Creation of refuge wetland habitat for the nationally-threatened fish species Dwarf Galaxias (*Galaxiella pusilla*) in the Cardinia Creek system, using an existing water authority retarding basin site.

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Key Points

- A multi-disciplinary technical study was undertaken to develop a detailed design for the construction of a new wetland habitat and drought refuge pond for the threatened fish species, dwarf galaxias (*Galaxiella pusilla*).
- The site was an existing retarding basin site in outer Melbourne, owned by Melbourne Water and managed primarily as a flood retention basin for Cardinia Creek, which runs through the site.
- The study required a series of technical assessments to determine: the ecological and hydrological habitat requirements of the dwarf galaxias and its habitat; hydrological characteristics of the site including existing stream flows, wetland connections, and potential water sources for the new wetland; a water balance analysis to determine required inflow rates to produce optimal wetting and drying regimes in conjunction with the engineering design to determine the footprint and bathymetry to produce the required conditions; and a detailed engineering design to produce the inflow structure, outfalls, and other design features including gravel filter pits to prevent invasion by exotic fish species.
- The site proved to be a suitable location for a new wetland habitat, with sufficient catchment stormwater inflows to provide for filling of the new wetland and a suitable wetting and drying regime, without disruption of the hydrological and flood retarding function of the current site.
- The wetland is now under construction and will contribute towards Melbourne Water's goals of biodiversity conservation, management of urban development and associated hydrological and ecological impacts, climate change mitigation, and multi-use benefits from existing assets.

Abstract

Dwarf galaxias (*Galaxiella pusilla*) are threatened by habitat loss and altered flow regimes. Climate change poses additional threats with lower streamflows and loss of wetland habitat, particularly drought refuge pools. Dwarf galaxias persist in Cardinia Creek despite historical catchment impacts and rapid urbanisation. Melbourne Water is committed to protecting the species and managing urbanisation-related threats. Their existing retarding basin site presented an ideal opportunity to create additional, connected habitat in the system.

We designed a wetland habitat using a multidisciplinary approach, incorporating:

- Required habitat and wetting/drying regime assessment

- Hydrological modelling of potential creek and stormwater inflows to create required water regime and habitat conditions, considering seepage and evaporation

- Design of wetland size, depth and location to create hydrological habitat; variable depths, extensive shallow areas and deeper, permanent pools

- Innovative engineering design; inflow pit and pipe sizing for correct inflows, gravel traps to prevent invasive fish ingress, and a creek outflow structure

- Recommended vegetation plantings in 6 zones from permanently inundated to riparian.

The site proved ideal for wetland habitat creation; stormwater provided suitable inflows, and outflow to the adjacent creek system maintained hydrological function. Creation of refuge pools within the wetland mitigates climate change risks for the existing creek population.

This project highlights opportunities to create habitat at retarding basin sites, providing multiple benefits and mitigating threats of urban development, altered stream hydrology and climate change. The robust technical methodology can be applied at any site, and delivered inexpensively. The project provides a model for management of similar threats and creation of habitat in other locations.

Keywords

Dwarf galaxias (*Galaxiella pusilla*), wetland habitat creation, urban stream hydrology, urban development, climate change, retarding basin, site multi-use benefits.

Introduction

The Cardinia region on the outer south-eastern fringe of Melbourne is experiencing rapid and widespread urban development. Native freshwater fish, including the nationally-threatened dwarf galaxias (*Galaxiella pusilla*), are known to occur in the region but are under threat from direct impacts including loss of habitat as well as indirect impacts such as the effects of urban development on altered stream hydrology. These impacts will likely be exacerbated by a changing climate and forecast lower stream flows, leading to the loss of habitat.

Melbourne Water has set objectives to improve waterway values, habitat, and biodiversity in the Cardinia region. Melbourne Water owns and manages the Cardinia Creek Retarding Basin in Beaconsfield, which is managed primarily as a flood mitigation asset but is also a Site of Biological Significance (SOBS). Melbourne Water is seeking to protect and enhance the biodiversity values of the site through the creation of additional wetland habitat for the dwarf galaxias fish that is found at the site and in the surrounding waterways.

This study developed a detailed design for a new wetland habitat pond at the site. The pond will provide additional habitat and drought refuge to support the existing population of dwarf galaxias, and mitigate against future impacts including climate change and urban development to support the regional fish population, and mitigate the likelihood of species extinction.

The development of the wetland design incorporated a number of technical elements including:

- Analysis of ecological and hydrological requirements of the dwarf galaxias and its habitat
- Assessment of the existing retarding basin site waterways and hydrology (Cardinia Creek and associated wetland areas of varying size, type and depth
- Catchment modelling and hydrological assessment to determine suitable water sources for the new wetland (including potential connections to Cardinia Creek, or inflows from the local stormwater catchment)
- Initial wetland footprint and 3D design based on site topography, and hydrological and ecological requirements of the new wetland.
- Modelling of available stormwater volumes and optimization of inflow rates to appropriately size infrastructure (pipe size, valves etc.) to provide the appropriate wetting and drying regime for the wetland with consideration of evaporation and seepage rates.
- Additional site testing for updated survey and soil/seepage testing.
- Final detailed wetland design incorporating final footprint and depth, top water level and invert level, batter slopes, inflow and outflow structures, and filter pits to prevent access to the pond by invasive fish species.
- Production of final detailed design drawings ready for construction.

Project tasks, method and outcomes are described in the following sections.

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Dwarf galaxias habitat and wetland design requirements

Dwarf galaxias are small, native freshwater fish that grow to ~40 mm. They are typically found in shallow, still to slow-flowing waterway and wetland habitats, with semi-permanent water and dense submerged and emergent aquatic vegetation. They are well adapted to dynamic hydrological conditions including seasonal inundation, retreating to small permanent habitats during dry periods and moving onto inundated floodplain habitat for spawning during wet periods. Regular wetting and drying cycles are also important from the perspective of food resources and predators. Prolonged inundation can lead to shifts in invertebrate communities from those dominated by food resources (prey species for fish) to those dominated by predators. Permanent inundation also favours invasive predator species such as Eastern gambusia (*Gambusia holbrooki*), which represent an additional threat to dwarf galaxias populations.

The new wetland is intended to augment existing habitat at the site, and to provide an area of permanent water to act as a drought refuge. Critical requirements for the wetland were therefore creation of habitat comprising shallow, still to slow-flowing water with dense submerged and emergent vegetation, and a hydrological regime providing variability in water depth across the wetland, with permanent pool areas and shallow margins that regularly wet and dry. Other considerations included locating the wetland above regular inundation level to reduce colonisation by gambusia, and ensuring a regular source of water that is not from creek flows. The wetland was also designed to minimise maintenance requirements, maintain the performance of the wetland system in the context of the retarding basin, minimise hydrological alterations to the broader site, and avoid damage to existing trees and biodiversity values.

Site overview and hydrology

The site review was completed to assess the site's hydrological characteristics and ecological values, and to determine the most suitable location for the new wetland accordingly. The Cardinia Creek retarding basin is located in Beaconsfield, ~42 kilometres south-east of the Melbourne CBD, and occupies ~45 hectares of low-relief land. Built in 1982 to control downstream floodwaters and erosion on Cardinia Creek, it is located at the start of the creek's floodplain system. The site includes several wetland areas and retains significant natural remnant vegetation, as well as large areas of mowed grass and parklands (Figure 1).

Figure 1. Aerial view of the Cardinia Creek retarding basin (RB) with approximate site boundary in yellow. Map prepared with aerial imagery from ArcGIS® software by Esri.

Cardinia Creek flows through the centre of the site, entering at the north-western end and flowing out of the site through a concrete culvert under a highway. Small tributaries and anabranches connect to the main creek channel through the site, which also receives stormwater from the local catchment through several piped stormwater inflows. There are several floodplain wetland areas on the site that are filled by creek overflows and local overland inflows; existing channel and wetland areas are highlighted in Figure 2.

Figure 2. Cardinia Retarding basin highlighting creek channel and wetland areas (blue). Map created using https://vic.digitaltwin.terria.io and Vicmap Hydro Watercourse and Water Area dataset.

The site has a number of biodiversity and conservation values which are reflected in site management plans and objectives. The Site Management Plan (Ecological Perspective, 2019) notes dwarf galaxias is the key species for which the site is being managed. Dwarf galaxias have repeatedly been detected within the retarding basin and the broader creek catchment. A 2010 survey recorded dwarf galaxias in an onsite wetland in the retarding basin, in Cardinia Creek, two small tributaries, and an anabranch wetland (Streamline Research 2010). The Victorian Biodiversity Atlas now contains more recent species records from 2019 showing continued presence at the site. However, this population is under threat from a number of direct and indirect impacts. The new wetland is intended to build resilience in the existing population by expanding the available habitat, and mitigating threats including climate change by providing permanent drought refuge habitat that is not reliant on existing creek flows.

Hydrological assessment and water balance modelling

The main hydrological features of the site are Cardinia Creek and associated floodplain wetlands, and stormwater drains that traverse the site. The creek takes a meandering form through the retarding basin, and is believed to have gradually shifted over geological time, with the former creek courses creating a series of narrow floodplain wetlands with various connectivity to the main channel (Ecological Perspectives 2019). The hydrological regime of Cardinia Creek has been significantly altered by the construction and operation of Cardinia Reservoir, including a permanent minimum release flow from the reservoir, resulting in a transformation from a largely intermittent flow regime to a more perennial system (Ecological Perspectives 2019). Extensive catchment urbanisation is also resulting in a significant overall increase in stormwater inflows to the creek.

Conversely, future streamflows in the region are expected to decrease as a result of lower rainfall forecast under long-term climate change. Drought is considered an important factor leading to a decline in dwarf galaxias populations in the Cardinia Creek catchment (Streamline Research 2010). Impacts include a reduction in the frequency and duration of inundation during two key periods: June to December, which coincides with the spawning period and is important for colonisation into new areas; and inundation during summer months to prevent floodplain habitats from completely drying out. The function of the proposed wetland as a drought refuge habitat, able to hold water at all times, is therefore a critical consideration in its design.

Water balance modelling

A proposed location for the pond was identified on the south-western side of the retarding basin, upslope from an existing wetland area. Based on analysis of previous flood events, inundation of this area due to flooding and backwater within the retarding basin is likely to begin to occur in a 20% AEP event, or nominally 1 in 5 years. Due to the relative infrequency of inundation at this location, additional sources of inflow were investigated. An existing stormwater outfall was identified approximately 200 metres from the proposed wetland location. This stormwater pipe discharges to an existing wetland complex before entering Cardinia Creek. A detailed analysis of the stormwater outfall including catchment inflows, pipe capacity, surcharge frequency, overland flow paths and total catchment inflows was completed. The stormwater inflows were sufficient to provide a water source for the filling of the pond. The calculations also determined that based on the available stormwater volume, water can be diverted from this stormwater outfall to the new refuge pond with minimal impact to the current watering regime for the existing wetland system.

A MUSIC model was constructed to provide inflows to a water balance spreadsheet model to explore the achievable wetting-drying cycles, the maximum drawdown during dry periods, and to determine the minimum design depth of the refuge pools to maintain a minimum water depth of 30 cm through summer as a permanent refuge in the base of the pools.

In order to develop and assess the water balance modelling, a first pass 3D model of the refuge pond was required to provide stage-storage information required for the water balance modelling. The pond model was developed using 12d Model civil terrain modelling software, using targeted parameters for depth, batter slopes and site constraints (i.e., proximity to existing vegetation and matching into batter slopes). A number of iterations between the 3D pond modelling, and the water balance modelling were completed to reach the desired wetting, drying and permanent ponded depth parameters that were being targeted.

A key water balance modelling parameter that was not initially defined was the assumed seepage rate for the pond. A range of seepage rates (from 0.0 to 3.6 mm/h) were initially modelled. This range of seepage rates was found to have a significant effect on the modelled water depth and wetting and drying regime, and it was also unclear whether additional measures, such as clay or plastic lining, would be required to avoid consistent drying of the pond. Lining the base would prevent or reduce water seepage from the wetland, and would be required if there was high seepage and/or low inflows, but would add to costs and maintenance issues.

On-site permeability testing was conducted to characterise the potential infiltration rates at the proposed pond location. The results indicated an average seepage value of 0.208 mm/hr, consistent with the mid-range values that were initially modelled. The assessed seepage rate combined with the modelled stormwater inflow enabled the wetland to be designed without the requirement for lining on the base of the wetland.

Based on the determined seepage value, and proposed refuge pond 3D model, the water balance modelling was undertaken based on varying inflow rates from the stormwater inflow pipe, ranging from 0.01 m^3/s to 0.001 m^3/s. In these models, all variables remain constant except the inflow rate. The resultant output plots show water depth, total and average annual inflow rates, and number/percentage of days where the wetland fills and overflow from the wetland occurs. Based on these results, an inflow of between 0.005 m^3/s and 0.001 m^3/s provides the best results. Water levels stay mostly above 0.5 m, occasionally dropping a little lower, but never drops below ~0.35-0.4m. This maintains a permanent pool within the deepest parts of the wetland and regular wetting and drying of the shallower wetland margins, providing a variety of water levels and suitable deep and shallow habitat conditions. The basin fills to its full depth regularly, and overflows around 25% of the time. Figure 3 shows modelled outputs for the wetland with an inflow rate of 0.001 m^3/s.

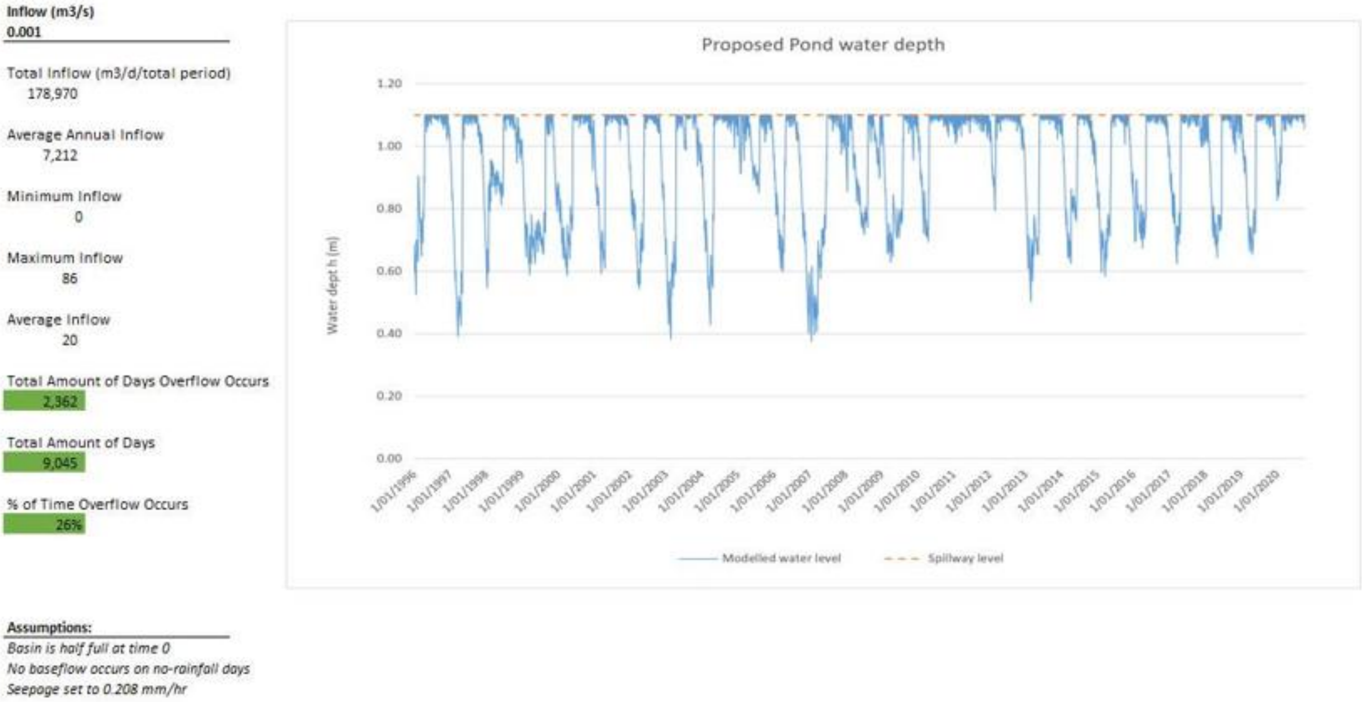

Figure 3. Modelled outputs of daily pond water level based on set inflow rates.

To optimize the inflow rate, a manually operated gate valve was proposed. This will allow Melbourne Water to easily manipulate the pond inflow rate to best suit the climate conditions, and to also allow for minor variation in the assumed modelling parameters.

Design

As established in the initial project stages, the proposed pond location is in an area expected to become inundated from flooding attenuation in 20% AEP events or larger. Inundation of the retarding basin cannot be relied upon to refill the refuge pond as frequently as required, so we designed the refuge pond to connect to an existing stormwater outfall. Use of stormwater to fill the wetland also provides protection from invasive species, as connection to other parts of the creek and wetland system that are known to contain invasive species (gambusia) is limited.

The design determined the existing stormwater outfall junction pit can be reconstructed with a new flow diversion pit, with trash rack and gate valve, to divert a small portion of stormwater from existing inflows to the new refuge pond. The remaining stormwater inflows will enter the existing wetland via piped or overland surcharge flows, as occurs currently. Two filter pits, consisting of removable perforated HDPE gravel-filled baskets will be positioned immediately upstream of the pond to prevent passage of noxious species from the upstream wetland area into the pond. A concrete weir and overflow channel shall be located at the eastern end of the pond. The weir crest level corresponds to the design pond top water level. The weir also acts as an overflow for large inflows generated by localised runoff from large storm events. The overflow channel, approximately 20m long, drains easterly to where it outfalls into an existing wetland further downstream before entering Cardinia Creek (Figure 4).

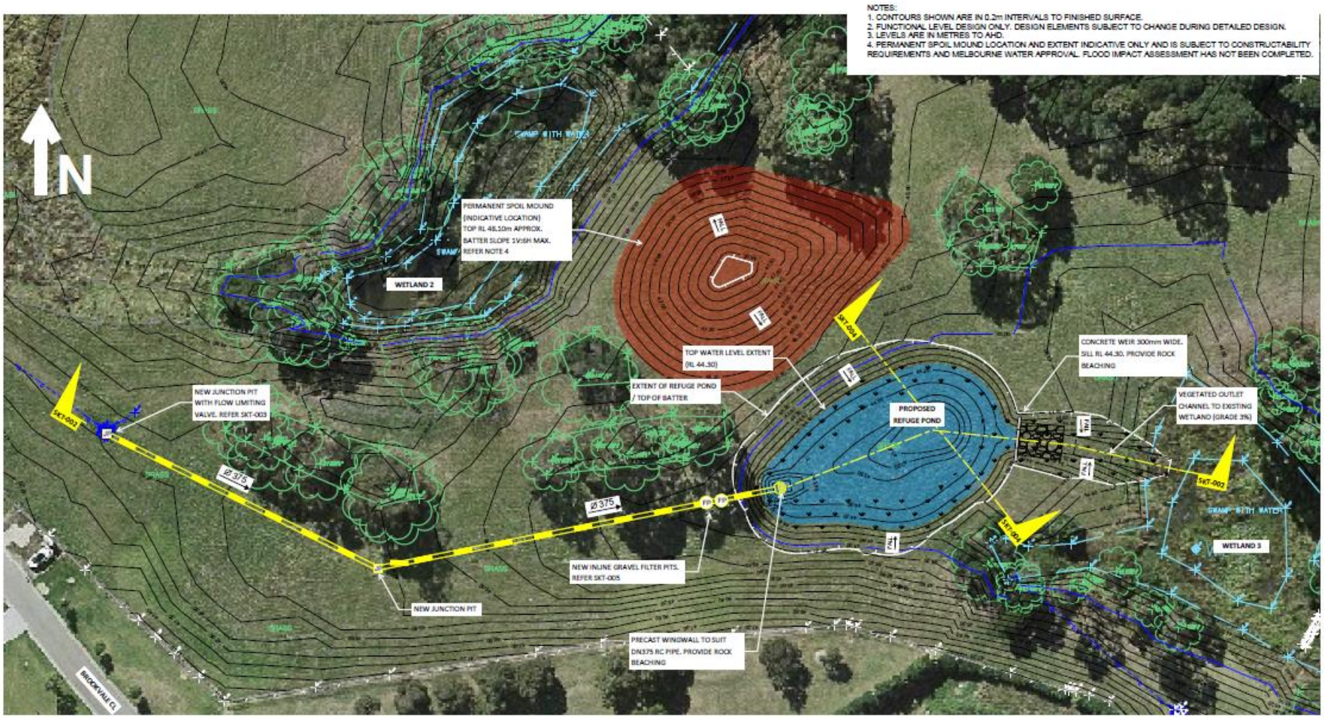

Figure 4. Aerial image of new wetland footprint, site contours, inflow and outflow structures.

The pond location has been selected to provide a sufficiently deep pond (based on the requirements of the water balance modelling), provide the shallow sloped batters required for vegetation establishment, and not significantly encroach on the surrounding terrain. Batter slopes within the pond typically vary from 1V in 5H to 1V in 20H, flatter in parts, and total depth from pond invert to the top water level is approximately 1.1m. The pond will be revegetated across its entire footprint to provide suitable habitat for the dwarf galaxias. Wetland design included recommended vegetation species for planting across six distinct zones reflecting the range of water depth, habitat and vegetation requirements for the dwarf galaxias. These are based on a fluctuating water depth and range from terrestrial through shallow to deep marsh, to fully submerged marsh (Figure 5).

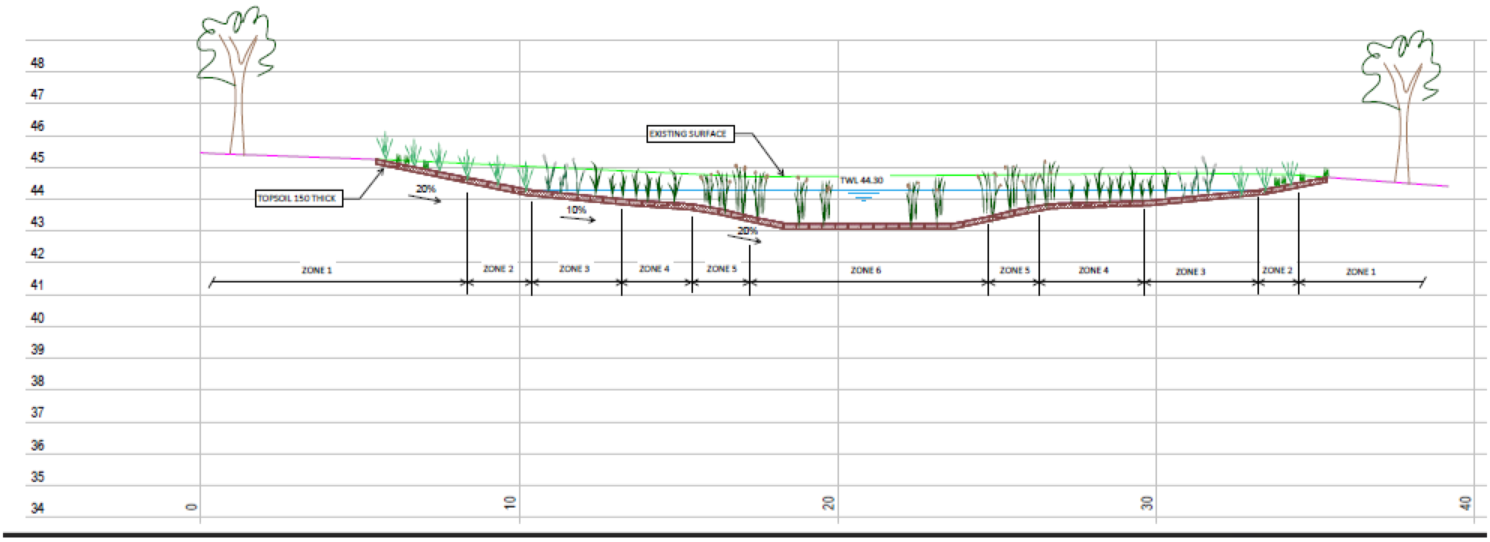

Figure 5 Cross section of wetland and revegetation zones

Conclusion

This project demonstrates a method for the successful design and creation of new habitat to protect and enhance threatened fish species, using an existing retarding basin site. The new drought refuge wetland habitat will help to mitigate current and future risks associated with urban development, habitat loss, altered catchment and stream hydrology, and future climate change. The use of an existing Melbourne Water retarding basin meant that land ownership and site management issues were minimised, and multiple benefits including flood mitigation, drainage management, mitigation of impacts from urbanisation, and biodiversity enhancement could all be realised within a single, existing site. The creation of a new wetland and drought refuge habitat helps to offset current impacts, protect and enhance existing biodiversity values, mitigate future climate change impacts and mitigate the risk of species extinction in a nationally-threatened fish species.

The project methodology was robust, multi-disciplinary, effective, and able to be completed relatively inexpensively. A series of simple yet robust modelling steps and calculations were able to determine the appropriate size, depth, location and water source for a wetland that meets all necessary hydrological and ecological requirements. The initial review stage identified critical data gaps which were able to be addressed through detailed field survey and soil testing as part of the project. The final design meets all key hydrological and ecological requirements for the dwarf galaxias habitat, and incorporates a number of unique design elements to maximise the operation of the system. These include barriers to invasive fish species, flexibility in operation to manage water levels under varying climate conditions, and appropriate inflow and outflow structures to ensure negligible impacts on the existing site hydrology and habitat values. Features to ensure safe and low-maintenance operation of the system, including the new stormwater junction pit, have also been incorporated into the design. Detailed drawings have been provided to Melbourne Water and the new wetland habitat is currently under construction.

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