



DRAFT REPORT:

Kororoit Creek Wetland Ecohydrology

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1 Introduction

Melbourne Water commissioned Alluvium Consulting Australia to assess the ecohydrology of a significant seasonal herbaceous wetland (SHW) adjacent to Kororoit Creek (Figure 1). In this report we provide a summary of modelling and investigation of the hydrologic regime of the wetland, in particular changes to the hydrology likely to occur once the catchment of the wetland is urbanised. Using the outputs from the model we have identified a range of management options to mitigate the impacts.

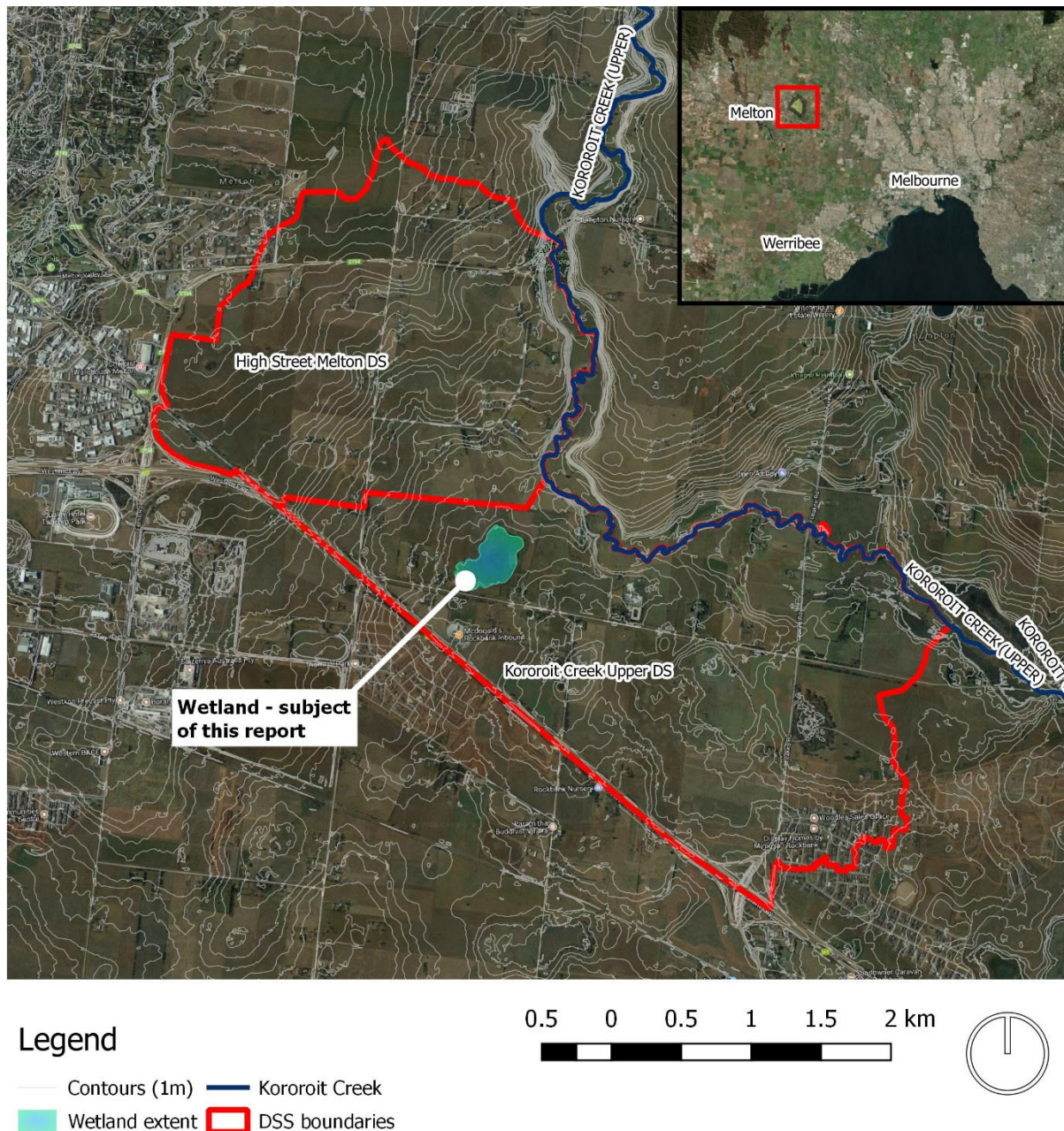


Figure 1. Kororoit Creek wetland location and site context

The wetland is located within the future High Street Melton Development Services Scheme (DSS, see Appendix A). The Kororoit Creek corridor is identified as a conservation area under the Biodiversity Conservation Strategy (BCS). The wetland on the right (south) bank of Kororoit Creek was identified as having possibly high quality SHW vegetation (Cook et al, 2013). The wetland is also an Area of Strategic Importance (ASI) for Growling Grass Frog (GGF).

The wetland is listed in *The impact of Melbourne's growth on 'seasonal herbaceous wetlands (freshwater) of the temperate lowland plains - Melbourne Strategic Assessment'*, (DEPI, 2013). Approximately 7.5 Ha of the wetland area is considered to be SHW, which is listed under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999. The wetland (including a buffer and proposed GGF wetlands between the wetland and Kororoit Creek) has a protection overlay in the Melbourne Strategic Assessment (MSA).

The purpose of investigations documented in this report is:

- To understand the current hydrologic regime of the wetland
- To understand the likely changes in the hydrologic regime of the wetland under future land use conditions as the catchment as urbanisation occurs in the wetland catchment
- To develop high level management options to mitigate the deleterious impacts on the ecological values of the wetland from changes in the hydrologic regime.

Both SHW and GGF are matters of National Environmental Significance, and changes to the hydrology that currently supports them is likely to be considered a controlled action under the EPBC Act.

1.1 Summary of findings

Urbanisation of the catchment in the High Street Melton DSS and western portion of the Kororoit Creek Upper DSS catchments will have a significant impact on the hydrology of the wetland. Two standard drainage designs show a significant change to the hydrology.

- Direct connection of impervious surfaces to the wetland will deliver significantly more water than under current conditions, resulting in extended inundation periods
- Impervious surfaces bypassing the wetland will reduce the wetting and inundation below the ecological requirements of the SHW in the wetland.

It is clear from the analysis that a business as usual drainage approach will lead to a reduction in the ecological values of the wetland. Four management options were identified to mitigate the impacts of changes in the hydrologic regime. Options include restrictions on urban development in the catchment and a variety of flow management approaches.

Further work is required to develop these options (shown in Section 5) and carry out a cost-benefit analysis to identify the preferred design solution.

The final design must:

- Provide a hydrological regime that provides seasonal water availability to support Seasonal Herbaceous Wetland vegetation.
- Allow for adjustment of the water flows to respond to seasonal water requirements and/or water level monitoring information.
- Provide the Stormwater treatment from the catchment flows to mitigate sediment and dissolved nutrient flows to the wetland.
- Be maintainable within normal expenditure budgets.

2 Existing conditions

2.1 Catchment description

The wetland is located adjacent to Beattys Road, approximately 2 km west of Leakes Road and 5 km east of Melton. The existing catchment area is 605 hectares, generally bounded by the Western Freeway to the south-west and Kororoit Creek to the east (Figure 2). The existing catchment is mostly cleared agricultural land with scattered dwellings, however the effective impervious area connected to the wetland is essentially zero. Culverts connect flows north-south across Melton Highway. The wetland and catchment are located outside the 100-year average recurrence interval (ARI) flood extent for Kororoit Creek, being effectively hydrologically disconnected from the waterway. The wetland surface extent is approximately 13 hectares. Mean annual rainfall for the site is approximately 500 mm based on the nearby Rockbank gauge.

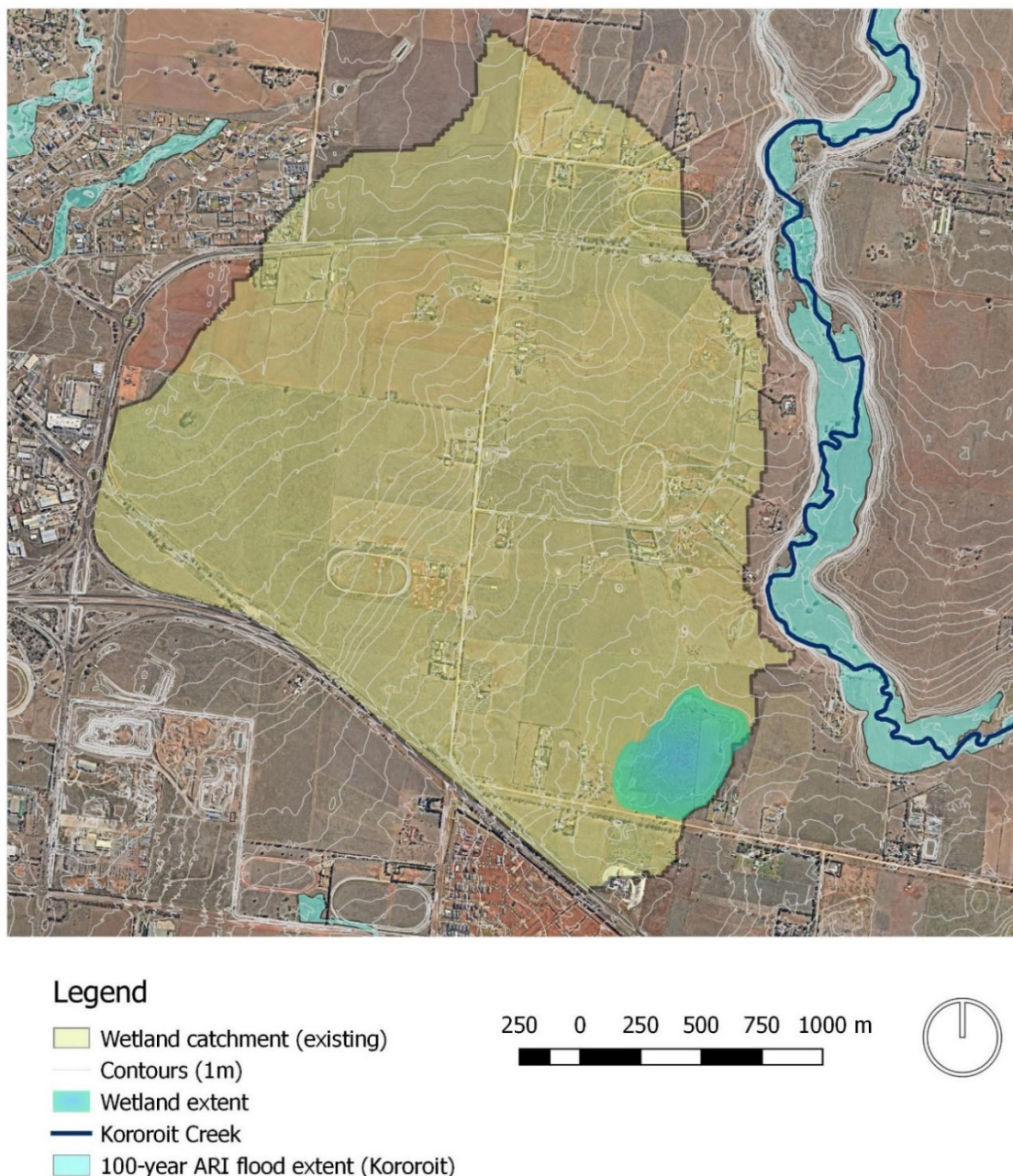


Figure 2. Existing catchment draining to the wetland

2.2 Regional groundwater conditions

Shallow aquifer conditions near the site include fractured upper tertiary/quaternary basalt, with local depths to water table of <5 m according to groundwater mapping conducted by DELWP and reported in GHD, 2017). There are no State Observation Bore Network (SOBN) bores close enough to study site to reasonably refine the estimate of local groundwater conditions. The depth of the site surface depression (<2m to the surrounding landscape) and likely groundwater contours are generally insufficient to encourage groundwater inflows into the wetland. As such, the surface expression of groundwater is considered unlikely at the wetland site and groundwater is not a major component of inundation. It is likely groundwater flows move in the direction of surface topography towards Kororoit Creek and do not intersect with the wetland depression.

An initial investigation suggests the wetland has high potential for being a groundwater-dependent ecosystem (GDE) given the extent of Plains Grassy Woodland Ecological Vegetation Class (EVC) mapped by DELWP within the wetland extent. In addition, previous hydrogeological assessments label the site as a 'potential GDE' (GHD, 2017). As such, it is possible continued ecosystem health will be sensitive to long-term changes in groundwater conditions.

The groundwater dependent vegetation at this site would be the mature River Red Gums which may access the deeper groundwater. The Seasonal Herbaceous Wetland vegetation will utilise the surface runoff water, when it is available, and not access the deeper aquifer resource.

2.3 Existing hydrologic regime

The existing hydrologic regime was characterised through a combination of anecdotal/historical evidence and rainfall-runoff modelling. Sequential aerial photography of the wetland was analysed to understand patterns of inundations over time. A MUSIC rainfall-runoff model was used to simulate the daily runoff behaviour and inflows into the wetland system.

Rainfall-runoff model parameters were calibrated using a nearest neighbour approach. There is limited streamflow gauging information in the immediate area to inform site-specific calibration. There are two streamflow gauges on Kororoit Creek in the broad vicinity of the study site:

- 231106A Kororoit Creek at Holden Road in Diggers Rest
- 231105B Kororoit Creek at Leakes Road in Rockbank

Although the Leakes Road gauge is closer to the wetland site, it represents a much larger catchment area and has a record 28 years shorter than the Holden Road gauge. A comparison of typical topographic elevation, mean annual rainfall and land use types from aerial imagery suggest both catchments are hydrologically similar to the local wetland catchment, hence the Holden Road gauge was used for calibration.

Further assumptions and a summary of calibration performance in the rainfall-runoff modelling are discussed in Appendix B. Note that features of the calibration catchment such as farm dams are implicitly accounted for through the calibration process.

Calibrated MUSIC model parameters were then adopted for the local wetland catchment, with adjustments to catchment area and fraction imperviousness to represent catchment-specific conditions. Baseflows were set to bypass the wetland, as the site surface depression is relatively shallow and local groundwater contours suggest deeper subsurface flows move relatively quickly toward Kororoit Creek. This was an important component in reconciling the modelled runoff behaviour with historical observations in wetland inundation. Therefore, since the effective impervious area is zero for the local catchment, the only flows contributing to the wetland are pervious area excess runoff (i.e. saturated or infiltration excess overland flows). In addition, infiltration was deliberately limited to replicate shallow groundwater conditions at the site.

Model performance was 'verified' using historical aerial imagery of the site. The verification process was undertaken by superimposing digitised aerial imagery over modelling results post-calibration. Robust model verification cannot be undertaken due to extreme data scarcity and uncertainty in 'observation' data. Only a handful of the historical inundation cycles are recorded (in 2010/2011 – see Figure 3), although images where the site remains dry despite heavy rain yields important information in reconciling runoff behaviour. The

primary purpose of the modelling exercise was to infer the regularity of inundation in the wetland under existing conditions. Very little data was available to further calibrate fine-scale inundation extent and infiltration.

The modelled outputs for inundation events in the wetland for the historical rainfall period since 1980 and the limited available historical information on inundation frequency are illustrated below (Figure 4). Overall, the model replicates the limited extent of observed data and does not predict inundation where none was observed (note, this can only be assessed for the period 2010-current). The scarcity of data and inherent uncertainty in using somewhat subjective interpretation of aerial images as 'observations' makes more systematic and quantitative analysis of error statistics redundant.

Based on the modelling results, the current hydrologic regime is characterised by the following features:

- Irregular inundation events on roughly a 2 to 5-year cycle
- Inundation gradually evaporates and infiltrates over several weeks/months
- Inundation events only occur for heavy rainfall after the catchment is saturated from previous events, i.e. tied to the seasonal distribution of rainfall patterns, not annual totals, and generally occurring in early summer months, likely driven by thunderstorms after the catchment has 'wetted up' from winter/spring rainfall.
- Inundation extent is approximately 13 hectares at a modelled full supply level of 109.5 mAHd. Approximately 120 ML of surface runoff is required to completely fill the wetland when empty. However, the inundation response is non-linear, and it only requires 10 ML to inundate half of this area (6.5 ha).

This indicates that it is likely the wetland already has an altered hydrology from the pre-European period, as the frequency of inundation in current conditions differs somewhat from typical conditions in EVCs that define SHW, which usually inundate on an annual cycle in average meteorological conditions.

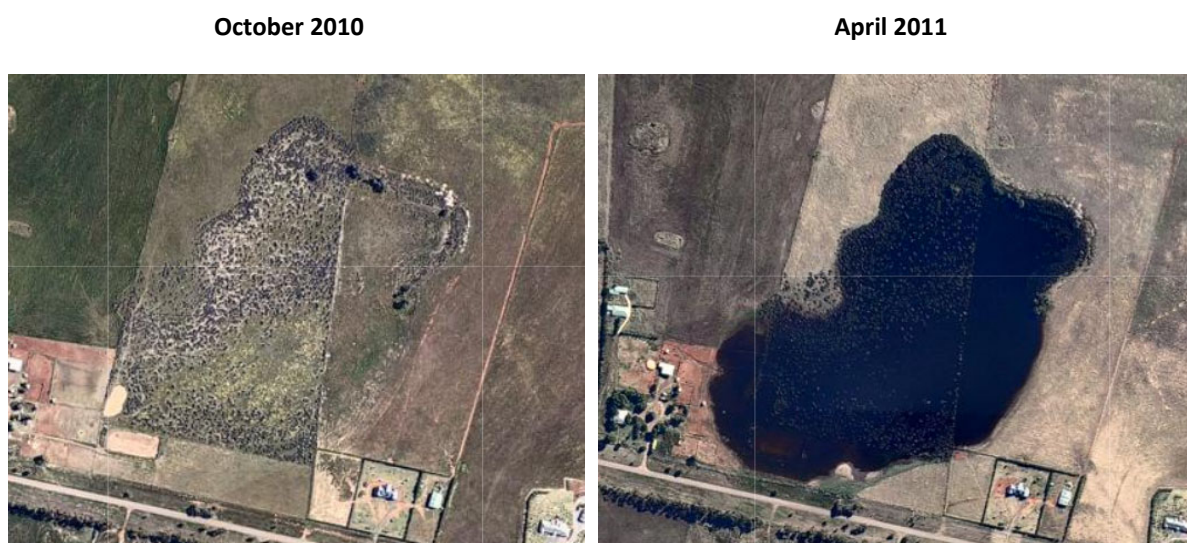


Figure 3. Observed wetland inundation event in 2011 and antecedent dry conditions

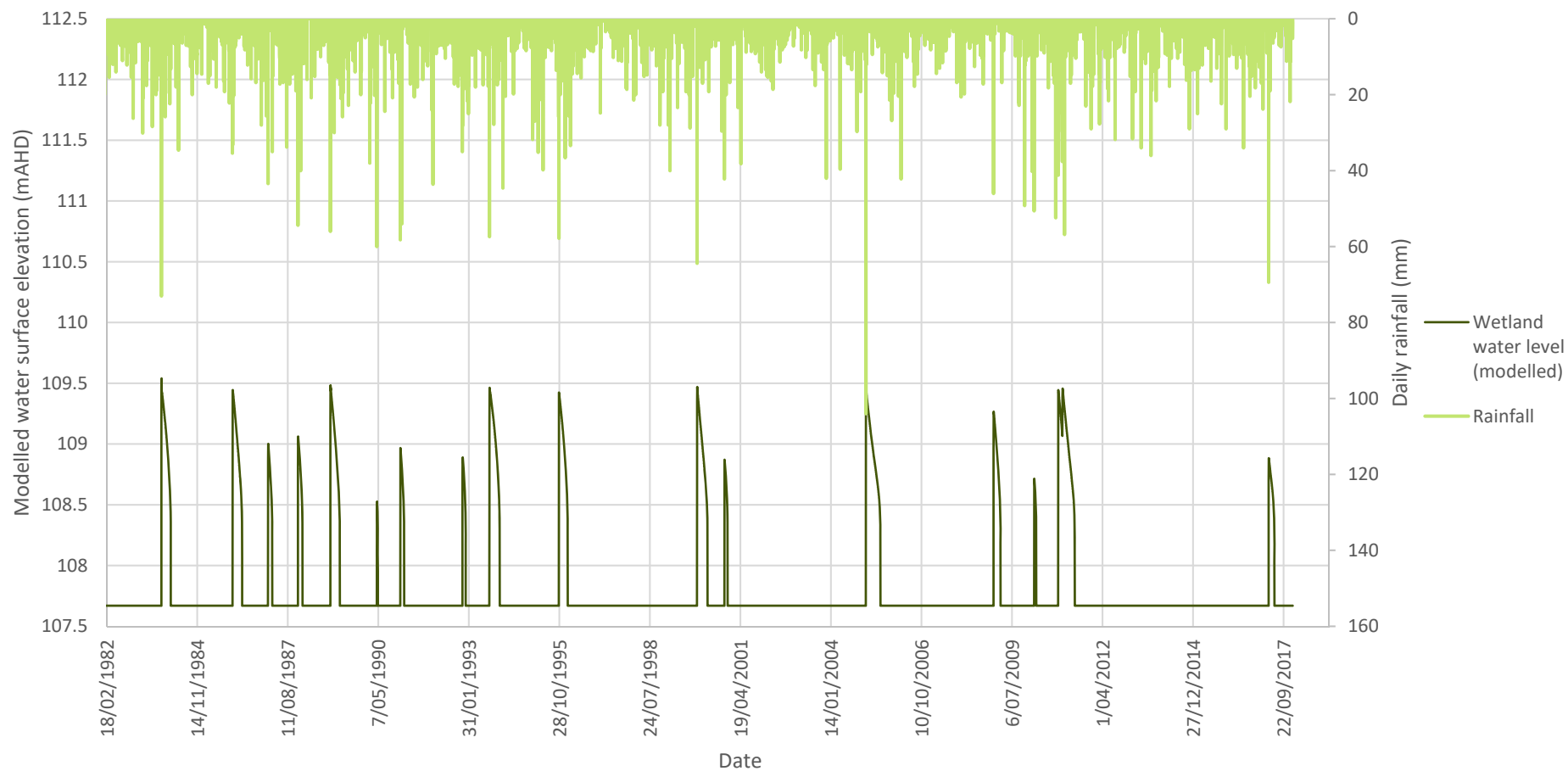


Figure 4. *Modelled inundation events in the wetland with local rainfall. Inundation peaks irregularly, typically around late spring/summer*

2.4 Biodiversity Conservation Strategy

The Department of Environment, Land Water and Planning (DELWP) conducted the MSA program to identify high value conservation for protection and enhancement in Melbourne's growth areas. The MSA includes the Growing Grass Frog Masterplan for Melbourne's Growth Corridors (DELWP, 2017) for specific areas of habitat protection and creation for the GGF. Sections of Kororoit Creek are included as high priority reaches within the MSA, including the area immediately to the north-west of the wetland site, which is designated as an ASI for future constructed GGF habitat ponds. In addition, the wetland itself has an ASI overlay due to it being considered as suitable intermittent breeding habitat for GGF populations in the adjacent ponds. These features and protected areas are demonstrated in Figure 5 with preliminary draft DSS assets.

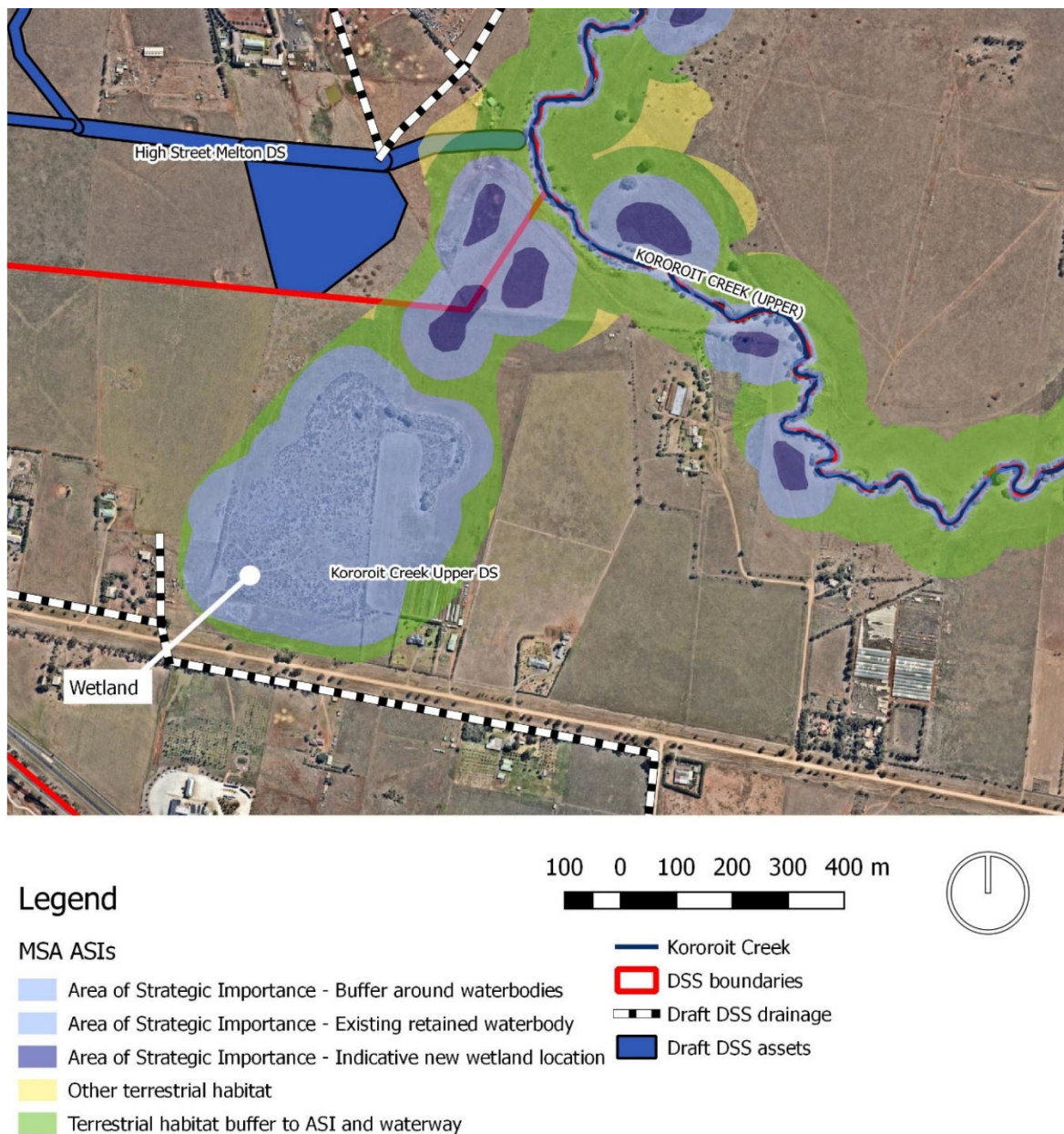


Figure 5. Melbourne Strategic Assessment Growing Grass Frog overlays surrounding the wetland site and draft DSS assets

2.5 Vegetation communities

The wetland is listed in report published by DELWP in 2013 as part of the Melbourne Strategic Assessment entitled *The impact of Melbourne's growth on 'seasonal herbaceous wetlands (freshwater) of the temperate lowland plains'*. Approximately 7.5 ha of the wetland area is considered to be SHW (EPBC-listed).

Vegetation mapping undertaken for the Rockbank Area Wetland Survey (Figure 6) shows a complex arrangement of vegetation communities across the wetland area. EVCs observed in the wetland are Plains Grassy Wetland, Plains Grassy Wetland/Lignum Swamp Complex & Plains Swampy Woodland/Lignum Swamp Complex. The site has topographical and floristic characteristics to indicate that the vegetation would be assessed as SHW (Cook et al., 2013). These communities, especially the SHW, will be expressed on the site depending on the seasonal water conditions.

The hydrologic regime of the wetland will affect these communities over time, with degradation occurring with increases or decreases in inundation extent and frequency.

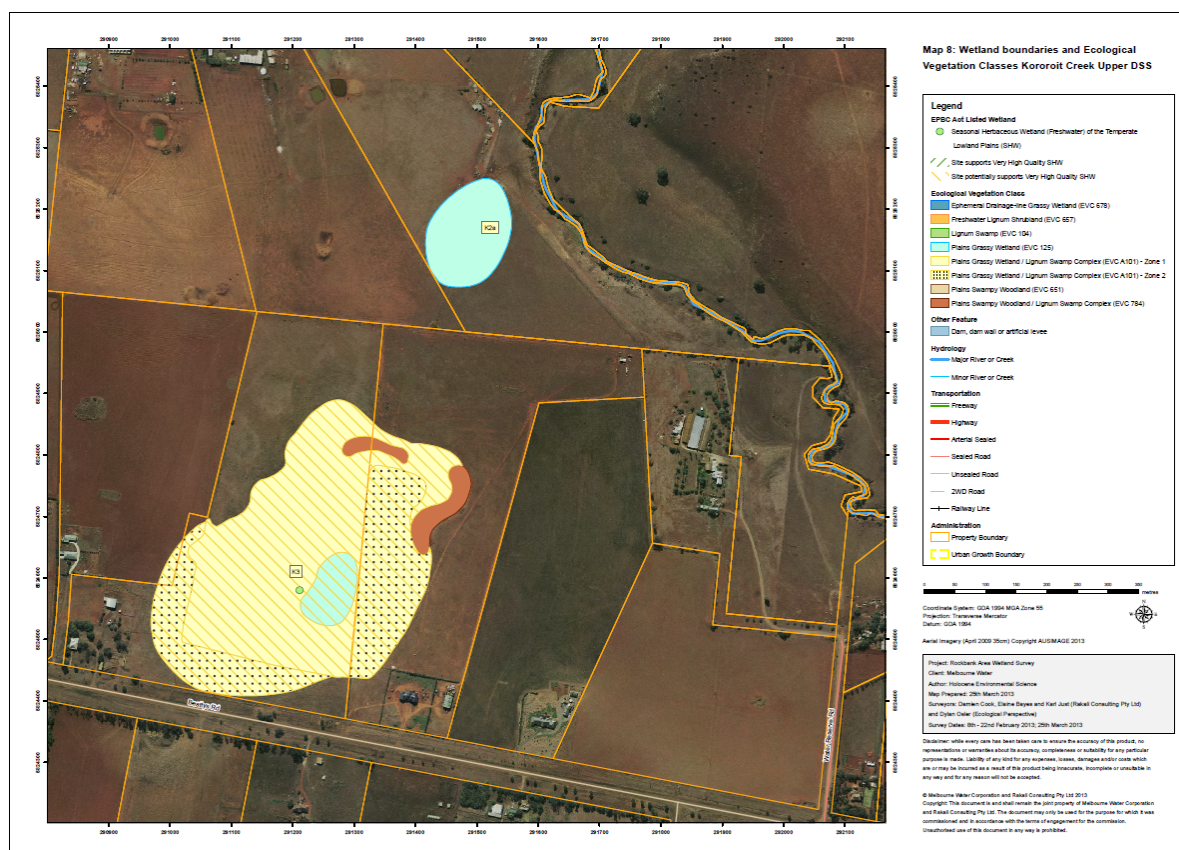


Figure 6. Wetland boundaries and Ecological Vegetation Classes Kororoit Creek Upper DSS (Cook et al., 2013)

2.6 The hydrology and water quality of Seasonal Herbaceous Wetlands

SHW are shallow (usually <500 mm but can be up to 800 mm deep) isolated freshwater wetlands that are filled by a local non-riverine catchment. They generally inundate seasonally (annually) and then dry out, with vegetation adapted to this wetting and drying cycle. The period between inundation is generally not greater than 3 years with annual inundation usually less than 6 months. The changes to the flows to the wetland in a development scenario activate two threats to this vegetation community highlighted in the EPBC listing advice:

- Altered hydrology of wetland sites (e.g. drainage, flooding)
- Altered water quality of wetland sites (e.g. salinity, nutrient loads, pollution)

Table 1 shows the hydrology required by SHW (blue highlighted row) and how altered hydrology can affect the ecology of these communities. The connected and disconnected catchment options are shown to significantly differ from the required hydrology. The almost certain likelihood of this occurring is informed by the hydrological modelling.

Activating these threats would be a notifiable action under the EPBC Act.

Vegetation community	Management objectives	Failure modes	Consequence of failure	Likelihood of failure	Recommended water regime			Depth (mm)	Mitigation Actions
					Frequency	Duration	Timing		
Seasonal Herbaceous Wetland	Persistence of SHW				Annual (Max 3 year interval between inundations))	4-6 months	June - January	<800mm	Desired hydrology regime
					Unmitigated water regime				
	Seasonal inundation	Inundation does not occur seasonally. (Insufficient Catchment area – reduced by development)	Major Change in vegetation assemblage and loss of SHW.	Almost certain	> 5 years	< 2months	July - Sept	100mm	- Consider alternative water supplies. - Prevent development via overlays and planning controls - Ensure seasonal inflow using diversion structure
	Seasonal inundation	Inundation period is longer than 9 months per annum – (Connected & developed catchment prevents wetland from drying out seasonally)	Major Change in vegetation assemblage and loss of SHW.	Almost certain	Annual	9 to 12 months	Jan - Dec	>1000mm	- Prevent development via overlays and planning - Reduce inflows to wetland via flow diversion.
	Species aligned to the vegetation community are present with herbaceous species >40% cover	Reduced frequency of inundation enables growth of exotic grasses	Major Change in vegetation assemblage and loss of SHW	Almost certain					Monitor vegetation cover and undertake strategic vegetation management
	Species aligned to the vegetation community are present with herbaceous species >40% cover	Increase in length of inundation promotes growth of Tall Marsh species especially <i>Phragmites australis</i>	Major Change in vegetation assemblage and loss of SHW	Almost certain					Monitor vegetation cover and undertake strategic vegetation management

Table 1: Seasonal Herbaceous Wetland hydrology, threats and mitigation.



3 Developed conditions hydrologic regime

3.1 Surface water

Urbanisation typically significantly changes the hydrologic characteristics of a catchment, and development within the DSS is expected to follow this pattern. The effect of development on the hydrologic regime of the wetland was simulated by changing the relevant MUSIC model parameters (i.e. fraction imperviousness, catchment area) to reflect future urban development under the current version of the DSS, as supplied by Melbourne Water and informed by the Vicmap Planning spatial layer dictating planning zone code provided by DELWP (data current as of May 2018). The changes between the existing catchment conditions and the ultimate DSS are summarised below (Table 1). The catchment plan showing the DSS assets in place and subsequent changes in wetland catchment area in line with Table 1 is presented below (Figure 7).

Table 1. Existing and developed conditions catchment attributes

Scenario	Catchment area (ha)	Fraction impervious
Existing	605	0
Developed	112	0.75*

*Assumed as an overall catchment average, given the inclusion of industrial zoning

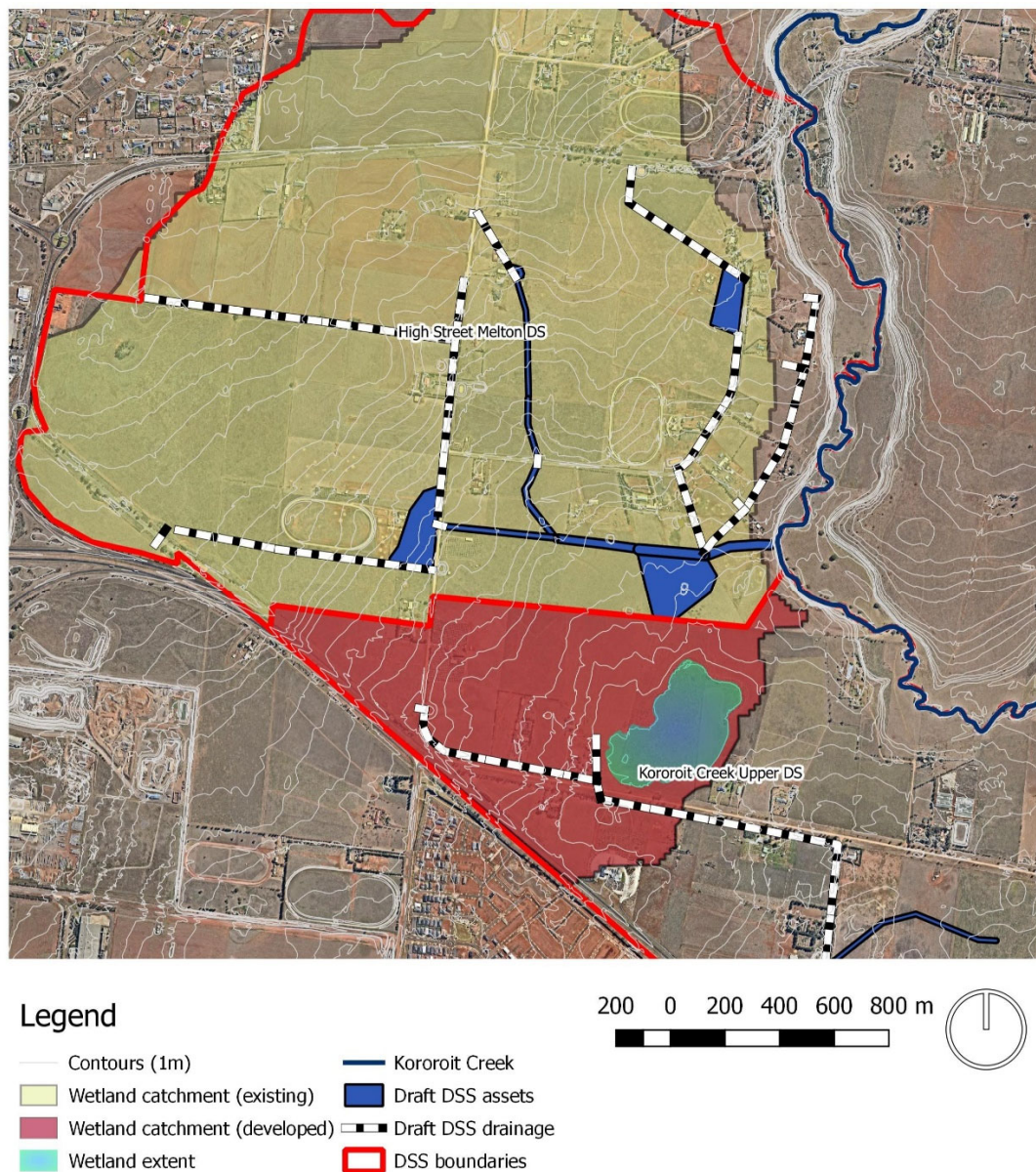


Figure 7. Revised wetland catchment with scheme development and draft scheme assets

Two scenarios considered for developed conditions:

- Direct connection of impervious surfaces to the wetland. In this **connected scenario** local high and low flow drainage systems directly connect to the wetland
- Impervious surfaces bypassing the wetland in this **unconnected scenario** local drainage (hence all impervious area) bypasses the wetland.

The two scenarios effectively represent the extremes in development impact, through either impervious area dramatically increasing flows to the wetland, or an efficient drainage system bypassing flows around the wetland, leading to lower inflows than under current condition, as the only supply of water is from direct rainfall on the wetland and its immediate surrounds.

These two possibilities affect the wetland in substantially different ways. Table 2 describes inundation occurrences throughout the simulation period and Figure 8 shows the changes in modelled surface water inflow volumes seasonally throughout the year. Figure 9 shows the proportion of days of inundation through the year. Note that Figure 9 lags Figure 8 due to the time taken for evaporation and infiltration to remove water in the wetland.

Table 2. Modelling scenario total inundation spells in the 38-year simulation period

Scenario	Catchment area in model scenario (Ha)	Number of inundation occurrences	Average duration of inundation (days)	Average time between inundation events (days)
Existing conditions	605	18	80	739
Developed - connected	112	868	55*	15
Developed - unconnected	112	12	6	1109

*This can be misleading due to small rainfall events causing inundation. The overall variability of inundation duration is increased, and some spells last several years (Figure 10)



Figure 8. Seasonal relationship of inundation days throughout the year for each modelling scenario, and average monthly rainfall

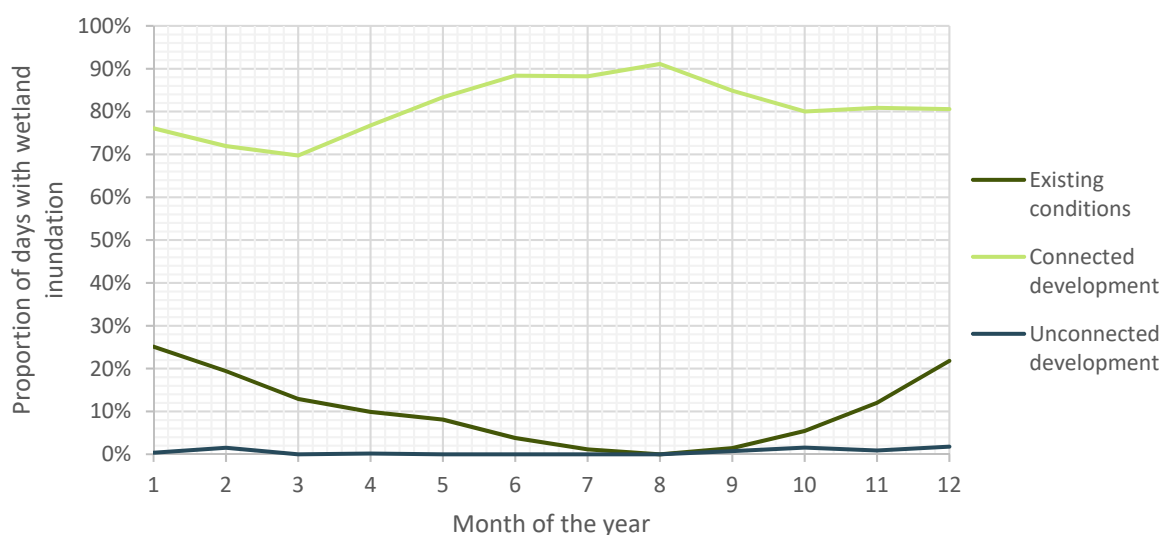


Figure 9. Seasonal relationship of inundation days throughout the year for each modelling scenario

Connection of the impervious surfaces in the revised (smaller) catchment that drains to the wetland vastly increases the volume of runoff flowing to the wetland, increasing the frequency of inundation to a near continuous state. This is despite the large reduction in catchment area post-development. Any inter-annual variability or seasonal behaviour is eliminated due to increased inflows. The average duration of inundation is reduced due to a higher frequency of smaller inundation volumes. Table 5 shows the inflows from the

connected catchment tracks to the rainfall pattern with resulting in significantly increased inflows to the wetland.

Conversely, if impervious areas are disconnected, the overall reduction in catchment area leads to reduced inundation extent and duration. Inundation frequency is generally preserved compared to existing conditions, although the volume of water and extent of inundation are vastly reduced, and seasonal patterns in the inflow volumes and proportion of inundation days are lost. Figure 10 and Figure 11 show the resulting modelled wetland behaviour across the 38-year simulation period.

Both possible outcomes from development have the potential to affect the viability of ecological communities at the wetland site. Management options should be prepared that mitigate any risk to sensitive or high value ecology and attempt to maintain the existing hydrologic regime, where possible.

3.2 Groundwater

Changes in long-term groundwater conditions have the potential to threaten ecological values at the site. A reduction in pervious area due to development will be associated with a reduction in water infiltrating in regional soils and recharging the groundwater system. Over time, and considering the possibility of future extractions, this may lead to a trend in lowering of the groundwater table, or new equilibrium groundwater conditions. In addition, reduced groundwater infiltration and catchment land use change may lead to some degradation of groundwater quality. If groundwater head or quality reduce, vegetation communities that rely on these could degrade or perish altogether. This may only present a threat to larger deep-rooted trees such as River Red Gums that inhabit the site and may not influence the value of key species that comprise EVCs relevant to SHW.

Detailed analysis on changes in groundwater conditions was outside of the scope of this study, but groundwater changes associated with development would be consistent with observations at other sites. It is recommended to monitor groundwater conditions and establish a management or adaptation plan such that a response to observed changes or threats can be mounted.

3.3 Water quality

The wetland current receives inflows from high rainfall intensity or volume events in the upstream (primarily rural catchment). It is expected that water quality from runoff in the urbanised catchment will be lower than the existing conditions, particularly due to elevated nutrient and suspended solid loads. Most pollutants are passed during low flow events given their higher frequency, so most of the pollutant load will be distributed through the local (i.e. piped) drainage system.

If impervious areas are directly connected to the wetland this will likely lead to elevated nutrient loads (e.g. nitrogen and phosphorus). This can have two implications depending on drying regimes:

- If the wetland is allowed to dry out, then elevated nutrient availability may preferentially shift the dominant vegetation assemblages away from herbaceous species toward grassy species
- If the wetland remains frequently inundated, then eutrophication increases the likelihood of algal blooms in summer months, followed by associated depletion of dissolved oxygen within the water extent. This can smother existing vegetation and has negative amenity outcomes for residents.

In the unconnected impervious areas scenario, water quality in wetland inflows is likely to be similar to existing conditions. The draft DSS does not currently include any stormwater treatment assets upstream of the wetland to mitigate the impact of poor water quality.

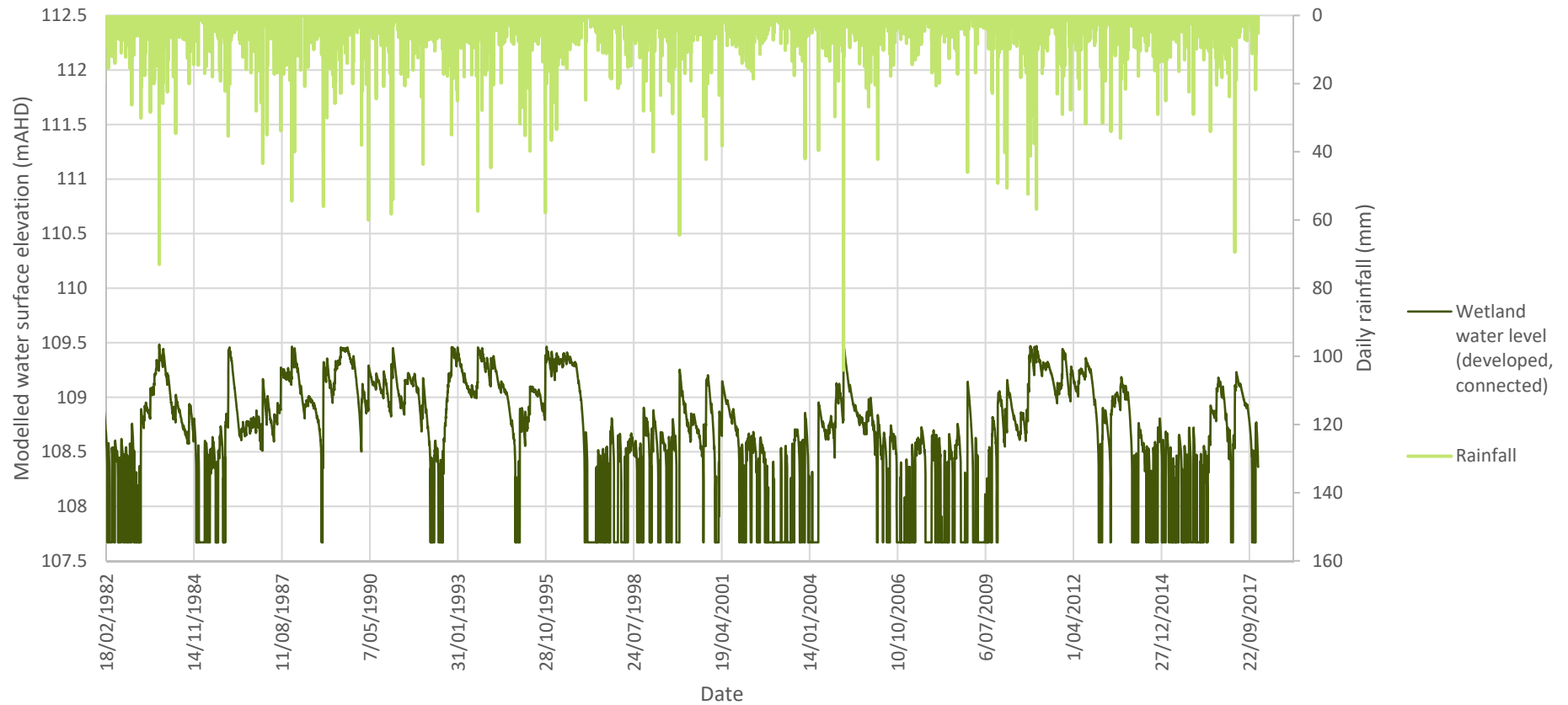


Figure 10. Modelled inundation events in the wetland with connected impervious areas post development. Inundation occurs significantly more frequently, with the wetland under water most of the year. Seasonal and intermittent properties are eliminated.

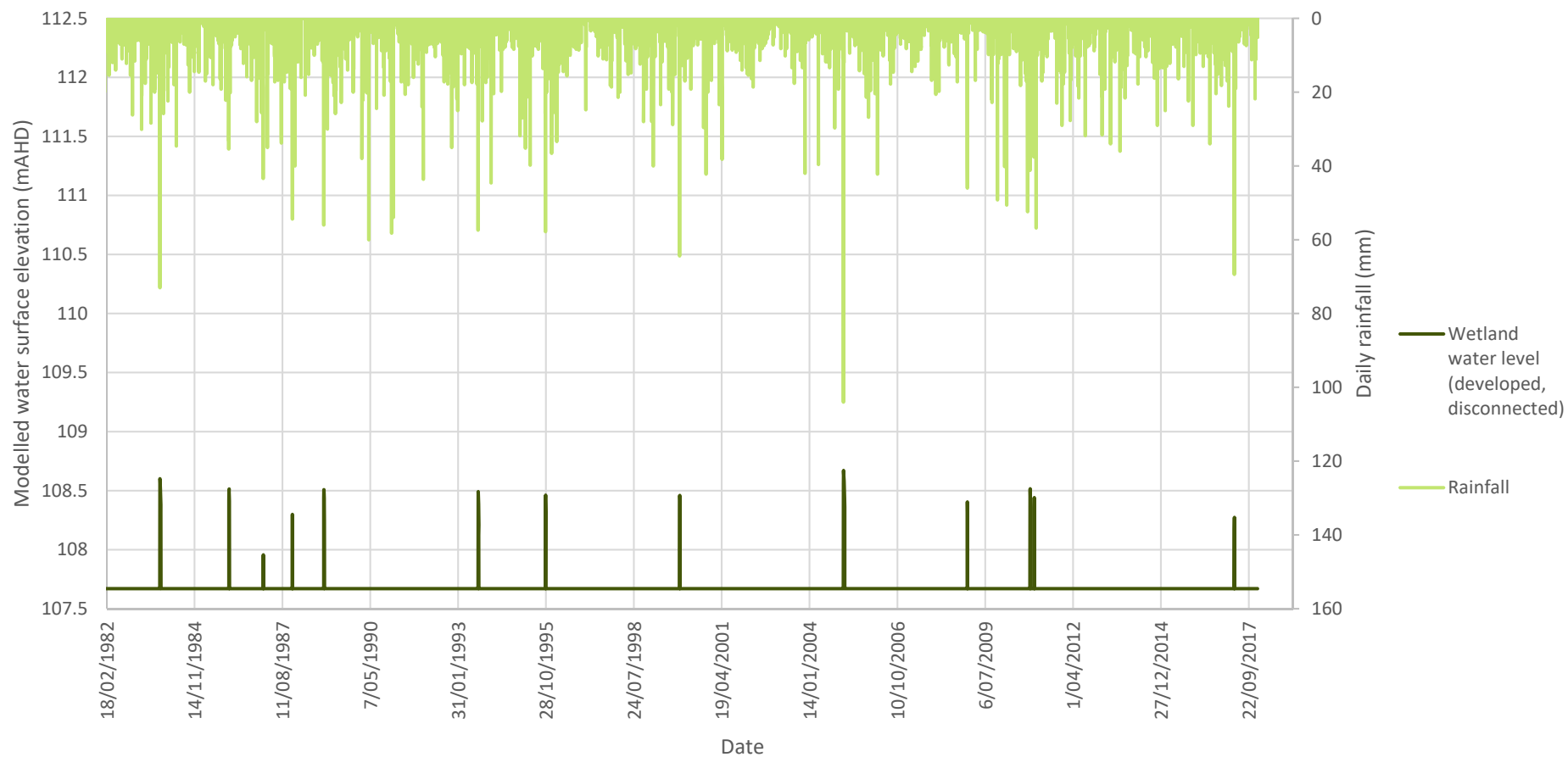


Figure 11. *Modelled inundation events in the wetland with disconnected impervious areas post development. Inundation occurs at approximately the same frequency as existing conditions, but the total volume, inundation extent and duration are significantly reduced.*

4 Other threats

This report focuses on threats to the surface water hydrologic regime supporting the SHW community due to development. However, there are other threats that may influence hydrologic factors or external pressures that should be considered with detailed investigation of mitigation measures.

4.1 Existing land use

Historic aerial imagery of the site shows agricultural cropping right up to the wetland vegetation boundary, and in some situations, encroachment into the wetland vegetation itself. Figure 12 shows an image from December 2015 where the property owner to the east has cropped within the inundation boundary. Previous imagery suggests relatively lower quality vegetation in the cropped area but with potential recruitment of SHW vegetation following inundation in 2011. This presents an ongoing threat to the wetland. Vegetation degradation during extended dry periods may be used as justification to expand the cropping area into larger sections of the wetland footprint. Once an area is cropped, it is very unlikely recruitment following periods of inundation for SHW species will be successful.

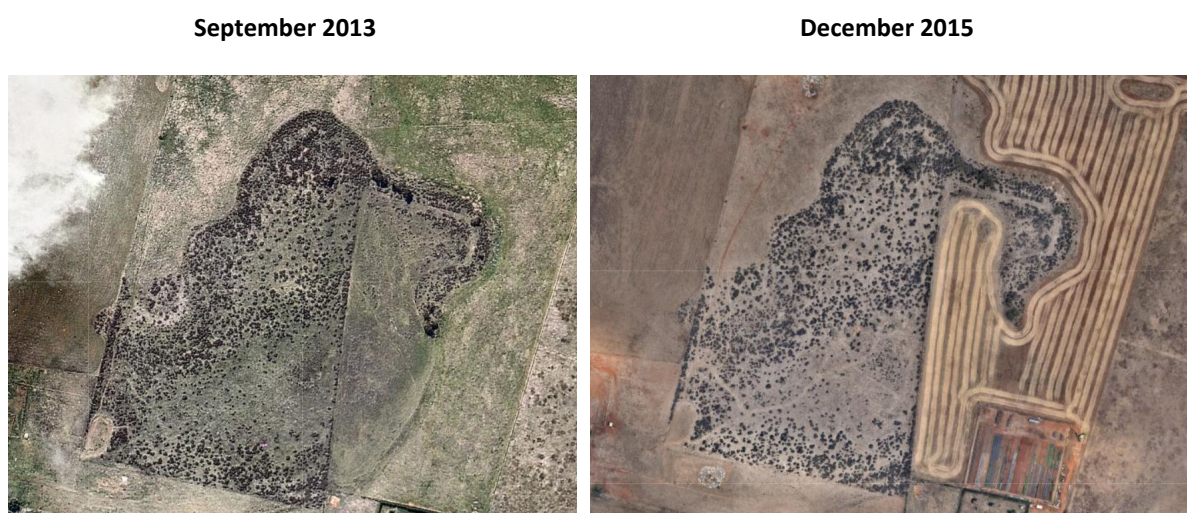


Figure 12. External cropping threats to the wetland and barriers to successful future recruitment

4.2 Climate change

Changes in climate have implications for water availability in the wetland. In general, current climate projections forecast decreases in long-term average annual rainfall but increases in the frequency of extreme rainfall events (DELWP, 2017). These two phenomena may counteract each other somewhat – the former reducing total water availability and antecedent catchment wetness reducing the proportion of runoff following a large rainfall event – and the latter by generating more runoff for particularly intense rainfall bursts. In addition, higher average temperatures will increase evapotranspiration rates and therefore further reduce soil moisture and length of inundation following a runoff event.

Investigation of site specific climate risks was outside of the scope of this study. However, the long-term viability of the SHW is expected to be sensitive to changes in rainfall distribution, volume and intensity, as well as changes in temperature and evapotranspiration.

It should be noted that the site has experienced significant natural climate variability in the observed record including the severe Millennium Drought and has appeared to tolerate these pressures. However, the cumulative effect of pressures from development and changes in climate may push the SHW beyond recovery. It is recommended that forecast climate change effects be investigated further before mitigation options are pursued in detail.

5 Mitigation options

Mitigation options are presented below to address the threats from a changed surface water hydrologic regime, which is considered the primary driver of inundation traits within the wetland. The options below assume the guiding objective is to maintain the existing hydrologic regime of the wetland.

Modelled development impacts have some degree of uncertainty. As such, options have been developed with a degree of flexibility in their implementation and ongoing management. In addition, options are considered that are sympathetic to the adjacent future GGF habitat ponds. Important to the success of any mitigation options is a monitoring program that observes the inundation frequency and ongoing health of the SHW over time.

5.1 Do not allow the catchment to develop

Preventing development in the catchment will remove the hydrologic and water quality threats to the wetland and preserve the existing hydrologic regime. Existing threats such as climate change and current land use pressures will remain.

However, it is understood the decision to develop has largely been made and a solution to enable the development will be required.

5.2 Create hydrologic buffer zone

It is likely by preserving a portion of the catchment in its current condition, some key components of the existing hydrologic regime can be retained. A hydrologic buffer zone can be established in the catchment upstream of the wetland that is isolated from the drainage network of adjacent developments. There is some opportunity to incorporate public open space to maximise the benefits of the buffer without compromising the health of the SHW. The water quality of inflows from any hydrologic buffer zone will need to be carefully considered to ensure it does not create deleterious impacts on the wetland (see Section 3.3).

Additional catchment modelling would be required to determine a suitable buffer zone, but the area required could be substantial. This buffer reserve would likely require statutory protection through planning overlays to avoid threats from development in the future.

5.3 Install operable flow diversion and WSUD devices in the drainage system

This option takes advantage of the increased runoff volumes under development conditions to deliver optimum watering requirements to the wetland. A flow diversion structure within the local drainage system could be designed to divert a proportion of the flow regime (e.g. flows between the 1 and 5-year ARI flow event) into the wetland.

Using a simple weir in a stormwater offtake pit, the height can be modified through a variable penstock to respond to the needs of the wetland during dry periods or isolate system in wet years. Water level and soil moisture monitoring could be used to trigger adjustments to the drainage system as per a defined hydrological regime. This necessitates an ongoing monitoring and adaptation program. However, given the wetland currently experience significant natural variability, it would likely be resilient to only intermittent (e.g. annual) monitoring and adjustment.

Diverting water from the local drainage system will have water quality implications due to runoff from the urban environment. Water sensitive urban design assets such as a small artificial sediment pond at the inlet to the wetland could be installed to mitigate impacts of poor water quality.

This option is technically possible but will require significant cultural change in the management institutions. The history of operable drainage devices demonstrates the challenges of maintaining institutional knowledge through staff changes and restructures, which is exacerbated if cross-agency collaboration is needed, and a long-term commitment is required. If the regime cannot be delivered the risk of ecosystem failure is highly likely, which would trigger an EPBC notification and potentially significant reputational risk to the organisation.

5.4 Water supply augmentation

Given inundation cycles are required at intermittent intervals across several years, it may be feasible to provide an alternative water supply to manually inundate the wetland to capacity. This could be achieved through supply of potable water or local groundwater directly to the wetland. This option does provide enhanced flexibility in delivering optimum watering requirements but suffers from requiring maximum management intervention and potentially very high ongoing costs.

This option is considered a possible backup or supplement in case of any of the previously identified options are observed to fail in operation.

6 Recommendation - Selection of a preferred option/options

It is clear from the analysis that a business as usual drainage approach will lead to a reduction in the ecological values of the wetland. Four management options have been identified that will mitigate the impacts of changes in the hydrologic regime.

Further work is required to develop these options and carry out a cost-benefit analysis to identify the preferred design solution.

The final design must:

- Provide a hydrological regime that provides seasonal water availability to support Seasonal Herbaceous Wetland vegetation.
- Allow for adjustment of the water flows to respond to seasonal water requirements and/or water level monitoring information.
- Provide the Stormwater treatment from the catchment flows to mitigate sediment and dissolved nutrient flows to the wetland.
- Be maintainable within normal expenditure budgets.

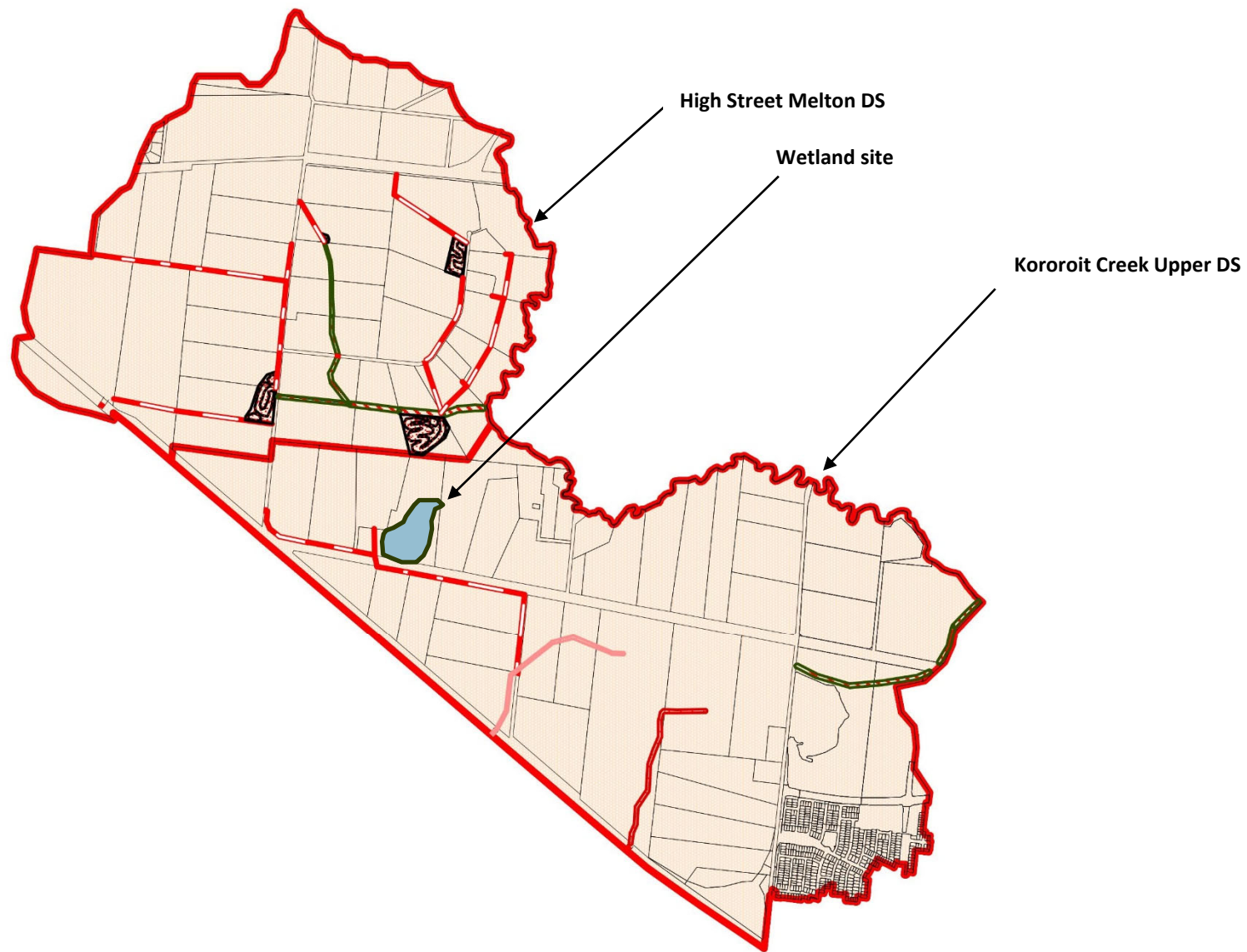
7 References

- Cook, D., Just, K., & Jolly, K. (2013). *Rockbank Area Wetland Survey*. Melbourne: Melbourne Water.
- Department of Environment and Primary Industries. (2013). *The impact of Melbourne's growth on 'seasonal herbaceous wetlands (freshwater) of the temperate lowland plains' - Melbourne Strategic Assessment*. Melbourne: Victorian Government Department of Environment and Primary Industries.
- Department of Environment, Land, Water and Planning. (2016). *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria*. Melbourne: Victorian Government Department of Environment, Land, Water and Planning.
- Department of Environment, Land, Water and Planning. (2017). *Growling Grass Frog Masterplan for Melbourne's Growth Corridors - Melbourne Strategic Assessment*. Melbourne: Victorian Government Department of Environment, Land, Water and Planning.
- GHD. (2017). *Kororoit Creek Upper Development Services Scheme Hydrogeological Desktop Assessment*. Melbourne: Melbourne Water.

Attachment A

High Street Melton DSS





Attachment B

Rainfall-runoff Model Calibration



Model calibration

The existing hydrologic regime was characterised through a combination of collation of anecdotal/historical evidence and rainfall-runoff modelling. A MUSIC rainfall-runoff model was used to simulate the daily runoff behaviour and inflows into the wetland system.

Rainfall-runoff model parameters were calibrated using a nearest neighbour approach. There is limited streamflow gauging information in the immediate area to inform site-specific calibration. There are two streamflow gauges on Kororoit Creek in the broad vicinity of the study site:

- 231106A Kororoit Creek at Holden Road in Diggers Rest
- 231105B Kororoit Creek at Leakes Road in Rockbank

Gauge and catchment features are discussed below (Table 3).

Table 3. Streamflow gauge characteristics near the study site

Name	Length of record (years)	Distance to site (km)	Catchment area (km ²)	Comment on hydrologic similarity
Kororoit Creek at Holden Road in Diggers Rest	38	7.2	74.7	Large catchment area relative to site catchment. Land-use, regional and local geology similar to site. Some higher elevation in the uppermost catchment.
Kororoit Creek at Leakes Road in Rockbank	10	2.4	100	Larger catchment area relative to site catchment. Land-use, regional and local geology similar to site. Some higher elevation in the uppermost catchment. Short gauge record limits the usefulness for calibration.

Model calibration adopts the Holden Road gauge as both candidates are considered hydrologically similar, but it has a much longer record. Note that using the donor catchment for rainfall-runoff model calibration leads to significant (unquantifiable) uncertainty in the calibrated model parameters. However, since the default values are given for an average of catchments around greater Melbourne with substantially different hydrological conditions, infrastructure and flow regulation, we consider the parameters calibrated to the Holden Road gauge more representative of site conditions in the wetland catchment.

An automated global calibration scheme was used. The calibration objective function was selected to avoid excessive bias toward either high or low flows, whilst preserving the total annual average inflows to the gauge. This includes consideration of the following statistics:

- Nash-Sutcliffe efficiency E - indicates model performance at replicating observed values, 1 being a perfect representation, 0 being the model is only as good as using the mean from the observed time series
- Bias – a measure of systematic deviation in modelled values against observations. Positive bias indicates the model is overpredicting, whereas negative bias suggests underprediction. A bias of 0 is optimal.
- Runoff volumes – the mean annual modelled and observed runoff

Table 4 shows the calibrated and default MUSIC model parameters. A summary of calibration performance is provided below against the use of default MUSIC parameters (Table 5, Figure 13 and Figure 14). Overall, the calibrated parameter sets have lower soil storage and a more rapid baseflow response than the default parameters. Although the rainfall-runoff model is conceptual only and soil-based parameters do not physically represent in-situ conditions, generally lower soil stores and rapid baseflow discharge could be representative of sandy or silty soils and fractured tertiary basalts in the catchment. The default parameter set leads to significant over-prediction of runoff volumes.

There was some difficulty in obtaining a calibration that replicated all aspects of seasonal hydrologic behaviour (note the deviation from observed very low flows in Figure 13). Aerial images showed a large number of small farm dams within the catchment which are not explicitly represented in the conceptual rainfall-runoff model. However, lower bias, higher efficiency and a comparison of hydrographs suggests the calibrated parameter sets leads to an improved simulation of the different runoff processes than the default parameters, especially on an annual timescale. The final calibrated parameter set slightly underestimates the total annual runoff – this is considered a conservative approach where the wetland is water supply limited.

Table 4. Calibrated and default MUSIC model parameters

Parameter	Default	Calibrated
Impervious threshold (mm)	1	2.5
Soil storage capacity (mm)	120	71
Initial storage (%)*	25	25
Field capacity (mm)	50	50
Infiltration capacity coefficient - a	200	315
Infiltration capacity coefficient - b	1	4.3
Initial groundwater depth (m)*	10	10
Daily recharge rate (%)	25	23
Daily baseflow rate (%)	5	48
Daily deep seepage rate (%)	0	0

*Initial conditions unchanged (long-term response not sensitive)

Table 5. Calibration performance statistics

Statistic	Default	Calibrated	Observed
Nash-Sutcliffe efficiency E	0.11	0.39	n/a
Bias	0.06	0.00	n/a
Average annual runoff (ML/y)	3,933	1,815	1,937

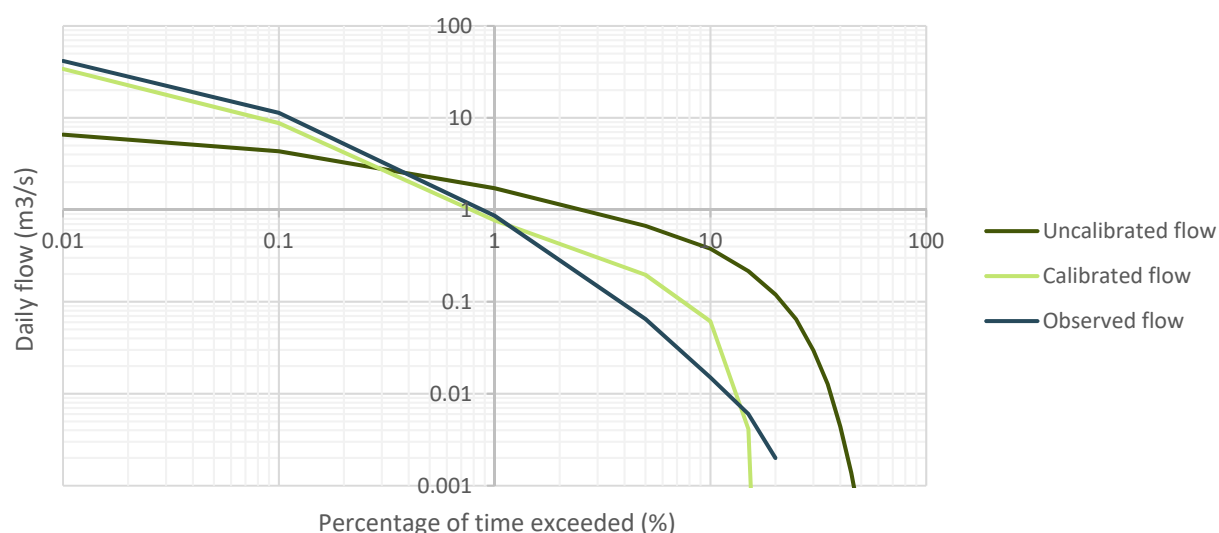


Figure 13. Comparison of flow duration curves from default, calibrated and observed data. Note logarithmic scales

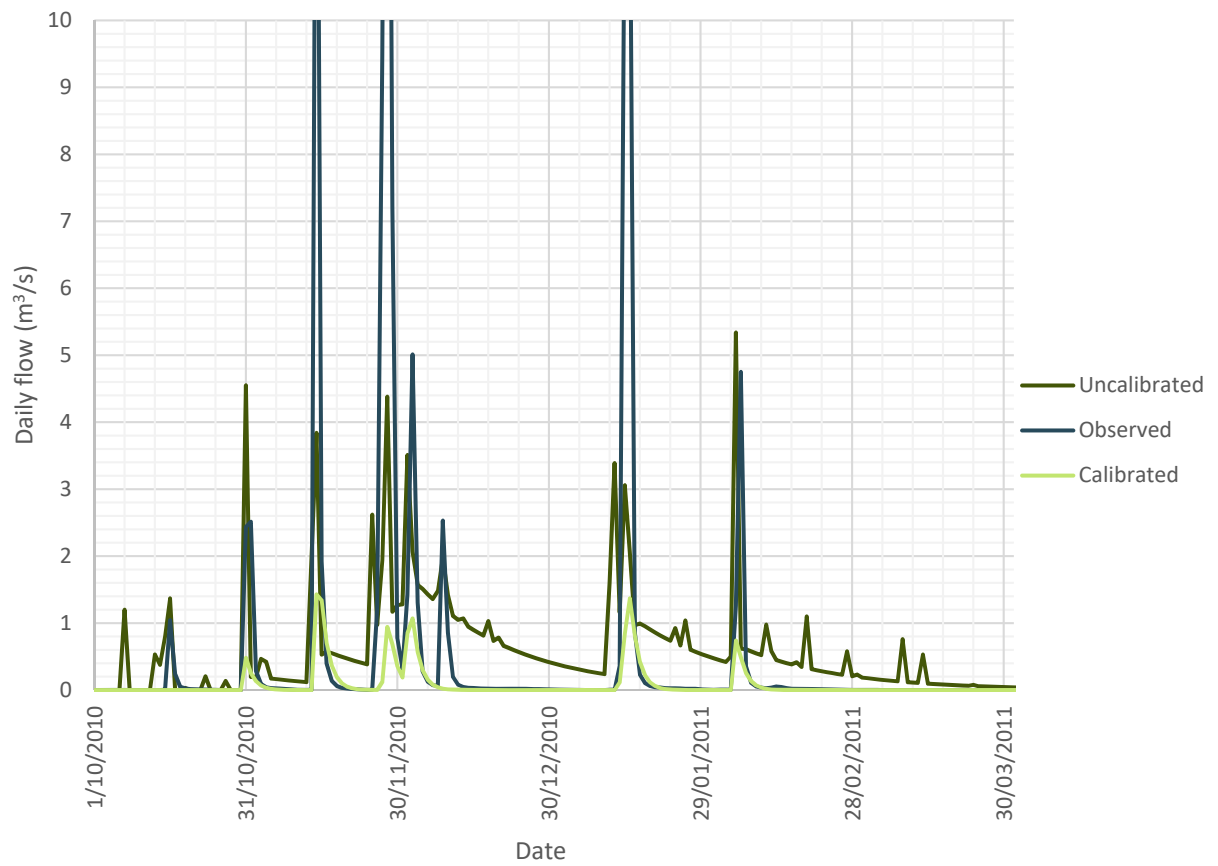


Figure 14. Example comparison of selected hydrographs between default, calibrated and observed data

