



**ACT LAnd Pty Ltd**  
Bay Ridge Estate  
North Batemans Bay Residential Development  
Stormwater Management Assessment for Modification of  
Development Approval

October 2017



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# 1. Introduction

ACT Land Pty Ltd engaged GHD Pty Ltd (GHD) to prepare an application for the modification of the development application (DA) approval number 172-7-2015 (the “Application”) for the Bay Ridge Estate, North Batemans Bay. The Application covered the amendment of the development to conform to the current zoning of the site, working within the footprint of the current development approval.

After a preliminary review of the Application, the NSW Department of Planning & Environment (the “Department”), requested GHD to provide a stormwater management assessment report with the Application. The purpose of the assessment was to confirm post-development flows out of the development area would equal pre-development flows after the addition of impervious areas on the site as a result of 48 additional dwellings and driveways.

The *Eurobodalla Shire Council Infrastructure Design Standard Version 1.0* (the “Standard”)<sup>1</sup>, in particular Section 9 (Large Scale Stormwater Detention), contains stormwater management requirements applicable to the proposed development. Section 9.4.2 of the Standard require that detention basins be designed to attenuate stormwater runoff for the critical storm with an average recurrence interval (ARI) of 1-in-100 years (ARI 100 year storm). One of the stated objectives of this requirement is the protection of Council’s existing stormwater drainage assets from overloading as a result of new developments which increase the amount of stormwater runoff being generated from a particular property.

As a result, GHD carried out a catchment runoff routing modelling study (the “Study”) for the development, using the modelling software xpraf, to verify that the proposed detention basins included in the proposed development—basins B, C and D (the “Basins”)—fulfilled the following two-fold conditions:

1. **Limiting peak flow to pre-development level:** That the Basins were able to limit the critical post-development peak flow to the critical pre-development peak flow for the ARI 100 year storm, and
2. **Stormwater attenuation:** That the Basins had sufficient volume to fully attenuate the critical post-development ARI 100 year storm without resulting in overtopping of flows.

This report describes the methodology used to carry out the modelling exercise and provides detailed information on the scenarios analysed, the different parameters used, as well as justifications for using the same.

The report, however, does not provide detailed design considerations or information regarding other aspects of the basins such as the rationale behind their location and siting, design of their inlet/outfall structure, batter slopes etc. This information will be provided in the detail design drawings and report that will be submitted to Council for the Construction Certificate application for those works.

This report is set out as follows:

- **Section 1 (Introduction):** this section provides the background to the Study and describes its objectives, scope and the methodology used to perform modelling analysis.
- **Section 2 (Modelling Parameters):** this section describes the modelling parameters used and describes the rationale for the selection of various modelling values. The

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<sup>1</sup> Eurobodalla Shire Council. *Infrastructure Design Standard*. Version 1.0, [www.esc.nsw.gov.au/development-and-planning/tools/development-control-plans/Infrastructure-Design-Standard-IDS.pdf](http://www.esc.nsw.gov.au/development-and-planning/tools/development-control-plans/Infrastructure-Design-Standard-IDS.pdf).

parameters cover catchment details for modelling the pre- and post-development catchments and the rainfall parameters used in the Study.

- **Section 3 (Results):** This section provides modelling results which includes the comparison of critical pre- and post-development peak flows and an assessment of the design Basins' ability to fulfil their stormwater management objectives.
- **Section 4 (Conclusion):** A summary of the results is provided in this section.

## 1.1 Objectives of the Study

The objective of the Study was to develop a hydrologic model using xprafits to determine if the Basins were able to achieve the following stormwater management requirements:

1. **Limiting peak flow to pre-development level:** That the Basins were able to limit the critical post-development peak flow to the critical pre-development peak flow for the ARI 100 year storm, and
2. **Stormwater attenuation:** That the Basins had sufficient volume to fully attenuate the critical post-development ARI 100 year storm without resulting in overtopping of flows.

## 1.2 Scope of the Study

The proposed Bay Ridge Estate is currently approved as a 157 lot development occupying an area of 88 hectares (ha). The proposed modification of to the approved development will increase the total yield to 205 lots. 57 residential lots have been created to date.

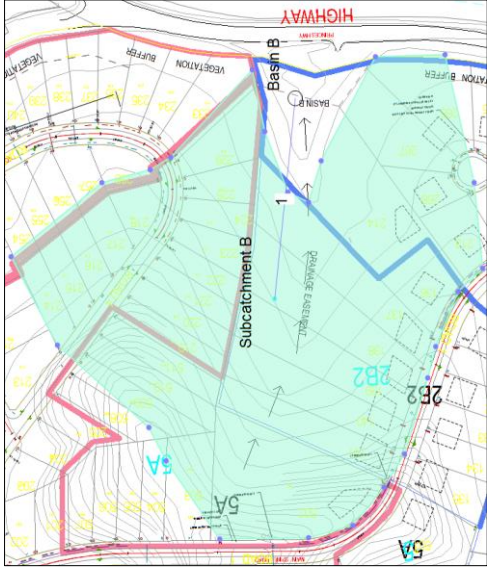
Within this development, the catchment areas for the Basins modelled in the Study were as follows:

- **For Basin B:** an area of approximately 10 ha.
- **For Basin C:** an area of approximately 30 ha.
- **For Basin D:** an area of approximately 19 ha.

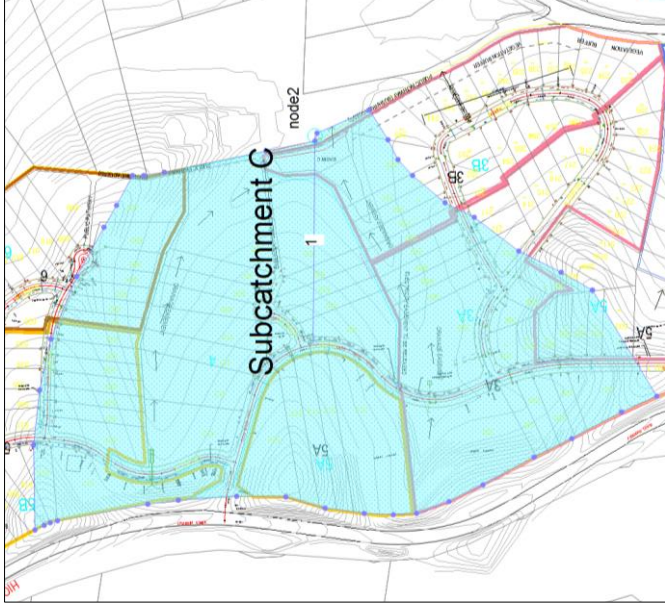
These catchment areas, once developed, would comprise a mix of residential lots including dwellings, driveways and roads. **Figure 1** provides a screenshot from the xprafits model illustrating the three catchments modelled.

In arriving at the critical peak flows for the post-development condition of the catchment area, attenuating impacts of any major or minor urban drainage infrastructure installed as part of the development were ignored. This resulted in a conservative estimate of the critical peak flows as it was assumed that there was no retention of any incident rainfall and runoff at any subcatchment as a result of drainage infrastructure. However, lag times were taken into account for connecting runoff from one subcatchment to an adjacent one downstream. The lag times were calculated using the methodology provided in the Standard.

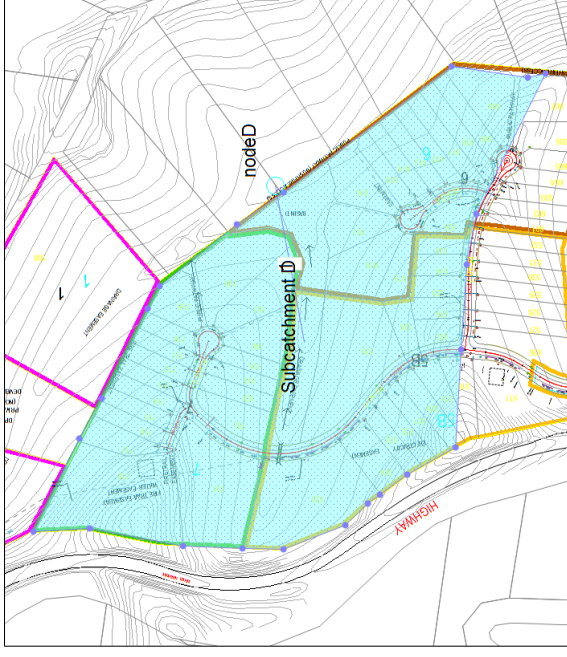
The scope of the Study did not include preparation of detailed design nor assessing the rationale behind the design consideration related to other aspects of the Basins such as the rationale behind their location and siting; design of their inlet/outfall structure, batter slopes etc. This information was provided in detail in the later applications for design approval (Construction Certificates). This Study does not address water quality management as a result of the proposed development.



A screenshot from xprfts illustrating the 10 ha catchment area for Basin B.



A screenshot from xprfts illustrating the 30 ha catchment area for Basin C.



A screenshot from xprfts illustrating the 19 ha catchment area for Basin B

**Figure 1 Screenshots from xprfts highlighting the different catchment areas modelled for the Study for Basins B, C and D within the Bay Ridge Estate.**

## 1.3 Background Resources

The primary background resource used in the preparation of the Study was the *Integrated Water Cycle Management (IWCM) Report for DA submission* prepared by GHD in July 2005 for Bay Ridge Residential Development (the “IWCM 2005 Report”)<sup>2</sup>. Parts of the IWCM 2005 Report, particularly those concerning selection of modelling parameters, have been cited in relevant sections of this Study.

## 1.4 Modelling Methodology

The following sections summarize the main steps followed in performing modelling analysis of the pre- and post-development catchments and assessing adequacy of basin discharge outlets and basin volumes in fulfilling stormwater management objectives.

### 1.4.1 XprafTs Modelling Software

Hydrological modelling was conducted using xprafTs, a comprehensive modelling program used to simulate runoff hydrographs at defined points throughout a watershed based on a set of catchment characteristics and specific rainfall events. Using xprafTs, a watershed can be subdivided into a number of subcatchments from which runoff hydrographs are produced and routed through any configuration of network storages, channels, and pipes to determine flood mitigation options, drainage strategies, or hydraulic design data.<sup>3</sup>

XprafTs uses the Laurenson non-linear runoff routing procedure to develop a subcatchment stormwater runoff hydrograph from either an actual event (recorded rainfall time series) or design storm using Intensity-Frequency-Duration (IFD) data together with dimensionless storm temporal patterns as well as standard Australian Rainfall and Runoff (ARR) data.<sup>4</sup>

XprafTs can employ either one of three loss models to generate excess rainfall; the model employed for the Study was the Initial/Continuing loss model with the estimated values for initial and continuing losses obtained from ARR 2016.

For hydrograph generation, xprafTs uses the Laurenson runoff routing procedure which offers a flexible model to simulate both rural and urban catchments; considers time-area and subcatchment shape; and, an efficient mathematical procedure for developing both rural, urban, and mixed runoff hydrographs at any subcatchment outlet.

Data requirements for xprafTs consist of:

- Catchment area
- Slope
- Degree of urbanisation (derived from the nominated fraction impervious area)
- Losses (observed or design)
- Rainfall data

Rainfall input can be of two types, either Design Rainfall or Historic Rainfall. Design rainfall may be entered as a dimensionless temporal pattern with average rainfall intensity.

For the Study, and in line with the requirements of the Standard, design rainfall patterns generated from ARR 1987 were used with intensity information derived from the Bureau of

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<sup>2</sup> GHD. *Bay Ridge Residential Development Integrated Water Cycle Management Report for DA Submission*. Canberra Investment Corporation, 2005

<sup>3</sup> “Tutorial 1 - An Overview of XprafTs - XprafTs 2013 Help Documentation.” Innovyze XP Resource Center, [help.xpsolutions.com/display/xprafTs2013sp1/Tutorial+1+-+An+Overview+of+xprafTs](http://help.xpsolutions.com/display/xprafTs2013sp1/Tutorial+1+-+An+Overview+of+xprafTs)

<sup>4</sup> Ibid.

Meteorology (BOM) website<sup>5</sup>. Xprafits uses the entered zone number of different regions of Australia to automatically compute the appropriate intensity for the given ARI and duration and the appropriate temporal pattern from the built-in standard temporal patterns from ARR 1987.

#### **1.4.2 Pre- and Post-development Catchment Modelling**

The pre-development catchments were modelled as a single catchment while the post-development catchments were split into multiple subcatchments based on post-development design.

Catchment parameters entered into the xprafits model included the area of the catchments, percentage im/pervious surface cover, slope, and im/pervious Manning's 'n' values.

#### **1.4.3 Rainfall Data and Critical Peak Flows**

Once the pre- and post-development catchments were set up in xprafits, ARR 1987 data such as rainfall intensities from IDF and temporal zones were used to generate rainwater runoff hydrographs to determine critical pre- and post-development peak flows for the ARI 100 year storm.

#### **1.4.4 Outflow Sizing**

Once the critical pre- and post-development peak flows were determined, the Basins' bottom pipe outflow rates were assessed to verify if the proposed design diameter limited the critical post-development ARI 100 year storm peak flow to the critical pre-development outflow for the same ARI.

#### **1.4.5 Basin Volume Optimization**

Once the bottom pipe outflow diameters were assessed and the required outflow rates confirmed, the volume of the Basins were assessed to confirm they would completely attenuate the ARI 100 year runoff volume without resulting in overtopping of flows.

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<sup>5</sup> *Intensity-Frequency-Duration*, Bureau of Meteorology, [www.bom.gov.au/cgi-bin/hydro/has/CDIRSWebBasic](http://www.bom.gov.au/cgi-bin/hydro/has/CDIRSWebBasic)

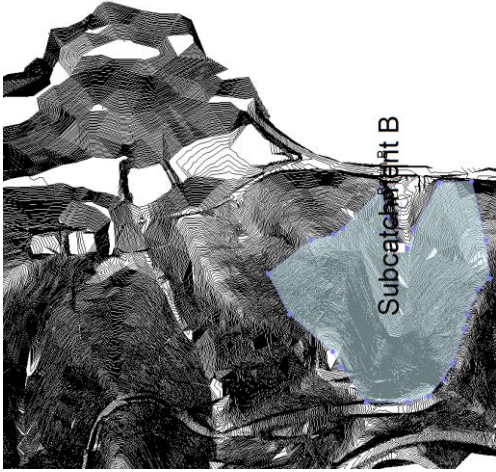
## 2. Modelling Parameters

This section describes the parameters used for modelling the pre- and post-development catchments and rainfall events. The rationale for the selection of these parameters have also been provided and where relevant, comparisons have been made with values used in the IWCM 2005 Report and other Australian design standards.

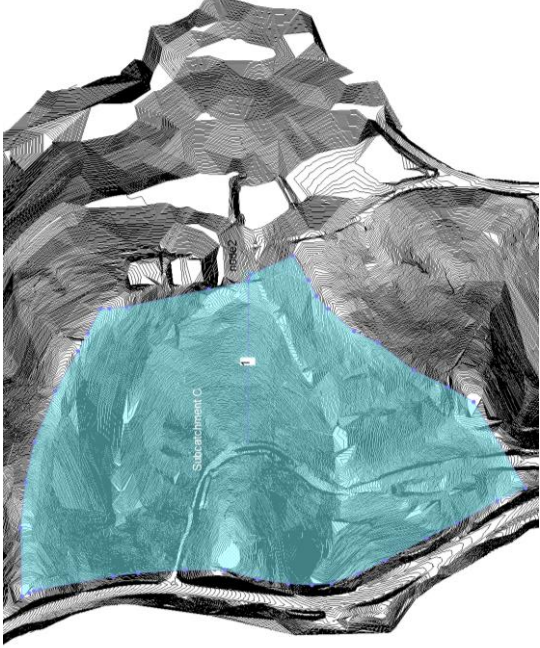
### 2.1 Pre-development Subcatchment

**Figure 2** below provides an illustration of the pre-development contour profile in the catchment areas of Basins B, C and D. The pre-development catchments were modelled as single catchments (as opposed to dividing them up based on post-development designed lots) for the pre-development scenario. xprafits, by default, divides a subcatchment into 10 equal sub-areas with rainfall applied to each sub-area, and the rainfall excess computed and converted into an instantaneous inflow.

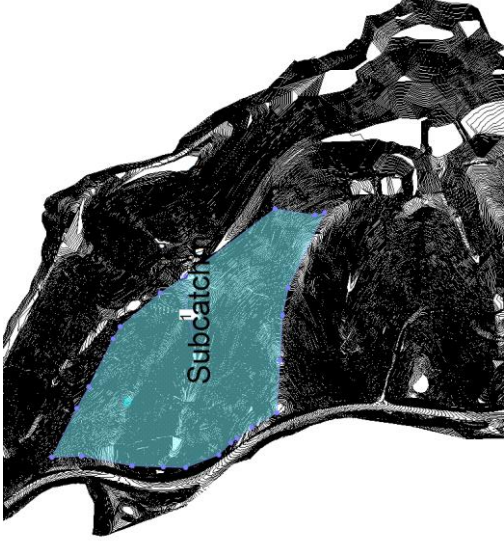
**Table 1** provides a complete list of the parameters used to model the pre-development catchments for the three Basins and describes the rationale behind the selection of the same.



Screenshot from xprafits indicating the pre-development catchment area for Basin B



Screenshot from xprafits indicating the pre-development catchment area for Basin C



Screenshot from xprafits indicating the pre-development catchment area for Basin D

**Figure 2 Screenshots from xprafits indicating the pre-development catchment areas modelled for Basins B, C and D.**

**Table 1 Modelling parameters used for the pre-development subcatchment.**

| Modelling Parameter             | Basin B | Basin C | Basin D | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------|---------|---------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Total Area</b>               | 10 ha   | 30 ha   | 19.3 ha | Area determined from CAD drawings.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Vectored Slope</b>           | 13.3 %  | 7 %     | 12 %    | Slope determined from CAD drawings with a contour profile of the pre-development subcatchment. The vectored slope was determined by measuring the slope along the longest overflow path.                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>% Impervious cover</b>       | 5 %     |         |         | A nominal value of 5 % was chosen to be consistent with the value used in the IWCM 2005 Report <sup>6</sup> . The value was chosen to allow for areas of very compacted soil or rock deposits in the pre-development catchments. The value is also consistent with the land use impervious percentage value of 5 % for bush land provided in the Standard <sup>7</sup> .                                                                                                                                                                                                                   |
| <b>Pervious Manning's 'n'</b>   | 0.08    |         |         | This value was also taken from the IWCM 2005 Report whose authors arrived at the number after a site inspection noting the catchment was covered with a number of trees as well as significant undergrowth throughout the area <sup>8</sup> . As the Standard is silent on Manning's 'n' values, the 0.08 value was compared with values provided in other design standards. For example, the value was consistent with the value used in Brisbane City Council's design standards which recommends a value of 0.08 for a watercourse floodplain with medium to dense brush <sup>9</sup> . |
| <b>Impervious Manning's 'n'</b> | 0.02    |         |         | As the IWCM 2005 Report was silent on the impervious Manning's 'n' value used, the value used for the Study was the default value of 0.02 used by xprafits. According to the xprafits user-manual, the value of 0.02 is appropriate for packed clay or asphalt or concrete paving <sup>10</sup> .                                                                                                                                                                                                                                                                                          |

## 2.2 Post-development Subcatchments

**Figure 3** below provides a screenshot of the post-development subcatchments for the three Basins as set up in xprafits. The pre-development catchments for each Basin were split into smaller subcatchments due to the varying nature of the design surface cover in the development area. The surface cover affects the perviousness and the Manning's 'n' used for modelling the subcatchments.

The Manning's 'n' values used for modelling the pervious and impervious parts of the subcatchments were as follows:

- Pervious:** 0.06 – This value was taken from the IWCM 2005 Report<sup>11</sup>. The value is consistent with the design intent of the development to limit clearing of natural vegetation of each lot. The value is also consistent with the value used in other design standards, for

<sup>6</sup> Page 13. GHD. *Bay Ridge Residential Development Integrated Water Cycle Management Report*.

<sup>7</sup> Table 7, page 47. Eurobodalla Shire Council. *Infrastructure Design Standard*.

<sup>8</sup> Page 13. GHD. *Bay Ridge Residential Development Integrated Water Cycle Management Report*.

<sup>9</sup> Table C.3, Appendix C. Brisbane City Council. *"Natural Channel Design."* Guidelines, Nov. 2003.

<sup>10</sup> Innovyze. *Manning's Roughness*,

[xpsolutions.com/webhelp/SECTION\\_11\\_\\_GLOBALS/11\\_4\\_Infiltration/Manning\\_s\\_Roughness.htm](https://xpsolutions.com/webhelp/SECTION_11__GLOBALS/11_4_Infiltration/Manning_s_Roughness.htm).

<sup>11</sup> Page 14. GHD. *Bay Ridge Residential Development Integrated Water Cycle Management Report*.

example, the Brisbane City Council's design standards recommend a value of 0.06 for a watercourse plain with "light brush and trees".<sup>12</sup>

- **Impervious: 0.02** – As the IWCM 2005 Report was silent on the impervious Manning's 'n' value used, the value used for the xprafits model was left at the default value of 0.02 appropriate for packed clay or asphalt or concrete paving<sup>13</sup>.

For each subcatchment, the percentage impervious surface cover was determined using the digital version of the design drawings. The area covered by roads, houses, landscaping etc. was individually determined and the overall balance between each impervious and pervious area separately determined for each subcatchment.

**Table 2** provides information on the percentage impervious cover of each of the subcatchments based on the area covered by houses, roads, pathways etc in each of them. **Table 3** provides the slope percentages for each of the post-development subcatchments.

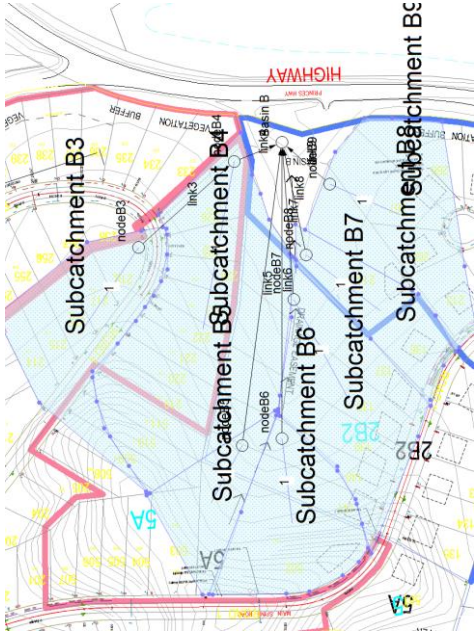
Flows from the upstream subcatchments were linked to the downstream subcatchments using links in xprafits. Simple links were used to simulate overland flows with only lag times required for input. The lag times are used by xprafits to specify length of flow travel time from one node to the next and the hydrograph is translated on the time base by this length of time with no attenuation of peak flow. The lag times were determined using information provided in the Standard<sup>14</sup>. **Table 4** provides information on the parameters used to work out channel flow times.

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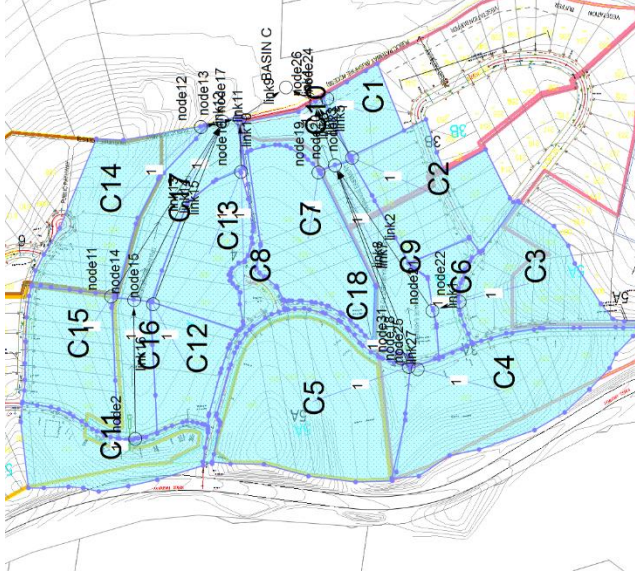
<sup>12</sup> Table C.3, Appendix C. Brisbane City Council. *"Natural Channel Design."*

<sup>13</sup> Innovyze. *Manning's Roughness*

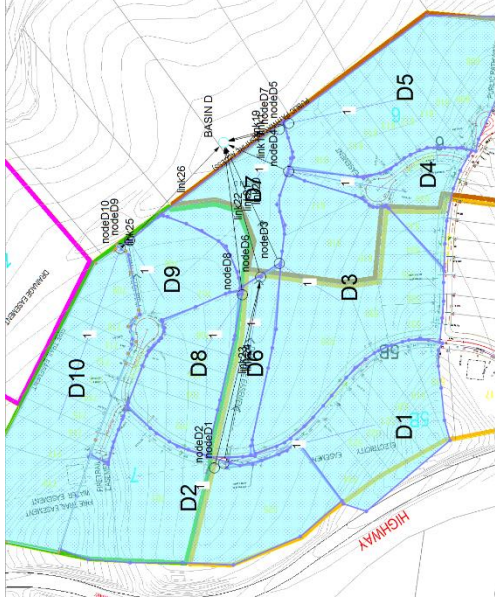
<sup>14</sup> Figure 4, page 90. Eurobodalla Shire Council. *Infrastructure Design Standard*.



Post-development catchment area for Basin B



Post-development catchment area for Basin C



Post-development catchment area for Basin D

**Figure 3 A screenshot of post-development subcatchments for Basins B, C and D as modelled in xprafits with their respective catchments split into smaller subcatchments due to the varying nature of the design surface cover in the development area.**

**Table 2: Calculation of % impervious surface cover in the post-development subcatchments**

| Area           | Total Area (ha) | Total Area (m <sup>2</sup> ) | No. of Houses | Area covered by Houses (m <sup>2</sup> ) | Full Road Length (m) | Half Road Length (m) | Public Pathway (m) | Road Area (m <sup>2</sup> ) | Impervious Total (m <sup>2</sup> ) | Total % impervious |
|----------------|-----------------|------------------------------|---------------|------------------------------------------|----------------------|----------------------|--------------------|-----------------------------|------------------------------------|--------------------|
| <b>Basin B</b> |                 |                              |               |                                          |                      |                      |                    |                             |                                    |                    |
| B3             | 1.3             | 13000                        | 7             | 2800                                     | 252                  | 0                    | 0                  | 3024                        | 5824                               | 44.80              |
| B4             | 2.775           | 27750                        | 9             | 3600                                     | 0                    | 0                    | 0                  | 0                           | 3600                               | 12.97              |
| B5             | 1.025           | 10250                        | 0             | 0                                        | 0                    | 0                    | 0                  | 0                           | 0                                  | 0.00               |
| B6             | 1.2             | 12000                        | 0             | 0                                        | 0                    | 0                    | 0                  | 0                           | 0                                  | 0.00               |
| B7             | 1.5             | 15000                        | 5             | 2000                                     | 0                    | 0                    | 0                  | 0                           | 2000                               | 13.33              |
| B8             | 0.7             | 7000                         | 0             | 0                                        | 0                    | 0                    | 0                  | 0                           | 0                                  | 0.00               |
| B9             | 1.5             | 15000                        | 3             | 1200                                     | 0                    | 0                    | 0                  | 0                           | 1200                               | 8.00               |
| <b>Basin C</b> |                 |                              |               |                                          |                      |                      |                    |                             |                                    |                    |
| C1             | 0.72            | 7200                         | 0             | 0                                        | 0                    | 0                    | 0                  | 0                           | 0                                  | 0.00               |
| C2             | 2.17            | 21700                        | 11            | 4400                                     | 155                  | 98                   | 0                  | 2448                        | 6848                               | 31.56              |
| C3             | 2.18            | 21800                        | 12            | 4800                                     | 0                    | 436                  | 0                  | 2616                        | 7416                               | 34.02              |
| C4             | 3.35            | 33500                        | 6             | 2400                                     | 0                    | 321                  | 0                  | 1926                        | 4326                               | 12.91              |
| C5             | 4.32            | 43200                        | 5             | 2000                                     | 0                    | 362                  | 0                  | 2172                        | 4172                               | 9.66               |
| C6             | 0.63            | 6300                         | 1             | 400                                      | 0                    | 212                  | 0                  | 1272                        | 1672                               | 26.54              |
| C7             | 2.38            | 23800                        | 5             | 2000                                     | 0                    | 0                    | 0                  | 0                           | 2000                               | 8.40               |
| C8             | 0.9             | 9000                         | 1             | 400                                      | 83.8                 | 224                  | 189                | 3105.6                      | 3505.6                             | 38.95              |
| C9             | 1.58            | 15800                        | 0             | 0                                        | 0                    | 32                   | 0                  | 192                         | 192                                | 1.22               |
| C10            | 0.69            | 6900                         | 0             | 0                                        | 0                    | 0                    | 0                  | 0                           | 0                                  | 0.00               |
| C11            | 1.77            | 17700                        | 1             | 400                                      | 122                  | 42                   | 0                  | 1716                        | 2116                               | 11.95              |
| C12            | 1.24            | 12400                        | 2             | 800                                      | 0                    | 0                    | 0                  | 0                           | 800                                | 6.45               |
| C13            | 1.66            | 16600                        | 5             | 2000                                     | 0                    | 0                    | 0                  | 0                           | 2000                               | 12.05              |
| C14            | 2.15            | 21500                        | 6.5           | 2600                                     | 0                    | 105                  | 0                  | 630                         | 3230                               | 15.02              |

| Area           | Total Area (ha) | Total Area (m²) | No. of Houses | Area covered by Houses (m²) | Full Road Length (m) | Half Road Length (m) | Public Pathway (m) | Road Area (m²) | Impervious Total (m²) | Total % impervious |
|----------------|-----------------|-----------------|---------------|-----------------------------|----------------------|----------------------|--------------------|----------------|-----------------------|--------------------|
| C15            | 1.88            | 18800           | 7             | 2800                        | 0                    | 295                  | 0                  | 1770           | 4570                  | 24.31              |
| C16            | 0.9             | 9000            | 0             | 0                           | 0                    | 0                    | 0                  | 0              | 0                     | 0.00               |
| C17            | 1.39            | 13900           | 0             | 0                           | 0                    | 0                    | 0                  | 0              | 0                     | 0.00               |
| C18            | 0.21            | 2100            | 0             | 0                           | 175                  | 0                    | 0                  | 2100           | 2100                  | 100.00             |
| <b>Basin D</b> |                 |                 |               |                             |                      |                      |                    |                |                       |                    |
| D1             | 1.95            | 19500           | 7             | 2800                        | 0                    | 271                  | 0                  | 1626           | 4426                  | 22.70              |
| D2             | 3.07            | 30700           | 2             | 800                         | 0                    | 105                  | 0                  | 630            | 1430                  | 4.66               |
| D3             | 3.38            | 33800           | 5.5           | 2200                        | 0                    | 327                  | 0                  | 1962           | 4162                  | 12.31              |
| D4             | 0.87            | 8700            | 2.5           | 1000                        | 123                  | 123                  | 0                  | 2214           | 3214                  | 36.94              |
| D5             | 2.74            | 27400           | 9.5           | 3800                        | 0                    | 57                   | 95                 | 722            | 4522                  | 16.50              |
| D6             | 0.84            | 8400            | 0             | 0                           | 23                   | 0                    | 0                  | 276            | 276                   | 3.29               |
| D7             | 1.17            | 11700           | 0             | 0                           | 0                    | 0                    | 0                  | 0              | 0                     | 0.00               |
| D8             | 1.26            | 12600           | 5             | 2000                        | 0                    | 105                  | 0                  | 630            | 2630                  | 20.87              |
| D9             | 1.27            | 12700           | 2             | 800                         | 155                  | 0                    | 83                 | 2192           | 2992                  | 23.56              |
| D10            | 2.73            | 27300           | 10            | 4000                        | 0                    | 0                    | 0                  | 0              | 4000                  | 14.65              |

**Table 3: Slope calculations for each of the post-development subcatchments.**

| Area           | Change in height (m) | Flow Distance (m) | Slope (%) |
|----------------|----------------------|-------------------|-----------|
| <b>Basin B</b> |                      |                   |           |
| B3             | 17.47                | 161               | 11%       |
| B4             | 41.78                | 280               | 15%       |
| B5             | 34.16                | 166               | 21%       |
| B6             | 31.42                | 142               | 22%       |
| B7             | 26.05                | 170               | 15%       |
| B8             | 20.73                | 152               | 14%       |
| B9             | 14.33                | 132               | 11%       |
| <b>Basin C</b> |                      |                   |           |
| C1             | 8.2                  | 102               | 8%        |
| C2             | 24.8                 | 223               | 11%       |
| C3             | 23                   | 176               | 13%       |
| C4             | 23                   | 306               | 8%        |
| C5             | 25.2                 | 179               | 14%       |
| C6             | 8.6                  | 111               | 8%        |
| C7             | 28.6                 | 169               | 17%       |
| C8             | 41.4                 | 494               | 8%        |
| C9             | 14.8                 | 230               | 6%        |
| C10            | 3                    | 18                | 17%       |
| C11            | 22.6                 | 132               | 17%       |
| C12            | 29.8                 | 160               | 19%       |
| C13            | 25.4                 | 218               | 12%       |
| C14            | 24                   | 291               | 2%        |
| C15            | 31.6                 | 153               | 21%       |
| C16            | 31                   | 209               | 15%       |
| C17            | 4.6                  | 257               | 2%        |
| C18            | 15                   | 175               | 9%        |
| <b>Basin D</b> |                      |                   |           |
| D1             | 30.8                 | 216               | 14%       |
| D2             | 28.6                 | 206               | 14%       |
| D3             | 25                   | 172               | 15%       |
| D4             | 22.4                 | 168               | 13%       |
| D5             | 17.6                 | 287               | 6%        |
| D6             | 15.4                 | 186               | 8%        |
| D7             | 14.8                 | 172               | 9%        |
| D8             | 17.8                 | 168               | 11%       |
| D9             | 28.8                 | 257               | 11%       |
| D10            | 43.6                 | 303               | 14%       |

**Table 4: Parameters used to work out channel flow times from Figure 4 (page 90) of the Standard.**

| No.                      | Catchment | Link Distance (m) | Link Slope % | Time (min) | Multiplier (4 – For grassed swales) | Channel Flow Time (m) |
|--------------------------|-----------|-------------------|--------------|------------|-------------------------------------|-----------------------|
| <b>Basin B</b>           |           |                   |              |            |                                     |                       |
| B1 - B2                  |           | 0                 | 0%           | -          | 4                                   | 0                     |
| B2 - B20                 |           | 48                | 6%           | 0.50       | 4                                   | 0.7                   |
| B3 - B4                  |           | 0                 | 0%           | -          | 1                                   | 0                     |
| B4 - B20                 |           | 0                 | 0%           | -          | 4                                   | 0                     |
| B5 - B20                 |           | 0                 | 0%           | -          | 4                                   | 0                     |
| B6 - B20                 |           | 0                 | 0%           | -          | 4                                   | 0                     |
| B7 - B20                 |           | 0                 | 0%           | -          | 4                                   | 0                     |
| B8 - B20                 |           | 0                 | 0%           | -          | 4                                   | 0                     |
| B9 - B20                 |           | 0                 | 0%           | -          | 4                                   | 0                     |
| <b>Basin C</b>           |           |                   |              |            |                                     |                       |
| node22 - node21 (link1)  | C6        | 60                | 21%          | 0.38       | 4                                   | 1.50                  |
| node21 - node20 (link2)  | C9        | 270               | 3%           | 4.00       | 4                                   | 16.00                 |
| node20 - node26 (link3)  | C10       | 0                 | 0%           | -          | 4                                   | -                     |
| node26 - BASIN C (link4) | N/A       | 0                 | 0%           | -          | 4                                   | -                     |
| node23 - node26 (link5)  | C10       | 0                 | 0%           | -          | 4                                   | -                     |
| node19 - node26 (link6)  | C10       | 0                 | 0%           | -          | 4                                   | -                     |
| node25 - node20 (link7)  | C9        | 315               | 4%           | 4.00       | 4                                   | 16.00                 |
| node18 - node20 (link8)  | C9        | 315               | 4%           | 4.00       | 4                                   | 16.00                 |
| node17 - BASIN C (link9) | N/A       | 110               | 2%           | 2.00       | 4                                   | 8.00                  |
| node16 - node17 (link10) | C17       | 0                 | 0%           | -          | 4                                   | -                     |
| node13 - node17 (link11) | C17       | 0                 | 0%           | -          | 4                                   | -                     |
| node12 - node13 (link12) | C17       | 0                 | 0%           | -          | 4                                   | -                     |
| node11 - node13 (link13) | C17       | 240               | 3%           | 3.50       | 4                                   | 14.00                 |
| node14 - node13 (link14) | C17       | 240               | 3%           | 3.50       | 4                                   | 14.00                 |
| node15 - node13 (link15) | C17       | 240               | 3%           | 3.50       | 4                                   | 14.00                 |
| node2 - node14 (link16)  | C16       | 234               | 12%          | 2.25       | 4                                   | 9.00                  |
| node31 - node18 (link27) | C18       | 0                 | 0%           | -          | 4                                   | -                     |
| <b>Basin D</b>           |           |                   |              |            |                                     |                       |
| D1 - D6                  | D6        | 192               | 5%           | 2.25       | 4                                   | 9.00                  |
| D2 - D6                  | D6        | 202               | 4%           | 2.50       | 4                                   | 10.00                 |
| D10 - D9                 | D9        | 65                | 4%           | 0.85       | 4                                   | 3.40                  |

## 2.3 Rainfall Parameters

The existing xprafits version 2016 uses the Laurenson non-linear runoff routing procedure to develop a subcatchment stormwater runoff hydrograph from design storm using IFD data together with standard ARR 1987 data. Therefore, all rainfall parameters used in the model were obtained from the ARR 1987 database<sup>15</sup>.

<sup>15</sup> Intensity-Frequency-Duration, Bureau of Meteorology, [www.bom.gov.au/cgi-bin/hydro/has/CDIRSWebBasic](http://www.bom.gov.au/cgi-bin/hydro/has/CDIRSWebBasic)

Xprafts' *Automatic Storm Generator* (ASG) was used to simulate ARI 100 year storms with various durations. The ASG allows users to derive the standard storms defined within ARR 1987 and apply local IFD, which can be sourced from the BOM.

Information obtained from BOM for the Study was as follows:

- **Location:** Bay Ridge
- **Coordinates:**
  - Latitude, -35.694
  - Longitude, 150.184
- **Storm Losses** – Estimates for the storm loss values were obtained from ARR 2016 as ARR 1987 does not provide the same.
  - Pervious surfaces (from ARR 2016)
    - Initial Losses (mm) = 27.0
    - Continuing Losses (mm/h) = 7.3.
  - Impervious (a conservative estimate)
    - Initial Losses (mm) = 1.0
    - Continuing Losses (mm/h) = 0.
- **IFD Coefficients** (please see **Figure 4**)<sup>16</sup>
  - 1 hour
    - ARI 50 year (mm/h) = 89.9
    - ARI 1 year (mm/h) = 30.4
  - 12 hour
    - ARI 50 year (mm/h) = 20
    - ARI 1 year (mm/h) = 6.41
  - 72 hour
    - ARI 50 year (mm/h) = 6.6
    - ARI 1 year (mm/h) = 1.93

A comparison of the ARR 1987 IFD data with the ARR 2016 IFD data for the same location revealed that the 1987 data was more conservative which implies the peak flow results and hence the overall design of the Basin will be on the safer more conservative side. For comparison, the ARR 2016 IFD values for the same durations were as follows:

- 1 hour
  - ARI 50 year (mm/h) = 65.2
  - ARI 1 year (mm/h) = 22.0
- 12 hour
  - ARI 50 year (mm/h) = 17.7
  - ARI 1 year (mm/h) = 6.37
- 72 hour
  - ARI 50 year (mm/h) = 6.76
  - ARI 1 year (mm/h) = 2.03

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<sup>16</sup> *Intensity-Frequency-Duration*, Bureau of Meteorology, <http://www.bom.gov.au/water/designRainfalls/ifd-arr87/index.shtml>.

- **Rainfall durations:** The following durations (in minutes) of the design storm for the ARI 100 year event were run for the pre- and post-development scenarios to identify the critical storms in each case:
  - 15, 20, 25, 30, 45, 60, 90, 120, 180, 270, 360, 540, 720, 1080, 1440, 2160, 2880, 4320.

**RAINFALL INTENSITY IN mm/h FOR VARIOUS DURATIONS AND RETURN PERIODS**

| DURATION | RETURN PERIOD (YEARS) |      |      |      |      |      |      |  |  |  |
|----------|-----------------------|------|------|------|------|------|------|--|--|--|
|          | 1                     | 2    | 5    | 10   | 20   | 50   | 100  |  |  |  |
| 5 mins   | 97.3                  | 126. | 162. | 184. | 213. | 251. | 280. |  |  |  |
| 6 mins   | 91.2                  | 118. | 152. | 173. | 200. | 236. | 264. |  |  |  |
| 10 mins  | 74.8                  | 96.9 | 126. | 144. | 167. | 198. | 222. |  |  |  |
| 20 mins  | 54.8                  | 71.5 | 94.7 | 109. | 127. | 152. | 172. |  |  |  |
| 30 mins  | 44.7                  | 58.5 | 78.2 | 90.3 | 106. | 128. | 144. |  |  |  |
| 1 hour   | 30.4                  | 39.9 | 54.1 | 62.9 | 74.3 | 89.9 | 102. |  |  |  |
| 2 hours  | 19.9                  | 26.3 | 35.9 | 41.9 | 49.7 | 60.4 | 68.8 |  |  |  |
| 3 hours  | 15.4                  | 20.4 | 27.9 | 32.6 | 38.7 | 47.1 | 53.7 |  |  |  |
| 6 hours  | 9.93                  | 13.1 | 18.0 | 21.1 | 25.1 | 30.6 | 34.9 |  |  |  |
| 12 hours | 6.41                  | 8.49 | 11.7 | 13.8 | 16.4 | 20.0 | 22.9 |  |  |  |
| 24 hours | 4.14                  | 5.50 | 7.67 | 9.07 | 10.8 | 13.3 | 15.3 |  |  |  |
| 48 hours | 2.61                  | 3.49 | 4.93 | 5.88 | 7.08 | 8.75 | 10.1 |  |  |  |
| 72 hours | 1.93                  | 2.59 | 3.69 | 4.41 | 5.33 | 6.60 | 7.63 |  |  |  |

(Raw data: 40.40, 8.55, 2.61, 89.37, 19.62, 6.47, skew= 0.080)  
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 \* ENSURE THE COORDINATES ARE THOSE REQUIRED SINCE DATA IS BASED ON THESE AND NOT LOCATION NAME.

**Figure 4: Rainfall intensities obtained from BOM's ARR 1987 database.**

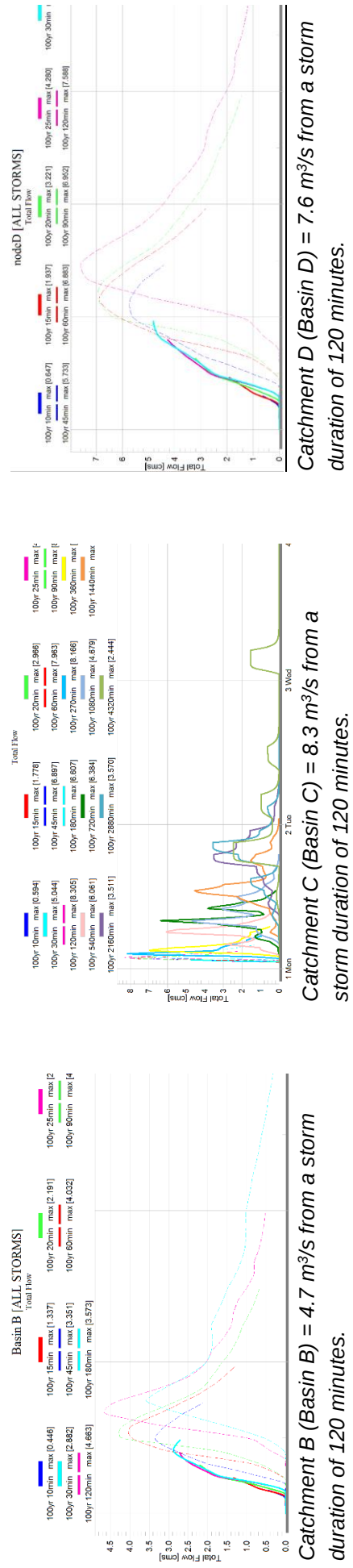
## 3. Results

This section describes the results of the Study providing a comparison between the critical pre- and post-development peak flows and modelling results which indicate the Basins' ability to achieve the design requirements for limiting post-development peak flows and fully attenuating the ARI 100 year storm runoff.

### 3.1 Pre-development Catchment

**Figure 5** below presents the peak flow results for the ARI 100 year storm for various storm durations on the pre-development catchments. Based on the results, the critical peak flows out of the three catchments for Basins B, C and D are as follows:

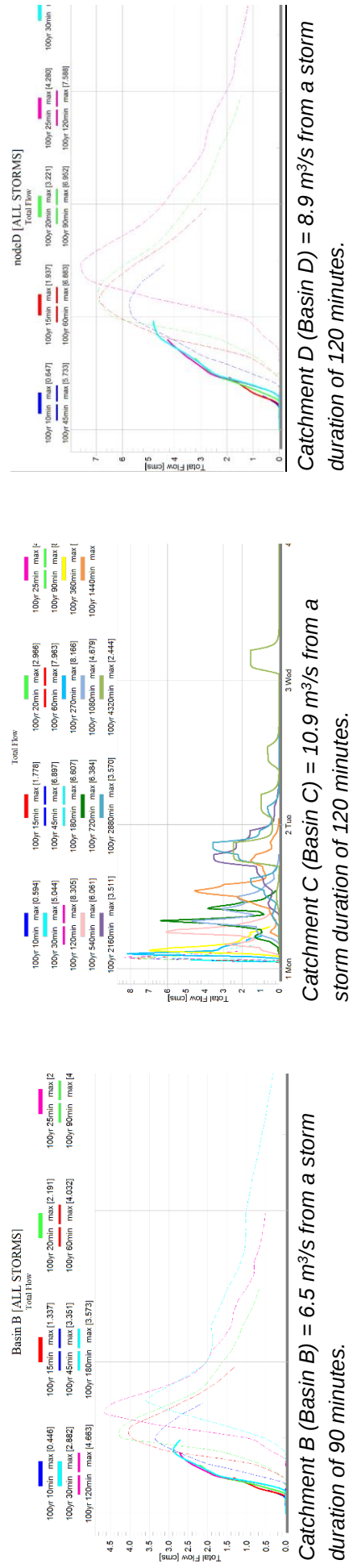
- **Catchment B (Basin B)** = 4.7 m<sup>3</sup>/s from a storm duration of 120 minutes.
- **Catchment C (Basin C)** = 8.3 m<sup>3</sup>/s from a storm duration of 120 minutes.
- **Catchment D (Basin D)** = 7.6 m<sup>3</sup>/s from a storm duration of 120 minutes.



### 3.2 Post-development Subcatchment

**Figure 6** below presents the peak flow results for the ARI 100 year storm for various storm durations on the post-development subcatchment. Based on the results, the critical peak flows out of the three catchments for Basins B, C and D are as follows:

- **Catchment B (Basin B)** = 6.5 m<sup>3</sup>/s from a storm duration of 90 minutes.
- **Catchment C (Basin C)** = 10.9 m<sup>3</sup>/s from a storm duration of 120 minutes.
- **Catchment D (Basin D)** = 8.9 m<sup>3</sup>/s from a storm duration of 120 minutes.



### 3.3 Comparison of Pre- and Post-Development Results without Basin

**Table 5** below provides a comparison of the critical pre- and post-development peak flows from the three subcatchments without the Basins. The results indicate that the critical peak flows for the post-development scenario are higher due to the increase in the pervious surface cover as a result of the development.

**Table 5: Comparison of the critical peak flows generated pre- and post-development without the Basin.**

|                       | Peak Flow (m <sup>3</sup> /s) | Critical Storm Duration (min) |
|-----------------------|-------------------------------|-------------------------------|
| <b>Subcatchment B</b> |                               |                               |
| Pre-development       | 4.7                           | 120                           |
| Post-development      | 6.5                           | 90                            |
| <b>Subcatchment C</b> |                               |                               |
| Pre-development       | 8.3                           | 120                           |
| Post-development      | 10.9                          | 120                           |
| <b>Subcatchment D</b> |                               |                               |
| Pre-development       | 7.6                           | 120                           |
| Post-development      | 8.9                           | 120                           |

### 3.4 Design Basin Performance

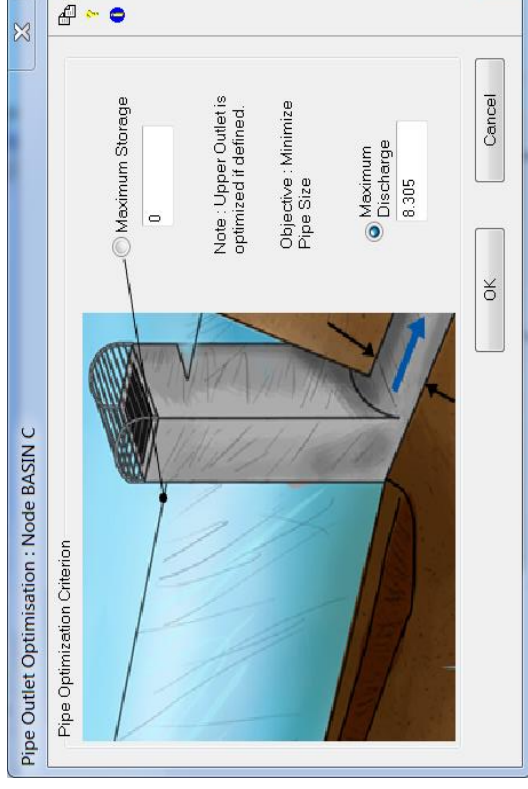
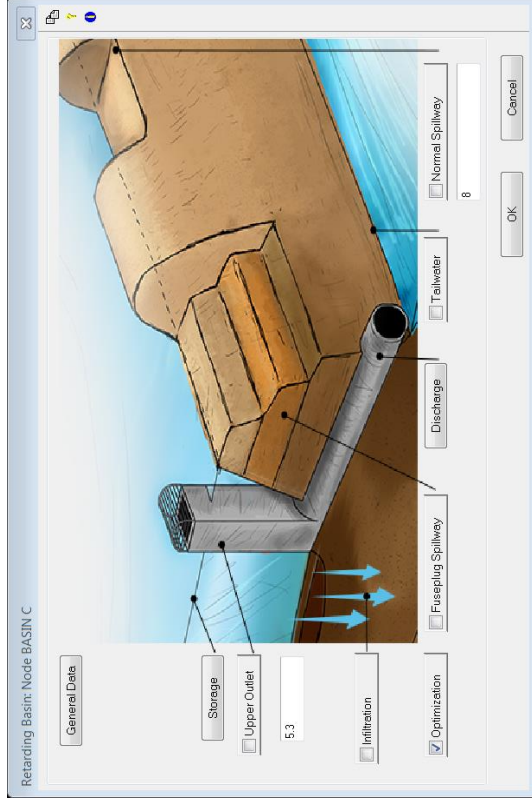
Using xpraf's basin outlet optimization function and running different iterations of stage-volume relationships, the design of the Basins was finalized ensuring the Basins were able to fulfil their objectives of limiting the critical post-development outflow rate and attenuating the entire volume of the ARI 100 year storm without resulting in overtopping of flows.

#### 3.4.1 Outlet Optimization

Results from xpraf's outlet optimization function indicated that the following diameters of pipe outlets would be the maximum size that will limit the post-development critical flow to the critical pre-development peak flow for the ARI 100 year storm:

- **Basin B – outlet pipe diameter = 1.50 m**
- **Basin C – outlet pipe diameter = 1.70 m**
- **Basin D – outlet pipe diameter = 2 no.s of 1.06 m**

**Figure 7** provides a few screenshots of xpraf's basin optimization interface.



**Figure 7: Screenshots from xprafits' basin optimization interface**

### 3.4.2 Basin Volume Optimization

**Table 6** provides the design stage-volume relationship for the Basins arrived at after multiple model runs and iterations based on the volume required for attenuation of the ARI 100 year storm.

**Table 6: Design Stage-Volume Relationship for Basins B, C and D**

| Basin B   |                           | Basin C   |                           | Basin D   |                           |
|-----------|---------------------------|-----------|---------------------------|-----------|---------------------------|
| Level (m) | Storage (m <sup>3</sup> ) | Level (m) | Storage (m <sup>3</sup> ) | Level (m) | Storage (m <sup>3</sup> ) |
| 2.4       | 0                         | 5.3       | 0                         | 16.8      | 0                         |
| 3         | 190.264                   | 5.4       | 0.114                     | 17        | 0.019                     |
| 3.2       | 354.057                   | 5.6       | 6.659                     | 17.2      | 1.921                     |
| 3.4       | 569.302                   | 5.8       | 30.838                    | 17.4      | 11.361                    |
| 3.6       | 829.347                   | 6         | 72.927                    | 17.6      | 34.369                    |
| 3.8       | 1138.132                  | 6.2       | 137.367                   | 17.8      | 77.799                    |
| 4         | 1492.387                  | 6.4       | 230.965                   | 18        | 158.133                   |
| 4.2       | 1891.306                  | 6.6       | 364.624                   | 18.2      | 287.521                   |
| 4.4       | 2341.789                  | 6.8       | 555.123                   | 18.4      | 476.061                   |
| 4.6       | 2854.773                  | 7         | 819.756                   | 18.6      | 726.504                   |
| 4.8       | 3438.747                  | 7.2       | 1169.368                  | 18.8      | 1037.884                  |
| 5         | 4101.936                  | 7.4       | 1613.773                  | 19        | 1409.299                  |
| 5.2       | 4843.335                  | 7.6       | 2160.843                  | 19.2      | 1840.918                  |
| 5.4       | 5649.671                  | 7.8       | 2823.231                  | 19.4      | 2331.961                  |
| 5.5       | 6078.438                  | 8         | 3586.254                  |           |                           |

The results on basin performance obtained from xprafits using the outlet diameters provided in the previous section and the stage-storage relationships provided in **Table 6** were as follows:

- **Basin B:**
  - **Peak outflow (m<sup>3</sup>/s):** 4.6 (slightly less than the pre-development critical peak flow for the ARI 100 year storm of 4.7 m<sup>3</sup>/s)
  - **Total inflow (m<sup>3</sup>):** 9,471
  - **Basin volume used (m<sup>3</sup>):** 1,703 (out of available 6,078)
  - **Basin stage used:** 4.1 m at full attenuation, out of maximum basin elevation of 5.5 m. A freeboard of 1.4 m will be available.
- **Basin C:**
  - **Peak outflow (m<sup>3</sup>/s):** 8.2 (slightly less than the pre-development critical peak flow for the ARI 100 year storm of 8.3 m<sup>3</sup>/s)
  - **Total inflow (m<sup>3</sup>):** 32,580
  - **Basin volume used (m<sup>3</sup>):** 3,227 (out of available 3,586)
  - **Basin stage used:** 7.9 m at full attenuation, out of maximum basin elevation of 8.0 m. A freeboard of 0.1 m will be available.
- **Basin D:**

- **Peak outflow ( $\text{m}^3/\text{s}$ ):** 7.5 (slightly less than the pre-development critical peak flow for the ARI 100 year storm of  $7.6 \text{ m}^3/\text{s}$ )
- **Total inflow ( $\text{m}^3$ ):** 20,502
- **Basin volume used ( $\text{m}^3$ ):** 1,599 (out of available 8,752)
- **Basin stage used:** 19.1 m at full attenuation, out of maximum basin elevation of 19.4 m. A freeboard of 0.3 m will be available

## 4. Conclusion

The previous section provides the optimum combination of stage-volume relationship of Basins B, C and D and the maximum outlet diameters to ensure that the Basins are successful in fulfilling the required stormwater management requirements stipulated in the Standard, namely, the twofold design objectives of:

1. **Limiting peak flow to pre-development level:** It will limit the critical post-development peak flow to the critical pre-development peak flow for the ARI 100 year storm, and
2. **Stormwater attenuation:** It has sufficient volume to fully attenuate the critical post-development ARI 100 year storm without overtopping of flows.

The detailed design drawings submitted along with this report shall demonstrate that the Basins were designed within the limits prescribed by the results of this Study. And, therefore, the Basins will be able to fulfil the twofold design objectives stated above.



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Document2

Document Status

| Revision | Author   | Reviewer |                                                                                     | Approved for Issue |                                                                                       |            |
|----------|----------|----------|-------------------------------------------------------------------------------------|--------------------|---------------------------------------------------------------------------------------|------------|
|          |          | Name     | Signature                                                                           | Name               | Signature                                                                             | Date       |
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|          |          |          |                                                                                     |                    |                                                                                       |            |
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