WAIRAKA STREAM DAYLIGHTING PROJECT

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ABSTRACT

Coinciding with the Unitec environmental sustainability strategy daylighting of the Wairaka stream is at the heart of creating positive environmental change on campus. Currently part of the stream flows through a 70m culvert hiding away its historic character and lessening its natural benefits. The paper analyses potential daylighting designs, and details a final design. A Stream Ecological Valuation performed on the downstream reach produced a baseline score of 0.58, indicating moderate water quality. The assessment highlighted the importance of maintaining similar geomorphology, and creating diverse aquatic and riparian habitats. Applying these findings three concepts were modelled including the existing culvert for the 2, 5, and 100 year Average Rainfall Intensity events using the hydrological modelling program HEC-RAS. A weighted attribute selection method incorporating Ecological, Social, Economic, and Cultural factors identified Concept 3 as the best design, scoring 6.96/10. Based on the 5 year storm it increased the channel capacity from 4.07m^3/s to 7.13m^3/s effectively reducing overland flow by 99.7% whilst reducing channel velocity from 1.91m/s to 1.52m/s. It can be concluded that daylighting will prevent flooding for the 5 year storm, improve the ecology, provide tranquility for staff and students, and restore part of Unitec and Mt Albert's cultural heritage.

KEYWORDS

Daylighting, urban streams, restoration, social, cultural heritage, student education

PRESENTER PROFILE

Avi graduated from Unitec Institute of Technology in 2013 with a Bachelor of Engineering Technology (Civil). He is now working as a Graduate Engineer for Harrison Grierson Consultants Ltd in the Land Development Division.

1 INTRODUCTION

Stream Daylighting was proposed for a 70m stream reach behind Buildings 24 and 36, at Unitec's Mt Albert Campus. This was identified as an important restoration opportunity due to the prior modifications made to the stream channel through urbanisation. It has been diverted and straightened into a concrete box culvert just below the ground surface, no longer resembling a natural stream channel. This has taken away many of the benefits that naturalised channels provide, and hides away a significant part of a historical feature of the Mt Albert environment.

In March 2010 a project team representative at Unitec was commissioned to develop a Unitec Environmental Sustainability Strategy (ESS). The main vision of the strategy is to transform Unitec into "an excellent business that is environmentally responsible, and an agent for positive environmental change". The report has outlined four distinct focus areas; teaching, research, advocacy, and campus operations. The goal for 'on campus' is to create "green and smart campus environments," (Fourie, 2011).

The stream Daylighting project of the Wairaka coincides with the vision and goals of Unitec's Environmental Sustainability Strategy, as it will improve the campus water flows and the habitat, helping to establish green and smart campus environments. This project will help towards the development of an eco-campus, with the project design also having the ability to produce an 'outdoor classroom' or laboratory for staff and students. This in turn has additional benefits helping towards enhancing the teaching and research areas on campus, generating both environmental awareness and added knowledge.

1.1 PURPOSE OF THE PROJECT

The objective of this project is to produce a design which will enhance the environmental, social, cultural, and economic factors within the Unitec campus and to the surrounding community. The design will be developed by employing methods of best practice, and in accordance with the Unitec Environmental Sustainability Strategy.

1.2 HISTORY OF THE WAIRAKA STREAM

The Wairaka stream has rich cultural significance to local Maori, with the stream being fed by a sacred spring on campus near building 180, shown in the Appendix. This groundwater spring flow comes from the Mt Albert basalt aquifer, most likely created by the volcanic eruptions 30,000 years ago. The culture originates from the history of the stream and its value to the Mt Albert region. It is said that around 950AD Toroa's famous daughter Wairaka travelled north from Whakatane on the Mataatua canoe to settle on Te Pu o Wairaka, now known as Owairaka or Mt Albert. The stories reveal that, "When she was thirsty, she demanded water, stamped her foot, whence water gushed out of the ground" (Truttman, 2007). This spring then became known as Te Wai Unuroa o Wairaka, which means the long drink of Wairaka.

The spring was a highly valued resource to the Ngati Awa people (original settlers), and was used for drinking water and for thanks-giving rituals and ceremonies. From (Truttman, 2007) the stream offered relief to the sick, as well as for healing, bathing, irrigation, and was a constant source of food. Native New Zealand Watercress (Puha) still grows readily in the stream near the Unitec Marae, and potentially was grown and harvested in the past.

Today the stream channel gently meanders from the spring through the Unitec grounds down to where it meets the confluence with the Oakley creek, which flows into the Motu Manawa Marine Reserve in the Waitemata Harbour shown in Figure 1. Clean water from the aquifer spring gives the stream constant base flows throughout the year, along with surface runoff from rainfalls which enter the channel, and reticulated stormwater from Mt Albert suburbs. There are two high quality wetlands in the upper reaches which remove contaminants and sediments present from Mt Albert stormwater, and runoff from Unitec buildings, car parks, and land. Along the stream banks there are some areas of dense native vegetation, however a large portion is lined by mown grass and some exotic trees. The channel is made of quite stable volcanic substrate, with some potential for erosion.

Nowadays the stream is a revered asset to Unitec and the wider community for not only its cultural significance, but also as a teaching resource, its ecological value, amenity, and the role it plays in the wider Oakley Catchment.

Photograph 1: Overlooking the wetland with the stream and Marae in the backdrop (source: Estrin, 2013); Photograph 2: Upper reaches of the Wairaka Stream (source: Estrin, 2013)

2 EXISTING SITE CONDITIONS

The existing site is a 70m stream reach running through a straight concrete box culvert, just below the ground surface as shown in Photograph 3. Next to the channel on the right hand side are two greenhouses, buildings 24 and 36 shown in the Appendix. These are both situated on the natural floodplain creating an artificial barrier for floods if the stream is opened. The western side slopes upwards at a low gradient from the stream bank, and is uninhibited for a 15m width over the entire length. This side provides a good location for future riparian planting and flood waters during large storms. Both sides of the channel are lined with mown grass providing some infiltration capacity. The stream then exits the culvert into a natural hard-bottomed channel. This section has a wider cross-section, with dense vegetation and good shading over the entire water surface.

Photograph 3: View upstream showing the box culvert (source: Estrin, 2013)

Due to the channel being so close to the surface there is a clear opportunity for daylighting to occur.

2.1 CURRENT LAND USE

The surrounding land use is environmentally friendly with limited vehicle and people traffic, causing minimal harm to the stream environment. However there are a number of operations which occur in the surrounding area. These include the following:

- Two medium sized greenhouses in operation on the eastern side in close proximity to the stream;
- Beehives and a beekeeping shed on the western side;
- A dog training facility opposite the beehives on the western side;
- A large fenced off planting area on the western side.

The proposed daylighting will prevent access to the western side by way of the existing route. In order to allow access for people and vehicles a 5T capacity bridge has been recommended by facilities management. The bridge crossing will be in a similar position to the current tracks in the ground, perpendicular to the stream (Sander, 2013).

2.2 POTENTIAL ISSUES

Potential issues associated with the project were identified to create increased awareness. This awareness promoted conscientious project planning which will help avoid and/or minimize any issues which may arise. Outlined below are limitations/issues which may hinder, or be adversely affected by the project:

- Unitec CAPEX budget limitations;
- Effects to stream habitat and wider Oakley Catchment;
- Getting an accurate representation from testing due to the short timeframe;
- Flooding risk if the channel design does not satisfy its requirements;
- Existing irrigation pipe running across the culvert;
- Current vehicle access over the existing culvert;
- Close proximity to greenhouse buildings 24 and 36 resulting in limited space;
- Potential disruption to nearby classrooms during construction;
- Potential opposition of various stakeholders to the project;
- Limited information of daylighting currently in Auckland.

3 STREAM ECOLOGICAL VALUATION

In order to measure the health of the existing stream near the daylighting site an assessment was carried out. This was required to help attain baseline data on the current stream quality and morphology to provide reference data for future monitoring, and to create concept designs. A Stream Ecological Evaluation (SEV) was chosen as the most appropriate method for assessing the overall stream health as it is a consistent test across all Auckland streams. The main SEV findings have been detailed in the paper.

Figure 1: SEV site relative to the Oakley Creek (source: google maps, 2013);
Photograph 4: View upstream showing the SEV site (source: Estrin, 2013)

3.1 SUMMARY

A Stream Ecological Valuation of the Wairaka stream was undertaken within the Unitec Mt Albert campus. It was carried out in order to attain the current ecological value of the stream reach below the existing culvert exit.

The assessed site covered a 60m length reach with an average elevation of 8.5m above mean sea level, located on the urban/rural fringe as shown above in Figure 1.

The SEV was undertaken on the 13th June 2013, during fine weather. Macroinvertebrate data was obtained from Senior Lecturer Mel Galbraith, while fish data was obtained from the NIWA Freshwater Fish Database (FFDB) and the Oakley Creek Watercourse Management Plan (WMP).

The Wairaka site scored an overall value of 0.58, indicating moderate water quality. The scores for the main function categories are shown below:

- Hydraulic Mean Function: 0.53;
- Biogeochemical Function Mean: 0.73;
- Habitat Provision Function Mean: 0.56;
- Biodiversity Function Mean: 0.39;

There is good water temperature control and dissolved oxygen levels over the full reach length. This is complimented by good decontamination of pollutants and a decent representation of fish species.

An increase in the variety of physical habitats along with fish spawning habitats would improve the habitat provision score. The stream would also benefit from more deciduous trees which would add more organic matter to the stream.

3.2 DATA ANALYSIS

Table 1 displays the key result areas of the assessment:

Table 1: SEV function scores

Site	**Wairaka 1**
Easting	
Northing	
Catchment Land Cover	**Urban**
Function	
Natural Flow Regime	0.30
Floodplain Effectiveness	0.53
Connectivity for Species Migration	0.30
Connectivity to Groundwater	1.00
Hydraulic Mean Function	0.53
Water Temperature Control	0.80
Dissolved Oxygen Levels	1.00
Organic Matter Input	0.30
In-stream Particle Retention	0.77
Decontamination of Pollutants	0.78
Biogeochemical Function Mean	0.73
Fish Spawning Habitat	0.46
Habitat for Aquatic Fauna	0.66
Habitat Provision Function	0.56
Fish Fauna Intact	0.77
Invertebrate Fauna Intact	0.21
Riparian Vegetation Intact	0.18
Biodiversity Function Mean	0.39
Overall SEV Score	**0.57**

The hydraulic mean function is 0.53, with very good connection to the groundwater (1.00), and a fairly effective floodplain (0.53). The channel is natural with no modifications however the score was brought down by having a natural flow regime value of only 0.3 which was due to the presence of 3 small stormwater pipes discharging to the stream reach.

The biogeochemical function score was 0.73 which is good. Water temperature control was very good due to high levels of shading through the entire reach by the riparian plantings, and this also compliments the high dissolved oxygen score of 1.00. The organic matter input is low as a result of a very small number of overhanging deciduous trees on either stream bank. There is also good decontamination of pollutants as there is a good distribution of substrates present and riparian ground cover filtering.

The habitat provision for the stream is moderate. There is a suboptimal physical habitat with some runs and riffles, woody debris, macrophytes, and native tree canopy available to fauna. There is also limited fish spawning habitat as only a small proportion of low gradient flood plains are available. There is however a good variety of substrate within the channel.

The biodiversity function mean is fairly low as a result of the poor MCI function score of 0.4, and only 0.06 represented by EPT. The stream does however have a good representation of fish species with a score of 0.77.

3.3 PROJECT DESIGN RECOMMENDATIONS

From the results there needs to be an improvement made to provide a greater proportion of high value habitat for fauna. This could potentially allow for a larger population of organisms within the stream and riparian corridor. Some recommendations are outlined below:

- Implement best practice design to improve the low scoring functions – Reduce stream bank gradients for fish spawning, provide a greater variety of habitat types, a greater mix of hydrological conditions, and more deciduous overhanging trees to add organic matter (leaves) to the stream.
- Planting will be very important to provide organic matter for food, habitat for lava to live, hatch, and climb enabling them to fly away. It will also eventually provide shading to the water which is important, uptake of runoff nutrients, and roughness to create flow turbulence. Some of the existing plant species should be used to keep the stream consistent, along with new plantings.
- Use channel dimensions similar to the existing stream. Basic characteristics discovered were uniform depths from bank to bank, relatively uniform channel widths, and a variable stream bank gradient. The channel resembled a comparable cross-sectional shape to a standard trapezoid.

4 CHANNEL DESIGN

4.1 GEOMETRIC DATA

A survey of the project site was undertaken. This included taking cross section profiles at points on the stream, above the culvert, and also of the east and west floodplains using a total station. Main features and spot heights were taken using GPS.

The data was used in AutoCAD to create a basemap of the site, and in HEC-RAS to model the existing stream channel and develop concept designs. Contours from the Auckland GIS viewer were also imported and used in areas which were not picked up by the survey.

4.2 PEAK FLOW DATA

The peak flows for the stream were required to perform the hydraulic analysis on each concept design. This data was used in HEC-RAS represented as three different profiles, the 2, 5, and 100 year ARI TP108 design storms. This enabled hydrological variables to be determined based on the peak flow, channel geometric data, slope, and roughness coefficients. These were chosen for the following reasons:

- The 2 year storm event is the most common and as a result will have a large influence on the stream morphology;
- The stream was designed based on the peak flow for the 5 year storm event;
- The 100 year event modelled the worst case (or closest to) flood scenario.

Tables 2 and 3 below show the results from the peak flow calculations for the site undertaken by Morphum Environmental Ltd. The data is based upon the Auckland Regional Council TP108 Guidelines for Stormwater Runoff Modeling in Auckland- Part A and Part B.

Table 2: Catchment sizes used to estimate peak flows

Catchment sizes [ha]				
Surface	**Current**	**%**	**Future**	**%**
Pervious	51.44	0.51	30.30	0.30
Impervious	49.56	0.49	70.70	0.70
Total	101.00	1.00	101.00	1.00

Table 3: Peak flow rates for different storm events for the site

Peak Flow Rate [m^3/s]								
ARI Events/ Surface Types	**2**	**5**	**10**	**20**	**50**	**100**	**WQV**	**EDV**
Pervious	0.611	1.145	1.548	2.002	2.635	3.192	0.027	0.053
Impervious	4.331	6.005	7.123	8.241	9.639	10.758	1.346	1.789
Total	4.942	7.151	8.671	10.243	12.275	13.950	1.373	1.843

4.3 MATERIALS AND IN-CHANNEL STRUCTURES

The following structures and materials have been identified after completing the channel geometric design. This was the case because in-channel structures cannot usually correct issues with the channel pattern (William A. Harman, 2011). Outlined below are the materials and structures along with their function/purpose and their respective benefits.

4.3.1 BIOMAC WOOLMULCH AND GRASS-STRIKE (R500):

This geotextile matting should be used to line both stream banks from the bank edge to the top of the rip rap. The product by Maccaferri is biodegradable reinforced wool matting, specifically used to establish plants and groundcover. It is used on slopes and has advantages including reducing soil moisture, providing nutrients for plant growth, inhibiting weeds, and improving erosion resistance (Maccaferri, 2013).

4.3.2 EROSION CONTROL TUBES:

Tubes should be implemented directly below the main stream bank plantings (just before the top of the rip rap) along both banks. Erosion control tubes by Maccaferri will provide the channel with the following advantages (Maccaferri, 2013):

- Stabilize the stream bank and protect against erosion;
- Provide a growth medium for stream bank vegetation;
- Retain and filter sediment through the use of compost, wood chips, or bark.

4.3.3 RIP RAP:

Rip-rap in the form of crushed basalt rock should be implemented to prevent scour on the channel surface, and also prevent undercutting between the bank and the channel. This will help reduce velocity through increasing roughness, and increase the dissolved oxygen by creating turbulence. It also has a natural appearance, and is easy to install and repair. Note that it will be used moderately along the base and will not change the nature of the stream as a good distribution of substrate also exists in the downstream reach.

4.3.4 LOGS/LARGE TREE BRANCHES:

Logs/branches should be used along the channel edges amongst the rip-rap and within the stream channel. This will create a more natural environment, and improved aquatic habitat. Wood within the stream will have the following benefits according to (Meleason, Quinn, & Davies-Colley, 2013):

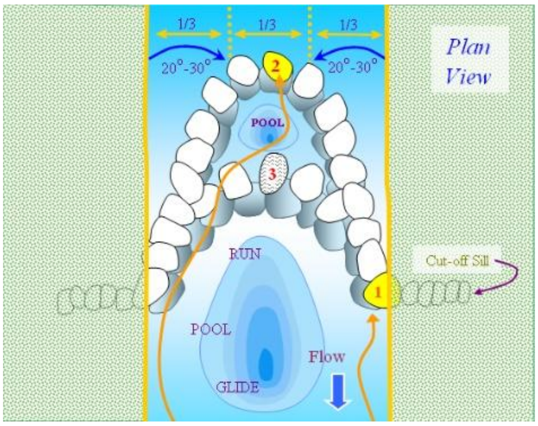
- Prevent bank erosion;
- Alter the direction and velocity of flow according to its position and size;
- Create damned pools and plunge pools;
- Increase the amount and diversity of the aquatic habitat;
- Help provide food sources by trapping and storing organic matter.

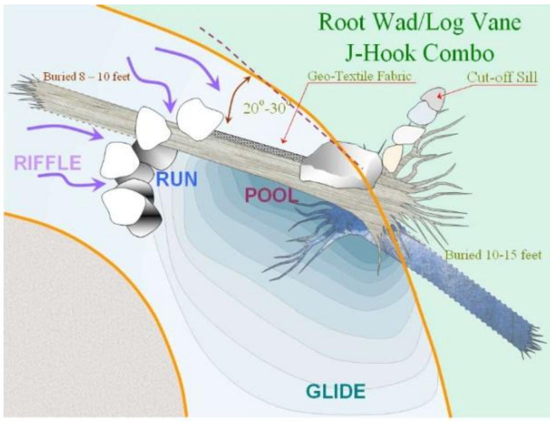
4.3.5 CROSS VANES AND J-HOOK VANES:

A combination of logs and rock should be used to create a J-hook vane and a cross-vane. The cross vane will enable the flow velocity to be slowed down by increasing roughness through its physical shape, and creating a pooling effect immediately downstream. The J-hook vane will be used along the outside of the meander bend before the transition to the existing open channel. This will act to direct flow around the bend towards the transition with the existing open channel. Figure 2 and 3 depict examples of both structures:

Figure 2: Channel cross vane (source: United States Dept. of Agriculture, 2007)

Figure 3: J-Hook log vane (source: United States Dept. of Agriculture, 2007)





4.4 CHANNEL GEOMETRICS

The downstream channel is significantly larger than the upstream both in depth and width. Designs have been based on the downstream dimensions to ensure that there is a smooth transition point. The characteristics of the stream remain relatively consistent, including the flow hydraulics once water enters the new channel.

4.4.1 CHANNEL WIDTH

To design the channel width the SEV measurements have been plotted to find an average across all cross sections. The average wetted perimeter was found to be 2.26m, with the average depths at both edges estimated to be 0.12m. Using the approximate average bank angle of 30° the average channel width at the base is calculated to be 1.83m. This width is however wider than the upstream channel which varies between 0.5 and 2.0m.

In reference to (William A. Harman, 2011) many alluvial channels are designed with a width:depth ratio of greater than 12. Over time the channel will narrow and this ratio decreases below 12. In the case of the downstream reach the ratio is 16.7 which is desirable. The recommendation for design was to incorporate a channel with of between 1-2m wide with a similar ratio to the one above.

5 CONCEPT DESIGN ANALYSIS

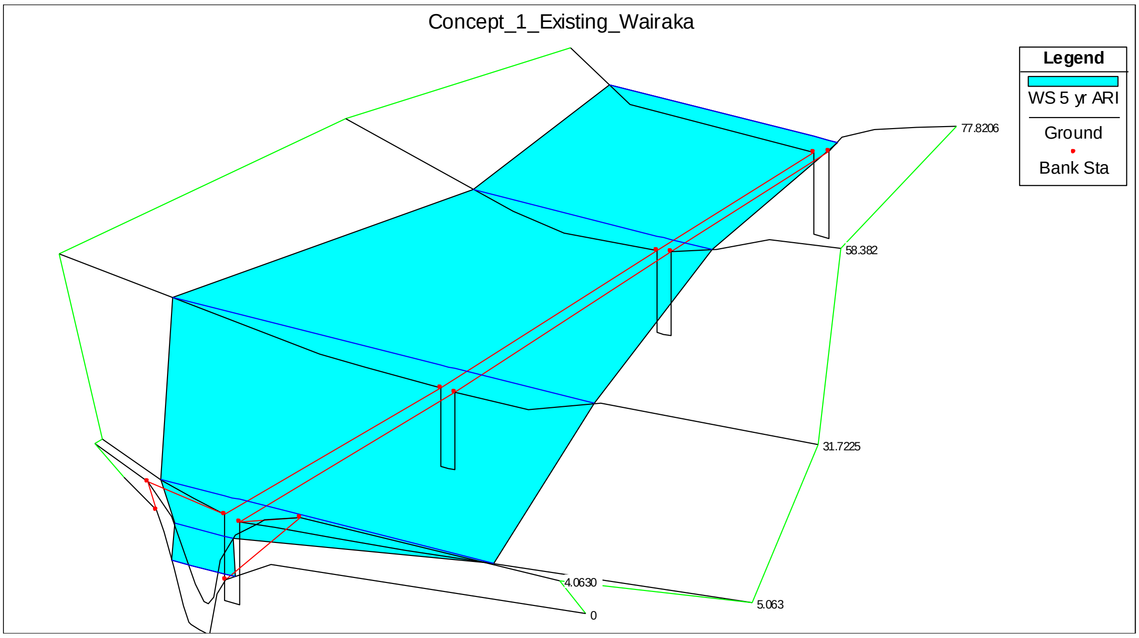
5.1 OPTION 1: EXISTING CHANNEL

Option one displays the current site and models the flow through the existing culvert. The culvert is modeled as an open channel (excluding the top 0.2m concrete portion) to allow the model to show the overland flow which would occur from catchment runoff. This enables the model to show a free water surface level for each storm event which is essential when comparing the existing model to the design concepts. In order to factor in for the unmodelled top section the Manning's roughness for the channel was increased by 0.04.

The following assumptions were made during modelling:

- Culvert geometrics were assumed to be equal through the entire length as it was only possible to take measurements at the exit point;
- The channel was assumed to be completely straight with a uniform surface;
- The surrounding buildings have negligible effects on the surface level, therefore were not modelled as ineffective flow areas.

Figure 4: X-Y-Z Plot of the channel 1 model showing the 5 year ARI event



5.1.1 PROFILE SUMMARY OUTPUTS TABLE FOR 5YR EVENT

Table 4 below shows the significant output variables for the 5 year ARI event.

Table 4: Output summary of the main variables for the 5 year event

Profile #	River Station	ARI Event (yr)	W.S. Elevation (m)	Hydraulic Depth Channel (m)	V Channel (m/s)	Q Channel (m^3/s)	Power Channel (N/m s)	Flow Area (m^2)
1	77.8206	5	10.08	1.51	2	3.63	57.92	1.82

Profile #	River Station	ARI Event (yr)	W.S. Elevation (m)	Hydraulic Depth Channel (m)	V Channel (m/s)	Q Channel (m^3/s)	Power Channel (N/m s)	Flow Area (m^2)
2	58.382	5	9.9	1.49	2	3.58	58.25	1.79
3	31.7225	5	9.77	1.57	1.2	2.25	11.99	1.88
4	5.063	5	9.6	1.62	1.91	3.7	48.88	1.94
5	4.063	5	9.08	0.6	2.45	7.15	361.18	2.92
6	0	5	8.91	0.65	2.49	7.14	369.26	2.87
Averages for culvert channel (Profile 1 - 4)			**9.69**	**1.36**	**1.91**	**4.06**	**107.64**	**2.07**

5.2 OPTION 2: STRAIGHT STEP-POOL CHANNEL

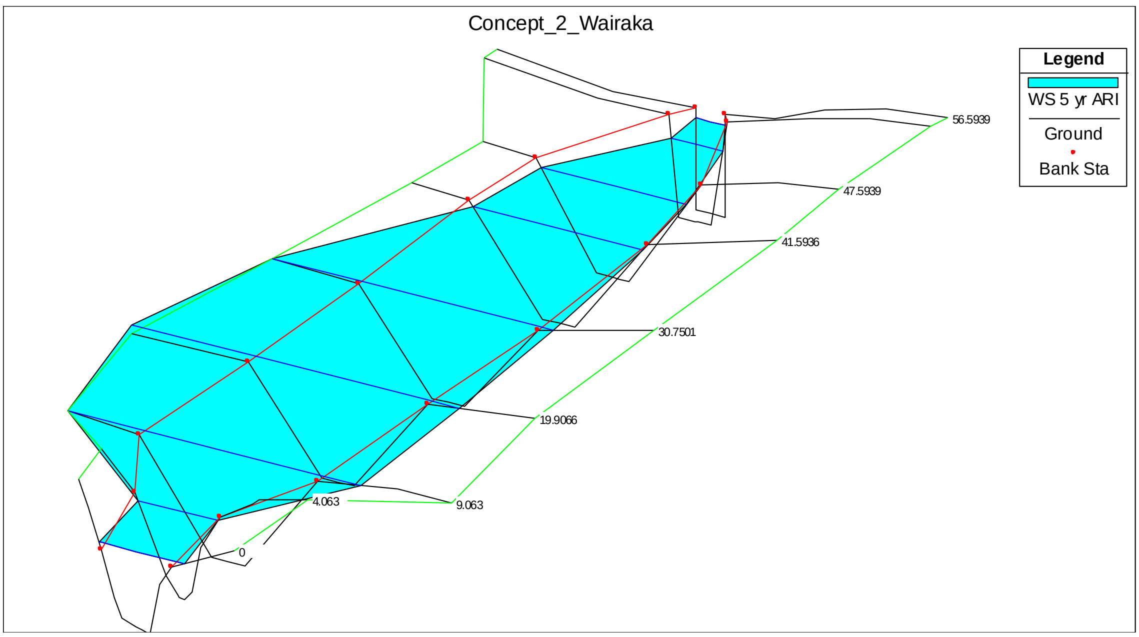
This channel opens up from the end of Building 24 with a straight channel alignment for 53m. It has been designed in the same location as the existing culvert which allows for a reduction in cut volume. The design also satisfies requirements to reduce bank slopes, increase the channel capacity, and include more in-stream structures. The main issue with this design is its location which would require a channel diversion during construction.

Due to the straight nature of the stream and the high velocities as the water exits the culvert a step-pool method has be designed. This is more common in higher gradient streams which have little sinuosity as a result of constraints. In this situation it will help to reduce velocity and erosion, create pools to enhance the habitat, and dissipate power which is especially high at the culvert exit.

The following assumptions were made during modelling:

- The channel was assumed to be completely straight with a uniform surface;
- The surrounding buildings were assumed to have negligible effects on the surface level, therefore not modelled as ineffective flow areas.

Figure 5: X-Y-Z Plot of the channel 2 model showing the 5 year ARI event



5.2.1 PROFILE SUMMARY OUTPUT TABLE FOR THE 5YR EVENT

Table 5 shows the summary table of the significant output variables for the 5 year ARI event.

Table 5: Output summary of the main variables for the 5 year event

Profile #	River Station	ARI Event (yr)	W.S. Elevation (m)	Hydraulic Depth Channel (m)	V Channel (m/s)	Q Channel (m^3/s)	Power Channel (N/m s)	Flow Area (m^2)
1	56.5939	5	9.56	1.17	3.43	7.15	1237.6	2.09
2	55.3939	5	9.37	0.8	2.82	7.15	655.17	2.54
3	47.5939	5	9.49	0.71	1.12	7.15	39.31	6.37
4	41.5936	5	9.48	0.71	0.96	7.15	24.37	7.46
5	30.7501	5	9.45	0.76	0.85	7.14	16.6	8.4
6	19.9066	5	9.43	0.81	0.78	6.96	12.47	8.95
7	9.063	5	9.41	0.86	0.76	7.12	11.24	9.43
8	4.063	5	9.08	0.6	2.44	7.15	355.38	2.93
9	0	5	8.91	0.67	2.5	7.14	368.55	2.86
Averages for design channel (Profile 1 - 8)			**9.41**	**0.80**	**1.65**	**7.12**	**294.02**	**6.02**

5.3 OPTION 3: MEANDERING RIFFLE-POOL CHANNEL

This channel was designed based on best practice in order to satisfy the project objectives. Along with standard design criteria there are project specific recommendations that were implemented. These include:

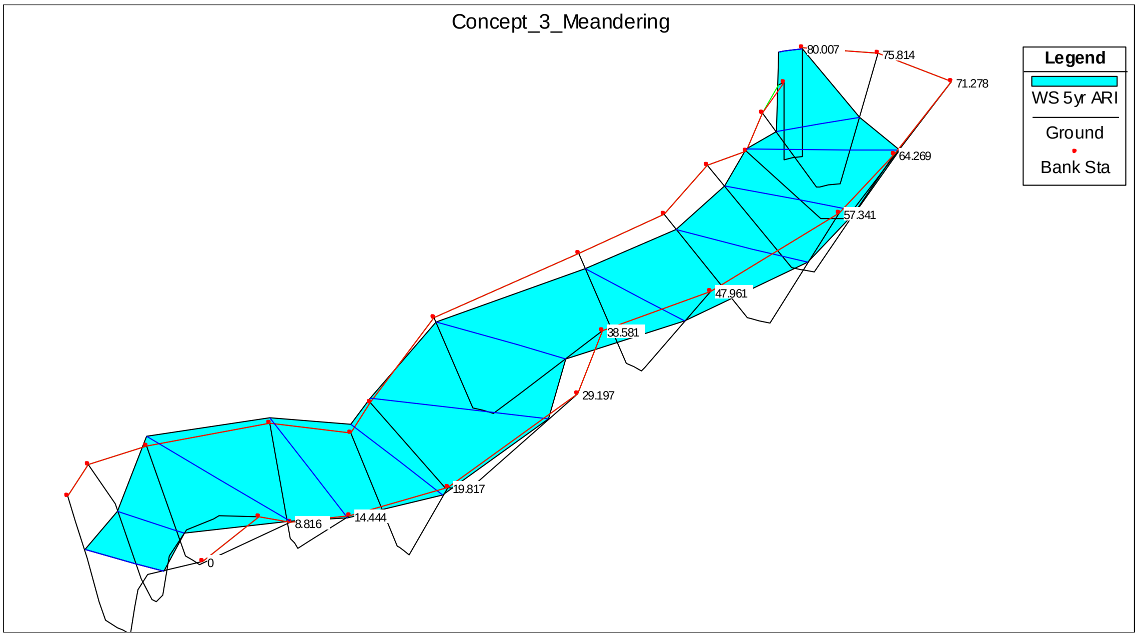
- Lower gradient stream banks;
- Trapezoidal shaped cross sections;
- Channel base widths similar to the downstream reach;
- A re-vegetation plan for the stream bank and riparian zone;
- Erosion control methods.

The channel incorporates a natural meander alongside the existing culvert which allows it to be constructed without requiring a costly stream channel diversion. This also satisfies the land use requirement to maintain space alongside Building 24 for vehicle access.

The following assumptions were made during modeling:

- The surrounding buildings were assumed to have negligible effects on the surface level, therefore not modelled as ineffective flow areas;
- The in-channel structures and materials were assumed to have no affect on the cross-sectional areas;
- The extent of the floodplain modelled was assumed to be sufficient to produce fair results.

Figure 6: X-Y-Z Plot of the channel 3 model showing the 5 year ARI event



5.3.1 PROFILE SUMMARY OUTPUT TABLE FOR 5YR EVENT

Table 6 shows the significant output variables for the 5 year ARI event.

Table 6: Output summary of the main variables for the 5 year event

Profile #	River Station	ARI Event (yr)	W.S. Elevation (m)	Hydraulic Depth Channel (m)	V Channel (m/s)	Q Channel (m^3/s)	Power Channel (N/m s)	Flow Area (m^2)
1	80.007	5	10.39	1.55	3.71	6.89	1591.05	1.86
2	75.814	5	9.72	0.57	2.38	7.15	406.61	3.01
3	71.278	5	9.77	0.59	1.36	7.15	74.74	5.25
4	64.269	5	9.69	0.58	1.45	7.15	90.12	4.94
5	57.341	5	9.62	0.59	1.35	7.15	73.25	5.29
6	47.961	5	9.55	0.6	1.25	7.15	57.75	5.7
7	38.581	5	9.48	0.62	1.24	7.15	55.59	5.76
8	29.197	5	9.45	0.66	0.99	7.15	27.6	7.22
9	19.817	5	9.42	0.73	0.86	7.15	17.59	8.31
10	14.444	5	9.42	0.74	0.64	7.15	7.27	11.11
11	8.816	5	9.41	0.79	0.62	7.15	6.38	11.55
12	4.063	5	9.09	0.6	2.43	7.15	352.44	2.94
13	0	5	8.94	0.55	2.33	7.15	317.94	3.07
Averages for design channel (Profile 1 - 12)			**9.58**	**0.72**	**1.52**	**7.13**	**230.03**	**6.08**

6 MODELING RESULTS DISCUSSION

Table 7 shows a summary comparison of the variables between each concept. An average for each variable has been calculated for the 5 year ARI event. This storm event was analyzed as it is the peak flow that the channel capacity has been designed to meet. Note that Profile 13 was not included in the 'mean' calculations as it is part of the existing downstream open channel. Profile 12 has been considered important as it is the tie in point so it has been included.

Table 7: Summary comparing the mean value of each variable between each concept

Concept #	ARI Event (yr)	W.S. Elevation (m)	Hydraulic Depth Channel (m)	V Channel (m/s)	Q Channel (m^3/s)	Power Channel (N/m s)	Flow Area (m^2)
1	5	9.686	1.358	1.912	4.062	107.644	2.07
2	5	9.409	0.803	1.645	7.121	294.018	6.02
3	5	9.584	0.718	1.523	7.128	230.033	6.08

6.1 WATER SURFACE ELEVATION ANALYSIS

The water surface level is the most important indicator of flood risk between the concepts. The water surface elevation was lower in both Concept 2 and 3 in relation to Concept 1. As shown in Table 7, Concept 2 has a lower water surface than Concept 3 by 0.175m. This is a result of having a channel thalweg which is 0.23m lower on average (average channel RL Concept 2 = 8.209m, average channel RL Concept 3 = 8.439m).

The difference between surface levels for Concepts 1 and 3 is 0.102m which is an improvement. This appears more significant when you consider that the velocity in the stream has slowed down by 0.389m/s which would result in an increased water level for Concept 3 if the same Concept 1 variables were used. This is represented by the Rational Formula where $Q = vA$ (1). Velocity v (open channel) is found using Manning's equation: $v = \left(\frac{1}{n}\right) R^{\frac{2}{3}} s^{1/2}$ (2), where $R = \frac{A}{P}$ (3).

The lower water surface will result in a minimized flood risk and a reduced affect when levels breach the bank.

6.2 HYDRAULIC DEPTH ANALYSIS

Hydraulic depth of the channel is significantly lower in Concepts 2 and 3 compared to Concept 1. This change is a direct result of increasing the cross sectional areas of the channel which enables a decrease of 0.56m and 0.64m respectively.

Concept 3 has a shallower depth than Concept 2 by 0.085m. This is largely a consequence of having a marginally larger average cross sectional area of 6.08m^2 in relation to 6.02m^2 despite having a base channel width of 1.5m compared to 2m.

6.3 CHANNEL VELOCITY ANALYSIS

There is a significant channel velocity reduction between Concepts 1 and 3 of 0.389m/s. This is due to the naturalized channel design which reduces the velocity through the following ways:

- By increasing the length of the reach using meanders (increases Manning's roughness co-efficient 'n');

- Increasing surface roughness using in-stream structures, vegetation, and pools and riffles (increases Manning's roughness co-efficient 'n');
- Increasing the wetted perimeter of the channel by channel widening, and reducing the bank angles (increases hydraulic radius 'R').

Observing the velocity output for Concept 3 shown in Table 6 we can see a significant decrease through Profiles 7 to 11 which is a result of the channel flow area increasing from 5.8m^2 to 11.6m^2. However we see a significant velocity increase from 0.62m/s to 2.43m/s as the daylighted channel transitions into the existing channel. Over the short distance of 4.8m (between Profiles 11 and 12) this is an issue which needs to be addressed.

The lower velocities in Concept 3 will have the following positive effects:

- A reduction in flood risk downstream;
- A reduction in channel scour, erosion and bank undercutting;
- The creation of more favorable conditions for aquatic fauna and macrophytes;
- Greater contact between the surface water and ground water.

6.4 FLOW ANALYSIS

As per the design recommendations both Concept 2 and 3 have channels carrying an average flow of 7.12m^3/s and 7.13m^3/s during the 5yr return event. This translates to channels which are effectively carrying 99.7% of the peak flow.

Capacity of Concept 1 is exceeded across the full length of the reach, with an average channel flow capacity of only 4.06m^3/s (when modelled as an open channel). This translates to 3.09m^3/s of overland flow which is 43% of the total 5 year peak flow.

With a difference of 3.07m^3/s between the existing model and Concept 3 there is a highly significant reduction in overland flow. As shown by the difference between Figure 4 and Figure 6 a large reduction occurs on both the eastern and western floodplains.

6.5 CHANNEL POWER ANALYSIS

Bagnold (1966); states that "Stream power is the rate of energy dissipation against the bed and bank of a stream or river, per unit downstream". It is a function of density, gravity, flow, channel slope, and channel width ($\Omega = \rho g Q s \div \mathfrak{b}$) (4). Due to its energy dissipation on the stream channel it has an influence over sediment/bed load transport which causes aggradation if power is too low or incision if power is too high (United States Environmental Protection Agency, 2012).

The results show that the stream power increases by more than double for the concept designs, from 108Nm/s for Concept 1 to 230Nm/s for Concept 3. Because the slope has remained almost constant this is a result of an increased channel flow capacity between the concepts.

The increase in power will result in high energy dissipation against the streambanks and bed which will need to be protected from incision and erosion. The positive aspect is that this will mitigate channel aggradation, preventing elevation of the channel bed to maintain its greater volume.

7 WEIGHTED ATTRIBUTE CONCEPT SELECTION

The scoring matrix and selection method is based on (Eppinger, 2008) and certain attributes chosen from (Heijs & Young, 2012). The criteria cover environmental, social, cultural, and economic factors. These are the areas which are deemed to be positively influenced by the stream daylighting.

7.1 SELECTION CRITERIA ATTRIBUTES

Shown in Table 8 are the most important selection criteria. Each have been given a corresponding weighting (%) depending on its importance to the design success. Note that each of the four areas carries an equal weighting of 25% however the individual attributes vary.

Table 8: Selection criteria and their corresponding weightings

Code	Selection Attribute	Weighting (%)
E	**Ecological**	**25%**
E1	In-Stream Habitat Provision	7%
E2	Riparian Habitat Provision	6%
E3	Fish Spawning Habitat	6%
E4	Water Quality	6%
S	**Social**	**25%**
S1	Amenity of the area	6%
S2	Education Resource	4%
S3	Health and Safety	7%
S4	Community Involvement	4%
S5	Cultural Value	4%
D	**Design/Engineering**	**25%**
D1	Natural Flow Regime	6%
D2	Floodplain Effectiveness	3%
D4	Erosion Minimization	3%
D5	Construction Feasibility	7%
D6	Flood Risk Mitigation	6%
C	**Cost (Economic)**	**25%**
C1	Cost of Construction & Implementation	10%
C2	Maintenance Costs	5%
C3	Long Term Costs	10%

7.2 SCORING MATRIX

Each attribute has a corresponding score from 1 to 10, 1 being the lowest and 10 being the highest. This rating is multiplied by the assigned weighting (%) and then added together to give a total score out of 10 for each concept.

Table 9: Scoring matrix displaying the weighted attribute selection method results

		Concept 1 Existing Culvert		Concept 2 Straight riffle-pool		Concept 3 Naturalized-Meandering	
Code	**Weighting**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**
E1	7%	2	0.14	7	0.49	8	0.56
E2	6%	2	0.12	7	0.42	7	0.42
E3	6%	1	0.06	4	0.24	6	0.36
E4	6%	3	0.18	6	0.36	8	0.48
S1	6%	2	0.12	7	0.42	8	0.48
S2	4%	1	0.04	5	0.20	6	0.24
S3	7%	8	0.56	6	0.42	7	0.49
S4	4%	0	0.00	5	0.20	5	0.20
S5	4%	0	0.00	7	0.28	8	0.32
D1	6%	3	0.18	6	0.36	8	0.48
D2	3%	3	0.09	4	0.12	4	0.12
D4	3%	10	0.30	8	0.24	9	0.27
D5	7%	10	0.70	5	0.35	8	0.56
D6	6%	2	0.12	7	0.42	8	0.48
C1	10%	10	1.00	5	0.50	3	0.30
C2	5%	8	0.40	5	0.25	6	0.30
C3	10%	5	0.50	8	0.80	9	0.90
Total Score			**4.51**		**6.07**		**6.96**

As shown above in Table 9 Concept 3 was found to be the most suitable design with a score of 6.96/10.

8 CONCLUSIONS

Daylighting of streams invites the potential for many positive benefits. Three potential daylighting designs were developed for the Wairaka stream. It was found that the most suitable design was Concept 3, an 80m open channel reach which incorporated gentle meanders, low bank slopes, natural in-channel structures, and native plantings. These features will enable the design to remedy the current problem the site faces. Concept 3 was detailed through a plan drawing, longitudinal section drawing, and cross-sectional drawings to show its main features and benefits.

There are four distinct areas which the design will enhance:

- Environment - It will enhance the environment by providing a greater number and variety of habitats both within the stream and the riparian corridor;

- Social - It will create a place for staff and students to enjoy, and provide learning opportunities within the engineering and science departments;
- Culture – It will help restore the stream which is a culturally significant feature of Unitec. Native plants will be incorporated along with informational signs to bring the culture to people's attention;
- Economic – The project will reduce future costs of removing or maintain the existing culvert. The new channel will also increase the value of the surrounding land.

This project will generate campus and community interest which can only be beneficial to creating positive environmental change on campus.

ACKNOWLEDGEMENTS

Caleb Clarke, Dr. Martin Neale, Richard Smedley, Amos Sander, Mel Galbraith, Mark Lowe, David Poyner.

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APPENDIX

Appendix: Site layout plan highlighting significant features