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Use of hydraulic modelling to aid decision making in the management of Oakley Creek

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Abstract: This paper presents how a hydrodynamic Modelling study can be used to maximise the collective efforts from the stakeholders to enhance the protection of a riparian environment. A hydraulic model of a sensitive part of the Oakley Creek in Auckland, New Zealand, was developed to identify and assess the existing and possible future erosion, flooding and storm water related issues. The stakeholders' were involved in all the stages of the project.

Oakley Creek has a catchment area of 1220 ha comprising of predominately residential land on the Auckland Isthmus, and discharges into the Waitemata Harbour adjacent to the North Western motorway interchange at Waterview. The creek traverses the Auckland City areas of Mt Eden / Mt Roskill and Mt Albert / Avondale, that have jointly administered activities within the catchments. The creek has the highest waterfall within the Auckland city limits and is an important waterbody protected and cared for by the council, residents, visitors, and community groups alike. The stakeholders of the Oakley Creek the Unitec Institute of Technology (UIT), the residents and students living in the area, the Oakley Creek interest groups, the ARC (Auckland Regional Council), Metrowater, and the community boards in Avondale and Eden/Roskill. The outcome of the modelling study was to address the resource issues by pin-pointing to the areas to prioritise channel re-vegetation efforts by the parties that restore the creek channel, and prevent it from further erosion.

In the study presented in this paper, a detailed survey of 1km of the creek was undertaken to determine the size and shape of the cross sections. A hydrodynamic model based on these data was then developed using MIKE11 software. The purpose of this model of the downstream part of the Oakley creek was to identify locations of excessive velocity along the channel where enhanced restorative solutions could be applied to mitigate the impact of further erosion. The developed model was initially calibrated for modest to high flow conditions. Simulations for extreme flow conditions then followed to highlight stretches of the creek where erosion was likely to remove significant volumes of the river bank, alluvial flood plane or even adjacent reserves.

The paper describes the appropriate treatment methods for each location varying from protecting the stability of adjacent slopes using planting of vegetation in areas of concern, to placement of gabion baskets to protect the actual creek bank itself. The most valuable outcome of the study was that the model results assisted the stakeholders determine where to focus the limited resources so that they targeted vulnerable areas identified to be at most risk from erosion in extreme weather conditions. The paper shows the restorative work carried out by the stakeholders in response to the predicted flow characteristics resulting from simulations under an extreme storm event.

***Keywords**:* MIKE11 modelling; Channel erosion; River basin management by stakeholders

1. INTRODUCTION

The relative ease of adapting Hydraulic modelling software to the wide range of conditions that prevail in river systems has made it a popular tool in river management. Recent examples of where such software has met the specific needs of river management are in flood forecasting (Marker, et al., 2004), optimisation of flooding systems (Monninkhoff and Li, 2009), estimation of sediment loads (Azmera et a., 2008), preparation of flood extent maps (Wallace, 2006), and the assessment of effects of wetland modifications on wetland loss and degradation (Thompson et al., 2004). The study presented in this paper is an attempt to use a hydrologic/hydraulic model of a medium-sized creek in Auckland in New Zealand, to assist the stakeholders associated with the wellbeing of the creek, to effectively control stream erosion.

1.1 The case study area

Oakley Creek is also known as Te Auaunga, which was the original name given to it by the Maori, the indigenous people of New Zealand. It drains a catchment of 1220ha in the western Auckland isthmus, between its headwaters in Mount Roskill and its outlet into the Waitamata harbour, having passed beneath the Great North Road and North Western Motorway freeway in its lower reaches. The elongated shape of the catchment gives rise to approximately 12km of open watercourse (ACC, 1991). The figures 1 and 2 below show side-by-side the layout of the catchment and the start and end points of the part of the stream that was modelled in this study.

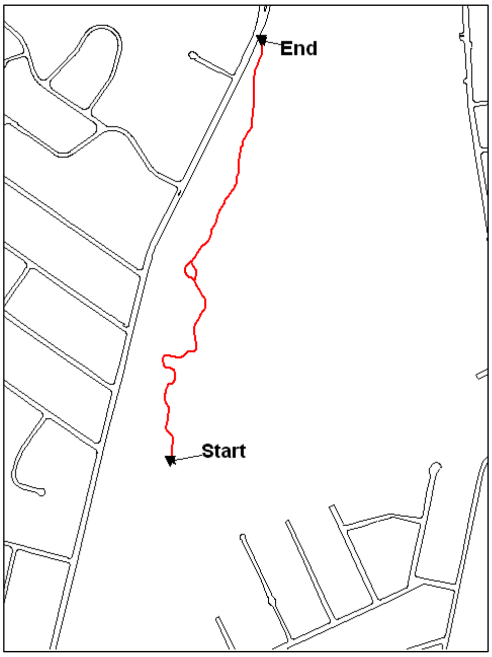

Figure 1: The location of the modelled creek

Figure 2: Aerial view of the catchment

The creek and its surrounding areas have an extensive history of use and occupation by local Maori groups. Activities included residential and defensive developments, extensive cultivations, bird trapping, harakeke and shellfish harvesting, wakato passages and fishing. Maori settlement and use in the area continued up until the 1860s. The creek holds historical and ecological value; however this is threatened by a number of factors. Some of these threats include the environmental and storm water run off contamination (Green, 2004). Today, the main land use of this catchment is residential and recreational. The Unitec Institute of Technology (UIT) campus of 6000ha is established on the downstream part of its right bank. There are some business developments further upstream of the catchment. The downstream part of the stream is very clean for an urban stream and is well-cared for by volunteer organisations such as Friends of Oakley. The creek is of high recreational value for the residents in the area with a well-frequented walkway on its right bank, and a sizeable waterfall, which is the largest of its kind within the limits of the Auckland City Council. Various educational and volunteer projects take place to clean the stream bed and its vicinity, to study the riparian ecosystems, and to re-vegetate the stream banks. The health of the stream, stability of its banks, and general sustainability of the stream is of utmost importance to the main stakeholders associated with the stream. They are the Unitec Institute of Technology, residents and students living in the area, the Oakley Creek interest groups, the ARC (Auckland Regional Council), which has this creek in its jurisdiction, Metrowater, a local authority responsible for stormwater and flood water management in the area, and the community boards in Avondale and Mt. Eden/Roskill, who are also responsible for its upkeep. The effectiveness of the voluntary group Friends of Oakley Creek (FOAK), in particular, is evident by its winning the ARC Sustainable Urban Communities Environmental Award in 2007.

This modelling project was undertaken as a final year project of a three year undergraduate B.Eng. Tech (Civil) programme. The main objective of modelling a 1km length of the creek prior to it entry to the estuary was to a) identify the location of areas of high velocity and erosion- prone stretches, and (b) gauge the extent of flooding in the main watercourse. Thereafter suitable mitigation measures were to be brought to the attention of the stakeholders via a series of regular meetings of the community groups to both inform and acquire feedback.

1.2 Characteristics of the stream

The Oakley Catchment discharges into the upper Waitemata Harbour with approximately 500m of the downstream end of the creek being tidally affected. The tidal variations in the Waitemata harbour are presented in Table 1. The highest recorded tide is RL 2.25m recorded on 26 March 1936.

Table 1 : Tidal characteristics (DOSLi Auckland Datum 1946)

Tide	Level RL (m)
Mean high water Springs	1.40
Mean high water	1.31
Mean high water Neaps	1.12
Mean sea Level	0.00
Mean Low water Neaps	-0.92
Mean low water	-1.10
Mean Low water springs	-1.34

The tide levels induce flooding in the Oakley Creek mainly in the open space zone adjacent to Great North Road. Frequent inundation is experienced in this part during the rainy season particularly when the high flows in the creek coincide with high tides in the harbour (Figure 3).

Figure 3: Inundation in lower Oakley Creek combined with high tide

1.3 Stream erosion

Streams are constantly in a dynamic equilibrium with their primary components – water, sediment, energy and vegetation. Channel scouring, exacerbated by excessive flow velocity, is the major cause for stream bed degradation. This perennial creek is susceptible to erosion thus necessitating an ongoing programme by stakeholders to re-vegetate the banks to mitigate the damage. The simple hydraulic model of the stream was expected to help in intensifying and optimising the riparian re-vegetation by more correctly focusing in high risk areas highlighted by the model. Following discussions with the representative of the community group, it was decided to develop the model to simulate the creek downstream of the waterfall, approximately for 1 km length, where the stream was anecdotally known to experience high velocities.

2. HYDRAULIC MODEL OF OAKLEY CREEK

The hydraulic model was developed using the 2007 version of the MIKE11 software (DHI, 2007).

2.1 Data

A site survey was undertaken to gather the cross section data with measurements taken at intervals sufficient to incorporate the significant changes in cross section and creek bed invert. The aerial and contour maps of the area were used to digitise a plan view of the river network, with dimensions of the concrete culvert beneath the motorway measured at site.

Observed stream flow data were sourced from Metrowater. The flow was recorded at 5 min intervals at the upstream end of the creek for a period of approximately six months (25/07/2002 to 31/01/2003). The observations contain medium to high flow events and the corresponding water levels at a footbridge across the creek were available for coarse calibration/validation of the model.

2.2 The model

Network and cross sections: The model consisted of four branches, the creek being the main one. Two short tributaries that drained two small watersheds in the vicinity of UIT, and a bifurcation that rejoins the creek forming a small island, constitute the other three branches. Table 2 summarises some modelled network parameters while Figure 4 displays a schematic of the plan view of the network.

Table 2 : Modelled network parameters.

Branch name	Length (m)	Number of points	Number of cross sections
Oakley Creek	1080	105	45
Oakley Branch	40	9	2
Unitec drain	30	2	2
Unitec catchment	45	5	2

Hydrodynamic parameters: The only calibration parameter of this simple model was the Manning’s n value. The water levels observed at a foot bridge for a few of the high-flow events were used to tuning the suitable Manning’s n which was finally set at 0.024 for the natural channels.

The higher-order fully-dynamic wave solution which includes all the terms – momentum flux, pressure force, friction force, and gravity - in its conservation of momentum equation, was sought. This solution scheme was deemed most appropriate because it accurately represents fast transients, tidal flows, rapidly changing backwater effects, flood waves, and steep channels all of which this creek exhibits.

Boundary Conditions: There are three flow and one tidal boundary conditions in this model. For the inflow boundary condition at the upstream end of the creek, observed flow in the creek was used (Figure 5). For the two short laterals, steady inflow values of 14.5 L/s and 3.5 L/s respectively were applied. Inflows from the laterals are insignificant, however, the values used were based on relatively high flow rates measured using a current meter at these locations.

Cyclic tidal variations were not imposed at the downstream boundary. Instead, a more reasonable constant water level of 1.12m, equivalent to a high neap tide, was applied to replicate the realistic and frequent scenario of a high flow coinciding with a high tide.

Model Simulation: Calibration meant verifying the water level at the footbridge to be approximately correct for the high-flow event of 14th August 2002. Model simulation was then continued for the entire period from 25/07/2002 10:50:00 a.m. to 31/01/2003 11:50:00 p.m. A short simulation time step of 10sec was used; simulation results were recorded at hourly intervals. Apart from the conventional outputs of water level and discharge, additional output of flow velocity was specified for this simulation.

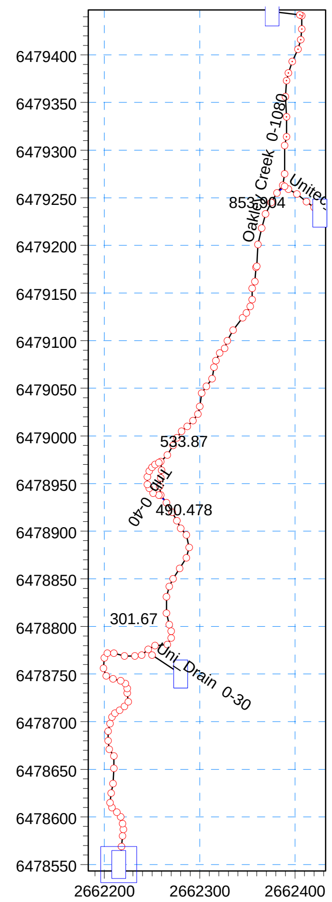

Figure 4: Schematic of the modelled network

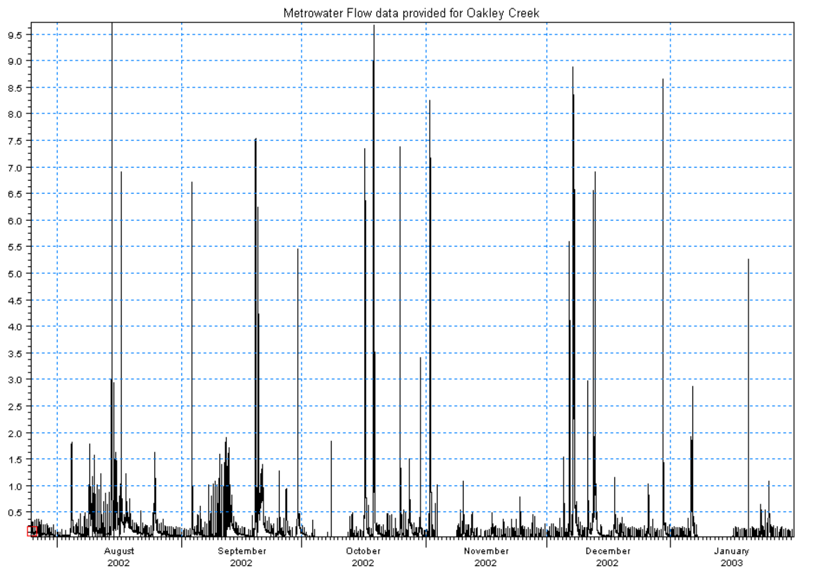

Figure 5: Measured inflow at upstream end of Oakley Creek in m³/s

2.3 Model simulation results

Figure 6 shows a longitudinal section of the downstream-most 580m of the creek at the highest water level experienced. The solid and the dotted lines at the top of the long section are the top edges of the left- and right-banks respectively. High water levels rise almost up to the channel bank-tops, and over-top the banks at a few locations. The abrupt drop in the water level observed at the downstream end represents the culvert restriction.

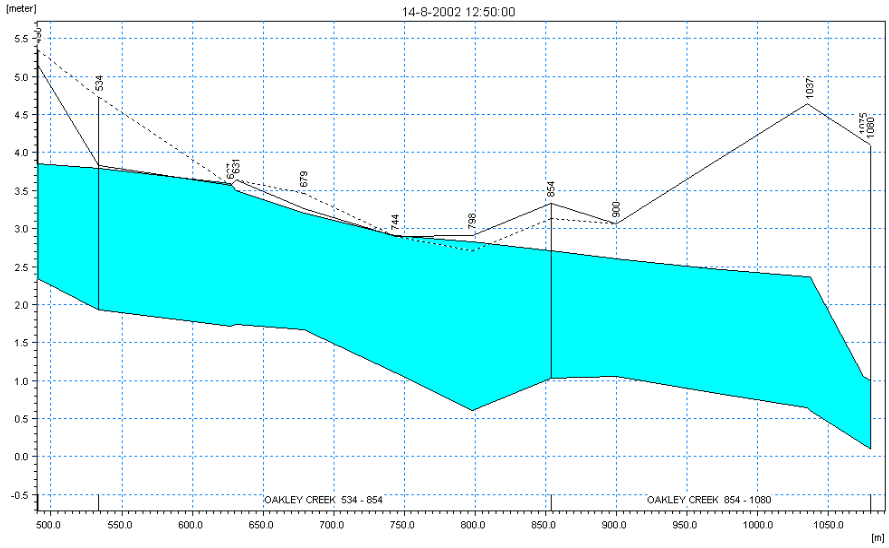

Figure 6: Longitudinal section of the downstream end of the creek.

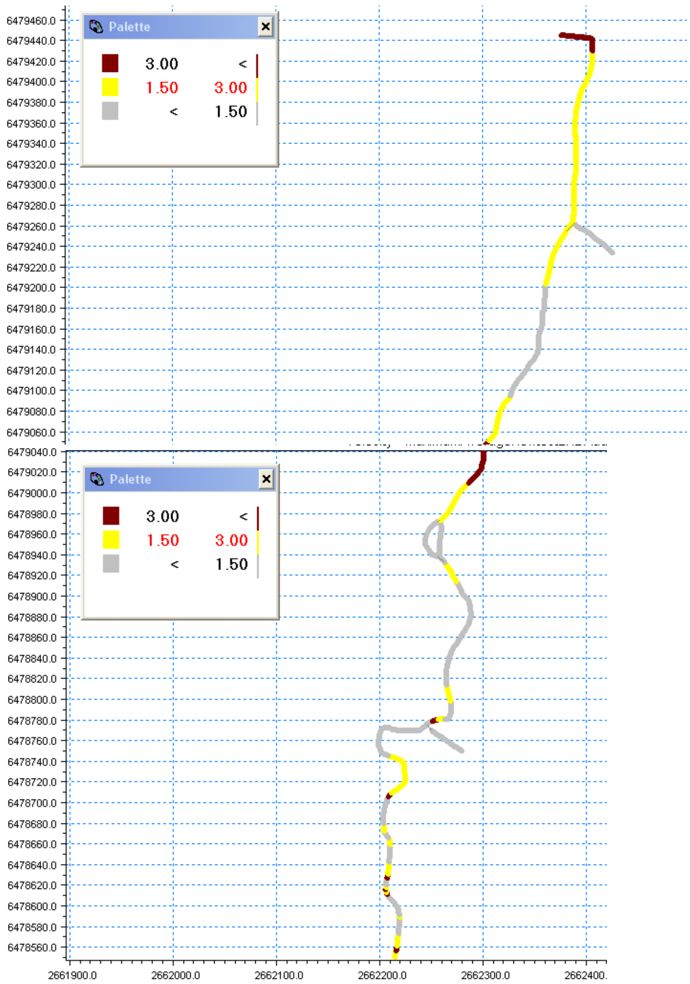

Figure 7: Maximum velocity (in m/s) distribution in the creek

Figure 7 shows a plan view of the modelled network with the variation of the maximum velocity along the creek. There are several segments of the stream where a velocity of 1.5m/s, a value considered high for the soil type, is exceeded; moreover, there are some limited sections where the velocity exceeds 3m/s. Some of these locations confirm the physical observations made during the numerous site walks prior to modelling. They have also been identified and earmarked for shrub planting and re-vegetation. Table 3 summarises the cross sections of the stream where the average velocity exceeds 1.5m/s.

Table 3: Locations of relatively high velocity

Chainage (m)	Velocity (m/s)	Chainage (m)	Velocity (m/s)	Chainage (m)	Velocity (m/s)
490.48	1.7	679	2.5	967.5	1.6
533.87	1.7	711.5	1.5	1001.25	1.6
580.5	2.4	825.95	1.6	1035	1.5
627	4	853.9	1.7	1036	1.5
629	3.1	876.95	1.7	1037	1.5
631	2.6	900	1.8	1040	3.4
655	2.5	933.75	1.7		

3. OUTCOMES OF THE PROJECT AND LIMITATIONS

3.1 Benefit to stakeholders from model outcomes

The hydraulic modelling results clearly demonstrated that there are significant parts of the stream that exceed an area-averaged velocity of 1.5m/s during high flow events. These were identified to be the vulnerable parts of the channel prone to erosion. The project was based on a participatory approach where the stakeholders were informed of the progress as well as being given an opportunity to give input and feedback on the interim results. Several site walkovers by all parties ensured that the model outcomes were in line with the ground truth. The final outcomes of the model simulations, i.e., identified vulnerable stretches of the creek, were communicated to the stakeholders for collective decision making regarding resourcing to intensify and/or prioritise re-vegetation and shrub planting programmes. The riparian vegetation has remarkable capacity to resist the forces generated by high velocity and reduce bank erosion and has been used in the past on these banks. Using results from the model and ground truth, several remedial measures, as summarised in Table 4, were proposed for each location.

Planting in Oakley Creek banks is carried out subject to ecosourcing concepts. Ecosourcing is the use of native plants to safeguard the genetic diversity within the local populations of native plants. The ARC's guidelines explain how to restore streamsides and which plants to use on the streambanks (ARC, 2001). Such practices have resulted in remarkable improvement to the riparian environment not only by protecting the streambanks from degradation but also by re-establishing the diversity of plants. This, in turn, has led to the regeneration of bird and fish life in the ecosystem.

Table 4: Proposed mitigation measures for locations identified as having erosion potential

Chainage (m)	Type of erosion and condition of the channel	Recommended remedial measure(s)
<460	Normal, erosion not excessive, some flooding expected	Do nothing
465-490	There is no visual erosion seen on the location, but exposed for future erosion	Re-vegetation
533-580	Some visible erosion, further erosion expected	Planting
580-640	Channel and rill erosion; can become worse with high velocities	Prioritise planting
640-714	Some erosion visible; vulnerable to further erosion, some flooding expected	Planting and possible channel stabilisation
795 – 1034	Gully and channel erosion observed; damaged existing vegetation,	Slope protection, planting, Gabion sack
900	Existing structure (pipe) threatened, some flooding expected	Channel protection construction

3.2 Reflections on participation of stakeholders in the project

The model outcomes were helpful in taking a collective decision to prioritise the recommendations. Planting of trees and shrubs in the vulnerable areas (Figure 8) was the most effective and low-cost option that has continued. However, with the knowledge of the erosion-prone areas, it has become easier to focus the limited resources and efforts in an optimum manner to enhance the maximum long term protection of the creek.

Figure 8: Re-vegetation of creek side-slopes (a co-author and volunteers from the community groups are in the picture)

3.3 Limitations of the study

Some of the limitations of this project are due to the one-dimensionality of the stream network model. The area averaged velocities indicate only the high longitudinal velocities. Observations however reveal that there are several locations with degradation caused by high lateral velocities combined with rill and gully erosion; these erosion mechanisms cannot be simulated with a simple model such as this.

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