	Moisture Content (%)	11.0
Density Ratio (%)	95.0	Moisture Ratio (%)	99.0

Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.85	Dry Density Ratio (%)	95.0
Moisture Content (%)	11.3	Moisture Ratio (%)	101.5

Specimen Conditions After Test			
Top 30mm Moisture (%)	11.1	Remaining Depth (%)	10.0

Correction applied to Penetration: 0.7mm

Determined at a Penetration of: 2.5mm

California Bearing Ratio (CBR): 30%

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 24/March/2020

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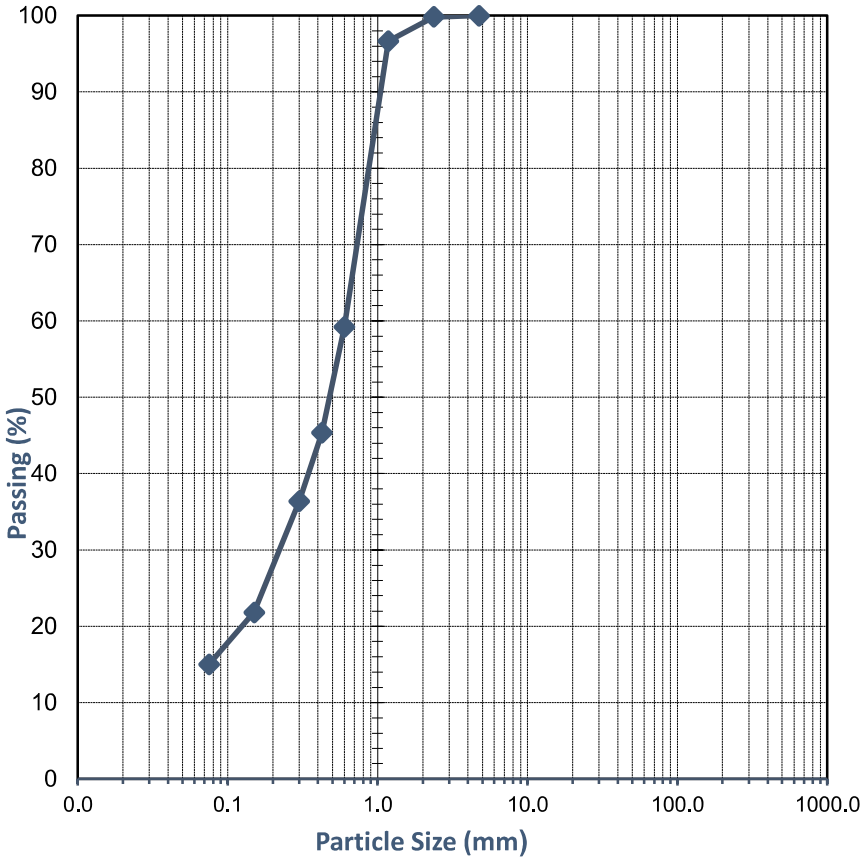
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4155_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4155
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP17, 0.3m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	
4.75	100
2.36	100
1.18	97
0.600	59
0.425	45
0.300	36
0.150	22
0.075	15



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.8.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4156_1_ECN
Project:	Proposed Residential Development	*Sample No.*	WG20/4156
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP19, 0.3m	*Date Tested:*	19/03/2020

TEST RESULTS - Emerson Class Number

Sampling Method:	**Sampled by Client, Tested as Received**
Source of Material:	**Not Specified**
Soil Description:	**Silty Sand**
Water Used:	**Distilled**

EMERSON CLASS NUMBER

5

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

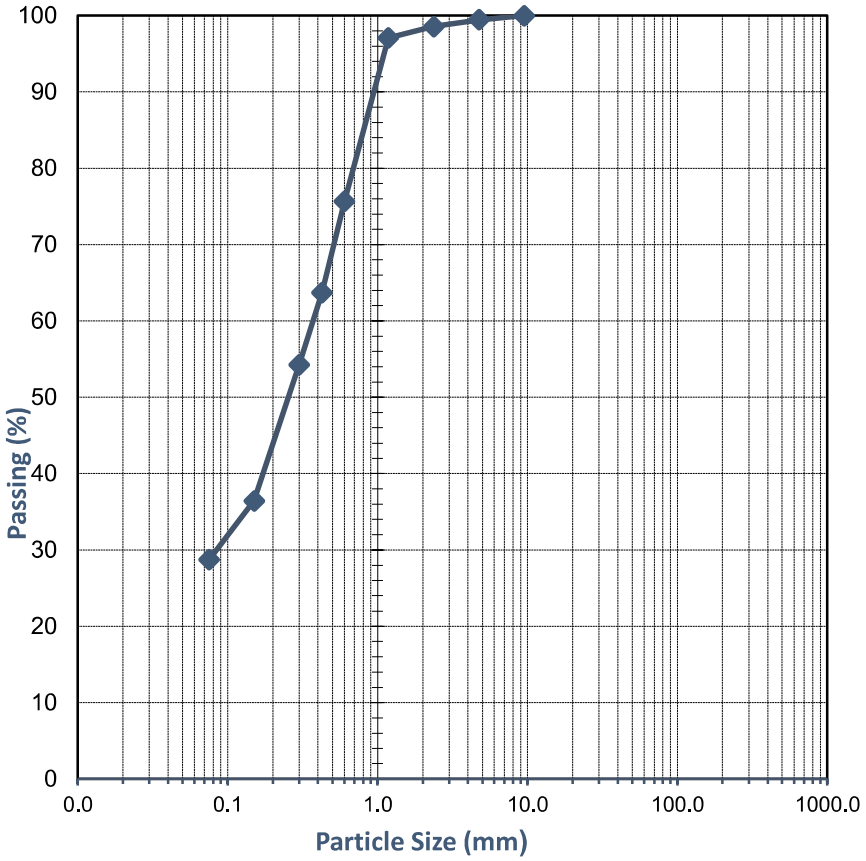
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4157_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4157
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP25, 0.3m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	99
2.36	99
1.18	97
0.600	76
0.425	64
0.300	54
0.150	36
0.075	29



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4157_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4157
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP25, 0.3m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**30**
AS 1289.3.2.1	**Plastic Limit (%)**	**15**
AS 1289.3.3.1	**Plasticity Index (%)**	**15**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**5.5**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.5.2.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4157_1_MMDD
Project:	Proposed Residential Dvelopment	*Sample No.*	WG20/4157
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP25, 0.3m	*Date Tested:*	17/03/2020

TEST RESULTS - Modified Maximum Dry Density

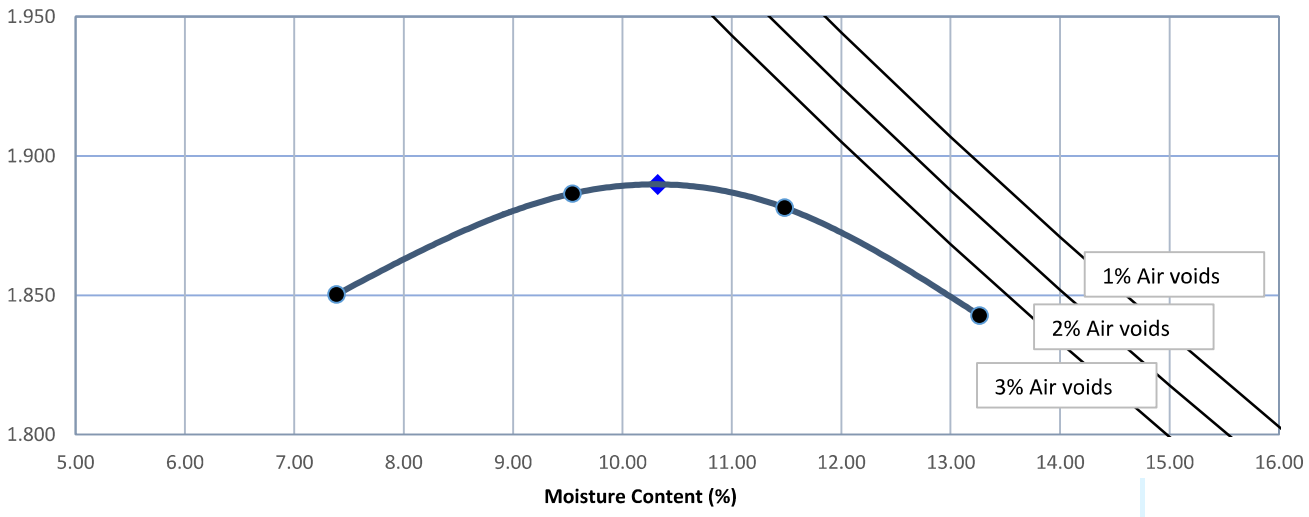
Sampling Method: Sampled by Client, Tested as Received

Sample Curing Time: 6 Hours

Method used to Determine Liquid Limit: Visual / Tactile Assessment by Competent Technician

Material + 19.0mm (%): 0 **Material + 37.5mm (%)** -

Moisture Content (%)	7.4	9.5	11.5	13.3	
Dry Density (t/m³)	1.850	1.887	1.881	1.843	



Modified Maximum Dry Density (t/m³) **1.89**

Optimum Moisture Content (%) **10.5**

Comments: *The above air void lines are derived from a calculated apparent particle density of 2.57 t/m³*

Approved Signatory:

Name: Kirk McConachy
Function: Laboratory Manager
Date: 19/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.6.1.1

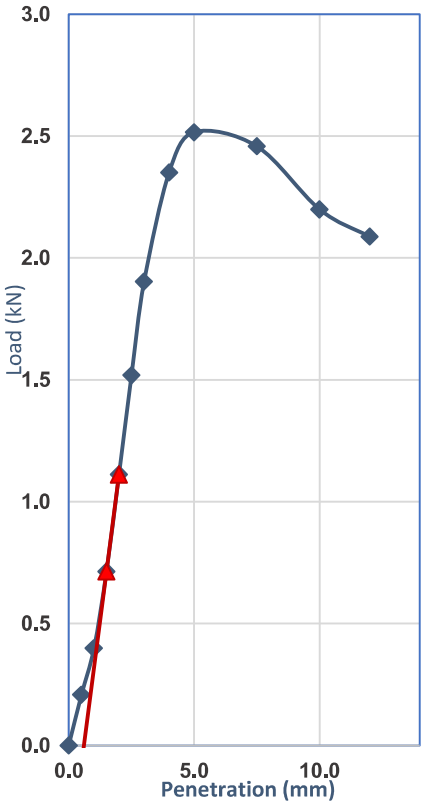
Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4157_1_SCBR
Project:	Proposed Residential Development	*Sample No.*	WG20/4157
Location:	Lots 487, 611 & 615 Arnold Road Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP25, 0.3m	*Date Tested:*	23/03/2020

TEST RESULTS - CALIFORNIA BEARING RATIO

Sample Description: Clayey Sand

Sampling Method: Sampled by Client, Tested as Received

Load Penetration Curve



Compaction Details			
Compaction Method	AS 1289.5.2.1	Hammer Type	Modified
Plasticity Determined by	Estimated	Curing Time (Hours)	26.0
% Retained 19.0mm	0	Excluded/Replaced	Excluded
Maximum Dry Density (t/m^3)	1.89	Optimum Moisture (%)	10.5
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100

Specimen Conditions At Compaction			
Dry Density (t/m3)	1.80	Moisture Content (%)	10.2
Density Ratio (%)	95.5	Moisture Ratio (%)	98.5

Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	1.0
Dry Density (t/m³)	1.78	Dry Density Ratio (%)	94.0
Moisture Content (%)	15.2	Moisture Ratio (%)	147.5

Specimen Conditions After Test			
Top 30mm Moisture (%)	12.2	Remaining Depth (%)	14.6

Correction applied to Penetration: 0.6mm

Determined at a Penetration of: 2.5mm

California Bearing Ratio (CBR): 15%

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 24/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

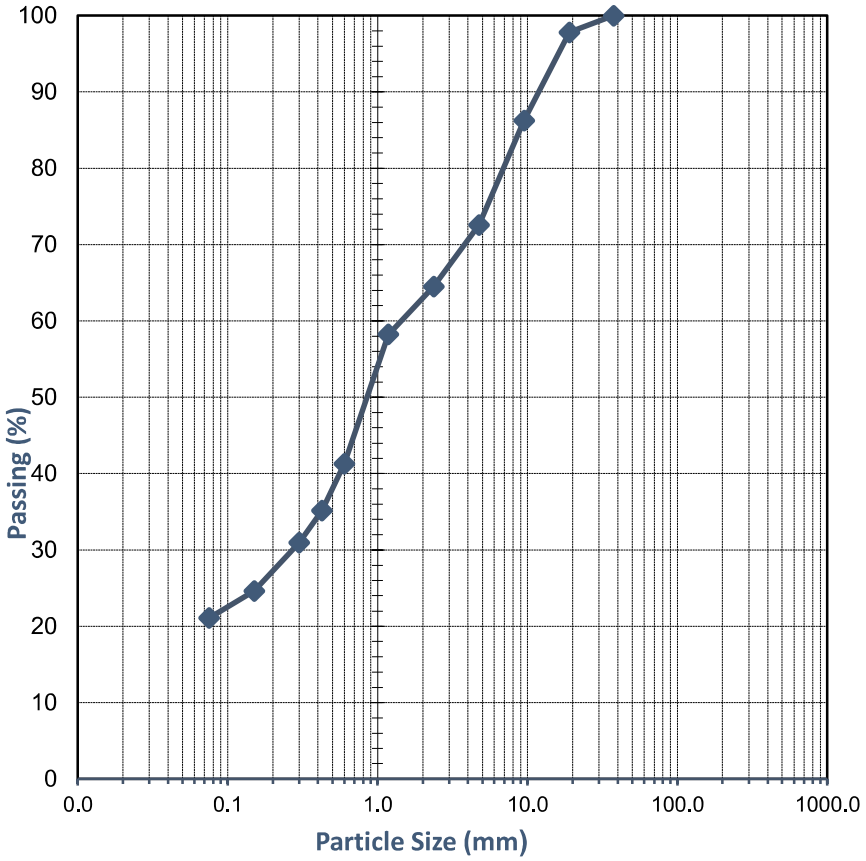
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4158_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4158
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP27, 0.5m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	100
19.0	98
9.5	86
4.75	73
2.36	64
1.18	58
0.600	41
0.425	35
0.300	31
0.150	25
0.075	21



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.1.1, 3.2.1, 3.3.1 & 3.4.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4158_1_PI
Project:	Proposed Residential Development	*Sample No.*	WG20/4158
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP27, 0.5m	*Date Tested*	20/03/2020

TEST RESULTS - Consistency Limits (Casagrande)

Sampling Method:	**Sampled by Client, Tested as Received**
History of Sample:	**Oven Dried <50°C**
Method of Preparation:	**Dry Sieved**

AS 1289.3.1.1	**Liquid Limit (%)**	**40**
AS 1289.3.2.1	**Plastic Limit (%)**	**18**
AS 1289.3.3.1	**Plasticity Index (%)**	**22**
AS 1289.3.4.1	**Linear Shrinkage (%)**	**8.0**
AS 1289.3.4.1	**Length of Mould (mm)**	**250**
AS 1289.3.4.1	**Condition of Dry Specimen:**	**Cracked**

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.7.7.1

Client:	Malf Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4159_1_SSI
Project:	Proposed Residential Development	*Sample No.*	WG20/4159
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP28, 0.8-0.9m	*Date Tested:*	19-23/03/2020

TEST RESULTS - SHRINK SWELL INDEX

Sampling Method: Sampled by Client, Tested as Received

Material Description: Sandy Clay

SWELL SPECIMEN	
Moisture Content Initial (%):	20.9
Dry Density - Initial (t/m^3):	1.68
Moisture Content Final (%):	20.8
Estimated Inert Inclusions (%):	0

SHRINK SPECIMEN	
Moisture Content Initial (%):	20.4
Extent of Crumbling:	Nil
Length/Diameter Ratio:	2.6
Extent of Cracking:	Nil

SHRINK SWELL INDEX	
Shrink Swell Index (I_{SS})	**1.2**

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 23/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

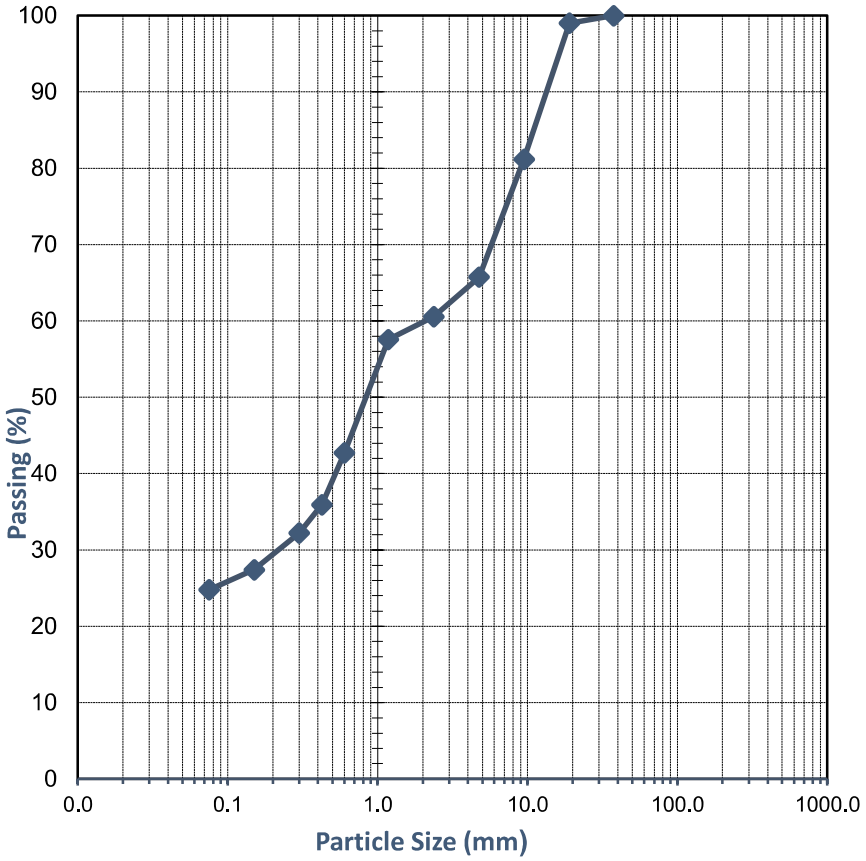
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4160_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4160
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP30, 0.6m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	100
19.0	99
9.5	81
4.75	66
2.36	61
1.18	58
0.600	43
0.425	36
0.300	32
0.150	27
0.075	25



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.3.8.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4160_1_ECN
Project:	Proposed Residential Development	*Sample No.*	WG20/4160
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP30, 0.6m	*Date Tested:*	19/03/2020

TEST RESULTS - Emerson Class Number

Sampling Method:	**Sampled by Client, Tested as Received**
Source of Material:	**Not Specified**
Soil Description:	**Clayey Sand, with Gravel**
Water Used:	**Distilled**

EMERSON CLASS NUMBER

6

Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.5.2.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4160_1_MMDD
Project:	Proposed Residential Dvelopment	*Sample No.*	WG20/4160
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP30, 0.6m	*Date Tested:*	18/03/2020

TEST RESULTS - Modified Maximum Dry Density

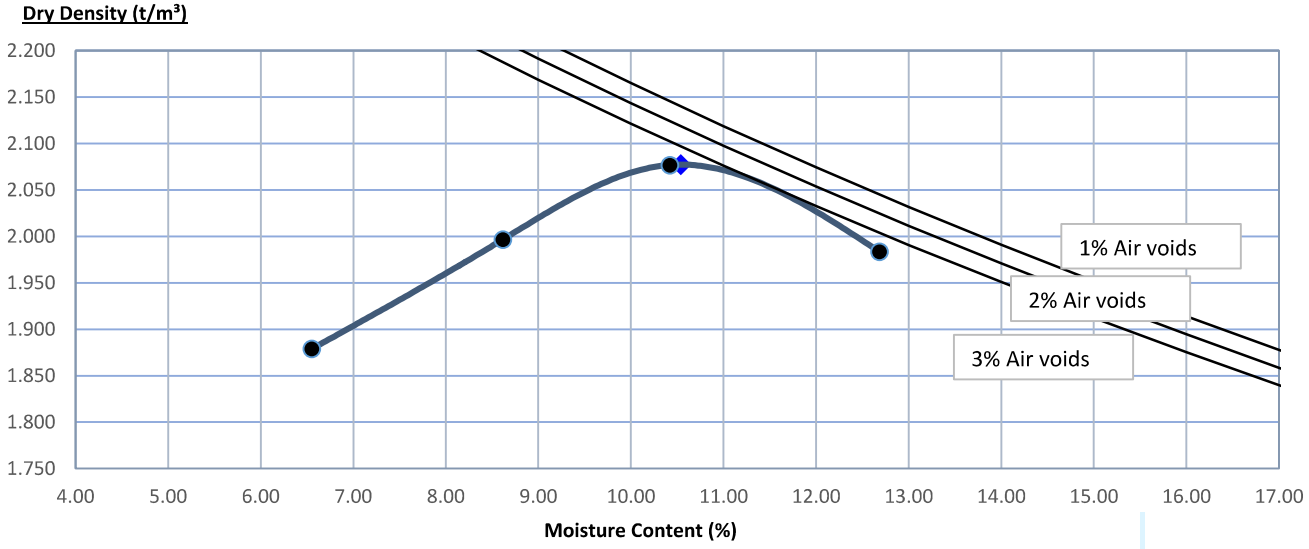
Sampling Method: Sampled by Client, Tested as Received

Sample Curing Time: 2 Hours

Method used to Determine Liquid Limit: Visual / Tactile Assessment by Competent Technician

Material + 19.0mm (%): 1 **Material + 37.5mm (%)** -

Moisture Content (%)	6.6	8.6	10.4	12.7	
Dry Density (t/m³)	1.879	1.997	2.077	1.984	



Modified Maximum Dry Density (t/m³) **2.08**

Optimum Moisture Content (%) **10.5**

Comments: *The above air void lines are derived from a calculated apparent particle density of 2.799 t/m³*

Approved Signatory:

Name: Kirk McConachy
Function: Laboratory Manager
Date: 19/March/2020

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SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - AS 1289.6.1.1

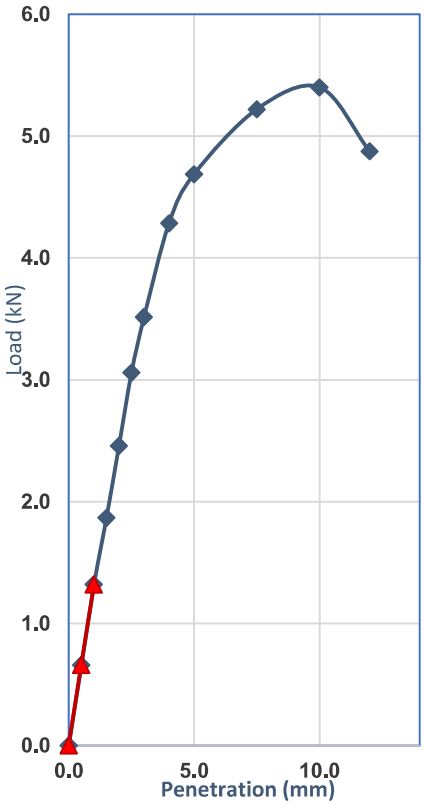
Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4160_1_SCBR
Project:	Proposed Residential Development	*Sample No.*	WG20/4160
Location:	Lots 487, 611 & 615 Arnold Road Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP30, 0.6m	*Date Tested:*	23/03/2020

TEST RESULTS - CALIFORNIA BEARING RATIO

Sample Description: Sandy Clay, with Gravel

Sampling Method: Sampled by Client, Tested as Received

Load Penetration Curve



Compaction Details			
Compaction Method	AS 1289.5.2.1	Hammer Type	Modified
Plasticity Determined by	Estimated	Curing Time (Hours)	27.0
% Retained 19.0mm	1	Excluded/Replaced	Excluded
Maximum Dry Density (t/m^3)	2.08	Optimum Moisture (%)	10.5
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100

Specimen Conditions At Compaction			
Dry Density (t/m3)	1.97	Moisture Content (%)	10.5
Density Ratio (%)	95.0	Moisture Ratio (%)	100.5

Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	1.0
Dry Density (t/m³)	1.95	Dry Density Ratio (%)	94.0
Moisture Content (%)	12.8	Moisture Ratio (%)	121.5

Specimen Conditions After Test			
Top 30mm Moisture (%)	12.1	Remaining Depth (%)	12.0

Correction applied to Penetration: 0mm

Determined at a Penetration of: 5.0mm

California Bearing Ratio (CBR): 25%

Comments:

Approved Signatory:

Name: Brooke Elliott

Function: Quality Manager

Date: 24/March/2020

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WESTERN GEOTECHNICAL & Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

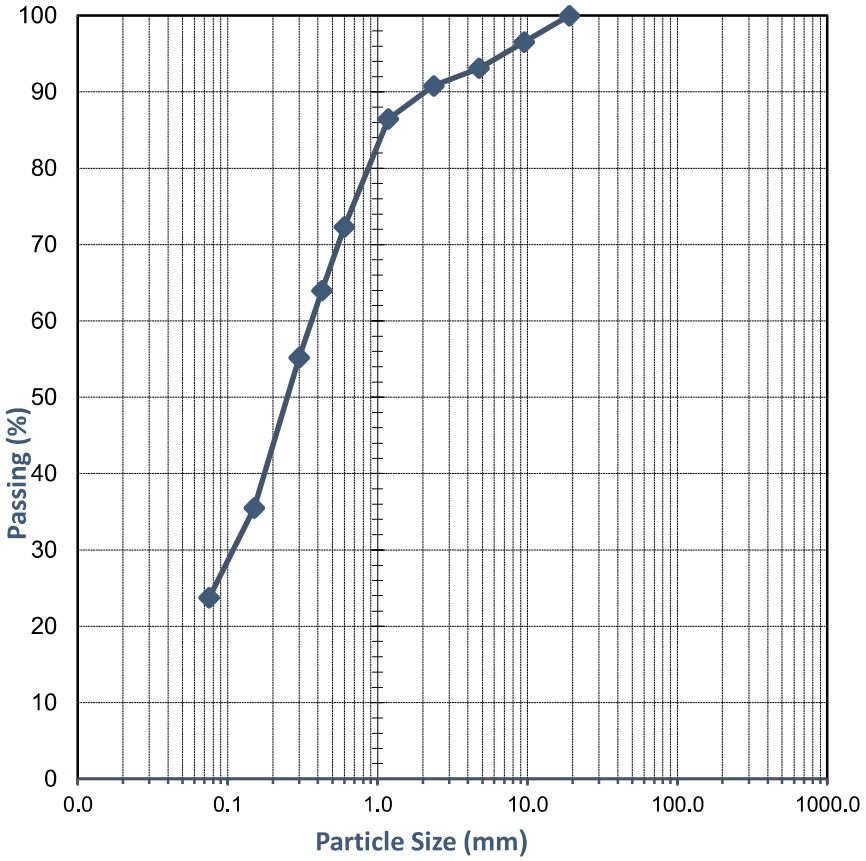
TEST REPORT - AS 1289.3.6.1

Client:	MALF Corp Pty Ltd	*Ticket No.*	S994
Client Address:	-	*Report No.*	WG20/4161_1_PSD
Project:	Proposed Residential Development	*Sample No.*	WG20/4161
Location:	Lots 487, 611 & 615 Arnold Road, Serpentine, WA	*Date Sampled:*	10/03/2020
Sample Identification:	TP32, 0.2m	*Date Tested:*	19/03/2020

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: Sampled by Client, Tested as Received

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	100
9.5	97
4.75	93
2.36	91
1.18	86
0.600	72
0.425	64
0.300	55
0.150	35
0.075	24



Comments:

Approved Signatory:

Name: Brooke Elliott
Function: Quality Manager
Date: 21/March/2020

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16-18 Hayden Court Myaree WA 6154
ph 08 9317 2505 fax 08 9317 4163
lab@mpl.com.au
www.mpl.com.au

CERTIFICATE OF ANALYSIS 241972

Client Details

Client	Douglas Partners Perth
Attention	Yujun Chen
Address	36 O'Malley St, Osborne Park, WA, 6017

Sample Details

Your Reference	**96660 - Lots 487, 611 & 615**
Number of Samples	4 Soil
Date samples received	17/03/2020
Date completed instructions received	17/03/2020
Location	Arnold Road, Serpentine

Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.

Samples were analysed as received from the client. Results relate specifically to the samples as received.

Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

Please refer to the last page of this report for any comments relating to the results.

Report Details

Date results requested by	23/03/2020
Date of Issue	23/03/2020

NATA Accreditation Number 2901. This document shall not be reproduced except in full.

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Results Approved By
Heram Halim, Operations Manager
Stacey Hawkins, Acid Soils Supervisor

Authorised By



Michael Kubiak, Laboratory Manager

Miscellaneous Inorg - soil					
Our Reference		241972-1	241972-2	241972-3	241972-4
Your Reference	UNITS	TP3, 0.8	TP19, 0.3	TP22, 0.4	TP30, 0.6
Date Sampled		10/03/2020	10/03/2020	10/03/2020	10/03/2020
Type of sample		Soil	Soil	Soil	Soil
Date prepared	-	20/03/2020	20/03/2020	20/03/2020	20/03/2020
Date analysed	-	20/03/2020	20/03/2020	20/03/2020	20/03/2020
pH	pH Units	5.0	5.0	5.1	5.7
Electrical Conductivity (EC)	µS/cm	110	36	13	84

ESP/CEC					
Our Reference		241972-1	241972-2	241972-3	241972-4
Your Reference	UNITS	TP3, 0.8	TP19, 0.3	TP22, 0.4	TP30, 0.6
Date Sampled		10/03/2020	10/03/2020	10/03/2020	10/03/2020
Type of sample		Soil	Soil	Soil	Soil
Date digested	-	20/03/2020	20/03/2020	20/03/2020	20/03/2020
Date analysed	-	20/03/2020	20/03/2020	20/03/2020	20/03/2020
Calcium	mg/kg	180	56	<50	78
Potassium	mg/kg	<50	<50	<50	<50
Magnesium	mg/kg	230	<50	<50	220
Sodium	mg/kg	<50	<50	<50	<50
Aluminium	mg/kg	<10	<10	<10	<10
Exchangeable Ca	meq/100g	0.9	0.3	<0.25	0.4
Exchangeable K	meq/100g	<0.13	<0.13	<0.13	<0.13
Exchangeable Mg	meq/100g	1.9	<0.41	<0.41	1.8
Exchangeable Na	meq/100g	<0.22	<0.22	<0.22	<0.22
Exchangeable Al	meq/100g	<0.07	<0.07	<0.07	<0.07
Cation Exchange Capacity	meq/100g	3	<1	<1	2

Phosphorus Retention Index					
Our Reference		241972-1	241972-2	241972-3	241972-4
Your Reference	UNITS	TP3, 0.8	TP19, 0.3	TP22, 0.4	TP30, 0.6
Date Sampled		10/03/2020	10/03/2020	10/03/2020	10/03/2020
Type of sample		Soil	Soil	Soil	Soil
Phosphorus Retention Index		1,090	1,080	23.3	8.81

Method ID	Methodology Summary
AGRI-003	Phosphorous Retention index (PBI) is equilabration of a sample with a solution containing P in CaCl solution at a soil: solution ratio of 1:10. A portion of the leachate is centrifuged, then an aliquot is diluted with DI water and the resultant solution is analysed for P by DA.
INORG-001	pH - Measured using pH meter and electrode base on APHA latest edition, Method 4500-H+. Please note that the results for water analyses may be indicative only, as analysis can be completed outside of the APHA recommended holding times. Soils are reported from a 1:5 water extract unless otherwise specified.
INORG-002	Conductivity and Salinity - measured using a conductivity cell at 25°C based on APHA latest edition Method 2510. Soils reported from a 1:5 water extract unless otherwise specified.
METALS-009	Determination of exchangeable cations and cation exchange capacity in soils using 1M Ammonium Chloride exchange and ICP-AES analytical finish.
METALS-009	Determination of exchangeable cations and cation exchange capacity in soils using 1M Ammonium Chloride exchange and ICP-AES analytical finish.
METALS-020	Determination of various metals by ICP-AES.

QUALITY CONTROL: Miscellaneous Inorg - soil					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date prepared	-			20/03/2020	[NT]	[NT]	[NT]	[NT]	20/03/2020	[NT]
Date analysed	-			20/03/2020	[NT]	[NT]	[NT]	[NT]	20/03/2020	[NT]
pH	pH Units		INORG-001	[NT]	[NT]	[NT]	[NT]	[NT]	102	[NT]
Electrical Conductivity (EC)	µS/cm	1	INORG-002	<1	[NT]	[NT]	[NT]	[NT]	104	[NT]

QUALITY CONTROL: ESP/CEC						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	241972-2
Date digested	-			20/03/2020	1	20/03/2020	20/03/2020		20/03/2020	20/03/2020
Date analysed	-			20/03/2020	1	20/03/2020	20/03/2020		20/03/2020	20/03/2020
Calcium	mg/kg	50	METALS-020	<50	1	180	170	6	103	#
Potassium	mg/kg	50	METALS-020	<50	1	<50	<50	0	101	#
Magnesium	mg/kg	50	METALS-020	<50	1	230	230	0	105	#
Sodium	mg/kg	50	METALS-020	<50	1	<50	<50	0	100	#
Aluminium	mg/kg	10	METALS-020	<10	1	<10	<10	0	97	#

QUALITY CONTROL: Phosphorus Retention Index						Duplicate			Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Phosphorus Retention Index			AGRI-003	[NT]	[NT]	[NT]	[NT]	[NT]	106	[NT]

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

Quality Control Definitions

Blank	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
Duplicate	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
Matrix Spike	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
LCS (Laboratory Control Sample)	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
Surrogate Spike	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

The recommended maximums for analytes in urine are taken from “2018 TLVs and BEIs”, as published by ACGIH (where available). Limit provided for Nickel is a precautionary guideline as per Position Paper prepared by AIOH Exposure Standards Committee, 2016.

Guideline limits for Rinse Water Quality reported as per analytical requirements and specifications of AS 4187, Amdt 2 2019, Table 7.2

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals (not SPOCAS); 60-140% for organics/SPOCAS (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

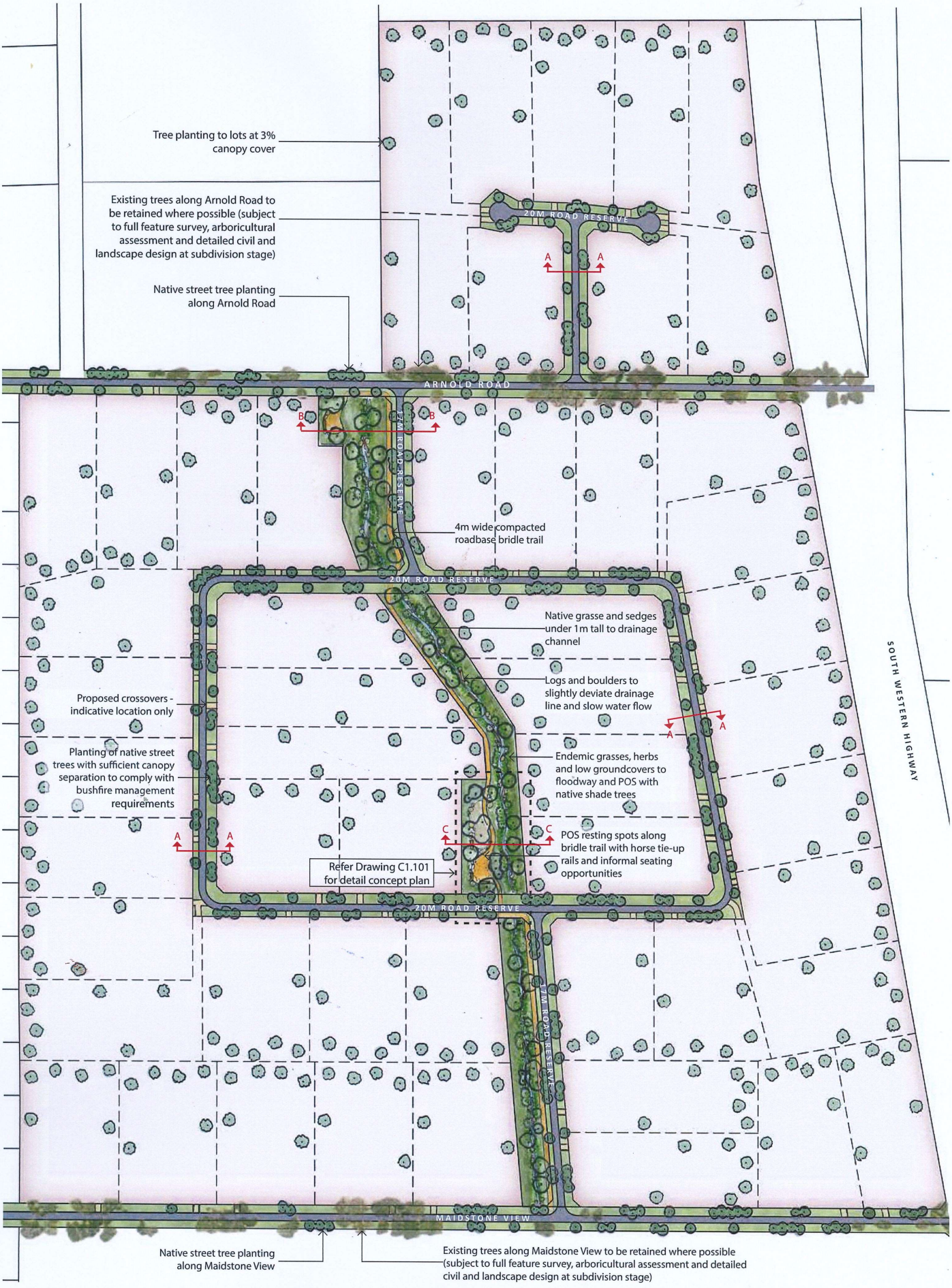
Measurement Uncertainty estimates are available for most tests upon request.

Samples for Microbiological analysis (not Amoeba forms) received outside of the 2-8°C temperature range do not meet the ideal cooling conditions as stated in AS2031-2012.

Report Comments

Matrix spike recovery was outside recommended acceptance criteria, however an acceptable recovery was achieved for the LCS. This indicates a sample matrix interference.

Appendix G
Landscape and Revegetation Strategy, Lots 611, 615 and 487 Arnold Road



ARNOLD ROAD, SERPENTINE

LANDSCAPE & REVEGETATION STRATEGY
DECEMBER 2020

JOB NO. 2002001
1:3000 @ A3

C1.101
REV F

0 15 30 60 90 150m

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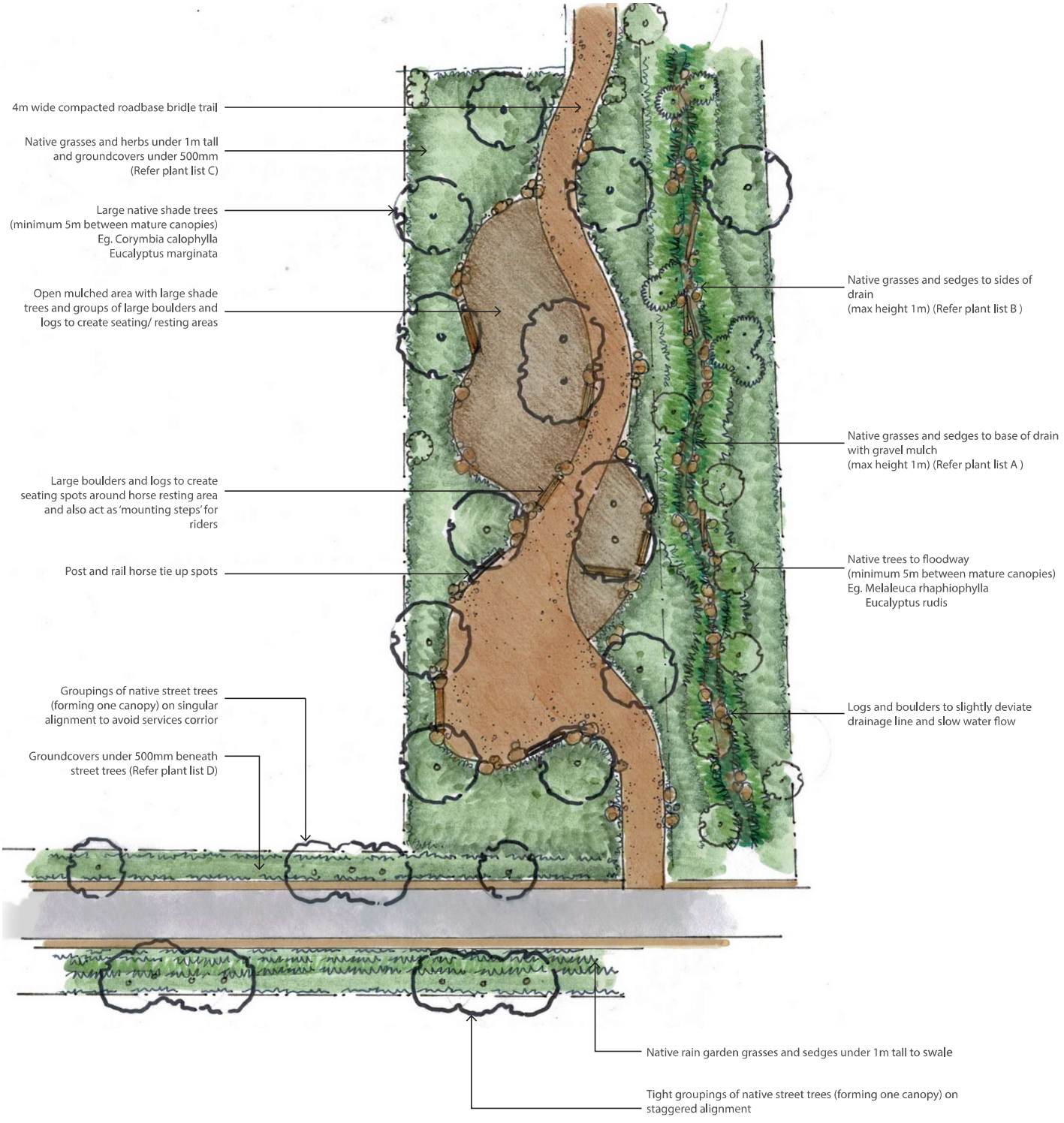

ARNOLD ROAD, SERPENTINE

INDICATIVE LANDSCAPE CONCEPT PLAN - POS AREAS
AUGUST 2020

JOB NO. 2002001
1:500 @ A3

C1.102

REV B

0 5 10 15 25m

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SECTION AA

ARNOLD ROAD, SERPENTINE

PREPARED FOR MALFCORP PTY LTD

LANDSCAPE CONCEPT SECTION

DECEMBER 2020

JOB NO. 2002001

1:50 @ A1

C2.101

REV A

0 .5 1 2 3 5m

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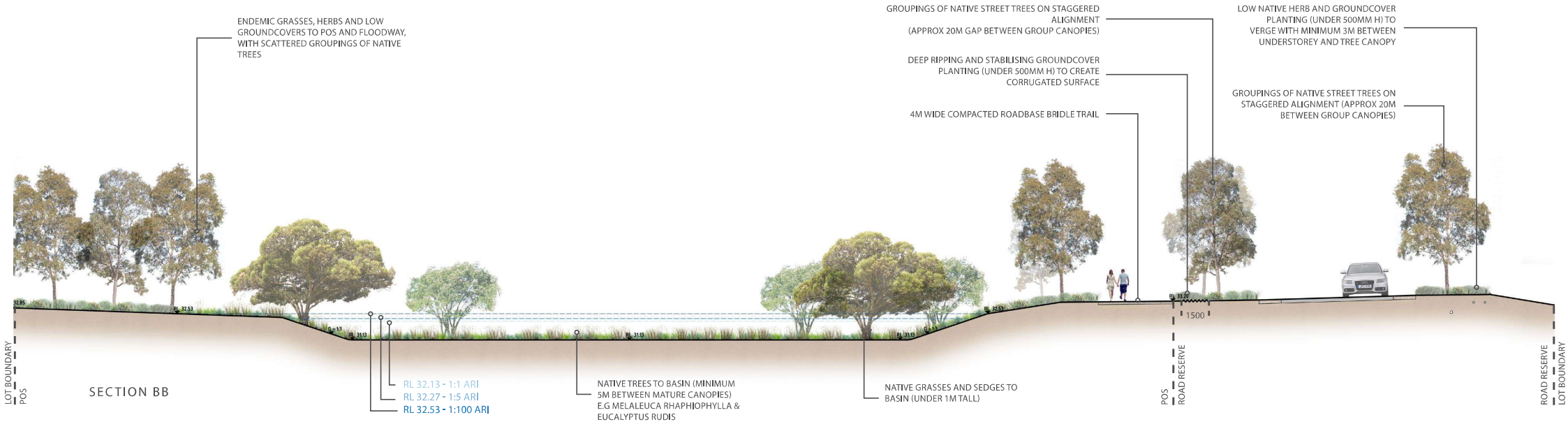

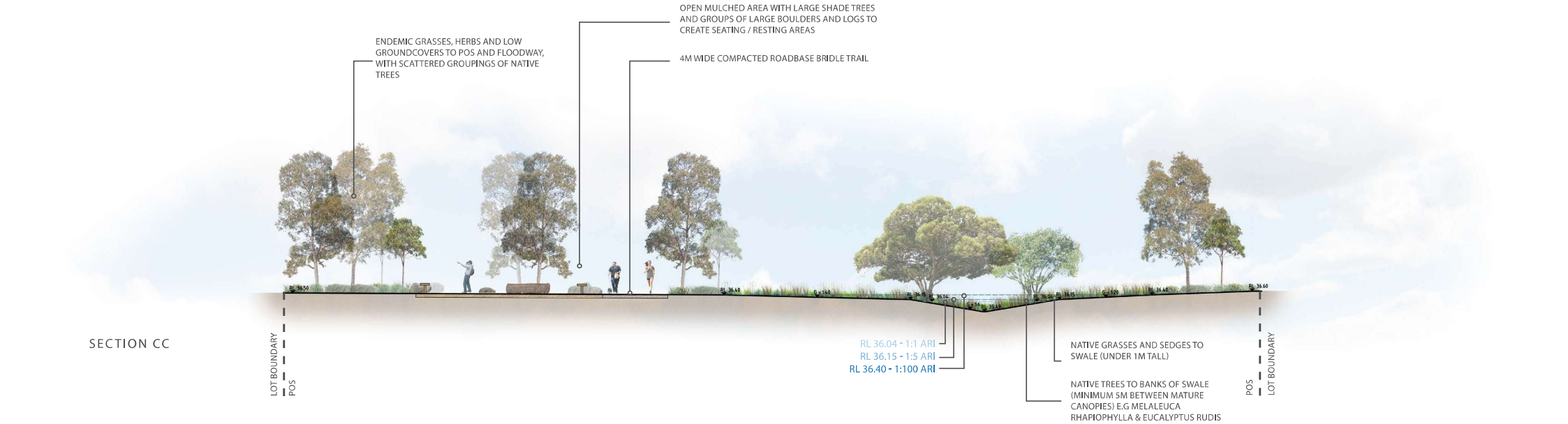

ARNOLD ROAD, SERPENTINE

PREPARED FOR MALFCORP PTY LTD

LANDSCAPE CONCEPT SECTION

DECEMBER 2020

JOB NO. 2002001

1:100 @ A1

C2.102

REV A

0 1 2 4 6 10m

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DRAINAGE CHANNEL BASE

(WET IN WINTER/DAMP IN SUMMER. REEDS, SEDGES & GRASSES UNDER 1M HIGH WITH GRAVEL MULCH)

BAUMEA JUNCEA
JUNCUS PALLIDUS
JUNCUS SUBSECUNDUS
LEPIDOSPERMA LONGITUDINALE



DRAINAGE CHANNEL SIDES

(DAMP IN WINTER/DRY IN SUMMER. REEDS, SEDGES & GRASSES UNDER 1M HIGH)

EUCALYPTUS RUDIS
MELALEUCA RHAPHIOPHYLLA

CAREX APRESSA
FICINIA NODOSA
JUNCUS PALLIDUS
JUNCUS SUBSECUNDUS

JUNCUS SUBSECUNDUS
LEPIDOSPERMA SQUAMMATUM
MEEBOLDINA SCARIOSA



UPPER FLOODWAY & POS

(GRASSES & HERBS UNDER 1M HIGH WITH LOW FLAMMABILITY AND GROUNDCOVERS UNDER 500MM)

ALLOCASUARINA FRASERIANA
CORYMBIA CALOPHYLLA
EUCALYPTUS MARGINATA

ACACIA LASIOCARPA PROSTRATE
ANIGOZANTHOS HUMILIS
ANIGOZANTHOS VIRIDUS
BRACHYSCOMBE IBERIDIFOLIA

CAREX APRESSA
CONOSTYLIS ACULEATA
DAMPIERA ALATA
DAMPIERA LINEARIS
DASYPOGON BROMELIIFOLIS
DIANELLA REVOLUTA
ERAGROSTIS ELONGATA
FICINIA NODOSA
GREVILLEA BIPINNATIFIDA
HEMIANDRA PUNGENS
HIBBERTIA HUEGELII
LOMANDRA 'VERDAY'

HOVEA TRISPERMA
LEPIDOSPERMUM SQUAMMATUM
LOBELIA ANCEPS
PATERSONIA OCCIDENTALIS
POA POIFORMIS
ORTHROSANTHUS LAXUS
SCAEVOLA GLANDULIFERA



STREETSCAPE

(LOW FLAMMABILITY RATED GROUNDCOVERS OR HERBS UNDER 500MM HIGH)

CORYMBIA CALOPHYLLA
EUCALYPTUS LANE POOLEI
EUCALYPTUS WANDOO

ACACIA LASIOCARPA PROSTRATE
ACACIA SALIGNA PROSTRATE
DAMPIERA LINEARIS
GREVILLEA BIPINNATIFIDA
HEMIANDRA PUNGENS



ROADSIDE DRAINAGE SWALES

(GRASSES/REEDS/HERBS UNDER 1M HIGH WITH GRAVEL MULCH & OCCASIONAL ROCK PITCHING)

CAREX APRESSA
CONOSTYLIS ACULEATA
DIANELLA REVOLUTA
FICINIA NODOSA
LEPIDOSPERMA SQUAMMATUM
LOMANDRA 'SHARA'
PATERSONIA OCCIDENTALIS



RESIDENTIAL LOTS

(TREES PLANTED IN ACCORDANCE WITH APZ STANDARDS)

CORYMBIA CALOPHYLLA
EUCALYPTUS LANE POOLEI
EUCALYPTUS WANDOO



ARNOLD ROAD, SERPENTINE

PROPOSED LANDSCAPE PLANT MIXES
AUGUST 2020

JOB NO. 2002001 C3.101 REV D
1:3000 @ A3

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Appendix H
Desktop Engineering Servicing Report, Lots 611, 615 and 487 Arnold Road

Lots 487, 611 & 615 Arnold Road, Serpentine

Desktop Engineering Servicing Assessment

Project No: 19-009



pritchard francis lite
civil engineering consultants

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Appendix One: Geotechnical Conditions

Appendix Two: Groundwater and Acid Sulphate

Appendix Three: Aboriginal Register

Appendix Four A: Typical Cross Section Details

Appendix Four B: Section Locations

Appendix Five: Western Power Underground Network

Appendix Six: Western Power Overhead Network

Appendix Seven: Telstra Network

Revision	Description	Author	Date

0	Issued for Inclusion in Report	Philip Patterson	19 March 2020

On behalf of MALF Corp Pty Ltd. Pritchard Francis Lite have undertaken an investigation associated with servicing of Lots 487, 611 and 615 Arnold Road, Serpentine.

1 Introduction

The below information and attached documents represent a summary of engineering services needing upgrade or extension to service the proposed subdivision over Lots 487, 611 and 615 Arnold Road, Serpentine.

2 Site Description

This development is situated about 60km south east of the Perth CBD in the Shire of Serpentine/Jarrahdale.

The site is reasonably flat and grades from a high of 45m at the south east corner of the site to a level of 32m along its northern boundary over a distance of 1km.

The only significant vegetation on the site is located along the existing Arnold Road reserve which bisects the site in an east/west direction. The rest of the site is typical grazing land with no trees or outcrops of vegetation.

3 Local Authority

As mentioned previously, the site is located in the Shire of Serpentine/Jarrahdale, who are aware of the development and who have been involved in meetings associated with this development.

4 Geotechnical and Environmental

4.1 Ground Condition

Geotechnical mapping indicates the site is made up of two distinct types of soils, as can been seen in Appendix 1.

On the western side of the development, soil conditions are of a sandy clay while the eastern section of the development is more a gravelly, clayey sand.

4.2 Flora and Fauna

With the lack of significant vegetation on the site it is unlikely the Shire will require a fauna survey to be undertaken but a flora survey may be required.

4.3 Acid Sulphate

The state government produces a map which identifies the possibility of acid sulphate conditions. This plan identifies areas of low and high risk. Information obtained for this development site indicates there is a moderate to low risk of encountering acid sulphate conditions on site. See Appendix 2.

4.4 Aboriginal Heritage

A search of the native title/heritage registry has been undertaken and there are no native title areas of interest noted on the land south of Arnold Road, however the area north of Arnold Road is registered as a Ceremonial Mythological area and will require further investigation. Appendix 3.

5 Roadworks

Meetings have been held with the Shire of Serpentine/Jarrahdale regarding road make up and configuration for this development. It has been agreed that the development will be serviced by 6m wide, sealed, un-kerbed road with 1.2m wide shoulders. The road will be constructed with one-way cross fall. Roads within the development will discharge water into a road side table drains while the main North/South road running along the main drain will discharge water towards the drain over a treatment area before discharging into the drain. The section detailed in Appendix 4 has been developed in association with Shire of Serpentine/Jarradale and DWER the achieve a low maintenance acceptable solution to handle drainage to run off from the road.

It is proposed Maidstone view will be constructed as a rural road and our intention would be for trees to be retained where possible, subject to full feature survey, arboricultural assessment and detailed civil and landscape design at subdivision stage. Our intention would be to work in conjunction with the Shire on this(as the Shire may need to allow some dispensations).

Vegetation on Arnold Rd, for our intention would be for trees to be retained where possible, subject to full feature survey, arboricultural assessment and detailed civil and landscape design at subdivision stage. Our intention would be to work in conjunction with the Shire on this (as the Shire may need to allow some dispensations).

Arnold Road, where it abuts the development, will be upgraded as part of the development work in accordance with traffic requirements and recommendations.

6 Stormwater Drainage

As mentioned in the previous section, internal roads will be constructed with one-way cross fall and will discharge into a roadside table drain that will cater for water runoff.

The main spine road will also be constructed with one-way cross fall and stormwater runoff will discharge across treatment areas before discharging into this main drain.

It is proposed to capture and treat stormwater from roads in table drains treatment areas in the road reserve adjacent to the main drain and in the main drain as agreed with Shire of Serpentine/Jarradale and DWER.

Lot access will be provided to individual lots and where these crossovers run over table drains, a dia 375mm pipe with headwalls is to be installed under crossovers.

All lot drainage will be contained on site.

7 Water Supply

There is an existing potable water supply system servicing the existing development to the west of this site that can be extended to service the new lots. This existing network consists of Ø150mm water main in Range View Loop and Lefroy Street that will be extended east and looped through the development providing a potable water supply to all lots.

8 Sewer Reticulation

Lots in the development require private effluent treatment systems to be installed by individual lot owners as no piped gravity system exists.

A Geotechnical Investigation has been carried out and a report prepared which confirms the use of on-site effluent disposed and treatment systems are acceptable.

In order for effluent systems to operate efficiently, a clean layer of sand should be placed above the existing ground beneath the treatment system to increase permeability. Alternatively, the cells could be placed in a mound above the existing ground which would allow infiltration to accommodate the primary effluent. This would need to be designed as part of the house build.

9 Gas Supply

There is no natural gas network in the area and no supply with be available for this development.

10 Electrical Services

10.1 Existing Power Distribution Network

The existing Western Power (WP) distribution infrastructure in the vicinity of the site comprises of a 22kV three phase aerial High Voltage (HV) and underground three phase Low Voltage (LV) network.

HV aerials exist along the eastern side of South Western Highway running in a south to north direction located within Lots 814-816. The next closest HV network is located approximately 800m northwest from proposed Lot 1 on Leslie Street or 800m west of proposed Lot 19 on Hardey Road. The HV spurs on these two roads spur from main HV feeder line located on the west side of Hall Road. The closest underground LV network is located on the northern verge of Maidstone View which originates from a pad mounted transformer on Lots 72/73 Rangeview Loop located approximately 280m west of proposed Lot 19.

Information on the capacity of the local zone substation can be determined from Western Power's public Network Capacity Mapping Tool (NCMT). The substation that appears to supply the HV network adjacent to the subject site is the Byford zone substation, which is located near the intersection of George Street and Thomas Road approximately 18.6km north as the crow flies. Currently there is less than 5MVA capacity in the zone substation. Within the next ten years, this is expected to stay the same, suggesting that Western Power have not scheduled/planned any reinforcement/upgrades for the area. The spare capacity in the adjacent HV network however can only be confirmed via an official application to Western Power such as a Design Information Package request or feasibility study request.

10.2 Likely Load

For the 51 rural residential free hold lots & 2 public open spaces, at Western Power's standard 5kVA per lot allocation, the total load will be in the order of 265kVA. As newly created lots, there are no load currently allocated to the lots.

10.3 Likely Power Supply Scenario

10.3.1 Site Supply Infrastructure

WP requires that all new developments are to be serviced by underground three phase power. WP also require any existing HV and LV aerials adjacent to the land being subdivided to be undergrounded and any existing consumers affected will have to have their consumer mains reconnected to the network.

In the freehold residential development scenario this would be by traditional WP owned and maintained Underground Residential Distribution (URD) 3-phase direct buried underground cabling from new transformer(s) to pillars servicing each freehold lot on the general basis of one pillar serving two adjacent lots.

Based on the estimated load for the site and proximity of the existing WP network to the proposed lots, the development will likely require new WP underground infrastructure to be installed. The existing adjacent network will not have the capacity to service the entire development.

To service the proposed development would likely require Western Power to remove bays of aerials on Chatfield Road and terminating HV feeder cables to these poles. Where capacity does not permit, HV connection will need to come from the HV network located on Hall Road or Hardey Road. The HV feeders will then supply a HV switchgear strategically placed within the development servicing a 315kVA transformer centrally located within the development which will supply power to the newly created residential lots. Where the transformer cannot be centrally located, a second transformer may be required due to power quality issues. Discussions with WP are required to determine the extent of aerial removal and whether alternative HV connection arrangements are possible. The spare capacity in the adjacent HV network can only be confirmed once an official application to Western Power such as a Design Information Package request or feasibility study request.

Typically, HV substations are placed on Public Open Space (POS) lots to avoid affecting one of the newly created residential lots. This cannot always be achieved due to the need to meet technical requirements. Typical land requirements for HV substations are as follows:

- HV Switchgear and transformer 6.2m (W) x 4m (D)
- Transformer only 3.7m (W) x 4m (D)
- Switchgear only 4.5m (W) x 3m (D)

10.3.2 Relocation of Existing Assets

From Dial Before You Dig plans, Western Power assets do not exist along the boundaries of the site and therefore, no relocations works are required around the site. Where communication pits exist within 15m of proposed HV connection points, pits may need to be relocated.

10.3.3 Headworks

As the load of the site is under 1.5MVA, we understand that it's currently WP's policy to allow the load to connect without any capacity headworks costs for any augmentation of the upstream network being passed on to the customer.

The NCMT indicated that available capacity is currently less than 5MVA. The estimated demand of this site is under 500kVA and will not likely have significant impact on the remaining capacity in the network and therefore should not warrant the project being responsible for contributing towards the costs of an upgrade at the zone substation, to create additional capacity.

The existing capacity of the HV aerial line in the vicinity to the site is unknown. This information must be sort from Western Power via a formal application. From the information available to us, we would anticipate significant load on the HV feeder, possibly in the order of the feeder's capacity. Therefore, it's plausible that some augmentation of the existing network may be required. This would most likely consist of the shifting of load between adjacent existing HV circuits.

This could include a section of new underground HV cable being installed at a location well away from the site and one or more pole top HV switches or padmount HV switchgear units being installed. The extent of the works is to be confirmed by Western Power.

10.3.4 Lighting for New Roadways

All newly created roadways will require new lighting to satisfy the requirements of AS1158 and the Local Government Authority. The lighting could consist of standard or decorative Western Power lighting poles, or if the Local Government preferred, "privately" (Local Government) owned lighting, where any range of suitable lighting products could be utilised, opening up the opportunity to use broader technologies and strategies, including:

- Architectural lighting poles and luminaires.
- High efficiency and low glare LED luminaires.
- Multi-technology poles, including banner mounts, CCTV cameras and power outlets.
- Time based, light level and motion detection-controlled lighting operation and output levels.

Currently no lighting exists on the sections of Arnold Road and South Western Highway which abuts the development site. With lighting installed on the development to the west on Rangeview Loop, it is expected that the Shire will request a proper lighting arrangement for this development.

South Western Highway falls under the management of Main Roads WA (MRWA). Any lighting and works proposed on this road reserve are to be reviewed/approved by MRWA.

10.4 Supply Timelines

Western Power will neither reserve capacity nor guarantee supply to this development without a formal request being lodged. A Subdivision Design Information Package (DIP) request must be prepared and submitted to Western Power for the design and construction of the proposed development to commence.

From the date of DIP request submission DIP is typically provided between eight to twelve weeks. Soon after, a design can be lodged with WP for conformance and quoting. From the date of the design being lodged with WP, the design acceptance and works quote is typically provided within eight to twelve weeks. Once the quote is paid and construction package is submitted, construction may commence.

To avoid any project delays, it is highly advised that a DIP request is prepared and submitted to Western Power as soon as possible.

10.5 Possible Constraints

The following may affect the ultimate utility services design and delay approval and construction timeframes.

- Vegetation occupying utility alignments on road reserve
- MRWA approval required for serviced proposed within South Western Highway Road Reserve
- WP easements for cables in private property
  - If extent of HV undergrounding is required to enter Lots 64 & 816 on Chatfield Road
  - Where non-standard alignments are proposed within lots
- Low owners approval for any works within private property
- Rail authority (arc infrastructure) approval for works in cables crossing rail reserve where HV connection point is confirmed to be off the Hall Road HV network
- Coordination between existing services
  - Existing communication network currently runs inside lot
  - Hardey's Creek Main Drain

11 Communication Services

11.1 Existing Communication Networks

Telstra's existing network is currently adjacent to Arnold Rd and South West Hwy with Telstra's Serpentine Exchange is located about 1500m route length to the north-west, so there is ready access to existing fixed line telecommunications infrastructure.

The proposed 51 rural residential development falls completely within NBN Co's Fixed Wireless Footprint, therefore NBN Co are Infrastructure Provider of Last Resort (IPoLR) for broadband and Telstra IPoLR for voice infrastructure. NBN Co must service the development with broadband, given that their existing network has coverage of the development, should the Developer wish to utilise NBN Co services. If the Developer were satisfied with Fixed Wireless infrastructure for broadband services, there would be no need to lodge an infrastructure with NBN Co. However, an infrastructure application would need to be lodged with Telstra, for voice infrastructure.

11.2 Developer Responsibilities

Developers have two obligations in relation to the provision of telecommunications infrastructure. Under the Telecommunications Act 1997, Developers are obliged to provide fibre ready pit and pipe to new developments and under the Federal Governments Telecommunications in New Developments (TIND) policy, Developers are required to provide telecommunications infrastructure as they do for other utilities. To ensure that telecommunications can always be provided, the federal government has specified the NBN Co and Telstra shall be IPOLR, in certain portions of the network.

11.3 Proposed Communications Network

Given the size of the development, NBN Co may consider reclassifying the area into its Fixed Line Footprint, in which case FTTP technology would be delivered to properties and NBN Co would be IPoLR for both broadband and voice infrastructure. If so, the developer would still be required to make the development fibre ready but in this instance would also be required to contribute to NBN Co's charges for fibre infrastructure. NBN Co would take ownership of new pit and pipe, under this scenario. If NBN Co won't reclassify the area, then the Developer would not be required to provide any capital contribution towards NBN Co's Fixed Wireless network, based on the current application of the TIND policy. Property owners only need to contact their Retail Service Provider of choice, for broadband services. Under these circumstances the Developer would still need to make the development fibre ready and approach Telstra for voice infrastructure. Telstra would take ownership of the pit and pipe and most likely provide copper infrastructure.

The development is only 100m from Fixed Line Footprint properties, so if accepted by NBN Co, it is unlikely that any Backhaul Charge would apply. Access to an existing Telstra P100 network is readily available on Arnold Rd, so we would not foresee the need for any Backhaul pit, pipe or fibre.

11.4 Network Relocations

Since Telstra pit and pipe has been installed through private property on the eastern side of lot 615, adjacent to South West Hwy and on the northern border of lot 487, adjacent to Arnold Rd, a relocation request would need to be lodged with Telstra to have these assets moved onto road reserve, unless there were extenuating reasons requiring that they remain on private property ie. protection of Flora and fauna. We recommend relocation to avoid encumbering the 10 affected lots. We are not aware of any other telecommunications carriers affected.

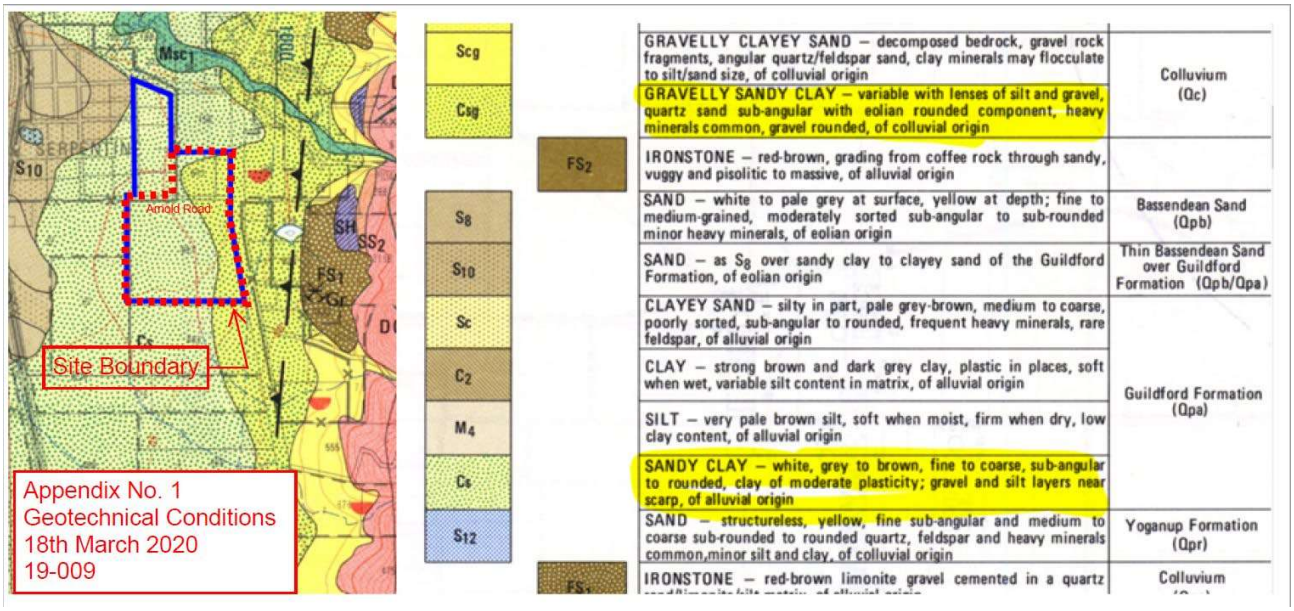
12 Conclusion

Based on information available, it would appear this land is capable of being serviced by essential services and the supporting information confirm this.

Appendices

Appendix One:	Geotechnical Conditions
Appendix Two:	Groundwater and Acid Sulphate
Appendix Three:	Aboriginal Register
Appendix Four:	A - Typical Cross Section Details B - Section Locations
Appendix Five:	Western Power Underground Network
Appendix Six:	Western Power Overhead Network
Appendix Seven:	Telstra Network

Appendix One: Geotechnical Conditions



Appendix Two: Groundwater and Acid Sulphate

E70/5209

Depth to water	Depth of water
-.- m	-.- m

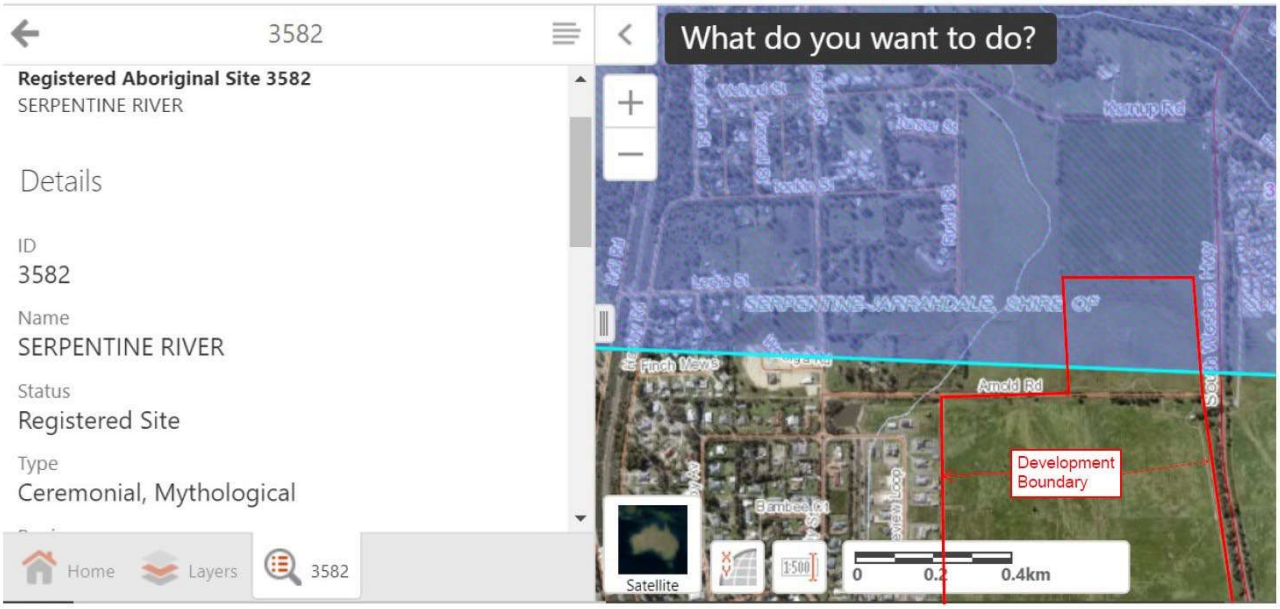
DEPTHS | WATER QUALITY

Groundwater Salinity	**500-1000** mg/L
Surface Geology Type	**Guildford Clay: alluvium (clay, loam, sand and gravel)|Qpg**
Iron Staining Risk	**Low risk**
Garden Bore Suitability	**Unsuitable**
Acid Sulfate Class	**Moderate to low risk**
Public Drinking Water Source Areas (PDWSA)	**N/A**

Appendix No. 2
Groundwater and Acid Sulphate
18th March 2020
19-009

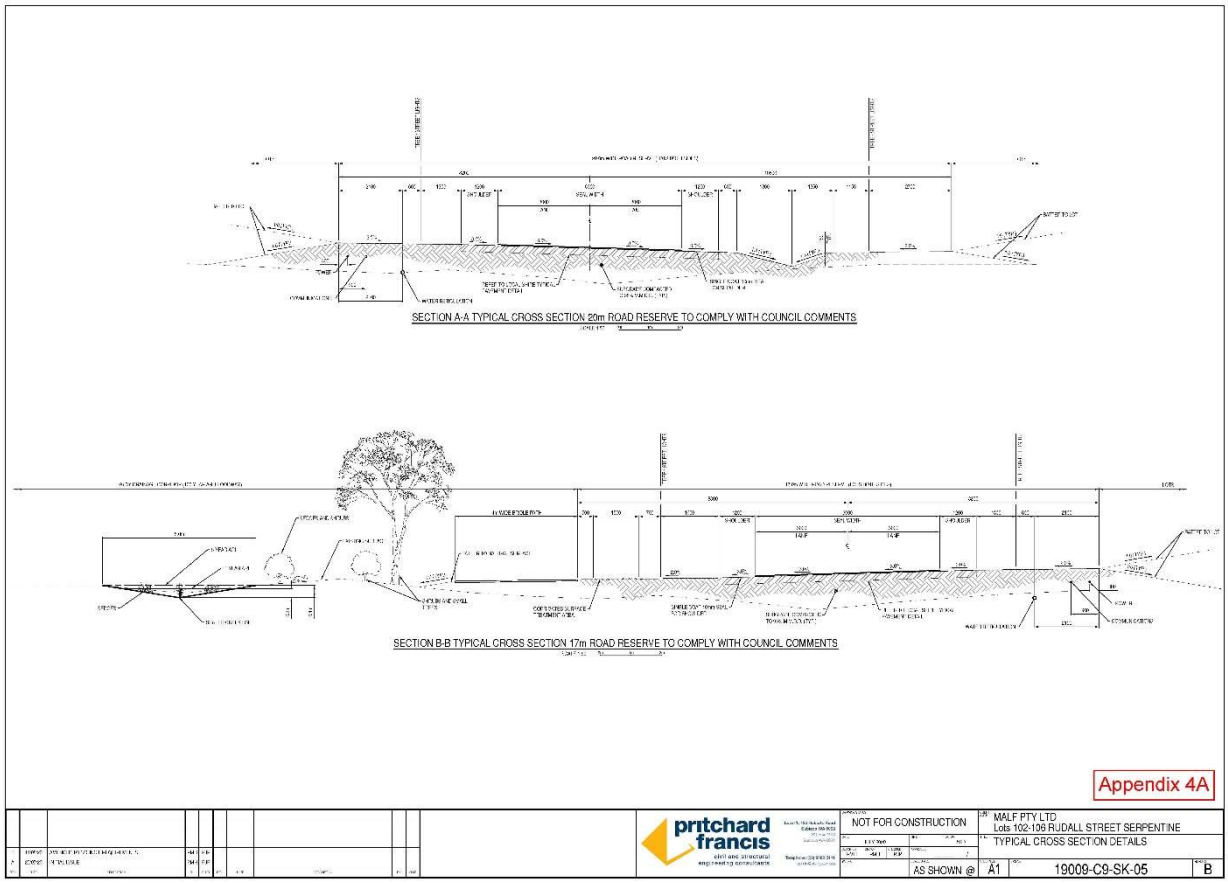


Appendix Three: Aboriginal Register

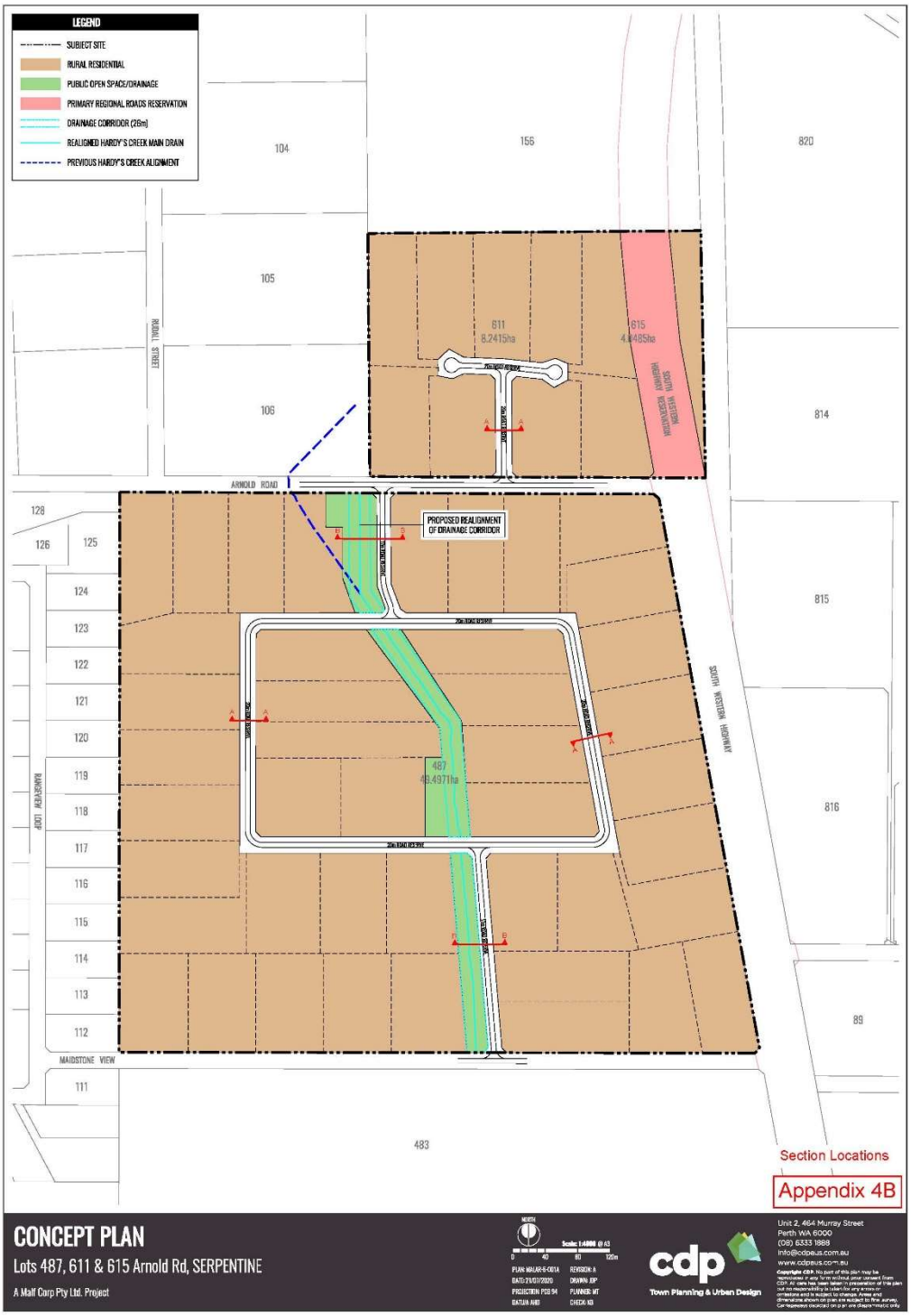


Appendix No. 3
Aboriginal Register
18th March 2020
19-009

Appendix Four A: Typical Cross Section Details



Appendix Four B: Section Locations



Appendix Five: Western Power Underground Network

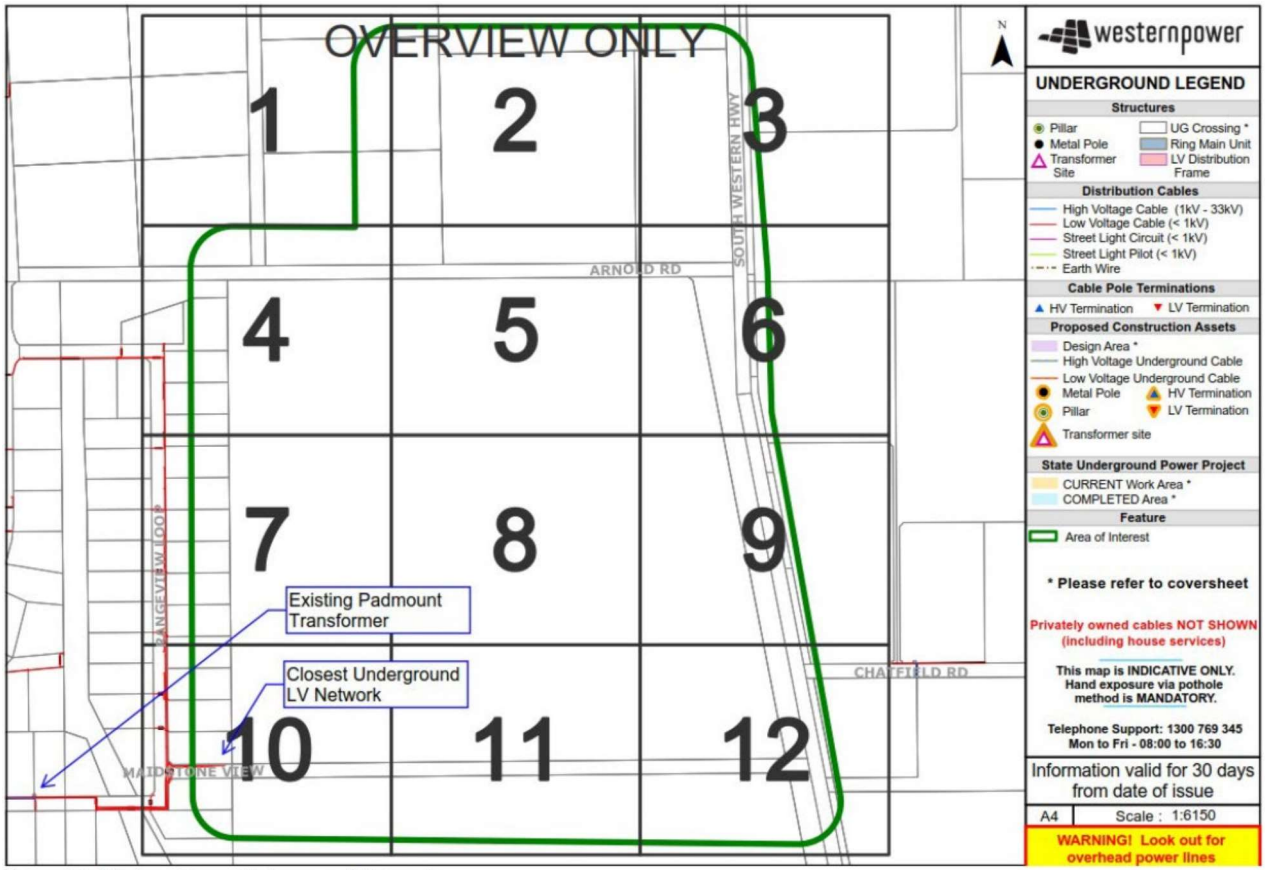


Figure 1.1: Western Power Underground Network

Appendix Six: Western Power Overhead Network

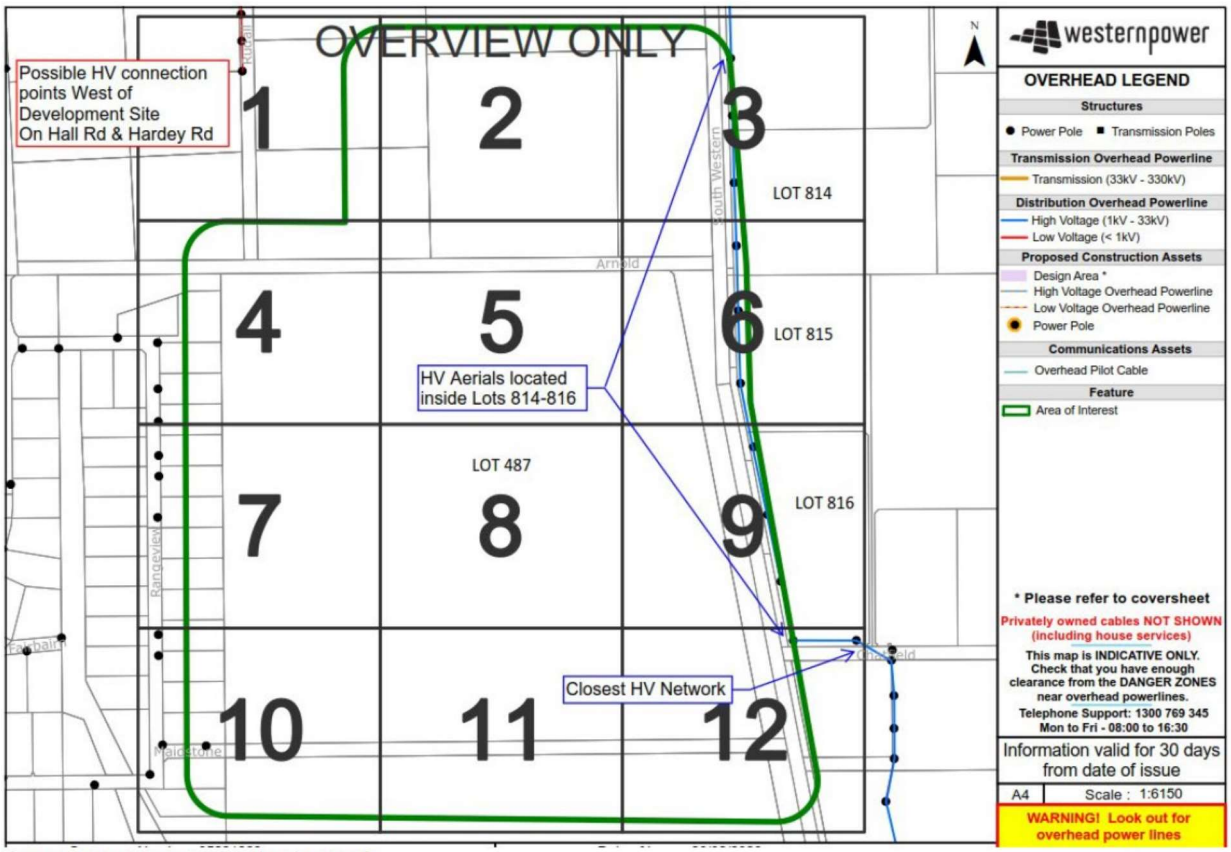
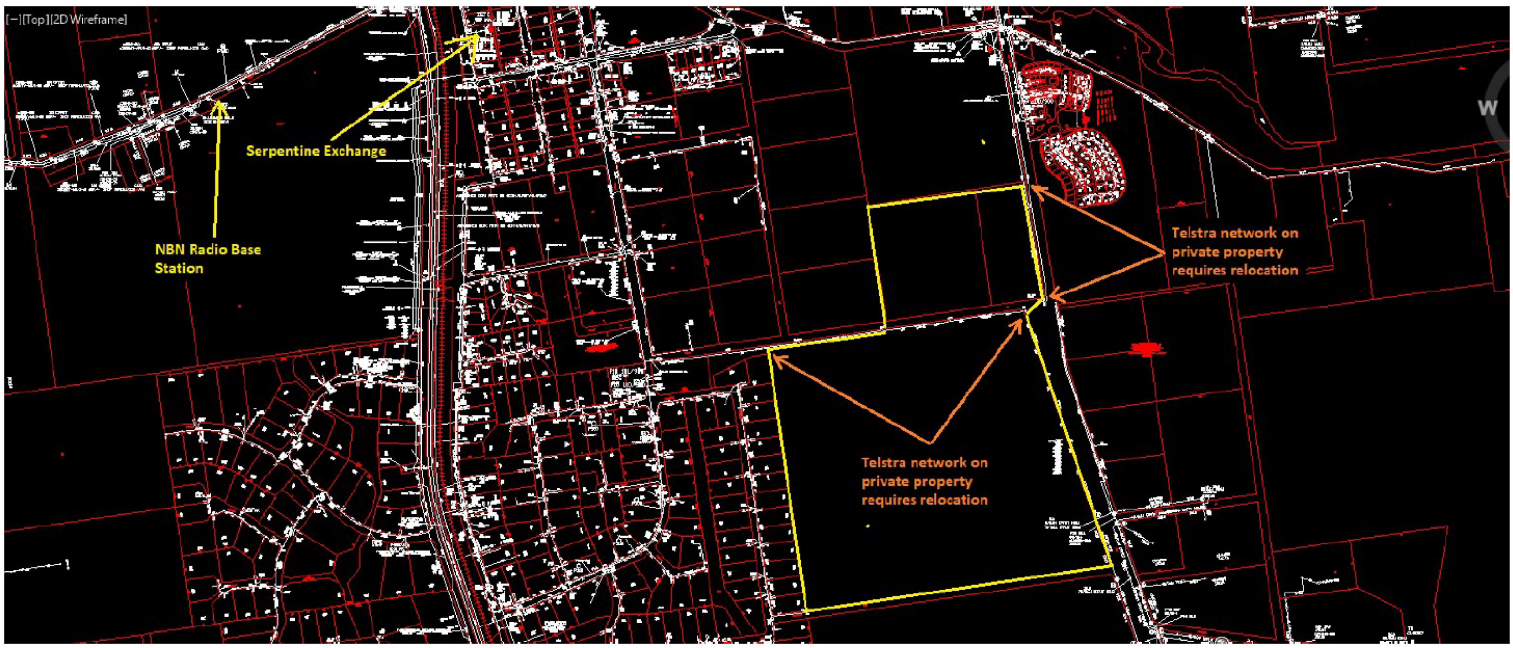


Figure 1.2: Western Power Overhead Network

Appendix Seven: Telstra Network



Telstra network Fig 1.3



Appendix I
Bioretention treatment correspondence with DWER and the Shire

Gerard Edwards

From: Carl Done <cdone@sjshire.wa.gov.au>
Sent: Friday, 7 August 2020 4:54 PM
To: Philip Patterson
Subject: Fwd: 19-009 Arnold Road, Serpentine - Cross Sections

Hi Phil,

Please see below from DWER. Will address other enquires Monday.

Carl

Sent from my iPhone

Begin forwarded message:

Carl Done
Coordinator Subdivisions

+618 9526 1512 +61 408 345 722
Shire of Serpentine Jarrahdale
6 Paterson Street Mundijong, WA 6123
www.sjshire.wa.gov.au

From: Brett Dunn <brett.dunn@dwer.wa.gov.au>
Date: 7 August 2020 at 3:10:46 pm AWST
To: Carl Done <cdone@sjshire.wa.gov.au>
Subject: RE: 19-009 Arnold Road, Serpentine - Cross Sections

Hi Carl,

Apologies to have missed your call.

Yes, I would consider your suggested approach as the best outcome and would have no problem with the modification to be presented in the UWMP.

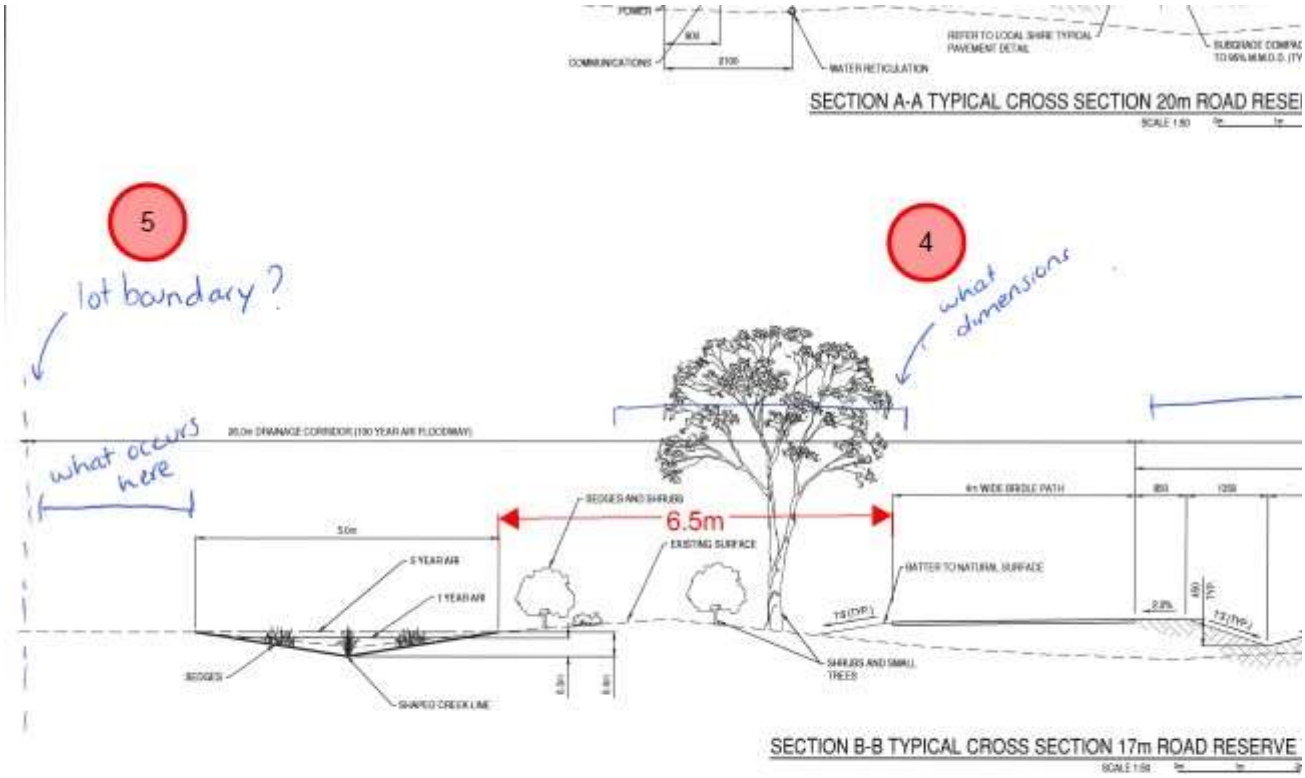
Thanks
Brett

Brett Dunn
Manager – Planning Advice
Kwinana Peel Region
Department of Water and Environmental Regulation
T: (08) 9550 4202 | www.dwer.wa.gov.au

From: Carl Done <cdone@sjshire.wa.gov.au>
Sent: Thursday, 6 August 2020 2:50 PM
To: Brett Dunn <brett.dunn@dwer.wa.gov.au>
Subject: FW: 19-009 Arnold Road, Serpentine - Cross Sections

Hi Brett,

Hope you are keeping well. Can I please ask for some clarification on an LWMS element. The LWMS states that the development is to retain and treat the first 15mm of rainfall. This is creating a situation where the consultant is proposing two drains adjacent to each other which to my mind is a poor spatial outcome and unnecessary infrastructure. Would DWER support a minor modification to the LWMS through the UWMP where treatment is achieved via a buffer strip between the road and Arnold Rd Creek to encourage sediment disposition and infiltration into surface soils as you can see In the below section the road will be a t least 15m from the creek with plenty of opportunity for flow across vegetated surfaces. My understanding is that such an approach is in line with DWER's stormwater decision making process whereby treatment is only required where flows are piped or directed. Surface water is considered exempt from strict treatment targets as overland flow is treatment!



If you can confirm for me the developer is more than willing to undertake the modification through the UWMP process but would like some feedback from DWER before proceeding.

Kind regards,

Carl Done
Coordinator Subdivisions

+618 9526 1512 +61 408 345 722
Shire of Serpentine Jarrahdale
6 Paterson Street Mundijong, WA 6123
www.sjshire.wa.gov.au

From: Phil Patterson [mailto:pp@pflt.com.au]
Sent: Friday, 31 July 2020 9:50 AM
To: Carl Done <cdone@sjshire.wa.gov.au>
Cc: Lara Iozzi <lara@malfcorp.com.au>; 'phil@cuttoneproperty.com.au' <phil@cuttoneproperty.com.au>; 'Marc Spagnolo (marc@mandlrealty.com.au)' <marc@mandlrealty.com.au>
Subject: 19-009 Arnold Road, Serpentine - Cross Sections

Hi Carl

With regards to our discussion re comments on the attached plan can you please look into, confirm your agreement and provide feedback on the following points

1. Verge on the eastern side is to stay as is to keep trees 1.3m off edge of shoulder
2. Attached is a plan showing location of sections
3. Installation of table drain to be discussed with DWER and shire to confirm if table drain is to remain as shown or be removed as per previous section
4. Distance between bridle path and drain is 6.5m
5. Yes this is a lot boundary which is off the page
6. Comment re connector road roads needing to be 7.4m wide as per below comment. We advise these roads being referred to could be classed as loop roads in that they only connect to Arnold Road to the north and the south road reserve and do not make a connection with any other roads or link through. Also the traffic volume on these roads would be in the order of 300 – 400 Vehicles per day which does not go any where near collector road volumes. We believe the 6.0m wide width for these roads is acceptable can you please confirm
7. We also believe loop roads should be 6.0m wide and as the minimum for cul-de-sac width is mentioned to be 5.6m for this development we believe it should stay at 6.0m wide as per sections. Can you advise if Shire are in agreement that all roads in this development be 6.0m wide.

Comments listed below from our two technical officers:

Crossovers

- Pavement widths should be in accordance with S 3.3.1.2 of the IPWEA guidelines. 7.4m for collector roads (the entrance and exit portion) and 5.6m for local roads (the loop Road portion).
- Secondary drain not required within the 17m RR (as it increases maintenance)

I have provided a mark up to the crossover designs.

Would you mind getting back to us on these comments so section can be finalised.

Philip Patterson
Project Director - Civil

T (08) 9382 5111 | D (08) 9382 5154 | M 0408 953 545
E philip.p@pfeng.com.au | W www.pfeng.com.au
430 Roberts Road, Subiaco WA 6008 | PO Box 2150 Subiaco WA 6904



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Appendix J
LWMS checklist

Appendix 2 Local water management strategy checklist

Local water management strategy item	Deliverable	☑	Notes
Executive summary			
Summary of the development design strategy, outlining how the design objectives are proposed to be met	Table 1: Design elements and requirements for best management practices and critical control points	☑	
Introduction			
Total water-cycle management – principles and objectives Planning background Previous studies		☑	
Proposed development			
Structure plan, zoning and land use Key landscape features Previous land use	Site context plan Structure plan	☑ ☑	
Landscape – proposed public open space areas, public open space credits, water source, bore(s), lake details, irrigation areas (if applicable)	Landscape plan	☑	
Design criteria			
Agreed design objectives and source of objectives		☑	
Pre-development environment			
Existing information and more detailed assessments (monitoring). How do the site characteristics affect the design?		☑	
Site conditions – existing topography/contours, aerial photo underlay, major physical features	Site condition plan	☑	
Geotechnical – topography, soils including acid sulfate soils and infiltration capacity, test pit locations	Geotechnical plan	☑	
Environmental – areas of significant flora and fauna, wetlands and buffers, waterways and buffers, contaminated sites	Environmental plan plus supporting data where appropriate	☑	
Surface water – topography, 100-year floodways and flood fringe areas, water quality of flows entering and leaving (if applicable)	Surface-water plan	☑	
Groundwater – topography, pre-development groundwater levels and water quality, test bore locations	Groundwater plan plus site investigations	☑	

Local water management strategy item	Deliverable	☑	Notes
Water sustainability initiatives			
Water efficiency measures – private and public open spaces including method of enforcement		☑	
Water supply (fit-for-purpose) strategy, agreed actions and implementation		☑	
Wastewater management		☑	
Stormwater management strategy			
Flood protection – peak flow rates, volumes and top water levels at control points, 100-year flowpaths and100-year detention storage areas	100-year-event plan Long section of critical points	☑ ☑	
Manage serviceability – storage and retention required for the critical 5-year ARI storm events Minor roads should be passable in the 5-year ARI event	5-year-event plan	☑	
Protect ecology – detention areas for the 1-year 1-hour ARI event, areas for water quality treatment and types of agreed structural and non-structural best management practices and treatment trains (including indicative locations). Protection of waterways, wetlands (and their buffers), remnant vegetation and ecological linkages	1-year-event plan Typical cross sections	☑ ☑	
Groundwater management strategy			
Post-development groundwater levels, existing and likely final surface levels, outlet controls, and subsoil drain areas/exclusion zones	Groundwater/subsoil plan	☑	
Actions to address acid sulfate soils or contamination		☑	
The next stage – subdivision and urban water management plans			
Content and coverage of future urban water management plans to be completed at subdivision. Include areas where further investigations are required before detailed design.		☑	
Monitoring			
Recommended future monitoring plan including timing, frequency, locations and parameters, together with arrangements for ongoing actions		☑	
Implementation			
Developer commitments		☑	
Roles, responsibilities, funding for		☑	

Local water management strategy item	Deliverable	☑	Notes
implementation			
Review		☑	

Appendix K
Septic setback correspondence with DWER

Gerard Edwards

From: Brett Dunn <brett.dunn@dwer.wa.gov.au>
Sent: Tuesday, 23 March 2021 3:58 PM
To: David Coremans; Shane McSweeney
Subject: RE: Submission regarding waterway setbacks for Lot 487, 611 & 615 Arnold Road Serpentine Structure Plan

CAUTION: This email originated from outside of RPS.

Hi David,

Thank you for your e-mail and the extra information around the proposal to date, to inform the Departments review of the Local Water Management Strategy.

With regard to water resource management considerations, the site is within a sewerage sensitive area, in the catchment of the Peel-Harvey Estuary system. As discussed Section 5.2.2 of the *Government Sewerage Policy* (GSP) does refer to reduced setback being considered on advice of DoH or DWER. The Departments position has remained that a reduction in the 100m setback between an onsite sewage disposal system and a drainage system that discharges to a waterway should only be considered where the drain does not intersect groundwater, and not in a sewerage sensitive area. This site does not satisfy these criteria.

However, Section 6 of the policy states "*Planning proposals that have received formal planning approval prior to publication of this policy may proceed subject to the conditions applicable at the time of the approval, for as long as that approval remains in effect*". It is noted that the rezoning of the site to "Rural Living A" was finalised on the 18 December 2018, and this planning decision was informed by the *Lot 487, 611 & 615 Arnold Road Serpentine Local Water Management Strategy* (Bayley Environmental Services, 2016) which was previously endorsed by the Department and the Shire of Serpentine-Jarrahdale. This LWMS (and original rezoning process) was based around a subdivision guide plan of 115 lots ranging in size from 4,000m^2 to 5,988m^2.

Since this time a revised Local Structure Plan has been submitted to the Serpentine-Jarrahdale Shire, with the lot layout now reduced to 52 lots, all over 1 ha, in order to meet the requirements of the GSP, with the exception of 7 lots that cannot site their wastewater irrigation areas more then 100m from the Hardy Creek Main Drain.

Though the Local Planning Scheme amendment on 18 December 2018 does not constitute a structure plan, the water resource assessment that informed the planning decision was undertaken relevant to the policy landscape of the time, for a higher density proposal. As such, acknowledging the previous planning history of the site (and relevant approved documents), and latest structure plans re-configuration to meet current GSP requirements as far as practical, the proposed lot layout is considered an appropriate and pragmatic outcome, conditional to:

- Wastewater irrigation areas for the 7 lots are located the maximum practical distance from the Hardy Creek Main Drain;
- Onsite wastewater systems are to have secondary treatment with nutrient removal; and
- Any necessary requirements of the Department of Health are adhered to.

The above is considered a rational approach and reflective of the intent of Section 6 of the GSP, and does not represent a precedent to other proposals that do not have previous planning approvals that pre-date the policy. I am satisfied for the Local Water Management Strategy to proceed on this basis.

Please feel free to contact me to discuss further.

Kind Regards,

Brett Dunn
Manager – Planning Advice
Kwinana Peel Region
Department of Water and Environmental Regulation
T: (08) 9550 4202 | www.dwer.wa.gov.au

Peter Cullen Water and Environment Trust
Fellow of the Peter Cullen Trust

From: David Coremans <David.Coremans@emergeassociates.com.au>
Sent: Wednesday, 17 March 2021 1:06 PM
To: Brett Dunn <brett.dunn@dwer.wa.gov.au>
Cc: Lara Iozzi <lara@malfcorp.com.au>; Shane McSweeney <Shane.McSweeney@rpsgroup.com.au>; Chrystal King <Chrystal.King@emergeassociates.com.au>; mark.hingston@dwer.wa.go.au
Subject: Submission regarding waterway setbacks for Lot 487, 611 & 615 Arnold Road Serpentine Structure Plan

Hi Brett

As discussed with you, the MALF Corp Lot 487, 611 & 615 Arnold Road Serpentine Structure Plan has been supported by a LWMS that DWER have provided comments on. It is noted that the LWMS was initially prepared based on 115 lots ranging in size from 4,000m2 to 5,988m2. The Government Sewerage Policy's (GSP) restriction on 1ha lots in sewerage sensitive areas has resulted in the lot yield reducing to 52 lots. This having a significant detriment to the development potential of the land.

As a result of DWER's comments from advertising of the Structure Plan, the proponent prepared a Site and Soil Evaluation (SSE) to demonstrate that the site is capable of managing effluent within the 1 ha land parcels onsite. As pointed out by DWER, the current structure plan will result in creation of 7 lots that are not able to achieve the 100m setback .

As discussed with you, there are significant environmental, bushfire and planning reasons why the approach in the current structure plan is appropriate (and it is not appropriate to reconfigure the 7 lots not able to achieve the 100m setback):

Risk posed to the environment can be mitigated

Both the GSP and the WQPN 70 allow for reduced setbacks where it can be demonstrated that the reduced setbacks will not have a significant impact on the environment or public health. We note that these policies do not exclude this discretion from being applied in sewerage sensitive areas or for drains that may connect to groundwater in winter. We understand that there are examples of the reduced setback being applied in sewerage sensitive areas.

There are many factors to demonstrate that there is a low risk to the downstream environment or public health including:

- As outlined in the LWMS, the soil conditions have been investigated and all soil types on the site have sufficient permeability and adequate PRI for on-site effluent disposal. The clayey soils and high PRI of the site mean that leachate emanating from the effluent disposal systems will be of high quality.
- The Hardy Creek Main Drain will be constructed and managed as a living stream incorporating dense vegetation, flow and soil modification for the specific purpose of removing nutrients and therefore the drainage system would not be considered to discharge into the Serpentine River "without treatment".
- All onsite effluent can be treated by secondary treatment systems with nutrient removal.

- There will be no direct pathway from effluent disposal areas with lots to the Hardy Creek Main Drain.
- Bio-retention swales located adjacent to the Hardy Creek Main Drain will treat and retain the first 15 mm of runoff from road reserves within Lot 487 and excess runoff from lots will flow over the road drainage network prior entering the Hardy Creek Main Drain living stream.
- Lots are all proposed to be large sizes, with a minimum of 1 ha.
- There are only seven lots which are not able to achieve a 100m setback for an effluent disposal area. All lots could achieve a modest setback of 30m from the HCMD.
- A surface water risk assessment has been carried out and the overall risk to the environment and public health is considered low as shown by Table 1 (from the SSE):

Table 1: Effluent disposal water risk assessment.

Site/system Feature*	Less constrained*	More constrained*	Proposed approach	Risk category	Response to risk category
Microbial quality of effluent	Effluent quality consistently producing ≤ 10 cfu/100 mL E. coli (secondary treated effluent with disinfection)	Effluent quality consistently producing ≥ 106 cfu/100 mL E. coli (for example, primary treated effluent)	Secondary treatment with disinfection will be mandated for all lots within the site. Secondary systems achieve 10 cfu/100 mL of E. coli.	Low	None required
Slope	0 – 6% (surface effluent application) 0 – 10% (subsurface effluent application)	> 10% (surface effluent application), > 30% subsurface effluent application	Adopt existing site levels - Slopes of around 4% or less.	Low	If required, subsurface application can be mandated
Surface water	Category 1 to 3 soils no surface water down gradient within > 100 m, low rainfall area	Category 4 to 6 soils, permanent surface water <50 m down gradient, high rainfall area, high resource/environmental value	Category 2, 4 and 6 in-situ soils, however fill to provide necessary clearances to groundwater. The HCMD is ephemeral. Moderate rainfall (1,153 mm/yr). Low environmental value within site	Moderate	Fill will be required beneath effluent disposal areas to address shallow groundwater, this can be permeable sand and could reduce the risk category
Position of land application area in landscape	Downgradient of surface water, property boundary, recreational area	Upgradient of surface water, property boundary, recreational area	Building envelopes located on-grade with the HCMD. Not located nearby public open spaces. Land application areas can be situated > 100 m from HCMD for most of the site. Position of application areas will be allocated at the DA stage.	Low-Moderate	Building envelopes could be utilised to ensure effluent disposal areas achieve a minimum setback of 30 m.
Drainage	Category 1 and 2 soils, gently sloping area	Category 6 soils, sites with visible seepage, moisture tolerant vegetation, low lying area	Category 2, 4 and 6 soils, gently sloping area.	Low-moderate	Fill will be required beneath effluent disposal areas to address shallow groundwater, this can be permeable sand. Design effluent disposal surface areas will be based on existing soils
Flood potential	Above 1 in 20 year flood contour	Below 1 in 20 year flood contour	Land application areas will be elevated above the (100 ARI) 1% AEP flooding top water levels.	Low	None required
Application method	Drip irrigation or subsurface application of effluent	Surface/above ground application of effluent	Treated wastewater will be applied via subsurface application	Low	Subsurface application can be mandated if required

Bushfire management issues

- If changes were implemented to reorientate lots to provide the 100m setback in all cases, the proposed changes to layout would increase the number of battle-axe lots required.
- Under the Guidelines for Planning in Bushfire Prone Areas, battle-axes should be avoided in bushfire-prone areas (such as the site). These should be avoided as they do not provide two-way access and egress for residents and may be easily blocked by falling trees or debris.
- While some battle-axe lots have already been proposed in the structure plan these have been kept to a minimum as it is the preference of DFES (and the Shire) that battle-axe lots are avoided unless there is no alternative. In this case there is an alternative (i.e. to not create any more).

Planning matters

- As mentioned above, the proponent has already been significantly affected because of the GSP stipulating a 1 ha minimum for lots in sewerage sensitive areas.
- During the current Structure Plan process, the proponent has already redesigned the lot configuration to address bushfire management concerns and the current design has been assessed as compliant by DFES. We have considerable concerns that reconfiguration of the lots as requested by DWER (which would create additional battle-axes lots) would not be considered compliant by DFES.

In light of the above, we consider that the 30m setback proposed by the Structure Plan has been appropriately justified for this site and seek DWER's support of the same.

We welcome any additional comments or queries that you may have regarding the site or the approach proposed, and look forward to DWER advice regarding the above

Regards

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We acknowledge all the respective Traditional Owners of Country throughout Australia and recognise their continuing connection to land, waters and culture. We pay our respects to their Elders past and present.

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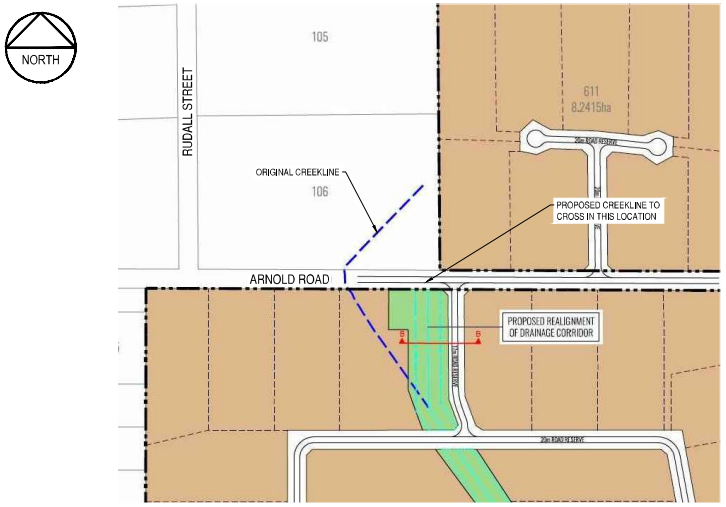
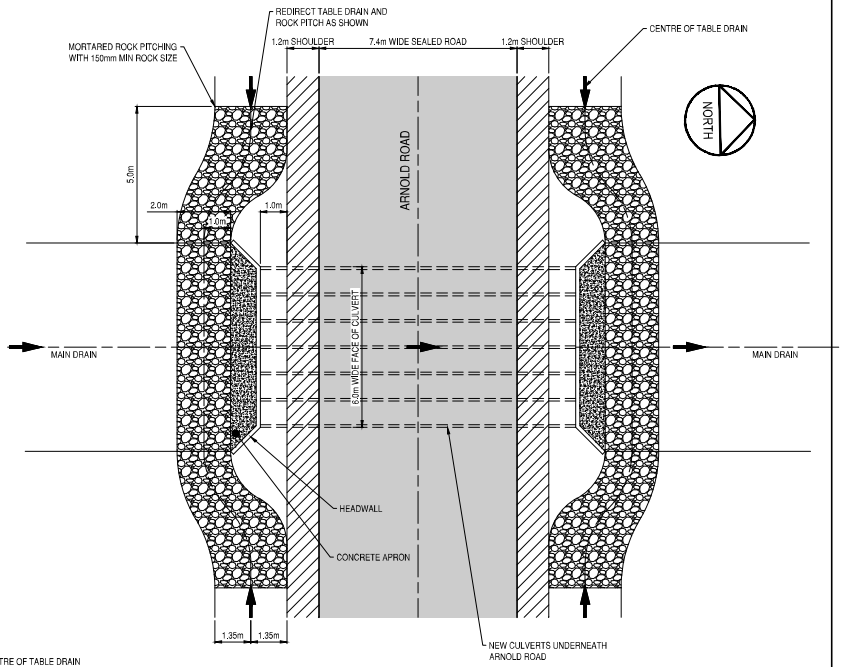
Appendix L
Arnold Road Creek Crossing Typical Table Drain Treatment Details



LOCALITY PLAN



PLAN VIEW ARNOLD ROAD MAIN DRAIN DETAILS

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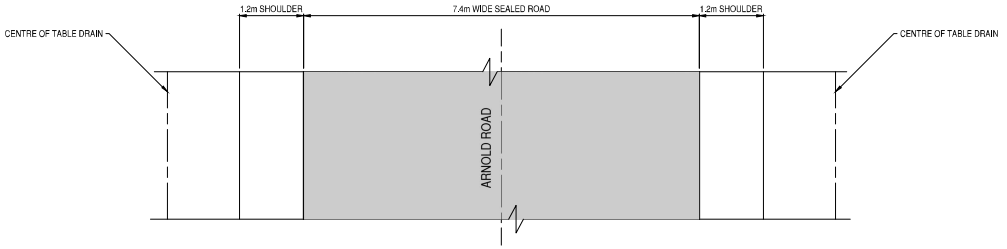

PLAN VIEW ARNOLD ROAD MAIN DRAIN CROSSING

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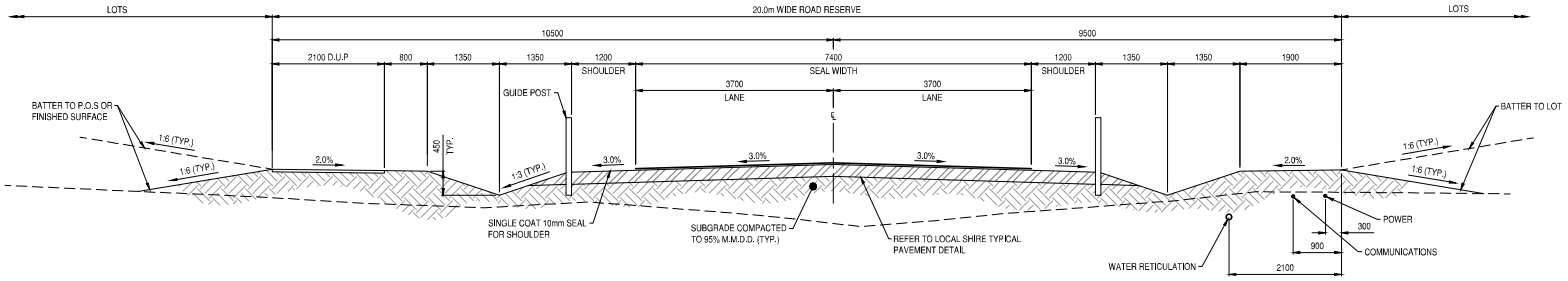


TYPICAL ARNOLD ROAD CROSS SECTION 20m ROAD RESERVE

SCALE 1:50 0m 1m 2m

REV	DATE	DESCRIPTION	BY	CHKR	REV	DATE	DESCRIPTION	BY	CHKR
A	28/2/2021	INITIAL ISSUE	RMH	PJP					

pritchard francis lite
civil engineering consultants

DRAWING STATUS: NOT FOR CONSTRUCTION

DATE: FEBRUARY 2021 | GRID: | DATUM: AHD

DESIGNED: RMH | DRAWN: RMH | CHECKED: PJP | APPROVED: .... / ....

W.A.P.C.: | SCALE CALC.: AS SHOWN @

CLIENT & JOB: MALF PTY LTD
Lots 102-106 RUDALL STREET SERPENTINE

TITLE: ARNOLD ROAD CREEK CROSSING
TYPICAL TABLE DRAIN TREATMENT DETAILS

SHEET SIZE: A1 | DRG No.: 19009-C9-SK-06 | REVISION: A

ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix g

Bushfire Management Plan

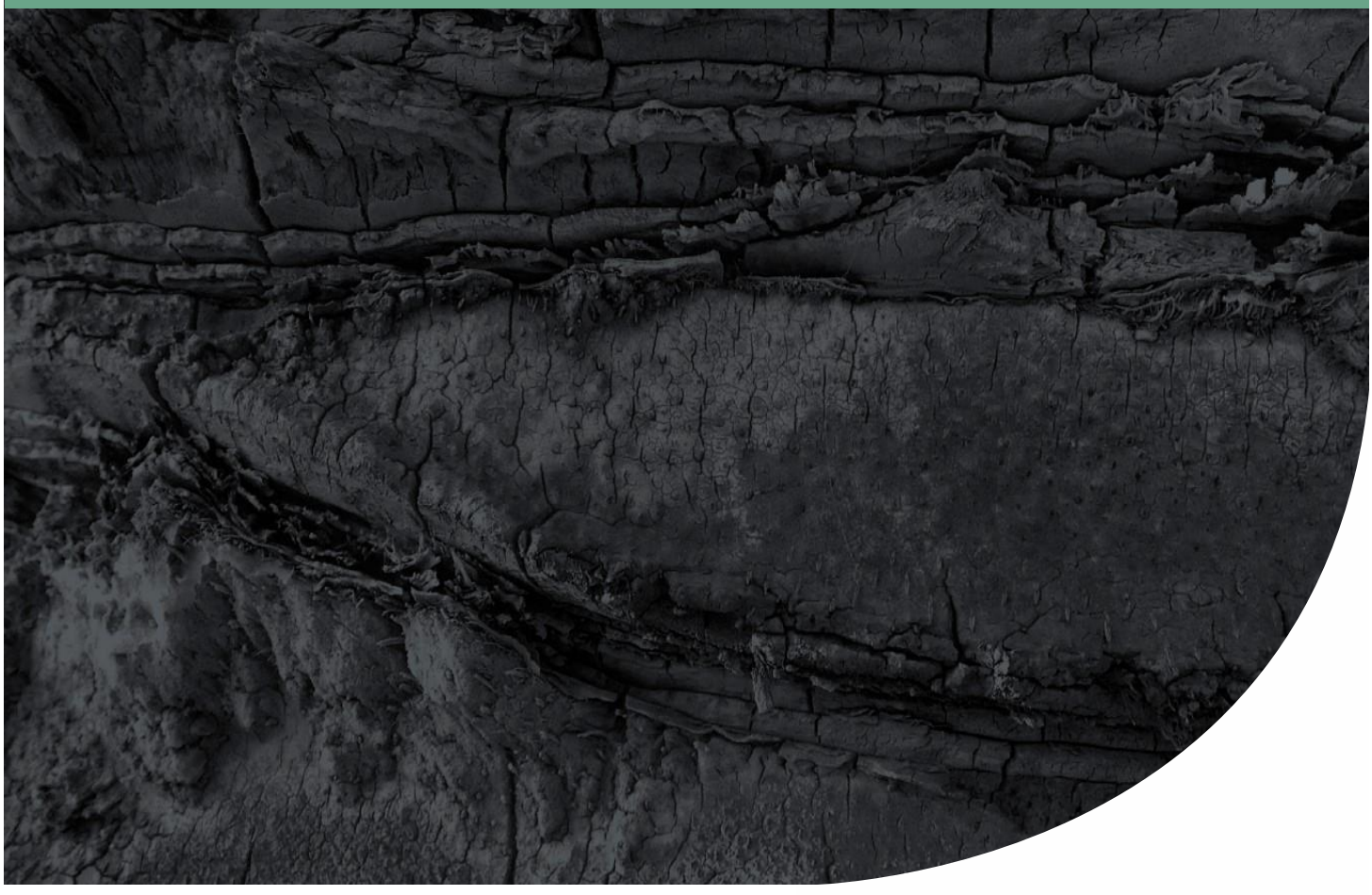
(Emerge Associates)

Bushfire Management Plan

Lots 487, 611 & 615 Arnold Rd, Serpentine

Project No: EP20-002(02)

Prepared for MALF Corp Pty Ltd
August 2021



Document Control

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Doc no.:	**EP20-002(02)--002**				
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	Document submitted to the client for review.				
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	Document updated based on project team comments.				
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	Document updated based on Shire of Serpentine-Jarrahdale comments.				
C	August 2021	Bianca Bertelli	BRB	Anthony Rowe	AJR
	Document updated based on Shire of Serpentine-Jarrahdale comments.				

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This document has been prepared primarily to consider the layout of development and/or the appropriate building construction standards applicable to development, where relevant. The measures outlined are considered to be prudent minimum standards only based on the standards prescribed by the relevant authorities. The level of bushfire risk mitigation achieved will depend upon the actions of the landowner or occupiers of the land and is not the responsibility of the author. The relevant local government and fire authority (i.e. Department of Fire and Emergency Services or local bushfire brigade) should be approached for guidance on preparing for and responding to a bushfire.

Notwithstanding the precautions recommended in this document, it should always be remembered that bushfires burn under a wide range of conditions which can be unpredictable. An element of risk, no matter how small, will always remain. The objective of the Australian Standard AS 3959:2018 is to "prescribe particular construction details for buildings to reduce the risk of ignition from a bushfire" (Standards Australia 2018). Building to the standards outlined in AS 3959 does not guarantee a building will survive a bushfire or that lives will not be threatened by the effects of bushfire attack.

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Executive Summary

MALF Corp Pty Ltd (the proponent) is seeking to develop Lots 487, 611 and 615 Arnold Road, Serpentine (herby referred to as 'the site') for rural residential purposes. The site is 61.8 hectares (ha) in size and is bound by privately owned land to the north, South Western Highway to the east, land proposed as an extension of Maidstone View to the south, adjoining privately owned land, and private residential landholdings to the west. The site is divided by Arnold Road.

The site is located within a 'bushfire prone area' under the state-wide Map of Bush Fire Prone Areas prepared by the Office of Bushfire Risk Management (OBRM 2019) as shown in **Plate 1**. The identification of a site within an area declared as bushfire prone necessitates that a further assessment of the determined bushfire risk affecting the site (in accordance with *Australian Standard 3959:2018 Construction of buildings in bushfire prone areas* (AS 3959)) and the satisfactory compliance of the proposal with the policy measures described in *State Planning Policy 3.7 Planning in Bushfire Prone Areas* (SPP 3.7) (WAPC 2015) and the *Guidelines for Planning in Bushfire Prone Areas Version 1.3* (the Guidelines) (WAPC and DFES 2017).

The purpose of this BMP is therefore to assess the bushfire hazards, both within and nearby the site, and identify the 'management' strategies required to ensure the development of the land is consistent with the intent of SPP 3.7 - *to preserve life and reduce the impact of bushfire on property and infrastructure.*

This BMP has followed the requirements of SPP 3.7 to identify bushfire risk and the bushfire protection measures that will make the land suitable for its intended purpose. As part of this, a Bushfire Attack Level (BAL) assessment involving the classification and condition of vegetation within 150 m of the site has been undertaken.

Given the previous clearing for agriculture, the site now generally consists of parkland cleared areas comprising pasture grasses which have been classified as grassland (Class G) in addition to surrounding the site associated with unmanaged paddocks within rural residential landholdings. Patches of forest (Class A) and woodland (Class B) vegetation has been identified external to the site to the north, east and south within the Arnold Road and South Western Highway road reserves and within adjacent rural-residential lots.

In order to resolve the potential for a bushfire to affect the site, a -post-development scenario has been assumed, in which the majority of the classified vegetation within the site has been removed or is managed in a 'low threat' standard. The exception being the Hardy's Creek Main Drain (HCMD) corridor which intersects the central portion of the site will be revegetated with plant species and classified as grassland vegetation. Two areas of Public Open Space (POS) areas are proposed as part of the Structure Plan, and along with future road swales and verges, these areas will also be classified as grassland vegetation in the post development scenario. The Shire of Serpentine Jarrahdale have prepared a Town Site Structure Plan for this area, which is intended to be developed for residential use in the short-term future. All other classified vegetation outside of the site is assumed to remain in its existing condition, and all existing management of vegetation will continue in the future.

The outcomes of this BMP demonstrate that as development progresses, it will be possible for an acceptable solution to be adopted for each of the applicable bushfire protection criteria outlined in the Guidelines. This includes:

- **Location**: there are no specific environmental or topographic assets restricting any works for the purpose of attaining a moderate bushfire hazard level for the land.
- **Siting and Design**: all future habitable buildings can be sited within the proposed development so that BAL-29 or less can be achieved based on the proposed structure plan. Whilst future lots within the site are subject to BAL ratings exceeding BAL-29 due to the grassland vegetation located external to the site and within the Harvey's Creek Main drain transecting the centre of the site, the proposed lots are adequately sized so future habitable dwellings need not exceed a rating of BAL-29.
- **Vehicular Access**: the proposed structure plan layout provides for an interconnected road network within the site that will connect to the existing public road network, specifically Arnold Road, and Maidstone View to the south of the site. Arnold Road will connect onto South Western Highway providing further egress to the north and south and Maidstone View will be connected to the internal loop to provide access to the west.
- **Water**: the development will be provided with a permanent and reticulated water supply to support onsite firefighting requirements.

The management/mitigation measures to be implemented through the proposed structure plan and future development of the site have been outlined as part of this BMP. Following certification, the BAL ratings determined within this BMP (or as part of future stage-based BAL assessments) can be used to support future building approval processes.

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Appendix A

Proposed Structure Plan (CDP Town Planning & Urban Design 2020)

1 Introduction

1.1 Background

MALF Corp Pty Ltd (the proponent) is seeking to develop Lots 487, 611 and 615 Arnold Road, Serpentine (herby referred to as 'the site') for rural-residential purposes, with the proposed structure plan layout provided in **Appendix A**. The site is 61.8 hectares (ha) in size and is bound by the rural-residential landholdings to the north, South Western Highway to the east, land proposed as an extension of Maidstone View to the south and private residential landholdings to the west, as shown in **Figure 1**. The site is divided by Arnold Road.

The entirety of the site is located within a 'bushfire prone area' under the state-wide Map of Bush Fire Prone Areas prepared by the Office of Bushfire Risk Management (OBRM 2019) as shown in **Plate 1**. The identification of a site within an area declared as bushfire prone necessitates that a further assessment of the determined bushfire risk affecting the site (in accordance with *Australian Standard 3959:2018 Construction of buildings in bushfire prone areas* (AS 3959)) and the satisfactory compliance of the proposal with the policy measures described in *State Planning Policy 3.7 Planning in Bushfire Prone Areas* (SPP 3.7) (WAPC 2015) and the *Guidelines for Planning in Bushfire Prone Areas Version 1.3* (the Guidelines) (WAPC and DFES 2017).

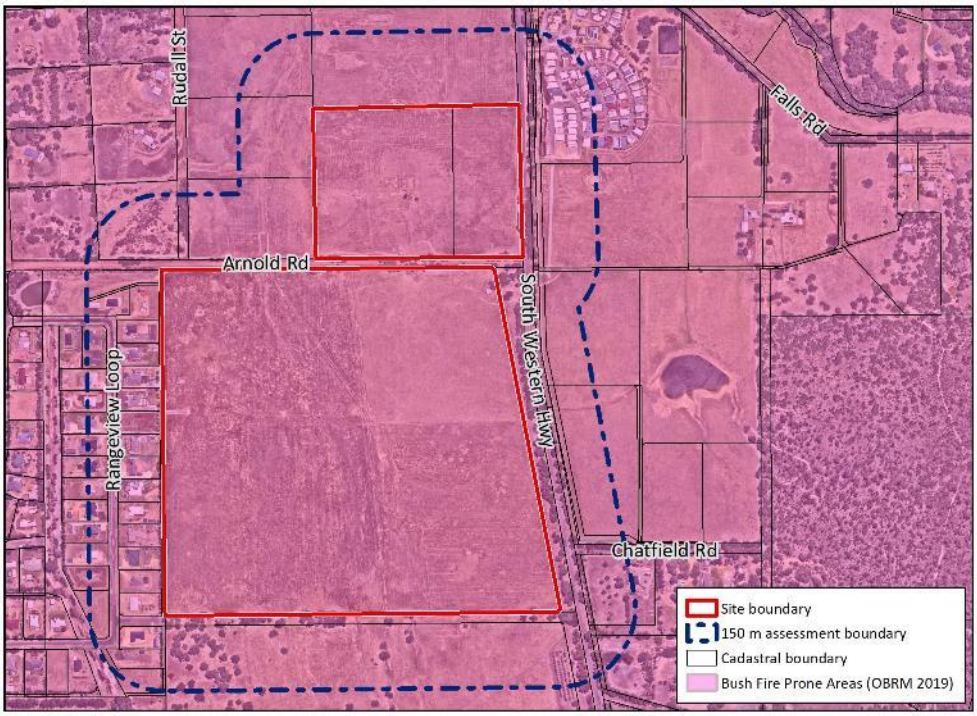

Plate 1: Areas within and surrounding the site identified as 'bushfire prone areas' (as indicated in purple) under the state-wide Map of Bush Fire Prone Areas (OBRM 2019).

1.2 Aim of this report

The purpose of this BMP is to assess bushfire hazards both within the site and nearby and demonstrate that the threat posed by any identified hazards can be appropriately mitigated and managed. This BMP has been prepared to support the proposed structure plan for the site and addresses the requirements of SPP 3.7 (WAPC 2015), the Guidelines (WAPC and DFES 2017) and (AS 3959) (Standards Australia 2018). The document includes:

- An assessment of the existing classified vegetation in the vicinity of the site (within 150 m) and consideration of bushfire hazards that will exist in the post-development scenario (**Section 3**).
- Commentary on how the future development can achieve the bushfire protection criteria outlined within the Guidelines including an indication of BAL ratings likely to be applicable to future dwellings (**Section 5**).
- An outline of the roles and responsibilities associated with implementing this BMP (see **Section 6**).

1.3 Statutory policy and framework

The following key legislation, policies and guidelines are relevant to the preparation of a bushfire management plan:

- *Bush Fires Act 1954*
- *Fire and Emergency Services Act1998*
- *Planning and Development Act 2005* and associated regulations
- *Building Act 2011* and associated regulations
- *State Planning Policy 3.7 Planning in Bushfire Prone Areas* (WAPC 2015)
- *Guidelines for Planning in Bushfire Prone Areas Version 1.3* (WAPC and DFES 2017)
- *Australian Standard AS 3959 – 2018 Construction of buildings in bushfire prone areas* (Standards Australia 2018)

1.4 Description of the proposed development

The site is proposed to be developed for rural residential purposes, in line with the proposed structure plan provided in **Appendix A**. The development within the site will include:

- rural residential development comprising 52 lots ranging from 1 ha to 1.16 ha in size;
- two areas of public open space (POS)
- the Hardy's Creek Main Drain (HCMD) corridor, and
- an interconnected public road network.

The proposed Structure Plan (CDP Town Planning & Urban Design 2020) includes the realignment of the Hardy's Creek Main Drain incorporating a 5 m wide vegetated buffer on each side of the channel to provide a safety margin for extreme (>100-year ARI) flood events. The drain will be redeveloped as a living stream and planted with sedges and local native trees. The drainage corridor will be designated as public open space and ceded to the Shire of Serpentine-Jarrahdale.

The site is divided by Arnold Road. The north section of Arnold road will provide for 9 lots, 5 of which will be served by a cul-de-sac not exceeding 200 m in length. A through-road is not achievable in this section, and the arrangement is prefereable to the establishment of battle axe lots, with individual access to Arnold Road.

The south section is serviced by a through road from Arnold Road through to Maidstone View road to the south. Both Arnold Road and Maidstone View run east-west and connect to South Western Highway which runs north-south.

The site is currently zoned 'Rural' under the *Metropolitan Region Scheme* (MRS), and was rezoned from 'Rural' to 'Rural Living A' through Amendment No. 193 to the *Shire of Serpentine-Jarrahdale Town Planning Scheme No. 2* (TPS 2), gazetted 29 January 2019, with the proposed residential development consistent with the zoning. A portion of the site to the north comprises land reserved for the South Western Highway Reservation under the MRS.

More broadly, the site is located within an area where land use has been changing over the last decade with structure planning west of the site, and ongoing development for residential use. The land immediately west of the site is planned for residential development as part of the Serpentine townsite expansion.

1.5 Description of land characteristics

The site has predominantly been cleared of native vegetation, with a review of aerial imagery indicating that the majority of the site was cleared prior to 1965 with the exception of scattered paddock trees (Landgate 2019). The Hardy's Creek Main Drain (HCMD) intersects the central portion of the site. The drain consists of an eroded channel, the banks of which are partly stabilised by pasture grasses but are continuing to erode where disturbed by cattle and occasional vehicles.

Surrounding land uses include:

- Broad-acre grazing paddocks containing scattered native trees to the north and south.
- Rural-residential lots to the east and west and land reserved for the South Western Highway extension to the north-east.
- Land zoned for urban development to the north-west.

The site and surrounds are generally flat, as shown in **Figure 1**, rising to the south-east. The topography within the site ranges from 32 m Australian Height Datum (m AHD) in the north-west portion of the site to 56 m AHD in the western portion of the site (DPIRD 2019).

2 Environmental Considerations

In accordance with the *Bushfire Management Plan – BAL Contour* template prepared by the Department of Planning, Lands and Heritage (2018), this BMP has considered whether there are any environmental values that may require specific consideration through either protection, retention or revegetation. To support this, a review of publicly available databases has been undertaken, with particular reference to the Shared Location Information Platform (SLIP) databases. A summary of the search results has been provided in **Table 1**.

The majority of the site has been cleared for agricultural (grazing) purposes and is mostly pasture grasses with scattered mature trees and small patches of native vegetation in a degraded condition. No vegetation within the site has been identified as significant (i.e. threatened ecological communities or threatened flora) or of regional or local significance.

Table 1: Summary of potential environmental considerations that may be associated with the site (based on a search of the SLIP databases)

Key environmental feature (information in brackets refers to mapping data source)	Yes / no / potentially occurring within the site	If yes / potentially, describe value that may be impacted
Conservation category wetlands and buffer (Geomorphic wetlands, Swan Coastal Plain (DBCA-019))	Yes	Not applicable. The site is identified as a multiple-use wetland, which is described as wetlands with few remaining wetland attributes. No specific management/ protection is required, with the hydrological function of MUWs maintained in accordance with Better Urban Water Management
RAMSAR wetlands (DBCA-010)	No	Not applicable.
Threatened and priority flora (DBCA-036)	Potentially	Not applicable.
Threatened and priority fauna (DBCA-037)	Potentially	Not applicable. Given the previous clearing for agriculture the site now generally consists of parkland cleared areas comprising of pasture grasses, with scattered paddock trees. The site provides potential habitat for species of threatened black cockatoo, limited to a small number of large marri trees. As part of the residential development, it is expected that several black cockatoo habitat trees will be retained within future POS areas and road reserves.
Threatened ecological communities (DBCA-038)	Potentially	Not applicable. The majority of the site contains vegetation in 'completely degraded' condition that comprises scattered native species with many planted non-native species. The site was not considered to contain any TECs.
Bush Forever areas (DPLH-019)	No	Not applicable.
Clearing regulations – Environmentally Sensitive Areas (DWER-046)	Yes	The eastern portion of the site is considered part of an Environmentally Sensitive Area that extends further to the east. The portion of the ESA mapped as occurring within the site is predominately cleared and is characterised by introduced grasses, which do not represent significant environmental values.
Swan Bioplan Regionally Significant Natural Areas 2010 (DWER-070)	No	Not applicable.

2.1 Native vegetation – modification and clearing

The eastern portion of the site is mapped as occurring within an ESA. The ESA is associated with a Threatened Ecological Community (TEC) within Bush Forever Site 468 approximately 460 m to the east of the site. While the vegetation within the site does not constitute a TEC, the boundary of the ESA encompasses a buffer area which extends into the site. Within ESAs, exemptions under the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004* do not apply (such as clearing for the construction of fence-lines, the reduction of fire hazards and the collection of firewood) and a Clearing Permit may be required prior to the clearing of any vegetation.

However, clearing permits or valid exemptions pursuant to the *Environmental Protection Act 1986* are not required where areas containing paddock grasses are proposed to be modified.

Scattered trees may be retained within public open space/road reserves where future earthworks allow. All vegetation outside the site is assumed to remain in its existing condition. No areas of native vegetation outside the site are proposed to be cleared by the proponent as part of the proposed development.

2.2 Revegetation and landscape plans

In accordance with the scheme provisions of the Shire of Serpentine Jarrahdale TPS No. 2, indigenous trees and shrubs are required to be planted by the subdivider within the site as part of future development. This revegetation will occur as part of managed gardens within each lot and will be managed to a low threat standard, to ensure the bushfire risk to future dwellings is reduced.

In addition, the Hardy's Creek Main Drain corridor transecting the central portion of the site and the road reserves within the site are proposed to be landscaped with sedges and scattered native trees. Based on the future drainage infiltration planting, these areas will be classified as grassland vegetation in the post development scenario. The management of the POS and road verges will be the responsibility of the proponent initially prior to handover to the Shire of Serpentine Jarrahdale.

3 Bushfire Assessment Results

Bushfire risk for the site has been appropriately considered both in context to the site and potential impact upon the site.

Appendix Two of the Guidelines provides a description for undertaking contextual hazard level assessment using the vegetation classifications from AS 3959. The purpose is to identify at the strategic level the Bushfire Hazard Level (BHL) over 150 m and the likely impact and intensity of a bushfire attack.

AS 3959 has been used to determine the impact on the site. Its objective is to reduce the risk of ignition and loss of a building to bushfire. It provides a consistent method for determining a radiant heat level (radiant heat flux) as a primary consideration of bushfire attack. It measures the Bushfire Attack Level as the radiant heat level (kWm^2) over a distance of 100 m.

AS 3959 also prescribes deemed to satisfy construction responses that can resist the determined radiant heat level at a given distance from the fire. It is based on six Bushfire Attack Level (BAL) ratings: BAL-LOW, BAL-12.5, BAL-19, BAL-29, BAL-40 and BAL-FZ.

3.1 Bushfire Attack Level assessment

In accordance with Appendix Five of the Guidelines, a method 1 BAL assessment has been undertaken to support the proposed development of the site and determine the BAL ratings likely to be applicable to future habitable buildings. This has been based on the vegetation classifications and the effective slope under the vegetation, with the result presented on the BAL contour plan.

Not all vegetation is a classified bushfire risk. Vegetation and ground surfaces that are exempt from classification as a potential hazard are identified as a low threat under Section 2.2.3.2 of AS 3959. Low threat vegetation includes the following:

a) Any Vegetation f type that is more than 100 m from the site.
b) Single areas of vegetation less than 1 ha in area and not within 100 m of other areas of vegetation being classified.
c) Multiple areas of vegetation less than 0.25 ha in area and not within 20 m of the site, or each other or of other areas of vegetation being classified.
d) Strips of vegetation less than 20 m in width (measured perpendicular to the elevation exposed to the strip of vegetation) regardless of length and not within 20 m of the site or each other, or other areas of vegetation being classified.
e) Non-vegetated areas, that is, areas permanently cleared of vegetation, including waterways, exposed beaches, roads, footpaths, buildings and rocky outcrops.
f) Vegetation regarded as a low threat due to factors such as flammability, moisture content or fuel load. This includes grassland managed in a minimal fuel condition, mangroves and other saline wetlands, maintained lawns, golf courses (such as playing areas and fairways), maintained public reserves and parklands, sporting fields, vineyards, orchards, banana plantations, market gardens (and other non-curing crops), cultivated gardens, commercial nurseries, nature strips and windbreaks.

3.1.1 Assessment inputs

Classifying bushfire hazards takes into account the vegetation structure within the site and surrounding area for a minimum of 100 m, in accordance with AS 3959. The assignment of the vegetation classifications is based on consideration of the fuel layers of different vegetation types. This can be broken-down into five segments as illustrated in **Plate 2** below.

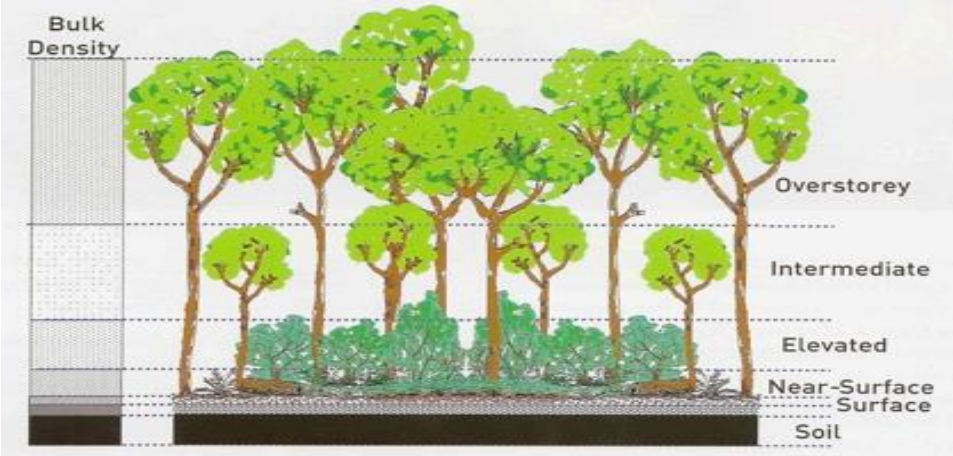

Plate 2: The five fuel layers in a forest environment that could be associated with fire behaviour (Gould et al. 2007)

A site visit was undertaken on 21 March 2020 providing and assessment of existing vegetation within the site and surrounding 150 m in accordance with AS 3959 and the Guidelines.

Table 2 below outlines:

- The pre-development AS 3959 vegetation classifications (and associated photo locations) are shown in **Figure 2.**
- The post-development AS 3959 vegetation classifications are shown in **Figure 3.**
- The effective slope for each area of classified vegetation present in the post-development scenario is shown in **Figure 4.**

Table 2: Vegetation classification, effective slope and future management

Pre-development (see Figure 2)			Post development (see Figure 3 and Figure 4)	
Plot no.	**AS 3959 classification**	**Site photo/s (location points shown in Figure 2)**	**Plot no.**	**AS 3959 classification, effective slope and assumptions**
1	**AS 3959 classification (Figure 2):** Forest (Class A) **Bushfire hazard level:** Extreme Patches of forest vegetation have been identified within the Arnold Road and South Western Highway road reserves external to the site, to the north and east. This vegetation is characterised by a mixture of planted *Eucalyptus spp*. and native *Corymbia calophylla* (marri) trees in addition to an understory of native shrub species. Areas of forest vegetation are characterised by surface, near-surface, elevated, intermediate and overstory fuel layers.	 *Photo location 1: Forest vegetation external to the site within Arnold Road reserve.*  *Photo location 2: Forest vegetation to the west of the site within Arnold Road reserve.*  *Photo location 3: Forest vegetation to the east of the site within South Western Highway road reserve*  *Photo location 4: Forest vegetation to the south-east of the site within Chatfield road reserve.*	1	**AS 3959 classification (Figure 3):** Forest (Class A) **Effective slope (Figure 4):** Flat/upslope Forest vegetation external to the site to the north and east will be retained as future development progresses. Therefore, this vegetation will pose a permanent bushfire risk to the site.

Pre-development (see Figure 2)			Post development (see Figure 3 and Figure 4)	
Plot no.	**AS 3959 classification**	**Site photo/s (location points shown in Figure 2)**	**Plot no.**	**AS 3959 classification, effective slope and assumptions**
2, 3	**AS 3959 classification (Figure 2):** Woodland (Class B) **Bushfire hazard level:** Extreme Woodland vegetation has been identified to the north, east and south of the site within adjacent rural residential landholdings and unmanaged road reserves. In addition, a small patch of woodland vegetation extends into the northeastern portion of the site surrounding an existing shed. The woodland vegetation within and external to the site is characterised by local *Eucalyptus* and *Corymbia* spp. growing to a height of 10 – 20 m with a predominantly grassy understory, with occasional scattered native shrubs.	 *Photo location 5: Woodland vegetation external to the site within Arnold Road reserve.*  *Photo location 6: Woodland vegetation within the northeastern portion of the site.*  *Photo location 7: Woodland vegetation to the east of the site within South Western Highway road reserve.*  *Photo location 8: Woodland vegetation to the south of the site within an adjacent rural residential lot.*	2, 3	**AS 3959 classification (Figure 3):** Woodland (Class B) **Effective slope (Figure 4):** Flat/upslope Woodland vegetation within the landholdings to the east, south and west of the site, including within the road reserves will be retained as future development occurs. This vegetation will, therefore, remain a bushfire hazard to the site.
			7	**AS 3959 classification (Figure 3):** Low threat vegetation (Exclusion 2.2.3.2(f)) **Effective slope (Figure 4):** Not applicable Woodland vegetation within the site will be converted to low threat vegetation within future lots in accordance with the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice. These lots are likely to include non-vegetated areas (e.g. dwellings, private driveways and firebreaks), however as the siting of these are currently unknown, it has been identified as low threat vegetation

Table 2: Vegetation classification, effective slope and future management (continued)

Pre-development (see Figure 2)			Post development (see Figure 3 and Figure 4)	
Plot no.	**AS 3959 classification**	**Site photo/s (location points shown in Figure 2)**	**Plot no.**	**AS 3959 classification, effective slope and assumptions**
4	**AS 3959 classification (Figure 2):** Scrub (Class D) **Bushfire hazard level:** Extreme Scrub vegetation is located to the north-west of the site within an adjacent rural residential lot. Scrub vegetation surrounding the site is characterised by small stands of *Allocasuarina fraseriana* (sheoak) trees, less than 6 m in height with continuous fuel loads from the surface and near-surface fuel layers through to the intermediate and overstorey fuel layers.	 *Photo location 9: Scrub vegetation to the north-west of the site*  *Photo location 10: Scrub vegetation to the north-west of the site*	4	**AS 3959 classification (Figure 3):** Scrub (Class D) **Effective slope (Figure 4):** Flat/upslope Scrub vegetation located to the north-west of the site is located outside of the site boundary and will,, therefore, pose a long-term bushfire risk to the site.

Table 2: Vegetation classification, effective slope and future management (continued)

Pre-development (see Figure 2)			Post development (see Figure 3 and Figure 4)	
Plot no.	**AS 3959 classification**	**Site photo/s (location points shown in Figure 2)**	**Plot no.**	**AS 3959 classification, effective slope and assumptions**
5	**AS 3959 classification (Figure 2):** Grassland (Class G) **Bushfire hazard level:** Moderate Grassland vegetation has been identified within the site, in addition to the north, east and south of the site associated with unmanaged rural paddocks. Grassland vegetation within and surrounding the site is characterised by open areas of unmanaged grassland with surface and near-surface fuel loads. Occasional scattered paddock trees are located within and surrounding the site, however, the overstorey density is less than 10%.	 *Photo location 11: Grassland vegetation within the central portion of the site.*  *Photo location 12: Grassland vegetation within the southern portion of the site.*  *Photo location 13: Grassland vegetation to the north of the site.*  *Photo location 14: Grassland vegetation to the east of the site.*	5	**AS 3959 classification (Figure 3):** Grassland (Class G) **Effective slope (Figure 4):** Flat/upslope Grassland vegetation located within the Hardey's Creek Main Drainage Corridor transecting the centre of the site and grassland vegetation external to the site will remain as future development within the site progresses. It is assumed this vegetation will remain in the same condition as the pre-development assessment and will, therefore, be a bushfire hazard for the foreseeable future.
			7	**AS 3959 classification (Figure 3):** Non-vegetated area (Exclusion 2.2.3.2(e)) **Effective slope (Figure 4):** Not applicable Where grassland vegetation within the site will be removed to facilitate the implementation of the proposed road network, these areas will have been identified as non-vegetated areas (exclusion clause 2.2.3.2 (e)).

Table 2: Vegetation classification, effective slope and future management (continued)

Pre-development (see Figure 2)			Post development (see Figure 3 and Figure 4)	
Plot no.	**AS 3959 classification**	**Site photo/s (location points shown in Figure 2)**	**Plot no.**	**AS 3959 classification, effective slope and assumptions**
5	Continued from above.	Continued from above.	6	**AS 3959 classification (Figure 3):** Low threat vegetation (Exclusion 2.2.3.2(f)) **Effective slope (Figure 4):** Not applicable The majority of the grassland vegetation within the site will be converted to low threat vegetation within future lots that will be managed to a low threat standard in accordance with the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice. These lots are likely to include non-vegetated areas (e.g. dwellings, private driveways and firebreaks), however as the siting of these are currently unknown, it has been identified as low threat vegetation.

Table 2: Vegetation classification, effective slope and future management (continued)

Pre-development (see Figure 2)			Post development (see Figure 3 and Figure 4)	
Plot no.	**AS 3959 classification**	**Site photo/s (location points shown in Figure 2)**	**Plot no.**	**AS 3959 classification, effective slope and assumptions**
7	**AS 3959 classification (Figure 2):** Low threat vegetation (exclusion clause 2.2.3.2(f)) **Bushfire hazard level:** Low. As required under the Guidelines, any areas within 100 m of moderate or extreme hazards have been shown as moderate, to reflect the potential increased risk. Low threat vegetation has been identified external to the site to the north, east and west associated with open paddocks managed to a low threat standard in accordance with the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice.	 *Photo location 15: Low threat vegetation to the south of the site.*  *Photo location 16: Low threat vegetation to the north-west of the site.*  *Photo location 17: Low threat vegetation to the east of the site.*	7	**AS 3959 classification (Figure 3):** Low threat vegetation (exclusion clause 2.2.3.2(f)) **Effective slope (Figure 4):** Not applicable The maintenance regimes for all existing low threat vegetation surrounding the site is assumed to continue in the long-term based on current land uses and management arrangements, in accordance with the requirements of the Shire of Serpentine Jarrahdale.

Table 2: Vegetation classification, effective slope and future management (continued)

Pre-development (see Figure 2)			Post development (see Figure 3 and Figure 4)	
Plot no.	**AS 3959 classification**	**Site photo/s (location points shown in Figure 2)**	**Plot no.**	**AS 3959 classification, effective slope and assumptions**
6	**AS 3959 classification (Figure 2):** Non-vegetated area (exclusion clause 2.2.3.2(e)) **Bushfire hazard level:** Low. As required under the Guidelines, any areas within 100 m of moderate or extreme hazards have been shown as moderate, to reflect the potential increased risk. Non-vegetated areas such as existing roads, parking areas, areas of mineral earth and water bodies within and surrounding the site have been excluded in accordance with Clause 2.2.3.2(e) of AS 3959.	 *Photo location 18: Non-vegetated surrounding hale bales within the central portion of the site*  *Photo location 19: Non-vegetated mineral earth firebreak around the perimeter of lot 615.*  *Photo location 20: Non-vegetated mineral earth firebreak around the perimeter of lot 487.*  *Photo location 21: Non-vegetated residential development to the west of the site.*	6	**AS 3959 classification (Figure 3):** Non-vegetated area (Exclusion 2.2.3.2(e)) **Effective slope (Figure 4):** Not applicable The existing maintenance regimes for all existing non-vegetated areas surrounding the site are assumed to continue in the long term.

3.1.1.1 Post development assumptions

The BAL assessment, to determine the predicated BAL ratings applicable to the site, has assumed the following:

- **Designated FDI**: 80
- **Flame temperature**: 1090 K
- **Vegetation classification**: forest (Class B), woodland (Class B), scrub (Class D) and grassland (Class G) vegetation identified within the post-development scenario, see **Figure 3**.
- **Effective slope beneath classified vegetation**: flat/upslope (see **Figure 4**)
- **Setback distances**: as per Table 2.5 in AS 3959 with the relevant distances used to inform the BAL contour plan provided in **Figure 6** and summarised in **Table 3**.

In addition to the above, the following key assumptions have informed this assessment:

- The majority of classified vegetation within the site will be removed or modified to achieve low threat in accordance with Section 2.2.3.2 of AS 3959. The existing area of woodland vegetation within the northern portion of the site will be retained and managed to a low threat within future lots in accordance with the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice. This may include:
  - Clearing of vegetation.
  - Regular maintenance including removal of weeds and dead material.
  - Where remnant trees are retained, these will be low pruned to 2 m from the ground.
  - Application of ground covers such as mulch or non-flammable materials.
  - Where grass/turf is present, this will be regularly cut so that the grass is maintained at or below 100 mm in height.
- The Hardy's Creek Main Drain corridor transecting the central portion of the site, the areas of POS and the road reserves within the site are proposed to be landscaped with native grass/sedge species and scattered native trees. As a result these areas will be classified as grassland vegetation in the post development scenario.
- Areas of low threat vegetation outside the site will continue to be managed and/or considered to achieve low threat in accordance with Section 2.2.3.2 of AS 3959 based on the existing maintenance regimes, and/or as per the Shire of Serpentine Jarrahdale's Firebreak and Fuel Hazard Reduction Notice.
- Other classified vegetation that has been identified outside of the proponent's landholdings has been assumed to remain in its existing state.

3.1.2 Assessment outputs

The BAL assessment completed for the site indicates that a BAL rating of BAL-29 or less can be achieved at future residential buildings based on the indicated spatial layout for the structure plan (**Appendix A**). Whilst future lots are subject to BAL ratings exceeding BAL-29, the future rural residential lots are suitably sized to ensure that future building envelopes can be located within areas not subject to a BAL rating exceeding BAL-29.

Table 3 provides a summary of the setback distances necessary from the identified classified vegetation to achieve the indicated BAL ratings, with the BAL Contour Plan (**Figure 6**) being a visual representation of these distances. The setback distances are based on the post-development classified vegetation (**Figure 4**) and effective slope (**Figure 5**) and are taken from Table 2.5 of AS 3959.

Table 3: Setback distances based on vegetation classification and effective slope and Table 2.5 of AS 3959, as determined by the method 1 BAL assessment

Vegetation classification (see Figure 4)	Effective slope (see Figure 5)	Distance to vegetation	BAL rating
Forest (Class A)	Flat/upslope	< 16 m	BAL-FZ
		16 - < 21 m	BAL-40
		21 - < 31 m	BAL-29
		31 - < 42 m	BAL-19
		42 - < 100 m	BAL-12.5
		> 100 m	BAL-LOW
Woodland (Class B)	Flat/upslope	< 10 m	BAL-FZ
		10 - < 14 m	BAL-40
		14 - < 20 m	BAL-29
		20 - < 29 m	BAL-19
		29 - < 100 m	BAL-12.5
		> 100 m	BAL-LOW
Scrub (Class D)	Flat/upslope	< 10 m	BAL-FZ
		10 - < 13 m	BAL-40
		13 - < 19 m	BAL-29
		19 - < 27 m	BAL-19
		27 - < 100 m	BAL-12.5
		> 100 m	BAL-LOW
Grassland (Class G)	Flat/upslope	< 6 m	BAL-FZ
		6 - < 8 m	BAL-40
		8 - < 12 m	BAL-29
		12 - < 17 m	BAL-19

		17 - < 50 m	BAL-12.5
		> 50 m	BAL-LOW

4 Identification of Bushfire Hazard Issues

From a bushfire hazard management perspective, the key issues that are likely to require management and/or consideration as part of future development within the site include:

- Provision of appropriate separation distance from bushfire hazards within the site and external to the site to the east, north and south of the site to ensure a BAL rating of BAL-29 or less can be achieved at future habitable buildings (built form).
- Notwithstanding the Shire of Serpentine Jarrahdale TPS No. 2, indigenous trees and shrubs are required to be planted by the subdivider, the planting should be undertaken in accordance with an Asset Protection Zonese standard (Guidelines V1.3) to avoid the risk of increasing the present modertate bushfire hazard level to an extreme bushfire hazard level.

These issues are considered further in **Section 5.**

5 Assessment Against the Bushfire Protection Criteria

This BMP provides an outline of the mitigation strategies for the structure plan that will ensure future subdivision and associated development progresses can achieve an acceptable solution under the bushfire protection criteria detailed within Appendix Four of the Guidelines (WAPC and DFES 2017). The bushfire protection criteria identified in the Guidelines and addressed as part of this BMP are:

- Element 1: Location of the development
- Element 2: Siting and design of the development
- Element 3: Vehicular access
- Element 4: Water supply.

As part of future development, it is likely that an 'acceptable solution' will be able to address the intent of all four bushfire protection criteria as part of future development of the site. A summary of how this can be achieved and an associated compliance statement for each has been provided in **Table 4.**

Table 4: Summary of bushfire protection criteria and compliance statement

Bushfire protection criteria	Intent	Method of compliance		Proposed bushfire management strategies	Compliance Statement
		Acceptable solution	Performance principle		
Element 1: Location	To ensure that strategic planning proposals, subdivision and development applications are located in areas with the least possible risk of bushfire to facilitate the protection of people, property and infrastructure.	A1.1 Development location		Based on the bushfire hazard level assessment (**Figure 3**), the site is located in an area of extreme and moderate bushfire hazard level. As development within the site is progressed, classified vegetation will be removed and development will be located within an area subject to a bushfire hazard level of low or moderate. The BAL contour plan (see **Figure 6**) indicates that the entirety of the site will be able to achieve a BAL rating of BAL-29 or less.	Based on the outlined management measures, future development would be able to comply with and meet the intent of Element 1: Location.
		Yes	N/A		
Element 2: Siting and design	To ensure the siting and design of development minimises the level of bushfire impact.	A2.1 Asset Protection Zone		One of the most important bushfire protection measures influencing the safety of people and property is to create an Asset Protection Zone (APZ) around buildings. The APZ is a low fuel area immediately surrounding a building and can include non-flammable features such as irrigated landscapes, gardens, driveways and roads. The post-development vegetation classification (**Figure 4**) identifies permanent bushfire hazards to the north, east and south of the site and within the Hardy's Creek Main Drain corridor transecting the central portion of the site, including the abutting areas of POS. Based on the outcomes of the BAL assessment and the BAL contour plan (see **Figure 6**), all future lots will be subject to a BAL rating less than BAL-29, due to setbacks provided by public roads and managed public open space, ensuring that development (i.e. future habitable buildings) within the site will be able to achieve a BAL rating of BAL-29 or less. Overall, the acceptable solution can be satisfied. Class 1, 2 and 3 buildings, where located within an area subject to a BAL rating higher than BAL-12.5 will be subject to higher construction standards in accordance with AS 3959.	Based on the outlined management measures, future development would be able to comply with and meet the intent of Element 2: Siting and design.
		Yes	N/A		

Table 4: Summary of bushfire protection criteria and compliance statement (continued)

Bushfire protection criteria	Intent	Method of compliance		Proposed bushfire management strategies	Compliance Statement
		Acceptable solution	Performance principle		
Element 3: Vehicular access	To ensure vehicular access serving a subdivision/ development is available and safe during a bushfire event.	A3.1 Two access routes		The proposed structure plan provides for two access roads that will service the lots within the site. The northern lots will connect onto Arnold Road via a cul-de-sac road. Arnold Road provides egress options to the east and west and connects onto South Western Highway which provides further egress to the north and south. The southern lots will connect to Arnold Road to the north and Maidstone View road to the south. The existing public road, Maidstone View to the south of the site will be extended as part of the development and constructed to the minimum standards outlined in Appendix Four of the Guidelines (WAPC and DFES 2017).	Based on the outlined management measures, future development would be able to comply with and meet the intent of Element 3: Vehicular access.
		Yes	N/A		
		A3.2 Public road		Existing public roads surrounding the site, as well as the proposed new public road, Maidstone View road, can and will comply with the minimum standards outlined in Appendix Four of the Guidelines (WAPC and DFES 2017) or as agreed with the Shire of Serpentine Jarrahdale and includes a minimum 6 m-wide trafficable surface.	
		Yes	N/A		
		A3.3 Cul-de-sac (including dead-end-road)		While cul-de-sacs should be avoided in bushfire-prone areas, two cul-de-sacs are proposed within the site. The cul-de-sac's will not exceed the maximum length of 200 m as required to meet the acceptable solution. The site is divided by Arnold Road.The northern section of Arnold road will provide for nine lots, five of which will be served by a cul-de-sac not exceeding 200 m in length. A through-road is not achievable in this section, and the arrangement is prefereable to the establishment of battle axe lots, with individual access to Arnold Road. The southern section is serviced by a through road from Arnold Road through to Maidstone View road to the south. Both Arnold Road and Maidstone View run east west and connect to the South Western Highway which runs north south. The Maidstone View road cul-de-sac will be less than 200 m in length measured from the access point from the south-eastern corner battle-axe lot. The cul-de-sacs will comply with the construction requirements outlined in the Guidelines (excluding the length), as provided below: • A minimum trafficable surface of 6 m. • A horizontal clearance of 6 m. • Support a minimum weight of 15 tonnes. • Will have a turn-around area with a minimum 17.5 m diameter head.	
		Yes	N/A		

		A3.4 Battle-axe		Whilst battle-axe lots should be avoided in bushfire-prone areas, the proposed lots are still considered to meet the acceptable solution given the connection to the broader road network. The battle-axe lots are able to achieve: • A minimum trafficable surface of 4 m. • A horizontal clearance of 6 m. • Support a minimum weight of 15 tonnes. • The length of the battle-axe access is less than 600 m. Additionally, the dwellings are likely to be located less than 100 m from the public road network, based on the size of the lot.	
		N/A	N/A		
		A3.5 Private driveway longer than 50 m		Based on the size of the lots proposed within the structure plan layout, private driveways longer than 50 m are potentially going to be constructed as part of future development. Any driveways longer than 50 m will meet the minimum standards as set out in the Guidelines, or as otherwise agreed with the Shire of Serpentine Jarrahdale. Based on the proposed structure plan, future lots are unlikely to have driveways longer than 200 m, and are therefore unlikely to require passing bays, however, will be required to meet the minimum standards as set out below: • A minimum trafficable surface of 4 m. • A horizontal clearance of 6 m. • A vertical clearance of 4.5 m. • Support a minimum weight of 15 tonnes.	
		N/A	N/A		
		A3.6 Emergency access way		Not applicable. Given the proposed subdivision provides for egress to at least two different destinations, emergency access ways are not required as part of the proposed development of the site.	
		N/A	N/A		
		A3.7 Fire service access routes (perimeter roads)		Not applicable. Future development within the site will be provided with appropriate vehicular access, as outlined above, and therefore fire service access routes are not required.	
		N/A	N/A		
		A3.8 Firebreak width		Due to the size of future rural-residential lots proposed as part of the development of the site, firebreaks will be required. These firebreaks will be required to satisfy the requirements as set out in the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice, which includes a minimum 3 m-wide firebreak within the internal boundary of the property.	
		Yes.	N/A		

Table 4: Summary of bushfire protection criteria and compliance statement (continued)

Bushfire protection criteria	Intent	Method of compliance		Proposed bushfire management strategies	Compliance Statement
		Acceptable solution	Performance principle		
Element 4: Water	To ensure water is available to the subdivision, development or land use to enable people, property and infrastructure to be defended from bushfire.	A4.1 Reticulated areas		Development is located within an Emergency Services Levy (ESL) Category 5 area, which indicates that bushfire events are responded to by the State Emergency Service and usually a bush fire brigade. Fire response services require ready access to adequate water supply during bushfire emergencies. The site will connect with a reticulated water supply and will include fire hydrants installed by the developer to meet the specifications of Water Corporation (Design Standard DS 63) (or similar standard, as agreed with the relevant water authority) and DFES. Fire hydrants on land zoned for residential purposes are generally required to be sited at or within 200 m of residential dwellings (Class 1a).	Based on the outlined management measures, future development would be able to comply with and meet the intent of Element 4: Water.
		Yes.	N/A		
		A4.2 Non-reticulated areas		Not applicable.	
		N/A	N/A		
		A4.3 Individual lots within non-reticulated areas (only for use if creating 1 additional lot and cannot be applied cumulatively)		Not applicable.	
		N/A	N/A		

5.1 Additional management strategies

5.1.1 Future approval considerations

The BAL assessment is a conservative and cautious assessment of the potential bushfire risk posed to future habitable buildings within the site based on the proposed management of vegetation and assumptions outlined in **Section 3**.

Following the creation of lot titles, a building licence will be required before the dwelling construction can commence. This BMP and the predicted BAL ratings (see **Figure 6**) can be used to inform the construction requirements for future dwellings.

5.1.2 Landscape management

5.1.2.1 Within the site

Public Open Space and Drainage corridor

Two Public Open space areas have been identified with the southern portion of the site. Based on the future landscape designs, the areas of public open space will be planted with native grasses, herbs and sedges, limited low native groundcovers, and scattered local native trees and will therefore be classified as grassland vegetation.

As part of the proposed structure plan, the drainage corridor which transects the central portion of the site will be replanted with native grasses, herbs and sedges, limited low native groundcovers, and scattered local native trees. The detailed design of the drainage corridor within the site will be determined in collaboration with the Shire of Serpentine Jarrahdale as part of the standard development process and is assumed to be designed to achieve a grassland classification.

Future lots

Future lots will be managed to a low threat standard by the future lot owners, in accordance with the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice and AS 3959. This will include management of any existing vegetation that is retained within lots and the ongoing maintenance of any gardens which will be developed as part of future private landholdings. Management of these areas to a low threat standard is likely to require:

- Clearing of vegetation.
- Irrigation of grass and garden beds (where required).
- Regular maintenance including removal of weeds and dead material.
- Low pruning of trees (branches below 2 m in height removed where appropriate).
- Application of ground covers such as mulch or non-flammable materials.
- Regularly mowing/slashing of grass to less than 100mm in height.

The proponent will be responsible for the initial maintenance of these areas, and following handover, the Shire of Serpentine Jarrahdale will be responsible for the long-term maintenance of the public open space areas to a low threat standard.

Proponent' landholdings

Whilst development is progressing in accordance with the proposed structure plan layout, if development is to occur in a staged manner, vegetation within 100 m of titled lots in the proponent's landholdings will be maintained to a low threat standard in accordance with the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice.

5.1.2.2 Surrounding the site

The private landholdings surrounding the site are assumed to be managed by the applicable landowners in accordance with the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice in perpetuity and/or in accordance with existing maintenance regimes. All other vegetation will remain in its existing condition for the foreseeable future.

5.1.3 Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice

The Shire of Serpentine Jarrahdale releases a Firebreak Notice on an annual basis to provide a framework for bushfire management within the Shire. The Shire of Serpentine Jarrahdale asis able to enforce this notice in accordance with Section 33 of the *Bush Fires Act 1954*. In addition, Section 33 1(b) also provides the Shire with additional power to direct landowners to undertake works to remedy conditions conducive to the outbreak or spread of bushfire.

Until development is progressed within the site, the proponent will be required to comply with the Firebreak and Fuel Hazard Reduction Notice, including the maintenance of minimum 3 m-wide perimeter firebreaks (or as agreed with the Shire of Serpentine Jarrahdale).

All landowners of future lots will be required to comply with the Firebreak and Fuel Hazard Reduction Notice as published, which for residential lots is likely to include ensuring that the property is cleared of all flammable material, except for living standing trees and ensuring that grass height is no longer than 5 cm.

5.1.4 Vulnerable or high-risk land uses

There is no vulnerable or high-risk land uses, as defined under SPP 3.7, proposed within the site at part of the proposed structure plan.

5.1.5 Public education and preparedness

Community bushfire safety is a shared responsibility between individuals, the community, government and fire agencies. DFES has an extensive Community Bushfire Education Program including a range of publications, a website and Bushfire Ready Groups. The DFES publication '*Prepare. Act. Survive.'* (DFES 2014) provides excellent advice on preparing for and surviving the bushfire season. Other downloadable brochures are available from http://www.dfes.wa.gov.au/safetyinformation/fire/bushfire/pages/publications.aspx

The Shire of Serpentine Jarrahdale provides bushfire safety advice to residents available from their website https://www.sjshire.wa.gov.au/community/fire-and-emergency-management. Professional, qualified consultants also offer bushfire safety advice and relevant services to residents and businesses in high-risk areas in addition that that provided in this BMP.

In the case of a bushfire in the area, advice would be provided to residents by DFES, Department of Biodiversity Conservation and Attractions (DBCA) and/or the Shire of Serpentine Jarrahdale on any specific recommendations with regard to responding to the bushfire, including evacuation if required. However, it is highly recommended that future residents make themselves aware of their responsibilities with regard to preparing for and responding to a potential bushfire that may impact them, their family and property, regardless of the BAL rating their properties are subject to.

6 Responsibilities for Implementation and Management of Bushfire Measures

Table 5 outlines the future responsibilities of the proponent (developer), future users of the site, and the Shire of Serpentine Jarrahdale associated with implementing this BMP with reference to ongoing bushfire risk mitigation measures for existing land uses (through compliance with the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice) or future mitigation measures to be accommodated as part of the future subdivision process. These responsibilities will need to be considered as part of the subsequent development and implementation process.

Table 5 Responsibilities for the implementation of this BMP

Management action	Timing
Proponent/developer	
If development within the site is staged, vegetation within the proponent's landholdings that is located within 100 m of titled lots will be managed to a low threat standard. Management should include (but is not limited to): • Clearing/modification of vegetation • Regular removal of weeds and built up dead material (such as fallen branches, leaf litter etc.) • Low pruning of trees (i.e. removal of branches less than 2 m in height) if individual trees are proposed for retention, particularly where these are located in future road reserves or public open space). • Application/re-application of ground/surface cover such as mulch or non-flammable materials as required. • Where the grass is present, this should be regularly cut so that the grass is maintained at or below 100 mm in height.	As part of the subdivision and to support the creation of lot titles, and ongoing where applicable.
Certify BAL ratings for all lots designated as bushfire prone at the time titles are created, based on the BAL Contour Plan and/or in accordance with a BAL assessment if the site conditions are different. The certified BAL ratings can be submitted by lot owners to the Shire of Serpentine Jarrahdale to support future building licences.	To support the creation of lot titles.
For each new lot created within areas exposed to a BAL rating exceeding BAL-LOW, a Section 165 Notification on the Certificate of Title in order to alert purchasers and successors in title of the existence of the overarching BMP and the requirements associated with meeting AS 3959 construction standards. This should be based on the outcomes of the BAL certification process and would apply to all proposed lots.	To support the creation of lot titles.
Install the public roads to standards outlined in Appendix Four of the Guidelines (WAPC and DFES 2017) or as agreed with the Shire of Serpentine Jarrahdale.	To support the creation of lot titles
Reticulated water supply and hydrants to be installed as per standard Water Corporation requirements unless otherwise agreed.	To support the creation of lot titles.

Table 5 Responsibilities for the implementation of this BMP (continued).

Management action	Timing
Property owner/occupier	
Ensuring construction of new dwelling/s complies with AS 3959, as per the applicable BAL rating, determined as part of this BMP (outlined within **Section 3** of this BMP) or through a separate BAL assessment. The BAL rating for a new dwelling should not exceed BAL-29.	As part of building design and construction
If dwellings are subject to additional construction in the future, such as renovations, compliance with AS 3959 is required (i.e. where located within a designated bushfire prone area and identified to have a BAL rating greater than BAL-LOW).	As part of building design and construction
Ensuring that their property complies with the Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice/s as published and/or in accordance with directions given by the Shire. This includes maintaining firebreaks and APZs. Should future landowners not manage vegetation within their landholding to a low threat standard, an APZ may be required. The requirement for APZs will be determined at building licence stage.	Ongoing, where applicable
Ensuring that where hydrants are located, these are not obstructed and remain visible at all times.	Ongoing, where applicable.
Shire of Serpentine Jarrahdale	
Providing fire prevention and preparedness advice to landowners upon request, including the *Homeowners Bush Fire Survival Manual: Prepare, Act, Survive* (or similar suitable documentation) and the latest Shire of Serpentine Jarrahdale Firebreak and Fuel Hazard Reduction Notice.	Ongoing, as required
Maintain all areas of developed POS under their management to a low threat standard in accordance with Section 2.2.3.2 of AS 3959, where required/applicable in accordance with approved designs and/or existing maintenance regimes.	Ongoing, as required
Maintaining public road reserves under their management to appropriate standards, where required/applicable.	Ongoing, as required
Monitoring vegetation fuel loads in public reserves (and private landholdings) and liaising with relevant stakeholders to maintain fuel loads at appropriate fuel levels, where required/ applicable.	Ongoing, as required
Monitoring compliance with the Shire of Serpentine Jarrahdale Firebreak and Fuel Reduction Notice and enforcing requirements as required.	Ongoing, as required
Water Corporation	
The Water Corporation is responsible for the ongoing maintenance and repair of water hydrants.	Ongoing, as required.

7 Applicant Declaration

7.1 Accreditation

This BMP has been prepared by Emerge Associates who have been providing bushfire risk management advice for more than six years, undertaking detailed bushfire assessments (and associated approvals) to support the land use development industry.

Anthony Rowe is a Fire Protection Association of Australia (FPAA) Level 3 Bushfire Planning and Design (BPAD) accredited practitioner (BPAD no. 36690) with over nine years' experience and is supported by a number of team members who have undertaken BPAD Level 1 and Level 2 training and are in the processing of gaining formal accreditation.

7.2 Declaration

I declare that the information provided is true and correct to the best of my knowledge.

Signature:



Name: Anthony Rowe

Company: Emerge Associates

Date: 22 July 2020

BPAD Accreditation: Level 3 BPAD no. 36690

8 References

8.1 General references

Department of Fire and Emergency Services (DFES) 2014, *Prepare. Act. Survive.*, Perth. August 2014.

Standards Australia 2018, *AS 3959-2018 Construction of buildings in bushfire-prone areas*, Sydney.

Western Australian Planning Commission (WAPC) 2015, *State Planning Policy 3.7 Planning in Bushfire Prone Areas*, Perth.

Western Australian Planning Commission and Department of Fire and Emergency Services (WAPC and DFES) 2017, *Guidelines for Planning in Bushfire Prone Areas Version 1.3*, Western Australia. December 2017.

8.2 Online references

Landgate 2020, *Locate V5*, viewed March 2020, https://maps.slip.wa.gov.au/landgate/locate/

Landgate 2020, *Map Viewer Plus*, viewed March 2020, https://maps.landgate.wa.gov.au/maps-landgate/registered/

Office of Bushfire Risk Management (OBRM) 2019, *Map of Bush Fire Prone Areas*, viewed March 2020, https://maps.slip.wa.gov.au/landgate/bushfireprone/

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Figures

Figure 1: Site Location and Topographic Contours

Figure 2: Existing Conditions - AS 3959 Vegetation Classification

Figure 3: Post Development Conditions – AS 3959 Vegetation Classification

Figure 4: Post Development Conditions – Effective Slope

Figure 5: Bushfire Attack Level Contours

Figure 6: Vehicle Access

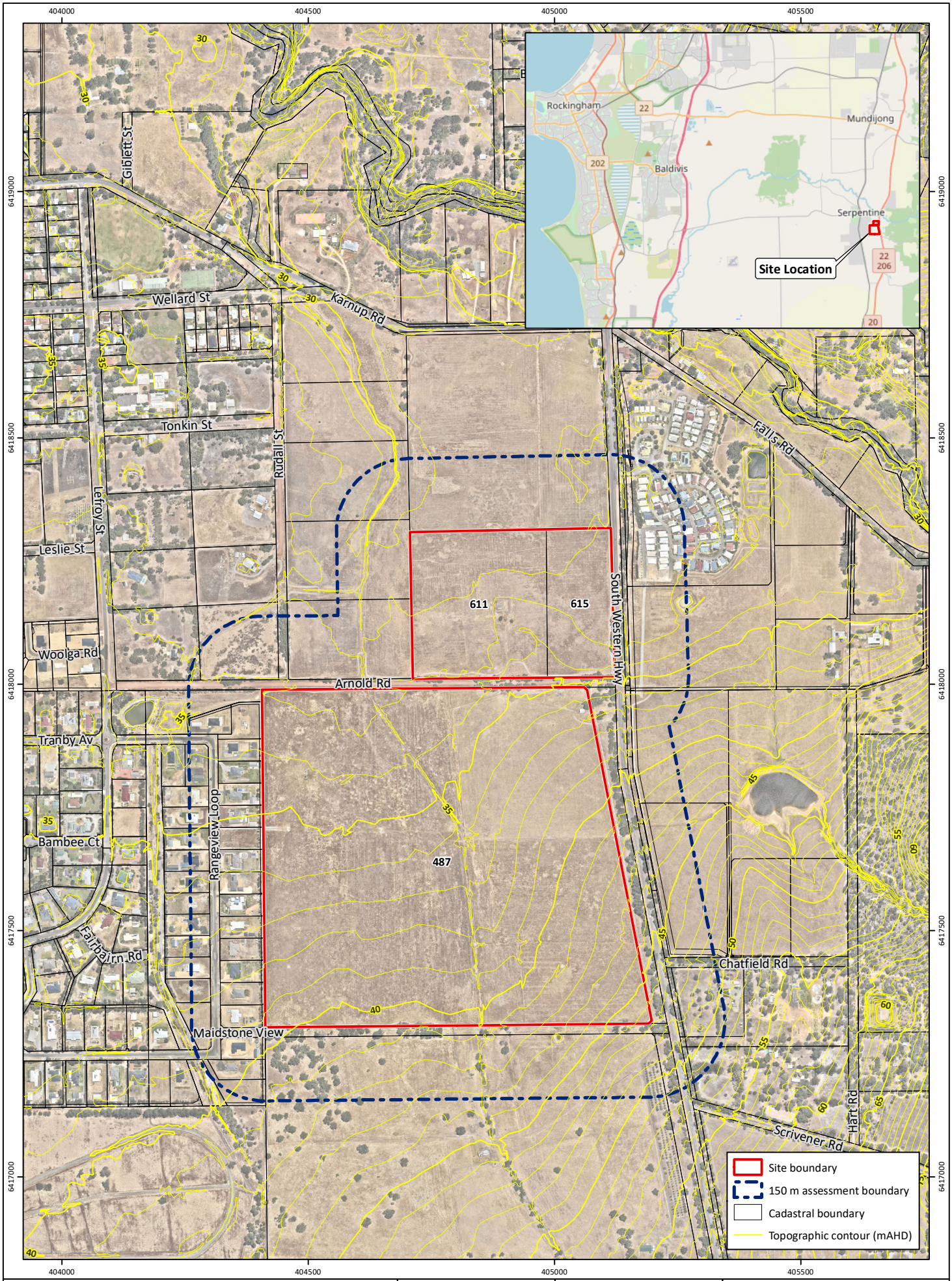

Figure 1: **Site Location and Topographic Contours**

Project:	Bushfire Management Plan Lots 487, 611 & 615 Arnold Rd, Serpentine
Client:	MALF Corp Pty Ltd

Plan Number:
EP20-020(03)--F02

Drawn:	GAR
Date:	18/03/2020
Checked:	BRB
Approved:	AJR
Date:	02/04/2020

N

0 100 200
Metres

Scale: 1:10,000@A4

GDA 1994 MGA Zone 50

emerge ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used

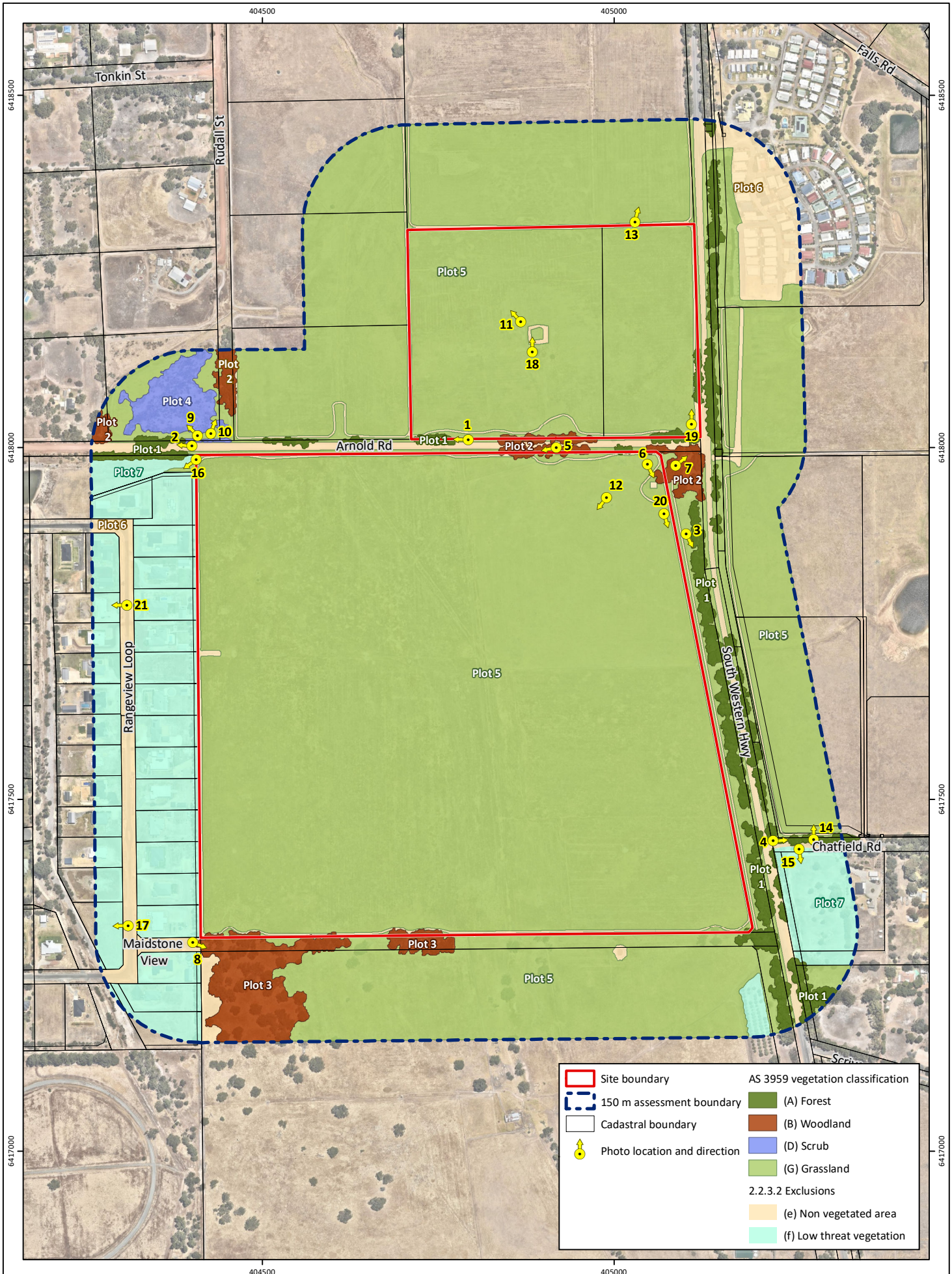

Figure 2: **Existing Site Conditions – AS 3959 Vegetation Classifications**

Project: Bushfire Management Plan
Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number: EP20-020(03)--F03

Drawn:	GAR
Date:	18/03/2020
Checked:	BRB
Approved:	AJR
Date:	02/04/2020

N

0 50 100 150
Metres

Scale: 1:7,000@A4

GDA 1994 MGA Zone 50

emerge ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used

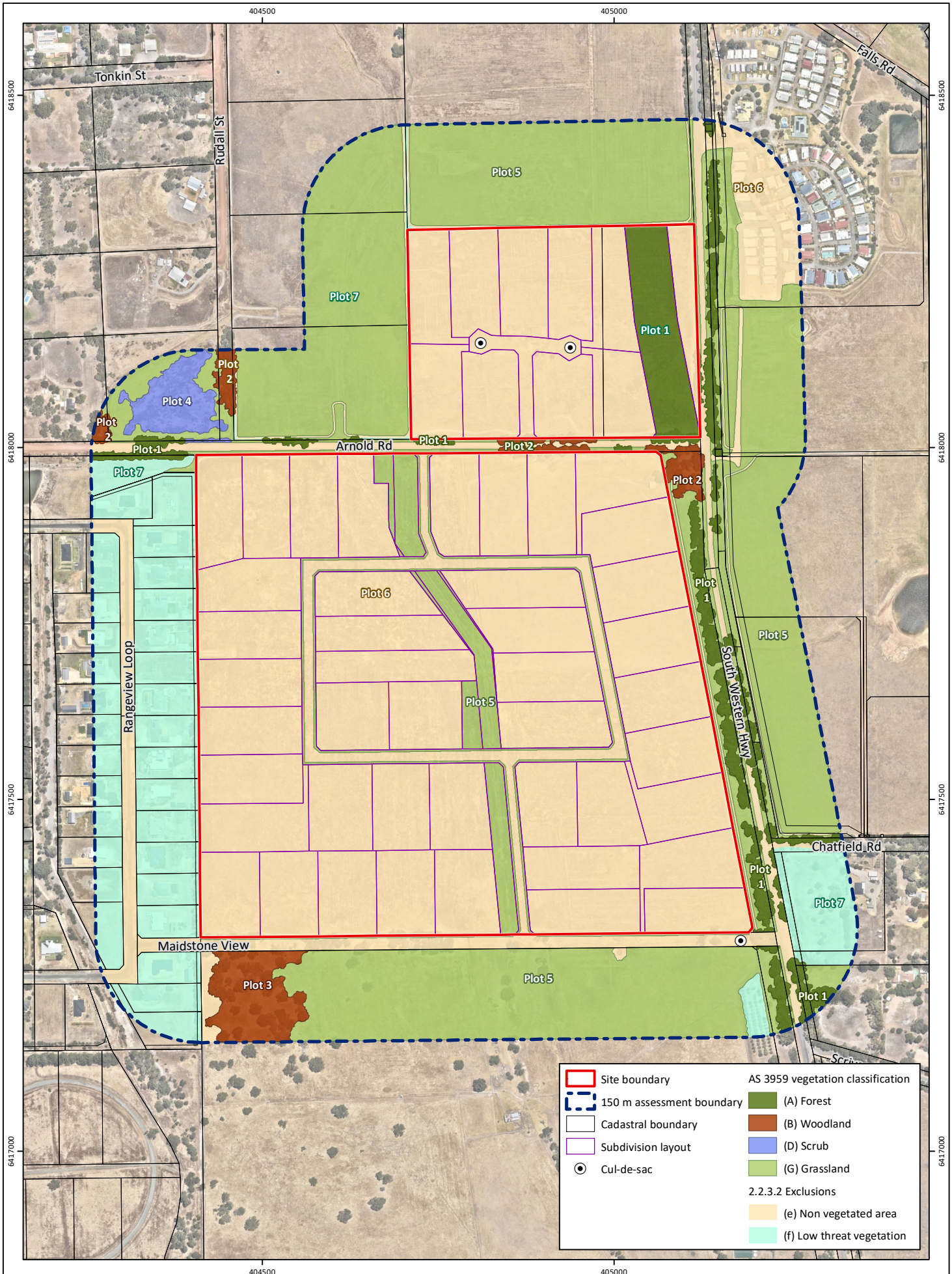

Figure 3: **Post Development Conditions – AS 3959 Vegetation Classifications**

Project: Bushfire Management Plan
Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number: EP20-020(03)--F04c

Drawn:	GAR
Date:	06/08/2021
Checked:	BRB
Approved:	AJR
Date:	09/08/2021

N

0 50 100 150
Metres

Scale: 1:7,000@A4

GDA 1994 MGA Zone 50

emerge ASSOCIATES

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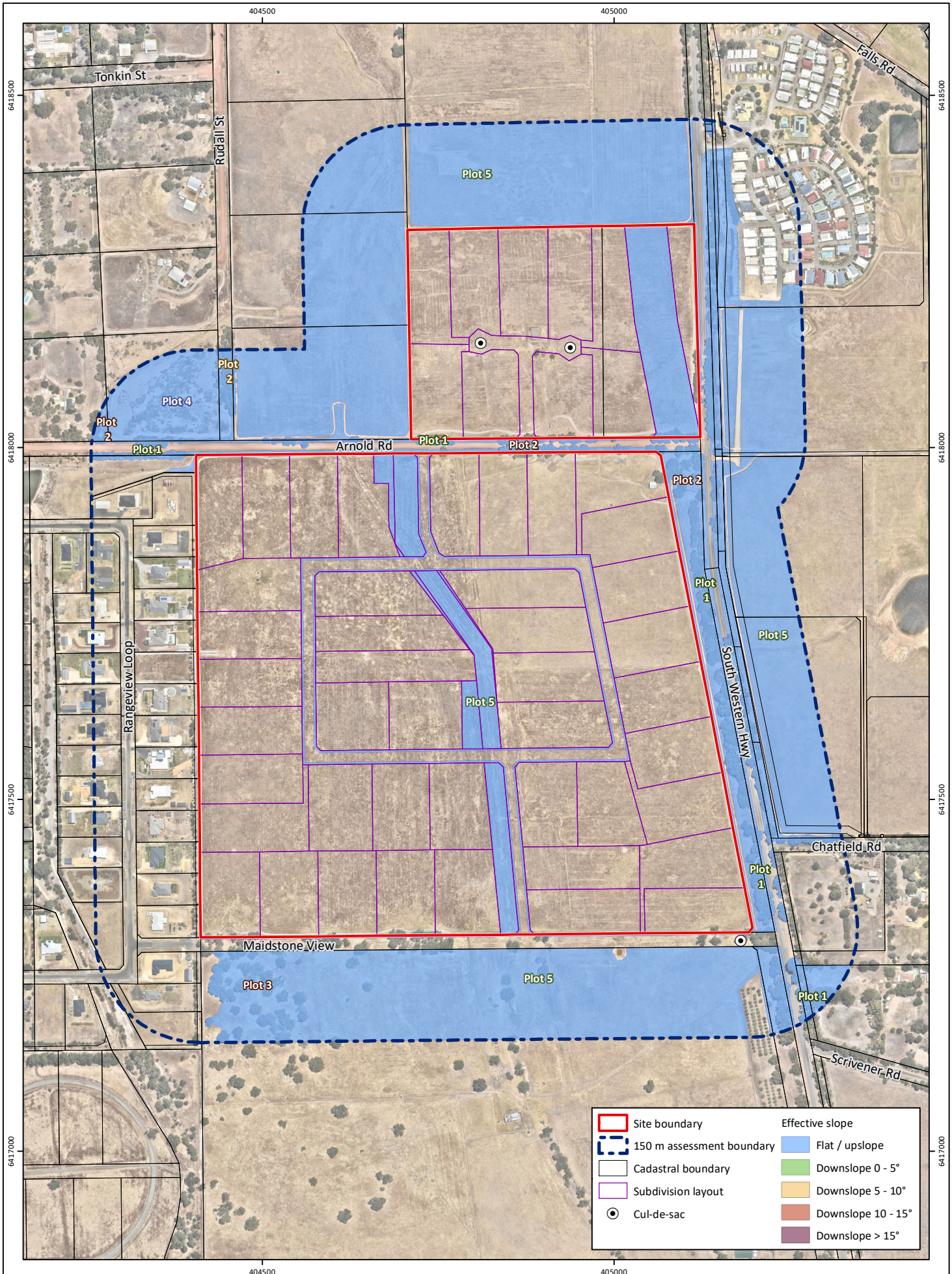

Figure 4: **Post Development Conditions – Effective Slope**

Project: Bushfire Management Plan
Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number: EP20-020(03)--F05c

Drawn:	GAR
Date:	06/08/2021
Checked:	BRB
Approved:	AJR
Date:	09/08/2021

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Metres

Scale: 1:7,000@A4

GDA 1994 MGA Zone 50

emerge ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used

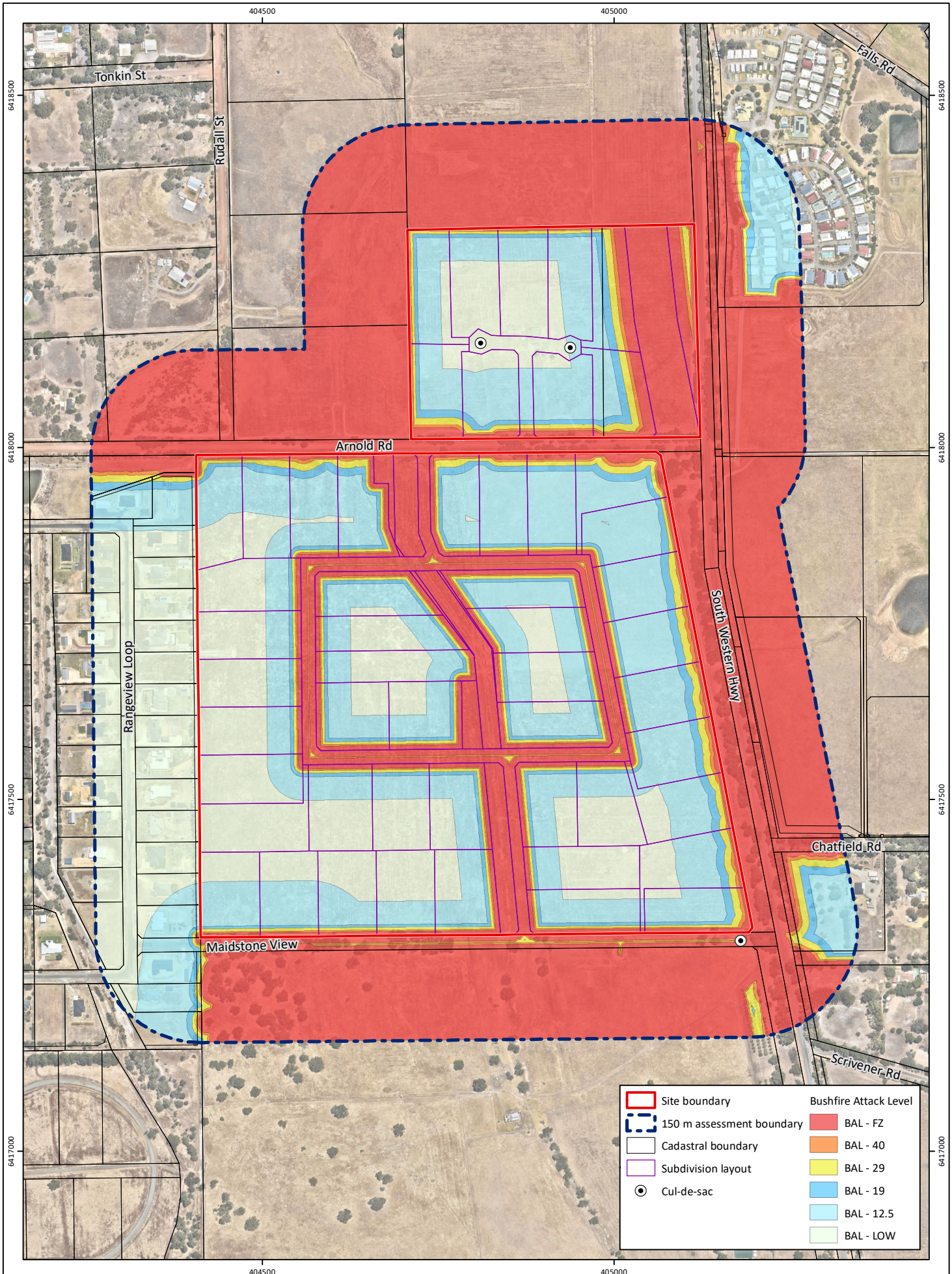

Figure 5: **Bushfire Attack Level Contours**

Project: Bushfire Management Plan
Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number: EP20-020(03)--F06b

Drawn:	GAR
Date:	06/08/2021
Checked:	BRB
Approved:	AJR
Date:	09/08/2021

N

0 50 100 150
Metres

Scale: 1:7,000@A4

GDA 1994 MGA Zone 50

emerge ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used

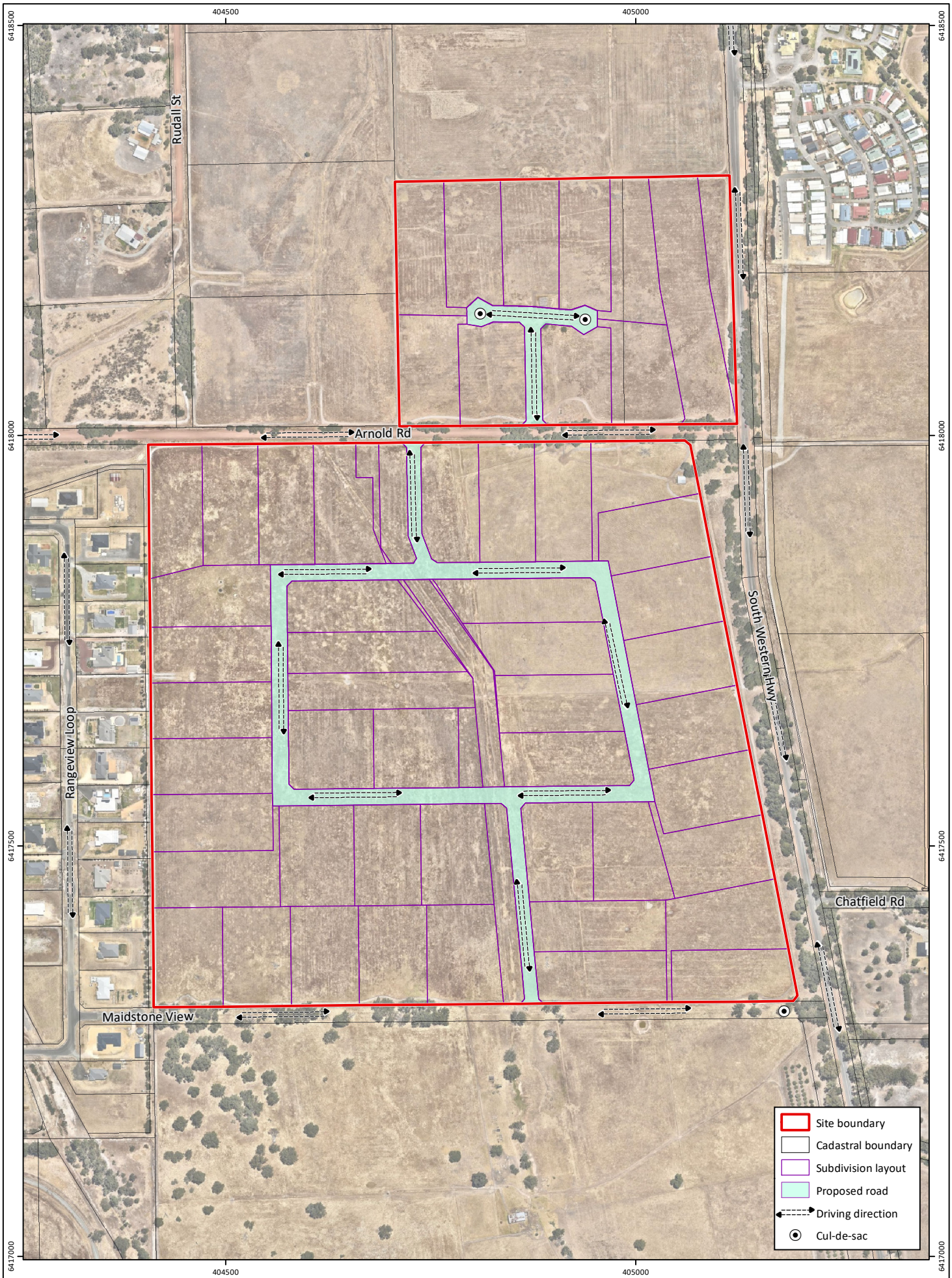

Figure 6: Vehicle Access

Project: Bushfire Management Plan
Lots 487, 611 & 615 Arnold Rd, Serpentine

Client: MALF Corp Pty Ltd

Plan Number: EP20-020(03)--F07c

Drawn:	GAR
Date:	09/08/2021
Checked:	BRB
Approved:	AJR
Date:	09/08/2021

N

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Metres

Scale: 1:6,000@A4

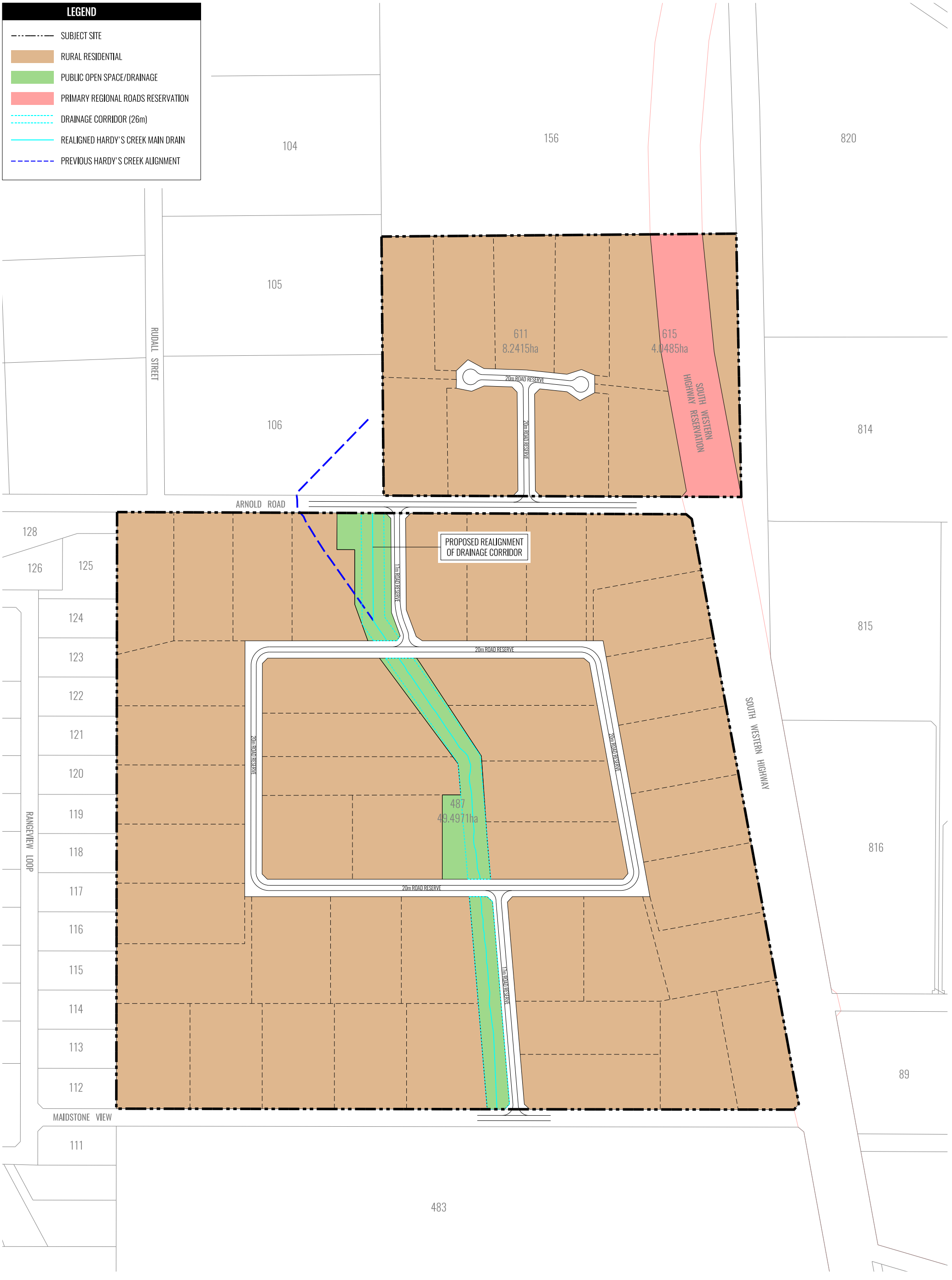
GDA 1994 MGA Zone 50

emerge ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used

Appendix A

Proposed Structure Plan (CDP Town Planning & Urban Design 2020)



CONCEPT PLAN

Lots 487, 611 & 615 Arnold Rd, SERPENTINE

A Malf Corp Pty Ltd. Project

NORTH

Scale: 1:4000 @ A3

0 40 80 120m

PLAN: MALAR-5-001A REVISION: A
DATE: 21/07/2020 DRAWN: JDP
PROJECTION: PCG 94 PLANNER: MT
DATUM: AHD CHECK: KB

cdp
Town Planning & Urban Design

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ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix h

Engineering Services Report

(Pritchard Francis)

Lots 487, 611 & 615 Arnold Road, Serpentine

Desktop Engineering Servicing Assessment

Project No: 19-009



pritchard francis lite
civil engineering consultants

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Appendix One: Geotechnical Conditions

Appendix Two: Groundwater and Acid Sulphate

Appendix Three: Aboriginal Register

Appendix Four A: Typical Cross Section Details

Appendix Four B: Section Locations

Appendix Five: Western Power Underground Network

Appendix Six: Western Power Overhead Network

Appendix Seven: Telstra Network

Revision	Description	Author	Date

0	Issued for Inclusion in Report	Philip Patterson	19 March 2020

On behalf of MALF Corp Pty Ltd. Pritchard Francis Lite have undertaken an investigation associated with servicing of Lots 487, 611 and 615 Arnold Road, Serpentine.

1 Introduction

The below information and attached documents represent a summary of engineering services needing upgrade or extension to service the proposed subdivision over Lots 487, 611 and 615 Arnold Road, Serpentine.

2 Site Description

This development is situated about 60km south east of the Perth CBD in the Shire of Serpentine/Jarrahdale.

The site is reasonably flat and grades from a high of 45m at the south east corner of the site to a level of 32m along its northern boundary over a distance of 1km.

The only significant vegetation on the site is located along the existing Arnold Road reserve which bisects the site in an east/west direction. The rest of the site is typical grazing land with no trees or outcrops of vegetation.

3 Local Authority

As mentioned previously, the site is located in the Shire of Serpentine/Jarrahdale, who are aware of the development and who have been involved in meetings associated with this development.

4 Geotechnical and Environmental

4.1 Ground Condition

Geotechnical mapping indicates the site is made up of two distinct types of soils, as can been seen in Appendix 1.

On the western side of the development, soil conditions are of a sandy clay while the eastern section of the development is more a gravelly, clayey sand.

4.2 Flora and Fauna

With the lack of significant vegetation on the site it is unlikely the Shire will require a fauna survey to be undertaken but a flora survey may be required.

4.3 Acid Sulphate

The state government produces a map which identifies the possibility of acid sulphate conditions. This plan identifies areas of low and high risk. Information obtained for this development site indicates there is a moderate to low risk of encountering acid sulphate conditions on site. See Appendix 2.

4.4 Aboriginal Heritage

A search of the native title/heritage registry has been undertaken and there are no native title areas of interest noted on the land south of Arnold Road, however the area north of Arnold Road is registered as a Ceremonial Mythological area and will require further investigation. Appendix 3.

5 Roadworks

Meetings have been held with the Shire of Serpentine/Jarrahdale regarding road make up and configuration for this development. It has been agreed that the development will be serviced by 6m wide, sealed, un-kerbed road with 1.2m wide shoulders. The road will be constructed with one-way cross fall. Roads within the development will discharge water into a road side table drains while the main North/South road running along the main drain will discharge water towards the drain over a treatment area before discharging into the drain. The section detailed in Appendix 4 has been developed in association with Shire of Serpentine/Jarradale and DWER the achieve a low maintenance acceptable solution to handle drainage to run off from the road.

It is proposed Maidstone view will be constructed as a rural road and our intention would be for trees to be retained where possible, subject to full feature survey, arboricultural assessment and detailed civil and landscape design at subdivision stage. Our intention would be to work in conjunction with the Shire on this(as the Shire may need to allow some dispensations).

Vegetation on Arnold Rd, for our intention would be for trees to be retained where possible, subject to full feature survey, arboricultural assessment and detailed civil and landscape design at subdivision stage. Our intention would be to work in conjunction with the Shire on this (as the Shire may need to allow some dispensations).

Arnold Road, where it abuts the development, will be upgraded as part of the development work in accordance with traffic requirements and recommendations.

6 Stormwater Drainage

As mentioned in the previous section, internal roads will be constructed with one-way cross fall and will discharge into a roadside table drain that will cater for water runoff.

The main spine road will also be constructed with one-way cross fall and stormwater runoff will discharge across treatment areas before discharging into this main drain.

It is proposed to capture and treat stormwater from roads in table drains treatment areas in the road reserve adjacent to the main drain and in the main drain as agreed with Shire of Serpentine/Jarradale and DWER.

Lot access will be provided to individual lots and where these crossovers run over table drains, a dia 375mm pipe with headwalls is to be installed under crossovers.

All lot drainage will be contained on site.

7 Water Supply

There is an existing potable water supply system servicing the existing development to the west of this site that can be extended to service the new lots. This existing network consists of Ø150mm water main in Range View Loop and Lefroy Street that will be extended east and looped through the development providing a potable water supply to all lots.

8 Sewer Reticulation

Lots in the development require private effluent treatment systems to be installed by individual lot owners as no piped gravity system exists.

A Geotechnical Investigation has been carried out and a report prepared which confirms the use of on-site effluent disposed and treatment systems are acceptable.

In order for effluent systems to operate efficiently, a clean layer of sand should be placed above the existing ground beneath the treatment system to increase permeability. Alternatively, the cells could be placed in a mound above the existing ground which would allow infiltration to accommodate the primary effluent. This would need to be designed as part of the house build.

9 Gas Supply

There is no natural gas network in the area and no supply with be available for this development.

10 Electrical Services

10.1 Existing Power Distribution Network

The existing Western Power (WP) distribution infrastructure in the vicinity of the site comprises of a 22kV three phase aerial High Voltage (HV) and underground three phase Low Voltage (LV) network.

HV aerials exist along the eastern side of South Western Highway running in a south to north direction located within Lots 814-816. The next closest HV network is located approximately 800m northwest from proposed Lot 1 on Leslie Street or 800m west of proposed Lot 19 on Hardey Road. The HV spurs on these two roads spur from main HV feeder line located on the west side of Hall Road. The closest underground LV network is located on the northern verge of Maidstone View which originates from a pad mounted transformer on Lots 72/73 Rangeview Loop located approximately 280m west of proposed Lot 19.

Information on the capacity of the local zone substation can be determined from Western Power's public Network Capacity Mapping Tool (NCMT). The substation that appears to supply the HV network adjacent to the subject site is the Byford zone substation, which is located near the intersection of George Street and Thomas Road approximately 18.6km north as the crow flies. Currently there is less than 5MVA capacity in the zone substation. Within the next ten years, this is expected to stay the same, suggesting that Western Power have not scheduled/planned any reinforcement/upgrades for the area. The spare capacity in the adjacent HV network however can only be confirmed via an official application to Western Power such as a Design Information Package request or feasibility study request.

10.2 Likely Load

For the 51 rural residential free hold lots & 2 public open spaces, at Western Power's standard 5kVA per lot allocation, the total load will be in the order of 265kVA. As newly created lots, there are no load currently allocated to the lots.

10.3 Likely Power Supply Scenario

10.3.1 Site Supply Infrastructure

WP requires that all new developments are to be serviced by underground three phase power. WP also require any existing HV and LV aerials adjacent to the land being subdivided to be undergrounded and any existing consumers affected will have to have their consumer mains reconnected to the network.

In the freehold residential development scenario this would be by traditional WP owned and maintained Underground Residential Distribution (URD) 3-phase direct buried underground cabling from new transformer(s) to pillars servicing each freehold lot on the general basis of one pillar serving two adjacent lots.

Based on the estimated load for the site and proximity of the existing WP network to the proposed lots, the development will likely require new WP underground infrastructure to be installed. The existing adjacent network will not have the capacity to service the entire development.

To service the proposed development would likely require Western Power to remove bays of aerials on Chatfield Road and terminating HV feeder cables to these poles. Where capacity does not permit, HV connection will need to come from the HV network located on Hall Road or Hardey Road. The HV feeders will then supply a HV switchgear strategically placed within the development servicing a 315kVA transformer centrally located within the development which will supply power to the newly created residential lots. Where the transformer cannot be centrally located, a second transformer may be required due to power quality issues. Discussions with WP are required to determine the extent of aerial removal and whether alternative HV connection arrangements are possible. The spare capacity in the adjacent HV network can only be confirmed once an official application to Western Power such as a Design Information Package request or feasibility study request.

Typically, HV substations are placed on Public Open Space (POS) lots to avoid affecting one of the newly created residential lots. This cannot always be achieved due to the need to meet technical requirements. Typical land requirements for HV substations are as follows:

- HV Switchgear and transformer 6.2m (W) x 4m (D)
- Transformer only 3.7m (W) x 4m (D)
- Switchgear only 4.5m (W) x 3m (D)

10.3.2 Relocation of Existing Assets

From Dial Before You Dig plans, Western Power assets do not exist along the boundaries of the site and therefore, no relocations works are required around the site. Where communication pits exist within 15m of proposed HV connection points, pits may need to be relocated.

10.3.3 Headworks

As the load of the site is under 1.5MVA, we understand that it's currently WP's policy to allow the load to connect without any capacity headworks costs for any augmentation of the upstream network being passed on to the customer.

The NCMT indicated that available capacity is currently less than 5MVA. The estimated demand of this site is under 500kVA and will not likely have significant impact on the remaining capacity in the network and therefore should not warrant the project being responsible for contributing towards the costs of an upgrade at the zone substation, to create additional capacity.

The existing capacity of the HV aerial line in the vicinity to the site is unknown. This information must be sort from Western Power via a formal application. From the information available to us, we would anticipate significant load on the HV feeder, possibly in the order of the feeder's capacity. Therefore, it's plausible that some augmentation of the existing network may be required. This would most likely consist of the shifting of load between adjacent existing HV circuits.

This could include a section of new underground HV cable being installed at a location well away from the site and one or more pole top HV switches or padmount HV switchgear units being installed. The extent of the works is to be confirmed by Western Power.

10.3.4 Lighting for New Roadways

All newly created roadways will require new lighting to satisfy the requirements of AS1158 and the Local Government Authority. The lighting could consist of standard or decorative Western Power lighting poles, or if the Local Government preferred, "privately" (Local Government) owned lighting, where any range of suitable lighting products could be utilised, opening up the opportunity to use broader technologies and strategies, including:

- Architectural lighting poles and luminaires.
- High efficiency and low glare LED luminaires.
- Multi-technology poles, including banner mounts, CCTV cameras and power outlets.
- Time based, light level and motion detection-controlled lighting operation and output levels.

Currently no lighting exists on the sections of Arnold Road and South Western Highway which abuts the development site. With lighting installed on the development to the west on Rangeview Loop, it is expected that the Shire will request a proper lighting arrangement for this development.

South Western Highway falls under the management of Main Roads WA (MRWA). Any lighting and works proposed on this road reserve are to be reviewed/approved by MRWA.

10.4 Supply Timelines

Western Power will neither reserve capacity nor guarantee supply to this development without a formal request being lodged. A Subdivision Design Information Package (DIP) request must be prepared and submitted to Western Power for the design and construction of the proposed development to commence.

From the date of DIP request submission DIP is typically provided between eight to twelve weeks. Soon after, a design can be lodged with WP for conformance and quoting. From the date of the design being lodged with WP, the design acceptance and works quote is typically provided within eight to twelve weeks. Once the quote is paid and construction package is submitted, construction may commence.

To avoid any project delays, it is highly advised that a DIP request is prepared and submitted to Western Power as soon as possible.

10.5 Possible Constraints

The following may affect the ultimate utility services design and delay approval and construction timeframes.

- Vegetation occupying utility alignments on road reserve
- MRWA approval required for serviced proposed within South Western Highway Road Reserve
- WP easements for cables in private property
  - If extent of HV undergrounding is required to enter Lots 64 & 816 on Chatfield Road
  - Where non-standard alignments are proposed within lots
- Low owners approval for any works within private property
- Rail authority (arc infrastructure) approval for works in cables crossing rail reserve where HV connection point is confirmed to be off the Hall Road HV network
- Coordination between existing services
  - Existing communication network currently runs inside lot
  - Hardey's Creek Main Drain

11 Communication Services

11.1 Existing Communication Networks

Telstra's existing network is currently adjacent to Arnold Rd and South West Hwy with Telstra's Serpentine Exchange is located about 1500m route length to the north-west, so there is ready access to existing fixed line telecommunications infrastructure.

The proposed 51 rural residential development falls completely within NBN Co's Fixed Wireless Footprint, therefore NBN Co are Infrastructure Provider of Last Resort (IPoLR) for broadband and Telstra IPoLR for voice infrastructure. NBN Co must service the development with broadband, given that their existing network has coverage of the development, should the Developer wish to utilise NBN Co services. If the Developer were satisfied with Fixed Wireless infrastructure for broadband services, there would be no need to lodge an infrastructure with NBN Co. However, an infrastructure application would need to be lodged with Telstra, for voice infrastructure.

11.2 Developer Responsibilities

Developers have two obligations in relation to the provision of telecommunications infrastructure. Under the Telecommunications Act 1997, Developers are obliged to provide fibre ready pit and pipe to new developments and under the Federal Governments Telecommunications in New Developments (TIND) policy, Developers are required to provide telecommunications infrastructure as they do for other utilities. To ensure that telecommunications can always be provided, the federal government has specified the NBN Co and Telstra shall be IPOLR, in certain portions of the network.

11.3 Proposed Communications Network

Given the size of the development, NBN Co may consider reclassifying the area into its Fixed Line Footprint, in which case FTTP technology would be delivered to properties and NBN Co would be IPoLR for both broadband and voice infrastructure. If so, the developer would still be required to make the development fibre ready but in this instance would also be required to contribute to NBN Co's charges for fibre infrastructure. NBN Co would take ownership of new pit and pipe, under this scenario. If NBN Co won't reclassify the area, then the Developer would not be required to provide any capital contribution towards NBN Co's Fixed Wireless network, based on the current application of the TIND policy. Property owners only need to contact their Retail Service Provider of choice, for broadband services. Under these circumstances the Developer would still need to make the development fibre ready and approach Telstra for voice infrastructure. Telstra would take ownership of the pit and pipe and most likely provide copper infrastructure.

The development is only 100m from Fixed Line Footprint properties, so if accepted by NBN Co, it is unlikely that any Backhaul Charge would apply. Access to an existing Telstra P100 network is readily available on Arnold Rd, so we would not foresee the need for any Backhaul pit, pipe or fibre.

11.4 Network Relocations

Since Telstra pit and pipe has been installed through private property on the eastern side of lot 615, adjacent to South West Hwy and on the northern border of lot 487, adjacent to Arnold Rd, a relocation request would need to be lodged with Telstra to have these assets moved onto road reserve, unless there were extenuating reasons requiring that they remain on private property ie. protection of Flora and fauna. We recommend relocation to avoid encumbering the 10 affected lots. We are not aware of any other telecommunications carriers affected.

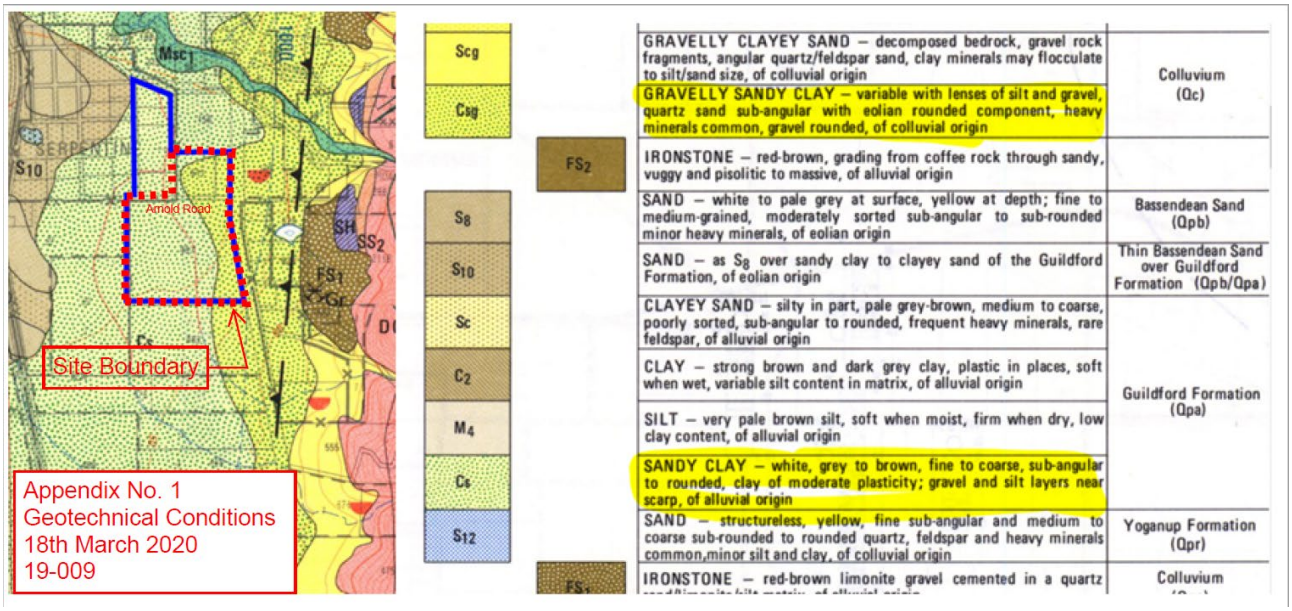
12 Conclusion

Based on information available, it would appear this land is capable of being serviced by essential services and the supporting information confirm this.

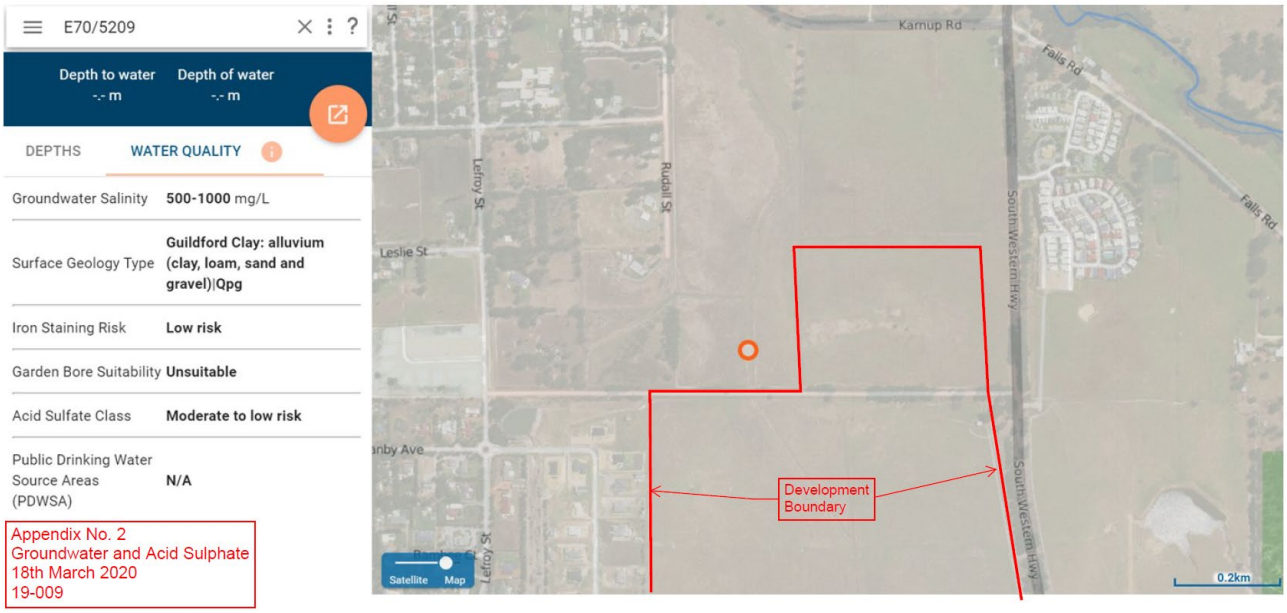
Appendices

Appendix One:	Geotechnical Conditions
Appendix Two:	Groundwater and Acid Sulphate
Appendix Three:	Aboriginal Register
Appendix Four:	A - Typical Cross Section Details B - Section Locations
Appendix Five:	Western Power Underground Network
Appendix Six:	Western Power Overhead Network
Appendix Seven:	Telstra Network

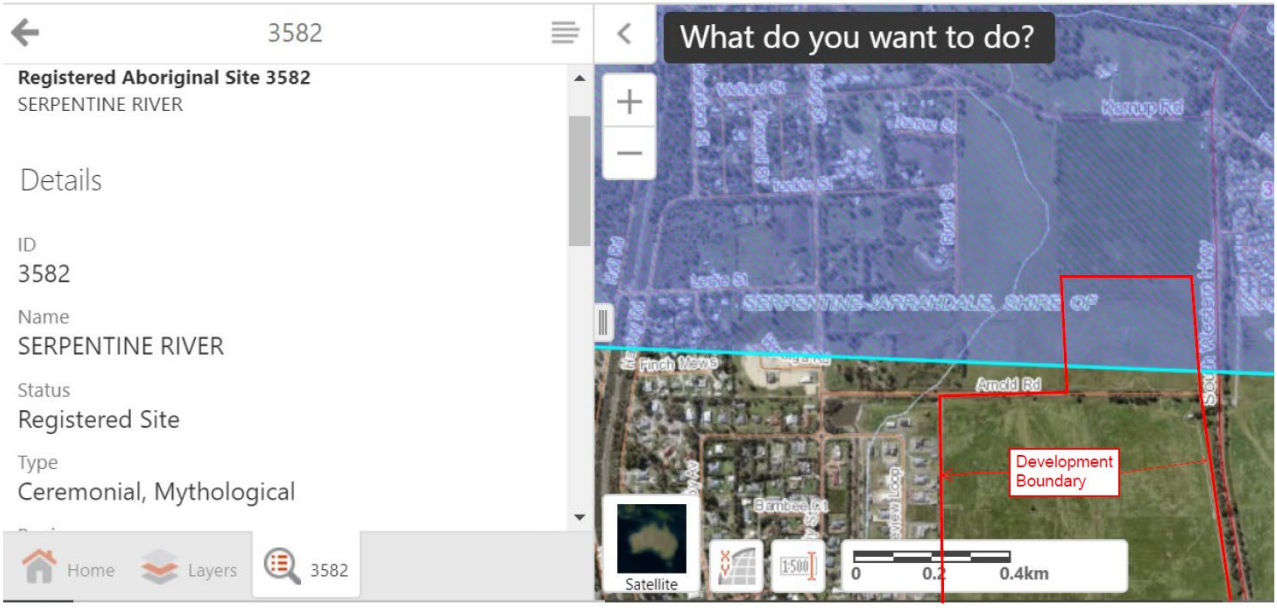
Appendix One: Geotechnical Conditions



Appendix Two: Groundwater and Acid Sulphate

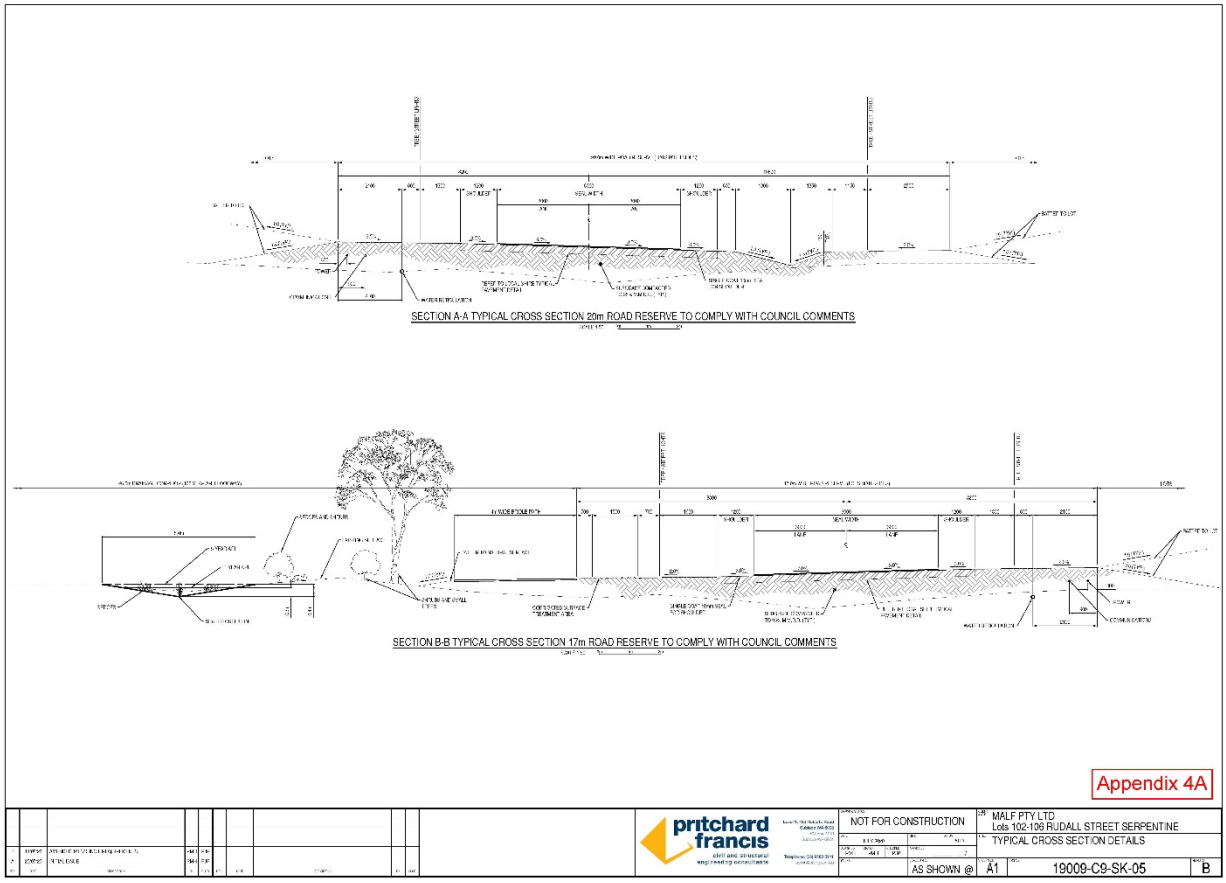


Appendix Three: Aboriginal Register

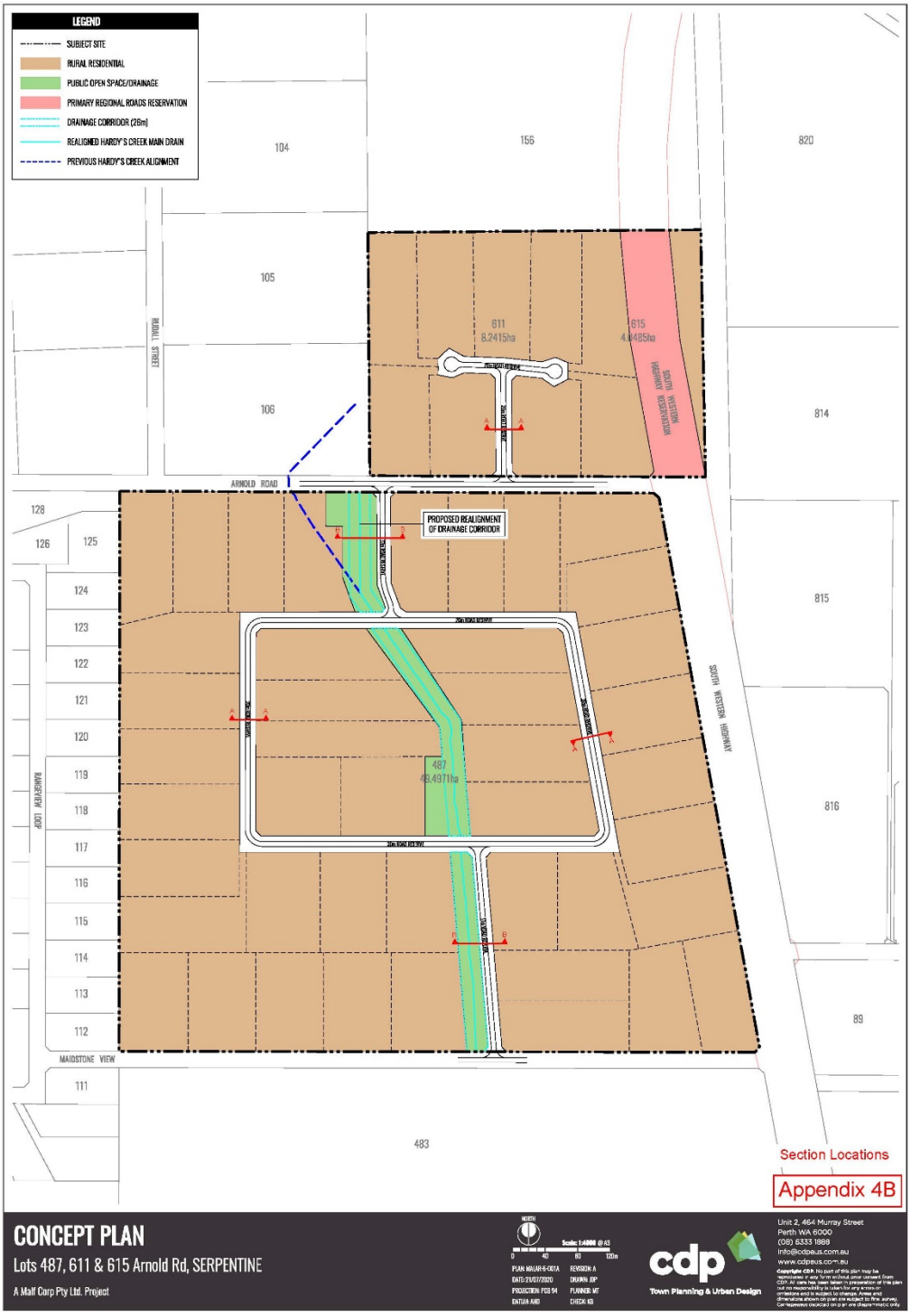


Appendix No. 3
Aboriginal Register
18th March 2020
19-009

Appendix Four A: Typical Cross Section Details



Appendix Four B: Section Locations



Appendix Five: Western Power Underground Network

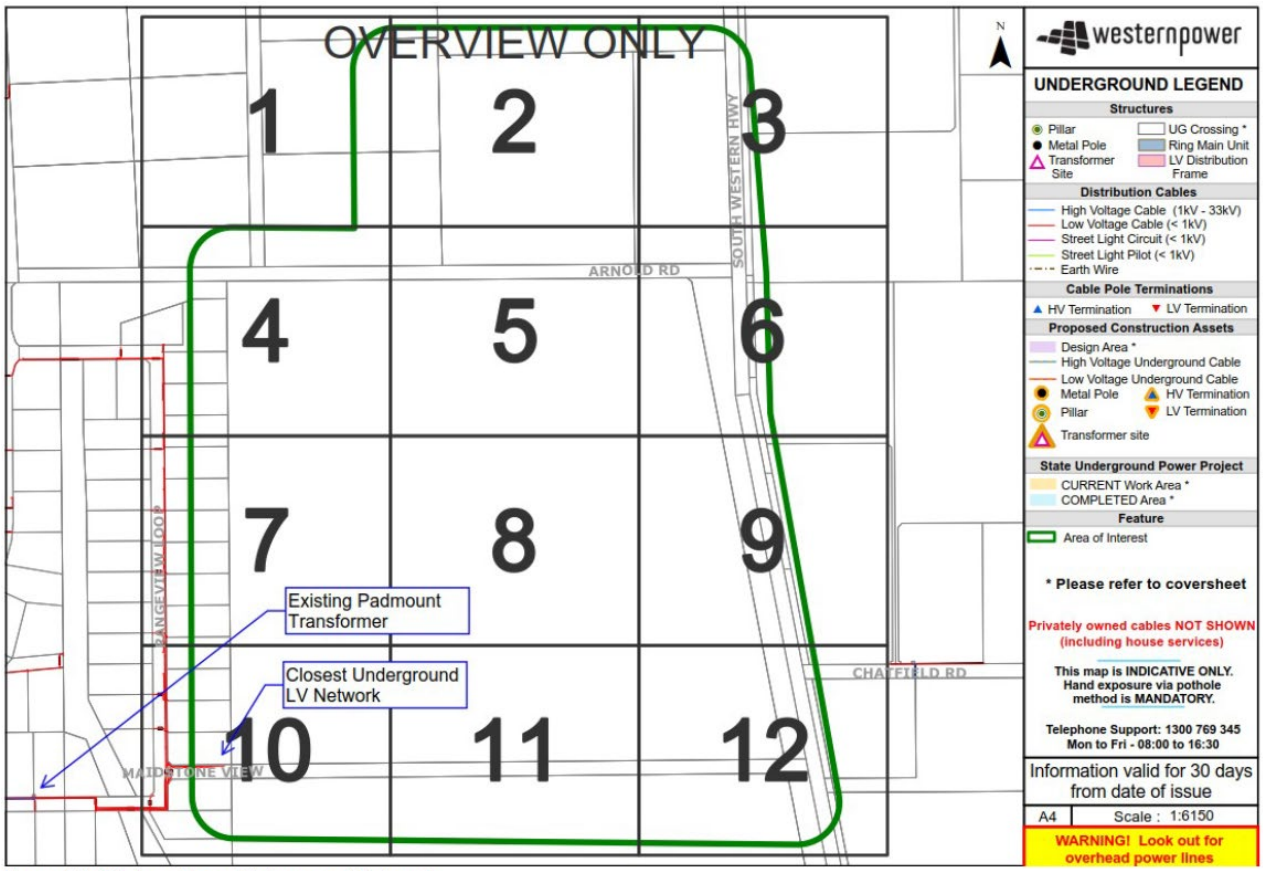


Figure 1.1: Western Power Underground Network

Appendix Six: Western Power Overhead Network

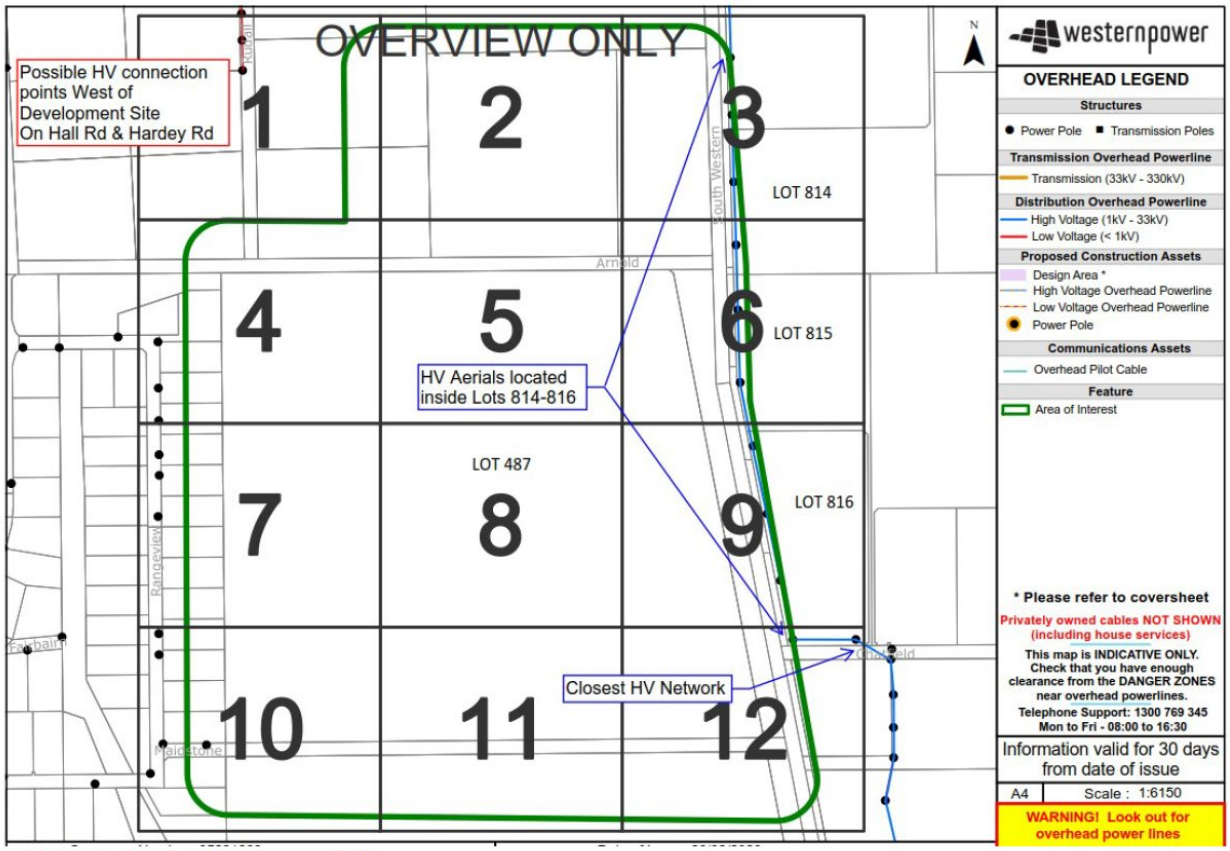
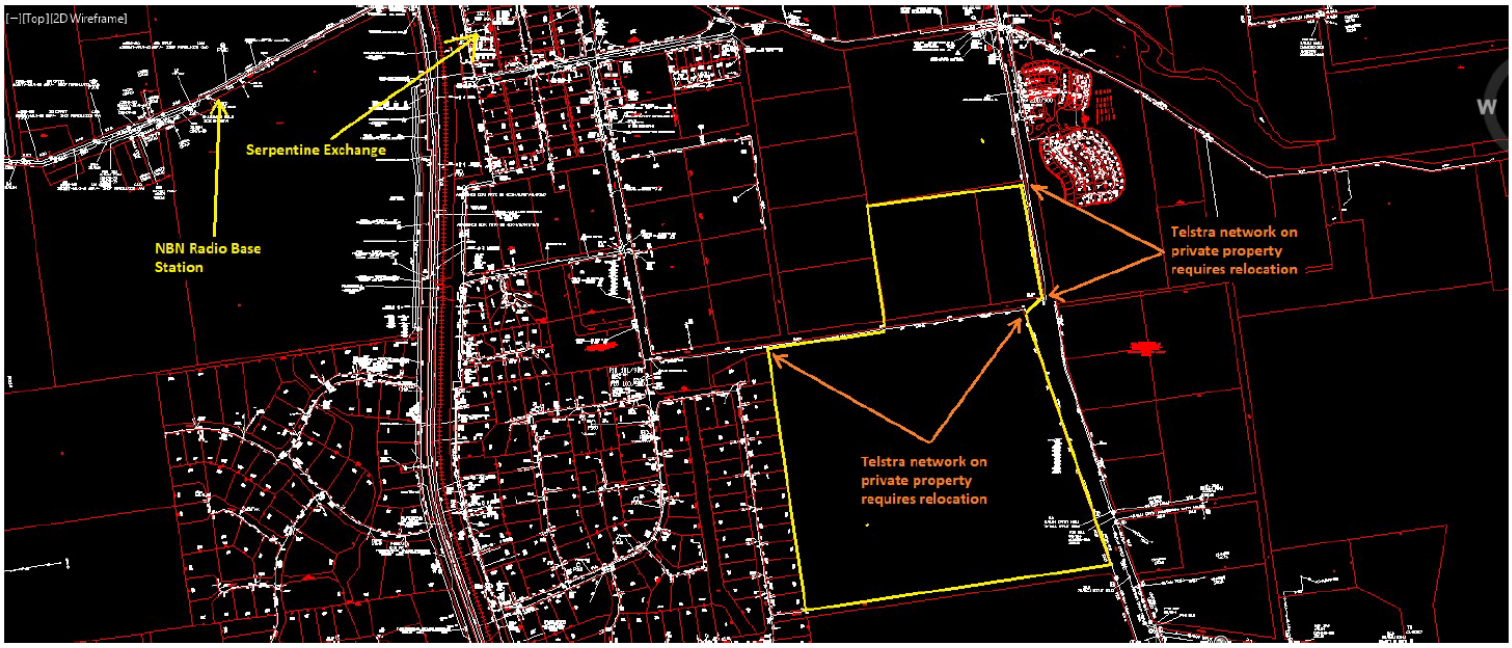
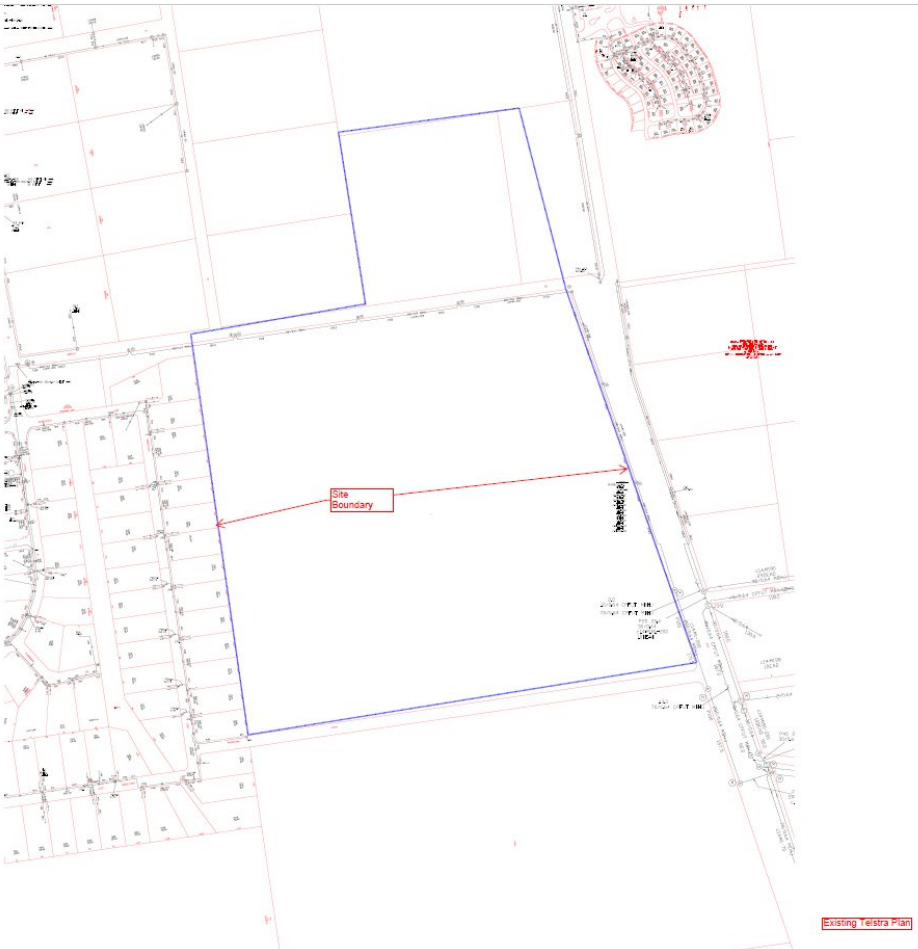


Figure 1.2: Western Power Overhead Network

Appendix Seven: Telstra Network



Telstra network Fig 1.3



ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix i

Road Traffic Noise Assessment

(Herring Storer)

HERRING STORER ACOUSTICS

SERPENTINE RURAL LIVING ESTATE
LOTS 487, 611 AND 615 ARNOLD ROAD
SERPENTINE

PROPOSED STRUCTURE PLAN

ROAD TRAFFIC (SPP 5.4)
NOISE IMPACT
ASSESSMENT

APRIL 2020

OUR REFERENCE: 25641-5-20071

Rochdale Holdings Pty Ltd A.B.N. 85 009 049 067 trading as:
HERRING STORER ACOUSTICS
P.O. Box 219, Como, W.A. 6952
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DOCUMENT CONTROL PAGE

ACOUSTIC ASSESSMENT

PROPOSED STRUCTURE PLAN
SERPENTINE

Job No: 20071

Document Reference: 25641-5-20071

FOR

MALF CORP PTY LTD

DOCUMENT INFORMATION

Author:	Paul Daly	**Checked By:**	Tim Reynolds
Date of Issue :	14 April 2020		

REVISION HISTORY

Revision	Description	Date	Author	Checked
1	Final Report	23/04/2020	PLD	
2	Revised LSP	17/09/2020	PLD	
3	Updated traffic information (MRWA)	22/12/2020	PLD	
4	MRWA Modelling Data	20/12/2021	PLD	

DOCUMENT DISTRIBUTION

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	2.1 ROAD TRAFFIC NOISE	1
3.	MONITORING	4
4.	MODELLING	4
5.	TRAFFIC NOISE ASSESSMENT	6

APPENDICIES

A	Proposed Structure Plan
B	Noise Contour Plots
C	“Quiet House” Design – General Information
D	MRWA Traffic Modelling

EXECUTIVE SUMMARY

Herring Storer Acoustics was commissioned by Roberts Day, on behalf of MALF Corp Pty Ltd to undertake an acoustical assessment of noise that would be received at proposed residential development of Lots 487, 611 and 615 Arnold Road in Serpentine from road traffic noise associated with the South Western Highway.

Under the Western Australian Planning Commission (WAPC) Planning Policy 5.4 "Road and Rail Noise" (SPP 5.4), the appropriate criteria for assessment for this development are:

EXTERNAL

$L_{Aeq(Day)}$ of 55 dB(A);
$L_{Aeq(Night)}$ of 50 dB(A).

INTERNAL

$L_{Aeq(Day)}$ of 40 dB(A) in living and work areas; and
$L_{Aeq(Night)}$ of 35 dB(A) in bedrooms.

Additional to the above, noise received at an outdoor living area should also be reduced as far as practicable, with an aim of achieving an L_{Aeq} of 50 dB(A) during the night period.

From information provided it is understood that the South Western Highway may, in the future, undergo a re-alignment, which would affect noise levels received within the development. Therefore, this report considers noise level associated with the current road alignment and the proposed future road alignment.

The results of the acoustic assessment indicate that without any noise amelioration, noise received at the residences in the future would exceed the "Noise Target" as outlined in the Western Australian Planning Commission (WAPC) Planning Policy 5.4 "Road and Rail Noise" by up to 7 dB(A) during the night period.

For residential developments, the possible noise amelioration options that are normally considered are:

- Noise bunds and / or barriers.
- "Quiet House" design applied to the first row of residences.

For the South Western Highway, we do not believe that it would be either practicable or desirable to construct noise barriers at the edge of the road reserve, between the road and the residence. As the first row of lots located adjacent to the South West Highway are larger than average, there is an opportunity to have building envelopes setback within the lots. This setback to the edge of the buildings envelopes, provides sufficient distance to reduce noise levels to a point where quiet house design, in the form of Package A to Package B would allow the internal noise criteria to be met. Additionally, any lots would require notification on titles.

Any lots exceeding the 50 dB(A) night target criteria would also require notification on Titles.

.

1. INTRODUCTION

Herring Storer Acoustics were commissioned by Roberts Day on behalf of MALF Corp Pty Ltd to carry out an acoustical assessment of noise received for the proposed Structure Plan of the residential development located at Lot 487, 611 and 615 Arnold Road, Serpentine.

As part of the study, the following was carried out:

- Determine by noise modelling the noise that would be received at proposed residences within this stage of the scheme amendment from vehicles travelling on the roadway (South Western Highway) for the future, for both the current and possible future road alignment.
- Assess the predicted noise levels for compliance with the appropriate criteria.
- Provide detailed information as to noise control requirements such as quiet house design, noise wall and notification on titles.

Note : Noise monitoring previously conducted as a part of the scheme amendment for this development has been used.

2. CRITERIA

2.1 ROAD TRAFFIC NOISE

The Western Australian Planning Commission (WAPC) released on 6th September 2019 State Planning Policy 5.4 *"Road and Rail Noise"*. The requirements of State Planning Policy 5.4 are outlined below.

POLICY APPLICATION (Section 4)

When and where it applies (Section 4.1)

SPP 5.4 applies to the preparation and assessment of planning instruments, including region and local planning schemes; planning strategies, structure plans; subdivision and development proposals in Western Australia, where there is proposed:

*a) noise-sensitive land-use within the policy's trigger distance of a transport corridor as specified in **Table 1**;*

*b) New or major upgrades of roads as specified in **Table 1** and maps **(Schedule 1,2 and 3);** or*

*c) New railways or major upgrades of railways as specified in maps (**Schedule 1, 2 and 3);** or any other works that increase capacity for rail vehicle storage or movement and will result in an increased level of noise.*

Policy trigger distances (Section 4.1.2)

***Table 1** identifies the State's transport corridors and the trigger distances to which the policy applies.*

*The designation of land within the trigger distances outlined in **Table 1** should not be interpreted to imply that land is affected by noise and/or that areas outside the trigger distances are un-affected by noise.*

*Where any part of the lot is within the specified trigger distance, an assessment against the policy is required to determine the likely level of transport noise and management/ mitigation required. An initial screening assessment (**guidelines: Table 2: noise exposure forecast**) will determine if the lot is affected and to what extent."*

TABLE 1: TRANSPORT CORRIDOR CLASSIFICATION AND TRIGGER DISTANCES

Transport corridor classification	***Trigger distance***	***Distance measured from***
Roads		
Strategic freight and major traffic routes *Roads as defined by Perth and Peel Planning Frameworks and/or roads with either 500 or more Class 7 to 12 Austroads vehicles per day, and/or 50,000 per day traffic volume*	*300 metres*	*Road carriageway edge*
Other significant freight/traffic routes *These are generally any State administered road and/or local government road identified as being a future State administered road (red road) and other roads that meet the criteria of either >=23,000 daily traffic count (averaged equivalent to 25,000 vehicles passenger car units under region schemes)*	*200 metres*	*Road carriageway edge*
Passenger railways		
	100 metres	*Centreline of the closest track*
Freight railways		
	200 metres	*Centreline of the closest track*

Proponents are advised to consult with the decision making authority as site specific conditions (significant differences in ground levels, extreme noise levels) may influence the noise mitigation measures required, that may extend beyond the trigger distance.

POLICY MEASURES (Section 6)

The policy applies a performance-based approach to the management and mitigation of transport noise. The policy measures and resultant noise mitigation will be influenced by the function of the transport corridor and the type and intensity of the land-use proposed. Where there is risk of future land-use conflict in close proximity to strategic freight routes, a precautionary approach should be applied. Planning should also consider other broader planning policies. This is to ensure a balanced approach takes into consideration reasonable and practical considerations.

Noise Targets (Section 6.1)

***Table 2** sets out noise targets that are to be achieved by proposals under which the policy applies. Where exceeded, an assessment is required to determine the likely level of transport noise and management/mitigation required.*

In the application of the noise targets the objective is to achieve:

- *indoor noise levels as specified in **Table 2** in noise sensitive areas (for example, bedrooms and living rooms of houses, and school classrooms); and*

- *a reasonable degree of acoustic amenity for outdoor living areas on each residential lot. For non-residential noise-sensitive developments, for example schools and child care centres the design of outdoor areas should take into consideration the noise target.*

It is recognised that in some instances, it may not be reasonable and/or practicable to meet the outdoor noise targets. Where transport noise is above the noise targets, measures are expected to be implemented that balance reasonable and practicable considerations with the need to achieve acceptable noise protection outcomes.

TABLE 2: NOISE TARGETS

Proposals	***New/Upgrade***	***Noise Targets***		
		Outdoor		***Indoor***
		Day (L_{Aeq}(Day) dB) (6 am-10 pm)	***Night (L_{Aeq}(Night) dB) (10 pm-6 am)***	***(L_{Aeq} dB)***
Noise-sensitive land-use and/or development	*New noise sensitive land use and/or development within the trigger distance of an existing/proposed transport corridor*	*55*	*50*	*L_{Aeq} (Day) 40(Living and work areas)* *L_{Aeq} (Night) 35 (bedrooms)*
Roads	*New*	*55*	*50*	*N/A*
	Upgrade	*60*	*55*	*N/A*
Railways	*New*	*55*	*50*	*N/A*
	Upgrade	*60*	*55*	*N/A*

Notes:

- *The noise target is to be measured at one metre from the most exposed, habitable façade of the proposed building, which has the greatest exposure to the noise-source. A habitable room has the same meaning as defined in State Planning Policy 3.1 Residential Design Codes.*

- *For all noise-sensitive land-use and/or development, indoor noise targets for other room usages may be reasonably drawn from Table 1 of Australian Standard/New Zealand Standard AS/NZS 2107:2016 Acoustics – Recommended design sound levels and reverberation times for building interiors (as amended) for each relevant time period.*

- *The 5dB difference in the criteria between new and upgrade infrastructure proposals acknowledges the challenges in achieving noise level reduction where existing infrastructure is surrounded by existing noise-sensitive development.*

- *Outdoor targets are to be met at all outdoor areas as far as is reasonable and practical to do so using the various noise mitigation measures outlined in the guidelines. For example, it is likely unreasonable for a transport infrastructure provider to achieve the outdoor targets at more than 1 or 2 floors of an adjacent development with direct line of sight to the traffic.*

Noise Exposure Forecast (Section 6.2)

*When it is determined that SPP 5.4 applies to a planning proposal as outlined in Section 4, proponents and/or decision makers are required to undertake a preliminary assessment using **Table 2**: noise exposure forecast in the guidelines. This will provide an estimate of the potential noise impacts on noise-sensitive land-use and/ or development within the trigger distance of a specified transport corridor. The outcomes of the initial assessment will determine whether:*

- *no further measures is required;*
- *noise-sensitive land-use and/or development is acceptable subject to deemed-to- comply mitigation measures; or*
- *noise-sensitive land-use and/or development is not recommended. Any noise-sensitive land-use and/ or development is subject to mitigation measures outlined in a noise management plan."*

3. MONITORING

Noise monitoring was undertaken at the boundary of the proposed development between the 2nd and 10th June 2016. From these measurements, the noise received at the development from vehicles travelling along the South Western Highway was determined.

The results of the noise data logging are summarised in Table 3.1.

TABLE 3.1 – DETERMINATION OF TRANSPORTATION NOISE AT LOGGERS, dB(A)

Location	$L_{A10\ 18hr}$	$L_{Aeq(day)}$	$L_{Aeq(night)}$
Boundary of Development (35 metres from the road edge)	64.7	61.3	58.3

Based on the noise monitoring, the calculated difference between the $L_{A10,18hour}$ and $L_{Aeq,8hour}$, and the $L_{Aeq10,18hr}$ and $L_{Aeq,16\ hr}$ is -6.5 and -3.4 dB. As the difference between day and night L_{Aeq} noise levels is less than 5 dB(A) (i.e. 3.1 dB(A)), hence, the night period is the critical period for compliance.

4. MODELLING

To determine the requirements of any noise amelioration, acoustic modelling was carried out using the computer program 'SoundPlan'. Acoustic modelling was carried out for road traffic flows 20 years in the future.

The future road traffic volumes were based on information provided on the MRWA ROM traffic section, with a copy contained in Appendix D.

Predictive noise modelling has allowed for 19,100 vpd in the future (2041). This equates to a 2 dB(A) increase in noise levels for the future road traffic volumes.

Other input data for the model included:

- Traffic data from MRWA (https://mrapps.mainroads.wa.gov.au/TrafficMap/) and as as contained in Appendix D.
- Noise source heights for the three road source strings (Passenger Vehicles, Heavy Vehicles Engine and Heavy Vehicle Exhausts) are +0.5, +1.5 and +3.6m, with a noise correction of -0.8 and -8.0 applied to the heavy vehicles engine and exhaust noise sources.
- Topographical data, with the ground level within the development based on natural ground levels as surveys conducted.
- A +2.5 dB adjustment to allow for façade reflection.
- Development receiver heights at 1.4m above ground level.

TABLE 4.1 - NOISE MODELLING INPUT DATA

Parameter	Current (Time of monitoring) South Western Highway	Future South Western Highway
Traffic flows	7,226 vpd	19,100 vpd
Heavy Vehicles (%)	19.6%	8%
Speed Limit (km/hr)	80/110	80/110
Road Surface	Chip Seal	Chip Seal
Façade Correction	+2.5 dB(A)	+2.5 dB(A)

Noise modelling was carried out for noise received within the development for current traffic volumes and road alignment to calibrate the noise model. Noise contour plots are contained in Appendix B for the day (Figure B1) and night (Figure B2) current traffic volumes for informational purposes.

Advise has been provided that in the future, there could be a possible change in the road alignment for the South Western highway, therefore the following scenarios were calculated:

- Future road alignment with future traffic volumes (Appendix B Figure B3 and B4)

Whilst there is no detail or design on the future alignment general information has been provided, with the proposed future roadway noted on the Structure Plan, as shown in Appendix A.

5. TRAFFIC NOISE ASSESSMENT

Under the WAPC State Planning Policy 5.4, for this development, the Noise Targets as listed in Table 2 are the appropriate noise levels to be achieved. Based on the noise monitoring, the difference between the $L_{Aeq(16hr)}$ and the $L_{Aeq(8hr)}$ would be less than 5 dB(A). Therefore, the night period would be the critical period for compliance and if compliance with the night period noise limit is achieved, then compliance with the day period noise limits would also be achieved. The policy states that the outdoor criteria applies to the ground floor level only, however, it also states that noise mitigation measures should be implemented with a view to achieving the target levels in least one outdoor living area.

For residential premises, the Policy states that residence should be designed to meet the following acceptable internal noise levels:

Living and Work Areas	$L_{Aeq(Day)}$ of 40 dB(A)
Bedrooms	$L_{Aeq(Night)}$ of 35 dB(A)

The results of the acoustic assessment indicate that noise received at the ground floor level of residences located adjacent to South Western Highway, could exceed the above acoustic criteria. In the worst-case location, the level of exceedance would be approximately 7 dB(A). Table 5.1 details the noise level at the building envelop for each proposed development Lot and the "Quiet House" design package required to achieve compliance. Figure 1 showing the location map of the receivers.

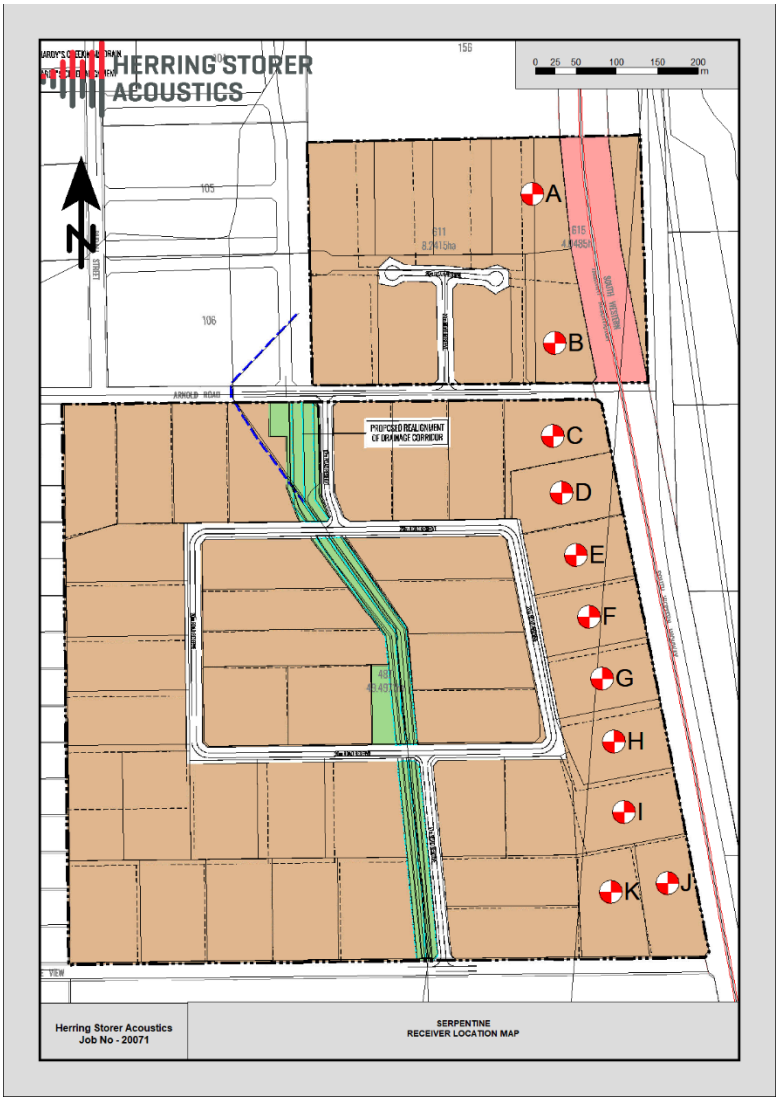


FIGURE 1 - RECEIVER LOCATION PLAN

TABLE 5.1 – DEVELOPMENT NOISE LEVELS

Location	Scenario 1 Future Traffic Volumes – Current Road Alignment		
	L_{AeqDay}	$L_{AeqNight}$	Requirements
A	58	55	B
B	59	56	B
C	58	55	B
D	58	55	B
E	58	55	B
F	58	55	B
G	59	56	B
H	59	56	B
I	58	55	B
J	61	58	B
K	56	53	A

Nil No Requirements

N Notification on Title
A Package A Quiet House Design
B Package B Quiet House Design

Therefore, to comply with the Policy, the following options have been provided:

- Quiet House Design Package A to B.
- Building envelopes (setbacks).

For South Western Highway, we do not believe that it would be either practicable or desirable to construct noise barriers at the edge of the road reserve, between the road and the residence. As the first row of lots located adjacent to the South west Highway are larger than average, there is an opportunity to have building envelopes setback within the lots. This setback to the edge of the building envelopes would provide sufficient distance to reduce noise levels to a point where "Quiet House" design, likely in the form of Package A to Package B, would allow the internal noise criteria to be met. Additionally, these lots also require notification on title of the impact of traffic noise from the future South Western Highway.

Any lots exceeding the 50 dB(A) night target criteria would require notification on Titles.

If considering residential development within areas above 50 dB(A), "Quiet House" design as outlined in SPP 5.4 guidance would be required to further ameliorate noise levels to meet internal noise level criteria.

The package requirement depends on the external noise levels, however, for guidance Figure 5.4 details the quiet house design for the future noise levels associated with the highway, without any noise control in the form of barriers, with a summary contained in Table 5.2 below.

TABLE 5.2 ROAD AND RAIL NOISE GUIDELINES SEPTEMBER 2019 (TABLE 2) : NOISE EXPOSURE FORECAST

Forecast Excess Noise Level, dB	Exposure Category	Policy requirements for noise-sensitive land-use and/or development
0 or less	**-**	No further measures Noise-sensitive land-use and/or development is acceptable, subject to: Mitigation measures in accordance with an approved noise management plan; Or quiet house package as specified
1 to 3	**A**	
-	***A+**	
4 to 7	**B**	
-	***B+**	
8 to 11	**C**	
-	***C+**	
12 to 15	**D**	Noise-sensitive land-use and /or development is not recommended. There is no default quiet house option due to excessive forecast noise: Professional design input is required in order to achieve compliance with relevant criteria. If noise-sensitive land-use and/or development is unavoidable, an approved noise management plan is required to demonstrate compliance with the noise target (see Table 1).
16+	**E**	

*Assists to mitigate short term noise events from freight rail.

Information on the deemed to satisfy constructions for the various "Quiet House Design" packages are contained in Appendix C.

Notes:

1 Given the location of the development and the projected market, we understand that 2 storey residences are unlikely, hence the "Quiet House" Design packages stated are for single storey residence only. If double storey residences are proposed, then it is recommended that specialist acoustic advice be sought by the proponent.

2 We understand that the development is a Proposed Structure Plan stage, hence the information contained in Appendix B regarding areas requiring "Quiet House" design will need to be refined once the lots have been defined and final heights are established. Additionally, any modifications to the Structure Plan, would vary the noise mitigation requirements relating "Quiet House" design outlined in Appendix C.

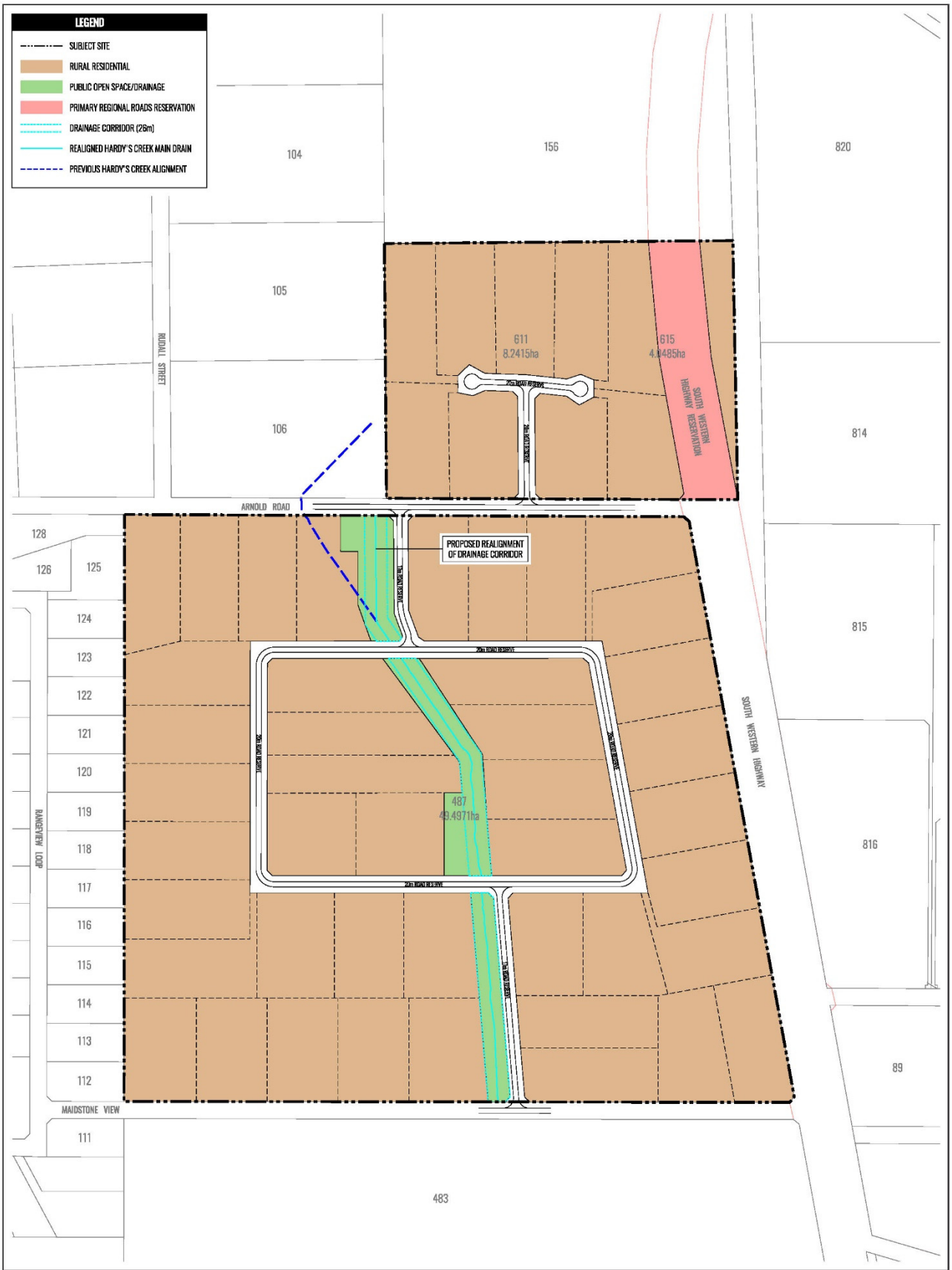
3 The summary of the Quiet House Design Packages attached in Appendix C, are "Deemed to Satisfy" constructions. Alternative constructions would be acceptable, provided they are supported by an acoustic report prepared by a suitably qualified acoustic consultant.

4 Quiet House Design requirements are likely to lessen for residential premises set back from the highway, as the façade residences will barrier those behind.

5 Additionally, these residences also require Notifications on Titles.

APPENDIX A

PROPOSED STRUCTURE PLAN



CONCEPT PLAN

Lots 487, 611 & 615 Arnold Rd, SERPENTINE

A Malf Corp Pty Ltd. Project

NORTH

Scale: 1:4000 @ A3

0 40 80 120m

PLAN: MALAR-S-001A REVISION: A

DATE: 21/07/2020 DRAWN: JDP

PROJECTION: PCG 94 PLANNER: MT

DATUM: AHD CHECK: KB

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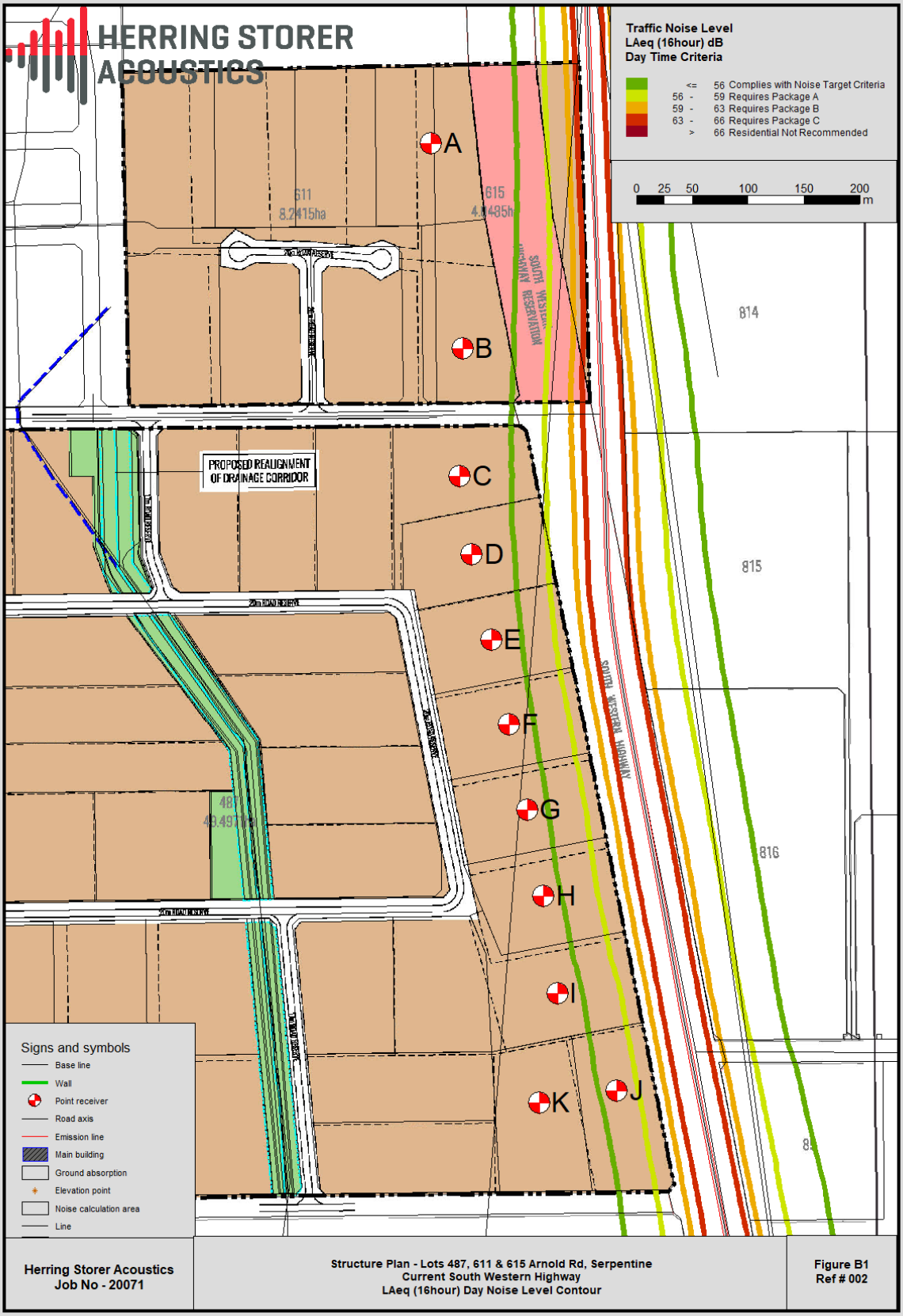
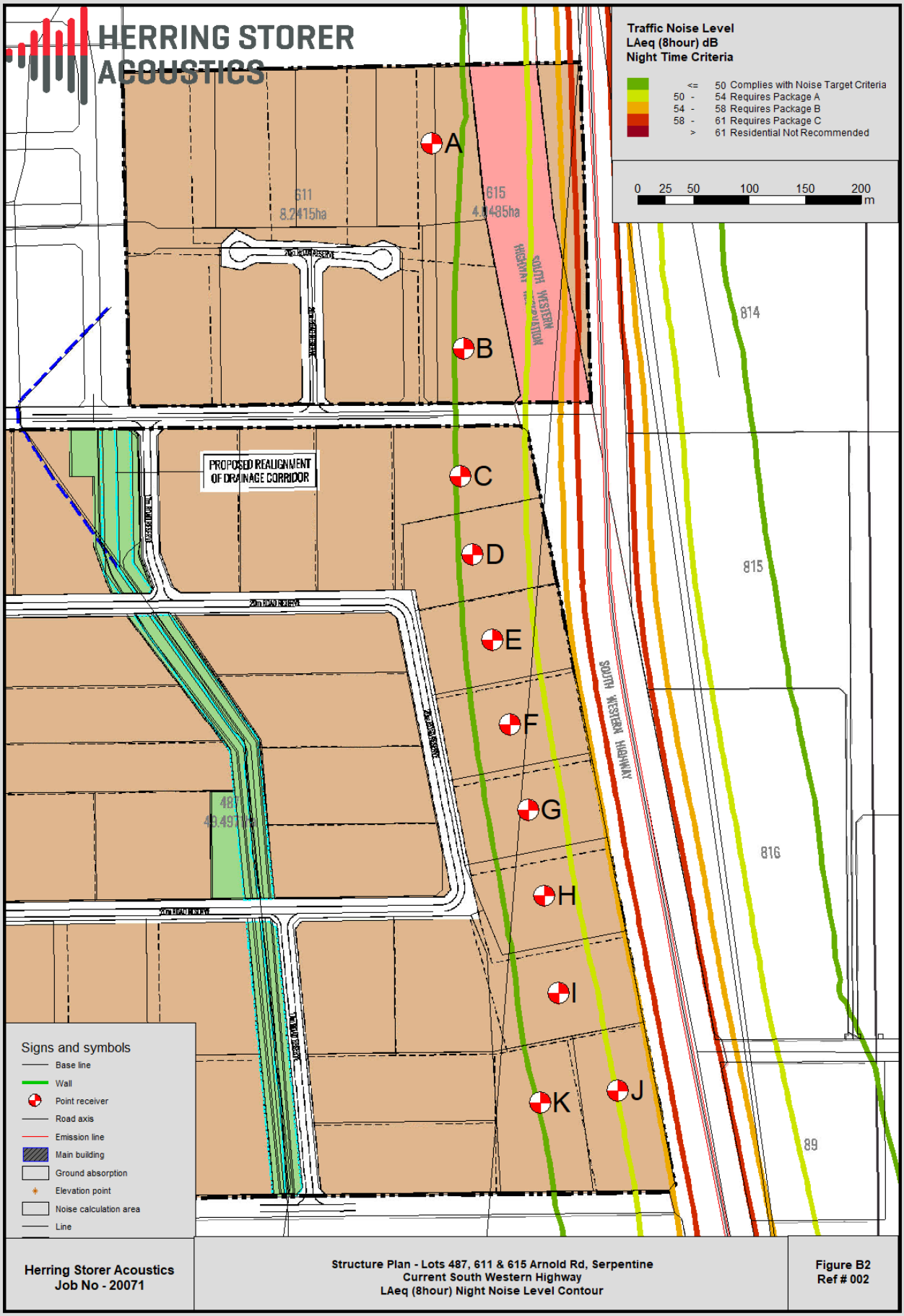
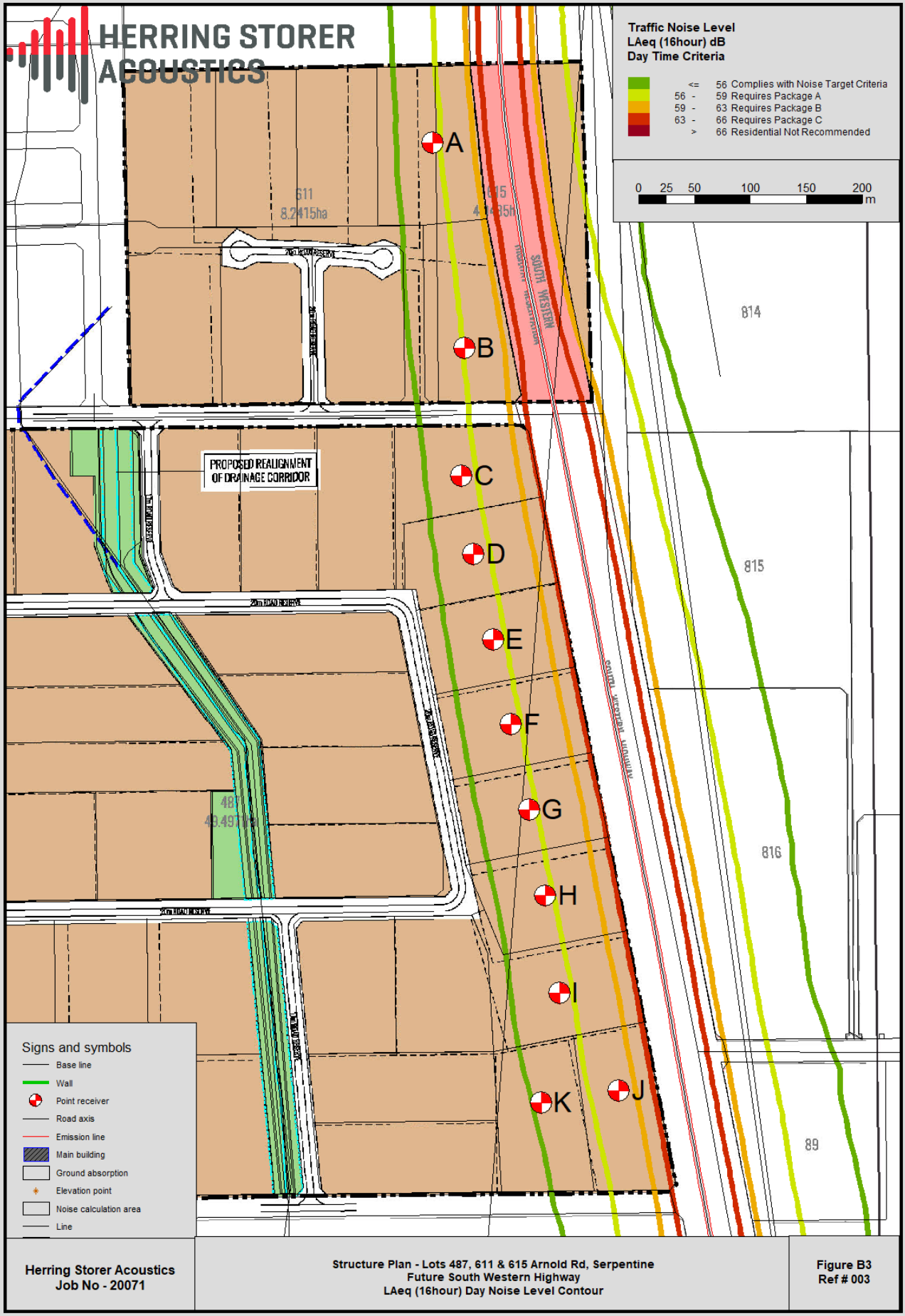
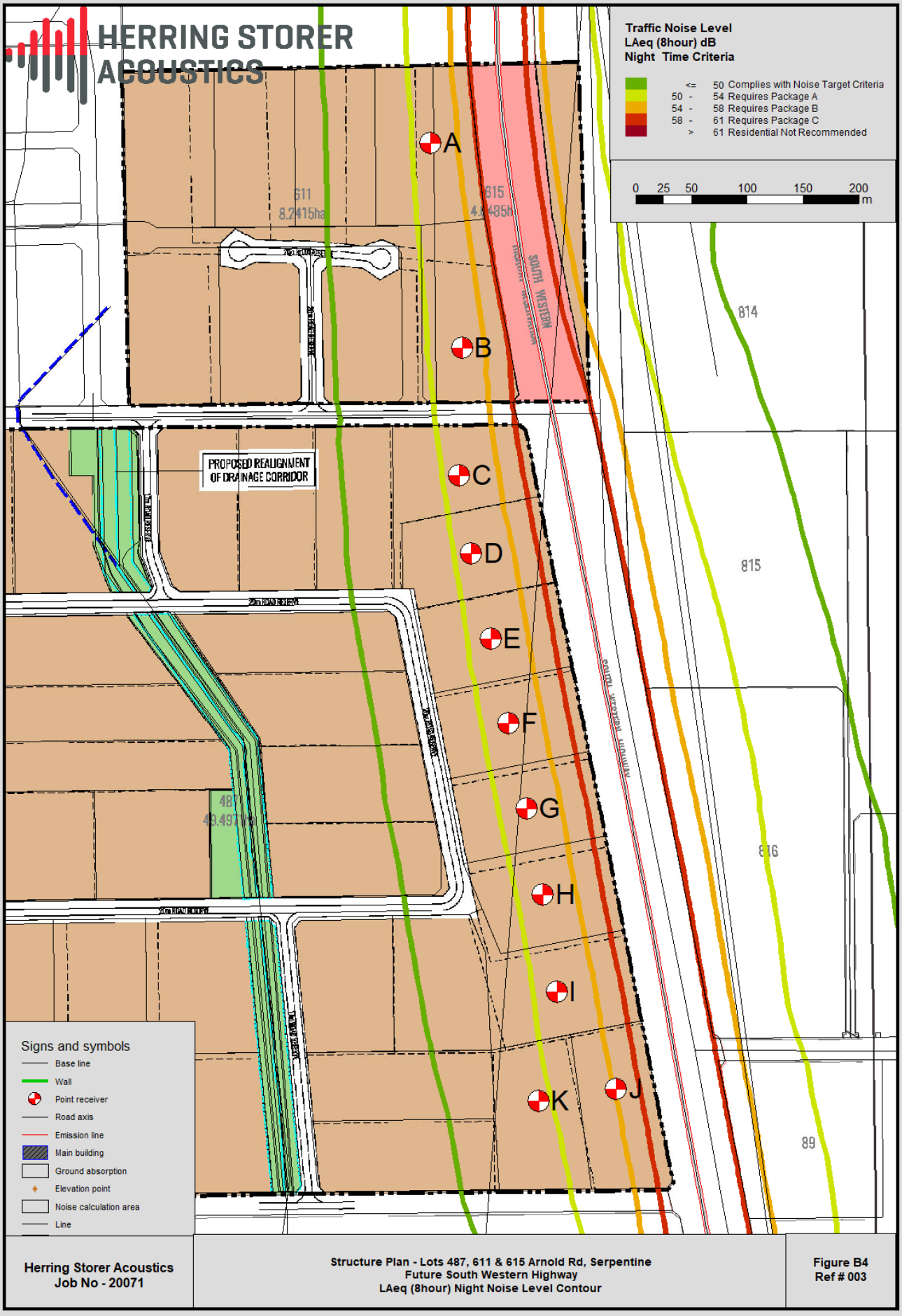
APPENDIX B

NOISE CONTOUR PLOTS


HERRING STORER ACOUSTICS
Traffic Noise Level
LAeq (16hour) dB
Day Time Criteria
<= 56 Complies with Noise Target Criteria
56 - 59 Requires Package A
59 - 63 Requires Package B
63 - 66 Requires Package C
> 66 Residential Not Recommended
0 25 50 100 150 200 m
A
B
C
D
E
F
G
H
I
J
K
611
8.2415ha
615
814
815
816
PROPOSED REALIGNMENT OF DRAINAGE CORRIDOR
SOUTH WESTERN HIGHWAY
Signs and symbols
Base line
Wall
Point receiver
Road axis
Emission line
Main building
Ground absorption
Elevation point
Noise calculation area
Line
Herring Storer Acoustics
Job No - 20071
Structure Plan - Lots 487, 611 & 615 Arnold Rd, Serpentine
Current South Western Highway
LAeq (16hour) Day Noise Level Contour
Figure B1
Ref # 002


HERRING STORER ACOUSTICS
Traffic Noise Level
LAeq (8hour) dB
Night Time Criteria
<= 50 Complies with Noise Target Criteria
50 - 54 Requires Package A
54 - 58 Requires Package B
58 - 61 Requires Package C
> 61 Residential Not Recommended
0 25 50 100 150 200 m
A
B
C
D
E
F
G
H
I
J
K
611
8.2415ha
615
4.9435ha
PROPOSED REALIGNMENT OF DRAINAGE CORRIDOR
SOUTH WESTERN HIGHWAY
814
815
816
89
Signs and symbols
Base line
Wall
Point receiver
Road axis
Emission line
Main building
Ground absorption
Elevation point
Noise calculation area
Line
Herring Storer Acoustics
Job No - 20071
Structure Plan - Lots 487, 611 & 615 Arnold Rd, Serpentine
Current South Western Highway
LAeq (8hour) Night Noise Level Contour
Figure B2
Ref # 002


HERRING STORER ACOUSTICS
Traffic Noise Level
LAeq (16hour) dB
Day Time Criteria
<= 56 Complies with Noise Target Criteria
56 - 59 Requires Package A
59 - 63 Requires Package B
63 - 66 Requires Package C
> 66 Residential Not Recommended
0 25 50 100 150 200 m
A
B
C
D
E
F
G
H
I
J
K
611
8.2415ha
615
814
815
816
89
PROPOSED REALIGNMENT OF DRAINAGE CORRIDOR
SOUTH WESTERN HIGHWAY
Signs and symbols
Base line
Wall
Point receiver
Road axis
Emission line
Main building
Ground absorption
Elevation point
Noise calculation area
Line
Herring Storer Acoustics
Job No - 20071
Structure Plan - Lots 487, 611 & 615 Arnold Rd, Serpentine
Future South Western Highway
LAeq (16hour) Day Noise Level Contour
Figure B3
Ref # 003



Herring Storer Acoustics Job No - 20071	Structure Plan - Lots 487, 611 & 615 Arnold Rd, Serpentine Future South Western Highway LAeq (8hour) Night Noise Level Contour	Figure B4 Ref # 003

APPENDIX C

"QUIET HOUSE" DESIGN INFORMATION

Road Traffic and Passenger Rail
Quiet House Requirements
(*Based on Table 3 of State Planning Policy 5.4 2019*)

Exposure Category	Orientation to corridor	Acoustic rating and example constructions					Mechanical ventilation/air conditioning considerations
		Walls	**External doors**	**Windows**	**Roofs and ceilings of highest floors**	**Outdoor Living areas**	
A **Quiet House A**	**Facing**	**Bedroom and Indoor Living and work areas to Rw + Ctr 45dB** **Stud Frame Walls** ➢ One row of 92mm studs at 60mm centres with: ➢ Resilient steel channels fixed to the outside of the studs; and ➢ 9.5mm hardboard or 9mm fibre cement weatherboards or one layer of 19mm board cladding fixed to the outside of the channels; and ➢ 75mm glass wool (11kg/m3) or 75mm polyester (14kg/m3) insulation, positioned between the studs; and ➢ -Two layers of 16mm fire-protective grade plasterboard fixed to the inside face of the studs. **Brick Walls** ➢ Single leaf of 150mm brick masonry with 13mm cement render on each face: **OR** ➢ Double brick: two leaves of 90 mm clay brick masonry with a 20mm cavity between leaves.	**Bedrooms**: ➢ Fully glazed hinged door with certified R_w+C_{tr} **28dB** rated door and frame including seals and 6mm glass **Indoor Living and work areas:** ➢ 35mm solid core timber hinged door and frame system certified to **Rw 28dB** including seals**: OR** ➢ Glazed sliding door with 10 mm glass and weather seals	**Bedrooms**: ➢ Total external door and window system area up to 40% of room floor area: Sliding or double hung with minimum 10 mm single or 6mm-12mm-10mm double insulted glazing (R_w+C_{tr} **28 dB**). Sealed awning or casement windows may use 6 mm glazing instead**: OR** ➢ Up to 60% floor area: as per above but must be sealed awning or casement type windows (R_w+C_{tr} **31dB**). **Indoor Living and work areas** ➢ Up to 40% floor area: Sliding, awning, casement or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulted glazing (R_w+C_{tr} **25dB**)**: OR** ➢ Up to 60% floor area: As per Bedrooms at up to 40% area (**Rw+Ctr28 dB : OR** ➢ Up to 80% floor area: As per Bedrooms at up to 60% area (R_w+C_{tr} **31 dB**).	**To R_w+C_{tr} 35dB** ➢ Concrete or terracotta tile or metal sheet roof with sarking and at least 10mm plasterboard ceiling	➢ At least one outdoor living area located on the opposite side of the building from the transport corridor and/or at least one ground level outdoor living area screened using a solid continuous fence or other structure of minimum **2 metres** height above ground level	➢ Acoustically rated openings and ductwork to provide a minimum sound reduction performance of **Rw 40dB** into sensitive spaces ➢ Evaporative systems require attenuated ceiling air vents to allow closed windows ➢ Refrigerant-based systems need to be designed to achieve National Construction Code fresh air ventilation requirements ➢ Openings such as eaves, vents and air inlets must be acoustically treated, closed or relocated to building sides facing away from the corridor where practicable
	Side On		As per "Facing" above, except R_w+C_{tr} values may be 3dB less, e.g. glazed sliding door with 10 mm glass and weather seals for bedrooms	As above, except R_w+C_{tr} values may be 3dB less, or max % area increased by 20%			
	Opposite		No specific requirements	No specific requirements			

Road Traffic and Passenger Rail
Quiet House Requirements
(*Based on Table 3 of State Planning Policy 5.4 2019*)

Exposure Category	Orientation to corridor	Acoustic rating and example constructions					Mechanical ventilation/air conditioning considerations
		Walls	**External doors**	**Windows**	**Roofs and ceilings of highest floors**	**Outdoor Living areas**	
B **Quiet House B**	**Facing**	**Bedroom and indoor living and work areas to R_w+C_{tr} 50dB** **Single leaf of 90 mm clay brick masonry with:** ➢ A row of 70 mm x 35 mm timber studs or 64 mm steel studs at 600 mm centres; ➢ A cavity of 25 mm between leaves; ➢ 50 mm glass wool or polyester cavity insulation (R2.0+) insulation between studs; and ➢ One layer of 10mm plasterboard fixed to the inside face ➢ Single leaf of 220mm brick masonry with 13mm cement render on each face ➢ 150mm thick unlined concrete panel or 200mm thick concrete panel with one layer of 13mm plasterboard or 13mm cement render on each face **Double brick: two leaves of 90mm clay brick masonry with:** ➢ A 50mm cavity between leaves ➢ 50mm glass wool or polyester cavity insulation (R2.0+) ➢ Resilient ties where required to connect leaves **Double brick: two leaves of 110mm clay brick masonry with** ➢ 50mm cavity between leaves and R2.0+ cavity insulation	**Bedrooms** ➢ Fully glazed hinged door with certified **R_w+C_{tr} 31dB** rated door and frame including seals and 10mm glass **Indoor Living and work areas** ➢ 35mm solid core timber hinged door and frame system certified to **Rw 28dB** including seals**: OR** ➢ Glazed sliding door with 10 mm glass and weather seals	**Bedrooms**: ➢ Total external door and window system area up to 40% of room floor areas: Fixed sash, awning or casement with minimum 6mm single or 6mm-12mm-6mm double insulted glazing (**Rw+Ctr 31dB**). ➢ Up to 60% floor area: as per above but must be minimum10mm single or 6mm-12mm-10mm double insulated glazing (**Rw+Ctr 34dB**) **Indoor Living and work areas** ➢ Up to 40% floor area; Sliding or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulted glazing (R_w+C_{tr} 28dB). Sealed awning or casement windows may use 6mm glazing instead. **: OR** ➢ Up to 60% floor area: As per Bedrooms at up to 40% area (**R_w+C_{tr} 31dB**). **: OR** ➢ Up to 80% floor area: As per Bedrooms at up to 60% area (**R_w+C_{tr} 34dB).**	**To R_w+C_{tr} 35dB** ➢ Concrete or terracotta tile sarking and at least 10mm plasterboard ceiling, R3.0+ insulation **OR** ➢ Metal sheet roof, sarking and at least 10mm plasterboard ceiling, R3.0+ insulation	➢ At least one outdoor living area located on the opposite side of the building from the corridor and/or at least one ground level outdoor living area screened using a solid continuous fence or other structure of minimum **2.4 metres** height above ground level	➢ Acoustically rated openings and ductwork to provide a minimum sound reduction performance of **Rw 40dB** into sensitive spaces ➢ Evaporative systems require attenuated ceiling air vents to allow closed windows ➢ Refrigerant-based systems need to be designed to achieve National Construction Code fresh air ventilation requirements ➢ Openings such as eaves, vents and air inlets must be acoustically treated, closed or relocated to building sides facing away from the corridor where practicable
	Side-On		**Bedrooms**: ➢ Fully glazed hinged door with certified **R_w+C_{tr} 28dB** rated door and frame including seals and 6mm glass **Indoor Living and work areas:** ➢ 35mm solid core timber hinged door and frame system certified to **Rw 28dB** including seals**: OR** ➢ Glazed sliding door with 10 mm glass and weather seals	**Bedrooms**: ➢ Total external door and window system area up to 40% of room floor area: Sliding or double hung with minimum 10 mm single or 6mm-12mm-10mm double insulted glazing (**R_w+C_{tr} 28 dB**). Sealed awning or casement windows may use 6 mm glazing instead. **: OR** ➢ Up to 60% floor area: as per above but must be sealed awning or casement type windows (**R_w+C_{tr} 31dB**). **Indoor Living and work areas** ➢ Up to 40% floor area: Sliding, awning, casement or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulted glazing (**R_w+C_{tr} 25dB**). **: OR** ➢ Up to 60% floor area: As per Bedrooms at up to 40% area (**Rw+Ctr28 dB**) **: OR** ➢ Up to 80% floor area: As per Bedrooms at up to 60% area (**R_w+C_{tr} 31 dB**).			
	Opposite		As above, except R_w+C_{tr} values may be 3dB less, or max % area increased by 20%	As above, except R_w+C_{tr} values may be 3dB less, or max % area increased by 20%			

Road Traffic and Passenger Rail
Quiet House Requirements
(*Based on Table 3 of State Planning Policy 5.4 2019*)

Exposure Category	Orientation to corridor	Acoustic rating and example constructions					
		Walls	**External doors**	**Windows**	**Roofs and ceilings of highest floors**	**Outdoor Living areas**	**Mechanical ventilation/air conditioning considerations**
C **Quiet House C**	**Facing**	**Bedroom and indoor living and work areas to R_w+C_{tr} 50dB** **Single leaf of 90 mm clay brick masonry with:** ➢ A row of 70 mm x 35 mm timber studs or 64 mm steel studs at 600 mm centres; ➢ A cavity of 25 mm between leaves; ➢ 50 mm glass wool or polyester cavity insulation (R2.0+) insulation between studs; and ➢ One layer of 10mm plasterboard fixed to the inside face **Double brick: two leaves of 90mm clay brick masonry with:** ➢ A 50mm cavity between leaves ➢ 50mm glass wool or polyester cavity insulation (R2.0+) ➢ Resilient ties where required to connect leaves	**Bedrooms** ➢ External doors to bedrooms facing the corridor are not recommended. **Indoor Living and work areas** ➢ Fully glazed hinged door with certified **Rw+Ctr 31dB** rated door and frame including seals and 10mm glass**: OR** 40mm solid core timber frame and door (without glass or with glass inserts not less than 6mm), side hinged with certified **Rw 32dB** acoustically rated door and frame system including seals	**Bedrooms**: ➢ Total external door and window system area up to 20% of room floor area: Fixed sash, awning or casement with minimum 6mm single or 6mm-12mm-6mm double insulted glazing (**R_w+C_{tr} 31dB): OR** ➢ Up to 40% floor area; as per above but must be minimum 10mm single or 6mm-12mm-10mm double insulted glazing (**R_w+C_{tr} 34dB**). **Indoor Living and work areas** ➢ Up to 40% floor area: Sliding or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing (**R_w+C_{tr} 31dB**). Sealed awning or casement windows may use 6mm glazing instead**: OR** ➢ Up to 60% floor area: As per Bedrooms at up to 40% area (**Rw+Ctr 34dB)**	**To R_w+C_{tr} 40dB** ➢ To al bedrooms, 2 layers of 10mm plasterboard, or one layer 13mm high density sealed plasterboard (minimum surface density of 12.5 kg/m2), affixed using steel furring channels beneath ceiling rafters/supports**: and** ➢ R3.0+ insulation batts laid in cavity **: and** ➢ Concrete or terracotta tile roof with sarking, or metal sheet roof with foil backed R2.0+ fibre insulation between steel sheeting and roof battens	➢ At least one outdoor living area located on the opposite side of the building from the corridor and/or at least one ground level outdoor living area screened using a solid continuous fence or other structure of minimum **2.4 metres** height above ground level	➢ Acoustically rated openings and ductwork to provide a minimum sound reduction performance of Rw 40dB into sensitive spaces. ➢ Evaporative systems require attenuated ceiling air cents to allow closed windows. ➢ Refrigerant-based systems need to be designed to achieve National Construction Code fresh air ventilation requirements ➢ Openings such as eaves, vents and air inlets must be acoustically treated, close or relocated to building sides facing away from the corridor where practicable.
	Side-on		**Bedrooms** ➢ Fully glazed hinged door with certified **R_w+C_{tr} 31dB** rated door and frame including seals and 10mm glass **Indoor Living and work areas** ➢ 35mm solid core timber hinged door and frame system certified to **Rw 28dB** including seals**: OR** ➢ Glazed sliding door with 10 mm glass and weather seals				
	Opposite		**Bedrooms**: ➢ Fully glazed hinged door with certified **R_w+C_{tr} 28dB** rated door and frame including seals and 6mm glass **Indoor Living and work areas:** ➢ 35mm solid core timber hinged door and frame system certified to **Rw 28dB** including seals**: OR** ➢ Glazed sliding door with 10 mm glass and weather seals	**Bedrooms**: ➢ Total external door and window system area up to 40% of room floor area: Sliding or double hung with minimum 10 mm single or 6mm-12mm-10mm double insulted glazing (**R_w+C_{tr} 28 dB**). Sealed awning or casement windows may use 6 mm glazing instead**: OR** ➢ Up to 60% floor area: as per above but must be sealed awning or casement type windows (**R_w+C_{tr} 31dB**). **Indoor Living and work areas** ➢ Up to 40% floor area: Sliding, awning, casement or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulted glazing (**R_w+C_{tr} 25dB): OR** ➢ Up to 60% floor area: As per Bedrooms at up to 40% area (**Rw+Ctr28 dB : OR** ➢ Up to 80% floor area: As per Bedrooms at up to 60% area (**R_w+C_{tr} 31 dB**).			

APPENDIX D

MRWA MODELLING DATA

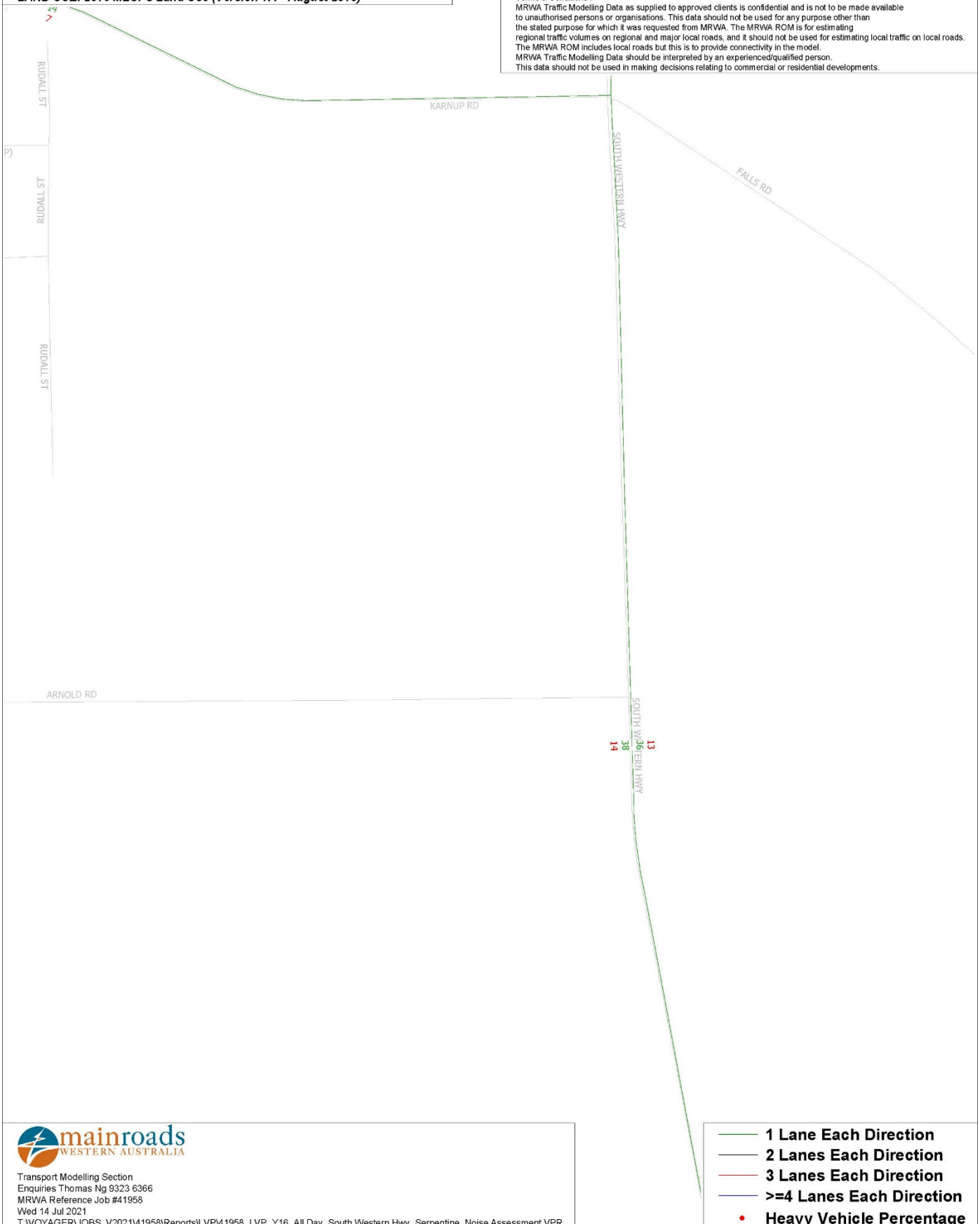
2016 ROM24 Scenario - Link Volume Plot for South Western Hwy, Serpentine Noise Assessment
LAND USE SCENARIO: MLUFS Version 1.4
All Day

MODEL ASSUMPTIONS

NETWORK: 2016 ROM24 Network (20-Year Road Network Development Plan)
LAND USE: 2016 MLUFS Land Use (Version 1.4 - August 2018)

ROM24 Multi-Modal Model V4.40
24-Hour Traffic Volumes (Factor X 100)

Terms & Conditions :
MRWA Traffic Modelling Data as supplied to approved clients is confidential and is not to be made available to unauthorised persons or organisations. This data should not be used for any purpose other than the stated purpose for which it was requested from MRWA. The MRWA ROM is for estimating regional traffic volumes on regional and major local roads, and it should not be used for estimating local traffic on local roads. The MRWA ROM includes local roads but this is to provide connectivity in the model.
MRWA Traffic Modelling Data should be interpreted by an experienced/qualified person.
This data should not be used in making decisions relating to commercial or residential developments.



mainroads WESTERN AUSTRALIA

Transport Modelling Section
Enquiries Thomas Ng 9323 6366
MRWA Reference Job #41958
Wed 14 Jul 2021
T:\VOYAGER\JOBS_V2021\41958\Reports\LVP\41958_LVP_Y16_All Day_South Western Hwy_Serpentine_Noise Assessment.VPR

- 1 Lane Each Direction
- 2 Lanes Each Direction
- 3 Lanes Each Direction
- >=4 Lanes Each Direction
- Heavy Vehicle Percentage

MRWA ROM24 Base Network - Version 2014
MRWA Transport Modelling Data as supplied to approved clients is confidential and is not to be made available to unauthorised persons or organisations

cube

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2041 ROM24 Scenario - Link Volume Plot for South Western Hwy, Serpentine Noise Assessment
LAND USE SCENARIO: MLUFS Version 1.4
All Day

MODEL ASSUMPTIONS

NETWORK: 2041 ROM24 Network (20-Year Road Network Development Plan)
LAND USE: 2041 MLUFS Land Use (Version 1.4 - August 2018)

ROM24 Multi-Modal Model V4.40
24-Hour Traffic Volumes (Factor X 100)

Terms & Conditions :
MRWA Traffic Modelling Data as supplied to approved clients is confidential and is not to be made available to unauthorised persons or organisations. This data should not be used for any purpose other than the stated purpose for which it was requested from MRWA. The MRWA ROM is for estimating regional traffic volumes on regional and major local roads, and it should not be used for estimating local traffic on local roads. The MRWA ROM includes local roads but this is to provide connectivity in the model.
MRWA Traffic Modelling Data should be interpreted by an experienced/qualified person.
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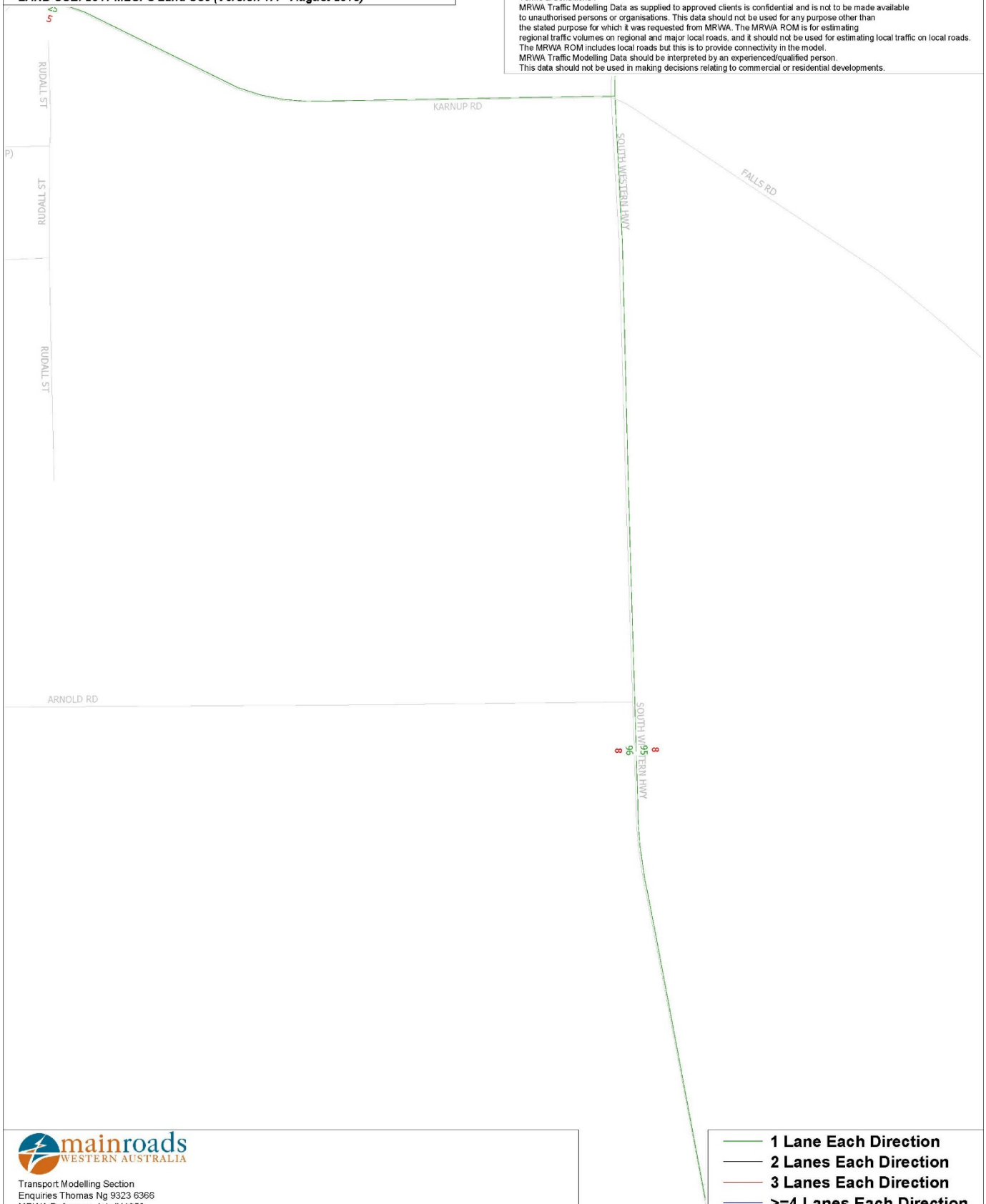

mainroads WESTERN AUSTRALIA

Transport Modelling Section
Enquiries Thomas Ng 9323 6366
MRWA Reference Job #41958
Wed 14 Jul 2021
T:\VOYAGER\JOBS_V2021\41958\Reports\LVP\41958_LVP_Y41_All Day_South Western Hwy_Serpentine_Noise Assessment.VPR

MRWA ROM24 Base Network - Version 2018
MRWA Transport Modelling Data as supplied to approved clients is confidential and is not to be made available to unauthorised persons or organisations

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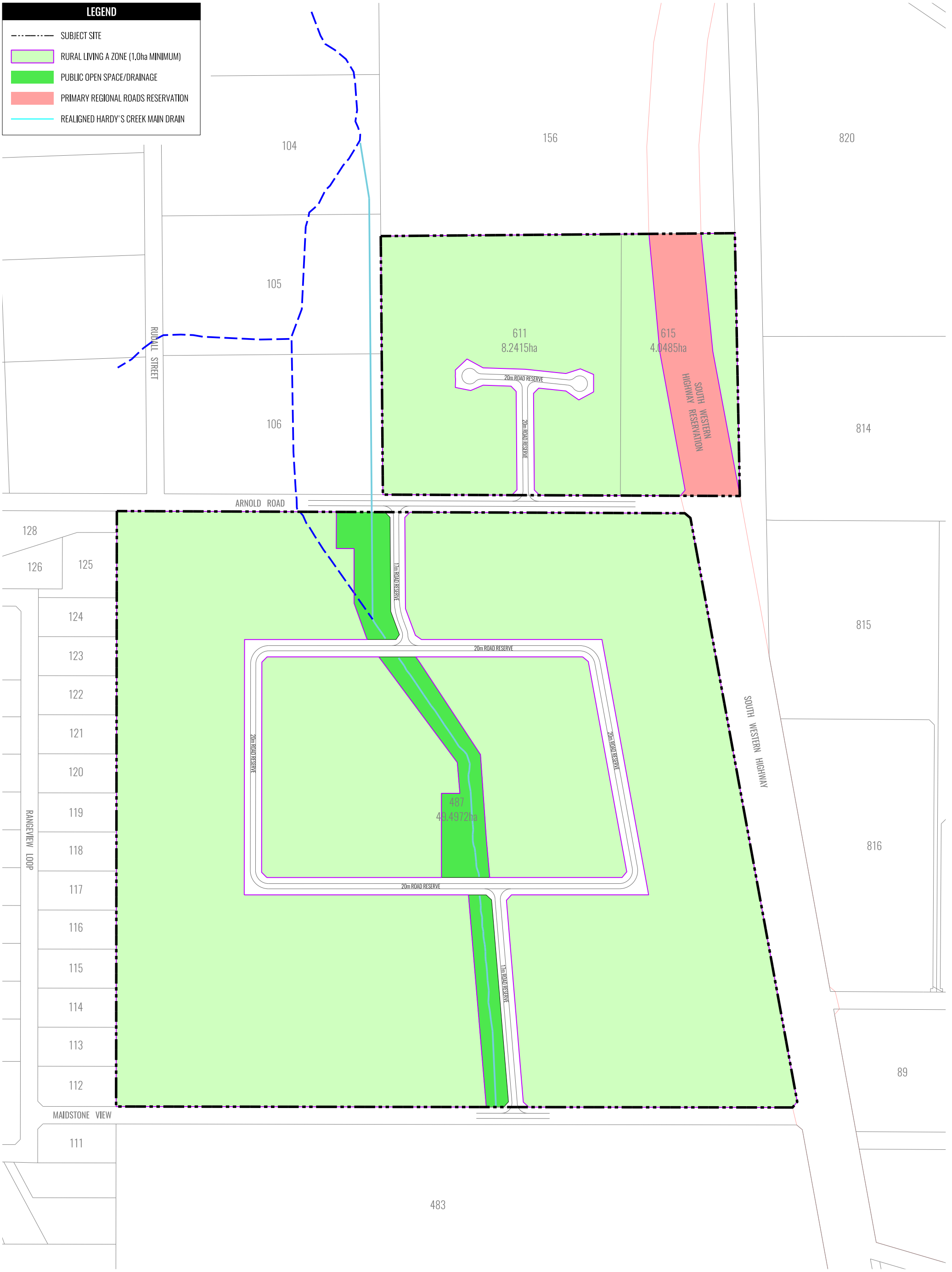
ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix j

Arnold Road Structure Plan Map

(RobertsDay)



STRUCTURE PLAN

Lots 487, 611 & 615 Arnold Rd, SERPENTINE

A Malf Corp Pty Ltd. Project

NORTH

Scale: 1:4000 @ A3

0 40 80 120m

PLAN: MALAR-5-007 REVISION:

DATE: 23/07/2020 DRAWN: JP

PROJECTION: PCG 94 PLANNER: MT

DATUM: AHD CHECK: KB

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ARNOLD ROAD LOCAL STRUCTURE PLAN
LOTS 487, 611 & 615 ARNOLD ROAD, SERPENTINE

appendix k

Site and Soil Evaluation Report

(Emerge)

Site and Soil Evaluation

Arnold Road, Serpentine

Project No: EP20-020(04)

Prepared for MALF Corp Pty Ltd
January 2021



Document Control

Doc name:	Site and Soil Evaluation Arnold Road, Serpentine				
Doc no.:	EP20-020(04)--004A FMH				
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A	January 2021	Fabio Hernandez	FMH	Dave Coremans	DPC
	For agency submission				

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Appendices

Appendix A

Proposed Structure Plan

1 Introduction

1.1 Project background

MALF Corporation Pty Ltd (the proponent) proposes to develop Lot 487, 611 and 615 Arnold Road, Serpentine, for rural residential purposes. This area, and a small section of road reserve adjacent to the north east is herein referred to as 'the site'. The site covers approximately 62 ha and is situated approximately 50 km south-east of the Perth central business district (CBD) within the Shire of Serpentine Jarrahdale (Shire of SJ). The location of the site is shown in **Figure 1**.

1.2 Planning context

The site is currently zoned 'Rural' under the Metropolitan Region Scheme and 'Rural Living A' under the Shire of SJ Town Planning Scheme No.2 (TPS2).

1.3 Proposed development

The site is proposed to be developed into 52 rural residential lots, each with an average size of approximately 1 ha. The proposed structure plan, provided in **Appendix A**, includes a drainage reserve associated with the Hardy Creek Main Drain (HCMD) which runs across Lot 487 and through the western portion of Lot 611 and 615 in a northerly direction. Internal roads will provide access to the lots via the centre of the site. A bio-retention drainage swale is proposed adjacent to the HCMD this will provide retention and treatment for the first 15 mm for road runoff.

Reticulated sewage will not be available within the site and thus provision for the disposal of wastewater will need to be considered and accommodated on-site, consistent with the requirements of the *Government Sewerage Policy* (DPLH 2019) and *AS/NZS 1547 On-site domestic wastewater management* (Standards Australia and Standards New Zealand 2012).

1.4 Purpose of this report

The *Government Sewerage Policy* (DPLH 2019) mandates that developments that will not be connected to reticulated sewer are required to prepare a site and soil evaluation (SSE) in accordance with *AS/NZS 1547 On-site domestic wastewater management* (AS 1547) (Standards Australia and Standards New Zealand 2012).

This document is intended to satisfy the requirements of the *Government Sewerage Policy* (DPLH 2019) for the preparation of a SSE. The SSE is intended to assess the site and proposed approach to developing the site and guide on-site wastewater disposal to ensure sustainable and effective on-site domestic wastewater management, thereby protecting public health and the environment.

To support a local structure plan, the SSE should determine capacity of proposed lots to contain sewage on-site, select and size treatment/on-site sewage management system (including land

application areas), identify management and monitoring options and define adequate on-site sewage management locations (DoH 2019a).

1.5 Previous and supporting documentation

1.5.1 Local Water Management Strategy

A local water management strategy (the LWMS) was prepared by Bayley Environmental Services (2016) to support a subdivision concept plan for the site. The LWMS describes the overarching water management context and strategy for the site.

Further, an addendum to the LWMS was undertaken by RPS (2020) in order to provide support for the updated structure plan of the site, and accounted for:

- The average lot size was increased from 0.44 ha to approximately 1 ha
- The road reserve area was reduced from 9.53 ha to 4.2 ha
- The HCMD was realigned 80 m to the east of Arnold Road
- Bio-retention treatment buffer strips were proposed adjacent to the HCMD (instead of roadside swales).

1.5.2 Flood modelling report

A flood modelling report to support the realignment of HCMD was prepared by Coterra Environment (2019) addressing the adjacent downstream lots of the proposed development, and accounting for the hydrological and hydraulic characteristics of HCMD living stream. The flood modelling also accounted for the realignment of the HCMD 80 m eastwards at Arnold Road to understand the revised flow characteristics of the HCMD. The modelling undertaken indicated that the proposed modification does not increase the flooding risk or peak flow within the HDMC either within or upstream of the site.

1.5.3 Other key documents

Other key documents which have been used to support this SSE include:

- Geotechnical report (Report on geotechnical Investigation, Proposed Residential Development Lots 487, 611 & 615 Arnold Road, Serpentine, WA (Douglas Partners 2020))
- Environmental Assessment and Management Strategy (Emerge Associates 2020)
- Structure plan (Concept plan (CDP Town Planning & Urban Design 2020).

2 Existing Environment

2.1 Climate

The closest weather station to the site which records rainfall and temperature data is located in Karnet (Bureau of Meteorology (BoM) station number 9111), situated approximately 11 km east of the site. Based on weather data collected from 1963 to 2020 at Karnet, the local area experiences an average of 1,153 mm of annual rainfall, an average of 4.0 mm/day evaporation, mean annual maximum temperature of 22.5 °C and a mean annual minimum temperature of 10.6 °C (BoM 2020).

2.2 Topography

The proposed development areas is divided by Arnold Road, Lots 611 and 615 to the north, and Lot 487 to the South. The northern lots are gently sloping with a north western aspect. Existing ground elevations north of Arnold Road range from 34 metres Australian height datum (mAHD) in the south east to 32 mAHD in the North West. The southern lot has a north western aspect. Existing ground elevations range from 46 mAHD in the south eastern portion of the site to 33 mAHD in the north western portion of the site. Topographic contours over the site and the immediate surrounds are shown in **Figure 1**.

2.3 Landforms and soils

2.3.1 Regional soil mapping

Regional soil mapping has been prepared across the Serpentine locality at a scale of 1:50 000 as part of a series of geological maps published by the Geological Survey of Western Australia (Jordan 1986). This mapping also outlines the expected broad level capability of soil and rock units to accommodate various land uses.

The mapping indicates that two soil units occur within the site, as shown in **Figure 2**. These include:

- **Sandy Clay (Cs)** described as 'white grey to brown, fine to course, sub-angular to rounded, clay of moderate plasticity; gravel and silt layers near scarp, of alluvial origin'. Jordan (1986) identified that in terms of land capability within this soil type, possible issues could exist for the use of septic tanks due to the possibility of seasonal flooding in certain areas across this broadly mapped soil unit. Jordan (1986) outlines that 'sand pads' may be required beneath building foundations.
- **Gravelly Sandy clay** (**Csg)** described as 'variable with lenses of silt and gravel, quartz sand sub-angular with eolian rounded component, heavy minerals common, gravel rounded, of colluvial origin'. Jordan (1986) identifies that in terms of land capability, possible issues could exist for the use of septic tanks when excavating due to the presence of recemented materials.

The Cs soil unit is identified as occurring the majority of Lots 661 and 665, with a lesser extent of the Csg soil unit. For Lot 487, the Cs soil unit is present in almost two thirds of the lot with the remaining portion composed by the Csg soil unit.

2.3.2 Soil landscape mapping

Land resources in the northern section of the Peel-Harvey catchment, Swan Coastal Plain, Western Australia Map (van Gool 1990) was prepared for regional and catchment land use planning purposes. The associated soil and landform mapping was prepared at a scale of 1:50 000 and identified the site as being situated on three broadly defined soil-landform 'land units'. These land units include:

- **Pinjarra P1a Phase** which was broadly described as 'flat to very gently undulating plain. Imperfect to poorly drained and generally not susceptible to salinity'. It identified this soil-landform land unit as having a 'Low' (IV) land use capability class for 'rural retreats housing and effluent disposal' attributed to the low soil absorption ability. The soil absorption rating is determined by a number of factors including waterlogging and inundation risk, soil permeability class, the presence of stones/boulders within the soil profile and the depth of the soil profile.
- **Pinjarra P4 Phase** which was broadly described as 'poorly drain flats whit generally acidic subsoils'. It identified this soil-landform land unit as having 'Low' (IV) land use capabilities for 'rural retreats housing and effluent disposal' attributed to the low soil absorption ability.
- **Forrestfield F2b Phase** which was broadly described as 'well drained low slopes and foot slopes up to 5-10%'. It identified this soil-landform land unit as having a 'Fair' (III) land use capability class for 'rural retreats housing and effluent disposal'.

The three formations cover different areas of each lot. The Pinjarra P1a land unit was identified as occurring in Lot 487 in most of the western portion and beneath Lot 611 on the south eastern corner. The Pinjarra P4 land unit was identified as occurring in the northern portion of Lots 611 and 615, whereas the Forrestfield F2b phase was only present in Lot 487 in the eastern and the south western corner of the lot.

The regional landform and soil mapping outlined above indicate that potential issues could arise for the use of onsite effluent disposal due to the potential for seasonal flooding, a high water table, low soil absorption and low microbial purification ability.

2.3.3 Geotechnical information

A geotechnical study covering the site was undertaken by Douglas Partners (2020). The purpose of the geotechnical study was to assess the subsoil and groundwater conditions within the site.

Fieldwork was carried out between 10 to 12 March 2020 and included:

- Excavation of 32 test pits using an 8 tonne backhoe to depths between 0.8 m to 2.5 m below the existing ground level.
- Dynamic cone penetrometer (DPC) adjacent to test pits.

- Infiltration testing at seven locations using the constant head method to depths around 0.3 m to 0.35 m. A falling head test was undertaken at a borehole adjacent to test pit location 28 at a depth of 0.4 m below ground level (BGL).

The fieldwork was conducted in general accordance with AS 1726-2017.

2.3.3.1 Test pits

General ground conditions across all 32 test pits can be summarised as comprising:

- Silty sand generally extending to 0.2 m BGL
- Clayey sandy gravelly soils from 0.2 m mostly predominant in the eastern portion of site with thicknesses of up to 2.5 m
- Gravelly sandy clay soils from the clayey sand, mostly on the western side of Lot 487 to the target depth (of 2.5 m) of the test pit.

During excavation groundwater was only observed at test pit 28 at an approximate depth of 2.3 mBGL.

The depth of the soil profile (depth to bedrock or impervious layer) encountered at each of the test pit locations is considered to be 'very deep' in accordance with Table A1.2 of *Land evaluation standards for land resource mapping : assessing land qualities and determining land capability in south-western Australia* (Van Gool *et al.* 2005).

Laboratory testing was carried out by Western Geotechnical and Laboratory Services on soil samples from 10 test pits. This included particle size distribution analysis for 10 samples, Atterberg limits of six samples and shrink swell index of three samples. The entire results of the laboratory testing are provided in the Report on Geotechnical Investigation (Douglas Partners 2020).

2.3.3.2 Soil zones

Douglas Partners (2020) found that regional geological mapping (see **Section 2.3.1**) of the site is generally consistent with the observed subsoil conditions. The subsurface material was relatively consistent throughout the site and could be delineated into two zones: Sandy Clay Zone and Gravelly Sandy Clay Zone.

Soils in the Sandy Clay Zone can be characterized as 0.2 m of topsoil (silty sand) overlaying a sandy clay layer extending to depths of between 0.5 to 2.5 m, and in some occasions underlain by clay. This zone covers all of Lots 611 and 615 and the eastern part of Lot 487.

The Gravelly Sandy Zone covers the western portion of Lot 487 and generally consists of 0.2 m of topsoil (silty sand), overlaying in some circumstances a sandy clay layer to depths of 0.2 to 2.5 m, underlain by gravelly clay.

Test pit locations are shown on **Figure 2** and detailed test pit logs are contained in the geotechnical report (Douglas Partners 2020).

2.3.3.3 Infiltration testing

Infiltration testing was undertaken at eight locations adjacent to test pits. Seven of them using the constant head method and one using the falling head method. Infiltration testing results are summarised in the **Table 1**.

Table 1: Summary of infiltration test results (Douglas Partners 2020)

Location	Depth (m)	Description of tested material	Measured Permeability	
			x 10^{-5} (m/s)	(m/day)
4	0.35	Dense silty sandy GRAVEL	0.4	0.3
8	0.3	Very dense sandy CLAY / clayey SAND, trace silt	8.3	7
17	0.3	Dense to very dense clayey SAND	1.3	1
19	0.3	Dense clayey SAND	14.4	12
25	0.3	Medium dense to dense clayey SAND, trace gravel	4.6	4
27	0.3	Very dense gravelly, clayey SAND	5.4	4.5
32	0.3	Dense clayey sandy GRAVEL	5.3	4.5
28	0.4	Medium dense SAND, with silt	4.2	3.5

2.3.4 Acid sulfate soils

Regional acid sulfate soil risk mapping (DWER 2020c) indicates that some of the site is classified as 'moderate to low risk' of ASS occurring within 3 m of natural soil surface and that the eastern portion is not classified with any risk of ASS occurring within 3 m of the natural surface. ASS risk mapping within and surrounding the site is shown in **Figure 3.**

2.4 Groundwater

The site is within the Serpentine Groundwater Management Area and the Serpentine 3 Sub-area. Information on the regional groundwater resources obtained from DWER (2020) indicates that the site is underlain by a multi-layered aquifer system comprised of the following:

- Perth - Superficial Swan (unconfined)
- Perth – Cattamarra Coal Measures (confined)
- Perth - Leederville (confined).

There is currently no publicly available regional groundwater level or quality data available for the site. Groundwater characteristics are documented in the Report on Geotechnical Investigations (Douglas Partners 2020) are summarised below.

Groundwater levels have been measured at multiple locations within the site and surrounds, and groundwater quality analysis was undertaken during March 2020. Groundwater was only observed at

test pit 28 south of Arnold Road, as shown in **Figure 2,** with an approximate depth of 2.3 m (approximately 38.6 m AHD) during the fieldwork undertaken in March 2020.

Much of the subject land is subjected to surface saturation and in some cases inundation in winter, which is likely to be the result of localised perched conditions and/or surface ponding of runoff.

The LWMS (Bayley Environmental Services (2016)) summarises that the groundwater system within the Serpentine area is very complex due to the variable permeability of the soils. The LWMS documented groundwater measurements at eight locations during September 2014 in order to determine the late winter groundwater levels (**Figure 6**). Based on the measurements taken, groundwater levels will be at or near the surface over most of the site during winter periods.

2.5 Wetlands

The entire site is mapped as a multiple use wetland (MUW) (UFI 16021) (DBCA 2020), as shown in **Figure 4**.

2.6 Public Drinking Water Source Areas

Publicly available Public Drinking Water Source Area (PDWSA) mapping indicates that the site is not located within or adjacent to a declared PDWSA (DWER 2020).

2.7 Sewage sensitive areas

Sewage sensitive areas are proclaimed under the *Government Sewerage Policy* (DPLH 2019) to protect groundwater and surface water systems. The *Government Sewerage Policy* dataset (DPLH 2020) indicates the entire site is identified as a sewage sensitive area and is associated with both category A 'Estuary catchments on the Swan and Scott Coastal Plains' and F 'Within 1 km of significant wetlands', as shown on **Figure 5.**

2.8 Surface water

The site is within the catchment of the Serpentine River, which flows from east to west north east of the site, before eventually discharging into the Peel Inlet.

The site is crossed by the Water Corporation drain, the HCMD, which extends approximately 1.2 km to the south east of the site and flows north through Lot 487 and adjacently to western side of Lot 611, before discharging into the Serpentine River approximately 940 m north west of the site, as shown in **Figure 6.** The drain is seasonal, flowing in winter and drying up during summer and consists of an eroded trapezoidal channel with a transversal section approximately 0.5 m to 1 m deep and 2 m to 10 m wide at the surface with a narrow, flat sandy bottom. The embankments are partially stablished by pasture grasses but are eroded (presumably where disturbed by cattle and occasional vehicles).

2.8.1 Pre-development surface water modelling

The pre-development peak flow rates within the HCMD reported in the LWMS (Bayley Environmental Services 2016) for a 100 year ARI (1 % annual exceedance probability (AEP)) rainfall event is 11.4 m^3/s at the Arnold Road box culvert. This flow rate exceeds the capacity of the channel. The excess flow is expected to break out from the central channel spreading across the adjacent land, which provides temporary storage. Top water level for the 100 year ARI event is reported as 33.2 mAHD at Arnold Road and 40.8 mAHD at the southern end of the site. However, the pre-development peak flood elevation is not considered relevant to the proposal as the implementation of the proposal will modify and realign the HCMD channel to convey the upstream flows and runoff from the site. Therefore, the post-development peak flow levels are more relevant to the capability of the site for onsite disposal of effluent. These are further discussed in **Section 3.3.2.**

2.9 Vegetation

The vegetation has been assessed and described in the Environmental Assessment and Management Strategy (EAMS) (Emerge Associates 2020). The entire site is described as parkland/cleared; heavily disturbed areas completely degraded comprising weeds with occasional native trees and planted vegetation.

2.10 Existing land use

A review of aerial photography shows that the land has been cleared and grazed since 1965 and no other land uses have occurred within site.

3 Land Capability

3.1 Determination of soil-terrain units

As discussed in **Section 2.2**, in general the site is relatively flat with gradients varying from 0% to 4%.

The maximum slope suitable for on-site wastewater systems is dependent upon the type of system proposed and ranges from 10% to 30% (Standards Australia and Standards New Zealand 2012), with surface application systems more sensitive to slope. The topography within the site does not exceed 10% and therefore does not pose an impediment to the onsite disposal of effluent.

Soil investigations (detailed in **Section 2.3.3**) generally align with regional geological mapping and show that the site can be either categorised as sandy clay or gravelly clay depending on the location of the test. Based on the assessment conducted by Douglas Partners (2020) and the regional geological mapping (Jordan 1986), the site has been categorised as either a Sandy Clay Zone or a Gravelly Sandy Clay Zone. Therefore, the boundary of these zones has been adopted from the regional geological mapping boundary between Sandy Clay (Cs) and Gravelly Sandy clay (Csg)(Jordan 1986). Lots 487, 611 and 615 can exhibit either unit. Individual lot-scale testing will be required to determine which soil-terrain unit the proposed systems will be underlain by. The soil-terrain units are shown in **Figure 2.**

3.2 Classification of soil-terrain units

3.2.1 Sandy Clay soil-terrain unit

Laboratory analysis was conducted on soil samples from 10 boreholes drilled adjacently to test pits as part of the geotechnical investigations (Douglas Partners 2020) (see **Section 2.3.3**). Samples were collected from boreholes located within both soil-terrain units. The soils were described based on AS1726-2017 and were assessed in the field by visual/tactile methods and described in combination with laboratory testing (where undertaken).

The classification of underlying soils within the sandy clay soil-terrain unit is described as either sand, sandy clay or clayey sand. The analysis undertaken in Lots 611 and 615, demonstrated that soil composition was relatively consistent at (an average of) 5.7 % gravel, 34.6 % sand, and 59.7 % fines. Within Lot 487 soil analysis also demonstrated that soil composition was relatively consistent across the samples, however the percentage of sand was greater with (average of) 0.7 % gravel, 81.3 % sand and 18 % fines.

Based on the indicative clay content percentages in Table E1 of *AS 1547* the corresponding soil category for the sandy clay soil-terrain unit for Lots 611 and 615 is ‘Category 6 (Heavy clay) (where there is 50% or more clay)’ and ‘Category 3 (Loam) (where clay varies from 10% to 25%)’.

Infiltration testing was undertaken in some test pits, with variable results. Measured rates from the geotechnical investigations varied from 1 m/day to 12 m/day, with an average of 5.33 m/day (see

Table 1)(Douglas Partners 2020). These rates are higher than the indicative saturated permeability rate for Category 3 and Category 6 (0.5 m/day to 3 m/day and 0.06 m/day to 0.5 m/day respectively) described in Table 5.1 from AS1547, and it is noted that in-situ permeability testing might be influenced by the presence of biological channels within the soil and not purely be the permeability of the soil.

Based on the above, the soil Category 3 and Category 6 are appropriate for the sandy clay soil-terrain unit, and the upper end of the indicative soil permeability from Table 5.1 of AS1547 is adopted for the purposes of the land capability assessment:

- Category 3 - 3.0 m/day
- Category 6 - 0.5 m/day.

The adoption of a lower indicative permeability range (than measured) is considered appropriate given the variability of permeability measurements within the unit. Additional soil and infiltration testing at the individual lot scale location proposed for wastewater application system may support the adoption of a less conservative soil category (and associated effluent disposal area). This should occur at the building licence/lot construction stage when the location of the wastewater system and application area will be detailed.

3.2.2 Gravelly Sandy Clay soil-terrain unit

The gravelly sandy clay soils encountered some test pits are either described as clayey gravel, gravelly clayey sand or clayey sandy gravel. The soil analysis demonstrated that these soils are generally composed of gravel (36 % to 55 %), sand (25 % to 43 %) and fines (20 % to 25 %) (Douglas Partners 2020). Based on these descriptions and Table E1 from the AS 1547:2012, the most appropriate category for the gravelly sandy clay soil-terrain unit is 'Category 4 (sandy clay loam) (20% - 30% clay)'.

In-situ infiltration testing and soil classification by Douglas Partners (2020) shows that the sandy gravelly sandy clays soil terrain unit is only found in some minor portions of the site. The permeability varied between 0.3 m/day to 4.5 m/day across the two test locations with an average of 2.4 m/day. In absence of further lot-scale infiltration testing soil Category 4 (sandy clay loam) is appropriate for the gravelly sandy clay soil-terrain unit. The adopted soil permeability for the purposes of this assessment is consistent with a highly to moderately structured soil category, and a permeability of 1.5 m/day.

3.2.3 Summary

The most appropriate soil categories for the two soil-terrain units within the site are summarised as:

Soil-terrain unit 1 (Sandy Clay) the soil Category 3 (Loam), highly to moderately structured is adopted and for Category 6 (Heavy clay), strongly structured is adopted.

Soil-terrain unit 2 (Gravelly Sandy Clay) the soil Category 4 (sandy clay loam), high to moderately structure is adopted.

3.3 Additional considerations

3.3.1 Slope

As discussed in **Section 3.1**, the site is generally flat (< 4 % grade) and with some minor localised side slopes of the HCMD generally <12.5 %. Location of treated effluent application areas will address slope considerations by ensuring that the application areas do not exceed 10 % grade, and are located well away from the HCMD (which will be within a dedicated drainage corridor). The slope within lots will be finalised following earth working of the site (which will involve the realignment of the existing HCMD 80 m eastwards at Arnold Road) however are expected to be generally flat/mimic the existing slopes which are < 4%. This would be detailed within future building licence applications.

3.3.2 Flood-prone areas

The *Government Sewerage Policy* (DPLH 2019) stipulates that on-site systems are not to be located in areas that are low-lying and prone to flooding in a 10% AEP rainfall event. Where areas may be subject to flooding, effluent disposal areas should be above the 10% AEP rainfall event.

The implementation of the proposal includes the realignment and modification of HCMD into a living stream to convey the upstream flows and runoff from the site northwards.

The post-development modelling (Coterra Environment 2019) provides 1% AEP flood levels within the realigned HCMD. 10% AEP event flood modelling is not available, and therefore the 1% AEP flood inundation levels are adopted as a surrogate for the purposes of this assessment. The 1% AEP flood elevations range from 40.09 mAHD at the southern boundary of the site, 32.53 mAHD at the flood storage upstream of Arnold Road and 32.39 mAHD immediately downstream of Arnold Road. These predicted flood elevations are less than the existing environment and as detailed in the LWMS addendum (RPS 2020) the 1% AEP event flood elevation will be retained within the design channel for the HCMD. The proposed lots will therefore not be considered flood prone, and for the purposes of achieving appropriate vertical clearance from flooding, the effluent disposal areas can be set at or above the existing surface levels.

3.3.3 Drainage system separation

The *Government Sewerage Policy* (DPLH 2019) indicate that on-site systems are not to be located within 100 m of a drainage system that discharges directly into a waterway or significant wetland without treatment, however it is noted that smaller setbacks may be considered where the reduced setbacks will not have a significant impact on the environment or public health. The proposed structure plan will locate seven 1 ha lots within 100 m of the HCMD. A further 12 x 1 ha lots would be partially located within 100 m of the HCMD.

As discussed in **Section 2.8**, the HCMD discharges to the Serpentine River approximately 940 m downstream of the site. Whilst the HCMD eventually discharges to the Serpentine River, it is over a very long conveyance pathway and would not be considered to discharge directly and without

treatment, as the HCMD will incorporate a living stream design approach, with dense vegetation and soil modification for the specific purpose of removing nutrients.

The proposed lot locations are considered to provide a low risk to the downstream environment or public health on the basis that:

- All onsite effluent can be treated by secondary treatment systems with nutrient removal.
- The clayey soils and high PRI of the site will provide additional nutrient retention capacity for overland flow/runoff.
- The adoption of a living stream approach to the realigned HCMD will increase the capacity of the waterway to provide additional treatment.
- There will be no direct pathway from effluent disposal areas with lots to the HCMD
- Bio-retention swales located adjacent to the HCMD will treat and retain the first 15 mm of runoff from road reserves within Lot 487 and excess runoff from lots will flow over the road drainage network prior entering the HCMD living stream.
- Lots are all proposed to be large sizes, with a minimum of 1 ha.
- There are only seven lots which are not achieve a 100 m setback for an effluent disposal area.
- All lots could achieve a modest setback of 30 m from the HCMD.

AS/NZS 1547 takes a risk-based approach to determining setback distances and states that horizontal setbacks from surface water features of between 15 m – 100 m should be considered, and ultimately determined from an assessment of the site-specific constraints. Seven potential constraints are identified for surface water setbacks (AS/NZS 1547 - Table R1 and R2). The scale of the constraints in relation to the lots located adjacently to the HCMD and overall risk associated with the HCMD is described in **Table 2** (which has been adapted from, and is consistent with the process outlined in Table R1 and R2 of AS/NZS 1547).

Table 2: Surface water risk assessment.

Site/system Feature*	Less constrained*	More constrained*	Proposed approach	Risk category	Response to risk category
Microbial quality of effluent	Effluent quality consistently producing ≤ 10 cfu/100 mL E. coli (secondary treated effluent with disinfection)	Effluent quality consistently producing ≥ 106 cfu/100 mL E. coli (for example, primary treated effluent)	Secondary treatment with disinfection will be mandated for all lots within the site. Secondary systems achieve 10 cfu/100 mL of E. coli.	Low	None required
Slope	0 – 6% (surface effluent application) 0 – 10% (subsurface effluent application)	> 10% (surface effluent application), > 30% subsurface effluent application	Adopt existing site levels - Slopes of around 4% or less.	Low	If required, subsurface application can be mandated

Table 2: Surface water risk assessment (continued).

Site/system Feature*	Less constrained*	More constrained*	Proposed approach	Risk category	Response to risk category
Surface water	Category 1 to 3 soils no surface water down gradient within > 100 m, low rainfall area	Category 4 to 6 soils, permanent surface water <50 m down gradient, high rainfall area, high resource/environmental value	Category 2, 4 and 6 in-situ soils, however fill to provide necessary clearances to groundwater. The HCMD is ephemeral. Moderate rainfall (1,153 mm/yr). Low environmental value within site	Moderate	Fill will be required beneath effluent disposal areas to address shallow groundwater, this can be permeable sand and could reduce the risk category
Position of land application area in landscape	Downgradient of surface water, property boundary, recreational area	Upgradient of surface water, property boundary, recreational area	Building envelopes located on-grade with the HCMD. Not located nearby public open spaces. Land application areas can be situated > 100 m from HCMD for most of the site. Position of application areas will be allocated at the DA stage.	Low-Moderate	Building envelopes could be utilised to ensure effluent disposal areas achieve a minimum setback of 30 m.
Drainage	Category 1 and 2 soils, gently sloping area	Category 6 soils, sites with visible seepage, moisture tolerant vegetation, low lying area	Category 2, 4 and 6 soils, gently sloping area.	Low-moderate	Fill will be required beneath effluent disposal areas to address shallow groundwater, this can be permeable sand. Design effluent disposal surface areas will be based on existing soils
Flood potential	Above 1 in 20 year flood contour	Below 1 in 20 year flood contour	Land application areas will be elevated above the (100 ARI) 1% AEP flooding top water levels.	Low	None required
Application method	Drip irrigation or subsurface application of effluent	Surface/above ground application of effluent	Treated wastewater will be applied via subsurface application	Low	Subsurface application can be mandated if required

** From the* AS/NZs 1547 On-site domestic wastewater management *(Standards Australia and Standards New Zealand 2012)*

The overall risk to the environment and public health from appropriate implementation of secondary wastewater treatment (with nutrient removal and disinfection) and subsurface application systems posed by the site is considered to be low.

Although the development of lots adjacent to the HCMD within the site is considered low risk, both topography and groundwater grade towards the HCMD (mostly from the eastern part of development area). On this basis a moderate horizontal separation of at least 30 m from the centreline of the HCMD living stream should be adopted. The exclusion area resulting from this setback is displayed in **Figure 7**. For those lots within 100 m of the HCMD, building envelopes or another method of ensuring this setback is achieved would be an appropriate mechanism to achieve the recommended setback.

3.3.4 Groundwater separation

As discussed in **Section 2.7**, the site is located within a sewage sensitive area. The required vertical separation from an on-site sewage system discharge point and the highest groundwater level within a sewage sensitive area (regardless of soil type) is 1.5 m in the *Government Sewerage Policy* (DPLH 2019). Guidelines for groundwater separation in AS 1547 (Table R1) states that vertical setbacks of between 0.6 m – 1.5 m should be considered. The development proposes to use sand fill to provide the requisite clearance to groundwater, and groundwater is recorded to be close to or at the existing natural surface level, it is appropriate to adopt a minimum fill level of 1.5 m beneath effluent disposal areas.

Based on the complexity and variability of the localised groundwater regime, it is stated in the LWMS that the groundwater levels during wet periods can be expected at the surface levels across the site (Bayley Environmental Services 2016). Therefore, the majority of the site does not achieve a clearance of 1.5 m to groundwater (for the existing environment). Wastewater application areas located within the future subdivision envelopes will be elevated with sand fill in order to achieve 1.5 m of separation from the pre-development maximum groundwater level. It is noted that this will be significantly higher than the 10% AEP event top water level, and therefore the elevation of effluent disposal areas is guided by groundwater being at or close to the surface. Vertical separation requirements are discussed in **Section 3.4**.

3.3.5 Other setbacks

Code of Practice for the Design, Manufacture, Installation and Operation of Aerobic Treatment Units (DoH 2015) specifies setback distances from infrastructure for land application (surface irrigation) areas and for treatment units. For a flat or gently sloping site these are:

Land application area (surface irrigation)

- A minimum of 1.8 m from boundaries with open fencing
- 1.8 m from buildings
- 1.8 m from any paved surface including driveways, paths etc.
- From swimming pools:

- 3.0 m on flat ground
- 3.0 m downslope
- 6.0 m upslope

- 30 m from wells, bores, dams or water courses used or available for human or animal consumption.

An ATU (or similar)

- 1.2 m from any boundaries or buildings
- 1.8 m from the surface irrigation disposal area
- 6.0 m from a well, bore, dam or any water course whether it is used for a domestic water supply or discharging to a proclaimed water catchment area.

Due the scale of these setbacks, demonstration of their provision will be detailed at the individual lot development/building licence stage.

3.4 Results

The soil-terrain units are acceptable for on-site wastewater treatment and land application in terms of geophysical characteristics (slope and soil characteristics). Though the sandy clay soil (Category 6) unit would require a larger land application area for adequate soil uptake.

The considerations described in **Section 3.3** provide additional constraints for on-site application of treated wastewater. These include:

Clearance above inundation of the 10% AEP event. (A more conservative approach is adopted using the 1% AEP as the design datum which is more conservative than the 10% AEP event required by *Government Sewage Policy* (DPLH 2019)). The 1% AEP event will be retained within the HCMD corridor proposed.

Proximity to the HCMD (within 30 m). Horizontal separation from the HCMD can be achieved by positioning of building envelopes such that they are at least 30 m from the HCMD centerline.

Groundwater vertical separation of 1.5 m. Clearance from groundwater (1.5 m is required) will be provided by elevating application areas with sand fill, an approach that is consistent with the *Government Sewerage Policy* (DPLH 2019).

4 Wastewater Management

4.1 Expected wastewater volume

The expected hydraulic load of households is based on the fact sheet: *Supplement to Regulation 29 – Wastewater system loading rates* (DoH 2019b). The rate of 900 L/day has been adopted for calculations in this SSE. The rate of 900 L/day corresponds to a standard residential dwelling with an occupancy of six persons. This is in line with the approach outlined in the *Government Sewerage Policy* (DPLH 2019) which advocates conservative estimates at the subdivision level, which can be refined at a later stage when the occupancy can be estimated with greater certainty. There is also some conservancy to account for the requirement of the system to treat the peak wastewater flow (e.g. if all water appliances are used simultaneously), consistent with AS 1547.

4.2 Appropriate treatment technology and onsite sewage management systems

As discussed in **Section 2**, the site is situated within a sewage sensitive area. The *Government Sewerage Policy* (DPLH 2019) mandates that where on-site disposal is proposed within a sewage sensitive area that a secondary treatment system (such as an ATU) with nutrient removal capability and disinfection is to be used. The performance requirements of secondary treatment systems and secondary treatment systems with nutrient removal are described in Section 7 of the *Government Sewerage Policy* (DPLH 2019).

Secondary treatment systems must be approved by the Department of Health (DoH) for use in Western Australia. An online list of currently approved systems, including those approved for nutrient removal, is maintained by DoH (2020).

Secondary treatment systems are to be installed and operated in accordance with the *Health (Treatment of Sewage and Disposal of Effluent and Liquid Waste) Regulations 1974*, the *Code of Practice for the Design, Manufacture, Installation and Operation of Aerobic Treatment Units* (DoH 2015) and AS 1547 (Standards Australia and Standards New Zealand 2012). Treatment systems must be serviced by an authorised service person on a regular basis (usually quarterly) as per the conditions of product approval issued by DoH.

4.3 Land application area requirements

The land application area is the area where the wastewater from a treatment system (primary or secondary) is applied into or onto the ground. Land-application systems typically either discharge wastewater via soil absorption systems (e.g. leach drains) or irrigation systems (e.g. subsurface irrigation or surface irrigation). The method by which wastewater is dispersed to the land influences the amount of land required for application.

The calculation of the minimum required land application area (i.e. with use of wastewater application in trenches) is described in Schedule 2 of the *Government Sewerage Policy* and is the estimated hydraulic load (occupancy multiplied by the design loading rate – see **Section 4.1**) multiplied by a conversion factor. The appropriate conversation factor is determined by selection of the proposed treatment type and the soil category (Table 2 of Schedule 2 from the *Government Sewerage Policy*). The land application area when other methods of application are proposed is calculated based on loading rates defined for varying systems in AS 1547 (Table 5.2). The calculated land application area for trench and spray/drip application for each soil-terrain unit is summarised in **Table 3**. Mounds, which are designed to overcome restrictive soils or high groundwater, are also included.

Table 3: Land application area requirements (secondary systems)

Soil-terrain unit	Soil category	Application System	Hydraulic loading (L/day)	Conversion factor (DPLH 2019)	Design irrigation rate (mm/day) (AS 1547)	Land application area (m^2)*
Sandy Clay – flat to slightly sloped	Category 3 (Loam)	Trench	900	0.25	-	225
		Spray/drip		-	4	225
		Mounds		-	24	37.5**
	Category 6 (Heavy Clays)	Trench		0.5	-	450
		Spray/drip		-	2	450
		Mounds		-	5***	180**
Gravelly Sand Clay – flat to slightly sloped	Category 4 (Sandy Clay Loam)	Trench		0.286		257
		Spray/drip		-	3.5	257
		Mounds		-	16	57**

**Application area and treatment systems setbacks are not accounted for.*
***Basal application area requirement for a flat location (< 3% grade). Design of mound is subject to minimum dimension, as per AS 1547.*
****Special design is required for this type of soils. Absorption rate shall be based on specific permeability testing, as per AS 1547.*

4.4 Capability of land to accommodate sewage application

The LWMS addendum states that all lots area approximately 1 ha. The land area required for on-site application of treated wastewater varies between 225 m^2 to 450 m^2 (with some additional land to account for setbacks if trenches are used) for the examples detailed in **Table 3**. Given that lots are >1 ha, building envelopes will need to be able to accommodate a nominal 300 m^2 building footprint area, approximately 500 m^2 for effluent disposal and in-lot setbacks plus sufficient area for other paved/hardstand areas. On this basis building envelopes are likely to be approximately 1,000 m^2. This is considered sufficient to enable the on-site treatment and application of wastewater.

It is noted that the land application areas within the clayey soil-terrain unit are based upon the in-situ soils. However, the application areas will be located on sand fill with a depth that will be variable based on grade of the existing surface and the separation distances required. This provides an additional level of conservatism to the approach proposed.

4.4.1 Cumulative impacts

The *Government Sewerage Policy* indicates that approval of on-site management of sewage is likely to set a precedent for similar proposals in the local water catchment, and that the cumulative impact should then be considered.

The key factors that determine the impact of on-site wastewater management (for the site and cumulatively in the catchment) and the reference to sections where the management plan for the site responds to these factors are summarised in **Table 4**.

Table 4: Cumulative impact summary

Key factor	Site management response reference
Density of development	Sections 1.3, 4.1, 4.3 and 4.4
Separation from the receiving environment	Sections 3.3.2, 3.3.3, 3.3.4, 3.3.5 and 3.4
Clearance from environmental impactors (i.e. flooding)	Sections 3.3.2 and 3.4
Type of treatment system utilised	Section 4.2

The approach proposed to developing the site appropriately mitigates the risk posed by onsite effluent disposal. It is assumed that similar standards will be applied to other developments under similar conditions and that the cumulative risk will therefore be appropriately mitigated.

4.5 Monitoring and maintenance

The *Code of Practice for the Design, Manufacture, Installation and Operation of Aerobic Treatment Units* (DoH 2015) details minimum standards for the design, manufacture, installation and operation of secondary treatment and application systems (i.e. ATUs), and provides guidance to local government as to how to assess the installation and ongoing operation requirements. Adherence to the Code is considered to be sufficient to ensure the risks associated with treatment and application of wastewater on-site are mitigated.

The *Government Sewerage Policy* notes that the State adopts a 'cautious approach' to the use of secondary treatment systems (DPLH 2019). A small number of studies and surveys have identified difficulties associated with the somewhat rigorous installation, maintenance, auditing and education requirements associated with secondary treatment system implementation (McGrath *et al.* 2015). If unchecked, these difficulties can increase the risk of system failure and subsequent health and environmental hazards.

It is expected that an appropriate auditing procedure will be implemented by the Shire of SJ to ensure maintenance of secondary treatment systems is occurring as required. Treatment system manufacture and installation companies typically offer an annual maintenance service with a certificate of completion that can be provided to demonstrate compliance. The owner of the system is responsible for continuing maintenance and providing any required documentation to the Shire for auditing.

5 Conclusion

The wastewater management strategy for the site, as outlined in this SSE, has been developed to be consistent with the approach and requirements detailed the *Government Sewerage Policy* (DPLH 2019) and *AS/NZS 1547 On-site domestic wastewater management* (Standards Australia and Standards New Zealand 2012). The approach for wastewater management within the site includes:

- Appropriate sizing of land application areas based on lot-scale geotechnical studies and classification of soil-terrain units.
- Ensuring sufficient space is available for treated wastewater application and adopting building envelopes (or other similar mechanism) to achieve adequate horizontal setback.
- Using fill to maintain vertical clearance requirements from the maximum groundwater level
- Ensuring that land application areas area above the 10% AEP event top water levels in the HCMD.
- Using secondary treatment systems with nutrient removal for all lots.
- Treated wastewater will be applied via subsurface application.
- Ensuring appropriate installation, monitoring and maintenance of systems in conducted.

The above investigations and management responses demonstrate that the site is able to accommodate the on-site treatment and application of wastewater from individual lots within the site, and that this can be achieved in a way that mitigates potential risks to receiving environments or the public.

6 References

6.1 General references

The references listed below have been considered as part of preparing this document.

Bayley Environmental Services 2016, Local Water Management Strategy-Lots 611, 615 and 487 Arnold Road, Serpentine.

CDP Town Planning & Urban Design 2020, Concept Plan.

Coterra Environment 2017, Lots 102 to 106 Rudall Street, Serpentine: townsite Flood modelling-summary of result (Rev 2).

Coterra Environment 2019, Arnold Road Flood Modelling Redesign.

Department of Biodiversity, Conservation and Attractions (DBCA) 2020, Geomorphic Wetlands, Swan Coastal Plain (DBCA-019).

Department of Health (DoH) 2015, Code of practice for the Design, Manufacture, Installation and Operation of Aerobic Treatment Units (ATU's), Perth.

Department of Health (DoH) 2019a, Guidance on Site-and-soil evaluation for on-site sewage management, Perth.

Department of Health (DoH) 2019b, Supplement to Regulation 29 and Schedule 9 - Wastewater system loading rates.

Douglas Partners 2020, Report on Geotechnical Investigation, Proposed Residential Development Lots 487, 611 & 615 Arnold Road, Serpentine WA, Revision 0.

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Emerge Associates 2020, Environmental Assessment and Management Strategy, EP20-020(01)--003B BRB EAMS.

Jordan, J. E. 1986, Serpentine Part Sheets 2033 II and 2133 III, Perth Metropolitan Region, Environmental Geology Series. Geological Survey of Western Australia, Perth.

McGrath, T., Shishkina, N., Theobald, R. and Rodriguez, C. 2015, Review of the Regulatory Requirements for the Maintenance of Aerobic Treatment Units and Greywater Treatment Systems in Western Australia.

RPS 2020, Lots 611, 615 and 487 Arnold Road, Serpentine - Addendum to the Local Water Management Strategy

Standards Australia and Standards New Zealand 2012, AS/NZS 1547:2012 On-site domestic wastewater management, Sydney, New South Wales. 2012.

van Gool, D. 1990, Land resources in the northern section of the Peel-Harvey catchment, Swan Coastal Plain, Western Australia Map, Department of Agriculture and Food, Western Australia.

6.2 Online references

Department of Health (DoH) 2020, *Approved secondary treatment systems*, last updated 10/07/2020, available from <https://ww2.health.wa.gov.au/Articles/A_E/Approved-Secondary-Treatment-Systems>

Department of Planning, Lands and Heritage (DPLH) 2020, *Government Sewerage Policy (2019)*, last updated 20/07/2020, available from <https://www.dplh.wa.gov.au/government-sewerage-policy>

Department of Water and Environmental Regulation (DWER) 2020, *Public drinking water source area mapping tool*, viewed November 2020, <https://www.water.wa.gov.au/maps-and-data/maps/public-drinking-water-source-area-mapping-tool>

Figures

Figure 1: Site Location and Topography.

Figure 2: Geology and Soils.

Figure 3: Acid Sulfate Soils risk mapping.

Figure 4: Sewage Sensitive Areas.

Figure 5: Geomorphic Wetlands.

Figure 6: Groundwater and Surface Water Features.

Figure 7: Structure Plan Response to Environmental Attributes.

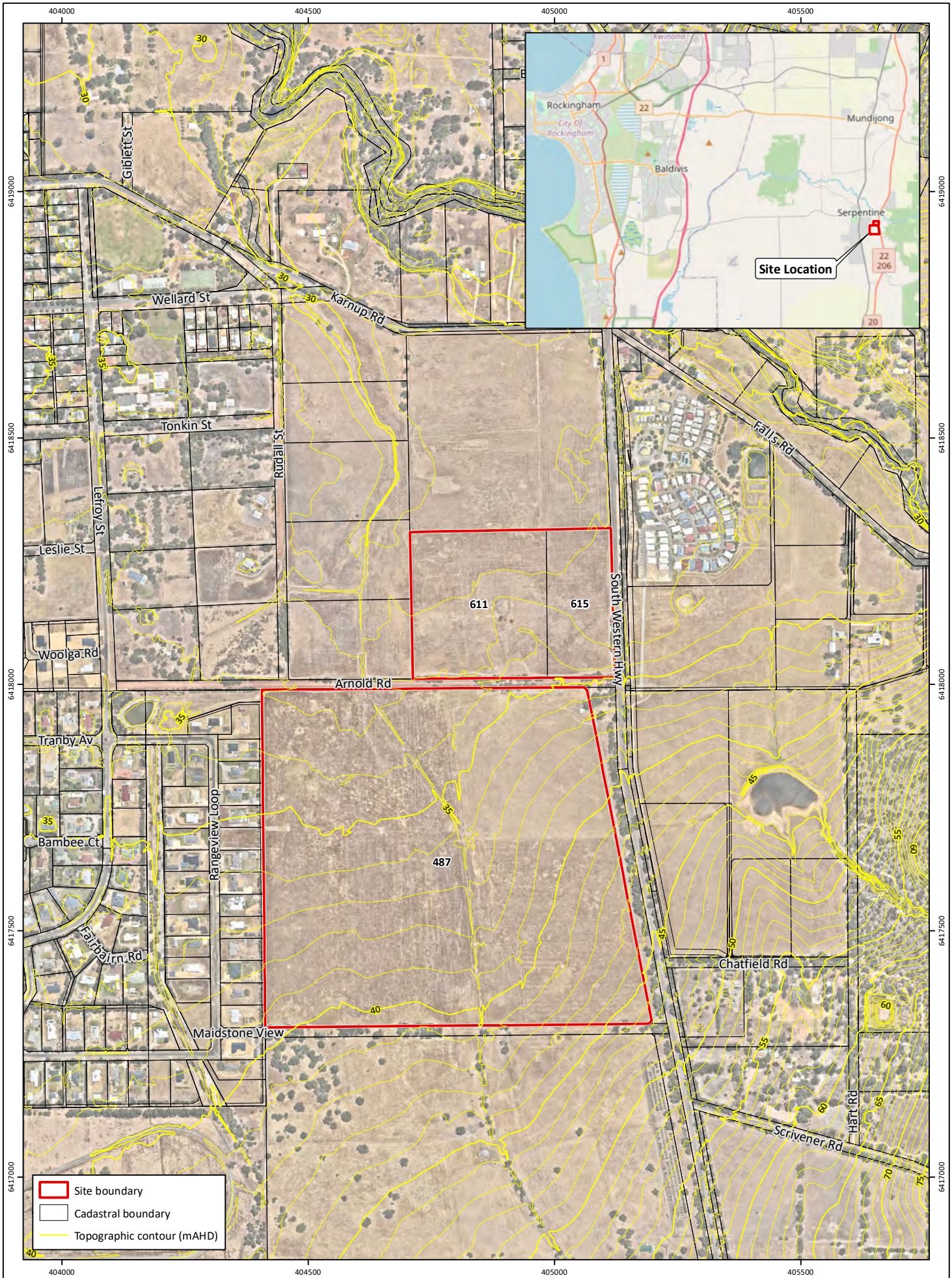

Figure 1: Site Location and Topography

Project:	Site and Soil Evaluation Lots 487, 611 & 615 Arnold Rd, Serpentine
Client:	MALF Corp Pty Ltd

Plan Number: EP20-020(04)--F20

Drawn:	GAR
Date:	08/01/2021
Checked:	FMH
Approved:	DPC
Date:	20/01/2021

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GDA 1994 MGA Zone 50

emerge ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used

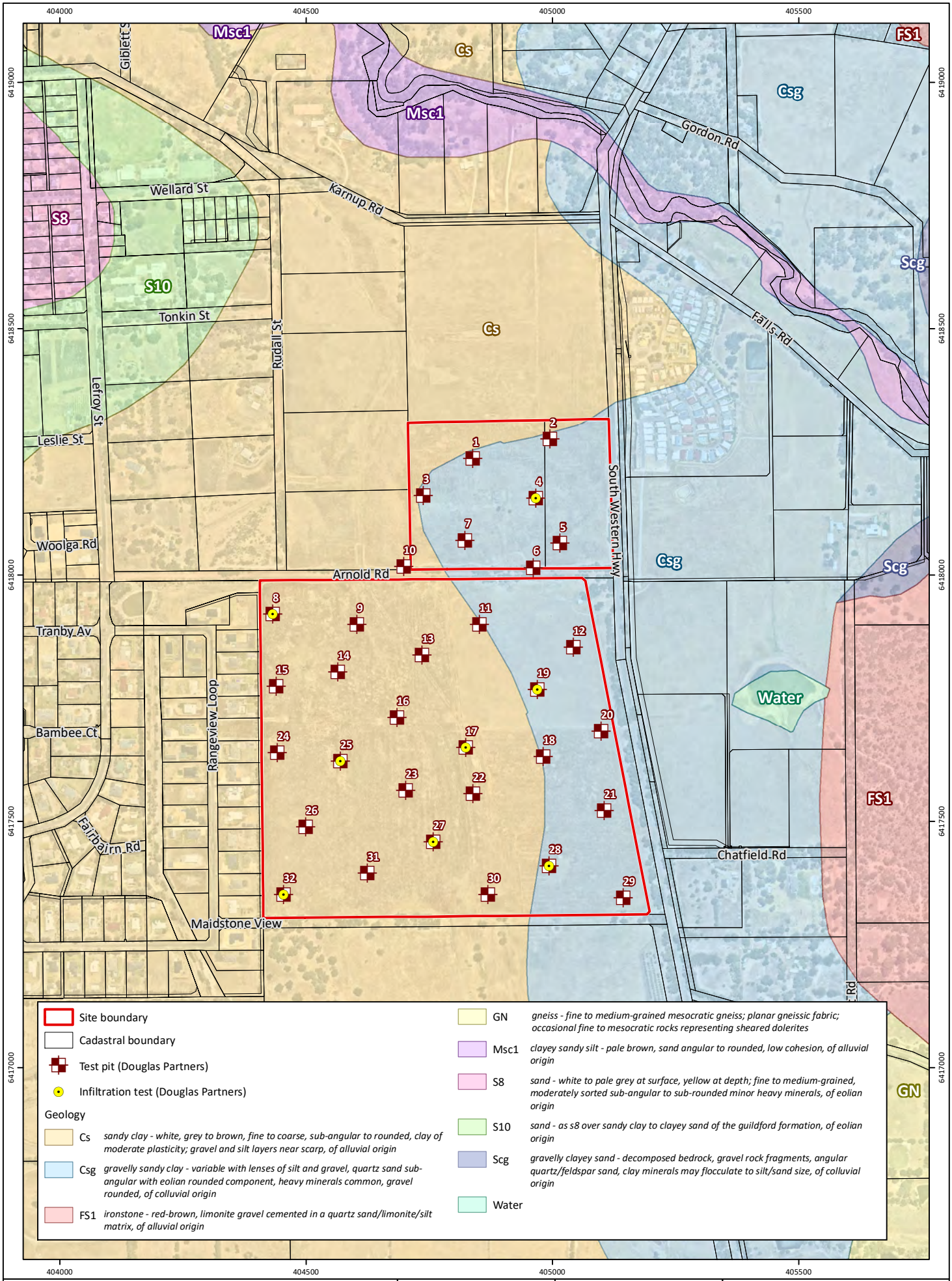

Figure 2: Geology and Soils

Project: Site and Soil Evaluation
Lots 487, 611 & 615 Arnold Rd, Serpentine
Client: MALF Corp Pty Ltd

Plan Number: EP20-020(04)--F21
Drawn: GAR
Date: 08/01/2021
Checked: FMH
Approved: DPC
Date: 20/01/2021

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emerge ASSOCIATES

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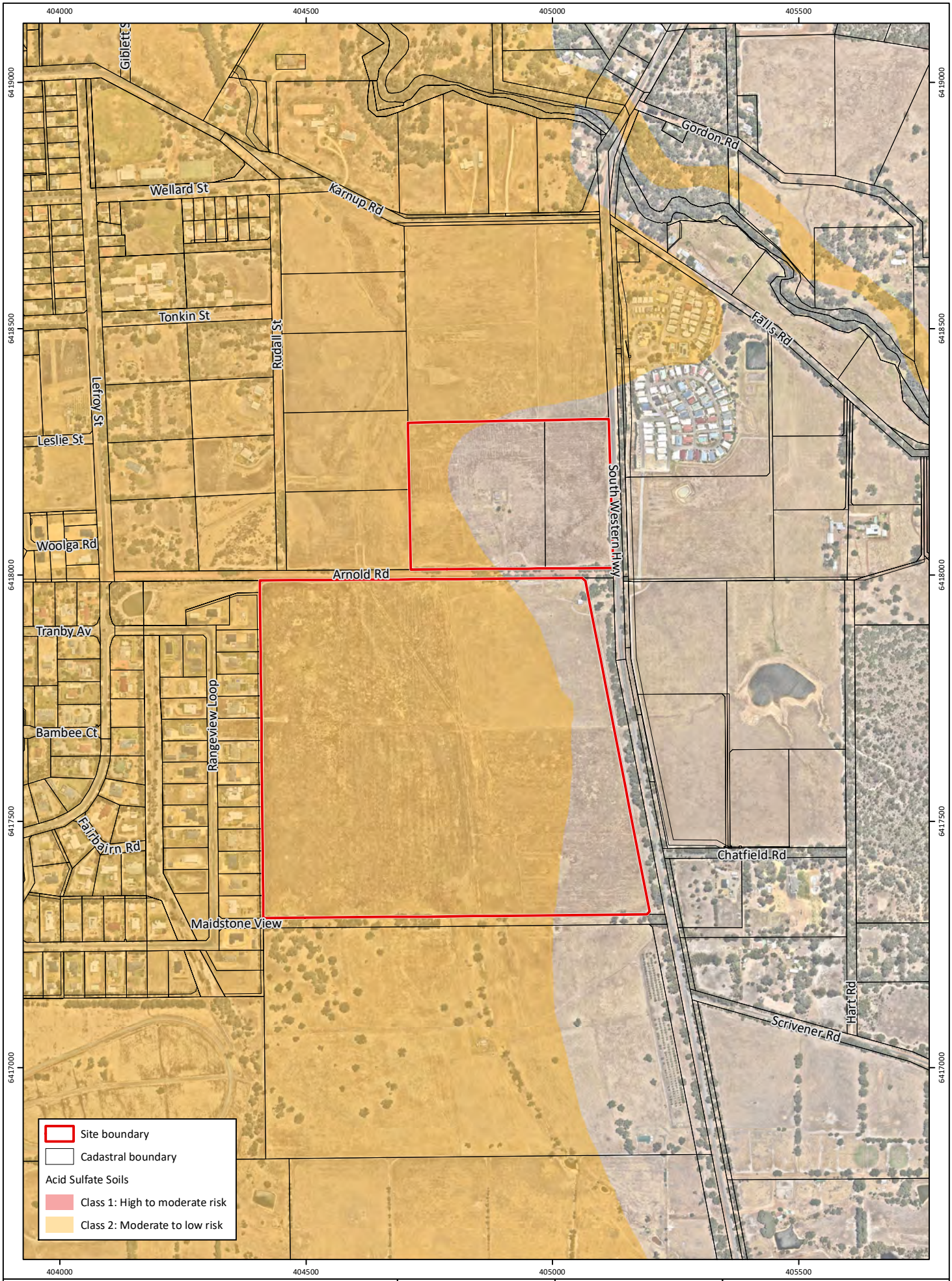

Figure 3: Acid Sulfate Soil Mapping

Project:	Site and Soil Evaluation Lots 487, 611 & 615 Arnold Rd, Serpentine
Client:	MALF Corp Pty Ltd

Plan Number:
EP20-020(04)--F22

Drawn:	GAR
Date:	08/01/2021
Checked:	FMH
Approved:	DPC
Date:	20/01/2021

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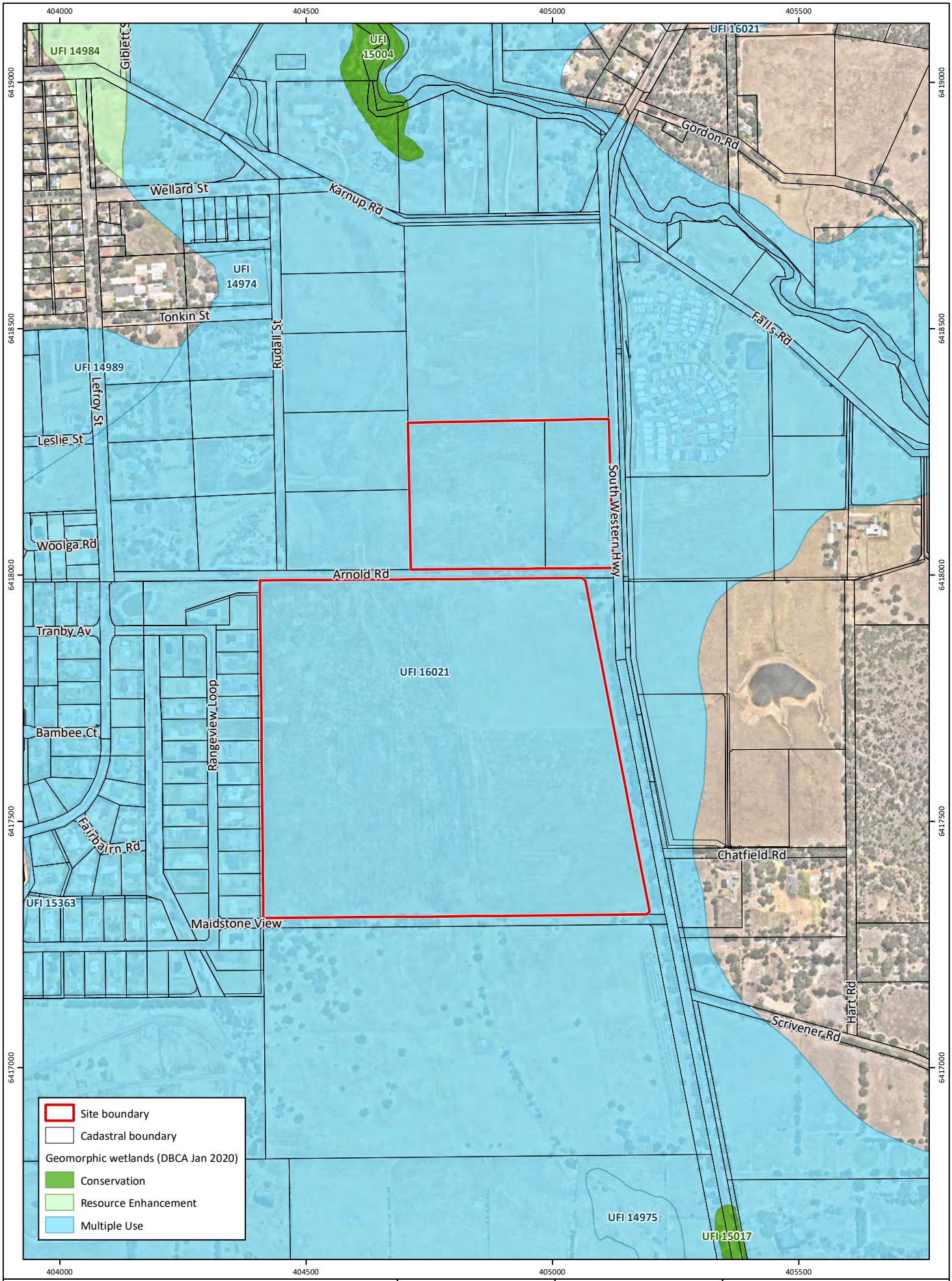

Figure 4: Geomorphic Wetlands

Project: Site and Soil Evaluation
Lots 487, 611 & 615 Arnold Rd, Serpentine
Client: MALF Corp Pty Ltd

Plan Number:
EP20-020(04)--F24

Drawn:	GAR
Date:	08/01/2021
Checked:	FMH
Approved:	DPC
Date:	20/01/2021

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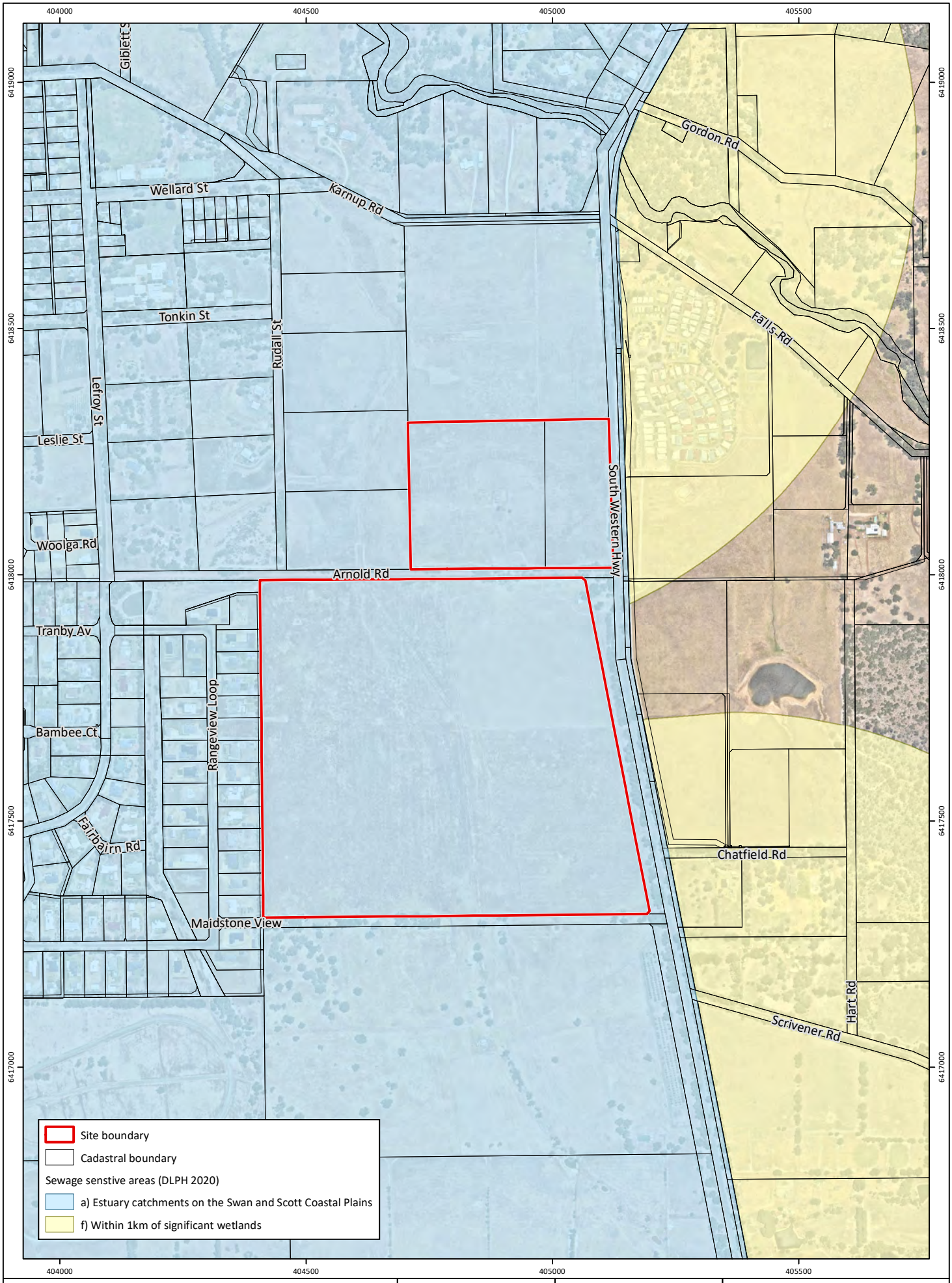

Figure 5: Sewage Sensitive Areas

Project: Site and Soil Evaluation
Lots 487, 611 & 615 Arnold Rd, Serpentine
Client: MALF Corp Pty Ltd

Plan Number:
EP20-020(04)--F23

Drawn:	GAR
Date:	08/01/2021
Checked:	FMH
Approved:	DPC
Date:	20/01/2021

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GDA 1994 MGA Zone 50

emerge ASSOCIATES

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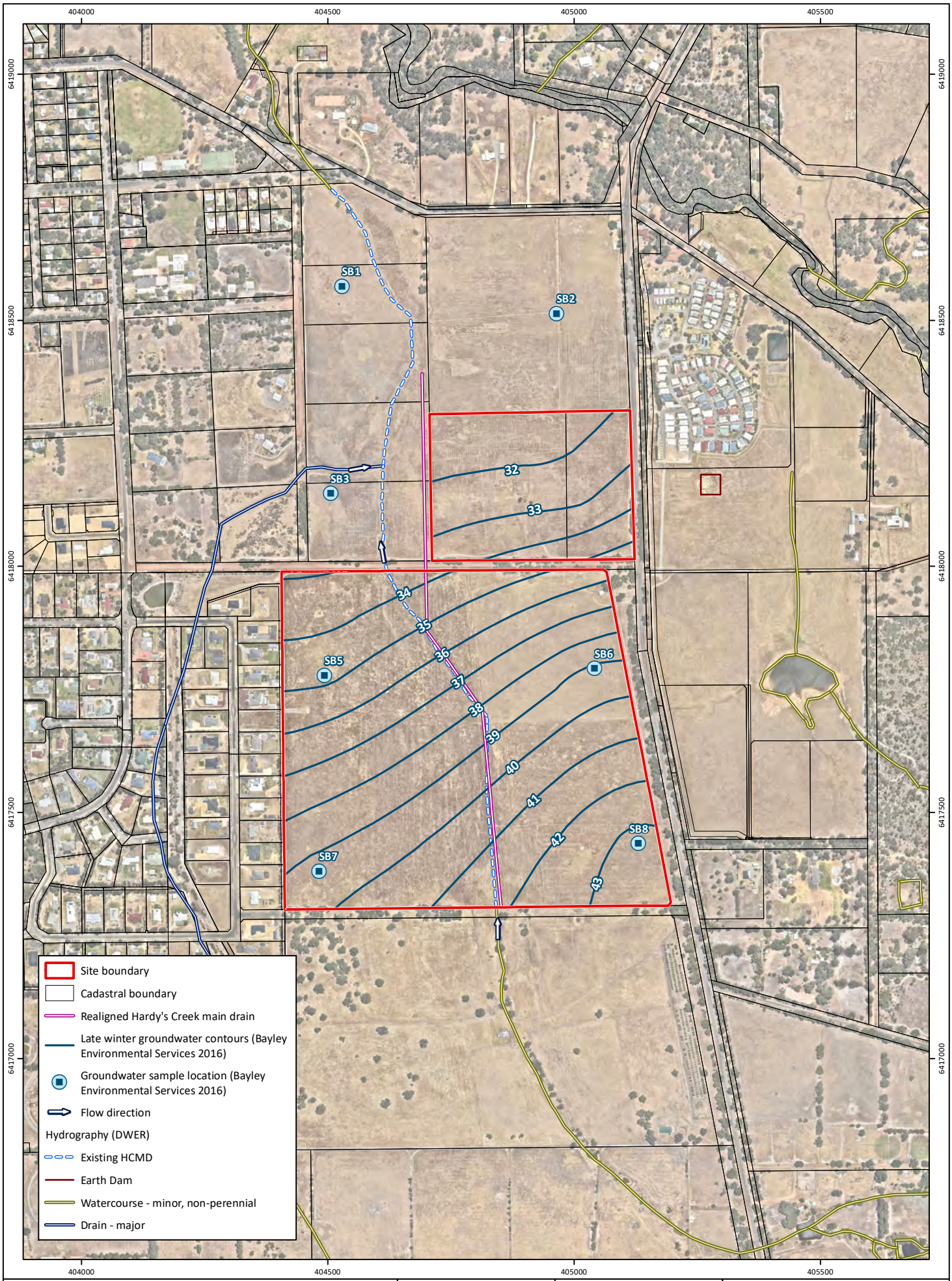

Figure 6: Groundwater and Surface Water Features

Project: Site and Soil Evaluation
Lots 487, 611 & 615 Arnold Rd, Serpentine
Client: MALF Corp Pty Ltd

Plan Number:
EP20-020(04)--F25

Drawn:	GAR
Date:	08/01/2021
Checked:	FMH
Approved:	DPC
Date:	20/01/2021

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GDA 1994 MGA Zone 50

emerge ASSOCIATES

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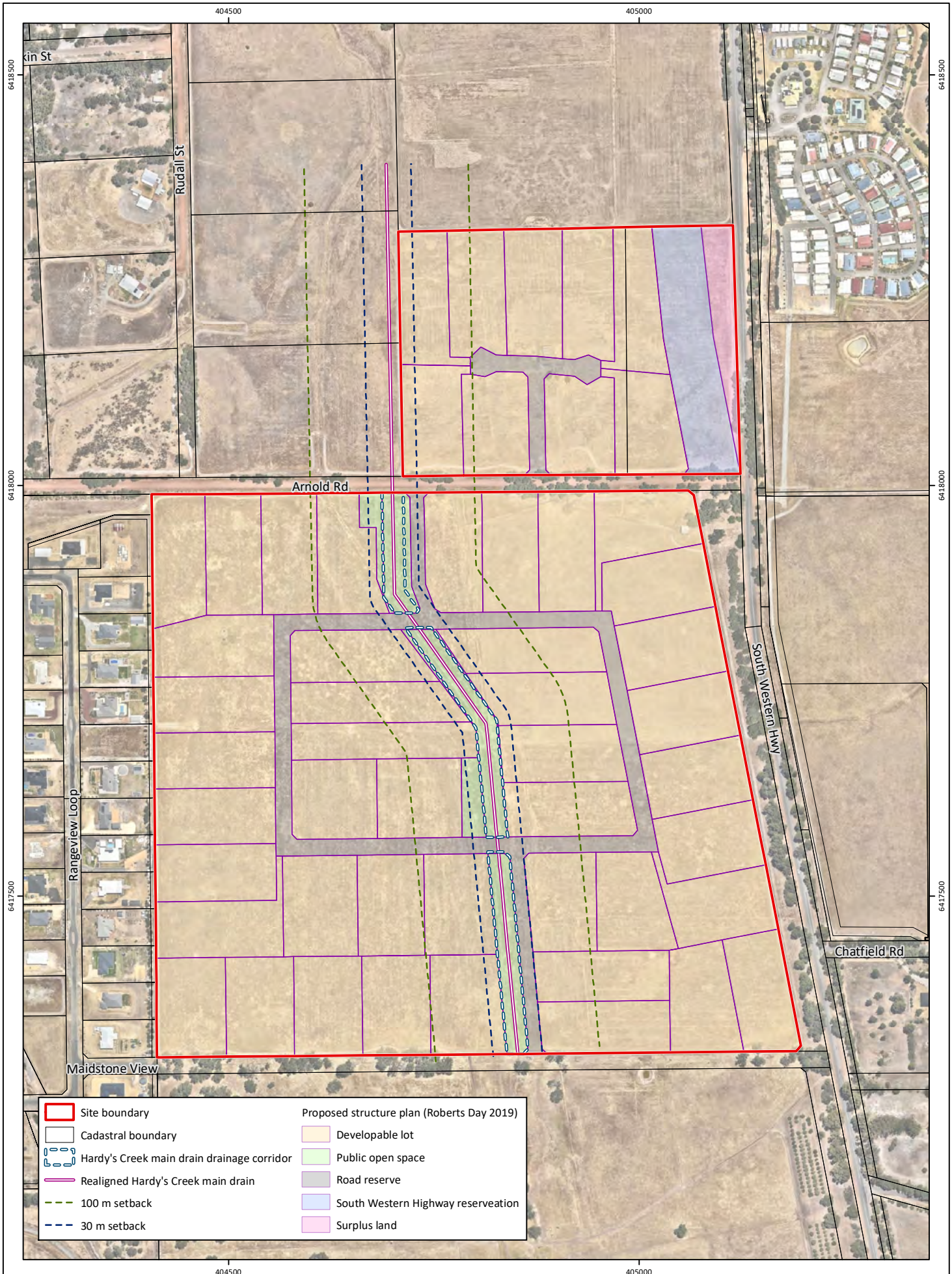

Figure 7: **Structure Plan Response to Environmental Attributes**

Project: Site and Soil Evaluation
Lots 487, 611 & 615 Arnold Rd, Serpentine
Client: MALF Corp Pty Ltd

Plan Number: EP20-020(04)--F26
Drawn: GAR
Date: 08/01/2021
Checked: FMH
Approved: DPC
Date: 20/01/2021

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Metres
Scale: 1:6,000@A4
GDA 1994 MGA Zone 50

emerge ASSOCIATES

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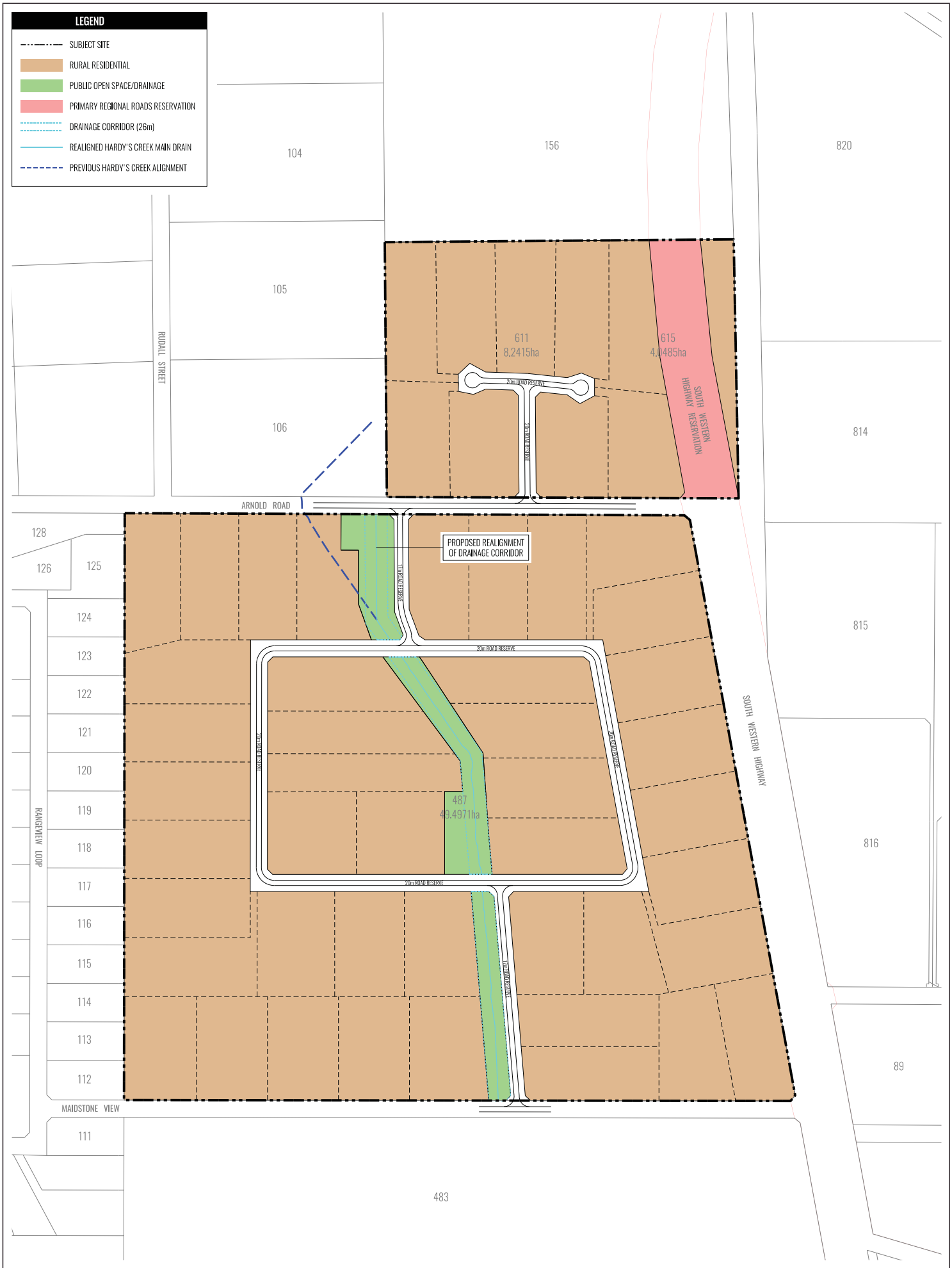
Appendix A

Proposed Structure Plan

CDP Town Planning & Urban Design



CONCEPT PLAN

Lots 487, 611 & 615 Arnold Rd, SERPENTINE

A Malf Corp Pty Ltd. Project

NORTH

Scale: 1:4000 @ A3

0 40 80 120m

PLAN: MALAR-5-001A REVISION: A

DATE: 21/07/2020 DRAWN: JDP

PROJECTION: PCG 94 PLANNER: MT

DATUM: AHD CHECK: KB

cdp Town Planning & Urban Design

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Perth WA 6000
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