Engineers & Consultants

Proof of concept summary report

Kokohuia Integrated Wetland

Final

Prepared for Whanganui District Council by Morphum Environmental Ltd
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Executive Summary

Morphum Environmental Ltd (Morphum) was engaged by Whanganui District Council (WDC) to provide a proof-of-concept assessment for a constructed wetland at Kokohuia, Whanganui. The wetland is intended to provide flood attenuation storage in addition to water quality improvements. Therefore the project provides the opportunity to deliver integrated outcomes which address both frequent and infrequent stressors on local infrastructure, property and the environment.

Flood attenuation is required to alleviate existing flooding issues within the downstream industrial estate on Heads Road which in recent years has suffered a number of damaging flood events with resultant economic impacts on local business. Being at the lower end of the Kokohuia Stream catchment, the site also provides an opportunity to address ongoing water quality and ecological impacts from urban development (both current and future) in the contributing catchment through the design of a large wetland system to be nested in the base of the proposed flood attenuation. This will provide robust treatment of stormwater runoff prior to discharge into the tidal reaches of the Wanganui River as well as providing significant cultural, amenity and biodiversity benefits.

This proof of concept report has assessed the existing site and investigated the practicalities of constructing this integrated wetland into the landform. This has considered the constraining levels of existing hydraulic connections, topography and adjacent properties. Based on this (and a number of underlying assumptions indicated in the Table 1), a maximum practical flood storage volume of approximately 30,000 m^3 is considered achievable within the site, assuming a maximum flood storage depth of 1.0 m (excluding freeboard). The total volume of earthworks cut necessary to achieve this flood storage capacity is approximately 67,000 m^3. An additional cut volume of approximately 10,000 m^3 is required to create the water treatment wetland beneath the flood storage. These volumes are intentionally optimised to evaluate the maximum potential for the site but can be subject to refinement in response to other project drivers during further design development. This will include further assessment of the actual flood storage requirements to provide an acceptable level of protection for the Heads Road industrial area including the projected impacts of climate change.

A number of recommendations for next steps are proposed to progress this project based on this proof on concept exercise. Table 1 below summarises the key dimensions and parameters which have been proposed for an optimised integrated treatment and flood attenuation asset for the site.

Table 1. Summary of Kokohuia wetland provisional parameters

Maximum flood storage level	103.5 m RL
Maximum flood storage volume	30,000 m^3
Flood storage earthworks volume	67,000 m^3
Wetland normal water level	102.5 m RL
Wetland surface footprint	28,000 m^2
Provisional maximum wetland flowrate	250 L/s
Wetland earthworks volume	10,000 m^3
Estimated total bulk earthworks	77,000 m^3

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1.0 Introduction

Morphum Environmental Ltd (Morphum) was engaged by Whanganui District Council (WDC) to provide a proof-of-concept assessment for a constructed wetland at Kokohuia, Whanganui. The wetland is intended to provide flood attenuation storage in addition to water quality improvements and therefore provides the opportunity to deliver integrated outcomes which address both frequent and infrequent stressors on local infrastructure, property and the environment. During periods of normal flow when the flood storage is not utilised, secondary functions are to provide water treatment to improve the quality of stormwater that discharges to the Whanganui River, and contribute to ecological enhancement of the wider site.

The intention of the proof-of-concept is to determine the wetland's operating parameters which will govern its performance. These have been intentionally optimised as a means of demonstrating the full potential for the site in terms of both flood attenuation and environmental improvements. In particular, operating water levels have been proposed which will define the potential flood storage volumes and corresponding constructed wetland scale and form. The expectation is that this information would give WDC the confidence to proceed to a detailed design phase.

This report provides a summary of these proposed operational parameters as well as an indicative layout of the wetland's functional components and summarises the general hydraulic function under different flow regimes. Further recommendations on next phases of works and implications of adapting the scale and function of the proposed wetland are made to inform progression of the project.

2.0 Site Context

The site of the proposed Kokohuia wetland is approximately 3.5 ha and was initially identified by WDC based on the large area of underutilised land and the aspirations to alleviate ongoing flooding on the downstream Heads Road industrial estate. The site receives flows from the 915 ha catchment which extends north. This currently discharges via an existing culvert beneath Puriri Street into the open channel which flows through the site prior to discharging into the Rogers Street drain. The catchment is currently largely rural landuse with small areas of residential development. Whilst the catchment has not been assessed as part of this investigation, we understand that the intention is for further residential and commercial development in the catchment to support future growth. Whilst any development must consider stormwater management as part of planning and delivery, the opportunity to integrate regional scale flood management into this site may offer significant benefits as the catchment is gradually developed. Further clarification around intent for catchment development will be important to quantify potential environmental benefits and define impacts of different flood mitigation scenarios.

The site is understood to be entirely owned by WDC and is located adjacent to the large decommissioned municipal landfill. The area is currently partly grazed by stock and covered in rank grass and weed species. A number of open channels currently flow through the site including the lower reaches of Kokohuia Stream which is highly modified and degraded. Figure 1 provides a view looking down the existing Kokohuia Stream which is cut into the landscape as a straight open channel.

Figure 1. View looking downstream from Kokohuia Stream channel at east end of Matipo Street. Proposed wetland site on right side of channel in image

The southern end of the site presently includes a vegetated wetland which receives inflows from a small open channel from the west. This wetland has been subject to community initiated restoration activities (planting and pest control) and is valued for its existing biodiversity and amenity value. It is noted that the existing wetland is currently dominated by large stands of Raupo (*Typha orientalis*) with limited diversity in terms of aquatic vegetation species. Whilst Raupo is a common plant in natural wetland systems it is typically not favoured in urban wetlands due to the tendency to out compete other species and create large impenetrable rafts of plant matter which force flows around the stands of Raupo rather than through. This (coupled with the seasonal dieback which releases nutrients to downstream receiving waters) reduces the effectiveness of the existing wetland to manage runoff from urban land uses. Figure 2 provides an image of the existing Kokohuia wetland system

Figure 2. Existing Kokohuia wetland with dominant stands of Raupo

It is recognised that the community 'investment' in the existing wetland area needs to be well understood to ensure that any further development of the site aligns with the aspirations of a range of stakeholders. In particular the interests of mana whenua and local iwi must be encapsulated in the design process to ensure that the wetland aligns with their collective values and can provide a long term opportunity to provide education, cultural resources and enhance the mauri of the entire Kokohuia Stream catchment. Preliminary discussions have included the potential for a dedicated 'Wetland Centre' which could be developed at the site. It is considered that this could greatly enhance the outcomes of the project but the viability of this has not been tested through this exercise.

A large community garden is currently developing at the north end of the site off Matipo Street. This community asset increases the value of the site and is considered particularly compatible with the development of a large wetland system with potential to provide irrigation water and significantly enhanced landscape amenity for the community.

Further discussion on the long term intentions for the area has identified the potential to extend Rogers Street from Hinau Street through to Puriri Street. This is currently identified as a paper road and could be readily aligned along the east side of the wetland system. Land to the east of the wetland could then potentially be developed for residential or commercial uses. We understand that this option has previously been investigated by WDC and could provide a suitable location for filling with soils excavated to develop the integrated wetland. The economic or technical feasibility of this development has not been investigated as part of this assessment but recommendations relating to the feasibility are included in Section 5.0. The ability to use excavated soil in close proximity to the wetland site will offer significant savings.

3.0 Wetland Operating Parameters

A provisional wetland footprint has been specified on the basis of existing land parcels and discussions with WDC. For the purposes of this assessment, the footprint has been optimised to maximise the potential for the site to provide flood attenuation and water quality improvements. The existing ground level defines the top of excavations with preliminary earthworks modelling based on uniform batters which would be planted and landscaped to complement the wetland amenity and provide riparian/terrestrial habitat value. Figure 4 shows the preliminary maximum extent of the earthworks footprint and existing site contours which show an overall ground surface fall of 3 m from north to south. Existing ground levels are based on 0.5 m contours sourced from the LINZ Data Service website. Note that the contours were adjusted for consistency with the survey data (Whanganui City Datum) by adding 100.10 m.

Operating water levels were determined on the basis of surveyed invert levels within the existing open channel, culverts and manholes (survey undertaken by A&C Surveys on 20 July 2016) and the existing ground levels. Figure 3 shows the critical surveyed inverts which are the basis for the proposed design parameters.

In developing a conceptual model of the proposed wetland consideration is given to the vegetated treatment component (wetland) and flood attenuation storage volume (which is only engaged in large flood events). Therefore the normal operating condition defines a wetland water surface which is then taken as the base on the flood storage which occupies the void space above.

3.1 Critical levels

The critical inverts that will govern the ultimate wetland base and water levels are those of the downstream manhole at Hinau Street (100.41 m), the tributary entering the main channel from the east (approximately 102.00 m) the channel entering the site from the west (102.70 m) and the upstream channel (104.66 m). These controlling inverts are shown on Figure 3. Surveyed channel, culvert and manhole inverts. In defining operational levels consideration is given to both these functional elements and the resultant volume of earthworks and scale of cut batters etc. Whilst ground water investigations have not been undertaken at this stage, consideration was also given to expected levels which are thought to be at or below the channel invert during normal conditions.

The invert of the Hinau Street manhole is considered to be the controlling minimum level assuming that the piped section downstream of this is not to be replaced. The channel can however be raised at this point but would need to take account of the effect on fish passage between the Whanganui River and the channel due to the steep grade or discontinuity that may result. The connection between the proposed bypass channel and wetland outfall with the existing reticulated network will need to be designed to incorporate appropriate fish passage with an intent for fish migration to be both through the wetland and via the bypass channel to connect with the minor tributary which enters from the east.

The relatively large fall in elevation between the most upstream and downstream inverts (4.25 m) provides flexibility in setting the final invert levels of the wetland water surface and therefore diversion and bypass weirs.

Figure 3. Surveyed channel, culvert and manhole inverts

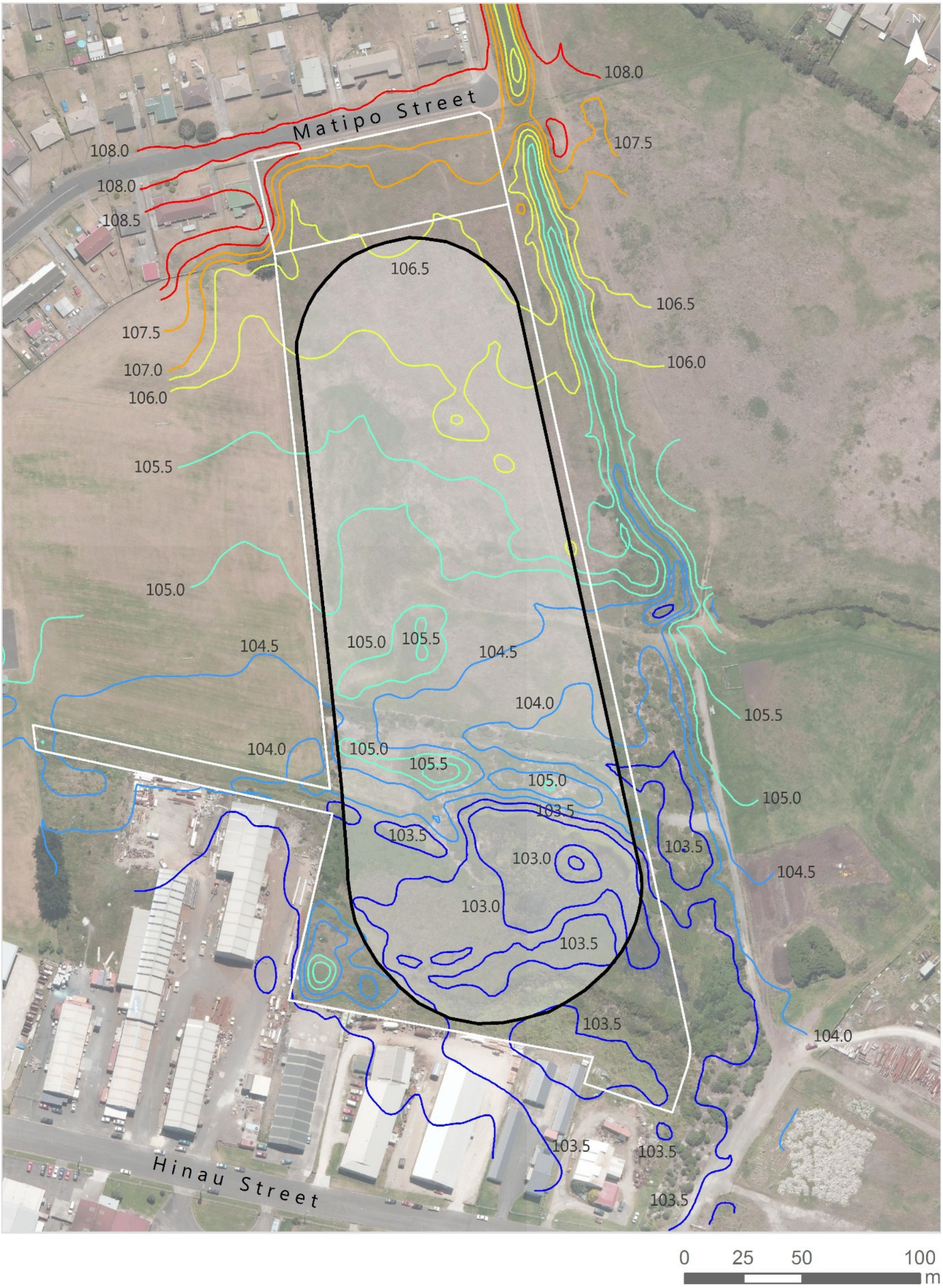

Figure 4. Provisional wetland footprint and existing ground levels

3.2 Wetland Operating levels and volumes

The wetland surface must be set to enable it to function under normal conditions with free outfall. In addition, the intent to ensure that ecological connections are maintained requires close consideration of fish passage and practicalities of the design to support this. This will include the design of inlet/outlet channels as suitable ‘ramps’ to support upstream migration of juvenile fish species. This will enable the passage of climbing species such as Kokopu, Koaro and Eels. An assessment of catchment specific species to target in the design process shall be undertaken to inform the detailed design to ensure that species which currently (or historically) inhabit the upstream catchment can be supported.

Based on consideration of the site levels and hydraulic connections it is proposed that a wetland water level of 102.5 m RL provides an optimum level to support functionality during regular flow events whilst supporting significant storage volume above for flood attenuation. This level is 500 mm lower than the water level in the existing wetland area. Based on this (and the design to support flood storage discussed in Section 3.3) a wetland area of 28,000 m^2 is feasible. It is noted that this is considered to be a maximum achievable vegetated wetland footprint (measured at normal water level) which could be subject to reduction depending on the overall landscape intent for the site, with potential cost savings by limiting the northward extent which requires greater proportional excavation volumes

Based on the proposed water level and the interaction with the upstream and downstream connections, the following would be required;

- Approximate 2 m drop from the upstream diversion weir to the wetland (forebay). This would be designed and constructed as a rock lined channel formed into the wetland batter with an overall grade of around 1V:20H to support fish passage. The inclusion of intermediate pools, riffles and diversity would further support juvenile fish movement.
- Approximate 2 m drop from the wetland outlet to the downstream channel invert (assumed to be set at 100.5 m to connect into the piped stormwater section. This would be designed and constructed as a rock lined channel formed largely as a steepened downstream section of the bypass channel with an overall grade of around 1V:20H to support fish passage. Therefore the wetland outlet could discharge directly into the bypass with juvenile fish able to move up the channel and either continue upstream or enter the wetland itself. The design of this will need to consider moderate to large flows within the bypass channel to ensure that these do not enter to wetland at this point or impede outflows.

The design of the wetland must include highly variable bathymetry (internal topography) to support a diverse and resilient plant community. This is achieved through a banded bathymetry where the cross section is uniform perpendicular to the flow direction and longitudinal grade creates sequences of shallow and deep marsh. This banded bathymetry increases the contact time between untreated water and the plant stems and surface sediments which are fundamental to treatment processes.

A dedicated sediment forebay shall be included at the inlet of the wetland. This is likely to be constructed within the wetland footprint (with shared water surface) but could also be located immediately adjacent to the inlet and be raised above the wetland itself. The design of the forebay will include provision for maintenance including access, a structural base (concrete or rock) to support heavy machinery and a level spreader weir to distribute inflows across the full width of the wetland.

Occasional deeper pools can provide areas of open water (without plants) and reduce velocities where constrictions occur. The wetland should achieve sustained 80% coverage with vigorous emergent macrophyte vegetation to support optimised water quality treatment. This is achieved through restricting deep marsh areas to 500 mm depth with shallow marsh being approximately 100 mm deep.

A high-level estimate of additional earthworks cut required to excavate the water treatment component of the wetland beneath the flood storage is 10,000 m^3. This is based on an average wetland depth of 350 mm and an approximate normal water level surface area of 28,000 m^2.

3.3 Flood Storage Volume

The overall maximum achievable flood storage volume is defined by the minimum inferred ground level at the southern extent of the site. This is approximately 103.5 m RL along the rear boundaries with the industrial buildings on Hinau Street. Options to raise this through bunding along the boundary could raise this level or provide freeboard above flood levels, but would require design to reflect the volume of impounded water and consideration of how these bunds would integrate into the remainder of the site. Based on the proposed wetland normal water surface of 102.5 m RL this provides a maximum practical flood storage depth of 1.0 m across the entire wetland footprint. This will support a peak flood storage volume of approximately 30,000 m^3 above the footprint of the wetland. Further attenuation storage will be achieved within the high flow bypass channel dependant on how the hydraulic connection with the wetland is configured and the grade of the bypass. This is estimated to be in the order of 1,000-2,000 m^3 additional flood storage.

The flood storage estimate is based on following assumptions:

- Batter slopes of 1:3 extend down from the existing ground surface. These shall be landscaped and in detailed design can include variability to enhance the amenity.
- A continuous 2 m wide pedestrian path is constructed on the batter to provide a pedestrian circuit and link with interest nodes. The level of this path can vary around the wetland but is intended to provide access close to the wetland edge and potentially link with key landscape elements (boardwalks, viewing platforms, bird hides, outdoor classrooms etc.). The level of protect for the path from flood inundation will be directly related to its elevation and can be considered to support primary and secondary access points etc.
- The minimum ground level at the southern end of the site is 103.5 m RL. Where this is not the case it is assumed that the ground surface can be raised to this level.
- The elevation difference between the mean sea level datum of the LINZ contours and the Wanganui City Datum of the invert survey is 100.10 m.

The total cut volume required to achieve the 1.0 m storage depth (not including wetland) is approximately 67,000 m^3. While the existing channel and culvert inverts do permit a lower wetland base to be constructed (with a corresponding increase in flood storage volume), this would obviously require a greater volume of cut and would set the normal water level at the northern end of the wetland at an undesirable depth below the ground level. The levels as proposed are therefore considered to represent a good compromise between flood storage capacity, wetland functionality from a water treatment perspective, and depth of excavation required.

3.4 Hydraulic control structures

The function of the wetland will be very reliant on the design and construction of a number of critical hydraulic structures which control inflows and outflows. These are fundamental to support both the water quality wetland function as well as engagement of the flood storage component. The following hydraulic elements will be required;

- **Diversion Weir -** A diversion weir structure will be located on-line to the existing Kokohuia channel and side cast divert frequent water quality flows into the wetland. The diversion weir will be sized to pass the design flow rate (to suit final wetland hydraulics into the wetland forebay in a controlled manner with a set depth of flow (head). Figure 5 shows a comparable inlet arrangement albeit on a much smaller scale.

- **Bypass Weir -** Once the design inflow to the wetland is exceeded, the depth will engage a main bypass weir which will convey flows into the main high flow bypass channel (which will broadly align with the existing channel). Upstream of the small tributary from the east, the bypass will be ephemeral and remain 'dry' between moderate to large events.
- **Wetland outlet –** Treated flows from the wetland will discharge at the downstream end via a weir which will define the water level within the wetland and control outfalls to reduce scour etc. Due to the intent to support fish passage through the wetland, the wetland will not include any extended detention and therefore the outlet can be broad and able to pass all inflows with minimal backwatering effects through the system. Consideration will need to be given to limit excessive inflows into the wetland from the bypass channel except during intended flood storage engagement.
- **Flood controls –** Engagement of the flood storage will be controlled by the inlet to the downstream reticulated network and the network itself. Through either existing capacity limitations or a designed throttle, the outlet from the bypass channel will have a limited capacity beyond which water will back up. The flowrate at which this will be triggered is undefined at this stage and can be defined based on optimising the management of the total available flood storage volume. This will need to consider climate change and could potentially provide a level of protection in exceedance of the 1% AEP event.
- **Backwater transfer –** Throttled flows will initially backwater within the lower portion of the bypass channel with a progressive increase in water depth. Depending on the intensity and duration of the event this will raise until it engages a designed connection through the bund which will separate the wetland from the channel. This could be achieved with a lowered section of bund or a number of box culverts set with invert levels around the 30.0 m RL level. When backwater reaches this level the flows will progressively fill the wetland from the downstream end and engage the flood storage depending on the magnitude of the event. Accumulated flood storage will drain via the same connection following cessation of peak catchment flows. In the instance that the total flood storage is overwhelmed, flows will discharge in a controlled manner via an overland flow path along Rogers Street.

Figure 5. Wetland inlet diversion and bypass, Norton Park, Palmerston North

4.0 Wetland function

The wetland will be designed to operate under a variety of flow conditions; the core function changes according to the prevailing flow regime. Its primary function transitions from stormwater treatment under frequent low flow conditions to flood storage in response to storm flows. The hydraulic behaviour under these scenarios is controlled by the inlet and outlet structures (discussed in section 3.4) whose size, elevation and position will be resolved during detailed design.

The term hydraulic efficiency in wetlands refers to the ability to maximise the contact between untreated inflows and treatment pathways in the vegetation and base sediments. This is achieved by distributing flows across the full width of the wetland and avoiding potential for short circuits where preferential flow paths can pass water with reduced treatment performance. This distributed flow and the wetland depth (measured where the width/depth creates the smallest cross section) define the velocity of flows through the wetland which must be managed to prevent biofilms being stripped from plant stems and reduce re-suspension of settled sediments during larger flow events. A maximum flow rate into the wetland in the order of 250 L/s is considered optimal in this case based on a critical cross-section of 0.10 m depth and 50 m width while maintaining a maximum velocity of 0.05 m/s. This is defined by the width of the inlet diversion weir crest.

Stormwater retention time is defined by the volume of the wetland water body and displacement of this based on flowrates. Therefore the overall retention time varies seasonally with an intent to achieve a minimum of 24 hours retention time for the target water quality events. This can be calculated based on either a continuous simulation approach or a static 'water quality volume' approach based on pre-determined event runoff (typically taken as 1/3 of 50% AEP event). This will be defined as part of detailed design and will enable the estimation of the predicted contaminant removal rates and can be used to inform other interventions elsewhere in the catchment.

Contact time in wetlands is therefore a function of the residence time and maximum exposure to vegetation. This is typically achieved through an elongated flow path (length to width ratio of approximately 5:1) and overall shallow depths to ensure suitable conditions for plant growth. In developing the design for the Kokohuia wetland it is proposed that the flow path could readily be optimised through integrating landscaped bunds and landscape elements to extend the wetland length and enable it to discharge to the channel upstream of the site's southern extent. This is shown in Figure 6 which provides an indicative schematic layout.

The elements as shown are provisional and indicative of general function only. There is scope to add landscape diversity through modifying batters slopes to create a variety of landforms and plant habitats at different water depths. These are best developed in collaboration with landscape architect input once the overall objectives and intent for the site are agreed.

Figure 6. Schematic layout of proposed wetland showing functional components

4.1 Hydraulic Function

The following sequence outlines the general operation of the wetland across a variable flow regime:

- Under baseflow conditions, all flows (provisionally up to 250 L/s) are diverted from the existing channel into the wetland. The maximum inflow rate is controlled by a diversion weir which must be designed to support upstream fish migration during low flow conditions.
- Wetland flows discharge into the dedicated sediment forebay via a designed chute to dissipate energy and support fish passage.
- Treated flows from the wetland discharge from the downstream outlet into the lower section of the bypass channel prior to discharge into the existing stormwater network under Rogers Road.
- Minor flows from the small tributary which enters from the east (perimeter cut off drain) discharge into the bypass channel under all conditions. From this point downstream the bypass channel functions as a perennial stream and shall be designed as a naturalised waterway with ecological attributes and high landscape amenity.
- Under higher flow conditions, once the maximum inflow permitted by the diversion weir is exceeded, the bypass weir is engaged. Flows in excess of the diversion weir threshold (provisionally 250 L/s) are discharged down the main high flow bypass channel. The upper section of the bypass channel remains dry between peak runoff events and could be piped (large capacity box culvert) to support use of surface area for landscape purposes.
- The discharge of flows from the bypass channel (includes flood flows, treated flows and east tributary flows) into the existing piped stormwater system is limited by a throttle at the inlet to the piped system. This can be either based on existing network constraints or custom sized hydraulic throttle. Flows in excess of the inlet capacity will then back up in the channel. If high flows persist, backwater level in the channel will raise and flow will spill into the wetland at a nominated spillway point whose invert is above the wetland's normal water level.
- Once the spillway is flooded the depth within the wetland will increase until the full surface area of the wetland is providing flood storage. Under these conditions, the section of channel downstream of the spillway will also contribute to flood storage.
- In the instance that long duration, high intensity storms exceed the nominated flood storage volume, excess flows will be conveyed as overland flow towards the river. It is noted that the motivation for the design is to significantly reduce the incidence of this and provide a high level of service in consideration of climate change impacts.
- Following the passing of flood flows, the wetland will drain down via the channel spillway and wetland outlet until the water surface returns to the normal wetland level.

4.2 Cost estimation

The capital cost to construct the wetland will be significantly influenced by the volume of earthworks and ability to re-use the material in close proximity. We understand that there are discussions relating to raising the land on the east of the site to support future development for residential/commercial activity. Utilising site sourced material to raise this area would provide considerable cost savings.

Based on the option of using excavated material to fill this area the cost of the total wetland system is estimated at $2.5-$3.0 million. This estimate is based on a number of preliminary assumptions and composed of the elements itemised in Table 2.

Table 2. Construction cost estimate

Item	Unit rate	Quantity	Cost estimate
Site establishment	LS	1	$85,000
Bulk earthworks for re-use	$10/m^3	77,000 m^3	$770,000
Wetland lining	$15/m^2	28,000 m^2	$420,000
Site sourced topsoil	$5/m^2	35,000 m^2	$175,000
Planting	$20/m^2	35,000 m^2	$700,000
Hydraulic structures	LS	1	$200,000
Channel naturalisation	LS	1	$150,000
TOTAL (excl. GST)			$2,500,000

This cost estimate does not include landscaping/building, road extension, construction contingency or design/consenting fees. This cost could increase significantly if material was needed to be transported beyond the site or if contaminated soils were encountered. It is not feasible to estimate the quantum of this accurately without further detail.

5.0 Summary and Recommendations

Based on preliminary analysis it is concluded that the site is very well suited to developing an integrated stormwater treatment and flood attenuation asset. This will address these core operational drivers whilst also providing considerable ecological, cultural and amenity benefits.

Table 3 summarises the key parameters for the combined wetland and flood attenuation.

Table 3. Summary of Kokohuia wetland provisional parameters

Maximum flood storage level	103.5 m RL
Maximum flood storage volume	30,000 m^3
Flood storage earthworks volume	67,000 m^3
Wetland normal water level	102.5 m RL
Wetland surface footprint	28,000 m^2
Provisional maximum wetland flowrate	250 L/s
Wetland earthworks volume	10,000 m^3
Estimated total bulk earthworks	77,000 m^3

The following actions are recommended to support the further development of the Kokohuia Wetland concept.

1. Engage with local iwi and stakeholders to ensure design development aligns with values and aspirations for the site and water management.
2. Undertake full catchment analysis to identified probable maximum development activity and impacts on peak flows and water quality (including allowance for distributed catchment measures).
3. Develop comprehensive flood mitigation strategy for the catchment to define optimal flowrates to downstream network and resultant flood attenuation volumes.
4. Further investigate solutions to alleviate fish passage issues on outlet pipe with consideration of maintaining outlet without blockage.
5. Develop concept for constructed fill pad for potential building development on east side of site
6. Undertake test on existing material in area of wetland to determine suitability for reuse as constructed engineered fill.
7. Install shallow groundwater monitoring bores to determine seasonal groundwater level
8. Develop detailed design of wetland including integration with landscape and overall urban design for area. Detailed design to refine operational hydraulics and final form of wetland.