Wetland Practice Note for Nelson and Tasman Councils

1. Introduction

Purpose

This practice note is intended to primarily support the design and delivery of constructed wetlands for stormwater treatment for water quality improvements. The applicant needs to ensure that requirements in the local Resource Management Plan and Engineering Standards are also complied with.

Table 1: abbreviations used

LDM	Land Development Manual (jointly owned by Tasman and Nelson councils)
ESCP	Erosion and Sediment Control Plan.
ARI	Annual Return Interval
LID	Low Impact Design
TRMP	Tasman Resource Management Plan
NRMP	Nelson Resource Management Plan

Where appropriate wetlands are also very well suited to be co-located with additional detention storage as part of flood mitigation, network capacity constraints or to reduce scour in downstream waterways. The design of such detention must be undertaken with due consideration to the critical wetland design elements which support water quality treatment as a priority. Whilst the design of detention storage is discussed at a high level in this document the specific design requirements and sizing are addressed in the LDM and the detention practice note.

To the reader

This practice note is one of a number of practice notes developed for stormwater management.

Please ensure this is the latest available version of the practice note. The practice note will be updated as technology and research progresses.

Currently Tasman District Council and Nelson City Council are preparing changes in the RMA plans and are developing a new joined “Land Development Manual” (LDM) replacing the existing engineering standards. It is the intension that these practice notes will be updated to show how to comply with these new requirements once these are operative.

The digital version of the practice note will include hyperlinks to enable easy navigation and to find more information elsewhere.

2. Description

Wetlands are devices with variable depths of permanent water and high cover of aquatic plants that use a combination of physical, chemical and biological processes to remove contaminants from inflowing and impounded waters. As a stormwater best management practice, the use of wetlands world-wide, and within New Zealand, is increasing due to their water storage, purification and contaminant removal characteristics (their primary purpose and function), and also their secondary benefits, including provision of wildlife habitat, ecosystem goods and services and amenity value. When designed and constructed appropriately, stormwater wetlands are visually appealing stormwater treatment options, improving public amenity and ecological values of urban environments.

Wetlands covered in this practice note are for the treatment of urban runoff and are not intended for treating tradewaste discharges, wastewater, agricultural/horticultural runoff or high sediment loads from construction sites. Wetlands can be configured to provide some or all of a catchments additional infrequent flood detention requirements and can replace more traditional detention basins with appropriate design considerations. The feasibility and suitability of this depends significantly on site specific considerations such as topography, drainage inverts, public safety and integration with whole of catchment planning. Any instances where the wetland footprint is to be inundated during flood events must ensure that protection of the wetland is a priority. This is achieved through ensuring that the wetlands remain offline and that flood engagement is through backwatering within the high-flow bypass channel or downstream network rather than uncontrolled discharge into the forebay.

3. Benefits

Wetlands are one of the preferred methods for stormwater management at a larger scale and are suited to treating flows from large development areas or large piped networks. The benefits of constructed wetlands include;

~ **Quality**. The inherent physical, biological and chemical treatment mechanisms and symbiotic processes in a vegetated wetland support the removal of a wide range of typical urban contaminants. The principal physical, chemical and biological removal mechanisms include sedimentation, adsorption, precipitation and dissolution, filtration, bacterial and biochemical interactions, volatilisation, and infiltration. The hydraulic retention time (the time stormwater remains in the wetland) is important to achieve a good treatment outcome. The hydraulic retention time can be expressed as the ratio of the mean wetland volume to mean outflow (or inflow) rate. Similarly, the hydraulic efficiency within a wetland is based on maximising the contact time of untreated water with the wetland vegetation and the removal mechanisms which it supports. This is achieved through ensuring that short-circuiting is avoided and that flows are dispersed across the full width of the wetland to maximise plant contact. Dense cover of emergent vegetation and planting of suitable riparian shade trees reduces the temperature of treated outflows.

~ **Quantity**. Stormwater wetlands provide some inherent downstream scour protection by slowing down and attenuating flows during rainfall events. Designed extended detention volume helps lower peak flow discharges and can attempt to mimic ‘natural’ discharges during frequent rainfall events. Wetlands can be designed as part of a larger ‘flood control basin’ or to reduce flows and volumes to protect downstream environment from erosion. Flow velocities through the wetland must be managed to reduce the risk of scour of plants and biofilm or the suspension of entrained sediments.

~ **Ecosystem Services**. Along with supporting a relatively high diversity of flora, fauna and fish, wetlands are recognised for having important roles in 'ecosystem goods and services'
~ **Amenity**. Well designed and maintained, functional wetlands integrate well into existing landscapes. Design can range from very natural looking wetlands to contemporary landscape features used in urban centres. Landscape amenity is key to the overall success (and acceptance) of wetlands and should be considered throughout the design process.
~ **Operation and maintenance**. Wetlands (where designed, constructed and operated properly) require less maintenance and are less expensive to maintain than other traditional treatment systems. Keys are fast establishment of plant cover and early maintenance to minimise weeds.


Examples of detention basins with healthy wetland plants in Tasman (left) and wetland in Nelson (right), 2017

4. Rules and requirements

In addition to this Practice Note the user/applicant needs to also ensure that any requirements in the operative Resource Management Plans and Engineering requirements are met.

5. Design requirements

The following is intended to guide a design reflect best practice, that work and are cost-effective to maintain.

This does not include meeting any other requirements; final discretion is with the Council consenting department.

Wetlands are complex and design shall be undertaken or peer reviewed by an experienced and qualified practitioner. Fundamental design considerations on key components are provided below.

1. Location considerations

Table 2: location considerations

Item	Consideration
Drainage	Ensure the target catchment is able to drain (by gravity) to the wetland preferably through a single inlet with an invert which enables the footprint to be achieved with efficient earthworks. Ensure the proposed outlet level (i.e. invert of receiving drains and/or watercourse) will enable drawdown of the wetland to at least the normal water level (NWL) during normal operating conditions, and allow control of water level during establishment so that extended detention is NOT used until plants are established/12 months old.
Discharge	Ensure that the discharge is suitable for the receiving environment. Consider appropriate mitigation standards for water quality, including temperature, and any additional detention requirements.
Maintenance access	Consider how machinery will access the wetland for construction and maintenance, including clean out of the sediment forebay and potential drying/storage of excavated materials (See also page 12)
Pre-treatment	Ensure a forebay is incorporated into the design unless approved catchment pre-treatment is provided. Pre-treatment may include swales and raingardens (See also page 8)

Item	Consideration
Offline and bypass	Vegetated wetlands shall be placed offline to the main channel/reticulated pipes for peak flows. Allowance must be made for appropriate bypass or high flow diversion upstream of the wetland (see also page 11). If the Wetland is to be integrated with any detention storage, this must be provided entirely above the top water level for water quality purposes and must ensure that the wetland is protected from high velocity flows in accordance with this practice note.
Draw down	Wetlands must be free draining by gravity to at least the NWL. Allowance shall be made for draining the wetland for maintenance and to periodically support plant succession following seeding. The forebay should be able to be drawn down (either by gravity or pumping) independently from the remainder of the wetland through the inclusion of an impermeable earth bund or similar.
Lining	Wetlands must be lined to at least the NWL with an appropriate impermeable liner to prevent water losses. Lining can be either compacted clay (*in situ* or imported) or synthetic products such as geo-synthetic clay liners (GCL) or HDPE in accordance with manufacturer's specifications. (see also page 13)
Water table	Where wetlands shall be constructed above shallow water tables, attention must be given to constructability and issues with lining. Construction timing (when groundwater recedes) or synthetic liners may be required.
Underground services	Contact utilities (power, water, gas) and check with the council for locations of underground services in your area. If underground services are near or in the proposed wetland location, consider relocating the wetland away from these services. If relocating is not an option due to site constraints, agreement on solutions will need to be arranged with asset owners/managers. Risks of compromising the device when maintenance of the other service is required can be reduced by using signs, conduits, using walkways or overflows as access points/protection etc).
Setback	Wetland areas shall be located at least 1.5 m from property boundaries. Wetlands shall not be located within a 1V:1.5H plane taken from the toe of any retaining wall without geotechnical certification confirming long term stability.
Overhead setback	Trees located to the north and west of the wetland and around any open water areas provide valuable shading, reducing water temperatures. Provide overhead setbacks to ensure mature trees do not interfere with utilities such as power lines. Relevant utility managers must be consulted for up to date guidance on setbacks etc.
Contaminated land	Contaminated soils cannot be used for wetlands. Excavations required for wetlands may therefore pose a financial risk as such material must be disposed of. Potential land contamination must be considered at the concept design phase based on information from site-specific investigations and will require specific risk management to prevent issues such as leaching to contaminated soils.
Slope stability	To minimise the risk of slope failure, wetlands should be placed greater than 15 m away from non-engineered slopes 15% or greater and consideration must be given to the risks of slope instability from saturating the toe of slopes. Where required, impermeable lining may be required to extend above the NWL to the top of operational water levels. Geotechnical advice shall be sought where appropriate.
Expansive soils	Wetlands placed within 5 m of a structure should be lined entirely to the top of operational water level. Structures include buildings (residential and commercial), retaining walls (>1m height), trafficable roads/rail, utility infrastructure (i.e. cell towers, transmission pylons and masts), playgrounds, private boundary fences and swimming pools.

2. Bathymetry

Wetland bathymetry (contours and water depths) must be configured to manage flow paths, water depths and velocities to achieve the required level of treatment while ensuring resilience to the anticipated frequency and duration of inundation. The intention is to prevent high velocity flows forming and ensuring robust plant communities can develop by preventing drying out of permanent water areas, and controls on the days of extended inundation.

Banded bathymetry comprises alternating shallow and deep sections interspersed with occasional open water ponded areas. The cross-section perpendicular to the flow direction is uniform to ensure even velocities across the full width of the wetland. This maximises water exposure to treatment processes associated with wetland vegetation and prevents the formation of preferential flow paths within the wetland footprint. The cross-section at the shallowest point of the wetland is the critical cross-section since this governs the flow rate necessary to achieve the design velocity. Hydraulic efficiency is optimised by maximising the wetland's length to width ratio and ensuring that flows engage the full width of the wetland.

3. Wetland design requirements

Table 3 Wetland Design requirements

Item	Description
Water Quality Volume (WQV)	Required where the wetland is providing a water quality function.
Live Storage Volume)	The live storage volume allows for greater residence time within the wetland which enhances several of the treatment processes including sedimentation, filtration and microbial action.

Flood mitigation can be provided within the wetland footprint as long as the entire attenuation volume is above the live water level (including EDV). Attenuation requirements for flood protection or network constraints are to be derived from the LDM and the Detention practice note. The design of the wetland hydraulics must protect the wetland from potential scour through the use of appropriately sized flood attenuation outlet controls which support backwater inundation of the wetland and prevent the risk of high velocities through the wetland causing re-suspension of sediments and scour of biofilms. Hydraulic controls to engage the flood attenuation should be positioned within the high flow bypass channel where possible to ensure that the wetland is fully protected from high velocity flows and remains offline under usual operating conditions. The design of these flood control aspects must be undertaken by a suitably qualified engineer and designed in accordance with the local requirements.

Wetlands shall be sized in accordance with the methods provided in the local requirements to calculate the water quality volume and flowrate.

4. Wetland components to be considered during concept design

The functional components to consider during the wetland layout development are outlined in Table 4. Treatment performance is based on the controlled passage of water through the vegetated elements of the wetland and the complex treatment processes these support. Attention to internal batters and longitudinal grade is required to ensure that flows are not concentrated into preferential flow paths which can result in short-circuiting and impaired performance.

Table 4 Wetland components to be considered during layout development

Item	Description
Main body	The main wetland body is the bulk of the area of the wetland and provides water quality treatment. The body is sized to provide the WWQV and the EDV (where included) in conjunction with the forebay. The main body can also provide storage for flood mitigation above the top of any extended detention volume level (EDV).
Forebay	The wetland forebay provides coarse sediment removal prior to runoff entering the main wetland body. The forebay should be 10% of the main body area. The volume of the forebay counts towards the WWQV.
High flow bypass	A high flow bypass shall be included that becomes active when storm events exceed the storage provided by the extended detention zone or inflows exceed the calculated peak water quality flowrate. The high flow bypass should be located before entry to the wetland and must have a minimum capacity of flows of up to network capacity or the 100-year event where the wetland is within an overland flow path. In instances where flood attenuation is required, this should be primarily supported through hydraulic control within the bypass channel which causes backwatering within the channel and engagement of the wetland flood storage. Where this is not possible and flood flows discharge into the wetland, it must be demonstrated that these flows will not cause excessive scour.
Maintenance access	A trafficable maintenance access track must be provided to the sediment forebay as a minimum to allow access for maintenance. This shall be a minimum 3.0 m wide and suitable for truck access with a maximum grade of 1V:8H. Vehicle access must also be provided to the outlet structure and foot access provided around the full perimeter for maintenance personnel.

5. Wetland shape, sizing and design parameters

Wetlands can have many shapes which typically respond to the site characteristics and topography. It is suggested to use a shape that can blend into the finished landscape and that will maximise other benefits such as amenity and provide for cost effective maintenance. Typical shape types are linear and kidney shape with the potential to increase the overall flow length through the use of internal baffles or bunds. Because wetlands should be offline from a natural stream, the inlet and outlet location often influence the shape along with topography.

Typical shapes are shown in Figure 1 which show the diversion into the forebay, bypass channels and outlets back into the downstream extent of the bypass. Further detail is provided in section 8.

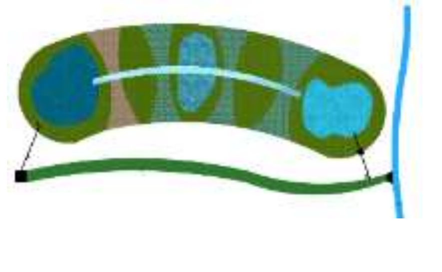
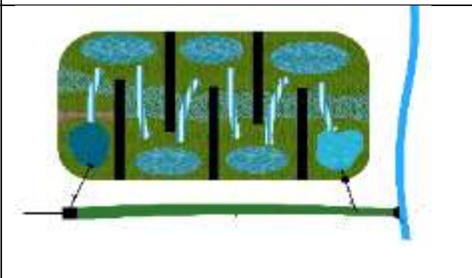
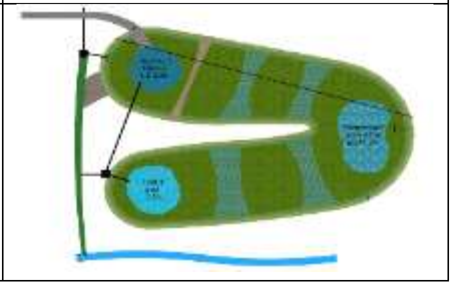
Linear	Extended flow path	Kidney Shape
		

Figure 1: various shapes of Wetlands for stormwater treatment

The sizing of wetlands provides sufficient capacity and conditions to support water quality treatment processes. This is achieved by sizing the wetland based on the calculated water quality volume and then designing the internal bathymetry to provide a mix of shallow and deep marsh zones to sustain robust emergent vegetation.

Figure 2 provides a schematic representation of an offline linear wetland configuration with key functional zones with a typical long section.

Terms used to describe the various wetland zones are given in Table 5.

Design parameters for the permanent storage zone (with and without EDV) are given in Table 5. Note that these do not include the forebay area which equates to an additional 10% of the total footprint area.

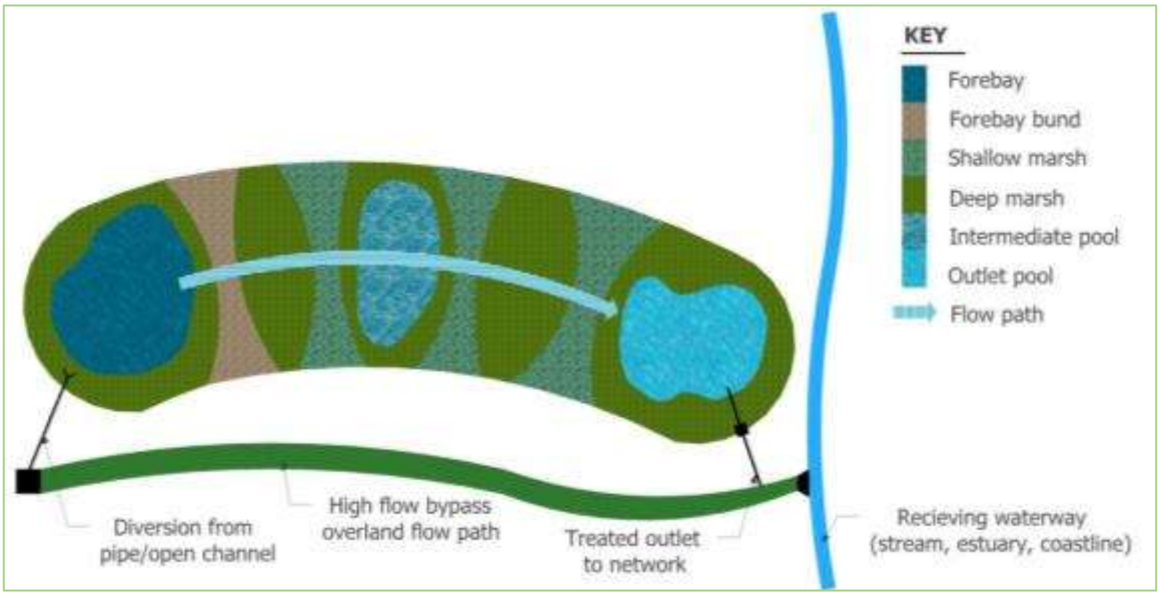


Figure 2: Schematic of typical zones in offline linear constructed wetland

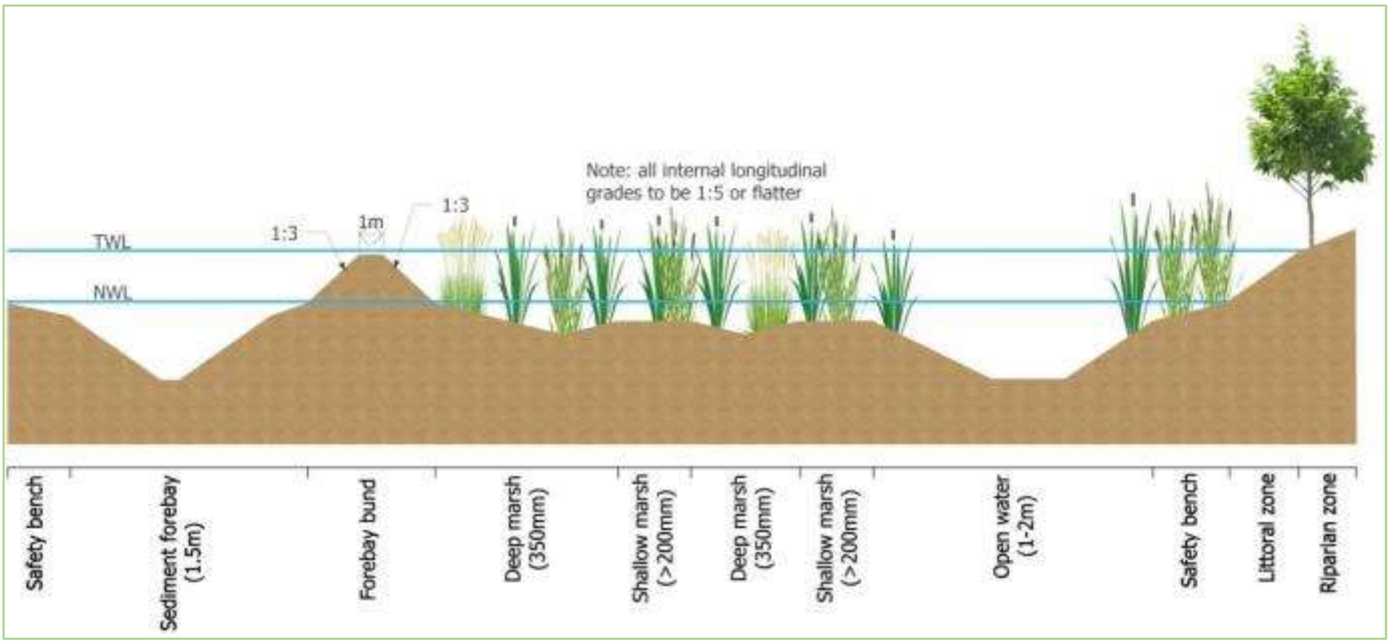


Table 5: Terms used for wetland sizing

Item	Description
Zone – Permanent storage zone (PSZ)	The PSZ is the base zone of the wetland main body excluding the forebay area. The water in this zone does not drain out between events (but can evapo-transpire). The PSZ is required within all wetlands to retain water and support the biological processes within the wetland.
Zone – Live storage zone (LSZ)	The LSZ is the storage zone above the permanent storage zone that provides the live portion of the WWQV. The live storage zone cannot be counted for flood storage during large events.
Zone – Flood storage zone (FSZ)	The FSZ is the storage zone above the live storage zone that provides flood storage only. The FSZ is only required if the wetland is providing flood mitigation or attenuating flows due to downstream network constraints, potential flooding or excessive downstream scour.
Depth – Normal water level (NWL)	The NWL is the top of the permanent storage zone. This water level is relatively constant between storm events and can only be reduced by evapotranspiration or controlled drawdown. The NWL is the top of the PSZ.
Depth – Live water level (LWL)	The LWL is the maximum height reached by the extended detention volume and is the top of the LSZ.
Depth – Flood water level (FWL)	The FWL is the maximum height reached during 100 year event (or other specified flood detention magnitude).

Table 6: permanent storage design parameters for wetland design

Wetland with no EDVDV included	Description
PSZ volume* x 0.80 = WQV	More than half the WQV needs to be permanent pool to allow pollutant removal between storm events. If there is no extended detention, the permanent pool should contain the entire WQV.
40% (±5%) PSZ area between 0.00 and 0.35 m deep at NWL	**Shallow marsh** water depths to support emergent macrophyte species provided in Table 14
40% (±5%) PSZ area between 0.35 and 0.50 deep at NWL	**Deep marsh** water depths to support emergent macrophyte species provided in Table 14.

Wetland with no EDVDV included	Description
10% (±2%) PSZ area between 0.50 and 1.20 m deep at NWL	**Intermediate deep pools** within main wetland body provide habitat diversity in the wetland. These should comprise no more than 10% of the main wetland body area.
10% (±2%) PSZ area between 0.50 and 1.50 m at NWL	**Outlet deep pool** provides a stilling area before discharge out of the wetland. This should comprise no more than 10% of the main wetland body area.
The length of the PSZ must be at least 5 times the width of the PSZ	Elongated wetlands prevent the risk of short circuiting.
Batters > 0.25 m below NWL maximum 1V:3H	Batters below safety bench extending to variable base
Extending from NWL a 2m wide safety bench must be provided at a maximum slope of 1V:8H	Planted Safety bench must extend around entire perimeter (including forebay) immediately below NWL.
Batters above NWL must be a maximum of 1V:3H	Planted batters above NWL to transition to existing ground.
Emergent Macrophyte vegetation to cover a minimum of 80% of main wetland area at NWL	Dense and diverse plant community critical to support treatment processes. The 80% coverage is supported by the distinct shallow and deep marsh zones
*PSZ volume is adjusted by 0.75 and 0.8 respectively to account for the plant mass volume in this zone.	

Figure 3 provides a schematic of a typical wetland edge with safety batter and planting to align with depth and inundation.

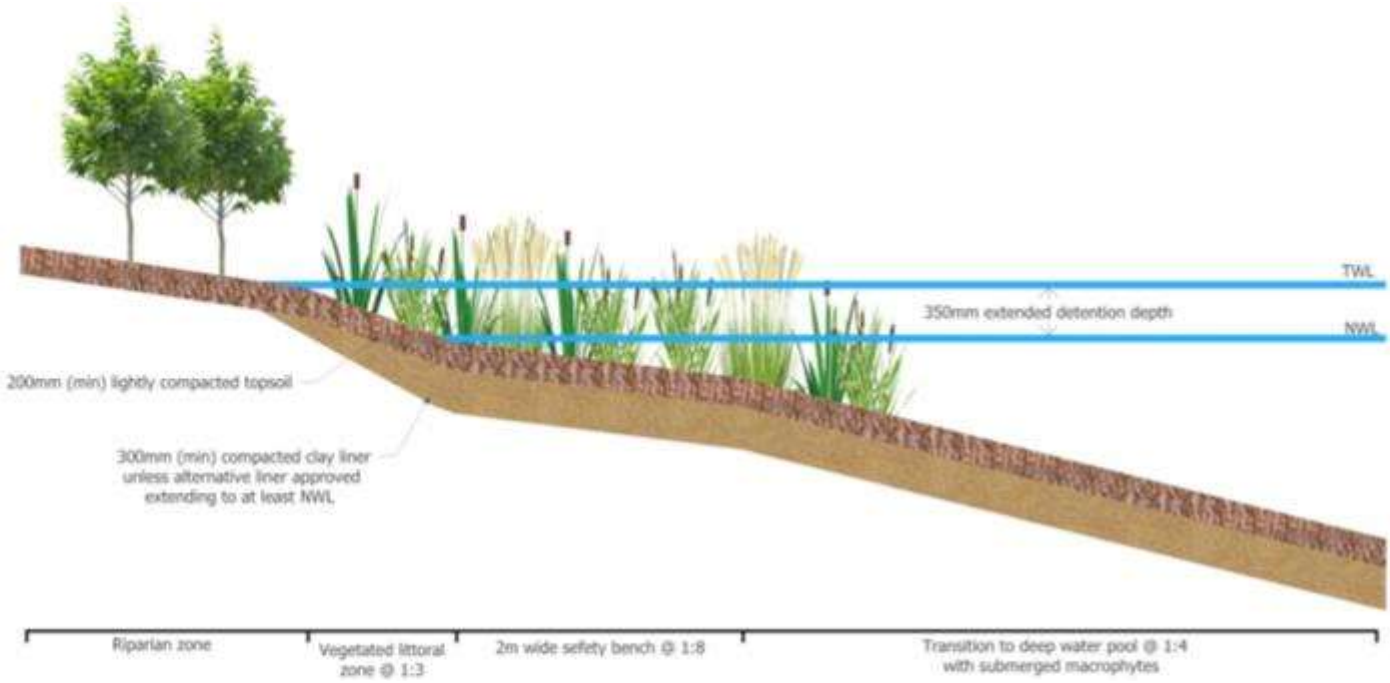


Figure 3: Typical wetland edge detail

6. Live storage zone design parameters

The live storage zone provides frequent, temporary storage of runoff during and immediately after storm events. Design parameters for the live storage zone are given in Table 6.

Table 7: Live storage zone design parameters

Wetland with EDV included	Description
Volume of LSZ = Extended Detention Volume	The extended detention volume needs to be entirely provided in the LSZ.
Volume of LSZ > WQV – PSZ volume	The water quality volume is provided in the LSZ and PSZ.
LSZ batters are a maximum of 1V:3H	Batters above normal water level are a maximum of 1V:3H.
LWL < 0.35 m above NWL	The depth of the LSZ should be no deeper than 0.35 m to support healthy plants.
Velocity of flow with depth at: NWL + (LWL – NWL) / 3 during peak flow of WQV event should be less than 0.05 m s^{-1}	Peak flow assuming a water level 1/3 of the way between NWL and LWL should be less than 0.05 m s^{-1} in the WQV event to avoid sediment resuspension and stripping of biofilms.

7. Sediment forebay design parameters

The sediment forebay comprises a deep, low-velocity pool to provide pre-treatment by retaining coarse-to-medium-sized suspended solids. This enables managed cleanout of these sediments and prevents smothering of the wetland treatment area, thereby increasing wetland longevity. A high-flow bypass is necessary to prevent re-suspension of accumulated sediment by inflows associated with storm events. Design parameters for the sediment forebay are given in Table 8.

Maintenance access to the forebay is necessary to allow periodic sediment removal. The forebay base is to be lined with compacted crushed rock or concrete so that excavator operators can distinguish between accumulated sediment and the forebay base.

The forebay is to be separated from the wetland body with an impermeable bund of compacted earth (with 200 mm topsoil in areas to be planted). The bund should have a 1 m wide crest that is level, set to the elevation of the NWL, and is well vegetated or includes a concrete level spreader beam.

Table 8: Sediment Forebay design parameters

Requirement	Description
Area of Sediment forebay = 0.1 x PSZ area (±5%)	The area of the forebay(s) needs to be in proportion to the PSZ area to provide sufficient storage for coarse sediments. If there are multiple forebays, the total forebay area should comply with this requirement.
Volume of Sediment forebay = 0.15 x PSZ volume (±10%)	The volume of the forebay(s) needs to be in proportion to the PSZ volume to provide sufficient storage for coarse sediments. If there are multiple forebays, the total forebay volume should comply with this requirement.
Forebay arrangement	The forebay shall have a surface length to width ratio between 2:1 and 3:1.
Maximum depth of Sediment forebay = 2 m	The forebay needs to be maintainable. Maximum depth is 2m as depths over 2 m can result in special equipment being required for maintenance.
Maintenance bench within 12 m of any part of forebay area	Unless maintenance access is provided into the base of the forebay, all parts of the forebay must be within 12 m of a maintenance bench (hardstand) to ensure the forebay can be dug out without the use of special equipment. The hardstand must be designed to support loading of suitable excavator.
Safety bench should be a minimum of 2 m wide and maximum of (1V:8H slope) extending from NWL.	Heavily vegetated safety bench to comprise 2 m wide bench extending from NWL

Requirement	Description
Batters below NWL maximum 1V:3H	Geotechnical advice on saturated slope stability required
Batters above NWL maximum 1V:3H	Batters above the NWL shall have a maximum slope of 1:3 where planted and 1:5 where mowing is required. Note, all wetlands which include EDZ will require planted littoral zones above the NWL.
Forebay Bund	The forebay shall be separated from the main wetland body with an impermeable bund with a crest at (or up to 100 mm below) NWL to support independent drawdown of the forebay water level. The bund shall be compacted earth with a formed level crest width of 1 m.

Figure 4 shows the typical layout of a forebay and Figure 5 shows a cross section through a typical bund separating the forebay from the main wetland body.

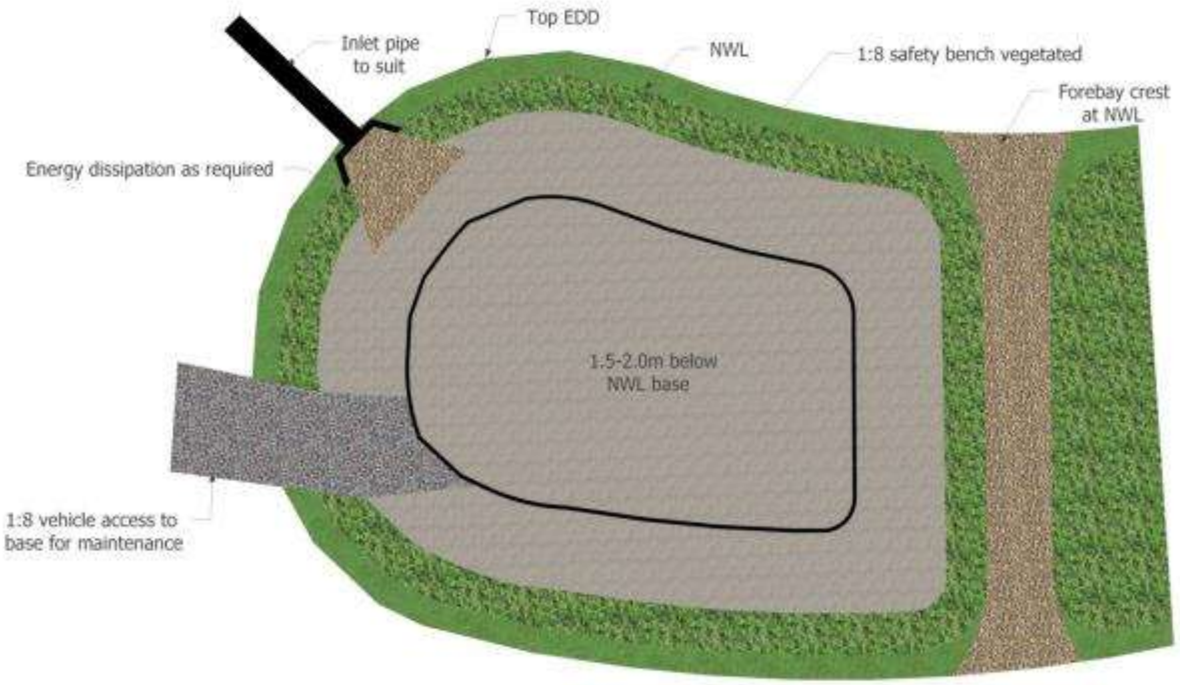


Figure 4: Typical forebay layout

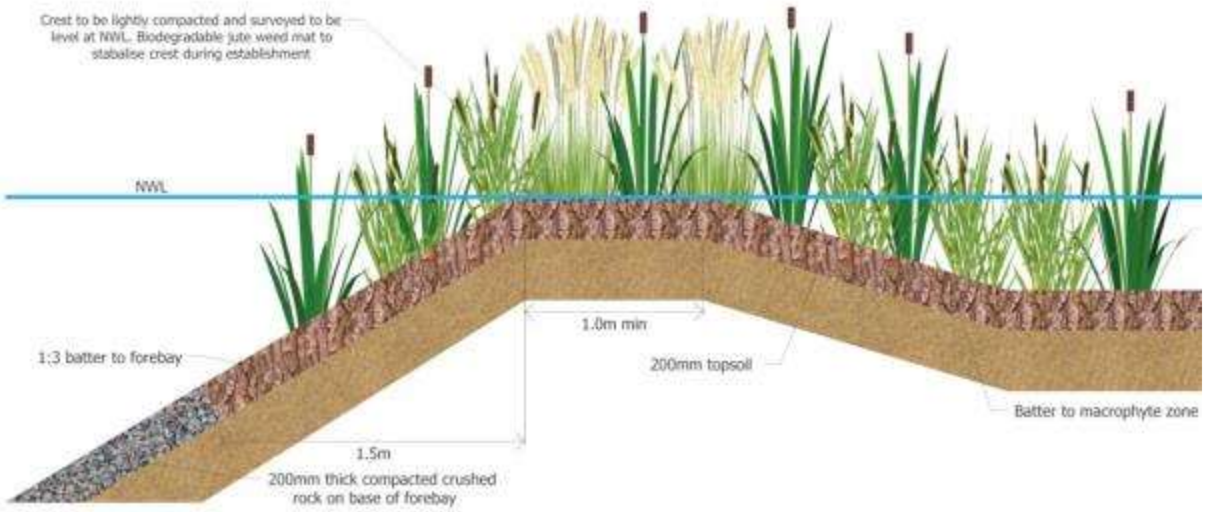


Figure 5: Typical wetland forebay bund cross section

8. Wetland inlet design requirements

To protect the wetland from the damaging effects of uncontrolled inflows, inlet design should include energy dissipation to reduce water velocity, prevent erosion around the inlet and provide an even distribution of flow into the wetland. Inlets must discharge to the forebay to ensure pre-treatment. Inlet design requirements are given in Table 9.

Table 9: Inlet Design Requirements

Parameter	Requirement	Verification method
Inlet pipe/channel	Any inlet elements must meet relevant Council design standards and be appropriately sized for design flows.	Approval at time of construction drawings sign off. All pipe sizes/channel dimensions to be marked clearly on as-built drawing set. Note this document does not cover design of upstream reticulated networks.
Diversion configurations	Any diversion works (including chambers, weirs, orifices and energy dissipaters) must be appropriately designed for the target inflows with consideration for operating hydraulics and head. Tolerances for critical structures must be stated in construction specifications.	As-built verification survey of all critical levels required to ensure diversion will function as intended.
Erosion protection	Design of inlets must consider potential for erosion from all design inflows. Energy dissipaters associated with inlets should aim to reduce water velocity, prevent erosion of areas surrounding the inlet, and provide an even distribution of flow into the wetland. Gross pollutant traps and debris screens can be included as part of the inlet design. Consideration should be given to storage capacity, potential clogging, and hydraulic implications when sizing gross pollutant traps, based on overall catchment characteristics.	Approval at time of construction drawings sign off supported by appropriate calculations.
Construction tolerances	Construction tolerance for the inlet is 5 mm.	As-built survey.

9. Wetland outlet design requirements

The outlet structure controls the water volume and hydraulic regime within the wetland, thereby performing both water quality and quantity functions.

Outlet structure design is determined by site characteristics, desired treatment functions, ecosystem connectivity, and maintenance considerations. Design requirements for outlets are given in Table 9.

Hydraulic control should be provided by a removable weir plate installed within a manhole located adjacent to the wetland outlet. Weirs should be sized the support the intended engagement of the extended detention volume and drawdown over 24 hours. A submerged pipe outlet draws off cooler deep water from the outlet pool, thereby reducing temperature-related effects on the receiving environment.

Outlet structures should enable periodic drawdown of the wetland volume for management and maintenance purposes as well as control normal water level in the wetland. Depth control is especially important during plant establishment so that plants are not drowned.

Table 10: Outlet design requirements

Parameter	Requirement	Verification method
Outlet hydraulics	Control outflows to either pass design flows in wetlands without extended detention or support drawdown of extended detention over average of 24-hr period.	Stage storage and stage outflow calculations to demonstrate hydraulic function
Outlet pool	Include a deep pool (1.5 m deep) at the downstream end of the wetland. Treated flows to be drawn from at least 500 mm below the surface via a pipe connection to the outlet control structure.	Earthworks model based on finished surface. As-built survey to verify finished levels.
Outlet structure	Hydraulic control to be contained within a suitable manhole or open chamber located on the batter adjacent to the wetland with flow control to define NWL and drawdown of event flows.	Design plans and As-built survey showing all critical levels within tight (5mm) tolerance level)
Outlet location	Outlet control structures must be accessible for inspection and maintenance (i.e. within manhole on batters). Submerged connection to outlet pool is to be included to avoid blockage and draw cooler water.	Design plans and as constructed drawings showing all critical levels within tight (5mm) tolerance level)
Fish passage	Fish passage shall only be required where viable upstream habitat exists for indigenous species. Where wetlands are located with fish passage required the design must include provision for passage in a range of typical operating events. Fish passage will not be achievable across the full range of operating conditions while also achieving operational requirements to support primary function of water quality improvements. The inclusion of any habitat provisions within the wetland itself (such as eel hides) must consider management of these species during future operations and maintenance.	Design plans and as constructed drawings
Discharge to receiving environment	All outfalls must comply with relevant Council standards to avoid scour and instability.	Design plans and as constructed drawings
Construction tolerances	Construction tolerance for the outlet is 5 mm.	As-built survey.

10. Bypass/spillway design requirements

A high-flow bypass is necessary to divert flows away from the wetland that are greater than the design maximum water quality flow rate. This is to ensure the biological treatment elements, such as macrophytes and biofilms, are not scoured by high-velocity flows and that accumulated sediments are not re-mobilised. The bypass must be placed upstream of the sediment forebay. Spillway design requirements are given in Table 11.

Table 11: bypass / spillway design requirements

Parameter	Requirement	Verification method
High flow bypass	Wetlands shall be constructed off line to flows in exceedance of the target treatment flowrate (lesser of calculated WQ flowrate or flowrate based on velocity calculations). This should be supported with an upstream diversion where possible such as modified manhole to side cast target flows into wetland inlet.	Design drawings and hydraulic calculations for all diversion structures and weirs.
Overflow outfalls	Design should include provision for an overflow spillway to be engaged at top of extended detention (or maximum standing water head where extended detention not included). The spillway should be located as close to inlet as possible and be sized to pass maximum flows without excessive head. Must be designed to withstand scour forces.	Design drawings and hydraulic calculations for all diversion structures and weirs.
Flood flow protection	Where wetlands are located online to large flood flows (including those engaged as part of flood attenuation) the design must consider potential risks in these infrequent events. Must demonstrate that have considered all flows up to 100-year event and included suitable spillways or throttled outlets with attenuation storage as part of design.	Design drawings and hydraulic calculations for all diversion structures and weirs.
Construction tolerances	Construction tolerance for the high flow bypass weir is 5 mm.	As-built survey.

Figure 6 shows the schematic arrangement of highflow bypass and potential re-engagement of the wetland footprint for infrequent flood detention. [to be improved in later version]

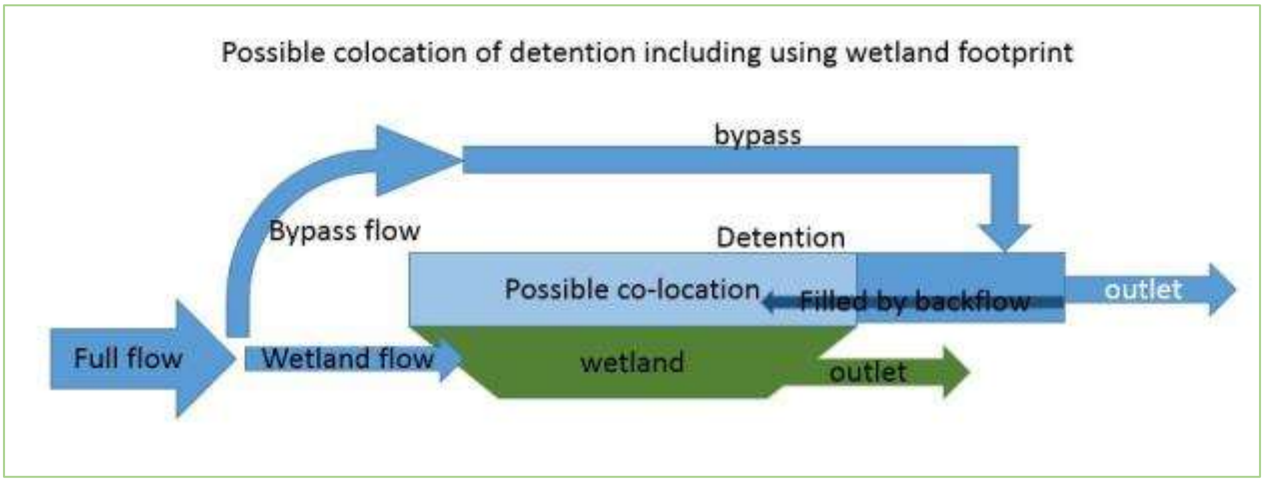


Figure 6: Schematic of functional arrangement to support flood detention above water quality treatment wetland

11. Maintenance access design requirements

Vehicle access to the sediment forebay is necessary to permit periodic cleaning out of accumulated sediment. Where it is not possible to clean the forebay from the perimeter hardstand, this must include trafficable access into the base of the forebay itself. Light vehicle access to other parts of the wetland must also be available for maintenance purposes. Pedestrian access to the entire perimeter is required for weed control and maintenance of vegetated areas.

Table 12: Maintenance access requirements

Parameter	Requirement	Verification method
Forebay access	Full 3m wide (minimum) trafficable access (crushed gravel or similar) must be provided to a suitable hardstand for small systems (where standard long reach excavator can access all areas of forebay from hardstand) or 4 m wide access track to base of forebay for larger wetlands. Access tracks into the forebay to be no steeper than 1V:12H and be constructed with a robust unsealed surface such as 150 mm cement treated crushed rock suitable for heavy vehicles.	Sign off as part of maintenance plan prior to construction approval

Wetland vehicular access	Vehicle access (ute) should be provided to at least 50% of the wetland perimeter (including to all hydraulic structures) along the top of extended detention depth or minor setback for landscape planting. Design of access track must consider other site users and public safety.	Sign off as part of maintenance plan prior to construction approval
Wetland pedestrian access	Pedestrian access must be provided around the entire perimeter including any bunds, structures or hydraulic controls. Preferred access routes should be marked on maintenance plans and maintained free of excessive vegetation growth above 1 m height. All pedestrian paths must comply with Council guidelines	Sign off as part of maintenance plan prior to construction approval

12. Wetland liner design requirements

Impermeable lining of all wetlands is critical to ensure that the water level is sustained during prolonged dry spells and that the emergent aquatic vegetation is supported. In situ soils may be suitable for use but will require verification testing and reworking to form a homogenous liner across entire wetland. Where in-situ soils are not suitably impermeable, an imported impermeable liner, either natural or synthetic, must be used. Liner design requirements are given in Table 13.

Table 13: Liner design requirements

Parameter	Requirement	Verification method
Permeability	Entire wetland (to top of normal water level) must demonstrate a permeability of $1x10^{-9}$ m s^{-1} or lower.	Geotech testing at time of construction or approval of synthetic liner prior to installation
Imported Natural Clay liner option	Minimum 300 mm of well compacted clay required across entire wetland including batters. Material must be uniform in composition and constructed to achieve consistent compaction across full area.	Imported and *In situ* clay material must be tested and approved prior to procurement to demonstrate permeability of 1 x 10^{-9} m/s at 95% standard maximum dry density. Post construction testing must confirm 95% standard maximum dry density to at least 300 mm depth. Minimum testing requirements of 1 test/150 m^2 compacted clay material (based on 300 mm uniform liner depth) to be tested by independent geotechnical engineers in accordance with NZ standards for clay liners.
In-situ Clay liner option	Minimum 300 mm of well compacted clay required across entire wetland. Approval must be sought for use of in-situ clay material versus imported clay. Where in-situ material is approved for use, all batters shall be completely re-constructed with clay liner to ensure no heterogeneity.	
Synthetic liners	Geo-synthetic Clay Liners (GCL) or HDPE (min 1.5 mm) may be suitable in absence of suitable clay source. Approval for material to be provided prior to specification including manufacturers testing and independently verified performance data. Consideration must be given to slope stability on batters to prevent sloughing.	Material to be pre-approved. Installation must be undertaken by approved installer with comprehensive QA procedures to verify integrity of all joins, welds, protrusions and anchoring. Protection of liner post installation critical during subsequent works. All membranes must be covered by at least 300 mm soil/rock to support plant growth and provide consolidating pressure for GCL.
Topsoil	Entire wetland (including batters and terrestrial areas) must include 200 – 300 mm depth of lightly compacted topsoil. Topsoil can be site sourced or imported but must be free of weeds, woody matter or contaminated soils. The topsoil must be suitable for horticultural purposes with suitable organic content and structure. Where possible, soils below the NWL should have lower organic content to reduce the incidence of	Material to be used as topsoil to be pre-approved by designer or suitably qualified horticulturalist/landscape contractor.

	nuisance filamentous algal blooms in the initial growing season.	

13. Planting and plant selection

Selection of suitable plants for wetlands is critical to ensure sustained performance under a range of conditions. To achieve this, the bulk of species used should be adaptable to the broadest ranges of depth, frequency and duration of inundation and a diverse range of species should be used, avoiding planting large blocks of single-species.

The following specifications are required:

- ~ Avoid mown grass adjacent to water as this attracts ducks and geese. Maintaining a dense edge of taller plants helps prevent common ducks and geese fouling the wetland.
- ~ Perennial, evergreen species should be planted in preference to non-perennial and/or deciduous species. Raupo is not recommended due to die-back in winter and tendency to over dominate other species.
- ~ A diverse assemblage of plants is preferable. Native local species (with seed eco sourced by nurseries) complement local vegetative communities and help ensure plants are well adapted to local climate, even though soil conditions are likely to be more compacted
- ~ Do not plant trees over liners unless there is adequate rooting depth (>600 mm) to minimise risk of liner being damaged by roots or being exposed if trees are uprooted
- ~ Plants must be supplied as individual plants (i.e. tubestock or pots) and shall not be substituted for manually separated reclaimed clumps or propagation trays cut into units. Plants must be healthy and robust with vegetation extending above the planted water depth,
- ~ Plants should be planted with a minimum density of 4 plants/m^2 to form full coverage of the shallow and deep marsh areas to achieve a minimum of 80% coverage within 2 growing seasons. Extended detention shall not be used during establishment, i.e. water levels should not overtop planted vegetation during the developmental growth phase during establishment. Species should be well mixed within their growing conditions to form a natural assemblage where possible. Up to 10% of plants can be ‘diversity’ planting (i.e. not purely selected for treatment characteristics) to increase overall biodiversity, particularly around the perimeter of the wetland.
- ~ Dense, rigid and tall marsh species should be selected as far as practical within deep marsh zones. Tall marsh species with spreading leaves should be selected adjacent to open water areas.
- ~ Vegetation that provides a high level of shading (including trees, shrubs and reeds / tall sedges) should be planted around and within the wetted margin of the wetland. Swamp forest is one of the most threatened are rare natural ecosystems in the Nelson Tasman district. Concentrate tall, spreading plants on the northern aspect of a wetland to help reducing water temperatures. Care must be taken where synthetic liners are used in areas with permeable in-situ soils. In these instances the use of large tree species should be avoided due to potential instability and risks of damage to synthetic liners.
- ~ Avoid planting in straight rows; plant in clusters so that area looks more natural and plants can shelter each other; where pasture or weed growth is anticipated, stake terrestrial plants as soon as they are planted so they are easy to find during maintenance
- ~ Be careful with organic mulches – these should not be used in areas where water will flow as this will wash them into surface waters; organic mulches at 70 to 100 mm depth on upper batters can increase establishment by reducing weed competition, keeping the soil cool and increase water available for plants. However, mulching wet, ‘heavy’ compacted soils will exacerbate wetness and anaerobic conditions – in such cases create rough surfaces during planting (+/- 100 mm) as this helps plants to access a variety of conditions.

Plant species tables are provided in Table 14 please refer to these tables for guidance on plant species suitable for use in wetlands Bold plants are the most resilient and fastest-growing. N= referenced in Living heritage guide http://nelson.govt.nz/environment/biodiversity-2/nelson-nature/resources/living-heritage-plant-guide, ‘Freshwater wetlands and waterways’ page 27-29 with ‘wet’ plant preference

Table 14: planting list for wetlands

Littoral Edge (extended detention depth above normal water level)	?		
	Austroderia richardii	N very sensitive to glyphosate	
	Blechnum minus/ novae zelandiae	N Swamp kiokio and kiokio	
	Coprosma propinqua	N mingimingi	
	Coprosma robusta	N karamu	
	Gahnia xanthocarpa	N mapere, giant cutty sedge	2m sedge
	Hierochloe redolens	N karetu, holy grass	
	Juncus australis	N rush (can be confused with weeds)	
	Carex dissita	N purei, makura	1m sedge
	Carex secta	N purei, makura	1m sedge
	Carex virgata	N purei, makura	1m sedge
	Cyperus ustulatus	N toetoe, upoko tangata (mainly coastal, < 10%, deciduous)	0.8m sedge
	Phormium tenax	N harakeke, flax	2m monocot clump former
	Phormuim cookianum	Mountain flax useful next to paths, not wet or compacted	
	Cordyline australis	N ti kouka, cabbage tree	
	Melicytus micranthus	N Manakura, swamp mahoe	
Shallow marsh; 0 – 250 mm depth	Carex geminata	N rautahi	1m sedge
	Carex secta	N	
	Coprosma tenuicaulis	?check	
	Carex virgata	N	
	Eleocharis acuta	sharp spike sedge	0.9m sedge
	Isolepsis prolifera	clubrush	0.5m rush
	Machaerina articulata	N jointed twig rush	1.8m sedge
	Apodasmia similis	**oioi**	
Deep marsh; 250 mm to 500 mm depth	4.Bulboshoenus caldwelii	N (prefers brackish water)	
	1.**Eleocharis sphacelata**	bamboo spike sedge	1m sedge
	2.**Shoenoplectus tabernaemontani**	kāpūngāwhā, lake clubrush	1-2m sedge
	3. Machaerina rubiginosa	N Baumea (M. articulata not in region)	0.9m sedge
'Trees' Where>0.6 m rooting depth (islands, edges), >5 m from areas that will be excavated (e.g., forebays), not over liners	Dacrocarpus dacrydiodes	N Kahikatea	
	Hebe stricta var atkinsonii	N Koromiko (not for wet, compacted areas)	
	Laurelia novae-zelandiae	N Pukatea	
	Leptospermum scoparium	N manuka	
	Syzygium maire	N Swamp maire	

Weeds to watch for and remove (see Hornwort (*ceratophyllum demersum*), *Egeria densa*, Senegal tea (*Gymnocoronis spilanthides), Lagarosiphon* major, and Parrots feather (*Myriophyllum aquaticum*) and fringed waterlilly (*Nymphoides peltata*)

These can rapidly invade waterways, crowd out native species and block channels. https://www.marlborough.govt.nz/repository/libraries/id:1w1mps0ir17q9sgxanf9/hierarchy/Documents/Environment/Biosecurity/PlantMeInstead.pdf)

6. Construction

The construction of wetlands must be undertaken by experienced operators who understand the requirements outlined in this practice note and the criticality of liners, hydraulic structures and plants. In particular the importance of the wetland liner and the considerations to achieve a continuous impermeable liner when working near or below the groundwater level.

Inspections and approvals through the construction process must be closely adhered to in accordance with the verification methods provided in this practice note.

Timing of planting and the management of water levels need to be considered. Planting of wetland plants shall be undertaken between September to May and terrestrial planting from May to October. The water level in the wetland shall be limited to at least 150 mm below the NWL until plants are growing vigorously and at least 50% of the stem height will remain above the NWL. Timing for this will vary depending on planting but will typically take 6 – 12 months.

Wetland establishment is a critical stage in construction. Wetlands shall be maintained by the developer/contractor for a minimum of 24 months from the time of practical completion. This shall include weed control, replacement of unhealthy plants and rectification of any construction flaws. At the time that wetland assets are vested to Council they must be in optimal condition as per the design intent. This must include a minimum of 80% plant cover at the normal water level, no invasive or noxious weeds and the sediment forebay must be fully cleaned out to ultimate as built levels.

7. Handover

Plant establishment is critical for a wetland to perform. Plants shall be maintained by the developer/contractor for 24 months from the time of practical completion (establishment phase). This shall include weed control, replacement of unhealthy plants and rectification of any construction flaws. At the time that the wetland is vested to Council all plants must have been growing for at least 3 months and be in good condition as per the design intent and/or a defect liability and bond provided where applicable.

Checking is required at several stages during the construction to ensure the wetland is constructed to specifications. At the hand-over stage particular attention is required to ensure the establishment phase is managed (e.g. by taking a bond) and that plant health is satisfactory.

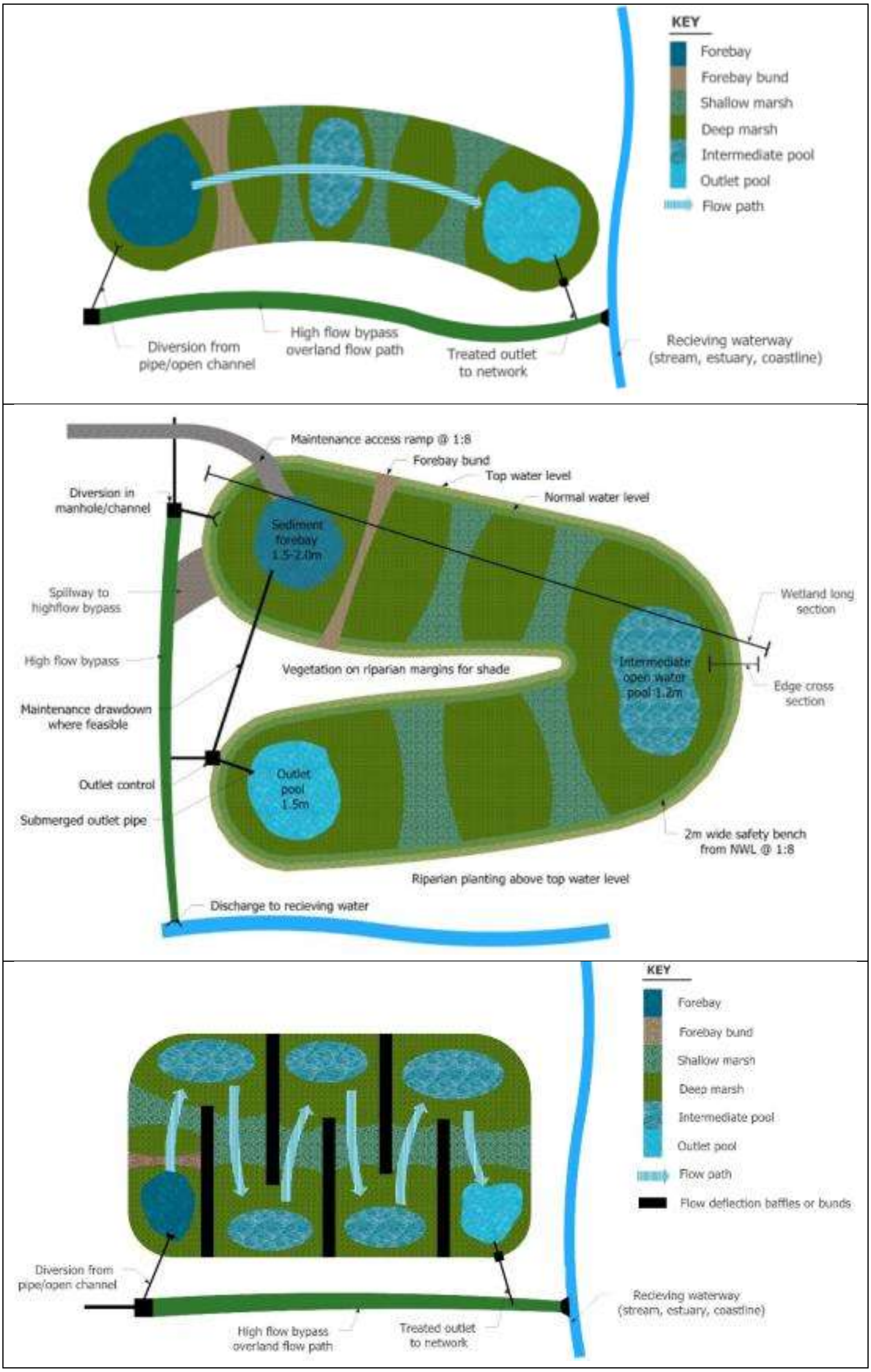
8. Responsibility and maintenance

This practice note only covers publically vested wetland systems. One of the important considerations with wetlands is long-term maintenance. Whilst wetlands are generally low maintenance it is important to understand the maintenance requirements as deficiencies can cause the systems to fail or function poorly without expensive remedial works, not NO maintenance. Some attention point are:

- Landscaped areas above the top operational water level should be mulched with minimum 75 mm hardwood mulch to suppresses weeds and retain moisture.
- Batters and landscaped areas may require regular, knowledgeable weeding for the first 24 months, or until canopy closure. Routinely (every 3 months) inspect all inlet and outlet structures to identify and rectify blockages, scour or structural issues
- Inspect wetland following any extreme weather events (>1 in 10 year storm) to rectify any scour or blockages
- Inspect the wetland annually to assess plant health and ensure that 80% plant cover is sustained. Where plants are in poor health or have died, work out why they have died, mitigate conditions, and replace as required.
- Inspect the wetland six monthly for evidence of invasive species (plants or animals). Where identified these shall be eradicated as soon as practical.

9. Attachments

9.1. Typical shapes and components



9.2. Plants for Nelson/Tasman stormwater treatment wetlands

Plants should be established at the driest part of their range so they can spread into deeper areas once root systems are established; not planted underwater like rice in paddy fields; water tables will therefore be lower during establishment than when operational, i.e. the shallow marsh zone will be dry, only the deep marsh will have water'

Table 15: planting list for wetlands. Bold plants indicate suggested use as dominant components, (N) indicates plant recommended for wetland restoration in Nelson's Living Heritage Guide.

Littoral Edge: Above the normal water level but inundated during rainfall as part of extended detention depth	*Astelia fragrans (Riparian)*	swamp astelia, kahaka	1.5 m spreading 1.5 m lilly, highly aesthetic, berries, minor
	Austroderia richardii (Riparian)	South island toetoe (N)	2 m spreading 2 m tussock was *Cortaderia.* very sensitive to glyphosate, mainly riparian
	Blechnum novae zelandiae (Riparian)	kiokio (N)	1.5 m fern, Minor, new foliage is attractive red
	Carex secta	purei, makura (N)	2m sedge when mature
	Carex virgata	purei, makura (N)	1m sedge
	Coprosma propinqua (Riparian)	mingimingi (N)	3 m divaricating shrub, with blue berries, minor
	Coprosma tenuicaulis(Riparian)	Swamp coprosma, hukihuki	3 m tangled but upright shrub with black berries, minor
	Cyperus ustulatus	umbrella sedge, upoko tangata (N)	0.8 to 1.5 m sedge, deciduous so can look messy, minor
	Juncus australis	rush (N)	0.6 to 1.2 m hardy rush of disturbed, wet pasture
	Jnucus edgariae	wiwi, common rush (N)	1.5 m spreading 1 m
	Juncus pallidus	giant rush (N)	1.7 m spreading 2 m
	Juncus sarophorus	blue rush (N)	1.5 m spreading 1 m
	Phormium tenax	harakeke, flax (N)	2 to 2.5 m monocot clump; plant at least 3 m from paths
Shallow marsh; Up to 200 mm below NWL	*Blechnum minus (Riparian)*	swamp kiokio (N)	1 m fern, once established forms a dense sward
	Carex geminata (need to be very careful to only plant in very shallow water (<100 mm)	rautahi (N)	0.8 to 1m sedge, can be regarded as 'untidy'
	Carex lessoniana*(need to be very careful to only plant in very shallow water (<100 mm)*	rautahi	1.5m sedge, can be regarded as 'untidy'
	Carex secta *and* ***Carex virgata***	purei, makura (N)	1 to 2m sedges complement each other to create dense, weed supressing swards
	Eleocharis acuta	sharp spike sedge	0.5 to 0.9m sedge

	Isolepsis prolifera	clubrush	0.3 to 0.5m spreading 2 m, fast-growing rush useful to include in areas that are periodically weed-eated
	Apodasmia similis	jointed rush (N)	0.5 to 1.3 m rush, primarily for brackish water but is very weed resistant once established and tolerant of a wide range of conditions
Deep marsh; Between 200 mm and 500 mm below NWL	*Bolboshoenus caldwelii*	n/a (N)	1.5 m sedge, prefers brackish water
	Eleocharis sphacelata	Kuta, ngawha, bamboo spike sedge	1-2m sedge grows in water up to 1 m depth, used for fibre
	Shoenoplectus tabernaemontani	kāpūngāwhā, lake clubrush (N)	1-2m sedge also used for fibre and rongoa (maori medicine)
Trees for riparian edge and adjacent areas that have suitable rooting depth and protection of liners	*Carpodetus serratus*	putaputaweta (N)	Small tree to 10 m can be covered in small white flowers attractive to insects, mainly better draining but moist soils
	Coprosma robusta	karamu (N)	Fast growing shrub with berries (for birds) that will spread from seed under suitable conditions
	Cordyline australis	yi kouka, cabbage tree (N)	Valuable narrow, architectural tree to 12 m tolerant of wind, provides fragrant flowers and fruit for birds and insects but little shade. Plant at least 3 m from any mown areas
	Dacrycarpus dacrydioides	kahikatea, white pine (N)	Noble, slow-growing, tall tree (20-30m), plant where weeds can be maintained for at least 3 years
	Hebe stricta var, atkinsonii	n/a (N)	Fast-growing shrub with large 'bottle brushes' of white flowers; other hebes are also used in nelson
	Hoheria angustifolia	houhere, narrow-leafed lacebark	Small tree to 10 m with tangled juvenile form
	Leptosopermum scoparium	manuka, teatree (N)	Small tree to 8 m with abundant white flowers tolerant of compaction and full sun
	Plagianthus regius	manatu, lowland ribbonwood	Small tree to 15 m
	Sophora microphylla	kowhai	Small tree to 10 m, attractive to tui, bellbird (nectar) and keruru (leaves) but needs reasonably free drainage, not ponded water

Footnotes

1. Most trees and shrubs will need to tolerate at least seasonable waterlogging unless they are planted on 'islands' or adjacent areas with deeper, free-draining soils
2. Phormium tenax is not recommended for standing water even though it will grow there due to its bunched, water-deflecting, growth form
3. Raupo has been excluded under the following rationale

- Has a tendency to overtake other aquatic macrophyte species and initially develops into large clumped areas of vegetation. These are particularly dense both above and importantly below the water level and result in flows being forced around the clumps resulting in preferential flow paths, reduced contact time between plant stems and stormwater and increased velocities causing stripping of biofilms. In the long term Raupo can cause large spreading clumps which can ultimately choke the flow and impact hydraulics
- Raupo's growth habit results in significant vegetation matter with succession and die back over winter (it is deciduous). This increases the organic loadings into the wetland and results in nutrient leaching. The same is true to an extent with Bolboschoenus but I like to include small numbers of that as that add significant aesthetics and food source
- Raupo is less effective at transferring oxygen to the root zone and submerged sediments, this is particularly important for a range of the chemical and biological processes.
- The dense mass of dead plant material above the NWL in winter/spring will retain moisture after drawdown and support mosquito larvae without predation within the main wetland body

4. Taller shrubs and small trees have been put in their own category, as an adequate root zone above a liner is required to reduce risk of liner from roots. Pukatea and maire have not been included but are valuable, long lived trees given overhead shelter and coastal locations for the latter (maire is also locally extinct) and extended weed control and continuously moist conditions for both. Melicytus micranthus (swamp mahoe) is a shrub that also prefers shelter and could be use in low numbers, once cover is present, to provide understorey within kahikatea plantings. Neomyrtus pedunculata could also be planted in low numbers but is probably vulnerable to the new pathogen myrtle rust.

Other comments

- Carex lessoniania removed from littoral and placed in shallow marsh Need to be careful with Carex planted in standing water as tendency for them to rot during establishment. Best to only plant in very shallow edges and ideally draw down water below NWL for establishment
- Gahnia xanthocarpa (N) removed as is usually found in low fertility wetlands and does not form a , also highly abrasive so difficult to maintain, often has high mortality during establishment but highly attractive seed heads
- Hierochloe redolens (N) not included as would tend to be removed/sprayed out as a grass weed unless specialist maintenance crew is engaged
- Carex dissita (N) is removed as it prefers shade – a forest groundcover under kahikatea, and only about 500 mm tall so not as effective as other species at supressing pasture weeds
- Bolboschoenus fluviatilis and B. medianua removed as not naturally found in the area, although at this latitude
- Carex maorica not included in shallow marsh, as generally difficult to source
- Machaerina/Baumea articulata is not included as it is both a species of low fertility areas and has a very restricted range on islands in Nelson area (so unnaturally expanding its range is not favoured); Machaerina rubinginosa is also a species of low-fertility wetlands so not included Rubiginosa grows well in stormwater wetlands and is suited to both shallow and deep marsh areas

9.3. Good and bad practise examples

Below are some photos of good and no-so-good examples of wetlands

	Well planted establishing wetland (6 months after planting)
	Well planted establishing wetland (6 months after planting)
	Submerged outlet pipe with connection to hydraulic controls within grated manhole

	Diverse shallow marsh species mix (9 months after planting)
	Established wetland (12 months after planting) showing dense vegetation across full width. Outlet pool in foreground
	Shallow and deep marsh areas planted at 4 plants/m^2. Photo 1 month after planting

	Boardwalk constructed on wetland bund. Open water on left as outlet pool with submerged connection beneath bund. Photo 1 month after planting.
	Reduced amenity through outlet design. Note lack of vegetation within wetland and/or batters
	Poorly designed outlet configuration with accessibility issues and discharge of surface waters with elevated temperatures. Limited vegetation cover in wetland

	Online wetland subjected to full flows from catchment with resulting resuspension of sediments etc
	Discharge of high flows into online wetland. Elevated suspended sediments from subdivision during build out phase
	Poor design outcome with limited planting, lack of littoral edge and degraded water quality reducing amenity

	Poor bathymetric design with edge planting only and clear preferential flow path through central deep channel
	Wetland vegetation in base of detention basin with permanently wetted base
	Well established wetland vegetation and riparian margins

9.4. Acknowledgements and source references

These practice notes, including many graphic, are largely based on information from the North Shore City Council Bioretention guidelines (2008), the Long Bay Practice Notes developed for North Shore city Council by D & B Kettle Consulting Ltd (2011) and the Bioretention Practices Notes for Hamilton City Council (2016).

9.5. Version, version control and change comments

The Practice notes were developed by Morphum Environmental with input from Robyn Simcock from Landcare related to planting specifications and overall peer review.

Summary of changes

Version	Date	comments
0.1	24 January 2017	First draft for comment from the Industry
0.2	13 July 2017	Second draft including planting requirements
1.0	16 June 2017	Immediate Release version, showing good practice, independent of local requirements

9.6. Want to know more?

There is a lot of information available related to Low Impact Design (LID, or Waster Sensitive Urban Design (wsud). Underneath are few references. It should be noted that all info in these documents is not necessarily agreed, up to date and/or applicable in the Nelson/Tasman area and that the application of LID is evolving over time.

- Landcare / Morphum Ltd: "Applying Low Impact (Water Sensitive) Design in Nelson Tasman", June 2016. A review of LID practices in Tasman and Nelson and issues experienced by council and the industry. Includes description of many different LID devices and recommendations for improvement.
- All Hamilton practice notes can be found on the Hamilton Council website
- Auckland council "Water Sensitive Design Guide GD04". An online resource, including background and wider design approach.
- Morphum Ltd: Draft-"Constructed Wetland Design Guide, April 2015" – for Auckland Council, was not published in the format delivered.