HARNESSING THE POWER OF NATURE FOR STORMWATER ENGINEERING

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ABSTRACT

Nature is a powerful beast and we can learn a lot from natural system processes and adaptability. Natural systems are constantly changing and all too often, conventional “hard” engineering solutions are unable to cope with these long term natural processes. Looking to nature for inspiration can provide solutions that are adaptable and have the ability to “heal” themselves, as well has providing better aesthetic and amenity value. Designs using “natural” solutions can be simple, effective and efficient. And, with a little thought, we can also reduce maintenance requirements and provide ecological benefit, whilst still providing the required engineering output of protecting property and infrastructure.

This paper looks at two bank stabilisation projects and a treatment wetland project to demonstrate the benefits and challenges of integrating nature into engineered stormwater solutions.

KEYWORDS

Stormwater, Natural Systems, Erosion and Sediment Control, Bank Stabilisation, Wetland.

PRESENTER PROFILES

Sarah Dudson is an Environmental Engineer with Opus International Consultants. During her eight years’ experience Sarah has developed broad infrastructure design skills across the three waters and has specialised in stormwater management, including design of stormwater conveyance and treatment systems, low impact design and strategy development. She understands the widening appreciation of stormwater as a resource, the lessons we can learn from nature and the importance of an integrated approach to stormwater management.

Andrew Broughton is a Civil Engineer with 20 years’ experience in water infrastructure including storrmwater, wastewater, potable water and irrigation. Andrew’s interest in using plants as part of engineering solution dates back to the early 90s where he successfully employed plants instead of a gabion basket solution to secure an unstable embankment for a sports field. He has used plants to control gully erosion, dissipate energy in steep swales and prevent wave damage on a dam wall. Andrew leads a successful Christchurch based, multidisciplinary design team. For the past 8 years Andrew has managed delivery of the Ashburton District Council’s (ADC) Water Services Contract.

Liam Foster is a Chartered Water and Environmental Manager with over thirteen years’ experience within water environmental consultancies working with local, national and multi-national organisations on projects in the UK, New Zealand and Brunei. Liam is an experienced technical delivery and team leader who has successfully delivered projects across a wide spectrum of land drainage and stormwater related projects. He has a background in hydraulic modelling, hydrology and stormwater design. Most recently he worked as the Wastewater Infrastructure Strategy Manager for one of the UKs largest Water & Sewerage Companies. He has recently moved to New Zealand and is a Principal Environmental Consultant with Opus International Consultants based in Christchurch.

1 INTRODUCTION

This paper looks at three real life examples of integrating nature into engineered stormwater solutions:

- Wheatstone Drain, where traditional "hard" engineering failed catastrophically;
- Mill Creek, where existing hard engineered bank protection was failing and the challenges with integrating a natural solution into a highly developed, urban environment; and
- "Pond C", where a natural wetland solution was used for a greenfields industrial development project.

2 WHEATSTONE DRAIN

Wheatstone Drain is an example that demonstrates the power of nature to destroy a traditional 'hard' engineering solution.

2.1 Background

Wheatstone Drain is part of the Ashburton district land drainage system. It provides land drainage through the wet season and during rain events, to maintain productive farm land. Wheatstone Drain is ephemeral, typically having permanent base flow for three to four months of the year during the wet season.

Wheatstone Drain was diverted in 2007 to facilitate construction of the Ocean Farm waste water treatment and disposal facility for the Ashburton District Council. The drain was diverted back into the Ashburton River above the new waste water facility using a grass lined trapezoidal open channel/swale.

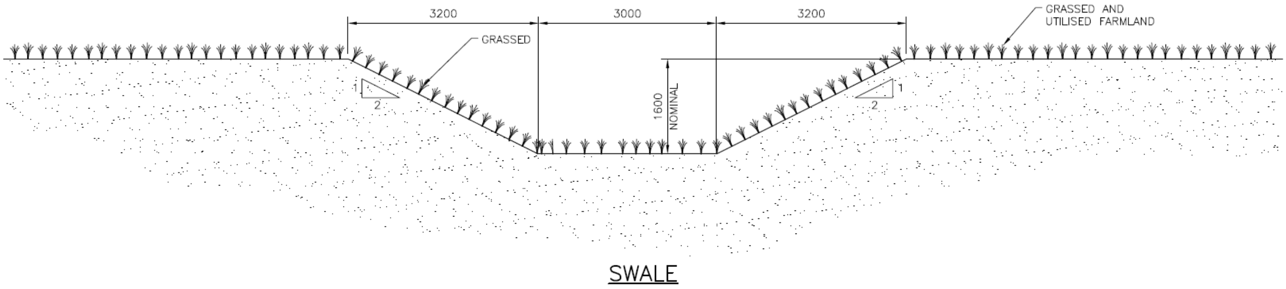

Figure 1: Cross section of the grass lined channel/swale

The redirected drain now crossed a 5 m high river terrace which required a drop structure to safely deliver the flow to the lower terrace and dissipate its energy to not pose a risk to the grass lined channel downstream of the terrace, or the terrace itself. The original design used a concrete structure design which is shown below in Figures 2 and 3.

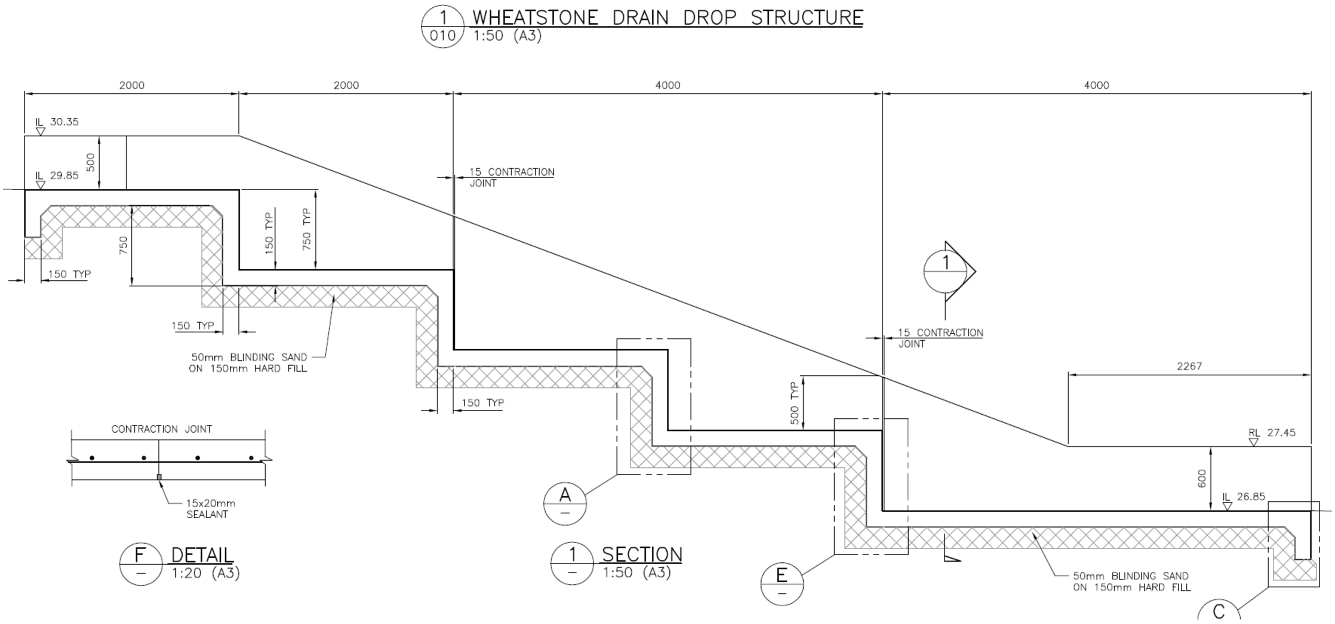

Figure 2: Details of the engineered concrete drop structure

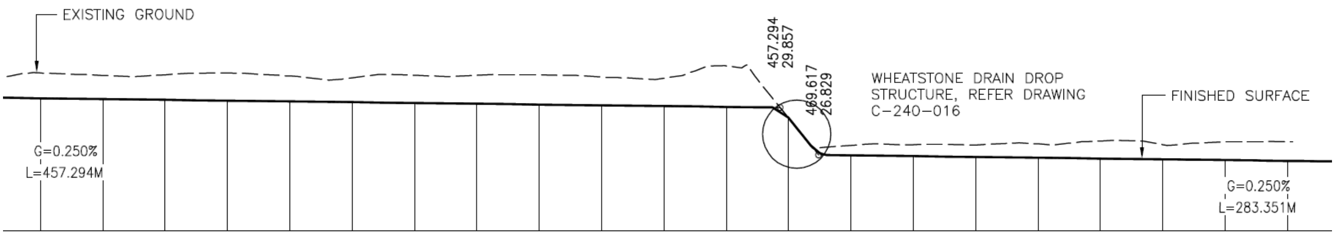

Figure 3: Long-section of the redirected Wheatstone Drain through the river terrace

2.2 The Power of Nature

A storm event causing high flows in the Wheatstone Drain resulted in the dramatic failure of the concrete drop structure. The flood flows revealed the power of water in the following chain of events:

1. Flood water overtopped the drop structure's wing wall; as a result
2. The terrace was seriously eroded and undermined the rigid drop structure;
3. The undermined concrete drop structure collapsed;
4. The collapsed drop structure allowed the erosion to track back along the grass line channel for over 100 m;
5. Eroded sediment was deposited downstream; resulting in
6. The banks of the drain downstream of the terrace were overtopped and flooded farmland.

Photographs 1, 2: Wheatstone Drain in flood after the failure

Photographs 3, 4: The aftermath of the failure

In addition to the failure of the drop structure, other consequential issues needed to be remedied as follows:

- Steep sides had formed where the drop structure had been washed out;
- These steep unstable banks were prone to ongoing collapse and erosion during high flow conditions;
- The banks were receding placing the neighbouring fencing and other farm infrastructure at risk;
- The regraded channel was receding upstream, increasing the area requiring remedial work;
- The material that had been washed out with the drop structure had been deposited in the drain downstream, raising the bed level such that it was now higher then adjacent farmland in places and increasing the frequency and risk of flooding that land;

- The highly erodible banks produced high sediment loads that were being discharged into the Ashburton River, resulting in non-compliance with the resource consent for the original drain works.

2.3 The Solution

The first solution proposed, a gabion basket and reno mattress solution, was cost prohibitive. Opus became involved in the Wheatstone Drain project to develop an alternative solution. The alternative solution would need to address the legacy of problems including erosion and sediment control, flooding and land stability. The solution would also need to be resilient in high flow flood conditions and environmentally friendly.

Fortunately, nature had already done a lot of the work for us. By washing out the drop structure, and part of the river terrace with it, the bed of the drain had re-graded itself to a more stable position such that there was no need for another drop structure.

Our solution focused on working with nature and using natural processes to provide stability and resilience to the design. The steeper grade of the re-formed channel was considered against what a natural system with steep grade would look like. The relatively small (40 mm) size of the stream bed material would be highly moveable during high flows, so in order for the channel to be relatively stable, what was missing was large boulder runs to hold everything in place. In addition, the banks had no topsoil and were too steep to support plant growth. A natural root system on the banks would include a relatively dense shallow root system to hold the topsoil together and then a bigger root system penetrating deeper into the subsoil to hold larger areas together. If these features could be added to the channel in the correct way, the Wheatstone Drain system could be self-healing such as is typical in nature. The channel bed would slowly settle and the boulders would stay in place and settle as well, if they were sized correctly. Small pockets of bank might suffer from minor erosion from time to time, however the plants root system would and extend down again, in effect being self-healing.

Key features of the alternative solution included:

1. Grading back the steep banks to a stable slope.

2. Installation of an initial shallow synthetic root structure in the from erosion protection matting over the lower half of the bank to provide immediate erosion protection and help to support initial vegetation growth.

3. Installing a boulder foundation at the toe of the embankment embedded in the channel bed and extending up the side of the embankments to provide protection from meandering low flows undermining the embankment. These boulders also helped to anchor the erosion protection matting in place along the toe. The boulders were sized to withstand the peak flow velocity in the drain.

4. Rock sills across the channel where installed at regular intervals along the steepest section of the drain, which is the most active and experiences the highest flow velocities. Large boulders set into the bed and extending up the sides where used to form the sills. These served to stabilise sections of the channel upstream and provide cut-offs should any streambed erosion form. The rock sills were reinforced on the sides of the banks with plantings of deeper rooted native plants. The rock sills allow the bed material freedom to move between sills whilst

protecting the drain from eroding the base of the channel any further upstream and from deposing any further eroded material downstream.

5. Planting the banks for the drain. As the grass and plantings establish, their root systems hold the soil together, helping to maintain bank stability and minimise surface erosion. Hydroseeding was used initially as the mulch provides immediate protection from surface erosion while the grass establishes.

The following photographs show the completed bank stabilisation works.

Photographs 5, 6: Completed Wheatstone Drain bank stabilisation works before and after installation of rock sills

The bank stabilisation works were finished just in time and were tested under high flow conditions only weeks after completion. The benefits of a design that integrated engineering with nature were immediately apparent. The rock sills did not stop movement of the bed material but had restricted this movement between sills. The result being the creation of a series of pools and riffles - nature’s own energy dissipation system. The rock toe, erosion protection matting and planting had also done its job to protect against surface erosion.

The removal of the concrete drop structure and the creation of a more natural drain also have ecological benefits. The pools and riffles have greatly improved in-stream habitat and fish passage along the drain from the Ashburton River has been restored. The riparian habitat will also improve over time as vegetation establishes.

Photographs 7, 8: Testing the Solution – The completed Wheatstone Drain works following a significant flood event.

3 MILL CREEK

The Mill Creek example highlights the challenges with integrating a natural solution into a highly developed, urban environment, where existing hard engineered bank protection was failing.

3.1 Background

The Mill Creek is historically an old overflow channel of the Ashburton that was cleared and enlarged in the 1870's to supply water to a Mill. As the permanent channel was formed it intercepted areas of high groundwater, adding a supplementary spring flow to the base flow in the creek. As the town of Ashburton developed around Mill Creek, the Mill became redundant and the role of the creek for land drainage, stockwater conveyance and stormwater outlet became essential.

Setbacks from Mill Creek were never enforced and development was allowed to occur right up to the edges of the creek. In some places ownership even extends to the centreline of the creek. The overall result being:

- Overall reduction in the capacity of the Creek
- Increased imperviousness of the catchment
- Increased stormwater discharges
- Increased flow velocities
- Erosion problems
- Risk of damage to significant structures, other infrastructure and land.

3.2 Bank Stabilisation Programme

For the last six years Opus has been involved in a progressive bank stabilisation programme for the Mill Creek. The first year focussed on the unstable sections of the creek, which were at risk of damaging significant structures and property.

One of the biggest challenges was designing a solution to protect property and structures in a highly developed urban environment, whilst improving, or at least maintaining, channel capacity.

Another challenge we were faced with was that the extent of the problem was not always apparent during the initial site inspection. In many cases what appeared ok from the surface was severely undercut and falling apart beneath the surface. And this was generally not discovered until the contractor was onsite carrying out the initial site clearance enabling works.

The following photographs highlight some of the bank stability problems and some of the constraints we had to work within.

Photograph 9-12: Pictures of undercutting and bank collapse along Mill Creek

Solutions were developed to suit a number of scenarios, depending predominantly on the available space and the severity of the problem. Other considerations included native soil type, existing vegetation and access.

Where space was available, the banks were graded back to a more stable slope. The lower part of the bank, from the toe to a little way above the permanent flow level was formed from boulders. The upper banks were planted to provide additional stability and protection from surface erosion.

Where space was tight due to proximity to structures or mature trees, the solution was low timber retaining walls or, if access to install the timber posts was prohibitive, gabion baskets were used.

Planting was an important aspect of the overall design and was often the most important topic in landowner consultation. The works were invasive on private property and in many cases resulted in loss of gardens and fence. Plant choices needed to meet landowner expectations, provide bank stabilisation, protection from surface erosion and be able to withstand periodic inundation during times of high flow. Plant choice also needed to consider the effect of planting on conveyance capacity and the subsequent maintenance and need for vegetation clearance in the future by landowners and Council to ensure channel capacity is not restricted.

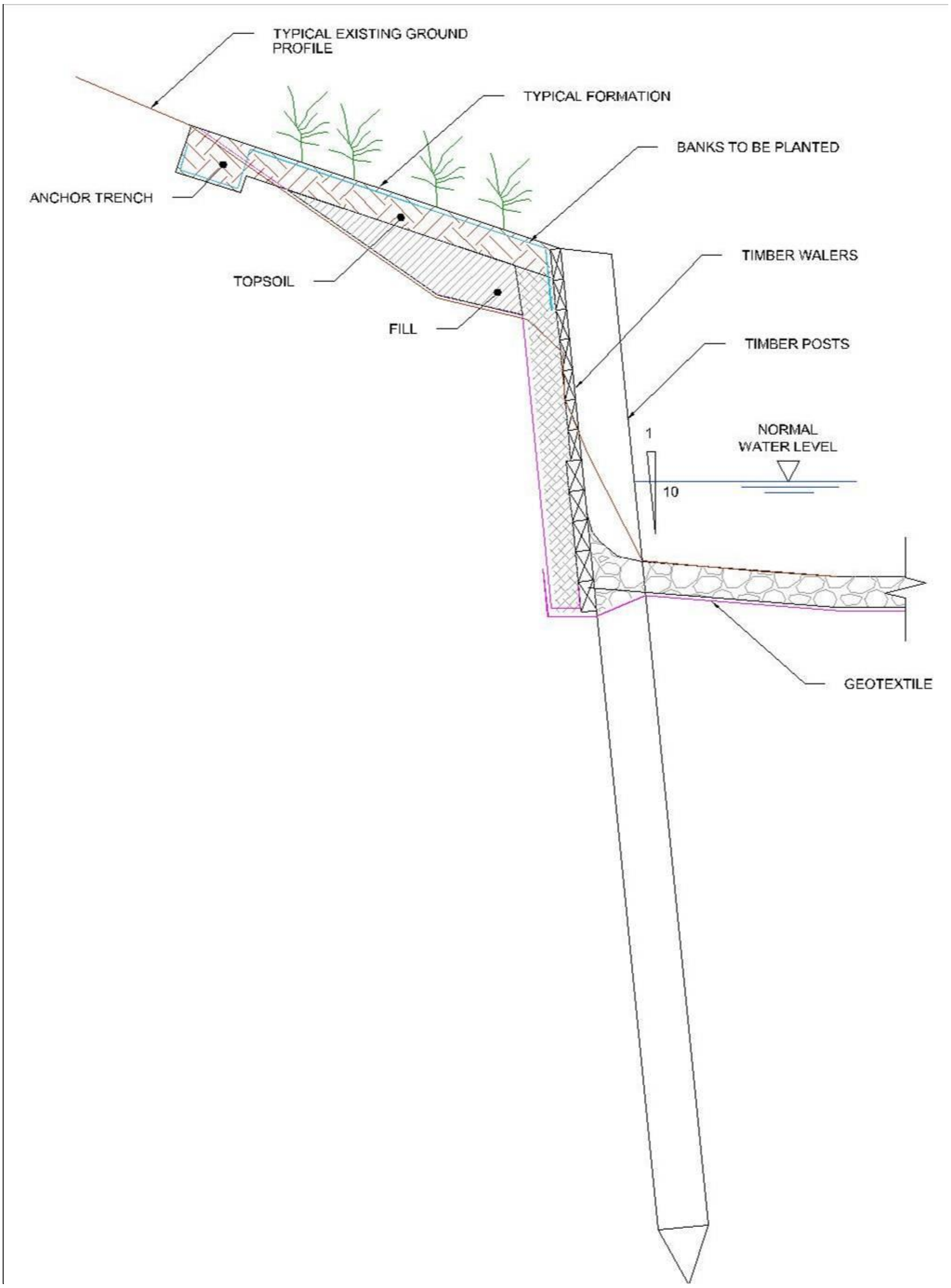

Figure 4: Timber retaining wall stabilisation solution

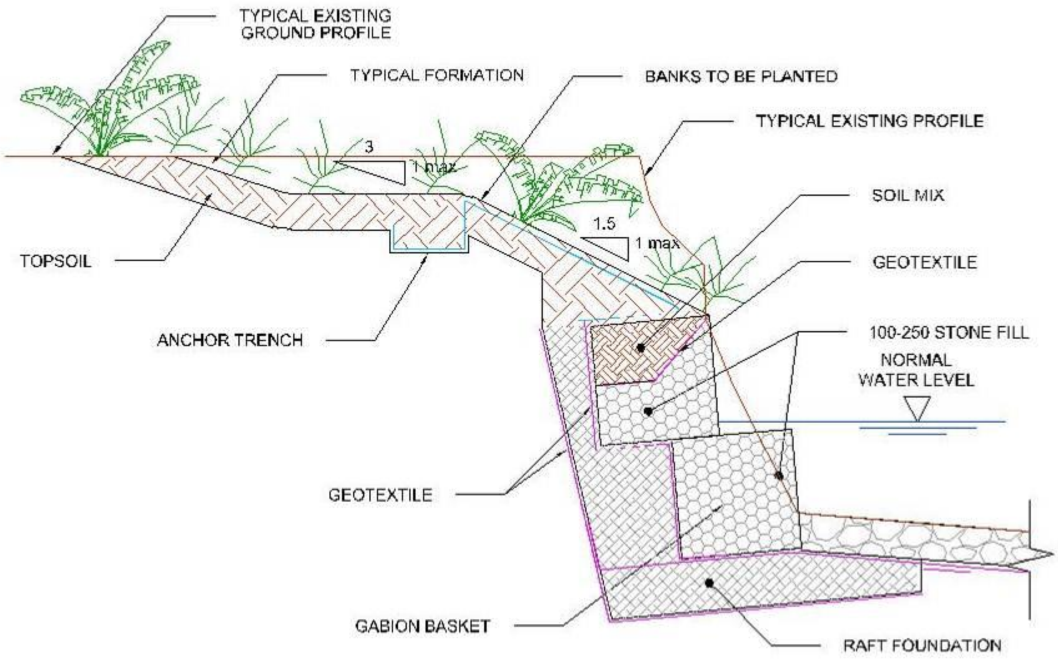

Figure 5: Gabion basket stabilisation solution

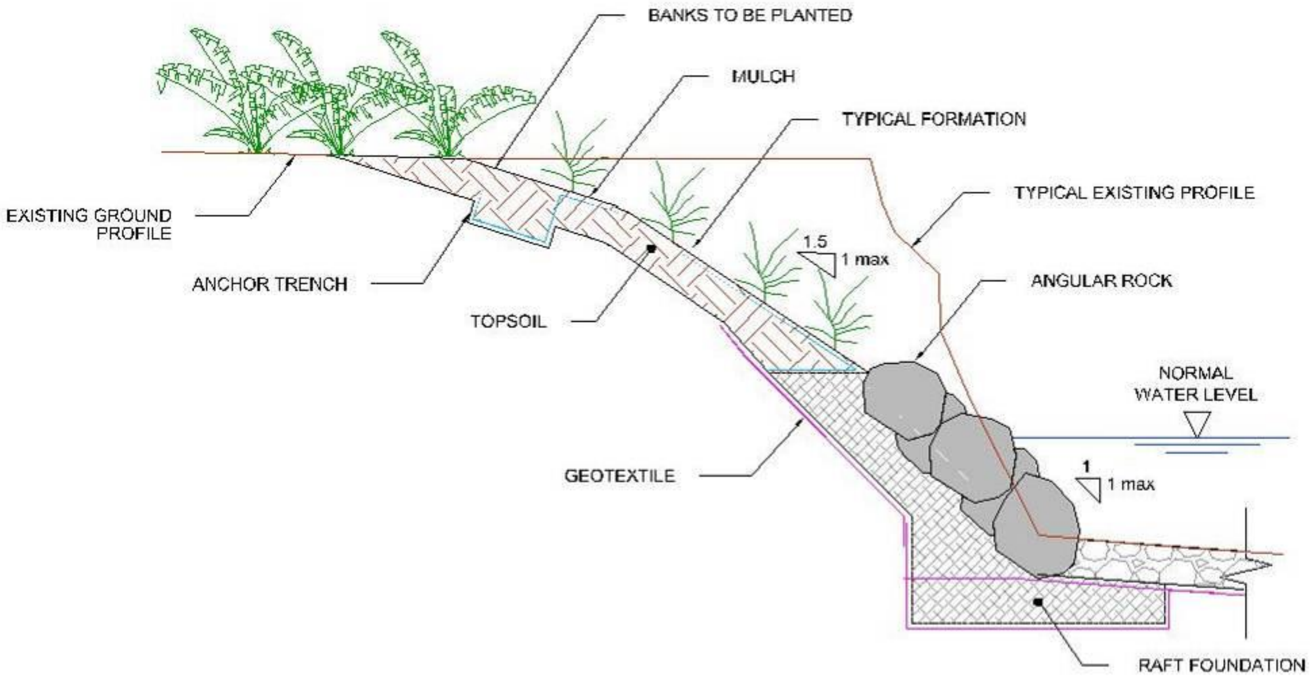

Figure 6: Rock faced stabilisation solution

Whist this project showcases how far engineering has come, giving higher weighting to environmental issues and opting for more natural rather than tradition ‘hard’ engineering bank protection measures, we still have a long way to go. By removing the undercut banks and overgrown vegetation that puts property at risk and limits flow capacity, we are also removing in-stream habitat and impacting ecological health. Ecological enhancement is likely to form the next iteration of engineering design.

Photographs 13-16: Completed bank stabilisation works

4 "POND C"

"Pond C" is a wetland that was constructed to treat stormwater runoff from a large greenfields industrial development in Rangiora.

Stormwater runoff from each industrial site is discharged into an open drain that carries the flow to a sediment forebay and then into the wetland. The wetland plants are carefully chosen for their ability to uptake metals and nutrients and to filter sediments. The wetland is made up of a series of deep pools and shallow planted margins arranged in such a way as to increase the flow path of through the wetland to maximise treatment potential and settlement of suspended solids. A spring flow along the open drain ensures a permanent flow through the wetland and prevents stagnant water.

The wetland is also designed flood in events greater than the water quality storm to provide some attenuation benefits.

One of the lessons learnt at "Pond C" was to avoid the use of topsoil below the water level of a wetland. The wetland plants can be planted in sandy gravel material and will get sufficient nutrients from the water; they do not need topsoil in order to grow. Whilst the topsoil helps the plants to establish, it is also a source of fine sediment that can be re-suspended by ducks and other animals. The fine silts stay suspended in the water for a long time and can result in a cloudiness at the outflow during low flow conditions when the inflow is clear.

The wetland has some key operation and maintenance features including:

- An access track around the perimeter which will allow plant to access the site for maintenance, even during wet periods;
- Deep pools are used to prevent the weed growth from clogging and spreading everywhere;
- Slopes are such that areas which need to be kept mowed are easy to mow;
- A gravel layer was installed above the clay liner to provide a footing for any plant that might need access in the future. The gravel layer also serves to protect the clay liner and let anyone know when they are getting near the clay lining so excavation can stop before the clay liner is damaged.

"Pond C" has developed into an attractive and amenity space that is not only functional, but, has created new and varied habitat through ecological enhancement, which will ultimately contribute to, increased biodiversity.

Photographs 17-18: Completed "Pond C" wetland

5 CONCLUSIONS

Engineering has come a long way from ‘pure’ engineering design and traditional ‘hard’ engineering solutions. We have developed a respect for the power and intelligence of natural systems and see the benefits of integrating these systems into our designs. And by doing so we are improving the resilience of our designs so they can adapt under the power of nature. The next iteration of design is to not only use nature’s systems to benefit our designs, but to seeking to benefit the natural world and biodiversity by incorporating ecological enhancement.

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