Six-minute pluviograph data was used for the five year period of rainfall data from 1/7/1959 to 31/6/1964 from the Williamtown station. The average rainfall for this period is 1,326 mm/yr, the dataset contains the highest recorded rainfall over a five-year period for the Williamtown station. As such, this is the best available dataset to represent a 5-year period at Tea Gardens.

3.4.2 Evaporation

Monthly areal potential evapotranspiration values were obtained for Tea Gardens from the Bureau of Meteorology data and are shown in **Table 3–2**.

Table 3–2 – Monthly Areal Potential Evapotranspiration

Month	Areal Potential Evapotranspiration (*mm*)
January	185
February	140
March	140
April	95
May	65
June	50
July	50
August	68
September	95
October	140
November	155
December	175
Total	**1358**

3.4.3 Soil Data

A rainfall-runoff calibration was undertaken for existing site conditions. The following parameters within the model were calibrated, based on the typical deep sandy soil conditions that are encountered on the site:

- Rain threshold (impervious area);
- Soil storage capacity (pervious area);
- Initial storage (pervious area);

- Field capacity (pervious area);
- Daily baseflow (groundwater) and
- Daily deep seepage (groundwater).

These soil parameters also allow for the high groundwater table.

All MUSIC models are automatically created with default parameters of soil storage capacity and field capacity, which represent Brisbane soil conditions. Appendix A of the MUSIC manual (v3, 2005) presents typical values of the soil storage and field capacities for the Australian capital cities. The values adopted in the Myall River Downs modelling are between the values presented for Sydney and Brisbane.

The daily deep seepage rate for the Myall River Downs model was increased from zero to one percent, to acknowledge the groundwater recharge process which occurs on-site. In calculating the quantity of pollutants exported from site, this loss to daily deep seepage was quantified (refer to **Table 3–6, Table 3–8** and **Table 3–9**).

Table 3–3 shows the adopted soil properties, all of the adopted parameters are well within the typical ranges allowed for by MUSIC (v3, 2005).

The model generates a volumetric runoff coefficient (C_v) of **0.30** for the existing site conditions when a 1% daily deep seepage is applied to the source nodes. The C_v marginally increases to 0.33 with 0% daily deep seepage.

Table 3–3 – Soil Properties

Parameter	MUSIC Default	Calibrated
Impervious		
Rain threshold	1	**2.5***
Pervious		
Soil Storage Capacity	120	**150***
Initial Storage	30	**25***
Field Capacity	80	**100***
Infiltration - a	200	**200**
Infiltration - b	1	**1**
Groundwater		
Initial depth	10	**10**
Daily recharge	25	**25**
Daily baseflow	5	**4***
Daily deep seepage	**0**	**1***

*denotes parameters that have been changed from default values

3.4.4 Pollutant Concentrations

The pollutant concentrations used for the various land-uses in the existing and developed catchments were derived from default MUSIC values and "*Stormwater Flow and Quality and the Effectiveness of Non-proprietary Stormwater Treatment Measures*" by the CRCCH and the Department of Civil Engineering at Monash University by Fletcher, Duncan et al, which was provided by the NSW EPA and is soon to be published (*i.e. this represents the most recent available data*). The adopted pollutant concentrations are shown in **Table 3–4**.

Table 3–4 – Adopted Pollutant Concentrations

	Pollutant Concentration (mg/L)					
	Wet Weather Concentration (mg/L)			**Dry Weather Concentration (mg/L)**		
	Suspended Solids	**Total Phosphorous**	**Total Nitrogen**	**Suspended Solids**	**Total Phosphorous**	**Total Nitrogen**
Source values used to approximate specific values						
Forested (*Fletcher, Duncan et al*)	40	0.08	0.9	6	0.03	**0.3**
General Urban (*Fletcher, Duncan et al*)	140	0.25	2	16	0.14	**1.3**
Rural (*Fletcher, Duncan et al*)	90	0.22	2	14	0.06	**0.9**
Local Existing Land Use						
Forested	40	0.08	0.9	6	0.03	**0.3**
Rural	90	0.22	2	14	0.06	**0.9**
Post-Developed Land Use						
Residential / Industrial	140	0.25	2	16	0.14	**1.3**
Trunk Drainage	40	0.08	0.9	6	0.03	**0.3**
Open Space / Parkland / Lake	**90**	**0.22**	**2**	**14**	**0.06**	**0.9**

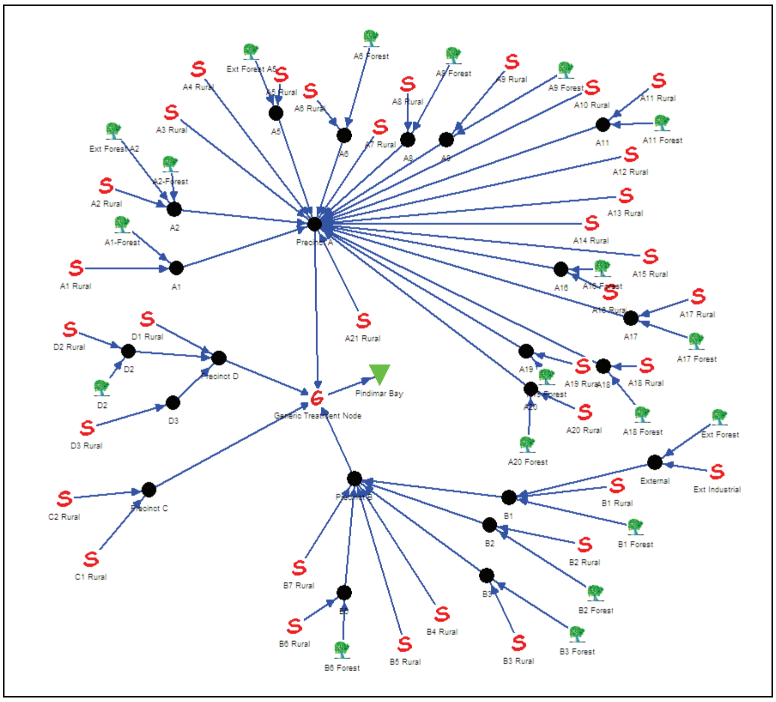
3.5 Existing Conditions

3.5.1 Model Inputs

The primary objective is to achieve a no nett increase in pollutant export relative to existing conditions. Therefore, the existing pollutant export from the site was estimated to establish the base case against which to measure the performance of the proposed development.

The existing catchment is defined in **Figure 8** and the data in **Table 3–5** was used to create a MUSIC model for the site. **Diagram 3-1** shows the MUSIC model network which was used to represent existing conditions.

Diagram 3-1 MUSIC Model Network (Existing Conditions)



Subcatchments that contain waterbodies have been modelled as partially impervious, this has been determined based on site inspections and aerial photography. Catchments with waterbodies are predominantly located in the forested catchments. As the existing model has been configured using a combination of forest and rural nodes through a number of subcatchments, the percentage impervious of forested subcatchments is also shown.

Table 3–5 – Existing Catchment Data

Sub Catchment	Area (*ha*)	Forest (%)	% Forest that is Impervious (Waterbody)
A1	3.15	30	0
Ext A2_1	17.22	100	0
A2	2.33	5	0
A3	5.24	0	-
A4	7.61	0	-
Ext A5_1	35.89	100	0
A5	4.55	0	-
A6	7.10	20	0
A7	5.41	0	-
A8	4.87	20	0
A9	4.12	10	0
A10	8.12	0	-
A11	2.09	10	30
A12	10.21	0	-
A13[1]	14.38[1]	0	-
A14	10.13	0	-
A15	7.08	0	0
A16	1.80	10	30
A17	2.72	10	0
A18	1.77	10	0
A19	1.17	10	30
A20	3.53	30	30
A21	8.22	0	-
Ext B1_1	22.93	100	0
Ext B1_2[2]	22.28[2]	0	-
B1	6.05	20	0
B2	5.66	10	20

[1] Subcatchment A13 was modelled as 50% impervious as it contains the existing sand mine waterbody.

[2] Subcatchment Ext B1_2 is the existing industrial area and was modelled as 80% impervious.

Sub Catchment	Area (*ha*)	Forest (%)	% Forest that is Impervious (Waterbody)
B3	2.37	30	20
B4	7.39	0	-
B5	8.35	0	-
B6	13.18	10	30
B7	9.38	0	-
C1	9.17	0	-
C2	4.81	0	-
D1	3.20	0	-
D2	10.10	5	0
D3	6.45	0	-
Total	**300**		

Based on **Table 3–5**, the land area within the Myall River Downs site boundary is 3% impervious (or a waterbody). As there is a significant amount of impervious land in Ext B1_2, the percentage impervious of the total catchment is 9% impervious.

3.5.2 Model Results

The calibrated MUSIC model was used to simulate pollutant export generated during a mean rainfall and evaporation year using the typical pollutant concentrations contained in **Table 3–4**.

For the purposes of comparing the post-development case with the existing case, the estimated annual export of pollutants generated by the site are shown in **Table 3–6**.

Additional modelling was undertaken to account for water lost to daily deep seepage, and its associated pollutants. Duplicate models were created with 0 % infiltration from the source nodes into deep seepage for both the existing and developed scenarios and a 0 mm/hr seepage in the infiltration basins modelled in the developed scenario.

The additional pollutant load ‘lost’ to groundwater was determined by calculating the difference in flows (ML/yr) in both the ‘with seepage’ and ‘without seepage’ models for both existing and developed scenarios. This additional flow was then multiplied by the EMC values published by Duncan et al, for the dry weather concentrations of a Forest/Natural land-use. This approximates the expected characteristics of groundwater flows.

Table 3–6 – Annual Pollutant Export Loads – Existing State

Scenario	Pollutant Load (*kg/yr*)		
	Suspended Solids	**Total Phosphorous**	**Total Nitrogen**
Existing State (with 1% seepage)	66,900	157	**1,530**
Flow Lost through Seepage	**120 mL/y**		
Existing State (incorporation of additional flows and pollutants generated from seepage)	**67,620**	**160.6**	**1,566**

3.6 Developed Conditions (*No Treatment*)

3.6.1 Model Inputs

To assess the treatment requirements, the existing state model was modified to reflect the degree of possible development. No treatment techniques were implemented in the developed (*no treatment*) model. The model was modified to reflect the impervious proportions of the catchment as defined in **Table 3–7**. The annual runoff coefficient for post-development conditions was calculated to be **0.51**.

It should be noted that the model was revised in accordance with the latest concept plan, to replace the marina and eco-resort in subcatchments D1, D2 and D3 with a conservation area (forest).

Table 3–7 – Developed Catchment Data

Sub Catchment	Land use	Area (ha)	Impervious Fraction
A1	Trunk Drainage	3.15	**0.5**
Ext_A2	Forest	17.22	**0**
A2	Trunk Drainage	2.33	**0.5**
A3	Residential	5.24	**0.6**
A4	Residential	7.61	**0.6**
Ext_A5	Forest	35.89	**0**
A5	Trunk Drainage	4.55	**0.5**
A6	Residential	7.10	**0.6**
A7	Residential	5.41	**0.6**
A8	Residential	4.87	**0.6**
A9	Trunk Drainage	4.12	**0.5**
A10	Residential	8.12	**0.6**

Sub Catchment	Land use	Area (ha)	Impervious Fraction
A11	Trunk Drainage	2.09	**0.5**
A12	Residential	10.21	**0.6**
A13	Lake	14.38	**0.7**
A14	Residential	10.13	**0.6**
A15	Residential	7.08	**0.6**
A16	Trunk Drainage	1.80	**0.5**
A17	Residential	2.72	**0.6**
A18	Trunk Drainage	1.77	**0.5**
A19	Trunk Drainage	1.17	**0.5**
A20	Trunk Drainage	3.53	**0.5**
A21	Residential	8.22	**0.6**
Ext B1_1	Forest	22.93	**0**
Ext B1_2	Industrial	22.28[2]	**0.8**
B1	Industrial	6.05	**0.85**
B2	Park	5.66	**0.1**
B3	Trunk Drainage	2.37	**0.5**
B4	Residential	7.39	**0.6**
B5	Residential	8.35	**0.6**
B6	Residential	13.18	**0.6**
B7	Residential	9.38	**0.6**
C1	Residential	9.17	**0.6**
C2	Residential	4.81	**0.6**
D1	Forest	3.20	**0.3**
D2	Forest	10.10	**0**
D3	Forest	6.45	**0**
	Total	**300**	**0.42**

In the developed conditions model, the impervious threshold value (depression storage) was reduced based on a composite of various impervious surfaces, as listed below:

- Threshold for both road surfaces and paved areas of 2.5 mm; and
- Threshold for roofs of 1 mm.

Crighton Properties advised that a typical lot would be 600 m^2 in area. A typical 3-bedroom single storey development would have a plan area in the order of 250 m^2. Based on the assumption that the lots would be 60% impervious, the lots would be comprised of 250 m^2 of roof area and 110 m^2 of paved surface. In an urban environment of 80% lots and 20% road, the depression storage would be 1.7 mm. Hence, the impervious threshold in the developed model was modelled as 1.7 mm.

It should also be recognised that the change in landuse along the drainage corridor would lead to an improvement in pollutant concentration. The removal of cattle would improve the quality of runoff through the subcatchments, particularly in the area of the existing channel north of subcatchment A9. Through the lower reaches of the site where the drainage corridor is in good condition, the functional riparian corridor will be widened.

3.6.2 Model Results

Additional modelling, as described in **Section 3.5.2** was undertaken to account for water lost to daily deep seepage and its associated pollutants was undertaken in the analysis of the Developed Conditions without Treatment scenario. Duplicate models were created with 0 % infiltration from the source nodes into deep seepage for both the existing and developed scenarios and a 0 mm/hr seepage in the infiltration basins modelled in the developed scenario.

The additional pollutant load 'lost' to groundwater was determined by calculating the difference in flows (ML/yr) in both the 'with seepage' and 'without seepage' models for both existing and developed scenarios. This additional flow was then multiplied by the EMC values published by Duncan et al, for the dry weather concentrations of a Forest/Natural land-use. This approximates the expected characteristics of groundwater flows.

The estimated annual export of pollutants from the developed (*no treatment*) site are compared with the existing conditions in **Table 3–8**.

Table 3–8 – Annual Pollutant Export Loads – Developed State (No Treatment)

Existing Conditions Scenario	Pollutant Load (*kg/yr*)		
	Suspended Solids	Total Phosphorous	Total Nitrogen
Developed State (1% Seepage, *No Treatment*)	189,000	361	3,040
Flow Lost through Seepage	90 ML/y		
Developed State (no treatment, incorporation of flows lost through seepage)	189,540	364	3,067

3.7 Proposed Conditions (With Treatment)

The proposed water management strategy was incorporated into the model and simulated (*refer* ***Figure 9***). The strategy consists of wetlands, bioretention systems and infiltration areas.

3.7.1 Bio-retention/Infiltration Areas

Bio-retention/infiltration areas (raingardens or leaky wells) promote filtration of stormwater in order to remove pollutants typically found in urban runoff (*i.e. TN, TP and TSS)*. Bio-retention/infiltration areas would be located on lots, within road reserves, open spaces and trunk drainage corridors. These areas would be planted with native grasses and fringe vegetation on a layer of coarse sand and soil.

A drainage system would be constructed beneath the infiltration area to encourage seepage into groundwater. It is considered that infiltration provides a key part of the water management strategy. The existing wetlands are supported by acid groundwater percolated through in-situ peat layers (*pers comm* Geoff Winning, Hunter Wetlands Research), therefore the infiltration is to be promoted under developed conditions to maintain this regime. A depth of filter media of 600 mm and extended detention depth of 200 mm were modelled.

As part of the LES, falling head tests were conducted across the site. The slowest measured seepage rate of 54.16 mm/hr has been adopted in MUSIC to estimate infiltration losses. This is a conservative estimate as much higher rates were measured on the site.

Rainwater tanks or leaky wells could be used in place of or in addition to infiltration areas. Rainwater tanks would capture roof runoff for non-potable reuse and would have the additional benefit of reducing potable water consumption.

In order to ensure that the bio-retention/infiltration areas would be able to be constructed above the groundwater table, extensive collaboration was undertaken with Martens Consulting Engineers. Martens undertook groundwater monitoring and modelling per their report titled Preliminary Hydrogeological Study and Concept Groundwater Management Plan, Myall River Downs, Tea Gardens, NSW. The results of groundwater modelling indicated that sufficient depth (in the order of 800 mm to 2 m) was available for the installation of filter media.

3.7.2 Wetlands

Wetlands would be created within the trunk drainage corridors by excavating up to 1.5 m below the channel base. These wetlands would be in contact with groundwater and hence, runoff must be pre-treated before it arrives at the wetlands to a quality equal or better than the groundwater quality.

The trunk drainage corridors will be separated from incoming ocean flows to RL 1.4 m AHD, which represents mean high water plus a sea level rise of 0.9 m.

Constructed wetland systems use sedimentation, filtration and pollutant uptake processes to remove pollutants from stormwater runoff. A wetland system can be constructed to provide allowance for detention volume (*extended detention*) to aid in the stormwater quantity management. Extended detention is no longer proposed for any wetlands within the trunk drainage corridors of Myall River Downs.

Due to the extremely flat nature of the trunk drainage corridors, the resultant flow velocities are predicted to be low in the channels and wetlands. As the proposed development would have relatively flat grading and a series of wetlands through the drainage channels, it is unlikely that erosion would be a problem through the drainage corridor.

To account for the occasional inundation of the channels by marine water, the proposed wetlands would be brackish where required. This would not affect the ability of the wetlands to function as stormwater quality control measures.

The runoff from the site would pass through wetlands prior to discharge from the site. It is important that the runoff from the proposed development mimic the existing hydrology especially for smaller storms. This will mean that the supply of freshwater over the longer term will remain similar, as if the existing landform were not developed. It is proposed that the permanent hydraulic controls would be implemented on the development to ensure that the environmental flow (up to the 1-year ARI storm) distribution would remain similar to the existing conditions. The flow regime to the west of the sand mine will be maintained following development, as well as the flow to the east to the Wallum Froglet habitat as addressed in **Section 2.6**. The structures to ensure environmental flows are maintained would be designed in a more detailed study, concurrent with adjacent landform design.

The annual flows along the eastern corridor to the Wallum Froglet habitat, were calculated utilising the MUSIC models. The models were configured to direct the external catchments along the eastern drainage corridor. Flows from the external catchments and also catchments B1 to B6 (inclusive) combine to produce an annual flow of 407.5 ML for the existing scenario and 397.4 ML for the developed scenario. Hence, the proposed development would maintain the existing flows through the habitat, and based on the MUSIC modelling, flows in the proposed development would not be significantly different to those in the existing scenario in an average year.

An investigation by Hunter Wetlands Research "Effect of Stormwater Basins on Water Quality in Frog Habitat in the Vicinity of Myall River Downs, Tea Gardens" (2008) was undertaken to determine the effect of the already constructed stormwater basins (constructed in 2000) at Myall River Downs and the adjoining Tea Gardens Grange. The investigation addressed concerns from Great Lakes Council that a further basin to be constructed for an aged-care facility at Myall River Downs may adversely affect nearby Wallum Frog habitat. The existing basins do not discharge surface water into the identified Wallum Frog habitat, and as such, the report addressed whether infiltration to groundwater from the basins affect groundwater or its surface water expression in the frog habitat. The report concluded that:

"Overall, the data indicate no evident impact on water quality within the Wallum Frog habitat area or other remnant habitat areas of water infiltrating into these areas from constructed stormwater basins. Indeed, the quality of water within the stormwater basins at the time of sampling was of high quality, comparable to background levels."

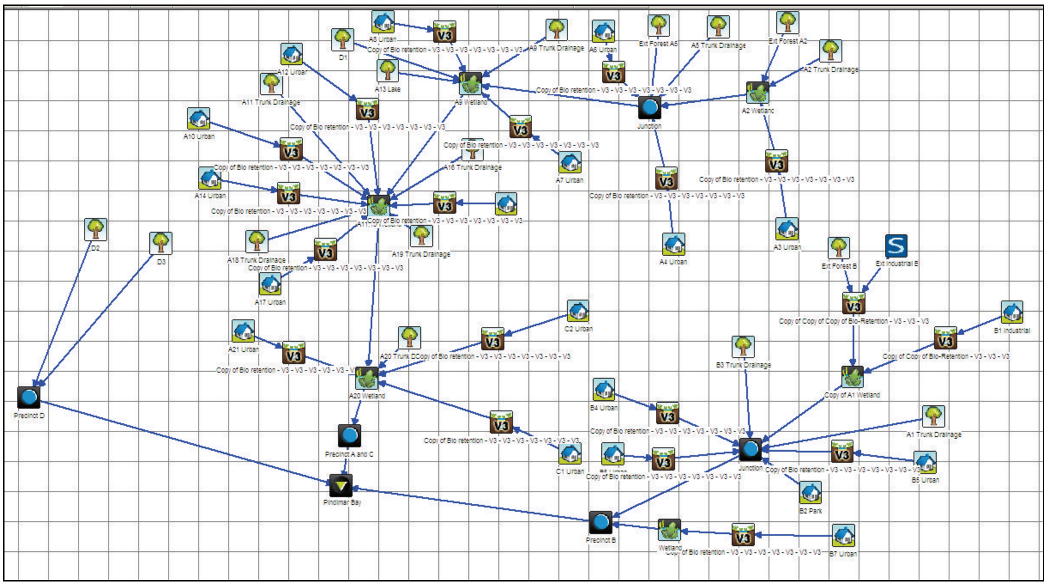
3.7.3 Vegetated Swales

Vegetated swales are depressed landscaped areas that remove gross pollutants through physical entrapment and nutrient uptake by plants. Vegetated swales have been located along minor drainage links, which discharge to the trunk drainage corridors.

3.7.4 Model Results

The water quality controls were incorporated into the MUSIC model for the developed scenario. **Diagram 3-2** shows the MUSIC subcatchment layout for the post developed conditions with treatment including infiltration, swales and wetlands.

Diagram 3-2 MUSIC Model Network (Developed Conditions – With Treatment)



The estimated annual export of pollutants from the developed (*with treatment*) site are presented in **Table 3–9,** a comparison of the three scenarios is presented in **Table 3–10**.

The annual runoff coefficient was calculated to be **0.29**, which is less than for the developed (*no treatment*) case and reflects the use of infiltration areas within the site.

Table 3–9 - – Annual Pollutant Export Loads – Developed (with treatment) Conditions

Scenario	Pollutant Load (*kg/yr*)		
	Suspended Solids	Total Phosphorous	Total Nitrogen
Prior to Wetlands			
Developed State (1% Seepage, with *Treatment*)	40,100	106	1,200
Flow Lost through Seepage	860 ML/yr		
Developed State (with treatment, incorporation of flows lost through seepage)	45,260	132	1,458
After Wetlands			
Developed State (1% Seepage, with *Treatment*)	33,400	109	1,290
Flow Lost through Seepage	860 ML/y		
Developed State (with treatment, incorporation of flows lost through seepage)	38,560	135	1,548

Table 3–10 – Annual Pollutant Export Loads – Comparison

Scenario	Pollutant Load (*kg/yr*)		
	Suspended Solids	Total Phosphorous	Total Nitrogen
Existing State	67,620	161	1,566
Developed State (*No Treatment*)	189,540	364	3,067
Developed State (W*ith Treatment – prior to wetlands*)	45,260	132	1,458
Reduction In Pollutants	**76%**	**64%**	**52%**
Developed State (W*ith Treatment – following wetlands*)	38,560	135	1,548
Reduction In Pollutants	**80%**	**63%**	**50%**

Note: All pollutant loads in Table 3.10 incorporate the flows and pollutants lost to seepage.

Table 3–10 shows that the water quality objective of maintaining pollutant export rates in the developed scenario at levels equivalent to the existing condition has been readily achieved. In fact there has been considerable improvement in the sediment and nutrient load discharged from the site. This would contribute to the long term improvement in receiving water quality.

The reduction in pollutant export (Developed State (No Treatment) compared Developed State (With Treatment) exceeds the DECC requirements of 80% reduction in suspended solids export and 45% reduction in nutrient export.

The results from **Table 3–10** support the claim that there would be an overall contribution to improving the receiving water quality.

3.8 Water Balance

The following table provides a summary of the site water balance as predicted by MUSIC. This table illustrates the various streams of water on the site, with rainfall being the input and evapotranspiration, runoff and deep seepage (to groundwater) being the outputs. In the MUSIC model, runoff is comprised of surface flow and baseflow, considered to be shallow groundwater flows that resurface.

Table 3–11 – Site Water Balance

Scenario	Rainfall	Evapotranspiration	Runoff	Surface flow	Baseflow	Deep Seepage
Existing	3,942 ML/y	2641 ML/y	1183 ML/y	591 ML/y	591 ML/y	118 ML/y
		67%	30%	15%	15%	3%
Developed no treatment	3,942 ML/y	1892 ML/y	2010 ML/y	1656 ML/y	355 ML/y	79 ML/y
		48%	51%	42%	9%	2%
Developed with treatment	3,942 ML/y	1971 ML/y	1143 ML/y	794 ML/y	352 ML/y	859 ML/y
		50%	29%	20%	9%	21%

It should be noted that MUSIC stands for Model for Urban Stormwater Improvement Conceptualisation and this model is not intended to predict complex interactions between groundwater and surface water. Due to the high groundwater levels under existing conditions and the intersection of groundwater by the linear wetlands under proposed conditions, it is stressed that the MUSIC results relating to water balance should be interpreted with caution. The MODFLOW groundwater modelling undertaken by Martens Consulting Engineers is considered to provide a more realistic representation of the groundwater conditions under existing and proposed conditions.

Water balance modelling by Martens Consulting Engineers indicates that a reduction in potential evapotranspiration across the development area would lead to additional surface flows at the site boundary. These flows are to be dispersed using a linear swale and/or wetland and dissipation zones to increase loss to evapotranspiration. Refer **Appendix 7** for further details.

3.9 Design Development

Revisions to the flood strategy required for climate change adaptation have resulted in changes to the proposed landform, including the introduction of additional open channels. These changes resulted in changes to the catchments. The above MUSIC modelling was undertaken based on the catchment plan for the previously proposed landform. However, the proposed strategy would not change with changes to the landform and the objectives in **Section 3.2** continue to apply.

Further modelling was undertaken to determine indicative treatment areas required for the development on an aggregated per hectare basis. It was found that for one hectare of urban development (plus 0.226 ha trunk drainage), approximately 280 m^2 of bioretention/infiltration area would be required, along with 140 m^2 of wetland to achieve the three objectives set out in **Section 3.2**.

Hence, it is expected that with changes to the development layout and landform, the water quality objectives will still be able to be achieved.

3.10 Maintenance of Water Quality Control Measures

3.10.1 Vegetated Swales (including Dispersal Swales)

Protection of vegetated swales during the construction phase is important to maintenance requirements when the system is operational. Protection of the area with silt fences and the installation of temporary turf prevents disturbance or scour of the filter media surface, and also any heavy sediment loads that will clog the surface of the filter media, potentially resulting in media replacement.

There are irrigation and weeding requirements whilst plants are in the establishment phase.

The following is an estimated list of maintenance tasks for the vegetated swales. The tasks and frequency required will vary with the detailed design of the adopted system and as such should be formulated at that stage. The following suggested maintenance measures are provided as a guide only and should not be relied upon. They also relate to established systems only.

Filter Media (where applicable):

- Inspect for the accumulation of an impermeable layer (such as oily or clayey sediment) on the surface of the filter media. A symptom may be that water remains ponded for more than a few hours after a rain event (every three months, after a rain event);
- Inspect for litter and remove if present, (every three months, after a significant rain event);

Horticultural tasks:

- Assess plants for disease or pest infection, treat or replace as necessary;
- Maintain original plant densities. Frequency - every three months or as required for aesthetics. Reduced plant density reduces pollutant removal and infiltration performance;
- Removal of weeds. Rapidly spreading weeds can reduce dominant species distributions, compromise long-term performance and diminish aesthetics. Application of herbicide should be limited to a wand or restrictive spot spraying as the bio-retention system is directly connected to ecological habitats. Frequency - every three months or as required for aesthetics;

Drainage Tasks:

- Ensure that perforated pipes are not blocked to prevent filter media and plants from becoming waterlogged. A small, steady and clear flow of water may be observed discharging from the pipe outlet some hours after a rain event. Note that smaller rainfall events after dry weather may be completely absorbed by the filter media. If necessary, flushing with air or water may be necessary. Frequency - every six months after a rain event;
- Ensure inflow areas and grates over pits are clear of litter and debris and in good, safe condition. Remove litter from pits. Frequency – monthly and occasionally after significant rain;

Other:

Occasionally observe vegetated swale after a rainfall event to check infiltration. Identify signs of poor drainage (such as extended surface ponding). Frequency - every six months after a rain event.

3.10.2 Bio-retention/Infiltration Basins

The bio-retention/infiltration basins would be primarily sub-surface water quality devices, however areas of shallow surface ponding would also be incorporated into the treatment. On lots, a downpipe would be connected to an infiltration device, buried beneath the surface.

For example, the infiltration system could consist of a series of Atlantis Cells wrapped in permeable geotextile, the area surrounding the cells would be filled with clean river sand. The basin is expected to have a life of approximately 50 years before clogging, at which time the filter material would need to be excavated and replaced.

3.10.3 Wetlands

Generally wetland maintenance can be broken down into the following two primary categories:

1. Aesthetic / nuisance maintenance:

   This type of maintenance is mainly important for public acceptance. It includes graffiti removal, grass trimming and weed control.

2. Functional Maintenance

   Functional maintenance is necessary for the effective removal of sediment and nutrients from the stormwater discharging from the wetlands. It includes weed control, rubbish removal, structural repair, slope repair, mosquito elimination, other erosion repair and monitoring plant establishment and health.

   Some sediment is expected at the inlets which may require removal in order to maintain the standard of stormwater treatment. Proper maintenance of the wetland can ensure long-term, functional and efficient stormwater treatment.

During the establishment period (i.e. first three years after construction), wetlands should be inspected frequently to observe maintenance requirements. During this period, plants may require watering, physical support, weed removal, or replanting etc.

3.11 Construction Phase Water Quality

Sediment and erosion control measures designed in accordance with the NSW Department of Housing "*Managing Urban Stormwater – Soils and Construction*" (*Blue Book*) and to the satisfaction of Council's requirements would be implemented during the subdivision construction. These controls would "help mitigate the impacts of land disturbance on soils, landforms and receiving waters" during the construction stage.

4. CONCLUSIONS

The following conclusions can be made for flooding, climate change, water balance and water quality at the proposed Myall River Downs development.

4.1 Flooding

The results indicate that the flooding constraints can be addressed through a strategy comprised of the following measures:

- Overland conveyance of flows in swales and channels;
- Trunk drainage would be wide to minimise flood levels;
- Minimise pipe lengths from the development to the channels;
- Minimise lengths of major overland flowpaths within roads;
- Offline flood storage at the location of the former sand mine;
- Minimise longitudinal grades for swales and channels;
- Incorporate wetlands into the main trunk drainage channels; and
- Creating the proposed channels by cutting on average 1 metre below existing surface levels; and
- Ensuring the surrounding development area is above the relevant level, by filling. The relevant levels are:
    - Final ground surface level: at or above the 100-year ARI flood level with climate change (consideration to be given to some areas with lot ground levels at 20yr ARI flood level plus 0.9 m sea level rise);
    - Roads: level to be minimum of 300 mm freeboard to 100yr ARI flood level without climate change. Preferable minimum level is 300 mm below 100yr ARI flood level plus 0.9 m sea level rise;
    - Evacuation routes: to have a flood depth no greater than 300 mm in the 100 year ARI flood level event with 0.9 m sea level rise; and
    - Habitable floor levels: at least 500 mm above the 100-year ARI flood level with 0.9 m sea level rise.

Environmental flows would be maintained through both the eastern branch (through limiting the capacity of the uppermost culvert) and along the western branch. High flows would travel along the western branch and be attenuated by utilising the offline storage basin (former sand mine).

Based on the flood modelling results, a substantial reduction in flood levels and fill volumes is possible compared to the estimates made in the LES, due to the strategy proposed in **Section 2.1**posed in **Section 2.1**.

4.2 Water Balance

Water balance modelling by Martens Consulting Engineering indicates that a reduction in potential evapotranspiration across the development area would lead to additional surface flows.

Linear swales and/or wetlands located outside the perimeter road are proposed to disperse flows. This infrastructure will direct flows into stormwater dissipation zones with the purpose of reducing runoff volumes. Some areas will be revegetated to aid in the evapotranspiration of runoff from the development.

4.3 Water Quality

It is proposed to adopt a water sensitive urban design approach in the management of runoff in the proposed development. This approach will incorporate a treatment train of measures managing runoff from its source to the site outlets, including rainwater tanks, infiltration devices on lots, swales and extensive wetlands.

Water quality modelling results show that the following three water quality objectives are met:

- No increase in the pollutant export loads from the existing to the post developed state;
- DECC treatment requirements, i.e. an 80% reduction in TSS, 45% reduction in TP and 45% reduction in TN when comparing the proposed development (no treatment) and proposed development (with treatment); and
- Treatment stormwater runoff prior to discharge via infiltration or into groundwater-connected wetlands such that the water quality matches or is better than the groundwater quality.

This would be achieved through a combination of wetlands, swales and bio-retention/infiltration basins.

This combination of measures will contribute significantly to the long term improvement in receiving water quality.

5. REFERENCES

1. Institute of Engineers, Australia, *Australian Rainfall and Runoff*, 1987
2. Department of Environment, Climate Change and Water NSW, 2009, *NSW Sea Level Rise Policy Statement*
3. Department Of Environment & Climate Change, 2007, *Floodplain Risk Management Guideline: Practical Consideration of Climate Change*
4. Department of Planning, 2009, *Draft NSW Coastal Planning Guideline: Adapting to Sea Level Rise*
5. Hunter Wetlands Research, Effect of Stormwater Basins on Water Quality in Frog Habitat in the Vicinity of Myall River Downs, Tea Gardens, 2008
6. MUSIC Development Team CRC for Catchment Hydrology, *MUSIC User Manual*, April 2005
7. Parsons Brinkerhoff, Myall River Downs Local Environment Study, 2003

Figures

FIGURE 1

MOUSE NETWORK SETUP
(INCLUDES CULVERT DETAILS)

J4305/FIG1_MouseNetworkSetup.jpg

FIGURE 2

MOUSE SUBCATCHMENT LAYOUT

J4305/FIG2_MouseSubcatchmentLayout.jpg

FIGURE 3

MOUSE NODE INVERT LEVELS (mAHD)

01753/FIG3_NodeInvertLevels.jpg

FIGURE 4

100 YEAR ARI FLOOD LEVELS (mAHD)

J4305/FIG4_100YrFloodLevels.jpg

FIGURE 5

CUMULATIVE FLOWS (m^3/s) FOR SCENARIOS 1 & 2

01753/FIG5_CummulativeFlows.jpg

FIGURE 6

100 YEAR ARI FLOOD LEVELS WITH 0.9m SEA LEVEL RISE (mAHD)

J4305/FIG6_100YrFloodLevels.jpg

FIGURE 7

100 YEAR ARI FLOOD LEVELS WITH 0.9m SEA LEVEL RISE AND 30% LARGER STORM (mAHD)

J4305/FIG7_100YrFloodLevels.jpg

FIGURE 8

LEGEND:

B5 Catchment name

Catchment boundary

Extent of current reporting

CATCHMENT PLAN

01753/FIG8_CatchmentPlan.jpg

FIGURE 9

STORMWATER QUALITY MANAGEMENT LAYOUT

(0560)J4305/FIG9_StormwaterQualityManagement.jpg

FIGURE 10

ITEM	DESCRIPTION
1	EXTENT OF SITE HOLDING 'MYALL RIVER DOWNS' AT TEA GARDENS.
2	EXISTING 7(A1) WETLAND ZONE.
3	EXISTING 7(B) BUFFER ZONE.
4	SQUIRREL GLIDER MANAGEMENT ZONE.
5	WATER MANAGEMENT & OPEN SPACE CORRIDORS.
6	COMMUNITY POCKET PARKS.
7	EXISTING QUARRY TO BE USED FOR WATER DETENTION & WATER QUALITY MANAGEMENT.
8	EXISTING 'TEA GARDENS GRANGE' RETIREMENT VILLAGE
9	'THE HERMITAGE' RETIREMENT VILLAGE UNDER CONSTRUCTION.
10	EXISTING RESIDENTIAL DEVELOPMENT.
11	SPORTING/PLAYING FIELDS (APPROX. 6 HA).
12	PROPOSED RESIDENTIAL LOT DEVELOPMENT.
13	LIGHT INDUSTRIAL SUBDIVISION
14	CLIMATE CHANGE TRANSITION ZONE
15	AGED CARE FACILITY (APPROVED)

LAND USE LEGEND

TOTAL SITE	HA	%
URBAN AREAS		
- RESIDENTIAL (INCLUDING POCKET PARKS)	105.98	30.46
- INDUSTRIAL	9.97	2.86
- AGED CARE FACILITY	2.86	0.82
- PLAYING FIELDS	6.90	1.98
- DRAINAGE CORRIDORS	35.66	10.26
TOTAL	**161.37 HA**	**46.38%**
CONSERVATION AREA	186.53	53.62%
TOTAL	**186.53 HA**	**53.62%**
TOTAL	**347.90 HA**	**100%**

LAND AREA LEGEND

URBAN SITES	HA	%
URBAN AREAS		
- A	18.80	17.74
- B	17.51	16.52
- C	11.65	11.00
- D	10.91	10.29
- E	11.76	11.10
MD1	1.83	1.73
MD2	4.39	4.14
MANUFACTURED HOME ESTATES	29.13	27.48
TOTAL	**105.98 HA**	**100%**

MYALL RIVER DOWNS

TEA GARDENS AUSTRALIA

DRAWING TITLE

CONCEPT PLAN

APPLICATION			
Part 3A Submission to N.S.W. D.O.P			
DATE	SCALE	DRAWING No.	REVISION
August 2010	1:5000 @ A1	MRD -03	DRAFT

TRUE NORTH

CRIGHTON PROPERTIES

Appendix 1 - Hydraulic Model Details

Table A-1 – Subcatchment Parameters and Peak Flow Rates

Catchment ID	Loading Point	Area (ha)	Length (m)	Slope (%)	Pervious Fraction (%)	Impervious Fraction (%)		Impervious Manning's n		Pervious Manning's n	Catchment Runoff from Model Results	
						Flat	Steep	Flat	Steep		100yr (m^3/s)	20yr (m^3/s)
1/1_2	1/1	11.63	350	10	100	0	0	0.02	0.02	0.08	2.92	1.93
1/1_3	1/1	2.07	200	10	100	0	0	0.02	0.02	0.08	0.65	0.46
1/1_4	1/1	5.16	250	10	100	0	0	0.02	0.02	0.08	1.51	1.02
1/1_48	1/1	4.07	220	10	100	0	0	0.02	0.02	0.08	1.25	0.86
1/1_49	1/1	5.46	320	1.00	100	0	0	0.02	0.02	0.04	0.71	0.44
1/1_6	1/1	16.82	450	1.00	30	35	35	0.02	0.02	0.04	5.7	4.38
13/1_7	13/1	3.15	190	0.10	100	0	0	0.02	0.02	0.05	0.26	0.15
13/1_8	13/1	6.05	300	1.00	30	35	35	0.02	0.02	0.04	2.28	1.76
13/2_42	13/2	2.33	44	1.46	100	0	0	0.02	0.02	0.05	0.85	0.61
13/2_43	13/2	5.24	339	0.51	40	30	30	0.02	0.02	0.04	1.59	1.21
13/2_5	13/2	9.8	420	2.00	100	0	0	0.02	0.02	0.08	1.34	0.82
13/2_52	13/2	7.42	400	10.00	100	0	0	0.02	0.02	0.08	1.74	1.14
13/3_1	13/3	15.21	540	10.00	100	0	0	0.02	0.02	0.08	3.02	1.91
13/3_24	13/3	7.61	307	1.00	40	30	30	0.02	0.02	0.04	2.59	1.98
13/3_50	13/3	20.68	610	2.00	100	0	0	0.02	0.02	0.08	2.17	1.32
13/3_51	13/3	4.55	310	0.10	100	0	0	0.02	0.02	0.05	0.28	0.16
13/4_25	13/4	7.10	340	1.00	40	30	30	0.02	0.02	0.04	2.35	1.79
13/5_23	13/5	5.41	366	1.00	40	30	30	0.02	0.02	0.04	1.76	1.34
13/6_27	13/6	4.87	186	1.00	40	30	30	0.02	0.02	0.04	1.86	1.43
13/6_28	13/6	4.12	249	0.10	100	0	0	0.02	0.02	0.05	0.29	0.17
18/2_22	18/2	10.21	371	1.00	40	30	30	0.02	0.02	0.04	3.3	2.51
18/2_29	18/2	2.09	98	0.10	100	0	0	0.02	0.02	0.05	0.28	0.17
18/2_30	18/2	8.12	285	0.50	40	30	30	0.02	0.02	0.04	2.56	1.95
18/4_31	18/4	1.80	140	0.10	100	0	0	0.02	0.02	0.05	0.19	0.11
18/4_38	18/4	10.13	315	1.00	40	30	30	0.02	0.02	0.04	3.42	2.61
18/4_55	18/4	7.08	275	1.00	40	30	30	0.02	0.02	0.04	2.47	1.89
18/5_32	18/5	1.17	110	0.10	100	0	0	0.02	0.02	0.05	0.14	0.09
18/6_34	18/6	3.53	123	0.10	100	0	0	0.02	0.02	0.05	0.4	0.24
18/6_35	18/6	8.22	139	1.00	40	30	30	0.02	0.02	0.04	3.37	2.58
2/1_26	2/1	9.74	470	14.00	100	0	0	0.02	0.02	0.08	2.29	1.5
2/1_39	2/1	17.58	610	0.00	50	25	25	0.02	0.02	0.04	4.49	3.38
23/1_19	23/1	1.80	98	1.00	40	30	30	0.02	0.02	0.04	0.79	0.61
23/1_57	23/1	5.13	221	1.00	40	30	30	0.02	0.02	0.04	1.89	1.45
27/1_15	27/1	20.45	600	1.00	40	30	30	0.02	0.02	0.04	5.92	4.5
27/1_46	27/1	126.85	2000	0.00	100	0	0	0.02	0.02	0.08	4.65	2.51
42/1_41	42/1	6.45	337	0.38	70	15	15	0.02	0.02	0.05	1.24	0.9
42/1_47	42/1	15.61	540	0.00	100	0	0	0.02	0.02	0.08	1.39	0.83
45/1_10	45/1	2.37	136	0.13	100	0	0	0.02	0.02	0.05	0.27	0.17
45/1_53	45/1	7.39	136	1.00	40	30	30	0.02	0.02	0.04	3.05	2.34
45/1_9	45/1	5.66	310	1.00	100	0	0	0.02	0.02	0.04	0.75	0.46
48/2_11	48/2	8.35	360	1.00	40	30	30	0.02	0.02	0.04	2.72	2.07
48/2_54	48/2	13.18	460	1.00	60	20	20	0.02	0.02	0.04	3.14	2.33
49/1_40	49/1	10.10	189	4.78	70	15	15	0.02	0.02	0.05	3.44	2.49
49/1_44	49/1	12.79	410	0.01	100	0	0	0.02	0.02	0.08	1.39	0.85
49/1_45	49/1	7.10	380	0.01	100	0	0	0.02	0.02	0.08	0.82	0.5
54/3_12	54/3	1.05	170	0.10	100	0	0	0.02	0.02	0.08	0.09	0.06
54/3_13	54/3	3.51	200	1.00	40	30	30	0.02	0.02	0.04	1.32	1.01
54/3_17	54/3	3.21	250	1.00	40	30	30	0.02	0.02	0.04	1.15	0.88
54/4_16	54/4	7.00	390	1.00	40	30	30	0.02	0.02	0.04	2.23	1.7
54/5_14	54/5	6.84	580	0.10	100	0	0	0.02	0.02	0.08	0.27	0.15
54/5_56	54/5	12.53	470	1.00	40	30	30	0.02	0.02	0.04	3.81	2.9
6/2_36	6/2	2.72	333	0.38	40	30	30	0.02	0.02	0.04	0.8	0.61
6/2_37	6/2	1.77	330	0.58	100	0	0	0.02	0.02	0.05	0.19	0.11
7/1_20	7/1	9.17	356	0.20	40	30	30	0.02	0.02	0.04	2.48	1.88
7/1_21	7/1	4.81	200	0.81	40	30	30	0.02	0.02	0.04	1.77	1.36
8/1_18	8/1	9.38	33	2.34	40	30	30	0.02	0.02	0.04	4.94	3.95
9/1_33	9/1	21.68	420	0.62	40	30	30	0.02	0.02	0.04	6.43	4.9

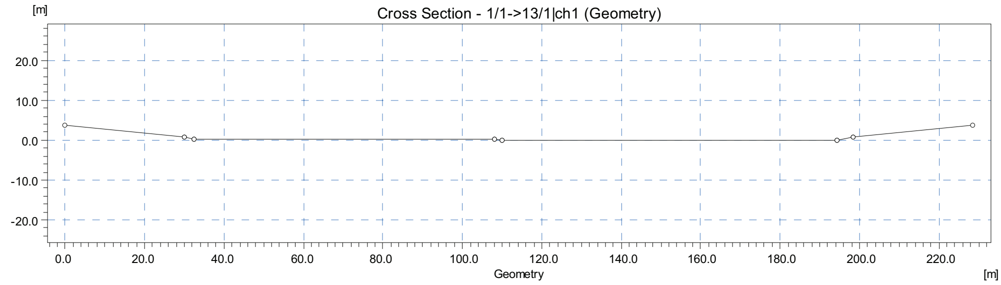
NB Rows highlighted in grey represent contributing external catchments

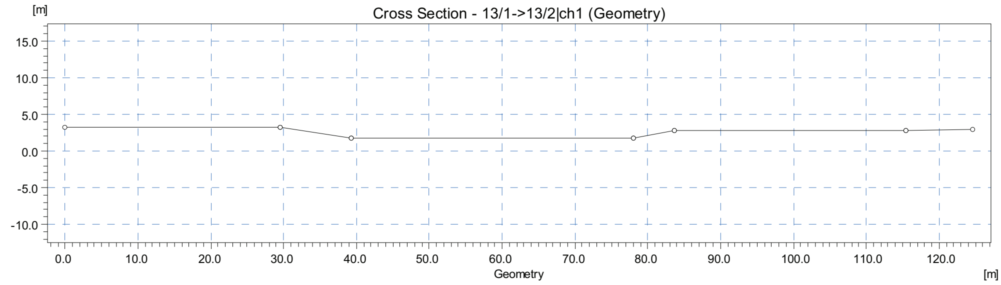
Table A-2 – Invert Levels at Nodes

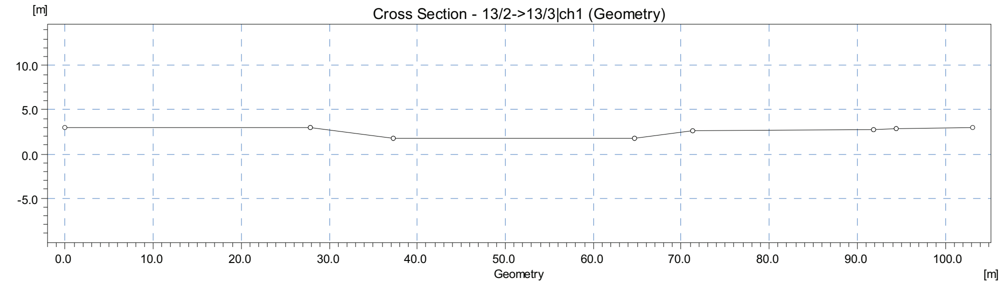
Node	Invert Level (mAHD)
1/1	2.6
13/1	2.2
13/3	1.62
13/5	1.4
13/6	1.4
18/2	1.4
18/3	1.4
18/4	1.4
22/1	1.4
41/1	1.9
48/1	1.72
51/1	1.46
54/3	0.6
54/5	0.4
54/6	0.2
38/1	2
5/1	1.4
2/1	1.4
15/1	1.4
18/1	1.4
13/2	1.83
13/4	1.45
6/2	1.4
6/1	1.4
27/1	-0.5
18/5	1.4
7/1	1.7
8/1	1.7
19/1	1.4
45/1	1.75
54/1	1.4
23/1	1.1
34/1	0.33
29/1	0.2
48/2	1.59
54/4	0.6
54/2	0.61
18/6	1.4
26/1	1
12/1	1.1
9/1	1.2
42/1	0.6
49/1	0.8
43/1	0.6
36/1	0.63
31/1	-0.399
50/1	0.8
26/2	0.8
44/1	0.8
28/1	0
30/1	0.2
32/1	-0.34

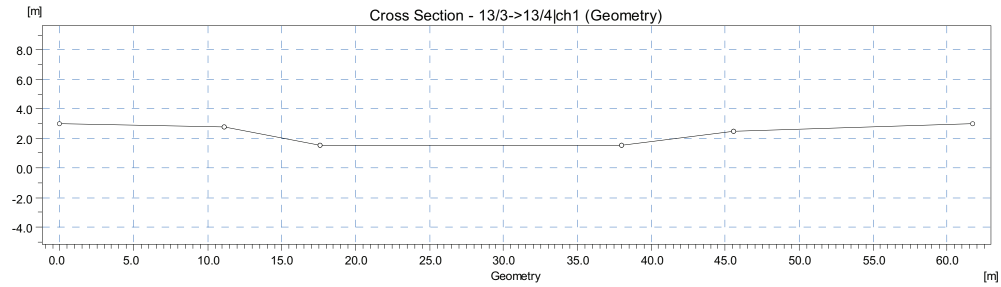
35/1	0.33
49/2	0.8
33/1	-0.252
44/2	0.8
50/2	0.8
28/2	0

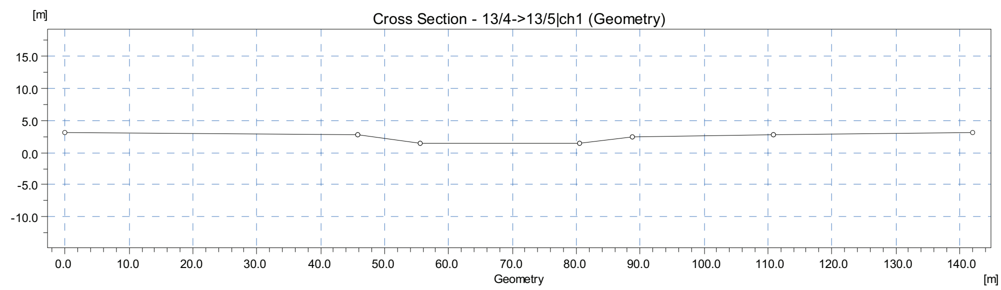
Model Cross Sections

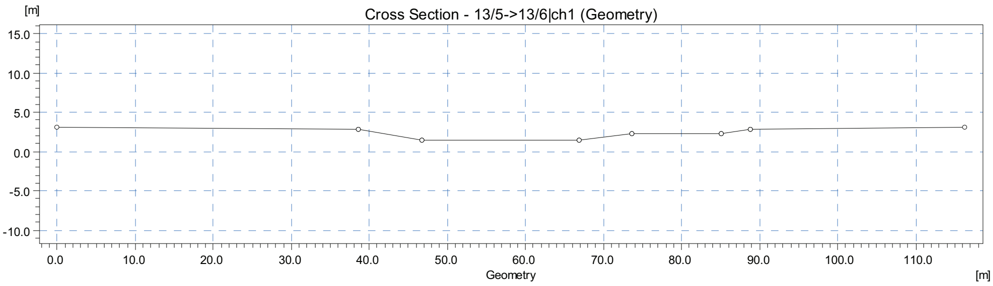








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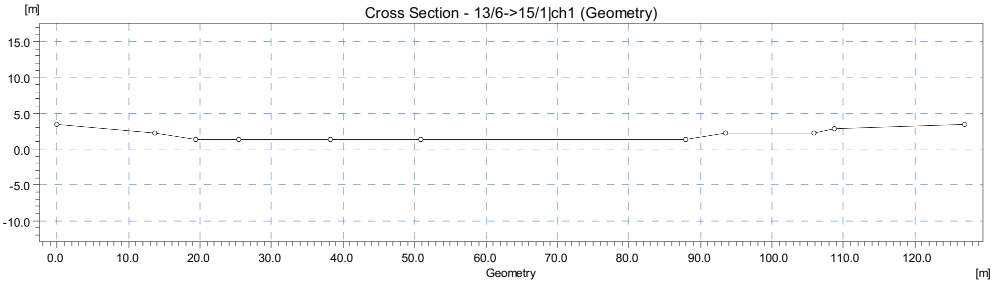
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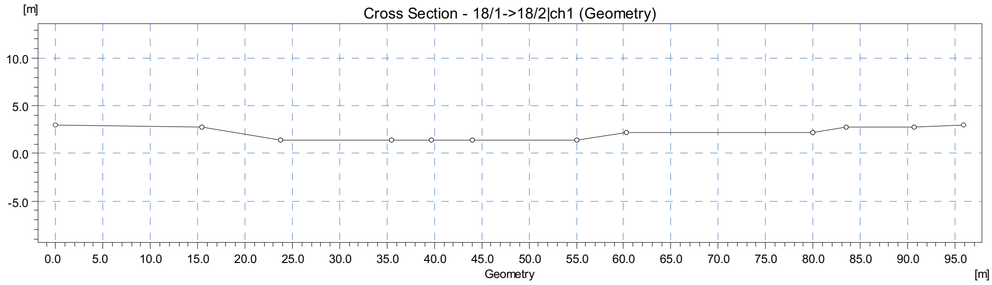
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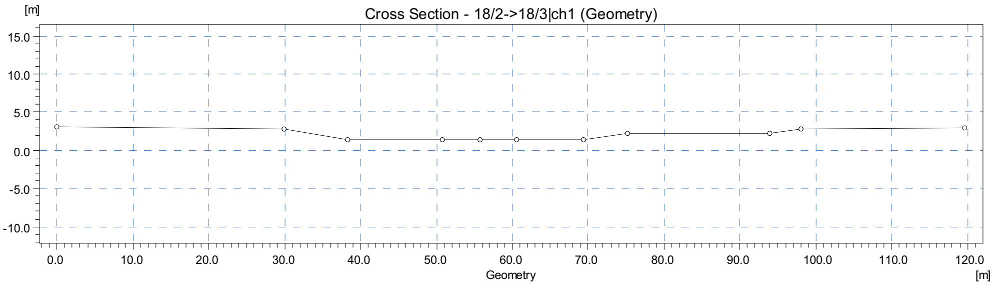
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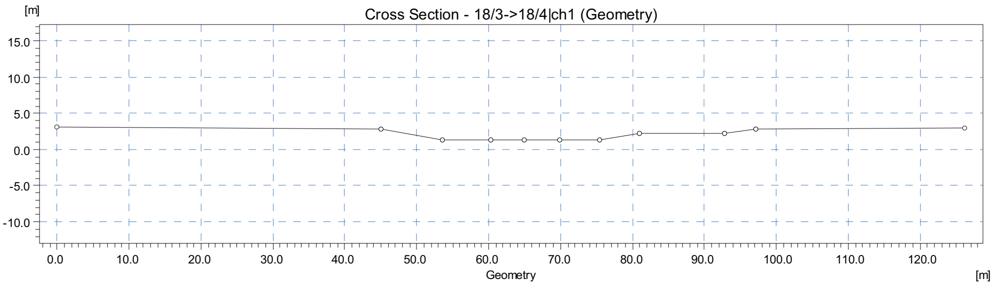
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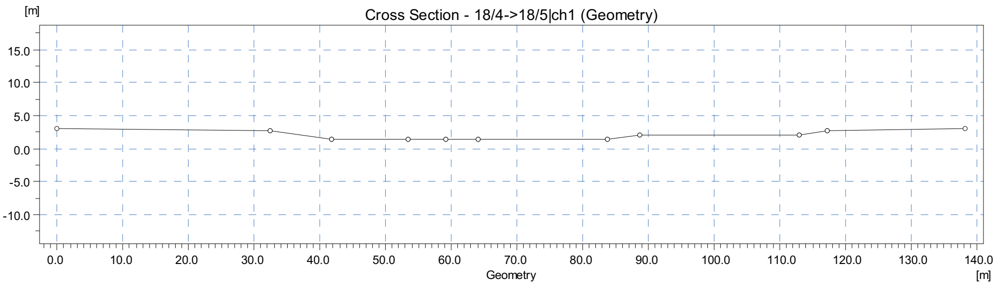
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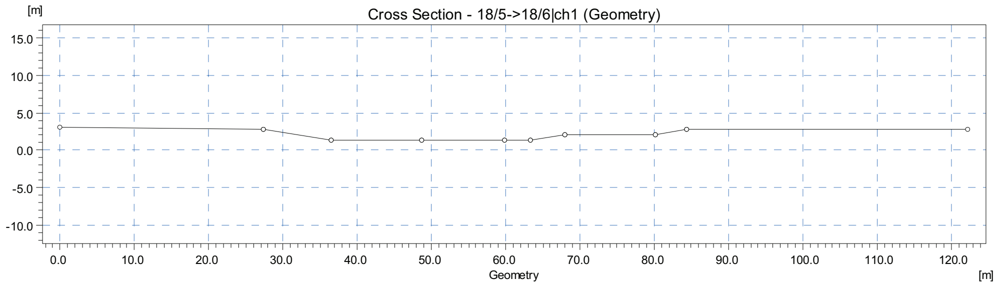
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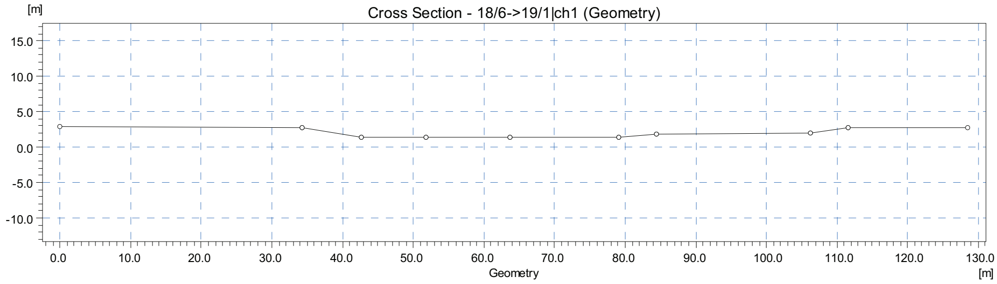
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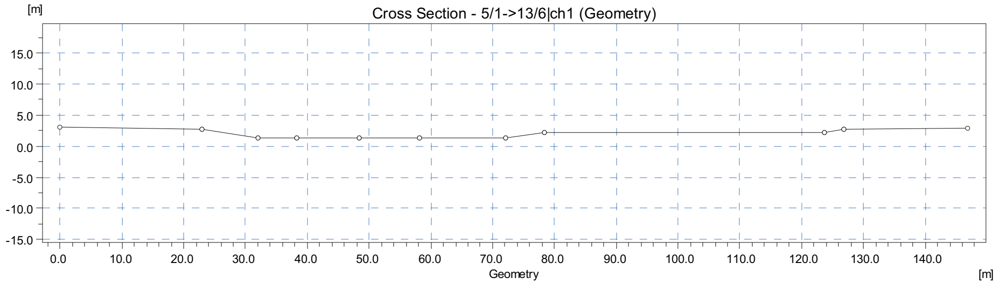
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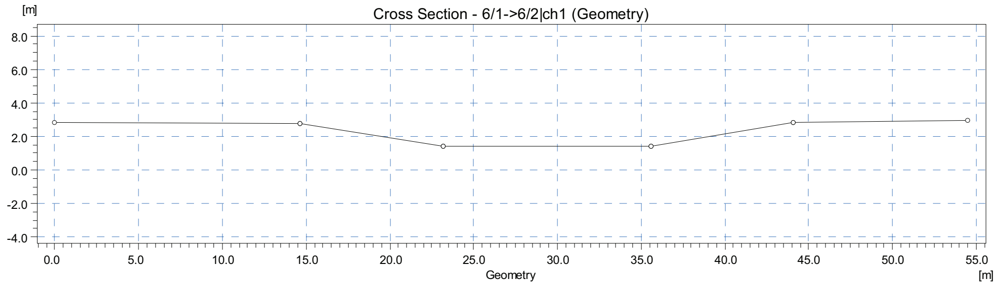
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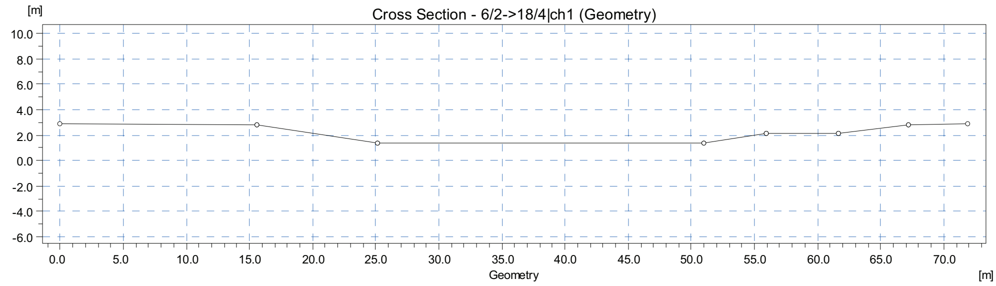
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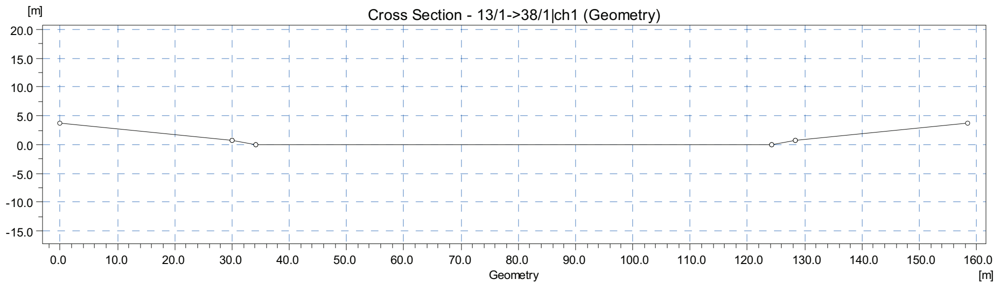
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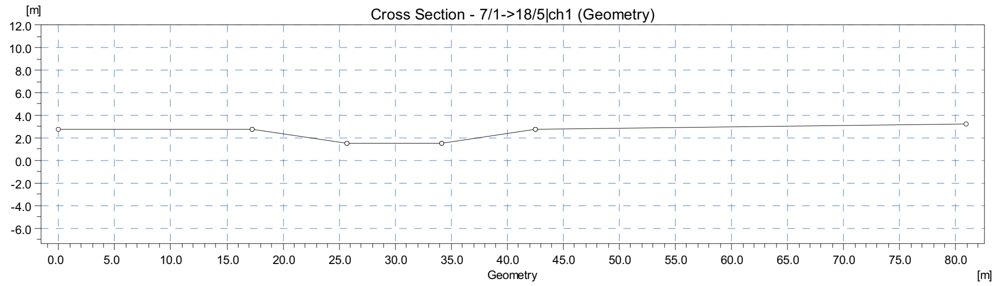
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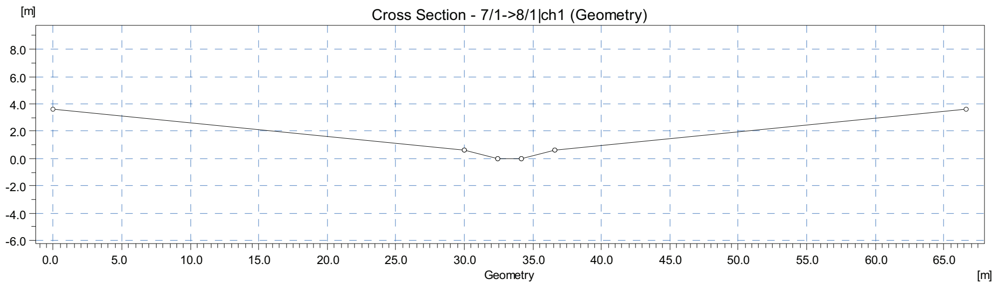
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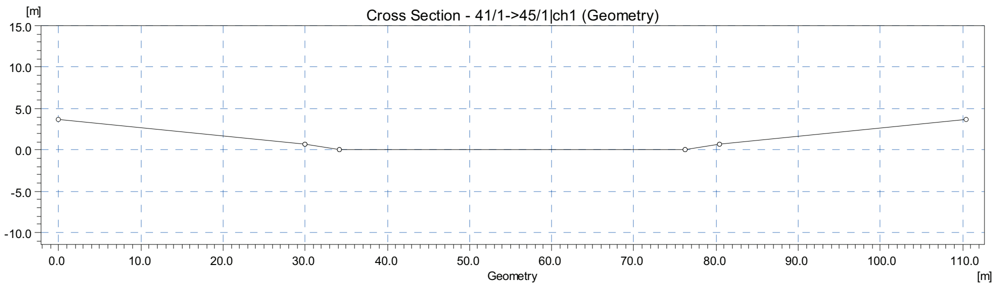
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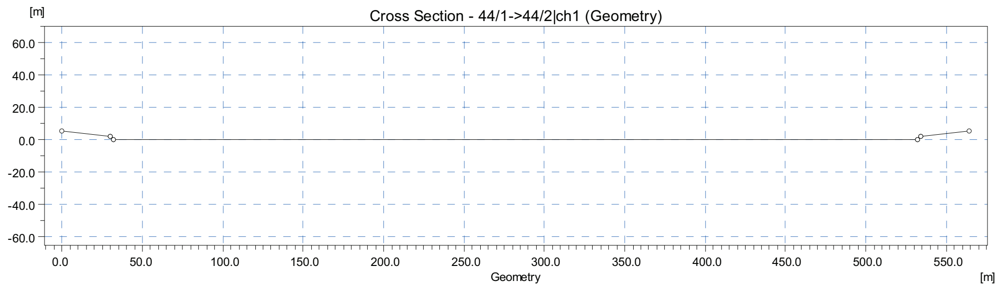
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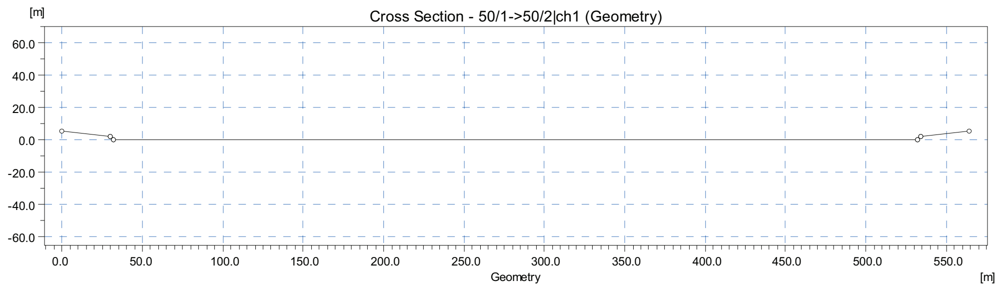
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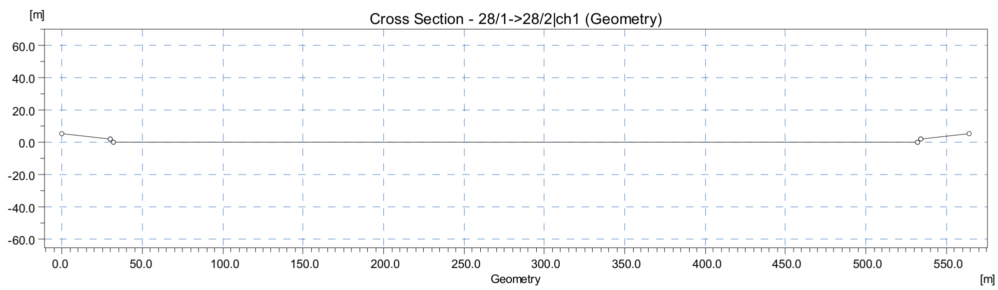
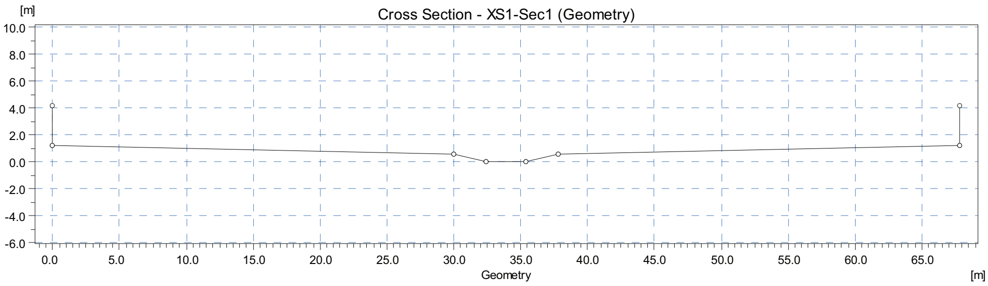
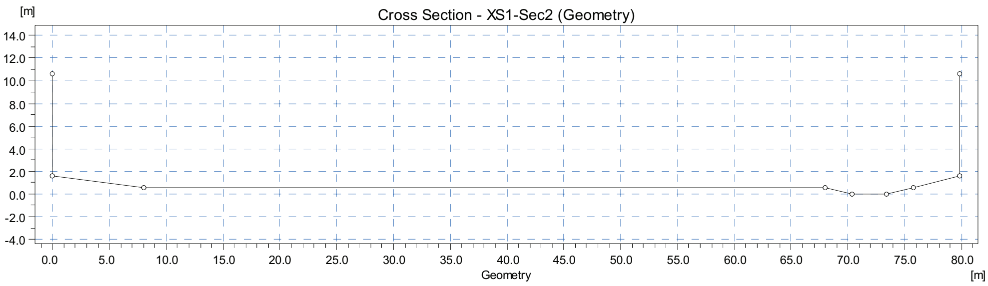
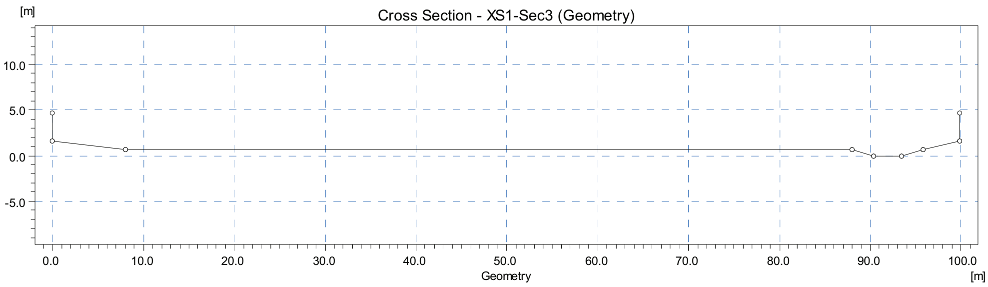
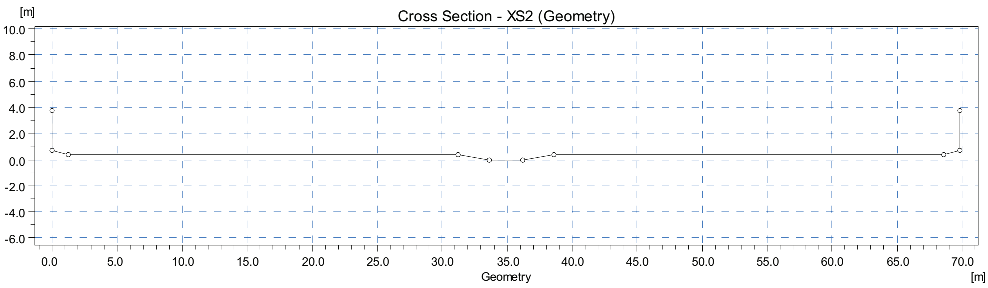
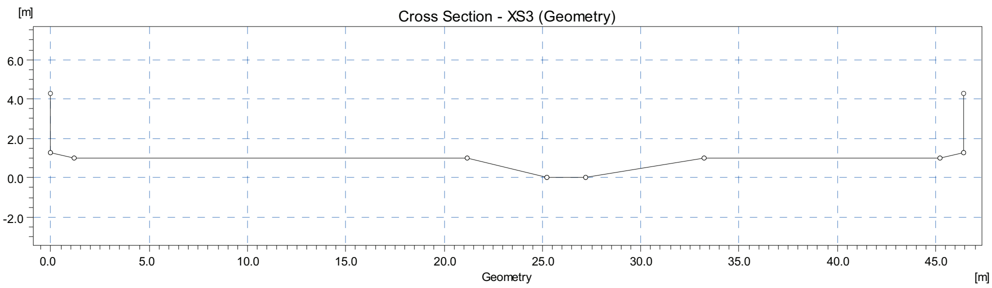

Cross Section - 28/1->28/2|ch1 (Geometry)
[m]
Geometry
[m]

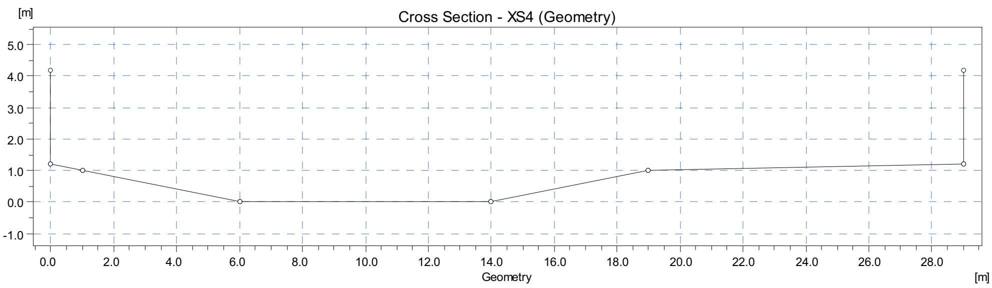

Cross Section - XS1-Sec1 (Geometry)
[m]
Geometry
[m]

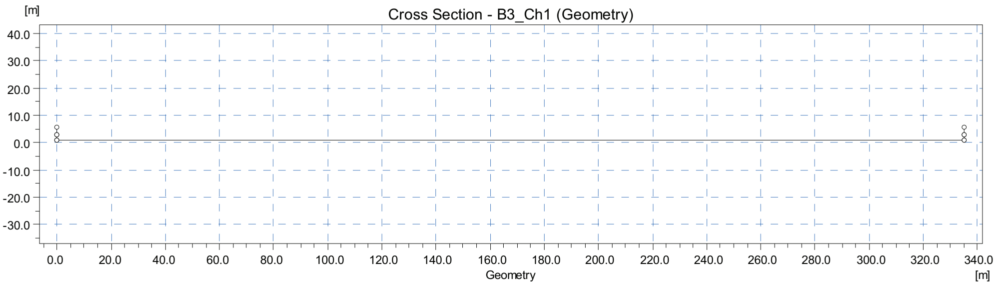

Cross Section - XS1-Sec2 (Geometry)
[m]
Geometry
[m]

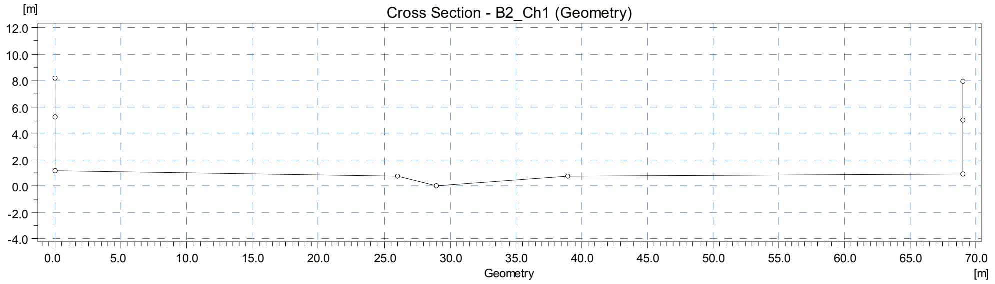

Cross Section - XS1-Sec3 (Geometry)
[m]
Geometry
[m]


Cross Section - XS2 (Geometry)
[m]
Geometry
[m]


Cross Section - XS3 (Geometry)
[m]
Geometry
[m]


Cross Section - XS4 (Geometry)
[m]
Geometry
[m]


Cross Section - B3_Ch1 (Geometry)
[m]
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
240.0
260.0
280.0
300.0
320.0
340.0
Geometry
[m]


Cross Section - B2_Ch1 (Geometry)
[m]
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
Geometry
[m]