Expert Witness Statement

Stormwater Management Issues Associated with the Proposed Development of Beveridge NW (PSP) and associated Wallan South PSP

Date: Tuesday 26 April 2022

Report By:

Christopher Mitchell Beardshaw

Principal Engineer

Afflux Consulting Pty Ltd

Emerald, VIC 3178

Qualifications:

BEnvEng (Hons), Monash University, 2002

MEngSci, UNSW, 2006

Graduate Certificate River Health Management, University of Melbourne, 2009

Affiliations:

Member, Institution of Engineers Australia

Immediate Past President, Stormwater Victoria Industry Association

Area of Expertise:

Key areas of expertise relevant to this report are summarised below.

- Assessment of flooding, water quality and waterway protection
- Urban and rural river design and management
- Data collection, processing and analysis
- Application of GIS
- 1 and 2 Dimensional Flood modelling
- Continuous rainfall simulation assessment

Afflux Consulting Pty Ltd

PO Box 457, Emerald VIC 3782

03 9036 2530 info@afflux.com.au afflux.com.au

Statement of Expertise

With my qualifications and experience, I believe that I am well qualified to provide an expert opinion of Stormwater Management issues associated with the site at Beveridge NW.

Report Contributors

Theresa Catherine Fuhrmann

Engineer

Afflux Consulting Pty Ltd

Emerald, VIC 3178

Qualifications:

BEng (Hons), Swinburne University, 2020

BBus, Swinburne University, 2020

Affiliations:

Member, Stormwater Victoria Industry Association

Area of Expertise:

Key areas of expertise relevant to this report are summarised below.

- Experience as Strategies Planner in Catchment Strategies and Services team, Melbourne Water Corporation
- Assessment of flood and stormwater management
- Data collection, processing and analysis
- Application of GIS

Scope of contribution:

Theresa assisted in the preparation of the report, including data review and figure preparation under my instruction and supervision.

Scope of this Statement and associated Report

Afflux Consulting have been engaged by Crystal Group to explore and advise on stormwater management aspects of the possible development of Wallan South PSP. I have been engaged to advise on the related hydrology within the Beveridge NW PSP.

Basis of Statement and Report

This statement and associated report is based on the following information:

- Hanna Swamp Investigation, Wallan South (Afflux, March 2021)
- Wallan South SWMS Extract (Memo) (Afflux, April 2022)
- Stormwater Management Issues Associated with the Proposed Development of Beveridge NW (PSP) and associated Wallan South PSP
- A number of studies associated with the Wallan South and Beveridge NW areas including
  - Wallan-Beveridge Pre-planning Waterways Assessment 2021 (Stage 1 to 4 – Desktop, field, modelling and final assessments), FINAL - August 2021, Alluvium
  - Hanna Swamp Investigation, Alluvium, June 2021
  - Other PSP documents and plans

Key Report Conclusions

I have reviewed the hydrology, hydraulics, and Stormwater management aspects of the land within the Beveridge NW PSP. From this understanding I can make the following points:

- The Beveridge NW reserve areas are uphill from the potential Wallan south drainage features. Any potential reserve's hydraulic connection between Beveridge NW from Wallan South will require major engineering works and a redirection of at least one major creek. This is a substantial engineering exercise and has significant cost, long term maintenance, viability questions, and uncertain achievement of ecological outcomes
- The catchment associated with the in Beveridge NW is approximately 1/3 of the total catchment area draining to the area previously known as Hanna Swamp. This limited catchment area can only hydrologically support a limited engineered ecological outcome. The engineering of the outcome would need to be carefully calibrated with the land uses of the catchment, and bunding and valve systems to meet the ecological outcomes
- The Beveridge NW portion of the depression experiences minor inundation in a regular year from rainfall. In a major rare design event this inundation may be up to 300mm for relatively short period (hours). Other than the dams within the area, the runoff drains relatively quickly under current conditions and makes its way north to the Strathaird/Taylors Creek systems
- An option involving minor bunding to construct pooling areas within the Beveridge NW area has been explored and found that a viable area to meet the nominal hydrologic requirements of inundation for a Seasonal Herbaceous Wetland (SHW) is approximately 4-8 hectares. If some of the catchment is to be urbanised this area can be increased to 9ha, but will require a pre-treatment wetland (or other) upstream of the SHW) A concept of these areas is shown below following the lowest contour.
- Significant work has been completed on a Stormwater Strategy for the proposed Wallan South PSP. This has found:

  - A wetland area of around 2 hectares is the most efficient treatment area if the southern portion of the PSP is to be developed (this includes catchment from the Beveridge NW catchment)
  - A retention volume of around 80ML (equal to 4-8Ha) is the most effective storage volume if the southern portion of the PSP is to be developed. This area can be co-located with a wetland
  - These stormwater requirements could be augmented with fringing ephemeral wetlands that may contain SHW species. An option with this is presented below.

- The management of any of the proposed SHW will require significant input to ensure that water levels are maintained for the selected ecology. These will essentially be managed hydrological systems and may require manipulation of valves and controls to meet a required ecology. Alterations (increases) to land use (urban development) and asset size will increase the active management requirement.
- The below concepts shown are engineered outcomes to create an ecological outcome. They will require ongoing management inputs, and are essentially 'fenced off' landscapes (though you could provide raised boardwalks through them). The use of this land for this purpose as a best and highest community outcome is something for the committee to consider
- I have reviewed the presentation by the Glenelg Trust as part of the Friends of Merri Creek at the C106 Panel. Whilst the submission is interesting, it is poorly supported by the climatic region and topographical evidence, in summary:
  - Whilst the depression area is extensive and obvious, it is not clear that it is an alluvial feature, and that the Strathaird Creek was ever directly connected to the main basin. At best it may have been connected to the lower end and entered and exited directly. It is more likely that the low flow of the creek entered the main valley and may have spilled into the Hanna Swamp area in larger events. The Hanna swamp hydrology is likely to be driven by rainfall on its local catchment.
  - The 1972 aerial photography as presented that the swamp extent relies upon is presumably the 28 March 1972 CAD dataset. This followed rainfall of 221mm (Nov '71), 106mm (Dec '71), 43mm Jan, '72) and 177mm (Feb, '72). Then annual rainfall for this region is around 750mm with monthly averages of between 71mm (Nov) and 53mm (Feb) for these months . The rainfall for 1970 and 1971 were 990mm and 923mm respectively (Toorourong Resevior Bom data). This photo is taken during a wet period, of a wet sequence of years. It is unsurprising that a grayscale aerial photo of this period would show substantial growth (dark areas) in a depression area.
  - The climatic region that Wallan is within is driven by intense thunderstorm events during the summer months (as shown in 1971/72) with a mean average monthly of rainfall of around 50-60mm throughout the year. This only raises to around 70mm in the spring months. Many of the examples of restoration in the presentation are of climatic regions with a much more defined winter rainfall that can fill and retain swampy areas for long periods of time during the winter. It is not clear from the Glenelg Trust presentation, and as is borne out in modelling supporting the below engineered concepts, whether it is possible for a thunderstorm/summer driven large rainfall climate to support long term wetlands without engineering works to manipulate basins and flow inputs.

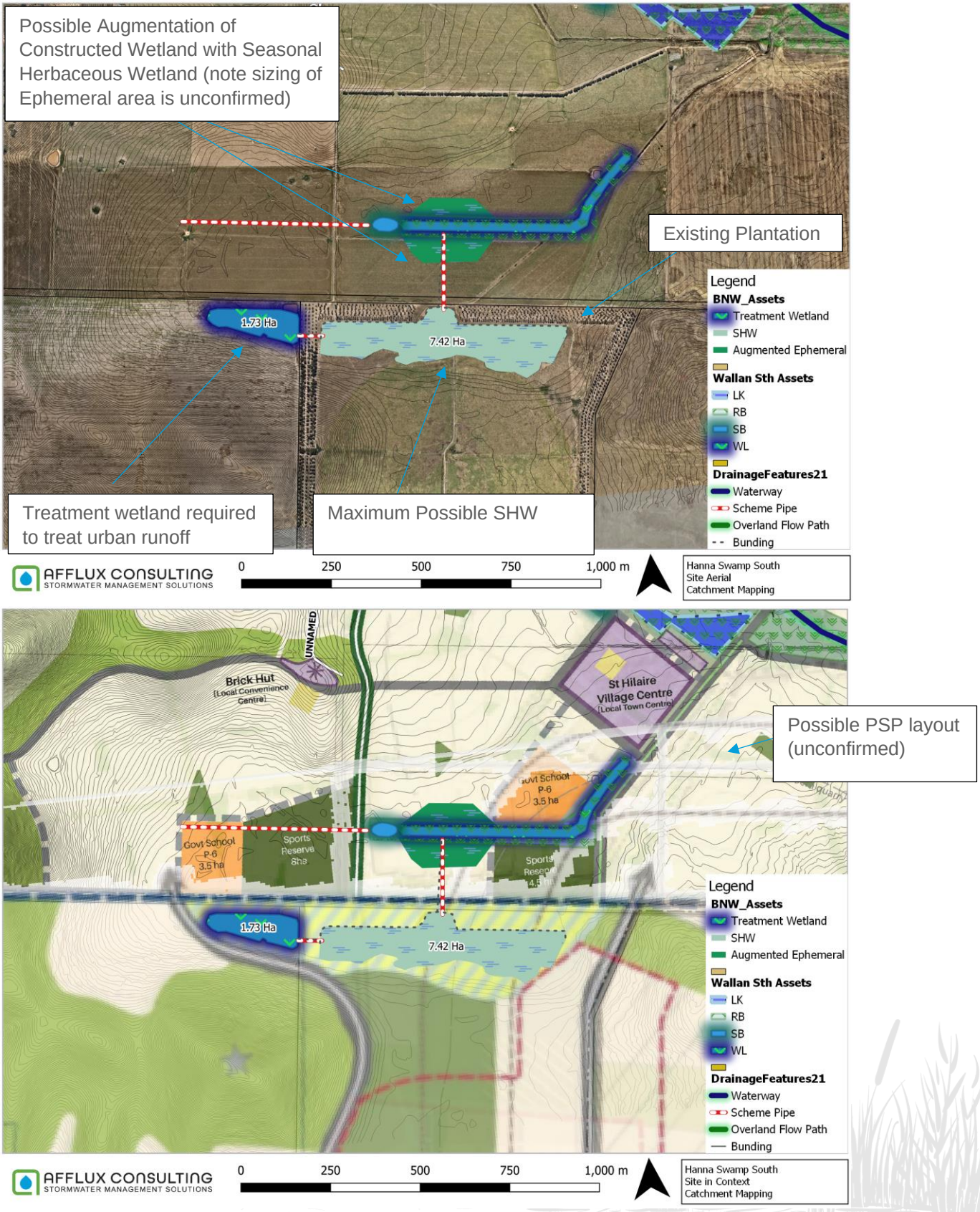


Figure 1. Possible Ephemeral Wetlands within greater urban context

Declaration

I have made all enquiries that I believe are desirable and appropriate. No matters of significance which I regard as relevant have to my knowledge been withheld from the Committee. Accordingly, I believe that the report is a complete and accurate statement of the hydraulic and water quality matters.

Chris M Beardshaw

BEnvEng (Hons), MEngSci, Grad Cert River Health

26 April 2022

Memo

Beveridge Northwest PSP Hydrological Investigation of areas draining to Hanna Swamp

To: Crystal Group

From: Afflux Consulting

Date: Tuesday 15 March 2022

This memo reviews and models the hydrologic inputs into the proposed Seasonal Herbaceous Wetland within the Beveridge Northwest PSP. This memo is intended to fill one of the many data gaps regarding the viability, size, and buffer requirements for a potential wetland area.

1.1. Background

The Beveridge North West PSP abuts the Wallan South PSP. These boundaries don't represent the hydrologic catchment boundary, as such the investigations into eco-hydraulic features and IWM response have often been fragmented across PSPs. This memo reviews the hydrology of the area to present some of the relevant findings for the combined catchment and to outline some of the important differences between sites. This should provide information on the varying requirements and potential stormwater management responses at the northern boundary of Beveridge North West PSP. In particular, the area defined as Hanna swamp and the implications this may have on the Wallan South PSP.

Review Documents and Definitions

Seasonal Herbaceous Wetland

As defined by the DELWP "Seasonal herbaceous wetlands" fact sheet:

> *"These wetlands are typically small, often less than five hectares, occurring on plains and slopes in the temperate climate zone of mainland south-eastern Australia, below 500 m elevation. They are shallow, fresh to slightly brackish, rainfall-fed wetlands that are usually wet in winter and spring and dry out over summer. In drought periods, however, they may be dry for many years. Their vegetation is dominated by native grasses, sedges and/or forbs. Trees and shrubs are sparse or absent."*

Source: *Seasonal herbaceous wetlands, Predicting their occurrence in south-east Australia, DELWP, 2018*

> *These wetlands are dynamic in terms of the species composition and hydrology and typically occur on relatively fertile soils, which are often poorly draining clays, are less than 500m elevation above sea level, areas with an average annual rainfall of 400 – 800mm, and located within seasonally inundated drainage-lines and depressions*

Afflux Consulting Pty Ltd
PO Box 457, Emerald VIC 3782
03 9036 2530 info@afflux.com.au afflux.com.au

> *(sometimes poorly defined) which are filled by rainfall. Vegetation is typically dominated by a ground layer of native wetland grass/rush/sedge and/or native wetland herbs, freshwater algae often are present , and characteristic fauna include invertebrate groups that are temporary water specialists.*

Source: Wallan-Beveridge Pre-planning Waterways Assessment 2021 (Stage 1 to 4 – Desktop, field, modelling and final assessments), FINAL - August 2021, Alluvium

No direct definition has been found for what would be viewed as a SHW within this context, however the Alluvium (2021) report notes a Glenelg Hopkins Catchment definition (a very different hydrological area) as:

Seasonal Herbaceous Wetlands (SHW) are isolated freshwater wetlands that are seasonally or intermittently filled by rainfall. They are usually inundated in the cooler months (winter – spring), and generally dry out by late summer, so surface water is not permanently present. Being dry for part of each year means they often disappear from the landscape (or at least seem to) and as a result most have been cropped or drained during dry periods, as SHW often occur on fertile soil in agricultural landscapes" (Glenelg Hopkins Catchment Management Authority, 2017).

SHWs are dependent upon seasonal wetting and drying patterns (Threatened Species Scientific Community TSSC, 2012), where the depth, duration and frequency of inundation is highly variable, however typically they are inundated for up to a few months and the depth of water is usually shallow. They are typically treeless, freshwater systems. Salinity is generally between 0 and 1000 mg/L (increasing to 3000 mg/L as water evaporates). Wetlands that are saline or have either groundwater or overbank flooding as their dominant water source are excluded from the SHW threatened community

Source: Hanna Swamp Investigation, Alluvium, June 2021

This report has taken this to mean that at least 1 month of inundation will occur on a regular basis (yearly/bi yearly) within the winter periods. An ecological definition will be required for further analysis, however this 30 consecutive day requirement has been found to be a common industry (undocumented) starting point. The current conditions as described in the attached Hanna Swamp Investigation (Afflux, 2021) have shown that the area is currently an efficiently drained system with only short periods of inundation.

Identification of seasonal herbaceous wetlands (SHW) are based on the Department of Environment, Land, Water and Planning (DELWP) model for prediction of occurrence of SHW and critically endangered ecological communities. The classification of a body as a SHW considers the occurrence of ecological vegetation classes (EVC) and their occurrence at Hanna swamp as investigated by Alluvium:

> *"Site surveys have identified the southern portion of Hanna Swamp as a Seasonal Herbaceous Wetland (SHW) based on the composition of its remnant vegetation. SHWs like Hanna Swamp are listed as being critically endangered within the Environmental Protection and Biodiversity Act (1999), with this listing occurring in 2012. They typically receive the majority of their water from local catchments as part of the swamp's wetting and drying regime. The filling of SHWs is typically intermittent and driven by local catchment and hydrological function. It is unlikely that Hanna Swamp received predictable inflows of the same duration, depth and timing on a regular and predictable annual cyclical basis."*

Source: Hanna Swamp Investigation, Alluvium, June 2021

Development Impacts on Stormwater Flow into SHW

All development has the potential to adversely affect downstream environments. Increased impervious areas resulting in increased volumetric and peak flows have been extensively researched and linked to downstream environmental degradation. Contaminants contained in the runoff have also been linked with adverse changes to both water quality and ecology. A SHW relies on natural (pre-developed) flows which will be dramatically impacted by the proposed BNW PSP layout. Receiving unmitigated natural flow regimes is not possible in an urbanised environment with roads, schools, playing fields, houses and town centres increasing imperviousness and altering water quality, flow volumes and timings.

> *"Urbanisation will introduce a number of risks associated with changed hydrology and poor stormwater quality requiring flow management and pre-treatment. This implies that protecting Hanna Swamp South will require additional land as a buffer and / or stormwater treatment and regulation asset. Any reconnection to Strathaird Creek would need to be designed to ensure appropriate water quality and frequency, timing, duration and depth of inundation to the SHW vegetation."*

Source: Hanna Swamp Investigation, Alluvium, June 2021

A natural flow regime for the identified area of the former Hanna swamp has significant implications on the Wallan South PSP and required engineering works. Simply diverting treated stormwater towards a SHW is not a viable replacement of natural flows; a high level of care must be placed on the management of frequency and volumes.

> *"Changes to hydrology from urbanisation will not be suitably managed by a buffer unless it includes a controlled inflow and wetland treatment system. The system will need to deliver adequate water quality and flow regimes delivering seasonal wetting and drying. Surface runoff would need to be diverted to prevent flooding of the SHW during the drier part of the year."*
>
> *"The system would need to treat the polluted 'first flush' of runoff while volumes from the later part of large rain events could be diverted to the swamp with minimal treatment, thereby maximising the flood mitigation and infiltration/evaporation benefits of retaining the wetland."*

Source: Hanna Swamp Investigation, Alluvium, June 2021

The Strathaird creek catchment, at a nominal diversion point is in the order of 750Ha. Of this area, only approximately 20Ha is proposed to have a future development impervious level of 30% or less. This is the point at which flow regimes are considered to be significantly altered and no longer resemble natural flow characteristics. At this point in time well over 150Ha of the land has already been developed to the point where it is considered to have a fraction impervious of over 60%.

More than just a provision of a buffer, the successful inclusion of a SHW within the PSP requires developed inflows to pre-treated to the required nutrient levels and that flows be carefully regulated via an adaptive and closely managed regime. The planned regime should be based on investigated data and ongoing monitoring of SHW. This would be a system requiring ongoing, intensive, specialist maintenance.

Importantly, Alluvium have pointed out that if the SHW is retained the surrounding land requires additional engineering assessment and specification within relevant planning documents. A requirement for consideration being to:

> *" Engineer surrounding land use change in ways which minimise hydrological change. This will require a detailed hydrological assessment. It is unknown how much change SHW can tolerate."*

Source: Hanna Swamp Investigation, Alluvium, June 2021

2. Current Conditions

The delayed decision for Hanna swamp's final, desired condition and size indicates authorities require a clearer decision-making process to facilitate the land use plan across PSPs. Naturally, the required input to attain the planned outcome, corresponds to the difference between desired outcome and initial conditions. Currently, the only known component is the initial conditions. These conditions form an important consideration for appropriate future land use planning. Particularly, as the disparity between initial conditions indicates a significant difference in inputs required.

Hanna Swamp (north) of the BNW PSP area

The land within Wallan South PSP referred to as *Hanna Swamp north* has been used in line with the VPP zone type Farm Zone (FZ), as shown in Figure 1. As a result, the swamp condition varies across PSP boundary as expected by the permitted uses outlined within the zone type provision.

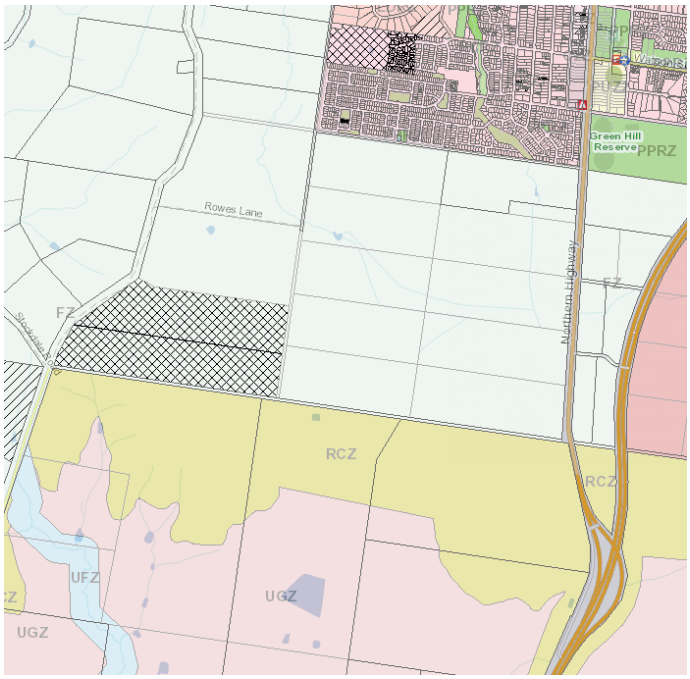


Figure 1. VPP land use at PSP boundary

The vegetation values have been presented as follows:

> *"Hanna Swamp North: The limited native vegetation values that remain in the north comprise robust, disturbance tolerant species derived from degraded EVC 125 Plains Grassy Wetland and does not meet the criteria for SHW (Alluvium 2021)."*

Source: Hanna Swamp Investigation, Alluvium, June 2021

> *"This confirms findings of a prior vegetation survey conducted by Biosis on the eastern 2/3 of Hanna Swamp north in 2016 when the wetland had been wet but was drying (Biosis 2018). They found small areas of Plains Grassy Wetland (EVC 125) of poor quality (weed cover >50%) in the drainage lines and patches in the SE corner of*

> *Hanna Swamp North that did not meet the criteria for SHW (four patches, total 2.32 hectares)."*

Source: *Hanna Swamp Investigation, Alluvium, June 2021*

In addition, the current seedbank is assumed to be no longer fully intact in the area and should not be assumed to be naturally recovered:

> *"Data is currently not available on the state of the seedbank in the northern portion of Hanna Swamp, but it is reasonable to assume the seedbank is no longer fully intact in this area. The degree to which plant species could return is unclear and would depend on reinstated seasonal hydrology and appropriate water quality, connectivity with the southern high values area and other local wetlands, and management of other threats such as invasive weeds, grazing, and elevated nutrient levels (Casanova 2012)."*

Source: *Hanna Swamp Investigation, Alluvium, June 2021*

Hanna Swamp (south) in BNW PSP area

This area has also experienced altered hydrology. The centre pivot irrigation system has provided the area with an artificial, watering regime that has likely sustained the area.

Figure 2 and Figure 3 show the centre pivot irrigation system supporting increased, regular wetting of the area.

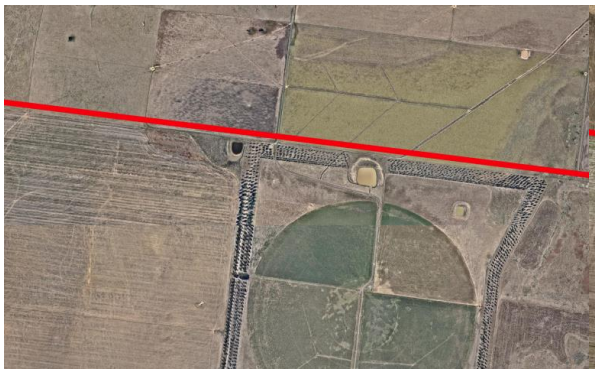


Figure 2. Aerial of site, Nearmap 2018

Figure 3. Aerial of site, Nearmap 2021

As expected with increased wetting, the vegetation in this area varies from the northern portion. Alluvium have outlined that portions of the swamp contain Plains Grassy Wetland (an EVC) as well as key SHW species:

> *"In addition to these defined EVCs a portion of the Plains Grassy Wetland on the South side of Hanna Swamp qualifies as a Seasonal Herbaceous Wetland as it meets benchmarks for species composition, hydrological function and landscape location."*

Source: *Wallan-Beveridge Pre-planning Waterways Assessment 2021 (Stage 1 to 4 – Desktop, field, modelling and final assessments), FINAL - August 2021, Alluvium*

More specifically:

> *"Hanna South is habitat for number of important species including one of State Significance. Coronidium gunnianum Pale Swamp Everlasting (B) which is listed as*

> *vulnerable. The southern section qualifies as a Seasonal Herbaceous Wetland of very high quality. This benchmark is met because the site contains more than three species as described in Key Diagnostic Characteristics and Condition Thresholds advice from the Federal Environment Department. In this case six species were identified including Calocephalus lacteus Milky Beauty-heads, Coronidium gunnianum Pale Swamp Everlasting, Eryngium vesiculosum Prickfoot, Lobelia pratioides Poison Lobelia. Montia australasica White Purslane and Ranunculus inundatus River Buttercup. 67 species comprising; 33 indigenous species, (1 planted i.e. Eucalyptus camaldulenis Red Gum (C)) and 33 exotic species. Notably Coronidium gunnianum a listed threatened species, numerous patches observed. Indigenous wetland flora is evident throughout, co-occurring with exotic species."*

Source: Wallan-Beveridge Pre-planning Waterways Assessment 2021 (Stage 1 to 4 – Desktop, field, modelling and final assessments), FINAL - August 2021, Alluvium

While Alluvium have recommended that the vegetation benchmark has been met they have reiterated that the hydrology and ecological threats must be managed appropriately:

> *"Hanna South is of very high conservation significance. Ecological values and hydrological function are a very high priority to retain, protect and improve. Its long-term trajectory is positive, it will maintain its values if hydrology is maintained and ecological threats are managed appropriately."*

Source: Wallan-Beveridge Pre-planning Waterways Assessment 2021 (Stage 1 to 4 – Desktop, field, modelling and final assessments), FINAL - August 2021, Alluvium

That is, that the current hydrology for the southern portion of the depression including the artificial wetting via irrigation must be either maintained or re-engineered. A reassessment of an appropriate hydrological regime will be required and may need a constructed engineered outcome to maintain the wetting regime. This report explores this possibility.

Hydrology

Afflux Consulting has undertaken a hydrological modelling analysis for the site. A summary of the results indicates the following current hydraulic conditions:

- Strathaird Creek is not connected to Hanna swamp;
- Hanna swamp extent collects rainfall runoff from sub-catchments immediately surrounding the extent as shown in Figure 4;
- Sub-catchment CA and the northern portion of Catchment Z are not indicative of natural catchments flowing into Hanna swamp;
- The peak flow depths through the Hanna Swamp extent are around 0.2-0.3m deep in the 1% AEP event, this is somewhat reflective of the existing drains across the site; and
- Hanna swamp extent discharges east towards the greater catchment outfall.

(This modelling was undertaken by Afflux, more detail can be found in Appendix A - Hanna Swamp Investigation - Wallan South, March 2021)

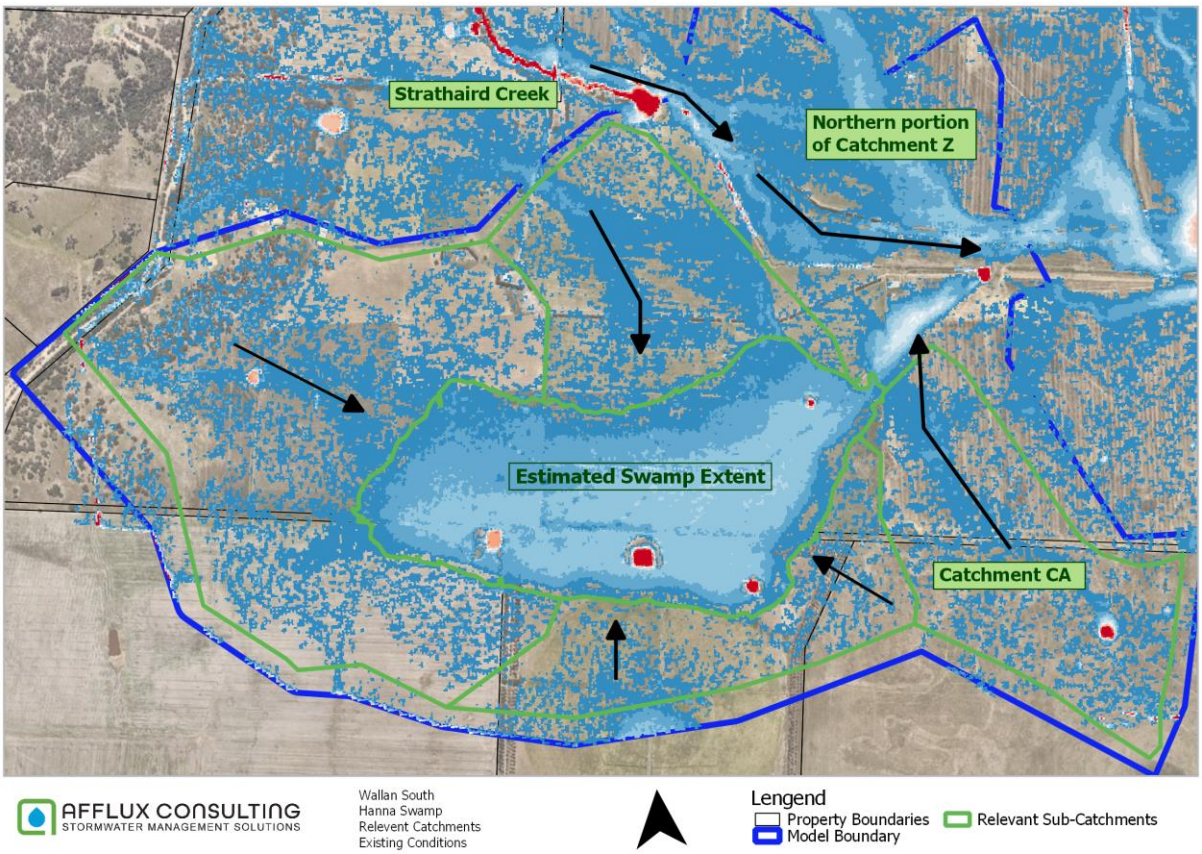


Figure 4. Local model boundary - Ephemeral Flooding Extent

In addition, Afflux have completed a water balance assessment of the current swamp extent a summary of which follows:

- The swamp experiences significant dry out periods during the 10 year rainfall period;
- The swamp can sustain a permanent pool less than 2% of the time which equates to ~3 days per year, this is notably below the 30 day benchmark;
- The current condition does not support the required inundation events to support a SHW;
- The area is well drained particularly in low flow or high frequency events and does not facilitate permanent pooling;
- Water balance assessments show that this area doesn't hold water for more than ~24 hours based on 40 years of rainfall data;
- Based on the hydrology within this region the minimum 1 month inundation does not exist under current conditions; and
- High levels of engineering input would be required to install a hydrologic regime that would support regular wetting and extended inundation.

More information can be found in Appendix A - Hanna Swamp Investigation - Wallan South, March 2021.

3. Proposed reinstated conditions

Afflux have conducted a water balance and inundation frequency assessment for the Hanna swamp south current catchment using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). This informs capacity for the catchment within BNW PSP to support a swamp.

Catchment descriptions

The following basic assumptions have been incorporated:

- The modelled catchments are as shown below (Figure 5);
- The model is built using a range of rainfall templates that include 10-year and greater periods of rainfall data;
- The model is built using the most recent guidelines including soil losses field capacity;
- All other parameters were set as per Melbourne Water Guidelines.

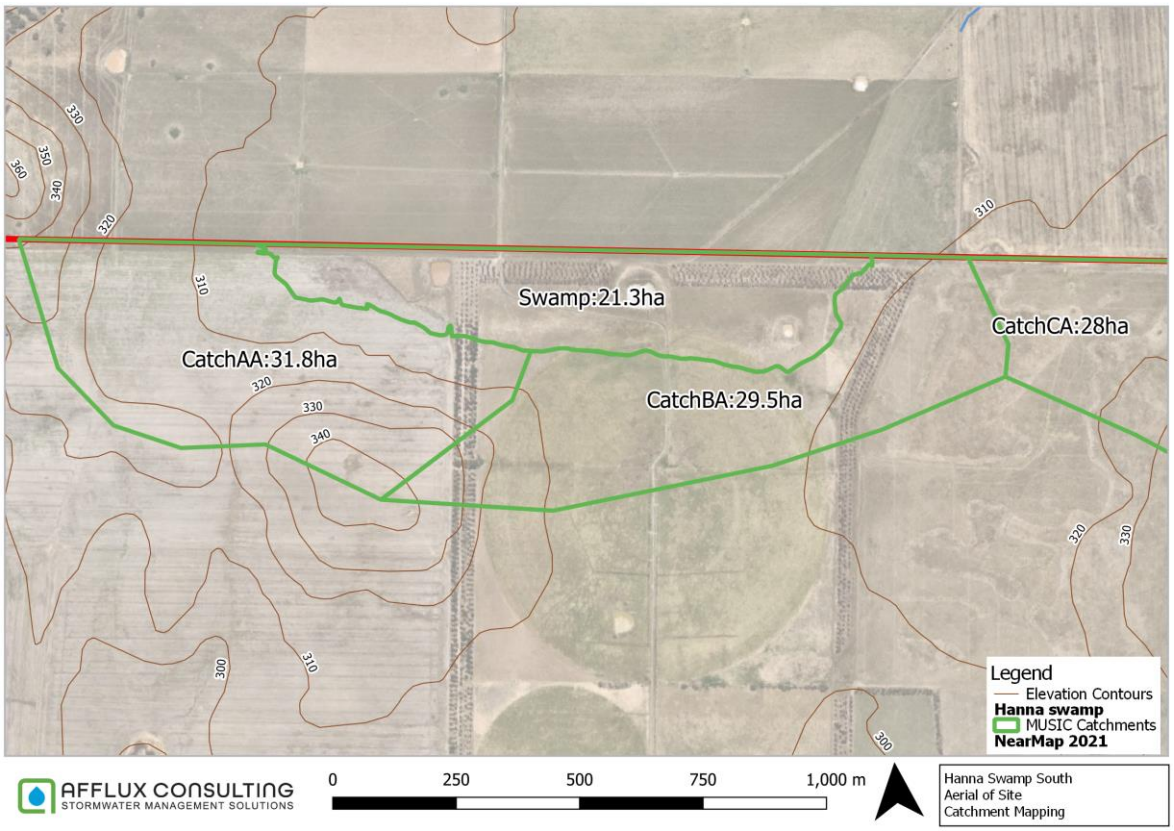


Figure 5. Catchment Area - Hanna Swamp South

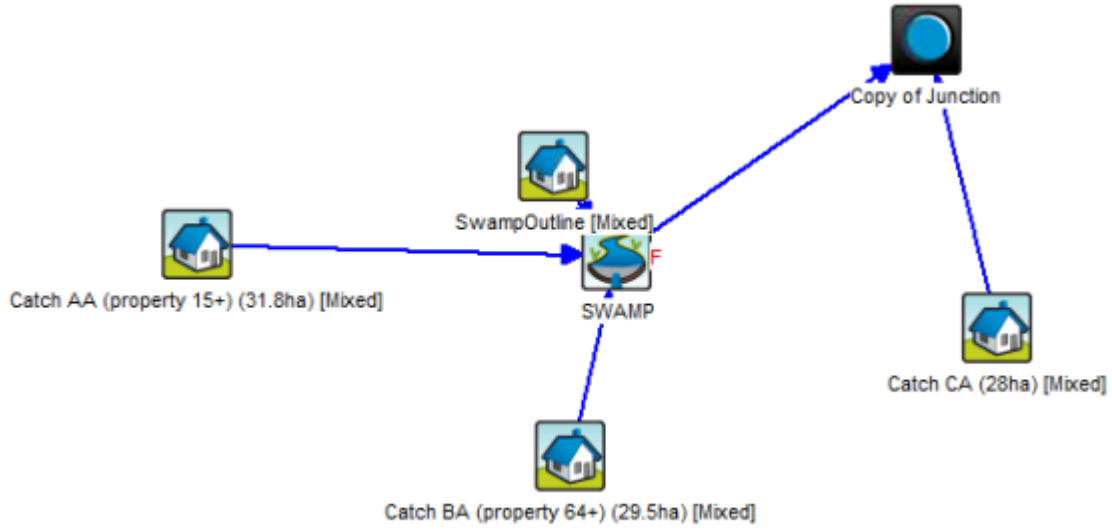


Figure 6. MUSIC model

Note: The Swamp Outline node represents the difference between contour outline and supportable swamp area trialled within system. That is, "SwampOutline" catchment equals 21.3ha minus the swamp area being trialled. This does not represent recommended buffer.

Additional assumptions for site specific parameters:

- Catchments have been kept at natural conditions with low perviousness;
- Low exfiltration rate of 0.036mm/hr representative of heavy clay;
- Swamp will be situated 100mm below lowest outlet (to support a permanent pool volume);
- The swamp outlet was restricted; and
- Outlet conditions were trialled for sensitivity.
- There are no considerations of potential land uses or hydralic controls (future roads) unless otherwise stated. This is a catchment area based assessment only.

Importantly, the assumption to keep the inflow catchments at values representing low perviousness (representative of a natural catchment) is based on the recognition that to support the swamp the upstream land must be remain undeveloped. If the catchment is developed there will be an increase in runoff available. However, the runoff must be treated prior to SHW inflow; an upstream treatment asset arrangement would be required. In addition, monitoring of flow quantity, quality and frequencies from the treatment asset into the swamp would be required.

Finally, the selected exfiltration rate represents the conditions of a reinstated SHW in these soils. This is unlike a lined constructed wetland which would be modelled with no infiltration.

Wetland viability - ecological

Matters of ecological viability are outside the expertise of our team. However, the case studies presented by Alluvium provide important lessons on past habitation projects forming a basis for practical recommendations, including the Braeside waterway case study:

> *"The success of the project is attributed to appropriate funding, willingness by the developer to innovate, and management by staff experienced in ecological*

restoration. Innovative techniques were successfully used, including spreading propagules to establish cryptogrammic crust and ecological burning, as well as established best practices including: careful site investigation, planning (including the use of local benchmarks), preliminary weed control, introduction of flora species, maintenance and monitoring. Consequently this approach was resource intensive per area involved.

Lesson learned: establishment of small, high value areas of SHW is possible within larger constructed areas of native vegetation in an urbanising context, but this requires substantial funding and willingness by developers and land managers to invest in innovative development and restoration. It is unlikely that resources would be available to support work of this level of detail over a large area. However, connectivity of the restored SHW patches to other SHW sites at the landscape scale is still a challenge."

Source: Hanna Swamp Investigation, Alluvium, June 2021

This indicates the importance of focusing on rehabilitating smaller, high value areas of SHW. Providing consideration for the ongoing resource management demand of such a large project.

Wetland viability - hydraulic

The MUSIC model indicated that a SHW begins to become viable for the catchment at 8ha. This is dependent on ecological parameters, however, from a hydraulic perspective an 8ha wetland is inundated ~18% of the time. This provides approximately 8-9 events (as shown in Figure 7) of the 1 month inundation requirement across a 10 year period, allowing for almost one event per year.

8 ha swamp - restricted outlet

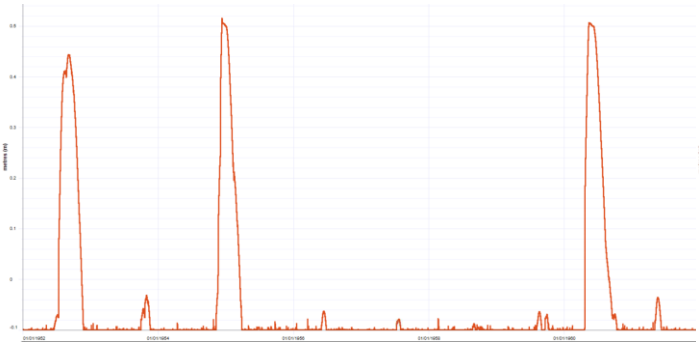


Figure 7. Water level (m) over 10 years for 8ha swamp (time on x axis)

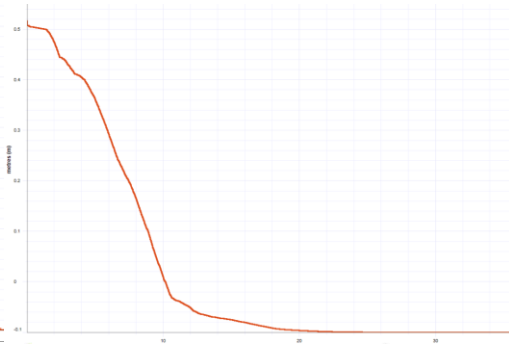


Figure 8. Water level exceedance

Key findings:

- Approximately 8 inundation events of more than a month over the 10-year rainfall period.
- Water level exceeds permanent pool volume ~10% of the time

8ha - larger outlet

To assess swamp sensitivity to drainage outlet conditions the outlet was increased to 300mm pipe.

Note: Selected trial pipe size not indicative of current or recommended outlet conditions, purely to assess sensitivity to variations in conditions.

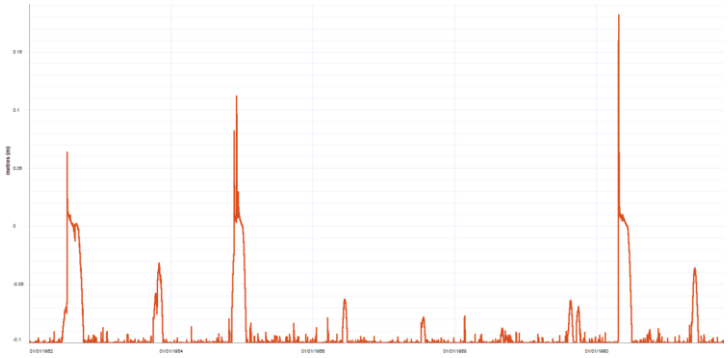


Figure 9. Water level (m) over 10 years for 8ha swamp (time on x-axis)

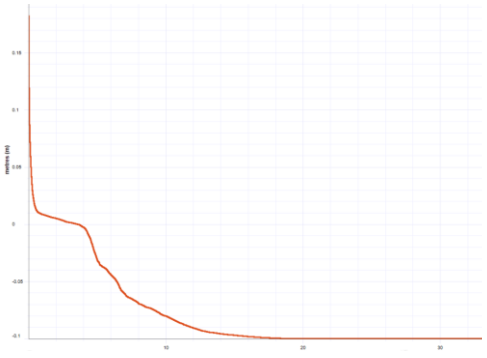


Figure 10. Water level exceedance

Key findings:

- Approximately 8 inundation events of more than a month over the 10-year rainfall period.
- Water level exceeds permanent pool volume ~4% of the time

Swamp will still have the same number (~8) of inundation events of the required 1 month inundation duration, and approximately ~16% inundation exceedance. The time to dry-out after rainfall events remains approximately the same, however the water level above permanent pool level is reduced - particularly within the 3 larger inundation events. Essentially this is indicating that a restricted outlet is required to ensure inundation periods in line with the SHW recommendations.

4ha swamp - restricted outlet

To assess the impact of SHW size on provision for surrounding catchment to provide additional flow requirements a reduced swamp size of 4ha was trialled.

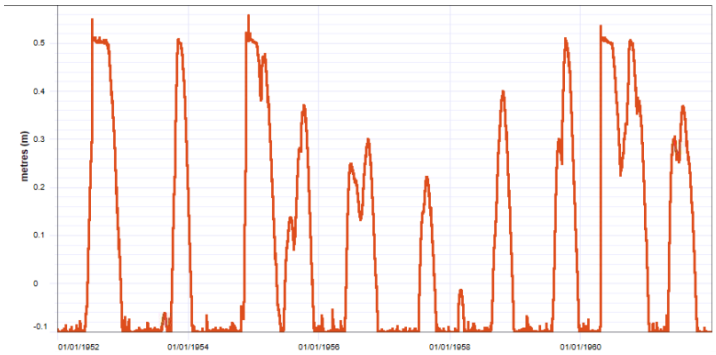


Figure 11. Water level (m) over 10 years for 4ha swamp (time on x-axis)

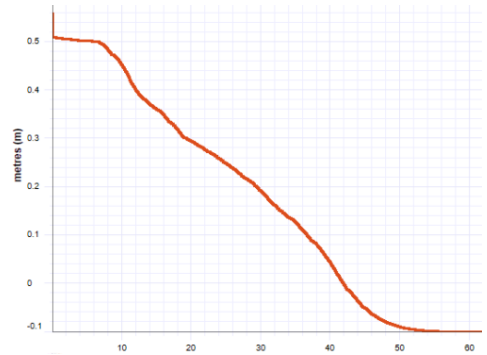


Figure 12. Water level exceedance

Key findings:

- Over 15 inundation events of more than a month over the 10-year rainfall period;
- Inundations events last significantly longer;
- SHW is inundated ~50% of the time;
- Water level exceeds permanent pool volume ~42% of the time.

This indicates that there is an increased provision to support additional flow requirements with swamp footprint reductions. This would decrease dry out times and must consider ecological requirements.

Urbanised Catchment Option (Current PSP proposed land uses)

A partially urbanised catchment condition in line within Nov 2021 PSP Draft Precinct Structure plan (Figure 16/Figure 16) was trialled for sensitivity to flow. The following assumptions were included within the model:

- Catchments were updated to reflect developed imperviousness as shown in Figure 13;
- Exfiltration rates, permanent pool volume, etc., were kept constant; and
- Outlet assumed a 300m pipe (as in "8ha- larger outlet" conditions).

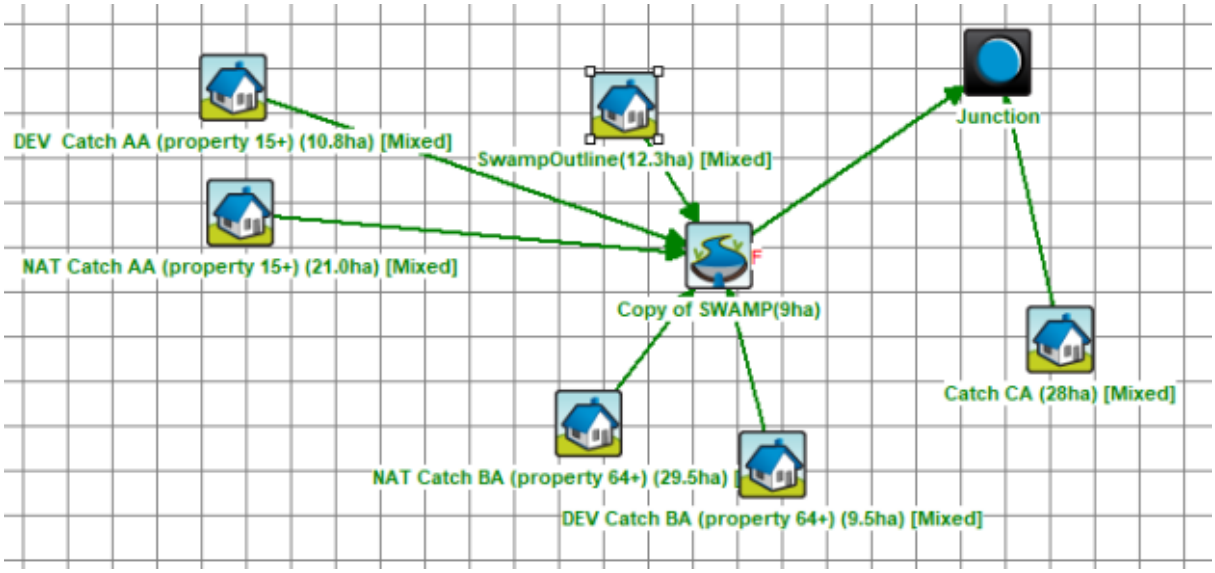


Figure 13. Developed catchments included in MUSIC model

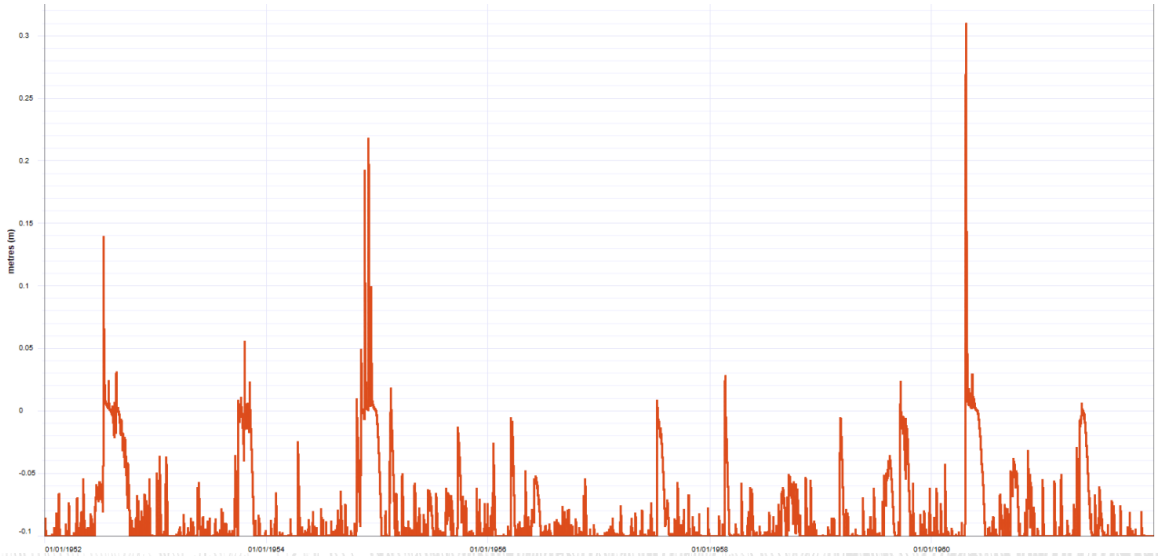


Figure 14. Water level (m) over 10 years for 9ha swamp - Developed conditions (time on x-axis)

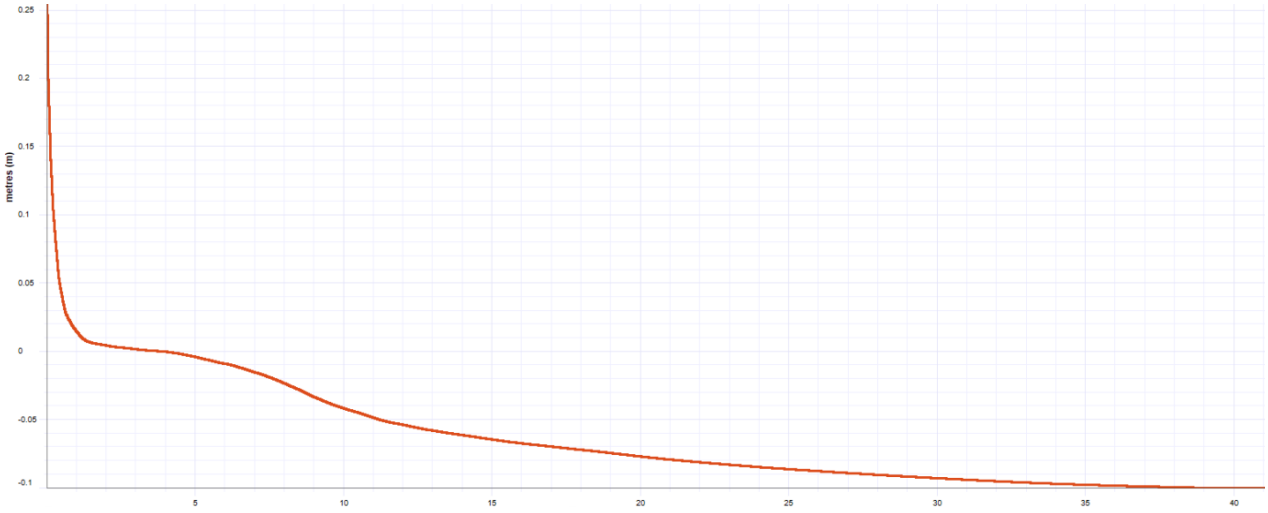


Figure 15. Water level exceedance - developed conditions

Key findings:

- The hydrology has altered significantly as compared to undeveloped conditions (a completely rural catchment);
- The number of minor events (under 30 days) registered within the swamp has increased significantly;
- There are approximately 8 of required inundation events (events over 30 days) making a 9ha swamp the maximum viable swamp size for developed conditions;
- Reliability of inundation events will increase as swamp size is reduced (i.e. smaller than 9ha);
- Water volume within swamp has increased with development;
- Water is present within the permanent pool over 35% of the time; and
- Water exceeds the permanent pool volume ~4% of the time.

This indicates that a 9ha swamp is the maximum hydraulically viable swamp size within developed conditions (i.e. the conditions currently proposed by the PSP). The introduction of developed flows has the potential to significantly alter ecological requirements. That is, the dry out periods for the SHW will be less than 65% (where, natural conditions allowed for dry out ~84% of the time). The increased frequency of inflows reduces the "ephemeral" nature as water is present more often.

This assessment considers the hydrological "low flow" conditions only. If this option is to be considered a number of other considerations would be required including:

- Attenuation requirements for the urban development. A retarding basin may need to be included either as part of this area or in addition to it
- Water quality control measures may be required to filter the water before discharge to the SHW. This would add additional land upstream of the location, and may need a level of monitoring to maintain.

Outfall considerations

A conceptual assessment was undertaken on outfall requirements from SHW for 1% AEP events. Flows for 1% AEP will be approximately 2-3 m³/s. This indicates a 1050 pipe outlet would be adequate for conveyance of flows, with the provision of an overland flow path. This could be reduced further through attenuation basins.

If the overland flow path and pipe outlet were proposed to outlet north (through Wallan South PSP) the slope should enable outlet pipe connection to developed pipe network levels (~1:300 fall). Noting that an active recreation land use in the Wallan South PSP would provide both a buffer area and overland flow requirements.

If the overland flow path and pipe outlet were proposed to outlet south (through Beveridge North West PSP). The outlet pipe and flow path could align with proposed arterial road as shown in Figure 16. This road would also be required to contain the overland flow.

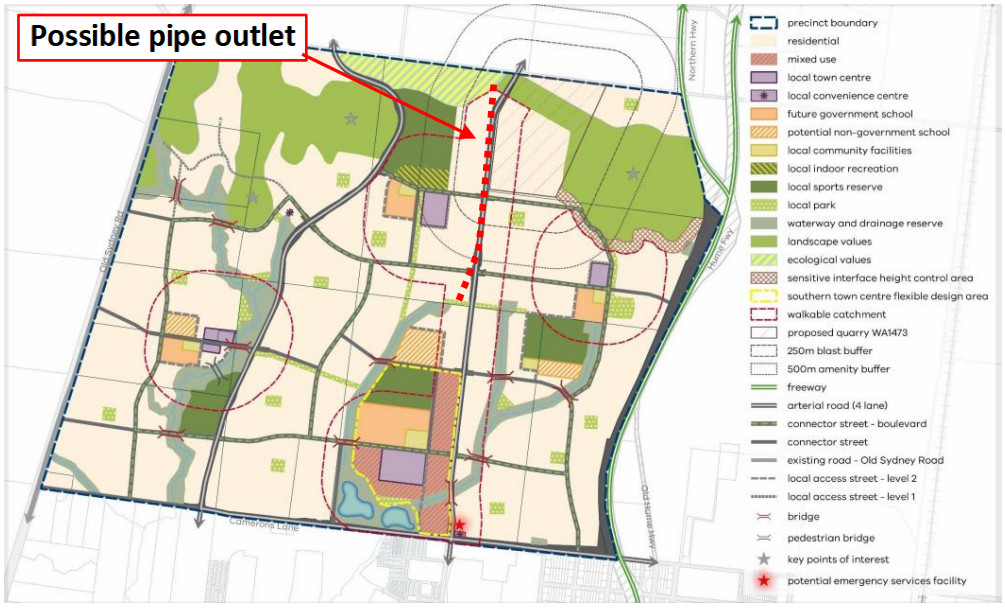


Figure 16. Beveridge North West PSP – Future Urban Structure with superimposed SHW outlet pipe

3.1. Recommendations

From an ecological perspective, the consistent recommendation found within submissions is that the southern section of Hanna Swamp be protected, retained and rehabilitated, provided adequate investigations are undertaken:

> *"The rehabilitation of the southern section of Hanna Swamp, within the Beveridge North West PSP, is possible and recommended, however there are a number of factors that will contribute to the success of that effort including, amongst other things, the suitable regulation of water flow and quality into the swamp. This is particularly important in the context of a future, urbanised catchment where hydrology will be significantly altered. There is no proposition that the northern section can be rehabilitated to its historical SHW form and quality. It is however proposed that the protection of the southern section may require a contribution of area in the northern section for the purposes of improving stormwater quality and regulating flow to the SHW."*

Source: Hanna Swamp Investigation, Alluvium, June 2021

There is no proposition to rehabilitate the northern section due to the much higher inputs required and limited available seedbank:

> *"The northern section of Hanna Swamp has limited existing ecological values and the persistence of a seed bank that could recover in the presence of suitable hydrology is questionable or at best, unknown. Restoration of the northern section to a functioning SHW would require significant effort and resources without certainty as to the quality of the outcome. It is not recommended that the north of Hanna Swamp be restored to a SHW, rather that it be used, at least in part to protect those values in the south."*

Source: Hanna Swamp Investigation, Alluvium, June 2021

From a hydrologic perspective the following points have been shown within viability assessments:

- The SHW to the south becomes hydrologically viable at 8ha (with engineering intervention); and
- Provision for adequate, natural watering regime increases as proposed SHW land take decreases.

To form a functioning SHW, this hydrologic data will need to be integrated with ecologists to determine the viability of the area. However, based on the current state of knowledge, and parameters for inundation (regular 1 month inundation periods), the maximum size of swamp is approximately 8ha for a fully rural catchment. It is more likely that a smaller footprint may be more manageable from a hydrological stand point.

3.2. Implications on restoration/rehabilitation of Hanna swamp

Buffer requirements

Afflux cannot undertake the ecological buffer requirements. However, the hydrological recommendations (for <8ha SHW) interact with the buffer/PSP as follows:

- The current swamp contour within BNW PSP indicates approximately 21ha available for swamp location at grade;
- The credited open space at Hanna swamp south location indicates approximately 20ha available for swamp location;
- Hydraulically only 3-5m buffer would be required which could overlap ecological buffer;
- Therefore, an 8ha SHW should fit within the BNW PSP proposed allocated area, as well as the provision of a buffer;
- If development within the SHW catchment is permitted a 9ha SHW (and buffer) should also fit within the proposed allocated area, though considerations for a pre-treatment urban wetland would be required. Presumably this could be part of the buffer;
- The buffer and SHW does not need to cross into the Wallan South PSP;
- Ecological buffer width should be considered by an appropriate expert.

Noting that the specifics on the location of the proposed SHW (and buffer) requires consideration of the location of any remnant, high value vegetation to be retained. The mapping is as yet undocumented.

The proposition that a section of the swamp in the north be used as a buffer implies the full allocated regional park land of the southern section can support a SHW, and therefore an additional buffer must come from the north:

> *"• A suitable buffer is critical to protecting the SHW ecological community on an ongoing basis. It is recommended that this include a buffer around the perimeter of the southern section and an allowance, potentially within Wallan South PSP, for a wetland asset to regulate flow and improve stormwater quality prior to flowing to the southern section.*
>
> *• The area that is to be set aside in the north, should that advice be followed, would be defined based on the objectives of the asset as a whole e.g. to protect the SHW in the south or potentially fulfil a broader role that meets some of the HWS performance objectives for the sub-catchment such as stormwater harvesting."*

Source: Hanna Swamp Investigation, Alluvium, June 2021

However, investigations into buffer requirements have not been undertaken:

> *"… detailed analysis as to the area and performance requirements of that buffer have not been undertaken. It is also worth noting that a buffer will only be as effective as the quality of maintenance it receives, which in turn requires appropriate monitoring."*

Source: Hanna Swamp Investigation, Alluvium, June 2021

A concept of what an 8-9ha wetland looks like within the PSP constraints can be seen below. A buffer to the Wallan Sth PSP has been provided on the suspected higher value eastern cell. If urban land uses are proposed to the west, it is suspected that the western cell would be a largely constructed wetland not requiring buffers.

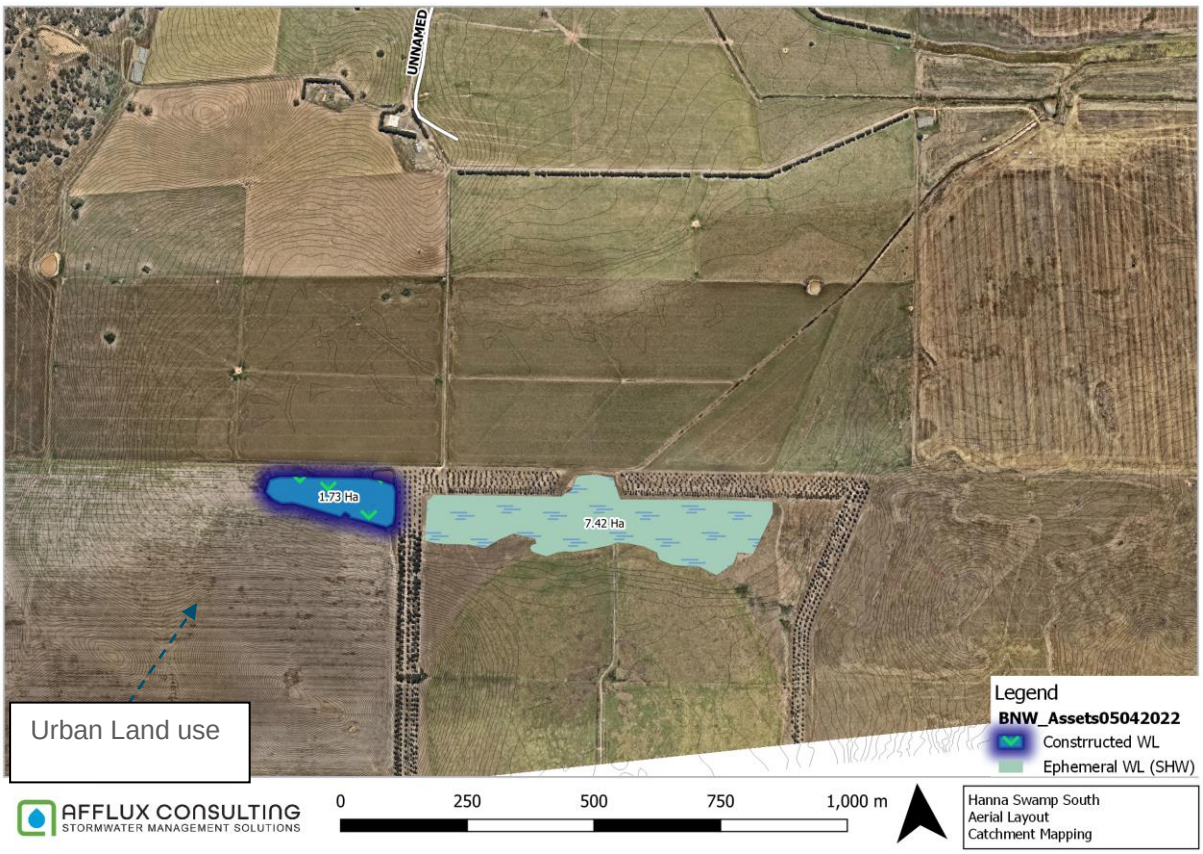


Figure 17. 8ha Land allocation

Gaps in knowledge

There are still various gaps within required knowledge for successful SHW rehabilitation, these include but are not limited to:

- Consideration of the desired condition for rehabilitation
- The corresponding input required to attain the desired condition
- The surrounding land use type and implications on design including interactions of outlet with urban drainage network
- Defined stormwater inundation frequencies (i.e. durations and volumes) to support ecological requirements specific to location
- Interaction with the Melbourne Water development services scheme (noting that it does not meet DSS objectives and would not be a replacement for a drainage asset)
- Maintenance requirements
- Organisational fiscal arrangements
- Responsible organisation, required organisational resourcing and any required capacity building

Most importantly, Alluvium have recommended that a rehabilitation and management plan be developed as part of further investigations:

> *"Development of a protection and enhancement plan is required to ensure that all stakeholders have a clear understanding of their objectives relating to the future direction of Hanna Swamp. This includes outlining the expected ecological outcomes in terms of indigenous species cover and diversity and how this may change over time and the potential for the asset to provide community amenity and liveability outcomes."*

Source: *Wallan-Beveridge Pre-planning Waterways Assessment 2021 (Stage 1 to 4 – Desktop, field, modelling and final assessments), FINAL - August 2021, Alluvium*

4. Conclusion

The exhibited information recommends pursuing rehabilitation of a portion of Hanna swamp. This portion is referred to as Hanna swamp south and sits within the BNW PSP at the boundary interface with Wallan South PSP.

A summary of the findings within this memo includes:

- The current and proposed land use changes have the potential to alter the rehabilitation potential of the SHW.
- Urbanisation in the area presents risks to SHW ecology due to the changes in hydrologic regimes and increased contaminants.
- Provision of runoff from a natural catchment has a better capacity to provide natural flows.
- The natural catchment within the BNW PSP can viably support <8ha SHW
- This supports the outcome to focus on rehabilitation of smaller, high value areas of a SHW
- If the catchment is developed a pre-treatment and flow regulation system must be incorporated
- A buffer to this area has been recommended to protect the SHW values
- This should be sufficiently provided for within the BNW PSP depending on ecological requirements
- Conceptual examinations indicate the outflows from the SHW catchment in a 1% AEP is ~2-3m³/s which can be conveyed through a pipe/ flow path arrangement
- Conveyance can occur either north through Wallan South PSP or south through the proposed road network in BNW PSP.
- A plan is required to outline the desired condition for rehabilitation and expected actions

AFFLUX CONSULTING
STORMWATER MANAGEMENT SOLUTIONS

HANNA SWAMP INVESTIGATION

Wallan South

Date	23 March 2021
Version	372-02
Author	TCF
Client	Crystal Group

Document History

Revision:

Version	372-02
Author/s	TCF
Checked	CMB
Approved	CMB

Distribution:

Issue date	23 March 2021
Issued to	Crystal Group
Description	Investigation of the former Hanna Swamp area. Investigation of viability of area and hydrological inputs

Climate Change Statement

A wide range of sources, including but not limited to the IPCC, CSIRO and BoM, unanimously agree that the global climate is changing. Unless otherwise stated, the information provided in this report does not take into consideration the varying nature of climate change and its consequences on our current engineering practices. The results presented may be significantly underestimated; flood characteristics shown (e.g. flood depths, extents and hazards) may be different once climate change is taken into account.

Disclaimer

This report is prepared by Afflux Consulting Pty Ltd for its clients' purposes only. The contents of this report are provided expressly for the named client for its own use. No responsibility is accepted for the use of or reliance upon this report in whole or in part by any third party. This report is prepared with information supplied by the client and possibly other stakeholders. While care is taken to ensure the veracity of information sources, no responsibility is accepted for information that is withheld, incorrect or that is inaccurate. This report has been compiled at the level of detail specified in the report and no responsibility is accepted for interpretations made at more detailed levels than so indicated.

Contents

1. Introduction 1

1.1. Information Sources 1
1.2. Site Visit 2

2. Hydrology 3

2.1. Hydrological modelling 3
2.2. Critical Duration Storm Results 5

3. Flood Modelling 6

3.1. Combined Modelling Approach 6
3.2. Model Parameters 6
3.3. Regional Flood Assessment 8
3.4. Local Flood Assessment 10

4. Water Balance 15

4.1. Rainfall Information 16
4.2. Evapotranspiration Information 17
4.3. Soil Infiltration Information 18
4.4. Current Condition with sensitivity checks 18

5. Discussion 25

5.1. Summary of DELWP assessments 29

6. Conclusions 31

Tables

Table 1. RORB Model Parameters 5

Figures

Figure 1. Aerial of study site 1
Figure 2. Site visit 2
Figure 3. Site visit 2
Figure 4. RORB model catchments and reaches 4
Figure 5. Comparison of Kc Estimates 5
Figure 6. Digital elevation model and model extent 7
Figure 7. Model parameters and setup 7
Figure 8. Regional flood model depth plot - 1% AEP 9
Figure 9. Local model boundary 10
Figure 10. Local Site Model Setup 11
Figure 11. Local flood model depth plot - 1% AEP (100y ARI) 12
Figure 12. Local flood model depth plot - 10% AEP (10 yr ARI) 12
Figure 13. Local flood model depth plot - 50% AEP (~2yr ARI) 13
Figure 14. Local flood model depth plot - 63.2% AEP (1yr ARI) 14
Figure 15. Local flood model depth plot - 98% AEP (3 month ARI) 14

Figure 16. MUSIC model 15
Figure 17. Catchment and Runoff Generation Processes 16
Figure 18. Greater Melbourne rainfall distribution 17
Figure 19. Average Annual pan evaporation map (mm) 18
Figure 20. Current Water Level (m) - Low exfiltration 19
Figure 21. Current Water Level Exceedance 20
Figure 22. Close-up of expected water level exceedance 20
Figure 23. Close-up on events 21
Figure 24. Current Water Level (m) - Medium- High exfiltration 21
Figure 25. Current Water Level Exceedance 22
Figure 26. Close-up on events 22
Figure 27. Current Water Level (m) - Highest exfiltration 23
Figure 28. Current Water Level (m) - Medium- High exfiltration 24
Figure 29. Current Water Level Exceedance 24
Figure 30. Average Cumulative Rainfall minus evaporation 25
Figure 31. Site Terrain levels and drainage channels 26
Figure 32. Biosis Vegetation assessment report June 2017 28
Figure 33. Water Observations from Space Digital Earth Australia Map (ga.gov.au) 29

1. Introduction

Afflux Consulting have been engaged by Crystal Group to assess the current functionality of the area formally known as Hanna Swamp located at the southern boundary of Wallan South PSP between Northern Hwy and Old Sydney Road, Wallan. This investigation will cover the current conditions of the swamp including:

- Regional flooding associated with the greater catchment
- Catchment mapping and localised catchment modelling
- Localised water balance and inundation assessments
- Assess area against DELWP criteria for a swamp

To complete these investigations a range of hydrological and hydraulic modelling has been undertaken.

Figure 1. Aerial of study site

1.1. Information Sources

A number of information sources have been used in the formation of this report; these include:

- Site inspection
- Aerial imagery
- DEPI planning scheme and cadastral information as accessed online

- Discussions and information as provided by Melbourne Water (RORB and MUSIC modelling information for Taylors Creek DSS)
- Historic flood and water quality studies
- Topographic information including required LiDAR data sourced commercially

1.2. Site Visit

A site visit of the swamp area was undertaken in February 2021. A number of photos of the existing site can be seen in Figure 2 and Figure 3. Key amongst the findings on site was the controlling drain and pipe systems as can be seen below. This central drain sits 1-1.5m below the natural surface, draining the entire flat plain.

Source: General Swamp Area

Figure 2. Site visit

Source: Swamp outfall drain and Pipe

Figure 3. Site visit

2. Hydrology

To understand the hydrology of the system a number of hydrological models have been formed. This section describes the probabilistic models used to understand the event based flows through the system.

2.1. Hydrological modelling

The 1% AEP (Annual Exceedance Probability) flood discharge for the site was estimated following ARR 2019 (Australian Rainfall and Runoff, 2019) processes. The primary model for flow evaluations for the site is a RORB model encompassing the greater regional catchment areas. RORB was produced by Laurenson and Mein as a runoff routing model for the production of flood hydrographs. It is considered the industry standard model for Victorian Flood studies.

The RORB model was supplied by Melbourne Water within the Taylors Creek Development Services Scheme investigations and reviewed.

RORB catchments and reaches

The greater regional catchment was broken into a number of sub-catchments and reaches as can be seen in Figure 4. Outlined ("Local Catchment") is the catchment relevant to Hanna Swamp investigations as discussed in sections below. The RORB model encompasses the entire Strathaird and Taylors Creek systems. Historically the Strathaird system may have been connected to the Hanna Swamp area, the hydraulic modelling of the system will investigate if this is still the case.

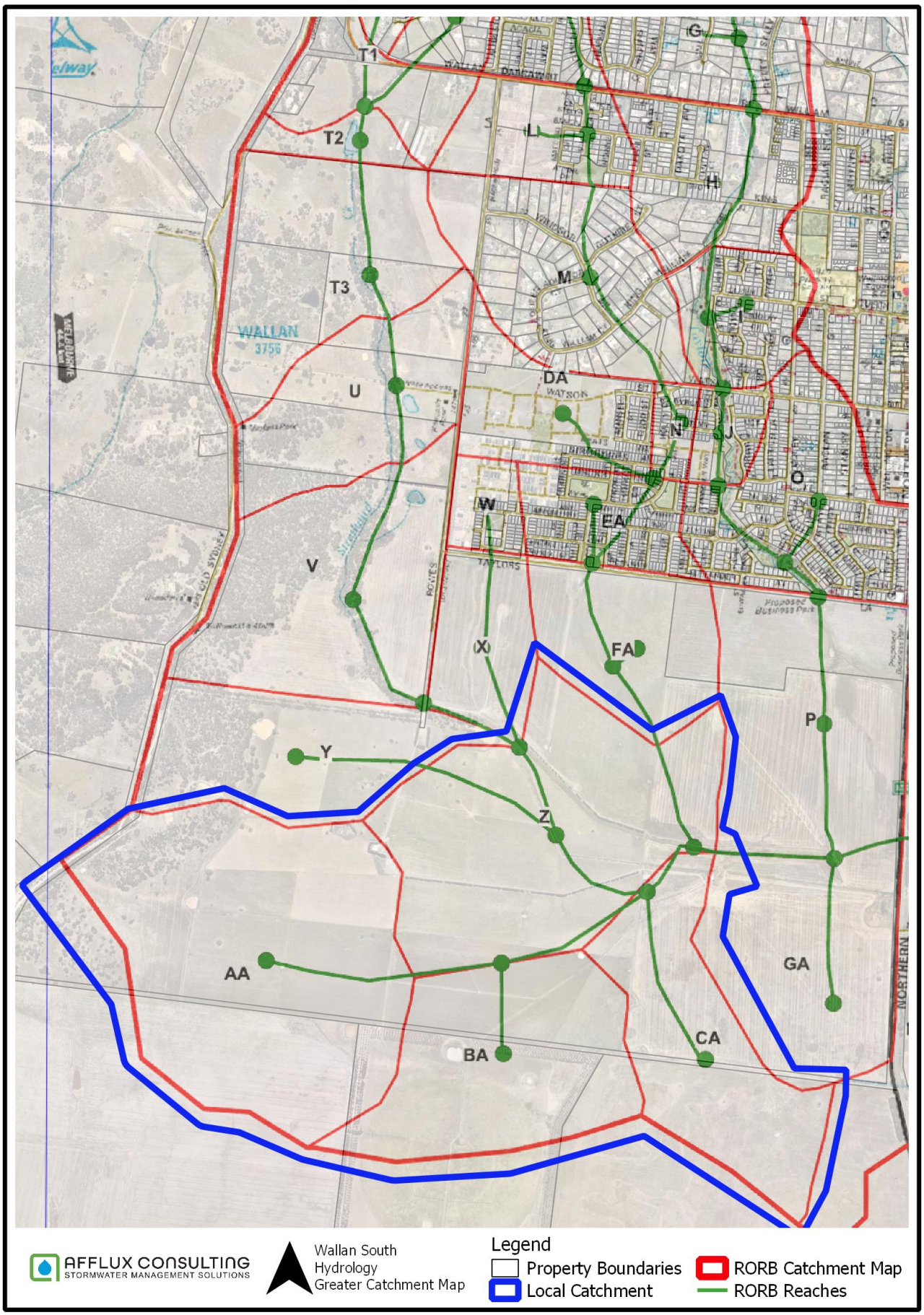


Figure 4. RORB model catchments and reaches

RORB Model Parameters and rainfall information

The supplied parameter files were supplied with the following losses and model parameters. This is consistent with the ARR Data Hub parameters. Additionally, we trialled a number of alternative parameters using hydrologic adjustment calculations to understand the uncertainty of the model. The range of possible flows are shown below, with the provided parameters highlighted (Figure 5).

Input Data	Value
Region	Southern Slopes
Impervious Losses	IL: 1 mm CL: 0 mm/h
Pervious Losses	IL: 20 mm CL: 3.5 mm/h

Table 1. RORB Model Parameters

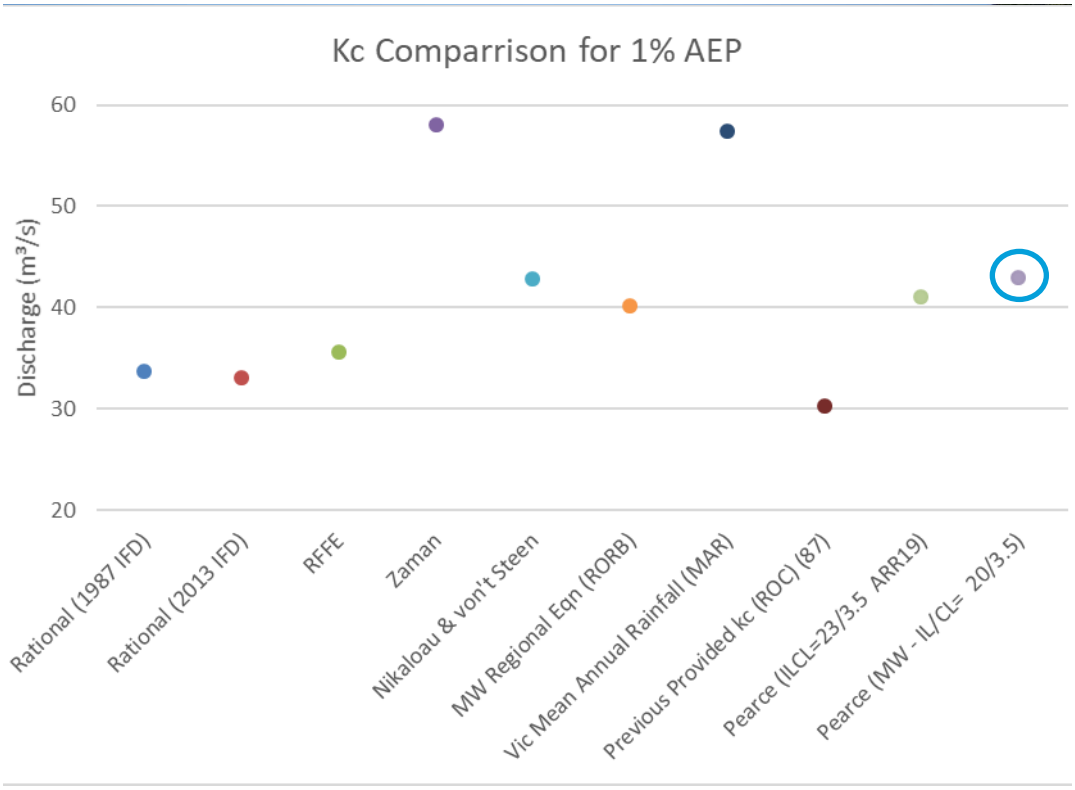


Figure 5. Comparison of Kc Estimates

The temporal rainfall patterns were taken from the ARR Data Hub as per guidelines, and as shown below, “Southern Slopes - Mainland” data set was applicable for this site.

2.2. Critical Duration Storm Results

The Ensemble Event approach was adopted, as per ARR2019 guidelines involving the use of a set of 10 temporal rainfall patterns. All temporal patterns were run from the 10min storm to the 120hr storm from gauged local catchments to derive a set of hydrographs for each event AEP and critical duration. This was run for the 1 year, 2 year, 10 year and 100 year ARI events. Noting that the 3 month event was derived from the 1 year event and the 100 year event was run for both the regional and local catchments. As recommended, only the mean hydrograph for the critical duration storm results are selected for design. Once the estimated rainfall magnitudes were decided upon, the hydraulic model is used to distribute the flows.

3. Flood Modelling

As part of flooding investigations for the site, the regional and local stormwater conditions were assessed.

A regional model was constructed to understand flood mechanisms during a 1% AEP storm event. The model was built and run in TUFLOW using a linked 1d/2d approach, parameters and data sources.

3.1. Combined Modelling Approach

The modelling approach combines a number of hydraulic and hydrologic techniques as a hybrid approach. The hybrid water inputs allow the model to capture the various flood movements and flow effects.

The major factors influencing flooding on the site and relevant catchment includes:

- the impact of flooding from rainfall on the immediate catchment;
- interactions with nearby creeks, creek tributaries and major overland flow paths due to large upstream events (particularly from Wallan township).

As a result, the method for modelling the hydrological process through this catchment is:

1. Determine the rainfall excess of each sub-catchment (in RORB) and identify peak upstream inflow hydrographs at relevant boundaries.
2. Develop a greater regional model for the area using the peak flows for the identified 1% AEP storm duration.
3. Introduce flows into the model at upstream source area boundaries to assess creek/overland flow path systems and apply rainfall on the whole of catchment using Rain on Grid (ROG) methodology.
4. Identify major overland flow interactions between sub-catchments.
5. Develop high-definition local model for the immediate site surrounds.
6. Determine the critical storm duration for the 1%, 10%, 50%, 63.2% and 98% storms (in RORB) for the local catchment and determine the associated rainfall excess.
7. Apply rainfall excess with direct rainfall (hydrograph distribution) to the grid areas relevant to the assessment of Hanna Swamp using the Rain on Grid (ROG) methodology within Tuflow to distribute the flows.
8. Assess the impact of flooding from rainfall on the immediate catchment.

3.2. Model Parameters

Initial model setup for the catchment model involved the accessing survey surface levels to ensure they represent an accurate depiction of the site at the proposed grid resolution. Model extent is based on topographical catchment boundaries and the bounds of Wallan South PSP. The catchments are kept consistent between hydraulic and hydrological models. Land use in the model has been determined based on inspection of aerial imagery and visual inspection and has been used to inform Manning's roughness factors in the model. Downstream boundary conditions have been established based on an examination of topography. This has been set a considerable distance downstream to ensure no undue model boundary influence.

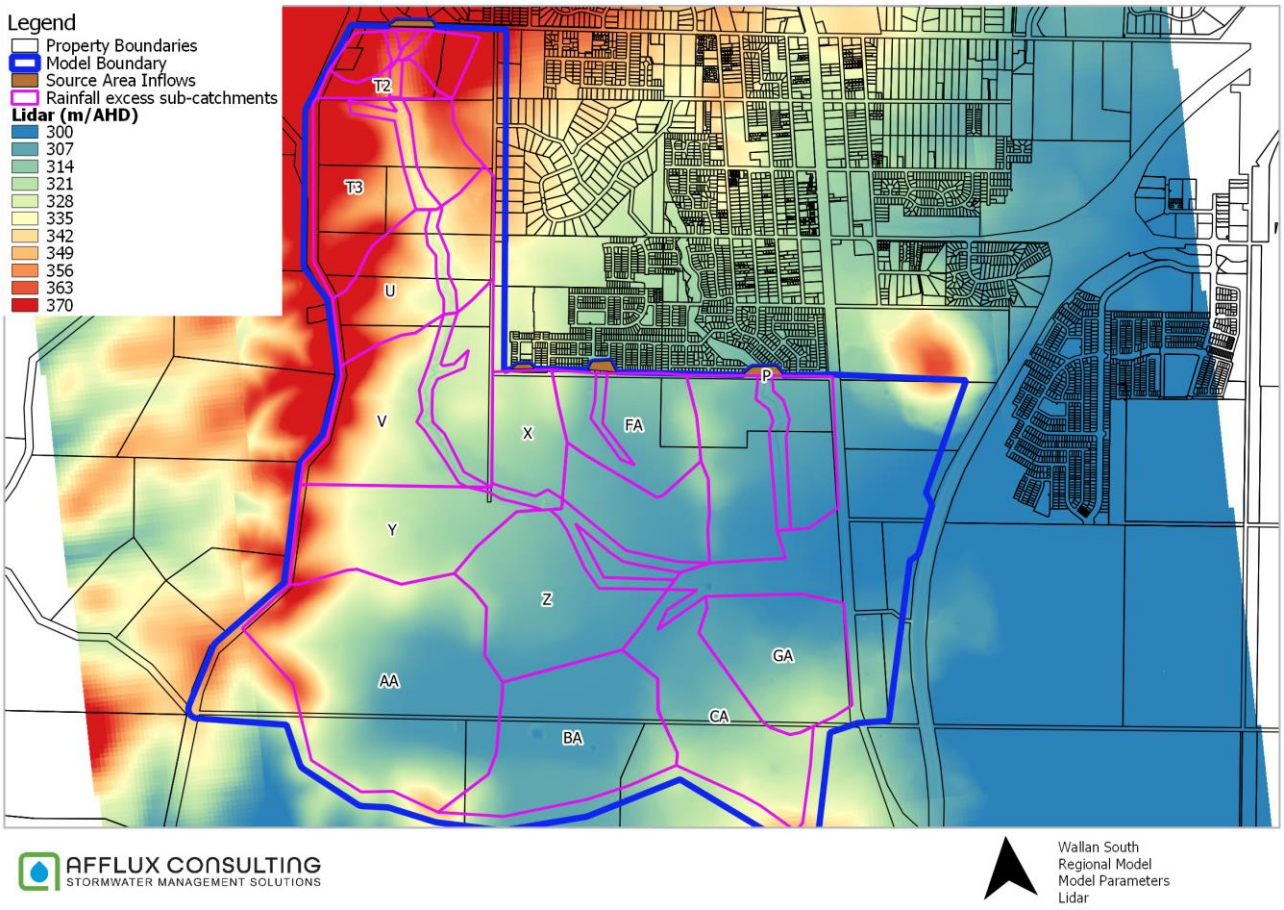


Figure 6. Digital elevation model and model extent

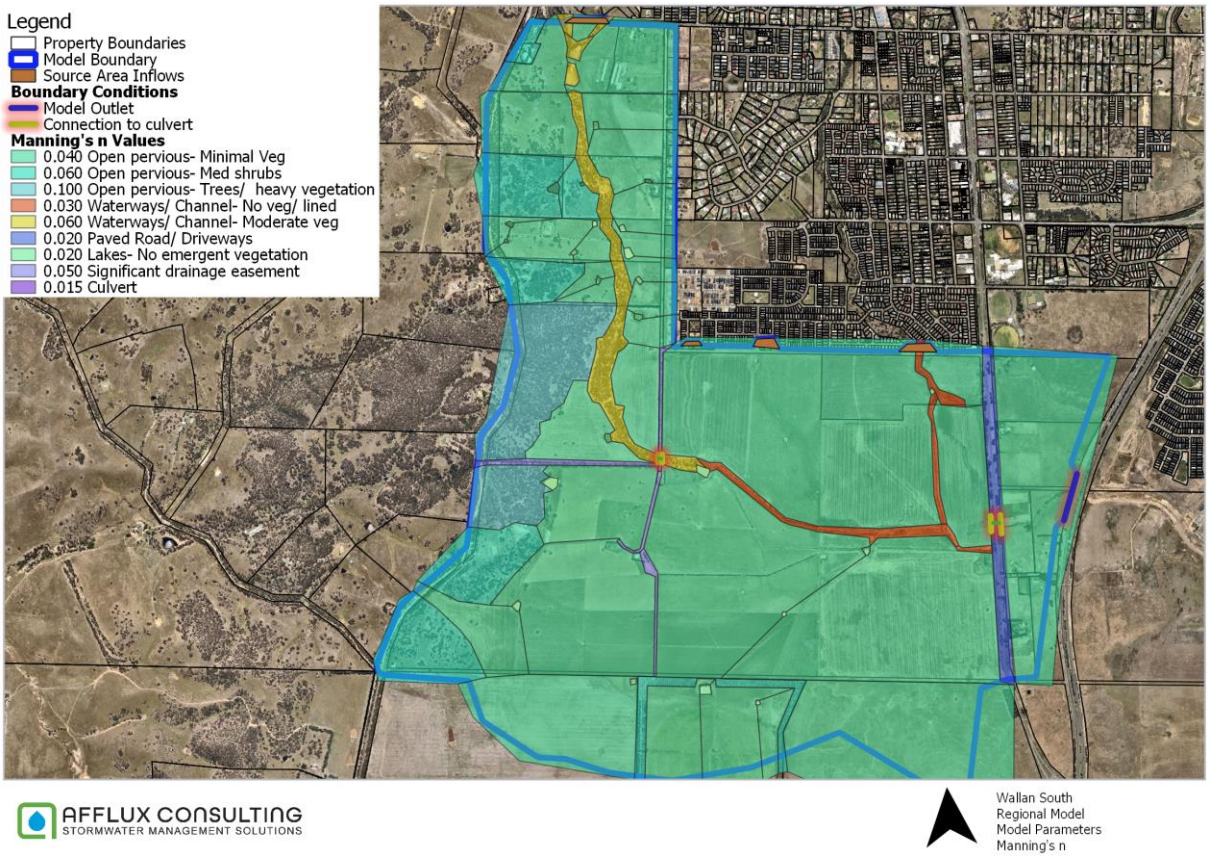


Figure 7. Model parameters and setup

3.3. Regional Flood Assessment

The impact of flooding from rainfall on the relevant regional catchment was assessed using a whole catchment model. The flood depths and peak flows from the critical event in the catchment flood modelling can be seen in Figure 8.

The key points from this analysis are:

- Strathaird Creek is not connected to Hanna Swamp
- Hanna swamp extent collects rainfall runoff from sub-catchments AA, BA and Z (south)
- Sub-catchment CA and Z (North) are not indicative of natural catchments flowing into Hanna Swamp
- The peak flow depths through the Hanna Swamp extent are around 0.2-0.3m deep in the 1% event; and
- Hanna swamp extent discharges towards the greater catchment outfall.

Shown in Figure 9 the flows within surrounding sub-catchments (identified in RORB model) were assessed alongside the local contours to estimate the estimated swamp catchment in current conditions. As shown, catchments CA and the northern portion of catchment Z are included within the model as the assessment of major overland flow paths indicate interactions with downstream swamp outflows and remain in the local model for accuracy. That is, and Strathaird Creek does not interact with Hanna Swamp.

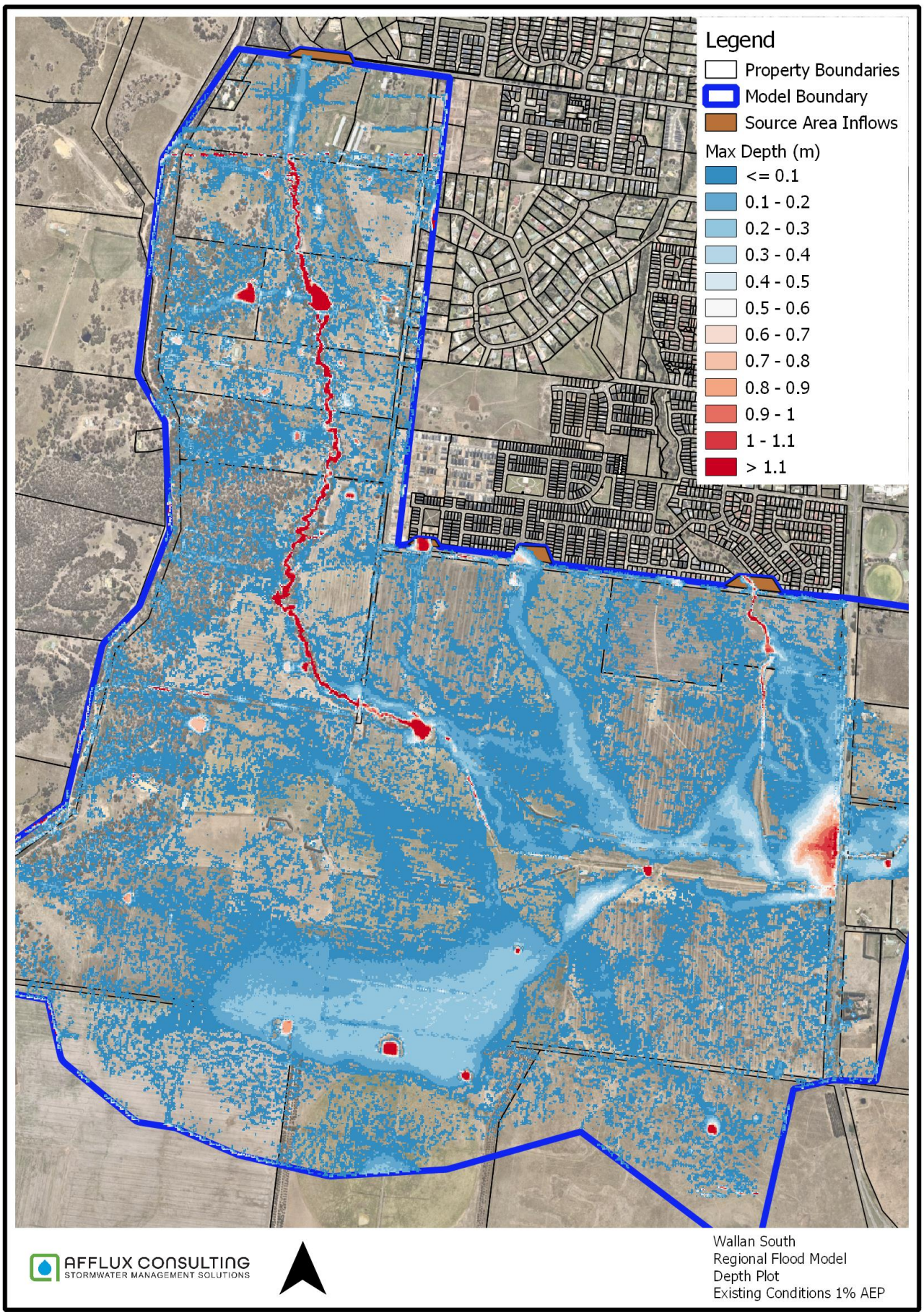


Figure 8. Regional flood model depth plot - 1% AEP

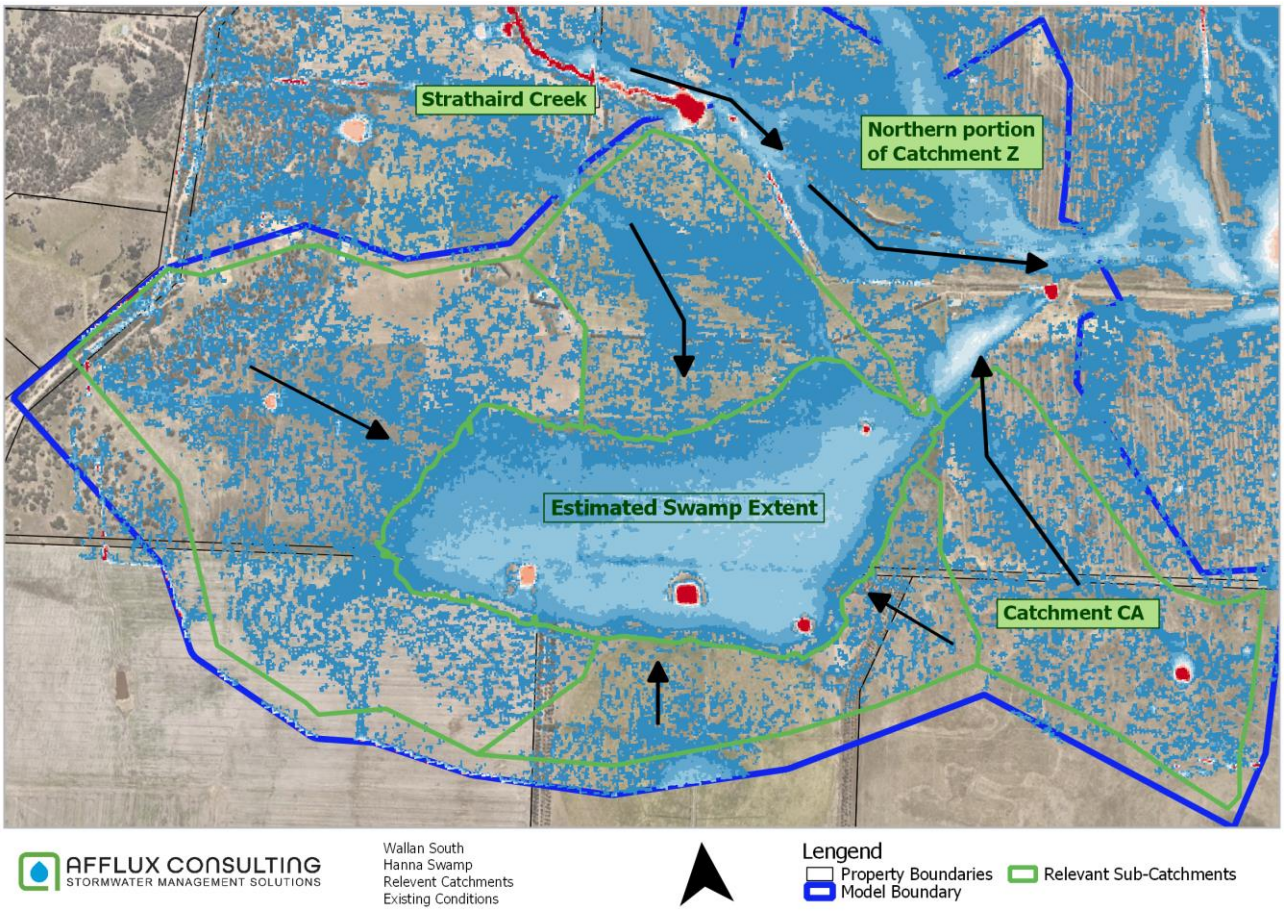


Figure 9. Local model boundary

3.4. Local Flood Assessment

Flows for critical storms (as defined in the hydrology section) were re-run through the area defined by the local model extent in Figure 10.

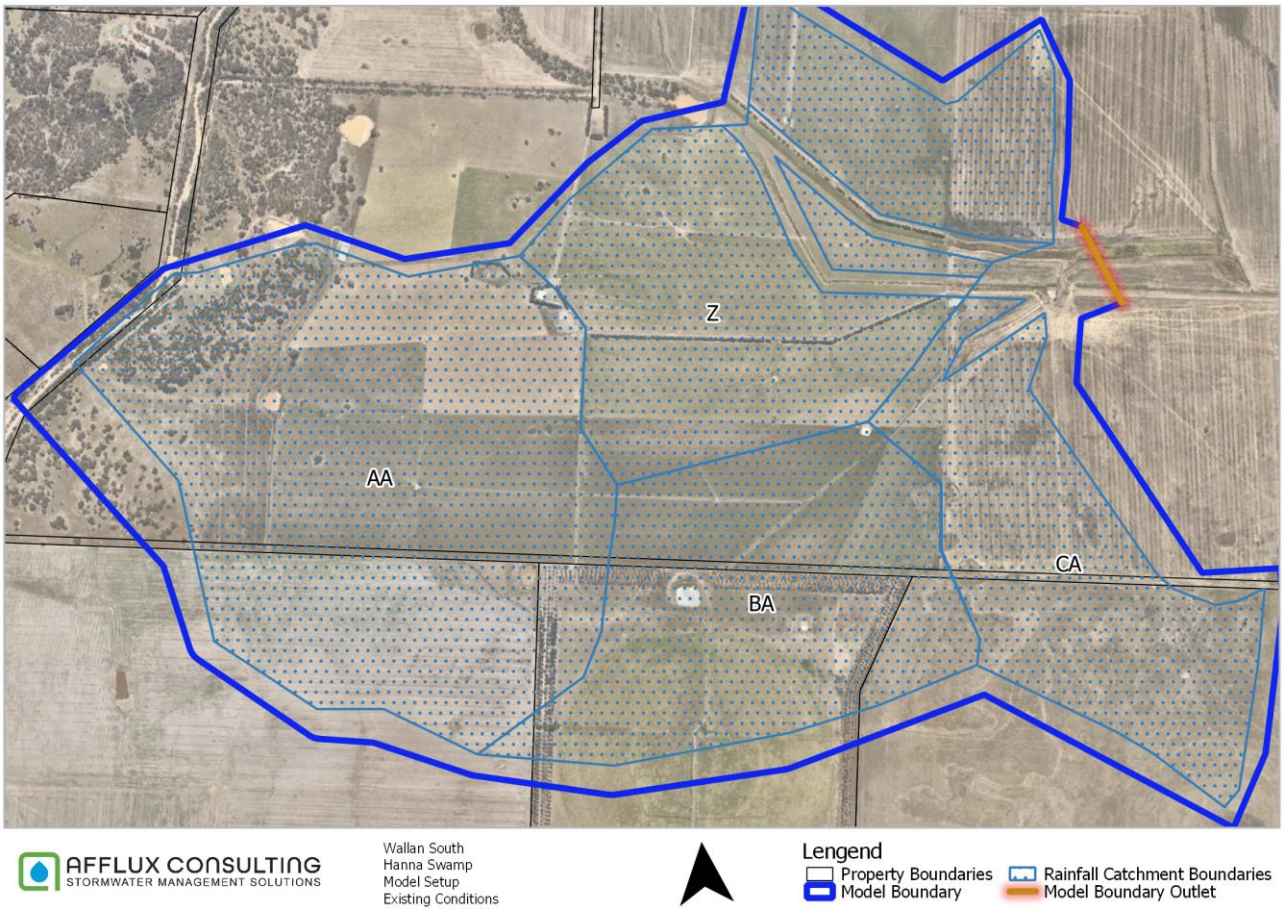


Figure 10. Local Site Model Setup

The assumptions made for this model were similar to those for the extended catchment model, with additional assumptions including:

- Critical duration storm presented for each of the storm frequencies plotted.
- ROG inflows (i.e. rainfall excess hydrographs) from key sub-catchments were defined by critical storms as identified within hydrology section
- Higher definition grid resolution was used

The flood model results for existing development conditions are plotted below.

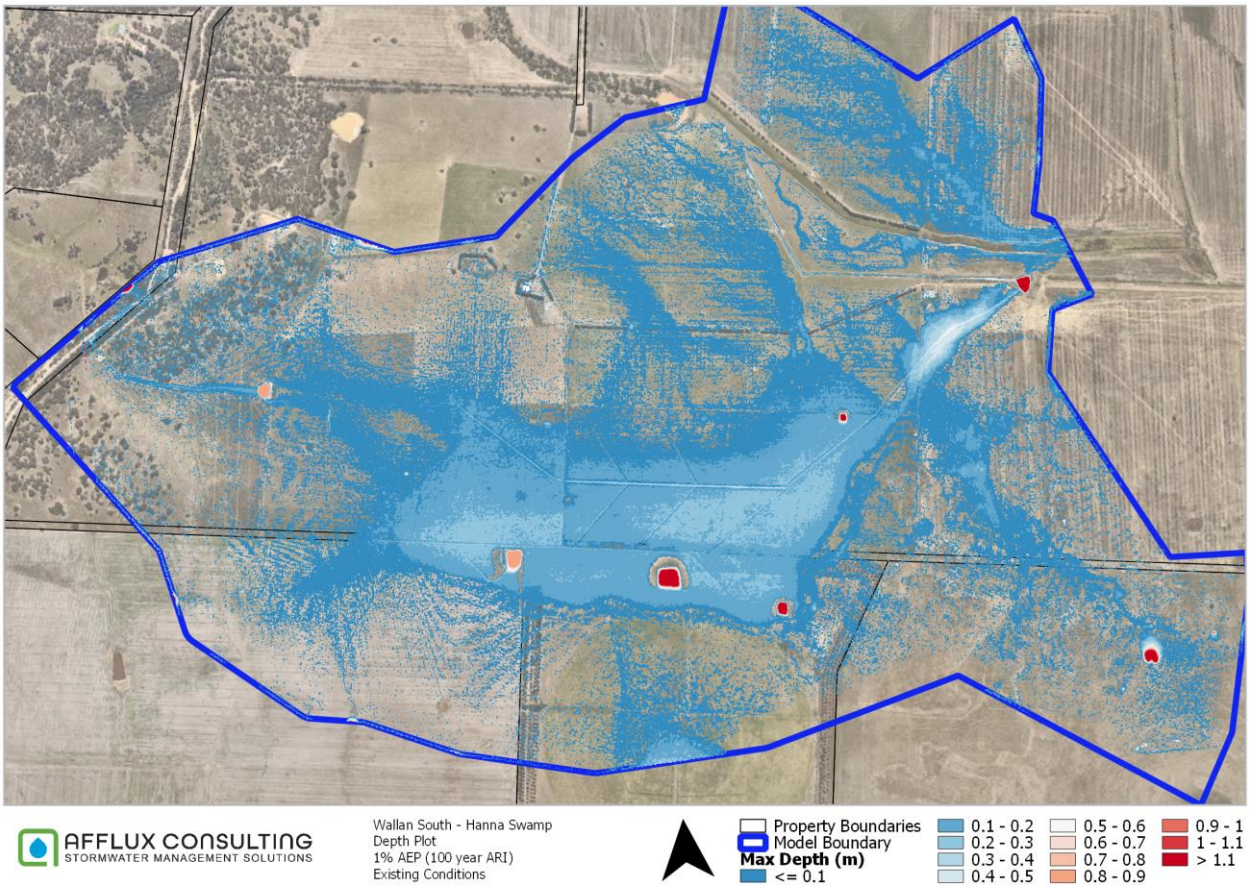


Figure 11. Local flood model depth plot - 1% AEP (100y ARI)

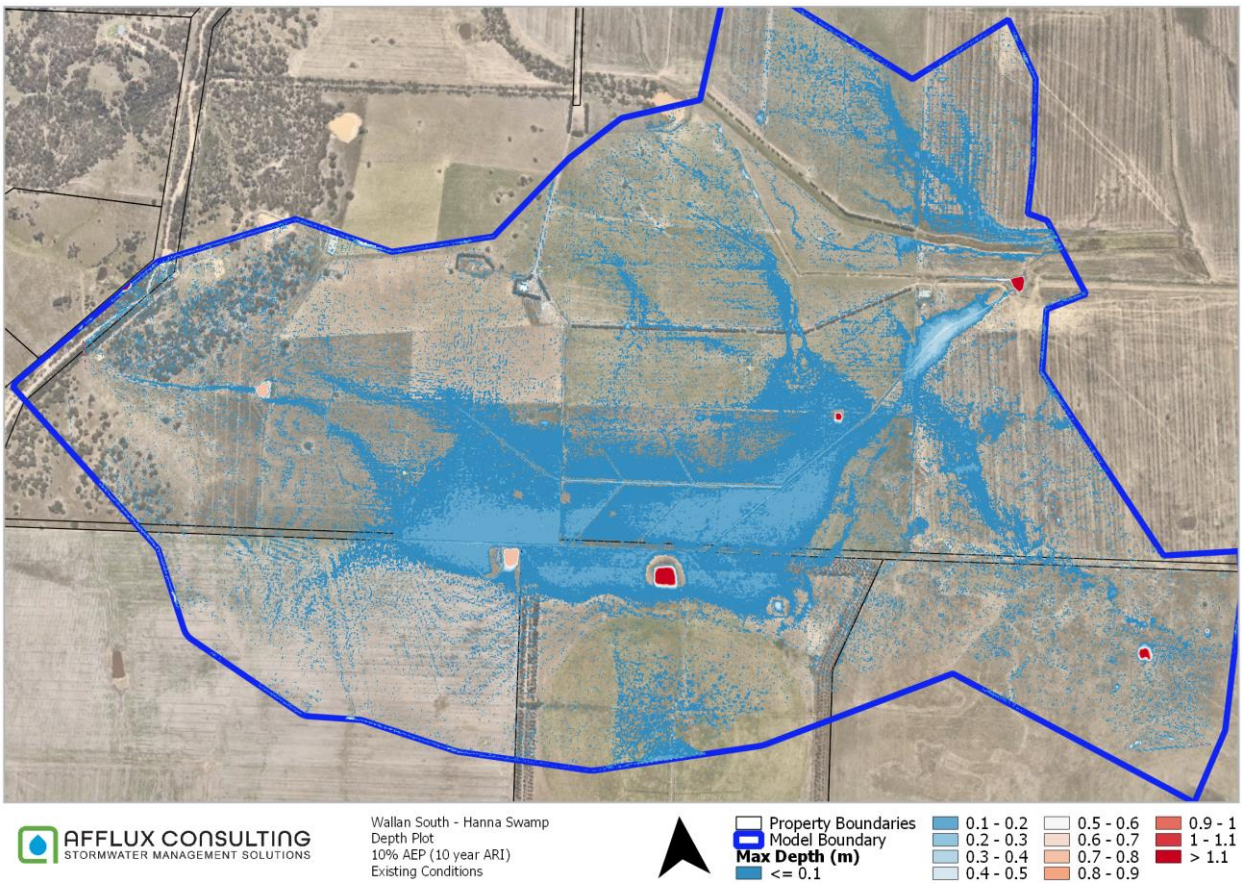


Figure 12. Local flood model depth plot - 10% AEP (10 yr ARI)

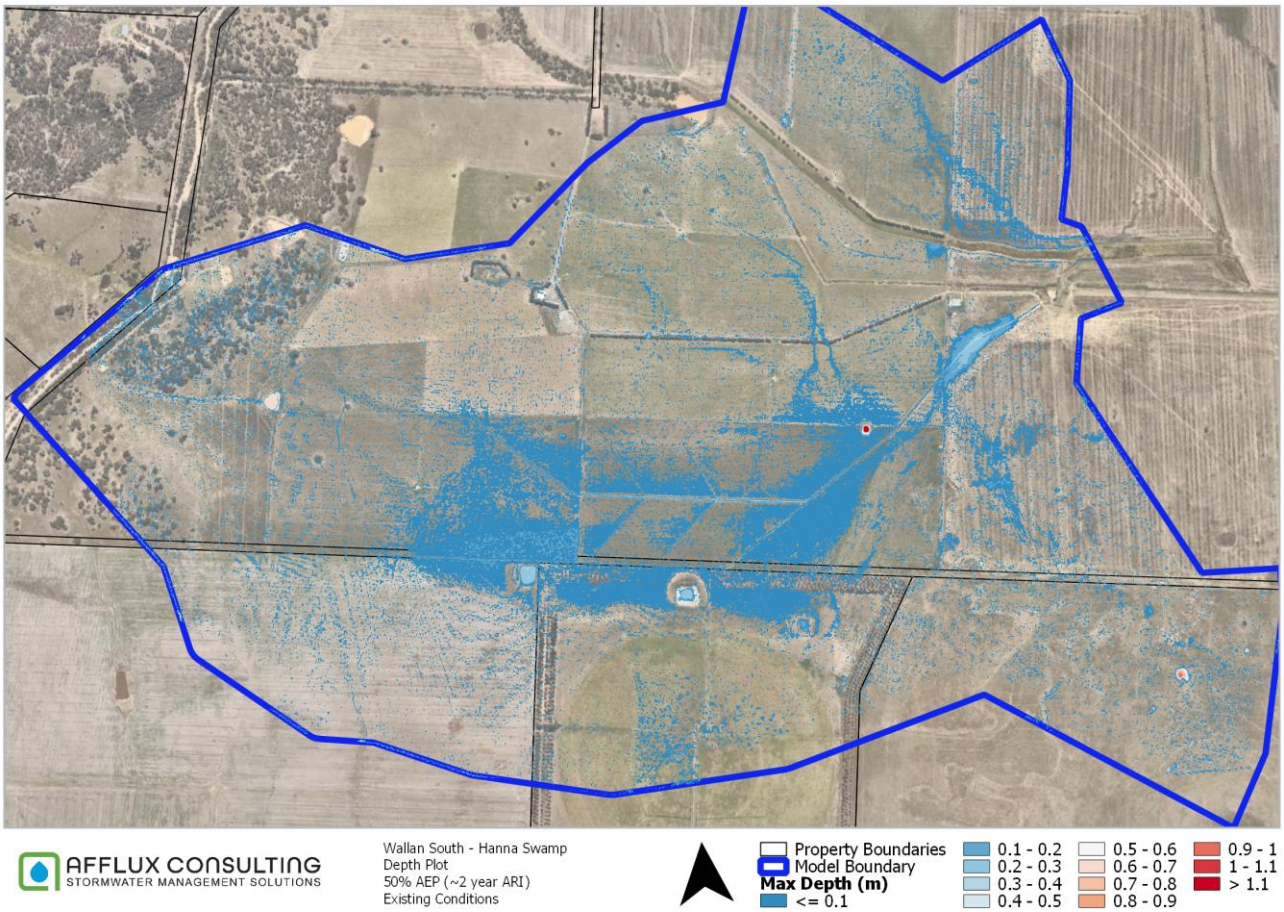


Figure 13. Local flood model depth plot - 50% AEP (~2yr ARI)

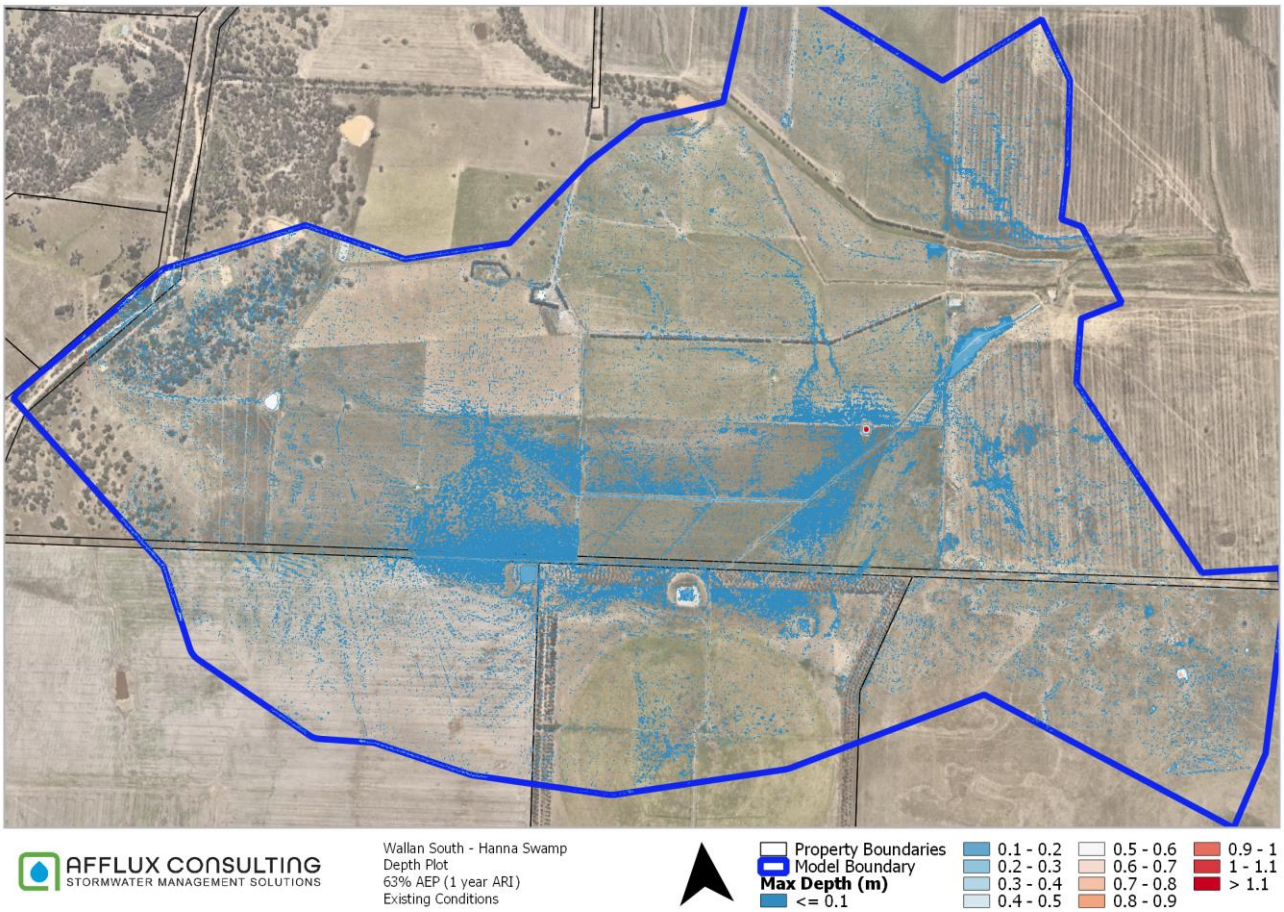


Figure 14. Local flood model depth plot - 63.2% AEP (1yr ARI)

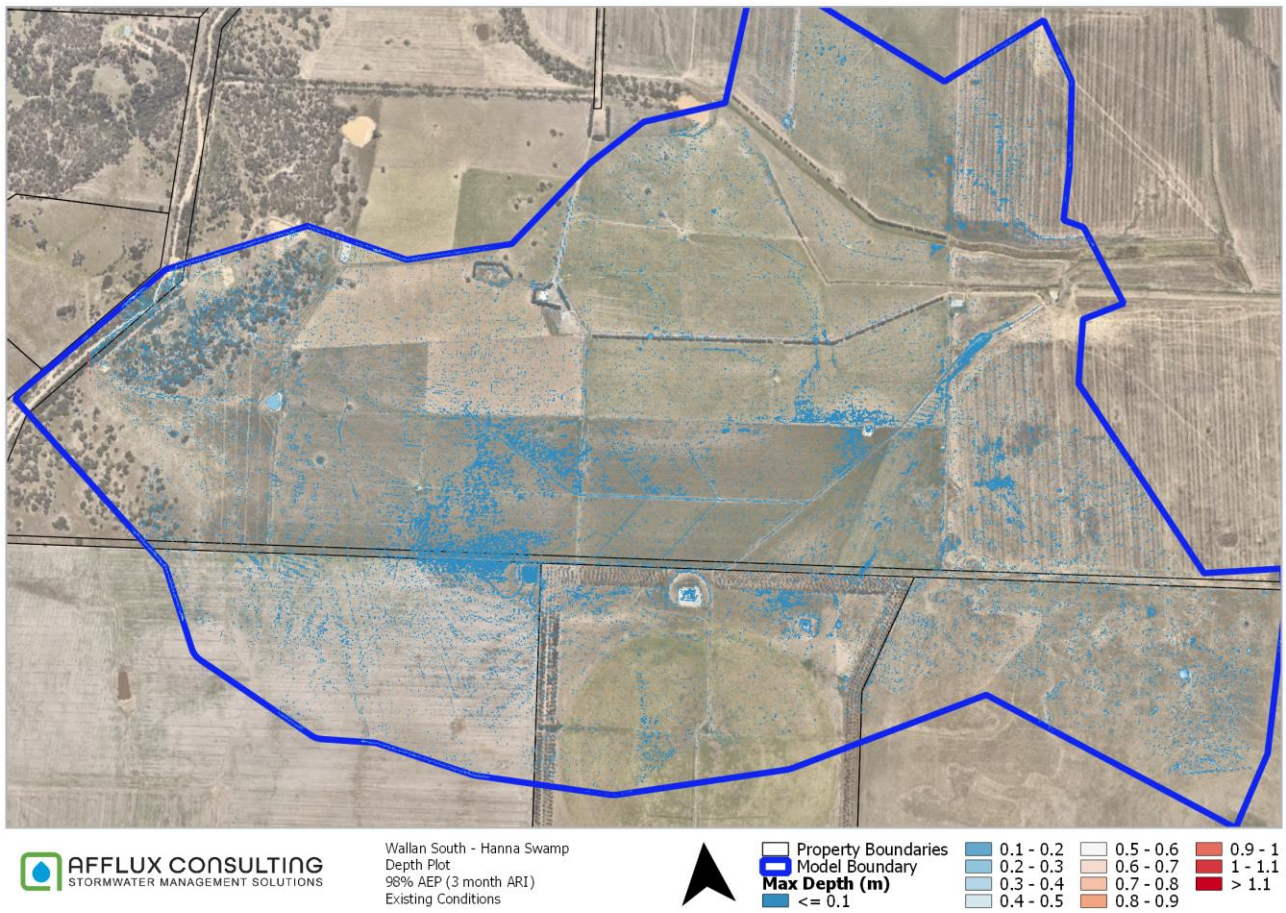


Figure 15. Local flood model depth plot - 98% AEP (3 month ARI)

These local flood models have shown that the area formally known as Hanna swamp in now well drained and retains little water during design flood events. The mapping shown only shows the maximum depth in ponded throughout the entire design event, and as can be implied by the low depths, the water quickly drains from the area post rainfall. If the system was more confined, greater depths and a longer duration of flows would be seen. In particular as shown in the lower events (63/98% AEP) the water does not accumulate and drains directly from the system. This is the opposite of what would be seen in a more intact swampy area, with low flows confined on site for long periods.

This concept is further explored in the site water balance section below.

4. Water Balance

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) was used to undertake the analysis of the swamp's expected inundation frequency. Guidance for model inputs was sourced from the IDM, Melbourne Water's MUSIC guidelines and local catchment knowledge.

The model has been set up with the following notes:

- The measured catchments are in alignment with hydrological models (Figure 9).
- Swamp outflow conditions are based on local survey and the hydraulic models to define the outflow relationships.
- The model is built using a range of rainfall templates that include 10-year and greater periods of rainfall data
- The model is built using the most recent guidelines including soil losses field capacity
- All other parameters were set as per Melbourne Water Guidelines.

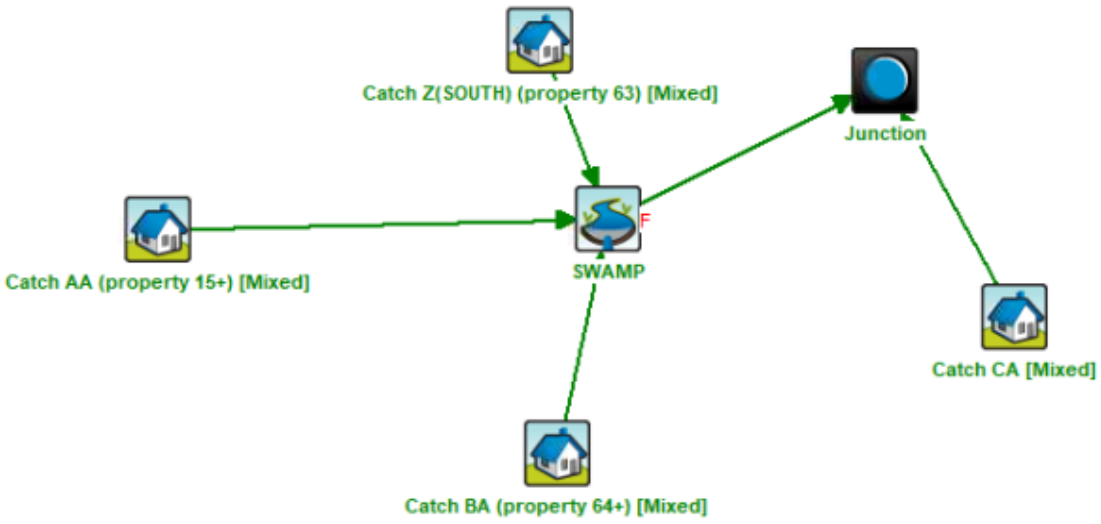


Figure 16. MUSIC model

The model is designed to outline some of the key hydrologic and runoff generation processes specific to Wallan and Hanna Swamp extent including:

- Infiltration excess runoff
- Rainfall
- Overland flow
- Evapotranspiration

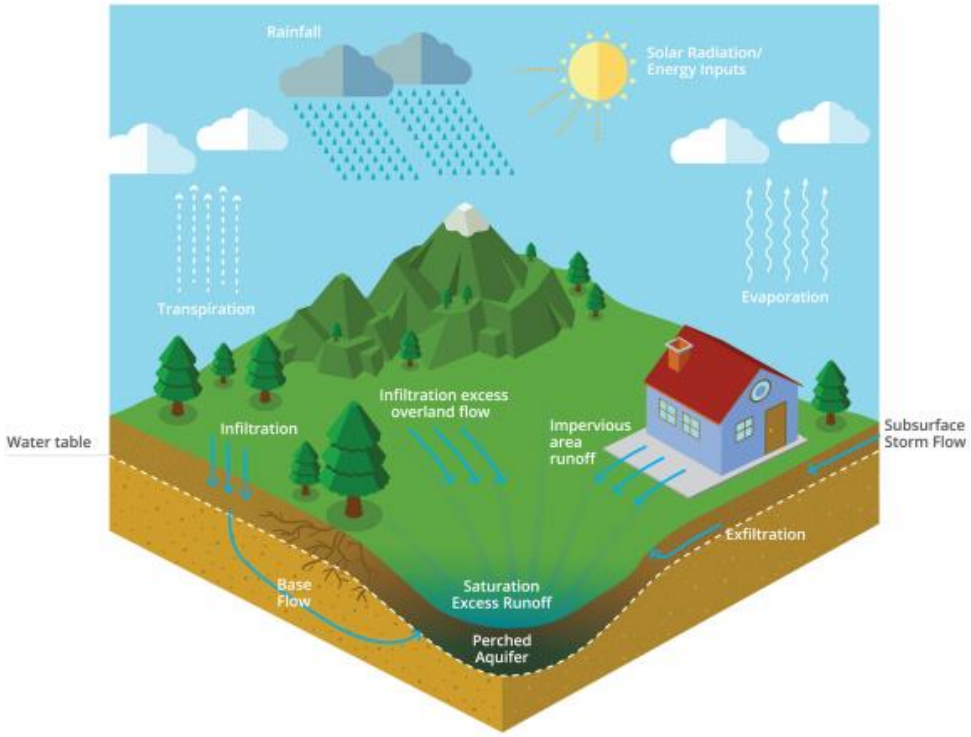


Figure 17. Catchment and Runoff Generation Processes

Source: ARR Book 4 - Catchment Simulation for design flood estimation.

4.1. Rainfall Information

To model an "average" rainfall period the stormwater industry in consultation with Melbourne Water have defined a number of 10 year periods of average rainfall for 6 distinctive rainfall climates within greater Melbourne.

The catchment is within the isopleth of the Melbourne City rainfall station (as defined by the Melbourne Water guidelines) and as such the associated average 10 year sequence of rainfall data was run at a 6 minute interval to match the lowest Time of Concentration of the catchment. The rainfall period used (the most average period) is from the 1950's for this area.

Expected rainfall ranges for Melbourne City are 650-750mm, in line with the annual rainfall expectations for this area. A separate model using a closer rainfall station was also tested below.

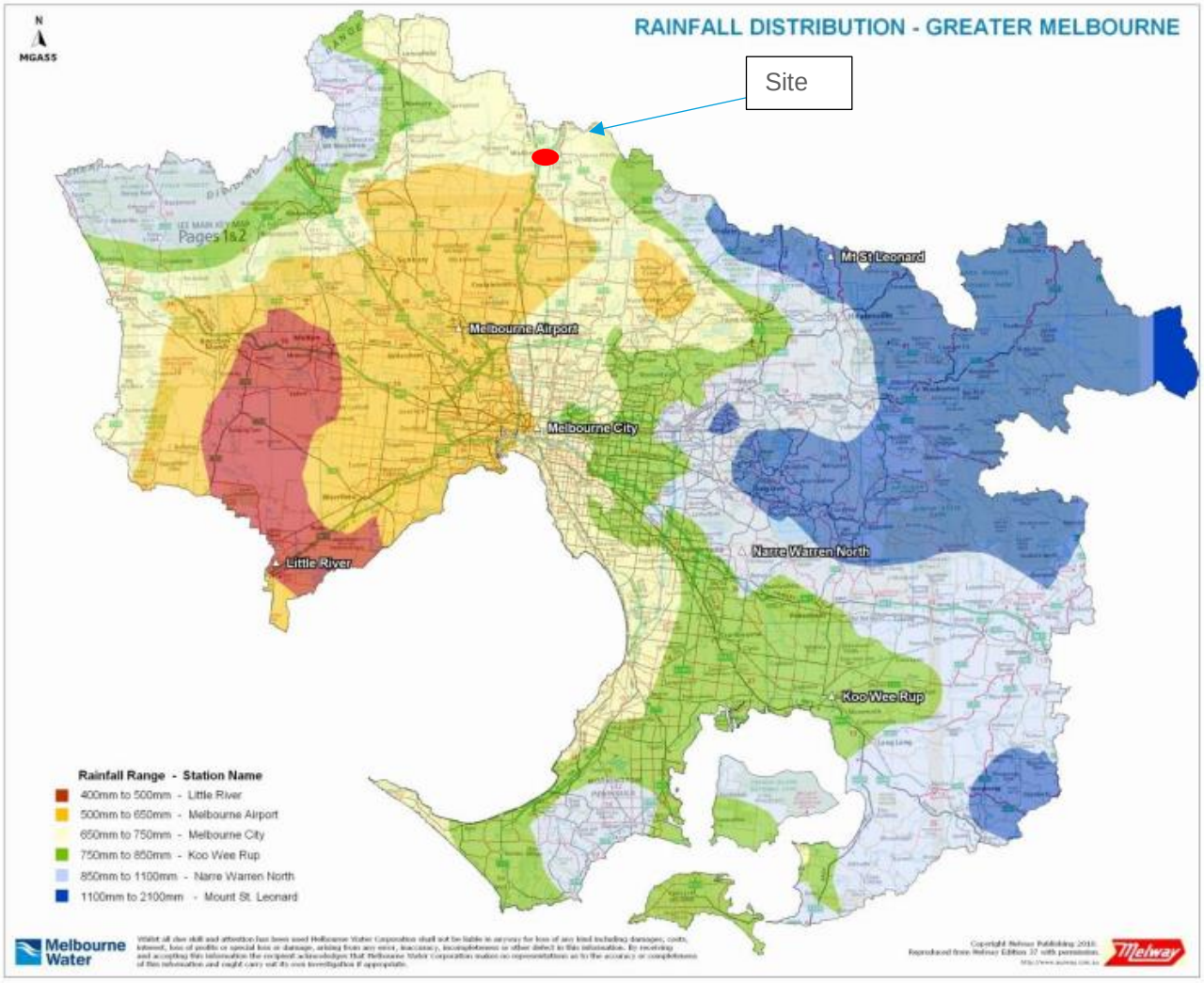


Figure 18. Greater Melbourne rainfall distribution

Source: Melbourne Water MUSIC Guidelines

4.2. Evapotranspiration Information

Evapotranspiration inputs are essential to MUSIC and are based on expected evaporation rates as estimated by BOM within their class A pan evaporation estimation processes. All the ~275 recording stations contain at least 10 years of evaporimeter data. Expected evaporation levels for this area are between 1200-1400mm (Figure 19).

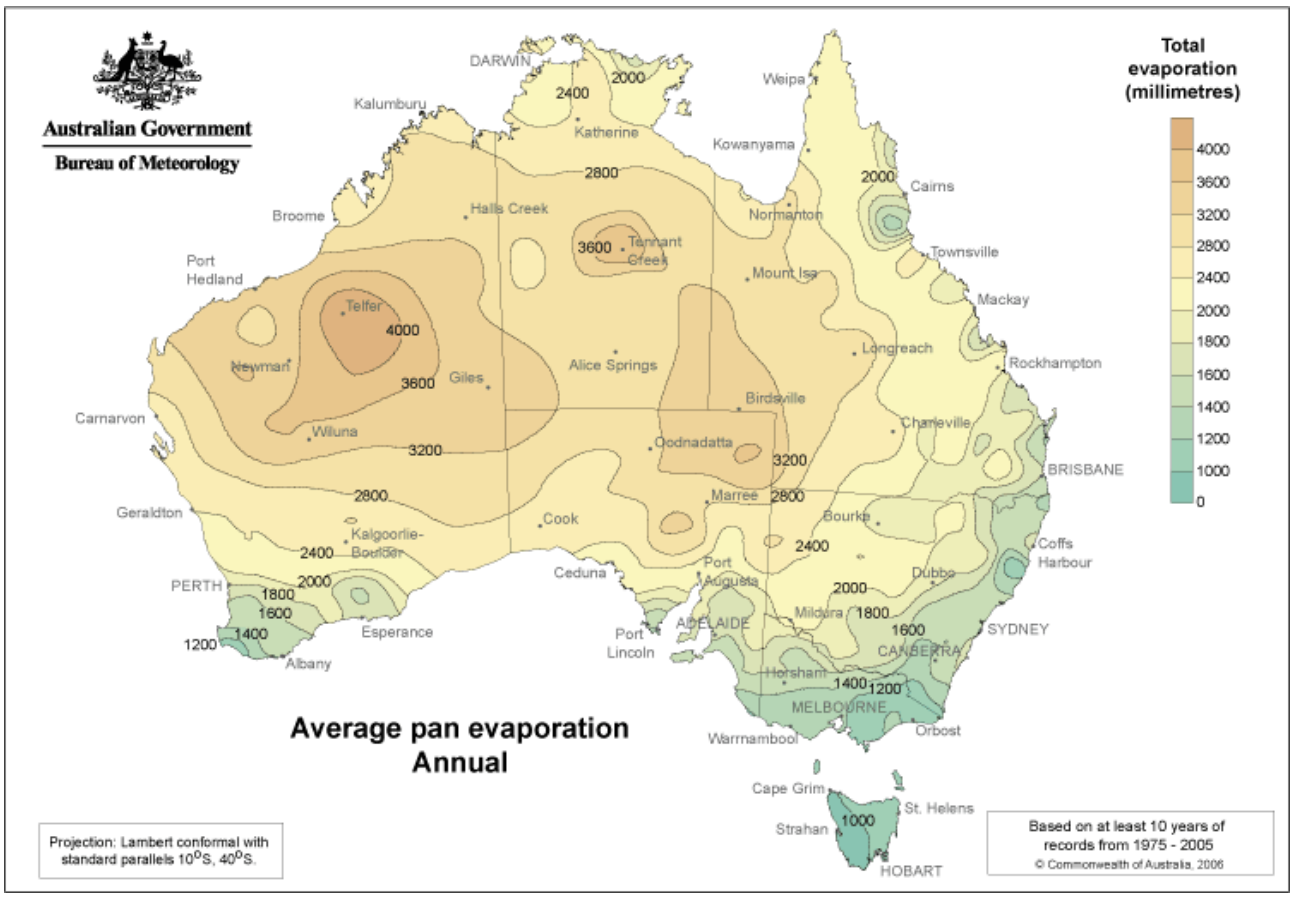


Figure 19. Average Annual pan evaporation map (mm)

Source: Bureau of Meteorology

4.3. Soil Infiltration Information

The rate at which rainfall infiltrates into the soil is dependent on:

- Soil saturation
- Rate at which water moves across soil surface
- Soil compaction and imperviousness
- Infiltration capacity of soil type

(ARR Book 4, p 6)

This catchment is expected to contain Silurian Kilmore Siltstone overlain by Newer Volcanics basalt flows.

As such, exfiltration rates representative of mediums clays were trialled within the swamp extent (0.36-3.6 mm/hr).

4.4. Current Condition with sensitivity checks

Sensitivity checks have been performed in subsequent analysis to assess the validity of results without in-situ soil testing, this allows comparison of the relative differences between exfiltration rates of 0.36-3.6mm/hr and a greater ability to assess expected frequency swamp inundation.

The MUSIC modelling confirms the swamp experiences significant dry out periods during an average 10 year rainfall period (Figure 20, Figure 24 and Figure 27). The water level is on the vertical access (shown in m) and time across the bottom access.

The water level exceedance graph shown in Figure 21 and Figure 25 shows the swamp is sustaining a permanent pool less than 2% of the time in the 10 year average rainfall period. This equates to around 30 days total across 10 years average, or less than 3 days per year of inundation. As can be seen in Figure 20, realistically most of these inundation events are in 3 distinctive wet periods. That is, the swamp may be active 3 times, for a total of less than 40 days combined over an average 10 year rainfall period. The individual events (noting that one of the wet periods in 1954 produced 2 inundation events) are shown in Figure 23 showing the exact periods of inundation.

Low Exfiltration (0.36mm/hr)

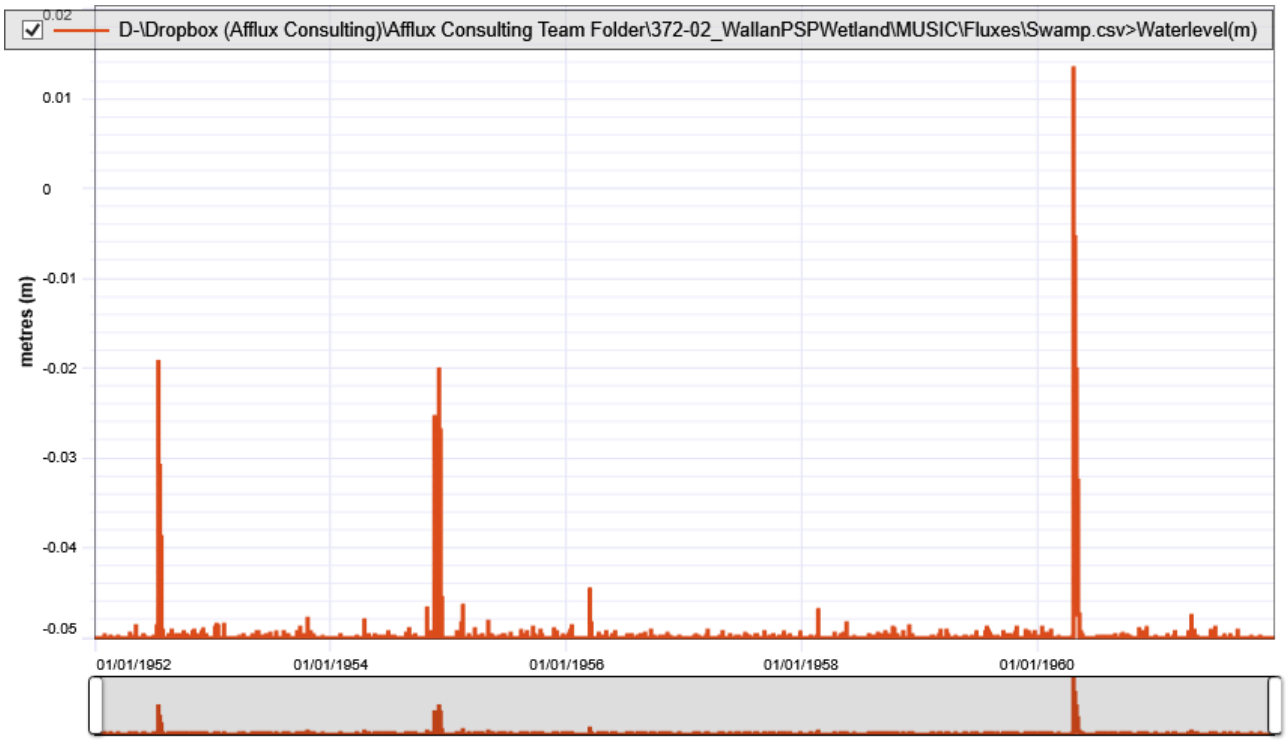


Figure 20. Current Water Level (m) - Low exfiltration

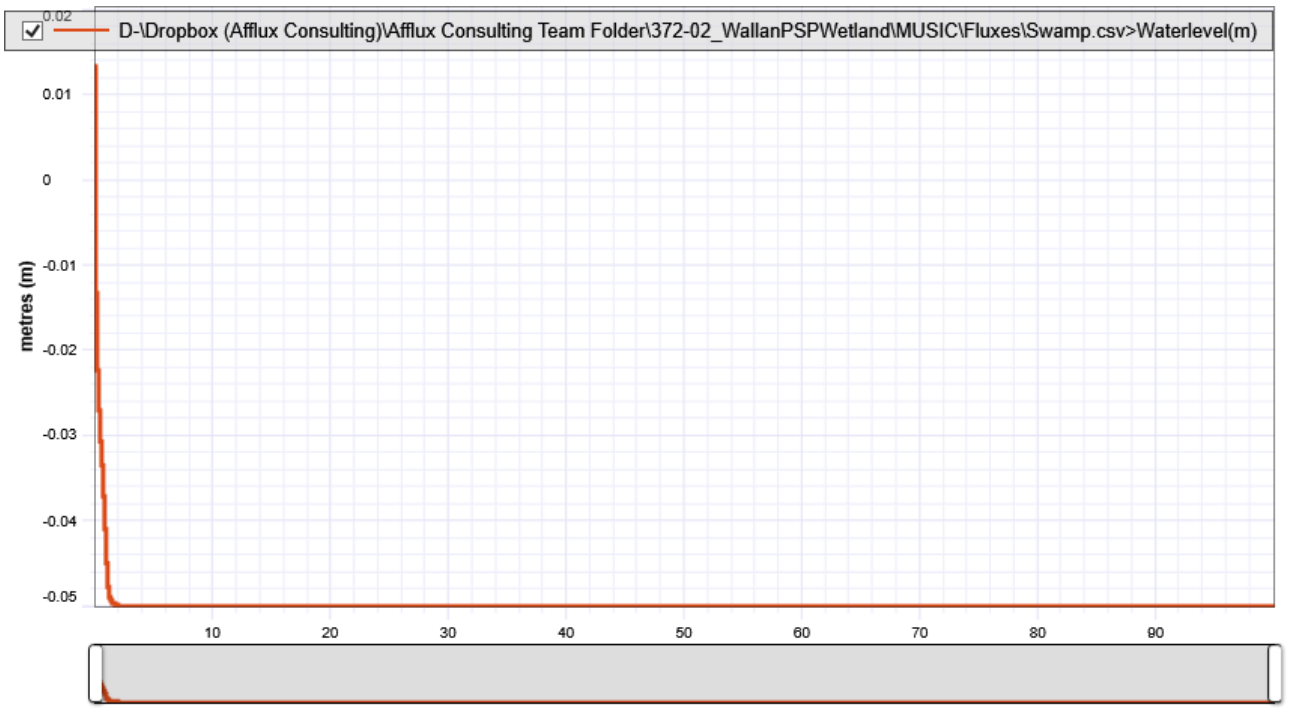


Figure 21. Current Water Level Exceedance

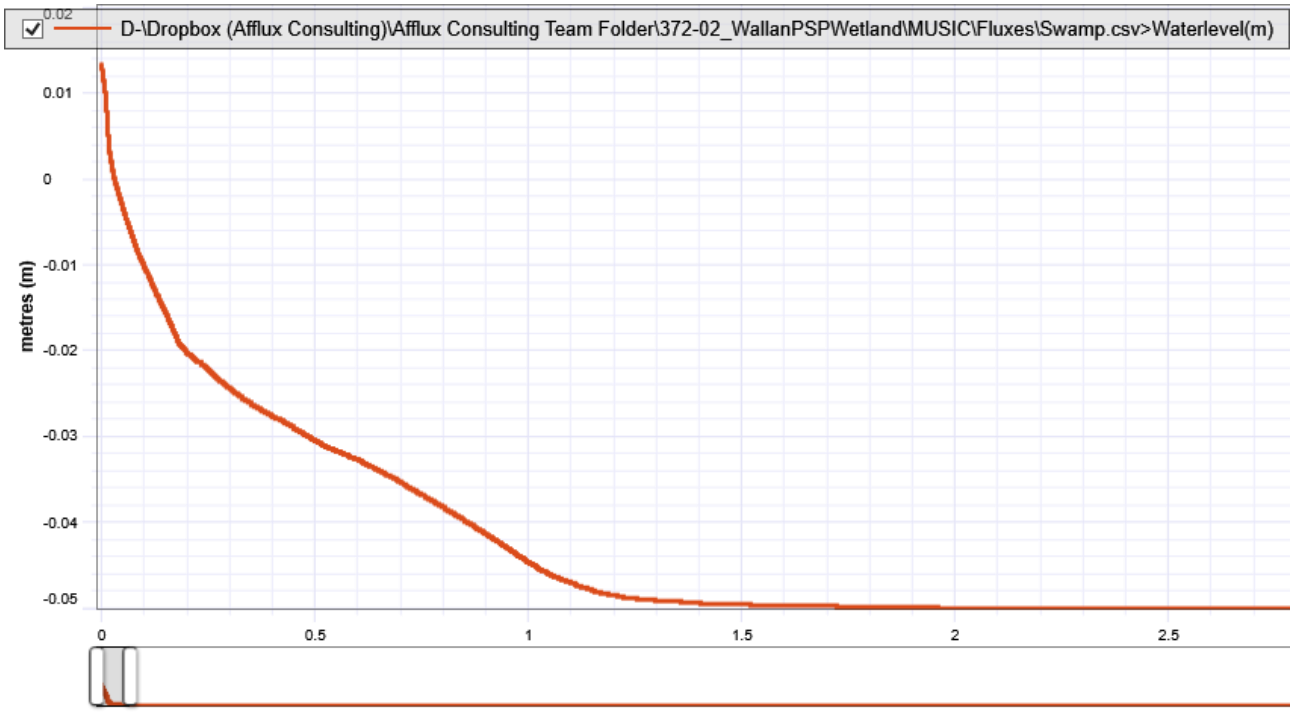


Figure 22. Close-up of expected water level exceedance

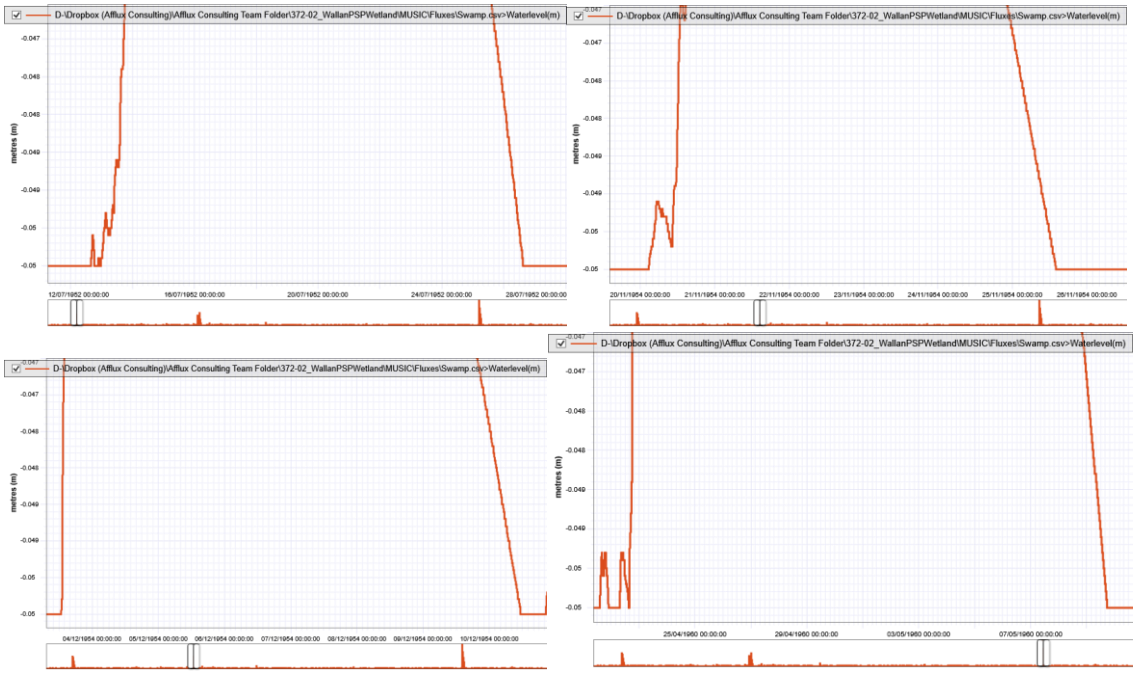


Figure 23. Close-up on events

Medium-Low Exfiltration (3.0mm/hr)

A slightly higher exfiltration rate was used to test the sensitivity of the area to groundwater rates. As can be seen this minor change significantly reduces the number and period of inundation. Realistically this shows that there is only 1 significant event across the 10 year period if this groundwater loss rate is taken into account. In the individual events (Figure 26) it shows that inundation of the area would be around 24 hours at the most. Taking this groundwater loss to a medium clay maximum (3.6mm/hr) does not show any further change to the inundation frequency (Figure 27).

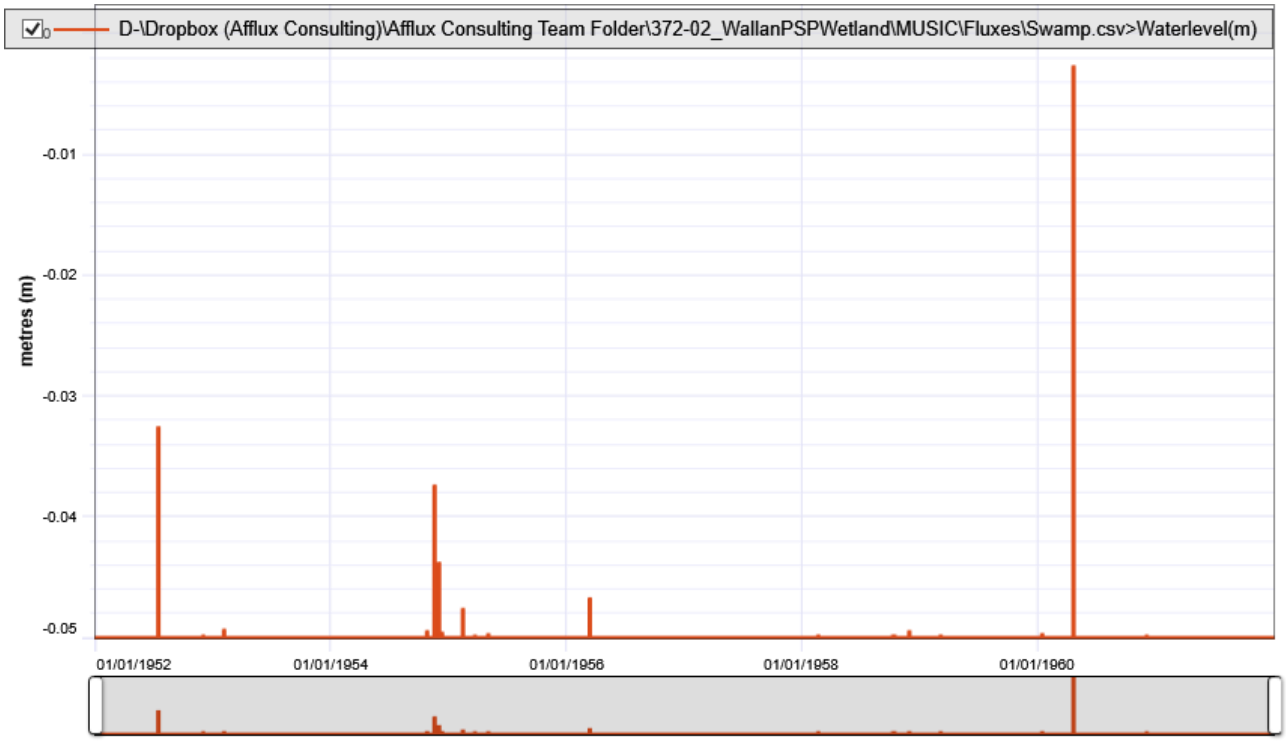


Figure 24. Current Water Level (m) - Medium- High exfiltration

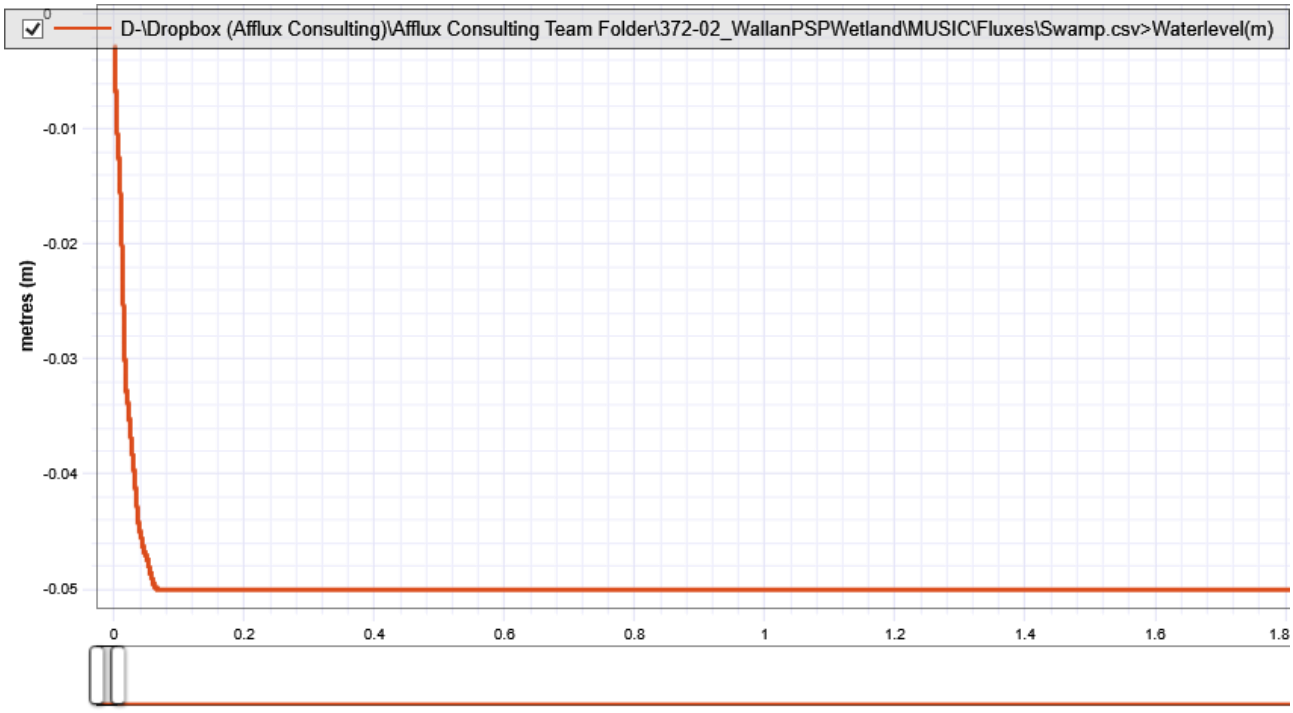


Figure 25. Current Water Level Exceedance

Zoom on events:

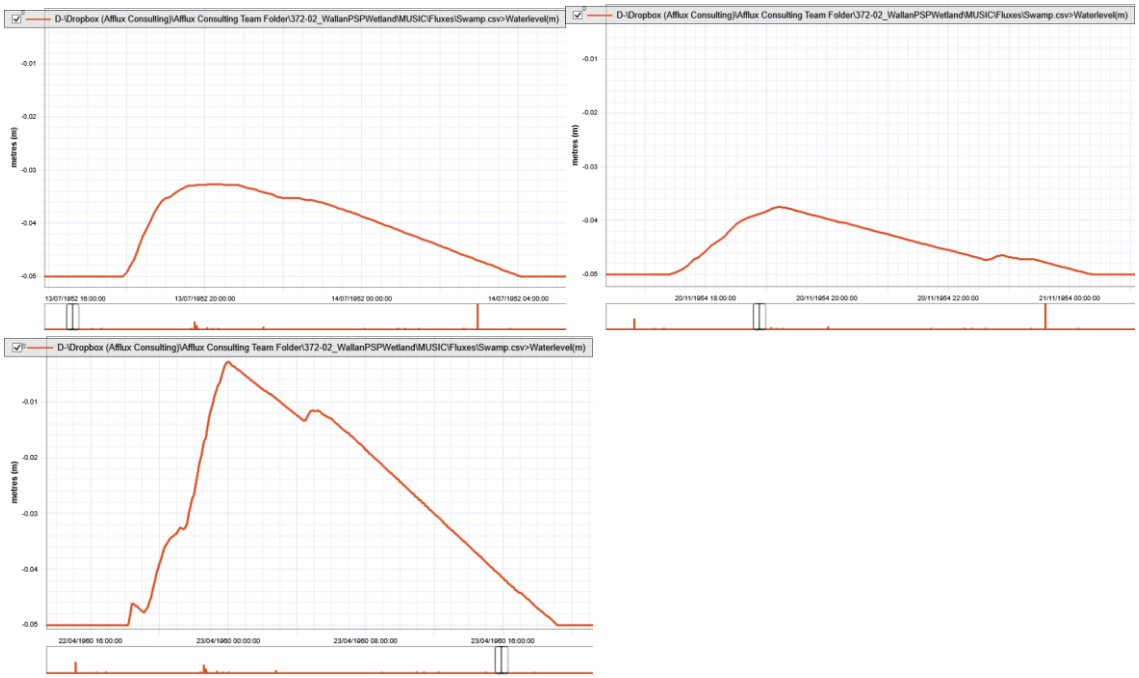


Figure 26. Close-up on events

Highest Exfiltration (still within range represented for medium clay) - 3.6mm/hr

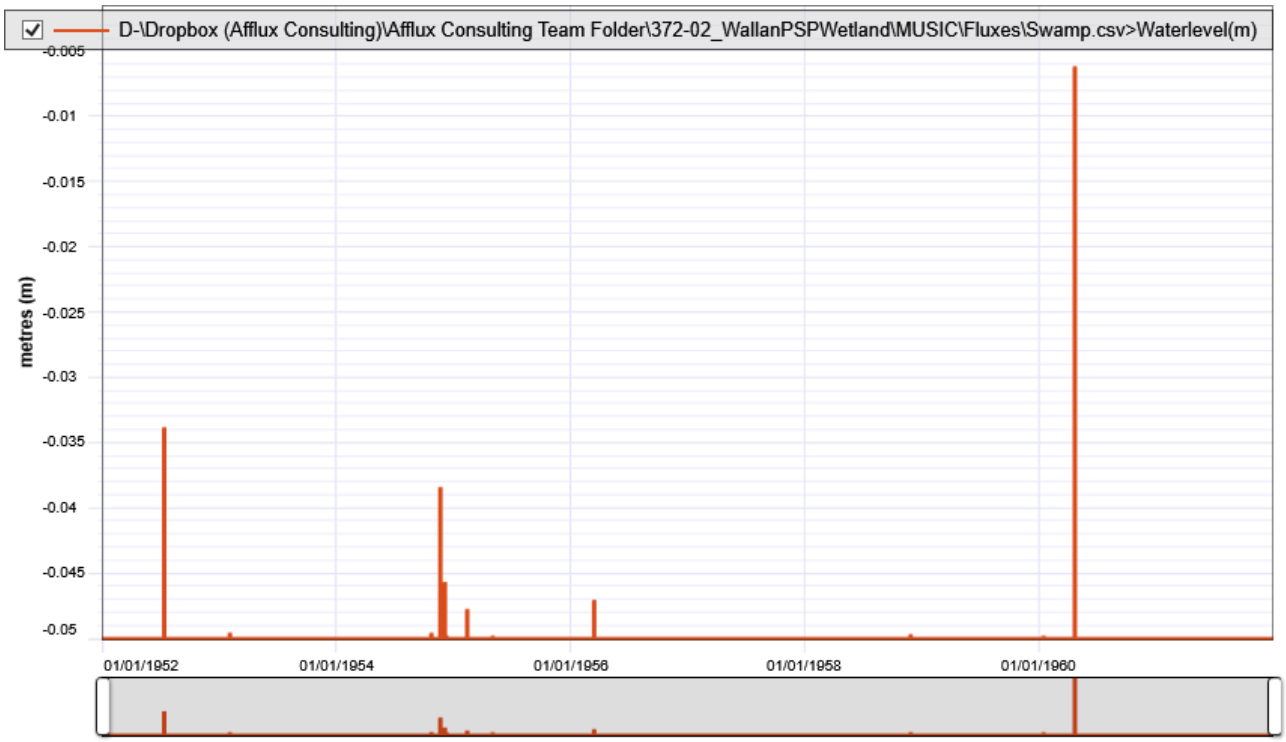


Figure 27. Current Water Level (m) - Highest exfiltration

Alternative rainfall - Low Exfiltration (0.36mm/hr)

Further sensitivity testing was done by simulation of MUSIC model with alternative rainfall and evapotranspiration inputs (i.e. not using Melbourne Water rainfall templates).

Pluviographic data was collected from approximately 40 years of rainfall observations from Lancefield recording station (station number: 87029) were input alongside the monthly average areal potential evapotranspiration data for the Melbourne City region (1930 - 1975).

Using the low exfiltration rate of 0.36mm/hr applicable to medium clays. Water levels and exceedance percentages are shown below (Figure 28 and Figure 29) noting the x-axis values of less than 0.5% expected exceedance and minimal expected exceedance above permanent pool volume over the 40 years of data.

Using this site-specific data, the inundation is even lower than for the average 10y data. Across the 45 year range, inundation of more than 1 cm was limited to about 50 cumulative days. That is, with the current drainage function, and using 45 years of rainfall data from the closest rainfall station, the area would expect to inundate very infrequently.

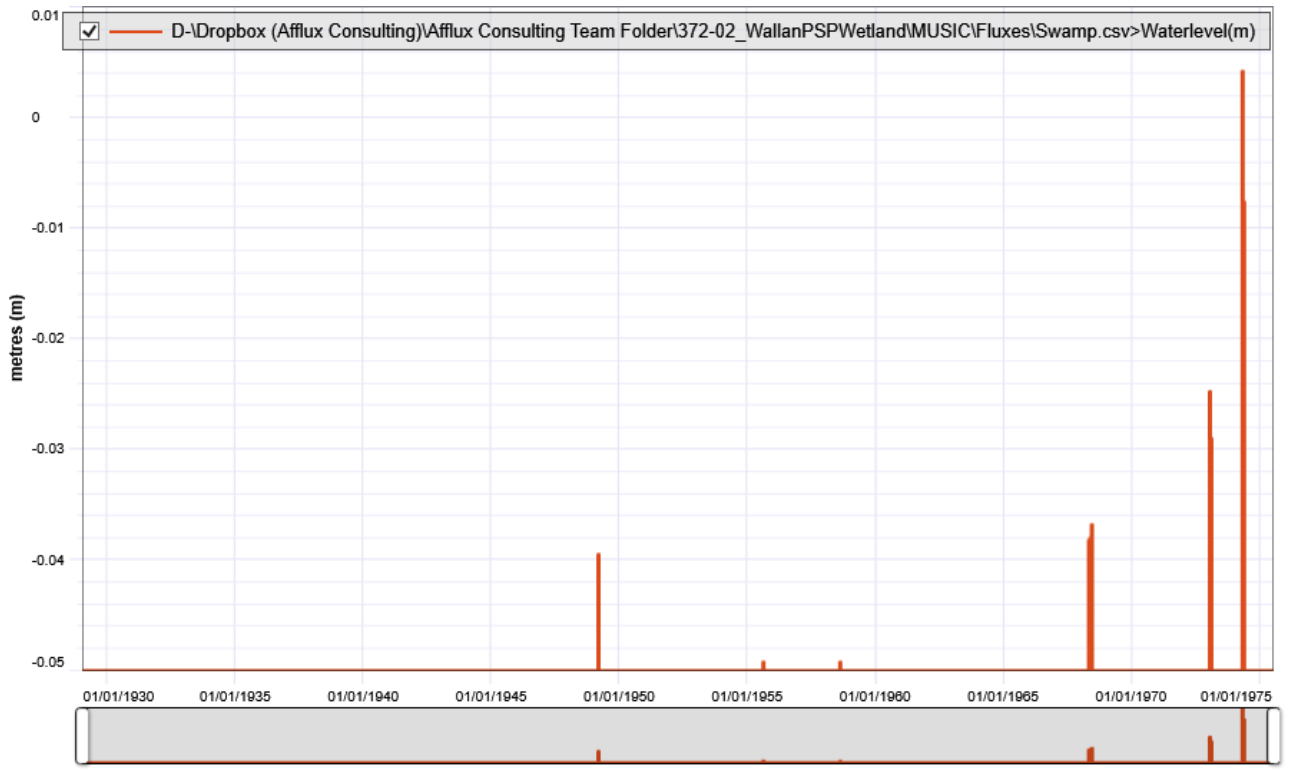


Figure 28. Current Water Level (m) - Medium- High exfiltration

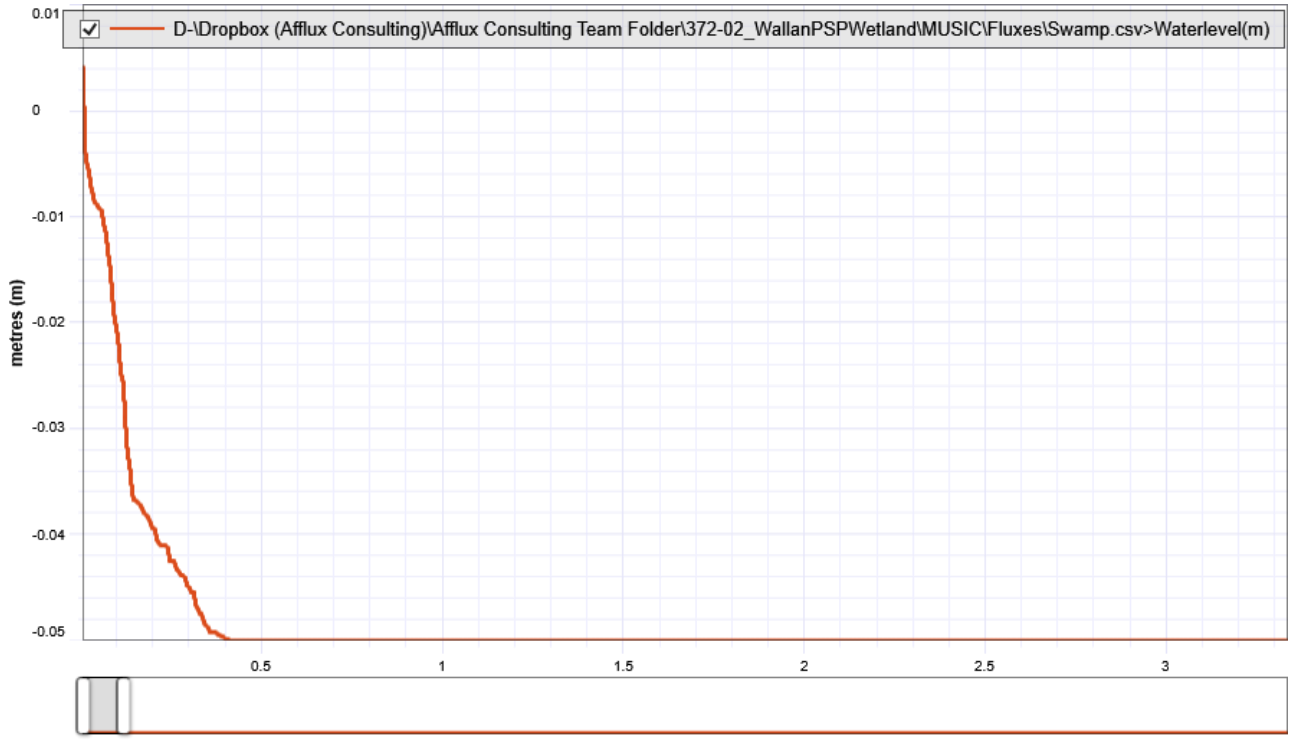


Figure 29. Current Water Level Exceedance

5. Discussion

A number of key points have been borne out of this modelling, these include.

Catchment connectivity and flow direction

The Strathaird creek has conclusively been shown to be disconnected from the area formally known as Hanna swamp. Figure 9 shows the flow direction during a major storm, with the relevant catchments inflowing into estimated swamp extent (based on contours and regional flood modelling). Even during a 1% inundation event the flows from Strathaird creek remain disconnected.

The approximate catchment for the swamp area has also been defined by this modelling, with approximately 172 ha draining towards the ~68 ha swamp extent. This totals around 240.5 ha rainfall runoff potential.

Local Climate Conditions

The expected rainfall of ~650mm over the total catchment extent is rapidly diminished by the natural climate demands including average potential evaporation demand of 1200-1400mm, outflow drainage (towards regional outlet) and soil infiltration rates (expected between 0.36-3.6mm/hr). Where potential evaporation represents evaporation rates that would occur provided there was unlimited water supply. Therefore, the swamp requires an extensive catchment to simply negate the natural climate conditions. This provides an indicative check for the regions where average cumulative rainfall minus evaporation indicates expectations of systems supporting frequent wetting (Figure 30 shows Agriculture Victoria's April to December cumulative average mapping for 25 years of data) .

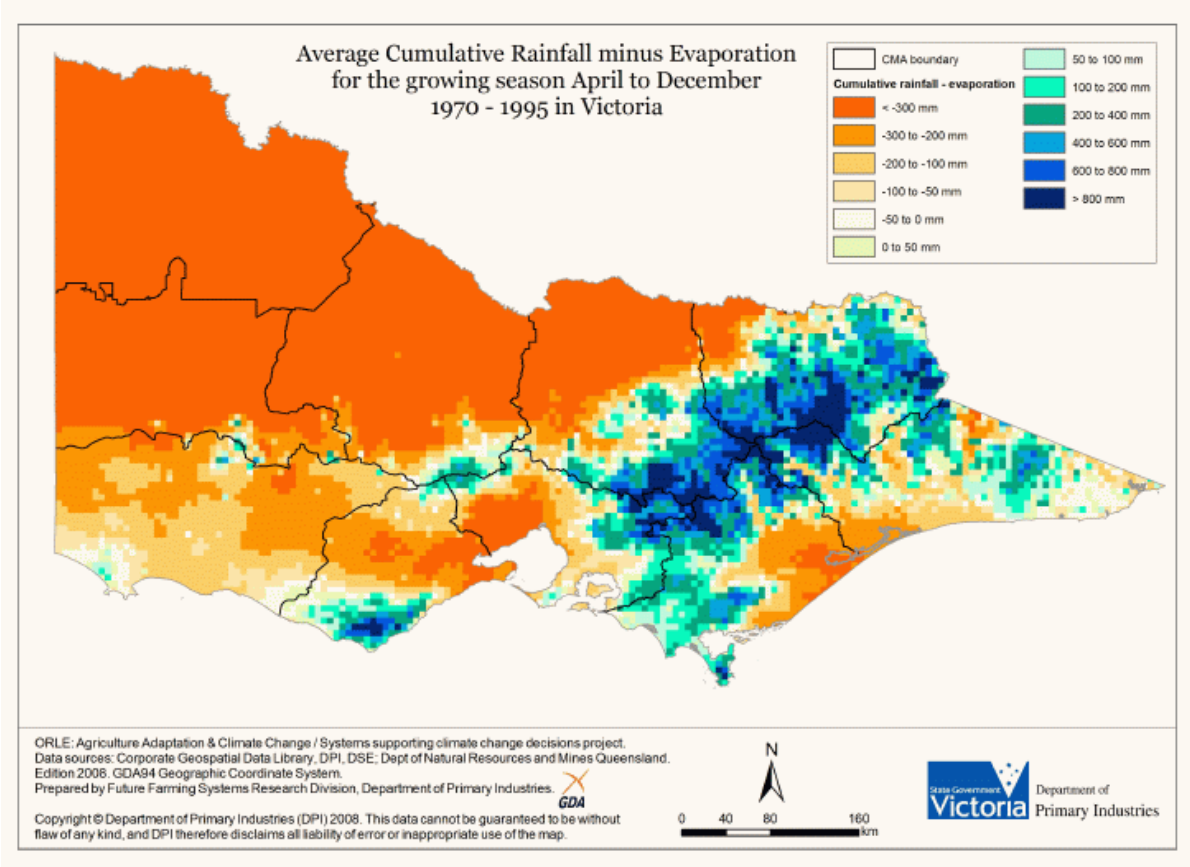


Figure 30. Average Cumulative Rainfall minus evaporation

What this effectively means, is that the current catchment of ~240 ha is too small to sustain a water body for any length of time, purely due to the macro water balance. The only viable method of sustaining the swamp would be to connect Strathaird Creek to the system, and to reduce the outflow conditions. This represents significant engineering works. As can be seen the existing terrain has additional significant drainage currently than would also require re-engineering.

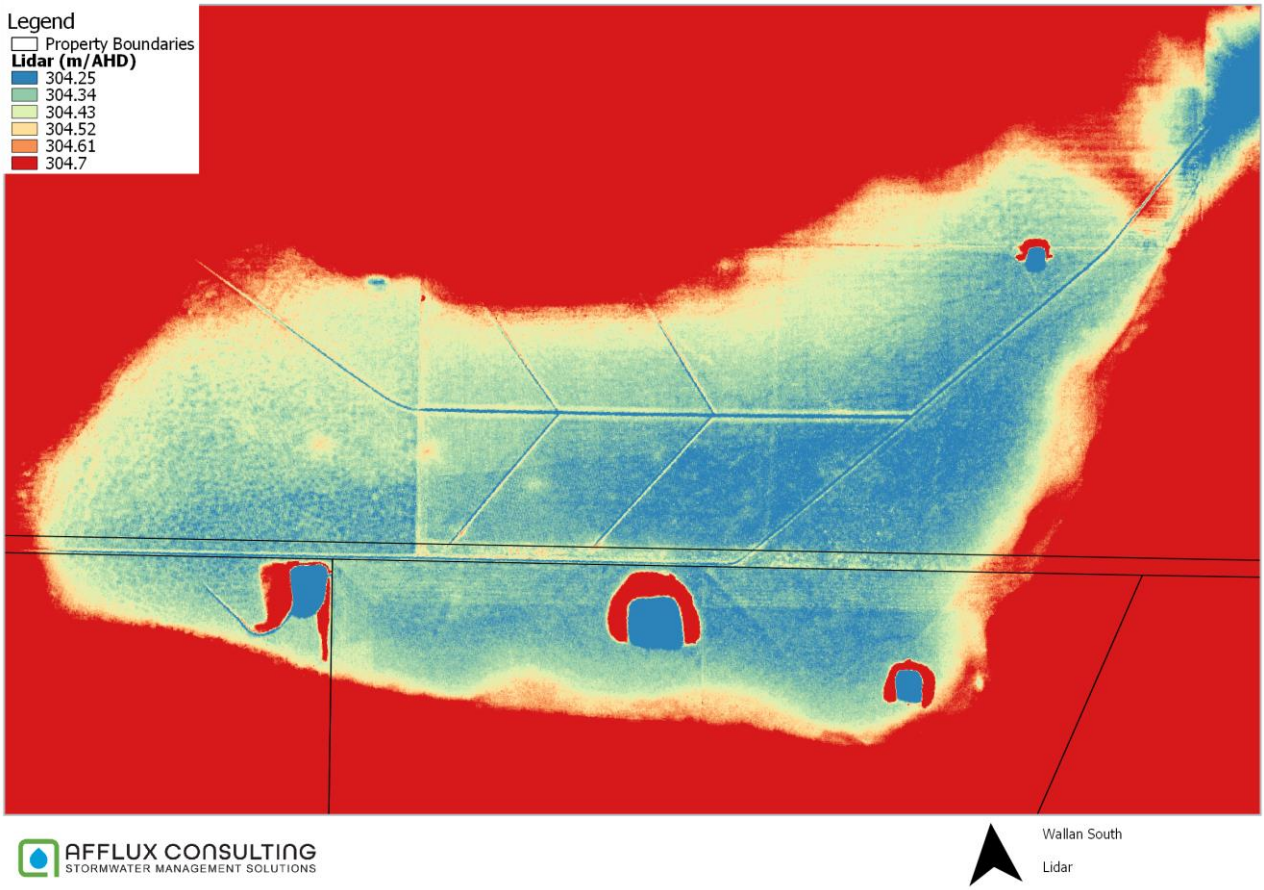


Figure 31. Site Terrain levels and drainage channels

Predicted Water Balance

As shown by the water balance modelling, at this point in time it is expected that very few inundation events could occur in the swamp area. At most these inundation events could last up to 7 days, but considering infiltration rates it is much more likely that they will last less than 24 hours. The area is well drained, does not have a large enough catchment for the climatic conditions, and cannot sustain permanent or even ephemeral vegetation in its current form.

Vegetation Assessments

Whilst not part of Afflux Consulting's expertise, the nexus between vegetation and hydrology is indicative of the prevailing conditions. Based on the modelling completed in this report, the hydraulic, hydrological analysis all point to the area not supporting swampy vegetation. The Wallan Beveridge Waterways Assessment *(Melbourne Water, 2020*) as referenced in the *Integrated Water Management issues and opportunities (Alluvium, Nov 2020)* report summarises some of the key ecological takeaways of this area:

> **Hanna Swamp:** Hanna Swamp is identified as a "notable wetland feature" within the southern section of the PSP. It has been observed to be substantially altered from its original form with "reduced surface area, reduced species diversity of flora and fauna and altered hydrology due to changed drainage conditions". The area within the Wallan South PSP is described as highly variable, being "managed for intensive agriculture….exotic pasture species dominate. Indigenous flora is currently restricted to drainage lines comprising robust common species indicating of a degraded conditions".
>
> In summary it is noted that it would require "high inputs to rehabilitate and maintain". The section within the Beveridge North West PSP qualifies as a Seasonal Herbaceous Wetland and reaches the high-quality benchmark.

Based on the modelling in this report it follows that only the low drainage lines that regularly drain the swamp area could support this vegetation. This is also supported by the current Biosis assessment of the area with almost no identified swampy area.

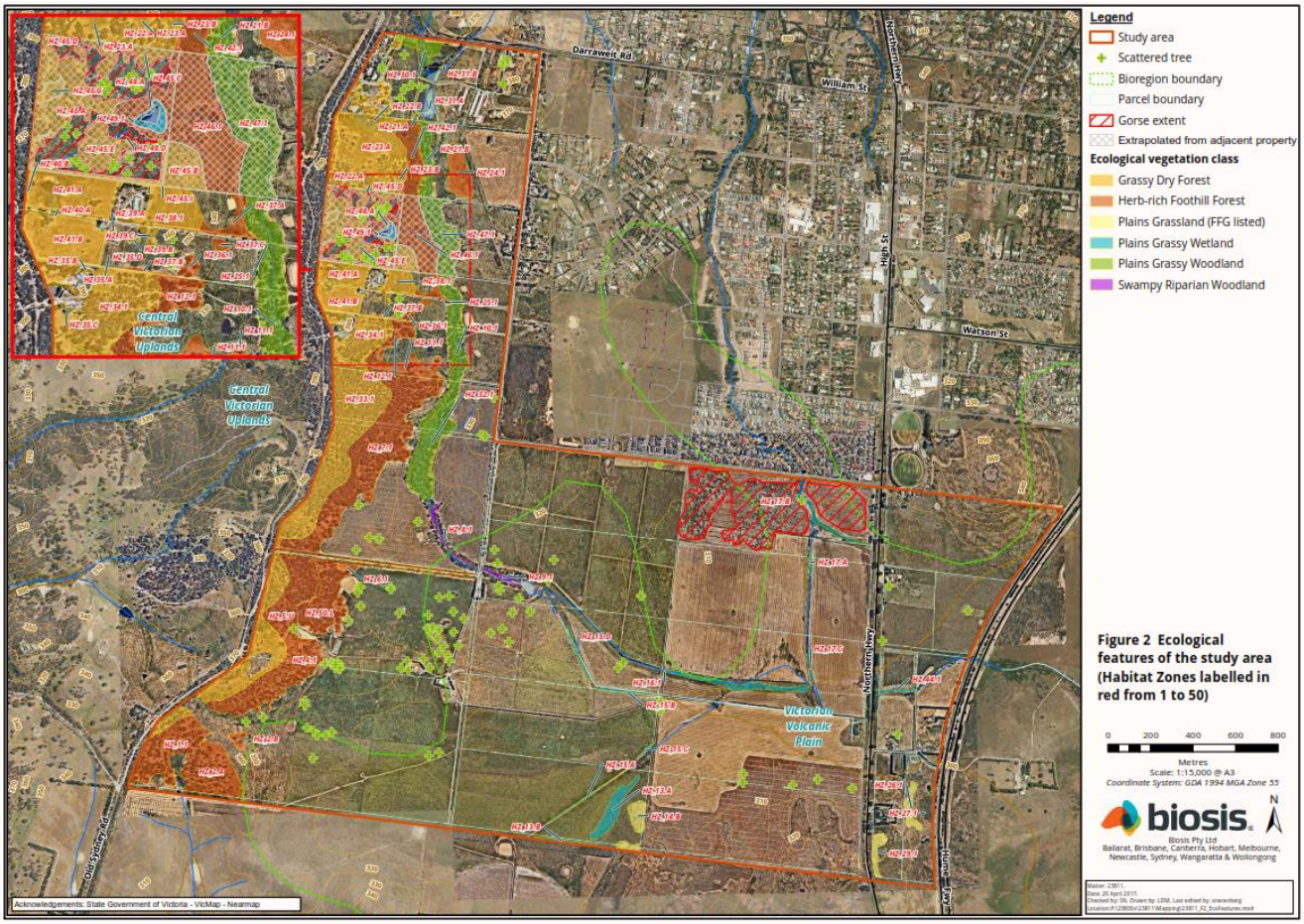


Figure 2 Ecological features of the study area (Habitat Zones labelled in red from 1 to 50)

Figure 32. Biosis Vegetation assessment report June 2017

Other Assessments

A number of other assessments of this area have been made in submissions to development panels for the area. Prominent amongst these is the use of "Space observations" as part of the Friends of Merri Creek submission to the Beveridge West PSP.

It should be noted that these are an experimental set of observations, based on pixilation data. At best they are helpful in showing low points in the environment, at worst they are misrepresentations of what effectively could be a day of rainfall. The use of the data states on the website:

As no confidence filtering is applied to this product, it is affected by noise where misclassifications have occurred in the WOfS water classifications, and hence can be difficult to interpret on its own. The confidence layer and filtered summary are contained in the Water Observations from Space Statistics - Filtered Summary product, which provide a noise-reduced view of the water summary. This layer contains Water Summary: what percentage of clear observations were detected as wet (ie. the ratio of wet to clear as a percentage). No clear observations of water causes an area to appear transparent, few clear observations of water correlate with red and yellow colours, deep blue and purple correspond to an area being wet through 90%-100% of clear observations. For service status information, see https://status.dea.ga.gov.au

For instance, from the submission report, it is put that the aggregated data shows that the wetlands is in existence.

Aggregated Landsat data for Hanna Swamp since 1987, which clearly matches the geomorphic shape of this natural wetland feature.

From this same dataset, if zoomed out, it also shows that the hill to the west of this location is also inundated frequently. The images also mostly show that the onsite dams have water in them at some point in the year. Whilst interesting, this dataset clearly has a low level of confidence and should not be used as the basis of any scientific analysis.

Figure 33. Water Observations from Space Digital Earth Australia Map (ga.gov.au)

5.1. Summary of DELWP assessments

The NVR team's requests for further information regarding the capacity of Hanna Swamp, its associated hydraulic/hydrologic regimens and thereby its capacity to support wetland-associated vegetation is discussed as below.

Important clarifications regarding reestablishment potential of Hanna swamp as outlined by the NVR team via email as discussed below:

Straithard Creek connection to Hanna Swamp

Page 11 of the Flora and Fauna Assessment completed for the Wallan South Precinct (WSP 2020) states 'Prior to agricultural development, Hanna Swamp would have been a seasonal wetland. However, with agricultural development of the area, the natural flow of Strathaird Creek was channelised to provide water and land for agricultural use. Despite this, Hanna Swamp is either partially or fully inundated approximately one in every three years'.

The WSP assessment references a significant body of work completed by Nature Glenelg Trust which sets out the current and potential ecological values of Hanna Swamp

As discussed within section 3.3 Regional Flood Assessment, Strathaird Creek is no longer connected to the Hannas Swamp catchment (see Figure 9). Additionally, the former swamp area is not capable of holding water for at least one month as shown by the detailed water balance calculations. Most importantly the vegetation in the area is not indicative of a wetting regime.

1% AEP flood extent

The Mapped Wetland area is covered by Melbourne Water's 1:100 Year flood extent layer.

The flood modelling has confirmed that in a 1% event the area will be inundated 200-300 mm as expected within a such a large geomorphic feature. As also shown in lower frequency events inundation extent is minimised with the current drainage infrastructure (i.e. cut drain).

Drainage infrastructure

The Mapped Wetland area is easily discernible as a geomorphic feature in aerial photographs, with the Land Capability Assessment prepared for the Wallan South and Wallan East PSPs (Jacobs 2020) noting 'The existing drains in this lower-central region of the site are flat and shallow, suggesting that there may be challenges in draining the area for proposed developments'.

Whist the above statement is true this assessment shows that the current drainage infrastructure is adequate for low flow events; a number of engineering considerations have been included in development assessments to meet the challenges of draining this area.

Inundation frequency

The report titled 'Inverlochy Farming Property, 175 Northern Highway, Wallan, Victoria: Preliminary Documentation' (Biosis 2019) raises the following uncertainty 'These modifications are likely to have altered the natural hydrology resulting in reduced residence times and reduced frequency and duration of inundation. The area of inundation is likely to have been reduced although further study would be needed to determine the exact degree of change'.

The analysis in this report has shown that maximum inundation is approximately 24 hours due to altered conditions; this is well below the 1 month inundation requirement.

Plains Grassy Wetland

The fact that the above noted assessment (Biosis 2019) identifies a large (1.7ha) remnant patch of Plains Grassy Wetland within the south-east section of Hanna Swamp, which had persisted despite site drainage and modification.

This is consistent with the hydraulic modelling (shown in Figure 15) and local topography. The south-eastern portion is within a separate sub-catchment. Additionally, given its size it will not meet the 1 month inundation requirement for this climatic region.

6. Conclusions

This report has investigated the current hydraulic and hydrological capacity of Hanna Swamp within the Wallan South PSP area.

This analysis has shown:

- Strathaird Creek disconnection from Hanna Swamp catchment extent
- The area formally known as Hanna Swamp is subject to hydrological regimes associated with the immediate (local catchment) rainfall runoff only
- The area is well drained particularly in low flow or high frequency events and does not facilitate permanent pooling
- Water balance assessments show that this area doesn't hold water for more than ~24 hours based on 40 years of rainfall data.
- Based on the hydrology within this region the minimum 1 month inundation does not exist under current conditions. Additionally, high levels of engineering input would be required to reinstate hydrology

For information on this report:

Chris Beardshaw
Principal Engineer

0417 169 182
chris-beardshaw-9ba7b079
chris@afflux.com.au
www.afflux.com.au

Afflux Consulting Pty Ltd
PO Box 457 Emerald VIC 3782

03 9036 2530

info@afflux.com.au

afflux.com.au

Memo

Wallan South SWMS Extract

To: Crystal Group

From: CMB

Date: Friday 22 April 2022

This memo details some of the calculations associated with the Stormwater Management Strategy (SWMS) for the Wallan South PSP. This memo highlights the most likely water quality and quantity requirements for the area given the topographical, geomorphological, soil science and hydrological conditions. This memo extracts key information from the SWMS (unpublished) for consideration as part of the Beveridge NW PSP.

Wallan South PSP Background

Afflux Consulting have been working on reviewing the stormwater management aspects of development within the Wallan South PSP for a number of years. The focus of the SWMS is to deliver the most efficient land development to meet the required stormwater policy should the land be rezoned. The key foci of the plan are therefore:

- To meet the current BPEM stormwater requirements
- To ensure that downstream properties are protected from increased flooding through attenuation of development flows
- To consider the existing, and future hydrological regimes of the area and their influence on development outcomes
- To ensure that the stormwater system is integrated and provides for the best possible environmental outcomes for a development scenario, in particular in considering the topographical and soil conditions of the area
- To ensure that the system appreciates both the outcomes and preferences of the Healthy Water Ways strategies, EPA practice notes on volumetric control, and integrated water management.

The Stormwater Strategy highlights are detailed below.

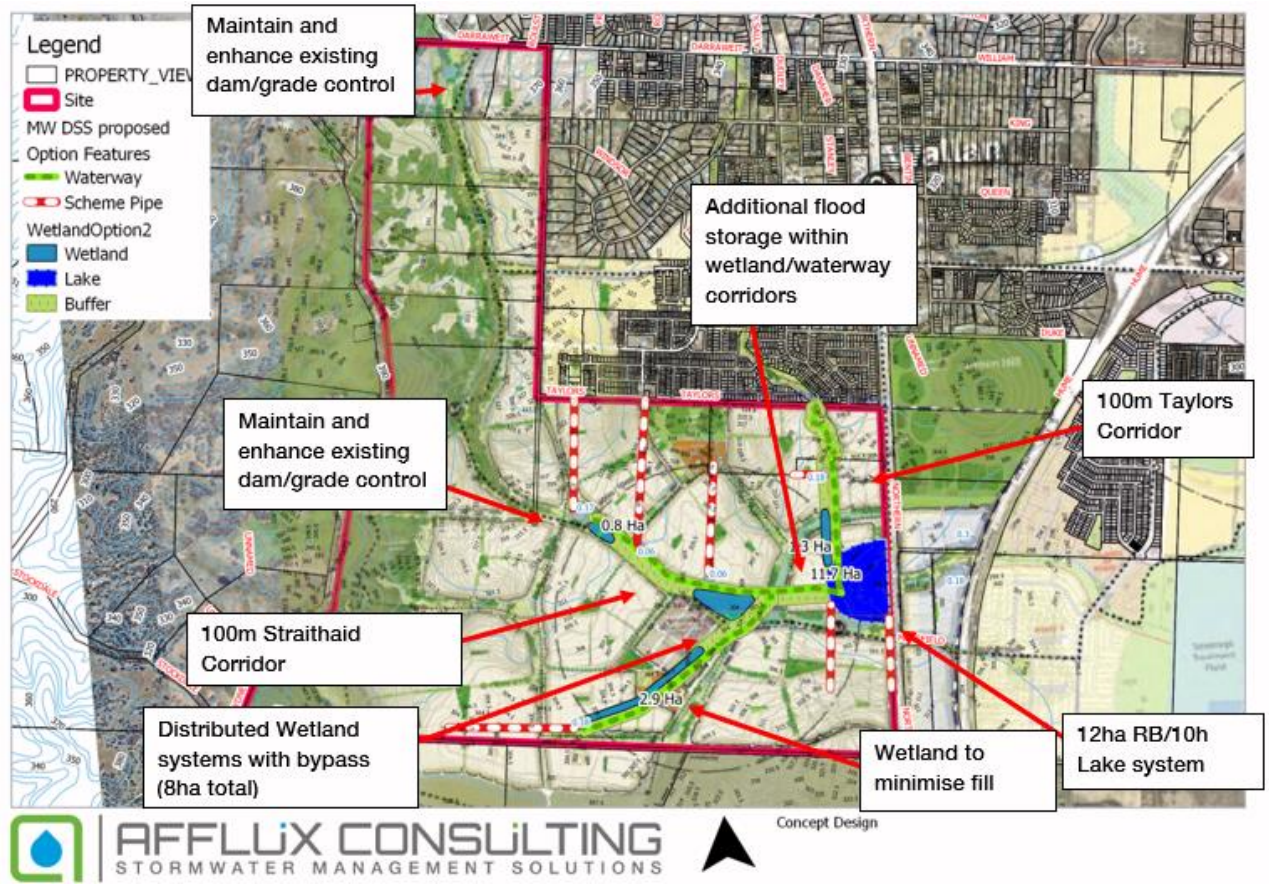
Wallan South PSP, Draft Stormwater Management Strategy, Afflux Consulting (December 2018)

This report was previously undertaken by Afflux to provide a preliminary Stormwater Management Strategy in anticipation of Wallan South PSP planning process. It was intended to inform opportunities, address concerns with the DSS and provide an outline of how stormwater requirements could be met within this area. The report also investigated IWM goals in line with the Healthy

Afflux Consulting Pty Ltd
PO Box 457, Emerald VIC 3782
03 9036 2530 info@afflux.com.au afflux.com.au

Waterways Strategy (Melbourne Water, 2018), recommending a 10ha lake for stormwater harvesting. This report formed a concept design for the waterway and scheme shown in the Figure 1, with the following points:

- A number of sediment ponds as labelled;
- Waterway corridors of 100m for two main waterways (a smaller waterway can be considered for the southern arm);
- Approximate Scheme Pipe layout to direct low flows to Sediment Ponds;
- Lake Harvesting and retardation system; and
- Wetland areas and approximate corridor widths.
- Topographical constraints and suggestions on efficient land use and fill minimisation



Source: Excerpt from Draft Stormwater Management Strategy, Figure 37 in report, Afflux (Dec 2018)

Figure 1. Concept design - annotated

Wallan South PSP - Stormwater Management Strategy, Afflux Consulting (unpublished)

An updated SWMS has been written for the catchment based on the most recent knowledge of the catchment and development planning. Only highlights relevant to the areas associated with Beveridge NW PSP are given here, however the updated SWMS includes:

- More detailed analysis of flows and catchment hydrological processes

- A better understanding of the topographical constraints, including a full terrain design and earthworks balance
- Detailed flood modelling of both the existing and development scenarios
- Refined water quality and retardation strategies

1.1. Existing Catchment Management Proposals - Melbourne Water

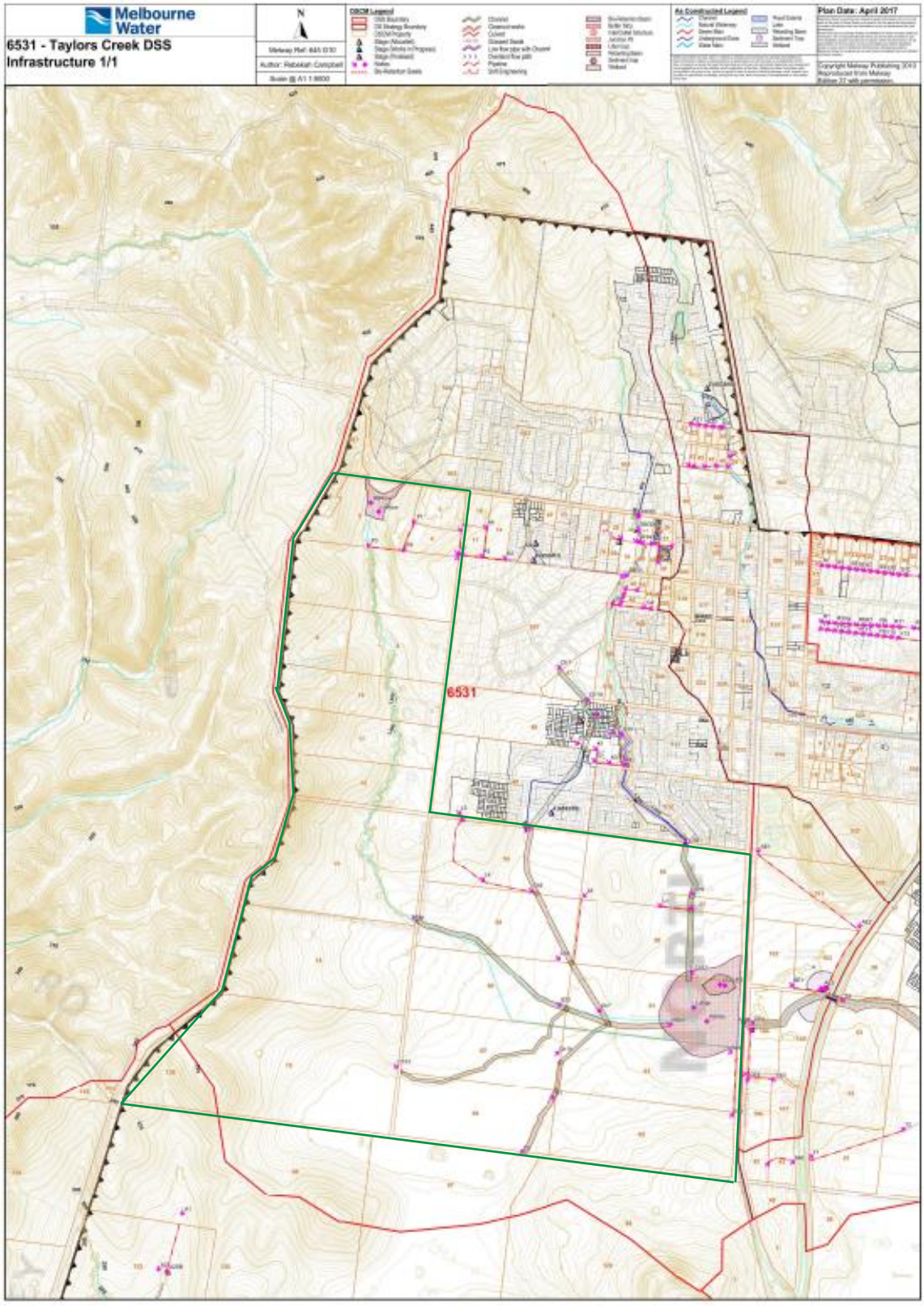
Drainage Services Scheme

Melbourne Water's role is to manage and protect Melbourne's large-scale water resources. The Drainage Services Schemes (DSS) fall under Melbourne Water's responsibility and examines catchment-based drainage strategies. The schemes were created to:

- Provide a safe and effective system for dealing with run-off;
- Ensure appropriate flood protection and environmental performance;
- Provide drainage services in the existing and growth areas of Melbourne; and
- Protect and enhance waterways and biodiversity values.

(Melbourne Water, 2007)

The site is shown within the Taylors Creek DSS below.



Source: Melbourne Water website accessed Sept 2021

Figure 2. Current MW preliminary scheme for Wallan South

Specific Concerns for the PSP

Based on the review of the catchment, and listed objectives and requirements, a number of catchment specific challenges have presented themselves, these include:

- Surrounding existing development and hydraulic controls within the scheme present significant constraints;
- The combined flow controls (flow limits at Northern Hwy) require extensive investigations into hydrology and hydraulic design of proposed systems;
- Water quality must meet the BPEM provisions at Hume Fwy (scheme outlet);
- The Healthy Waterway Strategy priority catchment goals and new EPA volumetric provisions should be considered and incorporated into design;
- The area is a known Sodic Soil area, all engineered structures should consider the design implications;
- The instability of soils in northern Melbourne region imposes limits on constructability and design. The possibility of permanent turbidity should be considered;
- Creation of additional constructed waterways presents significant engineering risk;
- Construction of the proposed works whilst other parts of the catchment are still undeveloped may require temporary structures;
- Constructability and long-term viability of Melbourne Water assets needs to be considered;
- Draining the land from one side of the former Hanna Swamp to the other presents significant design considerations; and
- Fill requirements and waterway offsets are major design considerations for this catchment.

1.2. Proposed Treatment Concept

Based on the investigations included in the SWMS, it is recommended that the development is treated by the following WSUD system shown in Figure 3.

The proposed concept considers each assets' function within the landscape. The design ensures effective treatment of stormwater at outlet while balancing additional development requirements (i.e. harvesting, fill management, engineering risk, etc.). Importantly, there has been a balance between centralised and distributed assets as stormwater controls only protect waterways downstream of where they are located. That is, the creek should be protected at each major outlet into the creek systems.

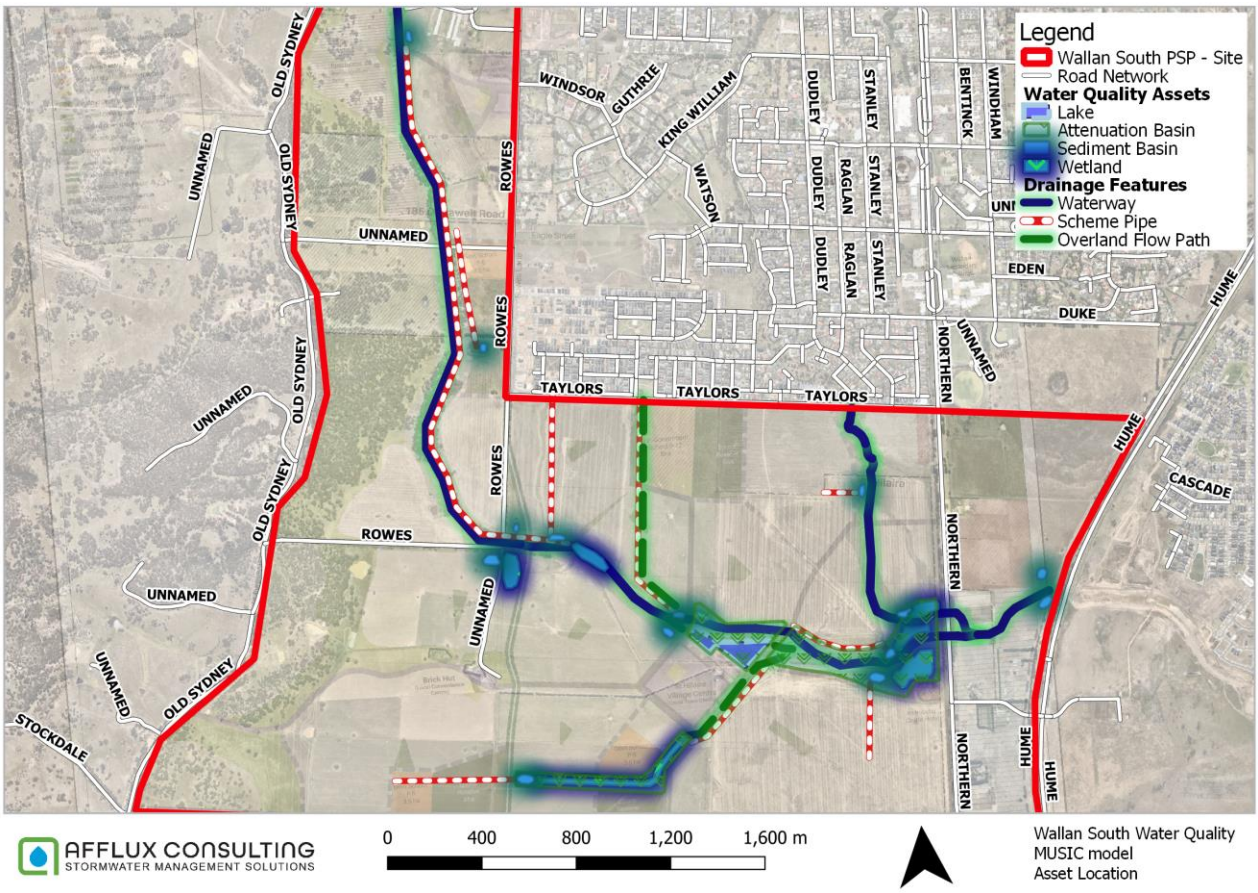


Figure 3. Recommended Water Quality Concept

1.3. Catchment Flows and PSP Hydrology

Existing Conditions Flows

Both the Existing Conditions flows and Development Conditions flows are modelled within the SWMS. The Key figures and flows are shown here

Table 1: Existing conditions flows at key reporting locations

Reporting Location	Notation on map	Design Peak Flow (3 hour storm) (m^3/s)
Site of Rowes Lane Storage (upstream of storage)	RWLN	5.1
Reach W-X – at Taylors Lane	W-X	1.6
Tomkins South Boundary – at Taylors Lane	TMKS	5.3
Taylors Creek - at Taylors Lane	TYCR-LN	19.5

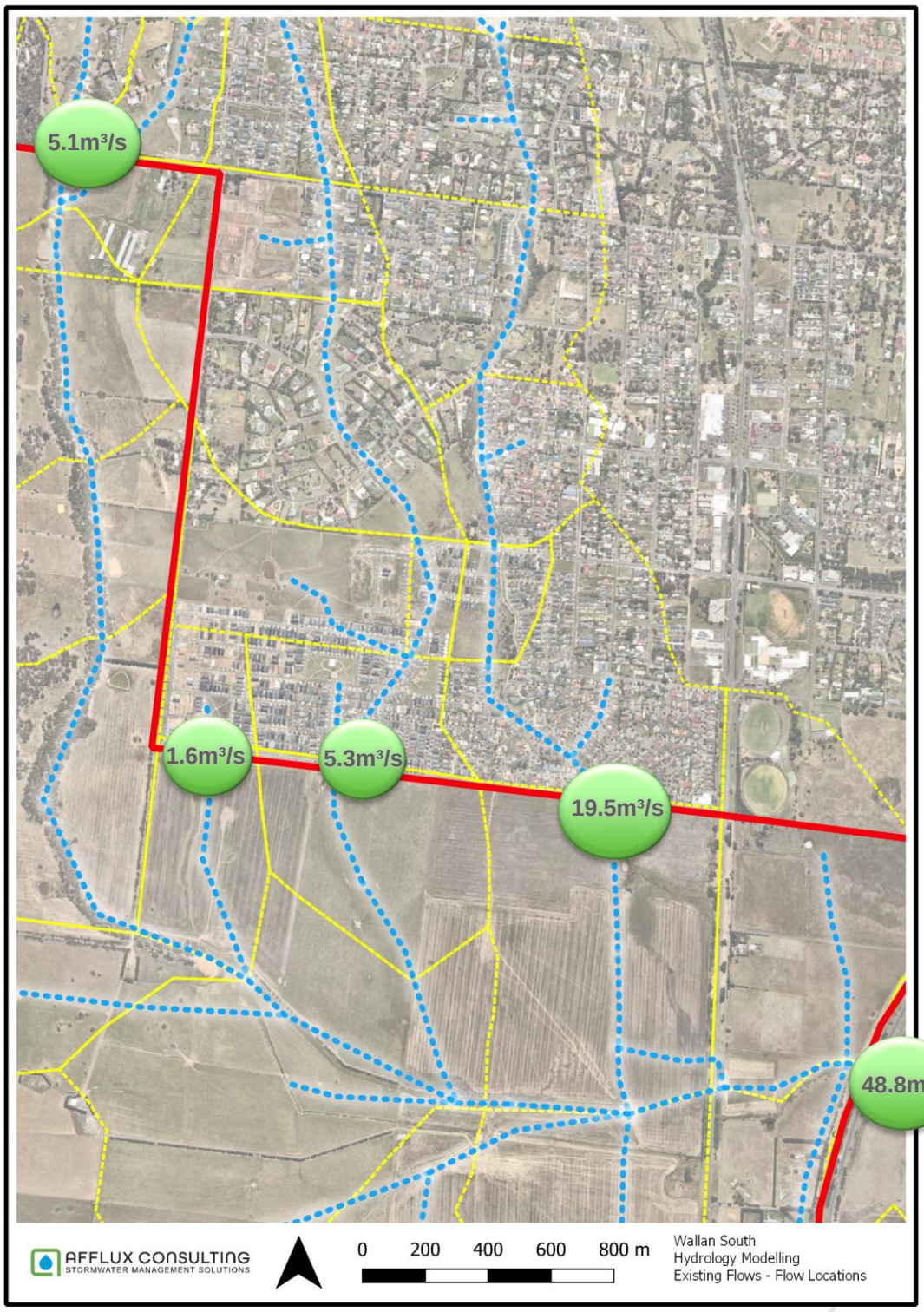
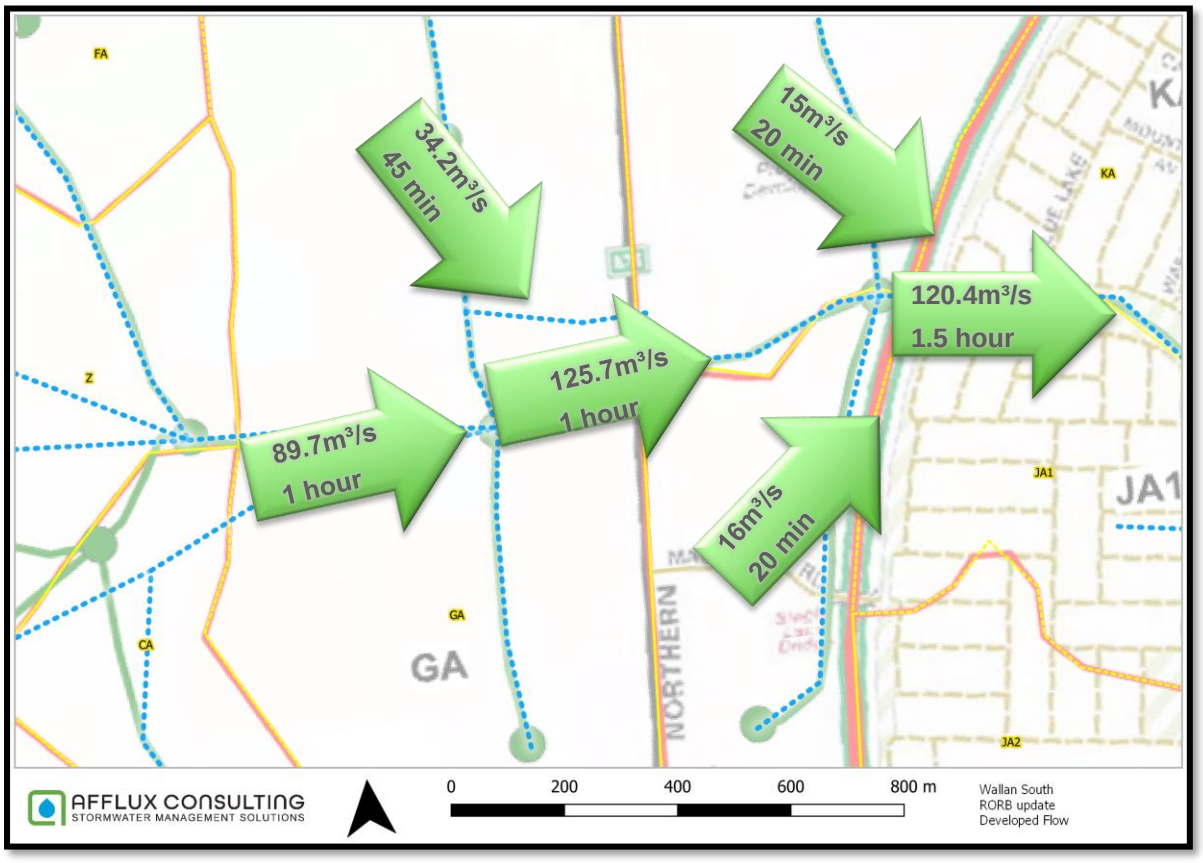


Figure 4. Key locations of existing (current) flows

Developed Conditions Flows



Source: Taylors_Creek_Developed_March2021.catg

Figure 5. Unattenuated flow peaks at key locations with corresponding storm durations

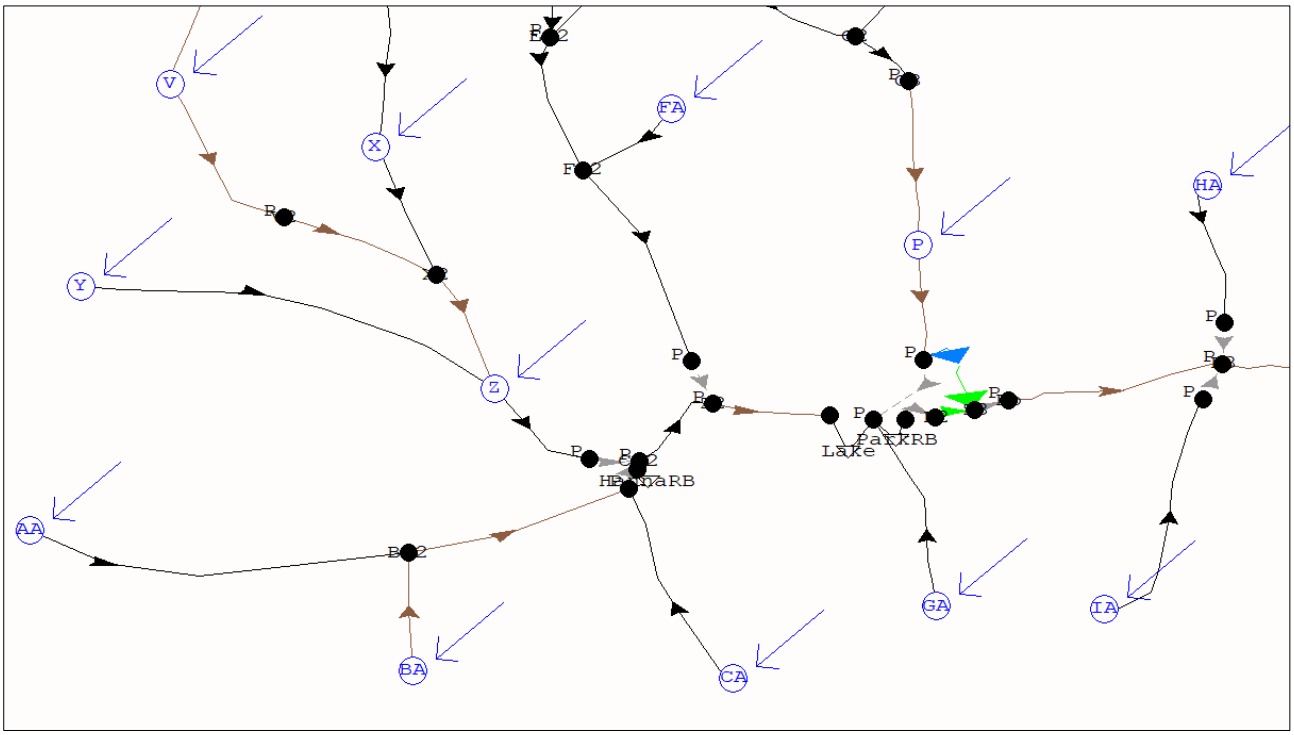
Key findings:

- The peak flows for key locations (and associated storm durations) are shown above (Figure 5);
- Peak flows for Taylors Creek and Strathaird Creek occur at similar storm durations;
- The similar storm durations indicate similar catchment time of concentrations;
- Similar time to concentration results in overlapping peak hydrographs which drastically increases the combined peak ; and
- This combined peak effect requires consideration of possible alternative conveyance options;

In comparison, the peaks occurring at the 20 min storm duration (downstream of Northern Highway before Hume Freeway) have minimal influence on ultimate catchment peak (at Hume freeway). The shorter time to concentration does not interact with greater catchment flows. Therefore, a general recommendation is to retain conveyance without attenuation of flows with shorter time to concentration (20 min storms) and scrutinise potential flow arrangements for overlapping peaks.

1.4. Storage calculations with for the Catchment

Proposed storages were trialled within the developed conditions RORB model as shown in Figure 6.



Source: Taylors_Creek_Developed_March2021_v7.catg

Figure 6. Developed conditions RORB with storages

Trial iterations provided initial storage estimates for the catchment.

Table 2: Initial storage calculations in RORB

Asset	Inflow (m³/s)	Outflow (m³/s)	Storage (m³)
Hanna RB	20.9	8.6	86,600
Lake	49.1	45.5	50,200
Park RB (NthHwy)	63.4	39.5	18,7000

Note: For peak at Hume Freeway, storm duration: 4.5 hours, TP: 27.

This provided initial storage estimates to be refined within hydraulic modelling.

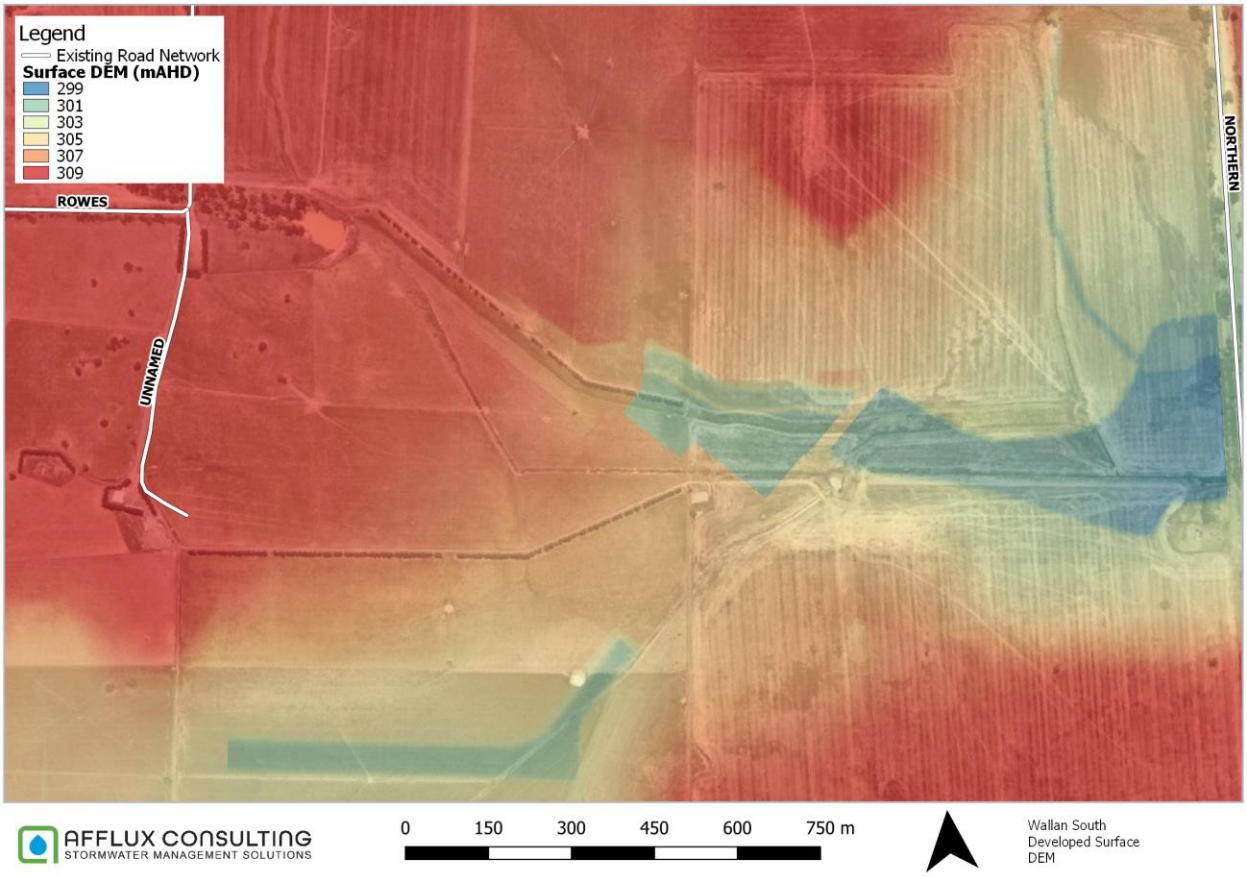
1.5. Development Surface

The previously discussed hydrology modelling (RORB) informed approximate storage requirements - this information was used to build a developed TIN (triangular irregular network). Beveridge Williams supplied the developed TIN based on the following key requirements:

- Minimise development fill;

- Meet base storage requirements (to safety criteria);
- Maximise storage efficiency;
- Ensure adequate waterway grade;
- Meet ultimate outlet conditions;
- Consider water quality co-location; and
- Offline lake operation and Strathaird Creek main channel requirements.

The TIN was used to generate the Digital Elevation Models (DEM) required for the hydraulic model. A number of TINs were modelled and refined. Figure 7 shows the developed DEM over the catchment area for the site.

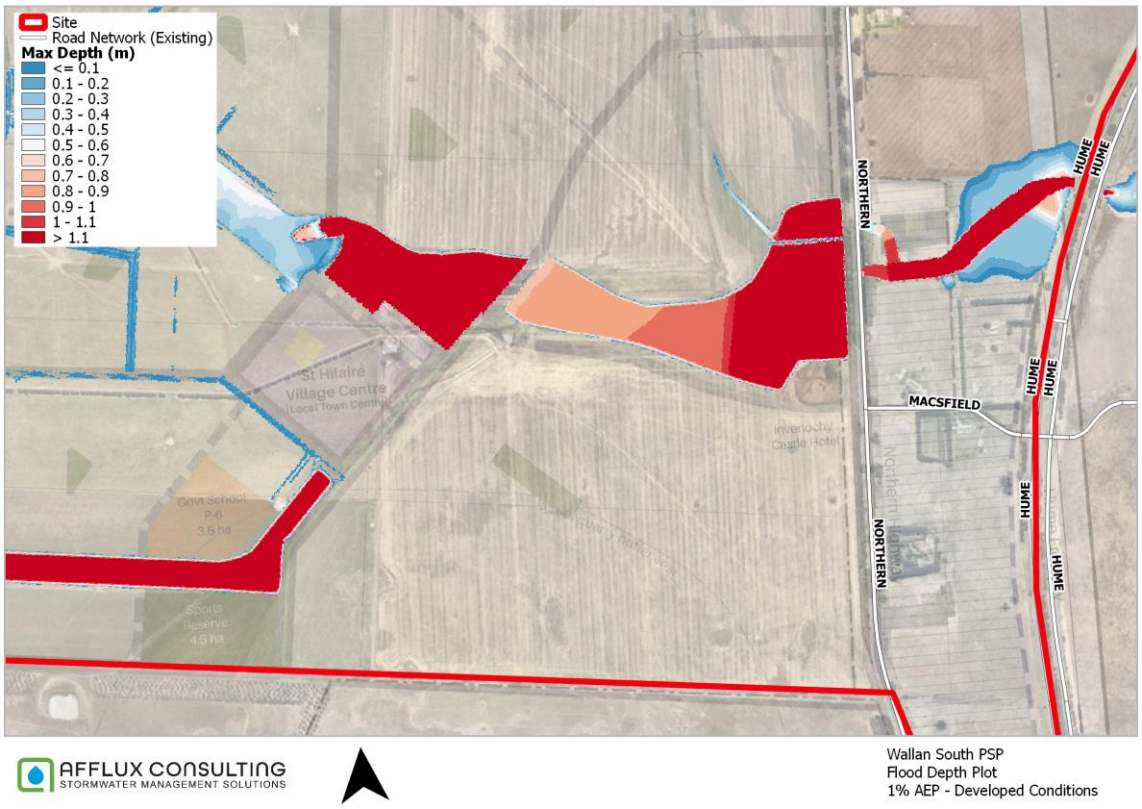


Source: Wallan_Dev7.tgc, TIN provided by Beveridge Williams 17/06/2021

Figure 7. Developed Surface DEM

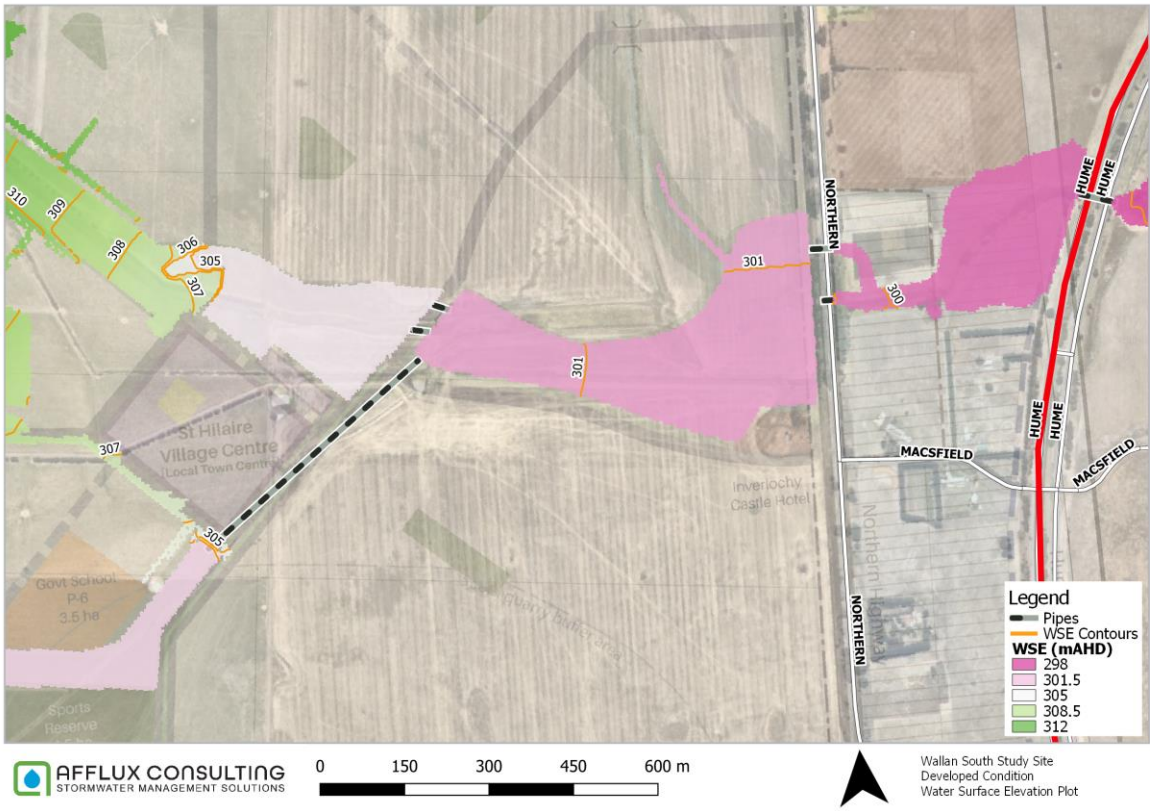
1.6. Developed Model Results

The flood conditions were modelled for a number of development surface iterations. Figure 8 and Figure 9 shows the storage configuration for the 1% rainfall event. If designed as recommended, the development can meet storage requirements, alongside competing development practicalities such as fill minimisation.



Source: Wallan_v09_d_Max.flt

Figure 8. Developed Flood Depth Plot – 1% AEP



Source: *Wallan_v09_h_Max.flt*

Figure 9. Developed Water Surface Elevation Plot – 1% AEP

Note: *The upstream Strathaird Creek channel requires additional formalisation not included within this development surface*

1.7. Water Quality Wetlands

Biological treatment of stormwater reduces the loads of nutrients entering receiving waters; an important aspect of best practice guidelines. The general philosophy is to construct wetlands in preference to other water quality measures due to their robustness in long term survival, reduced maintenance, and ability to store greater amounts of water above the Normal Water Level (NWL) in a retarding basin situation. Wetland surface area dictates the potential effectiveness of these treatments, with plant selection and density being limited by available treatment area. Wetlands are designed to service the three month flow or equivalent from the site.

Sediment ponds were modelled as 'Inlet Ponds' when in the same drainage reserve as the wetland nodes as per MUSIC guidelines. Sediment basins (/inlet ponds) are capable of reducing the sediment load into the wetlands themselves, hence increasing life expectancy. Sedimentation basins (i.e. inlet ponds) were sized using the Fair and Geyer equations, with the results summarised below.

Table 3: Sediment Basin Parameters

Sediment Pond	Sed Pond Size (m2)	Target Size	Fraction Removal	Clean out Frequency
SB_WL_HwyNth	1000	125 µm	95%	14.7 years
SB_WL_DSLakeNth	1000	125 µm	95%	17.5 years
SB_WL_Inverlocky	3500	125 µm	95%	18.1 years
SB_Hanna_WL	2000	125 µm	95%	26.1 years
Total Wet Area	7500			

Wetland input parameters and their corresponding treatment efficiencies are provided. A summary is shown below. Noting that treatment area does not include area required for batters, dry out and bypass arrangements (etc).

Table 4: Wetland Summary

Wetland	Treatment Area (m2)	TS (% Reduction)	TN (% Reduction)
WL_Rowes	10,000	86.1	48.7
OnlineGeoWetland	80,00	77.7	36.6
Lake	20,000	88.1	45.7
WL_DSLakeNth	7,000	83.7	50.2
WL_HwyNth	6,000	82.7	49.0
WL_Inverlocky	16,000	83.1	47.0
Hanna_WL	19,000	82.6	48.8
Total Wet Area	5.9 ha (+ 2 ha lake)	85.1	46.2

Note: Locations shown in Figure 10.

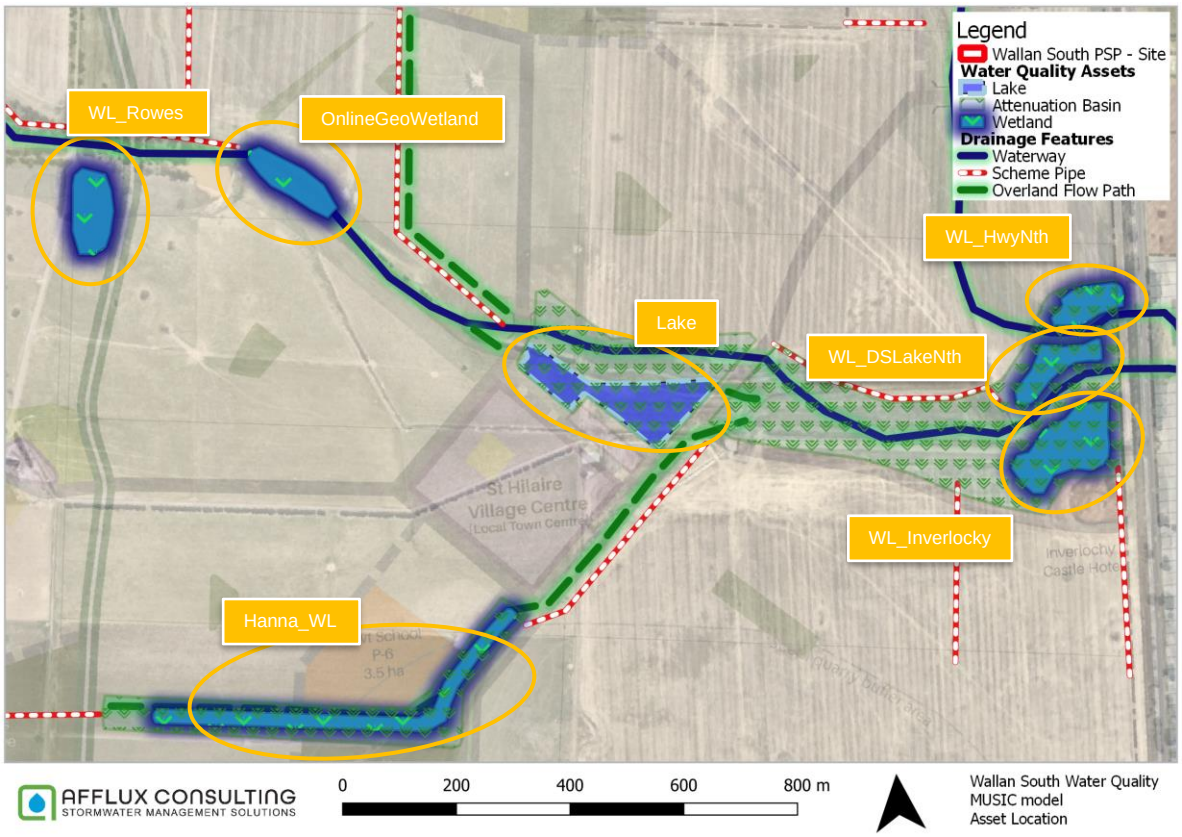


Figure 10. Wetland Location

Conclusions

A comprehensive SWMS has been produced for the Wallan South Area. Whilst the PSP is not finalised, and the layout subject to change, the following broad points can be made:

- The area to the south of the PSP needs to consider the topography of the area if it is to be developed. This impacts on the stormwater design, as flows must be conveyed across the landscape at general engineering grades. A large flat water body in this location (wetland) aids in this action. Without it, significant fill will be required for the site.
- The maximum wetland size required in this portion of the development is approximately 2ha in size
- The maximum retarding basin size in this area is approximately 80ML or the equivalent of 4-8ha or less in land take.
- These sizes assume the majority of the southern portion of Wallan South is developed.