Concept Stormwater Management Plan

for

11 – 17 Mosbri Crescent, Lot 1 DP204077, The Hill

for Crescent Newcastle Pty Ltd

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1. Introduction

1.1. General

Northrop Consulting Engineers have been engaged by Crescent Newcastle Pty Ltd to undertake a Concept Stormwater Management Plan for the proposed development as per the following information:

- Demolition of all existing structures.
- Earthworks, including mine grouting.
- Construction of residential accommodation comprising 172 dwellings, being:
  - 11 two-storey townhouse style dwellings fronting Mosbri Crescent, located above a basement car park.
  - Three residential flat buildings (Building A, B, and C) containing 161 dwellings, ranging from one to three bedrooms, being:
    - Building A including a nine-storey east wing and six-storey west wing.
    - Building B comprising seven-storeys and a roof top communal open space, with nine town house style dwellings facing the internal courtyard.
    - Building C comprising five levels.
- Interconnected car parking for Building A, B and C located on the ground floor and first level.
- Pedestrian path, providing connection from Mosbri Crescent to Kitchener Parade.
- Associated landscaping, communal open space, services and site infrastructure.

The purpose of this report is to address the management of stormwater in the proposed development of the site, in particular:

- Management of runoff from the external catchment in Arcadia Park and conveyance of flows through the site.
- Management of Stormwater Quantity within the site.
- Management of Stormwater Quality within the site.
- Downstream point of connection.

This report intends to discuss issues relating to the site at a level appropriate for a Development Application submission and should be read in conjunction with drawings DA-C01.01–DA-C30.02 (refer Appendix A). It does not attempt to provide detailed design solutions to all issues; rather it will investigate the feasibility of solutions based on information that we have gathered to date from a number of sources and provide outcomes which will be developed further at Construction Certificate and Construction phases of the project.

1.2. Site Description

The site is located in Mosbri Crescent, The Hill and is bound to the east by Arcadia Park, Hillview Crescent to the south and Kitchener Parade to the north. The site is developed with an existing NBN Television facility and associated infrastructure.

The first 60 to 70m of the site generally slopes downwards towards Mosbri Crescent at grades varying between 2% and 5%. The northern, eastern and western boundaries of the site have retaining walls ranging from 1.5 and 5m high to cater for the increase in grades towards Arcadia Park.

Arcadia Park falls to the site with grades varying between 20% and 35%. Two natural gullies and small-scale existing stormwater network meet the eastern boundary of the site. Existing drainage lines covey Council stormwater via Arcadia Park and subsequently through the development site. The park is predominantly medium to dense bushland, with minimal landscaping.

Two existing pit and pipe networks within the site discharges to the external stormwater network through Mosbri Crescent Reserve. A pit exists at the low point of the reserve. The Reserve is quite steep, and grades will be sufficient to allow connection from the site to this system (refer Civil Drawings in Appendix A).

2. Newcastle City Council Consultation

Consultation has been undertaken with Council during the design development. This included several meetings at Council chambers, a site inspection with Council Officers and telephone discussions with Ben Lovell and Alistair Peddie of Newcastle City Council (NCC). The main points raised by Council as preliminary feedback revolved around the treatment and management of Council infrastructure and runoff from Arcadia Park and the significant erosion issues which exist within the lower reaches of the gully lines. In regard to the erosion issues Council sought the development to include environmental management works to aid in stabilisation within the Park.

A number of options to manage NCC owned drainage infrastructure and runoff from Arcadia Park were discussed with Council Officers, including:

- Option 1 - Provide for piped and overland flow in an easement around the development footprint (down eastern and southern boundaries) with pipe located 6 – 7m below backfill. This option also required flows to build up behind the retaining wall in the Parks northern gully line to some 2 – 3m prior to flowing into the site. The option was not supported by Council due to maintenance and access constraints to pipes bedded in deep trenches. It was also noted that the buildup of water behind the retaining wall could have a negative impact on the already eroded gully lines in the Park.

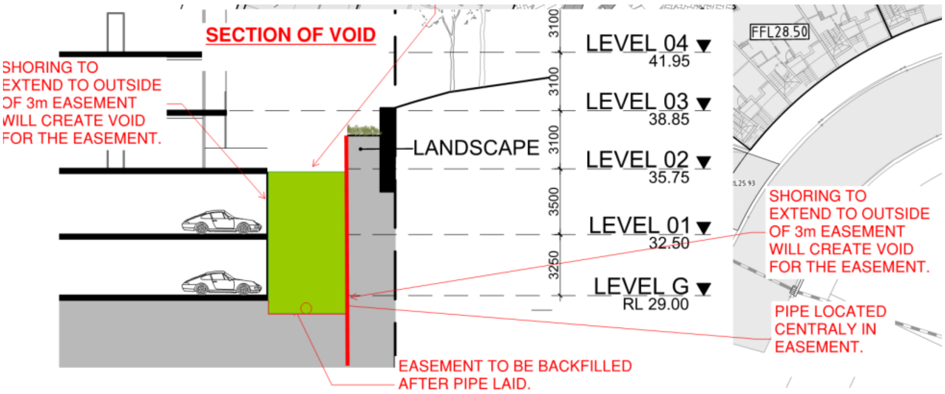

Figure 2 – Drainage Easement - Option 1

- Option 2 - Provide for an underground pipe and overland flow easement around the development footprint (down eastern and southern boundaries) in a void with propping of the shoring wall at a high level allowing for maintenance equipment below. This option was workshopped a number of times with Council Officers to ultimately be the desired solution.

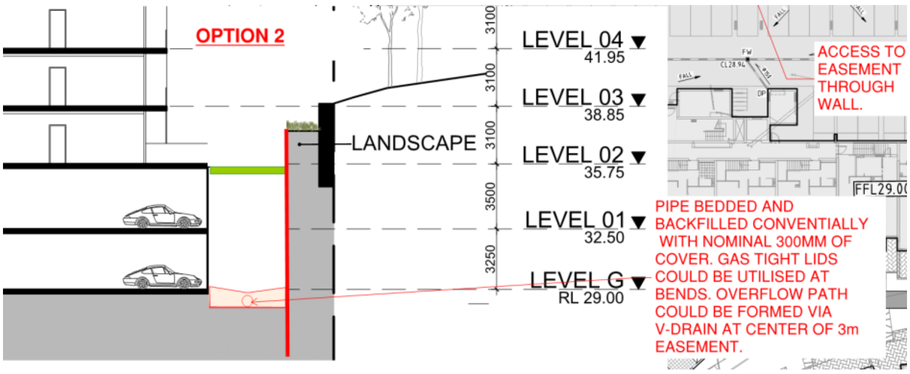

Figure 2 – Drainage Easement - Option 2

- Option 3 - Provide an above ground pipe and overland flow easement around the development footprint (down eastern and southern boundaries) in an enclosed void behind the basement carpark. The option was not supported by Council as it varied from their standard maintenance procedures and DCP requirements.

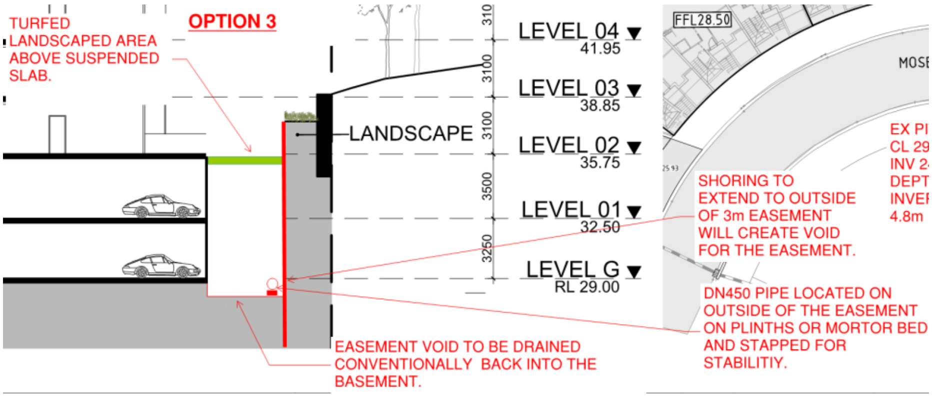

Figure 3 – Drainage Easement – Option 3

- Option 4 - Provide a pipe under the development utilizing the current alignment of the stormwater pipes on site. This was not supported by Council due to maintenance reasons and access constraints to pipe.

As noted above, all options were workshopped with Council Officers with the preferred option to achieve NCC objectives being Option 2.

3. Stormwater Management Philosophy

The stormwater management philosophy for the site considers the following items:

- Management of runoff from the external catchment upstream of the site (Arcadia Park).
- Management of stormwater from and through the development site.
- Mitigating impacts to downstream properties and stormwater systems, particularly from the low point in Mosbri Park.

A detailed hydrological and hydraulic model using the runoff routing software DRAINS was developed. The DRAINS model was built to replicate the existing scenario, as well as the developed site scenario. It is noted that ARR 2019 rainfall data has been adopted in the models to assess the system in line with current design standards.

Within each model contributing catchments (both internal to the site and external) have been included to determine expected piped and overland flow, pipe sizes and on-site detention sizing, as well as impacts to downstream areas.

Illustrative outputs from the DRAINS models set up for the site for varying storm events and scenarios are contained in Appendix B.

The following sections overline the results of this modelling and their relevance to the site stormwater management. DRAINS models may be provided to Council upon request.

3.1. Management of Upstream Catchments (Arcadia Park)

Arcadia Park spans the entire extent of the eastern boundary, with Survey and Council records indicating that it drains to the site from the east. This occurs via two low points on this boundary, both of which contain existing stormwater infrastructure which drain through the site. Taking this into consideration, inflows from the external catchment entering the site will be managed to cater for a significant storm events. Moreover, in response to Council’s concerns, consideration has been given to clearances between proposed easements along the eastern and southern boundaries and the building footprint on the site.

To determine the extent of stormwater runoff from upstream areas, the external catchments that drain to the site were mapped and are shown in Figure 4 below.

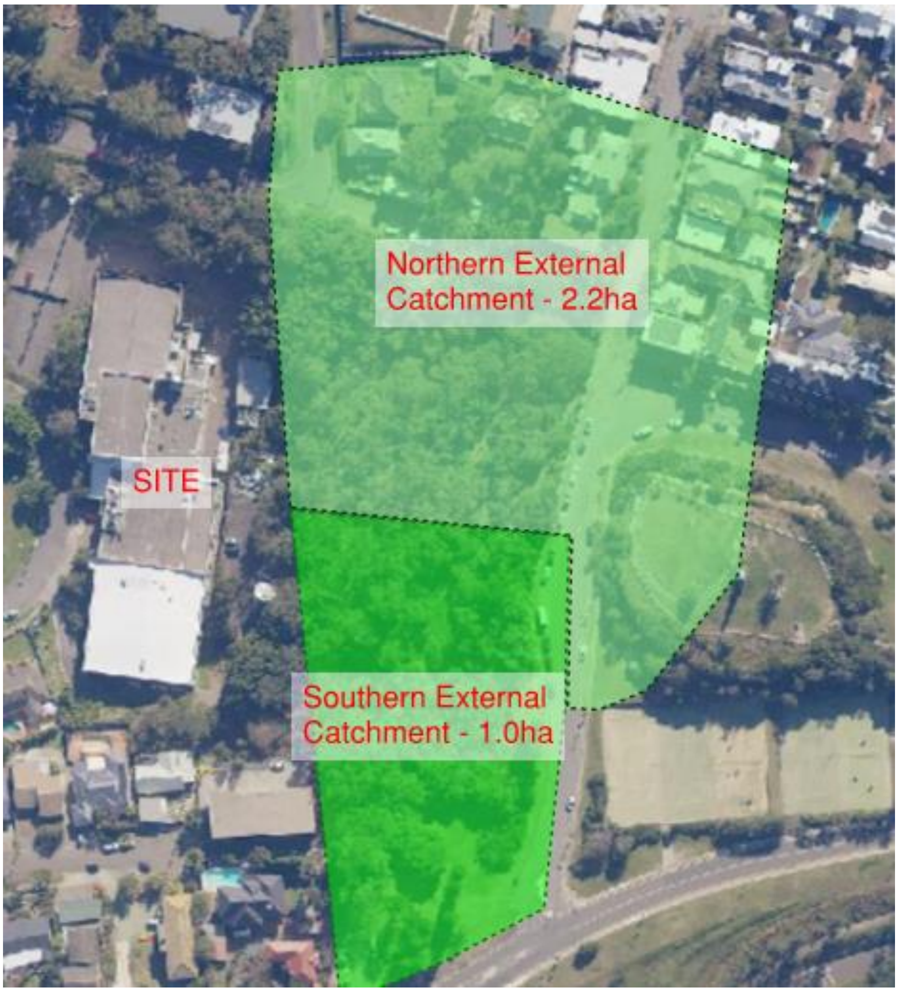

Figure 4 – External Catchment Plan, Including Arcadia Park and Surrounds

Table 1 below contains the peak flows as derived from the DRAINS model for the upstream catchments over a range of storm events. The combined values come from the Developed Scenarios where the layout of the site combines the flows from the two upstream catchments and conveys it through an easement on the southern side of the site.

Table 1. Peak Flow from Upstream Catchments

Catchment	Peak 5% AEP flow (m^3/s)	Peak 1% AEP flow (m^3/s)
Northern Catchment	1.03	1.54
Southern Catchment	0.48	0.73
Combined	1.41	2.11

3.2. Overland Flow Paths

Currently Arcadia Park drains into the site where flows are conveyed around and under the existing NBN building utilising overland flow and piped drainage.

To facilitate the collection and safe conveyance of runoff from Arcadia Park in the Developed Scenario, an overland flow path is proposed to follow the stormwater easement and piped system from the low points in Arcadia Park to Mosbri Crescent. This overland flow path will be sized to cater for the 1% AEP event, assuming varying degrees of blockage of the network.

DRAINS models incorporating 50% and 100% blockage of pits has been completed to determine the need for additional pits/inlet capacity along the easement, and the peak flow of water in the easement should a worse case event occur (100% blockage of pits and underground system). These scenarios are further discussed below.

The DRAINS model of the Developed Scenario has incorporated the drainage proposed in the easement, as well flows from the site and the detention basins.

The overland flow path route critical locations are indicated in Figure 5 and summarised below.

Figure 5 – Ground Level – Overland Flow Path and Critical Locations Analysed

- Critical Section A – this section is representative of the overland flow easement against the building along the eastern boundary and portions of the southern boundary. The easement through this section is 3.5m wide (min) with 0.5% longitudinal grade. Manning's roughness has been chosen as 0.035 which is consistent with short grass or a gravel surface. The peak 1% AEP flow (2.1m^3/s) reaching this section of the easement will be along the southern boundary after the inflow from the southern external catchment.
- Critical Section B – this section is representative of the overland flow easement against the landscape areas along the southern boundary. The easement through this section is 4.8m wide with 0.5% longitudinal grade. Manning's roughness has been chosen as 0.035 which is consistent with short grass or a gravel surface. The peak 1% AEP flow reaching this section of the easement is 2.1m^3/s.
- Critical Section C – this section is representative of the overland flow easement against the townhouses fronting Mosbri Crescent. The easement through this section is 3.5m wide with 0.5% longitudinal grade. It is likely that this section of the easement will be a loading zone or similar and contain a concrete driveway. As such a Manning's roughness has been chosen as 0.018 which is consistent with concrete. The peak 1% AEP flow (2.26m3/s) occurs after inflow from the detention overflow system.

To consider safety in regard to flow in the easement the following guidelines and their recommendations have been used.

1. CN *Stormwater Technical Manual* notes that a Velocity (V) x Depth (D) <0.36 is safe for small children.
2. *Australian Rainfall and Runoff (AR&R) – Appropriate Safety Criteria for people – Stage 1 Report April 2010* (refer Appendix D) states -

> *For children with a height and mass product (H.M) of between 25 and 50, low hazard exists for flow values of D.V < 0.4 m2s-1, with a maximum flow depth of 0.5 m regardless of velocity and a maximum velocity of 3.0 ms-1 at shallow depths. Under these flow regimes, the children tested retained their footing and felt "safe" in the flow. For adults (H.M > 50), low hazard exists for flow values of D.V < 0.6 m2s-1 with a maximum depth limit of 1.2 m and a maximum velocity of 3.0ms-1 at shallow depths Moderate hazard for adults exists between D.V = 0.6 to 0.8 m2s-1, with an upper working flow value of D.V < 0.8 m2s-1 recommended for trained safety workers or experienced and well equipped persons. Significant hazard for adults exists between D.V = 0.8 to 1.2 m2s-1. For flow values D.V >1.2 m2s-1 the majority of tests for adults indicated instability - the hazard is extreme and should not be considered safe for standing or wading.*

<table>
<tr><th>DV (m^2s^{-1})</th><th>Infants, small children (H.M ≤ 25) and frail/older persons</th><th>Children (H.M = 25 to 50)</th><th>Adults (H.M > 50)</th></tr>
<tr><td>0</td><td>Safe</td><td>Safe</td><td>Safe</td></tr>
<tr><td>0 – 0.4</td><td rowspan="5">Extreme Hazard; Dangerous to all</td><td>Low Hazard[1]</td><td rowspan="2">Low Hazard[1]</td></tr>
<tr><td>0.4 – 0.6</td><td>Significant Hazard; Dangerous to most</td></tr>
<tr><td>0.6 – 0.8</td><td rowspan="3">Extreme Hazard; Dangerous to all</td><td>Moderate Hazard; Dangerous to some[2]</td></tr>
<tr><td>0.8 – 1.2</td><td>Significant Hazard; Dangerous to most[3]</td></tr>
<tr><td>> 1.2</td><td>Extreme Hazard; Dangerous to all</td></tr>
</table>

[1] Stability uncompromised for persons within laboratory testing program at these flows (to maximum flow depth of 0.5 m for children and 1.2 m for adults and a maximum velocity of 3.0 ms^{-1} at shallow depths).
[2] Working limit for trained safety workers or experienced and well equipped persons (D.V < 0.8 m^2s^{-1})
[3] Upper limit of stability observed during most investigations (D.V > 1.2 m^2s^{-1})

The surface treatment of the overland flow path is critical to the conveyance of runoff as well as maintenance. The surface treatment has been chosen to:

- Cater for maintenance vehicles.
- Prevent erosion in major events, be easy to maintain or replace by Council if works are required.
- Respond to visual and landscaping needs for the development.

For this reason, concrete, pavers, or a Truegrid systems with gravel or short turf were considered by the development. To respond to the development's visual needs and be easy to replace if required, Truegrid (or a similar system) has been chosen as the preferred option. True grid allows for a gravel or short turf infill final surface treatment. It is designed to be strong enough for maintenance vehicles to traverse, while in flood events the plastic grid system contains the infill material such that erosion is minimised. Appendix C contains technical specification for the Truegrid system.

Table 2 below contains a summary of the flow characteristics in the easement from the Developed 1% AEP DRAINS model.

Table 2. Peak 1% AEP Flow in Easement

Location	Easement width (m)	Underground Pipe DN	Flow Depth (m)	VxD (surface flow)	Flow Depth (m) – 100% blockage
A	3.5	1050	0.37	0.36	0.49
B	4.8	1200	0.29	0.26	0.41
C	3.5	1200	0.22	0.32	0.35

Results shown in Table 2 confirm that the peak VxD in the 1% AEP event through the easement will meet or fall below the desired range set by the guidelines.

The 100% pit blocked results has been included to determine the peak water depth in a worse-case scenario. This shows flood depths of up to 500mm against Building C.

A 50% pit blocked scenario was also completed which displayed VxD results almost exactly equal with the 0% scenario. This was due to the piped system governing the easement flow characteristics at the critical points being reviewed. It is noted that additional pits can be added to the system to increase inlet capacity and mitigate blockage at detailed design stage.

Based on the results of the DRAINS modelling the following is concluded:

- The overland flow paths should be designed to contain runoff to at least 800mm. This will contain all 1% AEP flows with an appropriate freeboard.
- Access to the easement along the southern and eastern easement where against the new building and 3.5m wide should consider, where feasible, the use of fencing and gates to restrict access by small children. Fencing to be designed with flood flaps or similar so as not to obstruct flows during major events.
- Access to the easement against the landscaped area should be controlled by landscaping discouraging access to the easement except at one spot which should be identified with stairs or appropriate ramps.
- Signage and education of the residents should also be provided to make people aware of the likely hazards proposed by the easement during large storm events.

3.3. Management of Stormwater within the Site (Detention)

In order to meet compliance with Council DCP's for sites with a disturbed land area greater than 5000m^2, the greenfield site and proposed developed site catchments were defined and modelled in DRAINS. The criteria for the modelling included attenuating peak post-developed flows to equal or less than that of pre-developed conditions. The modelled internal catchment areas are indicated below in Figure 8, where green areas are pervious areas, brown areas the impervious areas, the southern bypass catchment is the hatched area, and the grey area shown on the primary driveway denotes the pavement bypassing treatment.

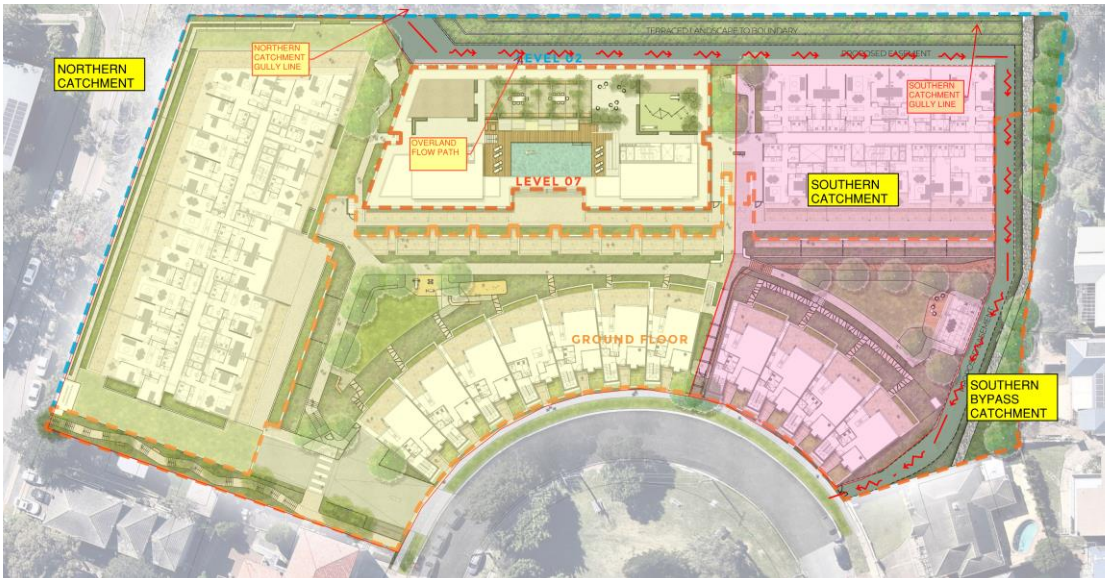

Figure 8 – Schematic of Catchment Areas

A breakdown of the catchment areas is given in Table 3 below.

Table 3 – Catchment Areas

Area Type	Areas (ha)		
	North Catchment	South Catchment	South Bypass
Pervious	0.122	0.082	0.030
Impervious	0.628	0.231	0.000

Peak hydrographs for the pre and post-developed catchments have been determined by comparing a range of storm durations for the 20%, 10%, 5%, 2% and 1% AEP storm events. The peak hydrographs, along with an iterative process of increasing detention volume and adjusting orifice and weir configurations until the post-developed discharge was less than that of the pre-developed discharge have been used to determine the detention volume required.

For the purposes of runoff modelling, pre-developed site conditions considered a greenfield site (0% impervious area with no detention basin). For the post-developed site conditions, the site was divided into two catchment areas (North and South) to reflect Figure 8. The North catchment was modelled as per the following:

- 63% impervious.
- 80m^3 below ground detention tank with a two-meter weir, 250mm low level outlet orifice and 250mm high level outlet orifice.

Additionally, the Southern catchment was modelled as per the following:

- 50% impervious.
- 80m^3 below ground detention tank with a two-meter weir, 300mm low level outlet orifice and 250mm high level outlet orifice.

Based on a survey of the site and the levels in the southern corner, a portion of the site has been assumed to bypass the internal stormwater network and treatment, discharging straight to the external stormwater network. This bypass area is indicated in Figure 8, which has been modelled as 100% impervious to reflect the most current Architectural drawings.

The estimated peak discharge from the catchment for the pre-developed and post-developed conditions, as predicted by the DRAINS analysis, can be seen in Table 4 below.

Table 4 – Pre-Developed Flows versus Post-Developed Flows

Storm Event	Pre-developed Peak Discharge (m^3/s)	Post-Developed Peak Discharge (m^3/s)
20% AEP	0.388	0.362
10% AEP	0.479	0.479
5% AEP	0.628	0.559
2% AEP	0.781	0.742
1% AEP	0.932	0.869

Table 4 shows that the stormwater quantity target is achieved, with post-developed peak discharges lower than pre-developed peak discharges for all modelled storms.

The tanks are proposed to be located below ground at the positions indicated in Northrop's drawing DA-C02.10. The tanks are to be combined detention and reuse, with segregation by means of an internal overflow weir such that overflows from the reuse will flow into the detention side of the tank for discharge. Design and construction details of the basins will be provided in the CC stage.

Stormwater runoff from the development will be conveyed to the below ground detention tanks via the internal pit and pipe system. Both tanks will have internal orifice flow controls and weirs, with outlets consisting of a piped outlet to the internal network for discharge to the external stormwater network in Mosbri Crescent as per the detail shown in Northrop drawing DA-C0210.

3.4. Reuse Strategy

A reuse tank with minimum 4kL volume will be provided to each townhouse fronting Mosbri Crescent. The reuse is to be reticulated through the dwelling for toilet and laundry use, and all tank overflows are to be directed over the tank weir to the adjacent on-site detention chambers.

Runoff from the roof catchments of buildings A, B and C are to be collected in their respective below ground reuse tank, with 75m^3 minimum reuse volume for buildings A and B, and 60m^3 minimum reuse volume for building C. These volumes were determined based on roof area sizes and "NSW MUSIC Modelling Guidelines" (BMT WBM, 2015) for the relevant number of occupants per dwelling, with one, two and three-bedroom dwellings considered. Both reuse tanks are to be connected to all dwellings on the Ground and Level 1 for use in toilets and laundry. The overflows from the reuse section of the below ground tanks are to spill into the detention section by means of an internal weir.

3.5. Basement Carpark Fronting Mosbri Crescent

To facilitate the drainage of car drip waste in the enclosed basement carpark, a network of floor waste pits will be provided at low points with minimum 0.5% fall to collect runoff from the carpark pavement. Runoff is to be conveyed via 150mm pipes to a pump-out pit with minimum volume of 3kL. A grated trench drain is to be provided at the base of the carpark ramp to collect any runoff from the ramp, which will be connected to the pump-out pit using 150mm pipe. A crest will be provided at the top of the ramp to limit runoff from the driveway. The pump-out pit is to be connected to a vertical riser, where it will pump runoff to a junction pit on the surface for discharge into the stormwater network as per the detail shown in Northrop drawing DA-C02.01.

3.6. Ground and Level 1 Carpark – Buildings A, B and C

The entire facility is internal and as such is not exposed to rainfall. Taking this into account, a floor waste network is considered sufficient to manage runoff from the pavements, with floor waste collection points placed at low points with minimum 0.5% fall to collect runoff. The network on the Ground Level is to mimic the Level 1 network, which will be connected using downpipes. The floor waste network on the Ground Level will be connected using 150mm pipe and convey runoff to the site stormwater network using a connection point at the northwestern boundary as per Northrop's drawing DA-C02.10.

3.7. Mitigation of Flows at Mosbri Park

The top of Mosbri Street and the development site are connected to an existing underground stormwater system that finds its way to the bottom of Mosbri Park (refer Engineering Drawings in Appendix A). At this location the Council stormwater system is piped behind existing private dwellings to Kitchener Parade. Council have advised that a critical part of the design of the development will be to avoid any flood impacts / increase in peak storm events at the bottom of Mosbri Park.

The DRAINS model was extended to this location to determine the impacts on flows at the low point in Mosbri Park. The following is noted from the DRAINS modelling:

- The Existing peak 1% AEP and 5% AEP flow at the bottom of Mosbri Park is 1.1m3/s and 1.03m3/s respectively.
- The Developed peak 1% AEP and 5% AEP flow at the bottom of Mosbri Park is 1.05m3/s and 0.96m3/s respectively.

As such results show a slight decrease in peak flows at the low point in Mosbri Park due to the development and how is manages stormwater. The results can be seen to be driven by the following design items:

- Flows in the developed case leaving the site are significantly smaller than those currently leaving the site. This is due to detention being required to reduce flows to levels where no impervious surfaces exist. Considering the site is now significantly covered by hard surfaces it stands to reason that the existing flows leaving the site are more than those expected after the introduction of detention.
- The DN1200 pipe in the drainage easement has been designed to convey flows safely through the development site. This pipe at Mosbri Street is to be connected into a smaller pipe (DN375) to minimise flows heading to the low point in Mosbri Park. The DRAINS model shows that surcharging of the underground system will occur at this connection point. Flow in the street at this point will head west down Mosbri Street avoiding Mosbri Park. Thus, reducing the overall flow reaching the low point in the park.

Consequentially, the DRAINS model shows that peak flows are not adversely impacted, due to the development at the low point in Mosbri Park.

4. Stormwater Quality Management Strategy

4.1. Stormwater Quality Philosophy and Targets

The proposed development will involve the construction of footpaths, hardstand and roof areas which will increase the mean annual pollutant load generated by a greenfields site. In accordance with Section 7.06 of the City of Newcastle DCP 2012, the proposed development will include controls to minimise filter pollutants and comply to the required pollutant targets. The controls will consist of vegetated swales, grass buffers, and filter cartridges located in the detention tanks.

To facilitate the water quality analysis, we have adopted the water quality target nominated in Section 7.06 of the DCP, reproduced in Table 4 below:

Table 4 – Stormwater Treatment Objectives for The City of Newcastle (2012)

Pollutant	Stormwater Treatment Objective
Total Suspended Solids (TSS)	85% retention of average annual load
Total Phosphorous (TP)	65% retention of average annual load
Total Nitrogen (TN)	45% retention of average annual load
Gross Pollutants	90% reduction in the average annual load of Gross Pollutants (>5mm)

4.2. Treatment Train Assessment

To substantiate the effectiveness of the proposed water quality control measures, stormwater quality modelling was undertaken using the Model for Urban Stormwater Improvement and Conceptualisation (MUSIC) V6.3.0. The Newcastle City Council MUSIC Link was used to create the meteorological template with a six-minute time step.

Modelling was completed in accordance with the “NSW MUSIC Modelling Guidelines” (BMT WBM, 2015). The catchment area was broken down into the two sub-catchments shown in Figure 5 to effectively simulate the proposed treatment measures along the treatment train. A schematic of the model is shown in Figure 7 below.
Considering the new stormwater easement is part of a separate stormwater system (carrying eastern catchment flows only), it has not been included in this model.

Figure 7 – MUSIC Model Layout Schematic

The source nodes adopted to represent the development were Sealed Road, Urban Residential and Urban Roof. The residential nodes were adopted in both catchments and were used to represent all areas other than roof and road catchments, with the impervious percentage of 63% adopted for the North catchment and 50% for the South catchment.

The treatment train incorporates:

- Primary treatment via 75kL (buildings A and B roof) and 60kL (building C roof) reuse below ground reuse tanks.
- Primary treatment of townhouse roof catchments via 4kL reuse tank per dwelling.
- Secondary treatment of roof catchments and landscaping/ footpath areas via proprietary filter cartridges located in the detention tanks.

Treatment nodes were created within the MUSIC model to represent the water quality treatment devices. A description of each of these measures is included below.

4.3. Reuse – Townhouses Fronting Mosbri Crescent

Runoff from the three-bedroom townhouse roof catchments will be collected and diverted to a 4kL rainwater tank located adjacent to each of the dwellings. The only re-use demand for input in the MUSIC model was toilets and laundry. A re-use total demand of 1.26kL/ day was adopted total for the seven-townhouses in the north catchment, and 0.72kL/ day in total for the four-townhouses in the south catchment based on the “NSW MUSIC Modelling Guidelines” (BMT WBM, 2015) for three occupants per dwelling. Both of the proposed systems satisfy minimum 80% of re-use demand which is considered an acceptable design outcome.

All downpipes reporting to the tank will be connected to a first flush device located prior to the tank inlet.

4.4. Below Ground Reuse Tanks – Buildings A, B and C

Runoff from the roof of buildings A, B and C are to be collected and diverted to a 75kL reuse tank for buildings A and B, and a 60kL tank for Building C. The reuse tanks are located below ground beneath the proposed landscaped area and are to overflow into the detention chamber. The adopted re-use demand for input in the MUSIC model was toilets and laundry for the Ground Level and Level 1 only. A re-use total demand of 5.24kL/ day was adopted for buildings A and B, and 2.50kL/ day for Building C based on the roof area quantities and “NSW MUSIC Modelling Guidelines” (BMT WBM, 2015) for the relevant number of occupants per dwelling, with one, two and three-bedroom dwellings to be incorporated within the buildings. The system connected to Buildings A and B satisfies 80% of re-use demand and 83% for Building C, which is considered an acceptable design outcome.

The roof of each building is to be connected to the reuse tanks with suitably sized downpipes.

4.5. Filter Cartridges

To attain the stormwater quality targets, proprietary filtration devices (SPELfilter full-height cartridges or similar) located within the detention tank or an approved equivalent, are proposed to provide secondary treatment to runoff. Four cartridges have been deemed necessary in the northern detention tank, and three cartridges have been deemed necessary in the southern detention tank. These cartridges assist in removing fine sediment, oil and suspended nutrients prior to discharge from site. The filtration cartridges will be housed within a chamber (vault) of the detention tank. The parameters for the SPEL Vault and Filter nodes were determined using SPEL’s “MUSIC Inputs Calculator,” which can be provided upon request.

4.6. Results

The MUSIC modelling results for the receiving node are shown in Table 5 below.

Table 5 – MUSIC Model Result Summary (Outlet Node)

	Source Load (kg/yr)	Residual Loads (kg/yr)	Percentage Reduction	Target Objectives
Total Suspended Solids (TSS)	856	128	85	85
Total Phosphorous (TP)	2,07	0.493	76.2	65
Total Nitrogen (TN)	21.1	8.27	60.7	45
Gross Pollutants	271	2.46	99.1	100

Table 5 shows that the proposed storm water quality management strategy is predicted to achieve the load reduction targets, as estimated by MUSIC. The associated MUSICLink Report can be found in Appendix E. MUSIC data files can be provided upon request.

5. Conclusion

This report has been prepared with consideration to and generally in accordance with the Newcastle City Council Development Control Plan (DCP) 2012, and the Newcastle City Council (NCC) Stormwater and Water Efficiency for Development Technical Manual 2017.

Given the results of the above investigations, it is reasoned that the development meets The City of Newcastle Council's requirements.

Runoff from the upstream external catchments in Arcadia Park will be managed through the provision of a drainage easement consisting of pits and pipes along the eastern and southern boundaries of the site, sized to accommodate the 1% AEP event. An overland flow path is also proposed to convey runoff from the external catchments in the event of blockage during the 1% AEP event, with consideration given to the overland flow path to ensure that there are not trapped low points within the development.

To comply with the City of Newcastle Council's requirements stipulated in the DCP, the proposed development will control and minimise disturbance and impacts of stormwater runoff on adjoining properties and receiving waters, as follows:

- The pollutant load reduction targets have been established to comply with those nominated in Section 7.06 (f) of the DCP.
- The treatment of stormwater for waterborne pollutants to achieve the selected treatment targets is achieved through the proposed treatment train. This includes the use of a rainwater tank, filter cartridges, and grass buffer strips incorporated into the landscaping throughout the site.

To comply with Section 7.06.02 of the DCP, the proposed development will include on-site stormwater detention and re-use for second quality water uses, as follows:

- Runoff from all roof areas of buildings A, B and C will be connected to their respective below ground reuse tanks for reuse on the Ground level and Level 1 for toilet and laundry uses.
- Runoff from all townhouse roof areas will be connected to individual rainwater tanks with minimum 4kL volume for internal reuse in toilet and laundry.
- Stormwater runoff from the site, including landscaped areas and footpaths, will be conveyed to the below ground stormwater detention tanks, from where it will be discharged into the external stormwater network in Mosbri Crescent. Filter Cartridges within the detention tanks provide treatment to runoff from hardstand areas.
- The proposed detention basins will reduce post-developed peak discharge to below the pre-developed peaks using a combination of outlet orifices and internal overflow weirs.

Based on the assessment outlined above it is our opinion that the proposed water drainage and treatment measures outlines within this report and associated design drawings will provide stormwater quality and quantity provisions that are commensurate with the intent of the City of Newcastle Council's Development Control Plan, relevant Council Technical Manuals and typical industry practice.

Appendix A – Concept Civil Design Drawings

MOSBRI APARTMENTS

11-17 MOSBRI CRESCENT
THE HILL, NSW, 2300

- CIVIL ENGINEERING PACKAGE -

DRAWING LIST

DWG NO	DRAWING TITLE
DA-C00.01	COVER SHEET, DRAWING LIST AND LOCALITY PLAN
DA-C10.01	EROSION AND SEDIMENT CONTROL PLAN
DA-C10.11	EROSION AND SEDIMENT CONTROL DETAILS
DA-C20.01	CIVIL WORKS LOWER GROUND FLOOR
DA-C20.11	CIVIL WORKS GROUND FLOOR
DA-C20.21	CIVIL WORKS LEVEL 2
DA-C30.01	CIVIL DETAILS SHEET 1
DA-C30.02	CIVIL DETAILS SHEET 2
DA-C30.03	CIVIL DETAILS SHEET 3
DA-C30.04	CIVIL DETAILS SHEET 4
DA-C40.01	CUT FILL PLAN
DA-C40.11	BULK EARTHWORKS PLAN
DA-C40.21	BULK EARTHWORKS SECTIONS

DRAWN: B.DUGGAN
DESIGNED: R.JEANS
JOB MANAGER: B.CLARK
VERIFIER: B.CLARK

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REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
1	ISSUED FOR COORDINATION	CH	BC	RC	19.12.18
A	ISSUED FOR APPROVAL	CH	BC	RC	21.12.18
B	RE-ISSUED FOR APPROVAL	CH	BC	RC	08.10.19
C	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21

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PROJECT
11-17 MOSBRI CRESCENT THE HILL, NSW, 2300

DRAWING TITLE
COVER SHEET, DRAWING LIST AND LOCALITY PLAN

JOB NUMBER **NL180367**

DRAWING NUMBER **DA-C00.01** REVISION **C**

DRAWING SHEET SIZE = A1

Date : 22.04.2022 5:10 PM Plotted By : WILLIAM CRITTENDEN Found : Y:\YEAR 2018 Jobs\NL180367 - Mosbri Cre\O - Drawings\CIVIL\#CAD\2-CAD FILES\01-DA\01\NL180367-DA-C01.01 COVER.dwg

LEGEND

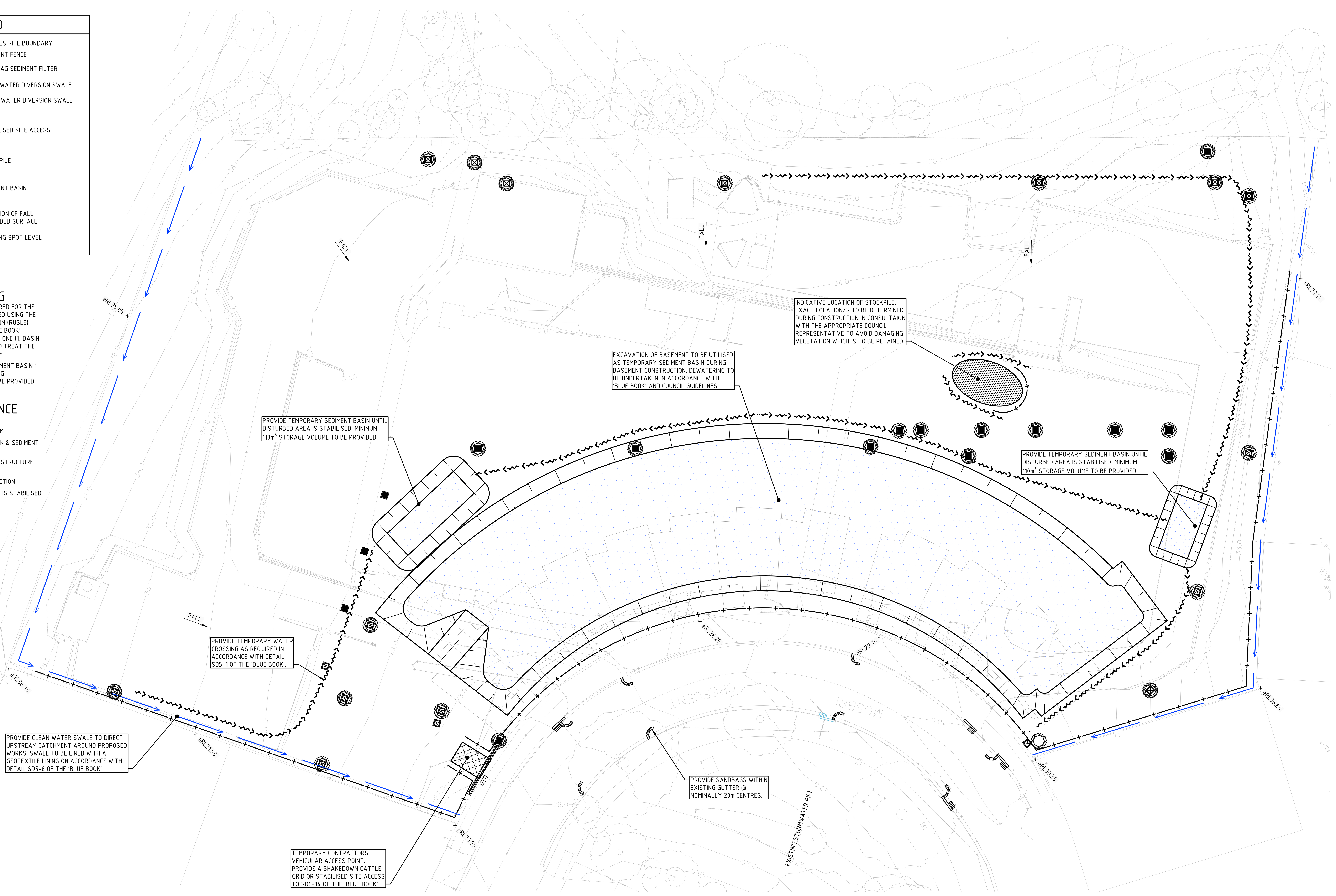
	DENOTES SITE BOUNDARY
	SEDIMENT FENCE
	SANDBAG SEDIMENT FILTER
	DIRTY WATER DIVERSION SWALE
	CLEAN WATER DIVERSION SWALE
	STABILISED SITE ACCESS
	STOCKPILE
	SEDIMENT BASIN
FALL	DIRECTION OF FALL IN GRADED SURFACE
+ eRL38.05	EXISTING SPOT LEVEL

SEDIMENT BASIN SIZING

- THE SEDIMENT STORAGE VOLUME REQUIRED FOR THE PROPOSED WORKS HAS BEEN DETERMINED USING THE REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE) METHOD IN ACCORDANCE WITH THE 'BLUE BOOK' GUIDELINES AS SUMMARISED IN TABLE 1. ONE (1) BASIN HAS BEEN PROPOSED TO INTERCEPT AND TREAT THE SEDIMENT LADEN RUNOFF FROM THE SITE.
- THE SIZE SHAPE AND LOCATION OF SEDIMENT BASIN 1 MAY CHANGE DUE TO PROPOSED STAGING IMPLICATIONS, DETAILS OF WHICH WILL BE PROVIDED AT CC STAGE.

CONSTRUCTION SEQUENCE

- INSTALL STABILISED SITE ACCESS.
- INSTALL CLEAN WATER PUSH BACK BERM.
- INSTALL SAND BAG OR GEOTEXTILE SOCK & SEDIMENT CONTROL FENCES.
- CONSTRUCT DRAINAGE EASEMENT INFRASTRUCTURE AND CONNECT CLEAN WATER RUN-OFF.
- UNDERTAKE ROAD & BUILDING CONSTRUCTION
- REMOVE SEDIMENT CONTROLS ONCE SITE IS STABILISED



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DESIGNED: R.JEANS
JOB MANAGER: B.CLARK
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SCALE 1:250@ A1
0 2 4 6 8 10 12m

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PROJECT
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DRAWING TITLE
EROSION AND SEDIMENT CONTROL PLAN

JOB NUMBER
NL180367

DRAWING NUMBER
DA-C10.01

REVISION
E

DRAWING SHEET SIZE = A1

Date : 22.04.2022 5:10 PM Plotted By : WILLIAM CRITTENDEN Found : Y:\YEAR 2018 Jobs\NL180367 - Mosbri Cre\O - Drawings\CIVIL\#CAD\2-CAD FILES\01-DA\01\NL180367-DA-C10.01 ESC.dwg

EROSION AND SEDIMENTATION CONTROL NOTES

1. ALL EROSION AND SEDIMENTATION CONTROL MEASURES MUST BE APPROPRIATE FOR THE SEDIMENT TYPE(S) OF THE SOILS ON-SITE, IN ACCORDANCE WITH THE 'BLUE BOOK' (MANAGING URBAN STORMWATER - SOILS AND CONSTRUCTION. LANDCOM, 2004), OR OTHER CURRENT RECOGNISED INDUSTRY STANDARDS FOR EROSION AND SEDIMENT CONTROL FOR AUSTRALIAN CONDITIONS. THIS INCLUDES SEDIMENT TRAPS AND LINING OF CHANNELS.
2. THE CONTRACTOR SHALL BE RESPONSIBLE FOR KEEPING A DETAILED WRITTEN RECORD OF ALL EROSION AND SEDIMENT CONTROLS ON-SITE DURING THE CONSTRUCTION PERIOD. THIS RECORD SHALL BE UPDATED ON A DAILY BASIS AND SHALL CONTAIN DETAILS ON THE CONDITION OF CONTROLS AND ANY/ALL MAINTENANCE, CLEANING AND BREACHES. THIS RECORD SHALL BE KEPT ON-SITE AT ALL TIMES AND SHALL BE MADE AVAILABLE FOR INSPECTION BY THE PRINCIPAL CERTIFYING AUTHORITY AND THE SUPERINTENDENT DURING NORMAL WORKING HOURS.
3. INSTALL SEDIMENT PROTECTION FILTERS ON ALL NEW AND EXISTING STORMWATER INLET PITS IN ACCORDANCE WITH EITHER THE MESH AND GRAVEL INLET FILTER DETAIL SD6-11 OR THE GEOTEXTILE INLET FILTER DETAIL SD6-12 OF THE 'BLUE BOOK'.
4. ESTABLISH ALL REQUIRED SEDIMENT FENCES IN ACCORDANCE WITH DETAIL SD6-8 OF THE 'BLUE BOOK'.
5. INSTALL SEDIMENT FENCING, OR OTHER SEDIMENT CONTROL DEVICES, AROUND INDIVIDUAL BUILDING ZONES/AREAS AS REQUIRED AND AS DIRECTED BY THE SUPERINTENDENT OR APPROPRIATE COUNCIL OFFICER.
6. ALL TRENCHES INCLUDING ALL SERVICE TRENCHES AND SWALE EXCAVATION SHALL BE SIDE-CAST TO THE HIGH SIDE AND CLOSED AT THE END OF EACH DAYS WORK.
7. THE CONTRACTOR SHALL ENSURE THAT ALL VEGETATION (TREE, SHRUB & GROUND COVER) WHICH IS TO BE RETAINED SHALL BE PROTECTED DURING THE DURATION OF CONSTRUCTION.
8. ALL VEGETATION TO BE REMOVED SHALL BE MULCHED ON-SITE AND SPREAD/STOCKPILED AS DIRECTED BY THE SUPERINTENDENT.
9. STRIP TOPSOIL IN AREAS DESIGNATED FOR STRIPPING AND STOCKPILE FOR RE-USE AS REQUIRED. ANY SURPLUS MATERIAL SHALL BE SPREAD ON-SITE AS DIRECTED BY THE SUPERINTENDENT OR REMOVED FROM SITE AND DISPOSED OF IN ACCORDANCE WITH EPA GUIDELINES.
10. CONSTRUCT AND MAINTAIN ALL MATERIAL STOCKPILES IN ACCORDANCE WITH DETAIL SD4-1 OF THE 'BLUE BOOK' (INCLUDING CUT-OFF SWALES TO THE HIGH SIDE AND SEDIMENT FENCES TO THE LOW SIDE).
11. ENSURE STOCKPILES DO NOT EXCEED 2.0m HIGH. PROVIDE WIND AND RAIN EROSION PROTECTION AS REQUIRED IN ACCORDANCE WITH THE 'BLUE BOOK'.
12. PROVIDE WATER TRUCKS OR SPRINKLER DEVICES DURING CONSTRUCTION AS REQUIRED TO SUPPRESS DUST.
13. ONCE CUT/FILL OPERATIONS HAVE BEEN FINALIZED ALL DISTURBED AREAS THAT ARE NOT BEING WORKED ON SHALL BE RE-VEGETATED AS SOON AS IS PRACTICAL.

SEDIMENT BASIN SIZING CALCULATION

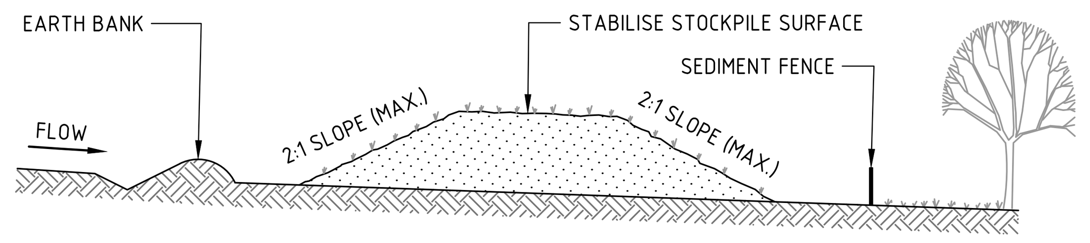
THE SITE IS LOCATED WITHIN THE KILLINGWORTH SOIL LANDSCAPE, WHICH HAS THE FOLLOWING PROPERTIES (IN ACCORDANCE WITH TABLE C17 OF THE "BLUE BOOK"):

SITE PARAMETERS - NORTH BASIN	
CONSTRAINT	VALUE
SEDIMENT TYPE	F
SOIL HYDROLOGY GROUP	A
K = SOIL ERODIBILITY (K-FACTOR)	0.036
R = RAINFALL EROSIVITY (R-FACTOR)	2190
S = 2 YEAR, 6 HOUR STORM INTENSITY	9.93 mm/hr
LS = SLOPE LENGTH/GRADIENT	5.52 (75m SLOPE @ 11% GRADE)
P = EROSION CONTROL PRACTICE (P-FACTOR)	1.3 (TYPICAL)
C = GROUND COVER (C-FACTOR)	1.0 (TYPICAL FOR STRIPPED SITE)
SOIL LOSS (RUSLE METHOD) (tonnes/ha/yr)	566
EROSION HAZARD (TABLE 4.2 BLUE BOOK)	HIGH

SITE PARAMETERS - SOUTH BASIN	
CONSTRAINT	VALUE
SEDIMENT TYPE	F
SOIL HYDROLOGY GROUP	A
K = SOIL ERODIBILITY (K-FACTOR)	0.036
R = RAINFALL EROSIVITY (R-FACTOR)	2190
S = 2 YEAR, 6 HOUR STORM INTENSITY	9.93 mm/hr
LS = SLOPE LENGTH/GRADIENT	4.61 (75m SLOPE @ 11% GRADE)
P = EROSION CONTROL PRACTICE (P-FACTOR)	1.3 (TYPICAL)
C = GROUND COVER (C-FACTOR)	1.0 (TYPICAL FOR STRIPPED SITE)
SOIL LOSS (RUSLE METHOD) (tonnes/ha/yr)	472
EROSION HAZARD (TABLE 4.2 BLUE BOOK)	HIGH

SEDIMENT BASIN SIZING - NORTH BASIN		
CONSTRAINT	VALUE	UNITS
CV = VOLUMETRIC RUNOFF COEFFICIENT	0.5	
R = 5 DAY, 75TH PERCENTILE RAINFALL	30.500	mm
A = CATCHMENT AREA	0.600	ha
SETTLING ZONE VOLUME (10xCVxRxA)	73.200	m^3
SOIL LOSS (CALC ABOVE)	103	m^3/ha/yr
A2 = DISTURBED CATCHMENT AREA	435	ha
SEDIMENT STORAGE VOLUME (0.17xSOIL LOSSxA2)	44	m^3
TOTAL BASIN VOLUME REQUIRED	118	m^3

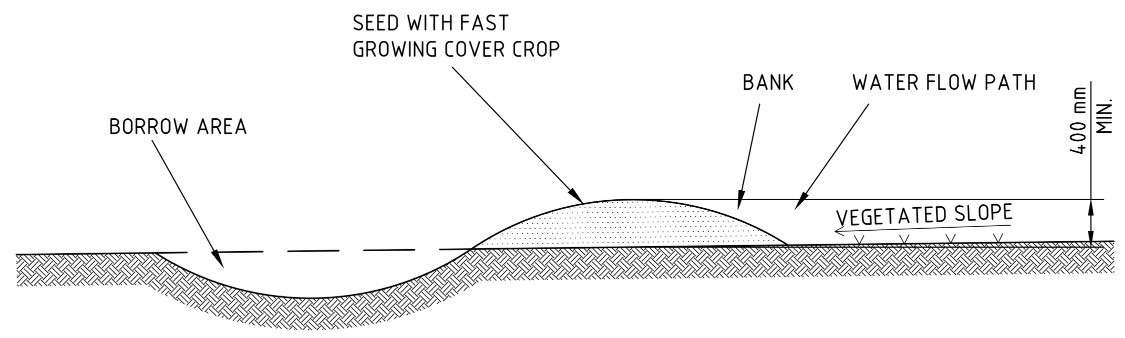
SEDIMENT BASIN SIZING - SOUTH BASIN		
CONSTRAINT	VALUE	UNITS
CV = VOLUMETRIC RUNOFF COEFFICIENT	0.5	
R = 5 DAY, 75TH PERCENTILE RAINFALL	30.500	mm
A = CATCHMENT AREA	0.600	ha
SETTLING ZONE VOLUME (10xCVxRxA)	73.200	m^3
SOIL LOSS (CALC ABOVE)	103	m^3/ha/yr
A2 = DISTURBED CATCHMENT AREA	363	ha
SEDIMENT STORAGE VOLUME (0.17xSOIL LOSSxA2)	37	m^3
TOTAL BASIN VOLUME REQUIRED	110	m^3



CONSTRUCTION NOTES

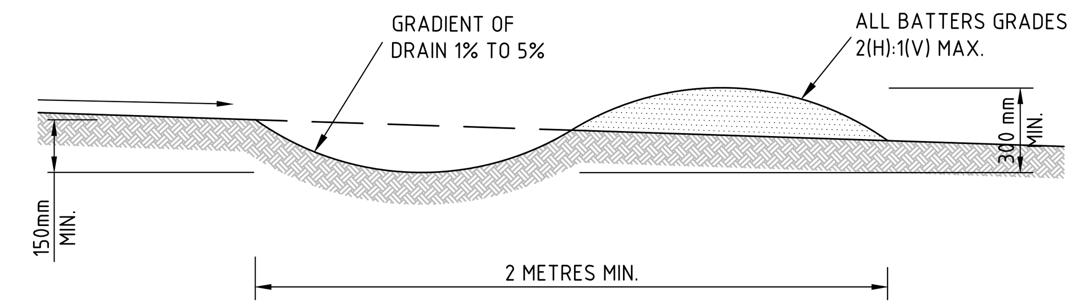
1. PLACE STOCKPILES MORE THAN 2m (PREFERABLY 5m) FROM EXISTING VEGETATION, CONCENTRATED WATER FLOW, ROADS AND HAZARD AREAS.
2. CONSTRUCT ON THE CONTOUR AS LOW, FLAT, ELONGATED MOUNDS.
3. WHERE THERE IS SUFFICIENT AREA, TOPSOIL STOCKPILES SHALL BE LESS THAN 2m IN HEIGHT.
4. WHERE THEY ARE TO BE IN PLACE FOR MORE THAN 10 DAYS, STABILISE FOLLOWING THE APPROVED ESCP OR SWMP TO REDUCE THE C-FACTOR TO LESS THAN 0.10.
5. CONSTRUCT EARTH BANKS (STANDARD DRAWING 5-5) ON THE UPSLOPE SIDE TO DIVERT WATER AROUND STOCKPILES AND SEDIMENT FENCES (STANDARD DRAWING 6-8) 1 TO 2m DOWNSLOPE.

STOCKPILES (SD 4-1)



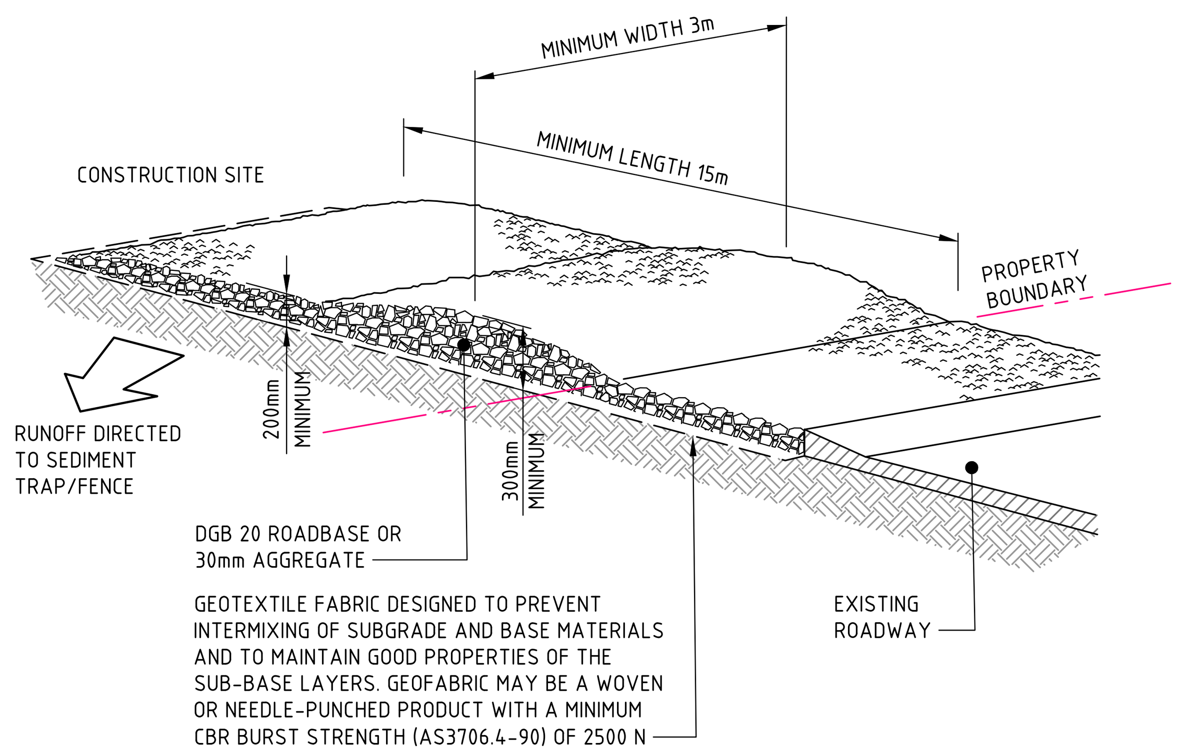
BACK PUSH BANK

NOTES
1. TO BE USED FOR CLEAN WATER DIVERSION DRAINS.
2. BORROW AREA TO BE ON DISTURBED (DIRTY) SIDE OF DRAIN.
3. AVOID REMOVING TREES AND SHRUBS IF POSSIBLE - WORK AROUND THEM.
4. ENSURE THE STRUCTURES ARE FREE OF PROJECTIONS OR OTHER IRREGULARITIES THAT COULD IMPEDE WATER FLOW.
5. BUILD THE DRAINS WITH CIRCULAR, PARABOLIC OR TRAPEZOIDAL CROSS SECTIONS, NOT V SHAPED.
6. ENSURE THE BANKS ARE PROPERLY COMPACTED TO PREVENT FAILURE.
7. COMPLETE PERMANENT OR TEMPORARY STABILISATION WITHIN 10 DAYS OF CONSTRUCTION.



WATER DIVERSION SWALE

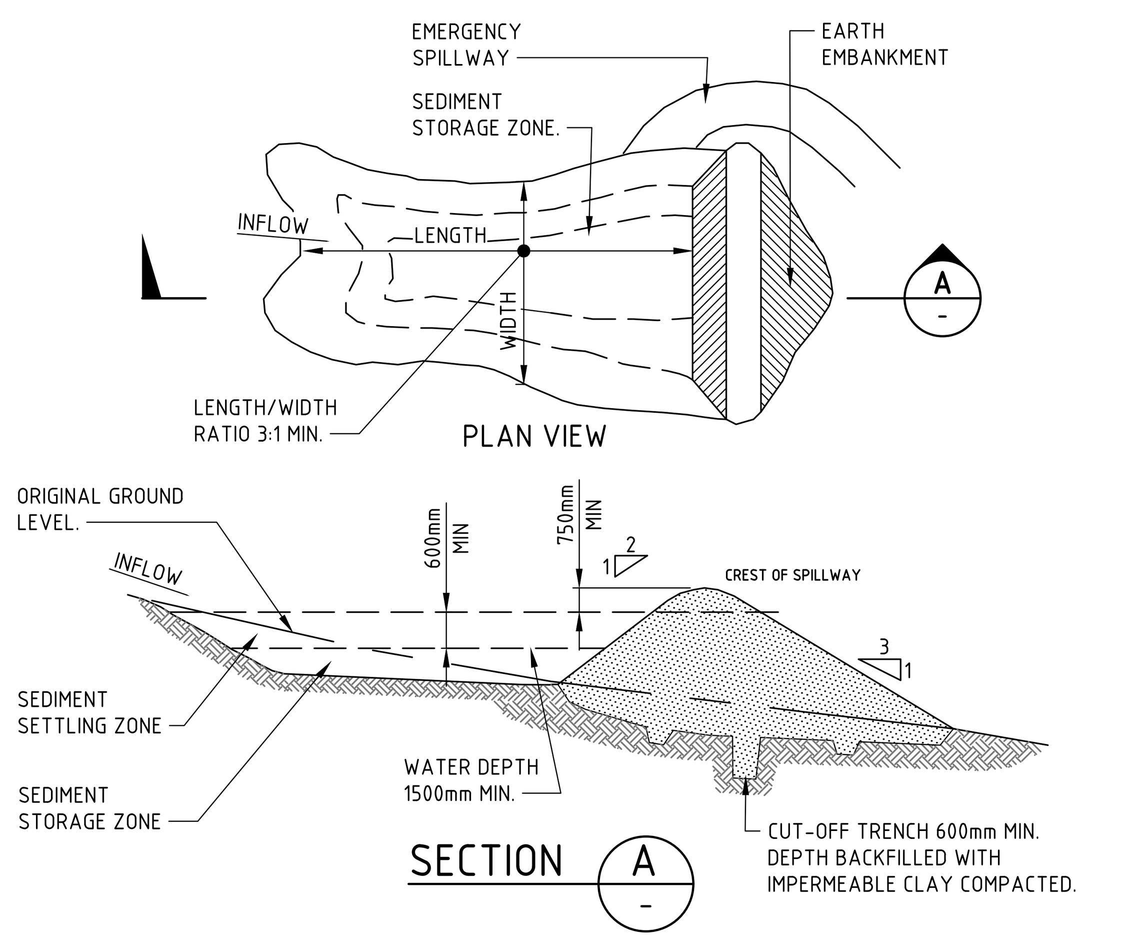
NOTES
1. TO BE USED FOR DIRTY WATER CUT OFF SWALES & CLEAN WATER DIVERSION DRAINS (IF LINED)
2. PROVIDE GEOFABRIC LINING TO SECTIONS OF CLEAN WATER DIVERSION
3. BUILD WITH GRADIENTS BETWEEN 1 PERCENT AND 5 PERCENT.
4. AVOID REMOVING TREES AND SHRUBS IF POSSIBLE - WORK AROUND THEM.
5. ENSURE THE STRUCTURES ARE FREE OF PROJECTIONS OR OTHER IRREGULARITIES THAT COULD IMPEDE WATER FLOW.
6. BUILD THE DRAINS WITH CIRCULAR, PARABOLIC OR TRAPEZOIDAL CROSS SECTIONS, NOT V SHAPED.
7. ENSURE THE BANKS ARE PROPERLY COMPACTED TO PREVENT FAILURE.
8. COMPLETE PERMANENT OR TEMPORARY STABILISATION WITHIN 10 DAYS OF CONSTRUCTION.



CONSTRUCTION NOTES

1. STRIP THE TOPSOIL, LEVEL THE SITE AND COMPACT THE SUBGRADE.
2. COVER THE AREA WITH NEEDLE-PUNCHED GEOTEXTILE.
3. CONSTRUCT A 200mm THICK PAD OVER THE GEOTEXTILE USING ROAD BASE OR 30mm AGGREGATE.
4. ENSURE THE STRUCTURE IS AT LEAST 15 METRES LONG OR TO BUILDING ALIGNMENT AND AT LEAST 3 METRES WIDE.
5. WHERE A SEDIMENT FENCE JOINS ONTO THE STABILISED ACCESS, CONSTRUCT A HUMP IN THE STABILISED ACCESS TO DIVERT WATER TO THE SEDIMENT FENCE.

STABILISED SITE ACCESS (SD 6-14)

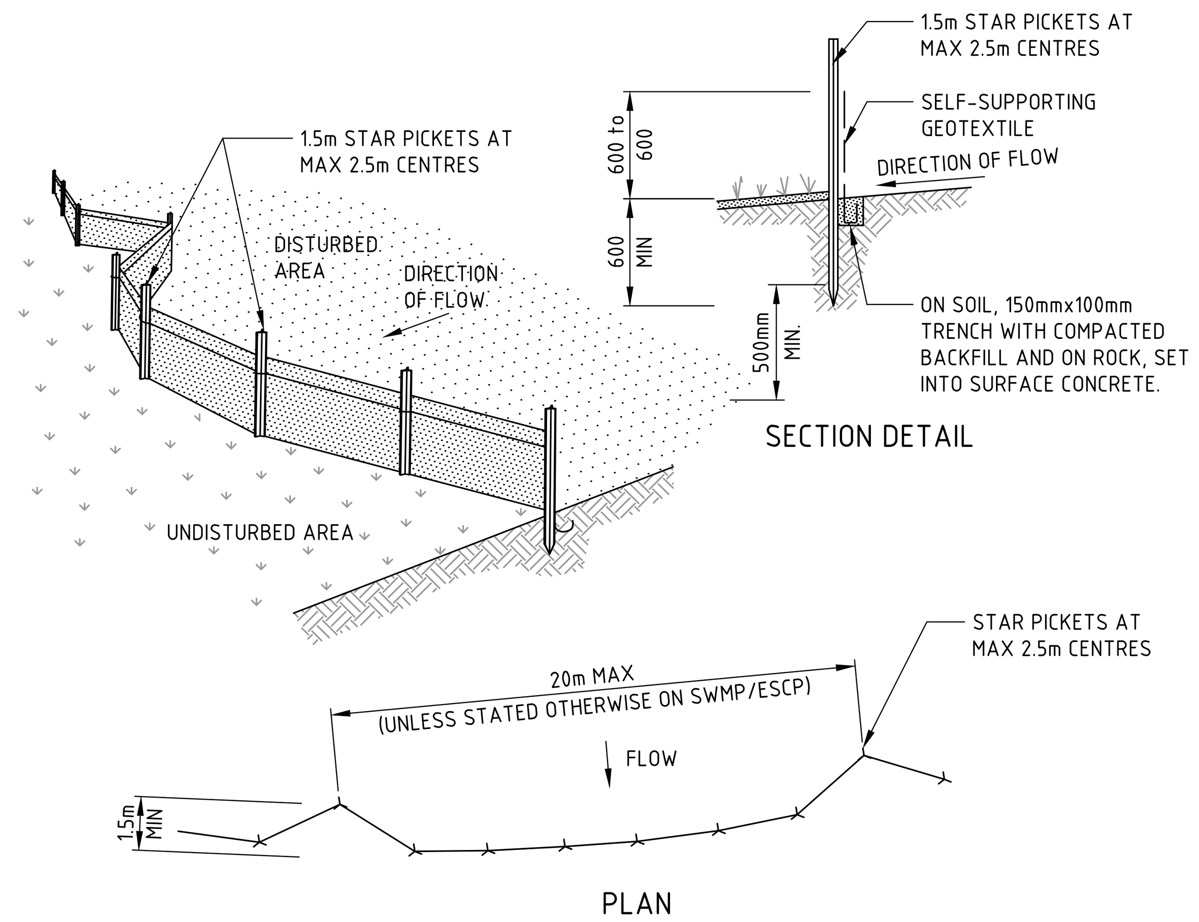


CONSTRUCTION NOTES

1. REMOVE ALL VEGETATION AND TOPSOIL FROM UNDER THE DAM WALL AND FROM WITHIN THE STORAGE AREA.
2. CONSTRUCT A CUT-OFF TRENCH 500mm DEEP AND 1200mm WIDE ALONG THE CENTRELINE OF THE EMBANKMENT EXTENDING TO A POINT ON THE GULLY WALL LEVEL WITH THE RISER CREST.
3. MAINTAIN THE TRENCH FREE OF WATER AND RECOMPACT THE MATERIALS WITH EQUIPMENT AS SPECIFIED IN THE SWMP TO 95 PER CENT STANDARD PROCTOR DENSITY.
4. SELECT FILL FOLLOWING THE SWMP THAT IS FREE OF ROOTS, WOOD, ROCK, LARGE STONE OR FOREIGN MATERIAL.
5. PREPARE THE SITE UNDER THE EMBANKMENT BY RIPPING TO AT LEAST 100mm TO HELP BOND COMPACTED FILL TO THE EXISTING SUBSTRATE.
6. SPREAD THE FILL IN 100mm TO 150mm LAYERS AND COMPACT IT AT OPTIMUM MOISTURE CONTENT FOLLOWING THE SWMP.
7. CONSTRUCT THE EMERGENCY SPILLWAY.
8. REHABILITATE THE STRUCTURE FOLLOWING THE SWMP.

(APPLIES TO 'TYPE D' AND 'TYPE F' SOILS ONLY)

EARTH BASIN - WET (SD 6-4)



CONSTRUCTION NOTES

1. CONSTRUCT SEDIMENT FENCES AS CLOSE AS POSSIBLE TO BEING PARALLEL TO THE CONTOURS OF THE SITE, BUT WITH SMALL RETURNS AS SHOWN IN THE DRAWING TO LIMIT THE CATCHMENT AREA OF ANY ONE SECTION. THE CATCHMENT AREA SHOULD BE SMALL ENOUGH TO LIMIT WATER FLOW IF CONCENTRATED AT ONE POINT TO 50 LITRES PER SECOND IN THE DESIGN STORM EVENT, USUALLY THE 10-YEAR EVENT.
2. CUT A 150mm DEEP TRENCH ALONG THE UPSLOPE LINE OF THE FENCE FOR THE BOTTOM OF THE FABRIC TO BE ENTRENCHED.
3. DRIVE 1.5 METRE LONG STAR PICKETS INTO GROUND AT 2.5 METRE INTERVALS (MAX) AT THE DOWNSLOPE EDGE OF THE TRENCH. ENSURE ANY STAR PICKETS ARE FITTED WITH SAFETY CAPS.
4. FIX SELF-SUPPORTING GEOTEXTILE TO THE UPSLOPE SIDE OF THE POSTS ENSURING IT GOES TO THE BASE OF THE TRENCH. FIX THE GEOTEXTILE WITH WIRE TIES OR AS RECOMMENDED BY THE MANUFACTURER. ONLY USE GEOTEXTILE SPECIFICALLY PRODUCED FOR SEDIMENT FENCING. THE USE OF SHADE CLOTH FOR THIS PURPOSE IS NOT SATISFACTORY.
5. JOIN SECTIONS OF FABRIC AT A SUPPORT POST WITH A 150mm OVERLAP.
6. BACKFILL THE TRENCH OVER THE BASE OF THE FABRIC AND COMPACT IT THOROUGHLY OVER THE GEOTEXTILE.

SEDIMENT FENCE (SD 6-8)

VERIFIER: B.CLARK
JOB MANAGER: B.CLARK
DESIGNED: R.JEANS
DRAWN: B.DUGGAN

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PROJECT
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DRAWING TITLE
EROSION AND SEDIMENT CONTROL DETAILS

JOB NUMBER
NL180367

DRAWING NUMBER
DA-C10.11

REVISION
A

DRAWING SHEET SIZE = A1

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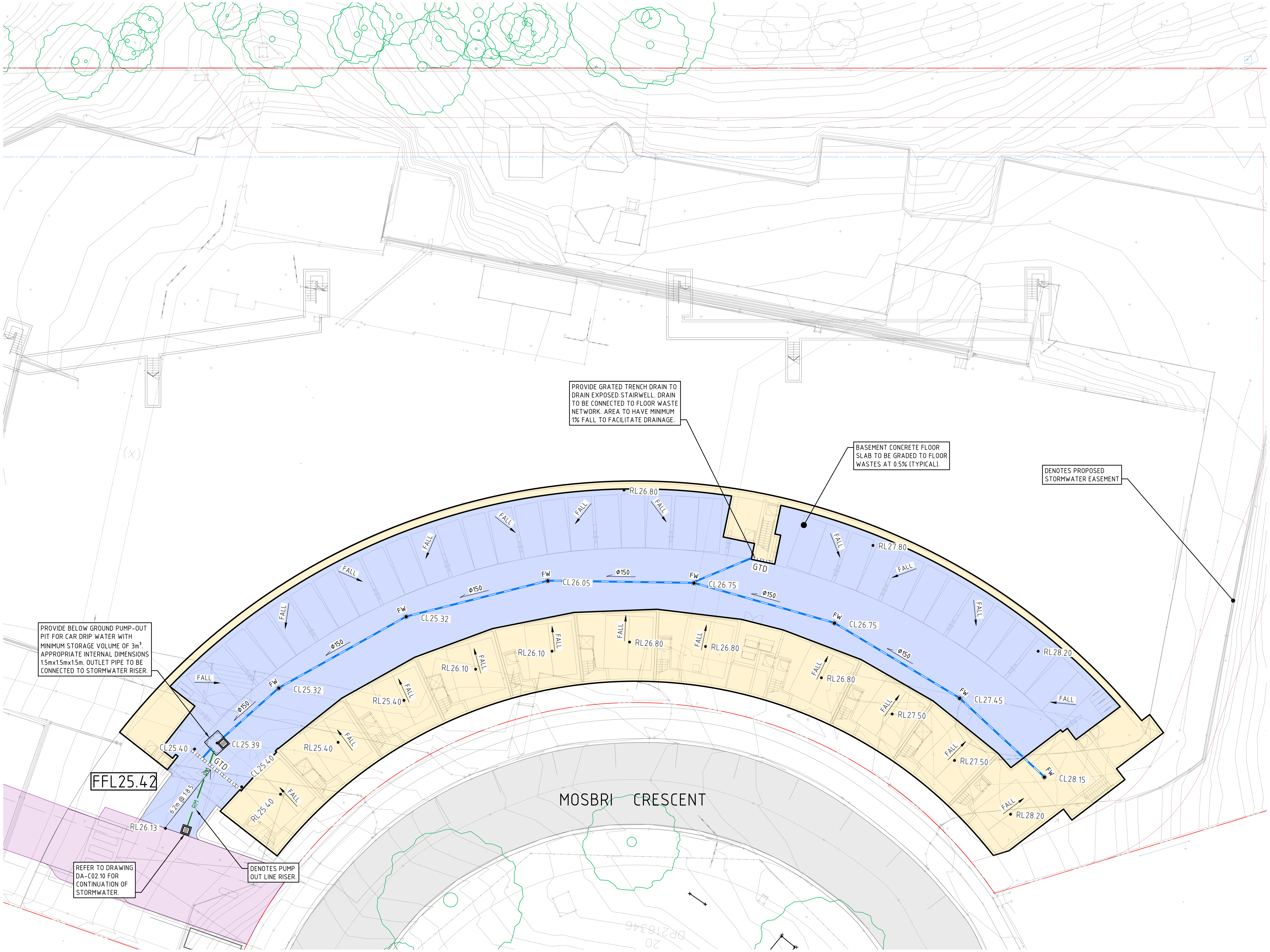

LEGEND

	SITE BOUNDARY.
	PROPOSED STORMWATER EASEMENT
	DENOTES SETBACK
	PROPOSED BUILDING. DETAILS TO BE PROVIDED AT CC STAGE.
	PROPOSED WORKS AS PART OF OTHER LEVEL.
	PROPOSED TRAFFICABLE PAVEMENT. DETAILS TO BE PROVIDED AT CC STAGE.
Ø150	PROPOSED STORMWATER PIPE.
RM — RM	PROPOSED WATER RISING MAIN.
	EXISTING STORMWATER PIPE.
GTD	GRATED TRENCH DRAIN
	GRATED INLET PIT / JUNCTION PIT / KERB INLET PIT. DETAILS TO BE PROVIDED AT CC STAGE.
	EXISTING GRATED INLET PIT / JUNCTION PIT/KERB INLET PIT
FW	PROPOSED FLOOR WASTE DETAILS TO BE PROVIDED AT CC STAGE.
FALL	PROPOSED DIRECTION OF GRADE.
FFL25.40	PROPOSED FINISHED FLOOR LEVEL.
• RL26.05	PROPOSED SPOT HEIGHT.

DRAWN: B.DUGGAN
DESIGNED: R.JEANS
JOB MANAGER: B.CLARK
VERIFIER: B.CLARK

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C	RE-ISSUED FOR APPROVAL	BD	BC	BC	22.04.21
D	RE-ISSUED FOR APPROVAL - SW EASEMENT ADDED	SF	BC	RC	26.04.21
E	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21

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ARCHITECT
marchesepartners

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SCALE 1:200@ A1 — 0 2 4 6 8 10m

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Ph (02) 4943 1777 Fax (02) 4943 1577
Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT
11-17 MOSBRI CRESCENT THE HILL, NSW, 2300

DRAWING TITLE
CIVIL WORKS LOWER GROUND FLOOR

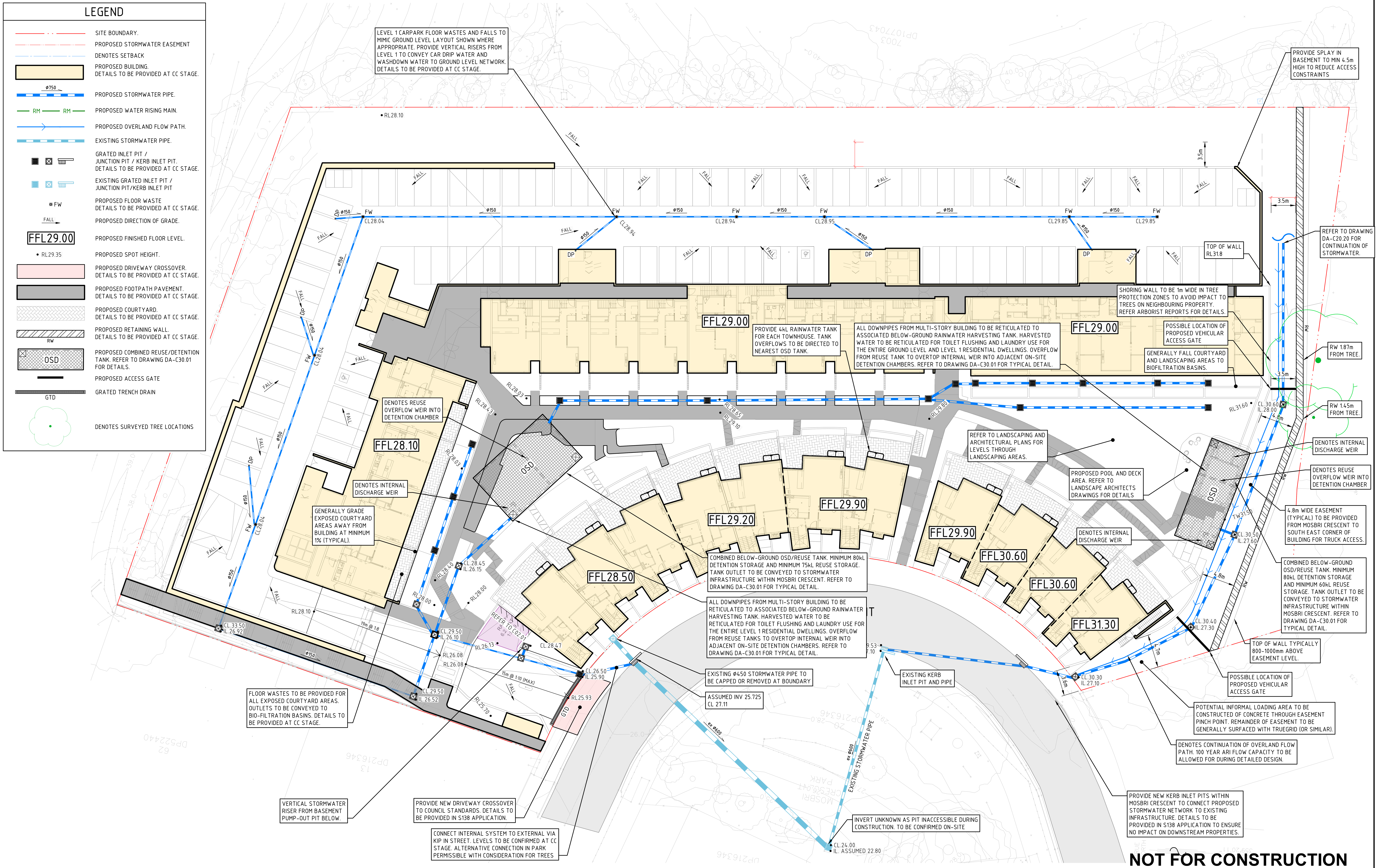
JOB NUMBER
NL180367

DRAWING NUMBER
DA-C20.01

REVISION
E

DRAWING SHEET SIZE = A1

Date : 22.04.2022 5:11 PM Plotted By : WILLIAM CRITTENDEN Found : Y:\YEAR 2018 Jobs\NL180367 - Mosbri Cre\O - Drawings\CIVIL\#CAD\2-CAD FILES\01-DA\01\NL180367-DA-C20.01 CIVIL WORKS BASEMENT.dwg



NOT FOR CONSTRUCTION

DRAWN: B.DUGGAN DESIGNED: R.JEANS JOB MANAGER: B.CLARK VERIFIER: B.CLARK

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
F	REVISED AS CLOUDED	RG	BC	BC	30.10.20
G	RE-ISSUED FOR APPROVAL	BD	BC	BC	22.04.21
H	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21
I	RE-ISSUED FOR APPROVAL	BD	BC	RC	20.01.22
J	RE-ISSUED FOR APPROVAL	BD	BC	RC	25.01.22
K	RE-ISSUED FOR APPROVAL	BD	BC	RC	21.04.22

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ARCHITECT: marchesepartners

SCALE 1:250@ A1

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PROJECT: 11-17 MOSBRI CRESCENT THE HILL, NSW, 2300

DRAWING TITLE: CIVIL WORKS GROUND FLOOR

JOB NUMBER: NL180367

DRAWING NUMBER: DA-C20.11

REVISION: K

DRAWING SHEET SIZE = A1

DRAWN: B.DUGGAN DESIGNED: R.JEANS JOB MANAGER: B.CLARK VERIFIER: B.CLARK

NOT FOR CONSTRUCTION

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
I	BORE HOLE LOCATIONS ADDED	BD	BC	RC	05.11.20
K	BORE HOLE IDENTIFICATION ADDED	BD	BC	RC	05.11.20
L	RE-ISSUED FORAPPROVAL	BD	BC	RC	22.04.21
M	RE-ISSUED FOR APPROVAL - SW EASEMENT ADDED	SF	BC	RC	26.04.21
N	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21
O	RE-ISSUED FOR APPROVAL	BD	BC	RC	21.04.22

CLIENT
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SCALE 1:250@ A1 0 2 4 6 8 10 12m

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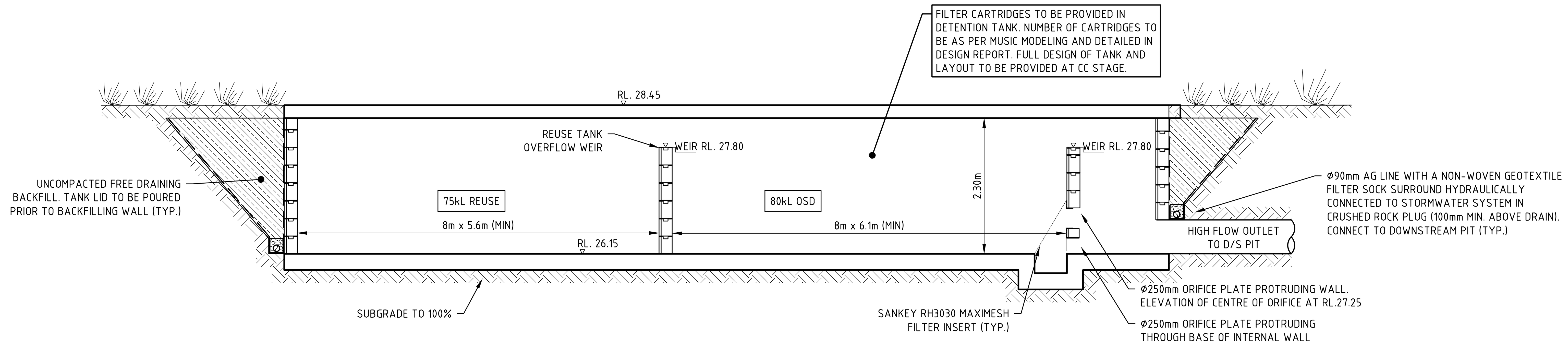
PROJECT
11-17 MOSBRI CRESCENT THE HILL, NSW, 2300

DRAWING TITLE
CIVIL WORKS LEVEL 2

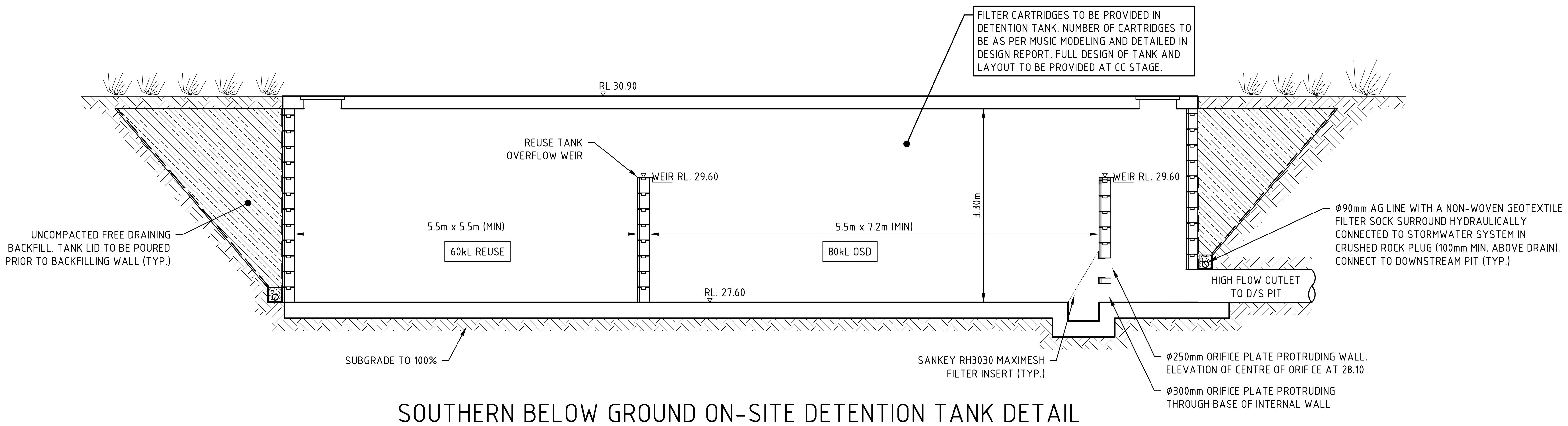
JOB NUMBER **NL180367**
DRAWING NUMBER **DA-C20.21**
REVISION **O**
DRAWING SHEET SIZE = A1

Date : 22.04.2022 5:11 PM Plotted By : WILLIAM CRITTENDEN Found : Y:\YEAR 2018 Jobs\NL180367 - Mosbri Cre\O - Drawings\CIVIL\#CAD\2-CAD FILES\01-DA\01\NL180367-DA-C20.20 CIVIL WORKS FLOOR 2.dwg



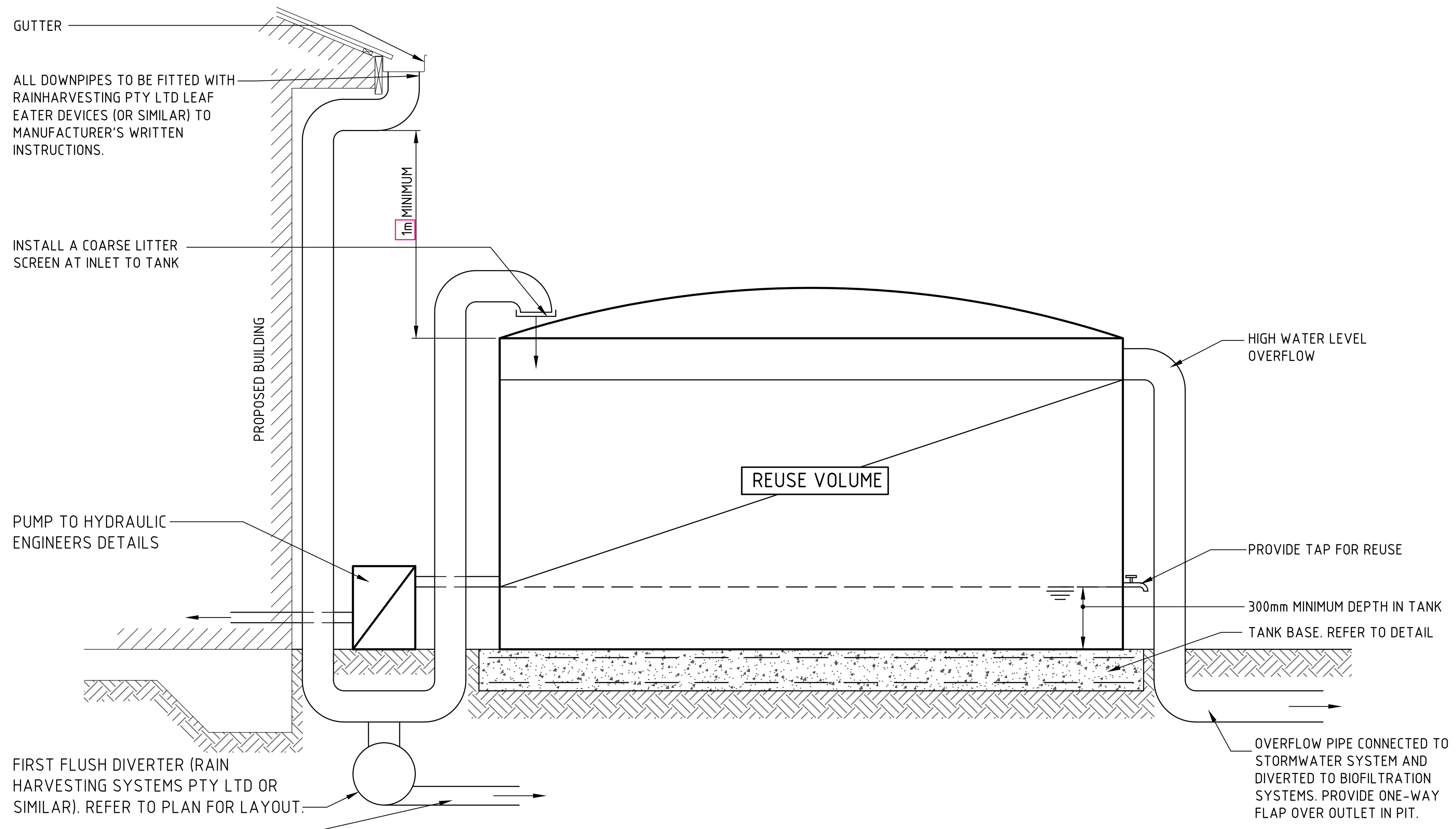
NORTHERN BELOW GROUND ON-SITE DETENTION TANK DETAIL

SCALE 1:50



SOUTHERN BELOW GROUND ON-SITE DETENTION TANK DETAIL

SCALE 1:50



REUSE ABOVE GROUND TANK DETAIL FOR TOWN HOUSES

NOTE: THE ENTIRE PRESSURISED DOWNPIPE SYSTEM SHALL BE AIR TIGHT AND BE ABLE TO WITHSTAND ATMOSPHERIC PRESSURE. THE PIPING SYSTEM SHALL BE MINIMUM SN6 AND FITTINGS WITH INTERNAL ULTRA VIOLET STABILISING (OR APPROVED EQUIVALENT).

DRAWN: B.DUGGAN
DESIGNED: R.JEANS
JOB MANAGER: B.CLARK
VERIFIER: B.CLARK

NOT FOR CONSTRUCTION

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
A	ISSUED FOR APPROVAL	CH	BC	RC	21.12.18
B	RE-ISSUED FOR APPROVAL	CH	BC	RC	08.10.19
C	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21
D	RE-ISSUED FOR APPROVAL	BD	BC	RC	21.04.22

CLIENT: **CRESCENT NEWCASTLE PTY LTD**

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ARCHITECT: marchesepartners

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SCALE 1:20@A1 0.0 0.2 0.4 0.6 0.8 1.0m
SCALE 1:50@A1 0.0 0.5 1.0 1.5 2.0 2.5m

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Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT: **11-17 MOSBRI CRESCENT THE HILL, NSW, 2300**

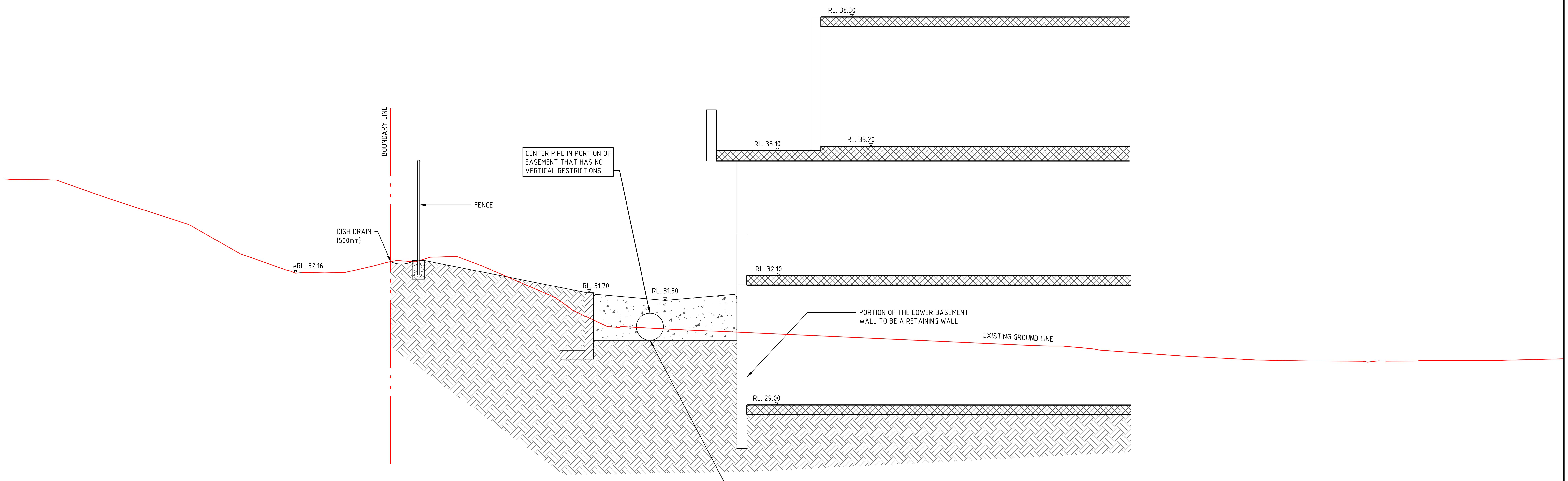
DRAWING TITLE: **CIVIL DETAILS SHEET 1**

JOB NUMBER: **NL180367**

DRAWING NUMBER: **DA-C30.01** REVISION: **D**

DRAWING SHEET SIZE = A1

Date : 22.04.2022 5:11 PM Plotted By : WILLIAM CRITTENDEN Found : Y:\YEAR 2018 Jobs\NL180367 - Mosbri Cres\D - Drawings\CIVIL\#CAD\2-CAD FILES\01-DA\01\NL180367-DA-C30.01 CIVIL DETAILS.dwg



SECTION 1 / C20.20
SCALE 1:50

DRAWN: B.DUGGAN
DESIGNED: R.JEANS
JOB MANAGER: B.CLARK
VERIFIER: B.CLARK

NOT FOR CONSTRUCTION

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
A	ISSUED FOR APPROVAL	CH	BC	RC	08.10.19
B	RE-ISSUED FOR APPROVAL	BD	BC	RC	12.08.20
C	RE-ISSUED FOR APPROVAL - EXISITNG GROUND LINE ADDED	SF	BC	RC	22.10.20
D	RE-ISSUED FOR APPROVAL	BD	BC	RC	28.10.20
E	RE-ISSUED FOR APPROVAL	BD	BC	BC	22.04.21
F	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21

CLIENT
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ARCHITECT
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SCALE 1:50@ A1
0.0 0.5 1.0 1.5 2.0 2.5m

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PROJECT
11-17 MOSBRI CRESCENT THE HILL, NSW, 2300

DRAWING TITLE
CIVIL DETAILS SHEET 2

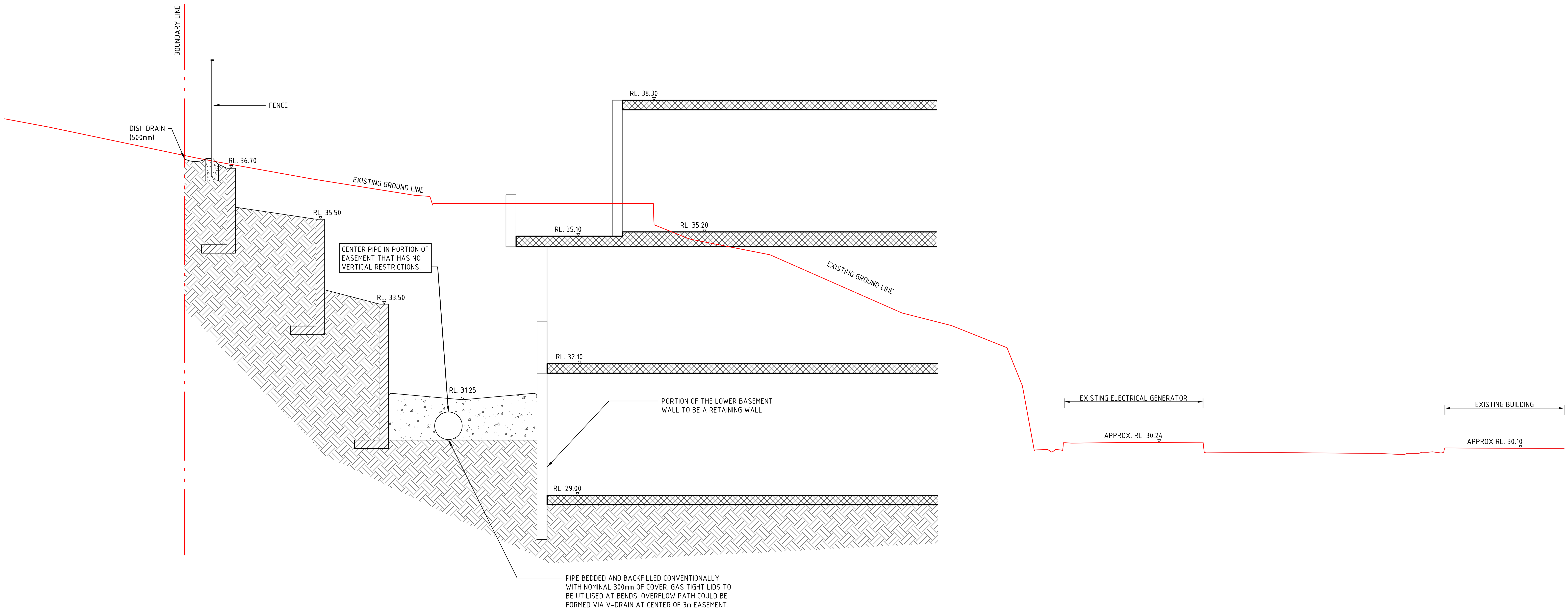
JOB NUMBER
NL180367

DRAWING NUMBER
DA-C30.02

REVISION
F

DRAWING SHEET SIZE = A1

Date : 22.04.2022 5:11 PM Plotted By : WILLIAM CRITTENDEN Found : Y:\YEAR 2018 Jobs\NL180367 - Mosbri Cre\O - Drawings\CIVIL\#CAD\2-CAD FILES\01-DA\01\NL180367-DA-C30.01 CIVIL DETAILS.dwg



SECTION 2 / C20.20
SCALE 1:50

DRAWN: B.DUGGAN
DESIGNED: R.JEANS
JOB MANAGER: B.CLARK
VERIFIER: B.CLARK

NOT FOR CONSTRUCTION

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
A	ISSUED FOR APPROVAL	BD	BC	RC	28.10.20
B	RE-ISSUED FOR APPROVAL	BD	BC	BC	22.04.21
C	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21

CLIENT
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SCALE 1:50@A1
0.0 0.5 1.0 1.5 2.0 2.5m

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Email newcastle@northrop.com.au ABN 81 094 433 100

PROJECT
11-17 MOSBRI CRESCENT THE HILL, NSW, 2300

DRAWING TITLE
CIVIL DETAILS SHEET 3

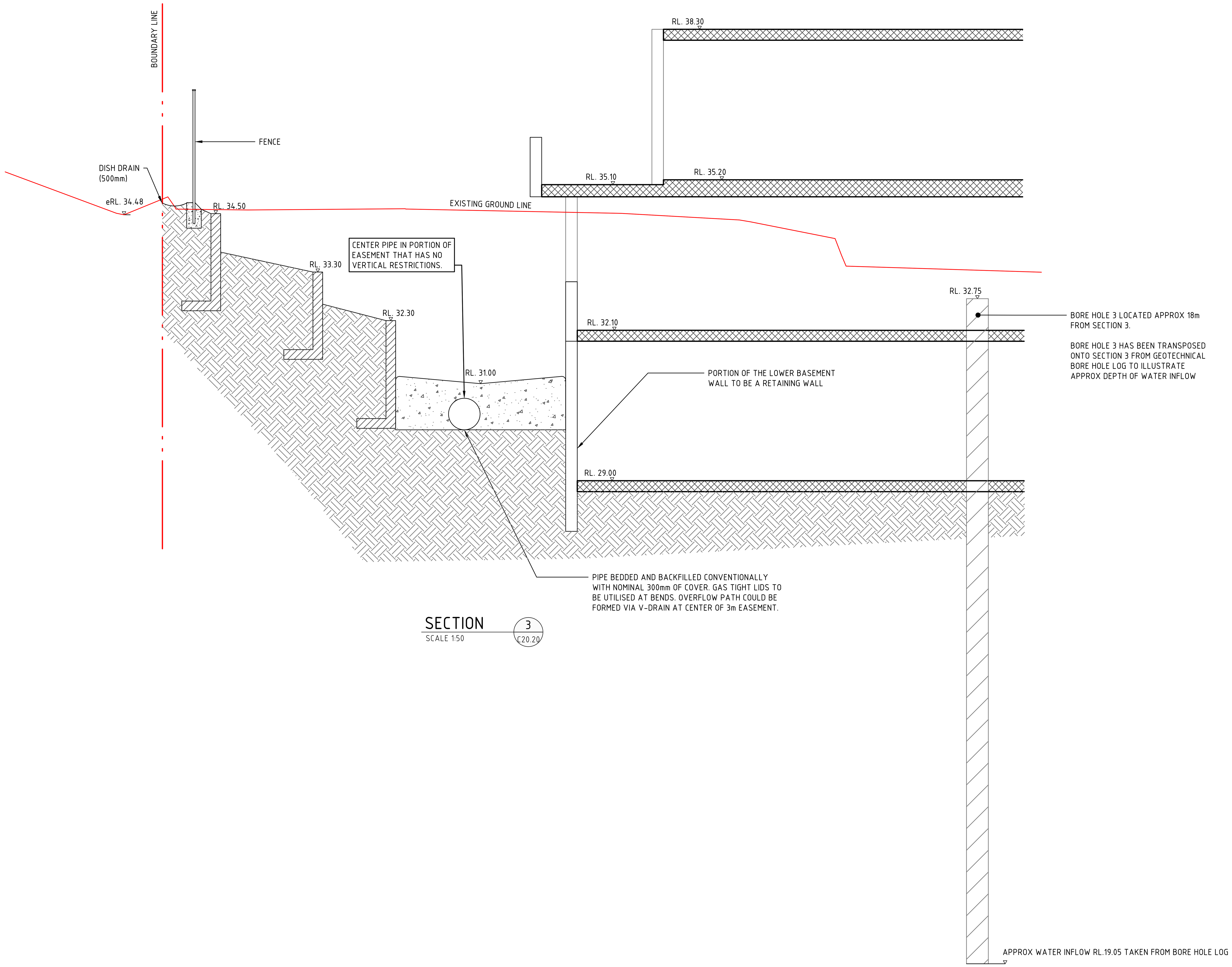
JOB NUMBER
NL180367

DRAWING NUMBER
DA-C30.03

REVISION
C

DRAWING SHEET SIZE = A1

Date : 22.04.2022 5:11 PM Plotted By : WILLIAM CRITTENDEN Found : Y:\YEAR 2018 Jobs\NL180367 - Mosbri Cre\O - Drawings\CIVIL\#CAD\2-CAD FILES\01-DA\01\NL180367-DA-C30.01 CIVIL DETAILS.dwg



SECTION 3 / C20.20
SCALE 1:50

DRAWN: B.DUGGAN
DESIGNED: R.JEANS
JOB MANAGER: B.CLARK
VERIFIER: B.CLARK

NOT FOR CONSTRUCTION

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
A	ISSUED FOR APPROVAL	BD	BC	RC	28.10.20
B	WATER INFLOW ADDED	BD	BC	RC	05.11.20
C	WATER INFLOW UPDATED	BD	BC	RC	05.11.20
D	RE-ISSUED FOR APPROVAL	BD	BC	RC	22.04.21
E	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21

CLIENT
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SCALE 1:50@ A1
0.0 0.5 1.0 1.5 2.0 2.5m

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PROJECT
11-17 MOSBRI CRESCENT
THE HILL, NSW, 2300

DRAWING TITLE
CIVIL DETAILS SHEET 4

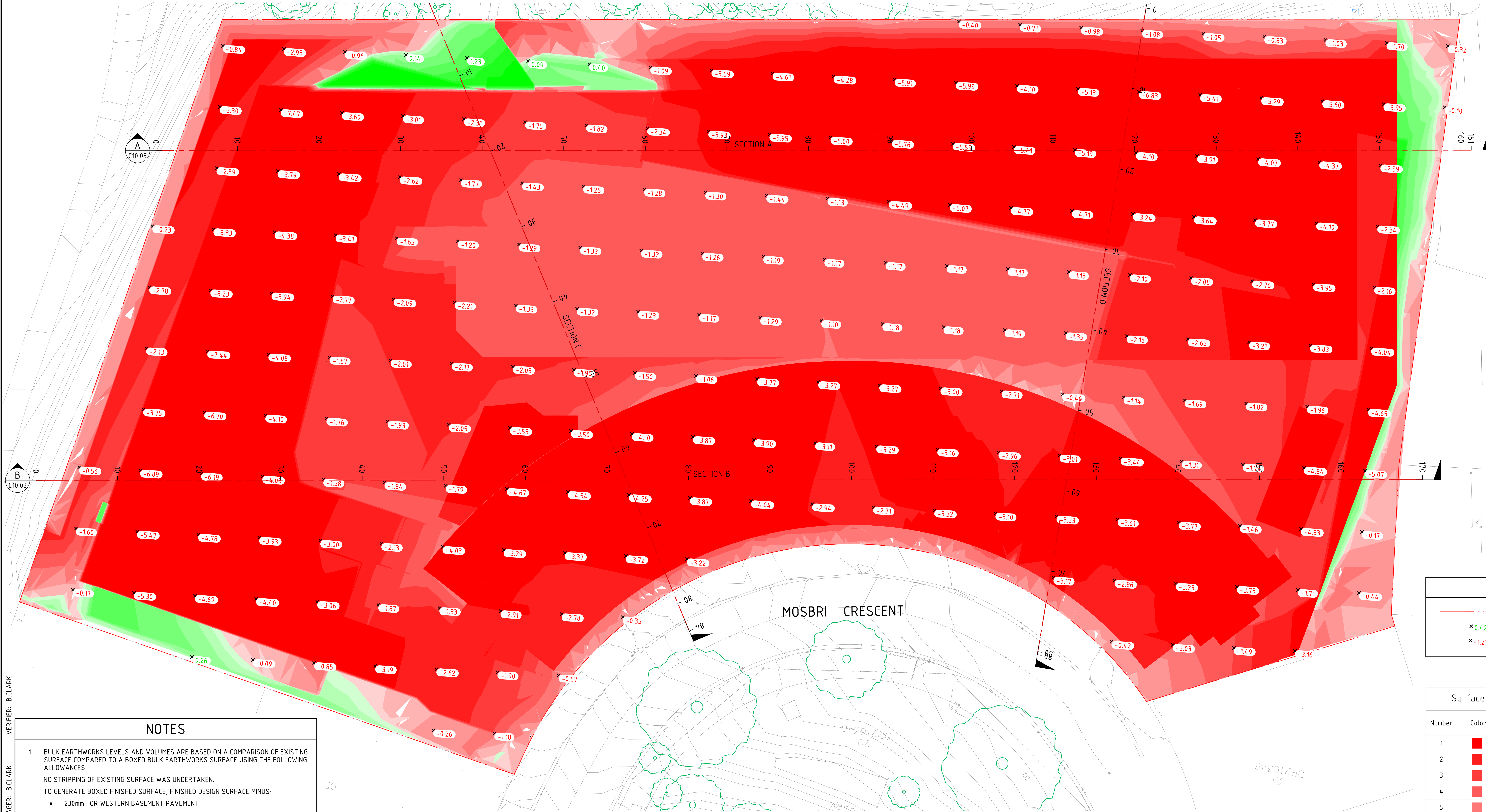
JOB NUMBER
NL180367

DRAWING NUMBER
DA-C30.04

REVISION
E

DRAWING SHEET SIZE = A1

Date : 22.04.2022 5:11 PM Plotted By : WILLIAM CRITTENDEN Found : Y:\YEAR 2018 Jobs\NL180367 - Mosbri Cre\O - Drawings\CIVIL\#CAD\2-CAD FILES\01-DA\01\NL180367-DA-C30.01 CIVIL DETAILS.dwg



LEGEND

— · —	SITE BOUNDARY.
× 0.42	DENOTES HEIGHT OF FILL
× -1.21	DENOTES DEPTH OF CUT

Surface Analysis: Elevation Ranges

Number	Color	Minimum Elevation (m)	Maximum Elevation (m)
1		-9.150	-3.000
2		-3.000	-2.000
3		-2.000	-1.500
4		-1.500	-1.000
5		-1.000	-0.500
6		-0.500	-0.250
7		-0.250	-0.100
8		-1.000	0.000
9		0.000	0.100
10		0.100	0.250
11		0.250	0.500
12		0.500	1.000
13		1.000	1.500
14		1.500	2.000
15		2.000	3.000
16		3.000	4.200

NOTES

1. BULK EARTHWORKS LEVELS AND VOLUMES ARE BASED ON A COMPARISON OF EXISTING SURFACE COMPARED TO A BOXED BULK EARTHWORKS SURFACE USING THE FOLLOWING ALLOWANCES;

   NO STRIPPING OF EXISTING SURFACE WAS UNDERTAKEN.

   TO GENERATE BOXED FINISHED SURFACE; FINISHED DESIGN SURFACE MINUS:

   - 230mm FOR WESTERN BASEMENT PAVEMENT
   - 210mm FOR LANDSCAPING AND BUILDING SURROUNDS
   - 210mm (AVERAGED) FOR NORTHERN AND NORTH EASTERN BASEMENT PAVEMENTS

3. NO ALLOWANCE HAS BEEN MADE FOR SELECT LAYERS OR UNSUITABLE MATERIAL THAT IS LIKELY TO BE PRESENT.
4. NO ALLOWANCE HAS BEEN MADE FOR TEMPORARY SEDIMENT DAMS
5. NO ALLOWANCE HAS BEEN MADE FOR RETAINING WALLS IN THE LEVELS OR VOLUMES PRESENTED ON THIS PLAN. (eg. FOOTINGS, BACKFILL MATERIAL ETC).
6. NO ALLOWANCE HAS BEEN MADE FOR SERVICE TRENCHES, DRAINAGE TRENCHES, DRAINAGE INFRASTRUCTURE (PITS, CULVERTS, ETC) IN THE LEVELS OR VOLUMES PRESENTED ON THIS PLAN.
7. NO ALLOWANCE FOR ANY TEMPORARY BATTERS DURING WORKS.
8. NO BULKING FACTORS HAVE BEEN CONSIDERED/ALLOWED FOR.
9. THE LEVELS AND VOLUMES ARE BASED ON SUPPLIED SURVEY DATA AND AS SUCH ARE APPROXIMATE ONLY, THE CONTRACTOR SHALL SATISFY THEMSELVES AS TO THEIR ACCURACY.
10. APPROXIMATE BULK EARTHWORKS VOLUMES BASED ON THE NOTES ABOVE ARE AS FOLLOWS;
    - BULK CUT = 34,453m^3
    - BULK FILL = 391m^3
    - BULK CUT/FILL BALANCE (EXCESS) = 34,062m^3

DRAWN: B.DUGGAN DESIGNED: R.JEANS JOB MANAGER: B.CLARK VERIFIER: B.CLARK

NOT FOR CONSTRUCTION

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
A	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21

CLIENT
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ARCHITECT
marchesepartners

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SCALE 1:250@ A1 0 2 4 6 8 10 12m

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PROJECT
**11-17 MOSBRI CRESCENT
THE HILL, NSW, 2300**

DRAWING TITLE
CUT FILL PLAN

JOB NUMBER
NL180367

DRAWING NUMBER
DA-C40.01

REVISION
A

DRAWING SHEET SIZE = A1

LEGEND

- SITE BOUNDARY.
- •BE.28.79m — BULK EARTHWORKS SPOT HEIGHT
- •EX.25.95m — EXISTING SPOT HEIGHT
- BEL 29.00 — BULK EARTHWORKS PAD LEVEL
- XX.XX — DESIGN CONTOURS
- XX.XX — EXISTING CONTOURS
- BATTERS
- SHORING

NOT FOR CONSTRUCTION

DRAWN: B.DUGGAN
DESIGNED: R.JEANS
JOB MANAGER: B.CLARK
VERIFIER: B.CLARK

REVISION	DESCRIPTION	ISSUED	VER'D	APP'D	DATE
A	RE-ISSUED FOR APPROVAL	BD	BC	RC	16.12.21

CLIENT
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SCALE 1:250@ A1 — 0 2 4 6 8 10 12m

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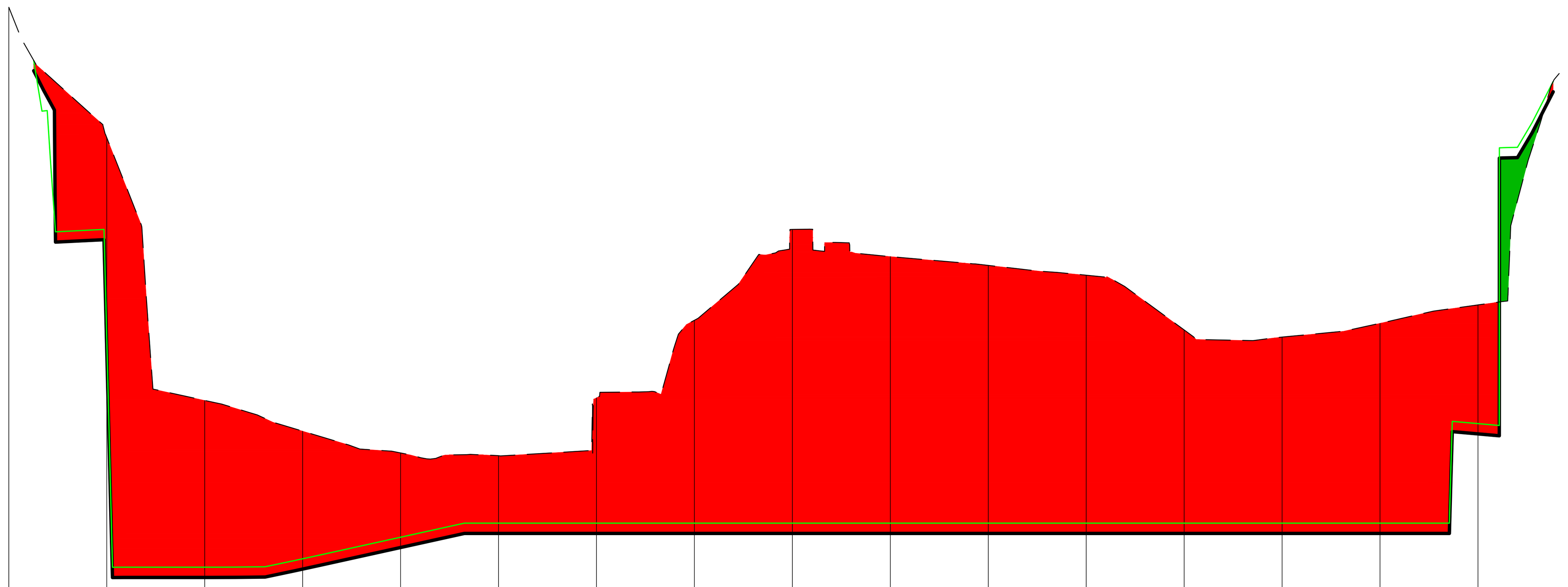
PROJECT
11-17 MOSBRI CRESCENT THE HILL, NSW, 2300

DRAWING TITLE
BULK EARTHWORKS PLAN

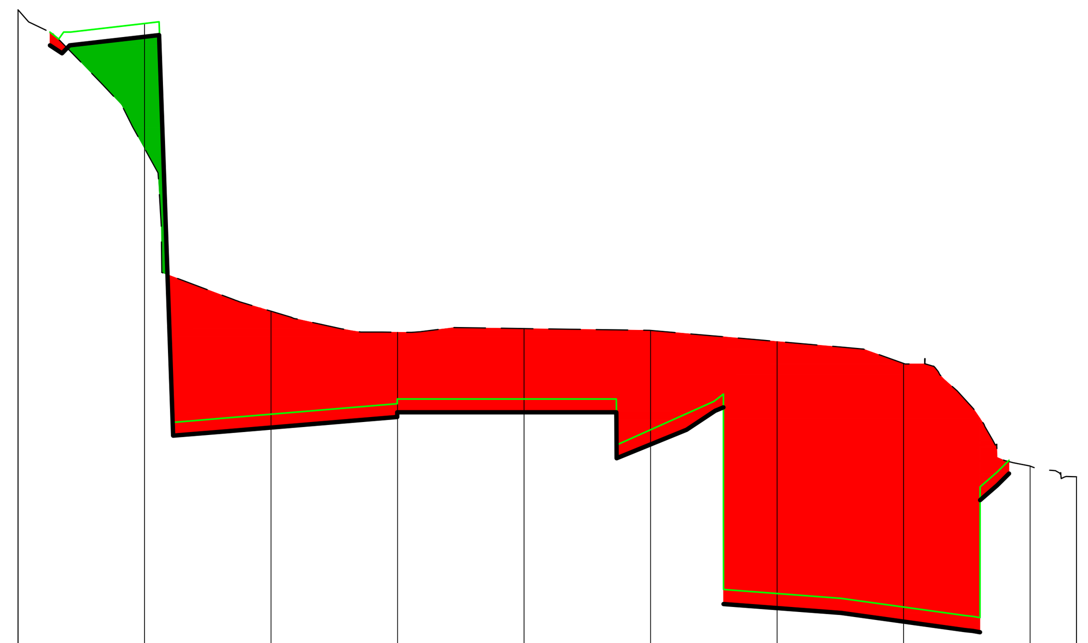
JOB NUMBER **NL180367**
DRAWING NUMBER **DA-C40.11**
REVISION **A**
DRAWING SHEET SIZE = A1



VERTICAL 1:100
HORIZONTAL 1:500.000
Datum 25.000

DESIGN - BEL		32.591	27.892	28.063	28.504	28.790	28.790	28.790	28.790	28.790	28.790	28.790	28.790	28.790	28.790	30.823	37.811		
EXISTING LEVELS	39.536	36.874	31.507	30.880	30.434	30.378	31.561	33.145	35.000	34.445	34.265	34.064	32.947	32.800	33.083	33.457	38.021		
DEPTH		-4.283	-3.615	-2.817	-1.931	-1.588	-2.771	-4.355	-6.210	-5.655	-5.475	-5.274	-4.157	-4.010	-4.293	-2.634	-0.210		
DESIGN - FSL		32.801	28.102	28.273	28.714	29.000	29.000	29.000	29.000	29.000	29.000	29.000	29.000	29.000	29.000	31.033	38.021		
CHAINAGE	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	157.674	160.000	161.268

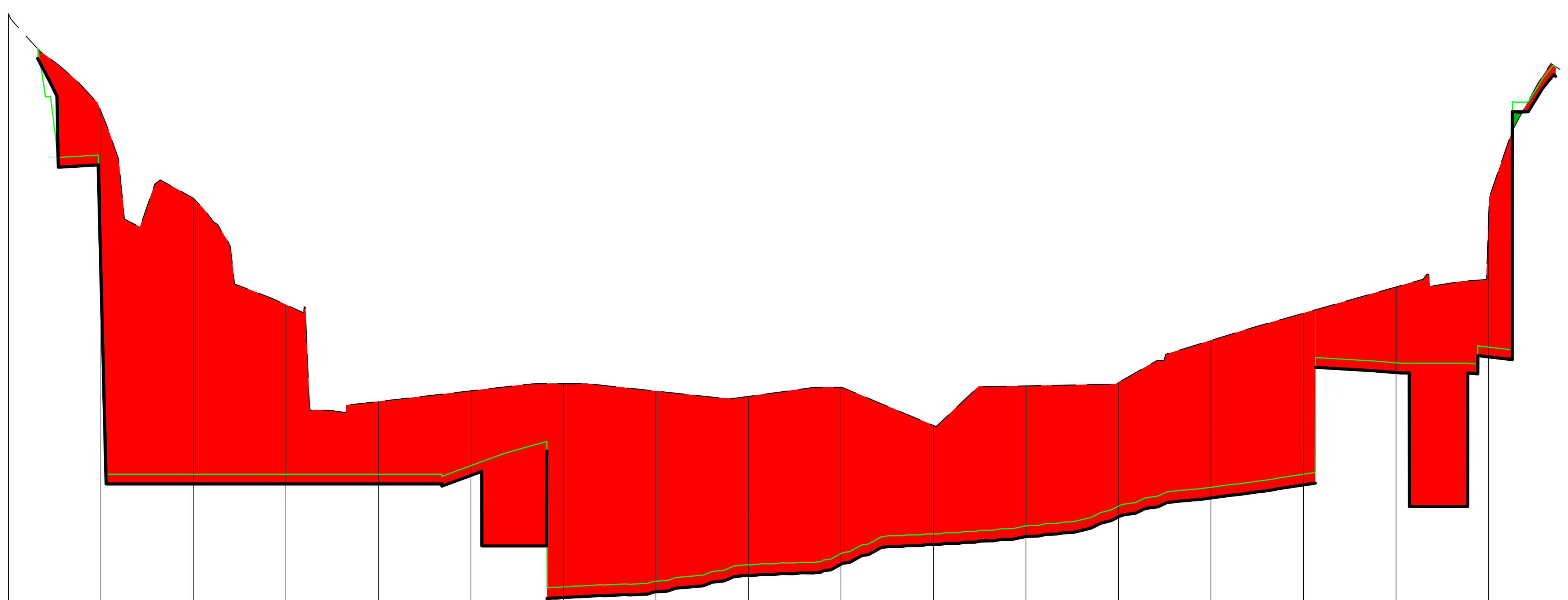
SECTION A - LONG SECTION



VERTICAL 1:100
HORIZONTAL 1:500.000
Datum 25.000

DESIGN - BEL		34.726	28.549	28.790	28.790	28.284	25.696	25.483		
EXISTING LEVELS	35.153	32.962	30.389	30.056	30.114	30.085	29.910	29.563	27.940	27.771
DEPTH		1.764	-1.839	-1.266	-1.324	-1.801	-4.214	-4.080		
DESIGN - FSL		34.936	28.759	29.000	29.000	28.515	25.926	25.713		
CHAINAGE	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	83.660

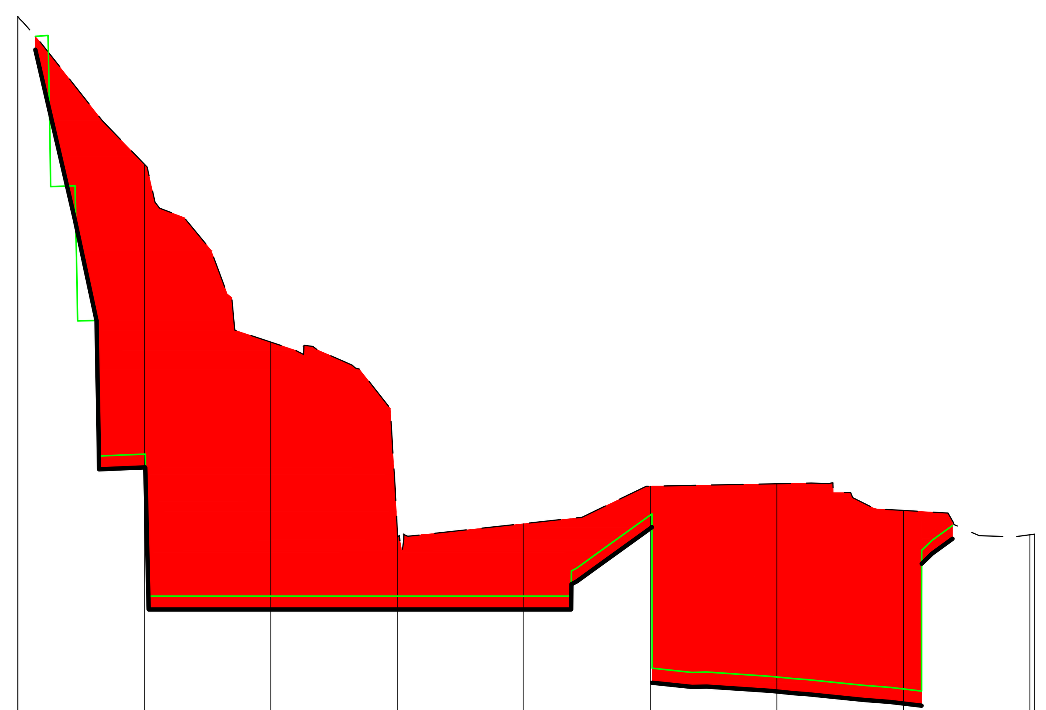
SECTION C - LONG SECTION



VERTICAL 1:100
HORIZONTAL 1:500.000
Datum 25.000

DESIGN - BEL		32.505	27.890	27.890	27.890	28.075	25.433	25.556	25.909	26.153	26.580	26.754	27.178	27.588	27.869	30.299	30.638	27.907	
EXISTING LEVELS	38.060	35.951	34.069	31.767	29.672	29.904	30.058	29.899	29.784	29.981	29.156	30.011	30.086	30.994	31.584	32.150	33.598	31.655	
DEPTH		-3.446	-6.179	-3.877	-1.782	-1.829	-4.625	-4.342	-3.876	-3.828	-2.576	-3.257	-2.908	-3.407	-3.714	-1.852	-2.960	-3.748	
DESIGN - FSL		32.715	28.100	28.100	28.100	28.285	25.663	25.786	26.139	26.383	26.810	26.984	27.408	27.818	28.099	30.509	30.848	36.916	
CHAINAGE	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	160.000	141.268	169.997

SECTION B - LONG SECTION



VERTICAL 1:100
HORIZONTAL 1:500.000
Datum 25.000

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EXISTING LEVELS	38.162	35.829	33.016	30.051	30.147	30.738	30.777	30.356	29.970	29.980
DEPTH		-4.795	-4.226	-1.261	-1.357	-0.666	-3.284	-3.052		
DESIGN - FSL		31.244	29.000	29.000	29.000	30.282	27.723	27.534		
CHAINAGE	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	80.375

SECTION D - LONG SECTION

DRAWN: B.DUGGAN
DESIGNED: R.JEANS
JOB MANAGER: B.CLARK
VERIFIER: B.CLARK

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PROJECT
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DRAWING TITLE
BULK EARTHWORKS SECTIONS

JOB NUMBER
NL180367

DRAWING NUMBER
DA-C40.21

REVISION
A

DRAWING SHEET SIZE = A1

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Appendix B – DRAINS Model Diagrams

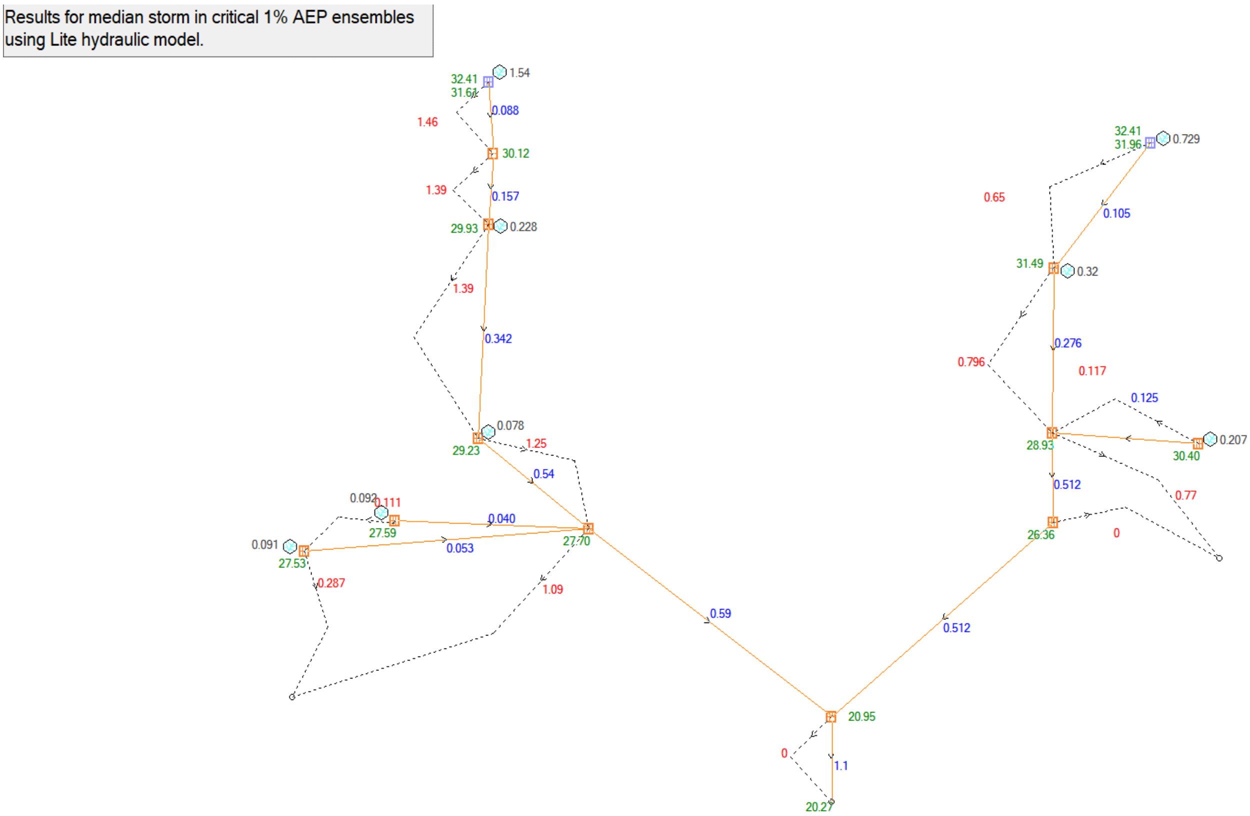


Figure B1 – DRAINS model layout for Existing Scenario 1% AEP

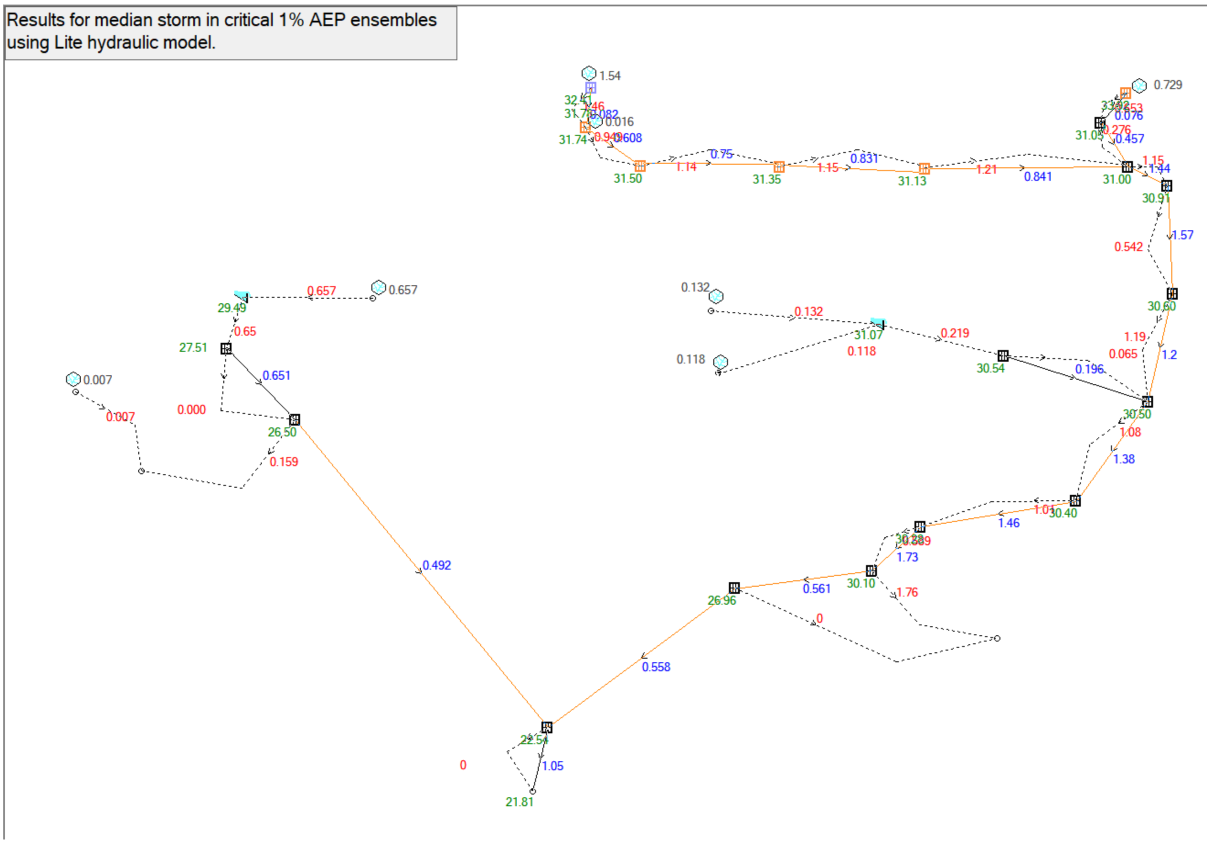


Figure B2 – DRAINS model layout for Developed Scenario 1% AEP

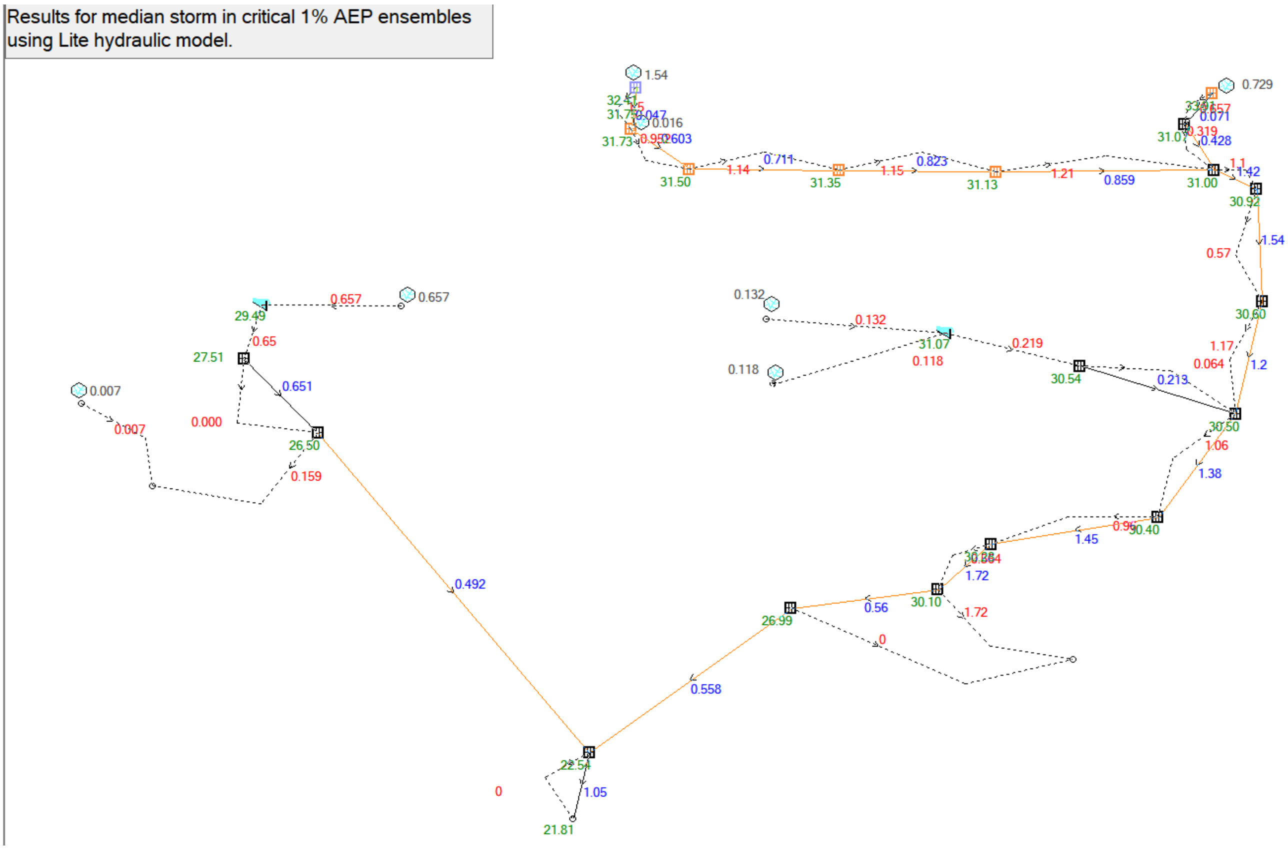


Figure B3 – DRAINS model layout for Developed Scenario 1% AEP – 50% Blockage

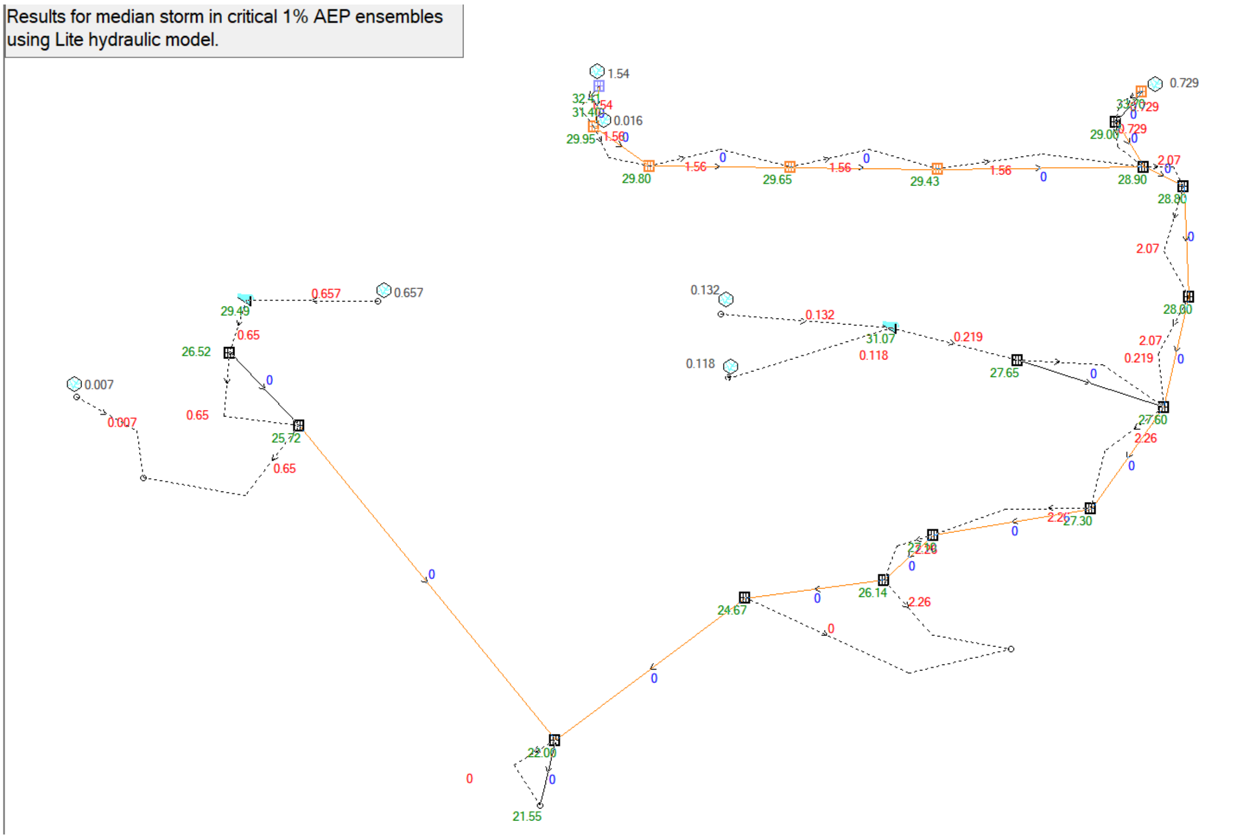


Figure B4 – DRAINS model layout for Developed Scenario 1% AEP – 100% Blockage

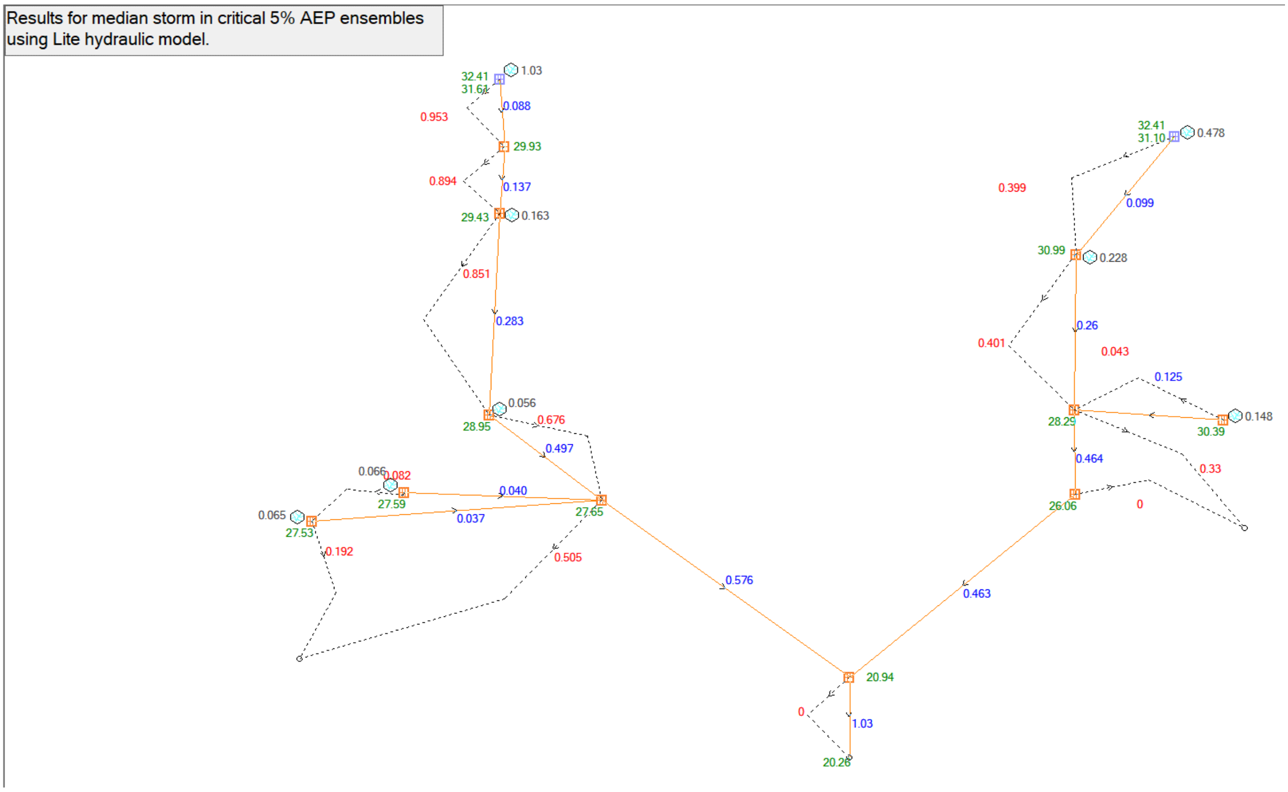


Figure B1 – DRAINS model layout for Existing Scenario 5% AEP

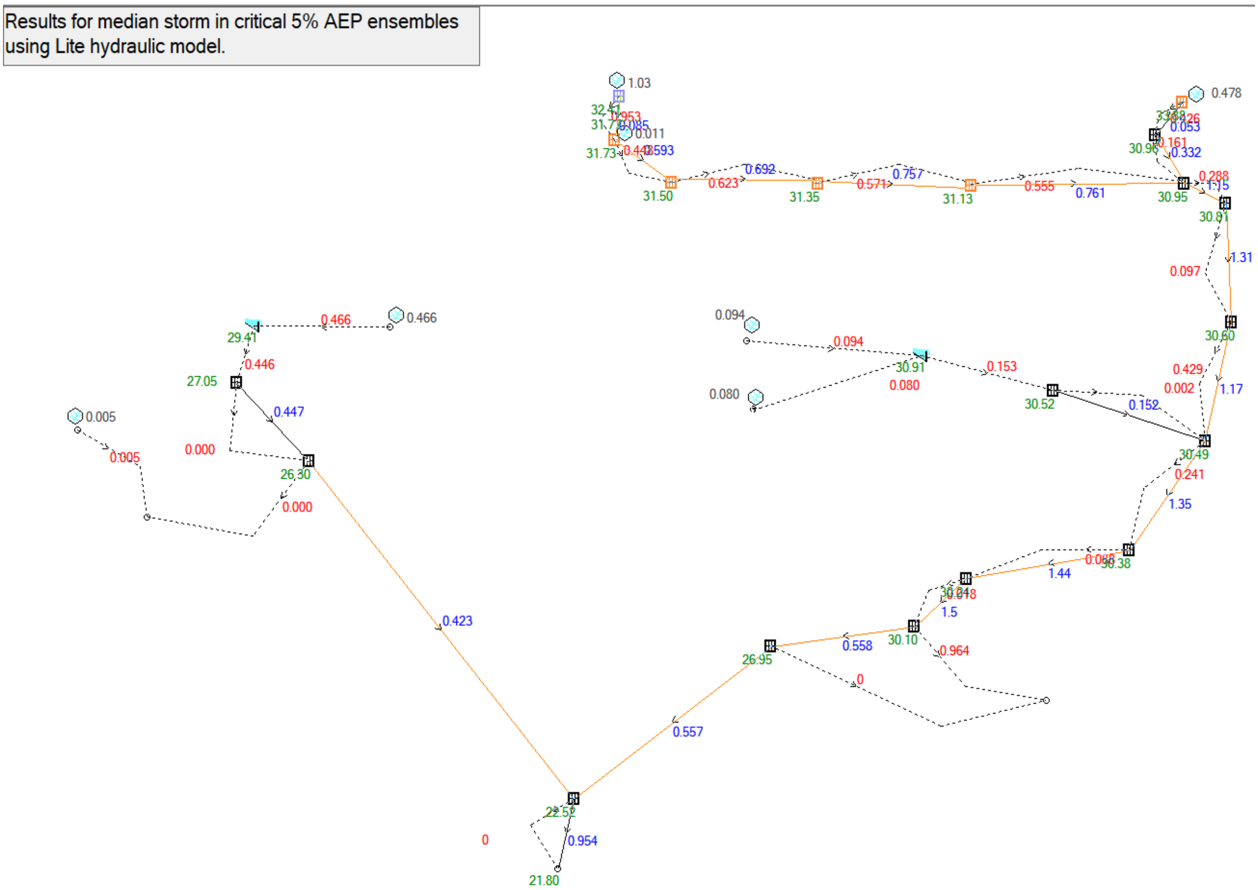
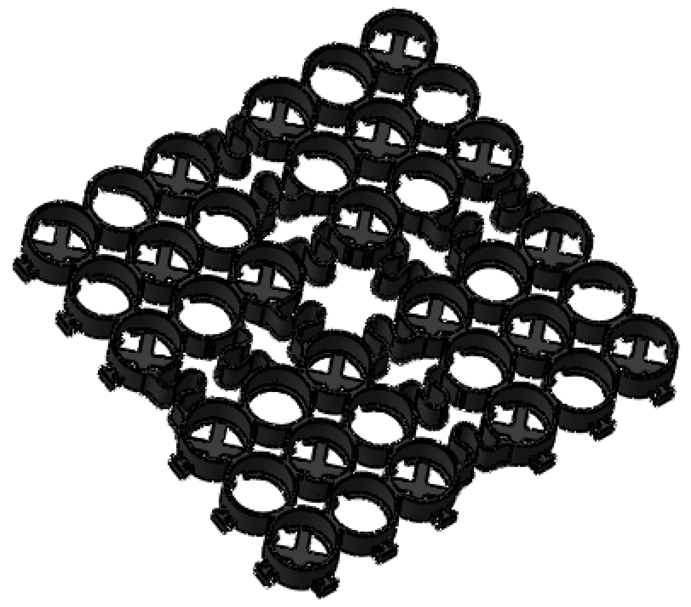


Figure B2 – DRAINS model layout for Developed Scenario 5% AEP

Appendix C – Truegrid Technical Guidelines

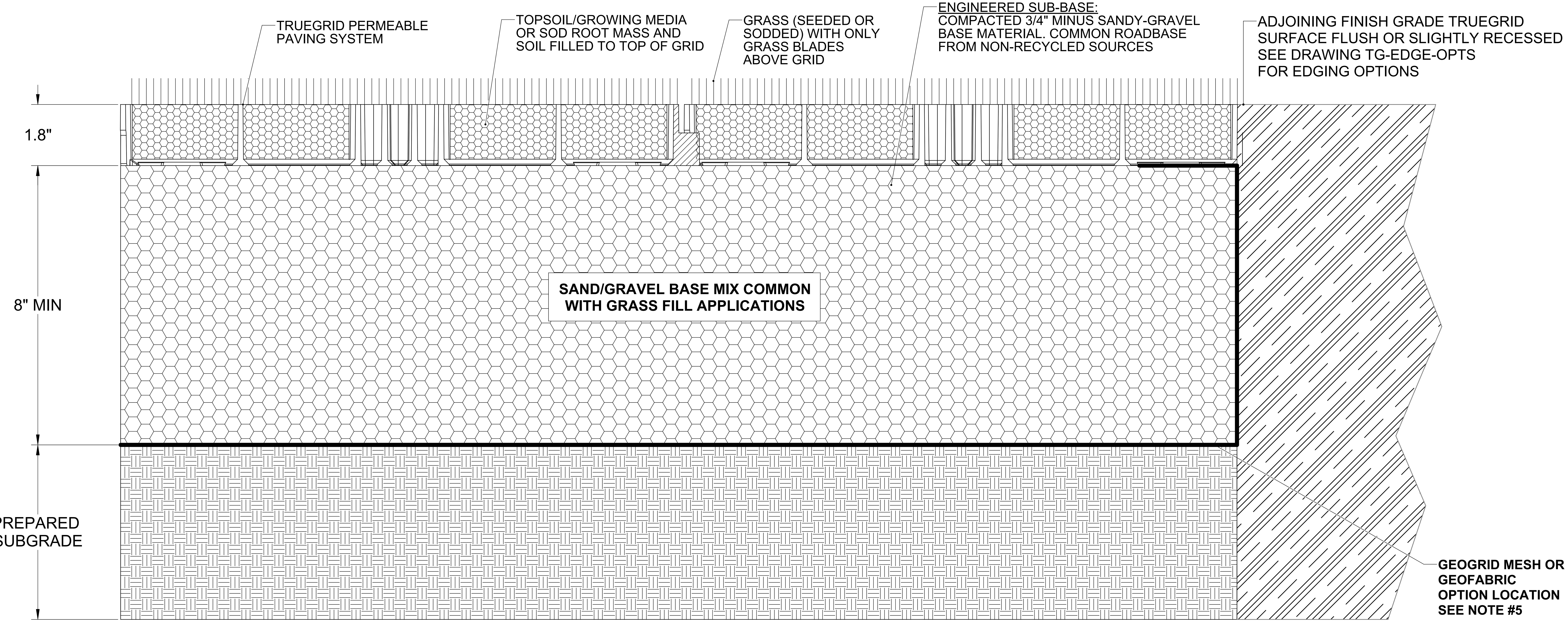
NOTES:

1. SUB-BASE DEPTH AND PREPARATION IS DEPENDENT ON SITE CONDITIONS PLUS LOADING REQUIREMENTS.
2. TRUEGRID PRO PLUS PRODUCTS ARE SUFFICIENTLY RATED FOR H-20 /HS-20 LOADING AND GREATER.
3. SEEDING METHOD: FILL SOIL/GROWING MEDIA TO TOP OF GRID. APPLY SEEDING OR HYDROSEEDING PER MANUFACTURERS' (BY OTHERS) REQUIRED APPLICATION RATES.
4. SOD INSTALLATION METHOD: FILL TOPSOIL/GROWING MEDIA HALF-WAY (~1") WITHIN TRUEGRID AND PRESS IN SOD SO THAT TOP OF GRID IS AT SOIL/ROOT LEVEL AND ONLY THE GRASS BLADES EXTEND ABOVE THE GRID.
5. GEOGRID MESH OR GEOFABRIC MAY BE REQUIRED BETWEEN SUBGRADE & SUBBASE FOR CERTAIN SOILS AND SITE SPECIFIC REQUIREMENTS.
6. NO STAKING NECESSARY WITH TRUEGRID PRO PLUS WHEN SLOPE IS BELOW 20 DEGREES. ASSESS PROJECT, AS NEEDED.
7. TRUEGRID PRO PLUS IS ADA COMPLIANT WITH PROPER FILL MATERIAL.
8. ALTERNATIVE ENGINEERED SUB-BASE MIXES CAN BE USED PROVIDED THEY PROMOTE GRASS GROWTH, HAVE ADEQUATE VOID SPACE FOR DRAINAGE, AND PROVIDE REQUIRED STRUCTURAL SUPPORT.
9. THIS CROSS SECTION IS FOR INFORMATION ONLY.



TRUEGRID BLOCK REFERENCE VIEW

PREASSEMBLED & DELIVERED IN 4' X 4' SHEET. RECONFIGURED AS NEEDED.NO EXTRA TOOLING OR ACCESSORIES REQUIRED



GRASS FILL HEAVY LOAD TRUEGRID PRO PLUS

APPLICATION:

HEAVY LOAD PARKING LOT, FIRE LANES, EQUIPMENT YARD, SERVICE ROADS.

MANUFACTURED IN NORTH AMERICA

1-855-355-GRID (4743)

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APPROVED BY:	C. White	2/28/2020

TRUEGRID

True to your project. True to the environment.

TRUEGRID GRASS FILL INSTALLATION HEAVY LOAD

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Appendix D – Australian Rainfall & Runoff

Appropriate Safety Criteria for People – Project 10

Australian Rainfall & Runoff

Revision Projects

PROJECT 10

Appropriate Safety Criteria for People

STAGE 1 REPORT

P10/S1/006

APRIL 2010

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AUSTRALIAN RAINFALL AND RUNOFF
REVISION PROJECT 10: APPROPRIATE SAFETY CRITERIA FOR PEOPLE

STAGE 1 REPORT

APRIL 2010

Project Australian Rainfall and Runoff Revision Project 10: Appropriate Safety Criteria for People	**AR&R Report Number** P10/S1/006
Date 12 April 2010	**ISBN** 978-085825-9454
Contractor Water Research Laboratory	**Contractor Reference Number** 08077.01
Authors R. J. Cox, T. D. Shand, and M. J. Blacka	**Verified by**

ACKNOWLEDGEMENTS

This project was made possible by funding from the Federal Government through the Department of Climate Change. This report and the associated project are the result of a significant amount of in kind hours provided by Engineers Australia Members.

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FOREWORD

AR&R Revision Process

Since its first publication in 1958, Australian Rainfall and Runoff (AR&R) has remained one of the most influential and widely used guidelines published by Engineers Australia (EA). The current edition, published in 1987, retained the same level of national and international acclaim as its predecessors.

With nationwide applicability, balancing the varied climates of Australia, the information and the approaches presented in Australian Rainfall and Runoff are essential for policy decisions and projects involving:

- infrastructure such as roads, rail, airports, bridges, dams, stormwater and sewer systems;
- town planning;
- mining;
- developing flood management plans for urban and rural communities;
- flood warnings and flood emergency management;
- operation of regulated river systems; and
- estimation of extreme flood levels.

However, many of the practices recommended in the 1987 edition of AR&R are now becoming outdated, no longer representing the accepted views of professionals, both in terms of technique and approach to water management. This fact, coupled with greater understanding of climate and climatic influences makes the securing of current and complete rainfall and streamflow data and expansion of focus from flood events to the full spectrum of flows and rainfall events, crucial to maintaining an adequate knowledge of the processes that govern Australian rainfall and streamflow in the broadest sense, allowing better management, policy and planning decisions to be made.

One of the major responsibilities of the National Committee on Water Engineering of Engineers Australia is the periodic revision of AR&R. A recent and significant development has been that the revision of AR&R has been identified as a priority in the Council of Australian Governments endorsed National Adaptation Framework for Climate Change.

The Federal Department of Climate Change announced in June 2008 $2 million of funding to assist in updating Australian Rainfall and Runoff (AR&R). The update will be completed in three stages over four years with current funding for the first stage. Further funding is still required for Stages 2 and 3. Twenty one revision projects will be undertaken with the aim of filling knowledge gaps. The 21 projects are to be undertaken over four years with ten projects commencing in Stage 1. The outcomes of the projects will assist the AR&R editorial team compiling and writing of the chapters of AR&R. Steering and Technical Committees have been established to assist the AR&R editorial team in guiding the projects to achieve desired outcomes.

Project 10: Appropriate Safety Criteria for People

Emergency management of flood situations in both urban and rural areas is directly concerned about the safety of people in floods. Over the past two decades there has been increasing concern about these safety issues and there is a need to revisit and update the criteria currently used. The current approach is based on the results of some studies undertaken in the 1970s. A body of research has been undertaken since then and there is a need to collate this research and to develop guidelines for authorities. As a result, it is anticipated that most of the work involved in this project will be the collation of research in this field and the development of appropriate guideline information.

The aim of Project 10 is to provide guidance on pedestrian safety and stability in floods.

Mark Babister
Chair National Committee on Water Engineering

Dr James Ball
AR&R Editor

AR&R REVISION PROJECTS

The 21 AR&R revision projects are listed below :

ARR Project No.	Project Title	Starting Stage
1	Development of intensity-frequency-duration information across Australia	1
2	Spatial patterns of rainfall	2
3	Temporal pattern of rainfall	2
4	Continuous rainfall sequences at a point	1
5	Regional flood methods	1
6	Loss models for catchment simulation	2
7	Baseflow for catchment simulation	1
8	Use of continuous simulation for design flow determination	2
9	Urban drainage system hydraulics	1
10	Appropriate safety criteria for people	1
11	Blockage of hydraulic structures	1
12	Selection of an approach	2
13	Rational Method developments	1
14	Large to extreme floods in urban areas	3
15	Two-dimensional (2D) modelling in urban areas.	1
16	Storm patterns for use in design events	2
17	Channel loss models	2
18	Interaction of coastal processes and severe weather events	1
19	Selection of climate change boundary conditions	3
20	Risk assessment and design life	2
21	IT Delivery and Communication Strategies	2

AR&R Technical Committee:

Chair	Associate Professor James Ball, MIEAust CPEng, Editor AR&R, UTS
Members	Mark Babister, MIEAust CPEng, Chair NCWE, WMAwater
	Professor George Kuczera, MIEAust CPEng, University of Newcastle
	Professor Martin Lambert, FIEAust CPEng, University of Adelaide
	Dr Rory Nathan, FIEAust CPEng, SKM
	Dr Bill Weeks, FIEAust CPEng, DMR
	Associate Professor Ashish Sharma, UNSW
	Dr Michael Boyd, MIEAust CPEng, Technical Project Manager *

Related Appointments:

Technical Committee Support: Monique Retallick, GradIEAust, WMAwater

Assisting TC on Technical Matters: Michael Leonard, University of Adelaide

* EA appointed member of Committee

PROJECT TEAM

Project team:

- Assoc Prof. Ronald J. Cox, UNSW[#]
- Dr Thomas D. Shand, UNSW
- Mr Matthew J. Blacka, UNSW

This report was independently reviewed by:

- Geoff O'Loughlin

EXECUTIVE SUMMARY

The safety of people on floodways or flooded streets is of major concern in urban stormwater design and floodplain management. Human activity in floodways is inevitable with much development already in flood prone areas. The safety of people can be compromised when exposed to flows which exceed their ability to remain standing and/or traverse a waterway. The current Australian Rainfall and Runoff (ARR) guidelines (I.E.Aust, 1987) stipulate that "*to prevent pedestrians being swept along streets and other drainage paths during major storm events, the product of velocities (V) and depths (D) in streets and major flow paths generally should not exceed D.V = 0.4 m^2/s*". The 2005 Floodplain Development Manual (DECCW, 2005) do not indicate constant D.V relationships, but do place upper bounds on both depth (0.8 m) and velocity (2.0 ms^{-1}) for people to wade safely.

Over the last four decades, a number of laboratory-based experimental studies have been undertaken within Australia and internationally to define the limits of stability within differing flow regimes. This report reviews and discusses previous experimental investigations of human stability as well as empirical expressions and safety guidelines derived from these studies. The entire data-set of relevant experimental results is re-analysed and tolerable flow conditions related to human safety and safe working conditions are produced. These are presented as a set of guideline values together with discussion on the limitations of their validity and other factors which may adversely affect stability.

Significant scatter is observed within individual experimental data sets and, to a more significant degree, when all data sets are combined. Additionally, markedly differing tolerable D.V values are observed for identical subjects. Discussion with investigators has indicated that "training" of the subject (Abt, pers. com, 2009) may enable higher flow values to be resisted as the subject learns how to position the body so to best resist the flow. The lowest stability values (D.V) for each subject is, in most cases, the first exposure test and more applicable to the general population whom have not had the benefit of such training prior to encountering flood water.

While distinct relationships exist between a subjects height and mass (H.M; mkg) and the tolerable flow value (D.V; m^2s^{-1}), definition of general flood flow safety guidelines according to this relation is not considered practical given the wide range in such characteristics within the population. In order to define safety limits which are applicable for all persons, hazard regimes are defined for adults (H.M > 50 mkg) and children (H.M = 25 to 50 mkg). Infants and very young children (H.M < 25 mkg) are considered unsafe in any flow without adult support.

For children with a height and mass product (H.M) of between 25 and 50, low hazard exists for flow values of D.V < 0.4 m^2s^{-1}, with a maximum flow depth of 0.5 m regardless of velocity and a maximum velocity of 3.0 ms^{-1} at shallow depths. Under these flow regimes, the children tested retained their footing and felt *"safe"* in the flow. For adults (H.M > 50), low hazard exists for flow values of D.V < 0.6 m^2s^{-1} with a maximum depth limit of 1.2 m and a maximum velocity of 3.0 ms^{-1} at shallow depths. Moderate hazard for adults exists between D.V = 0.6 to 0.8 m^2s^{-1}, with an upper working flow value of D.V < 0.8 m^2s^{-1} recommended for trained safety workers or experienced and well equipped persons. Significant hazard for adults exists between D.V = 0.8 to 1.2 m^2s^{-1}. For flow values D.V > 1.2 m^2s^{-1} the majority of tests for adults indicated instability - the hazard is extreme and should not be considered safe for standing or wading.

<table>
<tr><th>DV (m^2s^{-1})</th><th>Infants, small children (H.M ≤ 25) and frail/older persons</th><th>Children (H.M = 25 to 50)</th><th>Adults (H.M > 50)</th></tr>
<tr><td>0</td><td>Safe</td><td>Safe</td><td>Safe</td></tr>
<tr><td>0 – 0.4</td><td rowspan="5">Extreme Hazard; Dangerous to all</td><td>Low Hazard[1]</td><td rowspan="2">Low Hazard[1]</td></tr>
<tr><td>0.4 – 0.6</td><td>Significant Hazard; Dangerous to most</td></tr>
<tr><td>0.6 – 0.8</td><td rowspan="3">Extreme Hazard; Dangerous to all</td><td>Moderate Hazard; Dangerous to some[2]</td></tr>
<tr><td>0.8 – 1.2</td><td>Significant Hazard; Dangerous to most[3]</td></tr>
<tr><td>> 1.2</td><td>Extreme Hazard; Dangerous to all</td></tr>
</table>

[1] Stability uncompromised for persons within laboratory testing program at these flows (to maximum flow depth of 0.5 m for children and 1.2 m for adults and a maximum velocity of 3.0 ms^{-1} at shallow depths).
[2] Working limit for trained safety workers or experienced and well equipped persons (D.V < 0.8 m^2s^{-1})
[3] Upper limit of stability observed during most investigations (D.V > 1.2 m^2s^{-1})

It should however be noted that loss of stability could occur in milder flow regimes when adverse conditions are encountered including:

- **Bottom conditions**: uneven, slippery, obstacles;
- **Flow conditions**: floating debris, low temperature, poor visibility, unsteady flow and flow aeration;
- **Human subject**: standing or moving, experience and training, clothing and footwear, physical attributes additional to height and mass including muscular development and/or other disability, psychological factors;
- **Others**: strong wind, poor lighting, definition of stability limit (i.e. feeling unsafe or complete loss of footing).

As described within Cox et al. (2003), there is a lack of test data for very young children and frail/older persons. These populations are unlikely to be safe in any flow regimes and as such, care is required in locating aged care and retirement villages as well as childcare centres and kindergartens.

TABLE OF CONTENTS

1. Introduction

The safety of people on floodways or flooded streets is of major concern in urban stormwater design and floodplain management. Human activity in floodways is inevitable with much development already in flood prone areas. The safety of people can be compromised when exposed to flows which exceed their ability to remain standing and/or traverse a waterway.

Current design guidelines for safety of people on floodways in Australia are simplistic, generally based on the product of flow depth (D) and velocity (V). The current Australian Rainfall and Runoff (ARR) guidelines (I.E.Aust, 1987) stipulate that "*to prevent pedestrians being swept along streets and other drainage paths during major storm events, the product of velocities and depths in streets and major flow paths generally should not exceed 0.4 m^2/s*". In contrast, the velocity-depth relationships that define unsafe wading and vehicle instability as presented within the 1986 NSW Floodplain Development Manual (DPW, 1986) and adopted within the 2005 Floodplain Development Manual (DECCW, 2005) do not indicate constant D.V relationships (Figure 1), but do place upper bounds on both depth (0.8 m) and velocity (2.0 ms^{-1}) for people to wade safely.

Besides the safety of the general community, safety on floodways is important to rescue workers who are frequently required to operate in hazardous conditions. Emergency Management Australia (EMA) is the national government agency responsible for managing disaster situations. EMA has published a series of manuals to assist other agencies and local governments in the planning of emergency situations regarding flooding. In regard to "Flood Hazard", EMA advice is that "wading by able-bodied adults becomes difficult and dangerous when the depth of still water exceeds 1.2 m or when the velocity of shallow water exceeds 0.8 ms^{-1} and for various combinations of depth and velocity between these limits" (EMA, 1999). EMA acknowledge other local site factors other than depth and velocity need to be taken into account.

The two recognised hydrodynamic mechanisms by which stability is lost include *moment instability* and *friction instability* (Figure 2). A more comprehensive discussion is presented within Jonkman and Penning-Rowsell (2008) but, in brief, moment (toppling) instability occurs when a moment induced by oncoming flow exceeds that generated by the weight of the body (Abt *et al*., 1989). This stability parameter is sensitive to the buoyancy of a person within a flow and to body positioning and weight distribution. These factors are further discussed within the following analysis. Frictional (sliding) instability occurs when the drag force induced by the horizontal flow is larger than the frictional resistance between a persons feet and the ground surface. This stability parameter is sensitive to weight and buoyancy, clothing, footwear and ground conditions. A third cause of instability described within Jonkman and Penning-Rowsell (2008) is *floating,* which occurs when the water depth reaches a significant level and buoyancy forces lift the person from the ground regardless of velocity. Under floating conditions neither sliding or moment instability are applicable.

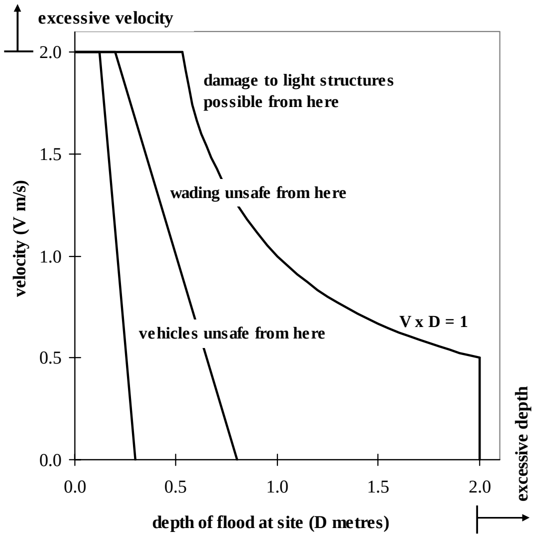

Figure 1 Depth-velocity relationships for floodway design (adapted from: Department Public Works, NSW, 1986).

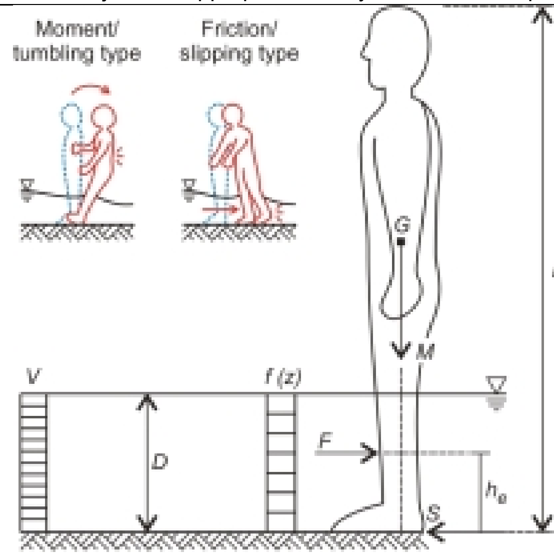

Figure 2 Models of moment and frictional instability (adapted from: Takahashi et *al*., 1992).

This report reviews and discusses previous experimental investigations of human stability as well as empirical expressions and safety guidelines derived from these studies. The entire data-set of relevant experimental results is re-analysed and tolerable flow conditions to ensure human safety and safe working conditions are produced. These are presented as a set of guideline values together with discussion on the limitations of their validity and other factors which may adversely affect stability.

2. Review of Previous Investigations

2.1 Experimental Data

Since the early human stability testing of children by Foster and Cox (1973), a number of laboratory and field-based studies have been undertaken both within Australia and Internationally. Abt et al. (1989) undertook laboratory testing of 20 adults in flows up to 3 ms^{-1} and depths of up to 1.2 m. Takahashi et al. (1992), investigated the safety of dock workers during wave overtopping of harbour structures using a funneled basin. These latter tests included detailed measurements of force, friction and sliding which were used to compare with a computational model developed during the study. Karvonen et al. (2000) used a moving platform within a test basin to examine the stability of rescue workers in the RESCDAM project and Yee (2003) expanded the earlier work of Foster and Cox (1973) by testing the stability of four young children. Jonkman and Penning-Rowsell (2008) report on a study by the United Kingdom Flood Hazard Research Centre where a professional stuntman is subjected to varying flow depths and velocities within a quasi-natural waterway.

Table 1 Comparison of experimental test parameters.

	Foster and Cox	**Abt et al.**	**Takahashi et al.**	**Karvonen et al. (RESCDAM)**	**Yee**	**Jonkman (FHRC)**
Year	**1973**	**1989**	**1992**	**2001**	**2003**	**2008**
Setup	Flume	Flume	Funnelled basin	Moving platform through basin	Flume	Sluice-controlled flood relief channel
Surface	Painted timber	Concrete, turf, gravel and steel.	Metal load cell	Steel grating	Painted timber	Concrete
Slope	Horizontal	1(V):115(H) and 1(V):38(H)	Horizontal	Horizontal	Horizontal	1(V):100(H)
Subject Characteristics	Children (9 -13 yrs)	Civilian adults with safety equipment	Adults	Rescue workers with safety equipment	Children	Professional stuntman
Subject Action	Standing, walking, turning and sitting	Standing, turning and walking	Standing	Standing, turning and walking	Standing, walking	Standing, walking
Failure mechanism	Subject feels unsafe or loses footing	Subject looses footing	Subject looses footing	Subject looses footing	Subject feels unsafe or loses footing	Subject looses footing
Number of subjects	6	20	3	7	4	1
Range of D, (m)	0.09 - 0.41	0.43 - 1.2	0.44 - 0.93	0.4 - 1.1	0.18 – 0.53	0.26 – 0.35
Range of V, (ms^{-1})	0.76 - 3.12	0.82 - 3.05	0.58 - 2.0	0.6 - 2.6	0.89 – 2.12	2.4 – 3.1
Range of D.V, (m^2s^{-1})	0.16 - 0.52	0.71 - 2.13	0.64 - 1.26	0.6 - 1.3	0.33 – 0.55	0.78 – 0.91
Range of H.M, (mkg)	32 - 53.2	62.3 - 172.8	106.6 - 133.6	77 - 195	20.8 – 32.5	116

While these studies have primarily focused on similar parameters including the height (H; m) and mass (M; kg) of subjects and the flow depth (D; m) and velocity (V; ms^{-1}), some variation in testing facilities and regimes exists across all the studies. A summary of study parameters is presented within Table 1 and more detailed discussion on individual studies is presented below.

2.1.1 Foster and Cox (1973)

Experiments were undertaken in a flume 6 m long, 0.6 m wide and 0.75 m deep. The base of the flume consisted of painted timber. The velocity and depths were controlled by sluice gates at each end of the flume. The subjects consisted of 6 male children aged from 9 to 13 years, 1.27 to 1.45 m tall, 25 to 37 kg mass and Height*Mass (H.M) from 32 to 53 mkg (Table 1). All subjects wore shorts. Clothing drag was negligible in all tests as water levels never reached the height of the shorts. Shoes were not worn during experimentation.

The subjects were tested standing, walking, turning and sitting within the flume both facing upstream and downstream. Safety criteria were based on the perception of the child as to safe and unsafe conditions, i.e. a threshold flow rate was identified when the child felt unsafe rather than when footing was lost. Consequently, inherent in the criteria developed for safe and unsafe flow conditions is the psychological tendency of the child. This point is noted in the report by Foster and Cox (1973) but is rarely noted in most safety criteria subsequently adopted.

Foster and Cox (1973) identified four conditions that could affect the safety of a child:-

- The child's physical attributes – this includes age, height, weight and muscular development.
- Psychological factors – an alert and active child may be more capable of movement in certain conditions whilst a passive child may struggle in such conditions.
- Hydraulic conditions – the flow regime is important to a person’s safety, in particular depth and velocity.
- Other factors – such as friction between the ground and child’s feet, the type of clothing worn, the movement of the child in the flow, uneven ground and possible impact of floating debris.

General conclusions were that relatively low flow depths (< 0.3 m) may be unsafe at high velocities (i.e. greater than around 1.5 ms^{-1}) and that standing stability reduces when trying to move in the flow, especially turning. Stability is the lowest when seated. This last conclusion is important as it infers that once footing has been lost, stability is further reduced and the likelihood of a person recovering footing is low.

2.1.2 Abt et al. (1989)

In conducting a test program to allow prediction of the approximate depth and velocity of flow in which a person will topple in flood flow, Abt et al. (1989) completed testing of 20 adults (male and female, 1.52 to 1.83 m tall, 41 to 91 kg mass and Height*Mass from 62 to 172 mkg: Table 1). Experiments were undertaken in a flume 61 m long, 2.44 m wide and 1.22 m deep using 0.5 and 1.5 percent grades.

A change in surface (from steel to concrete to gravel to turf) did not significantly affect the stability. This is attributed to most tests being conducted in relatively high depths (>1 m) for which friction underfoot is less important and instability is biased towards tumbling (moment) failure as opposed to clear sliding (friction) failure. If tests were undertaken at lower depths with high velocities, it would be expected that there would be a measurable difference in safety on different surfaces. An equation defining the threshold of instability of a person in flood flow was found by linear regression of the experimental data (Eqn. 1) where D.V is the flow regime, M is the subjects mass (kg) and H, their height (m). The resulting r^2 value of 0.48 indicated significant scatter in the data however, and inherent uncertainty in the derived expression.

$$D.V = 0.0929\left[e^{0.022(2.2M + H/25.4)+1.09}\right]^2 \quad (1)$$

2.1.3 Takahashi et al. (1992)

Takahashi et al. (1992) included detailed measurements of drag, friction and force moments when testing 3 adult males 1.64 to 1.83 m tall, 63 to 73 kg mass and Height*Mass from 107 to 134 mkg (Table 1). The research (published in Japanese) focus was the safety of dock workers in conditions of wave overtopping of harbour structures. The experiments were undertaken in a basin of 50 m length and 20 m width. As opposed to other experiments which used a flume, this facility operated by funnelling large amounts of water to generate higher velocities and depths. The subjects stood on a load cell platform that was capable of measuring force, friction and sliding. The subjects were exposed to increasing combinations of flow depth and velocity until they were physically washed off their feet in either "sliding" or "tumbling" mode as sketched in Figure 2.

Testing was undertaken for three different types of clothing (long boots, dry waterproof suit, and normal cotton trousers) and for a range of leather and rubber soled shoes on a range of surfaces including smooth and rough concrete as well as concrete covered with algae and seaweed. Coefficients of friction were measured and found to be typically around 0.6 and 1.0 respectively for smooth and rough concrete under wet conditions. The lowest values reported for concrete covered with relatively slippery seaweed are around 0.4. No data exists for asphalt road surfaces and/or grassed floodway surfaces.

With the benefit of continuous monitoring of depth, velocity and resultant forces (on the persons/subjects) during each test, Takahashi et al. (1992) were able to specifically calculate drag force coefficients and examine the stability of persons for water exposure from different directions. For front on water exposure and feet together the drag coefficient was found to vary between 0.6 and 1.1 depending upon the subject and the clothing being worn.

2.1.4 Karvonen et al. (2000)

The Helsinki University of Technology study (Karvonen et al., 2000) primarily focussed on defining the limits of human stability for a safe rescue action in a dam break situation. The study, referred to as the RESCDAM project, recognised that the limit of safety is affected by other factors such as lighting and turbidity.

Seven adult subjects were used in these experiments, consisting of 5 males and 2 females, 1.6

to 1.95 m tall, 48 to 100 kg in mass and Height*Mass from 77 to 195 mkg (Table 1). Two of the subjects were professional rescue personnel. As the focus of this study was on rescue worker mobility, all subjects wore Gore Tex rescue suits (equivalent to a dry suit) and one subject also wore waders. Subjects also wore fall arrest harnesses for safety. It is assumed that all subjects wore boots. Experiments were undertaken in a basin 130 m long, 11 m wide and 5.5 m deep. The water temperature was approximately 16 degrees. The water within the basin was stagnant, with a moving platform used to replicate flow. The platform consisted of two steel grates resulting in a 1.13 m wide and 1.17 m long platform. To define the limits for safe rescue action the velocity and depth of the platform was increased until the subject *"lost stability or manoeuvrability"*.

The method of this study is unique in that a platform was moved through stagnant water as opposed to exposing subjects to flowing turbulent water in a flume or the like. The RESCDAM study resulted in expressions defining the limits of human manoeuvrability in good (Eqn. 2a), normal (Eqn. 2b) and poor (Eqn. 2c) conditions, defined according to bed (uneven, slippery, obstacles), water (floating debris, low temperature, ice, poor visibility) and human subject (additional loads, disabilities, aged) conditions.

$$D.V = 0.006H.M + 0.3 \tag{2a}$$

$$D.V = 0.004H.M + 0.2 \tag{2b}$$

$$D.V = 0.002H.M + 0.1 \tag{2c}$$

2.1.5 Yee (2003)

Observing a lack in worldwide laboratory test data on the stability of very small/young children or very frail/older persons, Yee (2003) carried out stability testing of 4 young children (2 male and 2 female, ages 6 to 8 years, 1.09 to 1.25 m tall, 19 to 25 kg mass and Height*Mass from 20.7 to 32.5 mkg: Table 1).

The testing procedures were similar in most aspects to those previously reported by Foster and Cox (1973). Testing of the subjects in a sitting position was not however carried out. Failure was determined through observation and consultation with the subject. Video recording of all subject tests allowed failure scenarios to be clearly identified as either:

- a loss in stability resulting in the subject slipping or falling with assistance required; or
- a situation where the subject did not feel confident in undertaking set movements in the generated flow (depth and velocity) and stabilised themselves by grabbing the flume sides or an assistant.

The two failure definitions are not the same. The first defines failure of stability whilst the second defines the perceived limit of safety. The results are seen to be consistent with whilst extending the stability criteria originally determined for older and larger children by Foster and Cox (1973).

Subjects 1, 2 and 3 (with similar H.M values between 27.5 and 32.5 mkg) exhibited very similar failure behaviour with critical D.V values from 0.51 - 0.55 m^2s^{-1}. Subject 4 with a H.M of 20.7 mkg had a significantly lower critical failure value of D.V from 0.33 - 0.38 m^2s^{-1}. The lower stability of subject 4 cannot be explained merely in terms of his smaller height and mass. Based on detailed observations of behaviour of all subjects during testing, it is postulated that the difference in behaviour of subject 4 is due to his lower level of muscular development and coordination.

2.1.6 Jonkman and Penning-Rowsell (2008)

Controlled field experiments of human stability in sluice-control flow within the Lea River Catchment in the United Kingdom were undertaken by the Flood Hazard Research Centre (FHRC). The test subject was a professional stuntman 1.7 m tall and 68 kg in weight giving a combined Height*Mass of 116 mkg (Table 1). The subject wore rubber soled shoes and a drysuit (Water temp = 10° C) tightly drawn around his legs so cross-sectional area and drag were not unduly exaggerated. The subject undertook manoeuvres including standing and walking at right angles and into the flow.

At a depth of 0.35 m, flows inducing failure while attempting to remain standing ranged between 2.4 and 2.6 ms^{-1} (D.V = 0.84 and 0.91), although the subject began sliding without losing footing or balance at 1.8 ms^{-1}. At a depth of 0.26 m, the subject fell when attempting to walk into, or perpendicular to the flow at flow velocities of 3.0 ms^{-1} and 3.1 ms^{-1} (D.V = 0.78 and 0.81 respectively).

In all cases, failure was observed to occur after slipping backwards (i.e. frictional instability). This is likely biased by the relatively low water depths tested. The subject reported that ‘staying still’ was much easier than walking and that walking through the flowing water was ‘exhausting’. The subject additionally reported that carrying extra weight such as a child would have made balancing more difficult despite the higher resultant H.M value.

2.1.7 Summary

A comparison of the observed limiting flow regimes (D.V) as function of subject Height*Mass (H.M) for all experiments is presented within Figure 3. The data shows significant scatter, although a general increase in tolerable flow with increased subject (H.M) is evident. The linear regression line is indicated for all data and for all data excluding that of Abt et al. (1989), with regression coefficients of r^2 = 0.50 and 0.80 respectively.

The Abt et al. (1989) data indicates substantially higher stability than all other data for adults (Figure 3). This cannot fully be explained. It is partially explained in that the purpose of the experiments was to determine the absolute limit of stability of the subjects to failure (personal communication with Abt, SR, 10 October 2003), that is the subjects were made to fail as opposed to determining if safety was compromised and the limits for a safe rescue action which was the objective of the Karvonen et al. (2000) study. Clothing had lower drag than that applicable to testing by Takahashi et al. (1992) and Karvonen et al. (2000) and subject performance was noted to improve with practice.
Ramsbottom et al. (2004) analysed both the Abt et al. (1989) and Karvonen et al. (2000) data and concluded that, based on a Student T test, the data sets were statistically significantly different. The remainder of experimental data analysed during this study is more consistent with that of Karvonen et al. (2000); thus supporting the hypothesis that the Abt. et al. (1989) tests are

from a different statistical population.

Additional points of interest include markedly differing tolerable D.V values for identical subjects in the Abt et al. (1989), Takahashi et al. (1992) and Karvonen et al. (2000) tests. In the case of Takahashi et al., differing clothing, footwear and ground surfaces were tested which may partially explain the variation. However, there were less variables tested within the Abt et al. and Karvonen et al. tests. Variation in tolerable flow during these tests is attributed to “training” of the subject (Abt, pers. com, 2009); the subject learns how to position the body so to best resist the flow. The lowest stability values (D.V) for each subject is, in most cases, the first exposure test. These first exposure values of the Abt et al. (1989) data are more consistent with data from the other experimental sources.

Additionally, the specific differences in the terms of reference must be considered. Definition of the stability limit varied between studies. Such definitions included: when the subject felt unsafe and/or grasped the flume sides (i.e. Foster and Cox, 1973; Yee, 2003), when subjects either lost stability or manoeuvrability (i.e. Karvonen et al., 2000) and when their subjects were washed off their feet (i.e. Abt et al., 1989). Additionally, subjects within the Takahashi et al. (1992) study were required only to stand, whereas some degree of activity including walking and turning were required in the other studies.

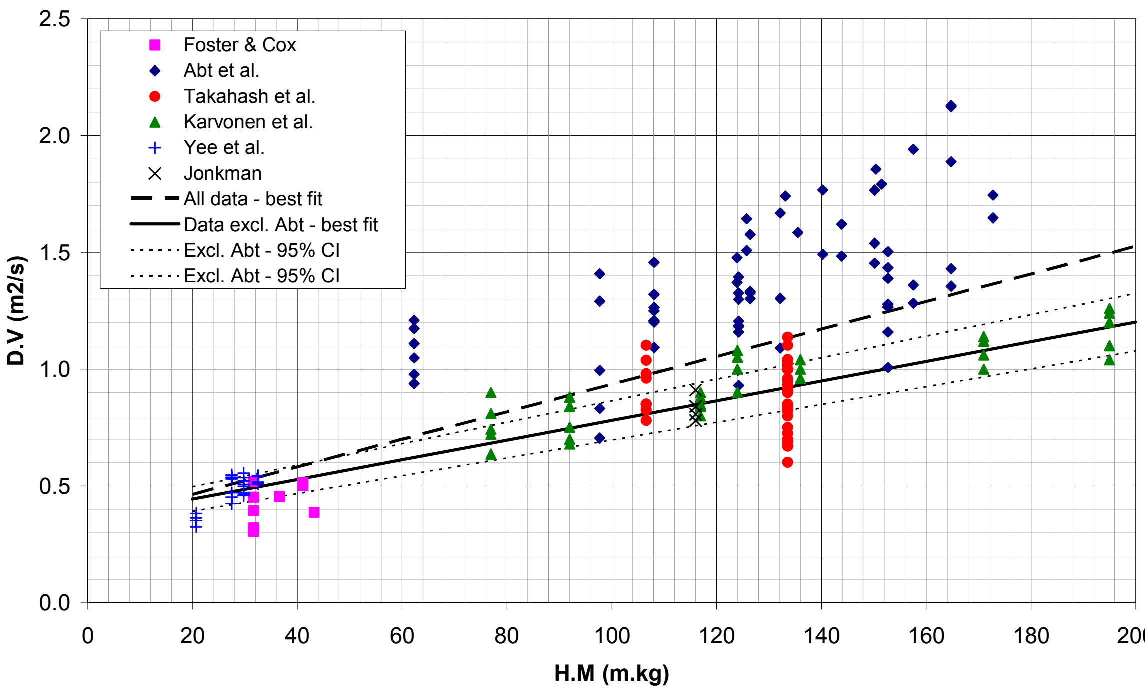

Figure 3 Combined limiting flow rates (D.V) found as function of subject Height*Mass (H.M) including the linear regression line for all data (- - -), for all data excluding that of Abt et al. (1989) (—) and the 95% confidence intervals for all data excluding that of Abt et al. (····).

2.2. Empirical and Theoretical Analysis

2.2.1 Takahashi *et al.* (1992)

Based on their experimental results, Takahashi et al. (1992) developed a computational model for stability incorporating the resolution of forces and moments including weight, flow drag and friction. Based on human ergonomic data, they adopted a human shape standardised in respect of height. For any given person's height and weight, computational resolution of weight, drag and frictional forces enables an estimate of critical velocity for either “sliding” or “tumbling rotation” modes of stability in a given water depth. In comparisons with the experimental measurements for the exposed human subjects, the calculated critical conditions using the computational procedure proved quite reliable for front and side exposure with either feet together or braced feet wide apart.

For water depths less than "in seam" (less than 0.48 person height), only two feet and legs are exposed to drag forces. Under such conditions for a relatively slippery surface such as concrete covered with seaweed or algae, critical values of D.V were found in the experiments to be 0.4 to 0.6 m^2/s for front or rear exposure and 0.7 to 0.8 m^2/s for side on exposure. If exposed in a sitting position, increased body drag reduces the critical D.V value to 0.3 to 0.5 m^2/s. This finding is in agreement to that of Foster and Cox (1973) who found stability to be lower in a seated position than standing.

2.2.2 Keller and Mitsch (1993)

Keller and Mitsch (1993) undertook a purely theoretical study of the stability of both cars and people. The study considered both moment and friction instability of a cylinder intended to represent a subject child, with an H.M value of 21 and an adult with a non-specified H.M value. The moment instability was defined as occurring when the overturning moment induced by the flow around a pivot point at the base of the cylinder exceeded the restoring moment due to subject weight. Frictional instability was defined as occurring when the drag force due to flow exceeds the frictional resistance of the subject’s feet. The study found the frictional mode of instability to be dominant in flow depths less than 0.55 m and moment instability to be dominant in depths greater than 0.55 m, with unstable D.V values ranging between 0.12 and 0.55 for the ‘child’ and between 0.35 and 1.4 for the adult (Figure 4).

The purely theoretical method described above is, however, highly dependent on the selection of friction and drag coefficients. A friction coefficient of 0.3 and drag coefficient of 1.2 were adopted within the study with no sensitivity assessment evident. Takahashi et al. (1992) measured friction coefficient values generally between 0.6 and 1.0 with a lowest value of 0.4 for concrete covered with relatively slippery seaweed. Similarly, Takahashi et al. (1992) found coefficient of drag values to range between 0.6 and 1.1 depending on the subject and clothing worn.

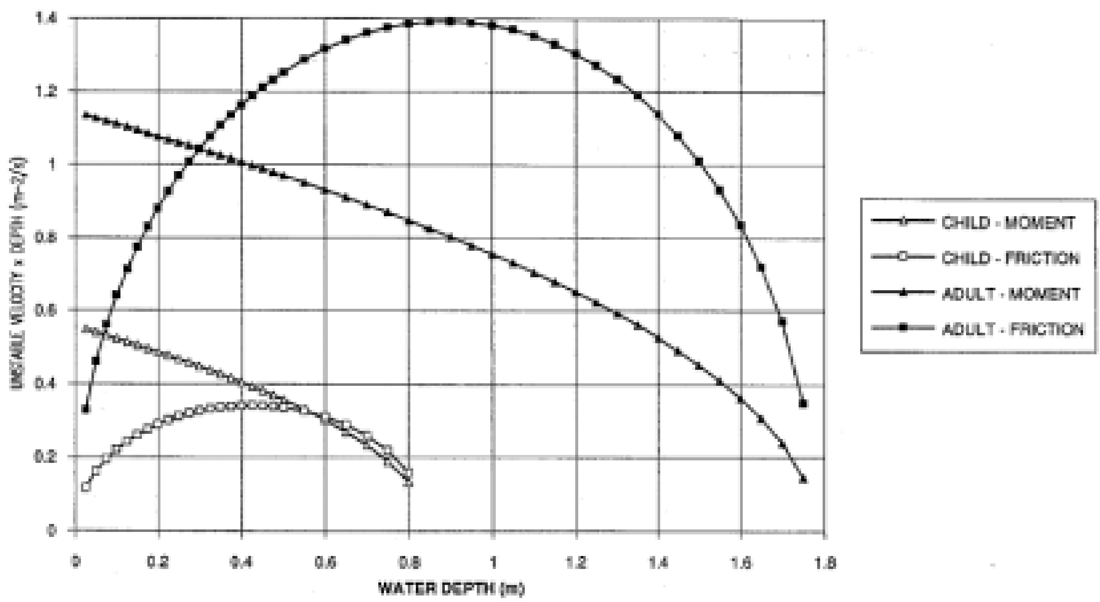

Figure 4 Theoretical unstable flow rates for a 'child' and 'adult' (source: Keller and Mitsch, 1993).

2.2.3 Lind et al. (2004)

Lind et al. (2004) use laboratory data collected by Abt et al. (1989) and Karvonen et al. (2000) to calibrate and compare three mechanical and four empirical stability models. The mechanical models were intended to simulate moment instability of a human form approximated by a circular cylindrical body, a square parallelepiped and composite cylinders corresponding to the two legs and torso. Results showed that the speed (V) and depth (D) of flow and the subject height (H) and mass (M) to be important parameters. Variation in critical flow regimes between the differing shapes was found to be small however, and the authors suggest that calibrated empirical models may provide better results.

The empirical expressions tested (Eqn. 3a – 3d) assign different weighting to the subject's height and mass (H.M), while calibrating the critical flow ($D.V_{cr}$) using an empirical coefficient K. The simple relation $D.V_{cr}$ = K * HM is not tested.

$$D.V_{cr} = K\left[M(1-D/H)\right]^{1/2} \tag{3a}$$

$$D.V_{cr} = K.M^{1/2} \tag{3b}$$

$$D.V_{cr} = K.M \tag{3c}$$

$$D.V_{cr} = K \tag{3d}$$

The coefficients for the various expressions are calibrated using the data of Abt et al. (1989) and Karvonen et al. (2000) and coefficients of variation for the various datasets found. Differences between male and female test subjects were found, but disappeared when height and mass factors were included in the expression. Differences between the test results of Abt et al. (1989) and Karvonen et al. (2000) are attributed (in part) to differences in clothing and drag factor.

Lind et al. (2004) suggest that the simplest formula (Eqn 3d) with critical flow depending solely on a calibrated coefficient should be used, with different coefficients used for males and females and for differing (summer and winter) clothing types. This however, contradicts earlier conclusions that height and weight parameters are important and that incorporation of these parameters resolves differences observed between male and female cases.

2.2.4 Yee (2003)

Yee (2003) developed a predictive computational model based on the work of both Takahashi et al. (1992) and Keller and Mitsch (1993) with the incorporation of parameters for velocity, depth (up to 1.5 m), subject height, mass and body shape, drag, friction, buoyancy and moment stability mass lever arm (distance from heel to centre of gravity). The model examined both sliding (friction) or tumbling (moment) failure. Adopting coefficients of 1.1 and 0.4 for drag and friction respectively and a fixed moment stability lever arm value of 0.1m, the model was found to reliably predict stability criteria comparable with the test results of Takahashi et al. (1992), Foster and Cox (1973) and all but the smallest subject in Yee (2003). Adjustment of the drag and frictional coefficients and the *lever arm* was required to improve the fit of the Abt et al. (1989) and Karvonen et al. (2000) data.

The Yee (2003) predictive computational model has been re-applied to all the data sets with improved agreement utilising consistent relative values of friction, drag and moment stability lever arm (as fraction of subject Height H) given in Table 2.

Table 2 Re-application of Yee (2003) model to various data sets

	Foster and Cox (1973)	**Yee (2003)**	**Takahashi et al. (1992)**	**Karvonen et al. (2000)**	**Abt et al. (1989)**
Friction coefficient	0.4	0.4	0.6	0.45	0.6
Drag coefficient	0.8	0.8	1.0	1.0	0.8
Moment stability mass lever arm	0.04 H	0.04 H	0.06 H	0.06 H	0.12 H

It is noteworthy that the lever arm for the Abt et al. data had to be increased to 0.12 H as the reported “trained” subjects used muscle/body balance to better resist the flow - effectively increasing the moment stability mass lever arm.

2.2.5 Ramsbottom et al. (2004; 2006)

Ramsbottom et al. (2004; 2006) (the UK DEFRA Flood Risk to People Report) tested various empirical equations (Eqn. 4a – 4c) using the Abt et al. (1989) and Karvonen et al. (2000) experimental data. The D.V values for each test subject in the experimental datasets were ‘averaged’, presumably to reduce scatter. However, as discussed earlier, training of subjects was observed, particularly in the Abt et al. (1989) data. By averaging values, an assumption of some training is incorporated into the derived hazard predictors. This assumption is not, however, necessarily valid with respect to the general population who may experience instability and safety risk at their first exposure to a flood hazard.

The equations are compared to the experimental datasets individually and combined, with linear regression values used as an indicator of goodness of fit. The strongest relationship was observed for Eqn. 4a, and much stronger relationships were observed for the individual datasets than combined. This indicates significant disparity between the two datasets, which, as discussed within Section 2.1.7, was confirmed using a student T test to show significant statistical difference.

$$H.M = K(D.V) + C \tag{4a}$$

$$H.M = K(D.V^2) + C \tag{4b}$$

$$H.M = K[D(V + 1.5)] + C \tag{4c}$$

Despite Eqn. 4a showing the best statistical fit to data, Eqn. 4c is adopted to undertake hazard rating analysis and combined with a factor to account for debris within the flow. The justification given for this selection is that some risk is posed by deep flows at low velocities. Additionally, the debris factor (DF) is not supported by experimental testing but assigned a value of 0, 1 or 2. A review of the 2004 study within Ramsbottom et al. (2006) revised the velocity coefficient from +1.5 to +0.5 and the debris factor (DF) from between 0 and 2 to between 0 and 1 to define various classes of flood hazard based on the term $D(V + 0.5) + DF$. Flood hazard regimes as proposed within Ramsbottom et al. (2006) are shown within Table 3.

Table 3 Suggested stability thresholds (Ramsbottom et al. (2006).

Flood hazard D.(V+0.5)+DF	**Description**	**Alternative name/ hazard class**
0	Safe (dry)	None
0 – 0.75	Caution	Low
0.75 – 1.5	Dangerous for some	Moderate
1.5 – 2.5	Dangerous for most	Significant
> 2.5	Dangerous for all	Extreme

These stability thresholds are compared to all available experimental data (Figure 5), with an assumption of 0 debris factor. Results show that almost all children (H.M <50) are unable to tolerate flows within the *low hazard zone*. Almost all experimental data including the lower ‘untrained’ values of Abt et al. (1989) lie within the *dangerous for some*, or *moderate hazard* regime. Data within the *dangerous for most*, or *significant hazard* is limited to the upper ‘trained’ values of Abt et al. and the larger Karvonen et al. test subject (H.M = 195). Additionally, there is no upper depth limit provided. Thus, large depths at low velocities are not necessarily classed as hazardous. This is impractical as once a subject becomes buoyant, they are inherently unstable and safety becomes dependent upon swimming ability.

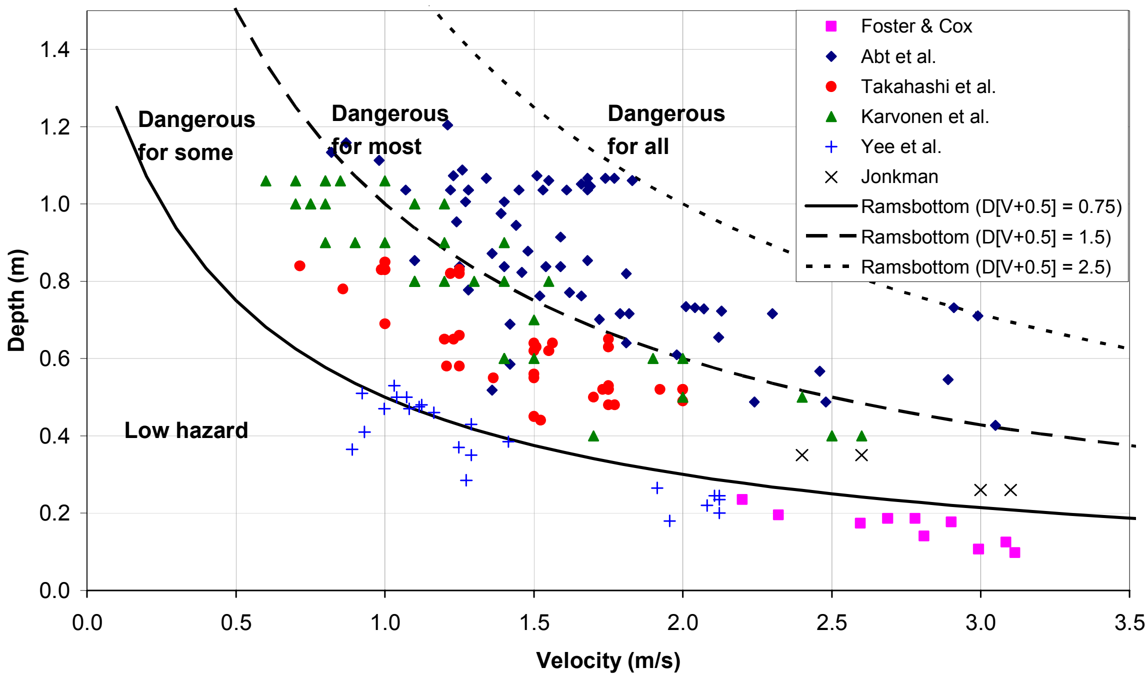

Figure 5 Comparison of Ramsbottom et al. (2006) stability thresholds with all available experimental data (note: debris factor is assumed 0).

2.2.6 Ishigaki et al. (2005; 2008; 2009)

Studies by Ishigaki et al. have primarily focussed on evacuation of persons from underground spaces including subways, shopping malls and basement parking during urban flood events. Laboratory experiments (Ishigaki et al., 2005, 2008a, 2008b, 2009) tested the ability of subjects to move through a corridor, up a staircase and to open a door at a range of water depths less than 0.5 m. The stability of subjects was not typically tested to failure but rather their time of travel was assessed to determine evacuation criterion. While the raw data obtained from these experiments has not been made available for the present reanalysis project, a number of evacuation criterion have been presented within published literature and are discussed below.

An evacuation criterion of V^2D = 1.2 was derived by Ishigaki et al. (2005) based on testing of evacuation time for 16 females and 33 males in water depths between 0.1 and 0.4 m and velocities of 0.5 to 1.125 ms^{-1}. Later testing (Ishigaki et al., 2008a, 2008b, 2009) was undertaken using young males (mean age = 25.8 years) to simulate aged persons by adding weights to the subjects' ankles and wrists. Using this method the authors estimate that aged persons about 70 years old have a walking speed of approximately 80% that of a normal male. Using these data, a number of criterion were derived by the authors including *criterion for safe evacuation* and *critical criterion of self-evacuation* for both normal and aged males. These criterion are based on a specific force per unit width (M_0 in Eqn. 5), with suggested critical values presented within Table 4 and compared to experimental data from other studies within Figure 6.

$$M_0 = V^2 D / g + D^2 / 2 \tag{5}$$

Table 4 Suggested evacuation criterion (Ishigaki et al. (2009).

Criterion	M_0
Safe evacuation for aged male	0.1
Safe evacuation for normal male	0.125
Critical criterion of self-evacuation for aged male	0.2
Critical criterion of self-evacuation for normal male	0.25

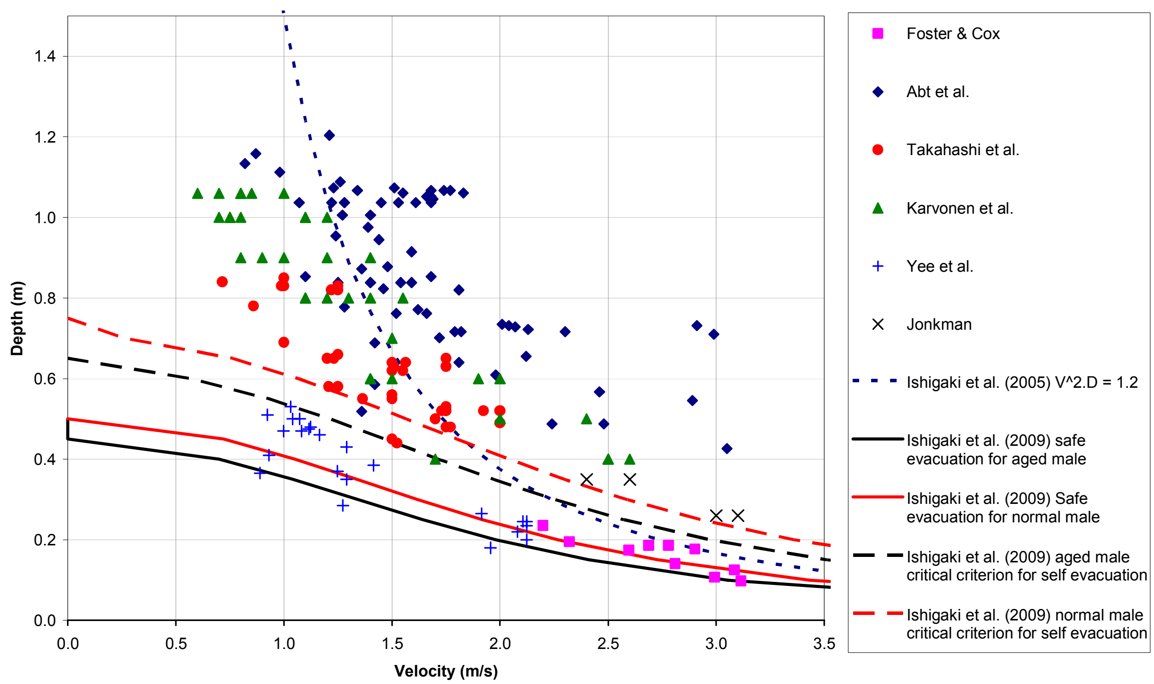

Figure 6 Comparison of Ishigaki et al. (2009) evacuation criterion with all available experimental data.

Results show good agreement between the *safe evacuation criterion* and the lower stability envelope of experimental data. Similarly, the *critical criterion for self evacuation* of normal males correlates well with the FHRC *stuntman* results reported in Jonkman and Penning-Rowsell (2008). The criterion of Ishigaki et al. (2009) match experimental data less well in deeper water (D > 0.5 m). This is attributed to a difference in definition, with the Ishigaki et al. (2009) criterion based on evacuation along both corridors and stairs, and due to the criterion being developed using experiments undertaken exclusively at depths < 0.5 m. The earlier criterion of $V^2D = 1.2$ (Ishigaki et al., 2005) closely approximates the mean adult experimental data through the entire depth and velocity range, although the criterion lies below most of the Abt et al. (1989) data.

3. Reanalysis of Experimental Data

A plot of the relationship between human (H.M; mkg) and flow regime (D.V; m^2s^{-1}) utilizing all available experimental data for persons standing or walking in flows is presented within Figure 7. Significant scatter is observed within the data. This scatter may be attributed, in part at least, to a number of external parameters including: test surface material; subject actions (standing or moving), experience and training, clothing and footwear and physical attributes additional to height and mass including muscular development and/or other disability; the definition of stability limit (i.e. feeling unsafe or complete loss of footing).

The use of human size characteristics (H.M) as an independent variable in defining general flood flow safety guidelines is not considered practical given the wide range in such characteristics within the population. In order to define safety limits which are applicable for all persons, hazard regimes are defined for adults (H.M > 50 mkg) and children (H.M = 25 to 50 mkg). Infants and very young children (H.M < 25 mkg) are considered unsafe in any flow without adult support. These hazard regimes are plotted together with available experimental data as a function of flow depth and velocity in Figure 8.

Low hazard regimes are indicated where D.V < 0.4 m^2s^{-1} for children (H.M = 25 to 50 mkg) and D.V < 0.6 m^2s^{-1} for adults (H.M > 50 mkg). These regimes encapsulate all data points except for very small children (H.M < 25 mkg) suggesting that, excluding adverse environmental parameters, all persons (other than very small children and frail older persons) should be able to navigate waterways regardless of experience in the low hazard regime.. A moderate hazard zone which is dangerous for some adults and all children is defined between D.V = 0.6 to 0.8 m^2s^{-1}. The flow value of D.V = 0.8 m^2s^{-1} defines the limit at which a professional stuntman began to lose footing within the Jonkman and Penning-Rowsell (2008) experiments and thus may be inferred to define the limiting working flow for experienced personal such as trained rescue workers. Between flow values of D.V = 0.8 to 1.2 m^2s^{-1} is a zone of significant risk (dangerous to most), with a flow value of 1.2 appearing to provide an upper limit on tolerable flow for all experiments and across all human size characteristics except for the upper 'trained' Abt et al. (1989) data.

Due to limitations of experimental data at depths greater than 1.2 m for adults and 0.5 m for children and at velocities greater than 3.2 ms^{-1}, these are suggested as upper bounds on the applicability of safety values. This upper depth limit of 1.2 m for adults is in agreement with that suggested by Emergency Management Australia advice (Cox et al., 2004) and is theoretically justified as subject buoyancy will rapidly decrease stability at greater depth, with safety then becoming dependent on swimming ability. This is an assumption which cannot be made for the population as a whole, especially children where an upper depth limit of 0.5 m is suggested. Similarly, a number of the subjects within experimental tests commented that maintaining footing was difficult in very rapid flows regardless of depth (Jonkman and Penning-Rowsell, 2008). Based on these comments and the lack of data at velocities greater than 3.2 ms^{-1}, specifying an upper bound of 3ms^{-1} on the applicability of safety values is prudent.

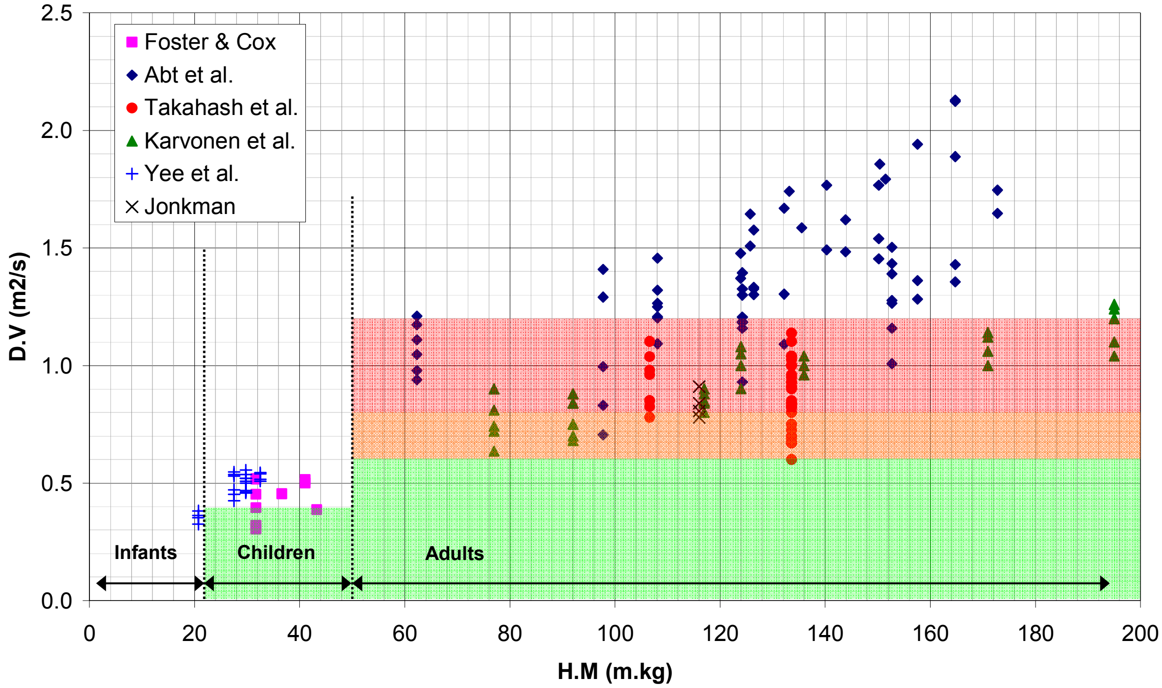

Figure 7 Flow values (D.V) indicating hazard regime as a function of subject height (H) and mass (M) for all experimental data sources. A low hazard zone ( ) is indicated for children (H.M = 25 to 50 mkg) and adults (H.M > 50 mkg). A moderate hazard zone ( ) which is dangerous for some adults is indicated, with D.V = 0.8 defining an upper working limit for trained adults. A significant hazard zone ( ) which is dangerous for most adults is indicated, with higher D.V values (D.V > 1.2m^2s^{-1}) constituting extreme hazard, dangerous for all adults.

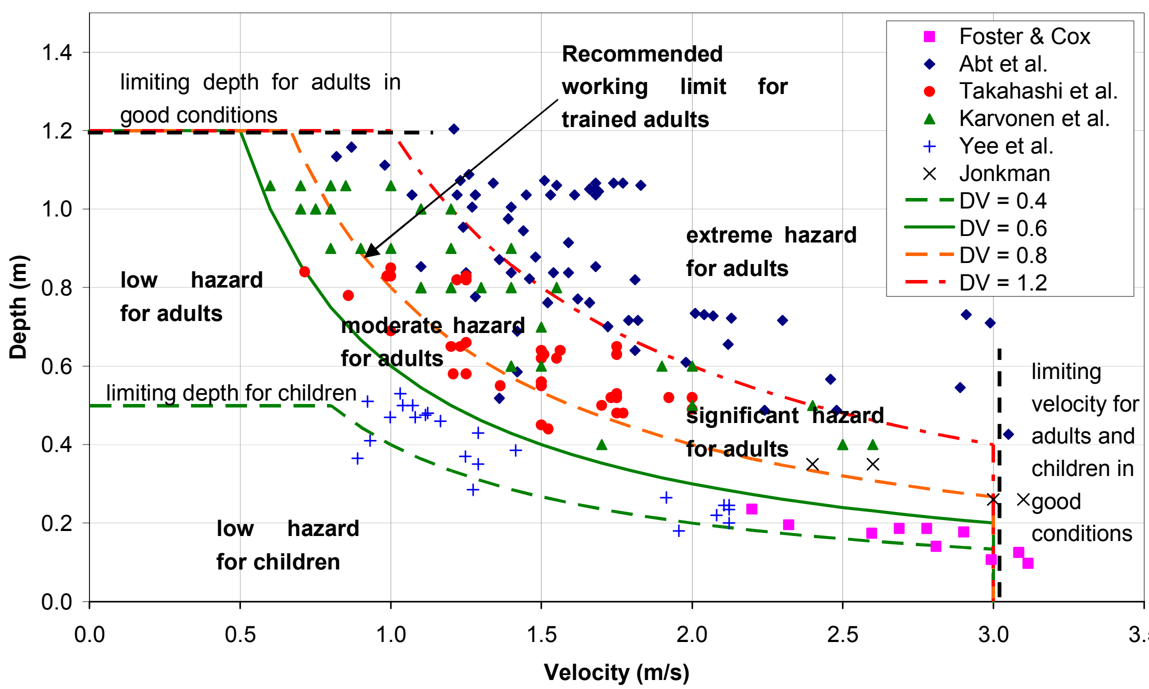

Figure 8 Proposed hazard regimes as a function of depth and velocity and compared to available experimental data.

While tests of stability while sitting have been excluded from analysis within Figures 7 and 8, studies have shown that once footing is lost stability is further reduced due to the greater surface area presented to the flow and that footing is unlikely to be regained unless a reduction in flow conditions occurs (Cox et al., 2004).

4. Conclusions and Recommendations

Human stability within floodways has been found to be dependent on many factors. The two most important factors are flow depth and velocity, with depth found to dictate whether loss of stability is by sliding (friction) or tumbling (moment) failure. High depths increase buoyancy and reduce friction underfoot typically resulting in tumbling failure while low depth-high velocity flows may cause sliding instability. Cox et al. (2004) suggest that high depth, low velocity flows are more dangerous as, once footing is lost, a person is more likely to be swept away and drowned.

Over the last four decades, a number of laboratory-based experimental studies have been undertaken within Australia and internationally to define the limits of stability within differing flow regimes. Significant scatter is observed within the individual data sets and, to a more significant degree, when all data sets are combined. This scatter may be attributed to a number of external parameters including the test surface material, required subject actions, subject experience, clothing and footwear and the definition of stability limit.

Based on the results of these studies, a number of empirical and computational models have been derived to predict safe flow thresholds. However, due to the typical exclusion of the above variables, model agreement with experimental data has often been poor. The current Australian Rainfall and Runoff (ARR) guidelines (I.E.Aust, 1987) stipulate that "*to prevent pedestrians being swept along streets and other drainage paths during major storm events, the product of velocities and depths in streets and major flow paths generally should not exceed 0.4 m^2/s*".

Two sets of safety criteria have been developed based on re-analysis of data collected during previous laboratory and field investigations. For children with a height and mass product (H.M) of between 25 and 50, low hazard exists for flow values of D.V < 0.4 m^{2}s^{-1}, with a maximum flow depth of 0.5 m regardless of velocity and a maximum velocity of 3.0 ms^{-1} at shallow depths (D < 0.2 m). Under these flow regimes, the children tested retained their footing and felt *"safe"* in the flow. For adults (H.M > 50), low hazard exists for flow values of D.V < 0.6 m^{2}s^{-1} with a maximum depth limit of 1.2 m and a maximum velocity of 3.0 ms^{-1} at shallow depth (D < 0.3 m). Moderate hazard exists between D.V = 0.6 and 0.8 m^{2}s^{-1}, with a tolerable working flow regime of D.V < 0.8 m^{2}s^{-1} recommended for trained safety workers or experienced and well equipped persons. Significant hazard exists between D.V = 0.8 to 1.2 m^{2}s^{-1}, with the upper limit of stability observed during the majority of investigations of D.V = 1.2 m^{2}s^{-1}. Above this flow rate hazard is extreme and should not be considered safe for standing or traversing.

Hazard regimes as a function of limiting flow values for infants, children and adults are presented within Table 5

Table 5 Flow hazard regimes for infants, children and adults

<table>
<tr><th>DV (m^2s^{-1})</th><th>Infants, small children (H.M ≤ 25) and frail/older persons</th><th>Children (H.M = 25 to 50)</th><th>Adults (H.M > 50)</th></tr>
<tr><td>0</td><td>Safe</td><td>Safe</td><td>Safe</td></tr>
<tr><td>0 – 0.4</td><td rowspan="5">Extreme Hazard; Dangerous to all</td><td>Low Hazard[1]</td><td rowspan="2">Low Hazard[1]</td></tr>
<tr><td>0.4 – 0.6</td><td>Significant Hazard; Dangerous to most</td></tr>
<tr><td>0.6 – 0.8</td><td rowspan="3">Extreme Hazard; Dangerous to all</td><td>Moderate Hazard; Dangerous to some[2]</td></tr>
<tr><td>0.8 – 1.2</td><td>Significant Hazard; Dangerous to most[3]</td></tr>
<tr><td>> 1.2</td><td>Extreme Hazard; Dangerous to all</td></tr>
</table>

[1] Stability uncompromised for persons within laboratory testing program at these flows (to maximum flow depth of 0.5 m for children and 1.2 m for adults and a maximum velocity of 3.0 ms^{-1} at shallow depths).
[2] Working limit for trained safety workers or experienced and well equipped persons (D.V < 0.8 m^2s^{-1})
[3] Upper limit of stability observed during most investigations (D.V > 1.2 m^2s^{-1})

It should however be noted that loss of stability could occur in lower flows when adverse conditions are encountered including:

- **Bottom conditions**: uneven, slippery, obstacles;
- **Flow conditions**: floating debris, low temperature, poor visibility, unsteady flow and flow aeration;
- **Human subject**: standing or moving, experience and training, clothing and footwear, physical attributes additional to height and mass including muscular development and/or other disability, psychological factors;
- **Others**: strong wind, poor lighting, definition of stability limit (i.e. feeling unsafe or complete loss of footing).

As described within Cox et al. (2003), there is a lack of test data for very young children and frail/older persons. These populations are unlikely to be safe in any flow regimes and as such, care is required in locating aged care and retirement villages as well as childcare centres and kindergartens.

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Appendix E – MUSICLink Report

THE CITY OF NEWCASTLE

MUSIC-*link* Report

Project Details		Company Details	
Project:	Mosbri Crescent	**Company:**	Northrop Consulting Engineers
Report Export Date:	20/12/2021	**Contact:**	Jamie Carroll
Catchment Name:	211217_NL180367_MUSIC_No Bio_JC	**Address:**	[redacted]
Catchment Area:	1.063ha	**Phone:**	[redacted]
Impervious Area*:	80.83%	**Email:**	[redacted]
Rainfall Station:	61078 WILLIAMTOWN		
Modelling Time-step:	6 Minutes		
Modelling Period:	1/01/1995 - 31/12/2008 11:54:00 PM		
Mean Annual Rainfall:	1125mm		
Evapotranspiration:	1735mm		
MUSIC Version:	6.3.0		
MUSIC-link data Version:	6.34		
Study Area:	Newcastle		
Scenario:	Newcastle		

* takes into account area from all source nodes that link to the chosen reporting node, excluding Import Data Nodes

Treatment Train Effectiveness		Treatment Nodes		Source Nodes	
Node: Receiving Node	**Reduction**	**Node Type**	**Number**	**Node Type**	**Number**
Flow	29.5%	Buffer Node	2	Urban Source Node	8
TSS	85%	Rain Water Tank Node	4		
TP	76.2%	Detention Basin Node	2		
TN	60.7%	Generic Node	2		
GP	99.1%				

Comments

Passing Parameters

Node Type	Node Name	Parameter	Min	Max	Actual
Buffer	Grassed area buffer NORTH	Proportion of upstream impervious area treated	None	None	0.75
Buffer	Grassed area buffer SOUTH	Proportion of upstream impervious area treated	None	None	0.75
Detention	SPELFilter Vault Full Height	% Reuse Demand Met	None	None	0
Detention	SPELFilter Vault Full Height	% Reuse Demand Met	None	None	0
Detention	SPELFilter Vault Full Height	Hi-flow bypass rate (cum/sec)	None	99	99
Detention	SPELFilter Vault Full Height	Hi-flow bypass rate (cum/sec)	None	99	99
Rain	Below Ground Reuse	% Reuse Demand Met	70	None	83.20
Rain	Below Ground Reuse	% Reuse Demand Met	70	None	79.9729
Rain	Rainwater Tank	% Reuse Demand Met	70	None	80.41
Rain	Townhouse RWT's	% Reuse Demand Met	70	None	79.94
Receiving	Receiving Node	% Load Reduction	None	None	29.5
Receiving	Receiving Node	GP % Load Reduction	90	None	99.1
Receiving	Receiving Node	TN % Load Reduction	45	None	60.7
Receiving	Receiving Node	TP % Load Reduction	65	None	76.2
Receiving	Receiving Node	TSS % Load Reduction	85	None	85
Urban	BLDG A & B ROOF	Area Impervious (ha)	None	None	0.327
Urban	BLDG A & B ROOF	Area Pervious (ha)	None	None	0
Urban	BLDG A & B ROOF	Total Area (ha)	None	None	0.327
Urban	Catchment NORTH	Area Impervious (ha)	None	None	0.205
Urban	Catchment NORTH	Area Pervious (ha)	None	None	0.121
Urban	Catchment NORTH	Total Area (ha)	None	None	0.327
Urban	Catchment SOUTH	Area Impervious (ha)	None	None	0.080
Urban	Catchment SOUTH	Area Pervious (ha)	None	None	0.082
Urban	Catchment SOUTH	Total Area (ha)	None	None	0.163
Urban	Driveway bypass E	Area Impervious (ha)	None	None	0.009
Urban	Driveway bypass E	Area Pervious (ha)	None	None	0
Urban	Driveway bypass E	Total Area (ha)	None	None	0.009
Urban	Highrise SOUTH	Area Impervious (ha)	None	None	0.113
Urban	Highrise SOUTH	Area Pervious (ha)	None	None	0
Urban	Highrise SOUTH	Total Area (ha)	None	None	0.113
Urban	Mobsbri 3beds NORTH	Area Impervious (ha)	None	None	0.065
Urban	Mobsbri 3beds NORTH	Area Pervious (ha)	None	None	0
Urban	Mobsbri 3beds NORTH	Total Area (ha)	None	None	0.065
Urban	Mosbri 3beds SOUTH	Area Impervious (ha)	None	None	0.037
Urban	Mosbri 3beds SOUTH	Area Pervious (ha)	None	None	0
Urban	Mosbri 3beds SOUTH	Total Area (ha)	None	None	0.037
Urban	Urban	Area Impervious (ha)	None	None	0.022
Urban	Urban	Area Pervious (ha)	None	None	0
Urban	Urban	Total Area (ha)	None	None	0.022

Only certain parameters are reported when they pass validation