



Northland Regional Council

Kerikeri River Catchment Flood Model Upgrade Report

August 2013

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1. Introduction

Northland Regional Council (NRC) commissioned GHD Limited in May 2013 to prepare a model build report for the Kerikeri River Catchment. This report summarises the modelling process, upgrade of the model at various stages, calibration of the model and preparation of floodplain mapping for various nominated design storms.

1.1 Background

GHD Limited was engaged by Far North District Council (FNDC) in January 2008 to undertake modelling of the Kerikeri River Catchment to prepare a Catchment Management Plan (CMP). Two separate models were utilized for the analysis of the Kerikeri River catchment. The urban area with stormwater pipe network was analysed using MOUSE while the rural area and sub-catchments belonging to the river system were analysed using MIKE11. The hydrological component of the MOUSE Runoff Model represented the Kerikeri Catchment as 388 sub-catchments connected to nodes within the hydraulic model. The MIKE11 Runoff Model was represented by 207 sub-catchments connected to nodes within the MIKE11 hydraulic model. A Catchment Management Plan (CMP) report was prepared for FNDC in February 2009 and is included in Appendix A of this report.

In October 2008, NRC and FNDC jointly engaged GOLOVIN to undertake a peer review of the MIKE11 and Mouse models. The reviewer recommended several adjustments to the model including further breaking of large sub-catchments, extension of river networks, use of an aerial reduction factor for design storms, use of another event for validation of model and use of March 1981 event for calibration. The peer review report (GOLOVIN) and the reply from GHD are included in Appendix B of this report.

Following the peer review of the model by GOLOVIN, GHD was engaged in July 2010 to upgrade the existing model to develop a MIKE Flood model. This upgrade included the development of a MIKE21 model for out of channel flows, extension of Pungaere Stream and Muangaparerua Stream networks in MIKE 11. The upgrading of the model was aimed to improve the calibration of the model, based on the January 2011 and March 2007 events, so that the model could be used confidently to identify the risk of flooding and to undertake option analysis to mitigate the flooding issues in the urbanised parts of the catchment.

1.2 Study Objectives

The principal objectives of the Kerikeri River Catchment Flood modelling study are:

- Calibration of the model using recorded storm events in the catchment.
- Determine the design flows and flood levels for the nominated design storm events for both existing and future land use for both existing and / future rainfall scenarios.
- Determine 10-year and 100-year ARI floodplain maps for the Kerikeri River Catchment based on the most recent topography, network and rainfall data.

1.3 Activities and Scope

The activities and scope of the present modelling study are:

- Upgrading of the model with additional survey information.
- Development of a hydrological and hydraulic model.
- Hydraulic model development, coupling one and two dimensional approaches.
- Linkage between hydrological and hydraulic model.
- Appropriate boundary condition selection.
- Calibration/Validation of the developed model with available recorded flood information.
- Floodplain mapping for the 10-year and 100-year ARI storm events under the Maximum Probable Development (MPD) land use with future rainfall scenario and 10-year ARI storm event under existing land use and present rainfall scenario.

1.4 Datum and coordinate system

The vertical datum used for LIDAR, channel surveys, flood levels, sea level, and all other model elevations was the OTP (One Tree Point 1964) datum.

The locational coordinate system (x,y) used for this study, and referred to in this report, is New Zealand Transverse Mercator projection (NZTM / NZGD 2000).

2. General Model Description

2.1 Location

The Kerikeri Stormwater Catchment Management Area is located on the East Coast of Northland. The catchment covers a total land area of some 14,690 hectares and has its headwaters located near the Waiare Road at the western ridgeline of the catchment. The catchment is roughly bounded by:

- Kapiro Road/Pungaere Road in the north
- Wairoa Road, Lodore Road and a ridgeline in the south
- A ridgeline in the South east located to the east of the Wairoa Stream
- Waiare Road in the west

The Puketotora and Kerikeri Rivers originate at the western end of the catchment, passing through foothills and emerging on flat terrain in the vicinity of the SH10. Both rivers descend over waterfalls downstream of the SH10, and flow along deeply incised river corridors to their confluence near the Golf View Road. The Kerikeri – Pungaere catchment ultimately discharges to the Kerikeri Inlet to the east at the coastal boundary. All stormwater discharges to the Kerikeri Inlet with no flow passing to adjacent catchments. The main areas of overflow within the catchment are from South to North, towards the Pungaere Stream.

The major channels within the Kerikeri Catchment are:

- Puketotora River discharging to the Kerikeri River near the Golf View Road
- Kerikeri River discharging to the Kerikeri Inlet
- Pungare River discharging to the Kerikeri Inlet
- Wairoa Stream discharging to the Kerikeri River at the Kerikeri Basin

Most of the reaches of the streams mentioned above also convey discharges from piped stormwater reticulation systems from the urban areas.

The catchment boundary along with its approximately 108 kilometres of river network is shown in Figure C-1 in Appendix C of this report.

2.2 Topography

The Kerikeri Catchment generally maintains an eastern aspect. It slopes steeply down from its western and southern boundaries along the ridgelines towards the receiving environment at the eastern end near Riverview Road. The catchment ground elevation ranges from 390mRL along the western ridgelines to sea level on the eastern tidal boundary.

Numerous streams originate in the hinterland to the catchment and traverse through the urban drainage area before discharging to the coastal area of the Kerikeri Inlet in the east.

The main Kerikeri CBD is located along a ridge which runs the length of the Kerikeri Road. Land Northwest of the road drains to the Puketotara, and Kerikeri River. Land Southeast of the road drains to the Wairoa Stream. Whilst this area is elevated, it is also relatively level, and stormwater drainage is therefore constrained. The Waipapa Road connects the Waipapa Township in the West to Landing Road in the East. The road generally follows high ground which separates the Kerikeri and Waipapa

catchments, and the area has been subject to development pressure. Flood overflows from the Kerikeri catchment to the Waipapa catchment occur across this road, between the Whiriwhiritoa Stream and the junction with the Rainbow Falls Road.

The area located immediately west of State Highway 10 (SH10) is relatively level ground, being underlain by basalt lava flows. This includes the Waipapa Industrial Estate, and areas alongside the Puketotara Road. Flood overflows occur in this area, and overtop the SH10 on both the North and South sides of the Kerikeri River. The Upper catchment is predominantly grassland and open hill country.

2.3 Geology

The New Zealand Geological Survey Map broadly maps the geology of the Kerikeri Catchment. The underlying geology consists of an area of thin Holocene undifferentiated alluvium (f) associated with the Kerikeri River. The vast majority of the catchment is underlain by Horeke Basalts (hr), which are defined as those localised basalt lava flows that do not have scoria cones as sources. Small amounts of Parahaki Volcanics (ph) (Rhyolite and Dacite) and Wairakau Andesites (wi) defined as andestic fragmental rocks also occur. The whole area is underlain by Waipapa Group (Y-K) Greywakes rock.

2.4 Existing and Future Landuse

The landuse within the Kerikeri River Catchment consists of fifteen categories as shown in Figure C-2 in Appendix C of this report. The majority of land within the Kerikeri River Catchment consists of rural production/general rural zone (82.88%) while the remaining area (17.12%) comprises the remaining, primarily urban, and lifestyle categories of land use. The current landuse within the Kerikeri River Catchment was determined using available aerial photographs of the catchment. For each sub-catchment used in this study, the landuse and impervious area were analysed for input into the hydrological module model under two categories of pervious and impervious area. Each category was then assigned different hydrological parameters as required to describe the actual processes. The existing imperviousness data was used to calibrate/validate the model using the measured flood levels at various gauge locations in the catchment

Based on the FNDC District Plan permitted activity standards for impermeable surfaces, Maximum Probable Development (MPD) impervious area percentages were applied for only urban landuse (zone) categories. The MPD imperviousness was used for the floodplain mapping for the future rainfall scenarios while the existing development (ED) landuse was used for the present day rainfall scenario. As advised by NRC MPD imperviousness was applied for only four categories of urban landuse as shown in Table 1 below. The MPD settings were primarily intended to test stormwater network capacity, as requested by FNDC.

Table 1: Landuse Category

Landuse Type	Area (ha)	% of Total	MPD Imperv. (%)
Conservation Zone (C)	254.3	1.73	Same as ED
Coastal Living (CL)	52.4	0.36	Same as ED
Coastal Marine Zone (CM)	47.5	0.32	Same as ED
Commercial Zone (CO)	23.3	0.16	100
Coastal Residential Zone (CR)	44.1	0.30	50
General Coastal Zone (GC)	0.1	0.00	Same as ED
Rural Production/General Rural Zone (GR)	12,175.3	82.88	Same as ED
Horticulture Processing Zone	4.0	0.03	Same as ED

Landuse Type	Area (ha)	% of Total	MPD Imperv. (%)
Industrial Zone (I)	45.7	0.31	100
Lakes and Rivers (LR)	324.3	2.21	Same as ED
Minerals Zone (MI)	180.6	1.23	Same as ED
Residential Zone(R)	232.3	1.58	50
Recreational Activities Zone (RA)	93.2	0.63	Same as ED
Road (RD)	313.2	2.13	Same as ED
Rural Living (RR)	900.8	6.13	Same as ED
Total	14,691.1	100.00	-

2.5 Stormwater Drainage System

The primary stormwater drainage system of the Kerikeri River Catchment consists of the river system, and the reticulated pipe network system within the Kerikeri and Waipapa Townships which discharge directly to the river system passing through the town. The river system within the Kerikeri Township generally lies within land designated as reserve. The rivers downstream of the main waterfalls are steeply incised and generally have minimal development contained within their immediate vicinity.

The River system generally has a high degree of bush cover. There are many footbridges, road crossing culverts and major road bridges within the township as well as outside of the Kerikeri Township. The downstream reaches of the Kerikeri River, Pungaere Stream and Wairoa Stream are significantly wider as they enter the Kerikeri Inlet.

A summary of the main assets that have been modelled in various modules of the MIKE Flood model are listed in Table 2 below.

Table 2: Kerikeri River Catchment Modelling Asset Information

Asset Type	Quantity	Model Module
River Network (km)	108.1	MIKE11
Cross-Section (nos.)	1,330	MIKE11
Bridge (nos.)	17	MIKE11
Culvert (nos.)	37	MIKE11
Pipe (nos.)	694	MIKE Urban
Manhole (nos.)	779	MIKE Urban

3. Model Upgrade undertaken to address Issues raised in earlier Peer Review

3.1 Issues and Actions

The peer reviewer (GOLOVIN) made a number of recommendations/Queries which can be found in Section 4 of the peer reviewer report attached in Appendix B of this report. The peer review of the original CMP was undertaken between 2008 and 2009. The following paragraphs briefly describe actions to meet the recommendations of the peer review, as undertaken in this more recent flood model upgrade:

Overland Cross-sections in MOUSE model

Recommendation/Query: MOUSE model is over-predicting the flood depth in some road overland flowpaths due to poor cross-section shape.

Action: 2D surface model MIKE21 has been developed based on LiDAR data. A substantial number of cross-sections have been surveyed and the extent of the river cross-sections is limited to stream/river banks and overland flow paths are now represented in the 2D surface model based on LIDAR. No further action was taken.

Overland Flow calculated by MOUSE model

Recommendation/Query: MOUSE model calculates overland flow when clearly the pipe [Stormwater pipe capacity] is perfectly adequate.

Action: The assessment by the peer reviewer was made for part of the network. The profile along the entire link indicates that there was a slight overflow from the upstream pipe because of its smaller size compared to the pipes on both sides. This overflow is being carrying downstream. This has been elaborated in Section 3.4.2 of GHD reply report attached in Appendix B of this report. All MOUSE (MIKE Urban) links to the 2D model (MIKE 21) have been redefined during this upgrade.

MIKE11 doesn't have proper bank markers

Recommendation/Query: MIKE11 cross-sections do not have correct right and left banks.

Action: Appropriate markers have been implemented so that the conveyance curve of a particular cross-section indicates monolithic increase. This has been explained in Section 3.4.3 of GHD reply included in Appendix B of this report. All MIKE 11 links to the 2D model (MIKE 21) have been redefined during this upgrade.

Flood Level in MIKE11 Cross-section is higher.

Recommendation/Queries: Flood levels go higher than MIKE11 cross-sections in a number of locations. Wrong flood level. Levels may go lower.

Action: This has been explained in Section 3.4.3 of GHD reply included in Appendix B of this report. Survey of new cross-sections was carried by NRC and the cross-section width was limited up to the banks of the river/stream. All MIKE 11 links to the 2D model (MIKE 21) have been redefined during this upgrade. The flood levels higher than bank level in MIKE 11 result in overflow to the 2D model.

Sub-catchment Size

Recommendation: Distribution of sub-catchment areas is disproportionate. If subcatchments are reduced, peak flows at Peacock Gardens may reduce by 200 m³/s. This may reduce flood levels by 300mm at Peacock Garden. Consider a hydrological model for the 3 biggest sub-catchments so sub-catchments are no greater than 4% of total area.

Action: The Muangaparerua Stream network, Puketotora Stream and Kerikeri River networks have been extended further with further divisions of the larger upstream sub-catchments located at the upper end of all these river/stream system. The flows at Tyrees Ford weir have been calibrated and validated. The peak flood level at Peacock Gardens was also calibrated for the March 2007 event.

Mass Error in MOUSE

Recommendation/Query: Mass errors in MOUSE calculations greater than 8%. MOUSE is generating water and giving misleading results. Need to find reason and fix. Mass error to be less than 2%.

Action: The method for calculating Mass error was that adopted for the QA/QC process of the Metrowater ICS and Flood Hazard mapping projects. This has been explained in Section 3.6 of GHD reply report included in Appendix B attached to this report.

File Naming

Recommendation: Filenames need to be better designated. Future modellers may be confused and use wrong files. Rename some files to reflect what they are and how they connect to simulations.

Action: All files for a particular simulation are under the particular scenario name and are appropriate. A number of the channel networks in MIKE 11 were renamed during this upgrade.

Area Reduction Factor

Recommendation: Recommend use of an area reduction factor with HIRDS rainfall depths. The reviewer commented that an ARF of 0.89 could reduce flows by 3-7% or about 50m³/s at Peacock Gardens.

Action: An area reduction factor of 0.93 was provided by NRC, based on a pilot study of rainfall records in Auckland done by the University of Auckland. This ARF is the same as UK NERC ARF for a 100km² catchment and 12hr storm. HIRDS rainfall depths were downloaded from NIWA's database for 50 locations based on 12hr duration, and event ARI. The ARF was applied to these total storm rainfall depths for all design storm simulations.

No Sensitivity Analysis

Recommendation: The peer reviewer commented that no sensitivity analysis had been undertaken, and that consequently there was major reliance on one calibration event. The result was uncertainty over flood level tolerances in lower catchment flood risk areas and what freeboard is appropriate. Test 2 or 3 different parameters types and check flood levels in key areas. March 1981 calibration will increase model confidence.

Action: During the model upgrade 2 events were used for calibration and validation. The January 2011 event was used initially for validation, and then further calibration of the model. A large number of flood debris levels for both March 2007 and January 2011 events spread all over the catchment have been calibrated, with the model result having high calibration fitness. The March 1981 event was not used as a calibration event as there is relatively limited data available on this event. Checks made by NRC on design storm results at several locations showed that 1981 flood levels exceed all design storm results.

No Modelling close-out

Recommendation: No modelling close-out section in the Appendix of the report. Future proofing of the modelling work is reduced. Needs a section on the model simulations, assumptions etc.

Action: The CMP report was based on requirement by the client, FNDC. However, appropriate sections have been added in this report.

Design Flows are not in-line with Gumbel analysis

Recommendation: The peer reviewer commented that design storms over predicted flow by 30% at Muangaparerua Tyrees Ford site, and consequently, Peacock Gardens flood levels maybe over estimated by 0.5m.

Action: The model upgrade has extended the Muangaparerua Stream network into the upper catchment, with significant addition of channel survey data, including for the Tyrees Ford weir at the gauge site. The model has been calibrated to achieve a very close stage and flow correlation to site data for both the March 2007 and Jan 2011 events. New design storm results generate a close fit with flow frequency analysis estimates for this site.

New NIWA analysis of 1981 and 2007 rainfall

Recommendation: The peer reviewer commented that the NIWA (2009) review of flood peaks in the Kerikeri catchment had changed the flow frequency for the Tyrees Ford site, and consequently an adjustment to rain depths and return periods should be considered.

Action: NRC has adjusted the rainfall depth using 50 locations spread over the entire catchment and an aerial reduction factor of 0.93 has been applied at all locations for all design storm simulation. The design storm flows have been cross checked against the revised flow frequency for the Tyrees Ford site, and a good fit has been established.

Peer Reviewer's Wish List of other Actions

Recommendation: a number of items were included in the peer reviewer's wish lists which are included in Table 4.2 of the peer review report attached in Appendix B of this report.

Action: Some actions have been taken in CMP report and in so much as possible others are included in this report.

4. Model Upgrades Undertaken to Improve Calibration Results and Flood Mapping

4.1 Model Upgrade to Improve Calibration

Significant upgrading of the model was undertaken to improve the calibration results of the model. The upgrading of the model has been undertaken by inclusion of the following:

- Extension of Pungaere Stream by approximately 11.50 kilometres up to its head water, including Manuwai dam, and inclusion of all tributaries between Pungaere Road and SH10 in MIKE11 model.
- Survey of 18 cross-sections along the Pungaere Stream upstream of SH10. Generation of 140 cross-sections from LiDAR and modification of the low flow channel using nearby surveyed cross-sections.
- Inclusion of approximately 2.05 km branch (Pungaere Branch 1) of Pungaere Stream across the Pungaere Road. Survey of five cross-sections along the Pungaere Branch 1. Two culverts were also surveyed for inclusion into MIKE11 model. Generation of 34 cross-sections from LiDAR and modification of the low flow channel using nearby surveyed cross-sections.
- Inclusion of approximately 1,229 m branch (Lake Manuwai) of Pungaere Stream connecting the Lake Manuwai Dam. Survey of three cross-sections along the Lake Manuwai branch. Six cross-sections were generated along spillway chute using as-built drawings. Generation of 24 cross-sections from LiDAR and modification of the low flow channel using nearby surveyed cross-sections.
- Inclusion of 87 m branch of Lake Manuwai branch in MIKE 11 model. Survey of one cross-section and generation of four cross-sections from LiDAR and modification of the low flow channel using nearby surveyed cross-sections.
- Extension of whiriwhiritoa Stream by about 1 km for inclusion into MIKE11 model. Survey of four cross-sections along this extension. Two culverts were also surveyed for inclusion into MIKE11 model. Generation of nine cross-sections from LiDAR and modification of the low flow channel using nearby surveyed cross-sections.
- Inclusion of 930 mm diameter farm culvert upstream of SH10 in Whiriwhiritoa Stream MIKE11 model network.
- Extension of the Kerikeri River network further upstream by approximately 5.4 km for inclusion into MIKE11 model. Five cross-sections along this extension were surveyed and one cross-section from LiDAR was generated.
- Survey of 10 cross-sections along the Whirawarawa Stream and its single branch. One bridge and one culvert were also surveyed for inclusion into MIKE11 model. Generation of 72 cross-sections from LiDAR and modification of the low flow channel using nearby surveyed cross-sections.
- Approximately 14 km of new network along the Muangaparerua Stream was generated using LiDAR and Surveyed cross-sections. The Tyrees Ford Weir and one bridge were surveyed for inclusion in MIKE11 model. The catchment was

further divided. Twenty-one cross-sections were surveyed by NRC. Twenty-two cross-sections were generated using LiDAR and modification of the low flow channel using nearby surveyed cross-sections was undertaken.

- Approximately 282 m of new Muangaparerua Branch1 was generated using LiDAR. Thirty-seven cross-sections were generated using LiDAR and modification of the low flow channel using nearby surveyed cross-sections was undertaken.
- Approximately 814 m of new Muangaparerua Branch2 was generated using LiDAR. Eleven cross-sections were generated using LiDAR and modification of the low flow channel using nearby surveyed cross-sections was undertaken.
- Inclusion of approximately 1.8 km branch (KerikeriRiver_Branch2) of Kerikeri River across SH10. Survey of four cross-sections along this branch. Survey of twin culverts across SH10 for inclusion into MIKE11 model. Generation of 18 cross-sections from LiDAR and modification of the low flow channel using nearby surveyed cross-sections.
- Extension of Puketotora Stream by approximately 3.9 km. Survey of five cross-sections and generation of 16 cross-sections from LiDAR with modification of the low flow channel using nearby surveyed cross-sections. A large number of cross-sections along the reach of this stream downstream of SH10 Bridge were generated and the low flow channel was modified using the nearby surveyed cross-sections. The old hydro-electric weir and the Golf View Road Bridge were surveyed for inclusion into MIKE11 Model.
- Survey of two cross-sections of the rocky bed (control) located upstream of the Rainbow Falls for inclusion in MIKE11 model. Four cross-sections around the sharp 90 degree bend in the Kerikeri River adjacent to Waipapa Road were also surveyed by NRC.

In addition to the survey of cross-sections as listed above a large number of cross-sections were generated using LiDAR and the low flow channel modified using the nearby surveyed cross-sections. These cross-sections were mainly generated along the Pungaere Stream upstream of landing Road, along Whiriwhiritoa Stream on both side of SH10, along Kerikeri River around the Peacock Garden and along Wairoa River.

4.2 Model Upgrade to Improve Flood Mapping

A number of upgrades to the model were undertaken either to improve the flood mapping of the catchment or incorporate new features constructed in the catchment after the calibration event of March 2007. The following improvements were undertaken:

- Survey of four cross-sections along Whiriwhiritoa Stream between SH10 and Waipapa Road, including control sections upstream of small waterfall.
- Inclusion of a newly installed 1.5 m diameter pipe culvert constructed beside the existing box culvert on the Whiriwhiritoa Stream at Waipapa Road.
- Inclusion of the Heritage bypass bridge in MIKE11 model which has been constructed after the March 2007 storm event. Extraction of demolished Stone Store Bridge from model.
- Inclusion of assets constructed during Waipapa Road upgrading. These include stormwater assets included in MIKE Urban model, the constructed road side drains included in MIKE11 model along with 12 private road crossing culverts.

The sub-catchments in this location were further divided taking into consideration the stormwater assets.

5. Summary of Final Model Build and Methodology

5.1 Modelling Software

One dimensional (1D) and two dimensional (2D) models were run simultaneously in a single hydro-dynamically coupled simulation. This combines the advantages of both modelling approaches by modelling overland flows in 2D and pipe and stream flows in 1D. The choice between the two (2) modelling methods is generally done by matching specific components with the best available data in order to achieve the highest confidence in results in each model.

Two dimensional methods describe multidirectional flows over a Digital Terrain Model (DTM). They are, therefore, preferred where a DTM gives a better topographical representation and where the flow is not unidirectional (simple channel flow) but can diffuse in many directions over a surface. For these reasons, the two dimensional model has been chosen to represent the surface terrain.

Several limitations apply to the two dimensional method:

- Low resolution of the LIDAR (especially for channels, narrow, covered or vegetated areas). The model DTM comprises 5m x 5m cells which are assigned a level based on the average of LIDAR values within the cell area. Specific features, such as stopbanks, and many road causeways across the floodplain, have been assigned a specific crest value in the model DTM based on survey information provided by NRC.
- Long calculation time.
- Instabilities in model calculation on steep slopes.
- Lack of ability to represent underground pipes and for these reasons, the pipe system was represented in Mike Urban 1D model.

The following DHI software as listed in Table 3 has been used to model the Kerikeri River Catchment.

Table 3: Software Used

Software Name	Software Version
MIKE FLOOD	Version 2011, SP7
MIKE11	Version 2011, SP7
MIKE 21	Version 2011, SP7
MIKE URBAN	Version 2011, SP7

MIKE FLOOD is a tool which integrates the one-dimensional models MIKE 11 and MIKE URBAN with the two-dimensional model MIKE 21 into a single, dynamically coupled modelling system. This realises the advantages of both modelling approaches by modelling overland flows in two dimensions and pipe/channel flow in one dimension.

MIKE 21 software describes multidirectional flow over a surface. The spatial domain is discretised into small cells to form a computational grid containing the elevation values used during the hydraulic simulation.

5.2 Hydrometric Data

Hydrometric data typically required are rainfall, flow and water level time series which are best obtained from long-term gauges for hydrological and hydraulic model calibration/validation. There are seven permanent automatic rainfall gauges and two daily gauges (Data is available on daily basis) within the vicinity of the Kerikeri River Catchment for calibration/validation of the model. NRC provided correlation coefficient for these two daily gauges to their nearest automatic gauge to generate time series data for input into the model. The details of the rain gauges are provided in Table 4 below.

Table 4: Details of the Rain gauges used in the Model Calibration

Location of Rain Gauge	Easting	Northing	Type
Muangaparerua at Tyrees Ford	1,680,246	6,100,325	Automatic
Kerikeri AERO AWS	1,683,424	6,097,163	Automatic
Kerikeri EWS	1,683,526	6,108,254	Automatic
Purerua AWS	1,692,678	6,113,569	Automatic
Bramley at Kaeo	1,672,077	6,108,873	Automatic
Waitangi at McDonalds Road	1,693,827	6,089,850	Automatic
Ohaewai	1,679,414	6,087,032	Automatic
Puketi Rd at Candy	1,668,388	6,097,699	Daily
Keriei at Kiakaha	1,686,448	6,104,981	Daily

There are two long-term level/flow gauges available in the Kerikeri River Catchment for the calibration/validation of the model, shown in Table 5 below. The Peacock Gardens site does not yet have a reliably established flow rating.

Time series for tides from Veronica Channel at Opua coastal gauge were used for the calibration/validation of the model. The recorded tides were used as the tidal boundary during the calibration/validation events at the outfalls of the Kerikeri River near Kerikeri Inlet. The details of the flow/level gauges are provided in the following Table 5 below.

Table 5: Details of the Level/Flow gauges within Kerikeri River Catchment

Flow/Level Gauge Location	Easting	Northing	Type
Muangaparerua at Tyrees Ford	1,680,460.5	6,100,567.9	Flow/Level
Peacock Garden	1,686,831.9	6,162,762.7	Level
Veronica Channel at Opua	1,701,913.0	6,091,757.0	Tidal

5.3 Topographic Data

A Light Detection and Ranging (LiDAR) survey of the Kerikeri River Catchment was available from FNDC/NRC. The main LiDAR survey was carried out by New Zealand Aerial Mapping (NZAM) in 2008 with vertical datum of OTP (One Tree Point). Large areas west of the State Highway 10 (SH10) were surveyed by NZAM in 2010. These areas include: The Puketotora Stream catchment from SH10 up to about 4 km upstream, a section of the Kerikeri River catchment west of SH10, the upper Whiriwhiritoa Stream catchment and the majority of the Pungaere Stream catchment west of SH10. The LiDAR data produces a dense scattering of points with ground elevation (1m grid). LiDAR data was used to generate the 2D ground surface, referred to as Digital Elevation Model (DEM). The DEM was used as input topography into the two-dimensional MIKE 21 model for simulating variations in flows and water levels in

overland flowpaths. The LiDAR coverage/2D model domain used in the model is shown in Figure C-3 in Appendix C of this report.

5.4 Hydrological Model

5.4.1 Method Used

The MIKE Urban hydrological model was used to determine the stormwater runoff in MIKE Urban sub-catchments while MIKE11 RR module has been used to determine runoff for the sub-catchments discharging to MIKE11 and MIKE21 networks (as source points).

The Kinematic Wave equation (Model B) Module was used to represent the runoff surfaces. For further information regarding the runoff method and modules used, including details of runoff calculations visit: <http://www.dhigroup.com/>.

The Kerikeri River Catchment hydrology is comprised of three separate hydrology methods:

MIKE Urban

- The Kinematic Wave equation (Model B) Module was used to represent the runoff surfaces.
- Runoff rate and volume calculated with the MIKE Urban Model B Module parameters using catchment length, catchment slope, impervious and pervious areas, wetting loss, storage loss, start infiltration, end infiltration, Horton's exponent and Manning's number.
- A separate analysis of pervious and impervious components was adopted using separate area within the same sub-catchment analysis.
- Estimation of the areas of different land use categories as outlined in Section 2.4. Sub-catchment slope calculated using the Equal Area Method as outlined in ARC TP108 of Auckland Council.
- Recorded 10-minute time series rainfall data, obtained from the NRC for the gauges as stated in Section 5.2 were used for the calibration of the model.
- 12 hour temporal rainfall pattern as provided by NRC based on their Priority Rivers studies were used for the simulation of design storms.

Mike 21

The sub-catchments without any pipe network or river network were modelled in MIKE21 as source points. Sub-catchment runoff hydrographs were generated and were applied directly to the 2D grid cell. Model B was used for the assessment of the hydrology for these sub-catchments. The hydrology was assessed by using model B of MIKE11 RR module.

Mike 11

The sub-catchments discharging directly into the river system were modelled in MIKE11 by connecting to the river networks. Model B was used for the assessment of the hydrology for these sub-catchments. The hydrology was assessed by using MIKE11 RR module.

5.4.2 Sub-catchments

The catchment and sub-catchment boundaries were delineated in ArcGIS software based on the 1m grid raster dataset based on LiDAR data, 0.25m interval LiDAR

contours, Topographic 20m contours, aerial photographs, overland flow paths (generated from the DEM based on LiDAR data), cadastral property boundaries, and the location of the stormwater collection system.

The Kerikeri River Catchment was divided into 931 stormwater sub-catchments which were used for modelling purposes for the design storm simulation. There are a few less sub-catchments used for the calibration event in the MIKE11 model. This is because of breaking of some sub-catchments subsequent to calibration, due to inclusion of stormwater network for the upgrading of the Waipapa Road implemented by Far North District Council (FNDC) in design storm simulations as discussed in Section 4.2 of this report. The locations of the sub-catchment boundaries for the stormwater system can be seen in Figure C-4 in Appendix C of this report.

Out of 931 sub-catchments, 474 sub-catchments are connected to MIKE11 networks and 413 are connected to stormwater manhole nodes within the 1D pipe network model MIKE Urban linking the hydrological model to hydraulic model. The remaining 44 sub-catchments are assigned as source points into the 2D model grids of the MIKE21 model.

5.4.3 Hydrological Parameters

Stormwater sub-catchment characteristics were defined using a combination of GIS data and data from field inspections. The slope for each of the stormwater sub-areas was determined using equal area method as specified in TP108, computed along the straight path from top of the sub-catchment to its exit at the bottom.

Each sub-catchment in the Kerikeri River Catchment has a percentage area of roofs, other paved areas and pervious area. This percentage was calculated in GIS based on impervious surfaces as stated earlier.

The assessment of sub-catchment road surfaces imperviousness was undertaken as a GIS integration of the sub-catchment boundary and the road surface. The resultant impervious area was assigned as flat impervious area within the model. This was carried out by GIS integration of the road surface GIS shape file received from council. The paved and roof areas were represented in the MIKE URBAN/MIKE11 RR model as steep and flat while the pervious area was represented in the medium category. These contributing areas were calculated using the percentage of the total sub-catchment that was made up of roofs, paved and pervious area.

Model B Parameters

Within the MIKE Urban/MIKE11 software it is possible to define different hydrological parameter sets for various types of surfaces in Model B. A parameter set is identified by a string of up to 13 characteristics that describes Wetting, Storage, Infiltration and the Surface Roughness of the catchment

Flow gauge data located within the Kerikeri River Catchment was collected for the calibration of the model. All impervious areas from a sub-catchment are simulated using the stormwater Model B. Initially, Model B Parameters were set based on geology of the area, physical characteristics of a sub-catchment and our modelling experience. Some parameters used are based on the physical characteristics of the sub-area such as average slope and flow path length. The start and end infiltrations for sub-catchments in Model B were estimated based on various geological soils in each sub-catchment. Finally, the Model B parameters were refined through the calibration process of the model.

A summary of various hydrological model parameters used in the model are given in Table 6 below:

Table 6: MIKE11 Model B Calibrated Hydrological Parameters

Parameters	Parameter Values
Wetting (mm)	0.50-10.00
Initial Loss (storage) (mm) – Flat Impervious Area	0.60
Initial Loss (storage) (mm) – Pervious Area	0.5-30.00
Start Infiltration (mm/hr) – Pervious Area	0.50-11.50
End Infiltration (mm/hr) – Pervious Area	0.05-2.06
Horton Exponent – Pervious Area	0.0015-0.0016
Inverse Horton's Equation	1.00E-009
Manning's Number (M) – Roof Area	80
Manning's Number (M) – Flat Impervious Area	70-80
Manning's Number (M) – Bush Pervious Area	12.50–80

5.4.4 Hydrological Assumptions

During the modelling process, assumptions were made in order to appropriately represent the flow situation.

- The sub-catchment boundary is primarily based on the land contours and therefore, exclusive analysis of directly connected/unconnected imperviousness related to roof runoff and runoff from private driveways and roads has not been undertaken. Higher imperviousness has however been adopted for urban catchments.
- The 10 year and 100 year Average Recurrence Interval (ARI) design storms as provided by NRC were used in the modelling. These were based on 12hr rainfall depths in HIRDS v3, and the temporal distribution was according to a hyetograph developed for NRC by MWH. Storms of greater intensity and duration than those modelled, or with a more adverse rainfall profile, may occur and may give rise to greater flooding than modelled. However the temporal distribution used generates design storm flows which are in reasonable agreement with flow frequency analysis for the Tyrees Ford gauge site.
- The effects of climate change on the hydrology have been taken into account based on rainfall for the 10yr ARI CC and 100yr ARI CC design storms that was provided by NRC. The 12 hour rainfall depths were downloaded from NIWA's HIRDS v3 database, using an allowance of 2.1 degrees Centigrade for temperature increase which is an MfE mid-point projection for Northland. An allowance has also been made for the projected effects of climate change on sea level rise in those design storms reflecting MFE baseline guidance of 500mm to the 2090's (2008). A sea level time series developed by MWH was used for the coastal boundary condition in design storm model simulations, and this time series was adjusted upwards by 500mm for the climate change scenario.
- Under the Maximum Probable Development (MPD) scenario, the impervious percentages for urban areas were determined according to the permitted activity zone rules in the District Plan for impervious surfaces. The MPD scenario was

just applied for urban zones in the model, and for only the futuristic climate change scenario design storms.

- Under the Existing Development (ED) scenario, the impervious area was derived from the aerial photographs. This was used for the 10yr ARI design storm run, reflecting existing development and existing climate.
- Where the existing imperviousness already exceeds the permitted imperviousness, the existing imperviousness was used in the MPD scenario.
- A total constant natural base flow of 20.05 m³/s at various locations along the river networks has been added in the stormwater system and was derived during the calibration process. This base flow was retained during the design storm simulations. The notable flows are 13.0 m³/s along Kerikeri River, 5.5 m³/s at chainage 0 of the Puketotara Stream, 0.05 m³/s along Ch. 0 to Ch. 100 of the Muangaparerua Stream and 1.5 m³/s along Waiwhakangarongaro Stream of the MIKE11 network. A very nominal low flow was assigned at the beginning of the other MIKE11 network and was required for modelling purpose.
- Horton losses have been applied to all pervious areas in the catchment. All other impervious areas are assumed to have no associated losses.
- The linkage between the hydrological model and the hydraulic model is done through individual source points. For each sub-area a runoff hydrograph is calculated in the hydrological model and applied as a source point in the hydraulic model.

5.5 Hydraulic Model

5.5.1 Method Used

The hydraulic model of the Kerikeri River Catchment was developed incorporating the existing stormwater pipe network, open channels, culverts, bridges, overland flow paths and off-channel storage as captured in LiDAR. The stormwater pipe network was modelled in MIKE Urban one-dimensional model whereas rivers/open channels are modelled in MIKE11 1D model and overland flow paths are modelled using MIKE 21 two-dimensional model. The hydraulic computation in 1D model is based on an implicit, finite difference numerical solution of basic 1-D free surface gradually varied unsteady flow equations (Saint Venant).

The hydrodynamic computation in MIKE 21 model is based on an Alternating Direction Implicit (ADI) finite difference numerical solution of the two-dimensional shallow water equations - the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. The model consists of continuity and momentum equations. It simulates unsteady two-dimensional flows in one layer (vertically homogeneous) fluids.

5.5.2 Hydraulic Model Network

The hydraulic model network is made up of three main hydraulic components-the primary drainage system, comprising the built stormwater system made up of the Stormwater pipe network in MIKE Urban. The culverts, bridges and rivers/channels are modelled in MIKE11 while the overland flow paths are modelled using MIKE 21 two-dimensional model.

A summary of various hydraulic model components is given in Table 7 below and briefly described in the following paragraphs below.

Table 7: Summary of hydraulic model components

Hydraulic Model Components	Values
MIKE Urban 1D Model	
Total number of stormwater network nodes	779
Total number of weirs	3
Total number of links	694
Total number of outlets	49
Total length of stormwater pipes (m)	23,292
MIKE11 1D Model	
Total number of networks	48
Total length of networks (km)	108.1
Total number of cross-section	1,330
Total number of bridges	17
Total number of culverts	37
Total number of Weirs	30
Total number of Reservoirs	1
MIKE 21 2D Model	
Total number of 2D model grid (8 m x 8 m cells)	2,164 x 1,860 = 4,025,040 cells

The locations of the 17 bridges used in MIKE11 model are presented in the Table 8 below:

Table 8: Locations of the Bridges used in the MIKE11 Model

Bridge Location	River/Channel Name	Chainage (m)
Puketotora SH10	Puketotora_Stream	4454.21
Kerikeri SH10	Kerikeri_River	10229.09
Pungare Steam SH10	Pungaere_Stream	11476.00
Wairoa River_Cobham Road	Wairoa_River	3331.50
Wairoa River FootBridge	Wairoa_River	5812.62
Heritage Bypass Bridge	Kerikeri_River	15341.96
Whirigatau_BRIDGE1	Whiringatau_Stream	41.88
Waimate North Road Crossing bridge	Whiringatau_Stream	611.86
US of Ford Road	Waiwhakangarongaro_Stream	5391.11
Amuri Road	Waiwhakangarongaro_Stream	5168.33
Valencia Lane	Waiwhakangarongaro_Stream	3916.30
Landing Road Bridge	Pungaere_Stream	21060.00
Mangakaretu Road	Maungaparerua_Stream	5106.37
Bridge on Jennings Road	Whirawarawa_Stream	3365.37
Pedestrian Box Culvert (Bridge)	Whiriwhiritoa_Stream	1542.67
Boat Bridge	Whiriwhiritoa_Stream	1286.60
Golf View Bridge	Puketotora_Stream	9450.40

There are thirty seven culverts along various MIKE11 networks and their locations are shown in the Table 9 below:

Table 9: Locations of the Culverts Included in MIKE11 Model

Culvert Name	River/Channel Name	Chainage (m)	Type
C1_SH10	Whiriwhiritoa_Stream	1734.9	Rectangular
C1_WaipapaRoad_Box	Whiriwhiritoa_Stream	2797.3	Rectangular
Hill Road Culvert	WairoaRiver_Branch3	32.72	Circular
Unknown Road	WairoaRiver_Branch5	13.97	Circular
Kemp Road 1	KerikeriRiver_Branch6	251.45	Circular
Kemp Road 2	KerikeriRiver_Branch8	15.82	Circular
Kemp Road 3	KerikeriRiver_Branch7	15.58	Circular
3_Culverts	KerikeriRiver_Branch5	63.27	Circular
Kendell Road C1	KerikeriRiver_Branch10	16.76	Circular
Kendell Road C2	KerikeriRiver_Branch10	172.76	Circular
Tui Place Culvert	KerikeriRiver_Branch10	223.52	Circular
Okura Drive	WairoaRiver_Branch4	19.23	Circular
Ford Road	Waiwhakangarongaro_Stream	5462.97	Circular
C12_WaipapaRoad_Pipe_New	Whiriwhiritoa_Stream	2797.3	Circular
Twin Culvert on SH10	KerikeriRiver_Branch2	1667.8	Circular
Culvert on KoroPewa Road	Whiriwhiritoa_Stream	267.71	Rectangular
Culvert on Koranae Road	PungaereStream_Branch1	810.92	Circular
Culvert on Pungaere Road	PungaereStream_Branch1	1866.02	Circular
Culvert on Ness Road	Whirawarawa_Stream	2370.9	Rectangular
Culvert2 off Kerikeri Road	KerikeriRiver_Branch4	892.28	Circular
Culvert1 Off Kerikeri Road	KerikeriRiver_Branch4	315.99	Circular
Lake manuwai Spillway Culvert	Lake_Manuwai	34.15	Circular
Farm Culvert on Whiriwhiritoa	Whiriwhiritoa_Stream	982.33	Circular
Farm Track Culvert	KerikeriRiver_Branch1	236.33	Circular
PuketotataraStream_Br1	PuketotaraStream_Branch1	21.5	Circular
D1C1	Waipapa_Ditch1	35.88	Circular
D1C2	Waipapa_Ditch1	77.61	Circular
D1C3	Waipapa_Ditch1	133.1	Circular
D1C4	Waipapa_Ditch1	149.88	Circular
D1C5	Waipapa_Ditch1	189.84	Circular
D1C6	Waipapa_Ditch1	234.25	Circular
D1C7	Waipapa_Ditch1	275.48	Circular
D2C1	Waipapa_Ditch2	149.44	Circular
D2C2	Waipapa_Ditch2	287.53	Circular
D3C1	Waipapa_Ditch3	5.7	Circular
D3C2	Waipapa_Ditch3	22.41	Circular
D3C3	Waipapa_Ditch3	106.78	Circular

There are thirty weirs along various MIKE11 networks. Most of the weirs are located at the water falls while some have been implemented in the model to avoid instability due significant drops between two subsequent cross-sections in the model. The locations of the weirs along with the network name are shown in the Table 10 below:

Table 10: Locations of the Weirs Included in MIKE11 Model

Weir Name	River/Channel Name	Chainage (m)
Rainbow2 Waterfall on Kerikeri	Kerikeri_River	15877.86
Charlies Rock Waterfall on Pungaere Stream	Pungaere_Stream	20211.61
Rainbow Waterfall on Kerikeri River	Kerikeri_River	13254.42
Waterfall on Wairoa River	Wairoa_River	4092.69
Waterfall on Wairoa Branch4	WairoaRiver_Branch4	1233.68
Weir1 Pungaere Branch3	PungaereStream_Branch3	1239.3
Wagaro Spillway	Waiwhakangarongaro_Stream	99.79
3rd Fall in Waingarō	Waiwhakangarongaro_Stream	4000.72
Tyrees Ford Weir	Maungaparerua_Stream	6933.33
Lake Manuwai Spillway Weir us of Culvert	Lake_Manuwai	0.2
Lake Manuwai Emergency Spillway	Emergency_Spillway	9.39
Waterfall on Puketotara	Puketotara_Stream	5340.09
Falls on PungaereStreamBr2	PungaereStream_Branch2	673.59
Weir 2 on Pungaere_Stream	Pungaere_Stream	7713.56
Weir 1 on Whirawarawa Stream	Whirawarawa_Stream	2490.69
Weir 2 on Whirawarawa Stream	Whirawarawa_Stream	3473.5
Weir 1	WairoaRiver_Branch5	301.69
Weir 1	KerikeriRiver_Branch5	118.44
Weir 1	KerikeriRiver_Branch4	4.51
Weir 2	KerikeriRiver_Branch4	192.29
Weir 3	KerikeriRiver_Branch4	140.46
Weir on KerikeriRiver_Br3	KerikeriRiver_Branch3	386.06
Weir 1 on KerikeriRiver_Br10	KerikeriRiver_Branch10	419.37
Weir 1 KerikeriRiver_Br9	KerikeriRiver_Branch9	510.65
Weir 3 on PungaereStream_Br4	PungaereStream_Branch4	162.31
Weir 2 on Lake Manuwai	Lake_Manuwai	78.07
Weir 2 on PungaereStream_Br4	PungaereStream_Branch4	216.4
Weir 2 on KerikeriRiver_Br9	KerikeriRiver_Branch9	338.27
Weir 3 on Lake Manuwai	Lake_Manuwai	153.83
Weir 1	KerikeriRiver_Branch6	305

Reservoirs

There are two reservoirs located at the headwaters of the catchment. The Lake Manuwai dam is located at the northwest corner of the catchment discharging overflow into the Pungaere Stream through a tributary. The catchment area of the Lake Manuwai dam is approximately 586 hectares. The lake (when full) covers an area of approximately 147 ha and has a total stored volume of approximately 12,000,000 m³ of which approximately 7,900,000 m³ is usable for irrigation.

The service spillway of the Lake Manuwai dam is a semi-circular weir intake with a 2.5 m radius, and invert level 153.0 mRL (OTP), which drops to a 1950 mm diameter pipe. This pipe passes through the dam embankment and discharges to an open concrete chute nominally 3 m wide and 900 deep.

The auxiliary spillway of the Lake Manuwai dam is on the true right-hand abutment of the dam. It has a concrete slab which is 50 m long (across the width of the spillway) and 4 m wide with an invert level of 153.75 mRL (OTP). The flow is then to a grass swale down the dam embankment to the stream. The top of the main dam crest is at 156 mRL (OTP).

The Reservoir details including the area-elevation-storage data have been incorporated into the MIKE11 model for both calibration/validation events as well as for the design storm simulations. The elevation-area-volume data for the Lake Manuwai dam is presented in Table 11 below:

Table 11: Elevation-Area-Volume data for Lake Manuwai

Elevation (m OTP)	Cumulative Area (m ²)	Cumulative Volume (m ³)
151.70	0	0
151.80	1,108,500	110,850
151.90	2,217,000	221,700
152.00	3,325,500	332,550
152.10	4,446,000	444,600
152.20	5,566,500	556,650
152.30	6,687,000	668,700
152.40	7,807,500	780,750
152.50	8,928,000	892,800
152.60	10,048,500	1,004,850
152.70	11,169,000	1,116,900
152.80	12,289,500	1,228,950
152.90	13,410,000	1,341,000
153.00	14,530,500	1,453,050
153.10	15,651,000	1,565,100
153.20	16,771,500	1,677,150
153.30	17,892,000	1,789,200
153.40	19,012,500	1,901,250
153.50	20,133,000	2,013,300
153.60	21,253,500	2,125,350
153.70	22,374,000	2,237,400
153.80	23,494,500	2,349,450
153.90	24,615,000	2,461,500
154.00	25,735,500	2,573,550
154.10	26,856,000	2,685,600
154.20	27,976,500	2,797,650
154.30	29,097,000	2,909,700
154.40	30,217,500	3,021,750
154.50	31,338,000	3,133,800
154.60	32,458,500	3,245,850
154.70	33,579,000	3,357,900
154.80	34,699,500	3,469,950
154.90	35,820,000	3,582,000
155.00	36,940,500	3,694,050

The starting water level of the Lake Manuwai dam for simulation of calibration/validation events was determined based on available observations by Kerikeri Irrigation which were provided by NRC. NRC also provided the starting water level of the lake for the simulation of the design storms, which was the service spillway intake level. These levels are provided in the Table 12 below.

Table 12: Starting Elevation of the Lake Manuwai for Various Events

Event Simulation	Reservoir Starting Level (m OTP)
March 2007 Event	151.70
January 2011 Event	152.44
Design Storm Events	153.00

The other reservoir is located at the southwest corner of the Kerikeri River Catchment at the headwater of the Waiwhakangarongaro Stream and is known as Lake Waingaro. The lake receives stormwater runoff from a catchment area of approximately 143 hectares. The lake area is approximately 44 hectares with a dam spill level of 178.6 mRL. The details of the reservoir and dam spillways were not included in the model because of limited data and small catchment area. The sub-catchment discharging into the Lake Waingaro was excluded during the calibration/validation events as information received from Kerikeri Irrigation indicated that inflow for these events went into dam storage, with no spillway discharge. The dam catchment area was included during the design storm events simulation as specified by NRC, as a default assumption for Priority Rivers design storms is that reservoirs are full to service spillway level prior to storm onset.

1D Model Nodes

MIKE Urban model links were utilised to represent stormwater drainage pipes and limited overland flowpaths within the Kerikeri urban area and Waipapa industrial area. The pipe data input to the model comprises: diameter, upstream and downstream inverts and connecting nodes based on the FNDC GIS asset database.

1D Model Weirs in MIKE Urban

Artificial Weirs were also used in the model to provide connectivity between adjacent pipe networks with short channel in between or no pipe information in the FNDC database. A pipe with short length and very steep gradient was replaced by a weir to avoid instability in the model.

1D Model Weirs in MIKE Urban

Artificial Weirs were also used in the model to provide connectivity between adjacent pipe networks with short channel in between or no pipe information in council database. A pipe with short length and very steep gradient was replaced by a weir to avoid instability in the model.

1D MIKE11 Model Links

Lateral links allow exchange of flow between MIKE 11 and MIKE 21 along a MIKE 11 network. Lateral flow from the watercourse to the floodplain is calculated using a weir structure, linking the water level in the MIKE 11 channel with the water level in the adjacent MIKE 21 grid cells.

The software default cell-to-cell method has been used in Kerikeri River Catchment. During the simulation, the MIKE 11 watercourse starts to spill into the MIKE 21 model when the water level in MIKE 11 reaches the level of the adjacent MIKE 21 cells. Transfer between MIKE 11 and MIKE 21 is controlled by default link parameters. For a more detailed explanation of linkages, please refer to the DHI 2011 Software help in

the MIKE FLOOD section – Options for standard and structure links (DHI Water & Environment, 2011).

2D Model Bathymetry

The bathymetry consists of the 2D ground surface (Digital Elevation Model) created from the LiDAR data. The dimension of the 2D ground surface (the grid size) is an important parameter as it sets the spatial resolution of the resultant floodplain. The 2D model grid used for Kerikeri River Catchment is 10,820m by 9,300m in size with a grid cell size of 5m x 5m. The bathymetry was modified where necessary to include the crest elevation along major roads.

2D Model Flooding & Drying Depth

The flooding and drying depths used in the MIKE21 model were 0.03m and 0.02m respectively.

Eddy Viscosity

Energy losses were specified between each cell using a constant eddy formulation. To represent the eddy viscosity, the velocity-based formulation was chosen with an eddy coefficient of $0.1\text{m}^2/\text{s}$.

1D-2D Models Coupling

Urban links were used to link the 1D and 2D models. Orifice flow equations were used for linking between manholes, pipe inlets / outlets and 2D model grids. Single grid cell were used for linking 1D and 2D models. However, where necessary, multiple cells were linked to resolve any instability issue. All manholes were coupled with 2D model grids.

5.5.3 Energy Losses

Energy Losses due to Surface Friction

Friction factors were assigned to the links as a Manning's Number "M" value of 75.0 for the stormwater pipes and 28.5 for overland flowpath in MIKE Urban model. Table 13 below shows the summary of friction factors for various types of links used in the MIKE Urban model.

Table 13: Summary of Friction Factor used in MIKE Urban Model

Link Type	Manning's Number (M)	MIKE Urban Material Type
Pipes (MIKE Urban)	75.0	Concrete (smooth)
Overland Flowpath (Mike Urban)	12.5	Plastic
Overland Flowpath (Mike Urban)	15.0	Ceramic
Overland Flowpath (Mike Urban)	25.0	Stone
Overland Flowpath (Mike Urban)	33.0	Iron
Overland Flowpath (Mike Urban)	75.0	Concrete (smooth)

The hydraulic roughness over the 2D model domain is expected to be variable based on various land uses. The catchment roughness in term of Manning's Number (M), which is the reciprocal of Manning's n, were assigned at each bathymetry grid cell based on aerial photographs, literature values and modelling experience. Road shape files in GIS format were received from FNDC and building footprints were generated using aerial photographs. Specific roughness values were assigned to these surfaces. Roughness values for other areas were assigned based on type of land covers. Table

14 presents the bed roughness values use in the two dimensional model for various land covers.

Table 14: MIKE21 - Bed Roughness Values for various Land Covers

Surface Type	Manning's Number (M)
Building Footprints	5.0
Rural Bush Area	16.7
Urban Build-up Area	20.0
Rural with light grass cover	25.0
Roads	50.0

Bridges and Culverts

All the bridge and culvert structures along the Rivers system were modelled in MIKE 11. Bridge sizes along with deck and soffit levels were captured from survey undertaken by NRC. The details of the culvert structures such as upstream and downstream invert levels, length and size were also provided by NRC. These structures were surveyed by NRC during various stages of the project. The vegetation of channel passing through the bridge and culvert structures was assessed from the available photographs taken during the survey and a Manning's "n" value was assigned. This roughness value was modified, as necessary, in order to achieve the calibration of surveyed flood levels in the vicinity of these structures.

The Federal Highway Administration (FHWA) Water Surface Profile (WSPRO) method has been used to calculate flow characteristics through the bridges using the MIKE 11 model. This method is based on the solution of the energy equation. Contraction loss is taken into account through the calculation of an effective flow length. Expansion losses are determined through the use of numerous experimentally based tables. The method takes the effect of eccentricity, skewness, wingwalls, embankment slope etc. into account through the use of these tables.

Water Courses

All the major rivers/streams namely Kerikeri River, Puketotara Stream, Pungaere Stream, Wairoa River, Whiriwhiritoa Stream, Muangaparerua Stream, Waiwhakangarongaro Stream and whiringatau Stream and their tributaries were modelled in MIKE11. As stated earlier, cross-sections were surveyed for this project during various stages. Cross-sections were also generated using LiDAR information and the low flow channels were modified using surveyed cross-sections where possible. The friction factor along various reaches of the river system was initially assessed using available aerial photographs and photographs taken during survey of the cross-sections. Subsequently, where necessary the friction factor was modified to achieve the calibration fitness between the predicted results by the model and the available records. Generally, low flow channel which is usually relatively clean has been assigned a lower friction value than the high flow channel (including river banks which tend to be more vegetated). A large number of simulations were undertaken during the calibration/validation process and NRC were well informed in setting the friction value specially along various river reaches to achieve the calibration fitness.

The summary of roughness used in the calibrated MIKE11 model is provided in the Table 15 below.

Table 15: Ranges of Manning's n-value used in MIKE11 Model

Structure Type	Manning's n-value
Bridges	0.035 – 0.085
Culvert	0.013 – 0.028
Open Channel (Ranges)	0.035 – 0.095

Structure Type	Manning's n-value
Kerikeri River	0.035 – 0.099
Pungaere Stream	0.035 – 0.095
Wairoa River	0.045 – 0.060
Puketotara Stream	0.045 – 0.090
Waiwhakangarongaro Stream	0.057 – 0.057
Whiriwhiritoa Stream	0.050 – 0.090
Whiringatau Stream	0.051 – 0.051
Muangaparerua Stream and Tributaries	0.070 – 0.070
Waipapa Road Upgrade Ditches	0.020 – 0.020

5.5.4 Limitations

- The model represents the situation at the time of the study and survey. No account has been taken of the execution of any later construction, operations or maintenance work that may affect system performance.
- No blockage has been assumed in the modelled manholes, pipes, culverts, bridges and entry points into the stormwater system. Potential blockages should be allowed for when considering freeboard.
- The model represents the flood risk for the 10-year ED and 10-year and 100-year ARI MPD future rainfall events with climate change allowances based on parameters derived from the calibration of January 2011 storm event. The model may not be applicable for representing lower return period events without modification.
- The model is valid for the prediction of flood hazards within the model extent at a catchment scale. Minor or localised flood risks (for example surface run off) may exist inside the model extent which is not represented in the flood mapping.
- The stormwater asset data supplied for this model by FNDC was found to contain a number of abnormalities such as negative or flat gradients during long section checks. In many cases the negative slopes were attributed due to incorrect up node and down node in council GIS data which have been corrected. Interpolation of pipe gradients was used to improve the longitudinal profile and rectify negative slope.
- The NRC flood mapping disclaimer for the Priority Rivers project should be referred to when consulting flood mapping generated by this flood model.

5.6 Boundary Conditions

5.6.1 Rainfall Data

Recorded 1 hour to 15-minute time series rainfall data, provided by NRC for the gauges as mentioned in Section 5.2 were used for the calibration/validation events. Some of these gauges are operated by the NZ Met Service, and NIWA.

The 12-hour design rainfall depth was provided by NRC for use in the model for the simulations of both future and existing scenarios for various ARI design storm events for flood hazard mapping. Details of the design storm rainfall are discussed in Section 7.1.2 of this report.

5.6.2 Tidal Data

The model has single outlet discharging into the Kerikeri Inlet near Skudders Beach Road. The measured 5-minute time series tide data recorded at the Veronica Channel at Opua was available from NRC for the period covering the calibration/validation events. The time series tide data was input to the model as the lower boundary condition for calibration of the model.

Time series tides both for the existing scenario and future scenario with storm surge were provided by NRC to use for the design storm runs for various ARI storm events for flood hazard mapping and are discussed in Section 7.3 of this report.

5.6.3 Potential Evapotranspiration

Potential evapo-transpiration rates as provided by NRC have been applied. The potential evapo-transpiration was assumed to be constant over a month. The monthly average evapo-transpiration is shown in Table 16 below.

Table 16: Monthly Average Evapotranspiration

Month	Evapotranspiration (mm)
January	168.3
February	128.1
March	81.2
April	53.6
May	42.5
June	43.4
July	59.9
August	84.0
September	111.7
October	139.1
November	141.7
December	168.3

5.7 Quality Assurance and Quality Checks

This model has been internally quality assured and checked in accordance with the GHD Limited Modelling Team standard processes. GHD Project Delivery Framework, quality policy and procedures. This process includes:

- Check of the MIKE 21 grid and the accuracy of the interpolation process from the LIDAR elevation points.
- Check if the choice to represent the flow with MIKE 11 or MIKE 21 is correctly justified in each instance.
- Check of linkage types between MIKE 11 and MIKE 21.
- Check of critical points (bridges, overflows).
- Sub-area location and area.
- Parameter Sets for MIKE Flood, MIKE Urban, MIKE 21 and MIKE 11.
- Model stability.

6. Model Calibration Set-up and Results

The Kerikeri River Catchment hydrological and hydraulic model was calibrated and validated using recorded rainfall and stream gauging data. Initially, GHD was engaged to undertake a calibration of the model using March 2007 event. Later, GHD was commissioned to validate the model using the recorded January 2011 event. Relevant aspects of the calibration/validation process are discussed in the following sections below:

6.1 Calibration Information

6.1.1 Rainfall

As stated in Section 5.2, time series rainfall data are available from seven automatic rain gauges within the Kerikeri River Catchment. NRC also provided daily total rainfall at two other locations within the catchment and their correlation with the neighbouring automatic gauges to generate time series data. The locations of these rain gauges are shown in Figure C-4 in Appendix C of this report. Long-term time series rainfall data was available from all the automatic rain gauges. The locational details are provided in Table 4 in Section 5.2 of this report for the rainfall gauges used in the modelling for the calibration event. The calibration/validation events rainfall is detailed in the Table 17 and Table 18 below:

Table 17: Details of the Jan 2011 Event at Rainfall Gauges

Location of Rain Gauge	Sub-catchment	Type	24 hour Rainfall (mm)
Muangaparerua at Tyrees Ford	Tyrees Ford – Kerikeri	Automatic	219.5
Kerikeri AERO AWS	Kerikeri (outside to the Northeast)	Automatic	252.0
Kerikeri EWS	Lake Manuwai (outside to the North)	Automatic	252.0
Purerua AWS	Lower Kerikeri (outside to the Northeast)	Automatic	258.6
Bramley at Kaeo	Lake manuwai (Outside to the Northwest)	Automatic	217.5
Waitangi at McDonalds Road	Wairoa (outside to the Southeast)	Automatic	275.5
Ohaewai	Waiwhakangarongaro (Outside to the South)	Automatic	224.0
Puketi Rd at Candy	Tyrees Ford (outside to the West)	Daily	147.0
Kerikeri at Kiakaha	Lower Pungaere (at the northern edge)	Daily	269.0

The rainfall for this 2011 event fell within one recording day 28th Jan 09:00 to 29th Jan 09:00. Rainfall recorded within the catchment was in the range 219.5mm – 269.0mm. The temporal distribution of rainfall at the various rain gauge sites was reasonably consistent, making this a very suitable event for calibration. The total rainfall depth for this event is reasonably consistent with the 12-Hour HIRDS v3 100-Year ARI CC MPD rainfall depths (with ARF of 0.93 applied – see Table 26), but the duration of rainfall in this event was 16 hours with a lower peak rainfall intensity of 31.8mm – 36.0mm / hour occurring between 5:30pm and 12:20am.

Table 18: Details of the March 2007 Event at Rainfall Gauges

Location of Rain Gauge	Type	24 hour Rainfall (mm) on 29 th March	24 hour Rainfall (mm) on 30 th March
Muangaparerua at Tyrees Ford	Automatic	268.5	121.5
Kerikeri AERO AWS	Daily	268	121.5
Kerikeri EWS	Automatic	207.2	120.6
Purerua AWS	Automatic	118.6	102.6
Bramley at Kaeo	Automatic	199.5	112.5
Waitangi at McDonalds Road	Automatic	188.5	146.0
Ohaewai	Automatic	181.5	72.0
Puketi Rd at Candy	Daily to 16:30	67.5 on 28th	190 on 29th
Kerikeri at Kiakaha	Daily	210.0	163.0

The March 2007 event was a longer duration event of approximately 36 hours, from 28th to 29th March. The total rainfall depth in the upper catchment was around 400mm with peak intensity of 38mm/hr occurring just before midday on 29th March. A 2 hour period of rainfall totalling 73mm at this time directly contributed to peak river flow which occurred in the early afternoon. River Flow and Level Data

6.1.2 River Flow and Level Data

Time series water level and flow data at two gauges as stated in Table 5 in Section 5.2 were available for the period of the calibration/verification events. NIWA has also an established rating curve at Tyrees Ford gauge location, which is an engineered V notch weir on the Muangaparerua Stream. No rating curve is available for Peacock Garden gauge in the lower river. The flows at Tyrees Ford weir recorded water level site were estimated using the NIWA rating curve that was provided by NRC.

6.1.3 Calibration/Validation Events

Based on the recorded data from the two gauges located within the Kerikeri River Catchment, the maximum level and flow at each gauge for the calibration/validation events are provided in Table 19 and Table 20 below. Recording at the Peacock Garden Gauge was unfortunately discounted by NIWA in 2010, so there is only a stage record for the March 2007 Event.

Based on peak flows at Tyrees Ford, the Jan 2011 event has an expected return period of 5 years, whilst the March 2007 event return period is 25 years.

Table 19: Details of the January 2011 Storm event at River Gauge

Gauge Location	Catchment Area (km ²)	Maximum Level (m RL)	Maximum Flow (m ³ /s)
Muangaparerua at Tyrees Ford	11.0	152.02	68.2
Peacock Garden	95.0	No Gauge	No gauge

Table 20: Details of the March 2007 Storm event at River Gauges

Gauge Location	Catchment Area (km ²)	Maximum Level (m RL)	Maximum Flow (m ³ /s)
Muangaparerua at Tyrees Ford	10.0	152.37	103.9
Peacock Garden	95.0	23.03 (recorded) 23.57 (surveyed)	No Flow Data

In Table 19, it can be seen that there is a conflict between recorded and surveyed flood level at Peacock Gardens for the March 2007 event. There is also a potential anomaly with the Peacock Gardens recorded data around the peak. NIWA report that gauge accuracy at Peacock Gardens is questionable at very high flow due to surging at this site.

A large number of surveyed flood debris levels were also available for model calibration.

6.2 Boundary Conditions

6.2.1 Tidal Boundary

The measured 5-minute time series tide data recorded at Veronica Channel at Opuia as stated in Section 5.6.2 was available from NRC. The time series tide data was input to the model as the lower boundary condition for the Kerikeri River at Kerikeri Inlet for the calibration/validation events of the model using the two recorded events (March 2007 and January 2011 events).

6.2.2 Potential Evapotranspiration

The monthly average potential evapotranspiration value of 168.3 mm for the month of January was used for the calibration of the January 2011 event while 81.2 mm was used for the March 2007 event.

6.2.3 Initial Conditions

An initial nominal flow of 0.00001 m³/s was used at all upstream open flow boundaries of the model for the purpose of running MIKE11 model. For MIKE Urban model, the initial base flow was set at zero. The minimum water depth both in urban link and node were set to one millimetre. The initial water depth for the MIKE11 network was set to zero.

6.2.4 Stream Base Flow

Stream base flow was assessed through calibration process. As stated in Section 5.4.4 that a total base of 20.5 m³/s was necessary to replicate the low flow at the gauges. This base flow was assigned at the beginning of a river network. The major base flow and the respective river network are shown in Table 21 below:

Table 21: Base Flow and the Respective River Network

River Network	Base Flow (m ³ /s)
Kerikeri River	13.0
Puketotara Stream	5.5
Waiwhakangarongaro Stream	1.5
Muangaparerua Stream	0.05

6.3 Calibration Results

6.3.1 Results at River Gauge Locations

The model results were viewed using the DHI MikeView Module to assess the goodness of fit between the modelled results and the observed values. The result verification tool of MikeView provides a range of parameter values to quantify the differences between the modelled and measured data. The major parameters are:

- Peak observed and modelled flow over the calculation period.
- Peak observed and modelled flood level over the calculation period.
- Correlation coefficient for the flow and level which is a measure of the interdependence between the measured data and modelled data and is reported as R^2 . A coefficient higher than 0.75 is an indication of better fitness.
- Observed and modelled volume for flow which is the accumulated volume under the flow hydrograph.
- Observed and modelled flow volume for level which is the accumulated volume under the water level hydrograph.
- Volume error between the observed and modelled volume under the flow hydrographs as percentage.
- Volume error between the observed and modelled volume under the water level hydrographs as percentage.
- A comparison of the Peak level and flow at the two gauge location are shown in Table 22 and Table 23 below.

Table 22: Comparison of Peak flow and level at the gauge location for March 2007 Event

Gauge	Peak Flood Level (mRL)			Peak Flow (m ³ /s)		
	Observed	Modelled	Difference (mm)	Observed	Modelled	Error (%)
Tyrees Ford Weir	152.37	152.38	6	103.9	102.2	-1.7
Peacock garden	23.03/ 23.57	23.27	240	-	597.3	-

Table 23: Comparison of Peak flow and level at the gauge location for January 2011 Event

Gauge	Peak Flood Level (mRL)			Peak Flow (m ³ /s)		
	Observed	Modelled	Difference (mm)	Observed	Modelled	Error (%)
Tyrees Ford Weir	152.02	152.00	18	68.2	65.2	-4.4
Peacock garden	-	23.20	-	-	562.3	-

It can be noted that the level gauge at Peacock garden was discontinued by NIWA in 2010 and is not available for January 2011 event.

As per the calibration requirement standard as set out in Section 3.8 of NRC's "Modelling Policy Statement for the Priority Streams Flood Risk Reduction Project" it is required that the modelled flood level should be within 100 mm of the measured level at the gauge. It can be seen from the above tables that model predicted flood level is higher than 100 mm at Peacock garden while it is within 20mm at the Tyrees Ford Weir. This difference was discussed and agreed by NRC, as there is some uncertainty over peak Mar 2007 flood level at Peacock Garden gauge. The requirement for the flow as per the aforesaid document is that the model predicted flow should be within $\pm 15\%$ of the recorded flow at the gauge and the above tables indicates that the peak flow difference at Tyrees Ford gauge is well below $\pm 15\%$.

The comparison plots (figure D-1 through D-5) for the time series modelled results against the gauge levels and flows are provided in Appendix D of this report. The plots also provided the comparison of the parameters as stated in Section 6.3.1. It can be seen from these plots that the volume error for the level are within $\pm 15\%$ of that at the gauge while volume error for the flow are also less than $\pm 15\%$ at all gauge locations. Mass balance checks were undertaken during the calibration process and were found reasonable for both events.

6.3.2 Debris Levels

The model was also calibrated using flood debris levels surveyed after the Mar 2007 and Jan 2011 flood events. The comparison of the model predicted level against the debris level for March 2007 event is shown in Table 24 below:

Table 24: Comparison of levels at Debris Locations for March 2007 Event

River Name	Chainage (m)	Debris Level (mRL)	Modelled Level (mRL)	Difference (m)
KERIKERIRIVER_BRANCH1	242.82	81.54	81.81	0.27
KERIKERI_RIVER	10256.85	74.53	74.35	-0.18
KERIKERI_RIVER	11255.12	71.64	71.67	0.03
KERIKERI_RIVER	12346.65	68.30	68.28	-0.02
KERIKERIRIVER_BRANCH11	15.43	68.30	68.36	0.06
KERIKERI_RIVER	12373.42	68.30	68.28	-0.02
KERIKERI_RIVER	12518.67	67.43	67.69	0.26
KERIKERI_RIVER	15442.73	26.80	25.83	-0.97

River Name	Chainage (m)	Debris Level (mRL)	Modelled Level (mRL)	Difference (m)
KERIKERI_RIVER	15751.30	23.21	23.32	0.11
KERIKERI_RIVER	17136.53	4.81	4.67	-0.15
KERIKERI_RIVER	17220.17	3.75	3.78	0.03
WHIRIWHIRITOA_STREAM	1290.48	77.99	77.85	-0.14
WHIRIWHIRITOA_STREAM	1543.97	75.05	75.32	0.27
WHIRIWHIRITOA_STREAM	1625.96	75.47	74.95	-0.52
WHIRIWHIRITOA_STREAM	1688.06	75.72	74.81	-0.91
Waipapa Silkwood Lane	--	28.00	27.55	-0.45
PUNGAERE_STREAM	6985.33	117.05	116.75	-0.30
PUNGAERE_STREAM	21021.95	5.14	5.06	-0.09
PUNGAERE_STREAM	21135.28	2.33	2.34	0.01
PUNGAERE_STREAM	10885.25	76.95	75.98	-0.97
PUKETOTARA_STREAM	4435.00	83.30	83.24	-0.06
WAIWHAKANGARONGARO_STREAM	6602.17	83.30	83.35	0.05
PUKETOTARA_STREAM	9446.63	31.88	31.93	0.05
WAIROA_RIVER	2733.20	61.89	62.00	0.11
WAIROA_RIVER	3324.89	58.22	58.23	0.01

The requirement for the calibration against the recorded debris level is that the model predicted flood level should be within ± 500 mm of the flood level measured at the debris locations. It can be seen from the above table that the model predicted flood level at all the locations are well within the tolerable limit except at four locations. These were discussed with NRC and accepted as isolated cases. In both cases where the difference between surveyed and model flood level is above 900mm, the surveyed flood level had been surveyed a long time after the Mar 2007 flood event, based on land owner information, and the confidence in surveyed flood level is therefore lower.

The model results were also compared with debris levels measured during the January 2011 event. The comparison of the model predicted level against the debris level for January 2011 event is shown in Table 25 below:

Table 25: Comparison of levels at Debris Locations for January 2011 Event

River Name	Chainage (m)	Debris Level (mRL)	Modelled Level (mRL)	Difference (m)
KERIKERIRIVER_BRANCH1	228.37	81.74	81.71	-0.03
KERIKERIRIVER_BRANCH1	261.63	81.73	81.74	0.01
KERIKERI_RIVER	10215.98	74.59	74.82	0.23
KERIKERIRIVER_BRANCH2	1471.06	74.60	74.83	0.23
KERIKERI_RIVER	10256.85	74.43	74.35	-0.09
KERIKERI_RIVER	11404.93	70.92	71.05	0.13
KERIKERI_RIVER	11680.53	70.38	70.13	-0.25
KERIKERIRIVER_BRANCH11	28.79	68.29	68.31	0.02
KERIKERI_RIVER	12847.73	65.70	65.60	-0.10
KERIKERI_RIVER	13207.50	62.27	61.88	-0.39
KERIKERI_RIVER	12528	66.67	66.58	-0.09

River Name	Chainage (m)	Debris Level (mRL)	Modelled Level (mRL)	Difference (m)
KERIKERI RIVE	-	68.25	68.32	0.07
KERIKER (South of Waipapa Rd)	-	68.36	68.44	0.08
KERIKERI_RIVER	12645.37	66.97	67.31	0.34
KERIKERI_RIVER	12645.37	66.97	67.31	0.34
KERIKERI_RIVER	12754.56	66.31	66.36	0.05
KERIKERI_RIVER	13072.59	63.76	63.68	-0.08
KERIKERI_RIVER	13162.53	62.94	62.67	-0.27
KERIKERI_RIVER	15313.59	25.67	25.74	0.07
KERIKERI_RIVER	15355.47	25.62	25.65	0.02
KERIKERI_RIVER	15424.22	25.31	25.54	0.23
KERIKERI_RIVER	16984.44	5.18	4.97	-0.21
KERIKERI_RIVER	17014.70	5.15	4.74	-0.41
KERIKERI_RIVER	17053.77	4.59	4.39	-0.20
KERIKERI_RIVER	17073.78	4.16	4.18	0.02
KERIKERI_RIVER	17103.08	3.77	3.78	0.01
KERIKERI_RIVER	17177.29	2.51	2.60	0.09
KERIKERI_RIVER	17306.38	2.03	2.55	0.52
KERIKERIRIVER_BRANCH4	1020.56	2.03	2.55	0.52
PUKETOTARA_STREAM	4436.75	83.34	83.32	-0.03
PUKETOTARA_STREAM	4462.5	82.79	82.94	0.15
PUKETOTARA_STREAM	4510.68	82.43	82.74	0.31
PUKETOTARA_STREAM	4545.45	82.65	82.60	-0.05
PUKETOTARA_SPILLWAY	55.01	82.18	81.89	-0.30
PUKETOTARA_SPILLWAY	198.84	79.90	79.18	-0.72
PUKETOTARA_STREAM	7441.91	38.78	38.45	-0.33
PUKETOTARA_STREAM	7572.98	38.80	38.30	-0.50
PUKETOTARA_STREAM	7606.21	38.59	38.18	-0.41
PUKETOTARA_STREAM	7674.02	38.14	38.17	0.03
PUKETOTARA_STREAM	7839.01	37.77	37.78	0.01
PUKETOTARA_STREAM	7879.00	37.48	37.68	0.20
PUKETOTARA_STREAM	7916.13	37.58	37.63	0.05
PUKETOTARA_STREAM	7948.26	37.54	37.54	0.00
PUKETOTARA_STREAM	7981.48	37.41	37.50	0.09
PUKETOTARA_STREAM	8020.03	37.49	37.42	-0.07
PUKETOTARA_STREAM	8575.46	35.63	36.12	0.49
PUKETOTARA_STREAM	8600.19	35.77	35.84	0.07
PUKETOTARA_STREAM	8664.53	33.88	34.36	0.48
PUKETOTARA_STREAM	8664.53	33.84	34.36	0.52
PUKETOTARA_STREAM	9002.77	31.97	31.94	-0.03
PUKETOTARA_STREAM	9029.83	31.78	31.87	0.09
PUKETOTARA_STREAM	9106.77	31.75	31.76	0.01
PUKETOTARA_STREAM	9235.13	31.53	31.58	0.05
PUKETOTARA_STREAM	9448.00	30.86	31.38	0.52
PUKETOTARA_STREAM	9464.89	30.68	30.36	-0.32
PUNGAERE_STREAM	11466.90	72.68	73.61	-0.93
PUNGAERE_STREAM	11491.14	72.88	73.31	-0.43
PUNGAERE_STREAM	20842.91	6.03	4.76	1.27
PUNGAERE_STREAM	20901.48	5.94	4.83	1.11
PUNGAERE_STREAM	20991.38	5.69	4.38	1.31

River Name	Chainage (m)	Debris Level (mRL)	Modelled Level (mRL)	Difference (m)
PUNGAERE_STREAM	21021.95	5.47	4.16	1.31
PUNGAERE_STREAM	21074.18	3.86	3.18	0.68
PUNGAERE_STREAM	21135.28	2.48	2.21	0.27
PUNGAERE_STREAM	21165.93	1.71	2.16	-0.45
WHIRIWHIRITOA_STREAM	979.77	81.66	81.33	0.33
WHIRIWHIRITOA_STREAM	1223.97	78.79	78.59	0.20
WHIRIWHIRITOA_STREAM	1263.11	78.55	78.24	0.31
WHIRIWHIRITOA_STREAM	1290.48	77.93	78.33	-0.40
WHIRIWHIRITOA_STREAM	1310.08	77.81	77.85	-0.04
WHIRIWHIRITOA_STREAM	1347.76	77.35	77.44	-0.09
WHIRIWHIRITOA_STREAM	1385.43	77.12	77.12	0.00
WHIRIWHIRITOA_STREAM	1490.88	76.17	75.74	0.43
WHIRIWHIRITOA_STREAM	1519.48	76.16	75.21	0.95
WHIRIWHIRITOA_STREAM	1543.97	75.16	75.26	-0.10
WHIRIWHIRITOA_STREAM	1599.81	75.04	74.38	0.66
WHIRIWHIRITOA_STREAM	1625.96	75.00	74.33	0.67
WHIRIWHIRITOA_STREAM	1662.59	74.98	74.12	0.86
WHIRIWHIRITOA_STREAM	1688.06	74.96	73.89	1.07
WHIRIWHIRITOA_STREAM	1714.57	74.95	73.78	1.17
WHIRIWHIRITOA_STREAM	2787.46	67.19	66.35	0.84
WAIROA_RIVER	2235.10	65.63	65.91	-0.28
WAIROA_RIVER	2270.20	65.42	65.40	0.02
WAIROA_RIVER	2480.79	63.80	64.32	-0.52
WAIROA_RIVER	2496.32	63.69	63.70	-0.01
WAIROA_RIVER	2519.81	63.46	63.71	-0.25
WAIROA_RIVER	2733.20	61.88	61.82	0.06
WAIROA_RIVER	2769.81	61.64	61.44	0.20
WAIROA_RIVER	2861.37	60.86	60.66	0.20
WAIROA_RIVER	2867.57	60.81	60.63	0.18
WAIROA_RIVER	2902.03	60.07	60.44	-0.37
WAIROA_RIVER	2939.77	59.80	59.95	-0.15
WAIROA_RIVER	2977.50	59.62	59.13	0.49
WAIROA_RIVER	3015.24	59.49	59.37	0.12
WAIROA_RIVER	3303.92	58.23	58.00	0.23
WAIROA_RIVER	3324.89	58.15	57.85	0.30
WAIROA_RIVER	3340.32	57.04	57.27	-0.23
WAIROA_RIVER	3411.19	56.49	56.55	-0.06
WAIROA_RIVER	3543.21	55.26	55.45	-0.19
WAIROA_RIVER	5654.28	5.25	5.24	0.01
WAIROA_RIVER	5721.61	4.32	4.21	0.11
WAIROA_RIVER	5721.61	4.32	4.21	0.11
WAIWHAKANGARONGARO_STREAM	3631.65	114.87	114.96	-0.09
WAIWHAKANGARONGARO_STREAM	3828.62	113.97	113.88	0.09
WAIWHAKANGARONGARO_STREAM	3928.37	112.43	112.68	-0.25
WAIWHAKANGARONGARO_STREAM	5179.22	87.33	87.45	-0.12
WAIWHAKANGARONGARO_STREAM	5206.00	87.31	87.28	0.03
WAIWHAKANGARONGARO_STREAM	5269.31	87.17	87.28	-0.11
WAIWHAKANGARONGARO_STREAM	6135.92	83.83	83.94	-0.11
WAIWHAKANGARONGARO_STREAM	6412.56	83.58	83.78	-0.20

River Name	Chainage (m)	Debris Level (mRL)	Modelled Level (mRL)	Difference (m)
WAIWHAKANGARONGARO_STREAM	6602.17	83.44	83.59	-0.15
WAIWHAKANGARONGARO on Springbank Road	-	83.13	83.20	-0.07
WAIWHAKANGARONGARO on Springbank Road	-	83.10	82.90	0.20
WAIWHAKANGARONGARO on Springbank Road	-	83.07	83.00	0.07

It can be seen from the above table that the difference between the debris level and the model predicted level well below the tolerable limit of ± 500 mm except for very few locations.

6.3.3 Longitudinal Profiles and Bank Spilling

Bank spilling across the banks of major rivers during March 2007 calibration event was investigated by drawing longitudinal profiles. These profiles were drawn along the Kerikeri River, Pungaere Stream, Whiriwhiritoa Stream, Puketotara Stream and Wairoa River. These longitudinal profiles are shown in Figure D-6 to D-10 in Appendix D of this report.

It can be seen Figure D-6 that the spilling across the banks of the Kerikeri River upstream of the Rainbow Falls (Ch. 13,274) occurs both upstream and downstream of the SH10 (Ch. 10,229)..

Figure D-7 indicates that there is spilling from Pungaere Stream both upstream and downstream of the SH10 (Ch. 11,476). The most significant area of spilling is in the lower reaches, between Ch. 15,160 and Ch. 21,060. There is spilling from both banks upstream of the Landing Road Bridge (Ch. 21,060).

Figure D-8 indicates that there is very little spilling of the banks of the Whiriwhiritoa Stream between SH10 (Ch. 1,735) and Waipapa Road (Ch. 2,797). However there is a very flat area around Ch. 2,400 where ponding occurs.

Figure D-9 indicates the longitudinal water surface profile along the Puketotara Stream. This figure indicates that there are some spilling around the SH10 bridge (Ch. 4,454) and occasional spilling upstream of the Golf View Road bridge (Ch. 9,450).

Figure D-10 indicates the longitudinal water surface profile along the Wairoa Stream. This figure indicates that there is insignificant spilling along this stream. However the stream runs through a residential area and high flood levels affect neighbouring properties.

An interesting feature of these longitudinal sections is the sudden drop associated with a water fall or chute in all of them. This is generally associated with the underlying basalt lava flows, which have proven resistant to downwards erosion by these watercourses.

7. Summary of Design Storms Set-up and Results

7.1 Design Storm Rainfall Depth and Aerial Reduction Factor

The design storm rainfall depths for various ARI storm events were derived from HIRDS v3 of the NIWA Rainfall data base. Considering the large size (approx. 147 km²) of the Kerikeri River Catchment and significant variation of elevations over the catchment fifty (50) locations were selected to derive the 12-hour rainfall depths. The rainfall depths along with their locational coordinates in a grid formation were provided by NRC for input into the model. NRC also provided the rainfall depths considering the aerial reduction factor for the catchment. The following sections briefly describe the rainfall depths and aerial reduction factor.

7.1.1 Aerial Reduction Factor

The rationale for the use of an Aerial Reduction Factor (ARF) is well established. ARF applied to probabilistic rainfall data should account for the lower probability that a predicted point rainfall depth, of a given ARI, will occur across an entire catchment. ARFs decrease both with increasing catchment area, and with shorter duration reflecting that a greater reduction should be made to predicted point rainfall to generate probabilistic areal rainfall for larger catchments as well as over shorter duration storms.

In New Zealand, the primary source of probabilistic rainfall data is the HIRDS package produced by NIWA on the basis of a statistical analysis of point rainfall data across the country. New releases of this data are made approximately every ten years, with the most recent version HIRDS v3, released in early 2010. Applying an appropriate ARF to point rainfall of a given ARI, based on catchment size and critical duration is promoted in TP108. This Auckland Technical paper includes both a storm hyetograph, and a set of ARFs to use for catchment assessments.

The NRC has adopted a different storm hyetograph, developed by MWH for the Northland Priority Rivers Project. The ARFs adopted by NRC were derived by Auckland University based on a pilot study of Auckland Rainfall records during a recent review of the TP108¹. The ARFs derived from that study are higher than the ARFs stated in TP108, resulting in higher design storm rainfall depths. For the Kerikeri catchment, an ARF of 0.93 has been adopted, which is the Auckland Uni Services factor for a 12hr storm in a 100 km² catchment. This is the same as the UK NERC factor (0.93) for same area and duration, but is higher than the equivalent TP108 ARF of 0.89.

7.1.2 Design Storm Rainfall Depth

The future 12-hour design rainfall depth due to future climate change was provided by NRC at 50 locations spreading all over the catchment for use in the model for simulation of future and landuse scenarios. NRC also provided 12-hour design rainfall depth for the existing climate scenario at the same 50 locations as for the future climate 12-hour rainfall. The future rainfall depths (reflecting climate change) were downloaded from HIRDS v3 database, using a temperature warming factor of 2.1 degrees celcius, which is an MFE (2008) mid-point projection for Northland to the year 2100.

¹ Dr A Y Shamseldin, Auckland Uni Services Ltd (2008) 'TP108 Rainfall: Updating for new Data with Provision for Climate Change'

The 12-hour rainfall depth for the various design storms undertaken for simulation is provided in the following Table 26 below and their locations are shown in Figure E-1 in Appendix E of this report.

Table 26: 12-hour Design Storm Rainfall for various ARI Events including ARF

Easting	Northing	10-Year ARI ED (mm)	10-Year MPD CC (mm)	100-Year MPD CC (mm)	Type
1,672,000.0	6,099,000.0	141.64	160.98	267.84	Rural
1,672,000.0	6,101,000.0	143.41	162.94	271.00	Rural
1,672,000.0	6,103,000.0	142.66	162.10	269.42	Rural
1,674,000.0	6,097,000.0	142.66	162.10	269.05	Rural
1,674,000.0	6,099,000.0	144.15	163.87	272.03	Rural
1,674,000.0	6,101,000.0	145.17	164.98	273.89	Rural
1,674,000.0	6,103,000.0	143.41	162.94	270.35	Rural
1,674,000.0	6,105,000.0	143.59	163.22	270.26	Rural
1,676,000.0	6,097,000.0	144.62	164.33	272.21	Rural
1,676,000.0	6,099,000.0	143.78	163.40	270.54	Rural
1,676,000.0	6,101,000.0	144.06	163.68	271.19	Rural
1,676,000.0	6,103,000.0	142.29	161.73	267.93	Rural
1,676,000.0	6,105,000.0	142.20	161.63	267.28	Rural
1,676,000.0	6,107,000.0	140.90	160.15	264.49	Rural
1,678,000.0	6,097,000.0	141.73	161.08	266.82	Rural
1,678,000.0	6,099,000.0	140.06	159.22	263.66	Rural
1,678,000.0	6,101,000.0	140.62	159.77	264.68	Rural
1,678,000.0	6,103,000.0	140.24	159.40	263.84	Rural
1,678,000.0	6,105,000.0	138.85	157.82	261.05	Rural
1,678,000.0	6,107,000.0	136.71	155.40	256.68	Rural
1,678,000.0	6,109,000.0	136.62	155.31	256.12	Rural
1,678,000.0	6,111,000.0	133.64	151.87	250.45	Rural
1,680,000.0	6,097,000.0	135.13	153.54	254.36	Rural
1,680,000.0	6,099,000.0	133.92	152.24	252.03	Rural
1,680,000.0	6,101,000.0	135.69	154.19	255.19	Rural
1,680,000.0	6,103,000.0	135.41	153.92	254.36	Rural
1,680,000.0	6,105,000.0	134.57	152.99	252.77	Rural
1,680,000.0	6,107,000.0	134.48	152.80	252.31	Rural
1,680,000.0	6,109,000.0	136.25	154.85	255.29	Rural
1,682,000.0	6,097,000.0	129.36	147.03	243.66	Rural
1,682,000.0	6,099,000.0	129.27	146.94	243.01	Rural
1,682,000.0	6,101,000.0	129.27	146.94	242.36	Rural
1,682,000.0	6,103,000.0	129.46	147.13	242.73	Rural
1,682,000.0	6,105,000.0	130.67	148.52	245.52	Rural
1,682,000.0	6,107,000.0	131.87	149.92	247.66	Rural
1,684,000.0	6,097,000.0	125.64	142.76	236.69	Rural
1,684,000.0	6,099,000.0	125.64	142.76	235.48	Rural
1,684,000.0	6,101,000.0	123.41	140.24	230.73	Urban
1,684,000.0	6,103,000.0	123.97	140.90	232.04	Urban
1,684,000.0	6,105,000.0	125.83	143.03	236.22	Urban

Easting	Northing	10-Year ARI ED (mm)	10-Year MPD CC (mm)	100-Year MPD CC (mm)	Type
1,686,000.0	6,097,000.0	122.85	139.59	231.57	Urban
1,686,000.0	6,099,000.0	122.39	139.13	229.15	Urban
1,686,000.0	6,101,000.0	119.60	135.97	222.92	Urban
1,686,000.0	6,103,000.0	119.41	135.69	223.20	Urban
1,686,000.0	6,105,000.0	122.67	139.41	229.99	Urban
1,688,000.0	6,097,000.0	118.76	134.94	224.50	Urban
1,688,000.0	6,099,000.0	120.25	136.62	225.90	Urban
1,688,000.0	6,101,000.0	117.27	133.27	219.20	Urban
1,688,000.0	6,103,000.0	117.18	133.18	219.67	Urban
1,688,000.0	6,105,000.0	120.71	137.18	226.46	Urban

7.2 Design Storm Temporal Profiles

Temporal rainfall profile was provided by NRC based on their “Priority Rivers Storm profile” for the simulation of the design storms. The temporal rainfall profiles were developed for both urban and rural catchments. The temporal profile used for the rural catchment was the one developed by MWH for the priority Rivers project, and this was applied to all rural areas within the catchment, comprising 88% of rainfall points. NRC also indicated that six locations were to be used for urban catchment with the temporal rainfall profile for the urban catchment. The urban areas temporal profile (12% of rainfall points) was derived by NRC by adjusting the rural profile to achieve HIRDS v3 short duration rainfall depths (from 10 minutes to 2 hours), as requested by FNDC for the testing of their stormwater networks. The plots of the temporal pattern for both urban and rural catchment are shown in Figure 1.

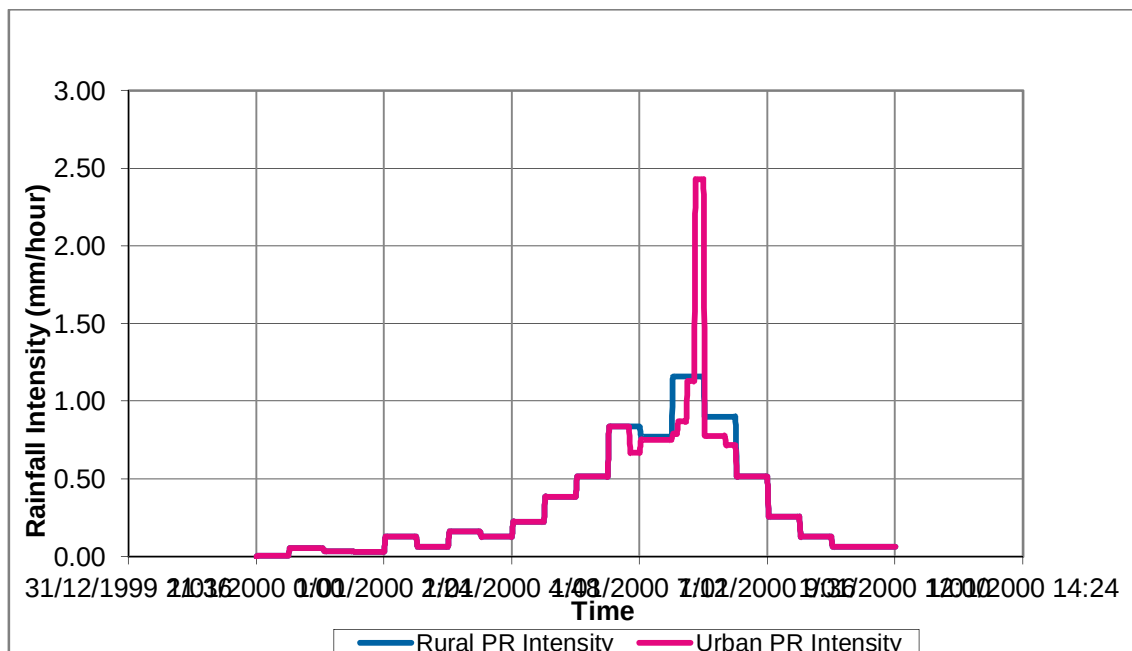


Figure 1: 12-hour Rainfall Intensity Priority Rivers (PR) Profiles 100-year MPD CC event

7.3 Tidal Boundary Conditions

Time series tides both for the existing scenario and future scenario with storm surge were provided by NRC to use for the design storm runs for various ARI storm events for flood hazard mapping. The tides were developed by MWH for the NRC Priority Rivers Project. The present day tidal peak within the time series is equivalent to a 2-year ARI sea level condition (based on frequency analysis of the Marsden Point dataset). This 2yr ARI sea level is above MHWS, and incorporates a modest storm surge allowance. The future climate tide series is the same dataset adjusted upwards by 500 mm for projected climate change induced sea level rise. This is an MfE (2008) baseline projection for sea level rise to the year 2100.

The time axis of this data was adjusted in such a way that the model predicted peak flood level at the downstream end of the river system coincided with the peak tide level. A plot of the tides for the design storm runs are shown in Figure 2 below.

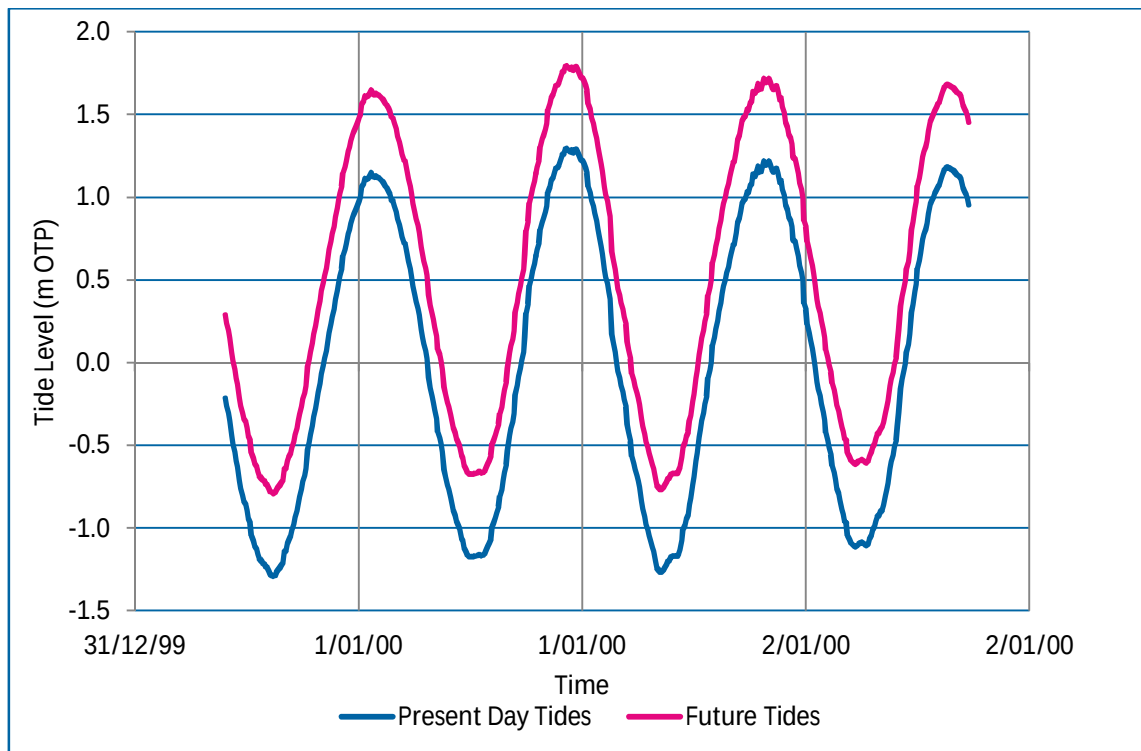


Figure 2: Time Series Tides used for the Simulation of Design Storms

7.4 Design Storm Results

The design storm simulations were carried out for flood hazard mapping for the following scenarios:

- 10-year ARI with existing land use and existing climate.
- 10-year ARI with future urban land use and with climate change allowances for rainfall and sea level.
- 100-year ARI with future urban land use and with climate change allowances for rainfall and sea level.

The peak flood level, peak flood depth and peak speed were extracted from the 2D model MIKE21 for plotting. The WaterRIDE software was used to generate the flood level and flood depth along the river/channel system in MIKE11 model. The two results were combined using WaterRIDE. The combined data for all the three scenarios has

been provided to NRC. The model predicted peak flood levels and flows at the gauge locations and other major road crossing for the three design storm simulations are provided in the following Table 27 through Table 29 below:

Table 27: Peak flood Levels and Flows at Gauges during 10-year ED Scenario

River/Stream	Location	Peak Flood Level (mRL)	Peak Flood Flow (m ³ /s)
Muangaparerua Stream	Tyrees Ford Weir	152.25	87.48
Kerikeri River	Peacock Garden	22.59	396.12
Puketotara Stream	SH10	83.15	182.06
Kerikeri River	SH10	74.56	149.39
Whiriwhiritoa Stream	SH10	72.59	9.36
Pungaere Stream	SH10	73.25	97.64
Kerikeri River	Heritage Bypass	24.90	365.36
Puketotara Stream	Golf View Bridge	29.94	234.22
Pungaere Stream	Landing Road	4.26	101.46
Wairoa River	Cobham Road	57.81	62.00

Table 28: Peak Levels and Flows at Gauges during 10-year MPDCC Scenario

Gauge location	Location	Peak Flood Level (mRL)	Peak Flood Flow (m ³ /s)
Muangaparerua Stream	Tyrees Ford Weir	152.39	103.36
Kerikeri River	Peacock Garden	23.01	507.71
Puketotara Stream	SH10	83.38	210.54
Kerikeri River	SH10	74.75	150.74
Whiriwhiritoa Stream	SH10	73.64	20.02
Pungaere Stream	SH10	73.45	117.20
Kerikeri River	Heritage Bypass	25.46	469.57
Puketotara Stream	Golf View Bridge	30.68	286.80
Pungaere Stream	Landing Road	4.67	137.08
Wairoa River	Cobham Road	58.82	105.18

Table 29: Peak Levels and Flows at Gauges during 100-year MPDCC Scenario

Gauge location	Location	Peak Flood Level (mRL)	Peak Flood Flow (m ³ /s)
Muangaparerua Stream	Tyrees Ford Weir	152.97	186.24
Kerikeri River	Peacock Garden	24.59	1023.21
Puketotara Stream	SH10	84.26	264.21
Kerikeri River	SH10	75.37	156.99
Whiriwhiritoa Stream	SH10	75.97	48.89
Pungaere Stream	SH10	74.40	232.74
Kerikeri River	Heritage Bypass	27.71	755.62
Puketotara Stream	Golf View Bridge	32.92	464.19
Pungaere Stream	Landing Road	6.40	331.78
Wairoa River	Cobham Road	58.78	102.77

It can be noticed from the above tables that there is a significant increase in flood level and flood flow at all the gauge locations during the 100-year ARI MPD climate change (CC) scenario compared to both the 10-year ED and 10-year MPD CC scenarios. This is because of significant increase in rainfall for the 100-year MPD CC scenario compared to the other two scenarios. It was found that on average the rainfall at each location during the 10-year MPD CC has increased by about 13.7% compared to the 10-year ED rainfall while the 100-year MPD CC has increased by about 88% compared to the 10-year ED Scenario. The maximum predicted flood depth maps for the three design storm simulations are provided in Figure E-2 to E-4 in Appendix E of this report.

The flood flows and flood levels generated by the model for the March 2007 calibration event, as reported in section 6.1.3, is similar at Tyrees Ford to 10-year MPD CC event while those for the January 2011 validation event are lower than the 10-year ED event at Tyrees Ford. The 24-hour rainfall depths recorded at the Tyrees Ford Weir during the March 2007 calibration event is about one and half times of HIRDS v3 10-year ARI rainfall depths for the 12 hour duration.

In the lower part of the catchment, Jan 2011 flood levels are close to 10-year MPD CC flood levels at many locations, including the Kerikeri River at SH 10 and Heritage Bypass Bridge, Whiriwhiritoa at SH10, Puketotara at SH 10 and Golf View Bridge. In the Pungaere Stream the Jan 2011 flood levels are closer to the 10-year ED event. These findings are not unexpected, as the catchment time of concentration at these locations are longer than for Tyrees Ford, and the January 2011 storm event generated rainfall of a higher return period with increasing storm duration.

March 2007 flood levels in the lower catchment were higher than both Jan 2011 and model 10-year MPD CC flood levels, but lower than model 100-year MPD CC flood levels.

The NRC holds flood levels for the March 1981 event at three locations within the catchment. This event is the largest known event to have occurred within the catchment since recorded human settlement. At two locations, Tyrees Ford and Landing Road, the March 1981 flood levels exceed model 100-year MPD CC flood levels. At the third location, the Kerikeri Basin, a direct comparison cannot readily be made, as the Old Stone Store bridge has been removed from the model, and this bridge had elevated flood levels during the March 1981 event. Based on a number of assessments, the March 1981 flood is considered to be well in excess of a 100 year event, in relation to both rainfall intensity and flood flow.

8. Discussion and Conclusions

- A hydrological and hydraulic model of the stormwater drainage network system in the Kerikeri River Catchment has been developed using MIKE FLOOD modelling software based on Model B rainfall-runoff modelling methods and 1-D and 2-D free surface gradually varied unsteady flow equations.
- The effect of predicted Climate Change has been included in the total rainfall depth for two of the design storms simulated. The allowances for climate change were assessed by NRC based on MfE guidelines, and the total rainfall depth with climate change allowance were provided to GHD for input into the model.
- A significant amount of data was collected during various phases of the project for upgrading of the model. These include survey of river cross-sections, river crossing structures such as bridges and culverts, and improvement of DTM along major roads which has significantly improved the calibration of the model.
- Historical rainfall and water levels/flow data was utilised to calibrate the model. The data included rainfall from 9 rain gauges, two stream gauging sites and one tidal gauge. The calibration process involved adjusting model parameters (within reasonable bounds) until an acceptable fit between recorded flood flows and levels and modelled flood flows and levels were achieved.
- The model was validated against the recorded rainfall and levels/flow data with an excellent match between the recorded data and the model predicted results.
- The calibration/validation of the model has replicated the overflows of Kerikeri River into the Waipapa Industrial Estate and across Waipapa Road, and the flooding of areas around Kerikeri Basin and Landing Road that occurs during large flood events.
- The model has achieved a high level of calibration correlation at both level/flow gauge locations.
- The model has achieved a reasonable level of confidence at almost all the debris level locations.
- The resulting 'calibrated' model was then used with HIRDS v3 design rainfall events to predict the 10-year ED, 10-year MPD CC and 100-year MPD CC return period flows (or the ARI - Average Recurrence Interval) and flood levels. The modelling approach generally provided a high level of confidence for predicted stream flood levels and flood extents within the confines of the main stream channels and their tributaries. The design storm flows are in alignment with flow frequency estimates for the Tyrees Ford flow dataset.
- The design rainfall on average for the 10-year MPD CC was found about 13.7% higher than the 10-year ED rainfall while the 100-year MPD CC was about 88% higher compared to the 10-year ED rainfall.
- There is no flooding of the Waipapa industrial area on the left bank of the Whiriwhiritoa Stream while there is flooding on the right bank upstream of the SH10 Bridge during 10-year ARI ED event. Flooding of the low-lying area between SH10 and Waipapa Road occurs during the 10-year ED Event as expected. The extent of flooding in these areas increases during 10-year MPD and 100-year MPD with climate change allowances. Widespread flooding of the area along the Whiriwhiritoa Stream including overtopping of the SH10 and

Waipapa Road is identified during the 100-year MPD with climate change event due to spilling from the stream as well as spilling from the stormwater manholes.

- The flooding across the Waipapa Road at the dog-leg of the Kerikeri River occurs during the 10-year ED, 10-year ARI MPD CC and 100-year MPD CC events. Limited flooding across the Waipapa Road due to spilling from the Kerikeri River during 10-year ARI Ed while the extent increases during 10-year MPD CC and 100-year MPD CC. The road also overtops at a number of locations during the 100-year MPD CC events.
- The SH10 overtops at Puketotara Stream, Kerikeri River and Pungaere Stream crossings for all design storm events except the Kerikeri River bridge overtops only during 100-year ARI MPD CC event. The SH10 between Puketotara Stream and Kerikeri Rivers overtops at a number of places, especially over the highway just south of the Kerikeri River Bridge.
- In the urban Kerikeri Township there is limited flooding from spilling from stormwater manholes during 10-year ED event and this extent increases slightly during 10-year MPD CC event. There is wide spread flooding from spilling from the stormwater manholes during 100-year ARI MPD CC event.
- There is scope for further work on assessment of flood flows in the Kerikeri catchment. Running a 50-year ED and / or 100-year ED design storm event would allow for further direct comparison of the flooding of the catchment at various critical locations such as the Tyrees Ford weir, the Waipapa industrial area, and flooding of Waipapa Road from spilling from Kerikeri River. Since model calibration has been undertaken, the NRC have re-established the Peacock Garden site, and installed new river gauges on the Pungaere Stream, and the Puketotara Stream. A new automatic rainfall gauge has been installed at the Kerikeri Golf Club. Data from these gauges in future will enable further calibration of the model to provide higher confidence, especially in model response time from the Puketotara and Pungaere catchments. The current version of the model has however been calibrated against a large number of debris levels for both the calibration and validation events.

9. Limitations

9.1 Purpose of this report

This is a model build report. The purpose of this report is to describe the model build, model calibration/validation and flood hazard mapping process for the Kerikeri River Catchment flood modelling study.

9.2 Limitations

This report has been prepared by GHD for Northland Regional Council and may only be used and relied on by Northland Regional Council for the purpose agreed between GHD and the Northland Regional Council.

GHD otherwise disclaims responsibility to any person other than Northland Regional Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

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The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

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Appendices

Appendix A – CMP Report

Appendix B – Peer Review Report

Appendix C – Catchment Boundary, landuse, DTM

Appendix D – Model Calibration Results

Appendix E – Locations of Design Storm Point Rainfall and Predicted Flood Depth Maps for various ARI Storm Events

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