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Final

Tweed Valley Hospital Hydrology Assessment

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EXECUTIVE SUMMARY

This report has been undertaken for Lendlease to assesses the hydrology impact of the proposed Tweed Valley Hospital development on the adjacent coastal wetland. In accordance with Department of Planning, Industry and Environment (DPIE) comments (27th March 2020), the report has been updated to assess the impact of seasonal flows and the impact on the wetland ecology.

The existing site was agricultural and horticultural land immediately adjacent to a coastal wetland with a small dam in the north west corner of the site. The proposed development utilises Water Sensitive Urban Design structures to control peak flows and improve water quality of discharge from site.

Central to the review is the Robert Bird Group (RBG) Stormwater Management Plan, which has been used as a base to undertake the assessment. The water quality (MUSIC) and water quantity (DRAINS) models were reviewed for suitability and then used to provide information relating to discharges into the coastal wetland. The stormwater design incorporates four basins to capture and treat development site rainfall runoff.

This report shall feed back into the ongoing design and submissions related to the overall water and ecological impact of the hospital development.

Key findings of the review are as follows:

- The proposed RBG stormwater management reduces 1% AEP (100 year Average Recurrence Interval) peak flows from the development to below existing levels for the whole of site, and with minor basin modification, the 20% AEP for all basins. This reduction of peak 1% and 20% peak flows to below existing levels is a design requirement

- During frequent rain events (more frequent than the 20% AEP) the developed stormwater discharge is above existing levels. The impact of increased and more frequent flows on the wetland is assessed as minimal benefit and is not necessary for the protection of the Wetland

- Stormwater management for the site incorporates 400 KL rainwater tanks and re-use of rainwater for irrigation

- The annual flow volumes for the current design are higher post development than pre development. The stormwater volumes entering the basin will not be further reduced than the 17ML per year as the use of infiltration treatment devices such as infiltration trenches, swales, rain gardens and permeable pavements etc could not be implemented due slope slip failure on the steep batters around the site due to waterlogged subsoil. Because of the geotechnical risks confirmed by RBG.

- According to the report dated 3rd December 2019 (Morrison Geotech – Clarification on General Drainage Comments – Tweed Valley Hospital – Cudgen Road, Kingscliff), the groundwater in the existing condition is connected to the wetland and therefore adding infiltration provides limited practical benefit.

- Infilling of the existing dam was assessed for a range of flood events and found to have no material impact on wetland flood levels, except a minor local affect for the frequent 4EY (four exceedance per year on average), due to the runoff filling in the local depressions

- Based on the monthly flow data modelled, the key wetland hydrologic metrics (drying period and frequency of inundation will not be altered significantly by the increased flows. In 10 of the 18 years modelled, a minimum of 4 months drying period under the existing and development scenario was observed.

- The monthly data, while broadly aligned to the seasonal weather patterns (wet season between November to March), showed a high degree of variability. For example, during 2012 it was observed that there was a dry period that extended over 8-9 months.

- The size of the hospital site catchment makes up approximately 2% of the overall catchment feeding the wetland area. This factor, combined with the erratic nature of rainfall events suggests that the wetland is adapted to deal with significant inflows at times, well beyond the changes likely to result from the additional flows from the hospital site. Subsequently, whilst the wetland vegetation community will show seasonal changes in response to hydrologic variation, the overall floristic assemblage is unlikely to be significantly altered.

1 Introduction

1.1 Purpose

The purpose of this report is to undertake a desktop review of the Stormwater Management Plan for the Tweed Valley Hospital undertaken by Robert Bird Group, and then extend the hydrology modelling to assess hydrological impacts on the adjacent coastal wetland from the stormwater measures.

The report also considers the impact of infilling an agricultural dam in the north western corner of the site.

The RBG Stormwater Management Plan does not include detailed components of the stormwater design and this review scope does not undertake an assessment of detailed design of the proposed water quality basins or stormwater network, rather to confirm that the RBG MUSIC water quality modelling and DRAINS water quantity modelling of the stormwater network are consistent with the Stormwater Management Plan in terms of hydrological aspects affecting the coastal wetland.

1.2 Scope

The scope of work incorporates the following:

- Desktop review of the RBG Stormwater Management Plan
- Hydrological assessment of the potential change to the downstream coastal wetland, due to the development
- Dam decommissioning (infilling) option assessment
- High level review of seasonal flows and the impact on wetland ecology.

In accordance with the proposal, the following steps were undertaken to review the hydrological impact of the development:

1. Review supplied background documentation relevant to the stormwater and water quality outputs to the wetland;
2. Develop a hydrologic model to determine the peak discharge for the 50%, 20% and 1% Annual Exceedance Probability (AEP) events, and compare to the pre-development case;
3. Develop a two-dimensional (2D) hydraulic model to determine the effect of the dam decommissioning option provided by RBG (existing and developed scenarios);
4. Assess the impact of changes in flow regimes on the wetland and communicate the outcomes for ecological assessment; and
5. Provide information for Input into the RBG Design Report and Design Drawings.

2 Review of Stormwater Management

2.1 Methodology

A desktop review was undertaken of the Stormwater Management Plan developed by Robert Bird Group. The review was assessed against standard industry practise and the requirements indicated to satisfy the respective draft conditions of consent from the NSW Department of Planning and Environment for Section B3.b.ii, and iii.

2.1.1 Summary of stormwater treatment

- The pre-development site was used for agriculture (mainly horticulture) with associated soil disturbance and potential for increased pollutant loads such as sediment and nutrients discharging into the coastal wetland. Previous site discharge had no significant water quality treatment that we are aware of, apart from a portion draining into an existing dam.
- The post development case aims to improve runoff water quality through the use of water sensitive urban design structures such as bio-retention systems and gross pollutant traps. Capture and re-use of rainwater is proposed with roof runoff rainwater tanks (400ML) and recycling for on-site irrigation.

2.2 MUSIC model review

Proposed water quality treatment design is tested using a comparison of pre and post development condition modelled using the industry standard MUSIC model (eWater, 2018).

The MUSIC model assesses the conceptual design of Water Sensitive Urban Design (WSUD) components and is the standard specified by most development codes in eastern Australia. Parameters to be used in each model are usually specified within design guidelines, however most are reasonably consistent unless site specific data is available.

No site specific water quality data has been provided for the Tweed area, and therefore the Tweed Shire Council Design Specifications and Queensland Urban Drainage Manual (2013) are relevant, with MUSIC pollutant parameter data in accordance with Water by Design MUSIC Modelling Guidelines (Nov, 2018) being the latest guideline, and considered applicable as used by RBG.

Rainfall data for the RBG MUSIC model was based on the data available for download from the eWater on-line Rainfall Data Tool (eWater, 2019). Data on the website has been assessed by eWater as suitable for MUSIC modelling of WSUD options. The recommendation by OEH is to assess data of 20 years minimum, however this length of record was not available at the 6-minute time increment recommended for this size site. A longer period of data (2003-2017) was obtained from the Bureau of Meteorology Climate Data Online (BoM, 2019), via purchase.

Table 1 shows the data available from a check of the Bureau of Meteorology database. The first site is the eWater MUSIC available data set which is under nine years in length. A second nearby site was found at Coolangatta with just over 14 years of data, and a third site at Gold Coast Seaway having 19 years of record (but 38km away), however it had several data gaps that significantly limit its use. Therefore, the Coolangatta site 040717 was used for analysis, being a longer period than Coolangatta Bowls, and also more recent and continuous.

Table 1: Available rainfall data for MUSIC modelling

Site	Data Start- Finish	Annual Rainfall	Comment
040052 Coolangatta Bowls (9.9km from site)	9/1972-6/1981	1934	MUSIC website data
040717 Coolangatta (12.2 km from site)	9/2003-1/2018	1438	Good quality recent data set, also used in this review
040764 Gold Coast Seaway (38.4 km from site)	3/2000-7/2019	1163	Significant data gaps and reasonable distance away

The MUSIC model catchment review is included with the DRAINS model review in the next section.

MUSIC model water quality objectives set by Tweed Shire Council (TSC, D7, 2016) are for the following pollutant load reductions:

Total Suspended Solids (TSS)	80%,
Total Phosphorous (TP)	60%
Total Nitrogen (TN)	45%
Gross Pollutants	90%

Analysis using alternative recent rainfall data from 2003-2017 was undertaken for comparison and results shown in Figure 1 (1972-1981 data) and Figure 2(2003-2017 data). The basins in the model are lined which reduces infiltration.

	Pre-development Annual Load	Post-development Annual Load (Untreated)	Post-development Annual Load (Treated)	% Reduction	TSC Target
Total Flow	78.7	136	134	1.7	N/A
TSS	29,900	32,200	5,580	82.7	80%
TP	31,500	71.6	21.3	70.3	60%
TN	183	429	201	53.2	45%
GP	415	2100	0.054	100	90%

Figure 1: Water Quality (MUSIC modelling) results copied from RBG (2019), MUSIC 1972-1981 data

	Sources		Residual Load		% Reduction	
	Pre	Post	Pre	Post	Pre	Post
Flow (ML/yr)	90.6	142	90.6	140	0	1.41
Total Suspended Solids (kg/yr)	35600	33800	35600	7000	0	79.3
Total Phosphorus (kg/yr)	37.2	75.2	37.2	26.4	0	64.9
Total Nitrogen (kg/yr)	207	454	207	236	0	48
Gross Pollutants (kg/yr)	412	1930	412	0.19	0	100

Figure 2: Water Quality (MUSIC modelling) results screenshot using more recent BoM 2003-2017 data

The results support the RBG (2019) assessment for pollutant load reduction to the required levels for TP and TN, however the TSS reduction using 2003-2017 data is shown as being just under the 80% level at 79.3%. This reduction could be easily improved to 80% with slight design modification, if required.

With regard to the mean total annual flow volume from site, this is shown as increasing by just over 50% from pre-development (90.6ML/yr) to post development (140 ML/yr) for 2003-2017 data. This is similar to, but lower than the 70 % increase indicated in RBG (2019, Table 5.2) annual load assessment of 78.7 ML/yr pre-development to 134 ML/yr post development using 1972 to 1981 data. The reason for the large increase is that the development has a significant area that has become impervious (roofs, carparks, roads, paths) compared to the original agricultural land that readily allowed infiltration. An option for reducing this is discussed later.

In terms of changes to total pollutant load, Total Suspended Solids (TSS) and Total Phosphorus (TP) are reduced below pre-development levels, while Total Nitrogen has increased by approximately 14% (207 kg/yr to 236 kg/yr). This result is consistent with an increase in TN found by the RBG assessment using 1972-1981 data. Again, this increase in total load can be reduced with some design modification. It is noted that the Landscape proposal in the SSD 9575 approval drawings included potential rain gardens.

Reducing the post development flow volumes to pre-development levels is difficult without a significant increase in storage, and mechanisms of transferring this to groundwater, which would also likely make its way to the adjacent wetland over a delayed period.

The impact on the wetland water levels is minimal and discussed later in the dam filling option, Section 4.
The ecological impact of this has been assessed in Section 5.

Following submission of revision 03 of this report to DPIE, the department requested changes to the design MUSIC model (April 2020, RBG model). The model has been updated to include the following changes and has been provided to SMEC for review:

- Commercial land use run-off parameters from 2018 Water By Design guidelines have been amended in respect of rainfall run-off and field capacity values. The updated model adopts the parameters as outlined in the 2015 NSW Music modelling guidelines.
- Rainfall data has been updated to use the 15 year (05/2003 to 01/2018) 6-minute rainfall data from the Coolangatta station (040717), obtained from the BoM, 2019), via purchase.
- A "natural" (bush/forest) sub-model has been created as well as the pre-development and post-development sub-models for comparison with the natural state.
- 1ha of catchment area has been excluded from the pre-development MUSIC model.
- A proposed 400KL rainwater reuse tank has been included in the model.

The following results have been obtained from the updated mode (refer Table 2):

Table 2: MUSIC modelling results (April 2020)

Mean Annual Load	Natural state (bush / forest)	Pre-development (agricultural land use)	Post-development (without treatment)	Post-development (with treatment)
Flow (ML/Yr)	66.1	71.2	118	105.0
Total Suspended Solids (kg/yr)	4,333	21,200	26,000	4,700
Total Phosphorus (kg/yr)	4.63	22.9	61.1	17.8
Total Nitrogen (kg/yr)	51.3	136	368	161

The updated MUSIC model demonstrates compliance with the TSC development control plan requirement to reduce the post development flows by the following reduction targets (compared with post development loads without treatment). Suspended solids 80%, Phosphorus 60%, Nitrogen 45%, gross pollutants 90%. It also demonstrates a significant overall improvement in water quality compared with the modelled pre-development state (other than a very small increase in nitrogen). It is noted that the MUSIC model has only accounted for a reduction in total flows of approximately 10.5ML for the rainwater tank (compared to the 17ML calculated by the project hydraulic engineer).

2.2.1 Seasonal Flow and Catchment Assessment

RBG's April 2020 MUSIC model (reviewed by SMEC) was used to assess the hydrological impacts and seasonal flow variances. In particular, the model was updated to consider monthly and seasonal (dry/wet) scenarios for the existing and developed footprint. The flow volume entering into the wetland was refined to monthly and longer period/seasons. It was determined that the peak wet season/periods for the development were generally in the months from November to March. The increase in monthly flow from the development for the full seasonal period were assessed. Maximum, average and minimum flow were observed to be 10.9 ML, 3.4ML and 0 ML respectively (based on a 15 year data period).

An assessment was carried out to quantify the impact of additional flow volumes entering the wetland due to hospital site for longer periods. Based on the modelled monthly inflow data, there is minimum 4 month drying period (<2ML/month) for the existing and developed scenario (10 of the 18 years modelled). It is noted that in 2012 there was minimal rain. Based on our assessment, it is noted that the runoff volume from the development, in the existing and developed scenarios is highly variable. In addition, the available data indicates that the wetting and drying sequence is unlikely to impact the hydrologic cycle of the wetland.

Due to limited topographic survey available for the wetland, inundation extents and depths cannot be accurately determined. Notwithstanding, a high level catchment analysis was undertaken to provide a regional context regarding the hospital runoff percentage. It was determined that the total external catchment area contributing to the wetland is approximately 850ha. while the hospital catchment area is 12.85ha. The hospital catchment is approximately 2% of the total external catchment (assuming that 75% of external catchment contributes to the wetland). Based on the available data, it is determined that the increase in runoff from the development is negligible when compared to the entire catchment inflows.

The impact of seasonal flows on the wetland will be further discussed in Section 5. Refer Appendix B for the catchment configurations, monthly flow data table and Monthly flow graph from 2003 to 2018.

2.3 Reducing post development flow volume

A 400KL rainwater reuse tank was modelled to collect and store rainwater from the hospital roof to use for irrigation and cooling tower. The results showed that the reusing stormwater will reduce the total stormwater discharge by approximately by 17ML per year on average.

Using the recommended MUSIC model parameters indicates that reducing post development annual flow volume to pre-development levels is not feasible due to geotechnical limitations on use of range of other water quality treatment devices such as infiltration trenches, raingardens and permeable pavements etc (refer Morrison Geotech – Clarification on General Drainage Comments – Tweed Valley Hospital – Cudgen Road, Kingscliff). The stormwater volumes entering the basin will not be further reduced than the existing limitation stated above of 17ML per year.

2.4 DRAINS model review

2.4.1.1 Model Parameters

A review of model parameters used for both MUSIC and DRAINS models was carried out as part of the review process to check consistency of the modelling data.

Table 3 and Table 4 show the model parameters used by RBG (2019) DRAINS and MUSIC models.

Table 3: RBG DRAINS model parameters for basins

	Basin A	Basin B	Basin C	Basin D
Total Catchment (ha)	7.385	0.3	1.44	3.41
% Impervious	60	50	85	50
% Pervious	40	50	15	50

Table 4: RBG MUSIC model parameters for basins

	Basin A	Basin B	Basin C	Basin D
Total Catchment (ha)	6.77	0.21	1.25	3.30
% Impervious	62	26	65	25
% Pervious	38	74	35	75

The SMEC review confirmed that the parameters used in the MUSIC models were more accurate, hence the DRIAN model parameters were changed to replicate MUSIC model parameter.

ARR2019 data hub parameters for the Tweed Hospital Site was downloaded in August 2019 based on the latitude and longitudes shown in Table 5.

Table 5: Co-ordinate details used for ARR2019 Data hub request

	Requested	Nearest grid cell
Latitude	28.2639	28.2625
Longitude	153.5655	153.5625

The rainfall intensity parameters used by RBG were compatible with the data extracted by SMEC.

2.4.1.2 Modelling Methodology and results

The development of the RBG DRAINS models was carried out using Horton/ILSAX type hydrological model with less abbreviated data for time of concentration of 5 mins for each basin. The Table 6 shows the individual outflow from each basin.

Table 6: RBG DRAINS model runs with 2016 - ILSAX

Basin	Catchment Area (ha)	1% AEP Flow (m^3/s)		20% AEP Flow (m^3/s)		50% AEP Flow (m^3/s)		1EY (m^3/s)		4EY (m^3/s)	
		EXST	**DEV**	**EXST**	**DEV**	**EXST**	**DEV**	**EXST**	**DEV**	**EXST**	**DEV**
Basin A	6.77	4.45	1.61	3.09	1.41	1.44	1.13	1.24	0.67	0.56	0.35
Basin B	0.21	0.19	0.18	0.13	0.12	0.06	0.06	0.05	0.05	0.03	0.03
Basin C	1.25	1.11	0.44	0.68	0.38	0.36	0.27	0.30	0.25	0.15	0.12
Basin D	3.30	2.40	1.17	1.75	0.99	0.83	0.61	0.70	0.54	0.33	0.29

SMEC developed a XP-RAFTS hydrology model to verify the DRAINS flows. ARR2016 Initial Continuous Loss (IL/CL) method was adopted for both the XPRAFTS and the DRAINS modelling.

Table 7 shows the individual outflow from each basin. The results revealed that the developed flows for the 1% AEP event are reduced to below existing levels. However, for frequent events 50% AEP (Basins A and B), and all basins in the 1EY and 4EY events are significantly higher than the existing flows. It is expected these outflows could be reduced to pre-development levels for each basin through additional modifications to the outlet design.

Table 7: SMEC DRAINS model runs with 2016 IL/CL numbers used for rafts modelling.

Basin	Catchment Area (ha)	1% AEP Flow (m^3/s)		20% AEP Flow (m^3/s)		50% AEP Flow (m^3/s)		1EY (m^3/s)		4EY (m^3/s)	
		EXST	**DEV**	**EXST**	**DEV**	**EXST**	**DEV**	**EXST**	**DEV**	**EXST**	**DEV**
Basin A	6.77	2.97	1.61	1.13	1.22	0.53	*0.65*	0.39	*0.54*	0.06	*0.26*
Basin B	0.21	0.12	0.14	0.05	0.07	0.02	*0.04*	0.02	*0.03*	0.00	*0.01*
Basin C	1.25	0.71	0.43	0.32	0.30	0.12	*0.24*	0.10	*0.20*	0.01	*0.10*
Basin D	3.30	1.75	1.12	0.80	0.73	0.30	*0.47*	0.23	*0.40*	0.03	*0.12*

A further assessment was carried out by SMEC to assess the combined flows at the outlet downstream of the dam for the development as a whole. Table 8 shows the combined outflows downstream of the dam. The results confirmed that the developed flows are greater than the existing flows for the 50% AEP, 1EY and 4EY rainfall events.

Refer Appendix A for hydrographs extracted from the DRAINS model for comparison.

Table 8: SMEC DRAINS model runs with 2016 IL/CL – Combined flows at the outlet.

Rainfall Event	Catchment Area (ha)	AEP OutFlow (m^3/s)	
		EXISTING	**DEVELOPED**
1% AEP	11.53	4.10	2.70
20% AEP	11.53	2.30	2.10
50% AEP	11.53	0.70	*1.20*
1EY	11.53	0.65	*1.10*

Rainfall Event	Catchment Area (ha)	AEP OutFlow (m^3/s)	
		EXISTING	**DEVELOPED**
4EY	11.53	0.10	*0.30*

2.4.1.3 Recommendation

The developed flows for the more common 50% AEP, 1EY and 4EY rainfall events are greater than the existing outflows. The impact of increased and more frequent flows on the wetland is assessed as minimal benefits. Therefore, refining the basin outflow design for the 1EY, 4EY and 50% AEP would have minimal benefit and is not necessary for the protection of the Wetland.

3 Coastal Wetland Assessment

3.1 Rainfall data assessment

As indicated in the previous section, the 6 minute rainfall data for MUSIC has a maximum term of approximately 14.7 years, from May 2013 to Jan 2018. To consider 20 years' worth of data, daily rainfall records are required. Site 04717 Coolangatta (~12 km from the site) was used which contains data from December 1982 to 2019, with a 17 month gap from January 1993 to end June 1994. (25 years continuous from 1994).

A summary of the rainfall data statistics is shown in Table 9 below. It shows that there is no significant difference whether considering the rainfall from 1982, or from 1994, noting that the days of rainfall have reduced. Therefore, daily data from 1994 and continuous data from 2003 for MUSIC modelling is supported.

Table 9: Summary of min 20 years rainfall data, site 04717 Coolangatta.

Statistic	1982-2018 -data gap 1/1993-6/94 (35 yrs)	1994-2019 (25 yrs)
Total days data	12,869	9,171
Average dry days between rain	4.79	4.80
Days of rainfall >1mm	3469 (27.1%)	2436 (18.9%)
Average rainfall (on a rainday (>0.2)	11.56 mm	11.46 mm
Average rainfall when >1mm per rainday,	14.6 mm	14.7 mm
Average rainday duration >1mm	2.29 days	2.28 days
Max days without any rain	54 (2012)	54 (2012)

3.2 Increase in flow to wetland from development

Frequent events (more frequent than the 50% AEP) have been shown by the MUSIC modelling to increase the annual flow volume to the wetland by approximately 50%. For the high flow events of 20% AEP and 1% AEP, the proposed bio-retention basins by RBG have been shown to reduce peak flow to below the existing level for the site overall.

The basin outlets are designed with scour protection (from the RBG SWMP), however a detailed design was not yet available. The outlet channel is straight forward to design to reduce scour potential, particularly where the outflow channel connects to the wetland.

As an example, using Manning's formula, for a peak 1% AEP discharge of 1.61 m^3/s from Basin A, assuming a maximum channel depth of 0.3m, slope of 1% and maximum velocity of 1m/s, the flow could be accommodated with a 5m wide base width, 1:4H side slope, rock channel (n=0.045).

The channel from the basin to the outlet point could be made narrower and deeper, with flow slowed down and spread out where it discharges to the wetland. The other basins have smaller outflows and would require smaller channels as a result. The channels could also be designed for additional infiltration as discussed in the groundwater, Section 3.4. RBG confirmed that the infiltration trenches are not feasible doe to geotechnical risks.

3.3 Comparison of pre and post development flows to wetland

A comparison of flow discharge from the developed bio-retention basins was undertaken in the DRAINS model review (Section 2.3) with hydrographs provided in Appendix A.

It was shown that for the more frequent events the developed flow and volumes exceeded the existing case.

Determining the impact on the coastal wetland is made difficult by the very flat nature of the area and the disconnected low flow points.

The coastal wetland is flooded on a regular basis from the Tweed River (BMT, 2018) with a 5% AEP flood depth of approximately 2m (correlating to RL 2.5-3.0 m AHD) and 1% AEP flood depth of approximately 3.0 m

Outflow from the 4EY and 1EY events from the development site, although higher than the existing flows, effectively only fill some of the localised depressions. This is shown in the later dam filling assessment, Section 4.

Table 10: Approximate flood levels in the wetland for frequent events.

Minor flood Event (development site only)	Estimated Water level m AHD
Existing dam water level (at time of RBG survey)	0.27
Surrounding ground level	0.6-0.8
4EY (avge 4 exceedances per year)	0.6
1EY (avge 1 exceedance per year)	0.7
20% AEP	0.75

The results from the table indicate that outflow from the development site has minimal impact on coastal wetland levels, and effectively only fills the local depressions. The assessment only considers the impact from the development site, as a worst case or conservative assessment.

It should be recognised that if a rain event occurs on the development site then it will also very likely occur on the wetland and therefore the rise in water level could actually be much more significant. There are no initial or continuing rainfall losses when rainfall occurs directly onto a water surface, and therefore the water level increase to the wetland may be higher than due to discharge from the development.

It is noted that the frequency of minor runoff events into the wetland may increase significantly due to the development, however the change in wetland flood level is expected to be less than 50mm from these events, and return to normal level within a day or so, if connectivity between wetland depressions and the natural outlet remain.

3.4 Groundwater

Geotechnical assessment by Wood and Grieve (W&G, 2018), indicates the site material to be Silty Clay overlaying basalt at depth. At the lower end of site permeability percolation tests (Bore Hole 22 and 23) were undertaken to depths of 0.5m within the proposed bio-retention area.

The results are shown in Table 11 and indicate high permeability values. The testing shows than rainfall readily infiltrates into the ground in the lower elevations of the site.

Table 11: Permeability values (taken from W&G, 2018)

Test number	Borehole 22 (Permeability (mm/hr)	Borehole 23 (Permeability (mm/hr)
Test 1	670.3	203.5
Test 2	83.5	60.9
Test 3	149.0	77.6
Average of Test 2 and 3	116.3	69.3

The result for Test 1 appears very high and may be a result of other issues. Therefore, to be conservative the lowest average permeability of 69 mm/hr was used for testing in the MUSIC model to assess the impact of infiltration. MUSIC model representative infiltration rates for medium clay are 0.36-3.6mm/hr, or up to 36mm/hr for sandy clay.

The W&G geotechnical report indicated that seepage may occur at the natural soil/weathered rock interface, especially following rain events, and that the groundwater level is dependent on rainfall, subsurface material and permeability of the ground, and proximity and type of vegetation.

Given the slope of the site is perpendicular to, and direct connected to the wetland, it is expected that any infiltration on site in pre and post development conditions would be a source of groundwater inflow to the wetland.

According to the report (Morrison Geotech – Clarification on General Drainage Comments – Tweed Valley Hospital – Cudgen Road, Kingscliff), the groundwater in the existing condition is connected to the wetland and therefore adding infiltration provides limited practical benefit.

RBG confirmed that the other SMEC recommendation for use of infiltration treatment devices such as infiltration trenches, swales, rain gardens and permeable pavements etc could not be implemented due slope slip failure on the steep batters around the site due to waterlogged subsoil. Because of the geotechnical risks, infiltration devices will not be feasible.

Also, the recommendation to remove the basin liner will not be feasible due to the same geotechnical risks mentioned above.

Therefore, the MUSIC model is run with the basins lined and water recycling via 400KL rainwater tank (from RBG). Refer Table 12 for the flow volumes.

Table 12: Flow Volumes (including rainwater tank)

Infiltration option tested (using 2003-2017 data)	Pre-development flow volume ML/yr average	Post Development flow volume ML/yr average
Current stormwater model with the four basins lined and water recycling via 400KL rainwater tank	71.2	105

3.4.1 Recommendation

The use of infiltration treatment devices such as infiltration trenches, swales, rain gardens and permeable pavements etc could not be implemented. The stormwater volumes entering the basin will not be further reduced than the volumes mentioned in Table 12. The existing, long established, coastal wetland area has proved resilient throughout

numerous inundation event well in excess of anything likely to result from the inflows from the proposed development. Therefore, it is unlikely to result in any significant structural change to the coastal wetland (dominant floristics of this community) due to monthly flows (Average 3.4ML) or 4 month drying period (<2mL/month) based on both the existing and developed scenario in 10 of the 18 years modelled (Refer Appendix B for more detail).

4 Dam filling options

4.1 Methodology

A TUFLOW hydrodynamic model was built for the purposes of assessing the flood level and flow impacts of the proposed dam infilling. The outlet flow from each of the four basins was extracted from the DRAINS model and utilised as inflows in the TUFLOW model. The TUFLOW model DEM was on a 2 metre grid resolution based off the provided survey and sourced LiDAR data. To model the dam infill an elevation of 0.3 mAHD was assumed for the surface level of the dam.

A rain on grid model of the existing case was modelled to determine flow paths surrounding the wetland and the dam. It was determined that very minor flows from the wetland reach the dam and therefore only the proposed development basin outflows were considered for this assessment.

4.2 Option 1: Impact of filling the dam to match surrounding ground level

The dam filling option has been assessed based on the Basin outflow for the two extremes of discharge, being the 1% AEP and 4EY events.

Figure 3 and 4 below show the difference in peak flood levels for the 4EY and 1% AEP event respectively. The grey shading indicates an impact of less than 10mm.

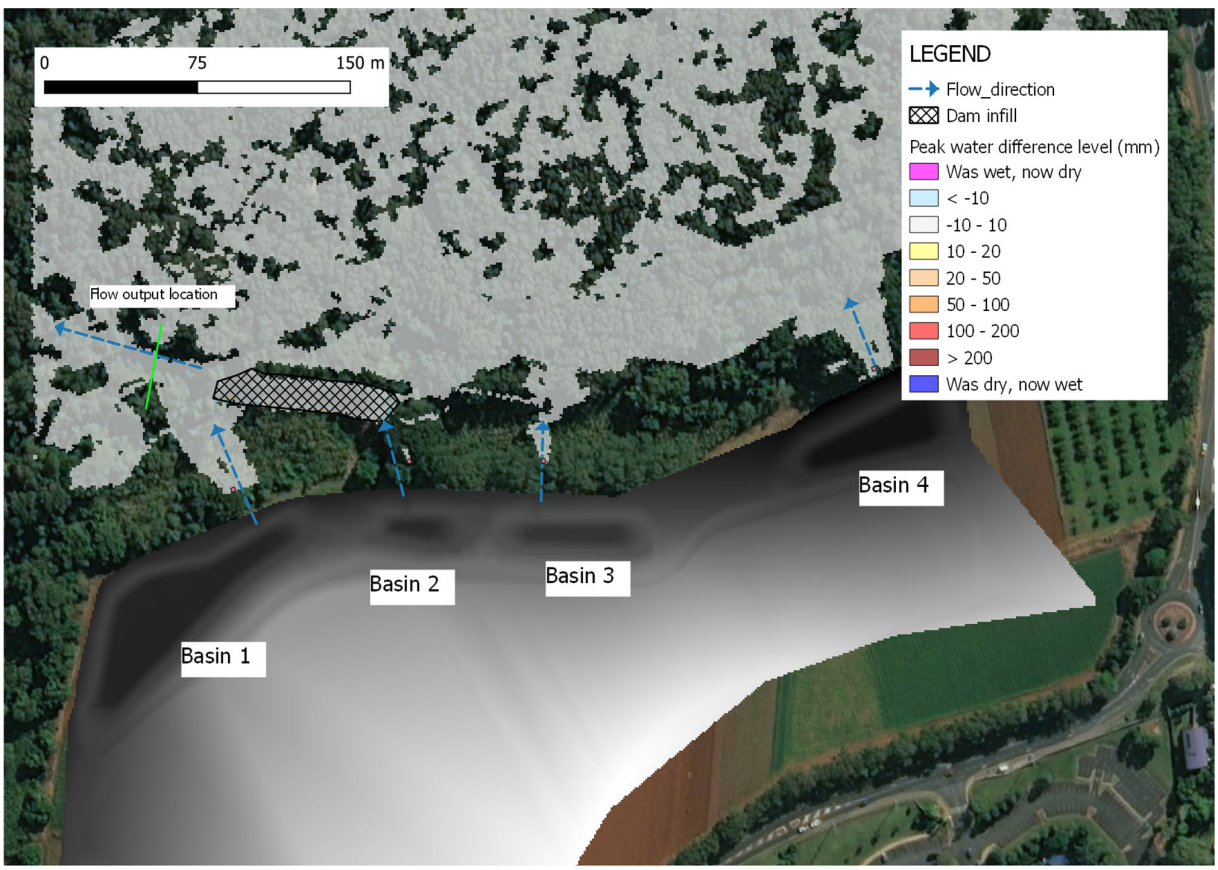

Figure 3: 1% AEP Peak flood level impact map

The impacts from in the infilling are larger for the 4EY event where the loss of storage is more significant relative to the storm volume. For the 4EY event the flood levels increase approximately 50 mm at the outlet of the dam. It is noted there is no increase in inundation extent from the dam infilling for any design event.

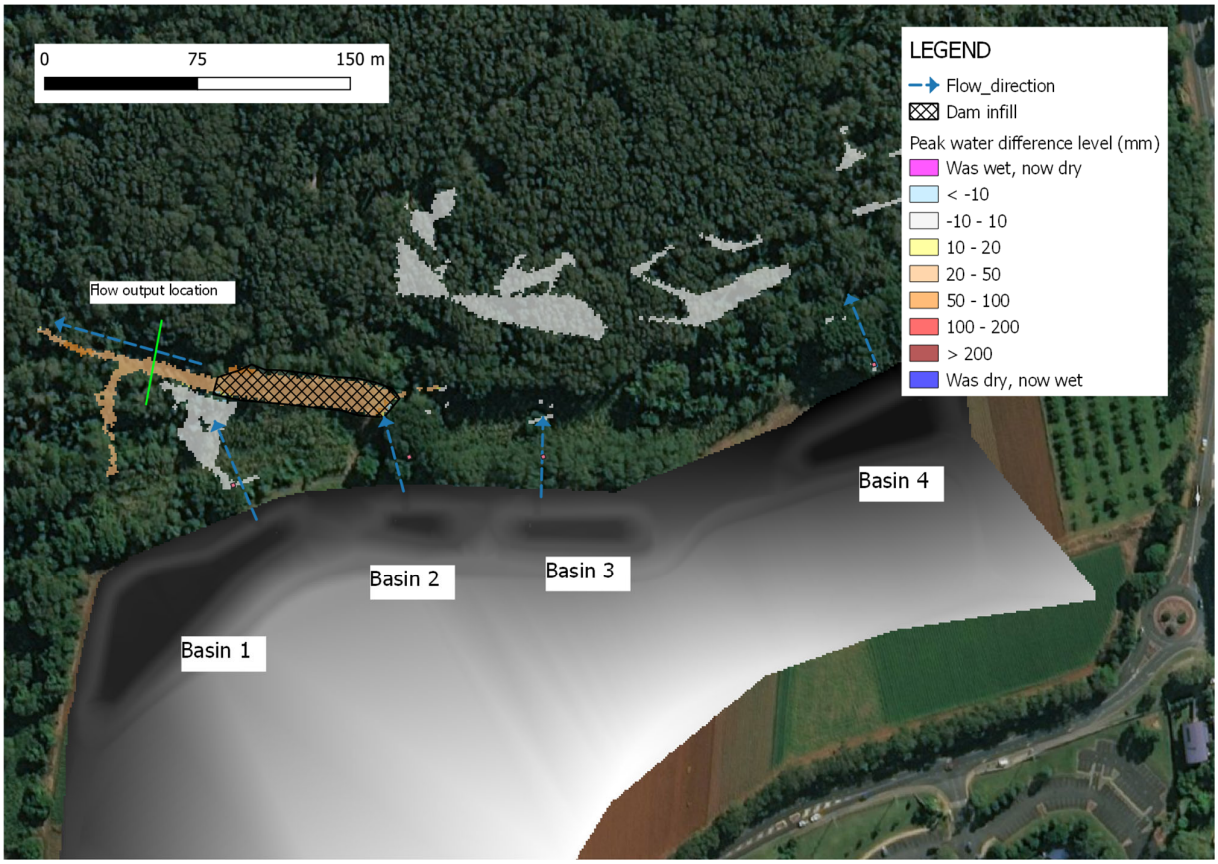

Figure 4: 4EY Peak flood level impact map

Figure-5 below shows the hydrograph plots for the outlet of the dam for the respective scenarios in the 1% AEP event. The loss of storage is seen early in the hydrograph although at the peak of the storm the loss of storage volume of the dam is negligible with peak discharges similar.

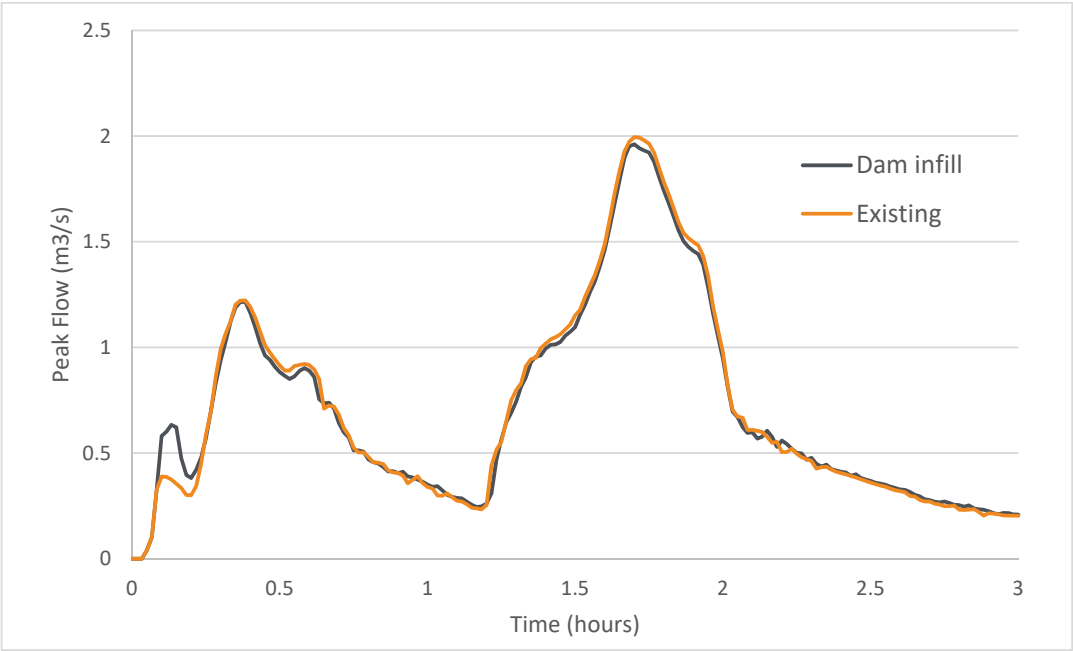

Figure 5: 1% AEP dam outflow hydrograph

Figure 6 below shows hydrograph plots for the outlet of the dam for the respective scenarios in the 4EY event. The peak flow is only 0.125 m3/s, and when compared to the volume of the wetland with an area of 30.7ha is almost negligible.

The change in flows and volume has not resulted in any increased inundation extent and from a flooding perspective is considered to have no impact on the 1% and 20% AEP flood levels, and no material impact from more frequent events from a hydrology perspective. Ecological impact should be assessed for the frequent events

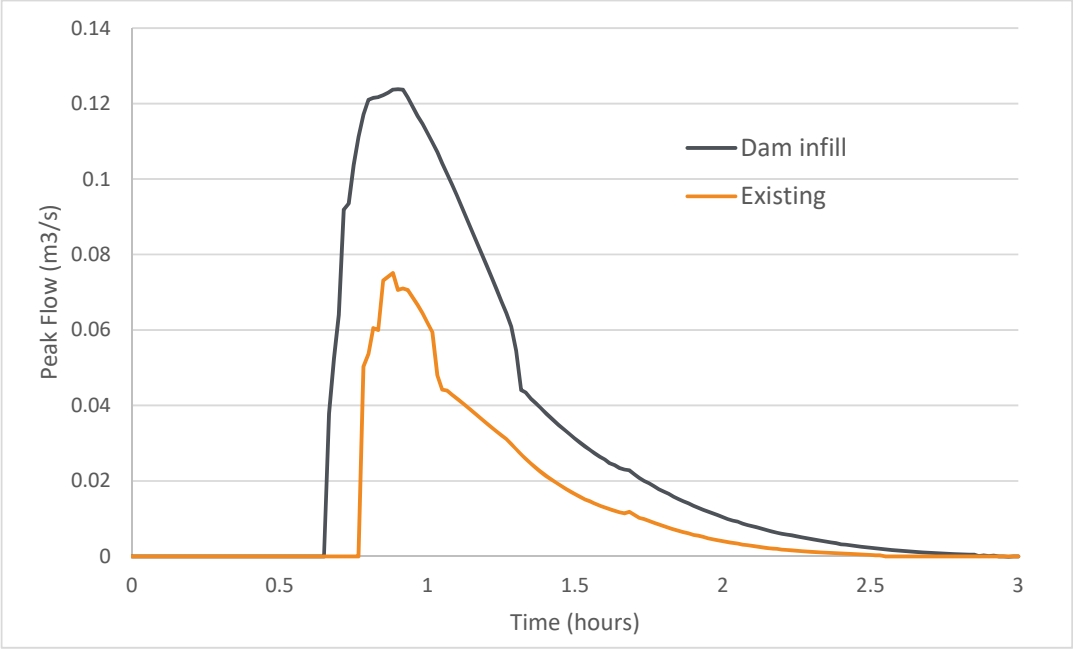

Figure 6: 4EY dam outflow hydrograph

4.3 Option 2: Impact of filling the dam with low flow channel

Although the dam filling has no impact from a flood perspective, it would be considered prudent to provide some form of low flow channel or path to allow low flows to drain, minimising isolated pools and soft spots that could affect maintenance access to the area for removal of Salvinia.

5 Ecological Values associated with the Coastal Wetland

Previous ecological assessment of the site (Greencap, 2019) identified a number of threatened species and ecological communities within and adjacent to the 36ha of mapped coastal wetland area.

These include:

- Swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions EEC;
- Lowland rainforest on floodplain in the NSW North Coast Bioregion EEC;
- Mitchell's rainforest snail *Thersites mitchellae* specimens were detected during BDAR threatened species surveys, however, all of these were recorded outside the Project Site boundary in the northern portion of former Lot 102 DP 870722 (Greencap 2019); and
- Two pH dependent amphibians were identified by the BAM Calculator as candidate threatened species – Wallum froglet *Crinia tinnula* and Olongburra frog *Litoria olongburensis.* There are records for these species within the 1,500 m assessment area and within the receiving catchment (Greencap, 2019).

As noted earlier in the report current modelling predicts a mean total annual flow from site to increase by almost 50% from pre-development (90.6 ML/yr) to post development (140 ML/yr), although previous discussion considers mitigation of these flow volumes.

5.1 Impacts on vegetation communities

5.1.1 Swamp sclerophyll forest on coastal floodplains

The composition of this community is primarily determined by the frequency and duration of waterlogging and the texture, salinity nutrient and moisture content of the soil, and latitude. The composition and structure of the understorey is influenced by grazing and fire history, changes to hydrology and soil salinity and other disturbance, and may have a substantial component of exotic grasses, vines and forbs (NSW OEH, 2019).

The vegetation within the mapped extent of the coastal wetland has previously been identified as predominately being Broad-leaved Paperbark (*Melaleuca quinquenervia*) Closed Forest to Woodland (TSC LGA Mapping, 2012). While Broad leaved paperbark cannot survive permanent inundation, they do have adaptations such as fibrous or adventitious roots around their lower trunk that are thought to function as breathing roots, helping the tree to survive during long periods of submersion (McJannet, 2008). Similarly the composition and diversity of the mid and understorey will vary with latitude and the length of time the swamp contains water, but can typically include shrubs such as quinine berry *Petalostigma pubescens*, and *Banksia sp.* on the margins; sedges such as soft twigrush *Baumea rubiginosa*, *Lepironia articulata* and bogrush *Schoenos breviofolius*; saw-sedges such as *Gahnia sieberiana*; reeds such as the common reed *Phragmites australis*; other grasses such as *Ischaemum spp*., swamp rice grass *Leersia hexandra*, blady grass *Imperata cylindrica* and saltwater couch *Sporobolus virginicus (DERM, 2010).*

Modelling of the additional inflows of water to the wetland have been undertaken on a monthly basis across 18 years of available rainfall data. The developed scenario showed a maximum monthly increase of 10.9mL, a minimum of 0mL and an average across the 177months of data modelled of 3.4mL/month. The result of the modelling and monthly distribution of the surface flows is illustrated in Appendix B. The higher increases generally followed the seasonal weather patterns associated with Northern NSW, with higher rainfall levels across the summer and early Autumn months leading to a drier winter and spring period. This was however, highly variable across the study period with outlying higher-level flow events occurring in the winter/spring period (eg June 2005 and June 2016) and very dry periods leading to low or no flows (late Spring Summer 2003/2004 and 2013/14). The Coastal Wetland adjacent to the hospital site is largely ephemeral in nature due to this variability, with some slightly elevated area likely to be dryer in nature.

McManus (et.al, 2007), has proposed an indicative hydrologic variable matrix for wetlands of this nature. A summary of the matrix is included as Table 13.

Table 13 -Wetland Category and hydrologic variable matrix.

Wetland category	Inundation Water (Typical)	Inundation Regularity	Inundation Depth	Duration of Drying	Frequency of Drying /Exposure (Once/unit)
Forest Swamp – Ephemeral	Freshwater	Medium	0 – 1+	4 – 8 months	annually

A key variable of this Matrix is the "Duration of drying". Defined by McManus (et al, 2007) as, "*an estimate of the period of time during any one "drying episode" the wetland sediments are exposed. The duration of drying may be short (hours) and highly regular (tidal coastal flats) or long (many years) and highly irregular (arid inland flats)*."

McManus (et al, 2007) notes the importance of this factor to soils stating that, "*for drying periods greater than a month some aeration of the sediments can be expected. Aeration of the sediments is an important factor in reducing the stress on plants growing in anoxic environments like flooded sediments."*

Using the above as guide it can be assumed that a drying duration of between 4-8 months of the year can be considered representative of a typical hydrologic regime for this vegetation community. Based on the modelled monthly inflow data the Coastal Wetland would have received a minimum 4 month drying period (<2mL/month) based on both the existing and developed scenario in 10 of the 18 years modelled (NB Data was limited for 2018). In the other years, under both scenarios, this length of drying duration was not met. This is not unexpected and as McManus (et al, 2007) observed with regard to the frequency of drying, "*This term is an estimate of how frequently the sediments of particular wetland categories experience a drying episode. The wetting and drying sequence can be a highly variable feature of a wetland."* This consistent with the modelled data which showed that the monthly data, while broadly aligned to the seasonal weather patterns, still showed a high degree of variability, with years such as 2012 having a drying period under both development scenarios which extended over 8-9 months. Based on the available data it appears unlikely the hydrologic cycle of the wetland will be changed significantly enough by the developed scenario to move away from the critical drying cycle times identified above.

The proposed installation of the treatment basins will lead to some localised concentration of flows to the wetland from the basin outlets. The distribution of flows at the discharge points is limited to the assumed flow paths which can be derived from the existing LIDAR survey data. Some potential for inundation in areas of micro relief is possible but any impacts are likely to be localised and, given the high degree of variability in the seasonal inflows to the wetland area, and the overall size of the catchment (the hospital site only represents approx. 2% of the wetlands catchment area, see Appendix B) significant measurable impacts are unlikely.

It is noted that flooding from Tweed River (BMT, 2018) indicates inundation depths for the wetland of approximately 2m for the 5% AEP event and 3m for the 1% AEP event. This suggests that the existing, long established, coastal wetland area has proved resilient throughout numerous inundation events well in excess of anything likely to result from the inflows from the proposed development. Given these factors, the addition of a monthly average of 3.4 mL of additional inflow from the developed site, is unlikely to result in any significant structural change to the dominant floristics of this community.

5.1.2 Lowland rainforest on floodplain

The occurrence of this community appears to be limited to the slightly elevated margins of the Broad-leafed paperbark community and is probably closely linked to the localised limits of the volcanically derived soils in the area. Given its occurrence in these slightly elevated locations it is considered unlikely to be materially impacted by the additional inflows expected and, given the seasonality of rainfall in the region, may in fact benefit from additional inflows during the drier winter period.

5.2 Impacts on Fauna Species

5.2.1 Mitchells Rainforest Snail *(Thersites mitchellae)*

Mitchell's Rainforest Snail is restricted to lowland subtropical rainforest and swamp sclerophyll forest with a rainforest understorey, typically on alluvial soils with a basaltic influence. It is apparently absent from other rainforest types in the area, such as littoral rainforest (Stanisic 1998). This type of correlation with particular rainforest communities is common in many land snail species in eastern Australia (Stanisic 1994). The limited research available suggests the

species is dependent on high moisture levels, low fire frequency, and a well-developed leaf litter layer. With consideration of those habitat preferences it seems unlikely that a minor increase in inflow levels will negatively impact the development or maintenance of existing habitat.

There may be potential positive impacts for this species associated with the reduction in sediments coming from the hospital site as the landuse is transferred from agricultural/horticultural use with exposed soils, to the proposed end use where all pervious areas are vegetated, and stormwater treated.

5.2.2 Wallum froglet *Crinia tinnula* and Olongburra frog *Litoria olongburensis*

Records of these two species exist within the 1,500 m assessment area and within the receiving catchment (Greencap, 2019). Survey was not undertaken to detect these species for the BDAR, as the directly impacted windrow vegetation was considered too degraded and/or did not represent suitable habitat for these species (Greencap, 2019).

Both species of frogs are more commonly associated with coastal sandplain swamps than with the Broad-leaved paperbark which is predominate in the mapped extent of the coastal wetland area. Wallum froglet has been recorded in swamp sclerophyll forests but is more typically associated with sedgelands and wet heathlands (Anstis, 2013). This habitat preference is also true of the Olongburra frog which has a strong preference for inundated areas characterised by the presence of emergent sedges, with upright species such as *Baumea* spp. and *Schoenus* spp. preferred by adult frogs for perching (Shuker, J.D. and Hero, J. (2012).

Given the uncertainty of the presence of these species in the mapped coastal wetland area and their preference for generally different habitat, including inundated areas with the presence of emergent sedge species, there is no obvious likelihood of a negative impact on these species as a consequence of changed inflows associated with the development.

If the species are present, the reduction in sediment load and residual agricultural chemicals, resulting from the changed land use and improved stormwater management is likely to be beneficial to these species.

6 References

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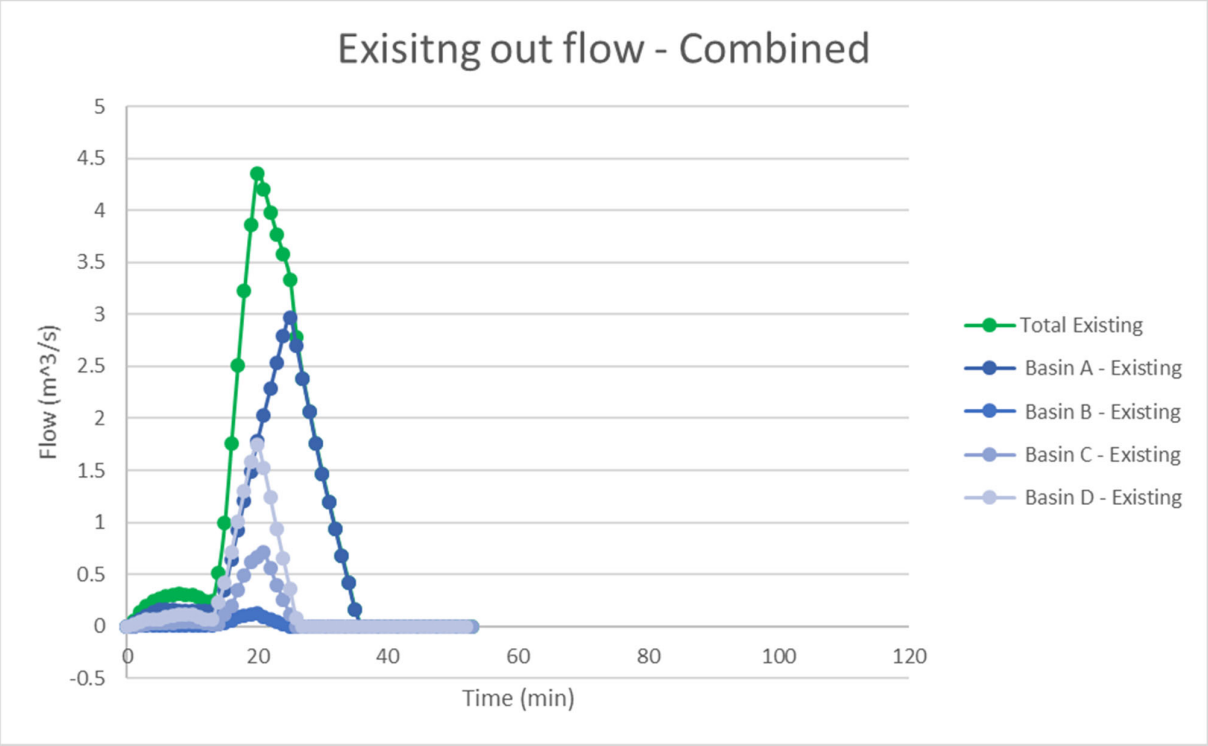
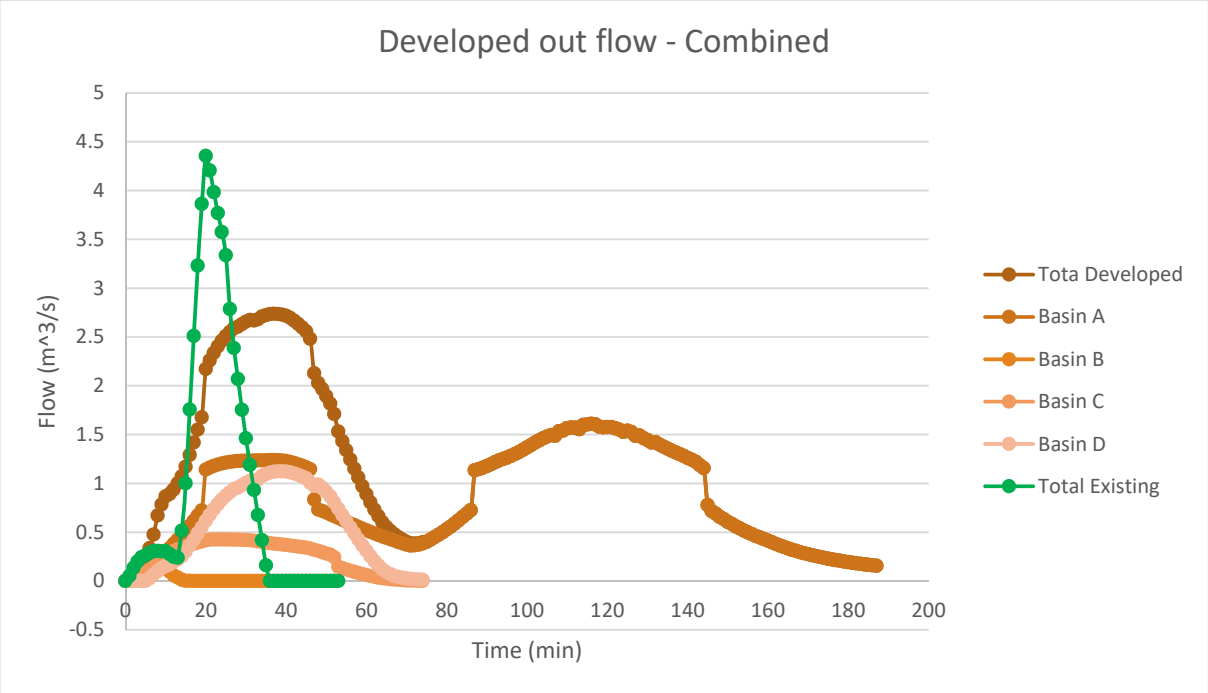
Appendix A DRAINS – Hydrograph outputs

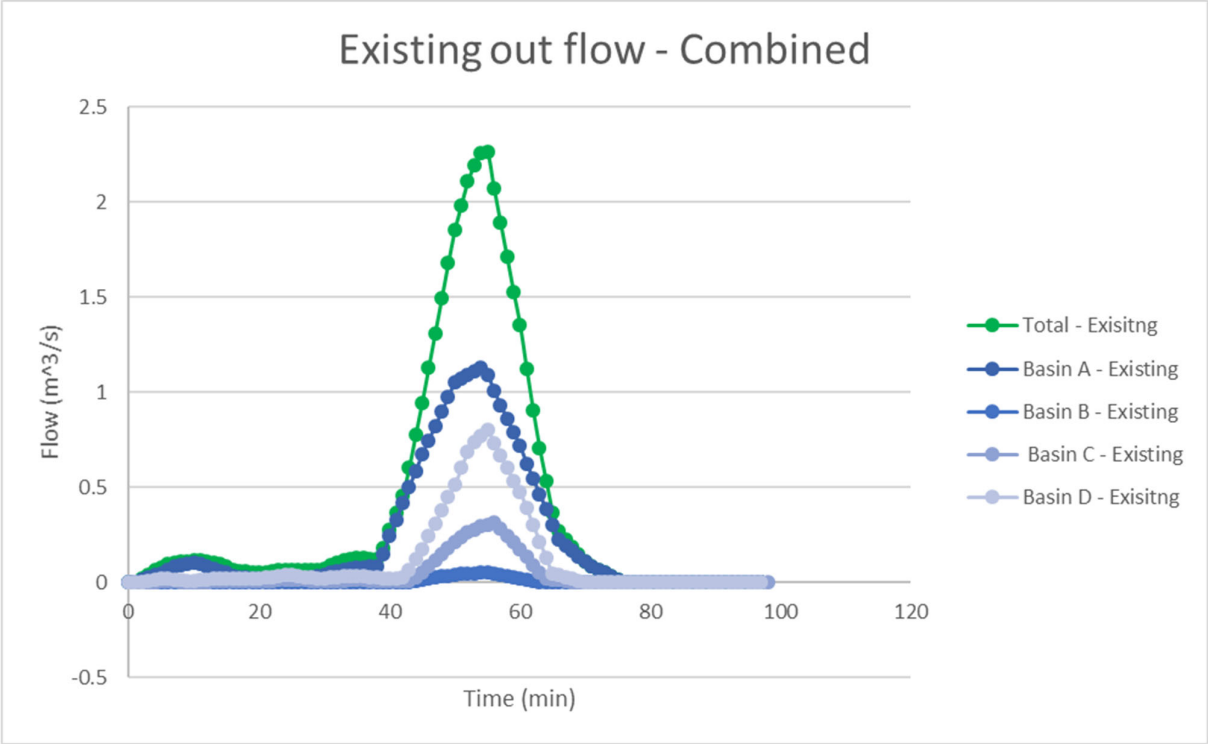
1% AEP – Existing



1% AEP – Developed



20% AEP – Existing



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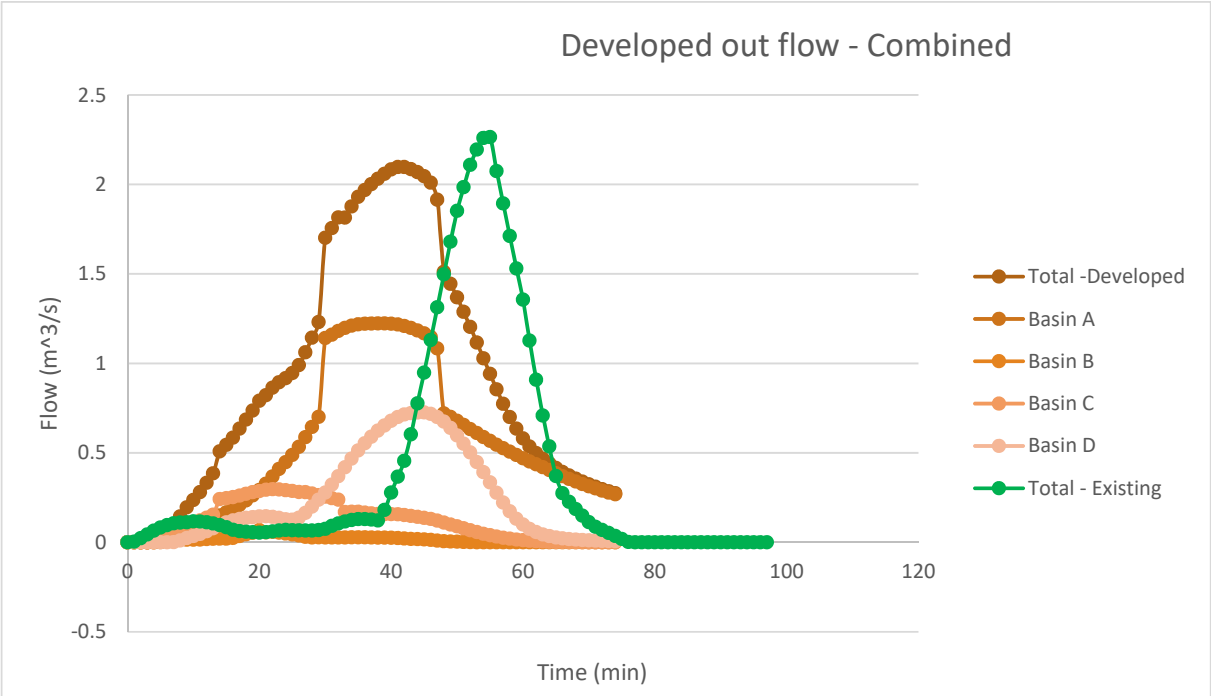
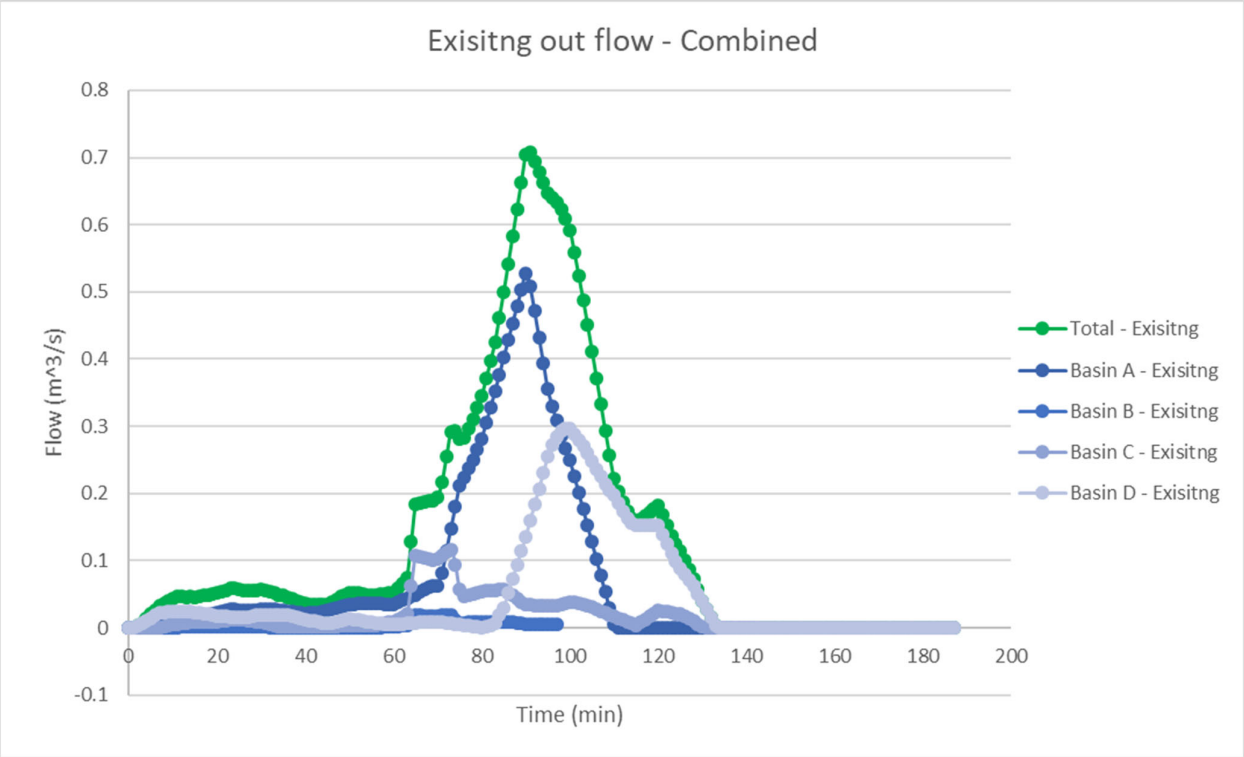
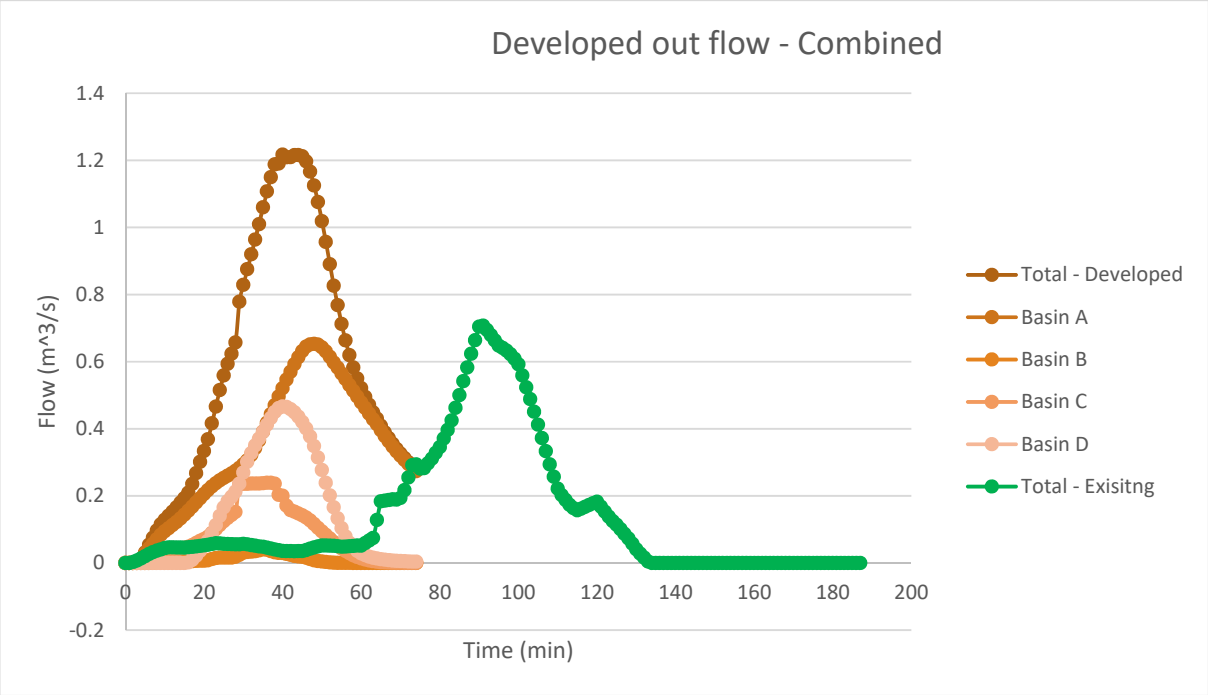


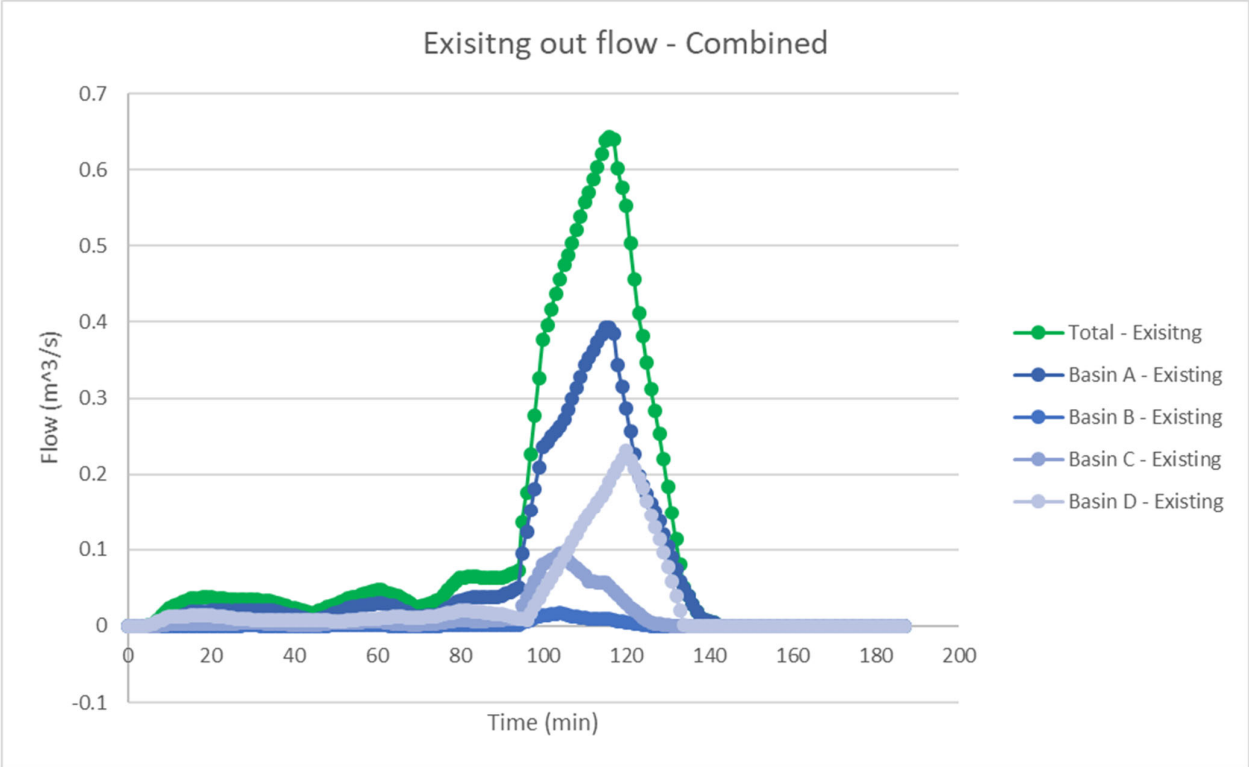
50% AEP – Existing



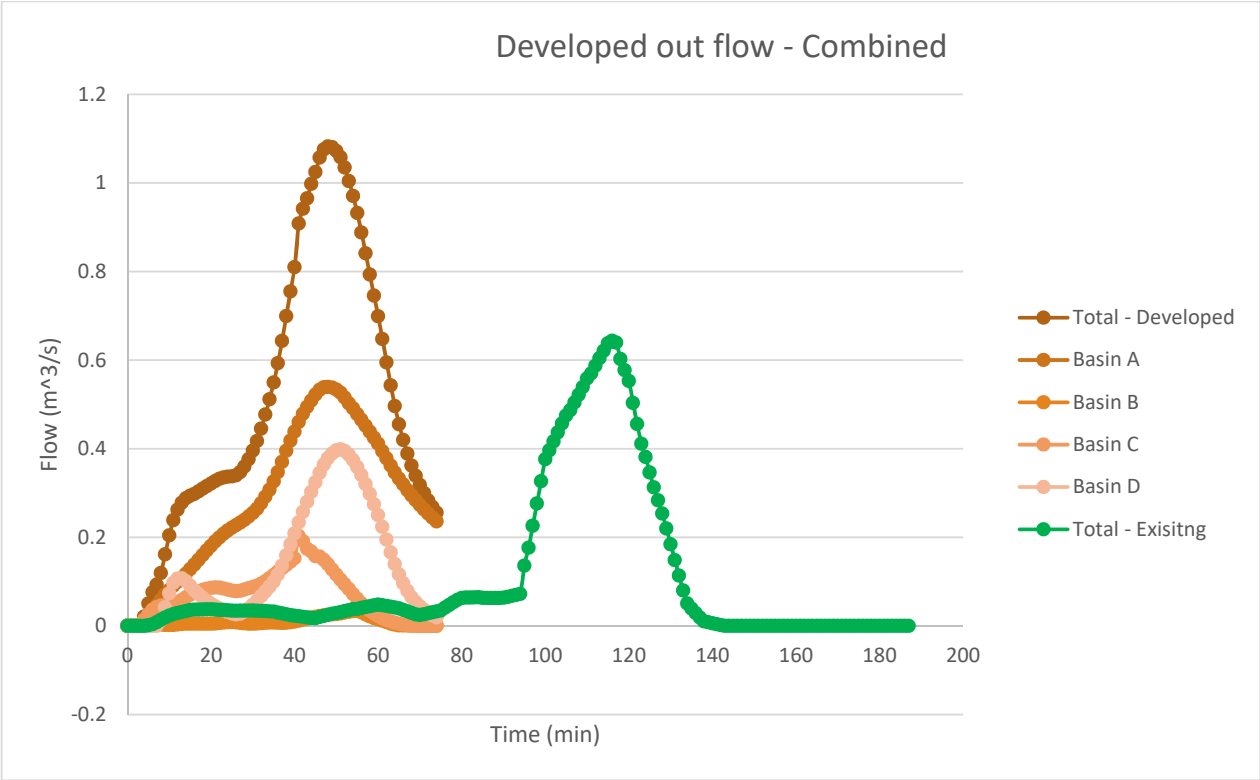
50% AEP – Developed



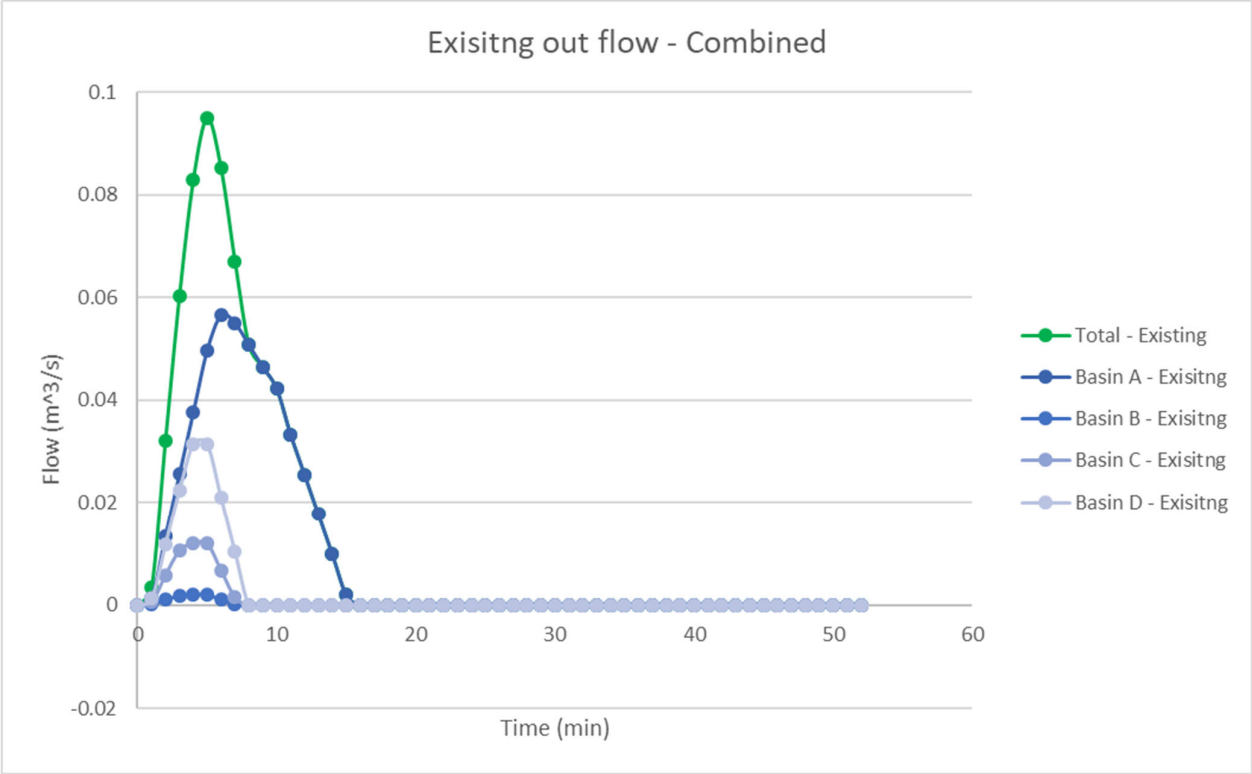
1EY – Existing



1EY – Developed



4EY – Existing



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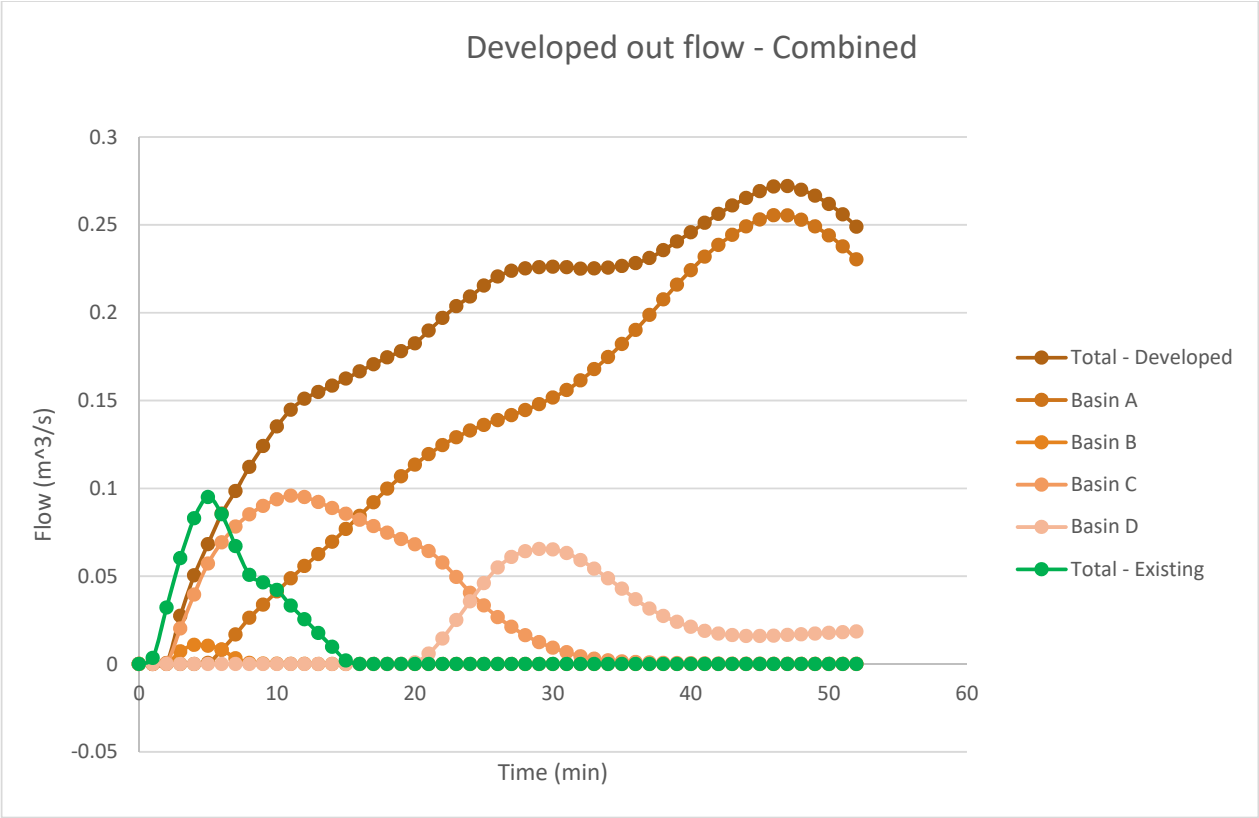
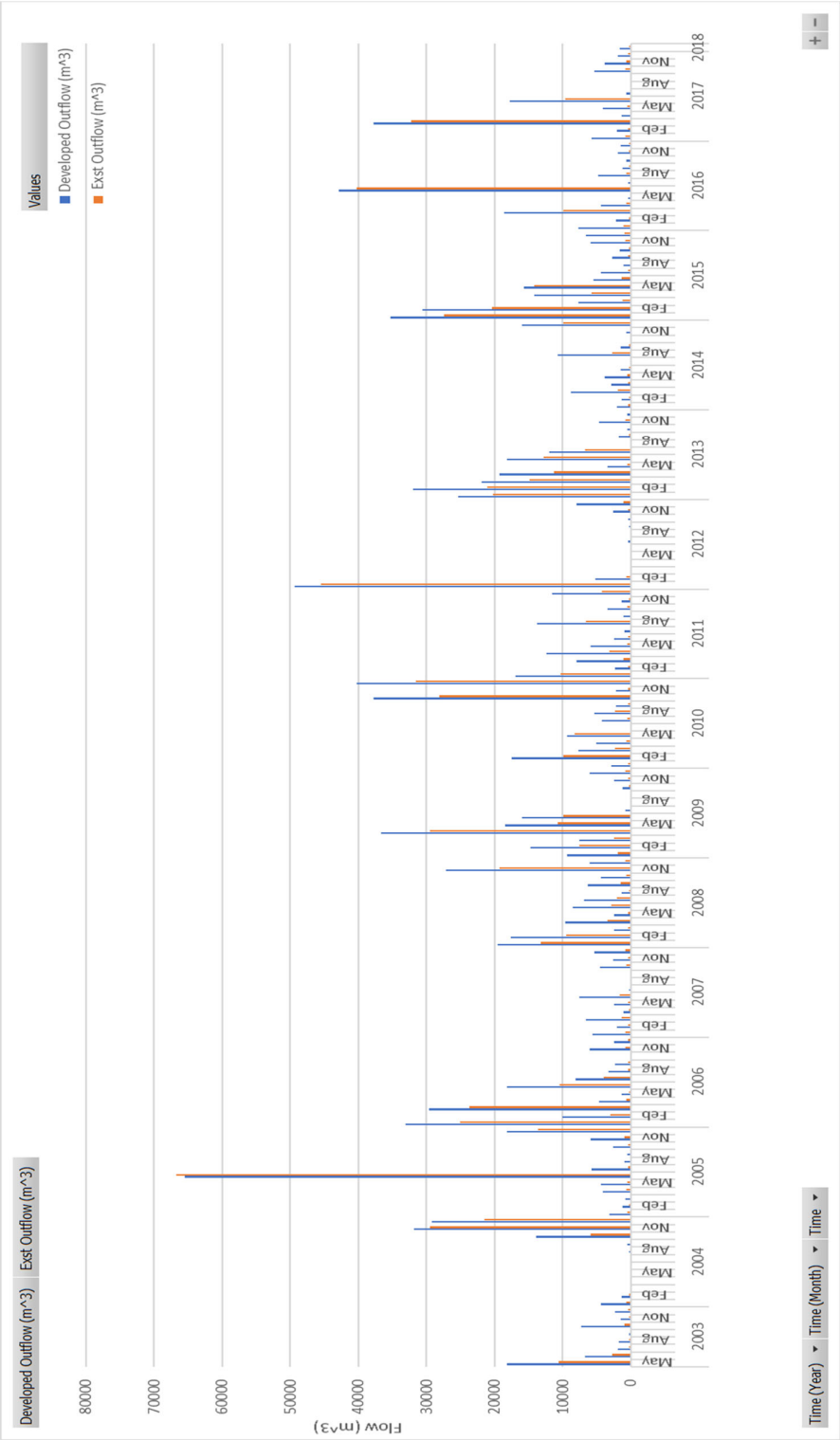


Appendix B Catchment Configuration, Monthly Flow Volume Graph and Data Table

Chart of Existing and Developed scenarios monthly flow volumes getting into wetland from May 2003 to Jan 2018



Summary of monthly flow volumes from May/2003 to Jan/2018

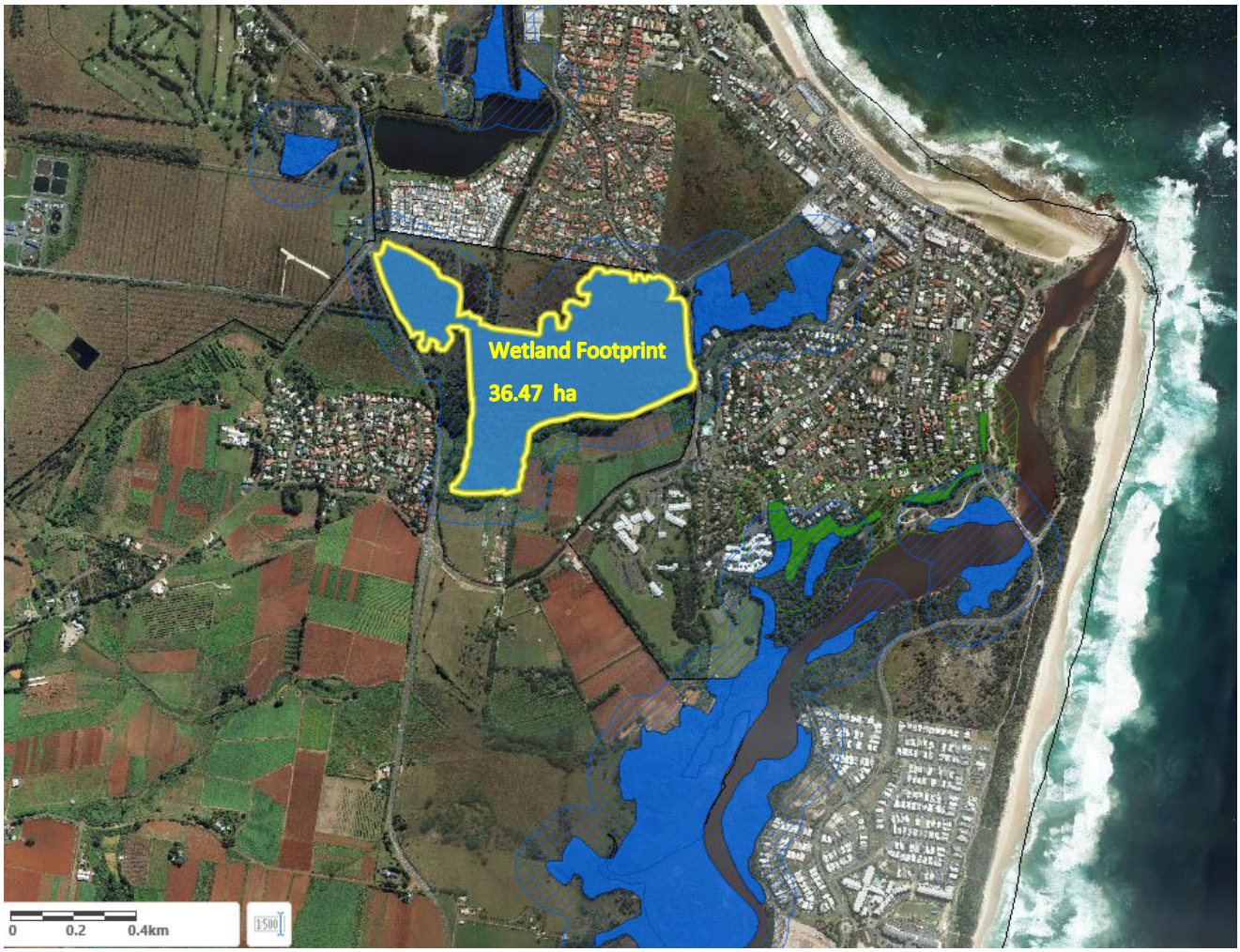
Year	Row Labels	Developed flow (m^3)	Exisitng Flow (m^3)	Increase in Flow (m^3)	Increase in Flow (ML)
2003	May	18100.6	10541.1	7559.5	7.6
	Jun	6751.3	2763.3	3988.0	4.0
	Jul	1916.8	226.4	1690.4	1.7
	Aug	1723.1	260.8	1462.3	1.5
	Sep	156.7	37.0	119.7	0.1
	Oct	7261.4	969.2	6292.2	6.3
	Nov	1478.4	242.6	1235.8	1.2
	Dec	2346.5	393.4	1953.0	2.0
2004	Jan	4311.7	629.2	3682.5	3.7
	Feb	1384.6	237.9	1146.7	1.1
	Mar	0.0	0.0	0.0	0.0
	Apr	0.0	0.0	0.0	0.0
	May	0.0	0.0	0.0	0.0
	Jun	0.0	0.0	0.0	0.0
	Jul	150.6	46.1	104.5	0.1
	Aug	206.3	55.3	151.0	0.2
	Sep	440.2	69.5	370.8	0.4
	Oct	13869.4	5947.3	7922.1	7.9
	Nov	31757.8	29420.7	2337.1	2.3
	Dec	29129.4	21410.8	7718.6	7.7
2005	Jan	3145.8	464.9	2680.9	2.7
	Feb	1232.2	228.1	1004.1	1.0
	Mar	773.3	142.8	630.5	0.6
	Apr	4054.1	628.0	3426.2	3.4
	May	4369.4	530.2	3839.1	3.8
	Jun	65520.2	66709.7	-1189.5	0.0
	Jul	5793.8	379.4	5414.4	5.4
	Aug	962.6	150.5	812.1	0.8
	Sep	541.9	106.7	435.3	0.4
	Oct	2555.3	412.6	2142.7	2.1
	Nov	5839.8	871.0	4968.8	5.0
	Dec	18124.0	13564.5	4559.5	4.6
2006	Jan	33109.6	25031.7	8077.9	8.1
	Feb	10036.4	3029.3	7007.0	7.0
	Mar	29646.6	23674.5	5972.2	6.0
	Apr	4588.2	624.1	3964.1	4.0
	May	1337.5	208.4	1129.1	1.1
	Jun	18145.3	10488.7	7656.6	7.7
	Jul	8109.0	3923.4	4185.6	4.2
	Aug	3301.9	388.1	2913.8	2.9

	Sep	2346.6	334.0	2012.6	2.0
	Oct	0.4	8.7	-8.3	0.0
	Nov	5998.8	787.3	5211.5	5.2
	Dec	2397.0	387.7	2009.4	2.0
	Jan	5626.0	778.1	4847.9	4.8
	Feb	2054.2	343.4	1710.8	1.7
	Mar	6512.6	1392.9	5119.7	5.1
	Apr	996.5	177.5	819.0	0.8
	May	2421.5	378.3	2043.2	2.0
2007	Jun	7547.4	1663.8	5883.6	5.9
	Jul	248.1	0.0	248.1	0.2
	Aug	0.0	0.0	0.0	0.0
	Sep	0.0	0.0	0.0	0.0
	Oct	4453.8	665.1	3788.7	3.8
	Nov	2570.7	411.5	2159.2	2.2
	Dec	5299.8	824.9	4474.9	4.5
	Jan	19595.0	13190.7	6404.3	6.4
	Feb	17656.4	9512.5	8143.9	8.1
	Mar	2444.9	393.2	2051.7	2.1
	Apr	9579.2	3361.0	6218.3	6.2
	May	2436.3	364.9	2071.4	2.1
2008	Jun	8503.9	2891.2	5612.7	5.6
	Jul	6794.8	2000.4	4794.4	4.8
	Aug	1292.9	195.2	1097.7	1.1
	Sep	6247.6	1505.6	4742.1	4.7
	Oct	4338.2	620.2	3718.0	3.7
	Nov	27063.7	19250.5	7813.2	7.8
	Dec	6000.3	785.9	5214.4	5.2
	Jan	9276.6	1876.5	7400.1	7.4
	Feb	14651.1	7565.7	7085.4	7.1
	Mar	7551.0	2438.5	5112.5	5.1
	Apr	36668.7	29419.7	7249.0	7.2
	May	18489.1	10654.8	7834.3	7.8
2009	Jun	15977.2	9856.8	6120.5	6.1
	Jul	745.9	65.6	680.3	0.7
	Aug	0.0	3.9	-3.9	0.0
	Sep	125.5	33.4	92.1	0.1
	Oct	1232.0	247.7	984.3	1.0
	Nov	2492.4	347.1	2145.2	2.1
	Dec	6002.7	766.6	5236.1	5.2
	Jan	2849.8	431.7	2418.1	2.4
	Feb	17529.1	9897.0	7632.1	7.6
2010	Mar	7706.0	2234.4	5471.6	5.5
	Apr	5090.5	689.4	4401.1	4.4
	May	9373.7	8194.9	1178.7	1.2
	Jun	0.0	0.0	0.0	0.0

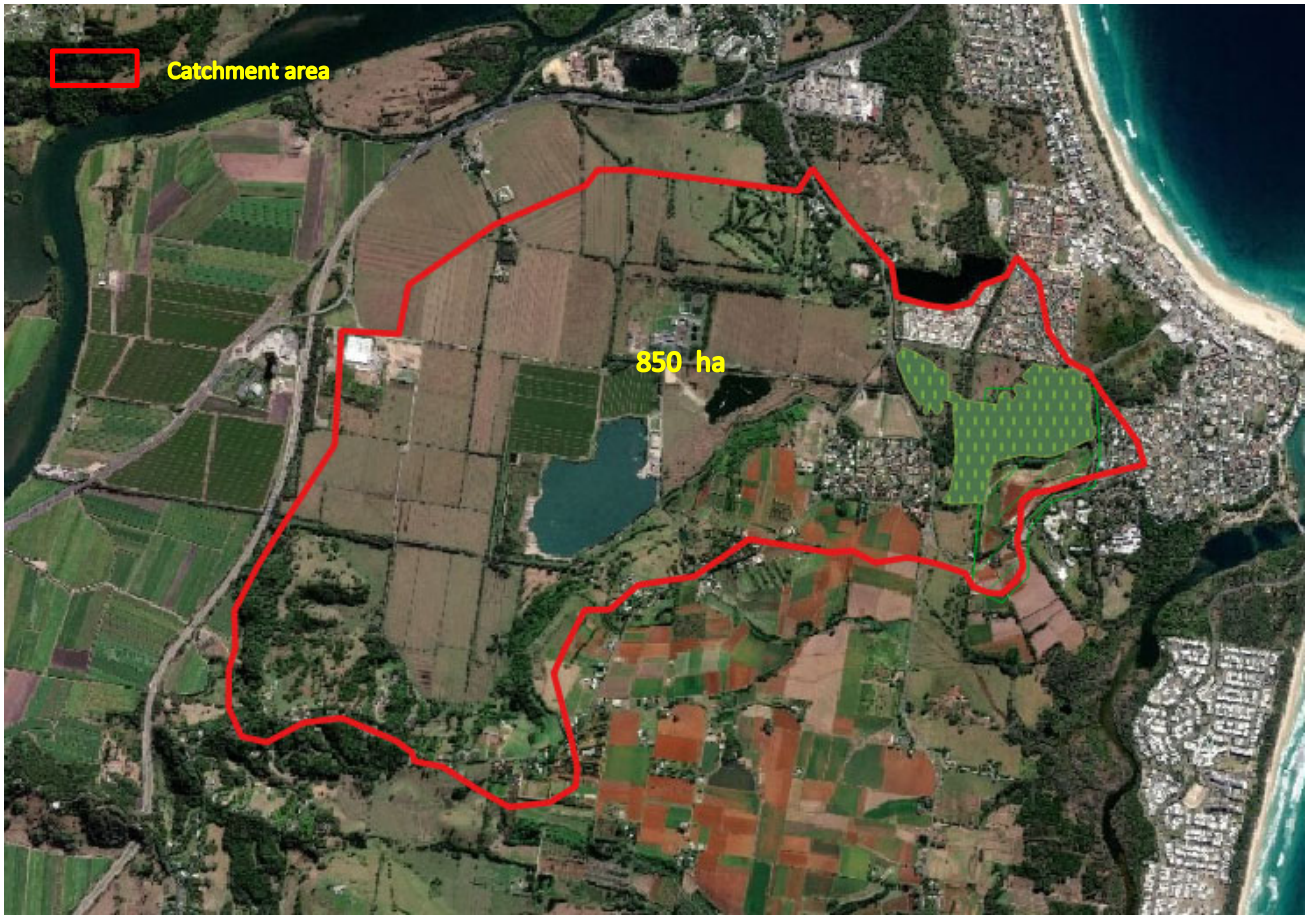
	Jul	4274.3	540.0	3734.3	3.7
	Aug	5277.3	2307.3	2970.0	3.0
	Sep	2195.6	357.7	1837.9	1.8
	Oct	37766.5	28150.7	9615.8	9.6
	Nov	2207.8	362.6	1845.2	1.8
	Dec	40277.6	31507.0	8770.6	8.8
	Jan	16966.2	10239.2	6727.0	6.7
	Feb	2357.5	385.4	1972.1	2.0
	Mar	7941.8	1110.3	6831.4	6.8
	Apr	12404.4	3159.8	9244.7	9.2
	May	5823.0	510.7	5312.3	5.3
2011	Jun	2464.8	307.9	2156.9	2.2
	Jul	917.7	141.3	776.4	0.8
	Aug	13759.3	6556.2	7203.1	7.2
	Sep	1070.3	29.5	1040.8	1.0
	Oct	3439.6	557.5	2882.1	2.9
	Nov	1307.4	222.7	1084.7	1.1
	Dec	11496.4	4275.6	7220.8	7.2
	Jan	49403.0	45433.2	3969.9	4.0
	Feb	5158.0	702.1	4455.9	4.5
	Mar	0.1	0.0	0.1	0.0
	Apr	0.0	0.0	0.0	0.0
	May	0.0	0.0	0.0	0.0
2012	Jun	0.0	0.0	0.0	0.0
	Jul	338.1	68.2	269.9	0.3
	Aug	112.0	29.5	82.5	0.1
	Sep	171.6	45.0	126.6	0.1
	Oct	386.4	70.8	315.6	0.3
	Nov	2629.3	412.0	2217.4	2.2
	Dec	7962.4	1080.1	6882.3	6.9
	Jan	25339.8	20202.0	5137.8	5.1
	Feb	31986.0	21052.5	10933.5	10.9
	Mar	21840.6	14860.2	6980.4	7.0
	Apr	19237.8	11200.0	8037.8	8.0
	May	3381.5	527.7	2853.8	2.9
2013	Jun	18216.4	12764.5	5451.8	5.5
	Jul	12015.7	6757.4	5258.3	5.3
	Aug	7.8	5.1	2.6	0.0
	Sep	1769.8	255.7	1514.1	1.5
	Oct	461.9	96.4	365.5	0.4
	Nov	4605.2	726.6	3878.6	3.9
	Dec	530.0	91.6	438.4	0.4
	Jan	2013.2	346.2	1667.0	1.7
2014	Feb	1286.3	223.8	1062.5	1.1
	Mar	8754.9	1866.5	6888.4	6.9
	Apr	2910.3	336.6	2573.7	2.6

	May	3825.9	555.9	3270.0	3.3
	Jun	1405.9	222.3	1183.5	1.2
	Jul	102.9	27.0	75.9	0.1
	Aug	10653.7	2729.3	7924.4	7.9
	Sep	1466.7	165.9	1300.8	1.3
	Oct	1.9	16.7	-14.8	0.0
	Nov	607.5	131.1	476.4	0.5
	Dec	15963.6	9836.0	6127.6	6.1
	Jan	35332.0	27427.1	7904.9	7.9
	Feb	30623.6	20320.2	10303.3	10.3
	Mar	7710.0	1236.2	6473.8	6.5
	Apr	14097.8	5808.0	8289.8	8.3
	May	15613.5	14209.8	1403.7	1.4
2015	Jun	5434.5	1299.4	4135.1	4.1
	Jul	4341.9	414.5	3927.4	3.9
	Aug	1082.4	154.2	928.1	0.9
	Sep	2709.9	431.6	2278.3	2.3
	Oct	1625.1	277.8	1347.3	1.3
	Nov	5947.2	812.4	5134.8	5.1
	Dec	6585.4	919.4	5666.0	5.7
	Jan	7678.8	990.5	6688.4	6.7
	Feb	2128.5	292.0	1836.5	1.8
	Mar	18550.8	9943.1	8607.8	8.6
	Apr	4341.2	615.6	3725.6	3.7
	May	344.1	54.0	290.1	0.3
2016	Jun	42812.4	40198.2	2614.2	2.6
	Jul	400.8	57.9	342.9	0.3
	Aug	4830.8	670.2	4160.6	4.2
	Sep	1256.4	218.8	1037.7	1.0
	Oct	687.8	132.5	555.4	0.6
	Nov	1925.3	285.6	1639.7	1.6
	Dec	1434.0	257.5	1176.5	1.2
	Jan	5745.0	831.3	4913.6	4.9
	Feb	2012.3	332.8	1679.5	1.7
	Mar	37811.4	32198.6	5612.8	5.6
	Apr	1282.6	128.5	1154.0	1.2
	May	4048.0	563.4	3484.6	3.5
2017	Jun	17723.6	9597.4	8126.2	8.1
	Jul	577.4	87.4	490.0	0.5
	Aug	119.9	30.8	89.1	0.1
	Sep	0.0	0.0	0.0	0.0
	Oct	5263.0	759.4	4503.6	4.5
	Nov	3750.2	608.1	3142.1	3.1
	Dec	1924.9	325.2	1599.7	1.6
2018	Jan	1666.8	239.1	1427.8	1.4

State Environmental Planning Policy (Coastal Management) 2018 – maps NSW Department of Planning and Environment



Approximate catchment upstream of the Wetland based on NSW free 1m Digital Elevation Model data downloaded from Elevation - Foundation Spatial Data



Catchment Details

Wetland Area =36.47 ha (as per SEPP Map 2018)

Contributing upstream catchment to the wetland = approximately 850ha

Assume 75% gets into the wetland = 637.5 ha

Hospital catchment = 12.85ha (2% of total catchment)

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