COMPOUND CHANNEL MODELLING CAPABILITY ASSESSMENT OF 1D HYDRAULIC MODEL

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ABSTRACT (200 WORDS MAXIMUM)

Accurate modelling of streams or open channels in urban catchment is vital for different types of engineering and environmental studies such as flood risk assessments, flood alleviation designs, water quality and ecological assessments.

The estimation of conveyance in existing one-dimensional hydrodynamic modelling software such as MIKE URBAN, MIKE11 and HECRAS is principally based on some form of the Manning Equation. This is an empirically derived equation and does not provide meaningful results for sudden changes in wetted perimeter with depth as generally encountered in natural watercourses comprising of compound sections with significant variations in flow velocity across the cross-section. A number of methods are used in existing one-dimensional hydrodynamic modelling packages to circumvent this physically incorrect results. Computation of conveyance in compound channel sections is somewhat different in various modelling packages resulting different flood level predictions.

This paper presents a modelling exercise for benchmarking the compound channel modelling capability of 1D hydraulic model (MIKE URBAN/MIKE11) by comparing modelling results with that of 2D (MIKE21) and 1D-2D (MIKE11-MIKE21) coupled modelling packages for Oteha Stream catchment under identical network, topographical and boundary conditions.

KEYWORDS

Compound Channel, Conveyance, Roughness, MIKE11, MOUSE, HEC-RAS, River Modelling

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1 INTRODUCTION

Modelling of stormwater drainage systems accurately is problematic. Precipitation falling over an urban catchment passes through an enormously complex hydrological and hydraulic system. In urbanized areas runoff is intercepted by formal stormwater drainage systems and conveyed along a network of pipes or channels until it is discharged into streams or watercourses. Streams form an integral part of the stormwater drainage system within the Auckland region and have environmental, amenity and cultural values. The total length of streams in the Auckland Region is estimated to be 16,650 km. A number of rivers flow through the region including the Hoteo, Wairoa and Kumeu-Kaipara rivers. Streams with their associated floodplains are the natural system for drainage of water and sediments into the sea.

It is widely accepted that increased development has profound effects on catchment runoff characteristics in terms of increased frequency, duration and magnitude of runoff peak flows and volumes which results in increased flooding, stream erosion and a sharp drop in aquatic diversities. More over climate change will exacerbate the flooding situation. Auckland Region will experience more frequent damaging floods. During last two years a number of damaging floods has been observed in Auckland. Several properties and critical infrastructure suffered damage during the flood events.

In Auckland, most floods occur as a result of spilling of flood waters from rivers, streams and watercourses. Protection of people and property from urban flooding requires better understanding of how stream channels behave during propagation of flood flows. Reliable prediction of flood levels is essential for estimating the magnitude and extent of flooding as well as flood damage assessments. A major area of uncertainty in stream flood risk assessments is that of accurately predicting the conveyance capacity of stream channels with floodplains, which are termed compound channels. The wetted perimeter of a compound channel changes significantly with depth, particularly once the level overtops the bank and spill onto the floodplain.

The estimation of conveyance in existing one-dimensional hydrodynamic modelling software such as MIKE URBAN, MIKE11 and HECRAS is principally based on some form of the Manning Equation. This is an empirically derived equation and does not provide meaningful results for sudden changes in wetted perimeter with depth as generally encountered in natural watercourses comprising of compound sections with significant variations in flow velocity across the cross-section.

A number of methods are used in existing one-dimensional hydrodynamic modelling packages to circumvent this physically incorrect result. Computation of conveyance in compound channel sections is somewhat different in various modelling packages resulting different flood level predictions. This problem has led to a thorough investigation of compound channel modelling capability of 1D hydraulic models, leading to development of best modelling practice to minimise the uncertainty in flood risk prediction.

This paper presents a modelling exercise for benchmarking the compound channel modelling capability of 1D hydraulic model (MIKE URBAN/MIKE11) by comparing modelling results with that of 2D (MIKE21) and 1D-2D (MIKE11-MIKE21) coupled modelling packages for Oteha Stream catchment under identical network, topographical and boundary conditions.

2 STREAM CAPACITY

The one-dimensional unsteady flow analysis is based on the assumption that the velocity is averaged over the channel cross-section and the effects of boundary friction and turbulence can be accounted for by representation of channel conveyance for steady uniform flow. In reality flow velocity varies across a stream channel section.

Conveyance is a quantitative measure of the carrying capacity of a stream channel section, since it is a directly proportional to the discharge (Q) (Chow, 1959). By the law of conservation of mass, the discharge of uniform flow in a channel is expressed as the product of the velocity and the water area. Based on Manning's uniform-flow equation, the conveyance (K) of a stream channel section is defined as

$$Q = V A = K S_f^{1/2} \text{ and } K = 1/n\, A\, R^{2/3}$$

where K (m^3/s) is the conveyance, A (m^2) is the flow area, R (m) is the hydraulic radius (area/wetted perimeter), Q (m^3/s) is the discharge, V (m/s) is the velocity, n is the Manning's roughness coefficient and S_f (m/m) is the 'friction' gradient which is equal to the channel gradient under steady uniform flow condition. Uniform flow will be developed if the resistance is balanced by the gravity forces. By definition, uniform flow occurs when the depth, flow area, and velocity at every cross section are constant and the energy grade line, water surface, and channel bottom are all parallel.

The expression $AR^{2/3}$ is called the section factor for uniform-flow computation (Chow, 1959). Conveyance is a function of the sectional properties of the stream channel and the channel resistance coefficient. It relates discharge to a measure of the 'energy' or 'friction' gradient.

The estimation of conveyance in one-dimensional unsteady flow modelling software such as MIKE URBAN, MIKE11 and HECRAS is usually based on some form of the Manning uniform-flow Equation. There are two major issues in using the Manning uniform-flow equation in practice - accurate conveyance estimation of a natural watercourse with compound sections and accurate estimation of an equivalent roughness of a simple natural watercourse (e.g. main channel) with distinctly different roughness values across the perimeter (e.g. channel bed and banks).

Conveyance Estimation:

Natural watercourses are usually comprised of compound sections with significant variations in flow velocity across the cross-section. A compound section is also known as a two-stage channel. Typically roughness is higher in the floodplains or overbank areas than in the main channel, with the effect that flow velocities are typically lower in the overbank areas than in the main channel. The main channel flow will have interaction with the flow in the floodplains or overbank areas resulting in severe momentum exchange at the interface. A significant complexity of flow occurs in the case of overbank or floodplain flow and 1D flow approximation no longer exists.

A compound natural channel requires special consideration in 1D hydraulic stream modelling. In the case of compound or two-stage channel, as the flow begins to cover the floodplain, the wetted perimeter of the section increases rapidly while the flow area increases slowly. Thus, in such a situation, the hydraulic radius, conveyance, velocity and discharge decrease with increasing flow depth, a situation which although computationally correct is physically incorrect (French, 1985).

A number of methods are used in existing one-dimensional hydrodynamic modelling packages to circumvent this computational problem. Historically two methods are used to account for the complexities of natural watercourses taking account of their shape, sinuosity and differential roughness:

- The Single Channel Method (SCM) uses various averaging techniques for producing a mean or single composite roughness in a section of simple shape.

- The Divided Channel Method (DCM) splits more complex section shapes into a series of simple subsections, calculating the discharge or conveyance in each subsection and summing the results. This method assumes that flow in each of the subsections is independent from other sections. This method would perform well if the different subsections are wide compared to water depth, such that the lateral transfer mechanisms at the interfaces can be neglected.

The SCM method uses one integrated Manning's roughness coefficient for the whole section, but it underestimates the conveyance capacity. When applied to idealized steady and uniform flows, normally the SCM underestimates and the DCM overestimates discharges in natural watercourses.

Conveyance is calculated in MOUSE/MIKE URBAN using a single composite roughness for the whole section (SCM method). This method may produce inconsistent flood level predictions due to decreases in conveyance with increasing depth during overbank flow in natural watercourses comprised of compound sections (refer to Section 3.1). As this method underestimates the conveyance capacity for natural watercourses it produces conservative extent of flooding which may lead to an unnecessary burden to the residents.

The conveyance estimation methods used in MIKE11 and HECRAS are based on DCM method. Channel conveyance for a compound channel in MIKE11 is estimated based on parallel channel analysis where the total conveyance of the section at a given elevation is equal to the sum of the conveyance of the parallel channels. These parallel channels are defined as those parts of the channel where the roughness value remains constant.

The default channel conveyance estimation method in HECRAS is DCM and requires that the flow be subdivided into units for which the velocity is uniformly distributed. The HECRAS approach is thus to subdivide the flow in the overbank areas using the input cross-section Manning's roughness break points (locations where n-values change) as the basis for this sub-division.

A simple trapezoidal open channel with overbank areas (Figure 1) is used to compare the computed channel conveyance using SCM and DCM methods. Table 1 and Figure 2 show the channel conveyance based on the DCM method is significantly higher (8.9% at 9.5m RL to a maximum of 46.4% at 8.8m RL) compared to the SCM method at elevations above channel banks (RL 8.5m).

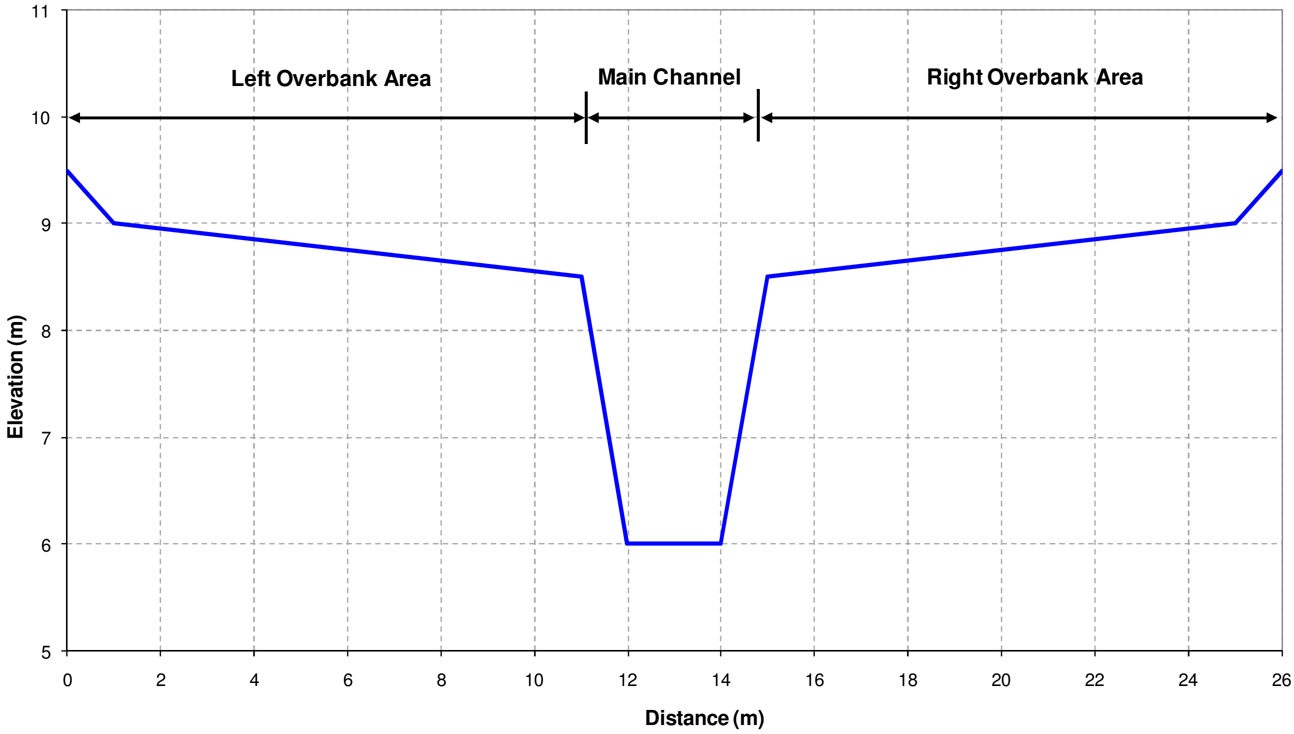

Figure 1: A simple trapezoidal open channel with overbank areas

Table 1: Channel conveyance comparison between SCM and DCM methods

Conveyance Estimation Methods	Elevation (m)	Width (m)	Area (A) (m^2)	Perimeter (P) (m)	R = A/P (m)	Conveyance 1/n $AR^{2/3}$ (m^3/s)
Single Channel Method	9.5	26.0	27.0	29.65	0.911	317.1
Divided Channel Method - Three Parallel Channels						
Left Overbank Area	9.5	11.0	7.8	11.13	0.696	76.1
Main Channel	9.5	4.0	11.5	7.39	1.557	193.1
Right Overbank Area	9.5	11.0	7.8	11.13	0.696	76.1
Sum =>		26.0	27.0	29.65		345.3 (8.9% higher)

Assumed Manning's Roughness, n = 0.08

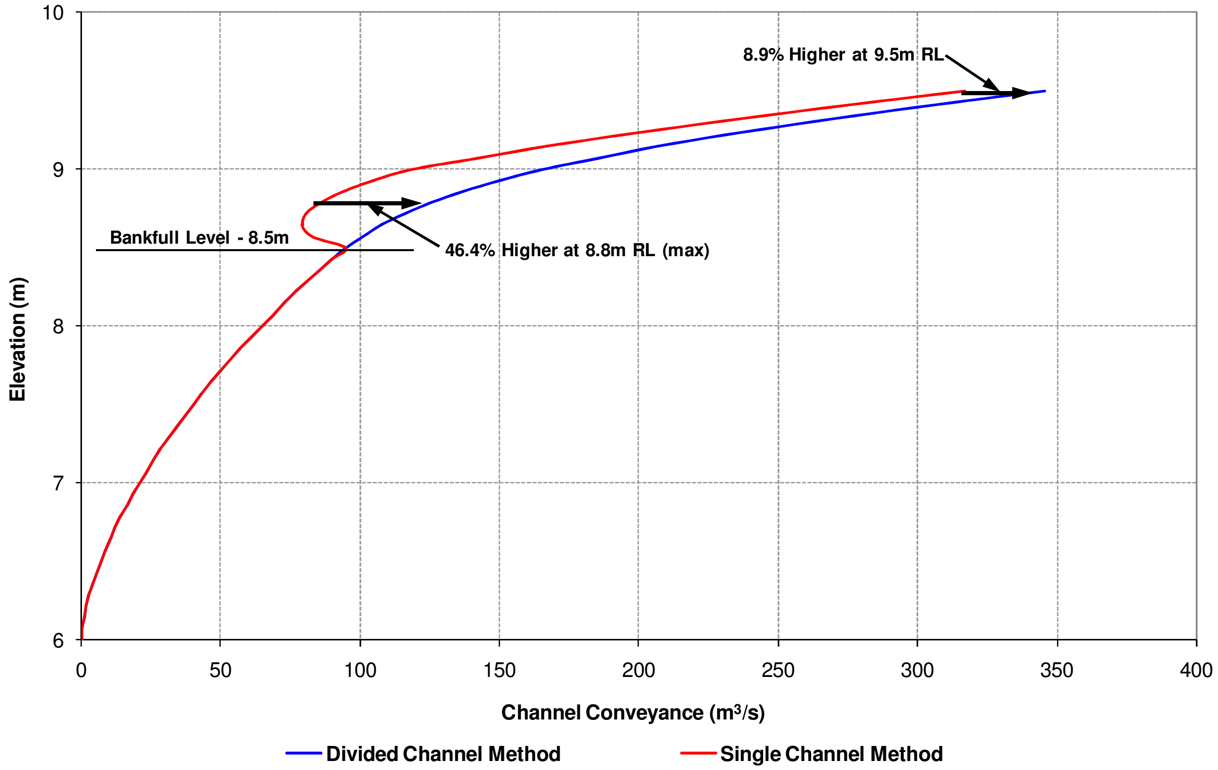

Figure 2: Channel conveyance comparison between SCM and DCM methods

Equivalent Roughness Estimation:

The one-dimensional unsteady flow analysis is based on the assumption that the effects of boundary friction and turbulence can be accounted for through resistance laws analogous to those used for steady uniform flow. Accordingly the majority of the 1D unsteady flow modelling software uses Manning uniform-flow equation and assigns Manning's roughness coefficient n to represent the effects of boundary friction and turbulence.

In general, Manning's n value identified in open channel flow through calibration using measured data in 1D model no longer represents energy loss due to boundary friction only but bulk representation of other energy loss mechanisms over a channel reach not explicitly modelled (e.g. turbulence generated from the main channel - floodplain interaction and helical secondary flows resulting from the planform channel sinuosity).

Natural watercourses may have distinctly different roughness characteristics from one part of the channel boundary to another e.g. channel bed and banks may have different Manning's n values. In applying the Manning uniform-flow equation to such channels, it is sometimes necessary to compute an equivalent n value for the entire perimeter and use this equivalent value for the computation of the flow in the whole section.

In general, an equivalent n value is used in a simple open channel cross-section not in compound or two-stage channel section. There are several formulas available that can be used to estimate an equivalent n value of a given stream channel. These formulas including their assumptions are discussed in Chow (1959). For the determination of the equivalent roughness, a channel cross-section is divided into a number of subsections such that the Manning's n value in each subsection remains constant.

The main channel in HECRAS is normally computed as a single conveyance element. The program determines if the main channel portion of the cross section can be subdivided or if a single composite main channel roughness value will be used based on the following criterion: if a main channel side slope is steeper than 5(horizontal):1(Vertical) and the main channel has more than one n-value, a single composite roughness n_c is computed according to Horton and Einstein formula which assumes that subsection has the same mean velocity. The Horton and Einstein formula normally overestimate equivalent n value.

The Lotter formula is based on the assumption that the total discharge is equal to the sum of the discharges in each subsection. The Lotter formula is used in MIKE11 to estimate equivalent n values as a function of depth when distributed Manning’s n values are assigned across the open channel cross-section raw data (without bank marker). The Lotter formula normally underestimates equivalent n value and in some cases it may provide an equivalent n value lower than the lowest n value assigned in subsections (Figure 3) which is physically incorrect.

A simple trapezoidal channel cross-section with a Manning’s n value of 0.03 for bed and 0.06 for banks (Figure 3) is used to compare the estimated equivalent n value using Lotter and Horton/Einstein formulas. The estimated equivalent n value for the trapezoidal channel is 0.025 (lower than bed roughness) in case of Lotter formula and 0.052 (nearly bank roughness) in case of Horton and Einstein formula.

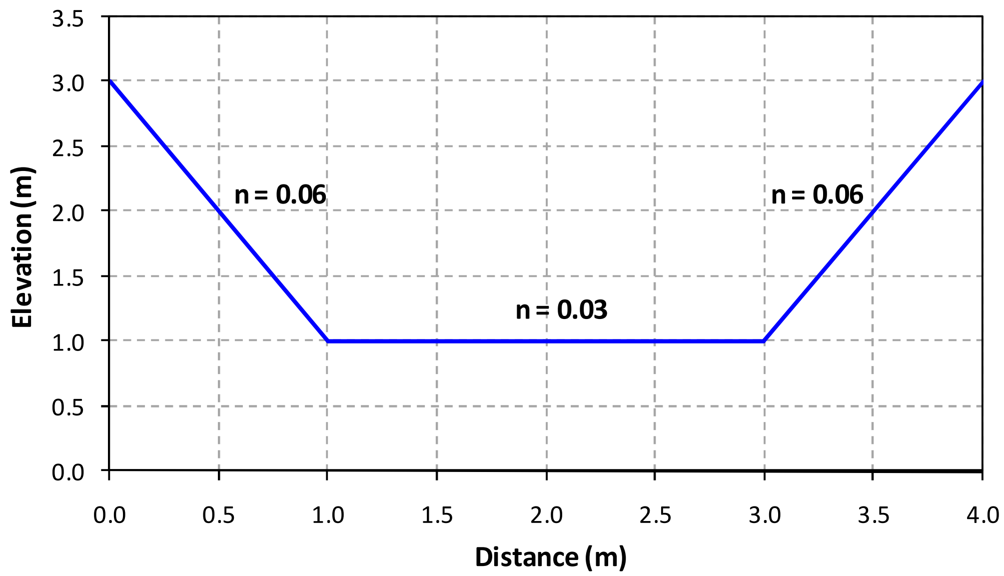

Figure 3: A simple trapezoidal channel cross-section with variable n values

The variability in estimating the channel conveyance and equivalent Manning's n values over a channel section creates an issue with consistency, this can become a significant problem if a dispute arises e.g. if the dispute ends up in environment court.

3 THE PROBLEM

3.1 LUCAS CREEK 1D FLOOD MODELLING

A major modelling issue was identified during options/scenarios modelling when comparing model simulation results between various options/scenarios.

The existing MOUSE stormwater network model of Lucas Creek Catchment was used to assess the effects of the proposed earthworks on the stream flood levels adjacent to the property (Figure 4). The modelling investigations were carried out for two scenarios – the existing condition using the existing stream cross-sections and the proposed earthworks condition using the modified stream cross-sections based on the proposed earthworks contours (Figure 5).

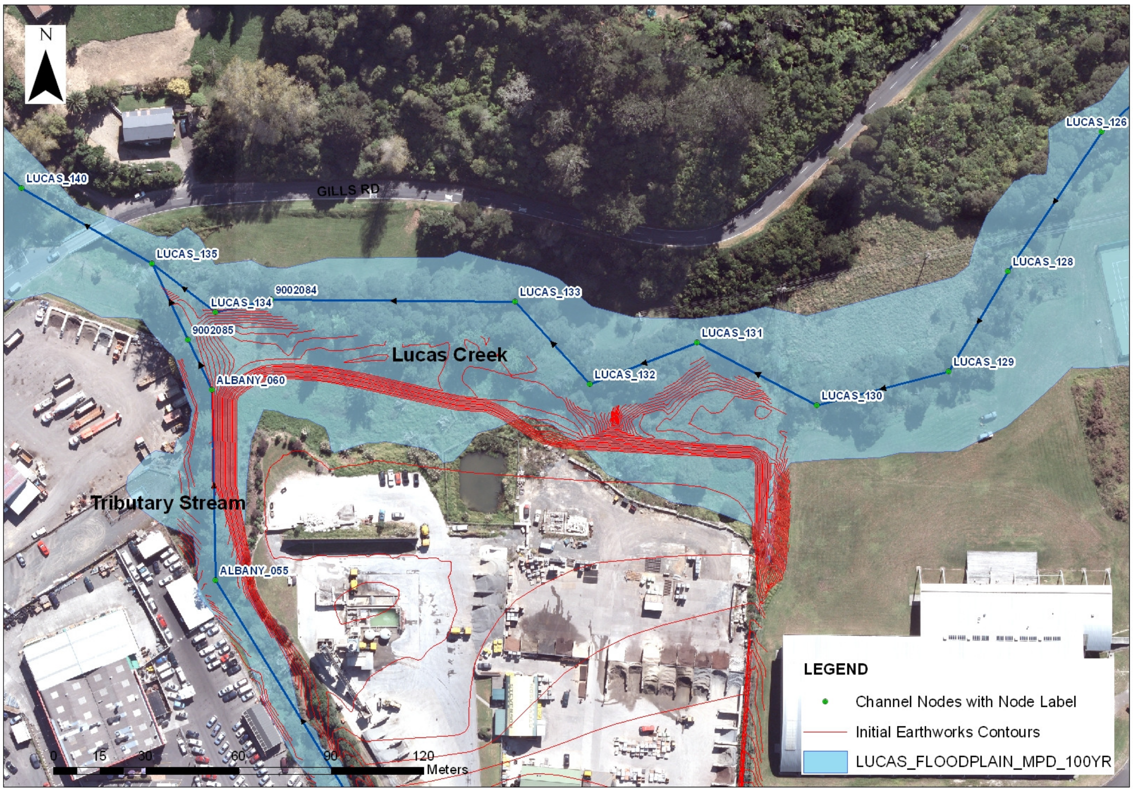

Figure 4: The 100-year ARI MPD floodplain with the initial proposed earthworks contours

A single composite Manning's n value was used for the whole section including the floodplain (SCM method) for both the scenarios. Model results showed the predicted flood level is decreased by 50mm in the Lucas Creek due to the proposed earthworks, which is physically incorrect as the stream cross-sectional area is reduced due to the proposed earthworks (see Figure 5). It has been identified that although the area is reduced but the hydraulic radius is increased compared to the existing cross-sections due to a decrease in wetted perimeter. Because of increase in hydraulic radius, conveyance is increased during overbank flow between 10.4m RL and 11.2m RL with the proposed earthworks compared to the existing condition as shown in Figure 6.

Lucas Creek channel conveyance is increased compared to the existing condition by a maximum of 33.2% at 10.93m RL. Due to the inconsistent model results, additional model simulations were carried out with parallel channels (main channel and floodplain channels) for both the scenarios. Final model results show the predicted flood level will be increased by a maximum of 0.21m in the Lucas Creek due to the proposed earthwork.

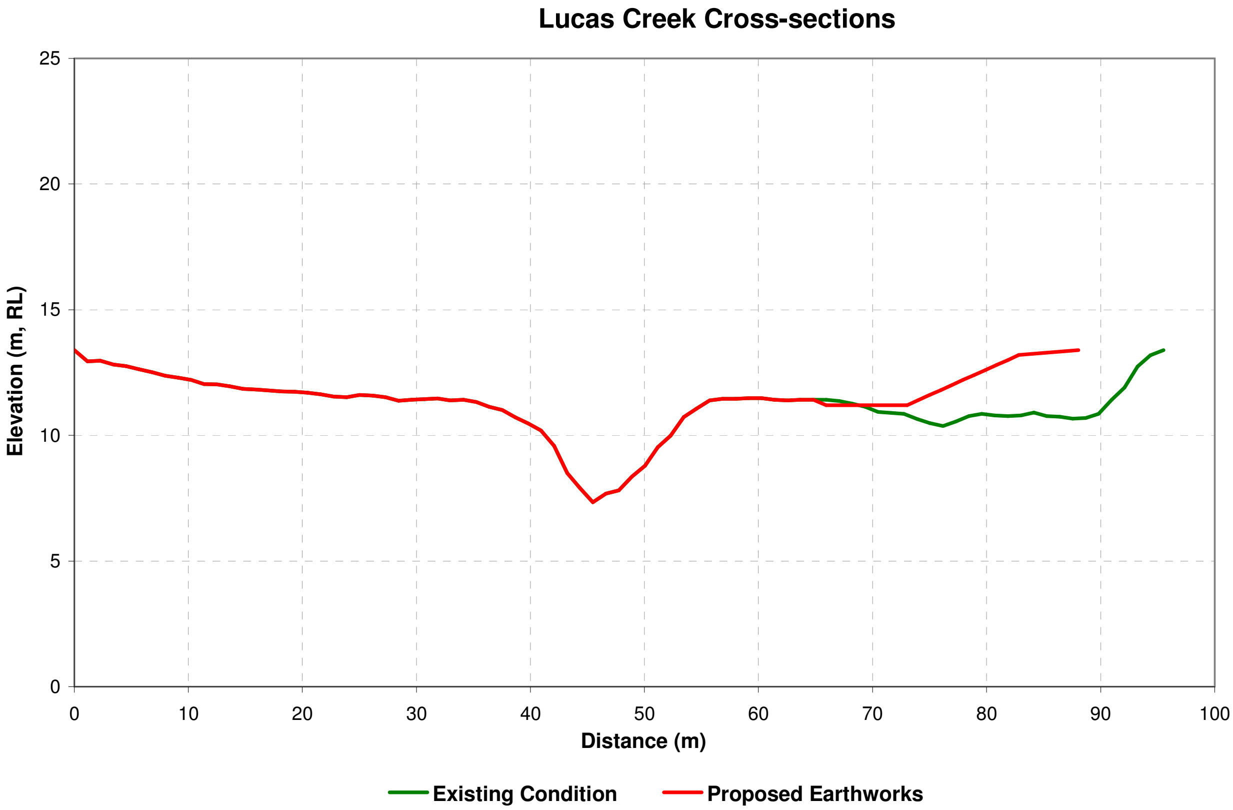

Figure 5: Comparison of Lucas Creek cross-sections between the existing and proposed earthworks scenarios

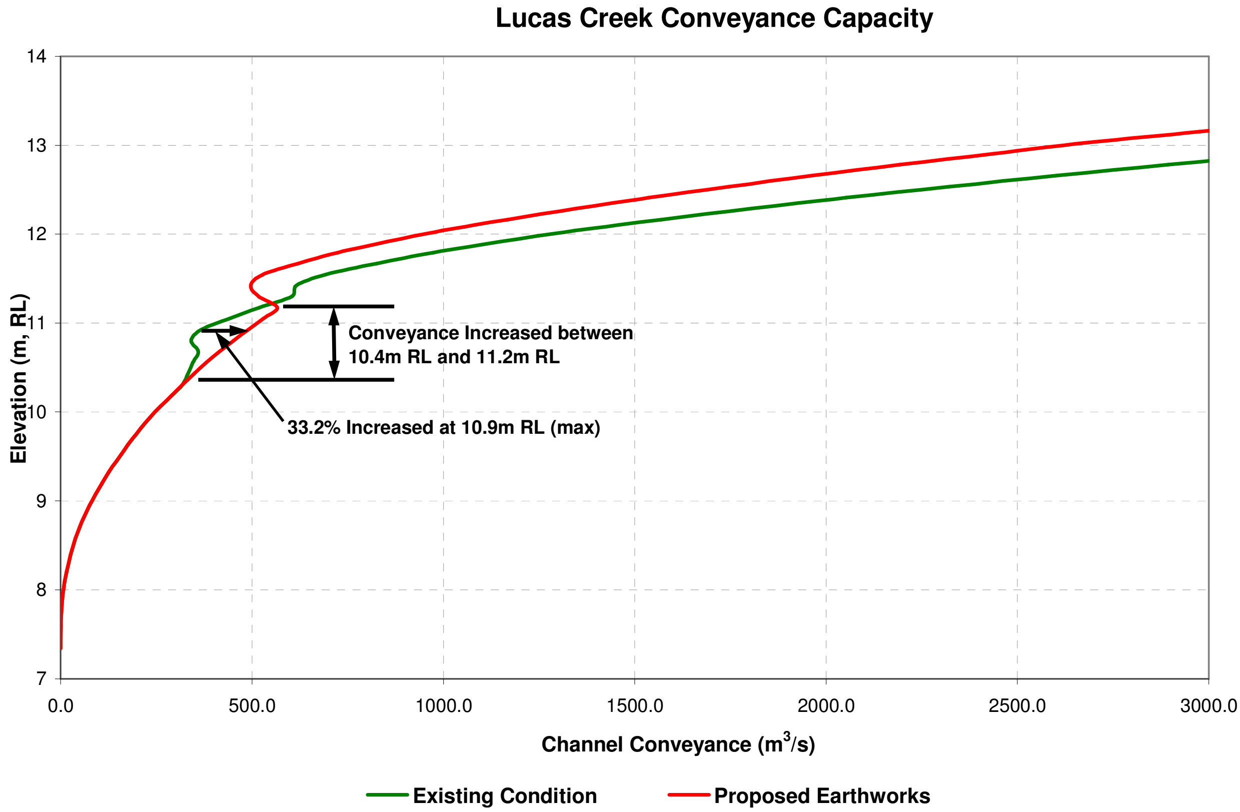

Figure 6: Comparison of Lucas Creek channel conveyance between the existing and proposed earthworks scenarios

3.2 OTEHA STREAM 1D FLOOD MODELLING

The Oteha Valley Catchment is located in the centre of North Shore City. Oteha Valley Stream is 11.5 km long with a contributing catchment area of approximately 1300 ha. The Oteha Valley Catchment was modelled in 2006 using MOUSE modelling software. Later in 2010 the model was converted into MIKE URBAN modelling software. The lower part of Oteha Stream has incised section with banks and floodplains heavily vegetated with trees. Oteha Stream bed and banks/floodplains have distinctly different roughness characteristics. The base CMP model used a single composite Manning's n value of 0.08 for the whole section including the floodplain of the Oteha Stream channels (SCM). The model predicted a total of 27 buildings habitable floors to be inundated during the 100yr ARI storm event (MPD land-use and future rainfall scenario) along the lower part of the Oteha Stream as result of spilling of flood waters from stream banks (Figure 7).

Oteha Valley Catchment model has been validated against measured data at two long-term permanent flow monitoring gauges for three storm events (2 to 10-year ARI). The flow gauge on Alexandra Stream at Rosedale Road culvert is located about 800m upstream of the predicted floor flooding areas (Figure 7). The flow gauge on Oteha Stream at upstream of Albany Highway Bridge is located about 600m downstream of the predicted floor flooding areas (Figure 7). In general the model has been validated within a reasonable agreement with the measured gauge data.

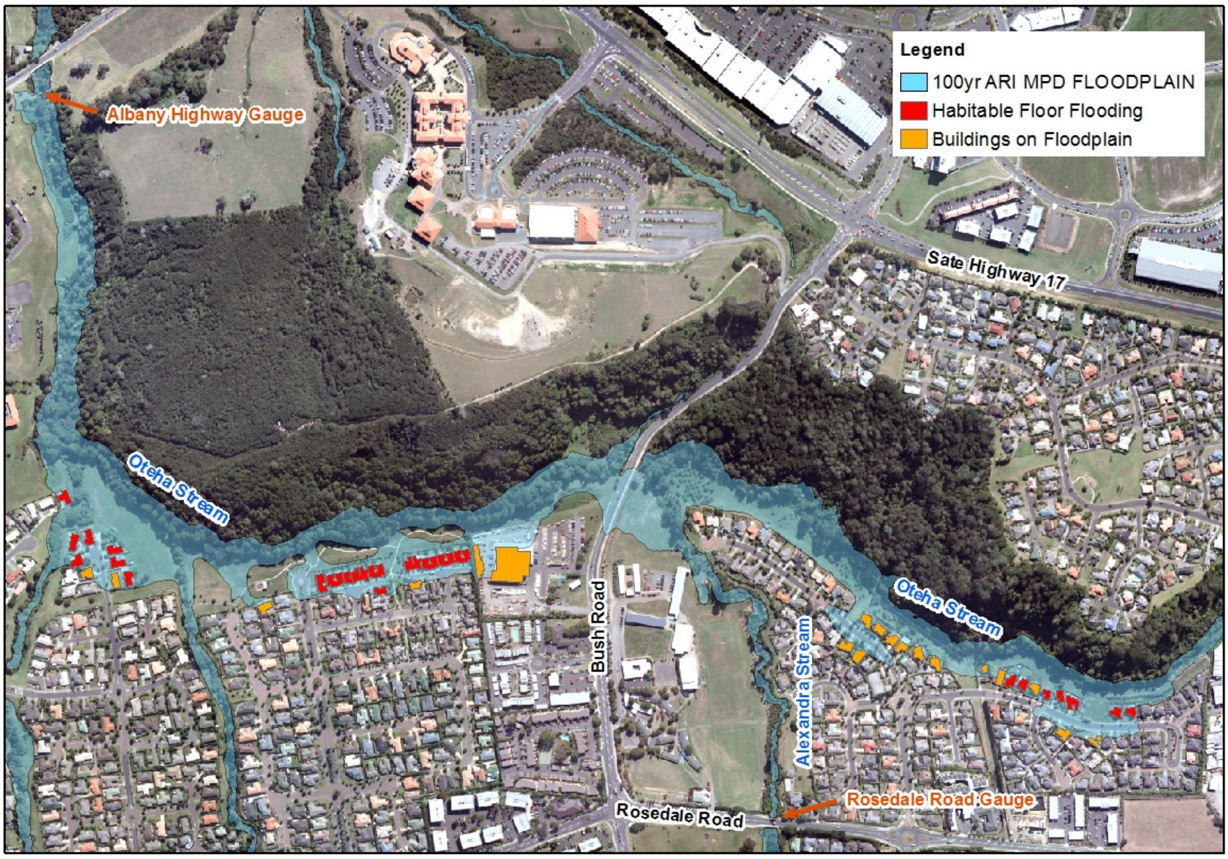

Figure 7: Oteha Stream 100yr ARI MPD floodplain with habitable floor flooding

MIKE URBAN 2009 has the option to include bank markers and distributed roughness values in stream cross-section, which allows estimating conveyance based on parallel channel or the DCM method for compound channels (similar to MIKE11). This leads to compare the model results in MIKE URBAN between SCM method (without bank markers) and DCM method (with bank markers).

The 1D hydraulic model of Oteha Valley Catchment was used to investigate the effects of bank markers and distributed roughness across the section on the predicted flood levels. Model simulations were carried out for the following two scenarios:

- with bank markers and a single composite n value of 0.08 (same n value as used in the base CMP model) for the whole section including floodplain of the Oteha Stream channels, and
- with bank markers and distributed roughness across the section i.e. Manning's n value of 0.045 for stream channel bed and 0.135 for banks and floodplains.

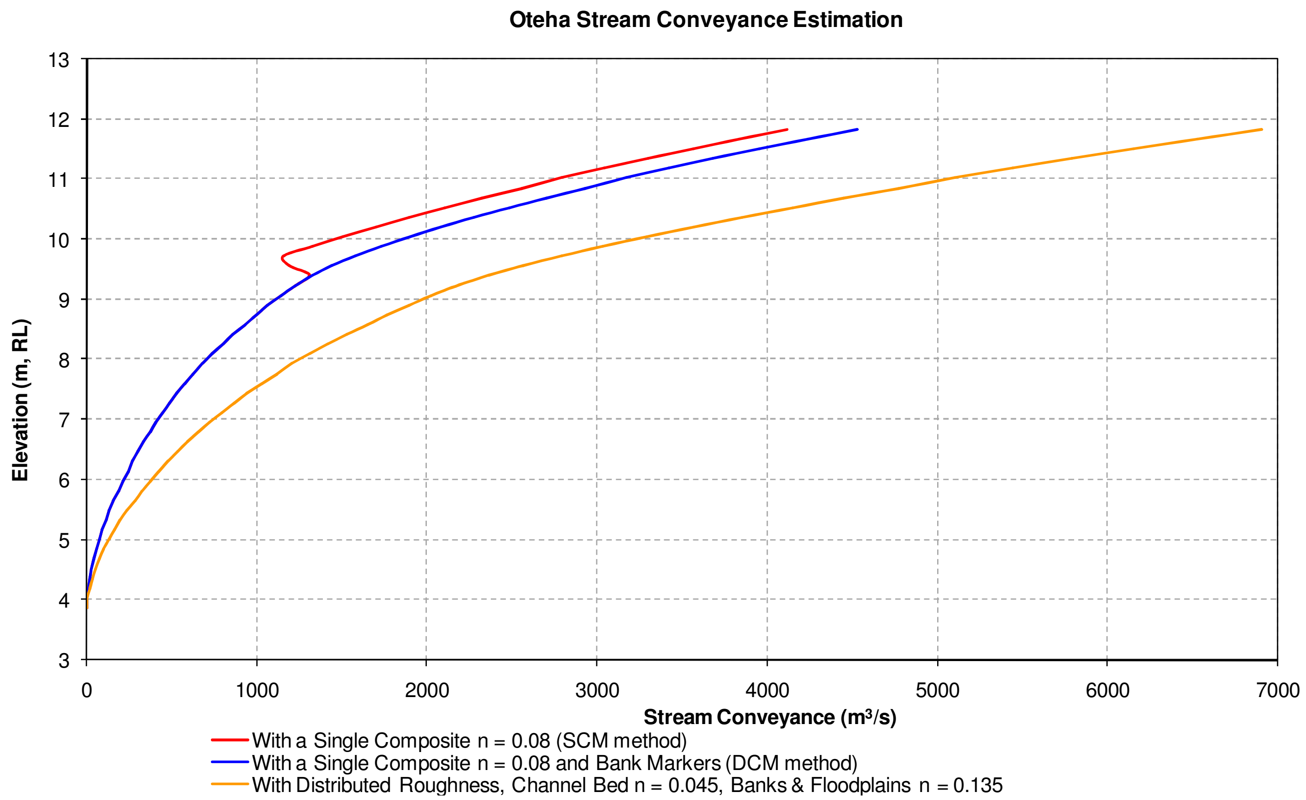

Figure 8: Comparison of Oteha Stream conveyance between SCM and DCM methods

Figure 8 above shows Oteha Stream channel conveyance is significantly increased using bank markers with a single n value and bank markers with distributed roughness values. Model results show using bank markers with a single n value predicted flood levels are decreased by 0.48m (Figure 9) on average along the lower part of the Oteha Stream and the number of predicted habitable floors flooding is reduced from 27 to 9 (Table 2). Using bank markers with distributed n values predicted flood levels are decreased by 0.92m on average along the lower part of the Oteha Stream and the number of predicted habitable floors flooding is reduced from 27 to 3 (Table 2).

A 1D hydraulic MIKE URBAN-MIKE11 coupled model of Oteha Valley Catchment was also developed by replacing lower part of Oteha Stream from MIKE URBAN to MIKE11 to investigate the effects of bank markers and distributed roughness across the section on the predicted flood levels in Oteha Stream under identical network, topographical and boundary conditions. Model results show using bank markers with distributed roughness values predicted flood levels are decreased by 0.70m on average along the lower part of the Oteha Stream and the number of predicted habitable floors flooding is reduced from 27 to 3 (see Table 2).

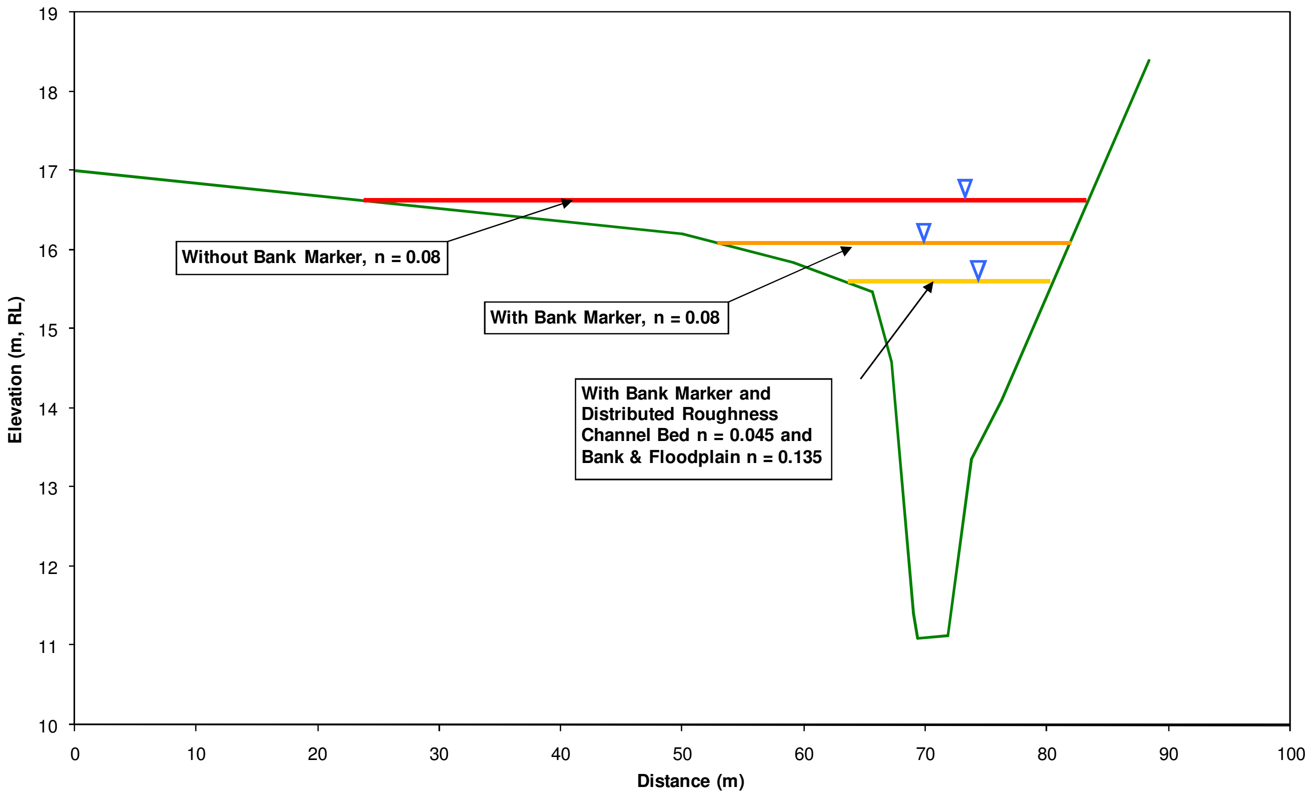

Figure 9: Schematic comparison of Oteha Stream predicted flood levels

Table 2: Comparison of Oteha Stream model results between SCM and DCM methods

1D Modelling Scenarios	Number of Predicted Habitable Floor Flooding during 100yr ARI MPD Storm event	Average Decrease in Predicted 100yr ARI MPD Flood Levels Compared to SCM Method
MIKE URBAN modelling with a single composite n = 0.08 and without bank markers (SCM method)	27	-
MIKE URBAN modelling with a single composite n = 0.08 and bank markers (DCM Method)	9	0.48m
MIKE URBAN modelling with distributed roughness and bank markers, bed n = 0.045 & banks & floodplains n = 0.135 (DCM Method)	3	0.92m
MIKE URBAN-MIKE11 modelling with distributed roughness and bank markers, bed n = 0.045 & banks & floodplains n = 0.135 (DCM Method)	3	0.70m

4 CURRENT BEST MODELLING PRACTICE

Although the Oteha Valley Catchment model was validated within a reasonable agreement with the measured gauge data, there remains uncertainty in flood level and number of predicted floors flooded due to the computational problems of conveyance estimation in natural streams with floodplains. This problem leads to the development of best stream modelling practice to minimise the uncertainty in flood risk prediction.

4.1 OTEHA STREAM 2D FLOOD MODELLING

A 1D-2D coupled model of Oteha Valley Catchment was developed by replacing lower part of Oteha Stream from MIKE URBAN to 2D MIKE21 model. The 2D Oteha Stream model was used to compare the model results with that of 1D MIKE URBAN hydraulic model of Oteha Valley Catchment under identical network and boundary conditions.

Oteha Stream channels with floodplains were modelled in 2D MIKE21 modelling software. The main input to the 2D hydraulic model consists of the topography and hydraulic roughness. The topography consists of the 2D ground surface (referred to as a Digital Elevation Model) created from the LiDAR data. A grid size of 2m x 2m was used for MIKE21 rectangular mesh. A Smagorinsky eddy viscosity formulation with a coefficient of 0.3 was used to model fine-scale turbulence losses.

The surveyed cross-sections of Oteha Stream channels were burned into the 2D ground surface using MIKE11 mapping tools. Interpolated cross-sections were generated at every 10m interval along the Oteha Stream planform using MIKE11 cross-section editor and then a 2m grid DEM of Oteha Stream channels was generated using MIKE11 mapping tools (hydrodynamic parameters editor) which was finally burned into the 2D ground surface DEM.

Model simulations were carried out with two scenarios - one with a Manning's n value of 0.10 for the whole 2D ground surface and the other with a n value of 0.045 for the Oteha Stream main channels and 0.135 for the remaining 2D ground surface. The predicted 100yr ARI MPD floodplain extents are compared in Figure 10 below.

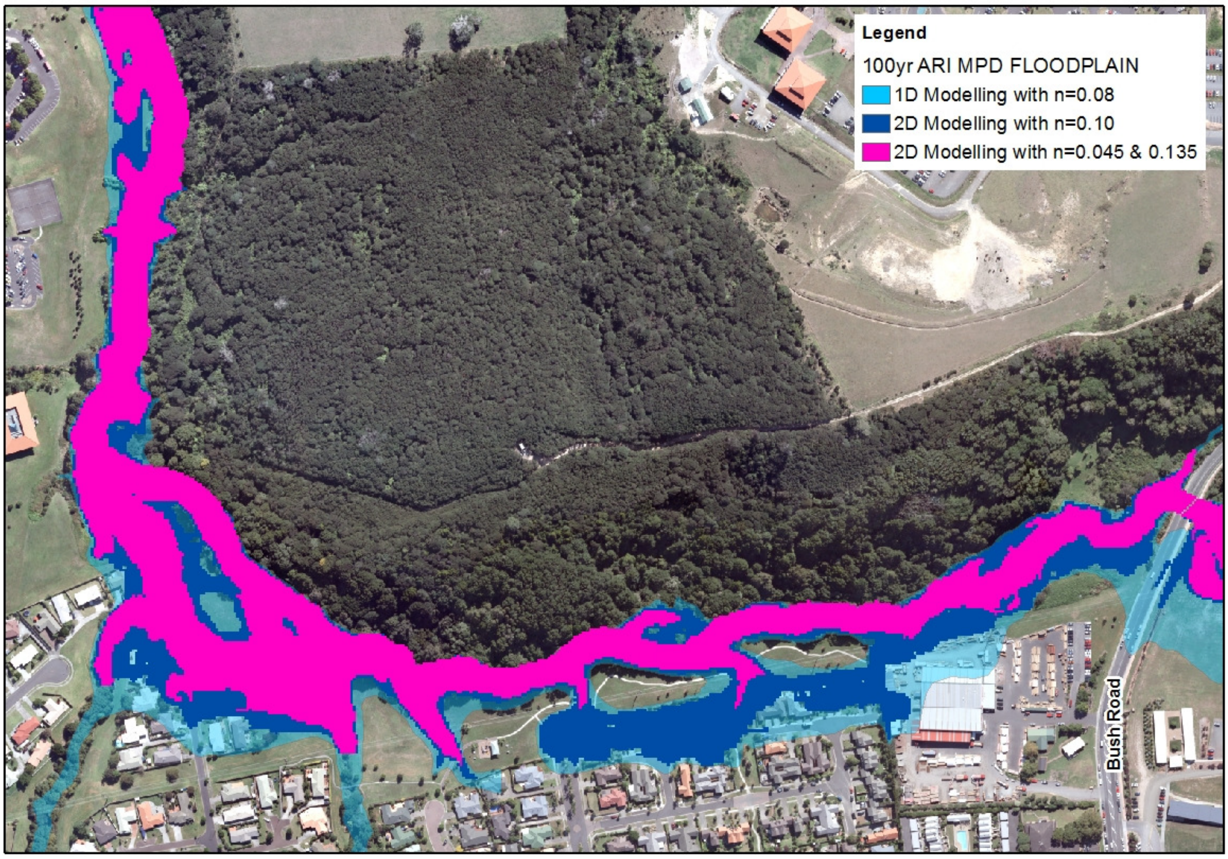

Figure 10: Comparison of Oteha Stream predicted floodplain extents

2D Oteha Stream model results show using a n value of 0.10 predicted flood levels are decreased by 0.46m on average along the lower part of the Oteha Stream compared to the base 1D CMP model and the number of predicted habitable floors flooding is reduced from 27 to 7 (Table 3).

Using a n value of 0.045 (main channels) and 0.135 (remaining 2D ground surface) predicted flood levels are decreased by 0.73m on average along the lower part of the Oteha Stream and the number of predicted habitable floors flooding is reduced from 27 to 1 (Table 3). This scenario shows similar results in terms of predicted flood levels compared to the DCM method used in 1D MIKE URBAN and MIKE11 models (Table 2).

Table 3: Comparison of Oteha Stream 1D and 2D model results

Modelling Scenarios	Number of Predicted Habitable Floor Flooding during 100yr ARI MPD Storm event	Average Decrease in Predicted 100yr ARI MPD Flood Levels Compared to 1D Model
1D MIKE URBAN modelling with a single composite n = 0.08 and without bank markers (SCM method)	27	-
2D MIKE21 modelling with n = 0.10 for 2D ground surface	7	0.46m
2D MIKE21 modelling with n = 0.045 (main channels) and n = 0.135 (remaining 2D surface)	1	0.73m

4.2 OTEHA STREAM 1D-2D COUPLED FLOOD MODELLING

A MIKE URBAN-MIKE11-MIKE21 coupled model of Oteha Valley Catchment was developed where the lower part of Oteha Stream main channel was modelled in 1D MIKE11 model and floodplains were modelled in 2D MIKE21 model. The 1D-2D coupled Oteha Stream model was used to compare the model results with that of 1D MIKE URBAN hydraulic model of Oteha Valley Catchment under identical network and boundary conditions.

Oteha Stream bed and banks have distinctly different roughness characteristics. A single composite Manning's n value was used for the Oteha Stream main channels. There are several formulas available that can be used to estimate an equivalent n value of a given stream channel. None of these formulas were used to estimate a single composite n value for Oteha Stream channels. CES software was used to estimate a single composite n value for various surveyed cross-sections of Oteha Stream channels.

The Conveyance Estimation System or 'CES' is a free software tool that is used to estimate the conveyance or carrying capacity of a channel based on the physics based depth-integrated Reynolds Averaged Navier-Stokes (RANS) equations. Various energy loss mechanisms in compound channel flow are treated individually. CES can be downloaded from *www.river-conveyance.net*, developed by Environment Agency for England and Wales, Northern Ireland Rivers Agency, Scottish Government, and HR Wallingford. Roughness Advisor, a component of CES software, is a large database of Manning's roughness coefficient values based on an extensive literature review of over 700 references covering existing methods and data for estimating roughness.

Manning's roughness values were assigned utilising the Roughness Advisor database for Oteha Stream main channel bed and banks considering surface material/ vegetation/irregularities. Following n value selections CES software were used to estimate channel conveyances for various surveyed cross-sections of Oteha Stream channels. Channel conveyances for the same Oteha Stream channel cross-sections were also estimated using MIKE11 software by assigning the same Manning's n values for bed and banks as shown in Figure 11 for a surveyed cross-section of Oteha Stream channel.

Figure 11 shows Oteha Stream channel conveyance estimated by CES software is significantly lower compared to that estimated by MIKE11 at the same elevation. CES software includes various energy loss mechanisms in channel flow due to variations in roughness/flow velocity across the section. Finally a single composite n value (uniform n in MIKE11) for Oteha Stream channel cross-sections were derived by matching estimated MIKE11 channel conveyances to CES channel conveyances (see Figure 11).

A reasonable and consistent composite Manning's roughness values (0.05 to 0.06) for various surveyed cross-sections of Oteha Stream channels were estimated using CES software. The estimated composite Manning's n values were increased by a correction factor for meandering channel reaches based on degrees of meandering (USGS, 1989). Final composite Manning's n values ranging from 0.05 to 0.078 were assigned for main channels in MIKE11 model for various Oteha Stream reaches. A Manning's n value of 0.10 was used for the 2D ground surface.

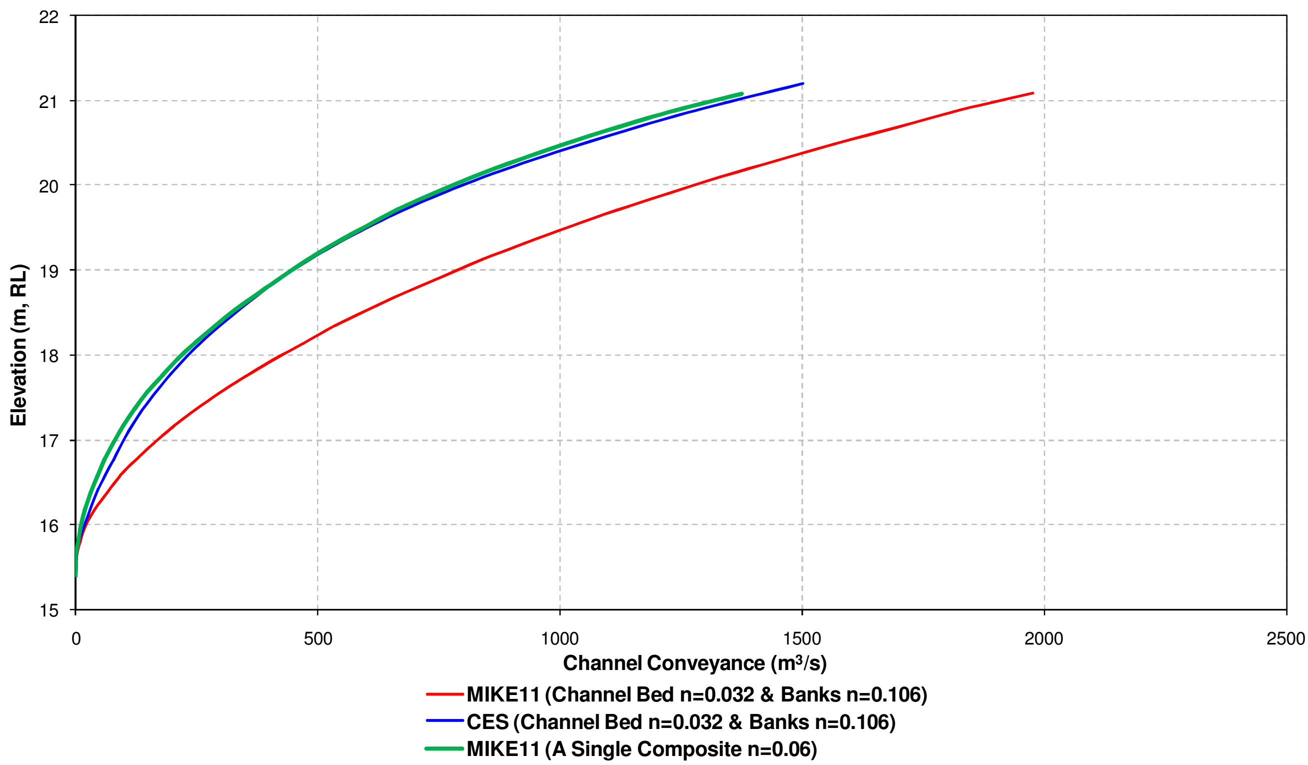

Figure 11: Comparison of estimated Oteha Stream channel conveyances

The predicted 100yr ARI MPD floodplain extents are compared in Figure 12. Model results show predicted flood levels are decreased by 0.78m on average along the lower part of the Oteha Stream compared to the base 1D CMP model and the number of predicted habitable floors flooding is reduced from 27 to 1.

This 1D-2D Oteha Stream modelling shows similar results in terms of predicted flood levels compared to the 2D Oteha Stream modelling with a n value of 0.045 for the main channels (Table 3) which is lower compared to that used in 1D-2D coupled modelling (0.05 to 0.078). This could be due to neglecting momentum exchange between main channels and floodplains in 1D-2D coupled model or lower main channel conveyance representation in the bathymetry of 2D stream modelling.

5 CONCLUSIONS

This stream modelling exercise provides a better understanding of various parameters affecting stream flood level predictions and aids in current best modelling practice. This study recommends the Divided Channel Method for estimating channel conveyance of natural streams with compound section shapes. In the case of a stream section of simple shape a single composite Manning's roughness value can be used to estimate stream channel conveyance.

Using bank markers (DCM Method) and a single composite roughness value for the main channel in 1D stream modelling in MIKE11 and MIKE URBAN software provides reasonable flood level predictions. Similarly 1D-2D coupled stream modelling with a single composite roughness value for the stream channel in 1D model provides reasonable flood level predictions.

Beside the errors associated with survey data, Manning's roughness values are the most significant contribution to uncertainty in flood level estimation. CES software can be used to select Manning's n values for various zones (e.g. bed/banks) of stream channel sections considering surface material, vegetation and irregularities and to estimate composite Manning's roughness values for stream channel sections with distinctly different roughness characteristics.

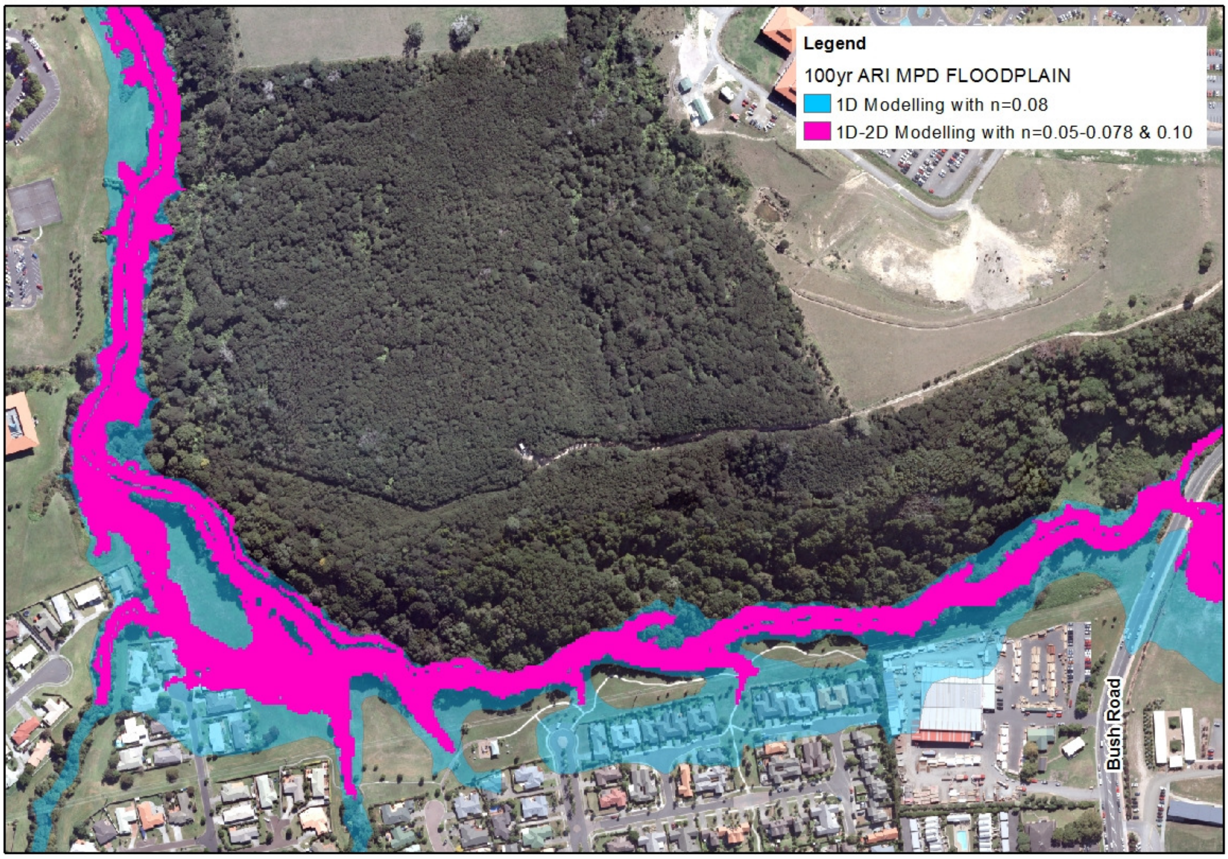

Figure 12: Comparison of Oteha Stream predicted floodplain extents

Explicit representation of channels and floodplains with their constituent roughness values allows a more reasonable physically representative estimation of flooding. In the example documented in this paper the estimates of habitable floor flooding changed from 27 to 1. Rough order cost to alleviate this flooding ranges from 9 million to alleviate flooding for 27 properties to less than half a million for 1 property depending on which modelling solution techniques is adopted.

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