CONTINUOUS SIMULATION MODELLING TO QUANTIFY STREAM EROSION AT CATCHMENT SCALE

A. Hay (Beca Ltd), H. Smith (Beca Ltd)

ABSTRACT

Housing intensification presents several significant challenges to the health of our urban waterways. If not appropriately managed, housing developments can lead to: degradation of the water quality, ecological health and cultural values of urban streams; reduced community amenity value; and increased flood risk to people and property. Of particular concern is changes in the hydrological characteristics of urban catchments due to intensification and impacts on bank erosion, sediment movement and channel morphology in urban streams. Quantifying the effects of future development, to design and consent appropriate mitigation methods is key.

Porirua Development is a partnership between Kāinga Ora, Porirua City Council and Ngāti Toa to replace 2,000 existing homes with approximately 3,800 new homes over a 20–25 year period within the Kenepuru Stream catchment. Te Aranga Alliance is delivering some of the enabling and civil works for Porirua Development. The Kenepuru Stream is already subject to substantial erosion, and increased urban development has the potential to exacerbate this, if not appropriately mitigated.

Building on existing assessment approaches alongside a coupled hydrological and hydraulic model, the potential effect of this urban development on stream erosion was assessed. The developed method was used to quantify the effect of urban development on Kenepuru Stream erosion and assess proposed mitigation methods.

Methodology included: establishing representative critical reaches of the stream throughout the catchment, by reviewing geology, ground conditions and existing erosion; Identifying the threshold velocities / shear stresses at which erosion will begin in the critical reaches; Long time series / continuous simulation hydrological and hydraulic modelling, running 10 years of historic rainfall data, to consider the effects of development on Kenepuru Stream erosion and study the relationship between stream hydrology, hydraulics and erosion; and modelling and selection of proposed solutions to mitigate the effects.

KEYWORDS

Erosion, water quality, hydraulic modelling, hydrology, detention

PRESENTER PROFILE

Andrew is a Civil Engineer at Beca Ltd. He has twelve years' experience in civil infrastructure design working in both the public and private sectors. Experience includes stormwater and wastewater conveyance, stormwater treatment, river engineering, airfield and highway drainage, and land development civil design.

Haddon is an Environmental Engineer at Beca Ltd. His focus has been on hydraulic modelling across three waters; using models to gain understanding of our water systems, the risks and opportunities they present and planning infrastructure to best serve communities and the environment.

1 INTRODUCTION

Housing intensification presents several significant challenges to the health of our urban waterways. If not appropriately managed, housing developments can lead to: degradation of the water quality, ecological health and cultural values of urban streams; reduced community amenity value; and increased flood risk to people and property. Of particular concern is changes in the hydrological characteristics of urban catchments due to intensification and the impact these changes have on bank erosion, sediment movement and channel morphology in urban streams. Quantifying the effects of future development to design and consent appropriate mitigation methods is key.

Building on existing assessment approaches, alongside a coupled hydrological and hydraulic model, a tool has been developed to inform evidence-based decisions regarding appropriate mitigation methods with regards to effects on streambank erosion. The developed method was used to quantify the effect of urban development on Kenepuru Stream erosion and assess proposed mitigation methods.

2 BACKGROUND

Porirua Development is a partnership between Kāinga Ora, Porirua City Council and Ngāti Toa to replace 2,000 existing homes with approximately 3,800 new homes over a 20–25 year period. These existing lots have been split into individual development sites ranging from single "quarter acre" lots to superlots of up to 3 ha in size. These lots are scattered throughout an urbanized catchment that flows to Kenepuru Stream. Figure 1 shows the extent of the development (pink boundary) which has been split into neighbourhoods (black boundaries). Kenepuru Stream runs along the northern boundary of the development (blue line).

Figure 1: Eastern Porirua Precinct (pink) and Neighbourhoods (black)

Te Aranga Alliance is delivering some of the enabling and civil works for Porirua Development. As part of the development project, Te Aranga Alliance is preparing Stormwater Management Plans, to inform stormwater upgrades and mitigation required to address existing issues and support development. In parallel, Wellington Water is in the process of preparing an overarching Stormwater Management Strategy as part of the renewal of their global stormwater consent. Although the Strategy is not yet finalized, Te Aranga Alliance has worked with Wellington Water to align the Stormwater Management Plans with the outcomes expected by the Strategy. Part of this management plan is a study into the effect of the development in the Cannons Creek East neighbourhoods (combined to form a study area) on erosion in Kenepuru Stream.

3 METHODOLOGY FOR ASSESSMENT

The following methodology was used to quantify the effect of urban development on Kenepuru Stream erosion and to use as a tool to assess the performance of proposed mitigation methods:

- Establish representative critical reaches of the stream throughout the catchment, through a multi-disciplinary team (geologist, geomorphologist, stormwater engineers) reviewing geology, ground conditions and existing erosion;
- Identify the threshold velocities / shear stresses at which erosion will begin in the critical reaches;
- Carry out long time series / continuous simulation hydrological and hydraulic modelling to understand the effects of development on Kenepuru Stream erosion. The hydrological model utilizes InfoWorks ICM's hydrological methods to represent runoff from pervious and impervious surfaces, medium-response rainfall derived inflows from soil and seasonal variation in groundwater-derived base flows. The hydraulic model used for the assessment is a 1D river model representing the Kenepuru Stream and key hydraulic features such as existing wetlands and lakes.
- Running 10-years of historical flow data under current and future land-use through the model and using the results to study the relationship between stream hydrology, hydraulics, and erosion.
- Modelling various hydrological mitigation options to understand the effect of these on potential stream erosion.
- Selection of preferred hydrological mitigation based on model outputs.

Instead of applying a catchment wide rule to hydrological mitigation that would be applied across all development sites, this methodology was developed as a tool to inform "evidence-based" decisions regarding appropriate mitigation methods with regards to effects on streambank erosion.

4 KENEPURU STREAM

4.1 CATCHMENT

The Kenepuru Stream has a catchment of approximately 1,300 ha and joins Porirua Stream approximately 500 m upstream of where Porirua Stream discharges into Porirua Harbour. The lower 300 m of the stream is tidally influenced. The catchment is a steep hill catchment with the highest point being Cannons Head (390 m above sea level) and the lowest reaches being at sea level.

The change in land use proposed by the developments in Cannons Creek East is proposed to increase the impervious area by 3.2%, see Table 1.

Table 1: Land use change in Cannons Creek East Study Area

	Pervious Area	Impervious Area
Existing	81.2%	18.8%
Future	80.6%	19.4%

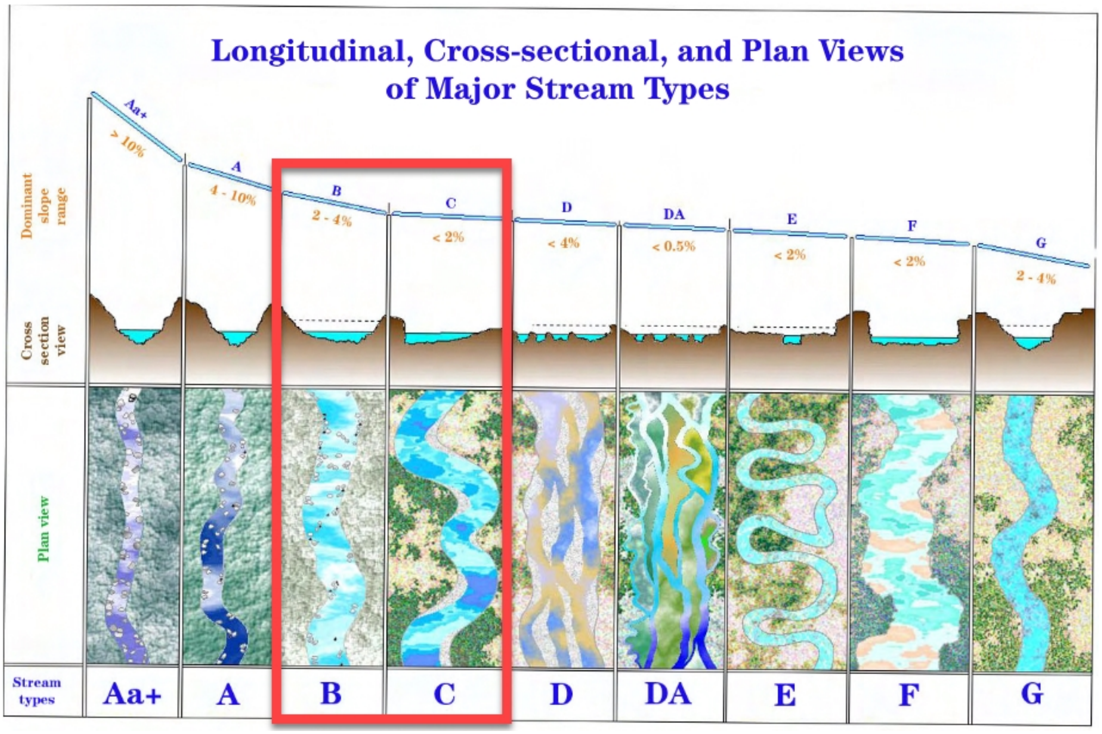
4.2 REPRESENTATIVE LOCATIONS FOR EROSION

The stream is currently eroding in the lower reaches where the bank material is finer. In the upper reaches where bedrock is much shallower, the form and magnitude of the erosion is different. For the purpose of understanding the erosion in Kenepuru Stream five locations along the stream were selected as representative locations of erosion risk by a multi-disciplinary team including a geomorphologist, engineering geologist, stormwater engineers and an environmental engineer. The selected locations were:

- Representative of vulnerable erosion along the Kenepuru Stream (typically where erosion was already evident), and
- Where it was considered that the modelling would give representative results (i.e. where the stream section is relatively uniform, rather than highly variable).

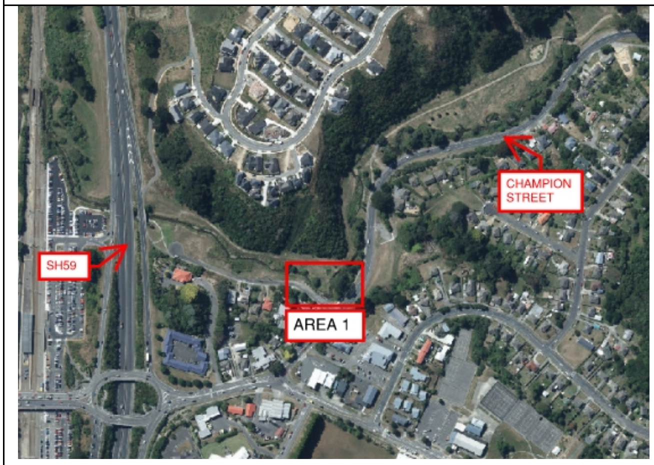
The locations do not necessarily reflect every location where erosion is occurring but are representative of the sections of Kenepuru Stream that are at risk from erosion. These were taken from the reaches that can be broadly categorized as stream types B and C according to Rosgen's method, see Figure 2.

Figure 2: Broad Level Stream Classification (United States Department of Agriculture, 2007)



The selected reaches can be found below in Table 2.

Table 2: Representative Reaches for Erosion

Reach Location	Reach Photo
	
	
	

<table>
<tr><th>Reach Location</th><th>Reach Photo</th></tr>
<tr><td>
</td><td></td></tr>
<tr><td>
</td><td></td></tr>
</table>

Results from Area 4 will form the main basis for the discussion in this paper, as this reach is immediately downstream of the proposed wetland in Cannons Creek Park.

4.3 THRESHOLD VELOCITIES

4.3.1 SHEAR STRESS METHOD

At Area 4 the stream bank appears to be comprised of track formation fill (comprised of fine to coarse gravel), overlying silt with trace to minor amounts of gravel. Slightly downstream, gravel lenses were observed interbedded in the silt layer near the stream bed. The material varies over a short distance, as is typical of the alluvial and fill nature of the material. Where exposed, the silty gravel is non-plastic, but the silty matrix may have some degree of cohesion. The presence of gravel may provide some armouring in the bed but not in the streambank.

For a cohesionless material of particle size 0.01mm – 0.1mm (silty sand) Chow from USSR Data (Elliot, et al., 2004) gives a threshold velocity range of 0.15m/s to 0.25m/s. This range was used for the threshold velocity at Area 4.

The threshold velocity range was "sense checked" using a combination of the Manning and Strickler equations and Shields parameter (Melville and Coleman, 2000), see equation 1.

(1)

Flow depth (y) was taken as 0.3m. This is the normal flow depth as surveyed on site.

A mean particle size (d_{50}) of 0.1mm was used. This was considered a sensible lower limit for where a material is governed primarily by gravitational force. This is considered conservative as smaller particle size begins to increase the threshold velocity for erosion due to the presence of interparticle connectivity. The calculation of critical velocity from equation 1 is more sensitive to particle size than flow depth.

Threshold velocity using equation 1 was 0.2m/s. This is within the range from Chow.

The threshold velocity was used as a general guide to evaluate incipient motion conditions for the given sediment size. The tool is a relative assessment, rather than an absolute one, with scenarios with different hydrology being compared against each other. The modelled results will give a velocity averaged across a cross section, whereas in reality, the velocity varies across the same cross section. The velocity also varies between sections, around bend and along straights.

In the baseline scenario, the stream velocities exceeded the threshold velocity lower bound at Location 4 less than 5% of the time.

4.3.2 ALTERNATIVE METHODOLOGIES FOR EROSION POTENTIAL

Determination of shear stress for the assessment of erosion potential seems to be most direct and robust method (Fassman-Beck, Voyde and Liao, 2013). The other alternative that was considered is the stream power method. The stream power method does not have the ability to account for cohesion (Irvine, et al., 2019). While the soils in the Kenepuru Stream do have some degree of cohesion, stream power method could have been a viable alternative. Shear stress was selected as the preferred methodology as a simple method that took into consideration site specific geology and was compatible with the relative velocity duration outputs of the continuous simulation model.

5 HYDROLOGICAL MITIGATION

The draft Stormwater Strategy prepared by Wellington Water identifies retention tanks as a potential solution for erosion, and Greater Wellington Regional Council often requests developers install retention tanks to mitigate the effects on erosion. While retention tanks can provide other benefits such as reduced consumption of potable water, they also come at a cost to install and maintain. Given that maintenance becomes the responsibility of the homeowner, there is a risk that they won’t be maintained, and they therefore become ineffective at managing stormwater volume over time. For these reasons, a centralised solution of a wetland with extended detention is preferred in Cannons Creek East, however there is currently no basis on which to assess the performance of the wetland (or other alternative options) against retention tanks with respect to the effects on erosion in Kenepuru Stream.

The models that have been developed allow a catchment-specific assessment to be made of the performance of different mitigation measures to allow an informed decision to be made.

5.1 RAINWATER RETENTION TANKS

The design parameters of rainwater retention tanks that have the most significant impact on the erosion reduction are the following:

- Tank volume: the maximum amount of roof runoff that can be stored for reuse;
- Connected roof area: to increase the volume of stormwater captured; and

- The demand extracted from the tank: Full tanks provide no benefit during rainfall events.

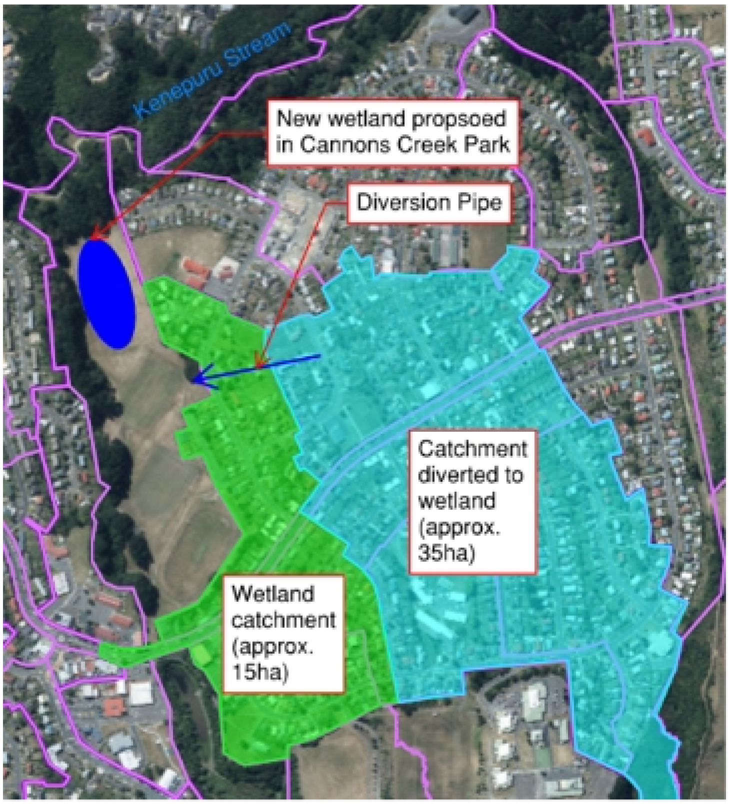
Three rainwater tank scenarios were modelled. The key parameters used in these scenarios were:

- 2 m^3 tanks on 50% of future state houses, none on market lots. Toilet demand only. This reflects a realistically achievable solution on state lots, i.e., those within Kāinga Ora control. The application of tanks to only 50% of houses reflects the fact that many existing state houses may only be refurbished, rather than fully redeveloped, and many other superlots would not exceed 3,000 m^2, and therefore would not trigger the need for a discharge consent under the Proposed Natural Resources Plan.
- 2 m^3 tanks on 100% of future state houses, none on market lots. Toilet demand only. This reflects an upper bound of what is achievable on state lots and includes tanks on houses that would not actually trigger a requirement for mitigation under planning rules (e.g., refurbished houses or superlots <3,000 m^2). This scenario is provided as a sensitivity test.
- 5m^3 tanks on 100% of future state houses and 100% of future market houses. Toilet demand only on state houses, toilet, and laundry on market houses. This is not realistically achievable but provides an absolute upper bound as a sensitivity test.

5.2 CANNONS CREEK WETLAND – EXTENDED DETENTION AND ATTENUATION

A wetland is proposed in Cannons Creek Park. In order to maximise the performance of the wetland, a new stormwater pipe was constructed in 2021 which diverts 35 ha of catchment into Cannons Creek Park and therefore into the future wetland, see Figure 3.

Figure 3: Proposed Wetland Catchment



The proposed wetland is comprised of three zones:

- Permanent wet area – the level of the water that permanently sits in the wetland.
- Extended detention – a depth / volume that is designed to drain down over 24 hours following rainfall events.
- Attenuation – further volume above the extended detention for attenuating the peak discharge in larger storm events (>50% AEP).

The volume of extended detention is the parameter that will have the most impact on the erosion in Kenepuru Stream, i.e. to address the increased runoff volume from greater impervious area in more frequent events. The permanent wet area was excluded from the model for the purposes of LTS modelling and the attenuation is only utilised in the larger storm events.

5.3 DEVICE COMPARISON

These two mitigation methods have different advantage and disadvantages, see Table 3:

Table 3: Hydrological Mitigation Device Comparison

Device	Advantages	Disadvantages
Rain tanks	Can be located on a lot-by-lot basis. Plenty of supply options for space efficient solutions. Can reduce demand on water supply by reusing rainwater.	Decentralised, therefore maintained by private entities, so a higher probability of not operating as designed over time. Requires separate plumbing into non-potable uses. Storage volume available based on use within dwellings. Could be up to a week before volume is available again. Doesn't recharge groundwater. Only collects runoff from roofs, not from roads or paved surfaces.
Extended detention	Centralised, therefore maintained by local authority, so lower probability of not operating as designed. Volume available within 24 hours of a rainfall event. Can be planned for and funded through developer contributions. Collects runoff from all impervious areas, i.e. all roofs, driveways and roads.	Following rainfall events when runoff is released, it increases the baseflow in the receiving environment, which still has some potential to exacerbate erosion. Requires agreement with the local authority for it to be adopted by them as an asset. Can require large open spaces or expensive underground tanks. Doesn't recharge groundwater.

6 CONTINUOUS SIMULATION MODELLING

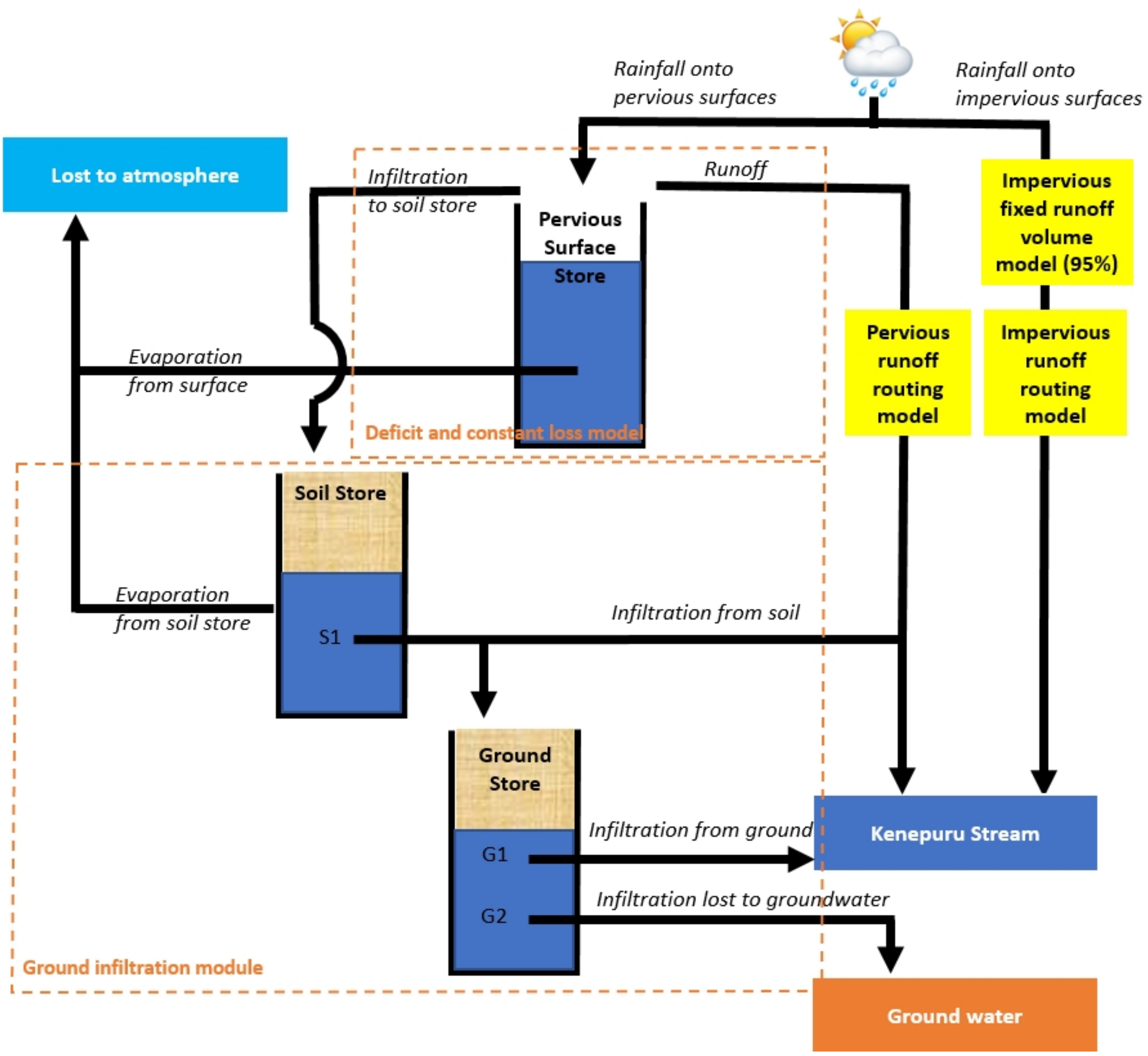
6.1 MODEL OVERVIEW

A coupled hydrological-hydraulic model was created for the erosion analysis in InfoWorks ICM (version 11.0). This model will be described hereafter as the *Erosion Risk Model.* It is made up of:

- A hydrological (rainfall-runoff transformation) sub-model which calculates flows from the sub catchments into the hydraulic model. ICM's hydrological methods were used to represent pervious & impervious runoff as well as soil and ground water infiltration. Separate model sub catchments were included for pervious and impervious surfaces.
- A 1D hydraulic sub-model that simulates Kenepuru Stream flows for 10 years of historical rainfall data (current climate). The 1D model was created using true sections surveyed on site for the critical reaches and 2013 LIDAR for the rest of the stream.

A schematic of the hydrological sub-model is shown in Figure 4.

Figure 4: Schematic of the hydrological model



6.2 MODEL CALIBRATION / VALIDATION

Model outputs were calibrated/validated using flow gauging data from the Kenepuru Stream as well as outputs from existing models from the National Institute of Water and Atmospheric Research (NIWA) and Wellington Water.

6.2.1 HYDROLOGICAL MODEL CALIBRATION / VALIDATION

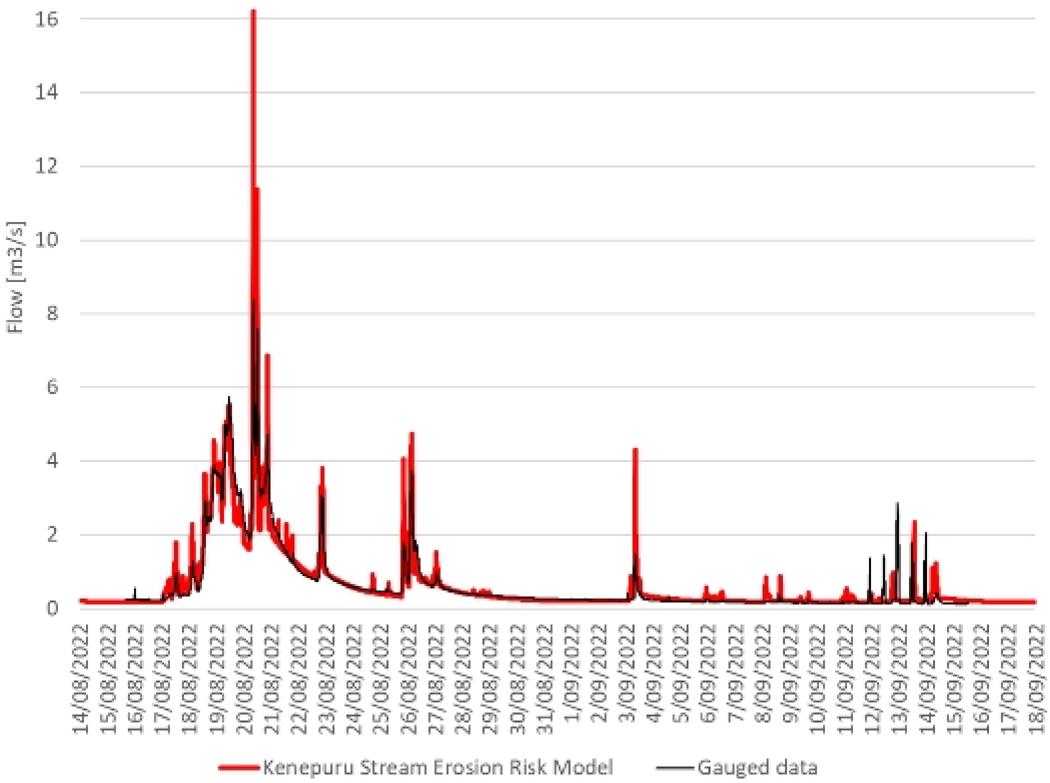
Four data sources were used to calibrate the hydrology:

- Flow gauging data;
- NIWA's NZ River Maps flow percentiles (taken from shiny.niwa.co.nz/nzrivermaps/);
- Wellington Water's InfoWorks ICM flood risk model; and
- NIWA's New Zealand River Flood Statistics website (https://data-niwa.opendata.arcgis.com/apps/new-zealand-river-flood-statistics-app/explore).

FLOW GAUGING DATA:
Flow gauging at several sites along the Kenepuru Stream was conducted in late winter and spring of 2022. At the SH59 bridge (downstream boundary of the model) a level recorder was installed on 15 August 2022, with level measurements used alongside six rating measurements to develop a draft rating curve. Flow measurements were also taken at a number of sites along the stream to assess the accumulation of flow from different sub-catchments. This flow gauging data was used to calibrate the hydrological sub-model of the Erosion Risk Model.

Post calibration modelled flows are shown to provide a reasonable match to rated flows, see Figure 5. The key flow metric relevant to the erosion analysis presented in this paper is the proportion of the time flows are in the range of around 1-10 m^3/s, as these medium-high flow periods are the primary cause of erosion.

Figure 5: Model flow vs. gauged flow data over the model calibration period



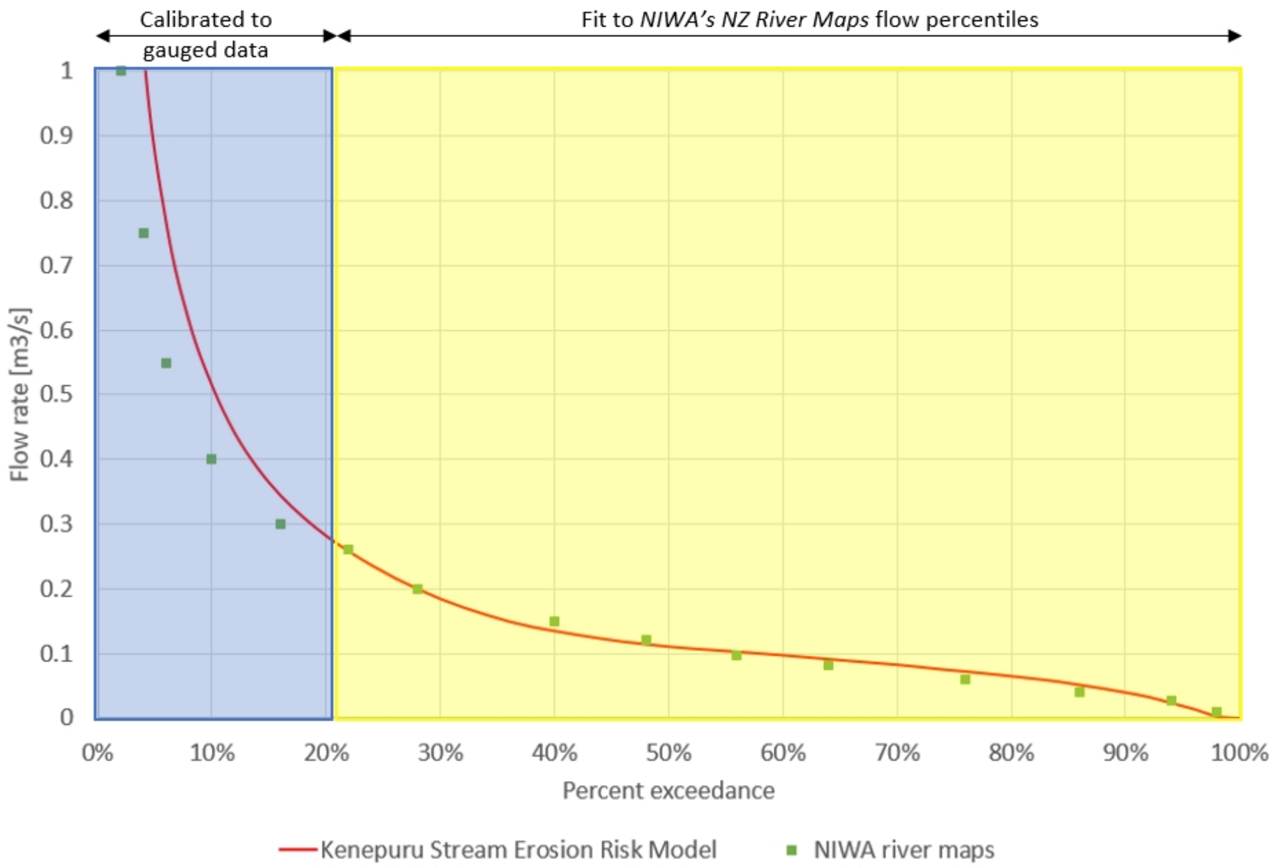
NIWA'S NZ RIVER MAPS FLOW PERCENTILES:
NIWA's data is standardised, regionalised data based on simplified assumptions. A flow duration curve was created using these percentiles and used to fit the low flows (>20% exceedance) of the Erosion Risk Model. The Infoworks ICM Ground Infiltration Module (GIM) is used to calculate the 'low flows', made up of medium-response rainfall derived inflows from soil, and seasonal variation in groundwater-derived base flows. Changes were also made to the GIM parameters when calibrating the model to the gauge data. The resulting parameters are given in Table 4; parameters adjusted during calibration are highlighted orange, with other left at assumed values.

Table 4: Ground infiltration module parameters

Component	Parameter	Value
Soil store	Soil depth (m)	1
	Percolation coefficient (days)	1.5
	Percolation threshold (%)	50
	Percolation percentage infiltrating (%)	30
	Porosity of soil (%)	20
	Evapotranspiration type	Linear
	Evapotranspiration depth (m)	1
Ground store	Porosity of ground (%)	20
	Baseflow coefficient (days)	100
	Infiltration coefficient (days)	150
	Baseflow threshold level (m)	0.2
	Baseflow threshold type	Absolute
	Infiltration threshold level (m)	0.2
	Infiltration threshold type	Absolute

Figure 6 is a flow-duration curve showing the resulting Erosion Risk Model flows compared to the NIWA NZ River Maps flow percentiles. The relevant section of the graph for comparison to NIWA NZ River Maps flow percentiles is for flows >20% exceedance, as the gauged data was used to calibrate medium to high flows (<20%). It shows that a good match to the NIWA River Maps flow percentiles has been achieved, with the model giving very similar flows for >20% exceedance.

Figure 6: Comparison of the Kenepuru Stream Continuous Simulation Model and NIWA river maps flow percentiles

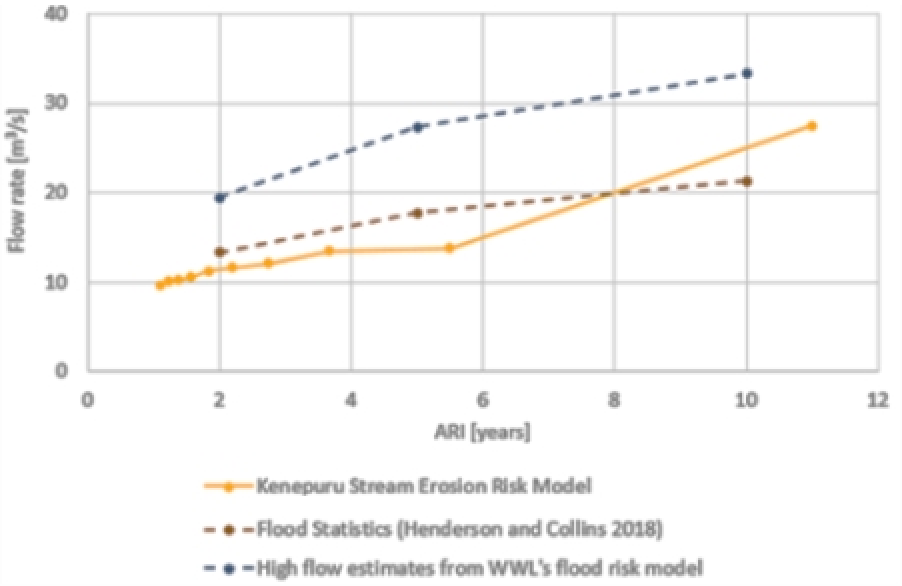


WELLINGTON WATER'S INFOWORKS ICM FLOOD RISK MODEL AND NIWA'S NEW ZEALAND RIVER FLOOD STATISTICS WEBSITE

Outputs from these sources were used to validate extreme flow estimates of the Erosion Risk Model. In order to be able to compare the results of the Erosion Risk Model with the available extreme flow estimates (given in terms of return periods), maximum annual flow rates were extracted from the Erosion Risk Model and ARIs assigned using the plotting position method (Weibull formula).

Figure 7 is a frequency plot comparing the high flow estimates obtained from the Erosion Risk Model to NIWA's New Zealand River Flood Statistics outputs and Wellington Water flood risk model. Modelled high flows were found to be of the same order of magnitude of the other estimates and therefore no changes to the model were made.

Figure 7: Comparison of the Kenepuru Stream continuous simulation model flows with NIWA's New Zealand River Flood Statistics and Wellington Water flood risk model. Kenepuru Stream continuous simulation model ARI estimates generated using the plotting position method (Weibull equation)



7 ANALYSIS LIMITATIONS

7.1 MODEL LIMITATIONS

The following is a list of the key limitations of the 1D hydraulic model:

- As a 1D model, velocity and depth outputs give average velocity across the channel; thus, cross channel velocity distributions cannot be assessed. During model development a 2D hydraulic model was trialed. It was found to give a much-improved representation of velocity distributions in medium-high flow periods but a poor representation of low flow velocities, as it was not possible to reduce 2D cell sizes small enough to represent channel cross sections with sufficient detail.
- Superelevation around bends, flow eddies, and turbulence is not represented in the 1D equations used.
- Stream bed elevations (outside the critical reaches) are taken from LIDAR, with no adjustments made for the stream bathymetry. For this reason, model velocity outputs will not be analysed in these sections of the model.
- Stream bed elevations are fixed throughout the entire 10 years of continuous simulations, based on 2013 LiDAR data and cross sections surveyed in June 2022. No bed level change due to erosion, deposition or sedimentation is modelled.

7.2 OTHER LIMITATIONS

There are other limitations to the analysis due to the difficulty of quantifying the effect of factors not relating to flow on bank stability. Such factors include:

- Changes in velocity are minimal. Therefore, commentary on the effects of such changes in hydrology or effects of mitigations has its limitations.
- Vegetation – Depending on type and location, vegetation can either increase or decrease bank stability.

- Bank weakening processes – Processes such as pre-wetting, desiccation and freeze-thaw cycles have an effect on bank stability (Thorne, Hey and Newson, 1997). Freeze-thaw unlikely to be a significant factor in Porirua.
- Geotechnical factors such as bank angle, soil stratification, rapid drawdown etc.

These limitations have been considered on a qualitative basis rather than quantified through the modelling process.

8 MODELLING RESULTS

8.1 MODELLED SCENARIOS

The modeling scenarios used in the erosion risk model are described below in Table 5.

Table 5: Summary of Modelling Scenarios

Name	Description	Land use
Existing	Existing Situation (no diversion pipe)	Existing land use (~2017)
Future	Future without mitigation (no diversion pipe)	Future land use within the Cannons Creek East Study Area, existing land use elsewhere
FRT1	Future with realistic rainwater reuse/retention tanks (no diversion pipe)	Future land use within the Cannons Creek East Study Area, existing land use elsewhere
FRT2	Future with high rainwater reuse/retention tanks (no diversion pipe) (sensitivity test)	Future land use within the Cannons Creek East Study Area, existing land use elsewhere
FRT3	Future with very high upper bound rainwater reuse/retention tanks (no diversion pipe) (sensitivity test)	Future land use within the Cannons Creek East Study Area, existing land use elsewhere
Future wetland	Future (with diversion pipe) with Cannons Creek Wetland	Future land use within the Cannons Creek East Study Area, existing land use elsewhere

8.2 RESULTS

Figure 8 shows the velocity duration curve for Area 4. The threshold velocity lower bound was exceeded approx. 5% of the time. i.e. over the 10 year period the threshold velocity (0.15m/s) was exceeded for 5% of the time or an average of 438 hours per year.

It should be noted that the x-axis of the flow duration curve is percent exceedance, which is the percentage of time that the flow exceeds the value plotted. So, for example, 1% exceedance means that for 1% of the 10-year time series (37 days, or an average of 3.7 days each year), the flow was exceeded. This is not the same as AEP, where a 1% AEP would mean that there is a 1% probability of the flow occurring in any given year.

As the development represents a small portion of the entire catchment, the differences in velocities are very small.

Figure 8: Area 4 - Velocity Duration Curve

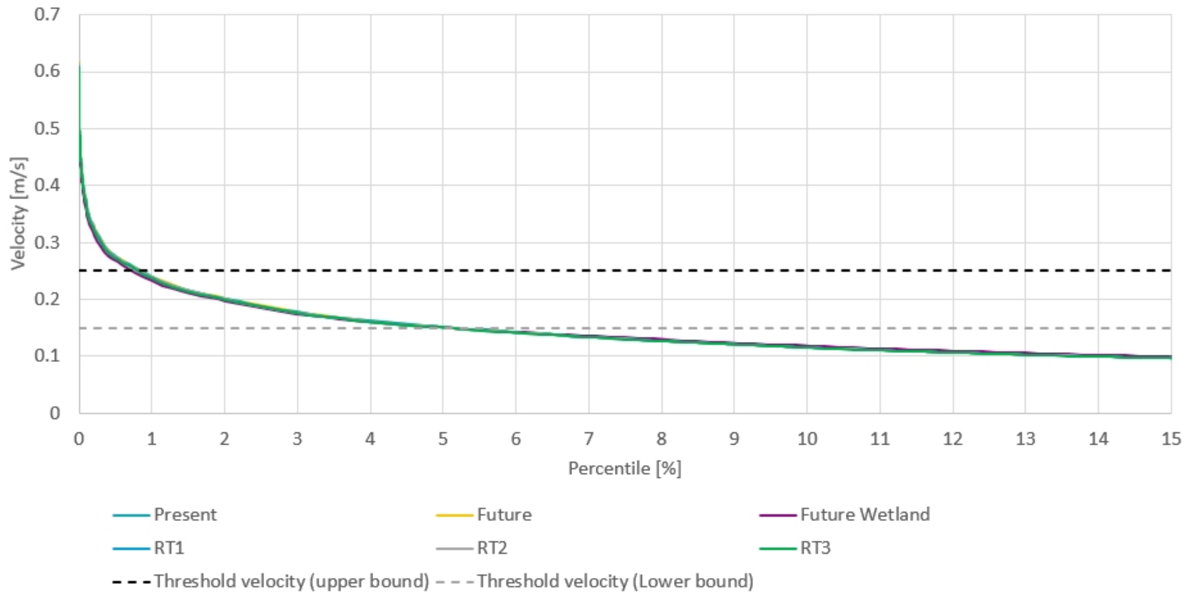
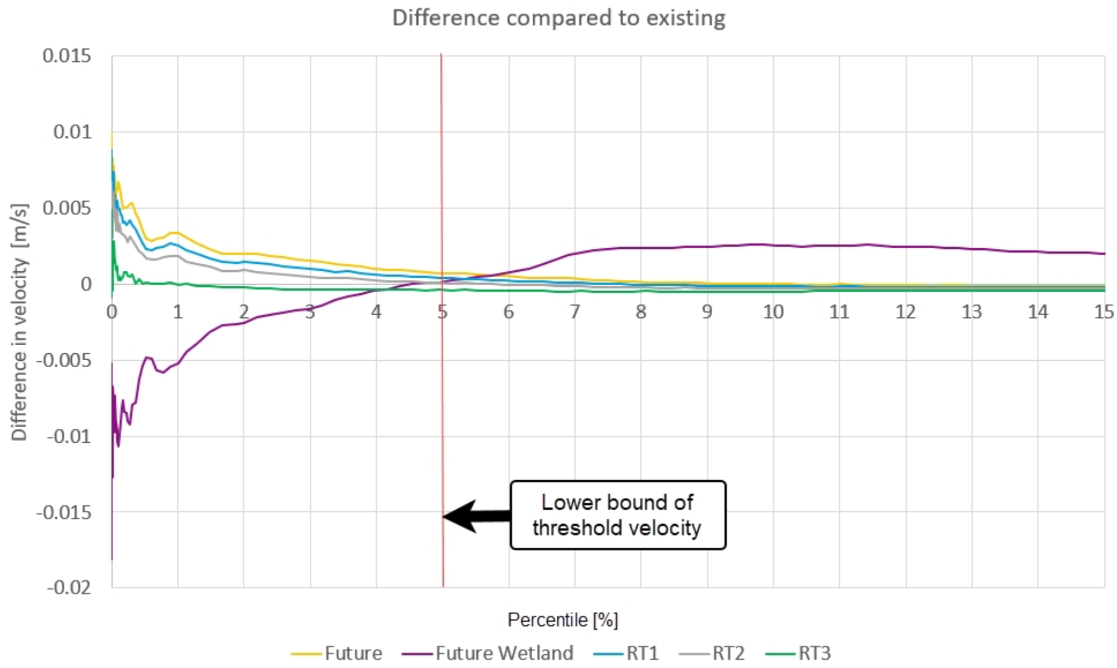


Figure 9 shows the same data but looking at the difference in velocity relative to the "Existing" scenario. The differences in this second figure are much more distinct. It is important however to note that the differences are small (generally less than 0.005m/s), and the conclusions drawn from these results have been made bearing this in mind.

Figure 9: Area 4 - Difference in velocity compared to existing.



The results are what we would expect given the nature of the scenarios:

Future:

The future has a small (<0.005m/s) increase in the velocities in rainfall events with low percentage exceedance compared with existing. This is due to the increased peak runoff rates and runoff volumes corresponding to the changes in catchment hydrology.

Rain tanks:

The rain tank scenarios behave similarly to the future scenario as they have the same land use. The low exceedance velocities are also elevated in the rainfall events with low exceedance due to the tanks filling up and overflowing during these events. The other factor is that these rain tanks only capture roof water so there is still the runoff from roads and other paved areas that flows to the stream without any mitigation. This can be seen in the RT3 scenario where, even with the 5 m^3 tanks, the 0-0.5% exceedance velocities are still increased, albeit by a very small extent.

The RT3 scenario brings performance close to existing across the range of percentiles with the exception of the 0-0.5% exceedance velocities for the aforementioned reasons. This scenario, however, would require 5 m^3 tanks being installed on every single Kāinga Ora and privately developed houses, including houses being refurbished and small sites (<3000 m^2) that would not trigger any requirements under the Regional Council's Proposed Natural Resources Plan. This scenario also assumes all of those tanks to be adequately maintained for their lives, and there is a risk that this is not the case.

Wetland:

The wetland, with attenuation for larger storm events and extended detention for the small events, outperforms the rain tanks in the larger storms (lower exceedance percentages), when the velocity in the stream is at or above the threshold velocity for erosion. Then it results in a slight increase in velocities for an extended period as the detention volume is released. However, at this time the velocity in the stream is below the threshold velocity lower bound for erosion, and the increase in velocity is not enough to increase the velocity in the stream above the threshold velocity.

Summary

The future increased impermeable area has resulted in a marginal increase in the velocities in Kenepuru Stream and therefore very slight increase in the risk of erosion.

Comparing the rain tanks to extended detention in a centralized wetland, large tanks on all properties (RT3) would be required to mitigate the effects of development and this would still need to be done in conjunction with hydraulic neutrality devices to mitigate the peak flows in the larger storm events. This would return the stream conditions to near present conditions.

The extended detention coupled with the attenuation in the wetland provides greater benefits in the medium to large storms. The potential downside risk of increasing the duration that stream flows are at or above the threshold velocity when extended detention is drawing down is not present in this case. This risk would need to be a consideration if extended detention was to be considered on all developments in the wider catchment, due to the small increases compounding with one another. The extended detention also has the benefits of being a centralised device maintained by the local council where functionality is guaranteed rather than decentralised devices privately maintained.

9 CONCLUSIONS

Building on existing assessment approaches alongside a coupled hydrological and hydraulic model, a tool has been developed to inform evidence-based decisions regarding appropriate mitigation methods with regards to effects on streambank erosion. The developed method was used to quantify the effect of urban development on Kenepuru Stream erosion and assess proposed mitigation methods.

The coupled 1D hydraulic/hydrological model proved to be a useful tool to study the relationship between stream hydrology, hydraulics and erosion. The relationship between these assessed on a relative, i.e., difference between scenarios, rather than an absolute basis. Absolute differences in velocity being small in relation to present stream flows.

When comparing hydrological mitigations, plumbed in rain tanks compared with extended detention in a centralised device, each has a different effect on the stream velocities. The model that has been developed enables these effects to be better understood in order to support informed decision making on appropriate mitigation measures for this specific catchment.

This tool will prove useful in the assessment of the effect of development in the future development zones in Eastern Porirua on stream erosion and what hydrological mitigations best suit those study areas.

ACKNOWLEDGEMENTS

The authors would like to thank Michael Bergman for his assistance with the hydraulic modelling; Christoph Kraus for his assistance with the geological profiling; Sarah Dye, Kate Purton, Philip Robins and Graham Levy for their valuable contributions to the technical content and Kāinga Ora for allowing the authors to use this project.

REFERENCES

Elliot, S., Jowett, I.G., Suren, A.M., and Richardson, J. (2004) A Guide for Assessing Effects of Urbanisation on Flow-Related Stream Habitat, NIWA, Wellington, 21-28.

Fassman-Beck, E.A., Voyde, E.A., and Liao. M., (2013) 'Defining Mitigation Targets for Stormwater Design in Auckland', Prepared by Auckland UniServices for Auckland Council.

Irvine, J., Brown, N. Speed, S., and Simon, A. (2019) 'Auckland's Approach to the Stream Erosion Problem' Water New Zealand Stormwater Conference.

Melville, B.W., and Coleman, S.E., (2000) Bridge Scour, Water Resources Publications, LLC, Highlands Ranch, 71-78

Thorne, C.R., Hey, R.D., and Newson, M.D. (1997) Applied Fluvial Geomorphology for River Engineering and Management, John Wiley & Sons Ltd, Chichester, 137-172

United States Department of Agriculture. (2007) Rosgen Geomorphic Channel Design, In Part 654 Stream Restoration Design National Engineering Handbook, 11-6