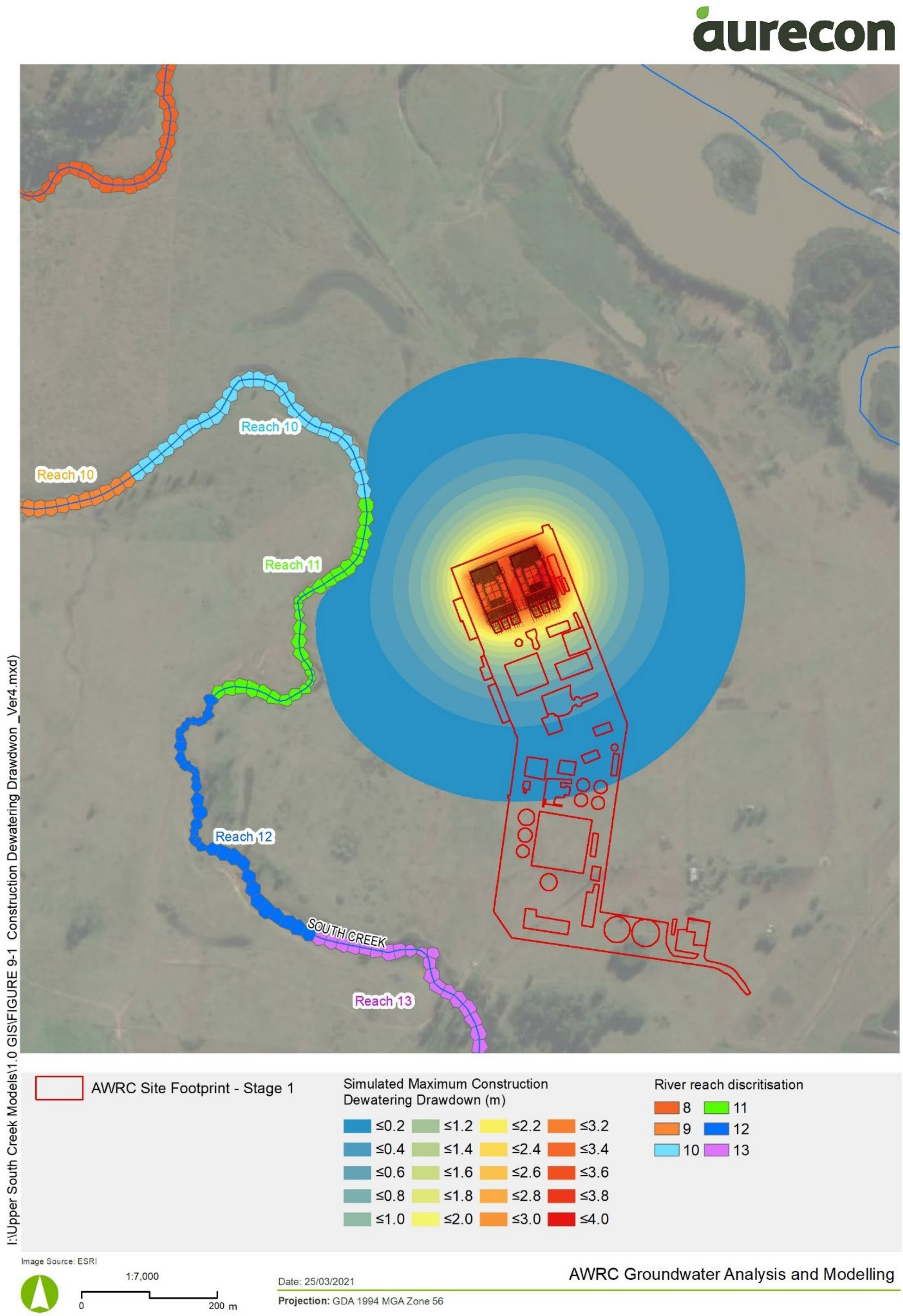


Figure 7-1 Simulated construction dewatering drawdown (Cone of depression extent)

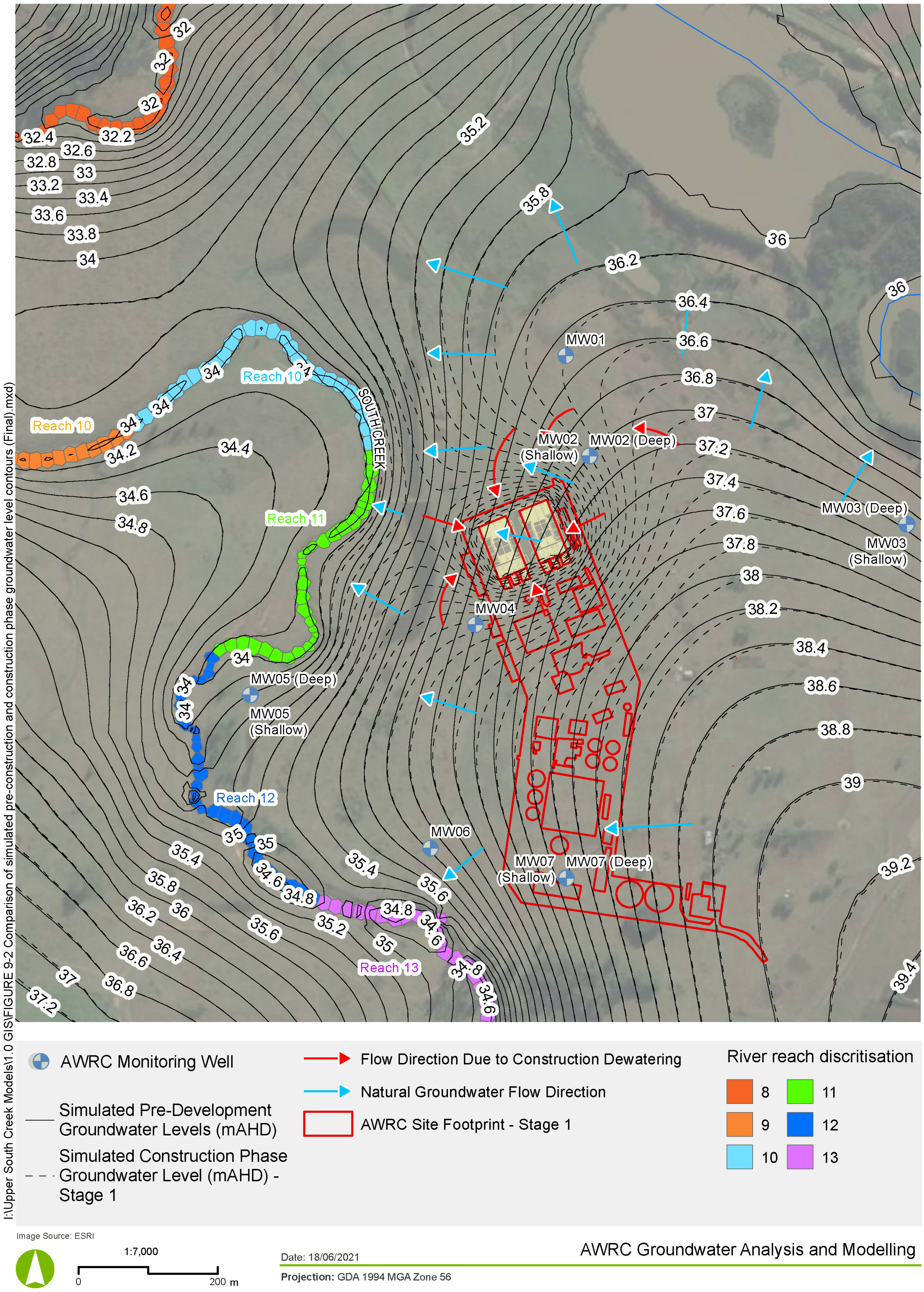


Figure 7-2 Comparison of simulated pre-construction and construction phase groundwater level contours

7.1.2 Operational phase

Underdrainage systems

Potential impact assessed in this section: Induced drawdowns from any underdrainage systems employed for underground structure floatation management, temporarily intercepting groundwater for GDEs and surrounding groundwater users.

Ongoing operational activities at the AWRC site have the potential to impact on groundwater levels in a range of ways.

The underdrainage systems employed for underground structure flotation management have the potential to impact on groundwater levels. Diffuser replacement (nominally every 5 years) would require emptying of bioreactors, causing a reduction in dead load. Groundwater may need to be dewatered to reduce buoyancy and negate potential floatation forces on the structure. This would be achieved through pumping of the subsoil drainage system, which may induce drawdown and locally lower the groundwater table. The inflow volumes from the underdrainage systems are expected to be relatively low and discontinuous (e.g. may only be required for the duration of specific maintenance activities).

The dewatering which will be required for maintenance purposes was also assessed via predictive numerical modelling (detailed provided in **Appendix A**). The modelling results indicate that during operation of underdrainage systems at the bioreactors, water levels in the aquifer will reach equilibrium in about 5 days, with inflows stabilising (i.e. maintaining a relatively constant inflow rate) at about 40 L/min (0.66 L/s). Note that initial inflows associated with draining the pore spaces will be relatively high (averaging 1,900 L/min (31 L/s)). The simulated average inflow rate is 50 L/min (3 m^3/hr). Estimates of the total volume expected to be pumped for each maintenance regime should be assessed based on this average flow. For example, for a 5-day maintenance period the total volume is estimated to be around 0.4 ML. The modelling assumed that the head (water level) in the aquifer will be lowered to 35.6 mAHD just below the base of the bioreactor tank floor slab.

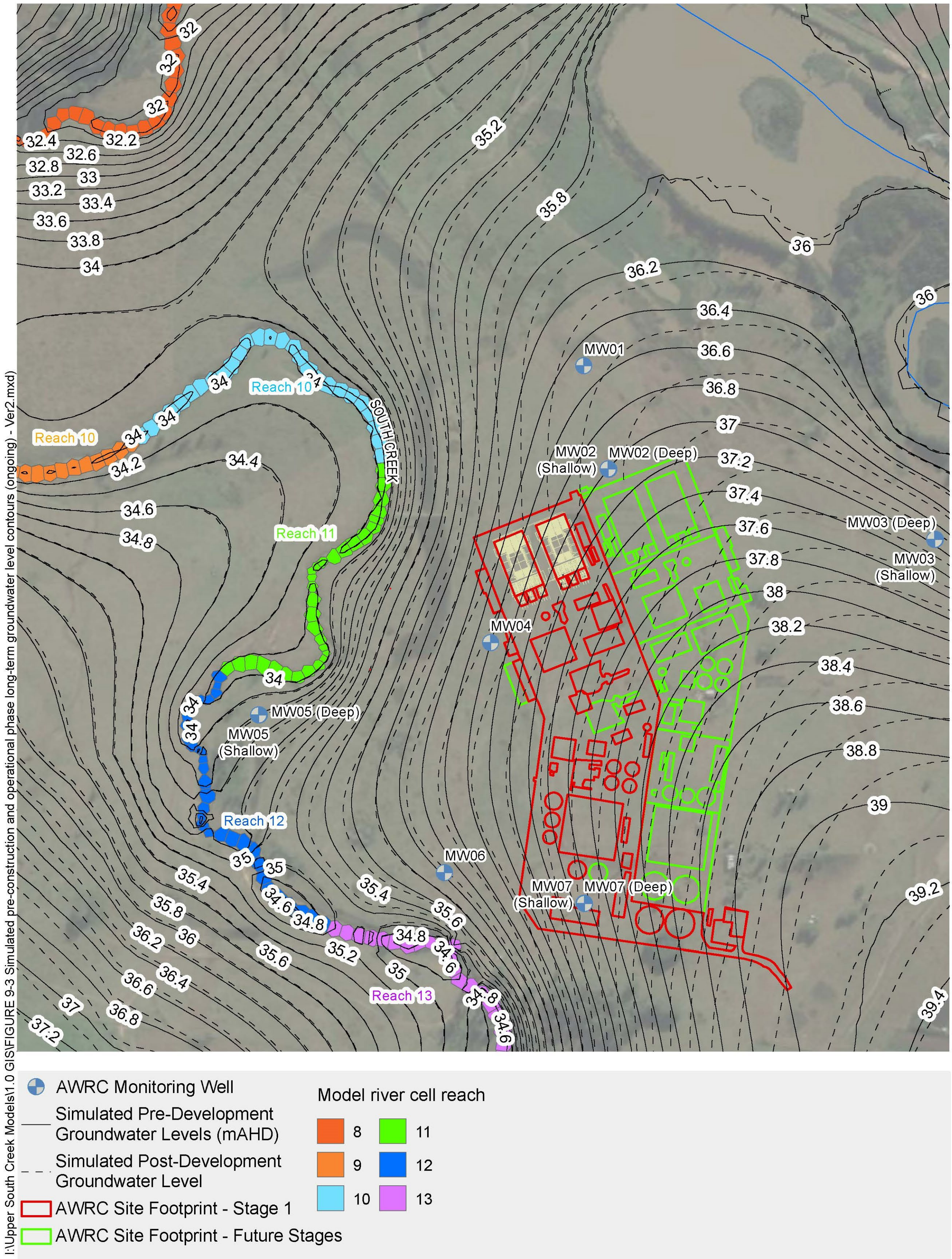
The extent of the drawdown is expected to be localised and the Level 1 minimal groundwater level/availability impact considerations are not expected to be exceeded. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered to be acceptable

An approach to manage the extracted groundwater would need to be developed and implemented through an appropriate dewatering management plan. Depending on extracted groundwater quality, treatment may be required to meet the applicable water quality criteria, prior to discharge (e.g. to a receiving surface water body). Further discussion on the management options for extracted groundwater is provided in **Section 8.2**.

The long-term potential impacts associated with the AWRC features would be due to localised reduction in groundwater recharge / infiltration due to impervious surfaces created at the site, which will lead to a local depression and long-term reduction in groundwater levels at the AWRC site occurring during operation. Predictive numerical modelling (detailed provided in **Appendix A**) indicate a corresponding minor reduction (approximately 1%) of baseflow in the creek reaches adjacent to the site. However, the strategy for stormwater management at the AWRC site is intended to re-create the pre-development environmental water balance by offsetting the lost recharge (due to the impermeable surfaces) through increasing post-construction recharge via detention basins and local irrigation. If this is achieved, it follows that the effects of the long-term impact on the local water balance would be minimal. More details regarding the AWRC stormwater strategy are provided in the USC Surface Water Impact Assessment Report (Aurecon Arup, 2021).

A comparison of pre-development groundwater levels and post-construction long term groundwater levels (i.e. during operational phase) is shown in **Figure 7-3** below. The predicted groundwater change in groundwater levels are within the range of acceptability defined by the NSW Aquifer Interference Policy (outlined in **Section 2.3**) in relation to the aquatic ecosystems (South Creek). Therefore, this is not expected to prevent the long-term viability of surrounding water-related assets and is considered acceptable. Climate change influences during future stages are not expected to exacerbate the impact, as the reduction in baseflow will be negligible in comparison to the predicted increase in surface water runoff.

The proposed monitoring, triggers and actions to address potential impacts during operation identical to those outlined in the previous section, with an overview provided in **Section 10**.



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Projection: GDA 1994 MGA Zone 56

AWRC Groundwater Analysis and Modelling

Figure 7-3 Simulated pre-construction and operational phase long-term groundwater level contours (ongoing)

Stormwater Irrigation

Potential impact addressed in this section: Increased groundwater recharge from stormwater irrigation at the AWRC site, leading to increased water levels of saline aquifer.

The Low Flow and Stormwater Study (as documented in the Surface Water Impact Assessment report (Aurecon Arup, 2021)) proposes harvesting stormwater from the ARWC site for irrigation application of the adjacent regional park as a means of contributing to the regional Waterway Health (flow) targets. The irrigation rate proposed will strike a balance between retaining stormwater in the catchment, providing for a quality regional park, and preventing salinification of groundwater by avoiding excessive infiltration of water into soils.

Proposed landscape planting across the adjacent regional park will comprise a mix of turf and native species giving a high-quality landscape character. The proposed irrigation rate (4.5 ML/Ha/yr) makes up the local rainfall deficit or shortfall between rainfall (approximately 700 mm/yr) and potential evapotranspiration (approximately 1200 mm/yr). Through controlled irrigation which avoids watering saturated soils and areas of no vegetation cover, the risk of increased groundwater recharge beneath the park and irrigated zones will be low.

Soil salinity mapping of the desktop assessment area (outlined in **Section 4.6.2**) and supplementary soil salinity testing as part of the *Soils and Contamination Impact Assessment* report, indicate that soil across the AWRC site exhibit non saline properties near surface. In several instances the sampling indicates a vertical salinity profile of saline to moderately saline soils within the 1 to 3 m below ground depths and this salinity profile is expected to increase at depth within nearing the water table.

The proposed controlled irrigation rate on low saline soils is therefore considered to have a combined low risk of salinity impacts on soils and underlying groundwater table.

7.2 Pipelines

7.2.1 Construction phase

Trenched Pipeline construction dewatering and groundwater management

Potential impact assessed in this section: Induced drawdowns from required dewatering activities, reducing the availability of groundwater for GDEs and surrounding groundwater users.

During trenched pipeline construction, groundwater is likely to be encountered during excavations where the pipeline invert depth intersects the groundwater table. Where this occurs, construction dewatering would be required to provide a stable platform for the construction of the pipelines.

To assess the significance of these impacts, likely groundwater inflow rates and the extents of induced groundwater drawdowns were calculated using analytical equations derived from Darcy's law (further detail provided in **Section 3.3.1**).

As groundwater conditions are expected to vary across the extent of the pipelines, the reference design alignment was divided into discrete sections based on "Hydrogeological Landscapes" (described in **Section 4.5**) to provide realistic inputs to the analytical calculations. For each section, reference design features and expected hydrogeological properties were collated to form the basis of the analytical calculations.

Analytical results for each section where then assessed in relation to surrounding GDEs and groundwater users and compared against the minimal groundwater level/availability impact criteria outlined in **Section 2.3**. The following sections detail the findings of each pipeline section, with summary/overview of all analytical results provided in **Table 7-13**.

7.2.1.1 Environmental Flows Pipeline

Environmental Flows Section 1: Mid-Nepean Hydrogeological Landscape

A summary of the reference design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-1**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-4**.

Table 7-1 Reference Design Features & Groundwater Conditions – E-Flows Section 1: Mid-Nepean HGL

Design Feature	Description		
Pipeline	Environmental Flows		
Trenched Length	1850 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	26 days (three crews operating simultaneously)		
Trenchless Length	0 m		
Approximate Pipeline Invert Depth (mBGL)	Min	Mean	Max
	2.0	3.2	5.7
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Nepean River (approx. 200 m distance)		
Hydrogeological Landscape	Mid-Nepean River		
Water Quality	Land salinity is low, groundwater is generally fresh (EC between 0.8-1.6 dS/m).		
Intersected Geology	Formation	Period	Lithology
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	Min	Mean	Max
	0	4	8
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.017	0.5	1.287
Storage Properties (Specific Yield)	Min	Mean	Max

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 17.1 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 238.8 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day, this equates to total groundwater inflows of 1,335.4 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest) with a high level of interaction with groundwater.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in Section 2.3), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to adversely impact the long-term health of the affected ecosystems and are considered acceptable.

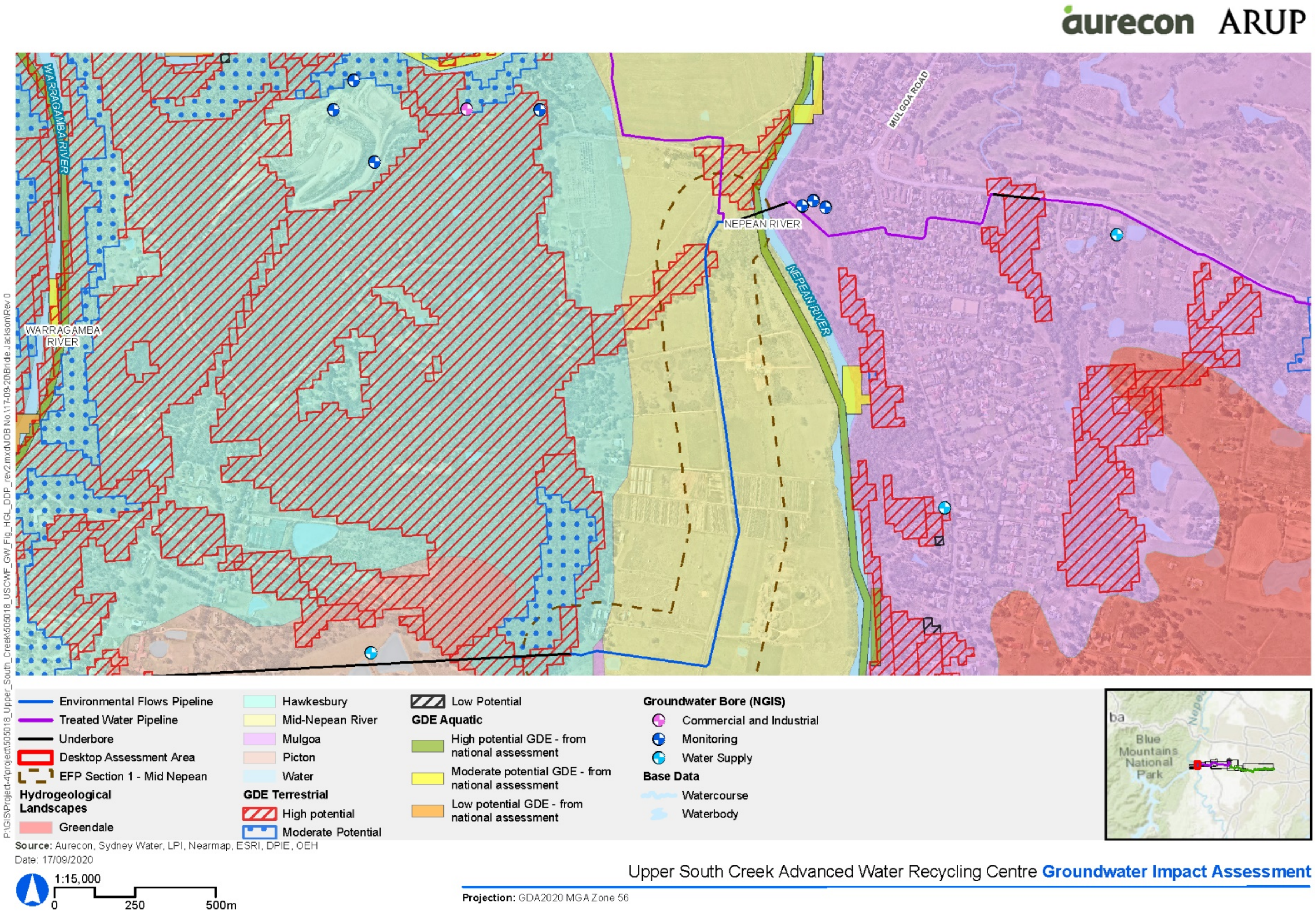

Figure 7-4 Environmental Flows Section 1: Mid-Nepean HGL

Environmental Flows 2: Hawkesbury Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-2**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-5.**

Table 7-2 Design Features & Groundwater Conditions – E-flows Section 2: Hawkesbury HGL

Design Feature	Description		
Pipeline	Environmental Flows		
Trenched Length	0 m		
Trenchless Length	2600 m		
Approximate Pipeline Invert Depth (mBGL)	Min	Mean	Max
	1.4	55	110
Groundwater Conditions	Description		
Most Relevant Constant Head Boundary(s)	Nepean River (approx. 800 m distance), Warragamba River (approx. 50 m distance)		
Hydrogeological Landscape	Hawkesbury (note: Picton HGL is considered less relevant due to the depth profile of the HDD alignment)		
Water Quality	Land salinity is low, groundwater is generally fresh (EC less than 0.8 dS/m).		
Intersected Geology	Formation	Period	Lithology
	Hawkesbury Sandstone	Mid-Triassic	Medium to very coarse-grained quartz sandstone, minor laminated mudstone and siltstone leases
Groundwater Depths (mbgl)	Min	Mean	Max
	8	N/A	N/A
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.01	0.2	0.5
Storage Properties (Specific Yield)	Min	Mean	Max
	0.05	1.5	0.3

Numerous ecosystems, both aquatic (Warragamba River) and terrestrial (Coastal Sandstone Ridgetop Woodland, Sydney Hinterland Transition Woodland, Cumberland Shale Sandstone Transition Forest, Hinterland Sandstone Gully Forest and Sydney Hinterland Transition Woodland), with a moderate to high level of interaction with groundwater are present.

A single registered water supply bore (private property off Silverdale Rd, Wallacia) is present in the vicinity of this pipeline section. Information on this water supply bore gathered from the landowner (discussed in **Section 4.7**) indicates that there is no significant aquifer present at the depth and location of the proposed HDD alignment and therefore groundwater impacts associated with construction dewatering are not expected in this section. Groundwater impacts associated with HDD pipelines have been qualitatively assessed in **Sections 8** and **8.2**.

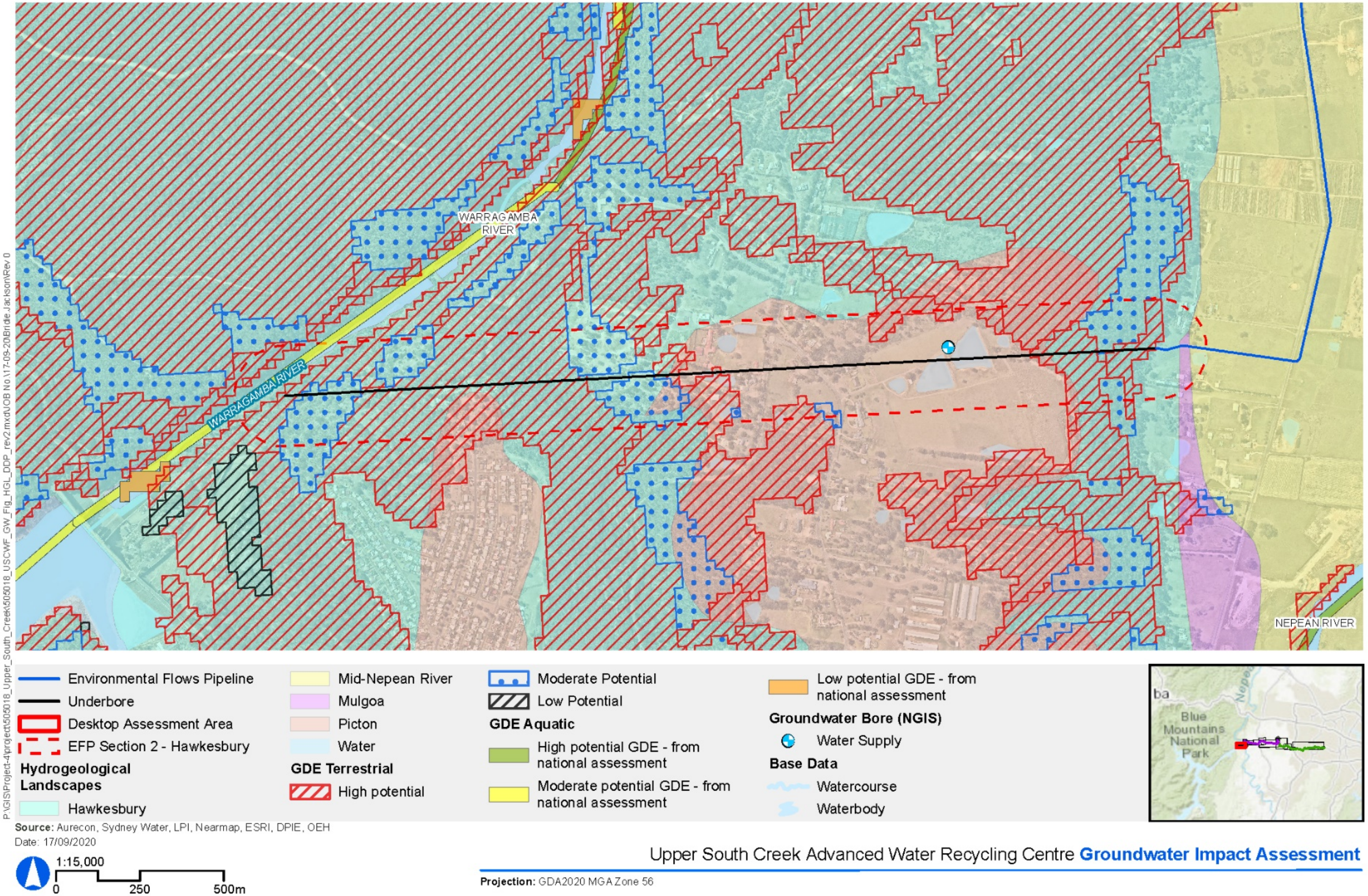

Figure 7-5 Environmental Flows Section 2: Hawkesbury HGL

7.2.1.2 Treated Water Pipeline

Treated Water Section 1: Mid-Nepean Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-3**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-6**.

Table 7-3 Design Features & Groundwater Conditions – Treated Water Section 1: Mid-Nepean HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	1,000 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	14 days (three crews operating simultaneously)		
Trenchless Length	180 m		
Approximate Pipeline Invert Depth (mBGL)*	Min	Mean	Max
	0.4	3.0	7.0
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Nepean River (approx. 120 m distance)		
Hydrogeological Landscape	Mid-Nepean River		
Water Quality	Land salinity is low, groundwater is generally fresh (EC between 0.8-1.6 dS/m).		
Intersected Geology	Formation	Period	Lithology
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	Min	Mean	Max
	0	4	8
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.017	0.5	1.287
Storage Properties (Specific Yield)	Min	Mean	Max

* Includes trenched pipeline sections only

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 13.2 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 183.5 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 552.3 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodland) with a moderate to high level of interaction with groundwater.

Impacts to the registered commercial/industrial water supply bore present approximately 230 m from this pipeline section are not expected.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in Section 2.3), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered to be acceptable.

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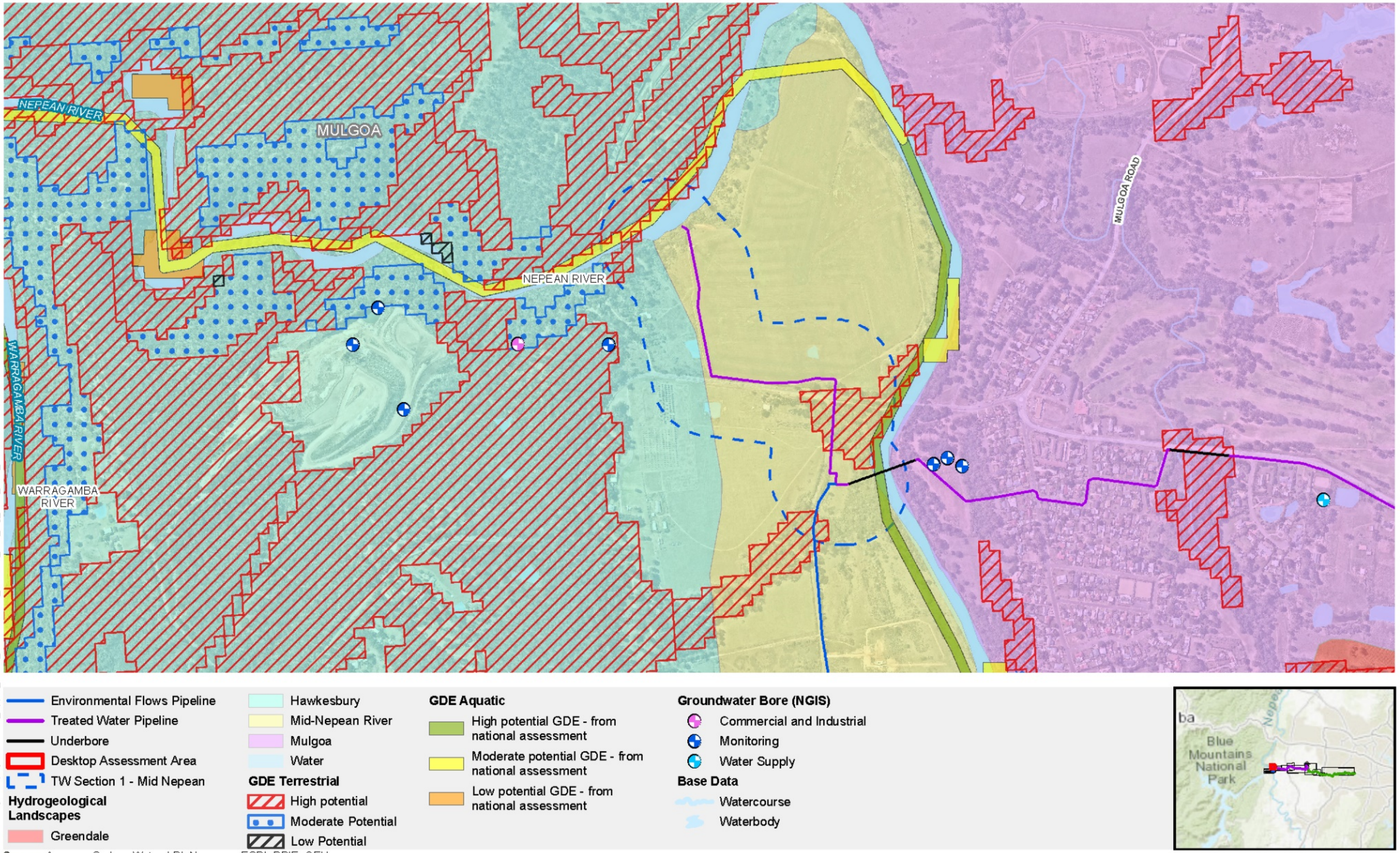

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Upper South Creek Advanced Water Recycling Centre **Groundwater Impact Assessment**

Projection: GDA2020 MGA Zone 56

Figure 7-6 Treated Water Section 1: Mid-Nepean HGL

Treated Water Section 2: Mulgoa Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-4**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-7**.

Table 7-4 Design Features & Groundwater Conditions – Treated Water Section 2: Mulgoa HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	2,800 m		
Approximate Trenched Pipe Lay Rate	18 m/day (Mixed greenfield and urban conditions, passing through Wallacia)		
Approximate Trenched Construction Duration	52 days (three crews operating simultaneously)		
Trenchless Length	150 m		
Approximate Pipeline Invert Depth (mBGL)*	Min	Mean	Max
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Nepean River (approx. 120 m distance)		
Hydrogeological Landscape	Mulgoa		
Water Quality	Land salinity is moderate, groundwater is generally brackish (EC between 1.6-4.8 dS/m)		
Intersected Geology	Formation	Period	Lithology
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	Min	Mean	Max
	2	5	8
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.017	0.5	1.287
Storage Properties (Specific Yield)	Min	Mean	Max

* Includes trenched pipeline section only

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 6.9 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 96.9 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 18 m/day per crew, this equates to total groundwater inflows of 1082.6 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodland) with a high level of interaction with groundwater.

Impacts to the registered water supply bore present approximately 70 m from this pipeline section (in a private property off Park Rd, Wallacia) are unlikely.

The predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in Section 2.3). The induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected water-dependent assets and are considered to be acceptable.

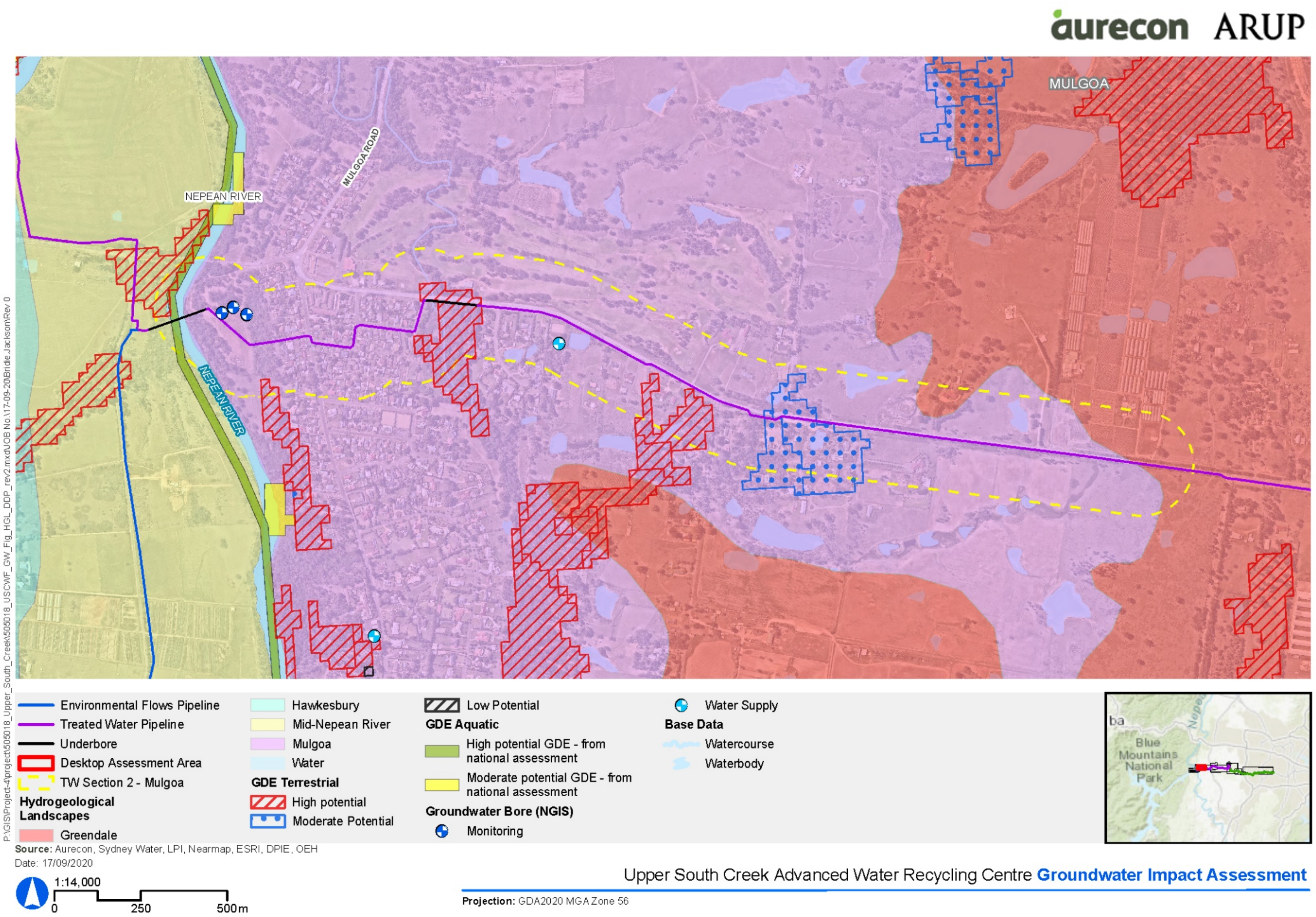


Figure 7-7 Treated Water Section 2: Mulgoa HGL

Treated Water Section 3: Greendale Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-5**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-8**.

Table 7-5 Design Features & Groundwater Conditions – Treated Water Section 3: Greendale HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	3,400 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	48 days (three crews operating simultaneously)		
Trenchless Length	120 m		
Approximate Pipeline Invert Depth (mBGL)*	Min	Mean	Max
	2.0	3.1	5.7
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Surrounding farm dams (approx. 300 m distance)		
Hydrogeological Landscape	Greendale		
Water Quality	Land salinity is moderate, groundwater is generally brackish (EC between 1.6-4.8 dS/m)		
Intersected Geology	Formation	Period	Lithology
	Residual / regolith soils associated with weathered Bringelly Shale	Middle Triassic	Residual/regolith soils associated with weathered shale, carbonaceous claystone, claystone, laminate, fine to medium-grained lithic sandstone, rare coal and tuff
Groundwater Depths (mbgl)	Min	Mean	Max
	2	4	6
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.05	0.3	0.484
Storage Properties (Specific Yield)	Min	Mean	Max
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 4.0 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 27.4 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 581.8 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting terrestrial ecosystems (Cumberland Shale Plains Woodland) with a high level of interaction with groundwater.

Impacts to the registered water supply and irrigation bores present approximately 400 m from this pipeline section are not expected.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in Section 2.3), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered to be acceptable.

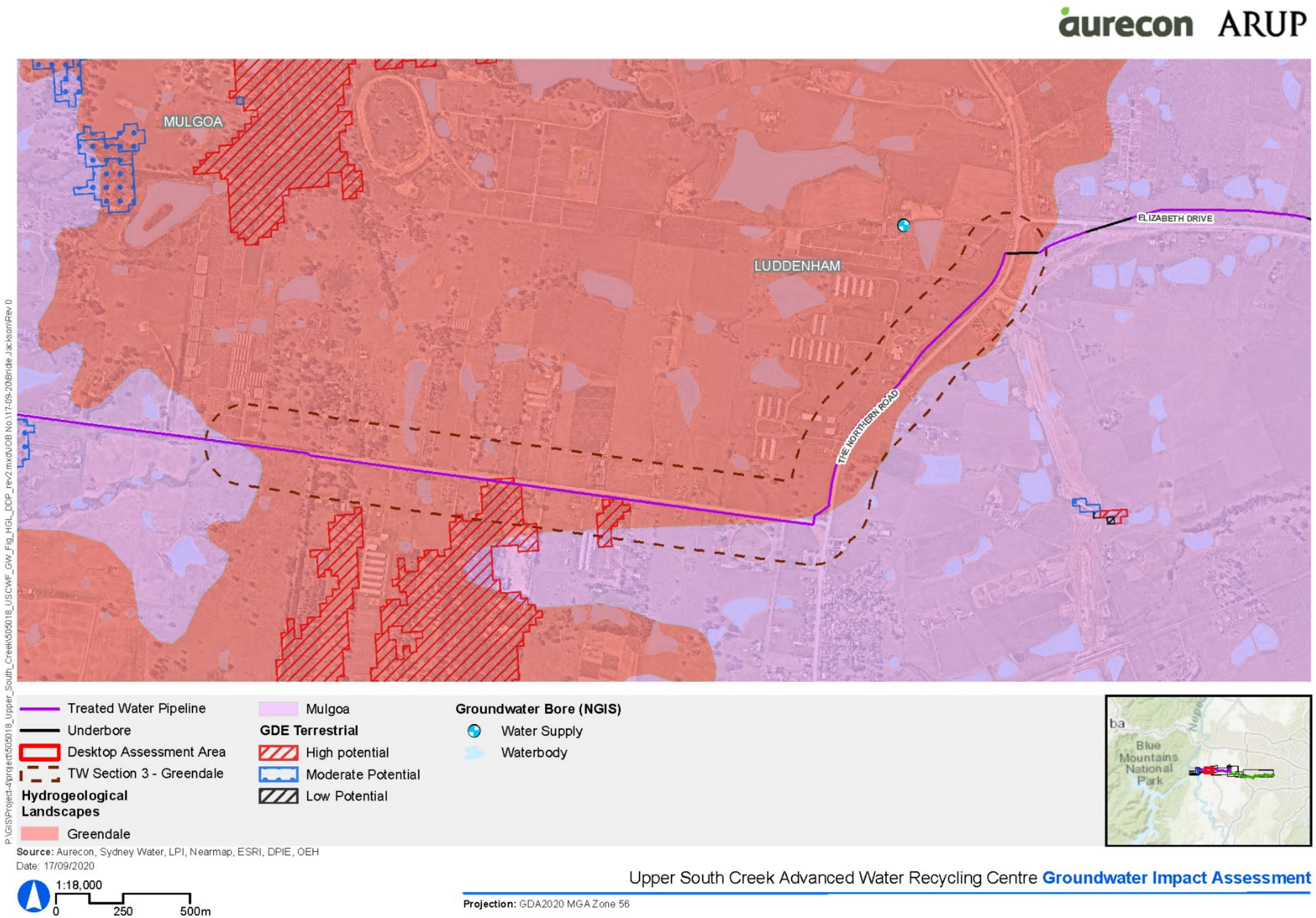


Figure 7-8 Treated Water Section 3: Greendale HGL

Treated Water Section 4: Mulgoa Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-6**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-9**.

Table 7-6 Design Features & Groundwater Conditions – Treated Water Section 4: Mulgoa HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	1,260 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	18 days (three crews operating simultaneously)		
Trenchless Length	445 m		
Approximate Pipeline Invert Depth (mBGL)*	Min	Mean	Max
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Surrounding farm dams (approx. 50 m distance)		
Hydrogeological Landscape	Mulgoa		
Water Quality	Land salinity is moderate, groundwater is generally brackish (EC between 1.6-4.8 dS/m)		
Intersected Geology	Formation	Period	Lithology
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	Min	Mean	Max
	2	5	8
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.017	0.5	1.287
Storage Properties (Specific Yield)	Min	Mean	Max
	0.1	0.15	0.2

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 5.8 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 80.5 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 311.6 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Impacts to the registered stock/domestic water supply bore present approximately 170 m from this pipeline section are not expected.

Water-dependent assets are not present in the immediate vicinity of the proposed alignment, therefore the predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in Section 2.3). The induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are considered acceptable.

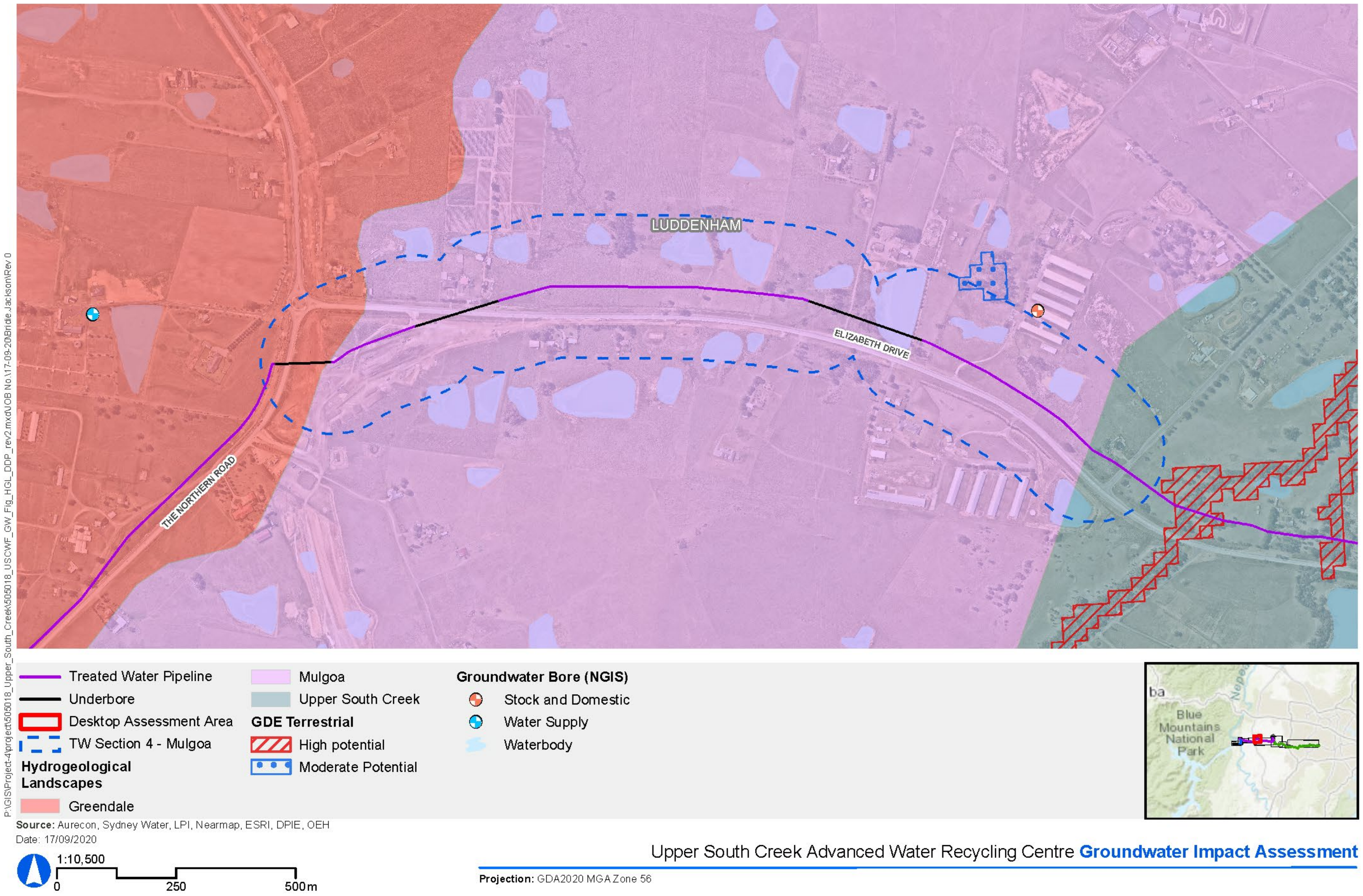


Figure 7-9 Treated Water Section 4: Mulgoa HGL

Treated Water Section 5: Upper South Creek Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-7**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-10**.

Table 7-7 Design Features & Groundwater Conditions – Treated Water Section 5: Upper South Creek HGL

Design Feature	Description		
Pipeline	Treated Water		
Trenched Length	6,250 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	87 days (three crews operating simultaneously)		
Trenchless Length	945 m		
Approximate Pipeline Invert Depth (mBGL)*	Min	Mean	Max
	2.0	2.9	6.8
Groundwater Conditions	Description		
Most Relevant Constant Head Boundary	Badgery's Creek (approx. 20 m distance)		
Hydrogeological Landscape	Mulgoa		
Water Quality	Land salinity is high, groundwater is generally saline (EC greater than 4.8 dS/m)		
Intersected Geology	Formation	Period	Lithology
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	Min	Mean	Max
	2	4	6
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.017	0.5	1.287
Storage Properties (Specific Yield)	Min	Mean	Max
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 4.7 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 65.4 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 1,224.1 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (South Creek) and terrestrial ecosystems (Cumberland Shale Plains Woodlands, Cumberland River Flat Forest, Castlereagh Ironbark Forest) with a moderate to high level of interaction with groundwater.

No registered water supply bores are present in the vicinity of this pipeline section.

The predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in Section 2.3). The induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

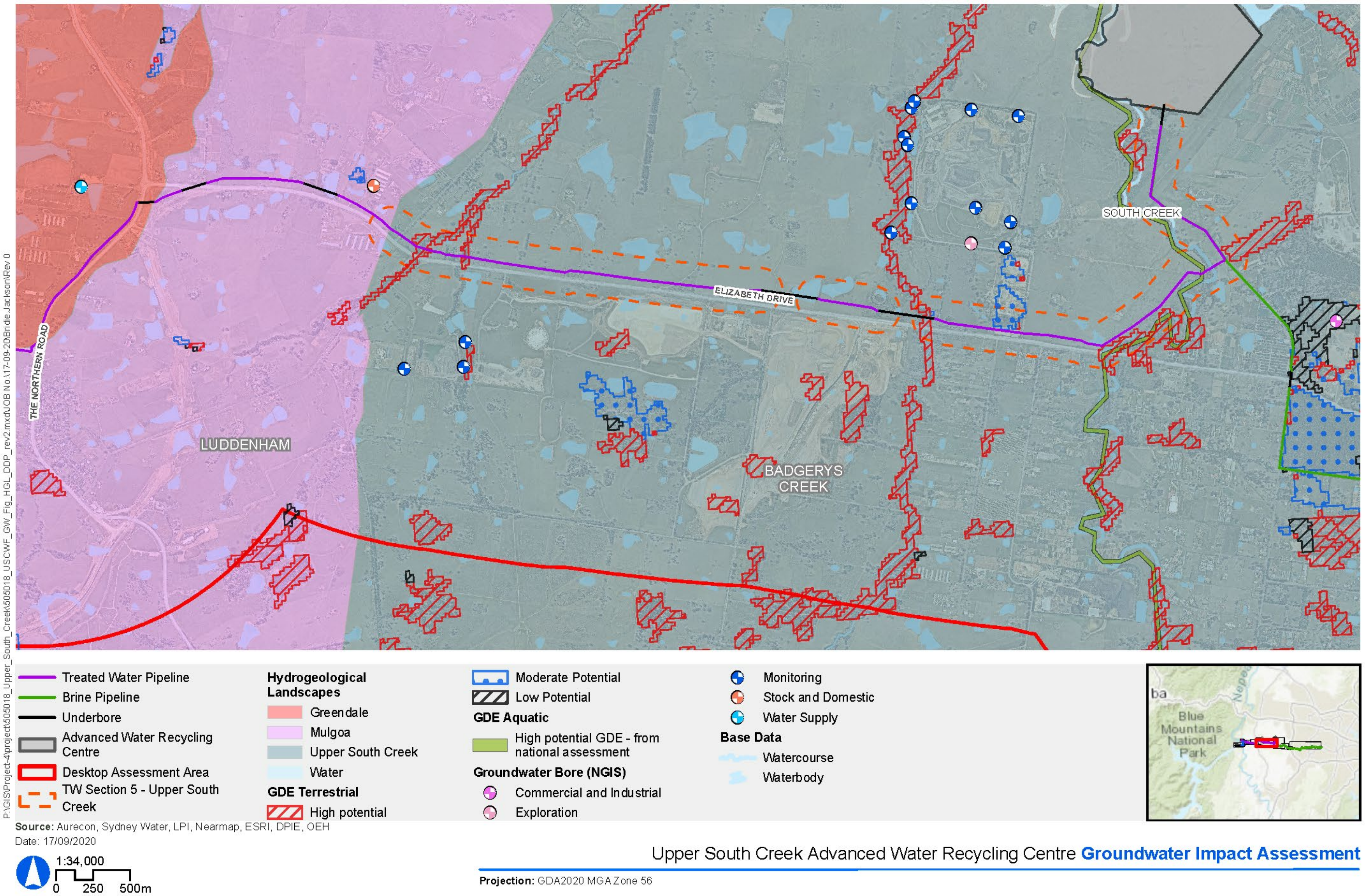


Figure 7-10 Treated Water Section 5: Upper South Creek HGL

7.2.1.3 Brine Pipeline

Brine Section 1: Upper South Creek Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-8**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-11**.

Table 7-8 Design Features & Groundwater Conditions – Brine Section 1: Upper South Creek HGL

Design Feature	Description		
Pipeline	Brine		
Trenched Length	4,800 m		
Approximate Trenched Pipe Lay Rate	24 m/day (greenfield conditions)		
Approximate Trenched Construction Duration	67 days (three crews operating simultaneously)		
Trenchless Length	120 m		
Approximate Pipeline Invert Depth (mBGL)*	Min	Mean	Max
	1.3	2.6	5.4
Groundwater Conditions	Description		
Most Relevant Constant Head Boundary	South Creek (approx. 150 m distance), Kemps Creek (approx. 20 m distance)		
Hydrogeological Landscape	Upper South Creek		
Water Quality	Land salinity is high, groundwater is generally saline (EC greater than 4.8 dS/m)		
Intersected Geology	Formation	Period	Lithology
	Unconsolidated	Quaternary	Fine-grained sand, silt and clay
Groundwater Depths (mbgl)	Min	Mean	Max
	2	4	6
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.017	0.5	1.287
Storage Properties (Specific Yield)	Min	Mean	Max
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 10.1 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 141.5 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 2,038.1 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting aquatic ecosystems (South Creek) and terrestrial ecosystems (Cumberland Shale Plains Woodlands, Cumberland River Flat Forest, Castlereagh Ironbark Forest, Castlereagh Shale-Gravel Transition Forest and Castlereagh Scribbly Gum Woodland) with a low to high level of interaction with groundwater.

Impacts to the registered commercial/industrial water supply bore present approximately 320 m from this pipeline section are not expected.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in Section 2.3), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

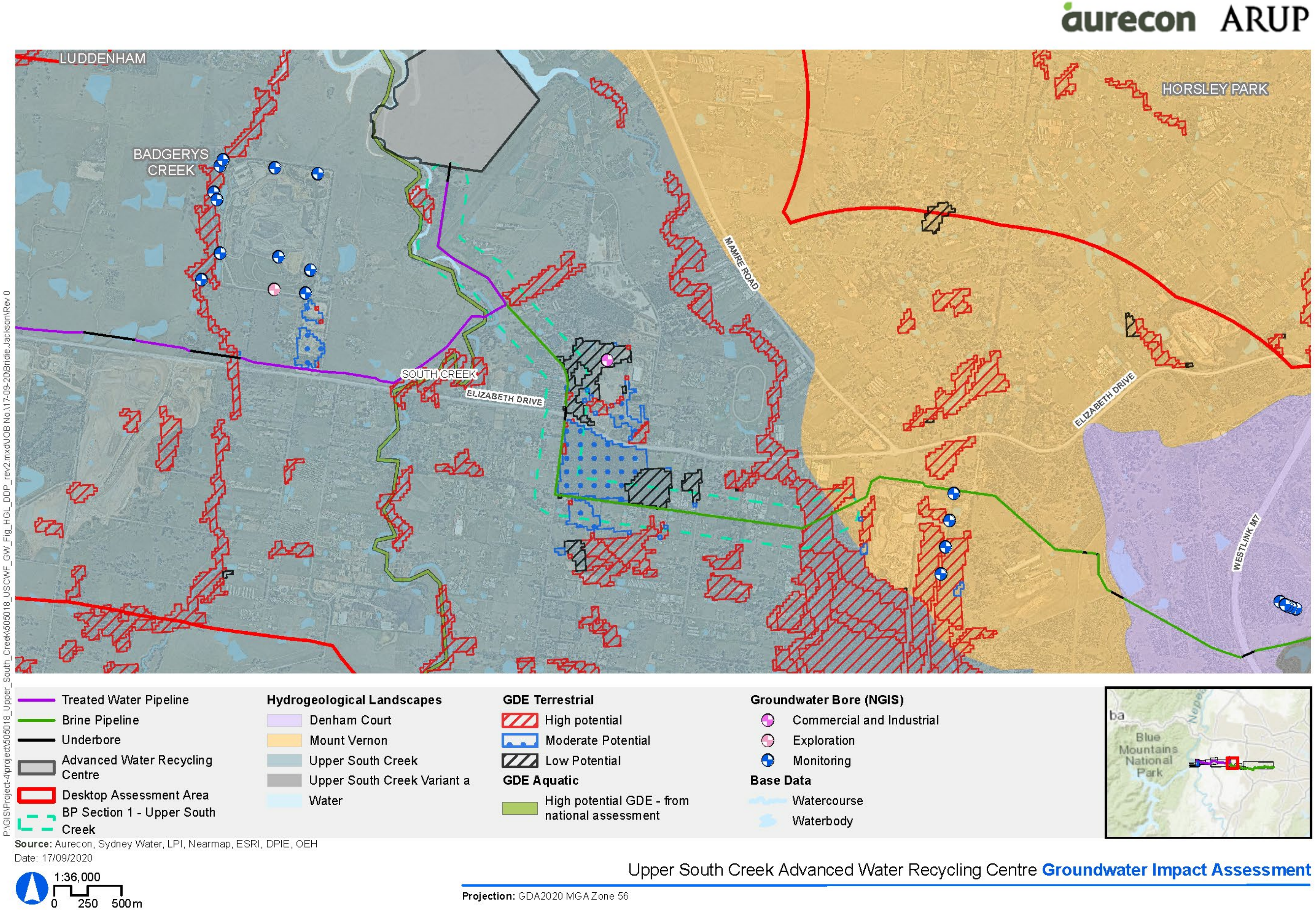


Figure 7-11 Brine Section 1: Upper South Creek HGL

Brine Section 2: Mount Vernon Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-9**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-12**.

Table 7-9 Design Features & Groundwater Conditions – Brine Section 2: Mount Vernon HGL

Design Feature		Description	
Pipeline		Brine	
Trenched Length		2,500 m	
Approximate Trenched Pipe Lay Rate		24 m/day (greenfield conditions)	
Approximate Trenched Construction Duration		35 days (three crews operating simultaneously)	
Trenchless Length		185 m	
Approximate Pipeline Invert Depth (mBGL)*	Min	Mean	Max
	1.3	2.0	3.8
Groundwater Conditions		**Description**	
Most Relevant Constant Head Boundary		Kemps Creek (approx. 250 m distance)	
Hydrogeological Landscape		Mount Vernon	
Water Quality		Land salinity is moderate, groundwater is generally brackish (EC between 0.8-1.6 dS/m)	
Intersected Geology	Formation	Period	Lithology
	Residual / regolith soils associated with weathered Bringelly Shale	Mid-Triassic	Residual/regolith soils associated with weathered shale, carbonaceous claystone, claystone, laminate, fine to medium-grained lithic sandstone, rare coal and tuff
Groundwater Depths (mbgl)	Min	Mean	Max
	2	4	6
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.05	0.3	0.484
Storage Properties (Specific Yield)	Min	Mean	Max
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 6.6 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 44.5 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 687.8 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodlands) with a moderate to high level of interaction with groundwater.

No registered water supply bores are present in the vicinity of this pipeline section.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in Section 2.3), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

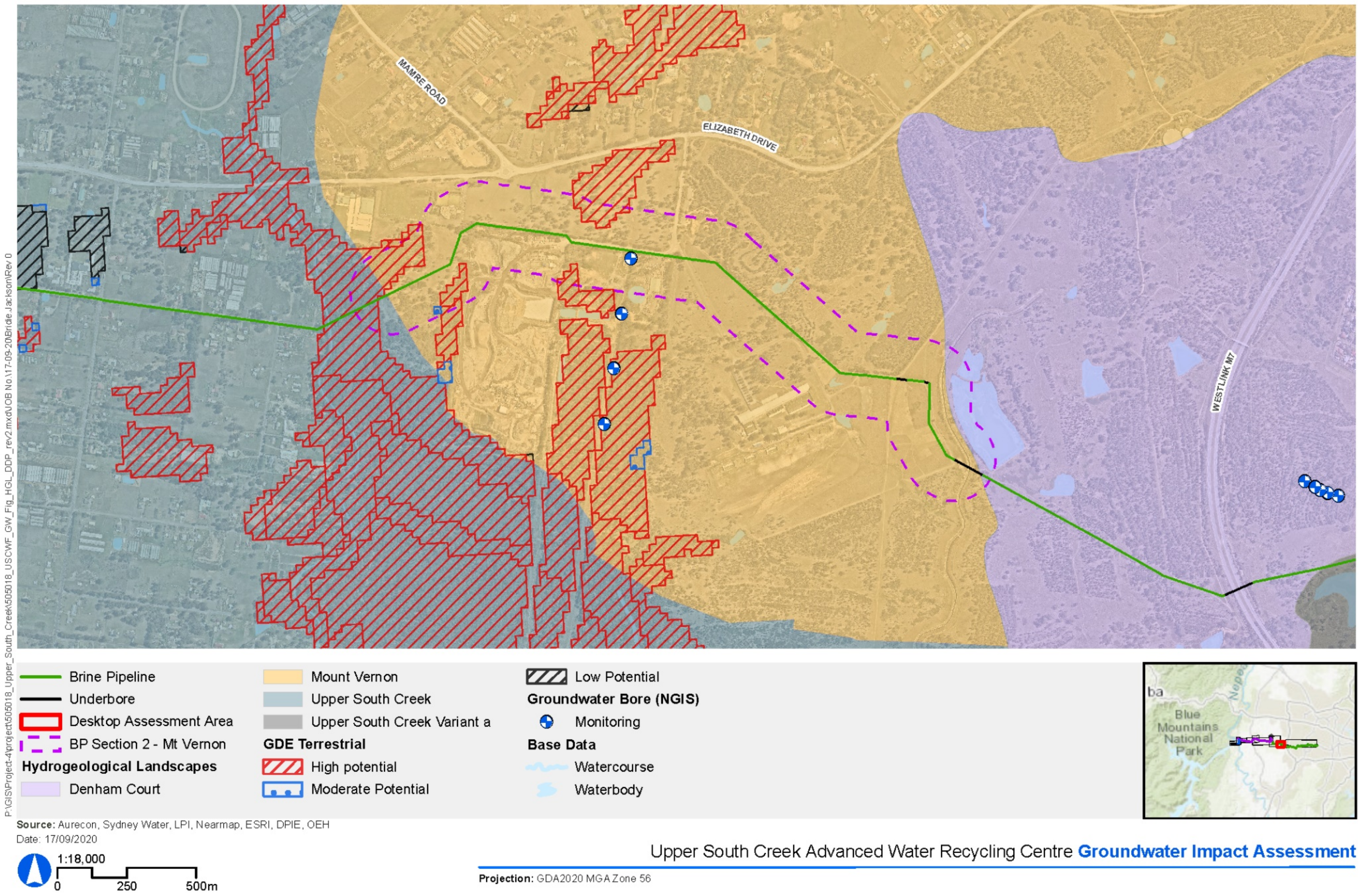


Figure 7-12 Brine Section 2: Mount Vernon HGL

Brine Section 3: Denham Court Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-10**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-13**.

Table 7-10 Design Features & Groundwater Conditions – Brine Section 3: Denham Court HGL

<table>
<tr><th>Design Feature</th><th colspan="3">Description</th></tr>
<tr><td>Pipeline</td><td colspan="3">Brine</td></tr>
<tr><td>Trenched Length</td><td colspan="3">1,220 m</td></tr>
<tr><td>Approximate Trenched Pipe Lay Rate</td><td colspan="3">24 m/day (greenfield conditions)</td></tr>
<tr><td>Approximate Trenched Construction Duration</td><td colspan="3">17 days (three crews operating simultaneously)</td></tr>
<tr><td>Trenchless Length</td><td colspan="3">115 m</td></tr>
<tr><td rowspan="2">Approximate Pipeline Invert Depth (mBGL)*</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><th>Groundwater Conditions</th><th colspan="3">Description</th></tr>
<tr><td>Most Relevant Constant Head Boundary</td><td colspan="3">Liverpool Offtake Reservoir (approx. 60 m distance)</td></tr>
<tr><td>Hydrogeological Landscape</td><td colspan="3">Denham Court</td></tr>
<tr><td>Water Quality</td><td colspan="3">Land salinity is moderate, groundwater is generally fresh (EC less than 0.8 dS/m)</td></tr>
<tr><td rowspan="2">Intersected Geology</td><td>Formation</td><td>Period</td><td>Lithology</td></tr>
<tr><td>Residual / regolith soils associated with weathered Bringelly Shale</td><td>Mid-Triassic</td><td>Residual/regolith soils associated with weathered shale, carbonaceous claystone, claystone, laminate, fine to medium-grained lithic sandstone, rare coal and tuff</td></tr>
<tr><td rowspan="2">Groundwater Depths (mbgl)</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>2</td><td>4</td><td>6</td></tr>
<tr><td rowspan="2">Hydraulic Conductivities (m/day)</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>0.05</td><td>0.3</td><td>0.484</td></tr>
<tr><td rowspan="2">Storage Properties (Specific Yield)</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>0.05</td><td>0.1</td><td>0.15</td></tr>
</table>

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 6.4 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 43.0 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 24 m/day per crew, this equates to total groundwater inflows of 323.9 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

No registered water supply bores or groundwater dependant ecosystems are present in the vicinity of this pipeline section.

Water-dependent assets are not present in the immediate vicinity of the proposed alignment, therefore the predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in Section 2.3). In addition, the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are considered acceptable.

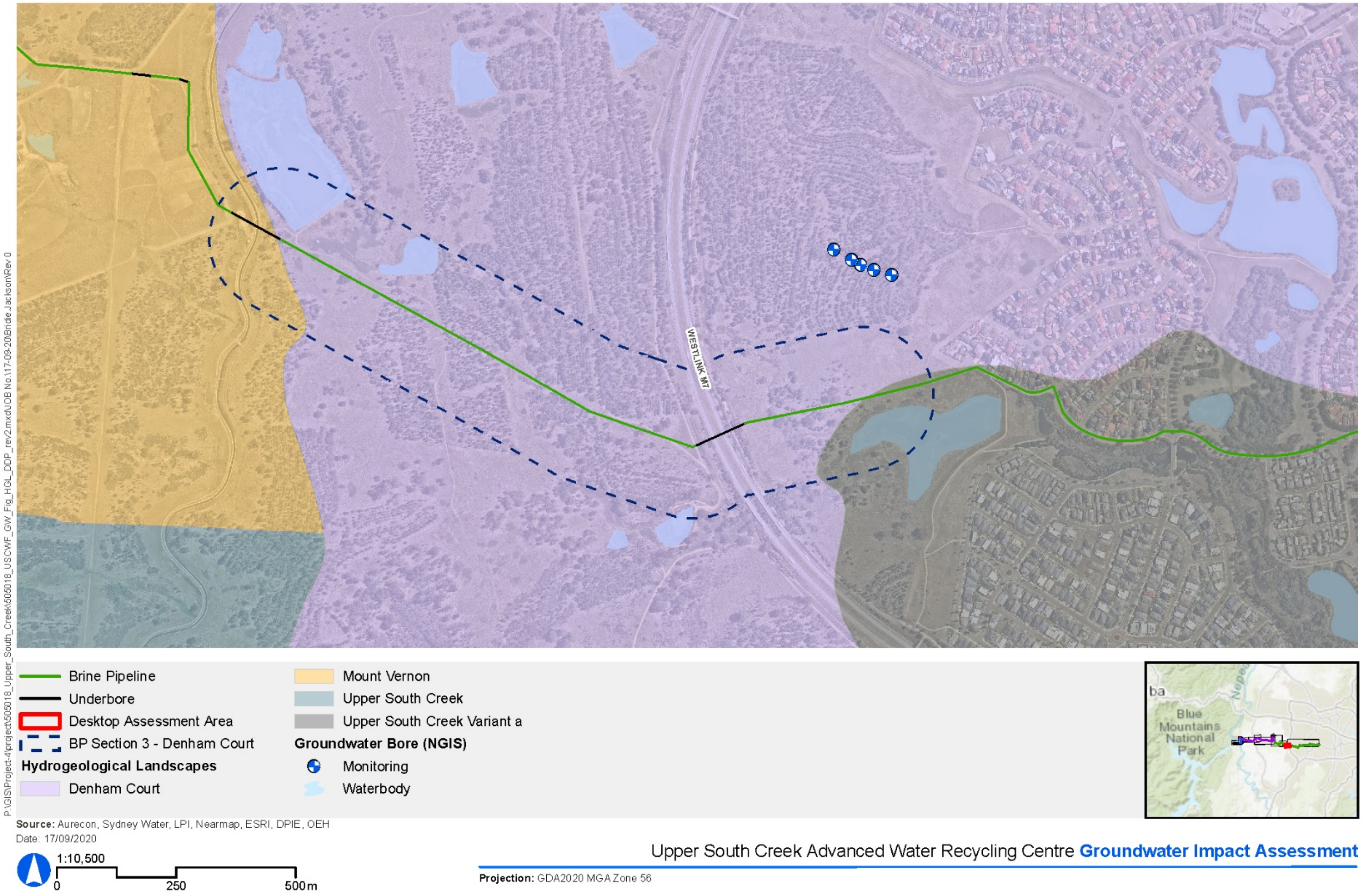


Figure 7-13 Brine Section 3: Denham Court HGL

Brine Section 4: Upper South Creek (Variant A) Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-11**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-14**.

Table 7-11 Design Features & Groundwater Conditions – Brine Section 4: Denham Court HGL

Design Feature	Description		
Pipeline	Brine		
Trenched Length	11,800 m		
Approximate Trenched Pipe Lay Rate	12 m/day (Urban conditions)		
Approximate Trenched Construction Duration	328 days (three crews operating simultaneously)		
Trenchless Length	820 m		
Approximate Pipeline Invert Depth (mBGL)*	Min	Mean	Max
	1.3	2.4	8.6
Groundwater Conditions	**Description**		
Most Relevant Constant Head Boundary	Green Valley Creek, Hinchinbrook Creek, Prospect Creek (approx. 50 m distance)		
Hydrogeological Landscape	Upper South Creek (Variant A)		
Water Quality	Land salinity is high, groundwater is generally brackish to saline (EC between 1.6-4.8 dS/m)		
Intersected Geology	Formation	Period	Lithology
	Unconsolidated	Quaternary	Fine-grained sand, clay and silt
Groundwater Depths (mbgl)	Min	Mean	Max
	2	4	6
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.017	0.5	1.287
Storage Properties (Specific Yield)	Min	Mean	Max
	0.1	0.15	0.2

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 0.8 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 10.7 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 12 m/day per crew, this equates to total groundwater inflows of 757.7 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting terrestrial ecosystems (Cumberland Shale Plains Woodlands and Cumberland River Flat Forest) with a low to high level of interaction with groundwater.

Impacts to the registered water supply bores present approximately 120 m from this pipeline section are not expected.

The predicted impacts are within the range of acceptability for the minimal groundwater level/availability impact criteria (outlined in Section 2.3). The induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

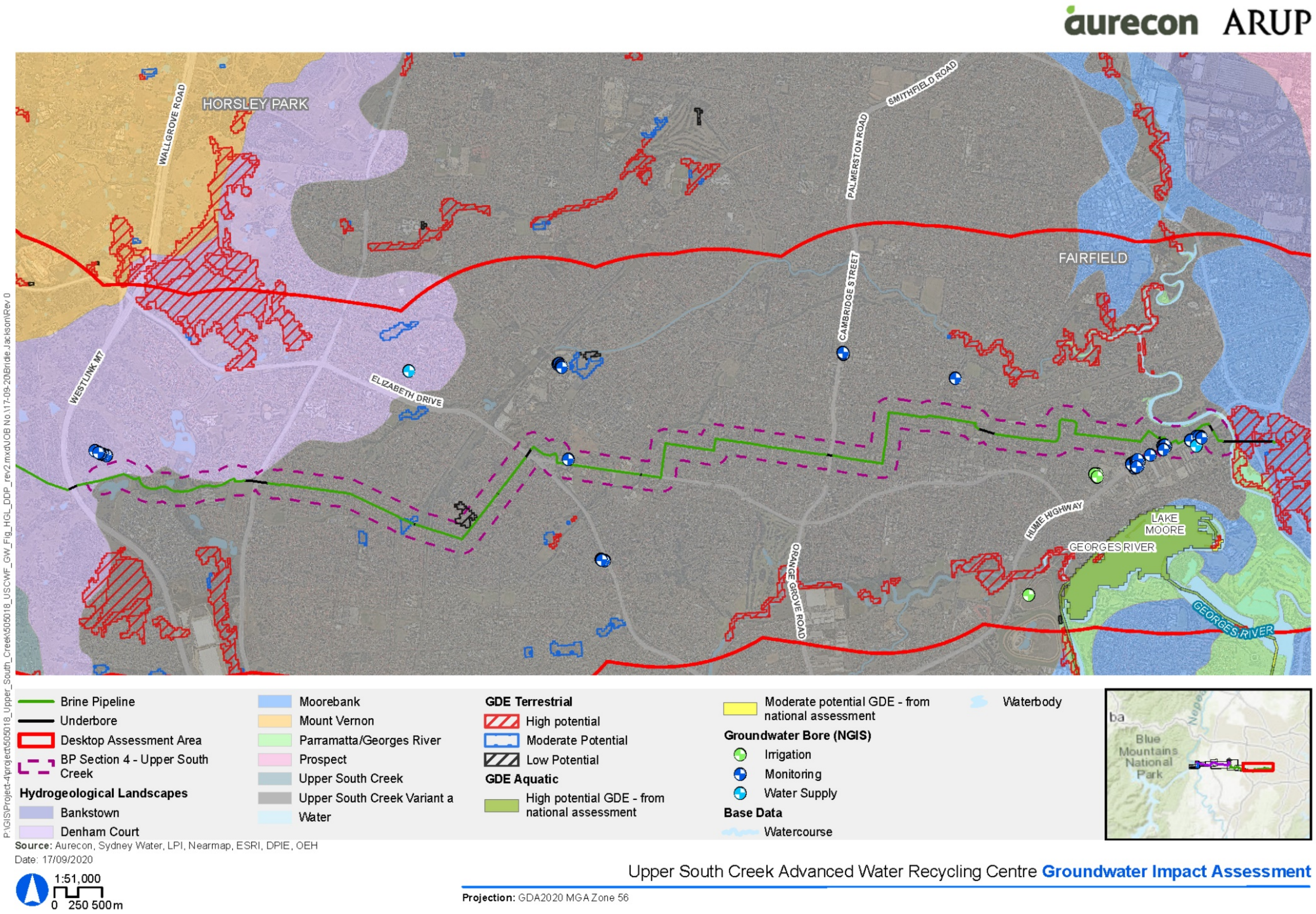


Figure 7-14 Brine Section 4: Upper South Creek (Variant A) HGL

Brine Section 5: Moorebank Hydrogeological Landscape

A summary of the design features and existing groundwater conditions in this pipeline section and hydrogeological landscape are provided in **Table 7-12**. The location and pipeline alignment in relation to registered groundwater bores and GDEs is illustrated in **Figure 7-15**.

Table 7-12 Design Features & Groundwater Conditions – Brine Section 5: Moorebank HGL

Design Feature	Description		
Pipeline	Brine		
Trenched Length	30 m		
Approximate Trenched Pipe Lay Rate	12 m/day (Urban conditions)		
Approximate Trenched Construction Duration	3 days		
Trenchless Length	530 m		
Approximate Pipeline Invert Depth (mBGL)*	Min	Mean	Max
	2.0	3.7	5.3
Groundwater Conditions	Description		
Most Relevant Constant Head Boundary	Prospect Creek (approx. 20 m distance)		
Hydrogeological Landscape	Moorebank		
Water Quality	Land salinity is moderate, groundwater is generally fresh (EC between 0.8-1.6 dS/m)		
Intersected Geology	Formation	Period	Lithology
	Unconsolidated	Neogene	Medium-grained sand, clay and silt
Groundwater Depths (mbgl)	Min	Mean	Max
	0	4	8
Hydraulic Conductivities (m/day)	Min	Mean	Max
	0.017	0.5	1.287
Storage Properties (Specific Yield)	Min	Mean	Max
	0.05	0.1	0.15

* Includes trenched pipeline sections only.

Based on analytical calculations, the likely groundwater inflow rate during trenched pipeline construction is 7.8 m^3/day (average hydraulic conductivity). It is possible that localised areas of higher permeability soils (e.g. max hydraulic conductivity) may be encountered during trenching, in which case groundwater inflows would increase substantially up to 109.3 m^3/day.

Based on the sensitivity to the chosen hydraulic conductivity value, along with other assumptions made in the calculations, it is recommended that the likely inflow rate be adopted as an indicative value only.

Across the full trenched length of this section with three crews working simultaneously and an approximate pipe lay rate of 12 m/day, this equates to total groundwater inflows of 23.5 m^3. Analytical calculations and assumptions are provided in **Appendix B**.

Dewatering during trenched pipeline construction of this section may induce drawdowns temporarily impacting terrestrial ecosystems (Cumberland Shale Plains Woodlands and Cumberland River Flat Forest) with a high level of interaction with groundwater.

No registered water supply bores are present in the vicinity of this pipeline section.

The predicted impacts are greater than the minimal groundwater level/availability impact criteria (outlined in Section 2.3), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.

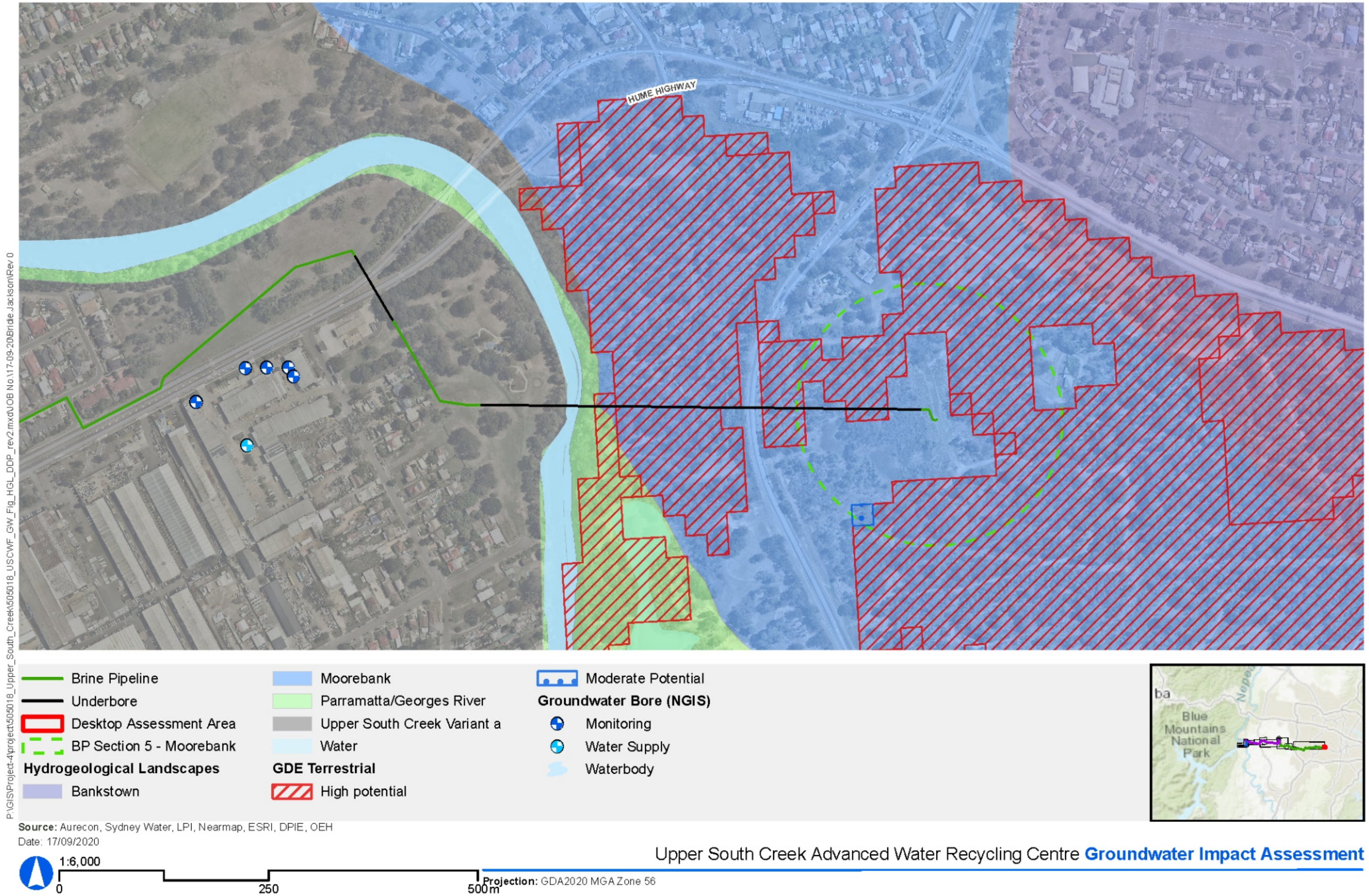


Figure 7-15 Brine Section 5: Moorebank HGL

Trenchless Pipeline Sections

Pipe Jacking and Microtunneling

Potential impact assessed in this section = Induced drawdowns from required dewatering activities, reducing the availability of groundwater for GDEs and surrounding groundwater users.

During microtunneling and pipe jacking activities, construction dewatering will be required at the launch and reception shafts if they extend below the groundwater table. The method used to support the shaft excavations and ground conditions would be the most important factors determining the amount of dewatering that would be required.

Groundwater impacts associated with the pipe-jacking and microtunneling shafts are expected to be minimised through appropriate construction techniques such as the use of a headwall and seal assembly within each shaft and watertight wall supports for the shafts.,

Dewatering along the alignment of the pipe-jacked sections may be required, depending on the pressure limitations of the chosen pipe jacking equipment. Frictional forces that build up around the pipeline is dependent upon many factors (e.g. ground conditions, overburden depth, pipe curvature and friction angle), including depth of the groundwater table. If these frictional forces cannot be overcome by the chosen equipment, dewatering along the pipe-jacking alignment may be the most practical ground treatment solution.

Potential groundwater impacts associated with pipe jacking and microtunneling have been qualitatively assessed as moderate (temporary, but potentially widespread unless mitigation measures are implemented).

Horizontal Directional Drilling

Potential impact assessed in this section = Groundwater seepage and/or unintentional return of drilling fluid to the surface or waterways via preferential pathways (e.g. fault lines, fractures or loose materials) during HDD construction (frac-outs).

When performing Horizontal Directional Drilling (HDD) in aquifers, there is a possibility of groundwater seepage occurring through the borehole, particularly in areas with elevated water pressures (e.g. semi-confined aquifers). Groundwater seepage will occur when hydraulic heads in the aquifer exceed the static pressures of the drilling fluid. In addition, if excavations associated with the entry and exit points for the HDD intersect the saturated material, seepage into the open excavations will occur and dewatering will be required (as with trenched pipeline construction).

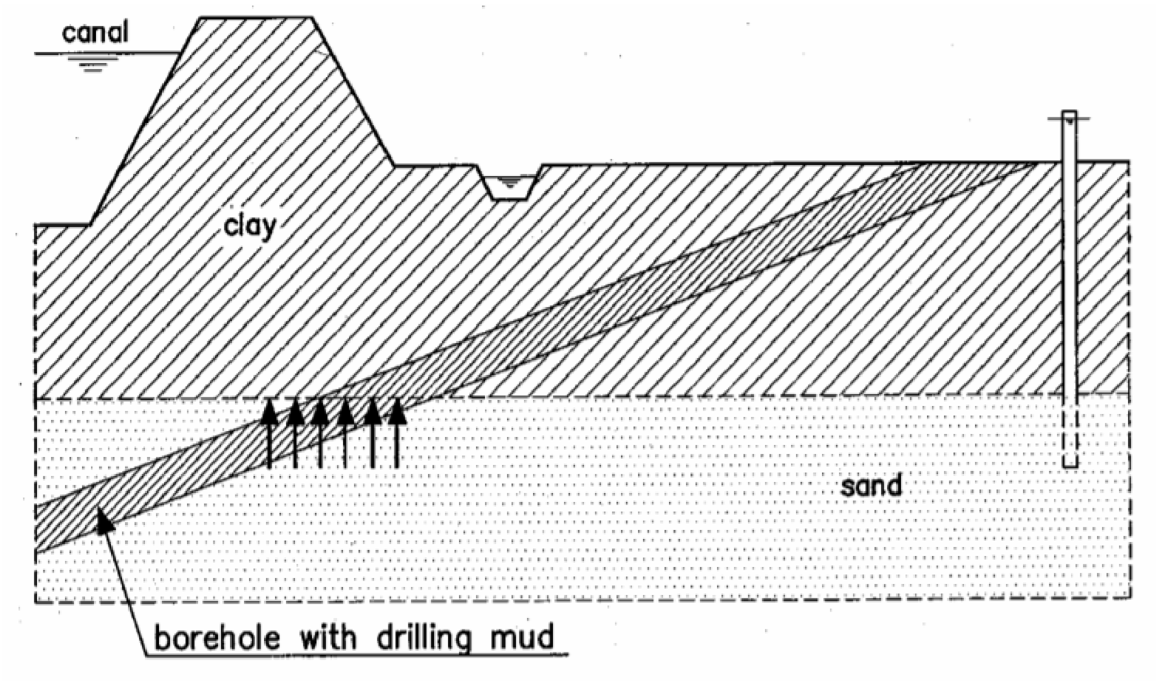


Figure 7-16 Upward groundwater seepage during HDD construction in semi-confined groundwater conditions (Hergarden et al., 2001)

Another potential impact from underbore / HDD construction is the unintentional return of drilling fluid to the surface. This occurs when the pressures in the drilling fluid exceed the overburden pressure or if preferential pathways (e.g. fault lines, fractures or loose materials) are present. Frac-outs can cause deleterious environmental effects, such as sedimentation within watercourses, groundwater and surface water quality impacts and harm to ecological communities (particularly in aquatic environments).

Groundwater quality can also impact the level of seepage that occurs during HDD construction. Groundwater across the majority of the desktop assessment area is expected to be brackish to saline (as discussed in **Section 4.6**), which can create conditions where the solids used in drilling fluids (e.g. bentonite) flocculate and sink, decreasing the density of the fluid. If the density of the drilling fluid becomes lower than that of the surrounding groundwater, seepage will occur.

Groundwater seepage during construction should be minimised to reduce environmental impacts, but also to reduce the risk of borehole collapse and subsidence of the ground surface (mitigation measures to reduce groundwater seepage outlined in **Section 8.2**).

7.2.2 Operational Phase

Groundwater seepage after construction of trenchless pipelines

Potential impact assessed in this section: Groundwater seepage via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.

Once trenchless pipelines are installed, drilling fluids will solidify. Therefore, groundwater seepage through the pipeline annulus is expected to be negligible. However, there will be a relatively short period after construction where the drilling fluid will still be in a liquid condition. If damage to the pipeline and leakage occurs during this period, upward groundwater seepage can be induced.

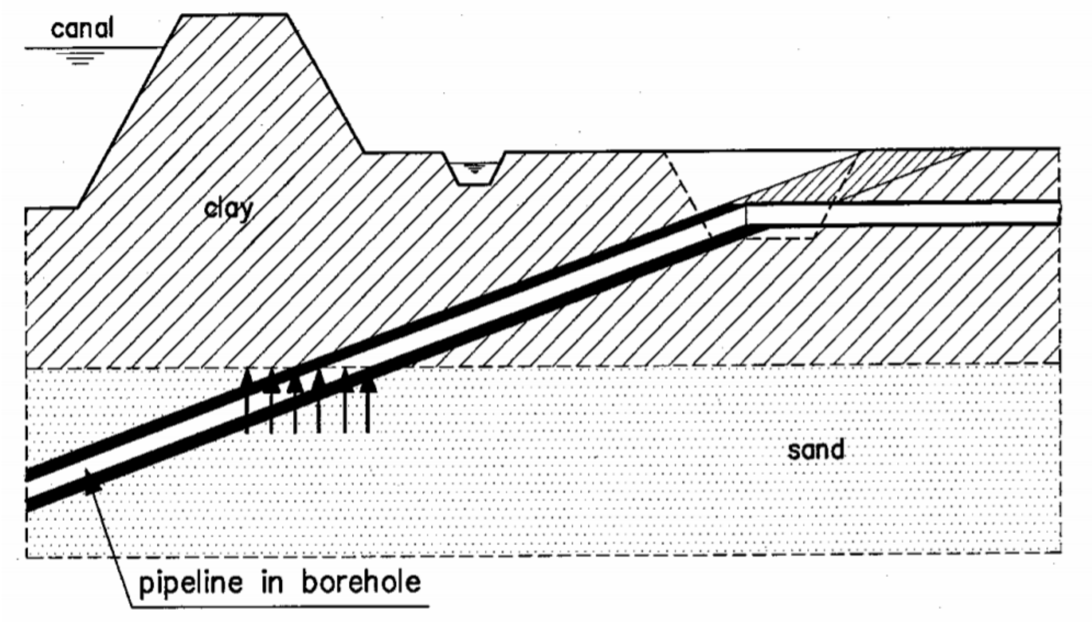


Figure 7-17 Upward groundwater seepage during HDD operation in semi-confined groundwater conditions (Hergarden et al., 2001)

Pipeline leaks/bursts

Potential impact assessed in this section: Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination.

Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination. Water transmitted through the treated water and environmental flows pipelines will be predominately fresh and unlikely to cause significant impacts to groundwater quality. Water transmitted through the brine pipeline will have much higher total dissolved solids and leaks/bursts occurring across this pipeline is likely to cause localised degradation in groundwater quality.

7.3 Other Key Considerations

7.3.1 Acid Sulfate Soils

Potential impact assessed in this section: Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts

As discussed in **Section 4.4.4**, potential ASS risk areas are present around Georges River and Prospect Creek in the eastern portion of the desktop assessment area.

If saturated materials in these areas were exposed to oxygen (e.g. drawdown of the groundwater table from construction dewatering), sulfuric acid and iron can be released from the ASS. This potentially results in a number of knock-on effects including:

- Leaching/mobilisation of metals from otherwise stable soil matrices, increasing the concentration of heavy metals in the groundwater to potentially toxic levels.
- Reduced durability of underground structures, such as steel and concrete, through corrosion; and

- Degradation of soil quality in affected areas, preventing vegetation growth.

7.3.2 Mobilisation and Migration of Contaminants

Potential impact assessed in this section: Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts

As discussed in **Section 4.6.1**, groundwater toxicants may be present in the desktop assessment area, associated with anthropogenic influences such as widespread agricultural land use, areas of disturbed terrain, landfilling etc.

Alterations to the groundwater systems, through construction dewatering and the construction of underground structures, could induce hydraulic gradients with the potential to induce contaminant migration. Migration of contaminant would be in sympathy with the direction of induced groundwater flows.

If this occurs, it is likely that extracted groundwater would contain contaminants and would therefore require management / treatment prior to discharge / disposal. Areas of environmental concern and their corresponding risk rating for the potential presence of contamination are discussed in further detail in the *Soils and Contamination Impact Assessment* report

7.3.3 Interception of aquifers during excavation

Potential impact assessed in this section: Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.

As discussed in **Section 4.6**, the local groundwater systems are generally highly saline and also relatively shallow. By increasing the vertical hydraulic connection between the local groundwater systems and the underlying regional systems through excavations, or by increasing the lateral hydraulic connection through the pipeline backfill material, preferential migration pathways may be formed affecting water qualities, hydraulic gradients and flow regimes in the groundwater systems.

This is considered likely to occur in the following areas:

- At the interface between alluvial deposits and the underlying Bringelly Shale. From a horizontal perspective, this is expected at the interface between these geologies as mapped in **Section 4.4**. From a vertical perspective, this is expected where the excavation is deep enough to intersect the different geological units (e.g. where the trenchless shafts extent into bedrock or where bedrock is encountered above the pipeline invert level).
- Due to the longer duration of construction dewatering at the AWRC site, dewatering is expected to induce an upward flow field which will potentially cause deeper low quality water to be mobilised into the upper alluvial system as illustrated in the hydrogeological conceptual model in **Figure 6-3**.
- In addition, the potential presence of localised perched aquifers occurring above clay rich lenses in the alluvial deposits have been noted in the HGLs listed below as outlined in **Section 4.5.6**. Where these are intersected, a connection between the perched aquifer and the underlying aquifer may be formed.
  - Mid-Nepean River HGL
  - Mulgoa HGL

- Greendale HGL
- Upper South Creek HGL
- Mount Vernon HGL
- Upper South Creek Variant A HGL
- Moorebank HGL

The severity of this impact is dependant upon the backfill material used upon completion of the excavation. Using a relatively impermeable material or vertical/horizontal cut-offs would minimise this impact.

7.4 Analysis Results Summary

7.4.1 All Trenched Pipeline Sections: Summary

Table 7-13 Trenched pipelines - construction dewatering analytical calculation summary

Pipeline Section	Approximate Trenched Pipe Lay Rate (m/day)	Approximate Duration of Trenched Construction (Full Section) (days)	Simulated Groundwater Drawdown (m)	Calculated Maximum Radius of Influence (m)	Estimated Groundwater Inflow Rates (m^3/day)			Estimated Total Groundwater Inflow (m^3)*		
					Min	Expected	Max	Min	Expected	Max
Environmental Flows Section 1: Mid-Nepean HGL	24	26	3.2	44	0.4	17.1	238.8	28.1	1,335.4	18,626.4
Environmental Flows Section 2: Hawkesbury HGL	N/A	0	Horizontal Directional Drilling (HDD) only. No trenched component.							
Treated Water Section 1: Mid-Nepean HGL	24	14	3	54	0.3	13.2	183.5	11.8	552.3	7,708.7
Treated Water Section 2: Mulgoa HGL	18	52	1.3	35	0.2	6.9	96.9	23.4	1,082.6	15,121.1
Treated Water Section 3: Greendale HGL	24	48	1.1	18	0.5	4.0	27.4	76.3	581.8	3,941.3
Treated Water Section 4: Mulgoa HGL	24	18	0.9	30	0.1	5.8	80.5	6.5	311.6	4,346.5
Treated Water Section 5: Upper South Creek HGL	24	87	0.9	37	0.1	4.7	65.4	26.1	1,224.1	17,061.6
Brine Section 1: Upper South Creek HGL	24	67	1.4	26	0.2	10.1	141.5	44.2	2,038.1	28,431.5
Brine Section 2: Mount Vernon HGL	24	35	1.8	17	0.9	6.6	44.5	90.3	687.8	4,668.3
Brine Section 3: Denham Court HGL	24	17	1.9	19	0.8	6.4	43.0	42.3	323.9	2,194.0
Brine Section 4: Upper South Creek (A) HGL	12	328	0.3	51	0.02	0.8	10.7	19.7	757.7	10,519.0

Pipeline Section	Approximate Trenched Pipe Lay Rate (m/day)	Approximate Duration of Trenched Construction (Full Section) (days)	Simulated Groundwater Drawdown (m)	Calculated Maximum Radius of Influence (m)	Estimated Groundwater Inflow Rates (m^3/day)			Estimated Total Groundwater Inflow (m^3)*		
					Min	Expected	Max	Min	Expected	Max
Brine Section 5: Moorebank HGL	12	3	4.7	41	0.2	7.8	109.3	0.5	23.5	327.9
Totals	**N/A**	**695**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	369.2	8,918.6	112,946.1

* The duration of active dewatering is assumed to be linked to the daily pipe lay rates. In this case, the completed segment would be backfilled following each day at which time dewatering for most of the section of the pipe is ceased (except at the open front end where sump dewatering may need to be continued to prevent flooding of the pipe). These estimates therefore represent minimum expected flow (See **Section 3.3.1** for an explanation of model limitations, assumptions and consequences). If unexpected conditions are encountered or there are delays with pipe preparations etc, extended dewatering may be required resulting in more pumped volume than presented in this table.

7.4.2 AWRC Summary

Table 7-14 AWRC Summary of construction dewatering numerical modelling results

Project Phase	Duration	Simulated Drawdown / depression (m)	Calculated Maximum Radius of Influence (m)	Estimated Average Groundwater Inflow Rates[C] (L/Min)			Estimated Total Groundwater Inflow (ML)			Impact on baseflow[D]
				Min	Expected	Max	Min	Expected	Max	
Construction Phase (Stage 1 only)	365	4	325	30	80	200	23	50	97	-6%
Operation[A]	Long-term	0.9[B]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-1%

[A] NB as mentioned in **Section 9.1.2**, it is intended to re-create the pre-development environmental water balance by offsetting the lost recharge through increasing operational recharge through detention basins and local irrigation. This will reduce the depression across the AWRC site.
[B] This occurs at the centre of the ARWC footprint reducing to zero before intersecting South Creek.
[C] These estimate are based on relatively stable flow rates after 30 days of pumping
[D] Affected river reaches – Reach 10 and Reach 11.

8 Impact Assessment

8.1 Potential Impacts

Potential impacts that may occur during the construction and operational phases are assessed in accordance with the methodology outlined in **Section 3**, leading to informed mitigation measures to prevent, minimise and / or contain these impacts.

The potential impacts associated with the construction phase activities of the project, also described in section 7 include:

- Induced drawdowns from required dewatering activities, potentially reducing the availability of groundwater for GDEs and surrounding groundwater users.
- Groundwater seepage and/or unintentional return of drilling fluid to the surface or waterways via preferential pathways (e.g. fault lines, fractures or loose materials) during HDD construction (frac-outs).
- Discharge of contaminated hydrostatic test water.
- Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts.
- Discharges of wastewater from any required dewatering activities may mobilise sediments and contaminants and increasing the turbidity and reducing the water quality in receiving waters.
- Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts.
- Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.
- Disruption of surface water and groundwater connectivity.

The potential impacts associated with the operation phase activities of the project, also described in section 7 include:

- Induced drawdowns from any underdrainage systems employed for underground structure floatation management, temporarily intercepting potential groundwater for GDEs and surrounding groundwater users.
- Groundwater quality impacts from infiltrating contaminated runoff from the operation of vehicles and machinery at the AWRC, chemical spills and overflow/leakages of untreated or partially treated wastewater to the groundwater systems.
- Groundwater seepage via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.
- Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination.
- Increased groundwater recharge from stormwater irrigation at the AWRC site, leading to increased water levels of saline aquifer.

The significance of each groundwater related impact during construction and operation of the project has been derived based on findings presented in **Section 7** in relation to the matrix of impact significance outlined in **Section 3.4.1**. This section was developed and applied to inform the project's reference design and ensure appropriate mitigation measures have been considered in relation to the sensitivity of environmental values and magnitude of impacts.

The following sections respond to the SEARs (**Section 1.4**) while providing an overview of potential construction and operational phase impacts for the AWRC site and pipeline alignments. The potential impacts have been assessed with consideration to the relevant components of the design, which were developed iteratively during the assessment to reduce potential impacts to groundwater across the project.

A summary of quantitative analysis results from dewatering activities (see **Section 7.1.1** and **Section 7.2.1**) in relation to the adopted impact assessment criteria is provided in **Table 8-1**.

The potential impacts associated with the construction phase activities of the project are identified and assessed in **Table 8-2,** any additional impacts potentially arising during the operational phase are indicated in Table 8-1.

Table 8-1 Impact assessment for induced drawdowns from required dewatering activities

Project Feature	Span of Active Dewatering	Calculated Maximum Radius of Influence (m)	Water supply bores within radius of influence	GDEs: GDEs present within radius of influence	GDEs: Potential for groundwater interaction	Maximum Calculated Drawdowns (m): At project feature	Maximum Calculated Drawdowns (m): At GDE	Maximum Calculated Drawdowns (m): At Water Supply bore*	Assessment against minimal groundwater level/availability criteria (Section 2.3)
AWRC	356 days	325	None	Aquatic ecosystems (South Creek)	High	3.9	0.2	N/A	GDE with high potential for groundwater interaction located within radius of influence, therefore drawdown criteria (0.1m) is exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Environmental Flows Section 1: Mid-Nepean HGL	24 m/day pipeline lay rate	44	None	Aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest).	High	3.2	3.2	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Environmental Flows Section 2: Hawkesbury HGL	N/A	Horizontal Directional Drilling (HDD) only. Impacts assessed qualitatively (see **Table 8-2** below)							
Treated Water Section 1: Mid-Nepean HGL	24 m/day pipeline lay rate	54	None	Aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodland).	Moderate to high	3.0	3.0	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 2: Mulgoa HGL	18 m/day pipeline lay rate	35	None	Aquatic ecosystems (Nepean River) and terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodland)	High	1.3	1.3	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 3: Greendale HGL	24 m/day pipeline lay rate	18	None	Terrestrial ecosystems (Cumberland Shale Plains Woodland)	High	1.1	1.1	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 4: Mulgoa HGL	24 m/day pipeline lay rate	30	None	None	N/A	0.9	N/A	N/A	No GDEs or water supply works within the calculated radius of influence. Drawdown criteria not exceeded.
Treated Water Section 5: Upper South Creek HGL	24 m/day pipeline lay rate	37	None	Aquatic ecosystems (South Creek) and terrestrial ecosystems (Cumberland Shale Plains Woodlands, Cumberland River Flat Forest, Castlereagh Ironbark Forest)	Moderate to high	0.9	0.9	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 1: Upper South Creek HGL	24 m/day pipeline lay rate	26	None	Aquatic ecosystems (South Creek) and terrestrial ecosystems (Cumberland Shale Plains Woodlands, Cumberland River Flat Forest, Castlereagh Ironbark Forest, Castlereagh Shale-Gravel Transition Forest and Castlereagh Scribbly Gum Woodland)	Low, moderate and high	1.4	1.4	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.

Project Feature	Span of Active Dewatering	Calculated Maximum Radius of Influence (m)	Water supply bores within radius of influence	GDEs		Maximum Calculated Drawdowns (m)			Assessment against minimal groundwater level/availability criteria (Section 2.3)
				GDEs present within radius of influence	Potential for groundwater interaction	At project feature	At GDE	At Water Supply bore*	
Brine Section 2: Mount Vernon HGL	24 m/day pipeline lay rate	17	None	Terrestrial ecosystems (Cumberland River Flat Forest and Cumberland Shale Plains Woodlands	Moderate to high	1.8	0.2*	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 3: Denham Court HGL	24 m/day pipeline lay rate	19	None	None	N/A	1.9	N/A	N/A	No GDEs or water supply works within the calculated radius of influence. Drawdown criteria not exceeded.
Brine Section 4: Upper South Creek (A) HGL	12 m/day pipeline lay rate	51	None	Terrestrial ecosystems (Cumberland Shale Plains Woodlands and Cumberland River Flat Forest)	Low, moderate and high	0.3	0.3	N/A	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 5: Moorebank HGL	12 m/day pipeline lay rate	41	None	Terrestrial ecosystems (Cumberland Shale Plains Woodlands and Cumberland River Flat Forest)	High	4.7	0.5*	N/A	Drawdown criteria (0.1m) for high potential GDE exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.

* Based on linear interpolation between point of maximum drawdown and edge of radius of influence (point of zero drawdown)

The overall impact significance associated with the sections in close proximity to any GDE's with high potential for groundwater interaction remains *Moderate*, even though the predicted impacts are considered acceptable, due to the high sensitivity of the environmental value.

Table 8-2 Impact assessment outcomes and significance (Construction phase)

Potential Impact	Project location/Activity	Impact significance
• Induced drawdowns from required dewatering activities, reducing the availability of groundwater for GDEs and surrounding groundwater users.	AWRC site: Excavation, dewatering and installation of underground infrastructures	Low Sensitivity of environmental values: Moderate (GDEs are present at the AWRC site) Magnitude of impact: Low (temporary and local) Baseflow reduction within adjacent reaches of South Creek. If the groundwater elevations drop below the water elevation in South Creek for a sustained period, then there will be a complete reversal of groundwater direction extending to the creek resulting in flow reversal at the riverbed. Under these conditions the affected section of the creek would be recharging the groundwater instead groundwater discharging as baseflow. It is considered that the aquatic ecosystems in these reaches may be impacted under such conditions. The induced drawdowns are expected to exceed the Level 1 minimal impact considerations defined in the NSW Aquifer Interference policy (outlined in **Section 2.3**). However, the induced drawdowns will be constrained to a short period of time during construction. Therefore, based on the reference design details and the available information, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.
	Pipelines Excavation, dewatering and installation of underground infrastructures	Low Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and local)

Potential Impact	Project location/Activity	Impact significance
		The induced drawdowns at the majority of pipeline sections are expected to exceed the Level 1 minimal impact considerations defined in the NSW Aquifer Interference policy (outlined in **Section 2.3**), however the induced drawdowns will be constrained to a short period of time during construction. Therefore, based on the reference design details and the available information, the predicted impacts are not expected to prevent the long-term viability of the affected ecosystems and are considered acceptable.
• Groundwater seepage and/or unintentional return of drilling fluid to the surface or waterways via preferential pathways (e.g. fault lines, fractures or loose materials) during HDD construction (frac-outs). • Discharge of contaminated hydrostatic test water	Pipelines: HDD and micro tunnelling	Moderate Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Moderate (localised) Any significant volumes of these chemicals entering the local water environment could lead to local ecological degradation or destruction, albeit temporary. Loss of groundwater storage from drilling fluids moving into aquifer material would be localised.
• Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts	AWRC site and pipelines: Excavation, dewatering and installation of underground infrastructures. ASS risk areas are present around Georges River and Prospect Creek in the eastern portion of the desktop assessment area	Moderate Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Moderate (temporary) Groundwater toxicants may be present in the desktop assessment area, associated with anthropogenic influences such as widespread agricultural land use, areas of disturbed terrain, landfilling etc.

Potential Impact	Project location/Activity	Impact significance
		Elevated concentrations of heavy metals and nutrients within groundwater, above project waterway objectives, have been identified in previous investigations (RMS 2019). The potential presence of saline or contaminated soils/groundwater and/or acid sulfate soils has been discussed in **Section 4.6.2**, **4.4.4** and **7.3.1**. Alterations to the groundwater systems, through construction dewatering and the construction of underground structures, will create a cone of depression that will direct groundwater in the affected area to flow towards the point of dewatering. If the cone of depression intercepts a contaminant source, it is likely that extracted groundwater would contain contaminants and would therefore require management / treatment prior to discharge / disposal. Areas of environmental concern and their corresponding risk rating for the potential presence of contamination are discussed in further detail in the Soils and Contamination Impact Assessment report. The analysis results presented in Section 7 indicate that existing registered bores relating to beneficial groundwater uses (e.g. irrigation, stock drinking water and raw drinking water) are not present in the maximum radius of influence and will therefore not be impacted. Due to the nature of the project activities, any potential migration of saline or contaminated groundwater induced during construction will be towards the point of dewatering, therefore changes to the existing groundwater quality and beneficial use category of the groundwater source will not extend beyond 40 m of the activity and the criteria outlined in Table 2-2 will be met.

Potential Impact	Project location/Activity	Impact significance
• Discharges of wastewater from any required dewatering activities may mobilise sediments and contaminants and increase the turbidity and reduce the water quality in receiving waters	AWRC site and pipelines: Discharges from dewatering activities	Moderate Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Moderate (temporary) Extracted groundwater quality is expected to vary across the project. Groundwater in some areas is expected to be fresh (e.g. in the Hawkesbury and Mid-Nepean Hydrogeological Landscapes), but groundwater across the majority of the project is expected to be brackish to saline (e.g. Upper South Creek Hydrogeological Landscape). Therefore, discharging the extracted groundwater without treatment is likely to have a deleterious impact to the receiving water body and exceed the NSW AIP criteria for water quality. An overview of the varying groundwater quality reported in each Hydrogeological Landscape across the desktop assessment area can be found in **Section 4.5.6**
• Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts	AWRC site, pipelines and access roads: Compaction and concreting	Low Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area). Magnitude of impact: Low (temporary and local)

Potential Impact	Project location/Activity	Impact significance
• Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.	AWRC site and pipelines: Excavation, dewatering and installation of underground infrastructures	High Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: High (permanent) The local groundwater systems are generally highly saline and also relatively shallow. By increasing the vertical hydraulic connection between the local groundwater systems and the underlying regional systems through excavations, or by increasing the lateral hydraulic connection through the pipeline backfill material, preferential migration pathways may be formed affecting water qualities, hydraulic gradients and flow regimes in the groundwater systems.
• Disruption of surface water and groundwater connectivity	AWRC site and pipelines: Horizonal directional drilling under a watercourse	Low Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area.) Magnitude of impact: Low (temporary and local) Any disruption in connectivity would be very localized.

Table 8-3 Impact assessment outcomes and significance (Operational phase)

Potential Impact	Project location/Activity	Impact significance
• Induced drawdowns from any underdrainage systems employed for underground structure floatation management, temporarily intercepting groundwater for GDEs and surrounding groundwater users.	AWRC site and pipelines: Excavation, dewatering and installation of underground infrastructures	Moderate Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Moderate (permanent but localised) The groundwater inflow volumes are expected to be relatively low and discontinuous (e.g. may only be required for the duration of specific maintenance activities). However, when combined with localised reduction in groundwater recharge / infiltration due to impervious surfaces created at the AWRC, long-term reduction in groundwater levels may occur during operation.
• Groundwater quality impacts from infiltrating contaminated runoff from the operation of vehicles and machinery, chemical spills and overflow/leakages of untreated or partially treated wastewater to the groundwater systems.	AWRC site: Operation of vehicles and machinery. Moving and storing chemical and untreated or partially treated wastewater throughout the plant	Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (localised) Any spills or accidental discharges will be temporary in nature but could lead to localised groundwater contamination (e.g. hydrocarbons, metals, suspended sediments, nutrients and biological constituents such as faecal coliforms).
• Groundwater seepage via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.	Pipelines: HDD and micro tunnelling	Low Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and local) Any significant volumes of these chemicals entering the local water environment may lead to local ecological degradation or destruction, albeit temporary. The likelihood of this occurring decreases once drilling fluid solidifies.

Potential Impact	Project location/Activity	Impact significance
• Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination.	Pipelines	Moderate Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area)) Magnitude of impact: Moderate (local) Any spills or accidental discharges will be temporary in nature but could lead to localised groundwater contamination. Water transmitted through the brine pipeline will have much higher total dissolved solids and leaks/bursts occurring across this pipeline is more likely to cause localised degradation in groundwater quality.
• Increased groundwater recharge from stormwater **harvesting and** irrigation at the AWRC site, leading to increased water levels of saline aquifer.	AWRC site: Harvesting of stormwater and irrigation application of adjacent regional park	Moderate Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Moderate (local) Underlying groundwater at the AWRC site is expected to be saline. Increasing the water levels in this area could lead to increased salinity in the localised area and degradation of the local fauna and flora as well as the surface water resources.

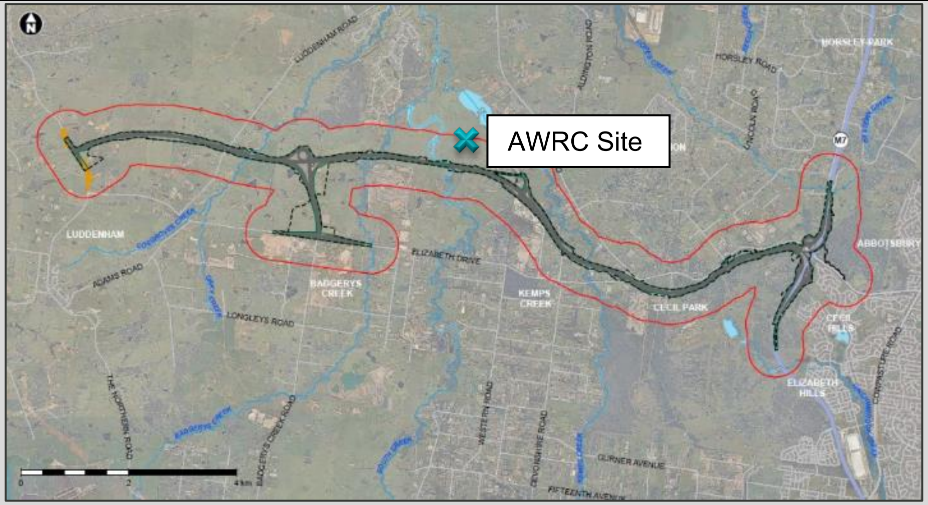
8.2 Cumulative Impacts

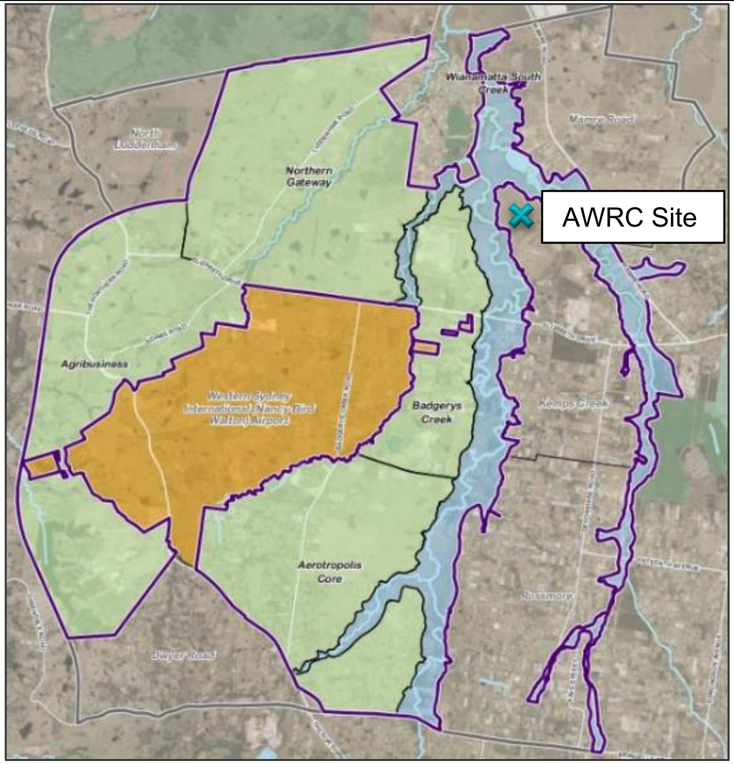
The Western Sydney Aerotropolis has been earmarked for major growth and urbanisation in the near future. This growth is the primary driver for the development of the AWRC project. However, rapid change in topography, surface coverage and general land use will result in major impacts to the natural environment, including groundwater.

When considered in isolation, any identified project impacts may be considered minor. These minor impacts may, however, be compounded, when the cumulative impacts of multiple projects on the same receivers are considered. As such, the potential groundwater impacts identified and discussed in **Section 8**, need to be considered alongside recently completed, ongoing and proposed projects. The major projects currently being proposed within close proximity to the project are indicated in **Table 8-4**.

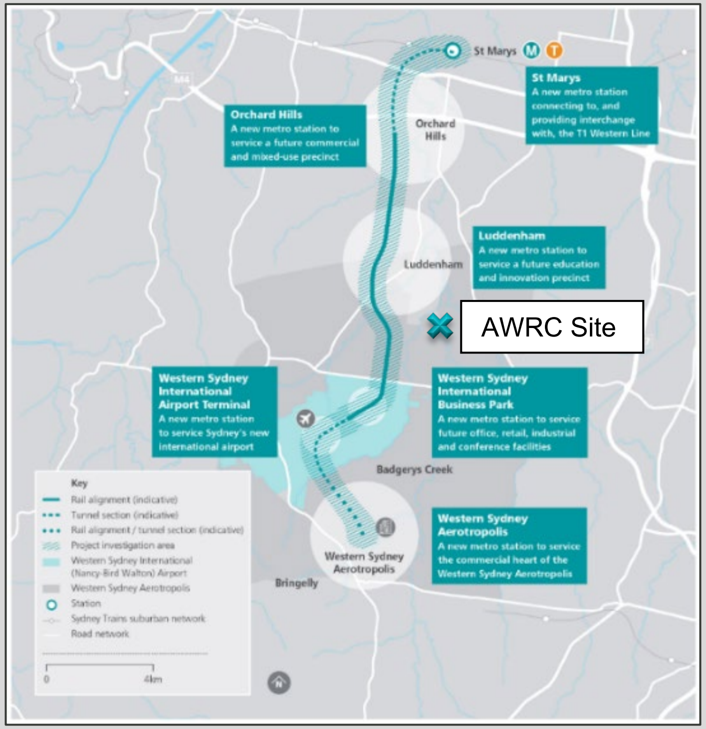
Table 8-4 Proposed major projects in close proximity to the project

Project	Project description, relation to current proposed AWRC project and expected residual impacts
Western Sydney Airport	The proposed Western Sydney Airport site will be located approximately 3.2 km south-west of the AWRC site, south of Elizabeth Drive. The site is primarily drained by Badgerys Creek and Cosgroves Creek. Construction at the Western Sydney Airport site has already commenced. The Western Sydney Airport EIS groundwater assessment (GHD, 2016) concluded that: • Impacts to registered groundwater bores are expected to be negligible during construction and operation of the airport. • Impacts to artificial wetlands within the airport site are expected to be negligible as they are located in low permeability clays with limited groundwater interactions. • Sensitive riparian vegetation will be retained along the corridors of Duncans, Oaky and Badgery's Creeks. This vegetation is expected to intersect alluvial deposits which has limited hydraulic connection to the shale aquifers potentially impacted by the airport. • There may be enhanced drawdown in localised areas where cuttings or building basements are present. Due to the hydraulic characteristics of the intersected geology, this impact is expected to be very localised. • Construction and development of the airport would reduce rainfall recharge and hence reduce groundwater discharge to surrounding creek systems. Historical water quality data and existing hydrogeological conditions that groundwater discharge forms a very low component of creek flow. • There is a risk presented by the migration of impact within the saline aquifer beneath shallow sensitive vegetation located along creek riparian areas with discharge to creeks and artificial wetlands in farm dams. The groundwater assessment suggests that the inherent hydrogeological conditions result in low risk of overall adverse groundwater impacts from construction and operation of the airport. There would be minor residual risks present which could be effectively managed using standard onsite procedural controls, engineered solutions and monitoring techniques.
M12 Motorway	The proposed M12 Motorway will run between the M7 Motorway at Cecil Hills and The Northern Road at Luddenham for a distance of about 16 kilometres and would be opened to traffic prior to opening of the Western Sydney Airport. The AWRC site itself is located within the extents of the M12 groundwater study area. The pipelines will follow a similar alignment to the M12 along portions of their routes.

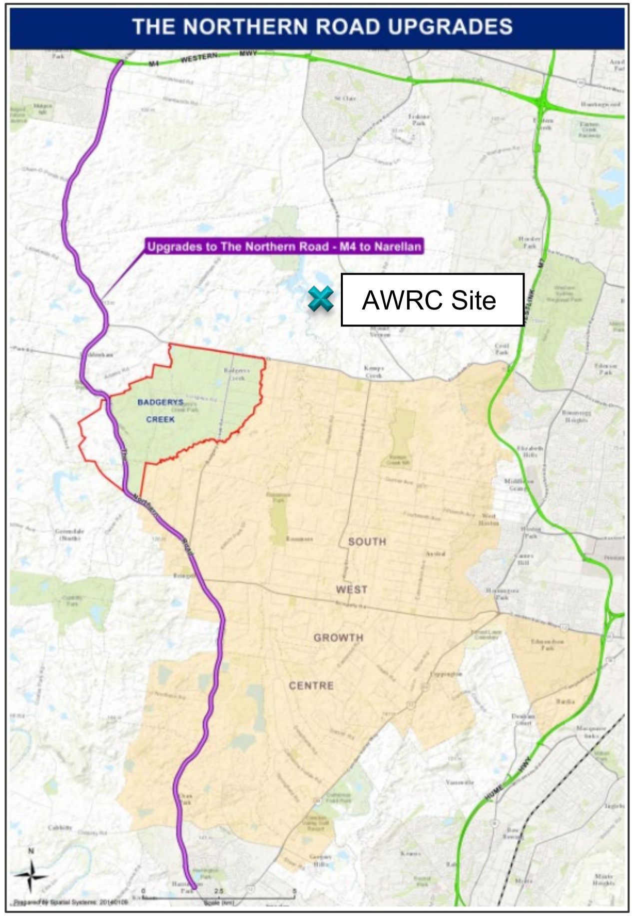
Project	Project description, relation to current proposed AWRC project and expected residual impacts
	 Based on the groundwater assessment and the proposed design, the project is expected to generate negligible impacts on groundwater, with the exception of groundwater cultural values. As such, the project was determined to present a negligible contribution to potential cumulative impacts associated with other major projects in the surrounding area. Direct interaction with groundwater systems is expected to be limited to: • A single cut in the west of the alignment (the “Western Cut”), which may intersect the water table by up to 1.6 metres over a distance of 250 metres. • Bridge footings, where piles are drilled below the water table.
Aerotropolis initial precincts	The Western Sydney Planning Partner (WSPP) has identified several precincts as priority precincts which will targeted for early land release. These precincts all directly border the Western Sydney Airport site, they include: the Aerotropolis Core, Badgerys Creek, Northern Gateway, Agribusiness and adjoining areas of Wianamatta-South Creek as indicated below. These precincts are primarily located within the South Creek catchment as the pipelines will transect several of them.

Project	Project description, relation to current proposed AWRC project and expected residual impacts
	 An integrated water management plan targeting these precincts is currently being developed. The purpose of the plan is to identify measures and control mechanisms to ensure sustainable water management practices are established and consequently mitigate the cumulative hydrological and geomorphological impacts that the rapid urbanization may lead to.

<table>
<tr><th>Project</th><th>Project description, relation to current proposed AWRC project and expected residual impacts</th></tr>
<tr><td>Sydney Metro – Western Sydney Airport</td><td>
The proposed new railway will link St Marys to the new airport and the Western Sydney Aerotropolis, alignment indicated below (Sydney Metro, 2020).



The project footprint is primarily located within the South Creek catchment (or its tributaries). The scoping document reiterates the degraded water quality within the area and references a water management system associated with the Western Sydney International Stage 1 which is expected to effectively mitigate potential flooding and water quality impacts. The EIS is currently being developed and expected impacts identified will need to be considered to determine the potential for compounding of impacts.
</td></tr>
</table>

The Northern Road Upgrade – Glenmore Road to Bringelly	The project will upgrade around 35 kilometres of The Northern Road between The Old Northern Road at Narellan and Jamison Road at South Penrith. The project will see The Northern Road upgraded to a minimum four-lane divided road, and up to an eight-lane divided road with dedicated bus lanes. The treated effluent pipeline will run alongside the Northern Road for a stretch of approximately 1.4 km. Construction works within this area may overlap. Groundwater impacts associated with the road construction are expected to be negligible. Post-construction, the road upgrades will likely result in increased local impervious areas, subsequently leading to decreased groundwater recharge. However, pipeline operational groundwater impacts are expected to be minimal for pipeline operation, therefore cumulative impacts should be negligible. 

Project	Project description, relation to current proposed AWRC project and expected residual impacts
Warragamba Dam Raising	Warragamba Dam Raising is a project to provide temporary storage capacity for large inflow events into Lake Burragorang to facilitate downstream flood mitigation and includes infrastructure to enable environmental flows. The EIS for this project is still being developed and thus potential impacts have not been assessed and published as yet. Cumulative impacts are expected to be minimal as the dam is located upstream of the e-flows discharge location, and the raising is aimed at storing major flood events rather than retaining more water on a regular basis.

These proposed major projects along with the general expected future urban development in the area have the potential to alter the groundwater conditions. These alterations could exacerbate any impacts arising from the construction and operation of the AWRC and the pipelines.

Generally major projects are designed and delivered in accordance with current environmental legislation and incorporate sufficient control measures to mitigate associated impacts and primarily targeting a Neutral or Beneficial Effect (NorBE) outcome. Given the widespread expected urbanization of the local environment, which would include numerous small-scale developments as well, the cumulative impacts from these smaller developments could become a more likely source of compounded impacts.

Most groundwater impacts associated with the AWRC project are expected to be minor and short-term (during construction). The AWRC project is not expected to generate significant groundwater impacts during operation. If the proposed mitigation measures are incorporated, the project would have a minor contribution to any foreseen cumulative groundwater impacts from other identified projects in the vicinity.

9 Mitigation Measures

A summary of the identified potential impacts along with their proposed mitigation measures and resultant impact significance are provided for the construction phase activities and are listed in **Table 9-1**. Any additional impacts associated only with the operational phase are indicated with their proposed mitigation measured in **Table 9-2**.

Table 9-1 Potential project specific mitigation measures (Construction phase)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
• Induced drawdowns from required dewatering activities, reducing the availability of groundwater for GDEs and surrounding groundwater users.	AWRC site: Excavation, dewatering and installation of underground infrastructures	Where feasible, select trench/shaft support systems like sheet piling that minimise groundwater drawdown, particularly in areas with coarse grained soils with higher hydraulic conductivity and storage properties. Possible construction dewatering techniques are: • **Open pumping techniques** (e.g. sumps and drains). A suitable and cost-effective approach in stable ground conditions (i.e. low permeability soils, small required drawdowns and no immediately adjacent source of recharge) after excavation. • **Pre-drainage/eductor techniques** (e.g. installation of dewatering well point(s)). Lowering of the water table prior to excavation may be required in more unstable ground conditions (i.e. high permeability soils and large required drawdowns). Develop a risk-based approach to assess drawdowns and impacts to South Creek during construction at the AWRC. This approach should include: • Monitoring the difference in elevation between South Creek and groundwater levels to verify the predicted drawdowns and assess the magnitude of impacts to South Creek • Identify trigger values to assess if groundwater elevations between the bioreactor and South Creek drop below the water elevation in South Creek for a sustained period. For example, if a drawdown greater than 1.5 m is observed in MW04, this would indicate a flow reversal at the riverbed is occurring (based on surveyed elevation of water levels in South Creek and the simulated pre-development groundwater levels indicated in	Low Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and localised)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
		Figure 7-2). The 1.5 m drawdown trigger at MW04 is based on the surveyed water level of 34 mAHD (observed on 7th July 2020) and the modelled groundwater level of 35.4 mAHD midway between the eastern bioreactor and South Creek. However, since the predicted reduction in baseflow is assessed as having low impact significance, no mitigation measures (e.g. reinjection of abstracted groundwater or cessation of dewatering) are expected to be required. The potential impacts to GDEs within South Creek are described in more detail in the *Aquatic and Riparian Ecosystem Impact Assessment* report.	
	Pipelines: Excavation, dewatering and installation of underground infrastructures HDD and micro tunnelling	Where feasible, select trench/shaft support systems like sheet piling that minimise groundwater drawdown, particularly in areas with coarse grained soils with higher hydraulic conductivity and storage properties. Possible construction dewatering techniques are: • **Open pumping techniques** (e.g. sumps and drains). A suitable and cost-effective approach in stable ground conditions (i.e. low permeability soils, small required drawdowns and no immediately adjacent source of recharge) after excavation. • **Pre-drainage/eductor techniques** (e.g. installation of dewatering well point(s)). Lowering of the water table prior to excavation may be required in more unstable ground conditions (i.e. high permeability soils and large required drawdowns). Where feasible, select trenchless construction techniques (like the use of a headwall and seal assembly in each shaft) that minimise groundwater drawdown. Where feasible, 'key' the launch and reception shafts into underlying material with relatively low permeability (e.g. competent bedrock) to reduce the amount of groundwater entering through the floor.	Low Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and localised)

<table>
<tr><th>Potential Impact</th><th>Project location/Activity</th><th>Mitigation measure</th><th>Impact significance following mitigation</th></tr>
<tr><td>Groundwater seepage and/or unintentional return of drilling fluid to the surface via preferential pathways (e.g. fault lines, fractures or loose materials) during HDD construction (frac-outs).</td><td>Pipelines:
HDD and micro tunnelling</td><td>Develop a process for assessing and mitigating the risk of ‘frac-outs’, including:
risk assessment by experienced personnel to determine the likelihood of “frac-outs” and if design changes or additional management actions are required
assess geotechnical conditions at each underbore / HDD site to determine the maximum allowable drilling fluid pressures.
based on the outcomes of the risk assessment, develop mitigation measures to reduce the risk of frac-outs and subsequent environmental impacts. These should include consideration of:
design to intersect more competent rock and avoid any preferential pathways such as fault lines, fractures, unconsolidated material etc).
casing at the entry / exit points where there are unconsolidated materials, reduced ground cover and reduced bearing pressure.
Drill pressure relief wells to provide a pathway for controlled release of drilling fluid pressures.
Continuous monitoring of drilling fluid properties during construction with alarms to alert the operator if nearing maximum allowable drilling fluid pressures.
Ceasing drilling if any unexpected variations in drilling fluid properties occur and investigating the cause.
Develop an incident response plan in the event of a frac-out occurring.</td><td>Low
Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area)
Magnitude of impact: Low (temporary and local)</td></tr>
</table>

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
• Mobilisation and migration of saline or contaminated groundwater or acid sulfate soils, altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts	AWRC site and pipelines: Excavation, dewatering and installation of underground infrastructures	Mitigation measures to reduce the amount of dewatering and minimise groundwater drawdowns will also be effective in mitigating the mobilisation and migration of contaminated groundwater and acid sulfate soils. These include: • Where feasible, select trench/shaft support systems like sheet piling that minimise groundwater drawdown, particularly in areas with coarse grained soils with higher hydraulic conductivity and storage properties. • Where feasible, select trenchless construction techniques (like the use of a headwall and seal assembly in each shaft) that minimise groundwater drawdown. Where feasible, 'key' the launch and reception shafts into underlying material with relatively low permeability (e.g. competent bedrock) to reduce the amount of groundwater entering through the floor. • Adopt a staged approach to dewatering by dewatering in discrete, smaller areas that align more closely to the construction schedule. In addition to the above, the following mitigation measure can be implemented to control the migration of contaminants in groundwater: • Construct adjacent recharge trenches to maintain saturation in high risk areas. If the extent of the drawdown is likely to include an area with existing contamination, consider constructing recharge trenches to limit the cone of depression and create a hydraulic barrier that could prevent the migration of contaminants. If acid sulfate soils are encountered and disturbed during excavation, the soil should be treated with an alkaline material (e.g. agricultural lime) to neutralise the material prior to reinstatement. Alternatively, the material should be disposed of in accordance with the NSW Waste Classification Guidelines. It is recommended that the implementation of these mitigation measures be considered alongside the areas of environmental concern outlined in the Soils and Contamination Impact Assessment Report.	Low Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and localised)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
• Discharges of wastewater from any required dewatering activities may mobilise sediments and contaminants and increase the turbidity of the receiving waters • Discharge of contaminated hydrostatic test water	AWRC site and pipelines: Discharges from dewatering activities	Develop and implement an approach to manage extracted groundwater and/or wastewater via one or a combination of these methods: • **Discharge to a receiving surface water body** such as creek, river, stream etc. An Environment Protection Licence (EPL) would be required under the Protection of the Environment Operations Act (1997). Water quality monitoring prior to discharge would be required to ensure WQO's are not exceeded and to demonstrate the discharge will not have significant deleterious impacts to the receiving water body. The EPL would stipulate the volume of water that could be discharged and the water quality discharge criteria (outlined in **Section 2.2**). Depending on extracted groundwater quality, temporary storage and treatment may be required to meet the applicable water quality criteria, prior to discharge. An overview of the varying groundwater quality reported in each Hydrogeological Landscape across the desktop assessment area can be found in **Section 4.5.6** • **Discharge to stormwater collection system.** This would require a similar level of assessment to discharging to receiving surface water body as described above. • **Discharge to sewer via a Trade Waste Agreement (TWA)** with the wastewater system operator. Discharge to sewer is to be conducted in accordance with the TWA, which may require temporary storage and treatment of the water prior to discharge. • **Land based application or reinjection / irrigation.** Feasibility of this option is dependent upon soil properties (infiltration rates, salinity etc.) at the reinjection / irrigation area. Generally precluded as a discharge option in areas with low permeability soils and salinity issues. However, for incidental or small volumes of extracted groundwater, this option could be considered provided the groundwater quality is suitable and other approval mechanisms are in place. Stability of nearby trenches / excavations and surrounding underground structures must be considered. • **Offsite disposal**. Extracted groundwater will be trucked offsite and treated and/or disposed of at a licensed wastewater treatment plant.	Low Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and local) If the identified mitigation measures are implemented, groundwater quality impacts are not expected to exceed the criteria outlined in **Section 2.2**.

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
• Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts	AWRC site, pipelines and access roads: Compaction and concreting	Capture all polluted runoff and dispose of appropriately via one or a combination of these methods: • **Discharge to a receiving surface water body** such as creek, river, stream etc. An Environment Protection Licence (EPL) would be required under the Protection of the Environment Operations Act (1997). Water quality monitoring prior to discharge would be required to ensure WQO's are not exceeded and to demonstrate the discharge will not have significant deleterious impacts to the receiving water body. The EPL would stipulate the volume of water that could be discharged and the water quality discharge criteria (outlined in **Section 2.2**). Depending on extracted groundwater quality, temporary storage and treatment may be required to meet the applicable water quality criteria, prior to discharge. An overview of the varying groundwater quality reported in each Hydrogeological Landscape across the desktop assessment area can be found in **Section 4.5.6** • **Discharge to stormwater collection system.** This would require a similar level of assessment to discharging to receiving surface water body as described above. • **Discharge to sewer via a Trade Waste Agreement (TWA)** with the wastewater system operator. Discharge to sewer is to be conducted in accordance with the TWA, which may require temporary storage and treatment of the water prior to discharge. • **Land based application or reinjection / irrigation.** Feasibility of this option is dependent upon soil properties (infiltration rates, salinity etc.) at the reinjection / irrigation area. Generally precluded as a discharge option in areas with low permeability soils and salinity issues. However, for incidental or small volumes of extracted groundwater, this option could be considered provided the groundwater quality is suitable and other approval mechanisms are in place. Stability of nearby trenches / excavations and surrounding underground structures must be considered. • **Offsite disposal**. Wastewater will be trucked offsite and treated and/or disposed of at a licensed wastewater treatment plant.	Low Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area). Magnitude of impact: Low (unlikely to occur) If the identified mitigation measures are implemented, groundwater quality impacts are not expected to exceed the criteria outlined in **Section 2.2**.

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
• Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.	Pipelines Excavation, dewatering and installation of underground infrastructures	• Install permanent vertical cut-offs within the trench to prevent the lateral migration of groundwater along the alignment of the pipelines. In the residual / regolith soils associated with weathered Bringelly Shale which is expected to have relatively low permeability, these trench cut-offs may be located at spacings of several hundred metres. In alluvial soils, or at river crossings, trench cut-off spacing should be significantly smaller e.g. every ten metres. • Horizontal trench cut-offs should also be considered where the perched aquifers are encountered, to prevent lateral migration and dewatering of the system. Maintenance of the perched layers may also be achieved through backfilling to prevent vertical migration.	Low Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (temporary and localised)
• Disruption of surface water and groundwater connectivity	Pipelines: Horizonal directional drilling under a watercourse	• Identify potential surface water - groundwater linkages around watercourses to be crossed by trenchless construction methods prior to drilling and subsequent avoidance of disrupting the connectivity as far as reasonable (e.g. where feasible, installing permanent vertical cut-offs between the shafts and the surface water bodies to prevent the lateral migration of groundwater into surface water bodies, and vice-versa).	Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur)

Table 9-2 Potential project specific mitigation measures (Operational phase)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
• Induced drawdowns from any underdrainage systems employed for underground structure floatation management, reducing the availability of groundwater for GDEs and surrounding groundwater users.	AWRC site and pipelines: Excavation, dewatering and installation of underground infrastructures	• Adopt a staged approach to dewatering by dewatering in discrete, smaller areas that align more closely to the maintenance schedule. • Consider the inclusion of vertical and horizontal drainage layers and "chimneys" with coarse filter material in order to achieve desired drawdowns against the underground structures more quickly and reduce the amount of dewatering required.	Low Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (localised).
• Groundwater quality impacts from infiltrating contaminated runoff from the operation of vehicles and machinery, chemical spills and overflow/leakages of untreated or partially treated wastewater to the groundwater systems.	AWRC site: Operation of vehicles and machinery. Moving and storing chemical and untreated or partially treated wastewater throughout the plant	• Adopt controls for storage and handling of chemicals, as outlined in the relevant Material Safety Data Sheets for each chemical. • Implement a spill response plan and incident response procedure. • All chemical storage and delivery areas to be designed to have sufficient storage volumes to contain a worst-case spill, including the full volume being delivered and the full volume stored simultaneously • Any spills that occur outside the containment area shall be contained within a first flush structure across roads and hardstand. Once full, flow bypass to surrounding waterways via the stormwater management system.	Low Sensitivity of environmental values: Moderate (existing local impacts. GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (unlikely to occur)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
• Groundwater seepage and/or unintentional return of drilling fluid to the surface via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.	Pipelines: HDD and micro tunnelling	• Confined aquifers under significant pressure are not expected to be encountered by the project, therefore the likelihood of this occurring is considered low and decreases as drilling fluids solidify. However, drilling fluid properties should be selected by experienced HDD construction personnel to account for drying times and reduce the risk of upward seepage of groundwater through the borehole annulus. • Allow adequate time for annulus grout to solidify before beginning pipeline operation, in accordance with the grout manufacturers specifications and recommendations.	Low Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (unlikely to occur)
• Water leaking from the pipelines during operation may cause localised increases to groundwater levels and potentially induce groundwater contamination.	Pipelines	• Adhere to existing Sydney Water operational management systems. • Implement maintenance plans as well as routine inspections to ascertain the condition of the pipes and auxiliary infrastructure • Actively observe pipe pressures to enable immediate identification of an incident • Implement an incident response plan which will include procedures directed at containing discharges and subsequent clean up requirements. • Implement automatic pressure releases in case of damage to the pipeline to minimise the risk of groundwater seepage and restrict impacts to a small area and time interval.	Low Sensitivity of environmental values: Moderate (GDEs and existing groundwater users are present across the desktop assessment area) Magnitude of impact: Low (unlikely to occur)

Potential Impact	Project location/Activity	Mitigation measure	Impact significance following mitigation
• Increased groundwater recharge from stormwater harvesting and irrigation at the AWRC site, leading to increased water levels of saline aquifer.	AWRC site: Harvesting of stormwater and irrigation application of adjacent regional park	• The stormwater management strategy for AWRC (detailed in the *Surface Water Impact Assessment Report*) is intended to re-create pre-development environmental water balance by offsetting the lost recharge due to AWRC impermeable surfaces through increasing post-construction recharge through leaky wetlands and detention basins, as well as local irrigation.	Low Sensitivity of environmental values: Moderate (existing local impacts) Magnitude of impact: Low (unlikely to occur) If this these mitigation measures are achieved, it predicted that the effects of the proposed stormwater management would maintain pre-development water balance, with localised and low impacts at the AWRC.

9.1 Management of Change / Unexpected Conditions

This impact assessment is based on the project's reference design. As the project progresses, changes to the design may be necessary which could change the magnitude of the identified groundwater impacts. The impact assessment has been carried out to provide some flexibility for these changes, for example a wider impact assessment area has been included so lateral alignment changes within this area have been accounted for. Where possible, a conservative approach has been adopted to assess 'worst-case' scenarios.

Design changes with the most potential to affect the magnitude of identified groundwater impacts would include:

- Excavation depths and extents (e.g. increasing the depth of the bioreactors).
- Pipeline construction methodology (e.g. trenchless vs trenched).
- Construction scheduling and pipeline lay rate.

Such changes to the design and construction should be assessed as part of tender evaluations to determine the change in magnitude of the potential groundwater impacts.

In addition, it is possible that unexpected hydrogeological conditions may be encountered due to previously unknown heterogeneities in the subsurface. For example, it is possible that during the implementation of a dewatering management strategy, that greater than anticipated groundwater volumes will require management due to an intercepted lens of very high permeability soils. To account for this possibility, uncertainty and sensitivity analyses have been included in this impact assessment (outlined in **Section 7**) which addressed a reasonable range of hydrogeological conditions that may be encountered.

Therefore, the impact assessment outlined in this report is considered sufficient to inform the project's Environmental Impact Assessment. It is recommended that the feasibility of the proposed mitigation measures be assessed in response to any additional information on groundwater conditions that is collected during detailed design or pre-construction monitoring (outlined in **Section 10**). During construction and operation, it is recommended that the mitigation measures be implemented through adaptive management strategies to mitigation groundwater impacts in response to the specific methodologies, schedules and potential unexpected conditions.

10 Monitoring Requirements

The findings of this EIS are based on the information available at the time of publication. The information has been considered sufficient to inform the level of detail required for this groundwater impact assessment. However, it is recommended that further works are conducted to collect additional information on groundwater conditions to inform detailed design and construction activities, which should be incorporated into the evolving Hydrogeological Conceptual Model.

The application of a groundwater monitoring program is important in ensuring construction and operational phase mitigation measures are effective, and groundwater impacts across the project do not exceed acceptable limits.

A groundwater quantity (i.e. levels and dewatering volumes) and quality monitoring program is recommended. Monitoring should incorporate pre-construction monitoring of groundwater conditions to form a baseline dataset to which the construction and operational monitoring data could be compared against. The baseline dataset would assist in developing site-specific action levels and responding to any identified impacts during construction and operation.

The groundwater monitoring program will include monitoring of groundwater levels (e.g. installation of pressure transducers / data loggers and manual water level dipping) and water quality sampling for the following general water quality indicators:

- Field measured physiochemical parameters (electrical conductivity, pH, turbidity, temperature, dissolved oxygen and redox potential).
- Total dissolved solids (TDS).
- Total suspended solids (TSS).
- Nutrients (including ammonia, nitrate, nitrite, total nitrogen and total phosphorous).
- Major ions (chloride, sulfate, sodium, potassium, magnesium, calcium, carbonate and bicarbonate).
- Other contaminants/toxicants of concern where applicable (e.g. heavy metals, hydrocarbons, biological constituents etc. See soils and contamination specialist report for further details).

The frequency, locations and water quality indicators for groundwater monitoring would be confirmed during detailed design.

Reporting of groundwater level and quality monitoring against site-specific guideline values should be conducted after each monitoring event throughout the establishment of the baseline dataset, during construction and during operation.

11 Key Findings & Conclusions

Construction of the proposed AWRC and pipelines has the potential to impact the groundwater systems in a number of ways, including:

- Induced drawdown of groundwater from required construction dewatering activities, reducing the availability of groundwater for Groundwater Dependent Ecosystems and surrounding groundwater users.
- Seepage and/or unintentional return of drilling fluid via groundwater to the surface via preferential pathways (e.g. fault lines, fractures or loose materials) during Horizontal Directional Drilling construction (frac-outs).
- Mobilisation and migration of contaminated groundwater or acid sulfate soil leachate (resulting from drawdown), altering pH and water quality and causing potential soil contamination and possible downstream ecological impacts.
- Discharges of wastewater from any required dewatering activities may mobilise sediments and contaminants and increasing the turbidity and reducing the water quality in receiving waters.
- Release of alkaline concrete wash water, which may cause localised soil, surface water or groundwater contamination and possible downstream ecological impacts.
- Interception of aquifers during excavation, leading to increased hydraulic connection between otherwise disconnected aquifers and/or lateral migration of groundwater along pipeline backfill material. Affecting water qualities, hydraulic gradients, and flow regimes in the groundwater systems.
- Disruption of surface water and groundwater connectivity.

Operation of the proposed AWRC and pipelines has the potential to impact the groundwater systems in several ways:

- Induced drawdowns from any underdrainage systems employed for underground structure floatation management, reducing the availability of groundwater for GDEs and surrounding groundwater users.
- Groundwater quality impacts from infiltrating contaminated runoff from the operation of vehicles and machinery at the AWRC, chemical spills and overflow/leakages of untreated or partially treated wastewater to the groundwater systems.
- Groundwater seepage via preferential pathways (e.g. fault lines, fractures or loose materials) after HDD construction.
- Leakage of water from pipelines during operation resulting in localised increases to groundwater levels and degradation in groundwater quality. Water transmitted through the treated water and environmental flows pipelines will be predominately fresh and unlikely to cause direct significant impacts to groundwater quality. Water transmitted through the brine pipeline will have much higher total dissolved solids and any leaks/bursts occurring across this pipeline has the potential to cause direct localised degradation of groundwater quality and/or groundwater dependent ecosystems.
- Increased groundwater recharge from stormwater irrigation at the AWRC site, leading to increased water levels of saline aquifer.

To minimise impacts to groundwater systems, a range of mitigation measures would be implemented during the detailed design, construction and operational phases of the project. These include:

- Design and construction of trench/shaft support systems that minimise groundwater drawdowns (e.g. sheet piling), particularly in areas with coarse-grained soils with higher hydraulic conductivity and storage properties.
- Where feasible, “key” the trenchless launch and reception shafts into underlying material with relatively low permeability (e.g. competent bedrock) to reduce the amount of groundwater that may enter through the floor.
- Adopting a staged approach to dewatering through dewatering in discrete, areas aligned closely with the construction schedule.
- Developing and implementing an approach to manage extracted groundwater. Depending on extracted groundwater quality, treatment may be required to meet the applicable water quality criteria, prior to discharge (e.g. to a receiving surface water body).
- Install permanent vertical cut-offs within the trench to prevent the lateral migration of groundwater along the alignment of the pipelines. In the residual / regolith soils associated with weathered Bringelly Shale which is expected to have relatively low permeability, these trench cut-offs may be located at spacings of several hundred metres. In alluvial soils, or at river crossings, trench cut-off spacing should be significantly smaller e.g. every ten metres. Horizontal trench cut-offs should also be considered where the perched aquifers are encountered, to prevent lateral migration and dewatering of the system. Maintenance of the perched layers may also be achieved through backfilling to prevent vertical migration.

The majority of these groundwater impacts will be constrained to a short period of time during construction and are not expected to impact the long-term viability of the affected ecosystems or groundwater resources.

The degree or severity of any impact during construction is largely based on the duration of dewatering and disruption of groundwater connection to any potential GDEs in the vicinity where a disruption occurs. Other factors include the depth to the groundwater table which influences the extent of dewatering required and the hydraulic characteristics of the intersected ground material.

A groundwater quantity (i.e. levels and dewatering volumes) and quality monitoring program is recommended. Monitoring should incorporate pre-construction monitoring of groundwater conditions to form a baseline dataset to which the construction and operational monitoring data could be compared against. The baseline dataset would assist in developing site-specific action levels and responding to any identified impacts during construction and operation.

Based on the available information and the analyses conducted in this impact assessment, with the successful implementation of the proposed mitigation measures the impacts to groundwater systems across the project are expected to be of low significance overall, with a minor contribution to any foreseen cumulative groundwater impacts from other identified projects in the vicinity.

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Appendix A – AWRC Numerical Modelling Report

March 2021

Upper South Creek Advanced Water Recycling Centre

AWRC Numerical Modelling Report

aurecon ARUP

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Figures

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Appendices

Cover photo: Image of borehole drill site located on the proposed AWRC site

1 Introduction

This report is provided as technical appendix for the Upper South Creek Advanced Water Recycling Centre (AWRC) Environmental Impact Statement (EIS) Groundwater Specialist Study Report. It provides the technical details of the process followed to develop the numerical model for the AWRC. Details of the conceptual hydrogeological model (CHM) including hydrostratigraphy and hydrogeological properties of the study area groundwater system are provided in the main text of the AWRC EIS Groundwater Specialist Study Report.

Maps showing locations of various infrastructure and general site layout arrangement of the AWRC are provided in the main text of the AWRC EIS Groundwater Specialist Study Report.

2 AWRC Site Groundwater Modelling Overview

2.1 Modelling objectives

The objective of the groundwater flow modelling has been to support evaluation of the risk posed on groundwater levels and quantities by the construction and operation of the AWRC. The purpose of this report is to document the process followed to model / simulate potential historical and future groundwater flow systems. An assessment of the resulting impacts informed from this modelling is provided in the main Groundwater Impact Assessment Report.

2.2 Scope of modelling

To fulfil the objectives the following tasks were completed:

- Description of the receiving hydrological and hydrogeological environment (including surface flow regimes and hydrogeological conceptual model)
- Reviewed publicly available documents, such as nearby hydrogeological studies for the Western Sydney Airport and M12 Motorway Environment Impact Statement documents with regards to evaluating groundwater conditions, including previous flow modelling
- Reviewed the Aurecon geotechnical reports including the ground model with regards to the vertical extent of geological units and potential water flow characteristics with the rocks based on interpretations of geotechnical investigations results of direct relevance to hydrogeology such as bore logs, rock recovery and rock quality designation (RQD), joint spacing and width and descriptions of any joint infilling, etc
- Short-term aquifer tests within shallow alluvial soils and deep fractured claystone
- Development of hydrogeological conceptual site model (CSM) in light of the field investigations carried for the AWRC and nearby projects (i.e. Western Sydney Airport and M12 Motorway)
- Constructed a groundwater numerical flow model for the AWRC
- Undertook calibration of the flow model
- Undertook sensitivity analysis of key input parameters to explore groundwater model response to these changes
- Using the adopted calibrated model of initial flow conditions, undertook predictive flow simulations that shows the extent of drawdown due to construction dewatering of AWRC
  - Predictive flow modelling results were used to evaluate potential conditions that could adversely impact on groundwater levels and / or water quality occur (including mobilisation of pre-existing contaminant plumes, such as associated with landfills near the AWRC)
  - Evaluation of the potential for adverse impacts to groundwater levels or water quality:
    - GDEs near the AWRC
    - Nearby groundwater users
  - Determination of volume of water expected to be generated during construction dewatering
- Prepared this report to document the modelling process, which was undertaken in general accordance with the Australian Groundwater Modelling Guidelines (Barnett et al., 2012)

2.3 Model exclusions, assumptions and limitations

The accuracy of the groundwater model presented in this report is limited to the accuracy and the distribution of the data used to represent hydrological properties of the groundwater flow system. The following exclusions, assumptions and limitations are associated with the groundwater modelling completed for this investigation:

- Simplifications to the geological structure have been made to translate a complex physical environment into a workable numerical framework represented by the HCM described in **Section 6** of the main AWRC Groundwater Technical Report developed based on available geological and hydrogeological data. The numerical model has therefore been developed as a conservative impact assessment tool.
- The fractured bedrock groundwater flow system has been represented by an Equivalent Porous Medium (EPM) method. One of the inadequacies of an EPM method is that although it replicates the behaviour of a regional flow system well, it is less suitable to reproduce small scale variations in conditions.
- The aquifer hydraulic parameters were based on tests at the AWRC site and some outside of the project site. The geologic conditions and hence the aquifer hydraulic parameters may vary from place to place and the adopted parameters may not be representative of the conditions further away from test locations. It should be noted that the available field test data such the hydraulic conductivities display a very wide range of possible applicable values. This wide range represent high uncertainty associated with the parameters.
- The groundwater flow model assumes that the hydraulic properties are uniform for each hydrostratigraphic layer or zone. In the field, the hydraulic properties will vary significantly across a given hydrogeological unit. As a result, the simplified model will predict a more uniform zones of groundwater drawdown.
- The model was developed with the express intent of providing sufficient information for purposes of this project. In developing the model, we have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request or enquiry were complete, accurate and up to date. Where publicly available data has been used, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware of any reason why any of the assumptions are incorrect.

2.4 Model Classification

The model was developed in accordance with the guiding principles in the National Water Commission (NWC) modelling guidelines (2012). Under NWC modelling guidelines (2012), groundwater models can be classified as either Class 1, Class 2 or Class 3 in order of increasing confidence based on the following factors:

- Available data
- Calibration procedures
- Consistency between calibration and predictive analysis
- Level of stress simulated in the model

The category of the groundwater numerical model for AWRC documented in this report generally adheres to conditions that would define it as a Class 1 model with numerous attributes for Class 2 models. Aurecon considers that there is sufficient groundwater data near the AWRC site and the model can be used to provide reasonably reliable predictions of the likely conditions associated with the construction long-term post-construction phases. Full attributes of model classifications are provided in the National Water Commission (NWC) modelling guidelines (2012). Key attributes are summarised below to provide context for Aurecon's assessment of the AWRC model class.

Class 1 models typically have inadequate calibration data and little or no field-based data for characterising aquifer parameters. Such models are used to provide high levels understanding of the likely conditions of the system. With Class 2 models, there is calibration data to provide reasonable calibration statistics although this may suggest significant errors in parts of the model domain. These would have some long-term data for transient calibration, although this may not extend to present day. Aquifer characteristics for Class 2 models are field tested. Class 3 comprises detailed data for calibration and aquifer parameters which are based on field tests.

3 Model Build

3.1 Modelling Strategy

The application of a computer based numerical model provides a powerful tool for the prediction of flow in a complex spatially and temporally varying environment. This approach applies a system of mathematical equations based on Darcy's Law for flow of water through porous media to simulate flow in the aquifer.

Groundwater numerical modelling can overcome the difficulties inherent in the assessment of hydrogeological systems using classical analytical methods, which assume aquifer homogeneity and more applicable to the interpretation of localised aquifer response. With a computer numerical model, it is possible to simulate complex conditions by introducing variations in aquifer transmissivity or hydraulic loads. This is accomplished by discretising the modelled area into a number of blocks each representing a volume of aquifer with constant hydraulic parameters. The accuracy of model predictions depends on the knowledge of all parameters having an impact on the groundwater regime, both in the area of interest as well as in more distant areas.

The development of a model also facilitates sensitivity analysis which provide a means of understanding the dominant parameters and mechanisms operating within a hydrogeological system.

Groundwater modelling for the AWRC was undertaken using MODFLOW-USG, with the aid of Groundwater Vistas pre- and post-processing environment. MODFLOW-USG is a relatively new version of the popular MODFLOW code (McDonald and Harbaugh, 1988) developed by the United States Geological Survey (USGS). 'USG' is an acronym for Un-Structured Grid, which relates to a variety of flexible unstructured model meshes, including those based on cell shapes such as prismatic triangles, rectangles, hexagons / voronoi, and other cell shapes supported by MODFLOW-USG (Panday et al., 2013). The use of flexible meshes available in MODFLOW-USG offers the following advantages compared to structured rectangular finite-difference grids available in standard MODFLOW:

- Flexible mesh they allow finer grid resolution to be focused solely in areas of a model that require it as opposed to refinement over the entire grid in standard MODFLOW, reducing the cell count significantly and improving model runtimes in the process.
- Spatial areas not required in the model may be omitted rather than deactivating cells or retaining "dummy" layers (e.g. for layer pinch-outs).
- Flexible meshes allow cell boundaries to follow important geographical or geological features, such as watercourses or outcrop traces, more accurately modelling the physical system.

Voronoi mesh type was used to represent model grid for the AWRC groundwater model in Groundwater Vistas. Spatial input data for both software was generated using ESRI Geographical Information Systems (GIS) software ArcGIS Spatial Analyst and 3D Analyst tools in conjunction with Microsoft Excel tools. Both manual approach and the parameter estimation program PEST (Doherty, 2014) were employed to adjust model parameters until the fit between model outputs and field observations was optimised in the weighted least square sense.

Table 3-1 provides a summary of the design software and versions used for the development of the AWRC groundwater model.

Table 3-1: AWRC Groundwater Model Design Software

Project feature	Description	Application
ArcGIS Spatial Analyst and 3D-Analyst in conjunction with Microsoft excel	v10.7	Development, analysis and computation of AlgoMesh and Groundwater Vistas spatial data, including representation of tunnel geometric data and construction schedules
AlgoMesh	v1.2.0.37827	Generation of MODFLOW-USG Voronoi mesh
MODFLOW	MODFLOW-USG Transport (formerly called beta)	Groundwater flow simulation
Groundwater Vistas	v7.24 (build 260), premium version	MODFLOW graphic user interface
PEST	v15.0	Model parameter estimation
Mod-PATH3DU	v2.0	Contaminant transport modelling, assessment of the capture zone for ARWC during construction

3.2 Model Domain and Mesh Design

Figure 3-1 shows the adopted model domain for the AWRC groundwater model domain covering an area of 52.6 km^2. The edge of the domain was selected to be remote to the anticipated hydraulic effects of the AWRC structures and to cover part of the AWRC pipelines crossing major tributaries, as well as incorporating nearby groundwater monitoring wells for M12 Motorway project and Western Sydney Airport project to use for model calibration.

AlgoMesh was used to discretise the horizontal extent of the model domain into Voronoi-based mesh elements required as input for MODFLOW-USG (refer **Figure 3-1**). Various mesh cell sizes were applied with small cell sizes along watercourses and AWRC site while allowing larger cells in areas further away from features of interest resulting in a total of 51,067 elements in each layer. Mesh cell resolution was assigned as follows:

- Maximum mesh cell resolution along watercourses and in alluvium areas – ±20 m
- Maximum grid cell resolution across AWRC site – ± 8 m

Definition of mesh cell resolution for linear features was incorporated in GIS polylines by setting the spacing of polyline vertices at the desired resolution that represents the width of the feature, for example the width river channel.

3.3 Model Layering

Vertically, the model domain was discretised into ten (5) layers with all the covering the full model extent. In areas where a particular hydrogeological unit pinches out (for example, due to erosion), the layer thickness was significantly reduced to 0.5 m, with same hydraulic properties as the layer below. This approach was applied to ensure that each layer represents a discrete hydrogeological unit provided in **Table 6-2** in the main text of the AWRC Groundwater Technical Report.

The following were considered for model layering:

- Accurate representation of key aquifer units
- Accurate representation of steep vertical gradients in the vicinity of AWRC bioreactors to simulate effects of construction dewatering

- Accurate representation of the construction details (screen depths) of the monitoring bores to allow more reasonable comparison of simulation results to observed values at corresponding depths during calibration.

The vertical boundaries between different geologies across the study area were developed based the lithology data provided on the bore logs developed by Aurecon geotechnical Team, in conjunction with the aquifer testing results in **Appendix A**. The AWRC bore logs are provided in **Appendix B**.

Figure 3-2 shows the proportions of the various soil/ground groups encountered in the boreholes at the proposed AWRC site, grouped into sands (SW, SP, and SC), gravels (GW, GP, and GC), silts & clays (ML, CL, CI, CL-CI, CI-CH, and CH), and rock (core loss zone, sandstone, interbedded mudstone and sandstone, laminate, and claystone).

The zone above 8 m to 10 m depth range is comprised of mostly a complex mixture of silts & clays with a small proportion of sands and gravel. This mixture of sediments constitutes more than 65% of the soil/ground encountered. At 8 m to 10 m depth range and below the quantity of the sediments reduces significantly with various rocks starting to dominate. Based on this information, the key units were identified; the alluvium (i.e. mixture of silts & clays, sands and gravel sediments) and fractured claystone overlying low permeability Bringelly Shale. A uniform thickness of 8 m relative to the ground surface was assumed for alluvium. The thickness for fractured claystone underlying the alluvial soil was assumed at 3 m. These thicknesses were applied throughout the model domain in the regions covered by the alluvium surface geology polygon (**Figure 3-1**).

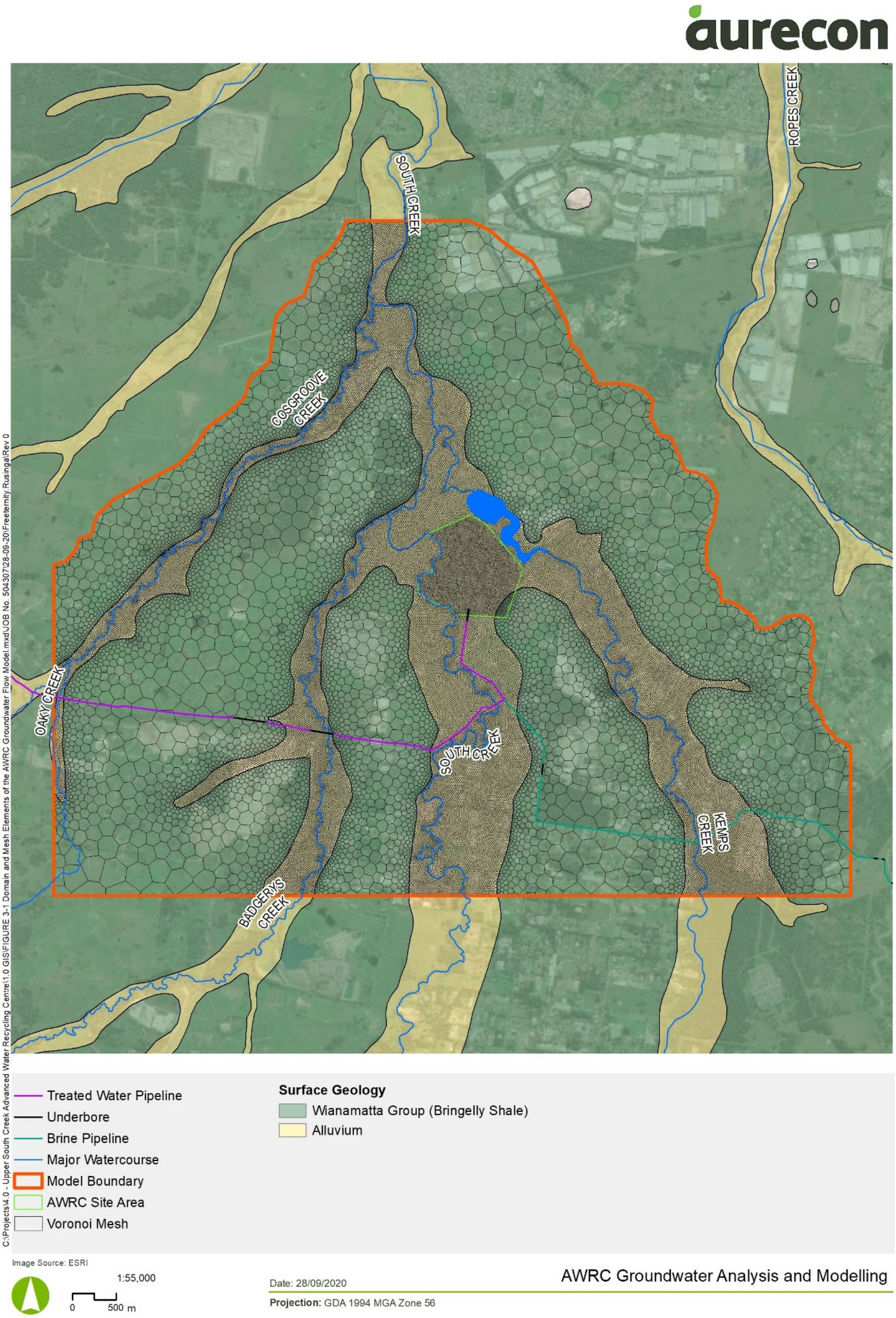

Figure 3-1: Domain and Mesh Elements of the AWRC Groundwater Flow Model

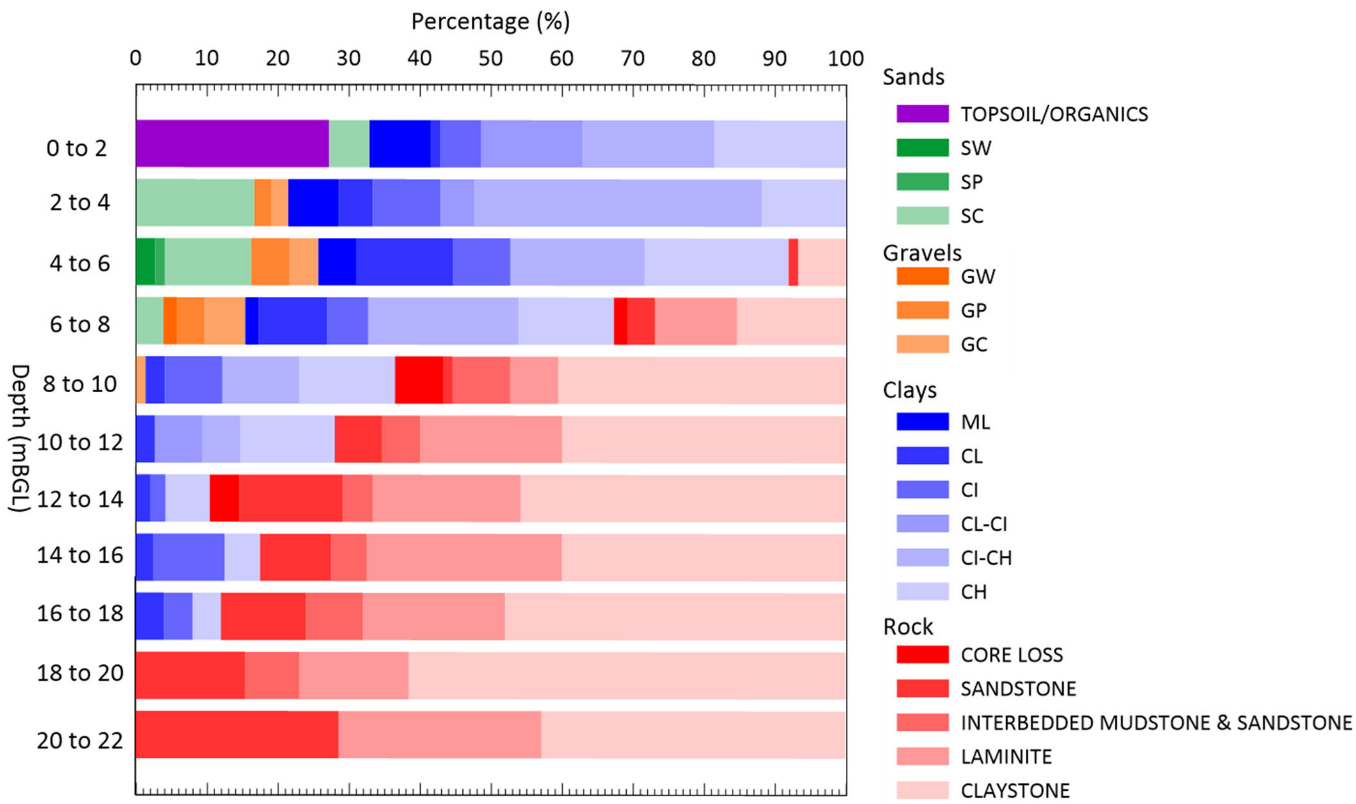

Figure 3-2: Proportion of Soil/ground at the Proposed AWRC site (Based on 29 Bore Logs)

3.4 Boundary Types and Locations

Model boundary conditions are shown in **Figure 3-3** and discussed below.

3.4.1 River Boundaries

Major watercourses (i.e. Kemps Creek, South Creek, Badgerys Creek and Cosgrove Creek) across the model domain were established in the model as 'River' cells using MODFLOW RIV Package to simulate the interaction between groundwater and surface water as follows:

- River stage: Set to river cell ground surface elevation + 0.3 m (based on surveyed river water levels in South Creek and Kemps Creek near AWRC site
- Riverbed elevation: Set at river cell ground surface elevation
- Hydraulic conductance of the riverbed: Set at 100 m^2/d for the main South Creek stem and 0.5 m2/d for the tributaries Kemps Creek, Badgerys Creek and Cosgrove Creek. These values were tested via calibration targeting average annual baseflow rates ranging from 2,000 m^3/d to 4,000 m^3/d. **Section 5.3** of the main text of the AWRC Groundwater Technical Report provides further details of the South Creek baseflow.

3.4.2 General Head Boundary

Regional flow into and out of the model area through Bringelly Shale was simulated using the General Head Boundary (GHB) condition. GHB boundaries allow water to enter the model where the GHB head is higher than modelled head in adjacent model cell and leave the model when the modelled head is lower than GHB head. Boundary cells with general head conditions were assigned in the northern model domain edge, as well as the eastern and western boundaries, and the southern boundary. Head values applied for GHB head were determined using the relationships of observed water level to topography derived from M12 Motorway groundwater monitoring records shown in **Table 3-2** and plotted in **Figure 3-4**. These were applied to Bringelly Shale in model layers 3 to 5. GHB conditions were setup allowing Groundwater Vistas to compute variable conductance values using modelled hydraulic conductivity values of the Hawkesbury Sandstone multiplied by the cell area.

3.4.3 No-flow Boundaries

The north-east and north-west edges of the model domain were specified as no-flow boundaries coinciding with the catchment divides for Thompsons Creek and Kemps Creek, respectively.

3.4.4 Seepage Face Boundaries for Large Deep Excavation Pits

There are three large deep pits within the model domain at the locations shown in **Figure 3-3**. The pit near the AWRC is a landfill site. An inspection of Google Earth images shows ponding water in these pits. The source of the water has not been confirmed at the time of issue of this report. A review of groundwater levels in groundwater monitoring wells near the pits shows that the surrounding groundwater levels area higher than the base of the deep portions of the pits. It has therefore been assumed that groundwater may be discharging into these pits. The pits were established in the model as ‘Drain’ cells using MODFLOW DRN Package to simulate potential groundwater seepage into these voids.

3.4.5 Recharge

The Water Sharing Plan for the Greater Metropolitan Region Groundwater Resources generally assumes an annual recharge rate of 6% of annual rainfall for assessing available yields within these groundwater aquifer systems. PPK (1999) applied a uniform recharge rate of 1% of annual rainfall in the Western Sydney Airport groundwater model across alluvium and Bringelly Shale aquifers included in the model. Applicable recharge for the AWRC groundwater model was determined via calibration (**Section 4**) by testing the model’s response to rates ranging from 1% to 12% of the annual rainfall recharge.

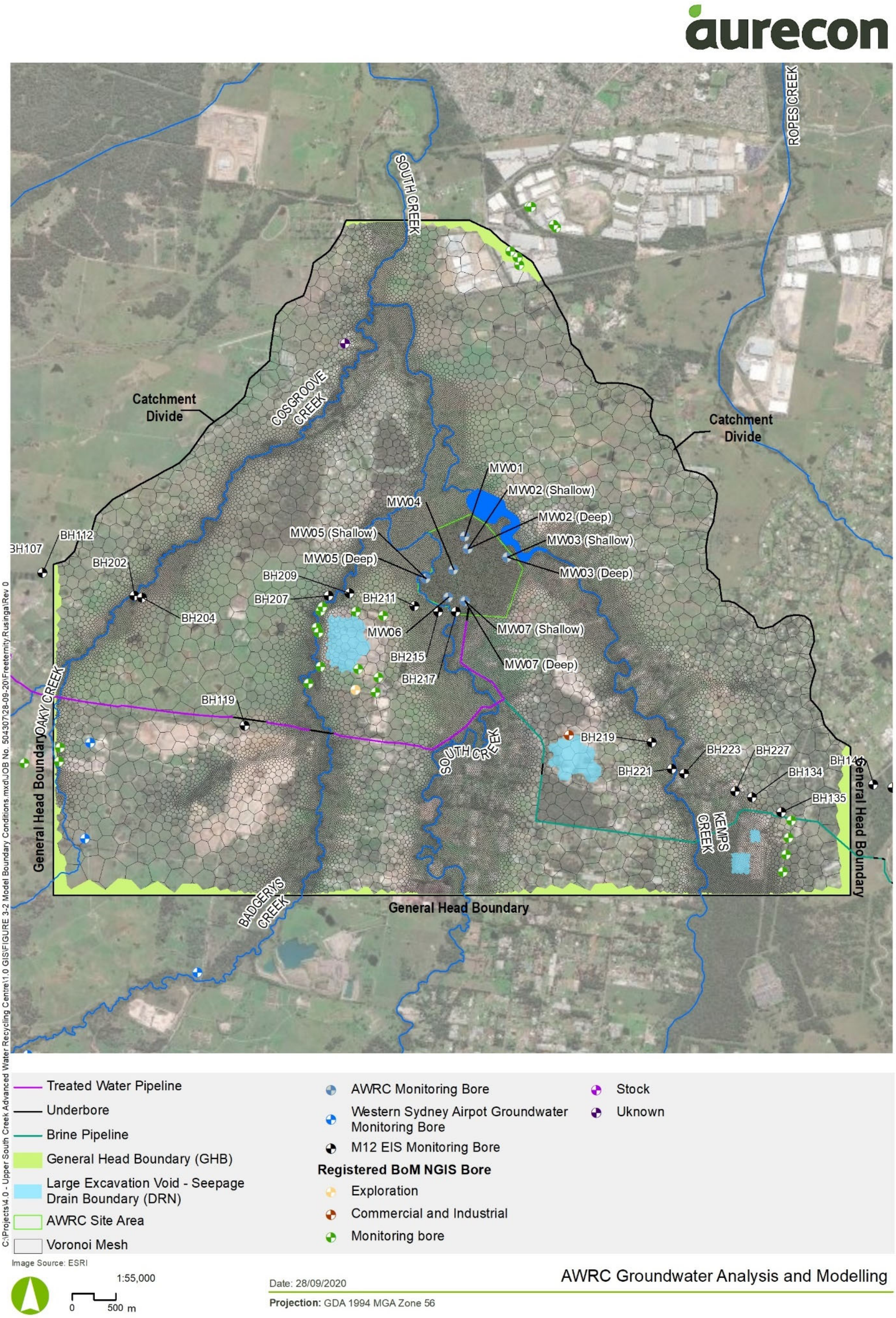

Figure 3-3: Model Boundary Types

Table 3-2: Historical groundwater levels within in Bringelly Shale (Coffey, 2015)

Well ID	Easting	Northing	Well depth (mBGL)	Ground surface level (mAHD)	Groundwater level (mAHD)	Depth to water (mBGL)	Date of GWL observation
D1	286840	6245879	15.20	104.20	96.30	7.90	18/07/1990
D2	287065	6246834	9.85	97.60	93.90	3.70	18/07/1990
D3	287295	6247189	10.00	105.70	102.35	3.35	18/07/1990
D5	288139	6247480	20.15	102.50	98.60	3.90	18/07/1990
D6	287790	6246539	25.10	112.90	105.50	7.40	18/07/1990
D7	288158	6245894	10.35	79.40	75.45	3.95	18/07/1990
D8	289089	6246504	10.05	92.10	84.20	7.90	14/09/1990
D9	289486	6247149	10.25	87.50	83.30	4.20	18/07/1990
D10	289772	6247874	10.00	88.00	83.30	4.70	18/07/1990
D12	291163	6249365	10.50	59.00	55.80	3.20	18/07/1990
D19	288395	6248129	15.00	88.90	83.40	5.50	-
D22	287250	6246322	20.00	103.20	94.10	9.10	-
D23	287118	6247517	20.70	105.60	96.00	9.60	-
D29	288388	6247031	10.05	95.10	87.50	7.60	-
A	288241	6244156	27.30	92.91	81.25	11.66	-
B	289670	6249305	38.50	71.18	61.79	9.39	-
C	285636.8	6247115	26.00	66.52	58.35	8.17	-
E Deep	287865.8	6244956	11.30	78.21	75.36	2.85	-
F Deep	288834.3	6245972	30.30	69.87	65.97	3.90	-
G Deep	290792.5	6246831	24.30	59.64	54.64	5.01	-
H Deep	289190.7	6244469	12.30	84.06	81.08	2.98	-
H Shallow	289188.9	6244469	4.50	84.03	81.62	2.41	-
J Deep	290053.5	6242999	42.30	70.86	65.22	5.64	-
K	289589.8	6248320	32.30	72.01	68.51	3.50	-

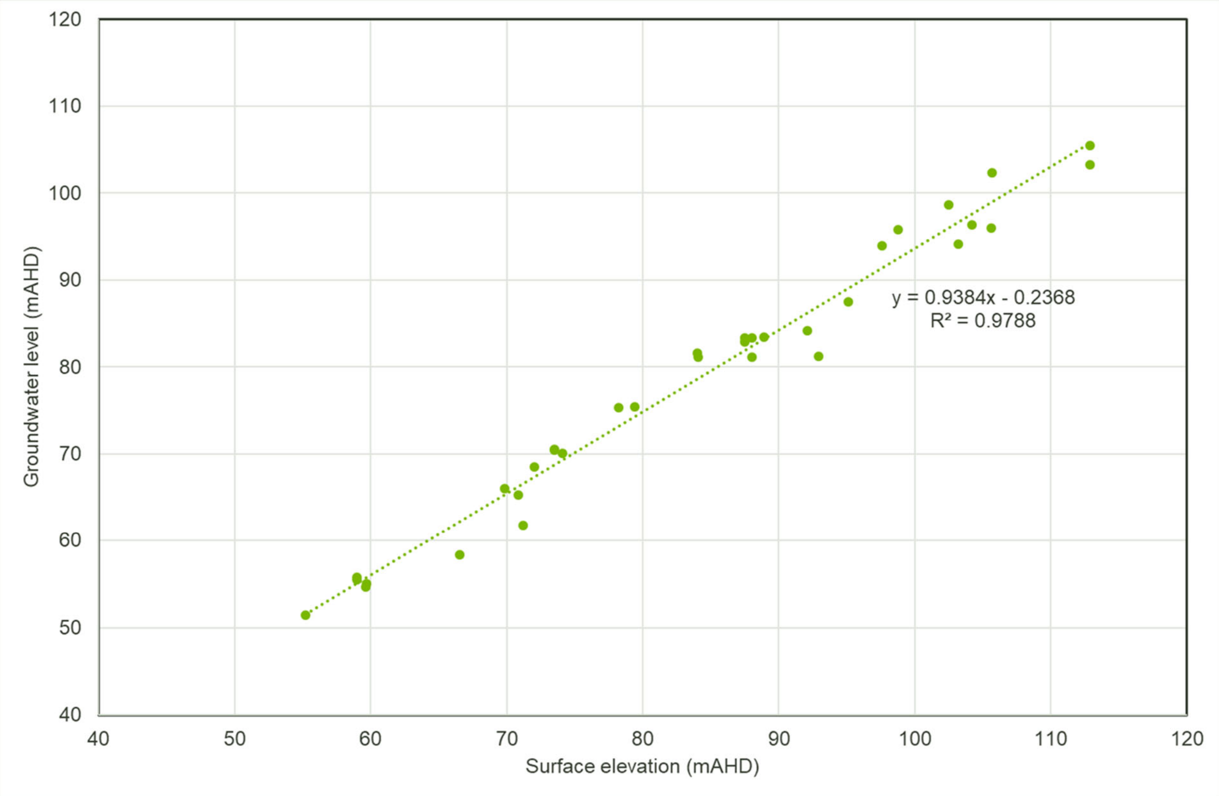

Figure 3-4: Potential relationship Between Topography and Water Level in Bringelly Shale

Recharge rates for the AWRC groundwater model were determined via calibration as outlined in **Section 4**, using MODFLOW Recharge Package.

3.4.6 Evapotranspiration

Evapotranspiration losses occur from the shallow soil zone. This process may be more predominant following wet season recharge of aquifers (i.e. evaporation rates will increase with higher water tables). Groundwater discharge through evapotranspiration was simulated using the MODLFOW Evapotranspiration (EVT) package. An extinction depth of 1 m was specified, below which EVT ceases to occur. A uniform evapotranspiration rate of 10% of annual rainfall adopted for the AWRC similar to the rate applied in the Western Sydney Airport groundwater model by PPK (1999).

3.4.7 Groundwater Abstraction

Review of the National Groundwater Information System (NGIS) groundwater database held by the Bureau of Meteorology (BoM) has identified one commercial and industrial water supply within 3 km of the AWTC site (**Figure 3-3**). Information regarding the abstraction rates for this bore had not been obtained at the time of issue of this report. This bore has therefore not been simulated in the model.

3.5 Model Time Frames

3.5.1 Steady-state Flow Modelling

Steady-state mode modelling was applied for calibration and the post-construction modelling to simulate likely long-term conditions associated with the proposed AWRC works with both Stage 1 and future stages in place.

3.5.2 Transient Flow Modelling

Transient mode modelling was applied to simulate potential impact of construction dewatering required for safe construction the AWRC Stage 1 bioreactors based on the current 100% construction schedule for the reference design shown in **Figure 3-5**, as follows:

- Bioreactor East: from 29/03/2023 to 19/03/2024 (356 days). These correspond to model stress periods 6 and 18, respectively
- Bioreactor West: from 29/05/2023 to 2/08/2024 (431 days). These correspond to model stress periods 7 and 21, respectively

Bioreactor - East	**295 days**	**Wed 29/03/23**	**Mon 22/04/24**
Detail excavation, prepare base and place subfloor drainage	40 days	Wed 29/03/23	Tue 23/05/23
FRP base	50 days	Thu 20/04/23	Fri 23/06/23
FRP Walls and misc structures	**150 days**	**Wed 10/05/23**	**Wed 15/11/23**
FRP inner walls	105 days	Mon 5/06/23	Mon 16/10/23
FRP outer walls	85 days	Wed 10/05/23	Fri 25/08/23
FRP Misc Pit Walls, walkways, etc	80 days	Mon 7/08/23	Wed 15/11/23
Water test tanks	40 days	Tue 3/10/23	Tue 21/11/23
Mech/Elec Fitoff	**100 days**	**Tue 19/09/23**	**Mon 5/02/24**
Fit mixers/membranes	60 days	Fri 27/10/23	Tue 23/01/24
Fit valves, weir plates and misc mechanical items	100 days	Tue 19/09/23	Mon 5/02/24
Fitoff Electrics & Controls	100 days	Tue 19/09/23	Mon 5/02/24
Finish external pipe connections	20 days	Wed 15/11/23	Mon 11/12/23
Backfill tank and finish area	40 days	Mon 29/01/24	Tue 19/03/24
Commissioning	60 days	Mon 5/02/24	Mon 22/04/24
Bioreactor - West	**340 days**	**Tue 23/05/23**	**Thu 8/08/24**
Detail excavation, prepare base and place subfloor drainage	40 days	Tue 23/05/23	Wed 12/07/23
FRP base	50 days	Wed 12/07/23	Wed 13/09/23
FRP Walls and misc structures	**145 days**	**Wed 13/09/23**	**Mon 25/03/24**
FRP inner walls	105 days	Mon 16/10/23	Wed 6/03/24
FRP outer walls	85 days	Wed 13/09/23	Wed 10/01/24
FRP Misc Pit Walls, walkways, etc	80 days	Mon 4/12/23	Mon 25/03/24
Water test tanks	40 days	Thu 22/02/24	Tue 16/04/24
Mech/Elec Fitoff	**100 days**	**Wed 17/01/24**	**Fri 24/05/24**
Fit mixers/membranes	60 days	Thu 22/02/24	Sat 11/05/24
Fit valves, weir plates and misc mechanical items	100 days	Wed 17/01/24	Fri 24/05/24
Fitoff Electrics & Controls	100 days	Wed 17/01/24	Fri 24/05/24
Finish external pipe connections	20 days	Wed 10/04/24	Mon 6/05/24
Backfill tank and finish area	40 days	Thu 13/06/24	Fri 2/08/24
Commissioning	60 days	Fri 24/05/24	Thu 8/08/24

Period over which dewatering will be required

Period over which dewatering will be required

Figure 3-5: Current Proposed 100% Reference Design Construction Schedule for AWRC Bioreactors

4 Model Calibration

4.1 Steady State Model Calibration

There are no long-term groundwater level monitoring records in the area covered by the AWRC groundwater model domain to determine the nature of groundwater flow dynamics. With no recent major works in this area which could be interfering with the groundwater system, it has been assumed that available ground water level data at AWRC and nearby projects are representative of steady-state groundwater conditions and this was used as the basis for steady-state calibration of the AWRC model.

Model calibration involves determination of the magnitude and spatial distribution of the key model hydraulic parameters that allow the model to reproduce the observed/estimated groundwater levels within the model area. A combination of automated adjustments using PEST version 15 (www.PestHomePage.org) and manual adjustments to zone values of hydraulic conductivity, recharge and hydraulic conductance parameters were undertaken such that the model-predicted groundwater levels generally matched the observed groundwater levels and estimated baseflow. The observed groundwater levels comprised 24 targets at the AWRC and M12 Motorway EIS monitoring bores shown in **Figure 3-3**.

The following performance metrics were used to judge the quality of the model conditioning and calibration simulations:

- The Scaled Root Mean Squared (RMS) Error for the model-predicted versus observed hydraulic heads for 24 monitoring bore locations, targeting 10% maximum suggested by the Australian Modelling Guidelines (Barnett et al 2012)
- The systematic/unsystematic nature and magnitude of over-prediction or under-prediction of hydraulic heads at 24 calibration targets (observation points)
- Discharge flow rates to the modelled rivers consistent with observed baseflow rates at Great Western Highway Gauge 212048
- Groundwater level contour gradients consistent with the observed groundwater levels.
- Strategies to reduce model non-uniqueness included:
  - Use of site-specific geology information as described in the bore logs to constrain the three-dimensional limits of the major hydrostratigraphic zones within the model domain
  - Setting calibration targets for hydraulic conductivity based on measured values from field-based aquifer testing. The details of the field investigations are provided in **Appendix A**
  - Adjusting aquifer parameters within field-measured ranges
  - Adjusting hydraulic conductance parameters for riverbeds within plausible bounds to achieve a reasonable calibration match to observed baseflow rate at Great Western Highway Gauge 212048.

The process followed is described below.

Hydraulic conductivities parameters were allowed to vary between the lower and upper bounds of field-tested range of hydraulic conductivity values presented in **Table 4-1** during PEST optimization runs (see the Geotechnical Factual Report (Aurecon Arup, 2021) for details on aquifer testing carried out at the AWRC). Recharge was applied as proportion of 745.6 mm annual rainfall by varying it between 1% and 12% in the alluvium aquifer and between 1% and 3% in the Bringelly Shale during PEST optimization runs.

Following optimization with PEST, the hydraulic conductance parameters of the riverbed were adjusted manually targeting average baseflow rates ranging from 2,000 m^3/d to 4,000 m^3/d (refer **Section 5.3** of the main text of the AWRC Groundwater Technical Report). Once acceptable baseflow was attained, minor adjustments were applied to the PEST optimised hydraulic conductivities and recharge parameters. Final hydraulic conductance values of 100 m^2/d for the main South Creek stem and 0.5 m^2/d for the tributaries Kemps Creek, Badgerys Creek and Cosgrove Creek were adopted for the model. These parameters produced net baseflow of 2,251 m^3/d generated within the model domain. The final calibrated hydraulic conductivities are included **Table 4-1**. Final recharge rates were obtained at 10% and 1% of annual rainfall for the alluvium and Bringelly Shale aquifer, respectively. Over the whole model domain, these recharge rates are equivalent to 3,568 m^3/d or 3.3% of annual rainfall (24.7 mm/yr). These calculations are based on 14.4 km^2 and 38.2 km^2 areas of alluvium and Bringelly Shale aquifers, respectively included in the model domain. EVT was not varied during calibration with a uniform rate of 10% of annual rainfall adopted for the AWRC similar to the rate applied in the Western Sydney Airport groundwater model as mentioned in **Section 3.4.6**.

Table 4-2 compares measured groundwater levels with simulated groundwater levels generated by the calibrated model. The best-match simulated water levels were within 1 m of the measured groundwater levels for 12 records. This represents 50% of the total records used, with 75% of these within 0.5 m of measured groundwater levels, predominantly at AWRC.

The scaled root mean square (SRMS) for calibrated model is 6.1%, and this is well below 10% maximum target suggested by the Australian Modelling Guidelines (Barnett et al 2012). **Table 4-3** summarises the statistics of the attained calibration with scatter plot of simulated versus observed groundwater levels presented in **Figure 4-1**. It was considered that the level of calibration achieved, particularly at AWRC, is reasonably good for the model to be used for prediction modelling of the proposed works for AWRC.

Table 4-1: Parameter Calibration Limits Used During for Hydraulic Conductivity

	3	Bringelly Shale	0.03	0.01	0.09	0.09	0.1 to 0.01	0.06	0.008
	3	Bringelly Shale	0.03	0.01	0.09	0.09	0.1 to 0.01	0.06	0.008
4 to 5	4	Bringelly Shale	0.03	0.003	0.001	0.009	0.1 to 0.01	0.03	0.003

Table 4-2: Measured versus simulated groundwater levels in monitoring wells

Bore ID	Easting	Northing	Model layer	Aquifer	Observed groundwater level	Computed groundwater level	Residual
BH119	291372.41	6249710.50	3	Bringelly Shale Aquifer	52.57	51.37	1.20
BH134	297251.60	6248876.40	3	Bringelly Shale Aquifer	54.40	56.30	-1.90
BH135	297594.01	6248705.90	3	Bringelly Shale Aquifer	58.17	60.67	-2.50
BH202	290089.91	6251218.30	2	Fractured claystone of the Bringelly Shale Aquifer	47.27	49.11	-1.84
BH204	290177.30	6251195.20	2	Fractured claystone of the Bringelly Shale Aquifer	48.02	49.29	-1.27
BH207	292341.60	6251217.10	2	Fractured claystone of the Bringelly Shale Aquifer	35.59	37.63	-2.04
BH209	292587.01	6251246.00	2	Fractured claystone of the Bringelly Shale Aquifer	35.75	36.93	-1.18
BH211	293340.01	6251097.00	2	Fractured claystone of the Bringelly Shale Aquifer	35.47	36.22	-0.75
BH215	293615.01	6251030.00	2	Fractured claystone of the Bringelly Shale Aquifer	34.30	35.43	-1.13
BH217	293817.01	6251033.00	2	Fractured claystone of the Bringelly Shale Aquifer	35.10	35.43	-0.33
BH219	296088.30	6249516.10	2	Fractured claystone of the Bringelly Shale Aquifer	41.88	44.55	-2.67
BH221	296319.71	6249207.70	3	Bringelly Shale Aquifer	41.44	45.28	-3.84
BH227	297056.01	6248945.00	4	Bringelly Shale Aquifer	53.95	53.11	0.84
MW01	293922.34	6251905.16	3	Bringelly Shale Aquifer	34.97	36.48	-1.51
MW02D	293957.24	6251760.59	3	Bringelly Shale Aquifer	36.16	37.00	-0.83
MW03D	294412.95	6251662.78	2	Fractured claystone of the Bringelly Shale Aquifer	37.33	37.16	0.17
MW05D	293469.20	6251417.88	2	Fractured claystone of the Bringelly Shale Aquifer	34.58	34.41	0.17
MW07D	293922.78	6251154.83	3	Bringelly Shale Aquifer	36.32	37.53	-1.20
MW02S	293956.33	6251761.00	2	Fractured claystone of the Bringelly Shale Aquifer	37.01	37.01	0.00
MW03S	294412.37	6251662.41	1	Alluvium Aquifer	37.34	37.17	0.17

Bore ID							
MW05S	293468.17	6251417.73	1	Alluvium Aquifer	34.38	34.41	-0.03
MW07S	293922.97	6251154.16	1	Alluvium Aquifer	37.16	37.54	-0.38

Table 4-3: Summary of steady state model calibration statistics

Absolute Residual Mean	1.09
Sum of Squares	51.13
Min. Residual	-3.84
Number of Observations	24.00
Scaled Residual Std. Deviation	4.9%
Scaled RMS Error	6.1%

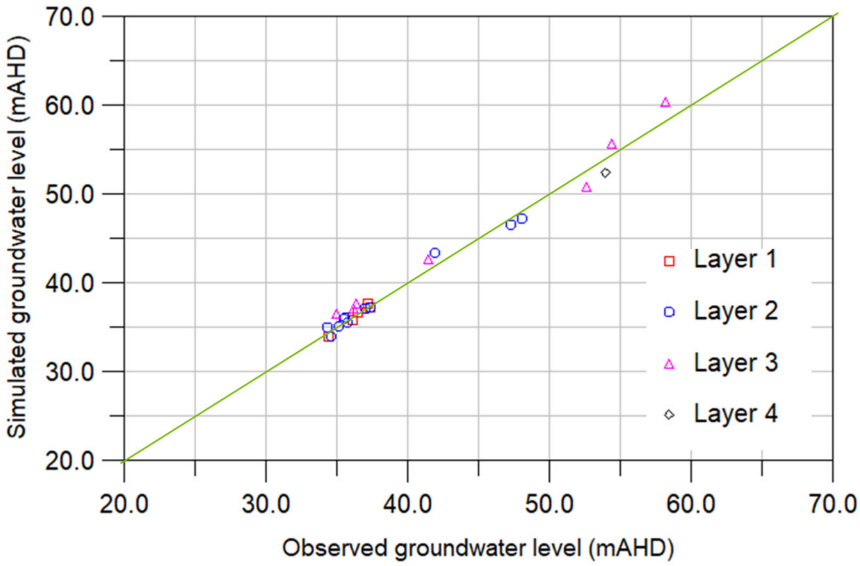

Figure 4-1: Scatter plot of simulated groundwater levels versus observed groundwater levels

4.2 Steady-state Water Balance

Table 4-4 presents the water balance for steady-state simulation, which indicates that inflow of the model water balance is dominated by aerial rainfall recharge. Outflow is dominated by loss of groundwater via baseflow. The simulated net baseflow is approximately 2.25 ML/d (or 2,250 m^3/d) which is within the estimated baseflow described in **Section 4**.

Table 4-4: Steady-state Water Balance

Regional GW Flow (GHB)	0.97	18.4%	0.73	13.9%
ET (from GW) (EVT)	0.00	0%	0.94	17.7%
Total	5.28	100%	5.28	100%

5 Model Sensitivity Analysis

Sensitivity analysis improves the understanding of the importance of the input data on simulated results and how the limitations related to these parameters may affect modelling results. **Table 5-1** summarises the calibration statistics for the steady-state sensitivity simulations. These results indicate that these variations in the modelled parameters generally result SRMS within 10% (max.) stipulated in MDBC, 2001 and Barnett et al., (2012). The model is most sensitive to the horizontal hydraulic conductivity This means that the model performance will be most impacted by uncertainty associated with this parameter.

NOTE: The aquifer hydraulic parameters used in the AWRC model are based on rising and falling head tests. These types of aquifer tests evaluate only a small volume of the aquifer at each tested well location. Poor rock recovery, low rock quality designation (RQD) and core losses observed by Aurecon as part of the logging of rock cores are indicators of potential open joints and fractured zones at AWRC and potential source of groundwater problems in terms of dewatering, that require further investigations. It is recommended to carry pumping tests as part of the development of the dewatering plan for the AWRC construction works.

Table 5-1: Steady-State Calibration Statistics for Sensitivity Runs

Absolute Residual Mean	1.09	1.86	1.81	1.11	1.44
Sum of Squares	51.13	101.25	135.83	52.59	83.40
Min. Residual	-3.84	-3.80	-6.57	-3.87	-4.63
Number of Observations	24.00	24	24	24	24
Scaled Residual Std. Deviation	4.9%	3.6%	9.7%	4.9%	5.0%
Scaled RMS Error	6.1%	**8.6%**	**10.0%**	**6.2%**	**7.8%**

Notes: K_h – Horizontal hydraulic conductivity; K_v – Vertical hydraulic conductivity

6 Predictive Modelling

The following predictive model scenarios were assessed.

6.1 Scenario 1: Construction Phase Modelling

This scenario relates to construction dewatering and it only applies to the Bioreactors which would penetrate below the water table. This scenario assesses potential impacts which could arise due to construction dewatering which will be required for the construction of the bioreactors. **Figure 6-1** shows a typical cross-section of the bioreactors based on the current version of the reference design. The base of the lower sand layer of the underdrainage system is proposed to be about 1.0 m below the slab of the bioreactor tank. This corresponds to a level of 34.7 mAHD. Observed groundwater levels across the footprint of the bioreactors varies from 36.4 mAHD at MW04 to 37 mAHD at MW2S. Construction dewatering will therefore be required to provide a safe working platform. The required drawdown for dewatering depends on hydrogeologic conditions.

The presence of a confined aquifer at shallow depth beneath the excavation would result in a risk of base heave if the piezometric head is not lowered adequately. A conservative approach is to lower the groundwater level below the formation level to at least 1 m clearance. A clearance of 1.5 m has been adopted for this modelling, meaning that the groundwater table would need to be lowered to RL 33.2 mAHD.

Dewatering modelling was undertaken using transient modelling with the aid of MODFLOW DRN package activated at the timeframes represented in the currently proposed construction program for Stage 1 reference design described in **Section 3.5.2** as follows:

- Bioreactor - East: 01 April 2023 DRN **on** – 01 May 2024 DRN **off**
- Bioreactor- West: 01 June 2023 DRN **on** – 01 September 2024 DRN **off**

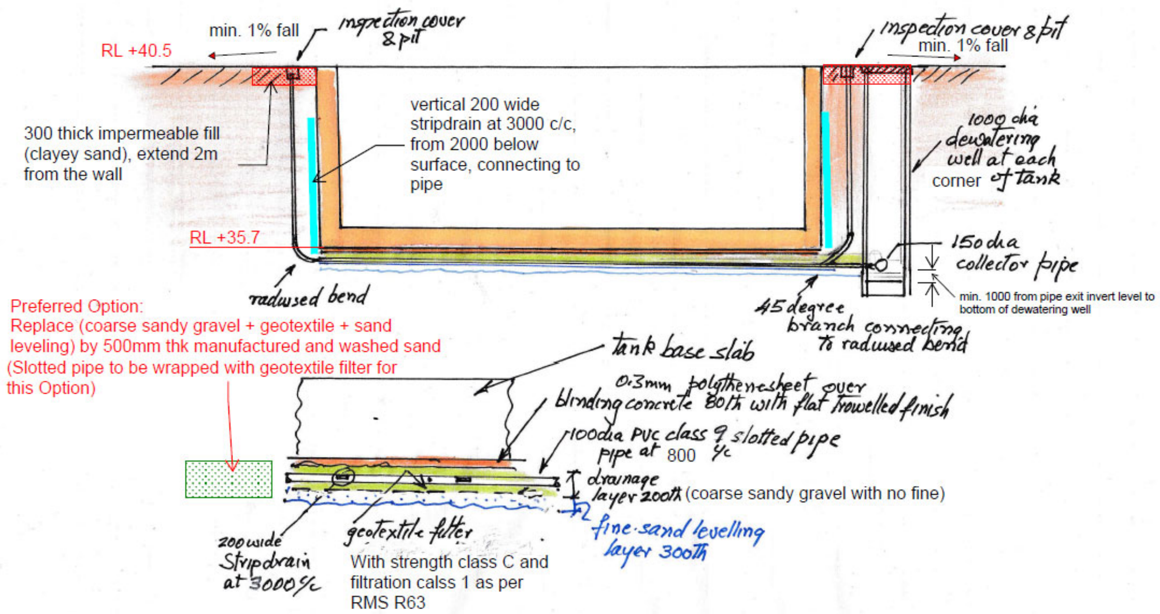

Figure 6-1: Schematic illustration of flushable tank underdrainage of the bioreactor

It should be noted that construction schedule for future stages had not been issued at the time of issue of this report. Due to nearly similar size and design, it is expected that these will be a similar impact to Stage

1 bioreactors. However, it is recommended that impacts of any future bioreactors be assessed via modelling once the construction schedule becomes available.

Modelling of Stage 1 construction dewatering above has assumed the construction will stick to the proposed schedule. In reality, construction program may be affected by other factors beyond the control of the contractor such as bad weather or other issues which could delay the works, resulting in an extended schedule. It is also possible that there may be efficiencies in the construction process.

Storage parameters are required in a transient model and the following were assumed:

- Alluvium: Specific yield (Sy) – 0.18 Specific storage – 0.0001
- Bringelly Shale: Sy – 0.1 Specific storage – 0.0001

A sensitivity / uncertainty analysis was also undertaken in order to assess the significance that variations in hydraulic conductivity (permeability), specific yield and recharge have on the simulated ground water inflow during construction based on the range of parameters in **Table 5-1**. For specific yield, a high value of 0.3 was tested. To maintain the equivalent hydraulic conductivity to recharge ratio, a scenario with doubled hydraulic conductivity and recharge flux was also tested.

6.2 Scenario 2: Operational Phase Modelling

The following could impact on the AWRC groundwater system post-construction:

- AWRC structures below the groundwater table which would partially block the natural groundwater flow pathway
- Impermeable surfaces across the AWRC site would result in the reduction of recharge
- Maintenance regimes which requires dewatering of the bioreactors sub-surface drainage (**Figure 6-1**)
- On site irrigation and potential exfiltration due to proposed biofiltration systems
- Storage and use of chemicals and contaminants

The effects of the first three were assessed through modelling.

The USC Surface Water Impact Assessment Report outlines the recommended strategy for stormwater management which entails the re-creation of pre-development environmental water balance by offsetting the lost recharge due to AWRC impermeable surfaces through increasing post-construction recharge through leaky wetlands and detention basins, as well as local irrigation. If this is achieved, it predicted that the effects of the proposed stormwater management would maintain pre-development water balance, with localised impacts where the works will be provided. This strategy for stormwater management is based on water balance modelling results and is assessed as appropriate for reference design. More detailed infiltration analysis is recommended during the detailed design phase when the final location of the facilities are determined.

In assessing the impacts of the AWRC structures below the groundwater table, which in this case are the bioreactor tanks, the portion of the tanks above the elevation of the tank slab was set to a no-flow internal boundary condition. This was applied to both Stage 1 and the potential future bioreactors. The reduction in recharge was simulated by setting the entire footprint of the AWRC as a zero-recharge zone. The model was run in steady state mode.

The dewatering which will be required for maintenance purposes was also modelled. This was completed using a combination of simple analytical and numerical modelling. Analytical modelling was completed using spreadsheet models based on equations developed by Marinelli and Niccoli (2000). The Marinelli and Niccoli (2000) analytical model is illustrated in **Figure 6-2**. The numerical model has been completed using a simple model developed using MODFLOW. The Marinelli and Niccoli (2000) model computes long-term groundwater inflow into pits and this was used as the basis for constraining the input data for the numerical model, in particular the conductance terms for the Drain (DRN) package in MODFLOW. The MODFLOW model was setup in transient mode to assess the dynamics of the groundwater system in response to dewatering as the basis for the design of the underdrainage system for AWRC bioreactors. The transient model was setup at hourly simulation time intervals, with the drain turned on at the 13-hr time interval.

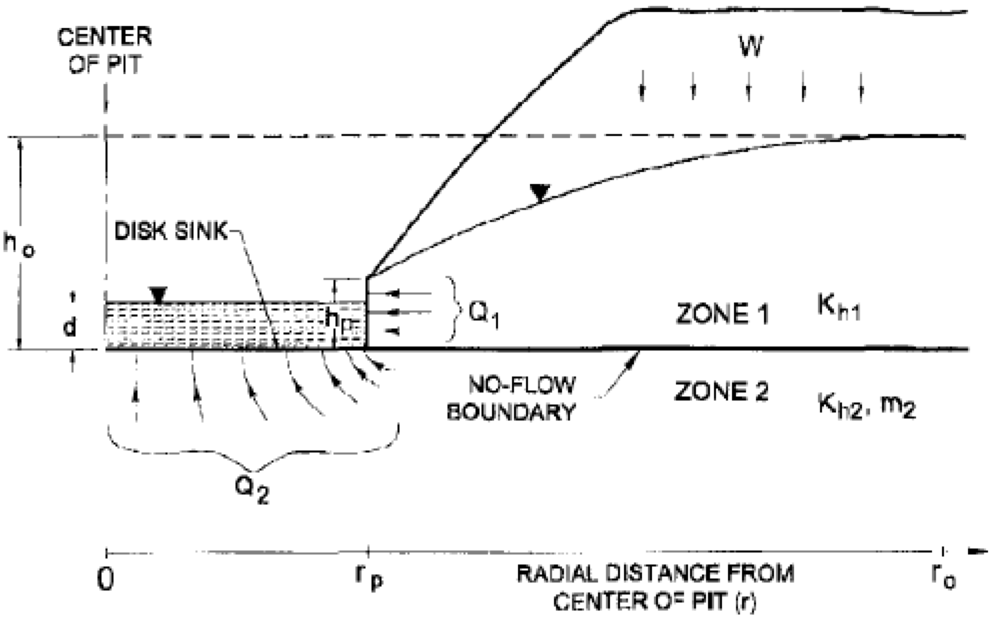

Figure 6-2: Pit inflow Analytical Model (Marinelli and Niccoli, 2000)

The model utilised worst-case conditions with the groundwater table assumed at ground surface at the start of dewatering operations for maintenance purpose. The model was set up prior to the developed of the regional model and it utilised hydraulic parameters derived from the nearby hydrogeology study by PPK (1999) for the Western Sydney Airport. The parameters are within the calibration range of the regional described above and considered appropriate for this assessment.

A summary of the mean hydraulic conductivity values applied are provided below:

- Alluvial aquifer – 0.14m/d.
- Shale aquifer - 0.043m/d with vertical hydraulic conductivity expected to be two to three orders of magnitudes lower than horizontal conductivity.

Storage parameters are provided in **Table 6-1**.

Groundwater recharge has been assumed at a rate of 6% in accordance with Water Sharing Plan for the Greater Metropolitan Region Groundwater Resources. A recharge rate of 41.8 millimetres/year (mm/yr) adopted for the Western Sydney Airport has been assumed for this assessment (GHD, 2016).

The numerical modelling assumed that the head (water level) in the aquifer will be lowered to 35.6 mAHD just below the base of the bioreactor tank floor slab (**Figure 6-1**).

The input data and assumptions applied in the Marinelli and Niccoli (2000) spreadsheet model are provided in **Appendix B**.

Table 6-1: Steady-State Calibration Statistics for Sensitivity Runs

Bringelly shale	0.001	0.1	0.01	0.00001	0.001	0.001

7 Analysis of Modelling Results

7.1 Scenario 1: Construction Phase Modelling Results

Figure 7-1 compares pre-development and construction dewatering groundwater levels. The construction dewatering groundwater levels shown in **Figure 7-1** relates to the maximum simulated conditions just before cessation of dewatering of Bioreactor- East on 1 May 2024 as outlined in **Section 3.5.2** and **6.1**. This point in time relates to the maximum period over which both the eastern and western bioreactors are subjected to dewatering. **Figure 7-2** shows the simulated maximum drawdown at this time of the assumed construction schedule.

Figure 7-1 includes IDs of the modelled river reaches for South Creek. An inspection of the simulated water balances for the modelled river reaches shows that a small section of South Creek (approximately 650 m length) will be impacted, with a slight reduction in baseflow to the creek in this area during construction reducing from an average of about 79 m^3/d to 74 m^3/d over Reach 10 and Reach 11. This represents a baseflow reduction of approximately 6% during construction. The degree of impact is dependent on the distance between the dewatering and the creek (reducing with distance). In terms of foundation design, the degree of impact increases with depth below current ground surface. This groundwater impact could affect the aquatic ecosystems (South Creek) with a high level of interaction with groundwater near the proposed AWRC site, in particular areas in Reach 10 and Reach 11. Full details of impact assessment are provided in the main Groundwater Impact Assessment Report.

The extent of influence due to construction dewatering is about 325 m from the central part of the bioreactor site as shown in **Figure 7-1** and **Figure 7-2**. The extent of influence is a term used to describe the cone of depression and it represents the radial distance from the area where dewatering is applied to the point where there is zero drawdown. Based on these modelling results, the impact of construction dewatering is expected to be of local extent, which will be contained within the extent of the footprint of the proposed AWRC site. Beyond this extent, the groundwater flow pattern is unimpacted.

To establish a dewatered or pressure-relieved condition, it is necessary to pump the water released by the aquifer from storage within it as the head is lowered to the desired level, before equilibrium is reached. In confined aquifers, the released water comes from elasticity of water and soil skeleton. For unconfined aquifers the released water comes from draining pore spaces. For confined aquifers the volume of water released from storage is usually small and can be neglected. But for unconfined aquifers, the storage release can be significant.

The aquifer at AWRC is an unconfined system and this condition will occur for dewatering of the AWRC aquifer. Simulated inflow rates for the eastern and the western bioreactors would stabilise at 52 L/min and 28 L/min, respectively on average in about 30 days after the storage within pore space is drained. Initial inflow rates to achieve these equilibrium flow rates averages at about 7,900 L/Min and 4,800 L/Min, respectively for the eastern and the western bioreactors, in the first 30 days of pumping. This relates to the initial volume of water which will be released from draining pore spaces. **Figure 7-3** provides simulated cumulative volume of water which will be pumped in the assumed dewatering period for Stage 1 works. Based on these results, the total volume of pumped water in 365 days of the proposed Stage 1 construction schedule will be about 50 ML (31 ML + 19 ML).

Based on the construction schedule described in **Section 6.1**, dewatering for preparations of the works for the Eastern Bioreactor was assumed to commence two months earlier than the Western Bioreactor. This explains why the cumulative volume generated for the Eastern Bioreactor is more than that of the Western Bioreactor in **Figure 7-3**. It should be noted that DRNs cells for simulating construction dewatering were applied to an area approximately equal to the plan area of the bioreactor tanks. In reality, the sides of the excavation would be battered back at least 1 in 1.5, meaning that the overall dimension to be dewatered would be much bigger. Typically, the well array would be designed to dewater bigger area. It implies that actual flow rate may be higher than the estimate above. The estimated inflow rates above provide an initial understanding of dewatering requirements of the likely volumes to be dealt with as the basis for developing a Dewatering Plan for the AWRC works. However, the dewatering plan should be supported by further field tests such as pumping tests as outlined in **Section 5**.

The simulated sensitivity of calculated inflows to model input parameters is provided **Table 7-1**. The results presented in **Table 7-1** show the highest degree of sensitivity to changes in horizontal conductivity of the unconsolidated sediments, with inflow doubling for horizontal hydraulic conductivity an order of magnitude higher than the calibrated values. The choice of one order of magnitude to test the sensitivity of inflow to the hydraulic conductivity values for this geology unit has been based on the falling-head tests completed at the AWRC site, which generally spanned two orders of magnitude.

It is considered unlikely that hydraulic conductivity of unconsolidated sediments would vary by more than one order of magnitude of the calibrated value. However, it should be these parameters were assessed using falling head tests only. Generally hydraulic conductivity analyses from this kind of test is known to underestimate in-situ hydraulic conductivities for soils. Full-scale pumping tests which allow more accurate determination of the hydraulic conductivities over a larger aquifer volume are recommended at detailed design phase or as part of the development of the Dewatering Plan.

The sensitivity of calculated inflows to other parameters in **Table 7-1** show little variation from the baseline calibrated scenario described above. The simulated drawdown also shown little variation. This similarity indicates that in this environment, quasi-steady state conditions are reached very rapidly at the AWRC site.

NOTE: The potential impacts of the solar panels during is a reduction in the permeable surface and groundwater recharge, this has not been directly modelled in the construction phase, but has been captured in the long-term modelling (see **Section 7.2**).

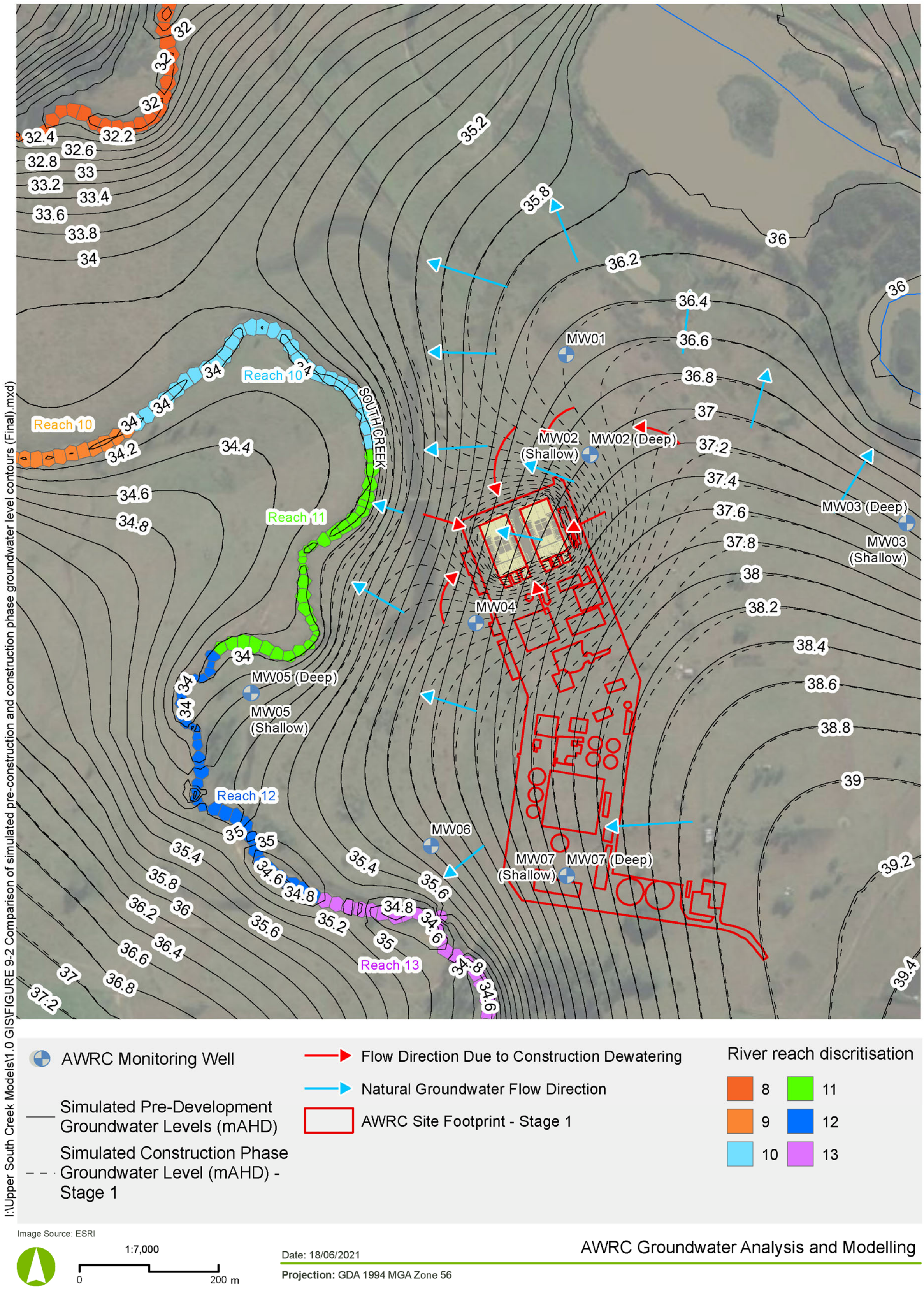

Figure 7-1: Comparison of Simulated Pre-construction and Construction Phase Groundwater Level Contours

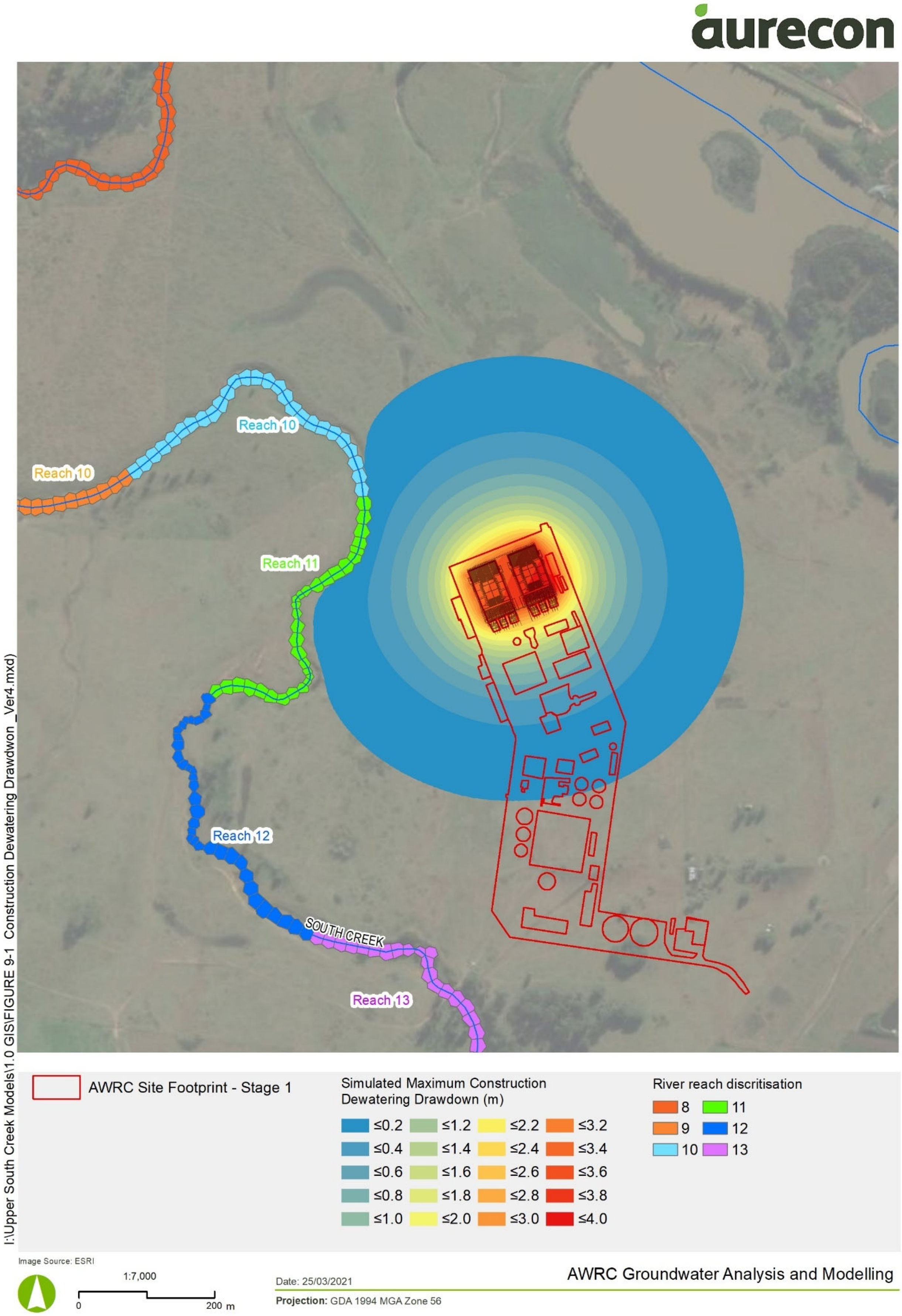

Figure 7-2: Construction Dewatering Drawdown (Cone of Depression)

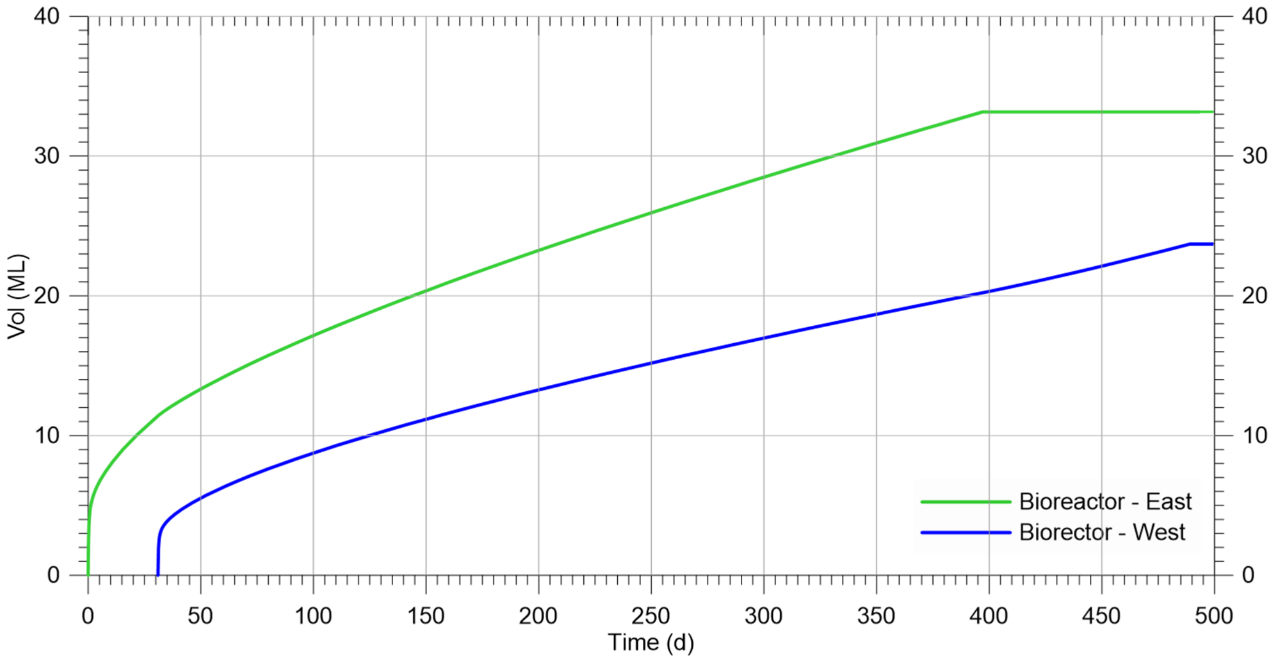

Figure 7-3: Simulated Cumulative Volume of Water During Construction Dewatering (Stage 1 only)

Table 7-1: Sensitivity analysis results for simulated groundwater inflow during construction

Low K_h	13	10	23
High recharge	31	20	51

7.2 Scenario 2: Operational Phase Modelling Results

Figure 7-4 compares pre-development and post-construction long-term groundwater levels generated based on steady state modelling. These results show that the reduction in recharge across the AWRC will result in local depression of the groundwater table of 0.9 m at the centre of the ARWC footprint reducing to zero before intersecting South Creek. Inspection of the simulated water balance indicates a corresponding minor reduction (around 1%) of baseflow in the creek reaches close the site.

The modelling results for dewatering maintenance regimes are presented in **Figure 7-5** and **Figure 7-6**. The modelling assumes that once the water in the dewatering tank has been lowered below the invert of the drainage blanket, the groundwater will be pumped at rates higher than the inflow rate. Under such circumstances, the hydraulic pressure head is expected to reduce to zero as depicted by the red plot in **Figure 7-5**. However, the groundwater table in in the vicinity of the tank would remain elevated at about 3 m above the drainage system. A drainage layer around the tank wall side should be considered to allow the groundwater table in contact with the wall to drop to the desired level. It is recommended to install the inspection piezometer/ well within the drainage layer.

Groundwater inflow will be very high initially due to draining of pore water reducing to 40 L/min (2.6 m^3/hr) for prolonged maintenance regimes of over 5 days as presented **Figure 7-6**. The simulated average inflow rate is 50 L/min (3 m^3/hr). Estimates of the total volume expected to be pumped for each maintenance regime should be assessed based on this average flow.

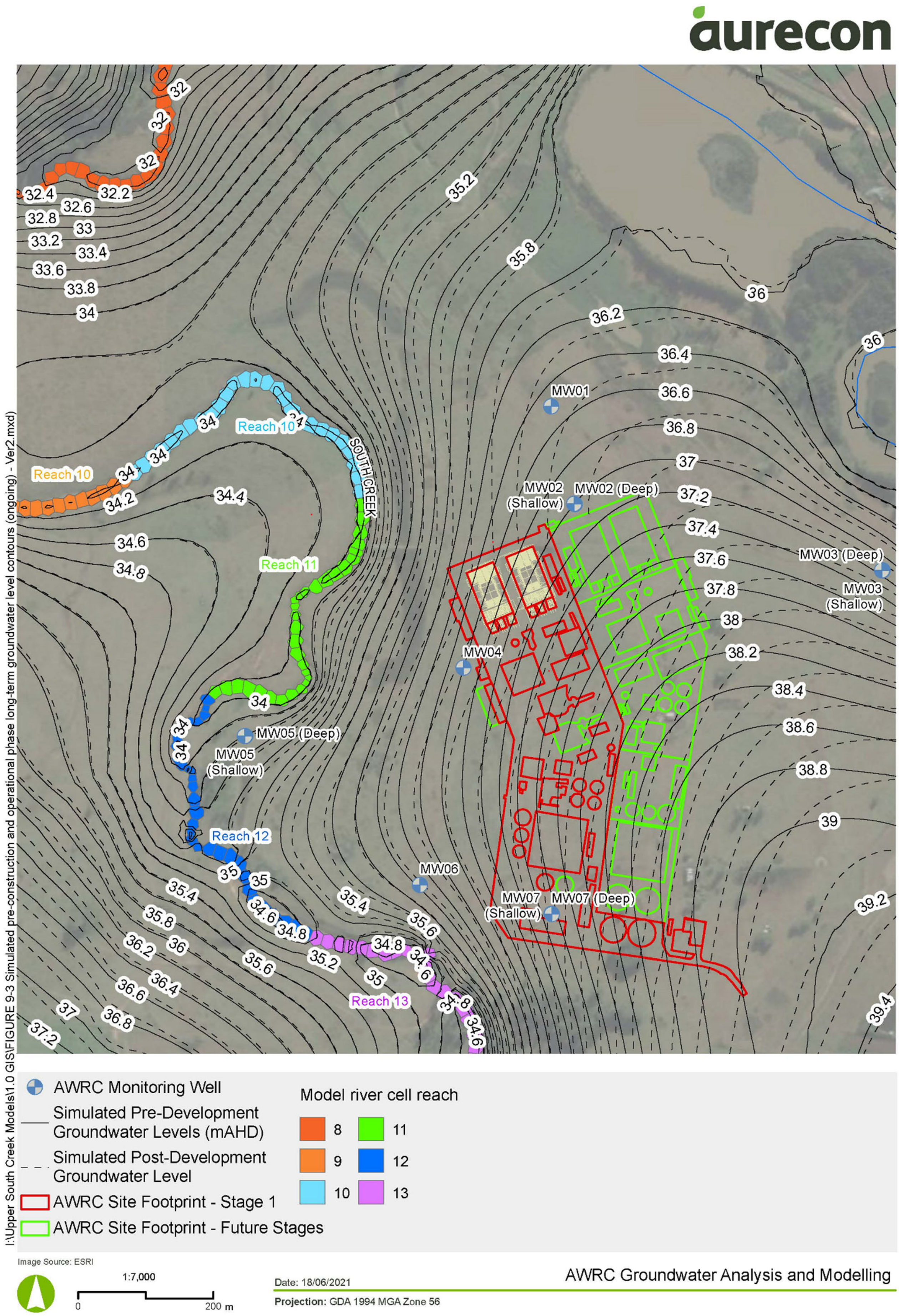

Figure 7-4: Simulated Pre-construction and Post-Construction Long-term Groundwater Level Contours

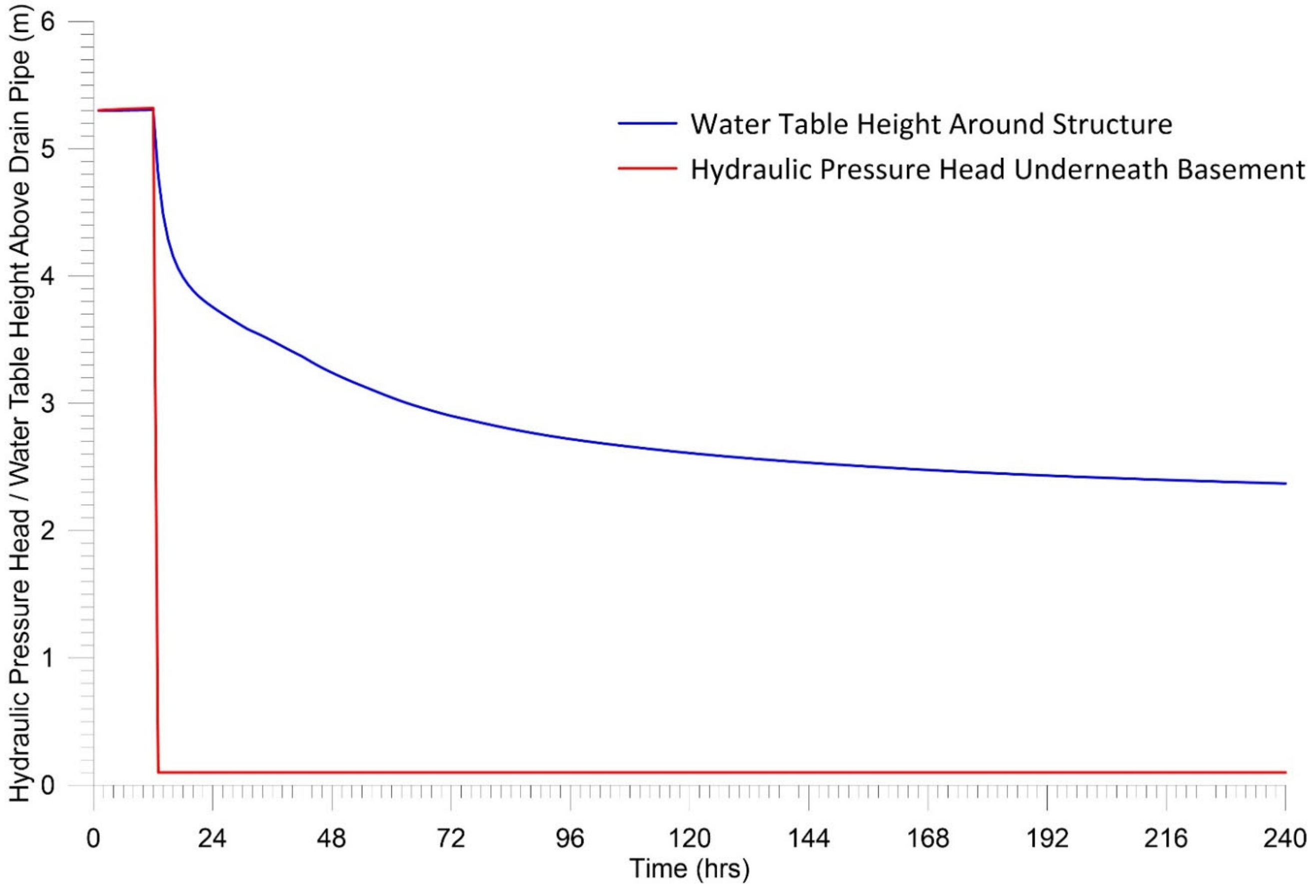

Figure 7-5: Simulated Hydraulic Pressure Head During Maintenance Dewatering

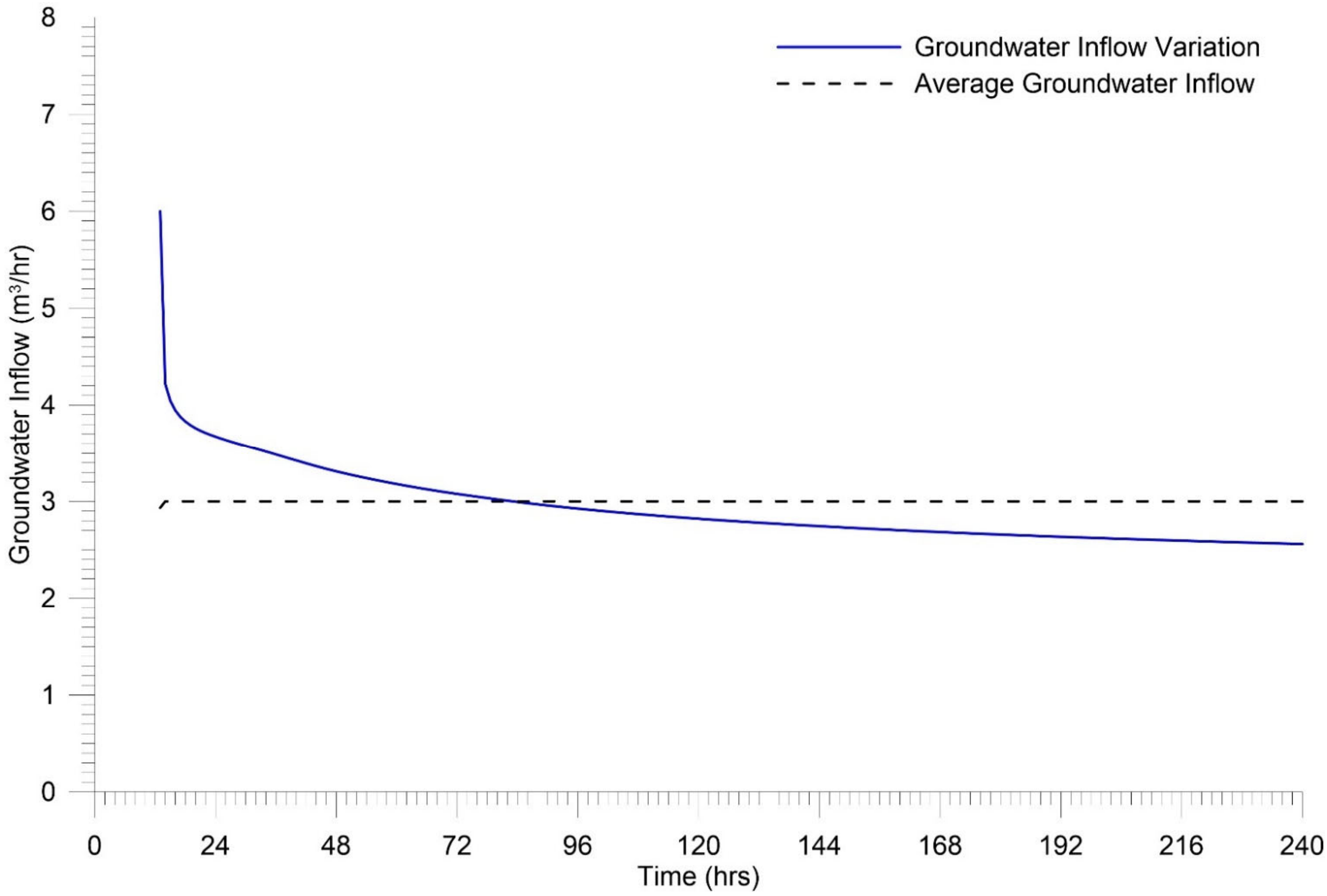

Figure 7-6: Simulated Groundwater Inflow During Maintenance Dewatering

8 Conclusions

A numerical model of regional extent has been developed for the AWRC to support evaluation of the risk posed on groundwater levels and quantities by the construction and operation of the AWRC. The model extent was selected to be remote to the anticipated hydraulic effects of the AWRC structures and to cover part of the AWRC pipelines crossing major tributaries, as well as incorporating nearby groundwater monitoring wells for M12 Motorway project and Western Sydney Airport project to improve model calibration.

The category of the groundwater numerical model for the AWRC site as documented in this report generally adheres to conditions that would define it as a Class 1 model with numerous attributes for Class 2 models. Aurecon considers that there is sufficient groundwater data near the AWRC site and the model can be used to provide reasonably reliable predictions of the likely conditions associated with the construction long-term post-construction phases.

The key findings, conclusions and recommendations of this assessment can be summarised as follows in line with the objectives of the modelling:

Scenario 1: Construction Phase

- The extent of influence due to construction dewatering is about 325 m from the central part of the bioreactor site as shown in **Figure 7-1** and **Figure 7-2**. Based on these modelling results, the impact of construction dewatering is expected to be of local extent, which will be contained within the extent of the footprint of the proposed AWRC site. Beyond this extent, the groundwater flow pattern is unimpacted.
- The impact of construction dewatering to South Creek baseflow has been assessed as being minor. A small section of about 650 m of the South Creek in Reach 10 and Reach 11 will be slightly affected.
- Simulated inflow rates for the eastern and the western bioreactors would stabilise at about 52 L/min and 28 L/min, respectively on average in about 30 days after the storage within pore space is drained. Initial inflow rates to achieve these equilibrium flow rates averages at about 7,900 L/Min and 4,800 L/Min, respectively for the eastern and the western bioreactors, in the first 30 days of pumping. This relates to the initial volume of water which will be released from draining pore spaces. **Figure 7-3** provides simulated cumulative volume of water which will be pumped in the assumed dewatering period for Stage 1 works. Based on these results, the total volume of pumped water in 365 days of the proposed Stage 1 construction schedule will be about 50 ML (31 ML + 19 ML). The simulated sensitivity of calculated inflows to model input parameters indicates that the maximum total volume of pumped water in 365 days could reach 100 ML depending on the hydraulic characteristics the dewatered sediments. The sensitivity of the extent of influence to the tested model parameter is marginal and is expected to be around 325 m stated above.
- It should be noted that DRNs cells for simulating construction dewatering were applied to an area approximately equal to the plan area of the bioreactor tanks. In reality, the sides of the excavation would be battered back at least 1 in 1.5, meaning that the overall dimension to be dewatered would be much bigger. Typically, the well array would be designed to dewater bigger area. It implies that actual flow rate may be higher than the estimate above, especially if the extent of the excavation work changes significantly or moved closer to the creek than compared to the layout assessed in this report. If significant changes are made to the designs assessed in this report, the modelling should be updated according. The estimated inflow rates above provide an initial understanding of dewatering requirements of the likely volumes to be dealt with as the basis for developing a Dewatering Plan for the AWRC works. However, the dewatering plan should be supported by further field tests such as pumping tests as outlined in **Section 5**.

Scenario 2: Operational Phase Modelling Results

- The modelling results show that the reduction in recharge across the AWRC when the proposed infrastructure has been built will result in local depression of the groundwater table. Inspection of the simulated water balance indicates a corresponding minor reduction (around 1%) of baseflow in the creek reaches close the site.
- For maintenance regimes, the modelling results for the required dewatering indicate that groundwater inflow will be very high initially (averaging 1,900 L/min) due to draining of pore water reducing to 40 L/min (2.6 m3/hr) for prolonged maintenance regimes of over 5 days. The simulated average inflow rate is 50 L/min (3 m^3/hr). Estimates of the total volume expected to be pumped for each maintenance regime should be assessed based on this average flow.

9 References

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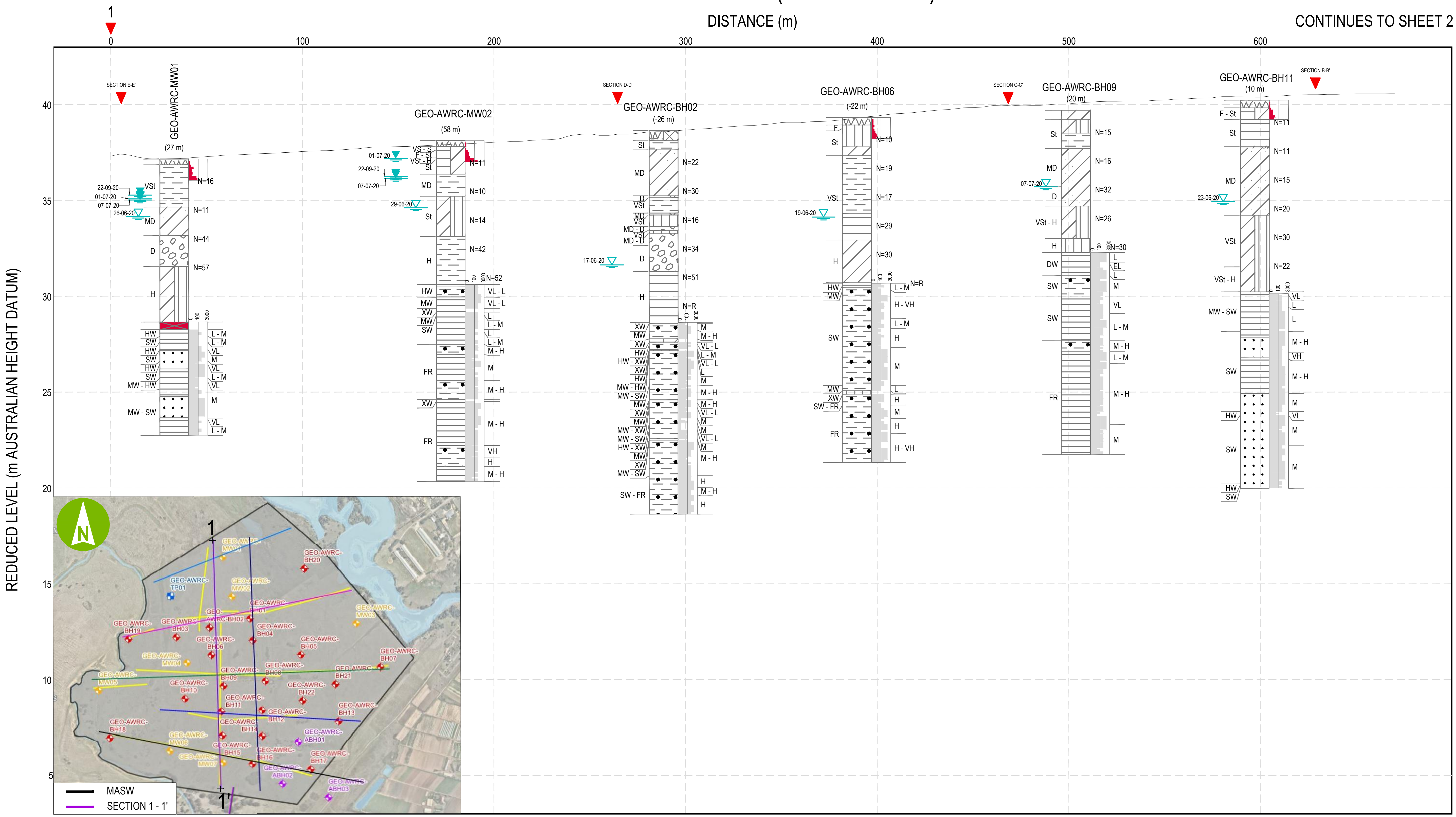
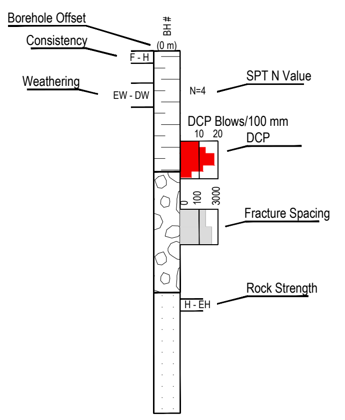
Appendix A – Geological Cross-sections

AWRC - SECTION 1 - 1' (SHEET 1 OF 2)



POST LEGEND



MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW PLASTICITY
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- GRAVEL - POORLY GRADED
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- CORE LOSS
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING

EXISTING SURFACE LEVEL

H 1:2000 (0, 20, 40, 60, 80, 100m)

V 1:200 (0, 2, 4, 6, 8, 10m)

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

Coordinate system: MGA56 Source: gINT

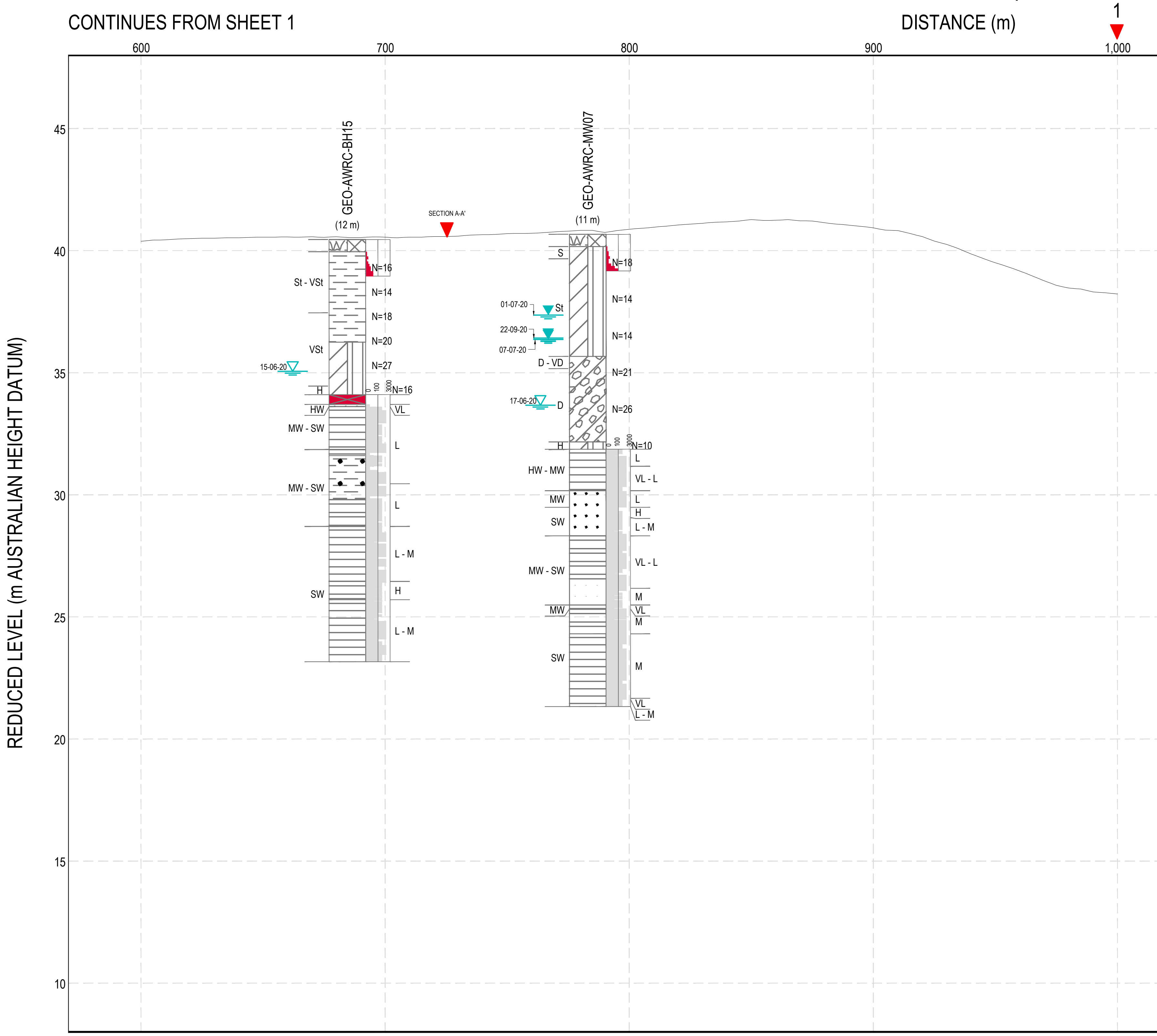
UPPER SOUTH CREEK AWRC

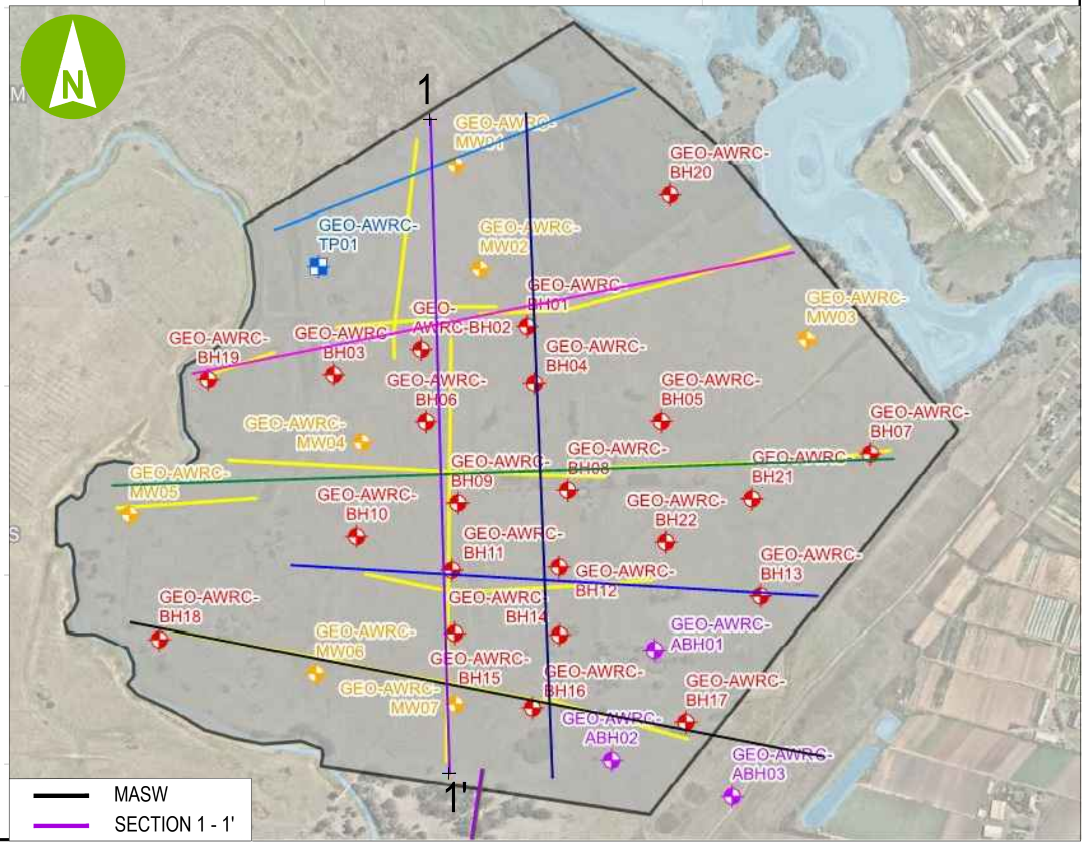
GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION 1 - 1' (SHEET 2 OF 2)

CONTINUES FROM SHEET 1





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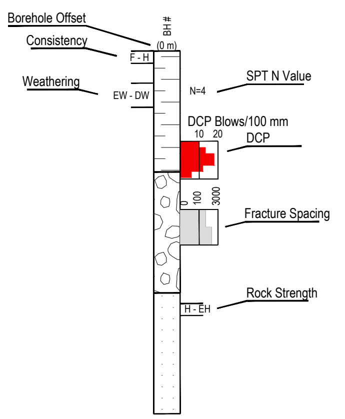


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY GRAVEL
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- CORE LOSS
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m

V 1:200
0 2 4 6 8 10m

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

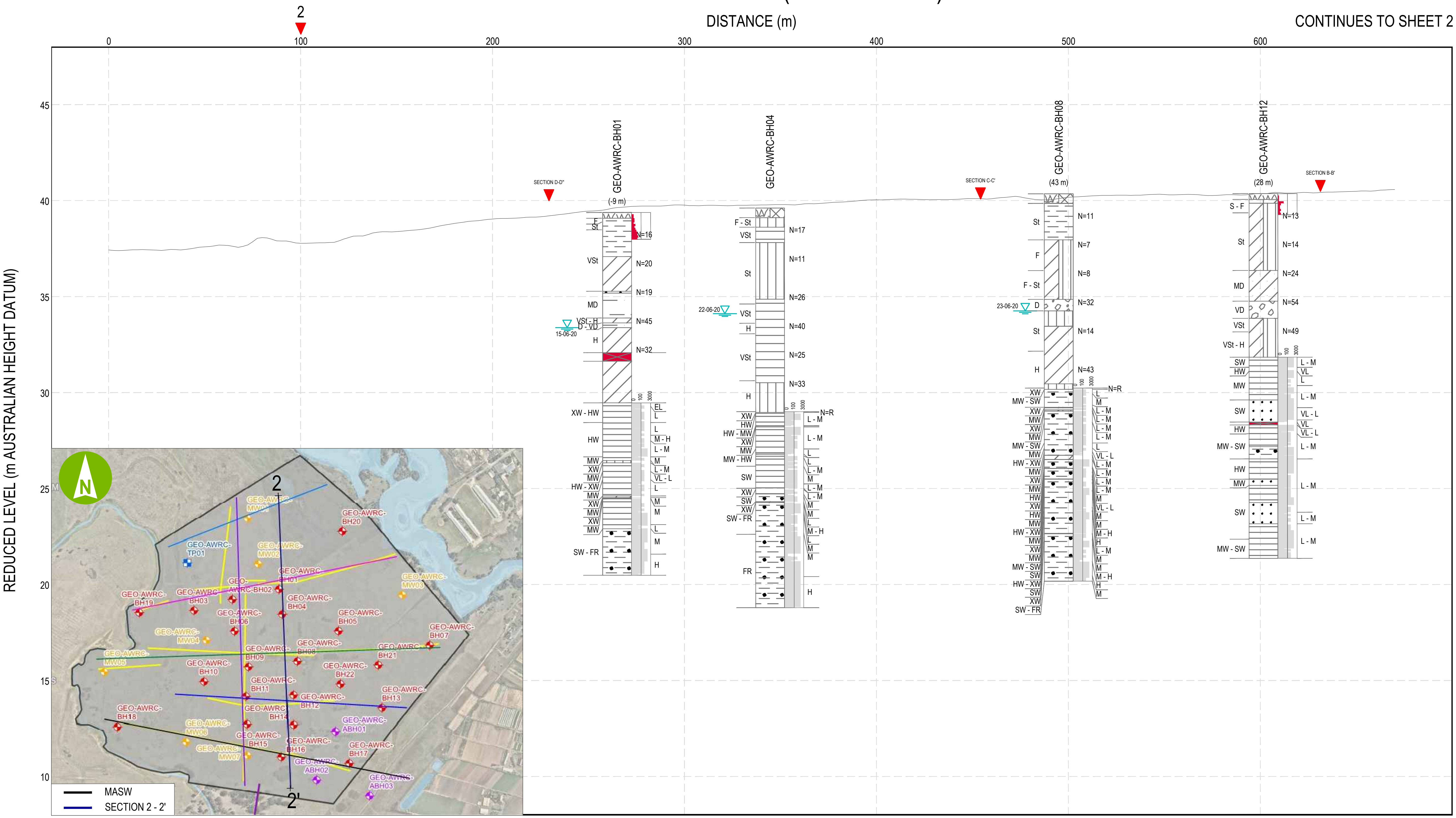
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION 2 - 2' (SHEET 1 OF 2)

CONTINUES TO SHEET 2



POST LEGEND

Borehole Offset
Consistency
Weathering
SPT N Value
DCP Blows/100 mm
DCP
Fracture Spacing
Rock Strength

MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW PLASTICITY
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- SAND - POORLY GRADED
- SAND - WELL GRADED
- GRAVEL - POORLY GRADED
- GRAVEL - WELL GRADED
- SANDSTONE
- CLAYSTONE
- LAMINITE
- CORE LOSS
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m
V 1:200
0 2 4 6 8 10m
Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

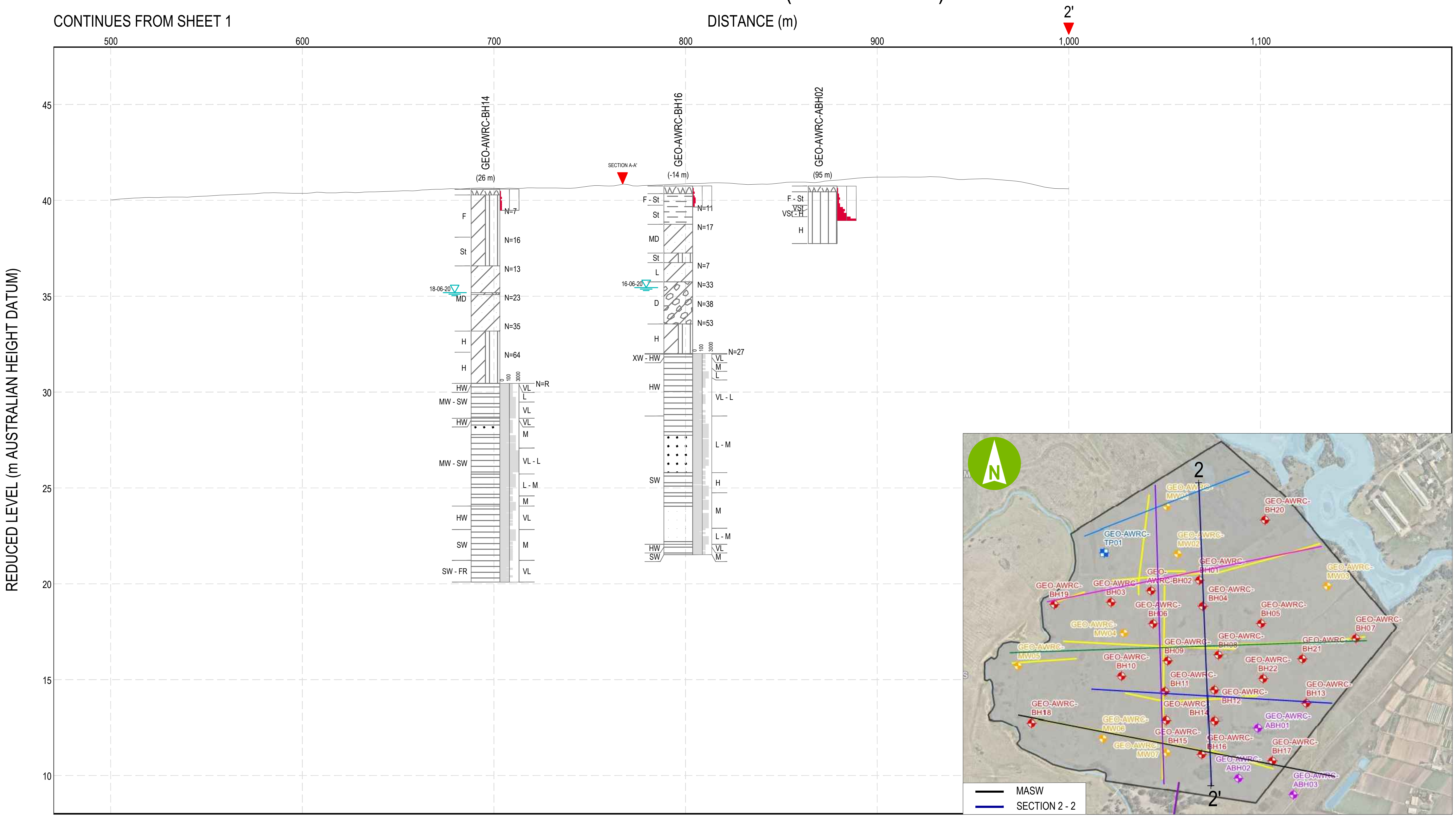
FINAL

Date: 30/10/2020 Version:0 Job No: 20036007
Coordinate system: MGA56 Source: gINT

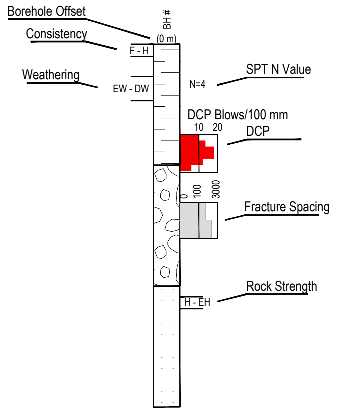
UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES
SYDNEY WATER

AWRC - SECTION 2 - 2' (SHEET 2 OF 2)

CONTINUES FROM SHEET 1



POST LEGEND



MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW PLASTICITY
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- CLAYEY GRAVEL
- GRAVEL - POORLY GRADED
- CORE LOSS
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m
V 1:200
0 2 4 6 8 10m
Coord.System: MGA94 Zone 56 Height Datum: AHD

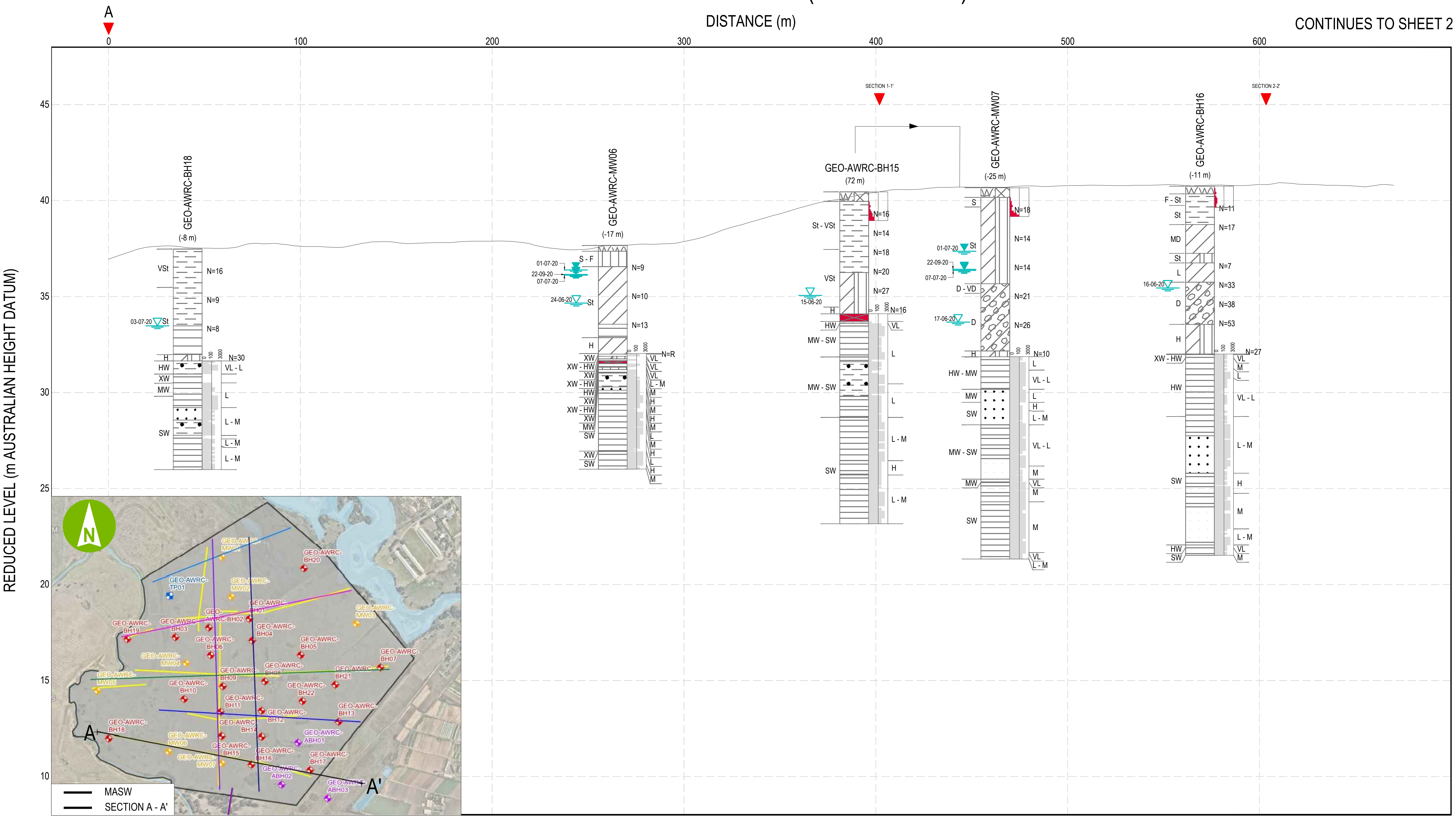
FINAL

Date: 30/10/2020 Version:0 Job No: 20036007
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES
SYDNEY WATER

AWRC - SECTION A - A' (SHEET 1 OF 2)

CONTINUES TO SHEET 2



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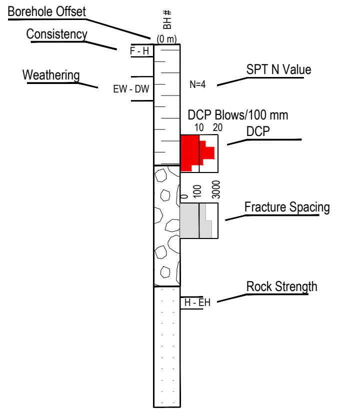


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- SILTY SAND
- CLAYEY GRAVEL
- CORE LOSS
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING

EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m

V 1:200
0 2 4 6 8 10m

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

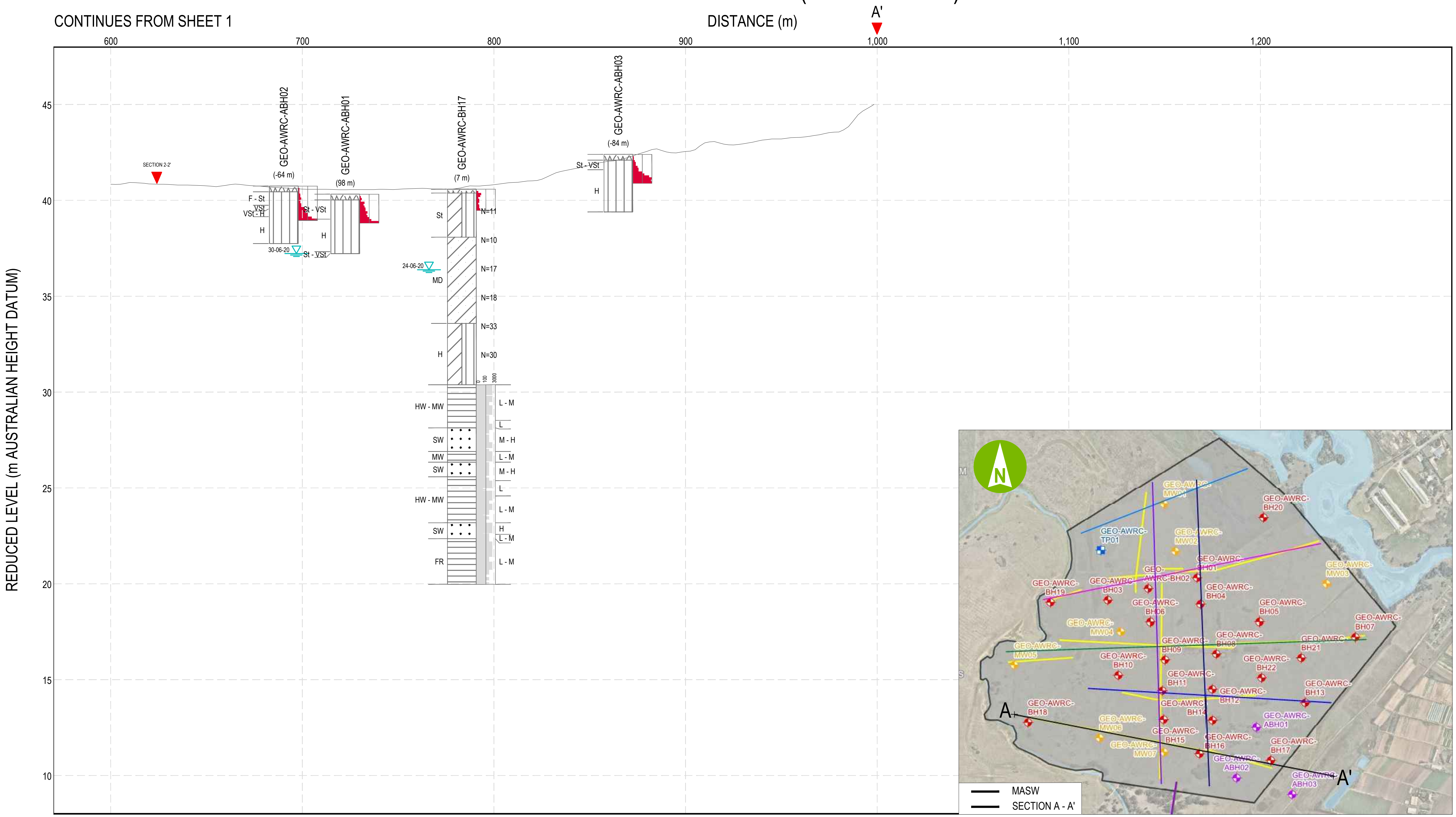
Date: 30/10/2020 Version:0 Job No: 20036007

Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION A - A' (SHEET 2 OF 2)



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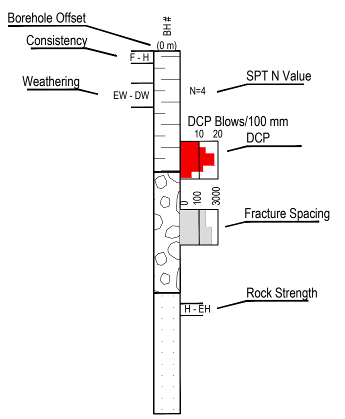


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- CLAYEY SAND
- SANDSTONE
- CLAYSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m
V 1:200
0 2 4 6 8 10m
Coord.System: MGA94 Zone 56 Height Datum: AHD

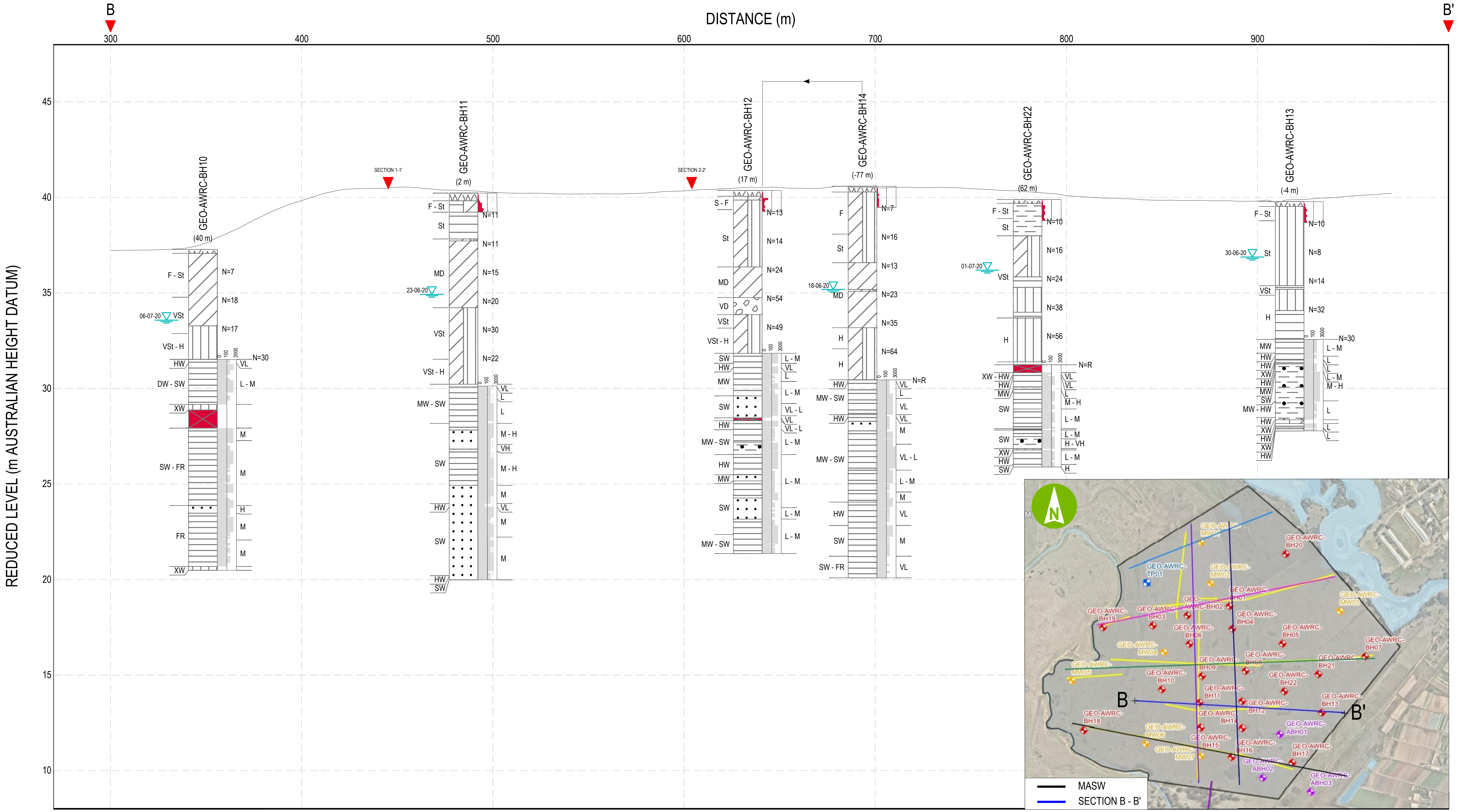
aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES
SYDNEY WATER

AWRC - SECTION B - B'



POST LEGEND

Borehole Offset
Consistency
Weathering
SPT N Value
DCP Blows/100 mm
DCP
Fracture Spacing
Rock Strength

MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW PLASTICITY
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- GRAVEL - POORLY GRADED
- CORE LOSS
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000
V 1:200
Coord.System: MGA94 Zone 56 Height Datum: AHD

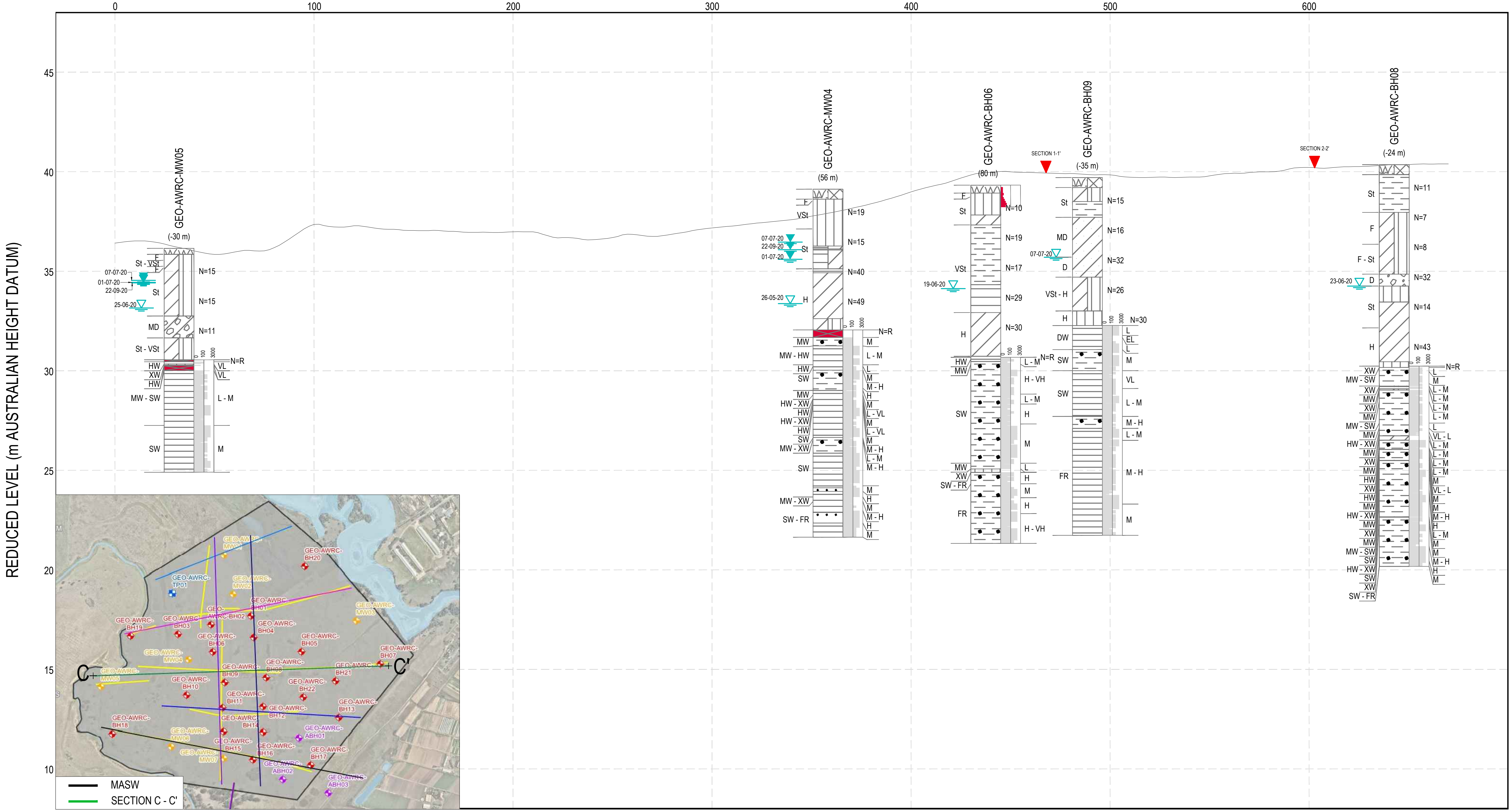
aurecon ARUP

FINAL

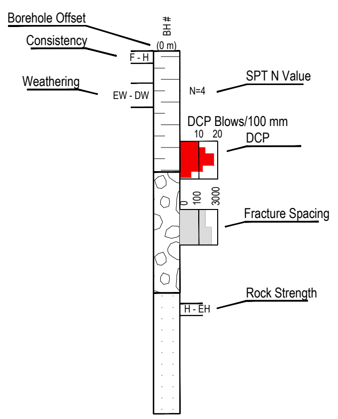
Date: 30/10/2020 Version:0 Job No: 20036007
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES
SYDNEY WATER

AWRC - SECTION C - C' (SHEET 1 OF 2)



POST LEGEND



MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW PLASTICITY
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- CLAYEY GRAVEL
- GRAVEL - WELL GRADED
- CORE LOSS
- SANDSTONE
- CLAYSTONE
- LAMINITE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m
V 1:200
0 2 4 6 8 10m
Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

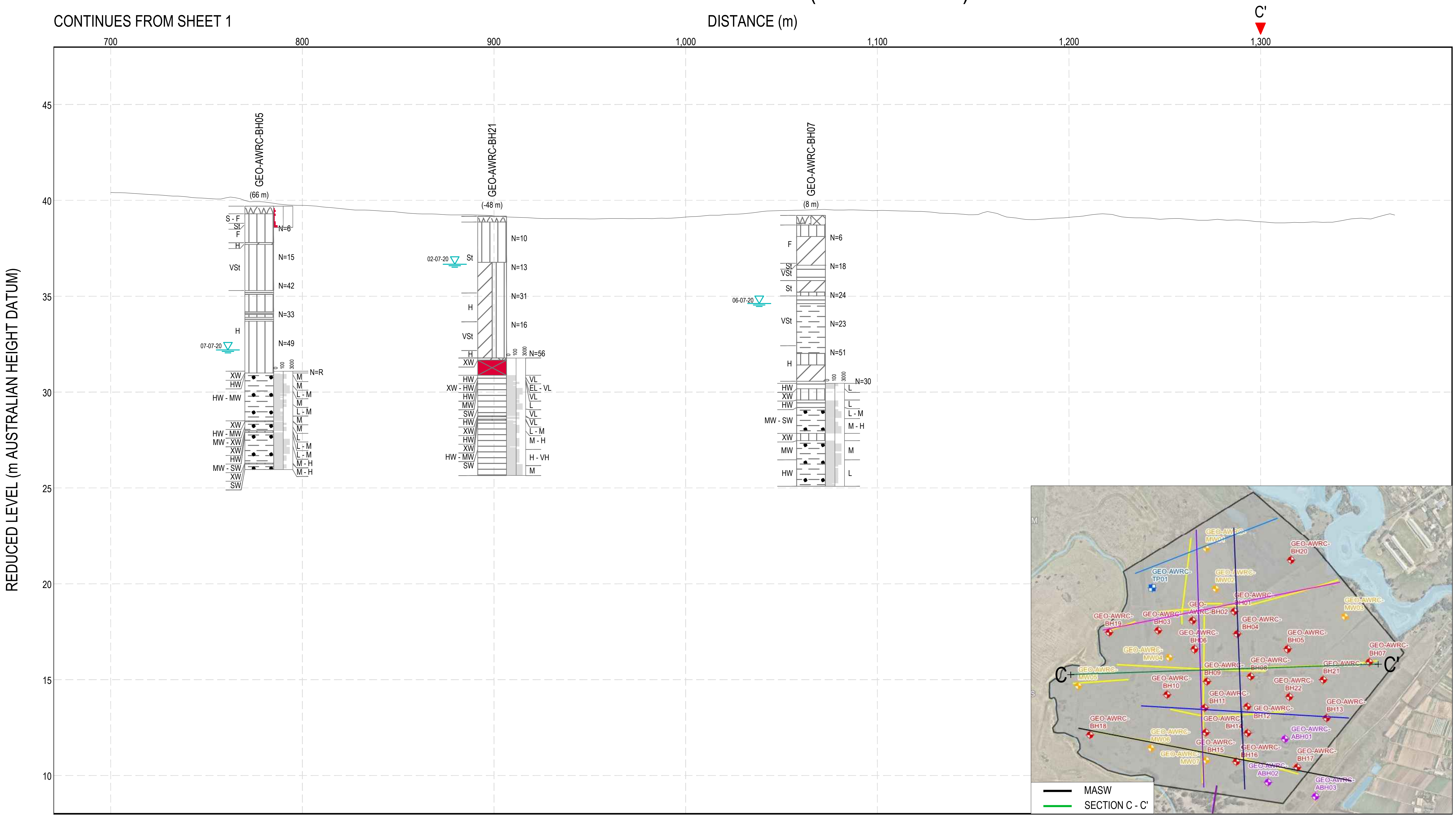
FINAL

Date: 30/10/2020 Version:0 Job No: 20036007
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES
SYDNEY WATER

AWRC - SECTION C - C' (SHEET 2 OF 2)

CONTINUES FROM SHEET 1



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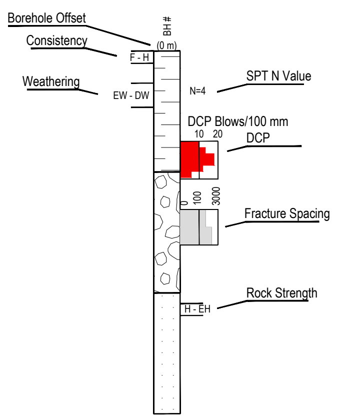
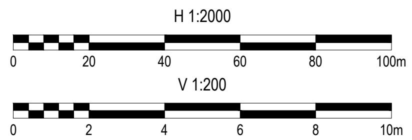


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW PLASTICITY
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- CLAYEY GRAVEL
- CORE LOSS
- CLAYSTONE
- LAMINITE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL



Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

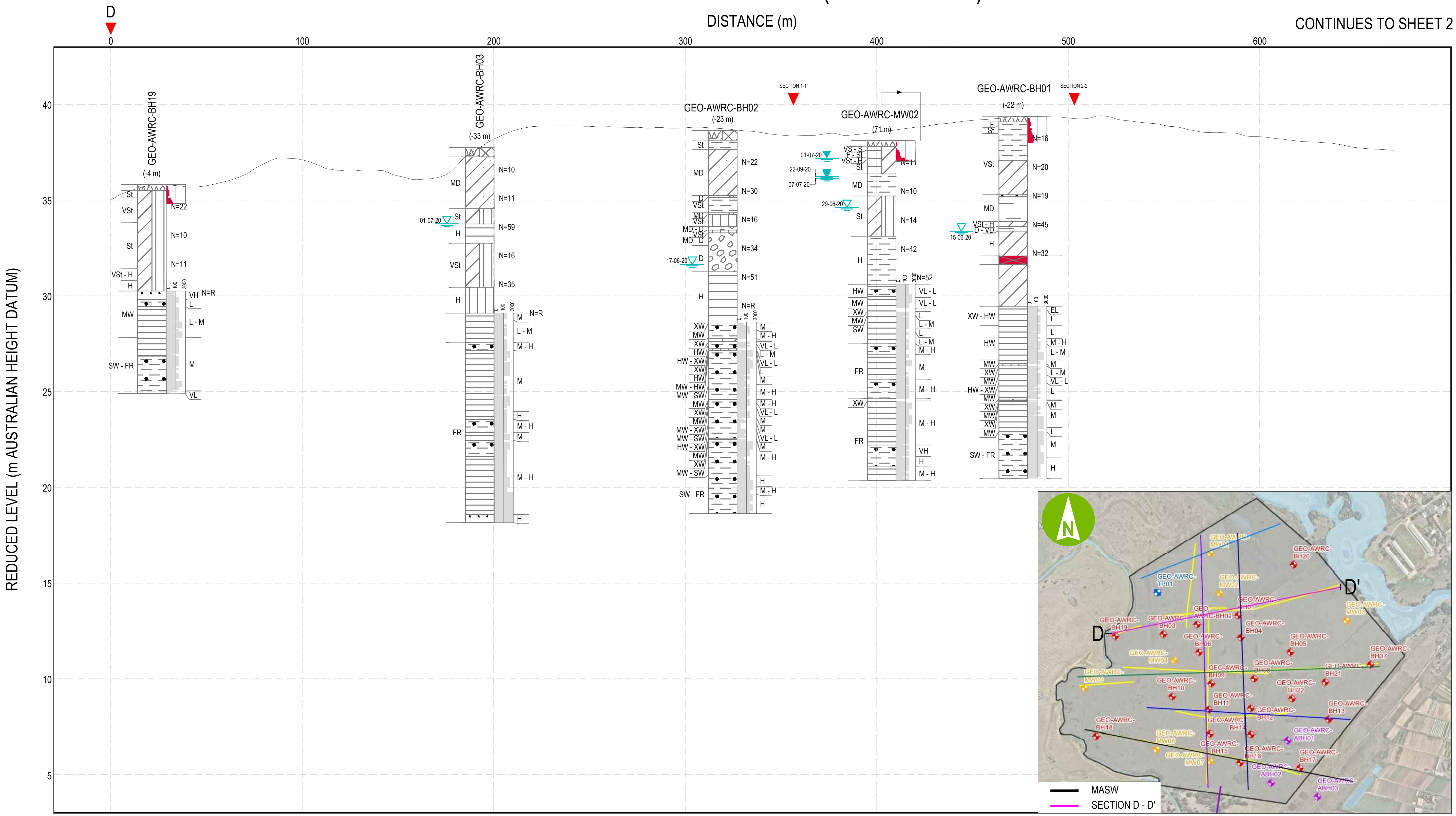
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION D - D' (SHEET 1 OF 2)



POST LEGEND

MATERIAL GRAPHIC

TOPSOIL	CLAY - MEDIUM TO HIGH PLASTICITY	SAND - POORLY GRADED	SANDSTONE	WATER LEVEL DURING DRILLING
CLAY - LOW PLASTICITY	CLAY - HIGH PLASTICITY	SAND - WELL GRADED	CLAYSTONE	WATER LEVEL MONITORING
CLAY - LOW TO MEDIUM PLASTICITY	SILT - LOW PLASTICITY	GRAVEL - POORLY GRADED	LAMINITE	
CLAY - MEDIUM PLASTICITY	CLAYEY SAND	CORE LOSS		

EXISTING SURFACE LEVEL

H 1:2000
V 1:200
Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

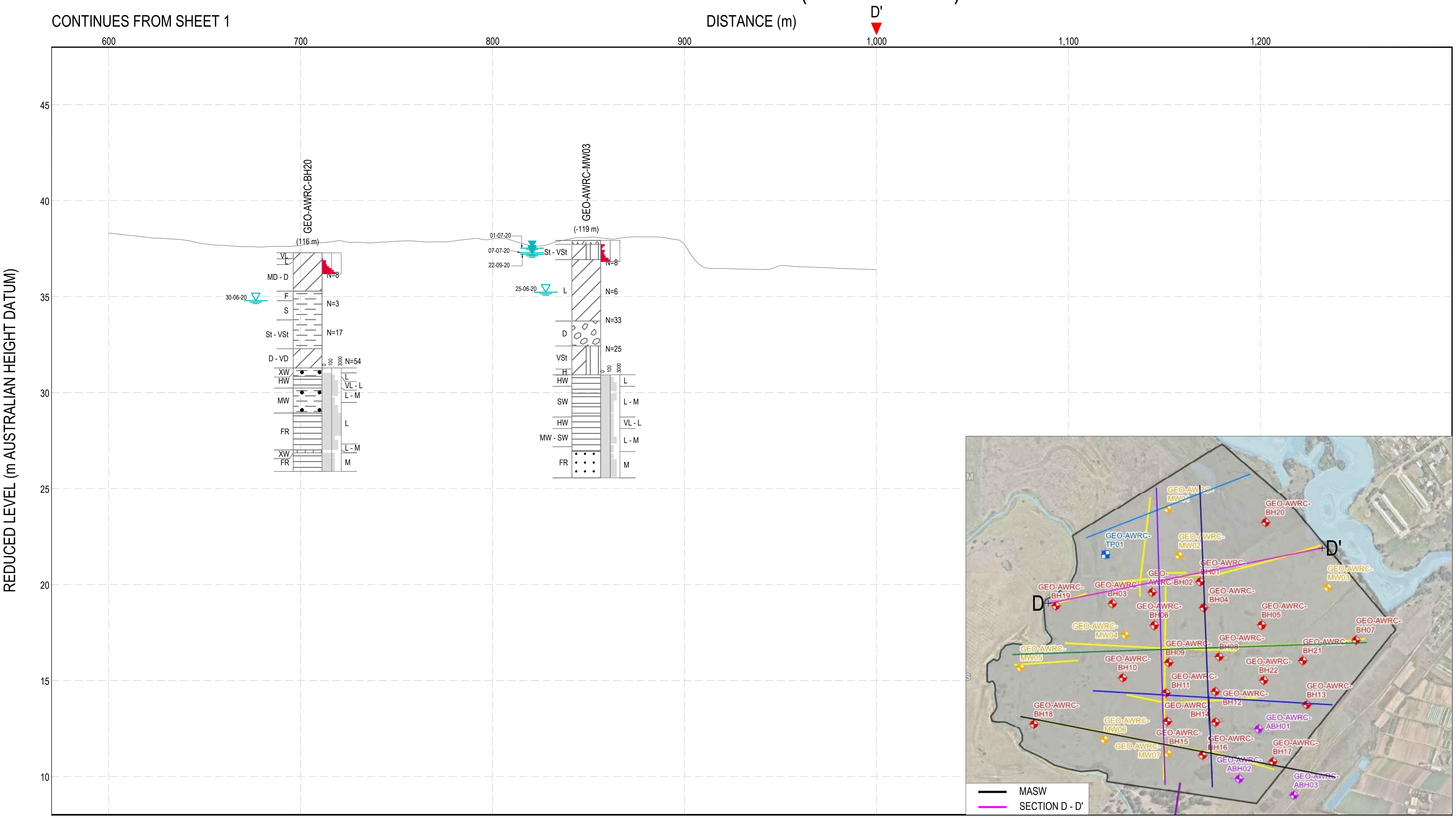
FINAL

Date: 30/10/2020 Version:0 Job No: 20036007
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC
GRAPHICAL LOG OF BOREHOLES
SYDNEY WATER

AWRC - SECTION D - D' (SHEET 2 OF 2)

CONTINUES FROM SHEET 1



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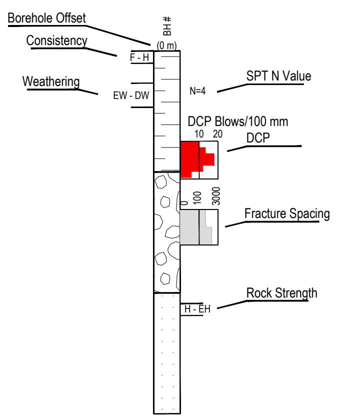


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- GRAVEL - POORLY GRADED
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000
0 20 40 60 80 100m
V 1:200
0 2 4 6 8 10m
Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

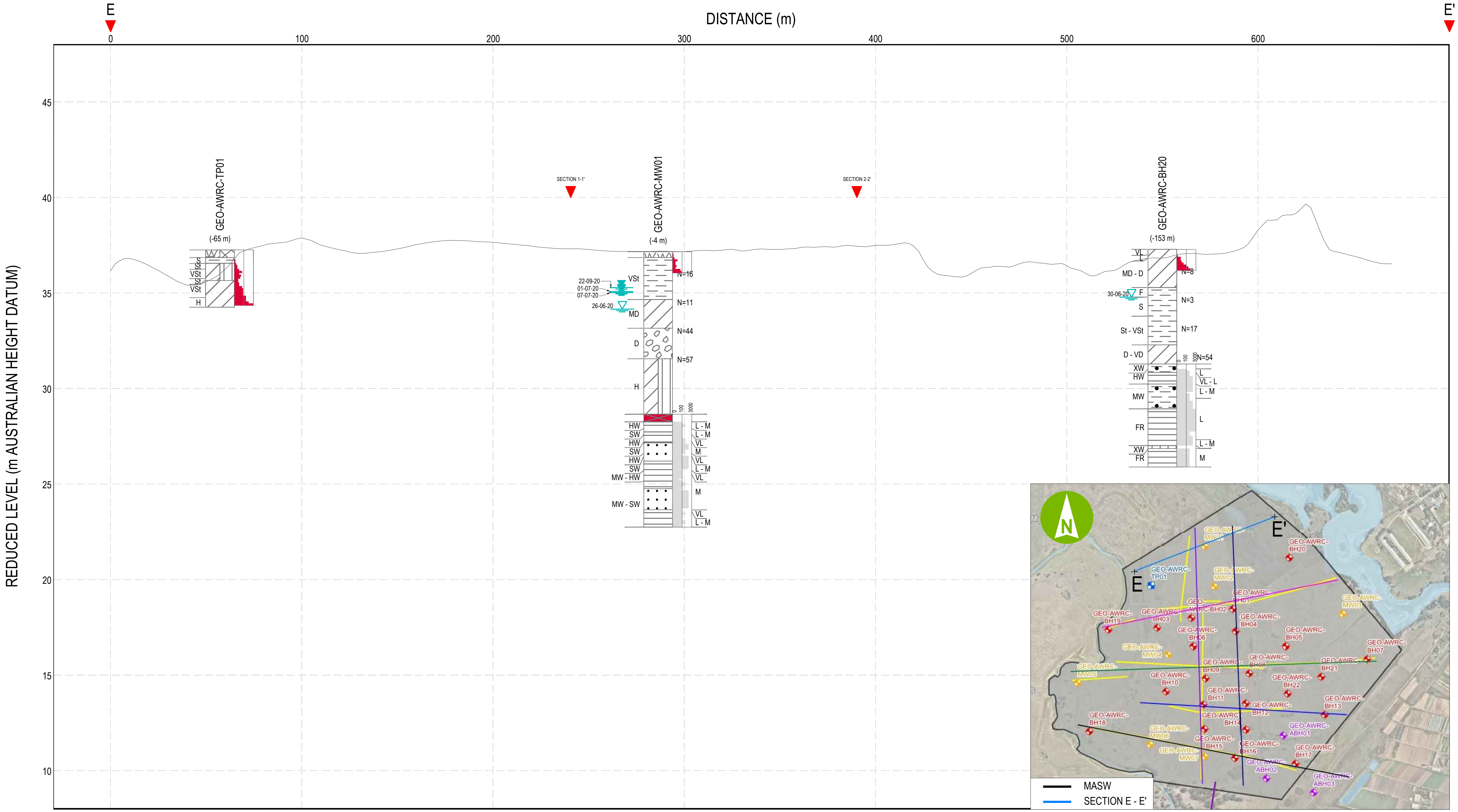
Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

AWRC - SECTION E - E'



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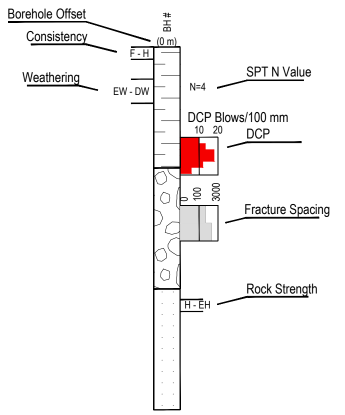


MATERIAL GRAPHIC

- TOPSOIL
- CLAY - LOW TO MEDIUM PLASTICITY
- CLAY - MEDIUM PLASTICITY
- CLAY - MEDIUM TO HIGH PLASTICITY
- CLAY - HIGH PLASTICITY
- SILT - LOW PLASTICITY
- CLAYEY SAND
- GRAVEL - POORLY GRADED
- SANDSTONE
- CLAYSTONE
- LAMINITE
- INTERBEDDED CLAYSTONE & SANDSTONE
- CORE LOSS
- WATER LEVEL DURING DRILLING
- WATER LEVEL MONITORING
- EXISTING SURFACE LEVEL

H 1:2000 (0, 20, 40, 60, 80, 100m)

V 1:200 (0, 2, 4, 6, 8, 10m)

Coord.System: MGA94 Zone 56 Height Datum: AHD

aurecon ARUP

FINAL

Date: 30/10/2020 Version:0 Job No: 20036007

Coordinate system: MGA56 Source: gINT

UPPER SOUTH CREEK AWRC

GRAPHICAL LOG OF BOREHOLES

SYDNEY WATER

Appendix B – Marinelli and Niccoli (2000) Spreadsheet model

Spreadsheet for calculating radius of influence (ROI) r_o using Niccoli et al. (1998) method.

$$h_0 = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left[r_0^2 \ln\left(\frac{r_0}{r_p}\right) - \frac{(r_0^2 - r_p^2)}{2}\right]} \;\ldots\ldots\ldots (1)$$

Equation (1) applied in cell J12

Legend
Input
Calculated
Goal Seek Cell J12 Set to Value - h_0 By Changing - r_0 cell J20
Calcuated Iteratively By Goal Seek Function. Choose Initial Value That is Close to r_o.

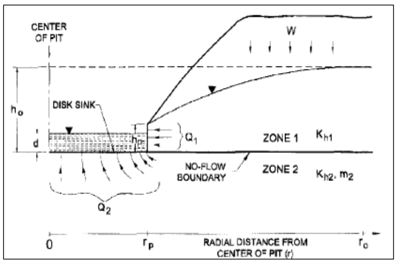
Scenario:

Height of water table at radius of influence (r_0) - Eq (1) Solved by Goal Se	h_0	5.30	m
Saturated thickness above the base of Zone 1 at r_p (saturated thickness at pit wall)	h_p	0.0	m
	K_{h1}	0.14	m/d
Horizontal hydraulic conductivity of material within Zone 1		1.62E-06	m/s
Distributed recharge flux	W	41.8	mm/yr
		1.15E-04	m/d
Effective pit radius	r_p	30.28	m
Radius of of influence (maximum extent of the cone of depression)	r_0	167	m
		183	m
Rounded to			

General calcs

Maximum Area (A) of Disturbance 64m (L) x 45m (W)		Equivalent/Effective Pit Radius r_p $r_p = \sqrt{A/\pi}$
(ha)	(m^2)	(m)
0.288	2880	30.28

Maximum groundwater level		0	mbgl
Drawdown during dewatering		5.3	mbgl
Height of water table at r_0 above Zone 1 base	h_o	5.3	m
Saturated thickness at pit wall during dewatering operation	h_p	0	m
Saturated thickness at pit wall post closure	h_p	-	m



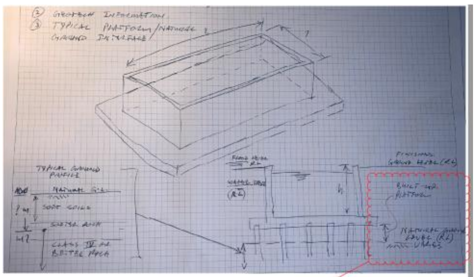
The following assumptions apply to this equation for Zone 1 / Layer 1:
- Steady-state, unconfined, horizontal radial flow.
- Uniformly distributed recharge at the water table.
- Pit walls are approximated as a right circular cylinder.
- The static (premining) water table is approximately horizontal.
- Groundwater flow is horizontal.
- Groundwater flow toward the pit is axially symmetric.

40.5 35.7 #FIELD! 35.2 5.3

Sources of Data:

Type	Model Data		Source
Pit design details	Foundationelevation information		Bioreactor design details as @ 09/07/2020 (Rev 100% Design
	Maximum area of disturbance at any time		Bioreactor design details as @ 09/07/2020 (Rev 100% Design
	Effective radius of pit	r_p	Disturbance area approximated to a circular geometrey
Groundwater Information	Maximum historical groundwater elevation site		Assumed worst case scenario with water level at ground
	Saturated thickness above the base of Zone 1 at r_p (saturated thickness at pit wall)	h_p	Assumption for the conditions during operation
	Height of water table at r_0 above Zone 1 base	h_o	Estimated from maximum groundwater elevation
	Horizontal hydraulic conductivity of material within Zone 1 (layer 1)	K_{h1}	Draft. Environment Impact Statement. Second Sydney Airport Proposal.
	Recharge	W	GHD (2015). Department of Infrastructure and Regional Development. Western Sydney Airport EIS Groundwater Impact Assessment

Prepared by: F Rusinga
Date: 12/07/2020



Natural ground level is close to the finished ground level.
Temporary excavation is required.

D E F G H I J K L M N O P Q R

Spreadsheet for calculating flow to a using Niccoli et al. (1998) method which applies separate solutions for the sides and the base.
This is a follow from ROI spreadsheet which determines the ROI for this procedure

Scenario:

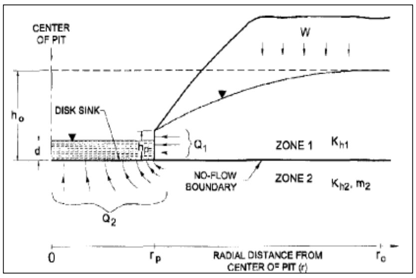
$$Q_1 = W\pi\left(r_0^2 - r_p^2\right)\ldots\ldots\ldots (2)$$

$$Q_2 = 4r_p\left(\frac{K_{h2}}{m_2}\right)(h_0 - d)\ \ldots\ldots\ldots (3)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}\ \ldots\ldots\ldots (4)$$

Input	
Calculated	

Head			
Height of water table at radius of influence	h_0	5.3	m
Depth of ponded area	d	0.0	m
Layer 2	From ROI worksheet		
Horizontal hydraulic conductivity	K_{h2}	0.14	m/d
		1.62E-06	m/s
Vertical hydraulic conductivity (2 to 3 time lower than Kh - PPK (1999))	K_{v2}	0.14	m/d
		1.62E-06	m/s
Anisotropy parameter - Eq (4)	m_2	1.0	
Distributed recharge flux	W	1.15E-04	m/d
		1.33E-09	m/s
Radius of quarry	r_p	30.28	m
Radius of of influence	r_0	167	m
Can be taken from ROI worksheet or other source			
Inflow			
Inflow through seepage face - Eq (2)	Q_1	1.13E-04	m^3/s
		0.11	L/s
		0.41	m^3/h
		9.75	m^3/d
Inflow through pit base - Eq (3)	Q_2	1.04E-03	m^3/s
		1.04	L/s
		3.74	m^3/h
		89.87	m^3/d
Total inflow	Q_T	1.15E-03	m^3/s
		1.15	L/s
		4.2	m^3/h
		99.6	m^3/d



The following assumptions apply to this equation:
- There is no groundwater flow between zones 1 and 2.

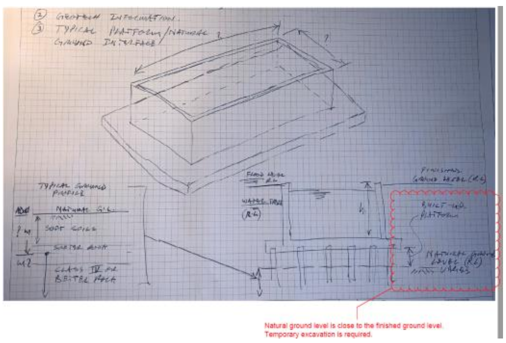
Zone 1
- Steady-state, unconfined, horizontal radial flow.
- Uniformly distributed recharge at the water table.
- Pit walls are approximated as a right circular cylinder.
- The static (premining) water table is approximately horizontal.
- Groundwater flow is horizontal.
- Groundwater flow toward the pit is axially symmetric.

Zone 2
-Steady state flow to one side of a circular disk sink of constant and uniform drawdown.
- hydraulic head is initially uniform throughout Zone 2.
- Initial head is equal to the eleveation of the initial water table in Zone 1.
- Flow to the disk is 3-dimensional and axially symmetric.

General calcs

Maximum Area (A) of Disturbance 64m (L) x 45m (W)		Equivalent/Effective Pit Radius r_p $r_p = \sqrt{A/\pi}$
(ha)	(m^2)	(m)
0.288	2880	30.28

From ROI worksheet			
Maximum groundwater level		0	mbgl
Drawdown during dewatering		5.3	mbgl
Height of water table at r_0 above Zone 1 base	h_o	5.3	m
Saturated thick. at pit wall during dewatering operatio	h_p	0	m
Saturated thickness at pit wall post closure	h_p	-	m



Sources of Data:

Type	Model Data		Source
Pit design details	Foundation elevation information		Bioreactor design details as @ 09/07/2020 (Rev 100%
	Maximum area of disturbance at any time		Bioreactor design details as @ 09/07/2020 (Rev 100%
	Effective radius of pit	r_p	Disturbance area approximated to a circular geometrey
Groundwater Information	Maximum historical groundwater elevation site		Assumed worst case scenario with water level at ground
	Saturated thickness above the base of Zone 1 at r_p (saturated thickness at pit wall)	h_p	Assumption for the conditions during operation
	Height of water table at r_0 above Zone 1 base	h_o	Estimated from maximum groundwater elevation
	Horizontal hydraulic conductivity of material within Zone 2 (layer 2)	K_{h1}	PPK (1999).
	Vertical hydraulic conductivity of material within Zone 2 (layer 2)	K_{v2}	PPK (1999).
	Recharge	W	GHD (2015)

Appendix B – Pipeline Groundwater Analytical Calculations

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Trenched Pipeline Groundwater Impacts - Analytical Calculation Summary

Pipeline Section	Approximate Trenched Pipe Lay Rate (m/day)	Approximate Trenched Pipe Length (m)	Approximate Trenched Construction Duration* (days)	Simulated Groundwater Drawdown (m)	Calculated Maximum Radius of Influence (m)	Estimated Groundwater Inflow Rates (m^3/day)			Estimated Total Groundwater Inflow (m^3)			Assessment against minimal groundwater level/availability criteria (Section 2.3)
						Min	Expected	Max	Min	Expected	Max	
Environmental Flows Section 1: Mid-Nepean HGL	24	1850	26	3.2	44.0	0.4	17.1	238.8	28.1	1335.4	18626.4	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Environmental Flows Section 2: Hawkesbury HGL		0	0	Horizontal Directional Drilling (HDD) only. No trenched component.								
Treated Water Section 1: Mid-Nepean HGL	24	1000	14	3	54.0	0.3	13.2	183.5	11.8	552.3	7708.7	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 2: Mulgoa HGL	18	2790	52	1.3	34.7	0.2	6.9	96.9	23.4	1082.6	15121.1	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 3: Greendale HGL	24	3400	48	1.1	17.5	0.5	4.0	27.4	76.3	581.8	3941.3	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Treated Water Section 4: Mulgoa HGL	24	1250	18	0.9	30.1	0.1	5.8	80.5	6.5	311.6	4346.5	No GDEs or water supply works within the calculated radius of influence. Drawdown criteria not exceeded.
Treated Water Section 5: Upper South Creek HGL	24	6250	87	0.9	37.1	0.1	4.7	65.4	26.1	1224.1	17061.6	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 1: Upper South Creek HGL	24	4800	67	1.4	26.2	0.2	10.1	141.5	44.2	2038.1	28431.5	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 2: Mount Vernon HGL	24	2500	35	1.8	17.0	0.9	6.6	44.5	90.3	687.8	4668.3	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 3: Denham Court HGL	24	1200	17	1.9	18.5	0.8	6.4	43.0	42.3	323.9	2194.0	No GDEs or water supply works within the calculated radius of influence. Drawdown criteria not exceeded.
Brine Section 4: Upper South Creek (A) HGL	12	11800	328	0.3	51.0	0.02	0.8	10.7	19.7	757.7	10519.0	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Brine Section 5: Moorebank HGL	12	30	3	4.7	40.9	0.2	7.8	109.3	0.5	23.5	327.9	Drawdown criteria (0.1m) for GDE with high potential for groundwater interaction exceeded. However, the drawdown of the water table will be temporary. Therefore, the predicted impacts are not expected to prevent the long-term viability of surrounding water-related assets and are considered acceptable.
Totals			695	N/A	N/A	N/A	N/A	N/A	369.2	8918.6	112946.1	

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

Environmental Flows Section 1: Mid-Nepean Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

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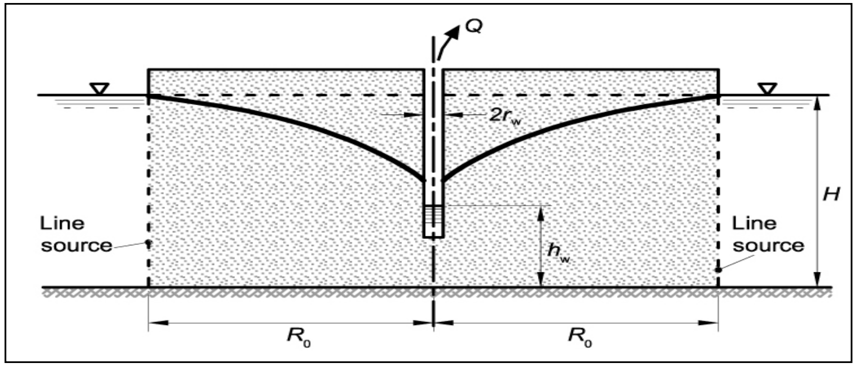
		expected		min	max	
Head						
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	*x*		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Mid-Nepean HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	*x*	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Treated Water Section 1: Mid-Nepean Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

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		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

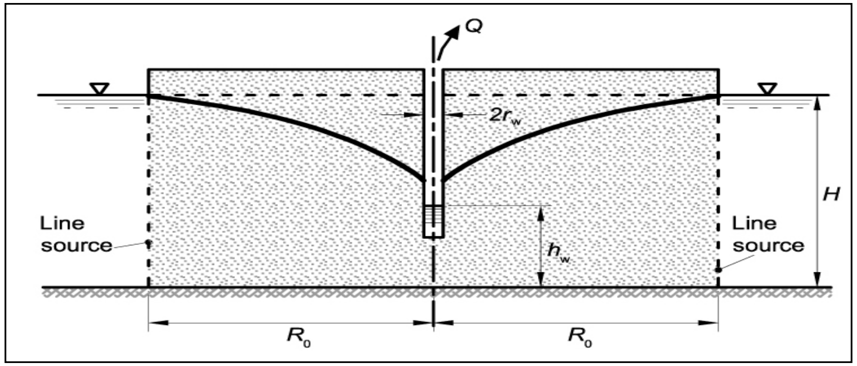
Treated Water 1: Mid-Nepean Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

$$Q=\left[\left(0.73+0.27\frac{(H-h_w)}{H}\right)\frac{Kx}{R_0}(H^2-h_w^2)\right]$$

Essential input
Optional input
Calculated

		expected		min	max	
Head						
Height of water table at radius of influence	H	9	m	9	9	m
Height of water table at well	h_w	6	m	6	6	m
Conductivity						
Hydraulic conductivity of aquifer	K	0.5	m/d	0.017	1.287	m/d
Radius						
Length of trench	*x*	24	m	24	24	m
Distance to line source, equal to radius of influence	R_0	33.68	m	6.21	54.04	m
Is R_0/H greater than or equal to 3 ?		Yes		No	Yes	
Total discharge from wellpoints	**Q**	13.15	m^3/d	0.28	183.54	m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Mid-Nepean HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	*x*	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Treated Water Section 2: Mulgoa Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation

- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

Treated Water 2: Mulgoa Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

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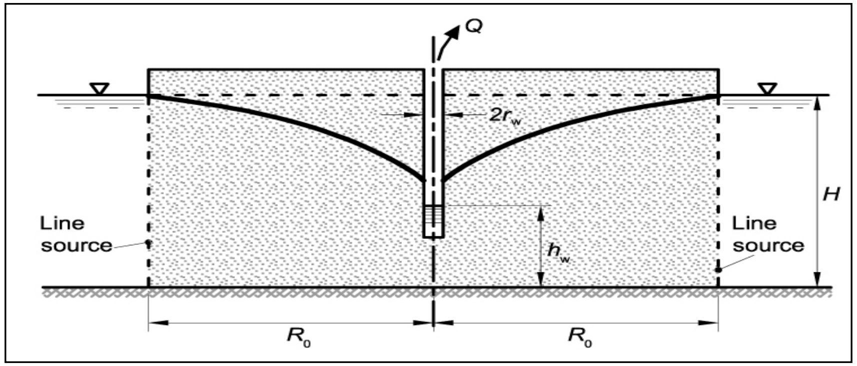
		expected		min	max	
Head						
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	x		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Mulgoa HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	x	Based on a pipe lay rate of 18 m/day (mixed urban and greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Treated Water Section 3: Greendale Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.30	m/d	0.05	0.484	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Residual/regolith soils associated with weathered Bringelly Shale
Factor	C	Flow into linear trench

Treated Water 3: Greendale Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

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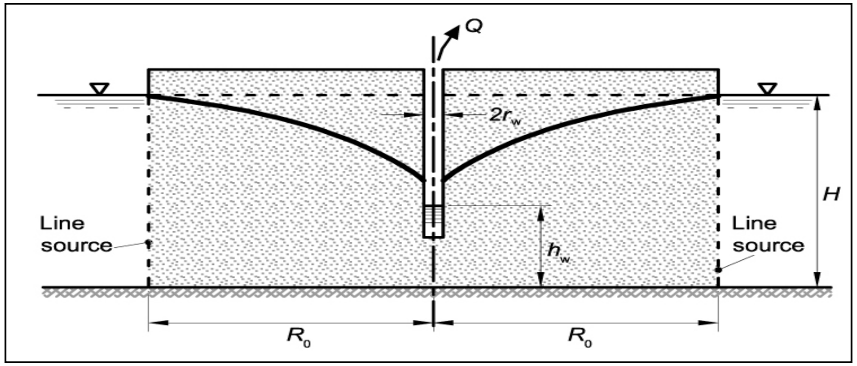
		expected		min	max	
Head						
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	*x*		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of residual/regolith soils in the Greendale HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Residual/regolith soils associated with weathered Bringelly Shale
Length of trench	*x*	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Treated Water Section 4: Mulgoa Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

Treated Water 4: Mulgoa Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

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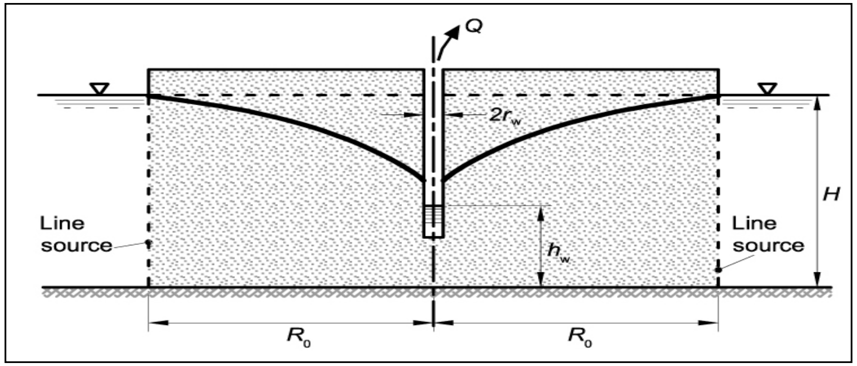
		expected		min	max	
Head						
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	x		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Mulgoa HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	x	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

Treated Water 5: Upper South Creek Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

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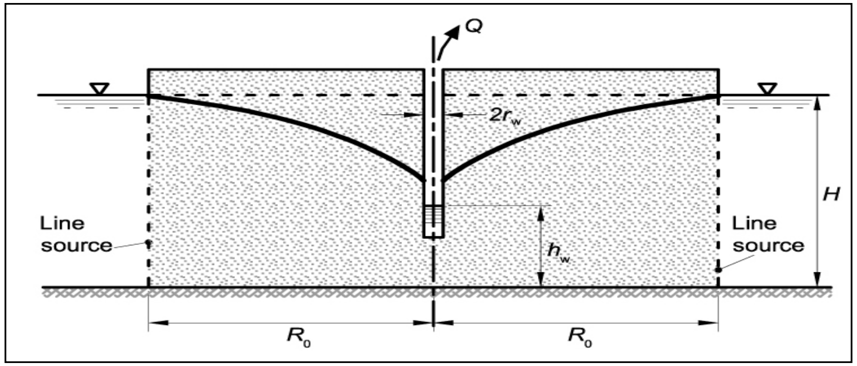
		expected		min	max	
Head						
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	*x*		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the USC HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	*x*	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Brine Section 1: Upper South Creek Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

Brine Section 1: Upper South Creek Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

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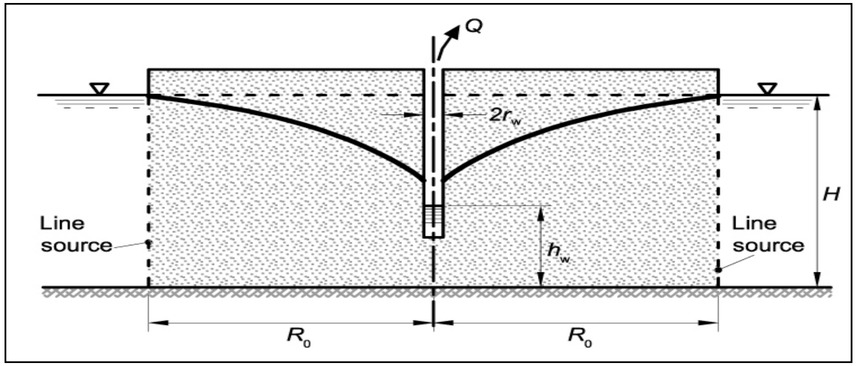
		expected		min	max	
Head						
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	x		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in USC HGL
Height of water table at well	h_w	hw = H + mean GW depth - max pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	x	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.30	m/d	0.05	0.484	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Residual/regolith soils associated with weathered Bringelly Shale
Factor	C	Flow into linear trench

Brine Section 2: Mount Vernon Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

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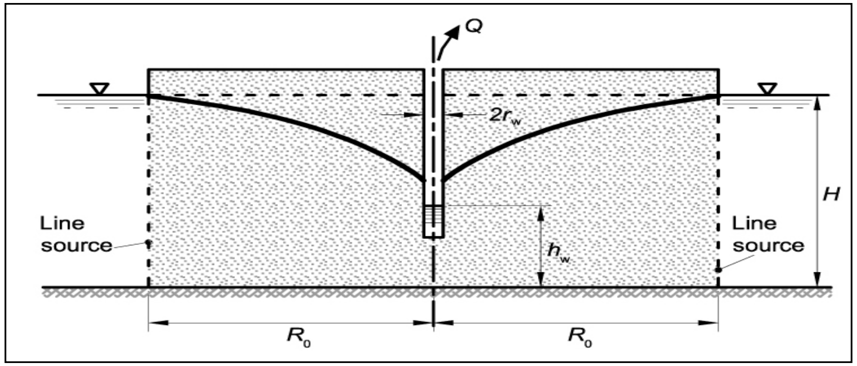
Head		expected		min	max	
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	x		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of residual/regolith soils in the Mount Vernon HGL
Height of water table at well	h_w	hw = H + min GW depth - max pipeline invert depth
Hydraulic conductivity of aquifer	K	Residual/regolith soils associated with weathered Bringelly Shale
Length of trench	x	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Brine Section 3: Denham Court Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.30	m/d	0.05	0.484	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Residual/regolith soils associated with weathered Bringelly Shale
Factor	C	Flow into linear trench

Brine Section 3: Denham Court Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

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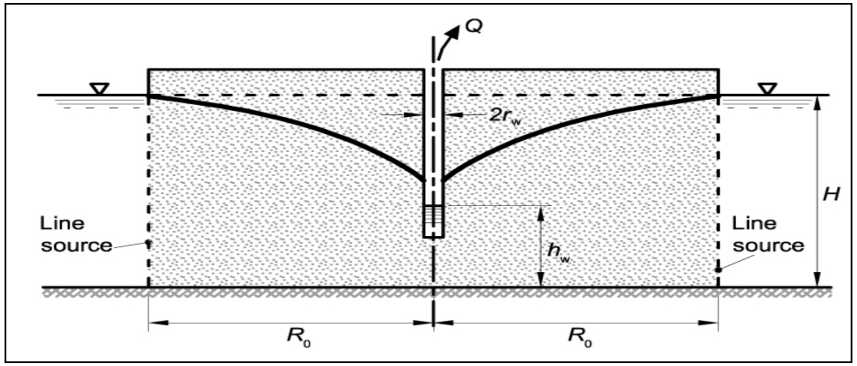
		expected		min	max	
Head						
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	x		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of residual/regolith soils in the Denham Court HGL
Height of water table at well	h_w	hw = H + min GW depth - max pipeline invert depth
Hydraulic conductivity of aquifer	K	Residual/regolith soils associated with weathered Bringelly Shale
Length of trench	x	Based on a pipe lay rate of 24 m/day (greenfield conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Brine Section 4: Upper South Creek (Variant A) Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

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		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Factor	C	Flow into linear trench

Brine Section 4: Upper South Creek (Variant A) Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

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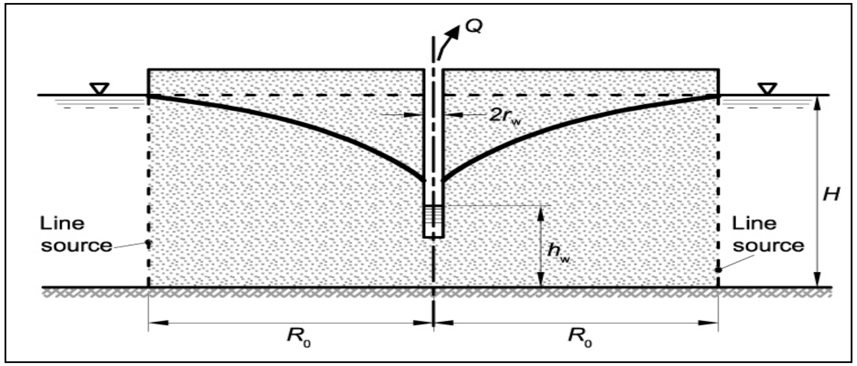
		expected		min	max	
Head						
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	*x*		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation
- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the USC-A HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (fine-grained sand, silt and clay)
Length of trench	*x*	Based on a pipe lay rate of 12 m/day (urban conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)

Brine Section 5: Moorebank Hydrogeological Landscape

Radius of influence (Sichardt)

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s		m			m
Hydraulic conductivity	K		m/s			m/s
		0.50	m/d	0.017	1.287	m/d
Factor	C			3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0		m			m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	Max drawdown = max pipeline invert depth - min groundwater depth
Hydraulic conductivity	K	Quaternary alluvial sediments (medium-grained sand, silt and clay)
Factor	C	Flow into linear trench

Brine Section 5: Moorebank Hydrogeological Landscape

Partial penetration by a single row of wellpoints of an unconfined aquifer midway between two equidistant and parallel line sources (Mansur & Kaufman, 1962)

ut
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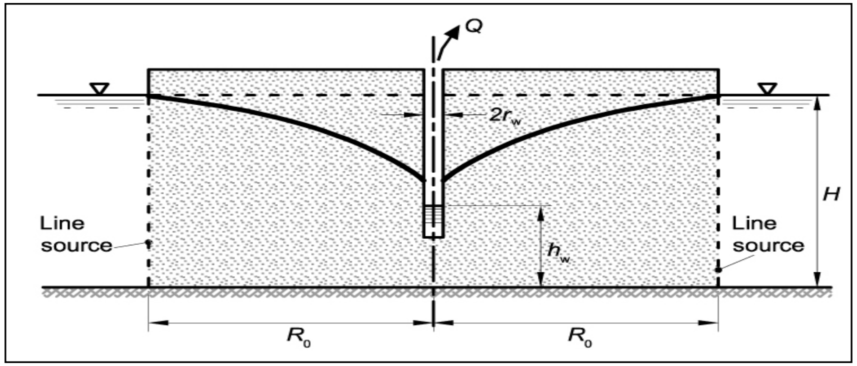
		expected		min	max	
Head						
Height of water table at radius of influence	H		m			m
Height of water table at well	h_w		m			m
Conductivity						
Hydraulic conductivity of aquifer	K		m/d			m/d
Radius						
Length of trench	x		m			m
Distance to line source, equal to radius of influence	R_0		m			m
Is R_0/H greater than or equal to 3 ?						
Total discharge from wellpoints	**Q**		m^3/d			m^3/d



(Figure adapted from Mansur & Kaufman, 1962)

The following assumptions apply to this equation

- the slot is infinite in length
- R_0/H greater than or equal to 3
- the aquifer is unconfined
- the aquifer is homogeneous, isotropic and of uniform thickness
- the Dupuit Forcheimer assumption is valid
- the aquifer has reached steady state conditions
- the initial water table is horizontal

Data sources (to complete an audit trail)

Height of water table at radius of influence	H	Approximate saturated thickness of alluvium in the Moorebank HGL
Height of water table at well	h_w	hw = H + min GW depth - mean pipeline invert depth
Hydraulic conductivity of aquifer	K	Quaternary alluvial sediments (medium-grained sand, silt and clay)
Length of trench	x	Based on a pipe lay rate of 12 m/day (urban conditions)
Radius of influence	R_0	Calculated radius of influence (Sichardt equation)