SOFT SOLUTIONS FOR HARD ENGINEERING PROBLEMS

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ABSTRACT

Urbanisation and infill development undermine the equilibrium of streams and natural wetlands. Streams receive greater flows resulting in destabilization of the banks, destroying habitat through increased sediment loads. Coastal wetlands suffer from sediment loading, increased heavy metal input, further degrading habitat. The degraded ecosystems are at best a burden and long term a source of a myriad of risks.

A fresh approach to recover damaged ecosystems requires stewardship of streams and wetlands by territorial authorities, network providers and property owners. From the stewardship approach, the urban streams and wetlands become assets that not only convey water, but provide social benefits and serve as habitats to our native flora and fauna. This paper examines restoration of degraded wetland and stream environments where appropriate soft engineering solutions can revitalise these living systems, bringing them back into equilibrium.

The majority of the natural streams in Auckland serve as part of the public stormwater network resulting in bank erosion, habitat loss and proliferation of pest species. During the March 2017 storms a 1.25 km creek in Howick experienced significant bank collapse which resulted in failure of a wastewater pipe bridge and loss of property along the riparian margins. Immediate remedial works resulted in a proposal for installing retaining walls along lengths of over-steepened banks to protect private property and public assets. However, the project evolved and an opportunity arose to apply soft engineering solutions adding ecological value to the urbanised stream. The applied solutions included longitudinal stone toes with coconut matting wrapped soil embankments, cross vanes, 'J' vanes and root wads. The soft solutions within the stream restoration create habitat complexity, hydraulic diversity, and opportunities to restore native flora and fauna. Moreover the root wads and fabric embankments will decompose over time allowing the restored riparian zone to function naturally.

Soft solutions can be applied to restoring both coastal and upland wetlands which are globally amongst the most threatened environments. Nearly 90% of NZ wetlands have been drained or filled resulting in reduced flood storage and localized flooding. Tawaipareire Wetland on Waiheke Island is amongst these. Located in the island's major industrial zone, which includes an old land fill site, the wetland sits at the bottom of a 106 ha catchment. Much of the lower catchment floods frequently, introducing contaminates into the nearshore environment. A new open channel has been designed to alleviate flooding. Added benefits were generated by including large rock spalls and intermittent planting of native salt marsh species, creating an ecological linkage between the mangrove area and the upland section of the wetland.

KEYWORDS

restoration, ecosystems, soft engineering, wetlands, streams

PRESENTER PROFILE

Linda joined ACH Consulting Ltd after immigrating to New Zealand in 2006. Trained in the US as an oceanographer and environmental engineer she has worked for NASA, Woods Hole Oceanographic Institution, US Geological Survey and others. A Scientist and an Engineer, she brings her multidisciplinary experience to blue-green infrastructure design.

1 INTRODUCTION

Auckland is a city intertwined with natural waters, including creeks, freshwater and saltwater wetlands. Each environment serves an important function within the water cycle. The urbanization of the riparian areas around the natural waters has led to an untenable relationship between the urbanization and the ecosystems which depend on the natural waters.

The creeks which run though Auckland's urban landscape are short, many having a total length of less than 3 km. The upper catchments are often steep. The streams and creeks within the established urban area serve double duty providing both habitat and acting as part of the public drainage network.

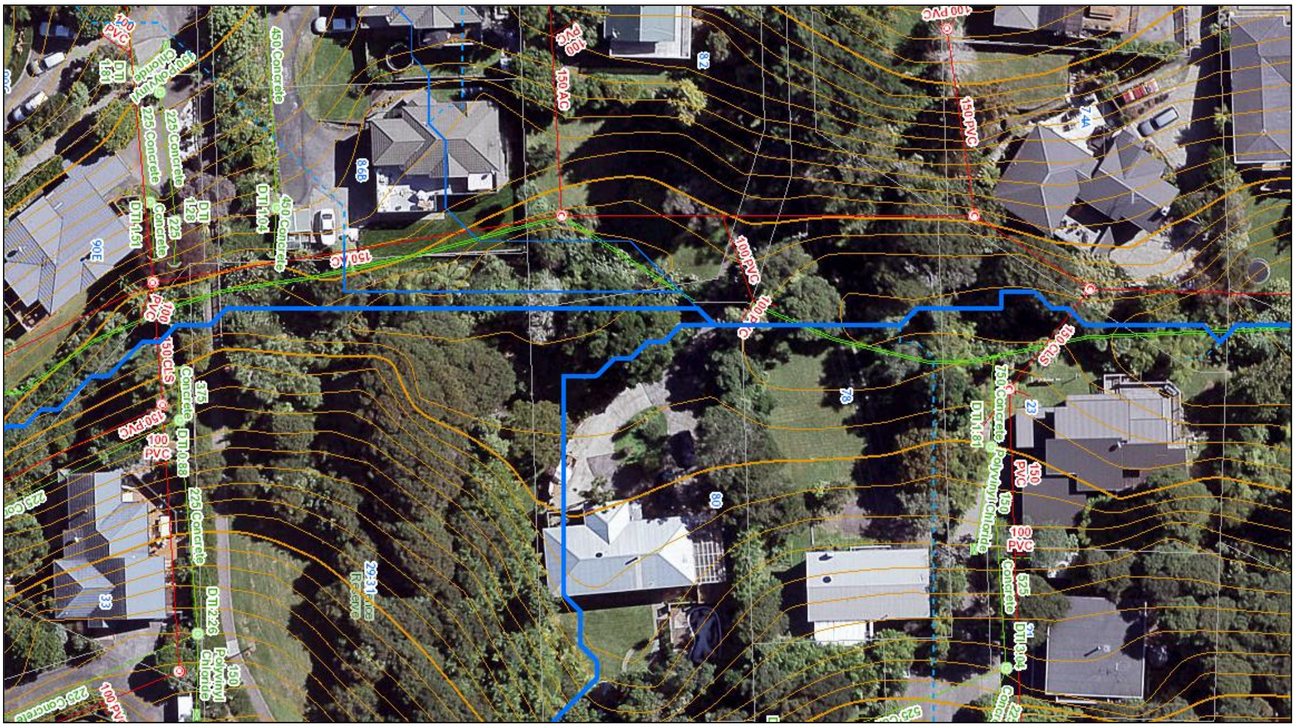


Figure 1: Typical Auckland unban stream (Kauri Lands Area).

Auckland has additional difficulties as much of the public wastewater infrastructure runs along the same gullies as the streams. As the stream banks erode, wastewater pipe lines collapse spilling untreated sewage into the natural waters. As the stream reaches are short much of the untreated sewage ends up on the beaches and in some cases will flow for days until temporary repairs can be made on the pipe lines. This last year has seen intense weather systems resulting in an unprecedented number of public infrastructure failures.

Where the contributing catchment to short streams has undergone infill development, standard mitigation measure have been inadequate with the greater percentage of stormwater detention tanks in overflow (as there is no capacity to ensure tanks are inspected and maintained). Lack of mitigation or malfunctioning mitigation increases the peak flows and accelerates bank erosion. Many of the streams and creeks border private property with little or no riparian corridor. As banks erode yards erode into the creek and property is damaged.

Where public infrastructure and private property are at risk, bank hardening has generally been the common practice. However bank hardening can result in bed scour, bank toe scour and channel deepening (Niezgoda & Johnson, 2006). Moreover, there is both a loss of riparian habitat and the flood plain becomes disconnected. High flow events bypass the flood plain and travel at high velocities within the deepened channel. The flood plain and riparian habitat become disconnected for the stream (Roni, et al., 2002).

Urban waterways encounter further problems upon discharging into the marine environment. The transitional wetlands that were once part of the drainage system, providing flood storage and filtration, have been reclaimed and filled in. Many downstream outlets are constricted by undersized, partially blocked culverts. Roads over these culverts are of sufficient height to act as dams. When the dam is overtopped the road is unpassable and can be damaged by the torrent of water.

The urbanization of streams and the wholesale reclamation of both upland and estuarine wetlands has exacerbated flooding, placing both public and private property at risk. The Auckland wastewater and stormwater network are in jeopardy. Land slips and erosion resulting from increased storm intensities and frequencies cause pipe lines to collapse or fail. The financial and environmental costs are significant.

Where a catchment reaches impermeability of greater than 10% the stream becomes compromised (R.C. Brears, 2017). At greater than 10% impermeability the stream will experience:

- Excessive bank erosion
- Loss of riparian vegetation
- Increased frequency and magnitude of flooding
- Greater contaminate loading
- Greater thermal loading
- Decrease in stream biodiversity

There are only 41 species of freshwater fish native to New Zealand, over half of which spend at least some of their lives at sea. Due to habitat reduction and isolating the stream environment from the estuarine environment only 10 species of the 41 natives are considered not threatened and one is known to be extinct (Goodman, et al., 2013).

When looking for solutions to urban flooding, threatened infrastructure and infill development it is important to consider the catchment as a whole. A catchment wide view allows the designer to recognize opportunities to create habitat.

There are a myriad of soft solutions which can be used in a variety of environments to stabilise the banks as well as recover or enhance damaged rivers and wetlands. Amongst them are:

- Stone toe protection with coir pillow planting
- Root wad composites
- Cross vanes
- ‘J’ vanes
- Placing of large rock Spalls

In weighing the options for stream bank protection, the opportunities for restoration or enhancement need to be considered. There are a number of factors that should be considered in any stream protection or restoration project. In an urbanised stream, protection and enhancement can generally only take place at a reach or site specific scale. As such, a methodology needs to be adopted which assesses the localized restoration within a catchment wide context.

2 METHODOLOGY FOR DESIGN

The methodology for the design phases of the projects both in Howick and the Tawaipareire Wetland required the following analysis.

- ***Driving Factors***
  - *Floods*
  - *Erosion*
  - *Landslips*
  - *Loss of Infrastructure Services*
    - *Wastewater*
    - *Water Supply*
    - *Roads*
  - *Environmental Degradation*
- ***Controlling Factors***
  - *Site Access*
  - *Land Availability*
  - *Channel Morphology*
- ***Desired Outcomes***
  - *Protect Infrastructure*
  - *Control Flooding*
  - *Stop Erosion*
  - *Protect private property*
- ***Opportunities***
  - *Create Habitat*
  - *Improve Stormwater Quality*
  - *Re-establish Wetland Ecology*
  - *Public Perception*
- ***Obstacles***
  - *Costs*
  - *Public Perception*

Hierarchical controls for design are accessibility, stream channel morphology and availability of land along the riparian margin. Where the riparian margin is available the flood plain can be restored, pest species eliminated and the stream banks regraded and planted. In many established urban areas there is little or no riparian margin.

In Auckland's clay rich soils the side slopes of the urban stream bank will obtain a 1:1 ratio or become severely undercut. Once a stream channel has morphed into an exaggerated 'U' shape, collapse of the stream banks is inevitable. The bank collapsing causes damage to surrounding infrastructure. Moreover, the stream bed is suffocated and both riparian and stream bed habitat are damaged (Niezgoda & Johnson, 2007). Where there are wastewater and stormwater pipes or pipe bridges within the riparian margins, stabilization of the stream bank is imperative for continued service.

2.1 STONE TOE PROTECTION WITH COIR PILLOW PLANTING

Stone toe protection is the first soft solution which could be applied. The stone toe protection is constructed by placing large spalls along the banks of the river up to the 2 year flood level. The spalls are keyed into the river bed and underlain by gravel to prevent scour. The stone toe protection will keep the stream in its current alignment preventing the banks from being undercut in high flow events (Baird et al. 2015). The stone toe protection can be combined with native planting above the 2 year flood level for ecological benefits.

Often in the urban catchment the corridor for the creek is confined by private property, buildings and roads. As such the revegetation of slopes must occur at a steep gradient. Coir wrapped soil pillows are then used to help establish vegetation on the steep slopes.

The method is known as Vegetated Reinforced Slope Stabilisation (VRSS). Layers of seeded soil are wrapped in biodegradable fabrics (i.e. coconut matting) and water tolerant shrubs and grasses are laid between each soil pillow.

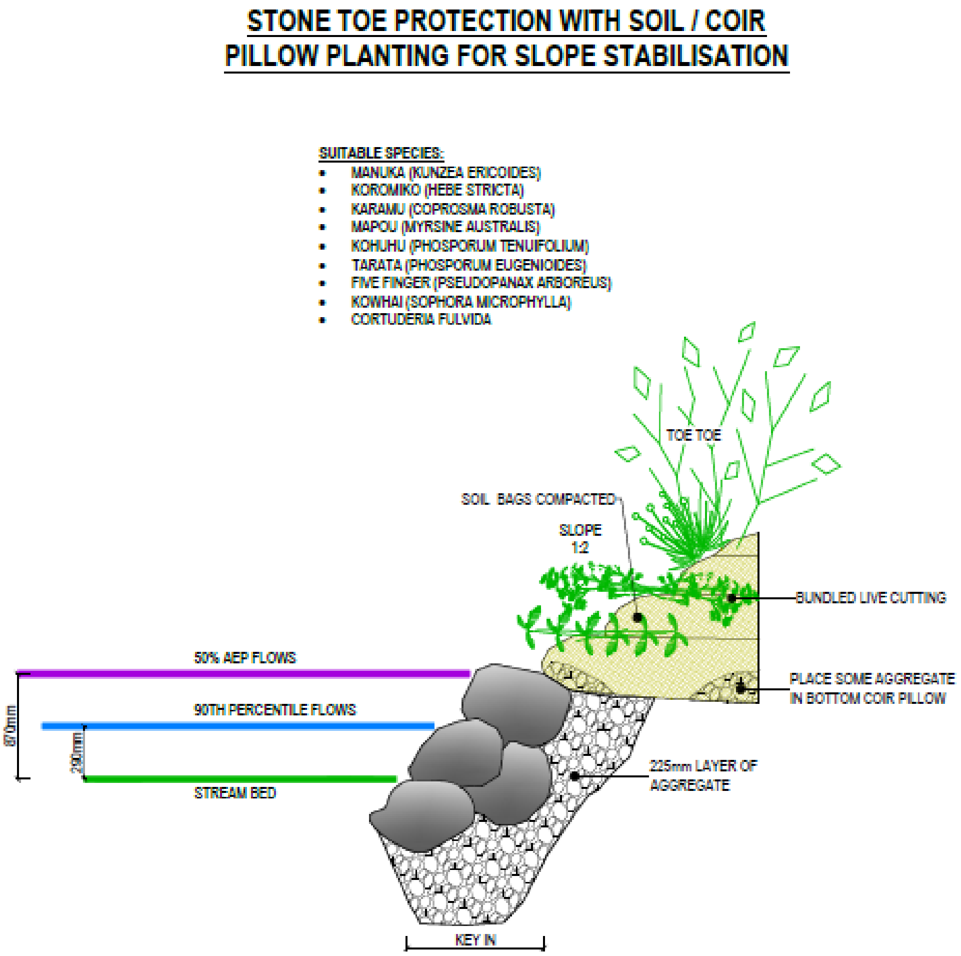


Figure 2: Cutaway plan of stone toe protection with VRSS

The pillows are keyed into the stream bed by filling the bottom pillows with gravel and placing gravel in the area immediately below the bottom most pillow.

The combination of the stone toe and VRSS does not generally require significant disturbance of the existing banks and is easy to construct. The application results in a stable stream bank that will not migrate even in high flow events. The VRSS not only provides a significant component of stabilization but the following ecological benefits:

- Habitat within the riparian margin
- Shading reducing thermal loading
- A source of organic material
- Reestablishment of native species.

The static nature of the bank can affect downstream bends in the river and may accelerate bank erosion (Baird et al. 2015). As such no one soft engineering solution should be applied in isolation but a combination, similar to the treatment train approach for stormwater.

2.2 ROCK VANES

The function of a rock vane within the river channel is to direct flow away from the banks. Where active erosion is taking place along an inside curve a 'J' vein can be used to direct flow away from the area of active erosion. The cross vane can also be used to direct flows away from the banks.

2.2.1 'J' VANES

The 'J' vane is constructed at the area of active erosion, generally at the point of maximum curvature of a meander in the stream. In larger river systems a series of 'J' vanes are placed along a large meander. The 'J' vane is constructed from large rocks or boulders and keyed in using smaller aggregate as shown in Figure 3.

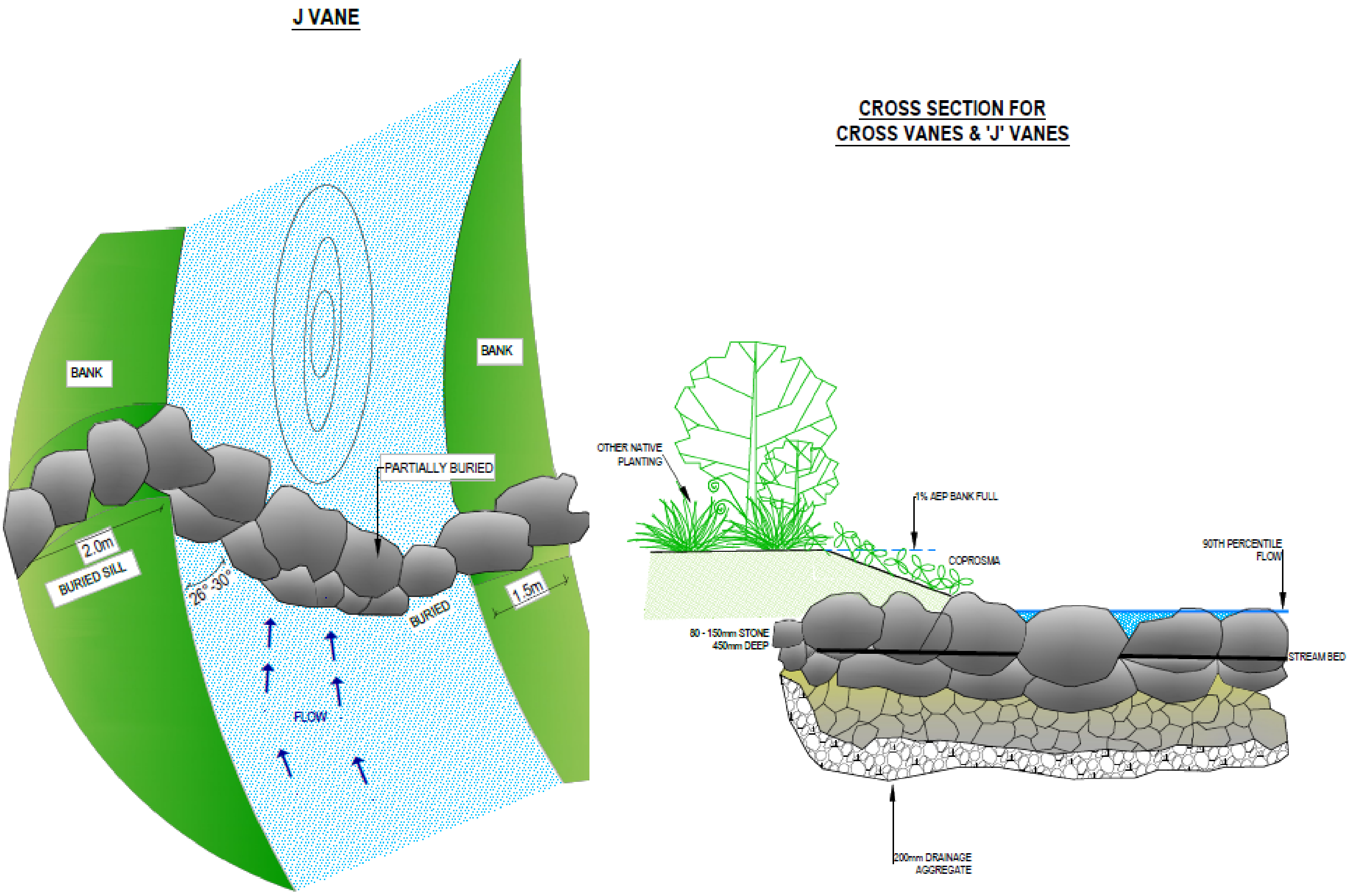


Figure 3: 'J' Vanes in plan view and elevation. Note: the angle of the 'J' vane in relation to the bank is between 26 and 30 degrees

Aside from directing flows away from the bank and reducing or arresting erosion the 'J' vane creates a deepened pool directly downstream of the structure, providing both a stilling basin and habitat for aquatic species. What is more 'J' vanes allow for sedimentation along the bank where revegetation works can occur at a later phase in the project. The 'J' vane can also be located in a straight reach of stream to promote meanders where required.

The 'J' vane can require regular maintenance where the boulders chosen are not of sufficient size to withstand migration by saltation during high flow events. The 'J' vane requires greater in-channel works than other vane structures but combined with planting can have long term benefits to the stream structure and the surrounding ecosystem (Baird et al. 2015).

2.2.2 CROSS VANE

Cross vanes are similar to 'J' vanes and are placed in a section of stream bed either in series or individually. Each rock vane is keyed into the bank at least 1.5 m and keyed into the stream bed using aggregate or gravel. The vane points upstream and forms a weir so that daily average flows overtop a small section in the center of the vane. The rock vane directs flows away from the banks inhibiting erosion and bank undercutting in higher flow events (Baird et al. 2015). Where a series of cross vanes is installed they can be spaced to create a series of weirs and can alleviate down cutting where the gradient of the stream is steep.

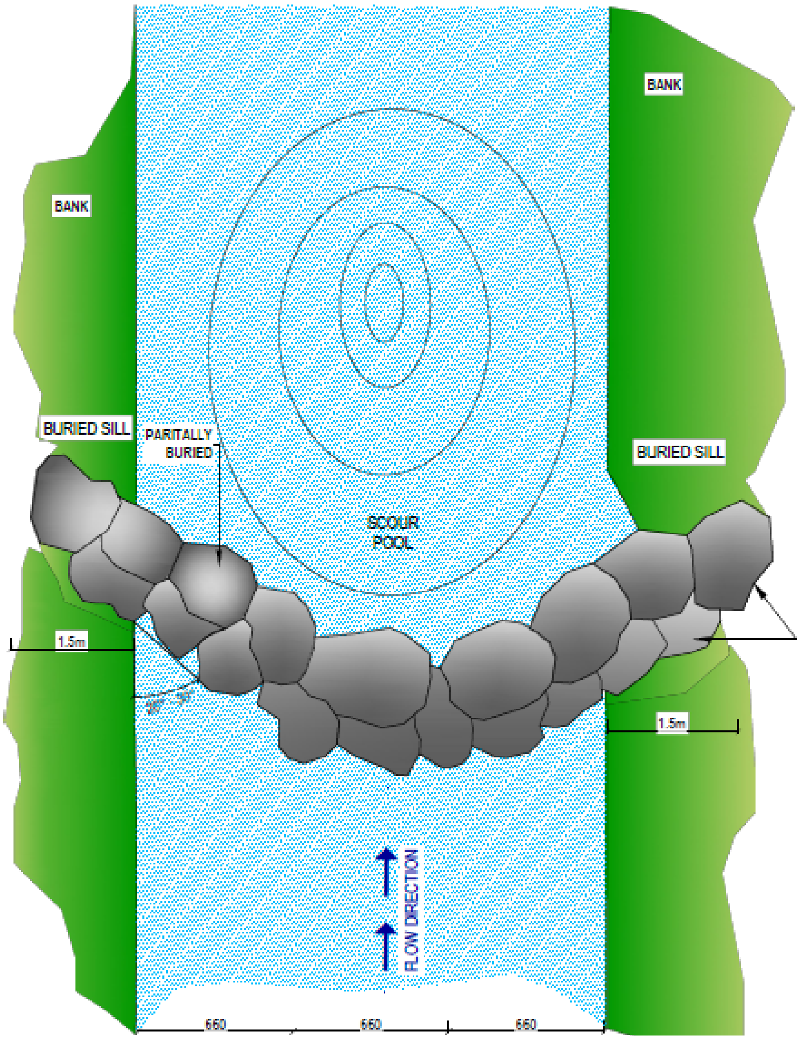


Figure 4: Plan view of a cross vane.

The cross vane also creates a deepened pool directly downstream, creating both hydraulic and habitat benefits. In series, in larger stream systems the cross vanes allow for sedimentation between the vanes promoting vegetation on small islands within the stream bed (Rosgen, 2001). Vanes should be accompanied by restoration of riparian vegetation where ever possible to both stabilize the banks and restore habitat.

With vanes saltation migration is always a risk as in high flow events boulders in the center of the stream can become loose and lodged in the rock pool. During the design phase tractive force for the stream should be assessed and appropriate sized boulders placed. As with any infrastructure, green or grey, maintenance checks following significant events should occur.

2.3 ROOT WAD COMPOSITES

Root wad composites, large woody debris and engineered log jams divert flows away from the stream bank by increasing hydraulic roughness and turbulent flows. They should be constructed using relatively hard woods (Australian gum, liquid amber) for durability. They are ideally suited to clay and silt rich soils as commonly found around Auckland.

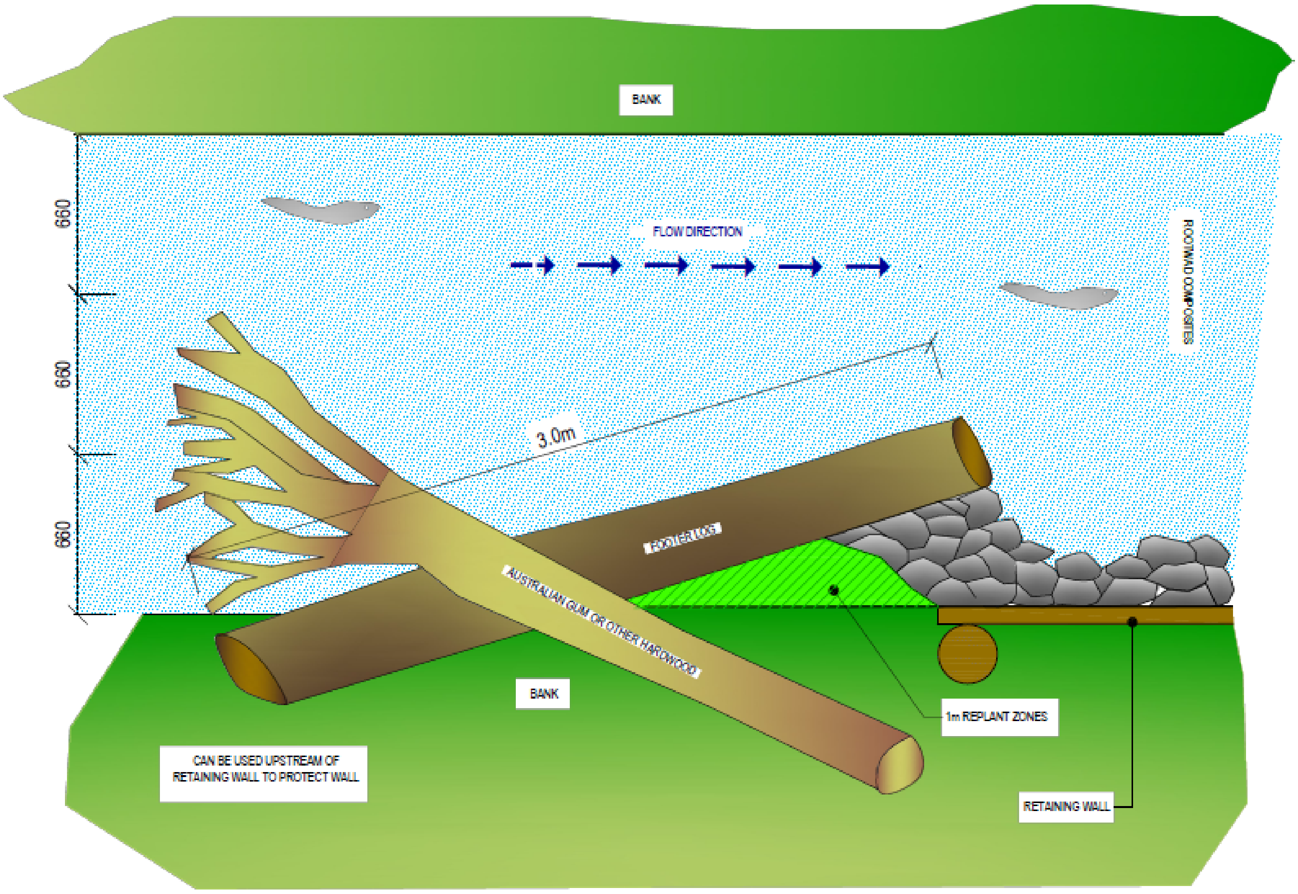


Figure 5: Root wad composite situated upstream of a retaining wall to prevent erosion behind the retaining wall.

The root wad composite has numerous ecological benefits, creating a variety of habitats. Cover and pools are provided around the root wad structure allowing aquatic organisms to thrive (T. Sylte and C. Fischenich, 2000). Localised sediment deposition occurs around the structure allowing riparian vegetation to take hold. The structure will naturally accumulate other woody debris further inhibiting future channel migration through back water effects. When the structure has reached its design life (approximately 15 years) the bank has stabilized and should remain stable as riparian vegetation has been given a chance to mature and sedimentation has occurred around the structure.

During the design phase care must be taken to anchor the tree trunks sufficiently so that they do not become dislodged during high flow events. Comprehensive revegetation around the root wad structure should be included in the design so as to allow bank stability to evolve. Root wad composites installed along urban streams require community engagement of the property owners adjacent to the stream so there is an understanding of the function and they are not removed by a property owner seeking to tidy up the stream area.

3 WETLAND RESTORATION

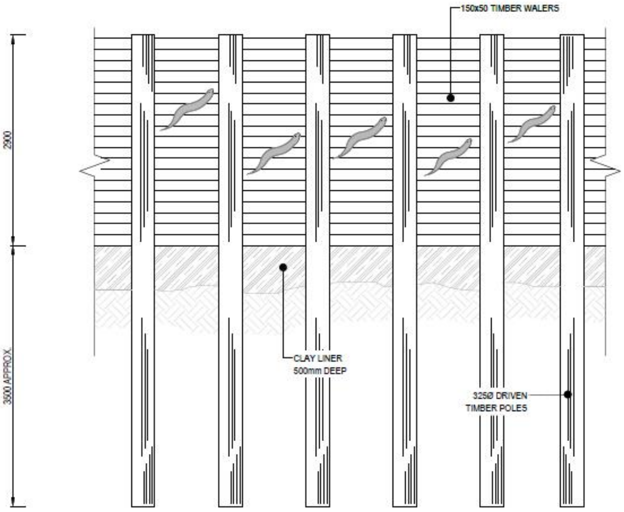
Wetlands are an integral part of any watershed yet they have been disappearing globally since the 1930's. Many coastal wetlands have been filled in, isolated and destroyed. New Zealand is thought to only have 10% of its original wetlands remaining (Ausseil et al 2008). The term wetland encompasses a varied variety of environments: bogs, swamps, coastal estuaries, marshes, dune slacks, all of which provide unique habitats to native flora and fauna. However in the urban stream catchment it can be difficult to restore and protect upstream wetlands due to land availability. The freshwater upstream wetlands were historically small in size taking up only a few square meters. These off-channel habitats were generally formed by channel migration (Roni et al, 2002). Where possible and appropriate small off-channel wetland areas should be considered as part of the overall restoration project.

The estuarine wetland plays a significant role in flood storage, wave buffering and ecology. New Zealand's threated fish species rely on them for migration as most of our native species are anadromous or catadromous, spending at least some of their life cycle at sea. Most estuarine wetland systems have been cut off from the sea by dikes formed during road building.

Photograph 1: 1954 Photo of Tawaipareire Creek Estuary.

In a coastal wetland environment the cessation or reduction of tidal exchange allows an opportunity for pest species to replace native species. The shift in plant species has had a direct and detrimental effect on the fish and bird populations. Restoration or enhancement of estuaries should seek to restore or mimic the natural systems. In instances where tidal exchange and habitat connection has been restored a healthy marsh environment developed in just over a decade (Frenkel & Morlan, 1991).

Wetland restoration requires both soft and hard engineering solutions in an urban environment. Road bridges and culverts need to include mechanisms for fish passage. Where the outlet of the estuary is confined by urban development the formation of a channel or fish road to restore connectivity is essential. Large spalls or boulders placed in the bottom of the channel planted with appropriate salt tolerant species allows for the connectivity to occur.



PROPOSED RETAINING WALL DESIGN
SCALE: NTS

DRAINAGE CHANNEL BASE

Figure 6: Hard and soft engineering solutions for wetland restoration.

Restoration and enhancement of coastal wetlands needs to include planting plans to re-establish native species and should be undertaken with care to determine which wetland species are best suited to the project and can assist in reducing the constituents of concerns. Part of the restoration should include phytoremediation. Adding native hyper accumulators to the plant palette in the urbanised environment will provide a group of plants that can accumulate large volumes of heavy metals and other contaminates without suffering adverse effects. This approach will allow for long-term success amongst the wetland natives in general.

The following guidelines should be considered as a restoration plan is developed:

- Herbaceous species that will stabilize the channel and banks that have value for fish and other wildlife.
- Species which are adaptable to a broad range of water depths.
- Survey of vegetation of nearby less degraded wetlands if available, to identify the conditions required by native species.
- Careful consideration of the placement of species that are expected to be foraged by wildlife as ducks and pukekos can strip a site. Temporary bird netting may be required in some instances until establishment has occurred.
- Selection of low maintenance vegetation is preferable.

The restoration of tidal exchange and connectivity of the wetland to the foreshore will allow for flood waters to drain efficiently during high flow events. The effects of sea level rise over the next century should be taken into account during the design process. A restored and healthy wetland environment will serve to dampen wave energy during coastal storms; however, it may be necessary to protect properties along the riparian zone. Significant filling should be balanced by creating flood storage elsewhere within the environment. Modeling of watersheds shows that the reduction of flooding, resulting from allowing free exchange of water between the foreshore and upland estuary, overrides the effects of predicted sea-level rise. Restoration of the connectivity of the lowest part of the watershed is imperative in any stream restoration project and puts context to various reach and site specific scale components of the project.

4 PROJECTS

Specific projects where soft engineering solutions were applied are described in the following sections. The Howick stream project in Luplau Crescent is currently under construction. The design for the Tawaipareire Creek wetland project is still being considered by Auckland Council and will require further design work.

5 HOWICK (LUPLAU CRESCENT)

The project involved the stabilization of a lower reach of an unnamed stream in Howick, Auckland. The reach of the project was the area between the upstream culvert at Liston Crescent and the downstream culvert at Granger Road. The catchment is at or near maximum impermeability and there are numerous stormwater outlets which discharge into the stream.

5.1 INFRASTRUCTURE AT RISK

The wastewater asset is adjacent to the natural stream which flows out to sea. The stream erosion within the reach is causing areas of the slopes on either side of the stream to become unstable. There is a large slip at 17 & 19 Liston Crescent which occurred on 3rd March, 2017 resulting in the failure of a wastewater pipe (Barnes, 2017). Other pipes within the reach are similarly at risk and as such stabilisation of the stream banks was required.


Photograph 2 & 3: Abutment being undermined. Undermined abutment with temporary support (Barnes, 2017)

5.1.1 PROPERTY OWNERS

The whole length of the stream from Liston Crescent to Granger Road is highly erodible and unstable. Further erosion and landslips may occur in the portions of stream not covered by the remedial works. The public desire is to have the banks of the entire stream stabilized. Many property owners, who feel that they have watched their valuable property slump away into the stream, prefer bank hardening and retaining to soft engineering. In general the riparian property owners view the stream as a liability not and asset.

5.2 DESIGN

The locations of the remedial works have been selected based on the parts of the stream that are adjacent to land and infrastructure at immediate risk. Much of the remedial works involve the construction of timber pole retaining walls.

The soft engineering solutions were included in the remedial works to minimise the need for hard structures within the stream while restoring some of the streams ecological value. The soft technologies included in the final design are as follows:

- Stone toe protection
- Coir pillows
- Planting of stream banks to increase bank stability
- Root wad Composites
- Cross Vanes
- 'J' Vanes

The combination of soft solutions will reduce the velocity and direct flow away from the banks. The ecological gains include restoring stream and riparian habitat and developing deeper pools in the centre of the channel.

Root wad composites will be placed upstream of retaining walls in order to reduce the hydraulic effects on the upstream ends of the retaining walls. They are placed at an angle to the flow direction and embedded into the stream bank to prevent them becoming dislodged. The large surface area on the roots provides a great habitat for aquatic life and helps to slow the velocity of the stream.

Cross Vanes will reduce scouring and undercutting of the stream banks and will reduce stream velocity in large flood events. 'J' Vanes are used where the stream has a natural curve directing the flow away from the outside corner of the curve where the banks are the most susceptible to erosion. In many instances one bank is to be hardened with timber pole retaining walls while soft engineering solutions were applied to the opposite bank.

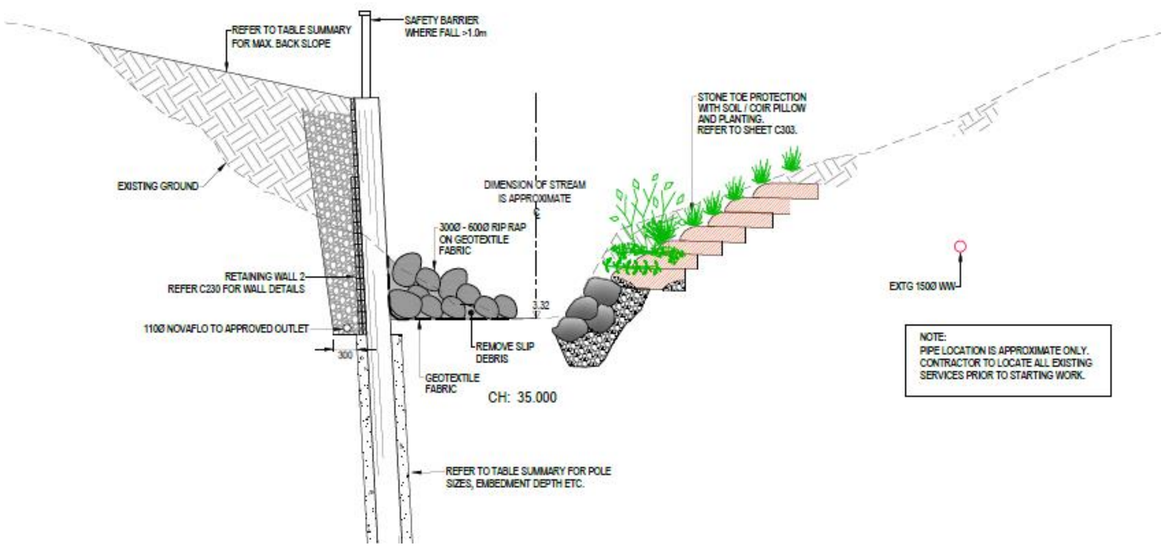


Figure 7: Stone toe protection with coir pillows and planting across from a timber pole retaining wall as part of the remedial works.

5.2.1 OBSTACLES

The stream has limited access for construction. Only one restricted access way through private property exists. The lack of understanding around soft engineering and the lack of supporting data has allowed for only limited applications of soft engineering solutions. It is hoped in future project phases that the idea of amenity values will be adopted by all the steak holders.

6 TAWAIPAREIRE CREEK &WETLAND

The lower Tawaipareire Creek, now part of the Tawaipareire Reserve, was a tidally influenced estuary prior to the construction of the Ostend Road causeway in 1917. Originally the lower catchment would have been a mix of brackish and freshwater ecological areas. The construction of Ostend Road and the infilling of approximately 2.2 ha of the upper estuary by landfill activities, thought to have dated back to the 1917, have effectively cut off the estuary from the nearshore marine environment and created a dam, resulting in the upper estuary being prone to flooding.

A refuse transfer station was constructed over the southern part of the landfill in the early 1990's and its expansion in 2009 raised the ground level further, increasing the obstruction to stormwater flows. The blockage was exacerbated by the filling of 4-6 Tahi Road and the infilling of an overland flow path between the Tahi Road properties and the transfer station.

The ongoing placement of fill and associated raising of the ground levels associated with the transfer station and adjacent properties has created a dam. The 1% AEP flood levels have been raised from RL 2.85 m to the current level of RL 4.7 m.

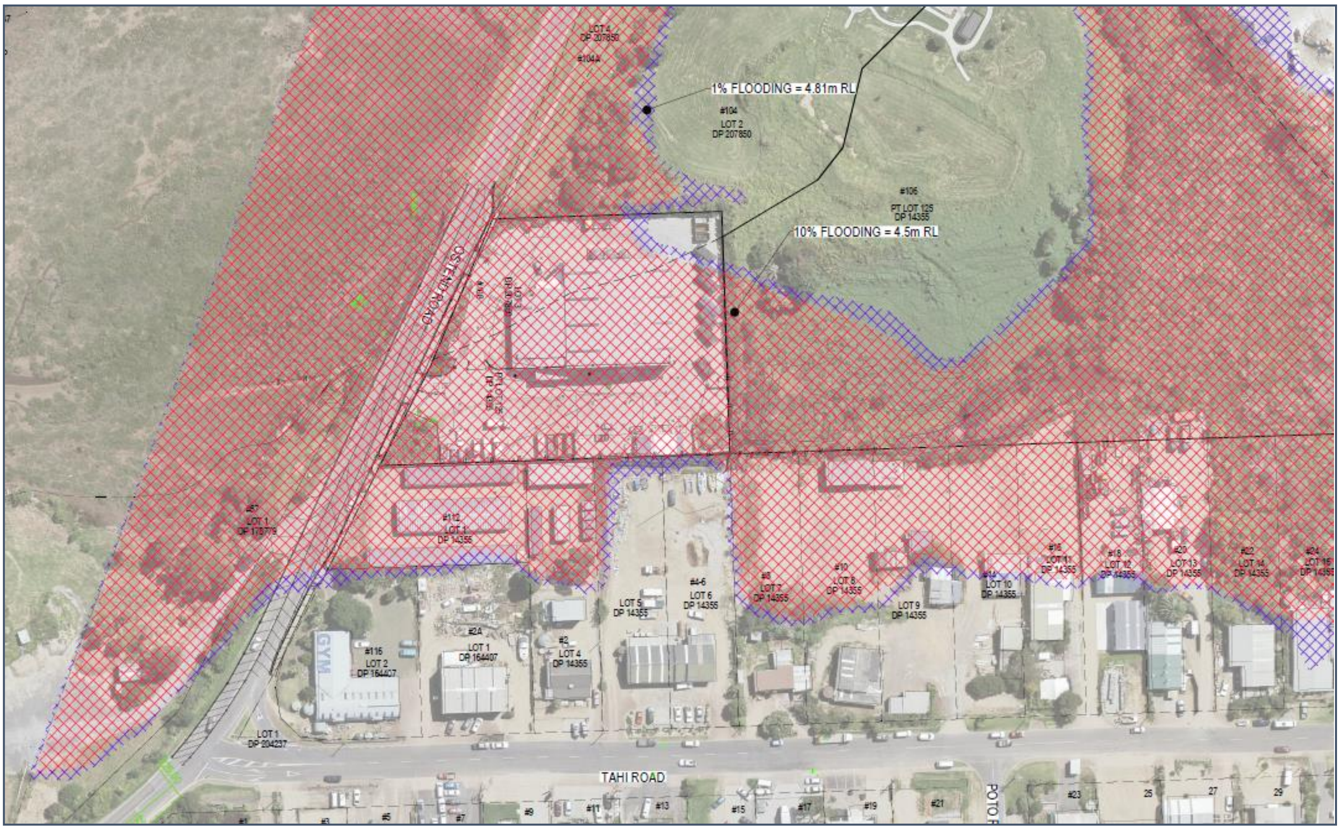


Figure 8: Extent of current flood plain.

The ecological costs have been significant. The tidal exchange between the Tawaipareire Reserve and the nearshore marine environment is severely compromised. The changes to wetlands have directly, or indirectly, brought about changes in the makeup of plant and animal populations, allowing pest species to take hold within the reserve forcing out native flora and fauna.

6.1 FLOODING EVENTS

Currently the 108 ha catchment is drained by a 160 m long, 825 mm diameter concrete pipe with no overland flow path available to drain flood water until it overtops the dam. The culvert which runs from a small wetland within the Tawaipareire Reserve to the mangrove area located south of Ostend Road has a maximum flow capacity of approximately 1.3 m^3/sec. The stormwater discharge into the reserve during the 10% AEP (1 in 10 year) rainfall event is 15 m^3/sec. As a direct result of the catchment modifications the properties along Tahi Road flood regularly.

Photographs 3, 4 & 5: Flooding during March 2017 (Curtesy of Ron Stevenson).

6.1.1 COMMUNITY ENGAGEMENT

Through community group meetings a plan and a set of goals were agreed upon. The goals included ecological social and economic benefits to the larger area as part of the flood remediation design. The idea is to develop some recreational aspects which present opportunities for visitors to the reserve. The interaction may be achieved through constructing walkways through the eastern part of the reserve as well as creating visual references and informative signage that connect people to the natural environment.

6.2 DESIGN

The main objective of the project was to develop an engineering solution which alleviates flooding at the bottom of the catchment. During the course of the investigations, the following secondary objectives were to be considered as part of the overall project:

- Reduce the amount of sediment reaching the reserve so as to protect the longevity of the infrastructure.
- Include wetland restoration to create better ecological outcomes.
- Promote native vegetation and reduction of pest species in the reserve.
- Achieve social benefits by creating a satisfying green space which is appealing to those using the reserve.

Several options to alleviate the flooding were explored and the recommended solution was to construct an open channel through the transfer station using timber pole retaining walls with a rock lined base. This solution best mimics the natural pre-development system by enhancing the tidal exchange within the Tawaipareire Reserve while alleviating the flooding.

Ancillary works in this project include the restoration of native flora and fauna in the reserve and wetland. The restoration of the wetland environment as a buffer between industrial land and foreshore area will improve water quality through bio-filtration. The project also required a new appropriately sized culvert be installed under the road. Best design practice dictates that the culvert include fish passage.

A retaining wall has been proposed along the shared boundaries of the commercial properties. Together with gabion baskets or gross pollutant traps the retaining wall would exclude sediment from the wetland and open channel site decreasing unwanted sediment input. This would also delineate the boundary between the wetland and the commercial properties which can be seen creeping into the wetland over time.

The project, once implemented, has the potential to provide social benefit to the community by making the reserve more useable. If the surrounding community within the Tawaipareire Creek catchment feels a greater connection to the wetland and associated waterway, they are more likely to be invested in ensuring that infrastructure endures.

6.2.1 OBSTACLES

The restoration of the wetland and alleviation of the flooding requires excavation in landfill material. Removal and handling of landfill material is expensive, and opening the closed landfill is a prohibited activity. Moreover works need to occur in the mangrove area, which is considered a Significant Ecological Zone, in order to restore the offshore outlet and alleviate the flooding upstream. Both activities will require a myriad of consents and may even require rulings from the environmental court.

7 CONCLUSIONS

Auckland is a city interwoven with natural waters, yet its relationship to natural waters has been tenuous at best. Infill development has resulted in erosion and degradation of our small urban streams. With only 41 species of native freshwater fish we should adopt greater stewardship of our natural waters. Wetlands, which in the past were perceived to hold little value, have either disappeared or been disconnected from the marine environment resulting in the proliferation of exotic pest species.

Beyond the ecological consequence of the degradation of urban waterways is the imminent risk to public infrastructure as result of a general disregard for our urban waters. The winter of 2017 saw an unprecedented number of wastewater pipe failures due to erosion and land slips along urban creeks. The flooding of Auckland roadways was frequent and significant. Climate change is predicted to bring with it storms of greater frequency and intensity coupled with sea level rise. With the coastal wetlands absent there is neither flood storage nor wave dampening. Certainly hard engineering can mitigate these problems, at least temporarily, but at what cost. Auckland will become a city of concrete waterways and seawalls with no connection to its natural waters.

Soft solutions offer up and opportunity to arrest erosion and stabilise stream banks. The stream restoration at Luplau Crescent offered the ability to create and restore some instream habitats with the use of cross vanes, 'J vanes, root wad composites and coir pillows. The use of the coir pillows with the stone toes add further value by preventing channel migration where there is a risk to property and infrastructure while restoring the riparian margin ecosystem.

The flood mitigation design work for Tawaipareire Creek Estuary offers a chance to not only alleviate flooding but to restore a severely degraded wetland environment. The estuary is cut off by Ostend Road, which will likely become unpassable during a severe storm event, particularly those coinciding with the king tide. With the wetland in its current state, full of pest species, it no longer functions as a filter for the pollutants entering the watershed. In a healthy state the wetland with its location on Waiheke Island, would act as a nursery to many fish species currently in decline. The design for alleviating the flooding has the potential to produce benefits beyond the catchment if the site specific design considers the entire watershed from the upper catchment to the sea.

There is now a global move to recover damaged and degraded waterways for their amenity values as well as the practical ones. In Los Angeles the city prepares to spend close to a billion dollars to restore an 11 mile stretch of the river, ripping up the concrete flood control channel that has been in place since 1938. The project will restore part of the ecosystem, provide flood storage in the riparian parks and create a public asset. Despite the expenditure the people have embraced the project and public perception is that the outcomes outweigh the costs.

In the era immediately following WWII, the exponential growth and economic drive towards the future saw the wholesale destruction and filling of tidal wetlands which were perceived to have little value. However on the east coast of the United States and globally, tidal wetlands and marshes are being restored because their practical and ecological significance has been recognized.

As Auckland continues its journey towards the future, the values of our natural waters should be acknowledged. The engineering designs which aim to protect infrastructure should endeavour to work in concert with the environment. Using a pallet of soft and hard engineering techniques, habitats for flora and fauna can be provided and social benefits achieved.

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