Oberon Stormwater Management Strategy

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Executive summary

This stormwater management strategy for the Borgs Oberon Timber Complex is to:

- support a Development Application for warehouse and additional hardstand areas that will increase the impervious area by approximately 2 ha
- provide guidance to Borgs in the management of on-site stormwater issues having regard to environmental requirements and the proximity of the site to the upstream Carter Holt Harvey plant.

The site was modelled using XP-SWMM and MUSIC to assess the stormwater flow and quality issues respectively to develop a suitable stormwater treatment train.

The peak instantaneous runoff rate from proposed future buildings is expected to marginally increase, however the industrial processes at the site require large volumes of water, which it is proposed to source from captured stormwater. Accordingly, the discharge from the site is not expected to increase significantly beyond predevelopment flow rates.

Water quality devices proposed within the strategy include the use of grassed swales to convey the water through the site and the expansion of an existing sediment basin to provide further treatment and to hold water that can then be re-used on-site. These devices are in addition to the recently implemented water quality devices on the upstream Carter Holt Harvey (CHH) site that are also expected to further improve the quality of water running on to the Borg site in the future.

Two stormwater strategy scenarios were investigated in MUSIC to help in the decision making process for the site. The first scenario involved the existing case and the second involved the proposed development with the associated conveyance and treatment devices.

The MUSIC modelling results indicate that the proposed treatment train would exceed Borgs Environmental Protection Licences requirements for Total Suspended Solids (TSS), Total Nitrogen (TN) and Total Phosphorous (TP). Further, they are expected to improve the overall water quality discharging from the site.

The proposed strategy for the site is described in Figure 4 and comprises:

- filling in of the two existing sediment dams and the existing channels to make way for the new proposed warehouse
- the inclusion of a new swale (Swale 1). Swale 1 has been design to accommodate flows for the 100yr ARI storm event whilst separating CHH and Boral stormwater flows up to the 1yr ARI event. The new swale has 1:1 side slopes and a lined bund to separately convey and treat the stormwater falling on and passing through the Borgs site in addition to the existing flows from the CHH and Boral sites
- a junction pit and approximately 30m of 1050mm diameter stormwater line to intercept the line from HPP Site 2 and StructaFlor and connect to the upstream side of proposed Swale 1
- constructing two (2) sets of twin 1050 mm diameter RCP culverts, approximately 33 m long to connect the proposed swale system (Swale 1) with the existing culverts upstream of ‘Gate 6’
- construction of a diversion bund at the upstream end of the existing CHH swale to separately convey CHH/Borgs and Boral stormwater flows to separate downstream swales

- retaining the two separate sediment dams located prior to the licensed discharge point to Kings Stockyard Creek to maintain flow segregation of the site.

1. Introduction

1.1 Background

PB was engaged by Borgs to undertake a stormwater management strategy for the Oberon Timber Complex site to allow for the construction of a new proposed warehouse and associated hardstand areas. Borgs recently purchased the site from Carter Holt Harvey (CHH) and are required to meet stormwater quality requirements in line with their Environmental Protection Licences (EPL) prior to discharging into Kings Stockyard Creek.

A spill of Aldrin/Dieldrin, an organo-chlorine pesticide (OCP) occurred prior to the purchase of the site by CHH. During rain events, soils contaminated with OCP were transported throughout the site's trunk drainage system and low levels of OCP were periodically measured at the discharge point. A Remediation Action Plan (RAP) was subsequently developed and mainly concentrated on preventing the movement of sediments, which allow the transport of the OCP, throughout the sites drainage network.

PB was previously commissioned by CHH to undertake an assessment of the existing trunk stormwater network at the 'HPP Site 2' and 'StructaFlor' sites, refer Figure 2, and propose a concept design for the improvement of this network. A strategy was then developed to prevent the mobilisation of contaminated sediments, limit the movement of sediments through the site's trunk drainage line, aerate water in some drainage channels and to make new channels and water quality structures to be machine maintainable.

The work previously undertaken on these upstream areas is expected to improve the quality of water running on to the Borg site. This is due to the implementation of water quality devices such as aeration cascades, gross pollutant traps with drive in sumps and closable gates across channels and culvert inlets.

1.2 Objectives and scope of works

The main objectives outlined by Borgs for the sites stormwater network were:

- improve water quality discharging from the site and adhere to the sites various Environmental Protection Licences (3035, 11566 and 887) requirements
- be capable of conveying the 100 year ARI rainfall event to the discharge location on Kings Stockyard Creek
- provide an adequately sized retention basin to allow water to be reused on-site
- minimise peak flow rates
- maintaining the separation of upstream CHH and Boral stormwater flows.

To achieve the objectives described above, the following works were carried out:

- review of existing data including drainage plans, water monitoring data and survey details

- site inspection to identify the key design objectives and assess the existing drainage system
- hydrological and hydraulic modelling of the existing and proposed drainage network using XP-SWMM software (expanded upon PB's previous XP-SWMM model)
- water quality modelling of the existing and post-development networks using MUSIC
- development of a practical and suitable stormwater management strategy
- preparation of a report outlining the modelling methodology, key results of the model, discussion of proposed works and conclusions and recommendations.

1.3 Site characteristics

The Borgs site is located within the township of Oberon, 45 km south-east of Bathurst, NSW. The site is situated at an elevation of approximately 1100 m AHD and has a total area of approximately 60 ha. A locality plan of the site is shown in Figure 1. The majority of the site comprises hardstand area with other land types being small pockets of pervious areas and open water dams.

Generally, the site grades towards the east and the licensed discharge point to Kings Stockyard Creek is located in the north eastern corner of the site. Figure 2 shows a breakdown of the total site area and differentiates between the different processes being undertaken.

A high ground water table is known to exist at the site and generally flows towards its north eastern corner. This fluctuating ground water table is a significant constraint of the site since excavation below this level cannot occur without consequential groundwater recharging taking place.

1.4 Existing drainage

The existing drainage network comprises vegetated open channels with culverts passing under road crossings. A 300 m long 1050 mm diameter RCP culvert, commencing at the north eastern corner of the 'HPP Site 2', conveys runoff from the 'HPP Site 2' and 'StructaFlor' areas to the sediment dam at the Borgs site. Survey levels obtained suggest that the majority of this culvert would be permanently submerged under the current design, which is not ideal and not considered to be engineering best practice. Overflow from the sediment dam then passes down a grassed channel before passing beneath the road (via three 1050 mm diameter culverts) at 'Gate 6'. It then runs down another grassed channel prior to another sediment dam.

After passing through the site's trunk drainage network, runoff is directed to a final sediment dam before discharging into Kings Stockyard Creek. This is the licensed discharge point for the site and discharges are quantified using a V-notch weir. The holding dam is also the location where contaminant sampling is carried out.

Runoff from the adjacent 'HPP Site 1' and a large upstream (approximately 20 ha) rural catchment area passes through a separate drainage network. Water from the 'HPP Site 1' area passes beneath Lowes Mount Road and then flows downstream in a swale parallel to the road for approximately 165 m.

This water then combines with the runoff from the upstream rural catchment (some of which is owned by CHH) before discharging into a sediment dam, separated from the aforementioned drainage network and the ‘HPP Site 2’ and ‘StructaFlor’ areas. This basin then overflows into a small swale before passing through another set of three 1050 mm diameter culverts under the road at ‘Gate 6’. Water from these culverts then flows along a swale adjacent to the northern boundary of the site before discharging into another sediment dam prior to discharging into Kings Stockyard Creek.

A detailed schematic of the site’s existing drainage network is provided in Figure 3. The figure shows the two trunk drainage lines that have been analysed for this study and distinguishes between pipe and channel links.

1.5 Available data

The following data was used during this investigation:

- aerial survey with 1.0 m contours in electronic format
- survey showing the invert levels of existing culverts
- invert levels under and immediately downstream of ‘Gate 6’ provided by Borgs
- specific culvert diameters and pit depths measured in the field by Borgs
- culvert diameters previously measured in the field by CHH staff
- previous XP-SWMM model developed for the site by PB including the first flush drainage line and the recent works completed on the ‘HPP Site 2’ and ‘StructaFlor’ sites
- pluviograph data (6-minute rainfall intensity) for Oberon (Jenolan Caves Road), from January 1993 to September 2005
- an approximate depth of the ‘HPP Site 1’ sediment dam provided by CHH
- an aerial schematic drawing of the proposed development
- estimates of the volume of water re-used on-site per day provided by Borgs
- water monitoring results at the Borg discharge point, the adjacent ‘HPP Site 1’ ‘north dam’ discharge point and at the ‘StructaFlor’ ‘gate 1’ discharge point.

A site inspection was also carried out on 21/10/2010 to determine and confirm the site characteristics and to develop a suitable catchment plan.

2. Design criteria

Design criteria for trunk drainage infrastructure were based on current best practices and requirements outlined by Borg's management staff during the site visit.

The following design criteria were adopted for the stormwater strategy:

- trunk drainage system is to be capable of conveying the 100 year Average Recurrence Interval (ARI) storm event from the site
- stormwater runoff should meet the Environmental Protection Licences limits for TSS (30 mg/L), True colour (160 Hazen), TP (0.3 mg/L), TN (10 mg/L) and BOD (20 mg/L)
- minimise peak flow rates.

Drainage swales and basins are to be designed to promote aeration where possible as runoff from the site has historically had high concentrations of Tannins that reduce the amount of Dissolved Oxygen (DO) in receiving waters. In addition, the system is to be designed to be retrofitted to allow for a possible mechanical aeration devise post development if required.

3. Design constraints and issues

3.1 Tannins

An issue brought about by the timber processes undertaken in the complex is the presence of tannins which leach out of wood products as they biodegrade on-site. This is evident due to the black discolouration of runoff within the sites drainage lines. The implication of this is that tannins reduce the amount of dissolved oxygen within the runoff. Adequate aeration of the runoff is therefore desirable wherever possible.

3.2 Flatness of the site

The site is constrained by the upstream culvert invert connecting into the existing first flush basin (sediment basin 1) and the culvert inverts below the road at 'Gate 6'. From survey data and information provided by Borg's staff on-site, the inverts of the 'Gate 6' culvert inlets are actually 170 mm above the upstream culvert outlet level that conveys runoff from the 'HPP Site 2' and 'StructaFlor' catchments. As such, significant amounts of water is expected to pond at the site prior to passing beneath 'Gate 6'. In addition, aeration cascade devices that accelerate water down the face of rock lined channels to promote higher oxygen levels in the water are not practical on the Borg site. Therefore, coupled with the known high water tables the stormwater strategy is very constrained by the extreme flatness of the site.

3.3 High ground water table

A high groundwater table is known to exist at the site and limits the amount of excavation that can occur in certain locations. Groundwater was not largely considered in this investigation but further analysis may be required in the detailed design stage.

3.4 Northern fibre dump

A fibre dump is located to the north of 'Gate 6'. This fibre dump is believed to have the potential to leach contaminants into the groundwater system and therefore the placement of a basin immediately up gradient (western side) of the groundwater flow is not recommended.

3.5 Separation of Carter Holt Harvey and Boral stormwater

During negotiations with adjacent landholders (CHH and Boral), it was identified that the combination of flows originating from the two sites, for a <1 year ARI event, would not be preferable. For this reason, distinct separation of flows originating from the two sites, up to a 1 year ARI event, is required to be maintained through to the final outfall at Kings Stockyard Creek.

4. Stormwater management strategy

4.1 Site strategy

The main stormwater strategy for the site is to convey and treat stormwater from the Borg and upstream sites using a large, flat grassed swale and by increasing an existing sediment basin, downstream of ‘Gate 6’. The increased retention of runoff at the sediment basin will allow water to be reused on-site and will settle out sediments. A detailed schematic of the proposed development and stormwater strategy is shown in Figure 4.

Due to the extreme flatness at the site the grassed swale will act more like an elongated basin and will retain a significant volume of water prior to discharging into the channel systems downstream from ‘Gate 6’. The geometry of the proposed development makes it problematic and unfeasible to convey the stormwater all the way to the culverts beneath ‘Gate 6’ via a grassed swale. The most practical and cost effective way to hydraulically link these two sections is to pipe the final 30 m or so beneath the corner of the development. In order to convey this runoff without backing up the upstream swale, four (4) x 1050 mm diameter culverts are required (layed in two separate arrangements).

The inlet levels of these culverts would be raised slightly higher than the upstream swale invert to effectively connect into the existing culverts below ‘Gate 6’. This would be achieved by constructing a large pit type area between the two sets of culverts. This pit is likely to be shotcreted, however the exact details of this pit will be confirmed at the detailed design stage. The alignment of these culverts and the proposed ‘large pit area’ can be seen in Figure 4.

Minor earthworks are proposed immediately downstream of ‘Gate 6’ to enable a flow diversion bund to be constructed to pass down the segregated flows to the existing swale system, nearest the warehouses on the site.

Calculations and XP-SWMM modelling of the existing culverts below ‘Gate 6’ indicate that they are adequately sized to convey the 100 year ARI flow rates from the upstream catchments. Some minor work to increase the capacity of the swales prior to the sediment dams may be required to safely convey water through the site. More detailed survey in the detailed design stage would be needed to confirm that the capacity of the downstream swale is adequate to cater for the increased flow rates.

As mentioned previously in Section 1.4 the culvert currently discharging into the first flush basin is permanently submerged. This is detrimental to the existing stormwater system for a number of reasons. Firstly it makes the culvert difficult to maintain. It also reduces the effective pipe capacity and the velocities in the pipe. This promotes sediment build up in the pipe that is not easily removed and reduces the self-cleansing ability of the pipe. The proposed site strategy will reduce the amount water backing up this culvert and will therefore improve water quality and bring it more in line with current best engineering practice principles.

4.2 Maintenance

Due to the flat longitudinal swale grades it is likely that a relatively large amount of sediment will build up in the proposed swale system. This is acceptable and indeed desirable provided that a strict and routine maintenance program is put into place.

The swales and basins will need to be cleaned on a regular basis and it should be obviously apparent when a significant amount of sediment builds up. Frequent inspections and swale invert mark posts are some possible methods to keep the swales operating at their optimal performance level.

5. Peak flows

5.1 General

Modelling was carried out using XP-SWMM, a one-dimensional hydrodynamic model, to assess the capacity of the existing drainage system and to provide flow rates to be used in the design of proposed water quality structures.

An existing XP-SWMM model was previously developed for the site, predominately for the upstream 'HPP Site 2' and 'StructaFlor' sites. This model included the trunk drainage line draining these upstream areas, the first flush basin and the Borg site. However, it did not include the 'HPP Site 1' area, the second sediment pond on the Borg site and the upstream rural area. These elements were added to the previous model and this enabled an assessment of the current networks capacity to be carried out.

The existing model was then updated to include the proposed development and the stormwater management strategy to size the conveyance and treatment devices and to assess flow rates post development. Provided below are details of the XP-SWMM models.

5.2 Catchment plan

A catchment plan of the site was based on available contour data and observations made during the site visit.

The study area was divided into three main catchments. The southern catchment consisted of the 'HPP Site 2' and 'StructaFlor' areas. This catchment was linked to the eastern catchment via the major culvert crossing under Lowes Mount Road. The eastern catchment was formed by the Borg site and the western catchment was formed by the large upstream rural catchment and the 'HPP Site 1' area. Each of the major catchments were subdivided and a catchment plan is provided in Figure 5.

5.3 Catchment parameters

The XP-SWMM model accounts for rainfall losses across a subcatchment by implementing an Initial-Continuing Loss Rate Model. The loss and roughness parameters used in the XP-SWMM model are provided below in Table 5-1.

Table 5-1 Adopted loss parameters in XP SWMM

Land type	Initial loss (mm)	Continuing loss rate (mm/hr)	Overland manning's 'n'
Hardstand	1.5	0	0.018
Pervious	20.0	2.7	0.03

Details of the modelled geometry of pipe conduits and open channels have been provided in Appendix A and this represents the configuration adopted for the estimation of the capacity of the existing drainage network. The developed modelled geometry can be seen in

Appendix B. Existing and developed sub-catchment data can be seen in Appendix F and G respectively.

Detailed design plans of the sites sediment basins, showing internal dimensions and outlet configurations were unavailable during the modelling exercise. These parameters were determined using information obtained during the site inspection and storage-height relationships were developed using the plan area of the basins. Since the basin's main function is to provide water quality storage, the amount of detention storage afforded by the dams is less critical for the modelling exercise.

During the site inspection Borgs management estimated that they re-use approximately 150 kL/day on-site. A conservative value of 100 kL/day was therefore adopted in this investigation. The existing basins were modelled in XP-SWMM with a combined nominal initial depth equivalent to the overflow depth minus 500 kL (or 5 days combined worth of re-use). The new proposed sediment basin was also modelled with an equivalent volume of 500 kL below the overflow level to allow for a consistent amount of water re-use between the developed and the existing scenarios.

5.4 Design rainfall

Hydrologic calculations were carried out using intensity-frequency-duration (IFD) data for Oberon, as calculated using the method described in Australian Rainfall and Runoff (AR&R) (1987). The calculated IFD table is provided in Appendix C.

Design rainfall pluviographs for a range of storm durations and recurrence intervals were generated by the XP-SWMM software using the calculated average rainfall intensity data for Oberon. This enabled the sizing of drainage and water quality structures to be carried out.

5.5 Model calibration

As mentioned previously, an existing XP-SWMM model from previous work for CHH was expanded upon for this investigation. Due to the absence of recorded stream flow data from the site, this model was previously compared against estimates from the probabilistic rational method (PRM), as described in AR&R (1987).

A comparison of the rational method and XP-SWMM predicted peak flows is provided in Table 5-2 for the 1, 5, 10, 20, 50 and 100 year ARI storm events. Details of the PRM calculations are provided in Appendix D.

Table 5-2 Comparison of rational method and XP-SWMM estimated flow rates at the site outlet

ARI	Rational method estimated flow (m^3/s)	XP-SWMM predicted flow (m^3/s)	% Difference to rational method estimate
1	2.1	2.8	+33
5	4.1	4.9	+20
10	4.9	5.7	+16
20	5.9	6.6	+12
50	7.7	7.4	-4
100	9.1	8.1	-11

5.6 Existing drainage network capacity

Using the previously developed XP-SWMM model and the additional 'HPP Site 1', Borg site and upstream rural catchments the capacity of the existing drainage network was assessed by comparing the flow depth within channels against the total channel depth indicated by the contour plan. The second sediment basin was also incorporated into the model to accurately reflect the real world processes occurring. With regard to the detention of stormwater, XP-SWMM only uses the storage available between the permanent water level and the top of overflow weirs.

Results obtained from the XP-SWMM model indicate that the sites drainage network, consisting of vegetated open channels and concrete culverts, is, generally, adequately sized to convey the 100 year ARI design event. The existing swales immediately prior to the sediment basin downstream of 'Gate 6' appear to be slightly undersized when water is overflowing from these basins. However this will need to be confirmed with more detailed survey data in the detailed design phase of development.

5.7 Proposed drainage network capacity

5.7.1 General

The XP-SWMM model was updated to assess the hydraulic performance of the proposed development and water quality structures.

Details of the modelled geometry of pipe conduits and open channels have been provided in Appendix B and this represents the configuration adopted for the estimation of design flow rates for the site's water quality devices.

5.7.2 Results

Estimated peak flow rates and water levels, for the 100 year ARI storm event, at key elements along the sites trunk drainage line are provided below in Table 5-3. The critical storm duration for each of the drainage elements is also provided.

Table 5-3 Estimated peak flow rates and flow depths

Element name	Drainage element	Peak flow (m^3/s)	Peak flow depth (m)	Critical storm duration (min)
Swale 1	Grassed Bunded Swale (1.5 m deep)	6.95	1.54	90
Culvert 1	4 × 1050 mm dia. RCP	6.58	NA	60
Gate 6 Culvert 2	3 × 1050 mm dia. RCP	3.36	NA	60
Gate 6 Culvert 3	3 × 1050 mm dia. RCP	3.07	NA	60
CHH and Borgs Flows Swale	Grassed Swale (0.68 m deep)	6.11	0.68	60
Boral Flows Swale	Grassed Swale (0.6 m deep)	2.14	0.50	60

The results show that the proposed drainage network is adequately sized to convey the 100 year ARI design storm with a minor increase in the capacity of the ‘CHH and Borgs Flows Swale’, as shown in Figure 4. The dimensions of this swale indicate the likely capacity that this swale will need to convey the 100 year flow. Exact dimensions of this swale will depend on site specific factors and will be decided upon during the detailed design stage. Results from XP-SWMM also indicate that building slabs should not be built below 1094m AHD.

5.8 Peak flow rate results

Both the existing and developed peak flow rates were estimated in XP-SWMM leaving the site at the licensed discharge location. These discharge rates can be seen below in Table 5-4 along with the critical storm event durations.

Table 5-4 Existing and developed peak flow rates at Gate 6

ARI	Existing peak flow rates (m^3/s)	Developed peak flow rates (m^3/s)	Relative increase (%)
1	1.65 (540 min)	1.82 (540 min)	9.3
10	3.62 (60 min)	4.85 (60 min)	25.4
100	7.17 (60 min)	8.78 (60 min)	18.3

It can be seen from Table 5-4 that the development is expected to slightly increase the peak flow rates discharging from the site. This occurs due to an increase in impervious area.

Detention of the peak flows discharging from these basins is largely dependent on the initial water level in the basins. Since the basins have a permanent storage volume below the outlet this initial water level is essentially dependent on the amount of water that has been pumped out and re-used on-site. Therefore the only detention that these basins provide is the volume between the initial water level and the overflow level. The main function of the sediment basins is to provide water quality storage rather than the mitigation of peak flow rates.

Unfortunately, traditional detention basin structures are difficult to integrate into the extremely flat site. In addition, a preferential geographic location for a possible detention basin (downstream of ‘Gate 6’) is limited by potential groundwater contamination issues with the northern fibre dump.

Given these considerable constraints and the large amount of water reused on-site, the modelled peak flow rates observed at the licensed discharge location are considered acceptable for the site. Additional basins and increased capacity of existing infrastructure prior to the site discharge location could be a future possibility if peak flow rates are later required to be mitigated further.

6. Water quality control

6.1 General

Water quality is currently monitored at several locations at the Oberon Timber Complex. Sampling results from three of these monitoring points were analysed during this investigation. These included the Borg discharge point, the adjacent 'HPP Site 1' 'north dam' discharge point and at the 'StructaFlor' 'gate 1' discharge point.

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) has been utilised as the key water quality modelling tool for this project. MUSIC is a continuous simulation water quality model used to evaluate the short and long-term performance of stormwater improvement devices that are configured in series or in parallel to form a 'treatment train'. MUSIC enables the end-user to determine if proposed systems can meet specified water quality objectives.

The MUSIC model considers suspended solids, total nitrogen and total phosphorus, which are typical components and key indicators of stormwater runoff. The key MUSIC model inputs are:

- rainfall and evaporation data
- catchment area and percentage impervious
- soil storage parameters
- pollutant event mean concentrations for source nodes.

All input parameters to the MUSIC model were derived from either climate data supplied by the Bureau of Meteorology (BOM) or estimated from the MUSIC model manual (2009) and other published papers.

MUSIC model outputs include:

- average annual pollutant export rates
- treatment train effectiveness, expressed in terms of pollutant reduction.

6.2 Existing conditions

6.2.1 MUSIC parameters

6.2.1.1 Rainfall and evapotranspiration

Six minute rainfall data for Oberon (Jenolan Caves Road) and Oberon Dam were obtained from the Bureau of Meteorology (BOM). The data for Oberon spanned approximately 12 years from 1993 to 2005 and the data for Oberon Dam spanned approximately 33 years from 1955 to 1988. Rainfall from the Oberon pluviograph data was used in the MUSIC modelling as it is the more recent of the two sets and contains the longest period without any missing data.

The mean annual rainfall recorded at this gauging station is 457 mm. A summary graph of rainfall used within the MUSIC models is provided in Appendix E.

Monthly average areal potential evapotranspiration values for the area were obtained from the *Climatic Atlas of Australia – Evapotranspiration* (BOM, 1999). Evapotranspiration values are given in Table 6-1. The total annual evapotranspiration was 1175 mm.

Table 6-1 Monthly average areal potential evapotranspiration values

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evapo-transpiration (mm/month)	160	120	115	80	55	40	45	60	85	120	145	150

6.2.1.2 Time step

The model was run with a time step of 6 minutes that spanned the period 2000 to 2005 as this was the longest period without any missing data. This time step was used to maximise the model reliability and output sensitivity.

6.2.1.3 Land use

The following land uses were defined within the model:

- rural – this represents the upstream rural catchment adjacent to the 'HPP Site 1' area
- industrial – this represents the developed areas of the site including buildings and pavement areas, with portions of intermittent pervious areas.

6.2.1.4 Hydrology

MUSIC hydrology parameters adopted for each land use are summarised in Table 6-2 are based on the default parameters provided in the MUSIC User Guide Version 4 (2009).

Table 6-2 MUSIC hydrology parameters for each land use

Parameter	Rural	Industrial
Impervious area		
Impervious percentage	5%	90%
Rainfall threshold (mm/day)	1	1
Pervious area properties:		
Soil storage capacity (mm)	120	120
Initial storage (%)	30	30
Field capacity (mm)	80	80
Infiltration capacity coefficient, a	200	200
Infiltration capacity exponent, b	1	1
Groundwater properties:		
Initial groundwater depth (mm)	10	10
Daily recharge rate (%)	25	25

Parameter	Rural	Industrial
Daily baseflow rate (%)	5	5
Daily deep seepage rate (%)	0	0

6.2.1.5 Event mean concentrations

The MUSIC model requires pollutant generation parameters for baseflow and stormflow conditions. Baseflow is derived from the groundwater store, which is recharged from the pervious soil store. Stormflow is generally generated from the impervious area, and under some conditions the pervious area as well.

Pollutant parameters for the rural area were based on concentrations documented in *Australian Runoff Quality (*Engineers Australia, 2006). The pollutant parameters for the developed parts of the site were obtained from the water quality monitoring data for the 'StructaFlor' 'gate 1' discharge point. This data was used as it was the only available sampling site that monitors runoff purely from the developed site (without any large undeveloped area) and was considered a good representation of the likely water quality that would run off all the highly developed areas at the site.

A summary of event mean concentrations adopted for baseflow and stormflow conditions are provided in Table 6-3. Baseflow and stormflow values for the industrial areas were the same since observed pollutant concentration averages were utilised in the MUSIC modelling.

Table 6-3 Baseflow and stormflow pollutant mean concentrations for each land use

Land use	Mean concentration		
	Total suspended solids (mg/L)	Total phosphorous (mg/L)	Total nitrogen (mg/L)
Rural - baseflow	18	0.06	0.9
Rural - stormflow	112	0.21	2.00
Industrial – baseflow	37	0.2	3.22
industrial - stormflow	37	0.2	3.22

6.2.2 MUSIC calibration

Due to the absence of site specific runoff quantity data, accurate calibration of the MUSIC model could not be undertaken. Instead, the predicted volumetric runoff coefficients have been compared against typical values for similar land uses documented in *Managing Urban Stormwater: Strategic Framework* (DEC, 1997).

A comparison of model predicted and typical volumetric runoff coefficients is summarised in Table 6-4 for each land use. Predicted volumetric runoff coefficients were calculated using the predicted runoff volume and the average annual rainfall reported in the model for the analysed rainfall period. As site actual observed specific pollutant data was used in the MUSIC model, calibration of the pollutant loads was not required.

Table 6-4 Comparison of typical and predicted volumetric runoff coefficients

Land use	Volumetric runoff coefficient	
	Typical	MUSIC predicted
Rural	0.2	0.19
Industrial	0.8	0.79

6.2.3 Existing water quality controls

6.2.3.1 Existing treatment devices

Water quality controls on the site currently consist of:

- vegetated open channels
- sediment basins both upstream and downstream of 'Gate 6'.

6.2.3.2 Modelling parameters

Sediment basins

The existing sediment basins were modelled in MUSIC using information obtained during the site inspection and aerial imagery. Storage-height relationships were then developed using the respective plan areas to model the pollutant removal characteristics of the basins as realistically as possible. Input data used to model the basins is shown below in Table 6-5.

Table 6-5 Existing sediment basin parameters

Parameter	Sediment basin 1	Sediment basin 2	Sediment basin 3	Sediment basin 4	Sediment basin 5
Low Flow By-Pass (m^3/s)	0	0	0	0	0
High Flow By-Pass (m^3/s)	100	100	100	100	100
Surface Area (m^2)	2300	1750	3000	900	900
Extended Detention Depth (m)	0	0	0	0	0
Permanent Pool Volume (m^3)	3060	4410	5520	1100	1100
Exfiltration Rate (mm/hr)	0	0	0	0	0
Evaporative Loss as % of PET	100	100	100	100	100
Overflow Weir Width (m)	2.5	2.8	9.0	3.5	3.5
Daily Re-Use Demand (kL/day)	50	50	0	0	0

Vegetated swales

Existing channels at the site were modelled as vegetated swales in MUSIC. These swales facilitate an even distribution and slowing of flows thus encouraging particulate pollutant settlement. The swale parameters used in MUSIC are the same as those used in XP-SWMM and are shown in Appendix A.

6.3 Developed conditions

6.3.1 General

The proposed development at the site including the proposed warehouse and adjacent hardstand areas was determined to increase the impervious area at the site by approximately 2 ha.

The proposed stormwater treatment train was investigated in MUSIC to determine the most practical and cost-effective water quality strategy that would comply with the EPL requirements for the site. It should be noted that this study only investigated the stormwater treatment devices that receive and are affected by runoff from the proposed development. Therefore the MUSIC results are not an accurate representation of what is likely to be observed at the licensed discharge location. However, they do allow an accurate approach to compare the existing pollutant loads with the developed pollutant loads post development.

The proposed stormwater management strategy involved a large, flat swale network that treats the runoff from the site and upstream areas and conveys the water into downstream sediment basins with increased storage capacity prior to discharge from the site. Due to the flat nature of the swale connecting the upstream areas to the culverts below 'Gate 6', it was modelled in MUSIC as a pond with a very small permanent pool volume, simply because this was predicted to provide a more accurate representation of the real life processes involved with the treatment of the runoff.

The swale treatment efficiency equations and parameters in MUSIC are not designed for flat grades and a sensitivity analysis conducted in MUSIC suggested that the swale nodes significantly overestimated the treatment capabilities of swales at very low grades. A summary of the treatment train can be seen in Figure 4.

6.3.2 Proposed water quality controls

6.3.2.1 Proposed treatment devices

Water quality controls proposed at the site include:

- grassed swales
- existing sediment basins with increased storage capacities.

6.3.2.2 Modelling parameters

Sediment basins

The sediment basins were modelled using plans of the proposed development to determine the available surface area for any potential upgrades to the basins. Similar storage-height relationships to those used to model the existing basins were then used to model the proposed basins, post development. A consistent amount of water re-used from the basins (100 m^3/day) was adopted in the model. Input parameters for the proposed basins and the proposed flat swale through the site can be seen below in Table 6-6.

Table 6-6 Proposed sediment basin parameters

Parameter	Proposed flat Swale 1	Upgraded basin 3	Upgraded basin 4
Low Flow By-Pass (m^3/s)	0	0	0
High Flow By-Pass (m^3/s)	100	100	100
Surface Area (m^2)	2205	3500	1800
Extended Detention Depth (m)	0	0	0
Permanent Pool Volume (m^3)	745	6435	2200
Exfiltration Rate (mm/hr)	0	0	0
Evaporative Loss as % of PET	100	100	100
Overflow Weir Width (m)	10.0	9.0	3.5
Daily Re-Use Demand (kL/day)	0	100	0

Vegetated swales

Proposed grass swales were modelled in MUSIC using the parameters shown in Figure 4. Many of the existing swales are expected to be retained as part of the stormwater management strategy and were therefore modelled in MUSIC with the same parameters used in the existing model. The CHH and Borgs Flows Swale downstream of 'Gate 6' was modelled with an increased swale capacity compared to the existing capacity, as this was a requirement identified by the XP-SWMM modelling.

6.4 MUSIC results

The MUSIC results at the site outlet for the existing and developed scenarios are shown below in Table 6-7 Pollutants investigated in the model include Total Suspended Solids (TSS), Total Phosphorous (TP) and Total Nitrogen (TN).

Table 6-7 MUSIC treatment train efficiency and results

	Pollutant	Flow (ML/year)	Mitigated pollutant load (kg/year)	Treatment efficiency (%)	Treated concentration (mg/L)	Meet EPL target?
Existing	TSS	87.3	1380	80.7	15.81	Yes (30 mg/L))
	TP	87.3	10.0	72.9	0.114	Yes (0.3 mg/L)
	TN	87.3	176	70.5	2.02	Yes (10 mg/L)
Developed	TSS	97.8	1530	80.4	15.64	Yes (30 mg/L))
	TP	97.8	11.2	73.0	0.114	Yes (0.3 mg/L)
	TN	97.8	218	67.6	2.23	Yes (10 mg/L)

It can be seen from Table 6-7 that both the existing and developed scenarios removed approximately the same amount of pollutants from the stormwater runoff discharging from the site. In addition, both scenarios meet the EPL targets for TSS, TP and TN. Existing pollutant concentration results discharging from the site are similar to what would be expected in this location, given that the investigation only considered the stormwater treatment devices that receive and are affected by runoff from the proposed development.

The observed average pollutant concentrations recorded leaving the Borg site are:

- TSS = 7.82 mg/L.
- TP = 0.08 mg/L.
- TN = 2.75 mg/L.

6.5 Discussion of water quality treatment strategies

From the stormwater management investigation and modelling results the proposed stormwater management strategy is a feasible and acceptable solution for the site post development. It provides similar treatment efficiencies to the existing system mainly because more runoff is directed through the enlarged sediment dam. In addition, by joining the two small dams immediately prior to the site discharge location the treatment capability of the system is increased because the northern dam can be utilised to treat more of the runoff from the site.

It should be noted that there is potential for the upgraded basin in the developed scenario to be further enlarged for additional water storage depending on considerations during the detailed design stage.

It is quite possible that infrequent higher pollutant levels are due to maintenance issues with the existing water quality treatment devices. Sediment build up in the existing channels was observed during the site inspection and may be adding to pollutant concentrations at the discharge location. The devices should be designed to be easily cleaned and inspected as discussed in Section 4.2.

Other pollutants that were not able to be modelled in MUSIC such as BOD and the true colour of the stormwater runoff are also expected to be treated to an adequate level by the stormwater management strategy, since these pollutants are generally linked to the pollutants modelled in MUSIC. For instance if the TSS is reduced then it is likely that the true colour of the runoff will also be reduced. In addition, the previous upstream works are expected to gradually improve water quality over the next year, and continue into the future, which will have beneficial impacts on the water discharging from the Borg site.

Aeration devices are able to be retrofitted to the system in the future if more Dissolved Oxygen (DO) is required within the stormwater treatment train.

7. Conclusions and recommendations

The stormwater management strategy for the proposed warehouse and associated hardstand development at the Oberon Timber Complex was required to manage runoff quality and quantity at the site. XP-SWMM and MUSIC were used to ensure that the final strategy was capable of conveying the 100 year ARI flow rates and that the site maintained pollutant runoff concentrations within its EPL limit requirements.

Two scenarios were investigated in MUSIC including the existing and developed cases. The proposed stormwater management strategy for the developed case was found to provide similar and adequate pollutant removal efficiencies with respect to the EPL limits. The final recommended stormwater strategy incorporated:

- Approximately 250 m of new grassed swales.
- Increasing the surface area and volume of one of the existing sediment basins by approximately 500 m^2.
- Construction of a new segregated swale used to separate and convey flows from the CHH and Boral sites.
- A junction pit and approximately 83m of 1050mm diameter stormwater line to intercept the line from HPP Site 2 and StructaFlor and connect to the upstream side of proposed Swale 1.
- The construction of 2 sets of 2 x 1050 mm diameter culverts approximately 33 m long to connect the proposed swale system with the existing culverts below ‘Gate 6’.
- Providing a diversion bund downstream of ‘Gate 6’ to maintain the separation of CHH and Boral flows up to the 1yr ARI event.
- Maintaining the two small sediment dams prior to the licensed discharge point.
- Checking the capacity of the existing swales and drainage to ensure compliance with the 100 year ARI standard.

This proposed stormwater management is in addition to water quality work previously undertaken by PB upstream of the Borg site. These upstream works are anticipated to further improve the water quality discharging from the site into Kings Stockyard Creek.

Peak flows at the site are expected to increase slightly due to the increased impervious areas however this was considered acceptable given the site constraints and the large amount of water re-used at the site.

If peak flow rates are required to be further attenuated in the future there is potential to increase the storage and detention capabilities of the existing sediment basins immediately upstream of the discharge point. Aeration devices could also be retrofitted to the proposed stormwater treatment devices to improve the performance of the system if required.

The proposed treatment devices will require frequent inspection and maintenance to maintain optimal performance.

8. References

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Figures

Client: Borg Construction
Project: Oberon Stormwater Improvement Works
Location: Oberon, NSW

PARSONS BRINCKERHOFF

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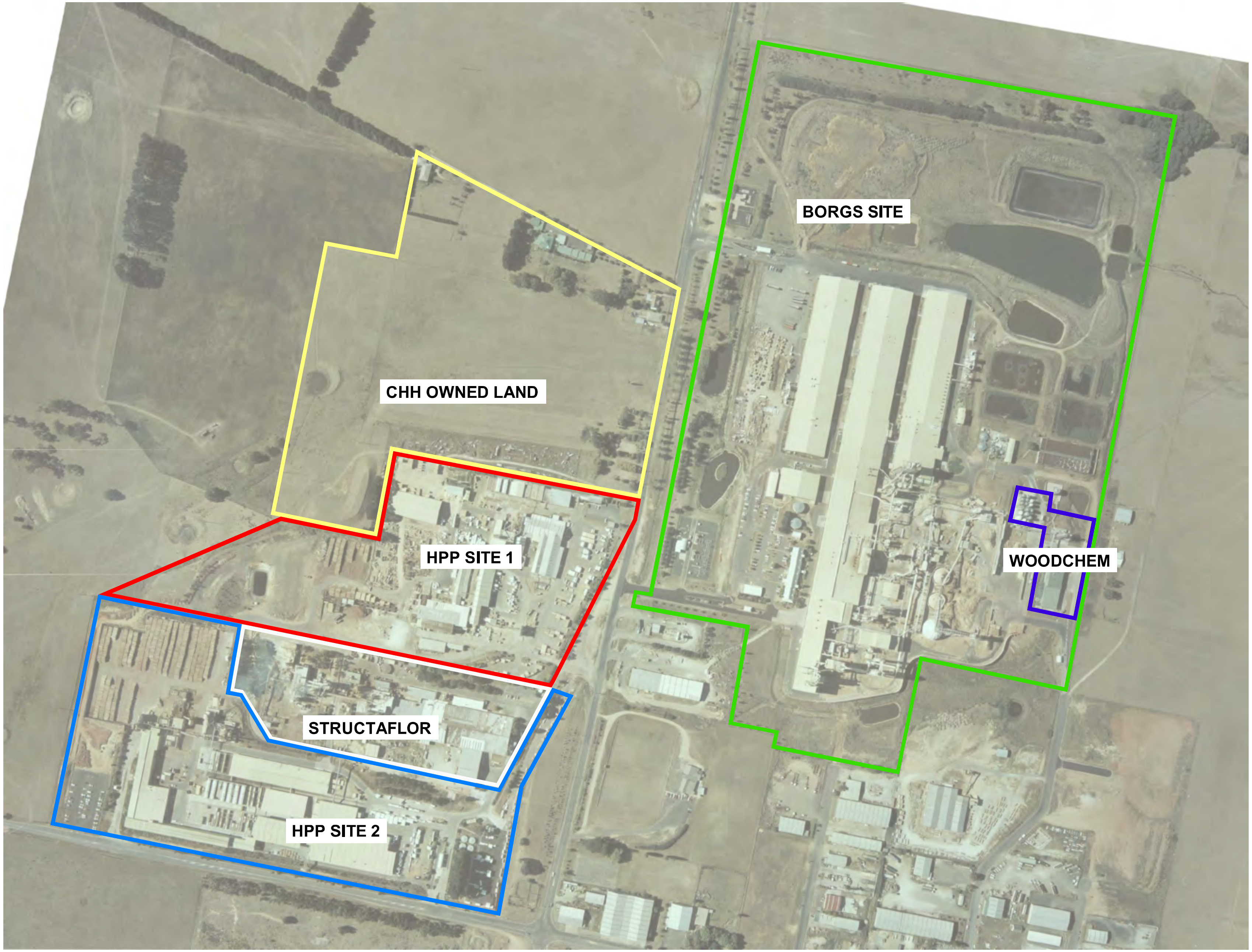
Locality Plan

Figure No. 1

Client: Borg Construction
Project: Oberon Stormwater Improvement Works
Location: Oberon,NSW

PARSONS BRINCKERHOFF



Breakdown of Site and Processes
Figure No. 2

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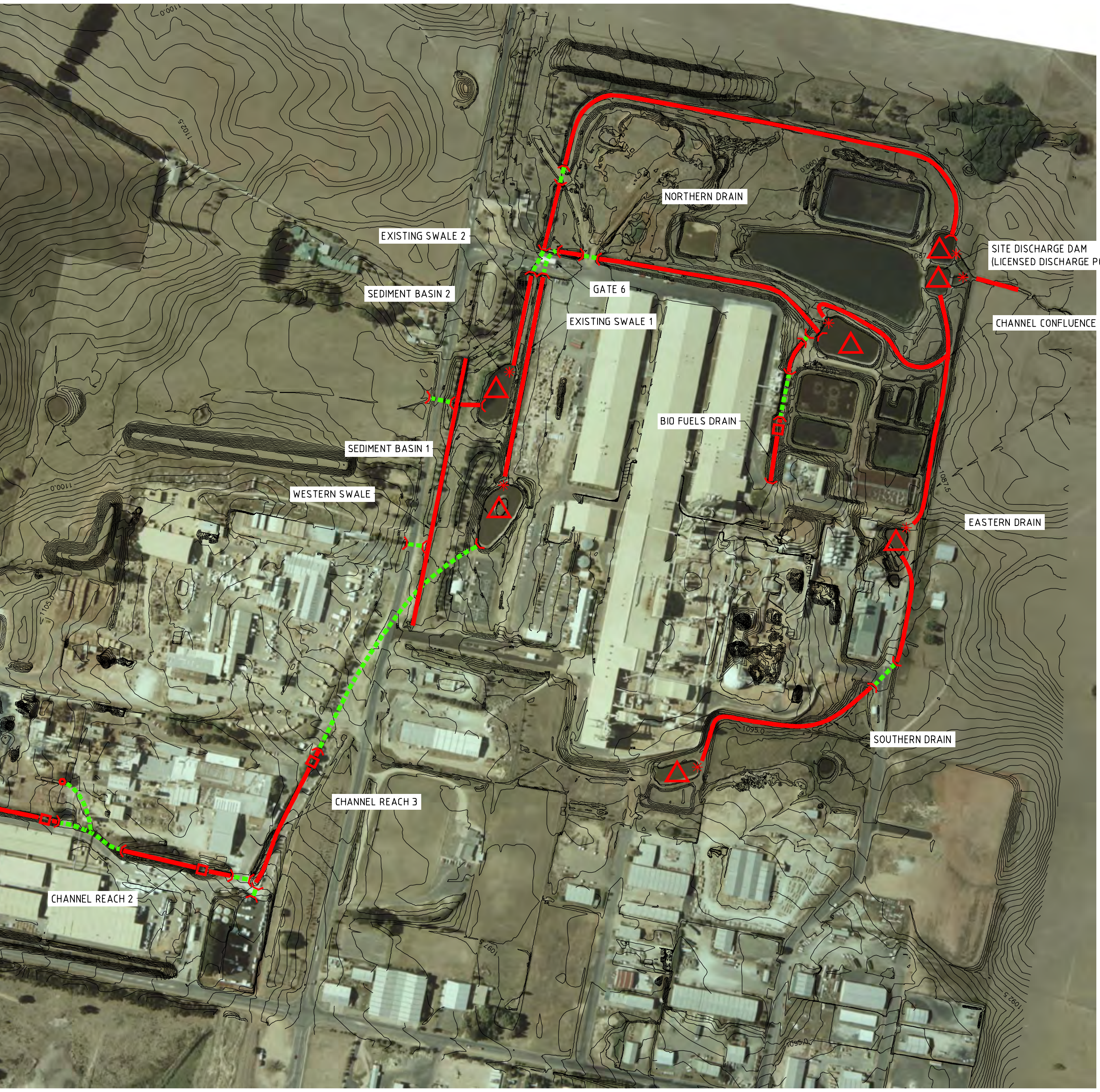

LEGEND:

OPEN CH

PIPE LIN

CULVER

OVERFL

STORAG

GPT

DRIVE IN

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Client: Borg Construction
Project: Oberon Stormwater Improvement Works
Location: Oberon,NSW

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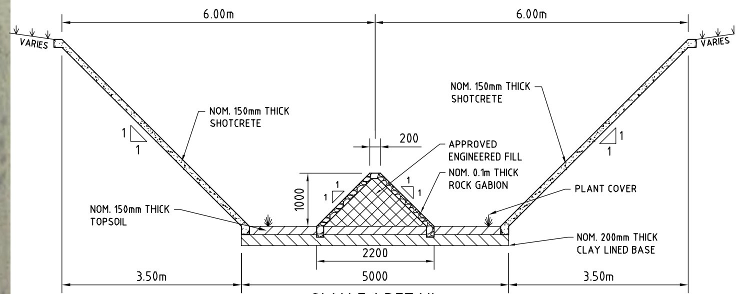

SWALE 1 DETAIL

SCALE 1:100

NOTE:
BUND IN PROPOSED SWALE 1 IS INCLUDED TO SEPARATE FLOWS FROM THE BORAL AND CHH SITES.

0 25 50 75
Full Size 1:2500 A3; SCALE (m)

0 1 2 3
Full Size 1:100 A3; SCALE (m)

Proposed Development and Stormwater Strategy

Figure No. 4

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Appendix A

Existing pipe conduits and open channels

Borg Oberon Project No. 2103481A
Hydrologic and Hydraulic Analysis Client Ref.
Existing XP-SWMM Link Data Date: 15/03/2011

Link Name	Length (m)	Shape	Roughness	Bottom Width (m)	Diameter/ Height (m)	Slope (%)	Left-hand Batter (1 in)	Right-hand Batter (1 in)
Pipe1	15	Circular	0.014	0	0.45	6.667	0	0
Link51	10	Trapezoidal	0.014	2	1.5	0	2	2
link2	30	Trapezoidal	0.014	2	2	0.667	3	3
lowflow	40	Circular	0.014	0	0.375	0.42	0	0
road	100	Trapezoidal	0.014	2	0.5	0	3	3
Link33	63	Trapezoidal	0.014	2	1.7	0.206	3	2
231.1	20	Circular	0.014	0	1.05	-0.2	0	0
road2	20	Natural	0.014	0	0	1	0	0
road2	20	Natural	0.014	0	0	1	0	0
Link38	85	Circular	0.014	1	1.2	0.771	3	3
Pipe5	20	Circular	0.014	0	0.375	8.9	0	0
culvert	300	Circular	0.014	0	1.05	2.053	0	0
234.1	10	Circular	0.014	0	0.05	0	0	0
overflow	10	Circular	0.014	0	0.05	0	0	0
Channel4	240	Trapezoidal	0.03	2.5	1.5	0.425	3	3
FFCUL	34	Circular	0.014	0	1.05	0.265	0	0
FFOV	10	Circular	0.014	0	0.05	0	0	0
FFOFL	10	Circular	0.014	0	0.05	0	0	0
Link86	39	Trapezoidal	0.05	4.6	1	0.026	3	3
weir1	10	Circular	0.014	0	0.05	0	0	0
overflow.1	10	Circular	0.014	0	0.05	0	0	0
channel8	80	Trapezoidal	0.03	2	1.5	1.938	3	3
242.1	10	Circular	0.014	0	0.05	0	0	0
weir	10	Circular	0.014	0	0.05	0	0	0
245.1	70	Circular	0.014	0	0.375	0	0	0
over	70	Circular	0.014	0	0.375	0	0	0
channel6	60	Trapezoidal	0.014	2	1.5	1	3	3
RCP	50	Circular	0.014	0	0.45	2	0	0
channel	60	Trapezoidal	0.02	7	1	0	2	2
channel7	50	Trapezoidal	0.02	2	1	2	3	3
Link37	100	Trapezoidal	0.03	3	2	1	3	3
Pipe3	55	Circular	0.014	0	0.75	4.349	0	0
channel9	50	Trapezoidal	0.03	2	1.5	0.7	3	3
channel10	220	Trapezoidal	0.03	2	1.5	0.25	3	3
pipe	30	Circular	0.014	0	0.45	2.5	0	0
bypass	10	Circular	0.014	0	0.05	0	0	0
lowFcul	20	Circular	0.014	0	1.05	0.5	0	0
lowFOF	10	Circular	0.014	0	0.05	0	0	0
lowfOF	10	Circular	0.014	0	0.05	0	0	0
Link30	80	Trapezoidal	0.03	3	0.5	0.525	4	4
Link31	100	Trapezoidal	0.03	3	0.5	1.059	4	4
Link32	80	Trapezoidal	0.03	3	0.5	0.713	4	4
Link34	63	Trapezoidal	0.014	2	1.9	0.111	3	2
top	50	Natural	0.02	3	0.2	1	3	3
low	38.181	Circular	0.014	0	0.3	0.909	0	0
southweir	10	Circular	0.014	0	0.05	0	0	0
Link95	10	Trapezoidal	0.03	10	2	1	3	3
Link39	60	Circular	0.014	1	1.2	0.707	3	3
rack	10	Circular	0.014	0	0.05	0	0	0
trash	10	Circular	0.014	0	0.05	0	0	0
Link67	61.23	Trapezoidal	0.014	2	1	1.943	1.5	1.5
Link36	320	Trapezoidal	0.03	2	1	2.188	3	3
STRUpipe1	65	Circular	0.014	0	0.45	0.277	0	0
Link71	13.131	Circular	0.014	0	0.3	0.998	0	0
Link70	16.698	Circular	0.014	0	0.3	1	0	0
twin250-1	24.6	Circular	0.014	0	0.25	2.2	0	0
twin250-2	24.6	Circular	0.014	0	0.25	2.2	0	0
Link74	24	Circular	0.014	0	1.05	2.625	0	0
Link77	20	Trapezoidal	0.03	10	1	2	3	3
Link78	40	Circular	0.014	0	0.6	0.89	0	0
Link76	20	Trapezoidal	0.03	2	1	1.12	1	1
pond2OF	10	Circular	0.014	0	0.05	0	0	0
Pon2OF	10	Circular	0.014	0	0.05	0	0	0
SWCUL	31.2	Circular	0.014	0	1.05	0.801	0	0
SWOVF	10	Circular	0.014	0	0.05	0	0	0
SWOV	10	Circular	0.014	0	0.05	0	0	0
Link87	77	Trapezoidal	0.05	1.5	1	0.039	4	4
Link79	107	Trapezoidal	0.03	2.86	0.7	0.636	4.4	4.4
Link75	164	Trapezoidal	0.03	1	1.5	0.717	1	1
HighFCul	24.8	Circular	0.014	0	1.05	0.605	0	0
HighFOF	10	Circular	0.014	0	0.05	0	0	0
HighFOF	10	Circular	0.014	0	0.05	0	0	0
Link90	291	Trapezoidal	0.05	3	1	0.704	3	3
Link91	170	Trapezoidal	0.05	1	0.8	1.053	5	5
Link92	103	Trapezoidal	0.05	3.5	0.65	0.728	6	6
weir2	10	Circular	0.014	0	0.05	0	0	0
weir2	10	Circular	0.014	0	0.05	0	0	0
Link94	100	Trapezoidal	0.03	3	2	1	3	3

Appendix B

Developed pipe conduits and open channels

Borg Oberon Project No. 2103481A
Hydrologic and Hydraulic Analysis Client Ref.
Developed XP-SWMM Link Data Date: 22/03/2011

Link Name	Length (m)	Shape	Roughness	Bottom Width (m)	Diameter/ Height (m)	Slope (%)	Left-hand Batter (1 in)	Right-hand Batter (1 in)
Pipe1	15	Circular	0.014	0	0.45	6.667	0	0
Link51	10	Trapezoidal	0.014	2	1.5	0	2	2
link2	30	Trapezoidal	0.014	2	2	0.667	3	3
lowflow	40	Circular	0.014	0	0.375	0.42	0	0
road	100	Trapezoidal	0.014	2	0.5	0	3	3
Link33	63	Trapezoidal	0.014	2	1.7	0.206	3	2
231.1	20	Circular	0.014	0	1.05	-0.2	0	0
road2	20	Natural	0.014	0	0	1	0	0
road2	20	Natural	0.014	0	0	1	0	0
Link38	85	Circular	0.014	1	1.2	0.771	3	3
Pipe5	20	Circular	0.014	0	0.375	8.9	0	0
Link95	299	Circular	0.014	0	1.05	1.866	0	0
Link87	125	Trapezoidal	0.03	3	1.5	0	2	2
Link91	10	Trapezoidal	0.03	20	2	0.2	0.01	0.01
weir1	10	Circular	0.014	0	0.05	0	0	0
overflow.1	10	Circular	0.014	0	0.05	0	0	0
channel8	50	Trapezoidal	0.03	2	1.5	3.1	3	3
weirA	10	Circular	0.014	0	0.05	0	0	0
weirB	10	Circular	0.014	0	0.05	0	0	0
weirA	10	Circular	0.014	0	0.05	0	0	0
weirB	10	Circular	0.014	0	0.05	0	0	0
245.1	70	Circular	0.014	0	0.375	0	0	0
over	70	Circular	0.014	0	0.375	0	0	0
channel6	60	Trapezoidal	0.014	2	1.5	1	3	3
RCP	50	Circular	0.014	0	0.45	2	0	0
channel	60	Trapezoidal	0.02	7	1	0	2	2
channel7	50	Trapezoidal	0.02	2	1	2	3	3
Link37	100	Trapezoidal	0.03	3	2	1	3	3
Pipe3	55	Circular	0.014	0	0.75	4.349	0	0
channel9	50	Trapezoidal	0.03	2	1.5	0.7	3	3
channel10	220	Trapezoidal	0.03	2	1.5	0.25	3	3
pipe	30	Circular	0.014	0	0.45	2.5	0	0
bypass	10	Circular	0.014	0	0.05	0	0	0
lowfcul	20	Circular	0.014	0	1.05	0.5	0	0
lowfOF	10	Circular	0.014	0	0.05	0	0	0
lowfOF	10	Circular	0.014	0	0.05	0	0	0
Link30	80	Trapezoidal	0.03	5	0.6	0.525	4	4
Link31	100	Trapezoidal	0.03	5	0.6	1.059	4	4
Link32	80	Trapezoidal	0.03	5	0.6	0.713	4	4
Link34	63	Trapezoidal	0.014	2	1.9	0.111	3	2
top	50	Natural	0.02	3	0.2	1	3	3
low	38.181	Circular	0.014	0	0.3	0.909	0	0
southweir	10	Circular	0.014	0	0.05	0	0	0
Link39	60	Circular	0.014	1	1.2	0.707	3	3
rack	10	Circular	0.014	0	0.05	0	0	0
trash	10	Circular	0.014	0	0.05	0	0	0
Link67	61.23	Trapezoidal	0.014	2	1	1.943	1.5	1.5
Link36	320	Trapezoidal	0.03	2	1	2.188	3	3
STRUpipe1	65	Circular	0.014	0	0.45	0.277	0	0
Link71	13.131	Circular	0.014	0	0.3	0.998	0	0
Link70	16.698	Circular	0.014	0	0.3	1	0	0
twin250-1	24.6	Circular	0.014	0	0.25	2.2	0	0
twin250-2	24.6	Circular	0.014	0	0.25	2.2	0	0
Link74	24	Circular	0.014	0	1.05	2.625	0	0
Link77	20	Trapezoidal	0.03	10	1	2	3	3
Link78	40	Circular	0.014	0	0.6	0.89	0	0
Link76	20	Trapezoidal	0.03	2	1	7.095	1	1
Link90	75	Trapezoidal	0.03	3	1.5	0	2	2
SWCul	31.2	Circular	0.014	0	1.05	0.801	0	0
FFCul	34	Circular	0.014	0	1.05	0.265	0	0
gateOF	10	Circular	0.014	0	0.05	0	0	0
G8OF	10	Circular	0.014	0	0.05	0	0	0
Link96	39	Trapezoidal	0.03	4.6	1	-0.333	3	3
HighFlow	10	Circular	0.014	0	0.05	0	0	0
HIGHF Weir	10	Circular	0.014	0	0.05	0	0	0
Link98	67	Trapezoidal	0.05	1.5	1	0.045	4	4
Link105	45	Trapezoidal	0.03	3	1.5	0	2	2
Link75	164	Trapezoidal	0.03	1	1.5	0.717	1	1
highfcul	24.8	Circular	0.014	0	1.05	0.605	0	0
highfOF	10	Circular	0.014	0	0.05	0	0	0
highfOF	10	Circular	0.014	0	0.05	0	0	0
Link100	291	Trapezoidal	0.03	3	1	0.704	3	3
Link101	170	Trapezoidal	0.03	1	0.8	1.053	5	5
Link102	103	Trapezoidal	0.03	3.5	0.65	0.728	6	6
newcul	32.5	Circular	0.014	0	1.2	0.462	0	0
new weir	10	Circular	0.014	0	0.05	0	0	0
newweir	10	Circular	0.014	0	0.05	0	0	0

Appendix C

Oberon IFD

Appendix D - OBERON

IFD ANALYSIS BASED ON AUSTRALIAN RAINFALL & RUNOFF (1987)

Site name: township

Site latitude = 33.70 degrees S
longitude = 149.85 degrees E
skewness = .16

2-year ARI, 1 hour intensity = 24.00 mm/hr
12 hour intensity = 4.75 mm/hr
72 hour intensity = 1.40 mm/hr

50-year ARI, 1 hour intensity = 46.00 mm/hr
12 hour intensity = 8.00 mm/hr
72 hour intensity = 2.50 mm/hr

IFD Table for Various ARIs and Durations

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	61.89	79.55	105.73	122.20	143.85	173.47	196.97	221.59	256.11
6 min	57.92	74.41	98.71	113.96	134.04	161.48	183.22	206.00	237.90
10 min	47.21	60.52	79.82	91.86	107.75	129.41	146.53	164.42	189.43
12 min	43.58	55.83	73.45	84.43	98.93	118.67	134.26	150.54	173.28
15 min	39.32	50.32	66.01	75.76	88.65	106.17	119.99	134.41	154.52
18 min	36.01	46.05	60.25	69.05	80.70	96.53	109.00	121.99	140.10
20 min	34.17	43.67	57.06	65.34	76.32	91.21	102.93	115.15	132.16
24 min	31.13	39.75	51.80	59.23	69.09	82.46	92.97	103.91	119.13
30 min	27.66	35.28	45.81	52.29	60.90	72.56	81.71	91.22	104.44
45 min	22.09	28.11	36.26	41.24	47.90	56.87	63.89	71.18	81.28
1.0 hr	18.70	23.76	30.51	34.61	40.10	47.49	53.27	59.25	67.52
1.5 hr	14.50	18.37	23.39	26.41	30.48	35.93	40.18	44.57	50.62
2.0 hr	12.06	15.25	19.29	21.71	24.99	29.36	32.76	36.26	41.08
3.0 hr	9.28	11.69	14.66	16.42	18.83	22.02	24.49	27.03	30.51
4.5 hr	7.13	8.96	11.13	12.41	14.16	16.49	18.28	20.12	22.63
6.0 hr	5.91	7.41	9.16	10.17	11.58	13.43	14.86	16.32	18.31
9.0 hr	4.55	5.69	6.96	7.69	8.72	10.07	11.11	12.16	13.60
12.0 hr	3.78	4.71	5.73	6.31	7.14	8.22	9.04	9.88	11.01
18.0 hr	2.91	3.63	4.44	4.91	5.56	6.42	7.08	7.74	8.65
24.0 hr	2.41	3.01	3.70	4.09	4.65	5.38	5.93	6.50	7.28
30.0 hr	2.08	2.60	3.20	3.55	4.03	4.67	5.16	5.66	6.35
36.0 hr	1.83	2.30	2.84	3.15	3.58	4.16	4.60	5.05	5.66
48.0 hr	1.50	1.88	2.33	2.59	2.95	3.43	3.80	4.18	4.70
72.0 hr	1.10	1.39	1.73	1.93	2.21	2.57	2.86	3.15	3.54

IFD Polynomial: ln I = a + b*ln(D) + c*ln(D)**2 + d*ln(D)**3 + e*ln(D)**4 + f*ln(D)**5 + g*ln(D)**6
where duration D is in hrs and average intensity I is in mm/hr

ARI	a	b	c	d	e	f	g	Max % error
1	2.9237773	-.6030622	-.0359619	.0083954	.0007065	-.0003096	-.0000065	.48
2	3.1633818	-.6092024	-.0374183	.0081530	.0009521	-.0002618	-.0000210	.47
5	3.4137657	-.6272701	-.0415871	.0074453	.0016614	-.0001217	-.0000634	.42
10	3.5400373	-.6370379	-.0438409	.0070626	.0020448	-.0000460	-.0000863	.56
20	3.6876110	-.6452721	-.0457409	.0067400	.0023681	.0000178	-.0001056	.71
50	3.8569763	-.6547223	-.0479214	.0063698	.0027391	.0000911		

```
 -.0001277  |     .88
 100 |   3.9718790   -.6611335   -.0494006    .0061187    .0029908    .0001408
 -.0001428  |    1.00
 200 |   4.0784338   -.6670789   -.0507725    .0058858    .0032242    .0001868
 -.0001567  |    1.11
 500 |   4.2093725   -.6743849   -.0524582    .0055996    .0035110    .0002435
 -.0001738  |    1.25
```

Overland Flow Travel Time Aid
Table of t*I**0.4 where t = time in min and I = intensity in mm/h

Duration	1 yr	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr	500 yr
5 min	26.05	28.80	32.27	34.19	36.49	39.32	41.37	43.37	45.95
6 min	30.42	33.62	37.66	39.89	42.57	45.86	48.24	50.56	53.56
7 min	34.65	38.30	42.86	45.39	48.42	52.16	54.85	57.48	60.87
8 min	38.77	42.84	47.92	50.72	54.10	58.25	61.24	64.16	67.93
9 min	42.79	47.27	52.83	55.91	59.61	64.16	67.44	70.64	74.77
10 min	46.71	51.59	57.63	60.96	64.98	69.92	73.48	76.95	81.43
12 min	54.30	59.96	66.90	70.73	75.36	81.04	85.14	89.13	94.28
14 min	61.61	68.01	75.82	80.12	85.32	91.72	96.32	100.80	106.59
16 min	68.68	75.78	84.43	89.18	94.94	102.01	107.11	112.06	118.46
18 min	75.53	83.33	92.77	97.95	104.25	111.98	117.54	122.95	129.94
20 min	82.19	90.66	100.87	106.48	113.29	121.65	127.67	133.52	141.08
22 min	88.69	97.81	108.77	114.78	122.10	131.07	137.53	143.81	151.91
24 min	95.03	104.79	116.48	122.88	130.69	140.26	147.15	153.84	162.47
26 min	101.24	111.62	124.01	130.80	139.08	149.23	156.54	163.63	172.79
28 min	107.32	118.31	131.39	138.55	147.30	158.01	165.72	173.21	182.87
30 min	113.29	124.87	138.63	146.15	155.35	166.62	174.72	182.59	192.75
40 min	141.69	156.08	172.99	182.21	193.53	207.38	217.34	227.01	239.47

Appendix D

PRM calculations

CHH Oberon | Project No. 2106252A
Hydraulic Assessment | Client Ref.
Rational Method Hydrologic Calculations | Date: 10-Dec-07

ARI	1	$^{10}I_1$ =	34.6 mm/h
C_{10}	0.20	Min Tc	5
Rainfall Data for:	OBERON		

Minimum tc	5
Method for tc	3

1 = Bransby Williams (Rural with main channel > 1000m)
2 = Regional tc=$0.76A^{0.38}$ (Small Rural)
3 = Kinematic Wave

	ARI	1	2	5	10	20	50	100
Rural:	FFy	0.52	0.64	0.82	1	1.21	1.52	1.78
Urban:	FFy	0.8	0.85	0.95	1	1.05	1.15	1.2

Subcatchment	Subcatchment Data					Runoff Coefficient			Subcatchment t_c				Channel Data			TIME OF CONC.		RAINFALL INTENSITY	CA	**FLOW**
	Area	%Imperv.	L	S	n	FFy	C	CA	Bransby.W	Regional	Kinematic	tc	L	v	t	u/s	this			
	ha	%	m	m/m	-	-	-	ha	Min.	Min.	Min.		m	m/s	Min.	Min.	Min.	mm/hr	ha	m^3/s
Catchment 1																				
S1	2.90	90.0%	270	0.020	0.01	0.8	0.666	1.9		11.9	10.7	10.7					10.7	48.1	1.93	0.3
Node2	0.30	90.0%	20	0.020	0.01	0.8	0.666	0.2		5.0	1.7	5.0				10.7	10.7	48.1	2.13	0.3
Node27	3.90	90.0%	260	0.010	0.01	0.8	0.666	2.6		13.3	13.3	13.3					13.3	43.6	2.60	0.3
Sump2	1.80	90.0%	140	0.030	0.01	0.8	0.666	1.2		9.9	5.8	5.8					5.8	61.6	1.20	0.2
Node 47	0.50	70.0%	70	0.012	0.01	0.8	0.559	0.3		6.1	4.9	5.0					5.0	64.9	0.28	0.1
Node33	1.30	70.0%	120	0.010	0.01	0.8	0.559	0.7		8.8	7.6	7.6	50	1	0.8	5.0	7.6	55.3	1.01	0.2
Node32												0.0	50	0.8	1.0	15.0	16.1	40.0	6.94	0.8
Node 5													210	0.8	4.4	10.7	15.0	41.3	5.93	0.7
Node6	1.20	90.0%	165	0.010	0.014	0.8	0.666	0.8		8.5	9.6	9.6	50	0.8	1.0	16.1	17.1	38.8	7.73	0.8
Node8	0.80	90.0%	95	0.010	0.014	0.8	0.666	0.5		7.3	6.5	6.5					6.5	59.0	0.53	0.1
Node7	0.30	90.0%	103	0.036	0.014	0.8	0.666	0.2		5.0	4.4	5.0	50	1.5	0.6	17.1	17.7	38.2	8.47	0.9
Node9	2.20	90.0%	315	0.010	0.014	0.8	0.666	1.5		10.7	15.4	15.4	155	1.5	1.7	17.7	19.4	36.5	9.93	1.0
culvert													300	2	2.5	19.4	21.9	34.4	9.93	0.9
Catchment 2																				
Sp1	3.50	80.0%	190	0.030	0.014	0.8	0.612	2.1		12.8	7.2	7.2				21.9	21.9	34.4	9.94	0.9
Node12	1.10	90.0%	70	0.015	0.014	0.8	0.666	0.7		8.2	4.5	5.0				21.9	21.9	34.4	10.68	1.0
Node13	0.70	90.0%	140	0.015	0.014	0.8	0.666	0.5		6.9	7.4	7.4	210	1	3.5	21.9	25.4	31.8	11.14	1.0
Node29	1.50	90.0%	260	0.010	0.014	0.8	0.666	1.0		9.2	13.3	13.3	90	1.1	1.4	25.4	26.8	31.0	12.14	1.0
Dump	0.60	50.0%				0.8	0.451	0.3		6.5		6.5				26.8	22.2	34.1	12.41	1.2
Node30	2.00	90.0%	260	0.01	0.014	0.8	0.666	1.3		10.3	13.3	13.3	70	1.1	1.1	22.2	23.3	33.3	13.75	1.3
Node31	2.00	90.0%	260	0.010	0.014	0.8	0.666	1.3		10.3	13.3	13.3	90	1.1	1.4	23.3	24.6	32.3	15.08	1.4
Node19	1.80	90.0%	140	0.05	0.014	0.8	0.666	1.2		9.9	4.8	5.0					5.0	64.9	1.20	0.2
Node20	0.4	90.0%	90	0.01	0.014	0.8	0.666	0.3		5.6	6.2	6.2	70	1.5	0.8	5.0	6.2	59.9	1.47	0.2
Node21	0.30	90.0%	90	0.01	0.014	0.8	0.666	0.2		5.0	6.2	6.2	55	1	0.9	6.2	7.1	56.8	1.67	0.3
SP4	3.8	90.0%	240	0.01	0.014	0.8	0.666	2.5		13.2	12.6	12.6					12.6	44.8	2.5	0.3
SP3	4.1	90.0%	280	0.05	0.014	0.8	0.666	2.7		13.5	7.9	7.9	305	1	5.1	12.6	17.7	38.2	5.3	0.6
SP2	1	50.0%	70	0.1	0.014	0.8	0.451	0.5		7.9	2.3	5.0				24.6	24.6	32.3	19.3	1.7
Dis Pond	0.7	0.0%				0.52	0.104	0.1		6.9		6.9	210	1.2	2.9	24.6	27.5	30.5	24.7	2.1

PARSONS BRINCKERHOFF

CHH Oberon Project No. 2106252A
Hydraulic Assessment Client Ref.
Rational Method Hydrologic Calculations Date: 10-Dec-07

ARI	5	$^{10}I_1$ =	34.6 mm/h
C_{10}	0.20	Min Tc	5
Rainfall Data for:	OBERON		

Minimum tc	5
Method for tc	3

1 = Bransby Williams (Rural with main channel > 1000m)
2 = Regional tc=0.76A$^{0.38}$ (Small Rural)
3 = Kinematic Wave

	ARI	1	2	5	10	20	50	100
Rural:	FFy	0.52	0.64	0.82	1	1.21	1.52	1.78
Urban:	FFy	0.8	0.85	0.95	1	1.05	1.15	1.2

Subcatchment	Subcatchment Data					Runoff Coefficient			Subcatchment t_c				Channel Data			TIME OF CONC.		RAINFALL INTENSITY	CA	**FLOW**
	Area	%Imperv.	L	S	n	FFy	C	CA	Bransby.W	Regional	Kinematic	tc	L	v	t	u/s	this			
	ha	%	m	m/m	-	-	-	ha	Min.	Min.	Min.		m	m/s	Min.	Min.	Min.	mm/hr	ha	m^3/s
Catchment 1																				
S1	2.90	90.0%	270	0.020	0.01	0.95	0.791	2.3		11.9	8.4	8.4					8.4	88.1	2.29	0.6
Node2	0.30	90.0%	20	0.020	0.01	0.95	0.791	0.2		5.0	1.4	5.0				8.4	8.4	88.1	2.53	0.6
Node27	3.90	90.0%	260	0.010	0.01	0.95	0.791	3.1		13.3	10.5	10.5					10.5	79.8	3.09	0.7
Sump2	1.80	90.0%	140	0.030	0.01	0.95	0.791	1.4		9.9	4.5	5.0					5.0	108.1	1.42	0.4
Node 47	0.50	70.0%	70	0.012	0.01	0.95	0.663	0.3		6.1	3.9	5.0					5.0	108.1	0.33	0.1
Node33	1.30	70.0%	120	0.010	0.01	0.95	0.663	0.9		8.8	6.0	6.0	50	1	0.8	5.0	6.0	101.0	1.19	0.3
Node32												0.0	50	0.8	1.0	12.7	13.8	70.1	8.24	1.6
Node 5													210	0.8	4.4	8.4	12.7	72.8	7.04	1.4
Node6	1.20	90.0%	165	0.010	0.014	0.95	0.791	0.9		8.5	7.5	7.5	50	0.8	1.0	13.8	14.8	67.6	9.18	1.7
Node8	0.80	90.0%	95	0.010	0.014	0.95	0.791	0.6		7.3	5.1	5.1					5.1	107.5	0.63	0.2
Node7	0.30	90.0%	103	0.036	0.014	0.95	0.791	0.2		5.0	3.4	5.0	50	1.5	0.6	14.8	15.4	66.4	10.05	1.9
Node9	2.20	90.0%	315	0.010	0.014	0.95	0.791	1.7		10.7	12.1	12.1	155	1.5	1.7	15.4	17.1	63.0	11.80	2.1
culvert													300	2	2.5	17.1	19.6	58.7	11.80	1.9
Catchment 2																				
Sp1	3.50	80.0%	190	0.030	0.014	0.95	0.727	2.5		12.8	5.6	5.6				19.6	19.6	58.7	11.81	1.9
Node12	1.10	90.0%	70	0.015	0.014	0.95	0.791	0.9		8.2	3.6	5.0				19.6	19.6	58.7	12.68	2.1
Node13	0.70	90.0%	140	0.015	0.014	0.95	0.791	0.6		6.9	5.8	5.8	210	1	3.5	19.6	23.1	53.8	13.23	2.0
Node29	1.50	90.0%	260	0.010	0.014	0.95	0.791	1.2		9.2	10.5	10.5	90	1.1	1.4	23.1	24.5	52.1	14.42	2.1
Dump	0.60	50.0%				0.95	0.536	0.3		6.5		6.5				24.5	22.2	54.9	14.74	2.3
Node30	2.00	90.0%	260	0.01	0.014	0.95	0.791	1.6		10.3	10.5	10.5	70	1.1	1.1	22.2	23.3	53.6	16.32	2.4
Node31	2.00	90.0%	260	0.010	0.014	0.95	0.791	1.6		10.3	10.5	10.5	90	1.1	1.4	23.3	24.6	51.9	17.91	2.6
Node19	1.80	90.0%	140	0.05	0.014	0.95	0.791	1.4		9.9	3.8	5.0					5.0	108.1	1.42	0.4
Node20	0.4	90.0%	90	0.01	0.014	0.95	0.791	0.3		5.6	4.9	5.0	70	1.5	0.8	5.0	5.8	102.5	1.74	0.5
Node21	0.30	90.0%	90	0.01	0.014	0.95	0.791	0.2		5.0	4.9	5.0	55	1	0.9	5.8	6.7	96.7	1.98	0.5
SP4	3.8	90.0%	240	0.01	0.014	0.95	0.791	3.0		13.2	9.9	9.9					9.9	81.9	3.0	0.7
SP3	4.1	90.0%	280	0.05	0.014	0.95	0.791	3.2		13.5	6.2	6.2	305	1	5.1	9.9	15.0	67.3	6.3	1.2
SP2	1	50.0%	70	0.1	0.014	0.95	0.536	0.5		7.9	1.9	5.0				24.6	24.6	51.9	23.0	3.3
Dis Pond	0.7	0.0%				0.82	0.164	0.1		6.9		6.9	210	1.2	2.9	24.6	27.5	48.8	29.3	4.0

CHH Oberon | Project No. 2106252A
Hydraulic Assessment | Client Ref.
Rational Method Hydrologic Calculations | Date: 10-Dec-07

ARI	10	$^{10}I_1$ =	34.6 mm/h
C_{10}	0.20	Min Tc	5
Rainfall Data for:	OBERON		

Minimum tc	5
Method for tc	3

1 = Bransby Williams (Rural with main channel > 1000m)
2 = Regional tc=0.76A$^{0.38}$ (Small Rural)
3 = Kinematic Wave

	ARI	1	2	5	10	20	50	100
Rural:	FFy	0.52	0.64	0.82	1	1.21	1.52	1.78
Urban:	FFy	0.8	0.85	0.95	1	1.05	1.15	1.2

Subcatchment	Subcatchment Data					Runoff Coefficient			Subcatchment t_c				Channel Data			TIME OF CONC.		RAINFALL INTENSITY	CA	FLOW
	Area	%Imperv.	L	S	n	FFy	C	CA	Bransby.W	Regional	Kinematic	tc	L	v	t	u/s	this			
	ha	%	m	m/m	-	-	-	ha	Min.	Min.	Min.		m	m/s	Min.	Min.	Min.	mm/hr	ha	m^3/s
Catchment 1																				
S1	2.90	90.0%	270	0.020	0.01	1	0.833	2.4		11.9	7.8	7.8					7.8	104.3	2.42	0.7
Node2	0.30	90.0%	20	0.020	0.01	1	0.833	0.2		5.0	1.4	5.0				7.8	7.8	104.3	2.66	0.8
Node27	3.90	90.0%	260	0.010	0.01	1	0.833	3.2		13.3	9.8	9.8					9.8	94.4	3.25	0.9
Sump2	1.80	90.0%	140	0.030	0.01	1	0.833	1.5		9.9	4.3	5.0					5.0	124.6	1.50	0.5
Node 47	0.50	70.0%	70	0.012	0.01	1	0.698	0.3		6.1	3.6	5.0					5.0	124.6	0.35	0.1
Node33	1.30	70.0%	120	0.010	0.01	1	0.698	0.9		8.8	5.6	5.6	50	1	0.8	5.0	5.8	117.7	1.26	0.4
Node32												0.0	50	0.8	1.0	12.2	13.2	81.7	8.67	2.0
Node 5													210	0.8	4.4	7.8	12.2	85.1	7.41	1.8
Node6	1.20	90.0%	165	0.010	0.014	1	0.833	1.0		8.5	7.0	7.0	50	0.8	1.0	13.2	14.3	78.7	9.67	2.1
Node8	0.80	90.0%	95	0.010	0.014	1	0.833	0.7		7.3	4.8	5.0					5.0	124.6	0.67	0.2
Node7	0.30	90.0%	103	0.036	0.014	1	0.833	0.2		5.0	3.2	5.0	50	1.5	0.6	14.3	14.8	77.2	10.58	2.3
Node9	2.20	90.0%	315	0.010	0.014	1	0.833	1.8		10.7	11.3	11.3	155	1.5	1.7	14.8	16.6	73.0	12.42	2.5
culvert													300	2	2.5	16.6	19.1	67.8	12.42	2.3
Catchment 2																				
Sp1	3.50	80.0%	190	0.030	0.014	1	0.766	2.7		12.8	5.3	5.3				19.1	19.1	67.8	12.43	2.3
Node12	1.10	90.0%	70	0.015	0.014	1	0.833	0.9		8.2	3.4	5.0				19.1	19.1	67.8	13.35	2.5
Node13	0.70	90.0%	140	0.015	0.014	1	0.833	0.6		6.9	5.4	5.4	210	1	3.5	19.1	22.6	61.9	13.93	2.4
Node29	1.50	90.0%	260	0.010	0.014	1	0.833	1.2		9.2	9.8	9.8	90	1.1	1.4	22.6	23.9	59.9	15.18	2.5
Dump	0.60	50.0%				1	0.564	0.3		6.5		6.5				23.9	22.2	62.4	15.52	2.7
Node30	2.00	90.0%	260	0.01	0.014	1	0.833	1.7		10.3	9.8	9.8	70	1.1	1.1	22.2	23.3	60.9	17.18	2.9
Node31	2.00	90.0%	260	0.010	0.014	1	0.833	1.7		10.3	9.8	9.8	90	1.1	1.4	23.3	24.6	59.0	18.85	3.1
Node19	1.80	90.0%	140	0.05	0.014	1	0.833	1.5		9.9	3.6	5.0					5.0	124.6	1.50	0.5
Node20	0.4	90.0%	90	0.01	0.014	1	0.833	0.3		5.6	4.6	5.0	70	1.5	0.8	5.0	5.8	118.1	1.83	0.6
Node21	0.30	90.0%	90	0.01	0.014	1	0.833	0.2		5.0	4.6	5.0	55	1	0.9	5.8	6.7	111.4	2.08	0.6
SP4	3.8	90.0%	240	0.01	0.014	1	0.833	3.2		13.2	9.2	9.2					9.2	97.0	3.2	0.9
SP3	4.1	90.0%	280	0.05	0.014	1	0.833	3.4		13.5	5.8	5.8	305	1	5.1	9.2	14.3	78.6	6.6	1.4
SP2	1	50.0%	70	0.1	0.014	1	0.564	0.6		7.9	1.8	5.0				24.6	24.6	59.0	24.2	4.0
Dis Pond	0.7	0.0%				1	0.200	0.1		6.9		6.9	210	1.2	2.9	24.6	27.5	55.4	30.9	4.8

CHH Oberon
Hydraulic Assessment
Rational Method Hydrologic Calculations

Project No. 2106252A
Client Ref.
Date: 10-Dec-07

ARI	20	$^{10}I_1$ =	34.6 mm/h
C_{10}	0.20	Min Tc	5
Rainfall Data for:	OBERON		

Minimum tc	5
Method for tc	3

1 = Bransby Williams (Rural with main channel > 1000m)
2 = Regional tc=0.76A$^{0.38}$ (Small Rural)
3 = Kinematic Wave

	ARI	1	2	5	10	20	50	100
Rural:	FFy	0.52	0.64	0.82	1	1.21	1.52	1.78
Urban:	FFy	0.8	0.85	0.95	1	1.05	1.15	1.2

Subcatchment	Subcatchment Data					Runoff Coefficient			Subcatchment t_c				Channel Data			TIME OF CONC.		RAINFALL INTENSITY	CA	FLOW
	Area	%Imperv.	L	S	n	FFy	C	CA	Bransby.W	Regional	Kinematic	tc	L	v	t	u/s	this			
	ha	%	m	m/m	-	-	-	ha	Min.	Min.	Min.		m	m/s	Min.	Min.	Min.	mm/hr	ha	m^3/s
Catchment 1																				
S1	2.90	90.0%	270	0.020	0.01	1.05	0.874	2.5		11.9	7.2	7.2					7.2	126.8	2.54	0.9
Node2	0.30	90.0%	20	0.020	0.01	1.05	0.874	0.3		5.0	1.3	5.0				7.2	7.2	126.8	2.80	1.0
Node27	3.90	90.0%	260	0.010	0.01	1.05	0.874	3.4		13.3	9.1	9.1					9.1	114.8	3.41	1.1
Sump2	1.80	90.0%	140	0.030	0.01	1.05	0.874	1.6		9.9	3.9	5.0					5.0	146.7	1.57	0.6
Node 47	0.50	70.0%	70	0.012	0.01	1.05	0.733	0.4		6.1	3.4	5.0					5.0	146.7	0.37	0.1
Node33	1.30	70.0%	120	0.010	0.01	1.05	0.733	1.0		8.8	5.2	5.2	50	1	0.8	5.0	5.8	138.5	1.32	0.5
Node32												0.0	50	0.8	1.0	11.6	12.7	97.8	9.10	2.5
Node 5													210	0.8	4.4	7.2	11.6	102.0	7.78	2.2
Node6	1.20	90.0%	165	0.010	0.014	1.05	0.874	1.0		8.5	6.5	6.5	50	0.8	1.0	12.7	13.7	93.9	10.15	2.7
Node8	0.80	90.0%	95	0.010	0.014	1.05	0.874	0.7		7.3	4.4	5.0					5.0	146.7	0.70	0.3
Node7	0.30	90.0%	103	0.036	0.014	1.05	0.874	0.3		5.0	3.0	5.0	50	1.5	0.6	13.7	14.2	92.0	11.11	2.8
Node9	2.20	90.0%	315	0.010	0.014	1.05	0.874	1.9		10.7	10.4	10.4	155	1.5	1.7	14.2	16.0	86.8	13.04	3.1
culvert													300	2	2.5	16.0	18.5	80.3	13.04	2.9
Catchment 2																				
Sp1	3.50	80.0%	190	0.030	0.014	1.05	0.804	2.8		12.8	4.9	5.0				18.5	18.5	80.3	13.05	2.9
Node12	1.10	90.0%	70	0.015	0.014	1.05	0.874	1.0		8.2	3.1	5.0				18.5	18.5	80.3	14.01	3.1
Node13	0.70	90.0%	140	0.015	0.014	1.05	0.874	0.6		6.9	5.0	5.0	210	1	3.5	18.5	22.0	73.0	14.63	3.0
Node29	1.50	90.0%	260	0.010	0.014	1.05	0.874	1.3		9.2	9.1	9.1	90	1.1	1.4	22.0	23.3	70.6	15.94	3.1
Dump	0.60	50.0%				1.05	0.592	0.4		6.5		6.5				23.3	22.2	72.6	16.29	3.3
Node30	2.00	90.0%	260	0.01	0.014	1.05	0.874	1.7		10.3	9.1	9.1	70	1.1	1.1	22.2	23.3	70.8	18.04	3.5
Node31	2.00	90.0%	260	0.010	0.014	1.05	0.874	1.7		10.3	9.1	9.1	90	1.1	1.4	23.3	24.6	68.5	19.79	3.8
Node19	1.80	90.0%	140	0.05	0.014	1.05	0.874	1.6		9.9	3.3	5.0					5.0	146.7	1.57	0.6
Node20	0.4	90.0%	90	0.01	0.014	1.05	0.874	0.3		5.6	4.2	5.0	70	1.5	0.8	5.0	5.8	139.0	1.92	0.7
Node21	0.30	90.0%	90	0.01	0.014	1.05	0.874	0.3		5.0	4.2	5.0	55	1	0.9	5.8	6.7	131.0	2.19	0.8
SP4	3.8	90.0%	240	0.01	0.014	1.05	0.874	3.3		13.2	8.5	8.5					8.5	117.9	3.3	1.1
SP3	4.1	90.0%	280	0.05	0.014	1.05	0.874	3.6		13.5	5.4	5.4	305	1	5.1	8.5	13.6	94.2	6.9	1.8
SP2	1	50.0%	70	0.1	0.014	1.05	0.592	0.6		7.9	1.7	5.0				24.6	24.6	68.5	25.4	4.8
Dis Pond	0.7	0.0%				1.21	0.242	0.2		6.9		6.9	210	1.2	2.9	24.6	27.5	64.3	32.4	5.8

CHH Oberon
Hydraulic Assessment
Rational Method Hydrologic Calculations

Project No. 2106252A
Client Ref.
Date: 10-Dec-07

ARI	50	$^{10}I_1$ =	34.6 mm/h
C_{10}	0.20	Min Tc	5
Rainfall Data for:	OBERON		

Minimum tc	5
Method for tc	3

1 = Bransby Williams (Rural with main channel > 1000m)
2 = Regional tc=0.76A$^{0.38}$ (Small Rural)
3 = Kinematic Wave

	ARI	1	2	5	10	20	50	100
Rural:	FFy	0.52	0.64	0.82	1	1.21	1.52	1.78
Urban:	FFy	0.8	0.85	0.95	1	1.05	1.15	1.2

Subcatchment	Subcatchment Data					Runoff Coefficient			Subcatchment t_c				Channel Data			TIME OF CONC.		RAINFALL INTENSITY	CA	FLOW
	Area	%Imperv.	L	S	n	FFy	C	CA	Bransby.W	Regional	Kinematic	tc	L	v	t	u/s	this			
	ha	%	m	m/m	-	-	-	ha	Min.	Min.	Min.		m	m/s	Min.	Min.	Min.	mm/hr	ha	m^3/s
Catchment 1																				
S1	2.90	90.0%	270	0.020	0.01	1.15	0.958	2.8		11.9	6.6	6.6					6.6	159.1	2.78	1.2
Node2	0.30	90.0%	20	0.020	0.01	1.15	0.958	0.3		5.0	1.3	5.0				6.6	6.6	159.1	3.06	1.4
Node27	3.90	90.0%	260	0.010	0.01	1.15	0.958	3.7		13.3	8.3	8.3					8.3	144.2	3.74	1.5
Sump2	1.80	90.0%	140	0.030	0.01	1.15	0.958	1.7		9.9	3.6	5.0					5.0	177.4	1.72	0.8
Node 47	0.50	70.0%	70	0.012	0.01	1.15	0.803	0.4		6.1	3.1	5.0					5.0	177.4	0.40	0.2
Node33	1.30	70.0%	120	0.010	0.01	1.15	0.803	1.0		8.8	4.8	5.0	50	1	0.8	5.0	5.8	167.4	1.45	0.7
Node32												0.0	50	0.8	1.0	11.0	12.0	120.4	9.97	3.3
Node 5													210	0.8	4.4	6.6	11.0	126.0	8.52	3.0
Node6	1.20	90.0%	165	0.010	0.014	1.15	0.958	1.1		8.5	5.9	5.9	50	0.8	1.0	12.0	13.1	115.4	11.12	3.6
Node8	0.80	90.0%	95	0.010	0.014	1.15	0.958	0.8		7.3	4.0	5.0					5.0	177.4	0.77	0.4
Node7	0.30	90.0%	103	0.036	0.014	1.15	0.958	0.3		5.0	2.8	5.0	50	1.5	0.6	13.1	13.6	112.9	12.17	3.8
Node9	2.20	90.0%	315	0.010	0.014	1.15	0.958	2.1		10.7	9.5	9.5	155	1.5	1.7	13.6	15.3	106.0	14.28	4.2
culvert													300	2	2.5	15.3	17.8	97.7	14.28	3.9
Catchment 2																				
Sp1	3.50	80.0%	190	0.030	0.014	1.15	0.880	3.1		12.8	4.5	5.0				17.8	17.8	97.7	14.30	3.9
Node12	1.10	90.0%	70	0.015	0.014	1.15	0.958	1.1		8.2	2.9	5.0				17.8	17.8	97.7	15.35	4.2
Node13	0.70	90.0%	140	0.015	0.014	1.15	0.958	0.7		6.9	4.6	5.0	210	1	3.5	17.8	21.3	88.5	16.02	3.9
Node29	1.50	90.0%	260	0.010	0.014	1.15	0.958	1.4		9.2	8.3	8.3	90	1.1	1.4	21.3	22.7	85.4	17.46	4.1
Dump	0.60	50.0%				1.15	0.648	0.4		6.5		6.5				22.7	22.2	86.5	17.84	4.3
Node30	2.00	90.0%	260	0.01	0.014	1.15	0.958	1.9		10.3	8.3	8.3	70	1.1	1.1	22.2	23.3	84.3	19.76	4.6
Node31	2.00	90.0%	260	0.010	0.014	1.15	0.958	1.9		10.3	8.3	8.3	90	1.1	1.4	23.3	24.6	81.6	21.68	4.9
Node19	1.80	90.0%	140	0.05	0.014	1.15	0.958	1.7		9.9	3.1	5.0					5.0	177.4	1.72	0.8
Node20	0.4	90.0%	90	0.01	0.014	1.15	0.958	0.4		5.6	3.9	5.0	70	1.5	0.8	5.0	5.8	168.0	2.11	1.0
Node21	0.30	90.0%	90	0.01	0.014	1.15	0.958	0.3		5.0	3.9	5.0	55	1	0.9	5.8	6.7	158.3	2.39	1.1
SP4	3.8	90.0%	240	0.01	0.014	1.15	0.958	3.6		13.2	7.8	7.8					7.8	148.1	3.6	1.5
SP3	4.1	90.0%	280	0.05	0.014	1.15	0.958	3.9		13.5	4.9	5.0	305	1	5.1	7.8	12.9	116.2	7.6	2.4
SP2	1	50.0%	70	0.1	0.014	1.15	0.648	0.6		7.9	1.6	5.0				24.6	24.6	81.6	27.8	6.3
Dis Pond	0.7	0.0%				1.52	0.304	0.2		6.9		6.9	210	1.2	2.9	24.6	27.5	76.5	35.6	7.6

PARSONS BRINCKERHOFF

CHH Oberon Project No. 2106252A
Hydraulic Assessment Client Ref.
Rational Method Hydrologic Calculations Date: 10-Dec-07

ARI	100	$^{10}I_1$ =	34.6 mm/h
C_{10}	0.20	Min Tc	5
Rainfall Data for:	OBERON		

Minimum tc	5
Method for tc	3

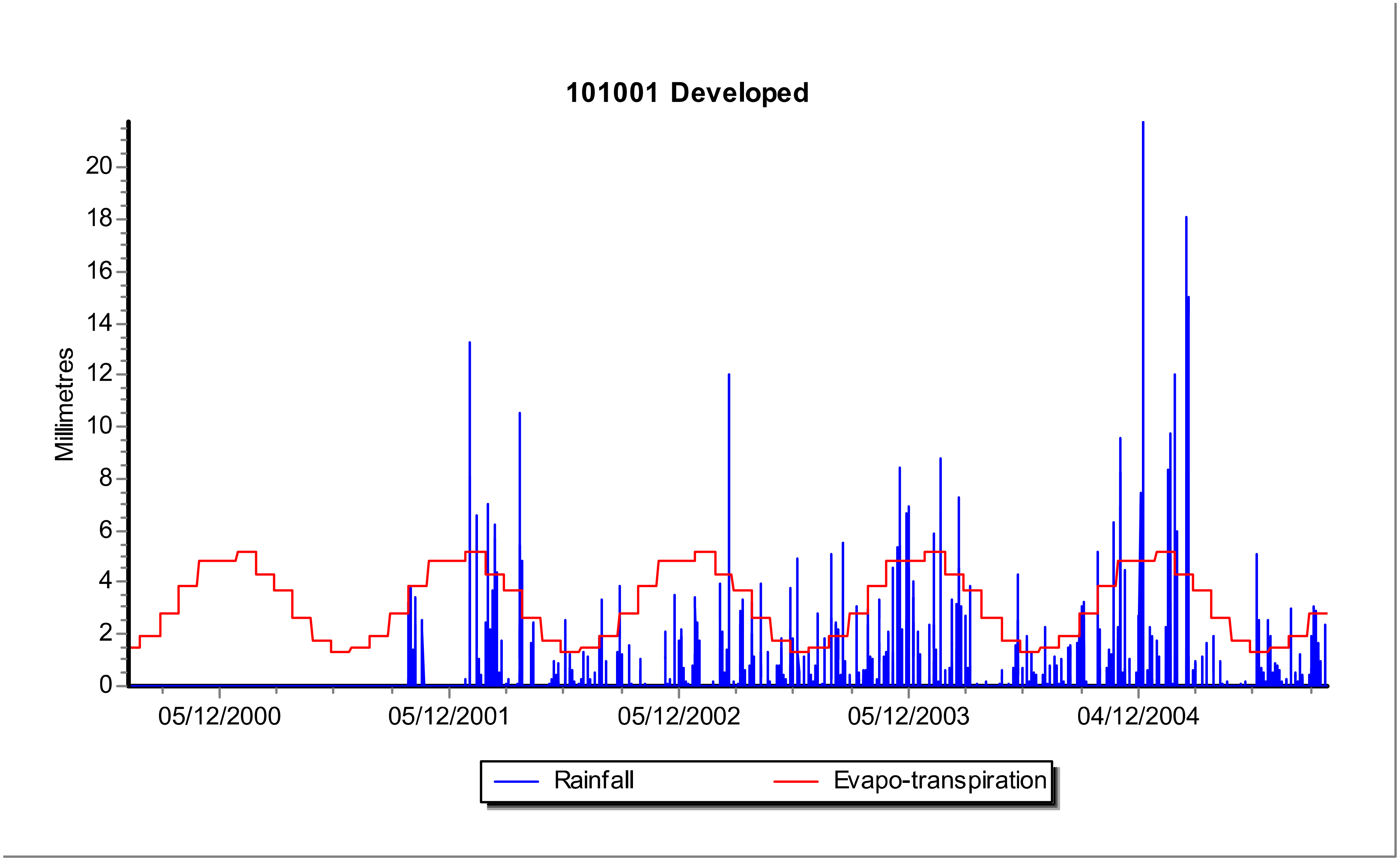
1 = Bransby Williams (Rural with main channel > 1000m)
2 = Regional tc=$0.76A^{0.38}$ (Small Rural)
3 = Kinematic Wave

	ARI	1	2	5	10	20	50	100
Rural:	FFy	0.52	0.64	0.82	1	1.21	1.52	1.78
Urban:	FFy	0.8	0.85	0.95	1	1.05	1.15	1.2

Subcatchment	Subcatchment Data					Runoff Coefficient			Subcatchment t_c				Channel Data			TIME OF CONC.		RAINFALL INTENSITY	CA	FLOW
	Area	%Imperv.	L	S	n	FFy	C	CA	Bransby.W	Regional	Kinematic	tc	L	v	t	u/s	this			
	ha	%	m	m/m	-	-	-	ha	Min.	Min.	Min.		m	m/s	Min.	Min.	Min.	mm/hr	ha	m^3/s
Catchment 1																				
S1	2.90	90.0%	270	0.020	0.01	1.2	0.999	2.9		11.9	6.2	6.2					6.2	185.9	2.90	1.5
Node2	0.30	90.0%	20	0.020	0.01	1.2	0.999	0.3		5.0	1.2	5.0				6.2	6.2	185.9	3.20	1.7
Node27	3.90	90.0%	260	0.010	0.01	1.2	0.999	3.9		13.3	7.8	7.8					7.8	168.7	3.90	1.8
Sump2	1.80	90.0%	140	0.030	0.01	1.2	0.999	1.8		9.9	3.4	5.0					5.0	202.0	1.80	1.0
Node 47	0.50	70.0%	70	0.012	0.01	1.2	0.838	0.4		6.1	2.9	5.0					5.0	202.0	0.42	0.2
Node33	1.30	70.0%	120	0.010	0.01	1.2	0.838	1.1		8.8	4.5	5.0	50	1	0.8	5.0	5.8	190.6	1.51	0.8
Node32												0.0	50	0.8	1.0	10.6	11.6	138.8	10.40	4.0
Node 5													210	0.8	4.4	6.2	10.6	145.6	8.89	3.6
Node6	1.20	90.0%	165	0.010	0.014	1.2	0.999	1.2		8.5	5.6	5.6	50	0.8	1.0	11.6	12.7	132.8	11.60	4.3
Node8	0.80	90.0%	95	0.010	0.014	1.2	0.999	0.8		7.3	3.8	5.0					5.0	202.0	0.80	0.4
Node7	0.30	90.0%	103	0.036	0.014	1.2	0.999	0.3		5.0	2.7	5.0	50	1.5	0.6	12.7	13.2	129.9	12.70	4.6
Node9	2.20	90.0%	315	0.010	0.014	1.2	0.999	2.2		10.7	8.9	8.9	155	1.5	1.7	13.2	14.9	121.7	14.90	5.0
culvert													300	2	2.5	14.9	17.4	111.8	14.90	4.6
Catchment 2																				
Sp1	3.50	80.0%	190	0.030	0.014	1.2	0.919	3.2		12.8	4.2	5.0				17.4	17.4	111.8	14.92	4.6
Node12	1.10	90.0%	70	0.015	0.014	1.2	0.999	1.1		8.2	2.7	5.0				17.4	17.4	111.8	16.02	5.0
Node13	0.70	90.0%	140	0.015	0.014	1.2	0.999	0.7		6.9	4.3	5.0	210	1	3.5	17.4	20.9	100.9	16.72	4.7
Node29	1.50	90.0%	260	0.010	0.014	1.2	0.999	1.5		9.2	7.8	7.8	90	1.1	1.4	20.9	22.3	97.3	18.21	4.9
Dump	0.60	50.0%				1.2	0.677	0.4		6.5		6.5				22.3	22.2	97.6	18.62	5.1
Node30	2.00	90.0%	260	0.01	0.014	1.2	0.999	2.0		10.3	7.8	7.8	70	1.1	1.1	22.2	23.3	95.0	20.62	5.4
Node31	2.00	90.0%	260	0.010	0.014	1.2	0.999	2.0		10.3	7.8	7.8	90	1.1	1.4	23.3	24.6	91.9	22.62	5.8
Node19	1.80	90.0%	140	0.05	0.014	1.2	0.999	1.8		9.9	2.9	5.0					5.0	202.0	1.80	1.0
Node20	0.4	90.0%	90	0.01	0.014	1.2	0.999	0.4		5.6	3.7	5.0	70	1.5	0.8	5.0	5.8	191.3	2.20	1.2
Node21	0.30	90.0%	90	0.01	0.014	1.2	0.999	0.3		5.0	3.7	5.0	55	1	0.9	5.8	6.7	180.1	2.50	1.3
SP4	3.8	90.0%	240	0.01	0.014	1.2	0.999	3.8		13.2	7.3	7.3					7.3	173.3	3.8	1.8
SP3	4.1	90.0%	280	0.05	0.014	1.2	0.999	4.1		13.5	4.6	5.0	305	1	5.1	7.3	12.4	134.3	7.9	2.9
SP2	1	50.0%	70	0.1	0.014	1.2	0.677	0.7		7.9	1.6	5.0				24.6	24.6	91.9	29.0	7.4
Dis Pond	0.7	0.0%				1.78	0.356	0.2		6.9		6.9	210	1.2	2.9	24.6	27.5	86.1	37.1	8.9

Appendix E

MUSIC rainfall graph


101001 Developed
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05/12/2003
04/12/2004
Rainfall
Evapo-transpiration

Appendix F

Existing subcatchment data

Borg Oberon Project No. 2103481A
Hydrologic and Hydraulic Analysis Client Ref.
Existing XP-SWMM Subcatchment Data Date: 15/03/2011

Node	Area (ha)	Impervious Percentage %	Slope	Infiltration Type
Sump1	2.9	90	0.02	Hardstand
Node2	0.3	90	0.01	Hardstand
Sump2	1.8	90	0.03	Hardstand
Node6	1.2	90	0.01	Hardstand
Node7	0.3	90	0.04	Hardstand
Node8	0.8	90	0.01	Hardstand
Node9	1.65	90	0.01	Hardstand
Sed pond1	3.36	90	0.01	Hardstand
Node11	0.8	90	0.02	Hardstand
Node11	0.3	0	0.10	Pervious
Node11	2.2	90	0.04	Hardstand
Node11	1	0	0.10	Pervious
Node11	0.3	100	0.10	Hardstand
sed pond2	0.3	90	0.01	Hardstand
sed pond2	0.4	0	0.20	Pervious
sed pond2	0.3	100	0.10	Open water
dis pond	0.61	0	0.04	Pervious
dis pond	0.09	100	0.10	Open water
Sed pond3	4.1	90	0.05	Hardstand
Node19	1.8	90	0.05	Hardstand
Node20	0.31	90	0.01	Hardstand
Node20	0.09	0	0.30	Pervious
Node21	0.24	90	0.01	Hardstand
Node21	0.06	0	0.30	Pervious
Node27	3.9	90	0.01	Hardstand
Node29	1.5	90	0.01	Hardstand
Node29	0.6	10	0.07	Pervious
Node30	2	90	0.01	Hardstand
Node31	2	90	0.01	Hardstand
Node33	0.1	90	0.01	Hardstand
Node34	3.8	90	0.01	Hardstand
Node36	0.55	90	0.01	Hardstand
Node47	0.2	80	0.03	Hardstand
Node47	0.2	80	0.03	Hardstand
Node47	0.15	100	0.03	Hardstand
Node51	0.106	100	0.01	Hardstand
Node52	0.096	100	0.01	Hardstand
Node54	0.11	100	0.01	Hardstand
Node55	3.42	90	0.01	Hardstand
Node57	20.25	5	0.02	Pervious
Node59	1.34	10	0.01	Pervious
Node65	1.09	5	0.01	Pervious
	66.6			

Appendix G

Developed subcatchment data

Borg Oberon Project No. 2103481A
Hydrologic and Hydraulic Analysis Client Ref.
Developed XP-SWMM Subcatchment Data Date: 15/03/2011

Node	Area (ha)	Impervious Percentage %	Slope	Infiltration Type
Sump1	2.9	90	0.02	Hardstand
Node2	0.3	90	0.01	Hardstand
Sump2	1.8	90	0.03	Hardstand
Node6	1.2	90	0.01	Hardstand
Node7	0.3	90	0.036	Hardstand
Node8	0.8	90	0.01	Hardstand
Node9	1.65	90	0.01	Hardstand
Sed pond1	3.36	90	0.01	Hardstand
Node11	1.1	100	0.02	Hardstand
Node11	0.654	100	0.01	Hardstand
Node11	0.436	0	0.01	Pervious
sed pond2	0.3	90	0.01	Hardstand
sed pond2	0.4	0	0.2	Pervious
sed pond2	0.3	100	0.1	Open water
dis pond	0.61	0	0.04	Pervious
dis pond	0.09	100	0.1	Open water
Sed pond3	4.1	90	0.05	Hardstand
Node19	1.8	90	0.05	Hardstand
Node20	0.31	90	0.01	Hardstand
Node20	0.09	0	0.3	Pervious
Node21	0.24	90	0.01	Hardstand
Node21	0.06	0	0.3	Pervious
Node27	3.9	90	0.01	Hardstand
Node29	1.5	90	0.01	Hardstand
Node29	0.6	10	0.07	Pervious
Node30	2	90	0.01	Hardstand
Node31	2	90	0.01	Hardstand
Node33	0.1	90	0.01	Hardstand
Node34	3.8	90	0.01	Hardstand
Node36	0.55	90	0.01	Hardstand
Node47	0.2	80	0.025	Hardstand
Node47	0.2	80	0.025	Hardstand
Node47	0.15	100	0.025	Hardstand
Node51	0.106	100	0.01	Hardstand
Node52	0.096	100	0.01	Hardstand
Node54	0.11	100	0.01	Hardstand
Node55	3.42	90	0.01	Hardstand
Node57	20.25	5	0.02	Pervious
Node59	0.554	100	0.01	Hardstand
Node59	0.786	0	0.01	Pervious
Node60	3.5	100	0.035	Hardstand
	66.6			