RESTORATION OF DUCK CREEK AS PART OF LAND DEVELOPMENT

D. Mead & L. Verry– Cardno (NZ) Ltd

ABSTRACT

"The Banks", Whitby demonstrates how large scale land development can provide a positive impact on the surrounding environment through the integration of restoration works. The development of the historic Whitby Golf Course includes approximately 320 residential sections alongside Duck Creek in Porirua City's hill suburb of Whitby. Duck Creek is an important natural resource for the local area and it discharges into the nationally significant Pauatahanui Inlet arm of Porirua Harbour. A key component of the development design was the realignment and restoration of a section of the stream (Duck Creek) to become a core amenity of the area. A Comprehensive Development Plan (CDP) was completed for the work with significant consultation with Porirua City Council, Greater Wellington Regional Council, Department of Conservation, Iwi, Residents Associations and other special interest groups. The design integrated surveying, engineering, planning, ecology, landscaping and flood modelling to provide a solution that satisfied the CDP intentions.

The restoration plan for Duck Creek had three main objectives; increase in ecological value, flood management, and public amenity enhancement. The design provided a central spine linkage along the majority of Duck Creek and created a native riparian habitat and passive recreation facilities. Flood modelling was undertaken and the design was developed to control and manage flood waters in Duck Creek in a safe, efficient and sustainable manner including allowing for climate change. The restoration included two full diversions / realignments of Duck Creek, placement of erosion protection, bank stabilisation works, planting and earthworks to raise the floodplain and change the profile of the river. The successful restoration of the waterway and adjoining areas required the balancing of the three key objectives and has successfully provided a valuable resource that the whole community can be proud of.

KEYWORDS

STREAM RESTORATION, FLOODPLAIN MANAGEMENT, LAND DEVELOPMENT

PRESENTER PROFILE

Dion Mead is a registered professional surveyor that specializes in project management of land development projects. Dion has been involved in the project from the development of the initial Comprehensive Development Plan through to construction today and has provided the coordination and project management

Laura Verry is a civil engineer with Cardno (NZ) Ltd in Wellington. She has a wide range of experience in civil/environmental engineering. She has a key engineering role in the design and construction management of the current stages of The Banks development.

1 INTRODUCTION

"The Banks", Whitby provides a showcase of best practice in integrating land development with ecological restoration to create an environment that current and future generations can enjoy and be proud of. A key component of the development design was the realignment and restoration of a section of the stream (Duck Creek) to become a core amenity of the area. A Comprehensive Development Plan (CDP) was completed for the work with significant consultation with Porirua City Council, Greater Wellington Regional Council, Department of Conservation, Iwi, Residents Associations and other special interest groups. The design integrated surveying, engineering, planning, ecology, landscaping and flood modelling to provide a solution that satisfied the CDP intentions.

The restoration plan for Duck Creek had three main objectives; increase ecological value, flood management, and public amenity enhancement. The design provided a central spine linkage along the majority of Duck Creek and created a native riparian habitat and passive recreation facilities. Flood modelling was undertaken and the design was developed to control and manage flood waters in Duck Creek in a safe, efficient and sustainable manner including allowing for climate change. The restoration included two full diversions / realignments of Duck Creek, placement of erosion protection, bank stabilisation works, planting and earthworks to raise the floodplain and change the profile of the river. The successful restoration of the waterway and adjoining areas required the balancing of the three key objectives and has successfully provided a valuable resource that the whole community can be proud of.

A number of positive design philosophies were utilised to ensure the development is interesting and appealing whilst still being compatible with the surrounding area. The design incorporated converting parts of Duck Creek and the adjoining land to recreational and access areas. This included a number of reserves and shared pathways. The general layout utilised 'soft' urban design features such as landscaping, flush road edging and wide grass berms/swales to create a visually appealing development.

The development utilised a number of stormwater quality management measures to reduce the levels of contaminants reaching the natural waterways to which the stormwater discharges. This was particularly critical due to the importance of the sensitive downstream environment in Pautahanui Inlet.

2 BACKGROUND

2.1 SITE DESCRIPTION

"The Banks" subdivision sits on 30 hectares of land in Whitby that formed part of the iconic Whitby Golf Course, which closed in 2003. The land is surrounded by existing shopping, amenities and residential properties with Duck Creek meandering through the site.

The site is located within the heart of the Whitby community which was established in 1971. It is home to over 20,000 people and approximately 6000 homes. The suburb is commercially centered on the Whitby Shopping Center, which contains a number of retail and commercial business.

The original topography of the development site is typical of a stream valley with Duck Creek at its centre. Duck Creek runs from south to north and flows into the Pauahatanui Inlet. The valley floor coincides with the floodplain for the creek, which varies in width

from 100 m to 200 m (approx.). The terrain gradually rises up on the sides of the floodplain toward the surrounding hillsides, most of which have been developed with residential properties.

Duck Creek meanders through the site on the valley floor and is typically 2 to 3 m wide during normal flows with a noticeable lack of established trees and bush to provide any ecological habitat or value. During the previous Golf Course activity, the stream was modified and diverted in many places from its original alignment.

The land surrounding the site consists of residential housing to the north and east. The Adventure Park playing field and Whitby Bowling Club are to the north-west. Further residential housing and some larger residential properties adjoin to the west. To the south, south-east and south-west are vacant rural and suburban properties that are or have been used for forestry plantations.

2.2 SIGNIFICANT NATURAL AREAS

Duck Creek is identified in various plans as a significant waterbody that requires protection. The development site lies within the sub-catchment of the Pauatahanui inlet. Pauatahanui Inlet is the largest relatively unmodified estuary in the southern North Island. It is a nationally significant wildlife site, providing habitat for indigenous birds. It is also a regionally important wetland containing the only large area of saltmarsh and sea-grass in the Wellington Region.

Figure 1: Site Location Plan

2.3 THE BANKS DEVELOPMENT

The Banks is a residential development with approximately 320 lots. The developments well thought out urban design and public spaces cement it as one of the most popular in the region, both for the residents and the surrounding community alike.

The Comprehensive Development Plan considered the set out and planning for the entire site, however, the detailed design and development of the land has been staged to meet commercial demands, as shown in Figure 2 below. Construction works started in December 2012 and the first four stages are now complete. The next two stages of the works are currently under construction and the final three stages are in the design phase.

The shape of any development of the land would have been influenced by the creek, therefore the developer wanted to utilise and improve Duck Creek as a recreational feature and ecological asset. Significant earthworks were required to raise ground levels above the floodplain of the lower lying area around Duck Creek.

The land development has proceeded through a rather convoluted and contentious process and two different landowners to arrive at the present layout.

Figure 2: Project Staging Plan

2.4 DEVELOPMENT INITIATION

A design charette was held in 2004/2005 to consider development options. The developer at the time considered that the esplanade reserve adjoining Duck Creek was not adequately compensated for and challenged the outcomes. Subsequently Porirua City Council introduced new planning provisions with Plan Change 9 in September 2007.

This plan change sought to create the "Duck Creek Flood Management and Comprehensive Development Policy Area". The land owner then took Porirua City Council to the Environment Court on two issues, one for a Judicial Review of Council's implementation of Plan Change 9, the other to seek a Declaration under section 311 RMA as to whether Duck Creek qualified for Esplanade reserve. To avoid further High Court proceedings, Council withdrew the proposed Plan Change and the developer agreed to a development moratorium period in March 2008. The agreement provided the basis for further design options to be explored with the help of Porirua City Council.

The Court Declaration hinged on defining the stream width to determine if esplanade reserve provisions of the RMA were applicable. In May 2008, the Court decided that the stream was in fact over 3 m wide based on the extents of the annual flood model prepared by Council.

Following the declaration, an agreement was reached to extend the moratorium proceedings, but the land owner could seek subdivision consent for land parcels that were larger than 4 hectares for esplanades provisions to apply. One such parcel contained Duck Creek itself, thus providing development opportunities for the other land parcels surrounding the Creek.

In 2009, Cardno was instructed by the owner at the time to prepare a Comprehensive Development Plan, working with local council, regional council, Department of Conservation, Iwi, Residents Associations and other special interest groups. The development moratorium was allowed to lapse on 1 June 2010 once sufficient progress had been made on the overall concept plan.

The purpose of the CDP was to incorporate a range of ideas while addressing the flooding, ecology and esplanade reserve issues. A major feature of the CDP was the realignment of Duck Creek in the southern portion of the site to create an improved riparian environment with surrounding residential sections that are protected from the 1 in 100 flood event.

3 PLANNING AND CONSULTATION

3.1 COMPREHENSIVE DEVELOPMENT PLAN VISION

The preparation of the Comprehensive Development Plan (CDP) was an important first stage leading into various resource consent applications to develop the land. To support the development of the CDP, a flood model and preliminary design for earthworks, services, roading and subdivision was undertaken for the future development concept.

The vision for development of the Duck Creek land was to continue to build upon the strong features and themes that were already established for the residents and community of Whitby. The development along and across the Duck Creek corridor aimed to feature high quality walkways similar to other parts of Whitby. There was a focus on opening up parts of Duck Creek as a recreational feature and increasing the opportunities for walkways. At the same time, appropriate methods and mechanisms were planned for treatment of stormwater runoff from development and for managing the floodwater of Duck Creek.

The CDP identified the following specific objectives for the development:

- The sustainable development of the former Golf Course land while recognising the local physical constraints and providing community facilities plus making provision for utility services;

- The creation of attractive residential house sites, including some with a stream side / reserve character;

- The provision of reserves and pathways along and across the majority of Duck Creek;

- The enhancement and protection of the Duck Creek riparian environment and ecological values;

- To continue extending and linking the existing network of open spaces and walkway / cycleway paths in Whitby;

- To control and manage flood waters in Duck Creek in a safe, efficient and sustainable manner including allowing for climate change potential;

- The establishment of an appropriate roading network that reflects the latest principles and best practice in road design for residential safety and amenity;

- To enhance the roading network by providing links within Whitby and to recognise and provide for future links to Transmission Gully;

While consultation on the Comprehensive Development Plan was positive, the major resource consent applications required full public notification due to the creek diversion. There was one submission in opposition to the application, and following the closure of submissions the applicant worked with the objector and the submission was amended to fully support the development. This indicates that the successful development of the CDP allowed for a level of overall community acceptance of the development concept with the finer details to be subject to assessment and scrutiny during the resource consent and submission process.

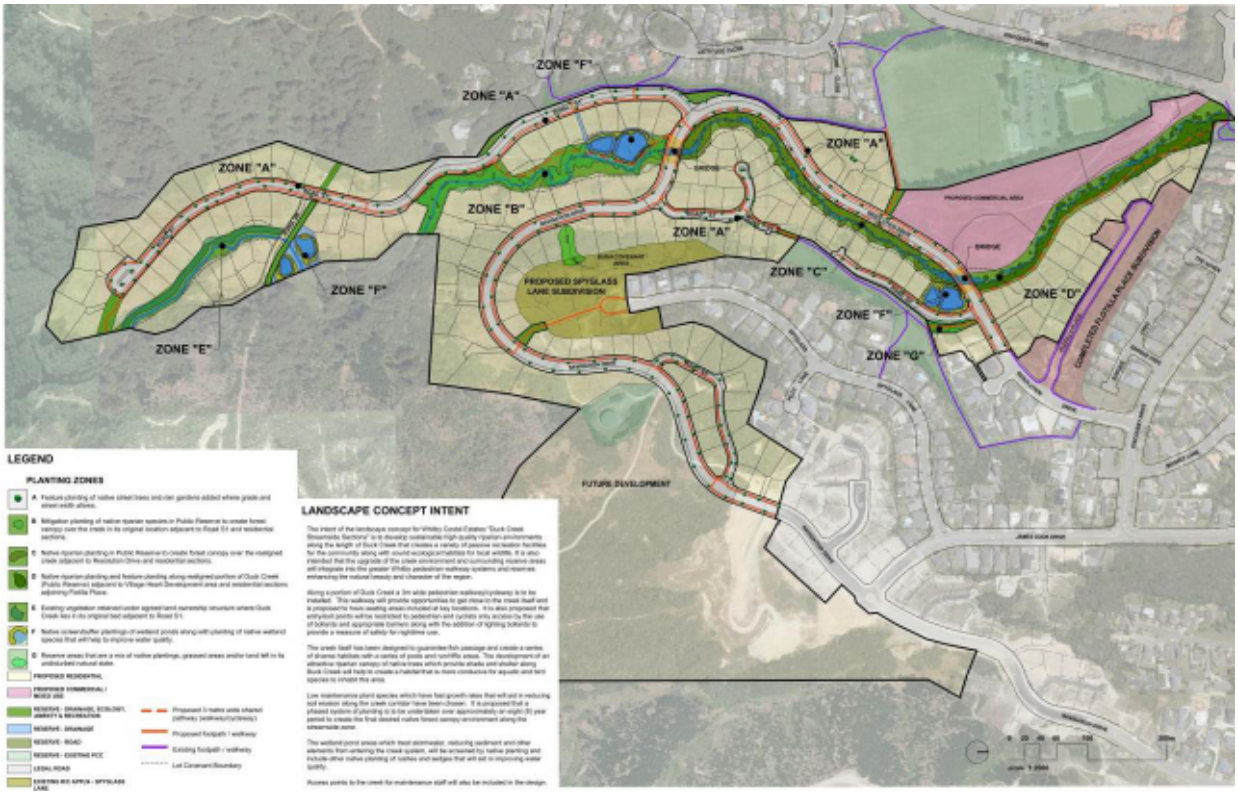

Figure 3: *Landscape Masterplan*

4 URBAN DESIGN

4.1 GENERAL (LAYOUT, EARTHWORKS, ROADING)

The objective of the earthworks design was to have a balance of cut to fill volumes to minimise both the effect of transport over local roads, and costs. In general, earthworks were required to reshape and fill parts of the floodplain and to provide flat platforms, and this material was sourced from the hillside. The design and final appearance of the earthworks were undertaken in a way to minimise 'un-natural' land forms while incorporating council road layout preferences. Roads were designed to follow the contours as far as possible. However, in order to achieve the desired connectivity and acceptable road gradients, bulk earthworks were required for certain road links.

The main feature of the proposed roading network was the extension of Resolution Drive up the Duck Creek valley, which then bends around to connect with Navigation Drive, thus providing a desirable loop in the road network. Due to the elongated nature of the property, a main access road leads off the loop road and extends up toward the head of valley generally beside the creek, this road will be a long cul-de-sac.

Due to the nature of the site and proximity of the roading network to Duck Creek, there was the opportunity to provide a softer solution within the roading corridor to enhance the visual amenity of the landscape. Any design solution presented that is not in accordance with local codes was received with some resistance. Consequently, a roading and transport assessment report was prepared to support a non-standard solution.

The proposed legal road widths and carriageway widths depart from the District Plan standards and from Council's "Code of Land Development & Subdivision Engineering 2010". The proposed road widths were designed to encourage an attractive low speed

environment with distinct parking areas, while still allowing access for all vehicles (including a possible bus route on the loop road) and the necessary space for infrastructure networks and services.

Figure 4: Typical road in The Banks

The general layout utilised 'soft' urban design features such as landscaping, flush road edging and wide grass berms/swales to create a visually appealing development. It is worth noting that these 'soft' design features have caused difficulties during building construction with private contractors carelessly damaging them. The developer had incorporated maintenance conditions with purchasers to ensure that any damage is remedied after construction, however, the appearance during construction is significantly compromised.

Figure 5: Example of 'soft' urban design features

4.2 PUBLIC AMENITY AND CONNECTIVITY

The development concepts encouraged the use of parts of Duck Creek and the adjoining land for recreational use and access. During the preliminary design of the concept plans, considerable effort was taken to consult with local council and the Whitby Residents Association as to the principles and design parameters for creating acceptable reserve areas and provision for roads and pedestrian/cycle paths.

This culminated in the reserves layout plans, which formed the basis for a reserves agreement with Council and for consultation with the local community.

The main design feature of the proposed reserves is that nearly the entire length of Duck Creek (existing and as proposed to be realigned) will be contained within a reserve area with a pathway adjacent or near to the stream.

The layout of the shared pathways was a prime factor to achieving a successful development that fits into the established patterns for Whitby. The consultation with Council focussed on the provision of a network of pathways with numerous links and route options. The objective was to provide high amenity links both along Duck Creek and across the Duck Creek valley.

The main reserve areas are centred on the Duck Creek alignment (and realignments) as a reserve for flood purposes and also for esplanade / recreation / ecological purposes. The reserve areas are either extensions of adjacent existing reserves to protect existing vegetation or are new reserve areas adjacent to Duck Creek and the path network.

Significant landscape works were undertaken as part of the subdivision development. These works address the streetscape as well as reserves with a particular emphasis on the planting of the stream diversions and wetland ponds so as to create and restore an enhanced ecological riparian environment for Duck Creek.

Figure 6: *Community spaces in development*

4.3 QUALITY OF STORMWATER DISCHARGING TO DUCK CREEK

Urban development creates additional runoff with increased levels of contaminants which can have significant effects on local waterways. There are many stormwater management tools which can be used to reduce the levels of contaminants reaching the sensitive natural waterways to which the stormwater discharges.

There is an extensive network of stormwater pipes in the surrounding developed urban area. This network of pipes collects stormwater from the surrounding houses and roads, which is then discharged to the Duck Creek (or to gullies beside the creek) at numerous points. Generally, these existing discharges have no quality or quantity controls.

The development of The Banks presented a great opportunity to utilise a number of low impact stormwater quality treatment systems, including the following:

- Swales;
- Wetland ponds.

The development also incorporates measures which will reduce pollutant runoff at the source. The developer has enforced the use of low contaminant roofing materials such as "Colorsteel". Education of the use of stormwater systems is used to reduce pollutant loading through incorporating "Drains to Streams" signage at roadside sumps and other stormwater system inlets.

This philosophy reduces the impact of the development on Duck Creek, and consequently on the downstream Pauatahanui Inlet. Each of these features are adapted for the particular parts of the site where they are most suitable to use.

Swales provide stormwater quality through bio-filtration methods, whereby sediment particles adhere to the plant and organic material as the stormwater runoff passes through them. In addition the swales reduce impermeable area, provide for groundwater recharge and reduce peak storm runoff. Swales were incorporated into the road cross sections where there was available space and the vertical grades were within guideline values. Swales on the roadside can collect road runoff while swales placed against the footpath can treat runoff from the adjoining lots. Swales were generally located within the front berm, between the footpath and road carriageway/parking.

Wetlands are complex water environments and utilise a variety of methods for stormwater treatment including settling, filtration, bio-filtration, microbial uptake, and plant uptake. They also reduce the impermeable area, can provide for groundwater recharge and reduce peak storm runoff. Two wetland ponds were constructed and they treat large areas of lots and roads which are served by a piped network. The wetland ponds add aesthetic benefit to the area as well as reducing contamination of the creek. They also provide ecological offset mitigation for creek length loss.

Where there is no practical measure, due to topography or space, treatment reverts to a traditional piped system. Due to the integration of the proposed development with the existing stormwater network a significant area of existing residential area is treated via the new devices. Treatment of existing areas will offset any new direct discharges to Duck Creek.

Some of the low level lots that adjoin Duck Creek itself have a covenant over a portion of the property that represents the extent of the 100 year flood event modelled water level. Within this covenanted area the homeowners are restricted on activities they can undertake within this area this includes: no building, no spraying, no fertilisers, no mulch and no compost heaps.

5 STREAM - INVESTIGATIONS AND DESIGN

5.1 ECOLOGY & DUCK CREEK RESTORATION

A key component of the development was that Duck Creek would become a core feature of the development. In doing so, the character and ecological function of Duck Creek would be restored and enhanced along the length of the stream.

The design philosophy for the management of Duck Creek had three main objectives:

1. Ecological enhancement of the stream and banks;

2. Stream and bank redesign to enhance flood management;

3. Create an attractive amenity area for adjoining properties and the general public.

In certain sections of the stream, preservation of the ecology was paramount. In other sections, where the ecology was impaired, stream and bank works focused on opportunities for enhanced flood management with opportunities for ecological restoration included. The proposed stream works offered three main options:

1. Existing streambed and banks retained and enhanced with additional planting;

2. Existing streambed retained and the banks re-shaped and restored with planting;

3. Stream realigned with flood management works and bank restoration planting.

Where the existing stream had high quality ecology, the existing stream alignment and banks were maintained. Wherever possible the realigned stream was co-located with a road, so as to provide an expansive area of public space with multiple access options to pathways along the stream banks.

The creek had been previously diverted to the eastern side of the property to facilitate the construction of a golf course. This placed the creek invert level well above that of the surrounding land, the realignment restored the creek channel back to its original position prior to the golf course construction. During construction the old original creek bed was located.

Two diversions of Duck Creek were required to realign the stream into a new channel. The main diversion was 960 m long and the second was 125 m long. The total length of stream flowing through the Duck Creek South site was 1,820 m. Of this, 300 m was untouched, 260 m was subject to bank re-contouring and 1,225 m was diverted resulting in an overall loss of 140 m of stream. However, the bed area and accessible river terraces for spawning increased from 6,000 m^2 to 11,200 m^2.

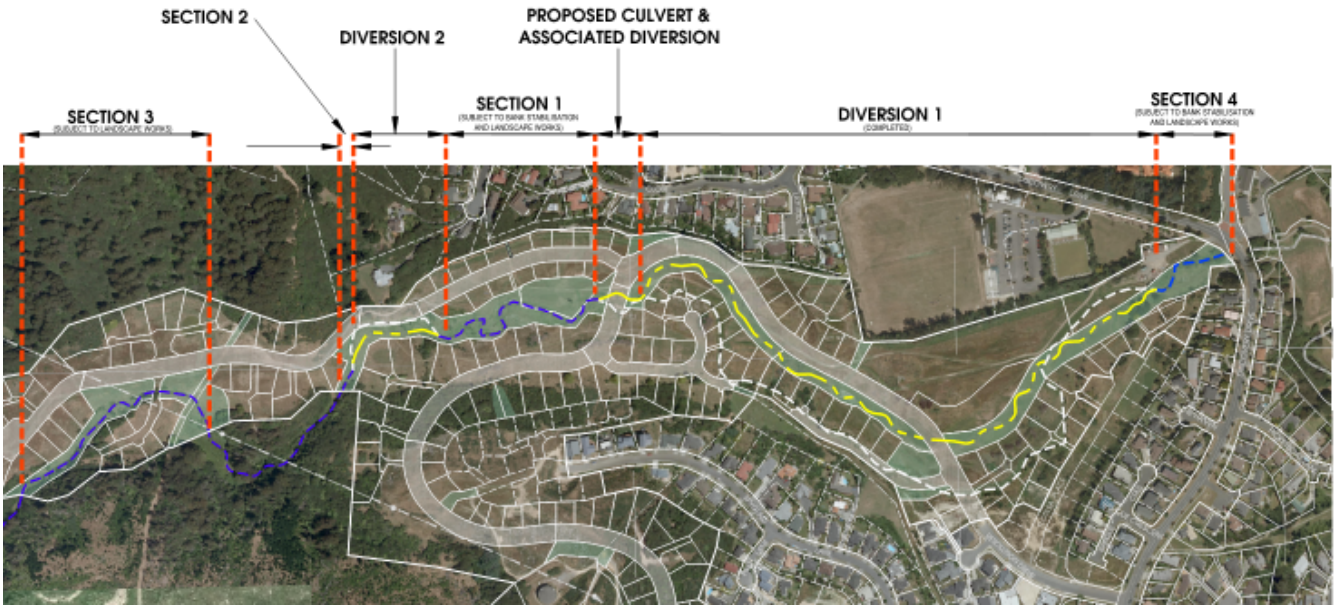

Figure 7: Duck Creek original and proposed alignments

In the realigned sections of the stream, the stream bed was reformed with a natural like meander that incorporates pools, riffles and low rocky cascades. The reformed stream bed is much wider and the vertical banks removed (see photograph below). This improved stream profile leads to much better ecology for the stream, while also providing a sufficiently wide flood corridor to convey the required flood event.

Figure 8: Duck Creek before and after remediation works

The new stream has varying profile in order to replicate a natural stream environment. The main bed meanders up to 3.1 m wide, with an adjacent 2 to 3 m wide floodable terrace on both sides, which then gradually slopes up to the 2090 100 year flood level. The slopes vary between 5% and 20%.

The consent documentation proposed that rather than submit detailed plans that predetermine a solution for every bend, run, riffle, pool and cascade, the application sought approval for the diversions to be undertaken as a "design – build" exercise under the direction of an Ecologist. Design parameters were confirmed as part of the consent with specific percentages of riffle/run/pool lengths being required.

The construction of the new channel involved the relocation of existing gravels from the old stream to the new channel. This was undertaken to assist enriching the substrata of the livened channel and seed it with aquatic flora and fauna.

Existing consent conditions require the monitoring and reporting of the Duck Creek from the headwaters through to the Pauatahanui inlet.

5.2 LANDSCAPING

The planting of the new diversions was designed to create a long term forest canopy over at least 80% of the riparian margins to enhance the restoration of Duck Creek. This percentage cover was recommended as that required to enhance ecological values. Balancing the planting of the creek corridor to ensure public amenity of the reserves is preserved while still ensuring the planting satisfies the ecological requirements was a challenging task. Re-vegetation of the riparian zone is being undertaken in stages, initially with fast growing pioneering species such as toe-toe and flaxes to provide shade cover and bank protection. These will then be inter-planted with other shrubs and trees that will largely take over and establish a higher more uniform canopy (see the Figure below).

Figure 9: Creek diversion planting design potential growth

A number of very large tree stumps were uncovered on a nearby construction site. These were strategically placed within the stream to enhance pool habitat for eels. In addition, the stumps result in a visually appealing stream feature as shown in the photograph below.

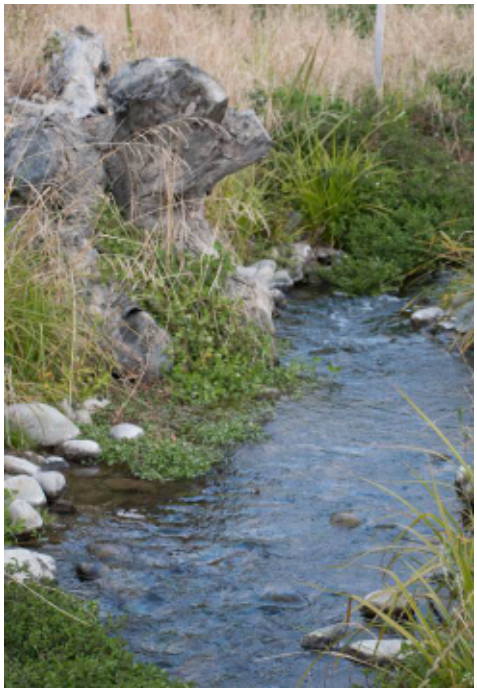

Figure 10: Tree stumps incorporated into remediation works

5.3 FLOODPLAIN MANAGEMENT

The previous topography and geometry of Duck Creek did not contain flood flows and overtopping of the Creek into neighbouring land was expected with the new

development. Therefore a number of flood protection measures were included in the design to manage the flood hazard within the catchment.

- The shape of the stream has been designed as a wider engineered profile to contain floods up to the 100 year design;
- New road corridors are constructed along the stream that are lower than surrounding residential properties to provide secondary flow paths;
- To manage the water depth in the new stream channel, the current floodplain landform surrounding Duck Creek has been raised by filling;
- Duck Creek can contain the majority of large storms up to the near 100 year event before spilling beyond the 20 m stream corridor;
- Roading is designed to return water back to Duck Creek at defined locations;
- The shape of the proposed lots in relation to the stream corridor is such that the lots will be graded higher so that the flood water spills to the road before encroaching on property. The height of the lots comply with the requirements of the New Zealand Building Code.

5.4 FLOOD MODELLING

A large proportion of the earthworks for the subdivision were located within the modelled 100 year floodplain of Duck Creek and 1.2 kms of creek alignment was required to facilitate the development. This had the potential to impact on the floodplain of the creek and the flood flows downstream. A full hydrological and hydraulic model of the Creek with the proposed earthworks and realignment was completed to assess the impact of the proposed development.

Any subdivision of land on a floodplain must consider the implications of flooding for the development and provide a solution for management of floodwaters to satisfy section 106 of the RMA. Feedback from residents throughout the CDP process indicated that development of the land was not possible due to "flooding" occurring over the land during a moderate rainfall event. Duck Creek had a variable longitudinal gradient that was affected by large meanders that resulted in overtopping/flooding of adjoining land. A significant element in the design process involved the creation of a high flow flood channel, taking into account climate change parameters.

In 2009 Cardno conducted a full topographical survey of the land comprising of the former golf course and surrounding Whitby Coastal Estates' land. The purpose of the survey was to capture sufficient detail for flood modelling purposes. The survey data was matched up with the surrounding local council contour data and used to build a digital terrain model (DTM) in 12d software of the larger area. 12d was used to design the earthworks for the proposed land development and the final earthworks produced another DTM of the final development topography.

A flood model was built using the XP SWMM 2010 Version 12.1 stormwater modelling software. The model is a 1D model constructed from cross sections created using 12d. The model was used to assess the proposed earthworks and stream realignment works in a range of flood events. As was agreed with local and regional council engineers, the design of the subdivision was to be based on the modelled flood waters of a 1 in 100 year

event under high climate change parameters to 2090. The flood model also accounted for daily tidal fluctuations and included a sea level rise factor of 0.5 m to 0.8 m.

In February 2010 the New Zealand Transport Agency (NZTA) published a report on rainfall for the Transmission Gully project which cuts across the head waters of Duck Creek. The NZTA study used rainfall data collected at rainfall stations in the study area, undertook a regional statistical analysis of the annual maximum 24 hour rainfall, determined rainfall depths for specific return periods and determined the temporal distribution of storm rainfall in the region. The study then provided projected climate change rainfall depths based on the Ministry for the Environment Guide for Local Government (MfE, 2008).

The design ground level of the subdivision under construction achieves building sites and minimum floor levels on the proposed lots that includes a freeboard of 300 mm above the 2090 100 year high climate change flood event.

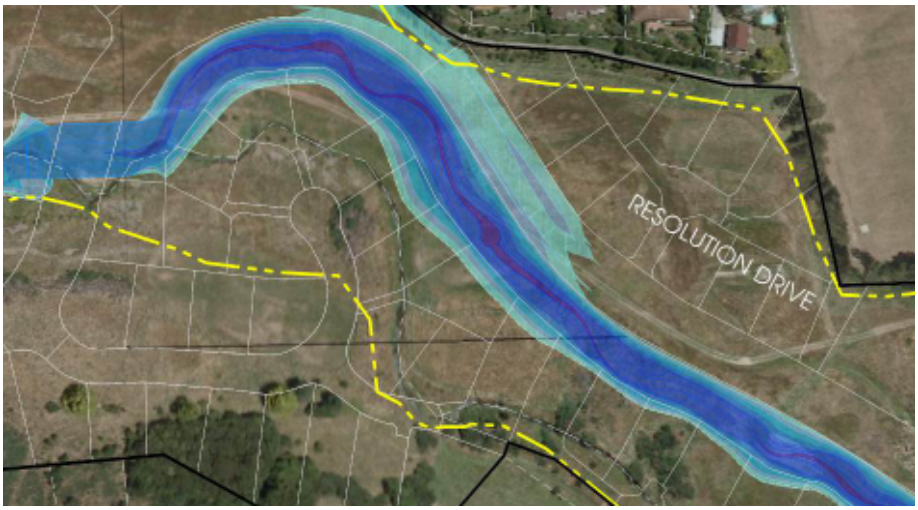

Figure 11: 2090H 100 year flood extent (yellow dashed line represents previous flood extent)

The flood modelling analysis required the modelling of two existing culverts, two proposed bridges and one proposed culvert. One of the existing culverts (Discovery Drive culvert) places restriction on the system downstream of the development. This large culvert has a pedestrian underpass that acts as a secondary flow path for the stream during flood flows. The Flood model incorporated these features to accurately model the tail water used to set minimum floor levels

Figure 12: The Banks Resolution Drive bridge

Figure 13: The Banks Navigation Drive culvert

Analysis was undertaken on the existing and proposed stream beds substrate to ensure the construction of the new aligment maintained the same partical size distribution of the existing streambed substrate. Rock armouring was positioned on some bends along both the realigned portion and existing creek banks where it was identified potential velocity was above that for which a planted batter was capable of withstanding. The length of rock amour is approximately 10% of the channel banks of the realignment section of the stream. This amour has been topsoiled and landscaped to ensure the aesthetics of the environment are not comprised.

5.5 STORMWATER PONDS

At specific points down the valley, stormwater treatment/wetland ponds have been constructed. These ponds hold a certain capacity of the stormwater run-off from the surrounding catchment where swales cannot be utilised due to steeper gradients. The introduction of such controls to improve the quality of the stormwater output has had the added benefit of treating the run-off from some of the existing developed areas. This is

because the new development is on the valley floor so the existing stormwater systems had to be extended so that run-off from parts of the surrounding hill sides passes through the new control measures as well. Hence it is likely that there is a net improvement of the stormwater quality discharging to Duck Creek during normal flows.

The ponds are designed to provide storage and filtration during lower flows first flush rainfall event (i.e. in the more frequent but less intensive storms), so as to improve water quality before discharging to the stream. In higher flows, when the stormwater ponds have reached capacity, the stormwater will be diverted from ponds via a controlled weir. During such higher flows, it is not practical to try and control the quality of the water while the entire stream system is in flood.

The forebay pond acts as a retention device as well as allowing initial settling of larger sediments. It is sized to store sufficient volume that the first-flush runoff can be slowly released into the wetland pond over a period of approximately 4 days. This slow release period reduces velocities and allows sufficient hydraulic residence time within the wetland pond. The forebay is up to 2m deep.

The wetland ponds are approximately 700 mm deep on average; there are deeper and shallower sections as suggested in TP10 (ARC, 2003) and NZWERF (NZWERF, 2004), with 40% up to 1 m deep and the remaining area less than 500 mm deep. The wetland ponds are fully planted with a hydraulic resistance or plant porosity factor of 0.75.

The wetland ponds outlet into Duck Creek via low flow outlet pipes. The level of the ponds and surrounding bunding is such to ensure that the pond is not inundated by Duck Creek in an event less than the 10 year event.

Due to the ponds having fish passage access, they incorporate a constant dry water flow running through via a controlled upstream intake, this offers value from both an ecological and residential visual appeal point of view.

Stormwater ponds had not been utilised in the district before, so there were no local standards to use. The ponds have therefore been designed in accordance with other council codes and general best practice. The ponds were initially keenly received by both local and regional council in the earlier stages, however in future stages of the development the local council did not request ponds be incorporated into the design.

The long term maintenance of the ponds following the expiry of the developers maintenance obligations will need to be addressed by Council to ensure the performance of the ponds are not compromised.

The design of these stormwater ponds was a desktop exercise that has not always transfered directly and easily to the real world. We have found that a significant amount of manipulation and calibration has been required in the construction phase to optimize the pond operation.

Figure 14: *Resolution Drive stormwater/wetland pond*

Figure 15: *Navigation Drive stormwater/wetland pond*

6 CONSTRUCTION

Construction of the subdivision has progressed on time and to budget. Working in close proximity to a regionally significant waterway has created some challenges for all stakeholders. Through proactive decision making and with the full support of local and regional councils, issues encountered were solved in a timely manner.

The minimisation of erosion and active management of sediment runoff from the earthworked areas is a key focus of the earthworks contracts. The erosion and sediment control measures adopted for this development are therefore aimed at ensuring a high level of protection against sediment discharges into Duck Creek during low to medium intensity rainfall events, and protection against uncontrolled discharges and scour during high intensity rainfall events.

The management procedures for the control of erosion and the treatment of sediment run-off, from earth-worked areas, for this project are based on the following principles:

- Not working during inclement weather;
- Minimise disturbance;
- Staged construction;
- Protect steep slopes;
- Protect water bodies;
- Stabilise and rehabilitate exposed areas rapidly and progressively;
- Install perimeter controls;
- Employ detention devices;
- Implement an evolving CMP;
- Inspect the performance of the procedures;
- Maintain all erosion and sediment control measures to ensure maximum efficiency;
- Install additional measures prior to medium to high intensity rainfall events, where practicable.

Site specific solutions have been developed and implemented, taking into account construction and maintenance requirements. The solutions have been used very successfully in the previous stages of the project and are currently in use on the current stages. Similar concepts are used on most well managed earthwork projects throughout New Zealand and are based on the methods documented in Auckland Regional Council's TP90 and Greater Wellington Regional Council's, "Erosion and Sediment Control Guidelines for the Wellington Region".

Figure 16: Stage 1 & 2 earthworks

On Wednesday 10th April 2013 Duck Creek was officially diverted into the new alignment constructed as part of the stage one works. The significance of this milestone event drew a large gathering to witness the first flow of water down a new creek that will become a significant asset to the community. Attendees included representatives from local and regional council, and Guardians of the Pauatahanui Inlet.

Figure 17: *Duck Creek Diversion 1 Commissioning*

7 CONCLUSIONS

The diversion of Duck Creek to enable residential development on the former Whitby Golf Course has not been without difficulty.

The process of developing a Comprehensive Development Plan for the subject land ensured all stakeholders were consulted and seriously listened to. The hard work undertaken to prepare this document ultimately paved the way for what was surprisingly a non-eventful publically notified consent process.

The new alignment and modified banks of the existing channel have performed well through two wet Wellington winters. The integration of the main channel within a wider floodplain allows moderate rainfalls events to easily be accommodated in the creek and for larger floods to flow across the floodplain and secondary overflow paths without adversely affecting property.

Ongoing bi-annual ecological monitoring has concluded that the diversions are off to a great start, while there has not been a full recovery in fish abundance, the channel is in the early stages of development and the habitats are continuing to rework and develop with each rainfall event. Overtime it is anticipated an increase in fish abundance will occur. To facilitate this, the ongoing implementation of the landscape planting will continue to ensure a tree canopy is obtained.

Construction of the subdivision has been undertaken with a high regard for the sensitive receiving environment. All contractors involved with the project now have a higher level of understanding in the importance of good construction methodology this ensures impact on the receiving environment is minimised. The construction of the new stream divisions, structures and associated infrastructure has been completed to a high standard and is a project those involved in should be proud of.

The feedback received from the public following the construction of the first stages has been positive and the subdivision linkages of share paths are being utilised by all generations, who are now able to walk along the banks of Duck Creek and enjoy the amenity created. As landscape planting further establishes the amenity of the subdivision will only increase, creating a unique environment to live in and enjoy.

Figure 18: Duck Creek development