Official Height Standard Change

From 1 July 2024, Auckland Council adopts the official height standard for New Zealand called New Zealand Vertical Datum 2016 (NZVD2016).

This model was carried out prior to the height standard change.

All levels included in this modelling report are in Auckland Vertical Datum 1946 (AUK1946/AVD1946).

Levels in this report can be transformed from Auckland Vertical Datum 1946 into New Zealand Vertical Datum 2016 by applying an offset value.

For example:

$$H_{NZVD2016} = H_{AVD1946} - \text{Offset Value}$$

The height transformation value can be derived by using the conversion raster available on the LINZ website below:

https://data.linz.govt.nz/layer/103953-auckland-1946-to-nzvd2016-conversion-raster/

IMPORTANT!!

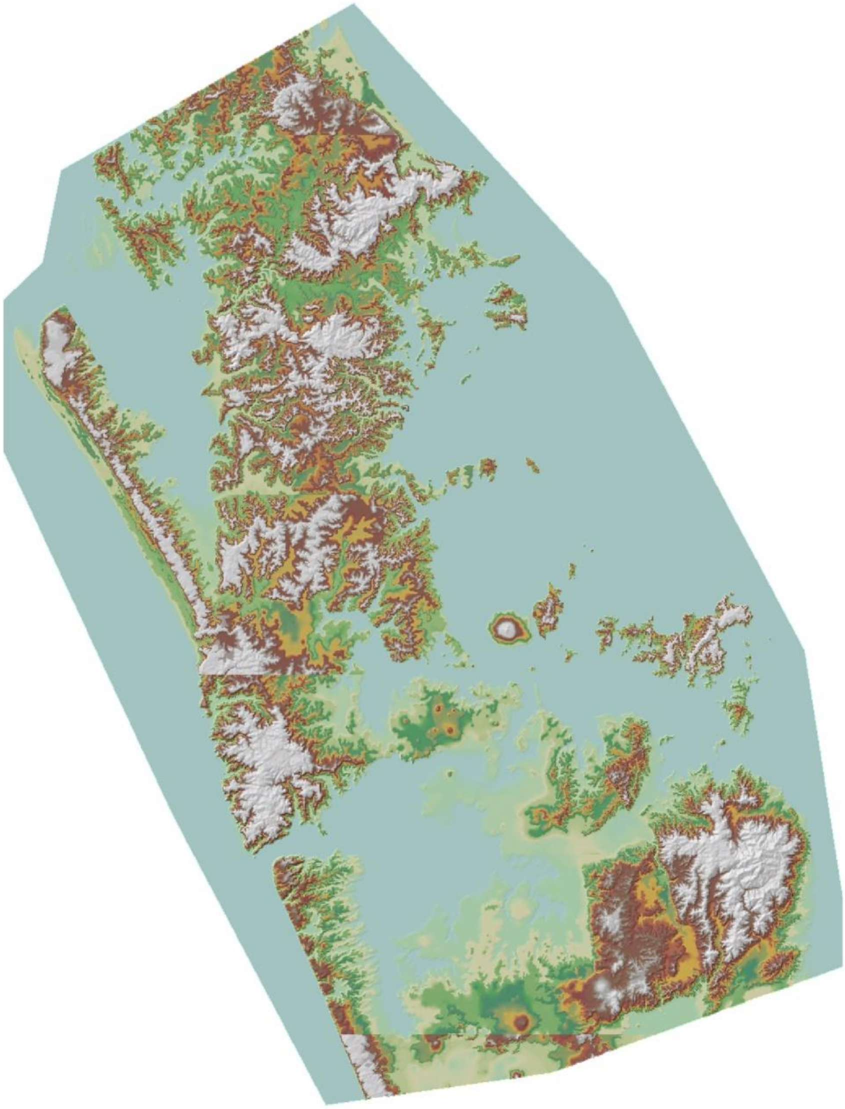
This document contains two PDFs:

1. **Volume 1 Report**
2. **Volume 2 Flood Hazard Maps**

1. Volume 1 Report

Auckland Regional Council

Rapid Flood Hazard Mapping of the Auckland Region
Volume 1: Hydraulic Modelling



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Project	Project No
Auckland Rapid Flood Hazard Mapping of the Auckland Region Volume 1: Hydraulic Modelling	50140

Authors	Date / Approved by
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DHI	Library	1

CONTENTS

APPENDICES

EXECUTIVE SUMMARY

DHI were engaged by the Auckland Regional Council to undertake the production of flood hazard maps to be used by the Auckland Regional Council for strategic planning purposes and prioritisation of detailed flood studies.

The rapid flood hazard mapping has been carried out for the following catchments: Auckland City; Great Barrier Island; Waitakere City; Manukau City; Franklin District; Rodney District; and Papukura District. A total of area of 4,600 km^2 has been mapped.

The flood hazard maps were produced by simulating the application of spatially distributed design rainfall time series data on to a digital elevation model derived from LiDAR ground survey data sets. The simulations were carried out using the DHI MIKE 21 computer modelling software. The software represents the digital elevation model as a rectangular grid (raster data set) with a resolution of 10 m x 10 m and 20 m x 20 m for urban and rural catchments respectively. Rainfall is translated in to flood water on the catchment with hydrological losses being accounted for (10 mm initial and 2.5 mm/h continuous). The software simulates the movement of the flood water over the surface by applying the 2 dimensional, depth averaged, continuity and momentum equations for fluid flow. The outputs from the model simulations are a rectangular grid (raster data set) of flood depths varying as a function of time.

The maximum flood depths at each grid point have been mapped in GIS providing spatial coverage of the flood depth at a horizontal spatial resolution of 10 m x 10 m for urban areas and 20 m x 20 m for rural areas.

The flood maps produced are suitable for use in: strategic planning studies; identification of areas at potential risk of flooding; and prioritisation of scheduling of more detailed catchment flood studies. A qualitative validation of the flood maps and consideration of the limitations in the modelling approach are recommended when analysing the results of the study.

The project was completed over the course of a year with the project starting on the 1st of May 2008 and finishing on the 30th of June 2009.

1 INTRODUCTION

1.1 Project Scope

DHI were engaged by the Auckland Regional Council (ARC) to carry out a rapid flood hazard mapping (RFHM) study for the following areas in the Auckland Region, mapping a total area of 4,600 km^2:

- Auckland City;
- Great Barrier Island;
- Waitakere City;
- Manukau City;
- Franklin District;
- Rodney District; and
- Papukura District.

The objective of the study was to provide a rapid, regional wide coverage of flood hazard for the 100 year Annual Recurrence Interval (ARI) rainfall event utilising the LiDAR ground survey data previously acquired by the ARC. The intended use of the flood hazard mapping is for use by the ARC for strategic planning purposes and prioritisation of more detailed flood studies.

The flood hazards to be mapped were the maximum spatial extent of the flood spread and the maximum flood depth on a rectangular grid at a spatial resolution of 10 m x 10 m for urban and 20 m x 20 m for rural catchments.

1.2 Execution of Project Services

The project programme was divided in to six phases. Table 1-1 presents the scope of work carried out in each of the phases. Additionally, a phase was implemented which investigated the sensitivity of the flood hazard predictions to different representations of rainfall losses.

Table 1-1: Execution of project services

Phase	Tasks completed	Number of models	Date started	Date completed
Phase I	Project start up Franklin District models	8	1/5/08	30/9/08
Phase II	Rodney District models	14	22/7/08	30/9/08
Sensitivity Testing	Sensitivity testing to determine the appropriate rainfall losses to use	Test cases	22/7/08	30/9/08
Phase III	Rodney District models Auckland City models Papakura District models	4 6 2	9/10/08	23/12/08*
Phase IV	Waitakere City models	8	8/4/09	30/6/09
Phase V	Manukau City models	9	21/4/09	30/6/09
Phase VI	Great Barrier Island model	1	27/5/09	30/6/09
Final	Final reporting	-	-	30/6/09

*ACC catchments delivered on the 19/6/09

1.3 Project Deliverables

DHI were contracted to provide the following deliverables as part of the RFHM project:

- Digital GIS raster grids of the maximum flood depth and spread for each modelled catchment
- Digital PDF files of maximum flood depth and spread flood hazard maps for each modelled catchment
- Digital GIS polygon (.SHP) of the flood spread extent for each modelled catchment;
- Final report detailing the work carried out and presenting in hardcopy the flood hazard maps for each modelled catchment

The digital GIS data is supplied in an ESRI geo-database version 9.2. An external hard drive containing the following data was provided to the ARC:

- Final report in PDF format;
- Polygon shape file of the maximum flood spread extent for each catchment modelled;
- Polygon shape file of the watershed for each catchment modelled; and
- Raster dataset of the maximum depth for each catchment modelled.

1.4 Outline of Report

The work undertaken in this study is documented in two volumes of reports:

- Volume 1: Hydraulic Modelling; and
- Volume 2: Flood Maps.

Within this report (Volume 1) Section 2 provides an overview of the study approach; Section 3 presents and discusses the input data used in the study; Section 4 provides a summary of the details of modelling and model parameters; Section 5 provides details on the results and discusses the associated limitations in the results; Section 6 presents conclusions from the study; and Section 7 provides details of the references used in the study. Appendix A presents the report detailing the work carried out as part of the sensitivity analysis work investigating the effect of rainfall losses on the rapid flood hazard mapping.

2 OVERVIEW OF STUDY APPROACH

2.1 Technical Approach

The points below highlight the technical approach to the RFHM. Further, specific, details of the modelling work carried out are provided in Section 4 of this volume.

2.1.1 Rainfall

The 100 year Annual Recurrence Interval (ARI) design rainfall storm profile has been established in accordance with the Guidelines for Stormwater Modelling in the Auckland Region, planned to be published in 2010. Because of the large spatial coverage of the modelled catchments the spatial variation in design rainfall depths has been taken in to account within each of the catchments – this has been based on recently revised, but unpublished, rainfall depth data.

2.1.2 Rainfall losses

Net rainfall has been derived by accounting for hydrological losses from the gross rainfall timeseries in advance of any simulations. Initial losses and continuing losses have been subtracted from the rainfall timeseries data.

2.1.3 Terrain model

Each catchment has been delineated to define its watershed boundary. The catchment surface is then represented by a rectangular grid. The grid has been defined to have a resolution of 10 m x 10 m grid cells for urban areas and 20 m x 20 m grid cells for rural areas. The ground surface levels for the catchment grid are derived from the ARC LiDAR survey data sets. This forms the surface elevation model that is used in the hydraulic simulations. State Highway cross drainage structures (e.g. bridges and culverts) have been assumed to be able to pass the flood flows associated with the 100 year ARI design rainfall.

2.1.4 Hydraulic roughness

Surface roughness is represented using Manning's M friction coefficient and it is mapped on to a rectangular grid of the same resolution as the ground surface grid. The surface roughness is derived from a land use database (ref. LINZ).

2.1.5 Water level boundaries

Water level boundaries at the estuaries where the catchment drainage discharges to the ocean have been represented by a constant water level timeseries representing mean sea level (MSL).

2.1.6 Numerical simulation

A 2-dimensional (depth averaged) hydrodynamic simulation has been carried out for each catchment with the net rainfall timeseries and coastal water levels as inputs to the model. The rainfall has been applied to each of the grid cells within the catchment. The hydrodynamic simulation solves the 2-dimensional (depth averaged) continuity (mass balance) and momentum (force balance) equations to generate the 2-dimensional time evolution of flood water movement on the catchment surface.

The DHI MIKE 21 modelling software has been used for the hydrodynamic simulations.

2.1.7 Results

The results from the hydrodynamic model have been processed to provide flood hazard maps of the maximum water depth at each grid cell for each catchment. The extents of the flood envelope have also been processed in to a GIS polygon coverage.

2.2 Model coverage

The Auckland Region containing the hydrological catchments were defined in the following sub regions based on the city or district council boundaries (where appropriate):

- Auckland City;
- Great Barrier Island;
- Waitakere City;
- Manukau City;
- Franklin District;
- Rodney District; and
- Papukura District.

Each of the sub regions have been divide further in to model areas. The model areas have been defined by balancing the size of the sub region with the computational time that is required to carry out the simulations. Each model area can, therefore, contain more than one hydrological catchment. Figure 2-1.presents the delineation the model areas and Table 2-1 presents further details of the model areas.

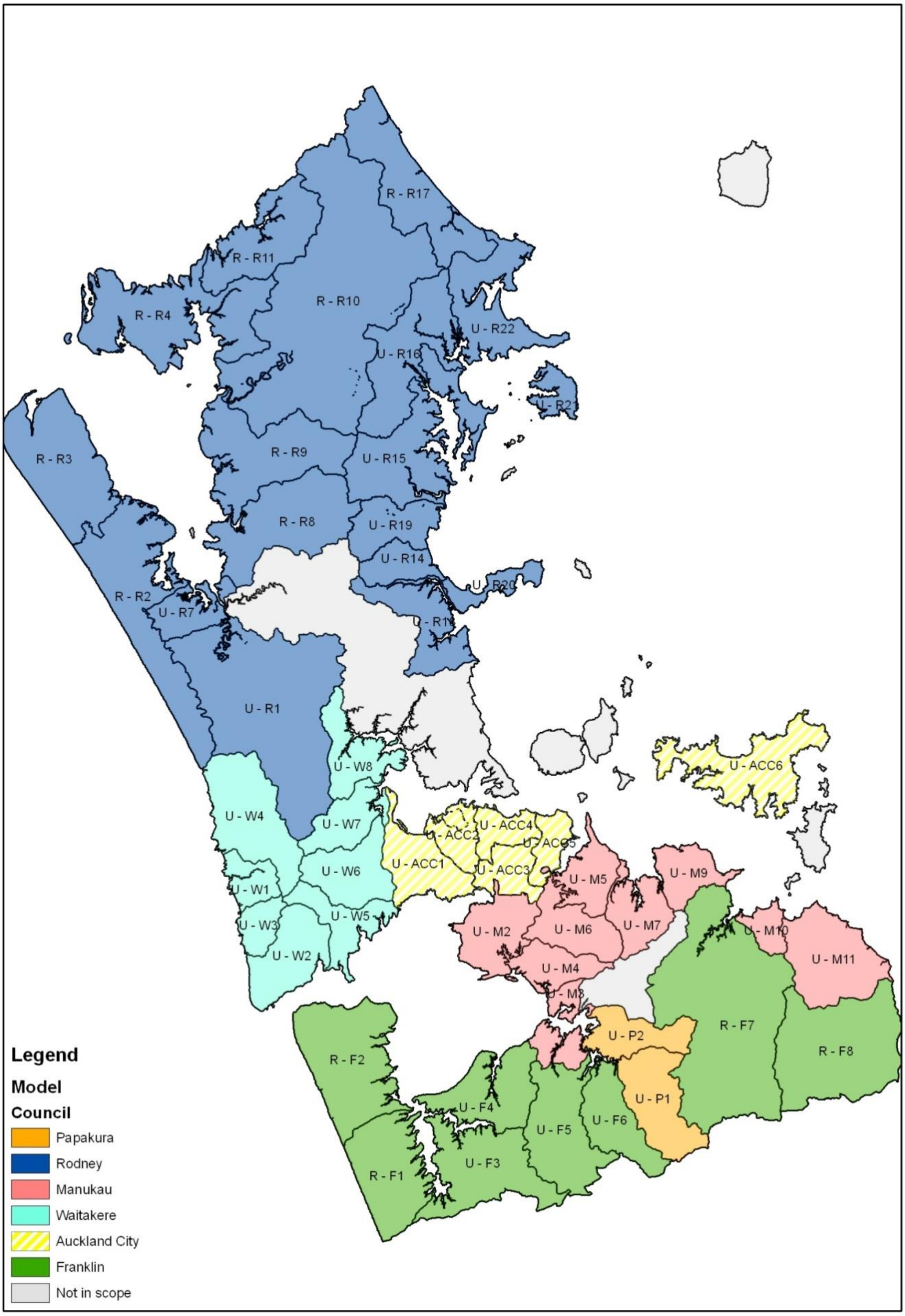

Figure 2-1: Model areas for RFHM for the Auckland Region

Table 2-1 Details of model areas for RFHM for the Auckland Region

Model ID	Catchment Name	Cell Size (m)	Area (km^2)	Simulation Time (hours)
Acc1	Whau River	10 x 10	91	43
Acc2	Meola Creek	10 x 10	49	23
Acc3	Onehunga	10 x 10	41	25
Acc4	Hobson Bay	10 x 10	37	20
Acc5	Tamaki	10 x 10	53	26
Acc6	Waiheke Island	10 x 10	330	118
F1	Waiuku River	20 x 20	149	17
F2	Matakawau Creek	20 x 20	230	41
F3	Waitangi Stream	10 x 10	140	98
F4	Taihiki River	10 x 10	124	101
F5	Whangapouri Stream	10 x 10	101	79
F6	Ngakoroa Stream	10 x 10	62	63
F7	Wairoa River	20 x 20	281	308
F8	Waikato River	20 x 20	157	26
GB	Great Barrier Island	20 x 20	764	118
M10	Kawakawa Bay	10 x 10	28	13
M2	Mangere	10 x 10	105	114
M3	Waimahui Creek	10 x 10	64	35
M4	Puhinui River	10 x 10	54	25
M5	Eastern Beaches	10 x 10	76	37
M6	Otara Creek	10 x 10	53	52
M7	Whitford	10 x 10	50	25
M11	Tawhitokino Stream	10 x 10	166	60
M9	Omana - Duders Beach	10 x 10	68	30
P1	Hingaia - maketu Stream	10 x 10	77	105
P2	Hays Creek	10 x 10	63	48
R1	Kaipara River	10 x 10	266	297
R10	Waiteitei Stream	20 x 20	428	274
R11	Maeneene Stream and Te Hana Creek	20 x 20	109	23
R14	Orewa River	10 x 10	40	27
R15	Te Kapa River	10 x 10	212	152
R16	Matakana River	10 x 10	113	96
R17	Poutawa Stream	20 x 20	208	38
R18	Weiti and Okura River	10 x 10	64	66
R19	Waiwera River	10 x 10	59	27
R2	Puharakeke and Mairetahi Creek	20 x 20	469	81
R20	Whangaparaoa Peninsula	10 x 10	82	37
R21	Kawau Island	10 x 10	52	23
R22	Cape Rodney	10 x 10	217	290

Model ID	Catchment Name	Cell Size (m)	Area (km^2)	Simulation Time (hours)
R3	Te Ikatauhou Creek	20 x 20	276	48
R4	Tauhoa River	20 x 20	310	44
R7	Matawhero Stream	10 x 10	48	52
R8	Makarau	20 x 20	135	25
R9	Omaumau Creek	20 x 20	173	31
W1	Bethells Beach	10 x 10	36	19
W2	Huia	10 x 10	92	44
W3	Piha	10 x 10	32	25
W4	Okiritoto Stream	10 x 10	133	65
W5	Big Muddy Creek	10 x 10	96	45
W6	Henderson East Creek	10 x 10	61	33
W7	Lawsons Creek	10 x 10	45	25
W8	Riverhead	10 x 10	65	73

3 INPUT DATA

3.1 Input Data Sources

Table 3-1 presents details of the input data used in this study. All data was issued to DHI by the ARC.

Table 3-1 Input data to RFHM study

Data	Description	Provided by
LiDAR	Land level data points for the entire region. Data collected in 2006	ARC
Aerial photography	Digital images in .JPEG format with geo-referencing, both rural and urban resolutions, for the entire region Data collected in 2006	ARC
Road Centerlines	GIS polyline shape file of the road centrelines for the Auckland region	ARC
State Highway structure locations	GIS point shape file of the cross drainage structure locations on the State Highways for the Auckland region	ARC and Transit New Zealand
Catchment Boundaries	GIS polygon shape file of the catchment boundaries for the Auckland region	ARC
Franklin structure locations	GIS point shape file of the additional State Highway crops drainage structures for the Franklin District	FDC and Opus
Soakage to groundwater drainage areas	GIS polygon shape file of the area in Auckland City where surface storm water drains into the aquifer system	ARC
Land use definitions	GIS polygon shape file of land use classifications for New Zealand referred to as the LDCB2 database, compiled from Landsat 7 satellite imagery from 2002	MfE
TP108 rainfall contours	Spatial distribution of the 24 hour rainfall depth totals for the Auckland region. Rainfall depths and spatial distribution based on updated TP108 data unpublished at time of study (June 2009)	ARC
Boundary water level data	Mean Sea Levels for the Auckland, Manukau and Kaipara harbours	LINZ

4 MODELLING

4.1 Rainfall data processing

The 24 hour, 100 year ARI design rainfall event was used in model simulations to produce corresponding flood hazard information.

The design rainfall event was defined in accordance with the TP108 Guidelines for Stormwater Runoff Modelling in the Auckland Region (ARC, 1999) and updates to the TP108 carried out by ARC in May 2008. No technical publication reference is available for the updates to the current TP108 as the work is unpublished at the time of writing of this report.

The design rainfall event has been described as a spatially varying timeseries of rainfall intensities for each catchment.

The spatial distribution for the design rainfall event was defined in accordance with the updated TP108 methodology and data. Contours of the annual maxima rainfall depths were scaled to the produce the 24 hour, 100 year ARI rainfall depth contours using the appropriate growth factor (1.974). The resolution of the spatial variability has been defined at 10 mm differences in rainfall depths. Figure 4-1 presents the 24 hour, 100 year ARI rainfall depth contours for the Auckland Region.

The temporal distribution for the design rainfall event was defined in accordance with the updated TP108 methodology and data. The total rainfall depths have been fitted to a 24 hour temporal distribution with a resolution of 5 minutes. The rainfall data is represented as intensities in mm / day as required by the hydrodynamic modelling software. Figure 4-2 presents a time series plot showing the 24 hour temporal profile.

The rainfall timeseries data has been adjusted to account for rainfall losses. A separate investigation was undertaken to assess the sensitivity of flood hazard predictions on rainfall losses (DHI 2008). The findings from the study indicated that an initial loss of 10 mm and a continuing loss of 2.5 mm/hr be applied. The Auckland City catchments ACC1 to ACC5 used alternative rainfall losses to provide a more representative description of the losses through discharge to groundwater via soakage. The losses applied were equivalent to the 24 hour 5 year ARI design rainfall.

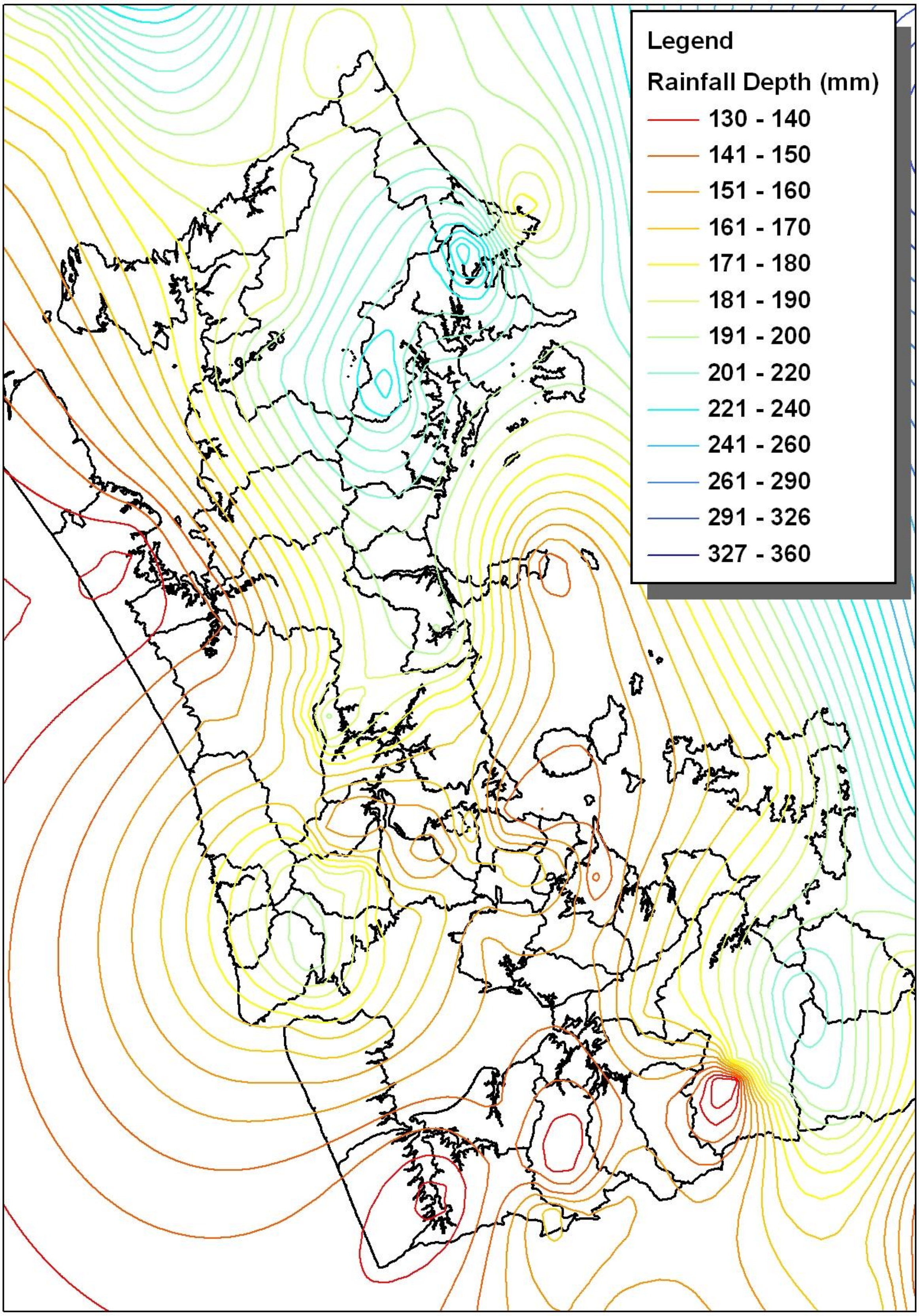

Figure 4-1: Depth distribution of the 1% AEP 24 hour storm. Source: ARC Guidelines for Stormwater Modelling in the Auckland Region, planned to be published in 2010.

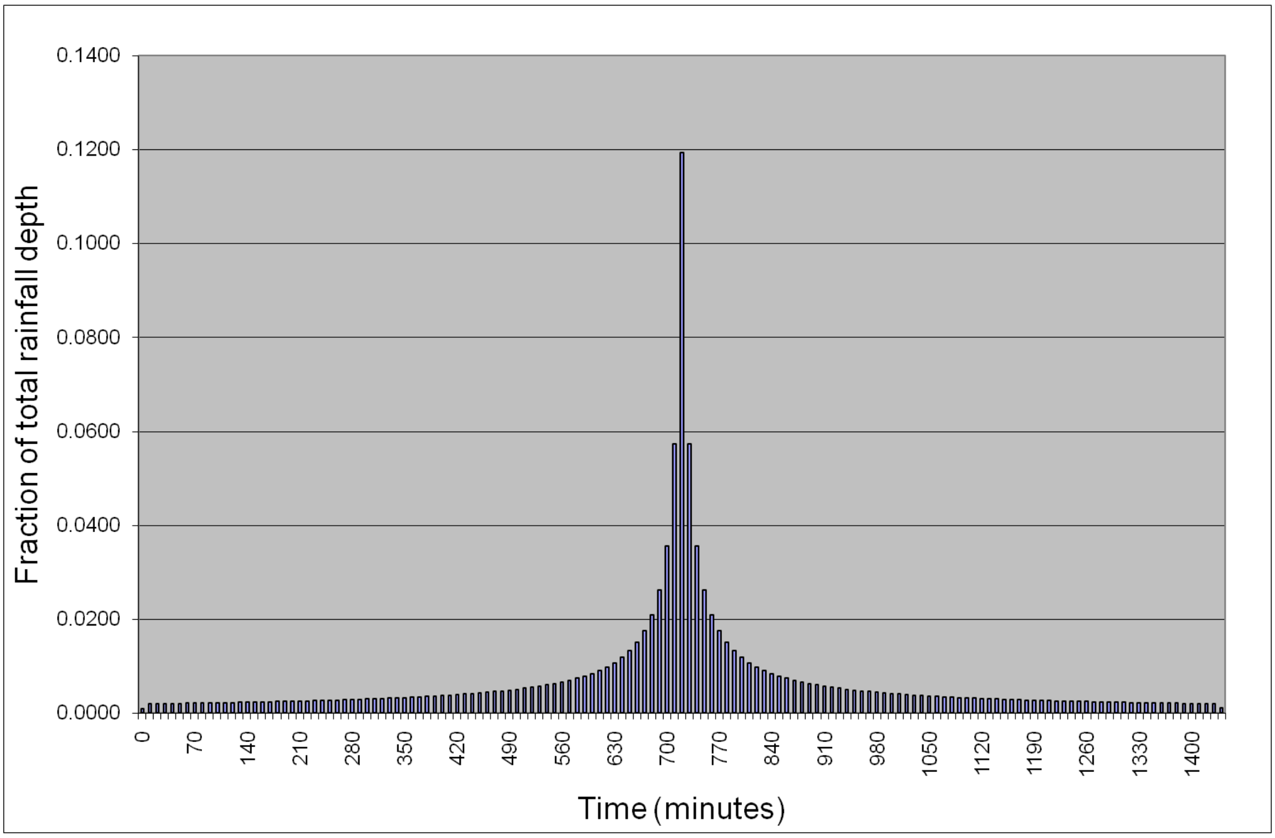

Figure 4-2: 24 hour design storm at 10 minutes intervals. Source: ARC Guidelines for Stormwater Modelling in the Auckland Region, planned to be published in 2010

4.2 LiDAR data processing

The LiDAR data provided by the ARC comprised the bare earth data. This LiDAR data was processed in ESRI ArcGIS to produce a terrain dataset (a variable resolution triangulated irregular network (TIN) digital elevation model (DEM)) for the entire Auckland Region. For each model area the terrain dataset was converted in to a rectangular grid (know as a raster dataset) with a resolution of 10 m x 10 m for urban areas and 20 m x 20 m for rural areas for use in model simulations.

The classification of rural and urban catchments was based on the Urban / Rural land classification tiles supplied by the ARC as shown in Figure 4-3.

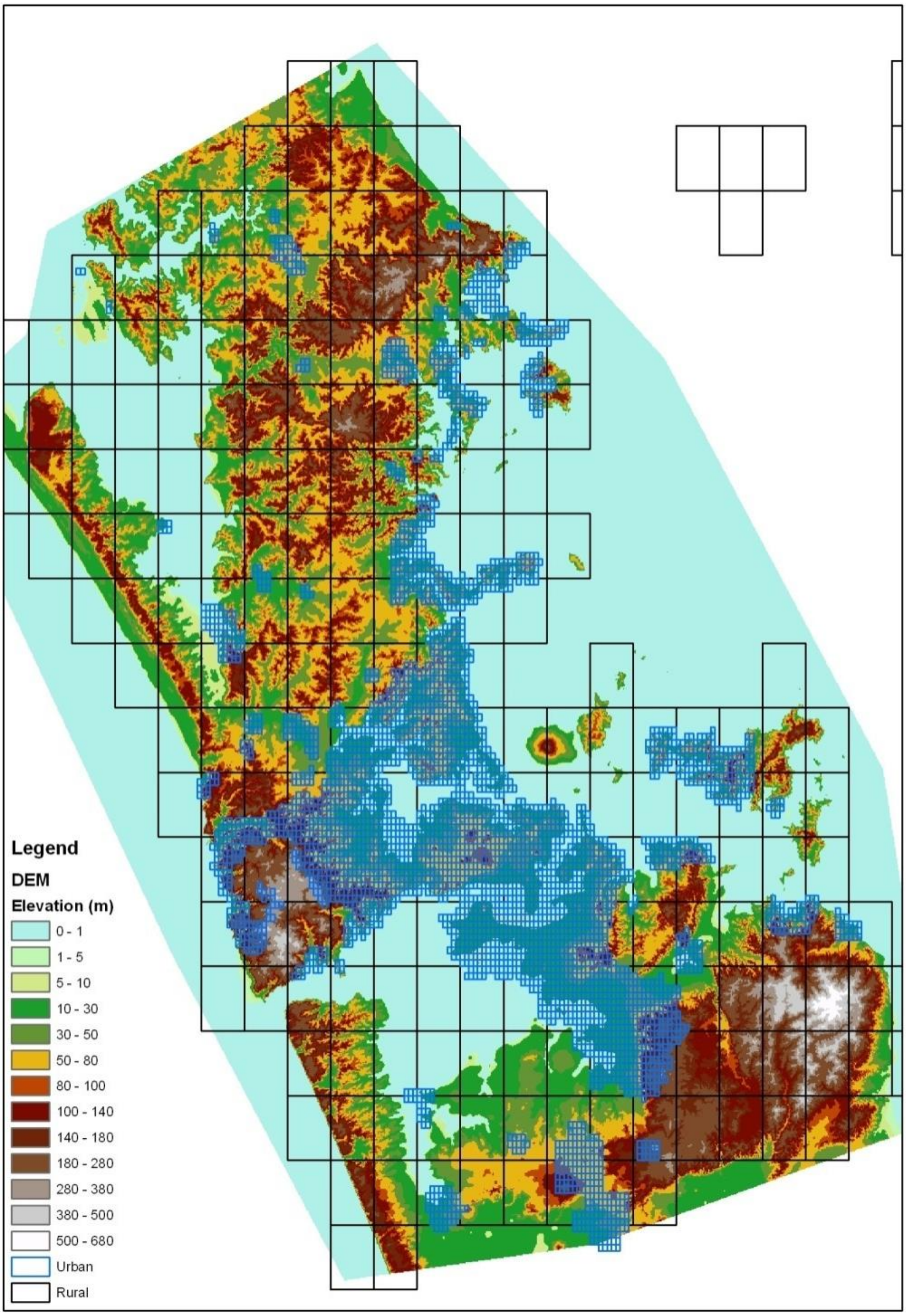

Figure 4-3: Rural/Urban Land Use Distribution (urban shown as fine scale grids and rural shown as coarse scale grids)

4.3 Sub catchment delineation

The resulting raster data sets were analysed using tools in ESRI ArcGIS (version 9.2) spatial analyst to delineate the correct hydrological catchment boundaries. The raster data set was pre-processed by filling in the depressions within the grid. The resulting terrain is analysed to define the accumulated flow paths from the high to low ground elevations and the polygon encapsulating these accumulated flow paths represents the hydrological catchment boundary. Figure 4-4 presents an example of the hydrological catchment delineation based on accumulated flow paths for the Orewa River catchment.

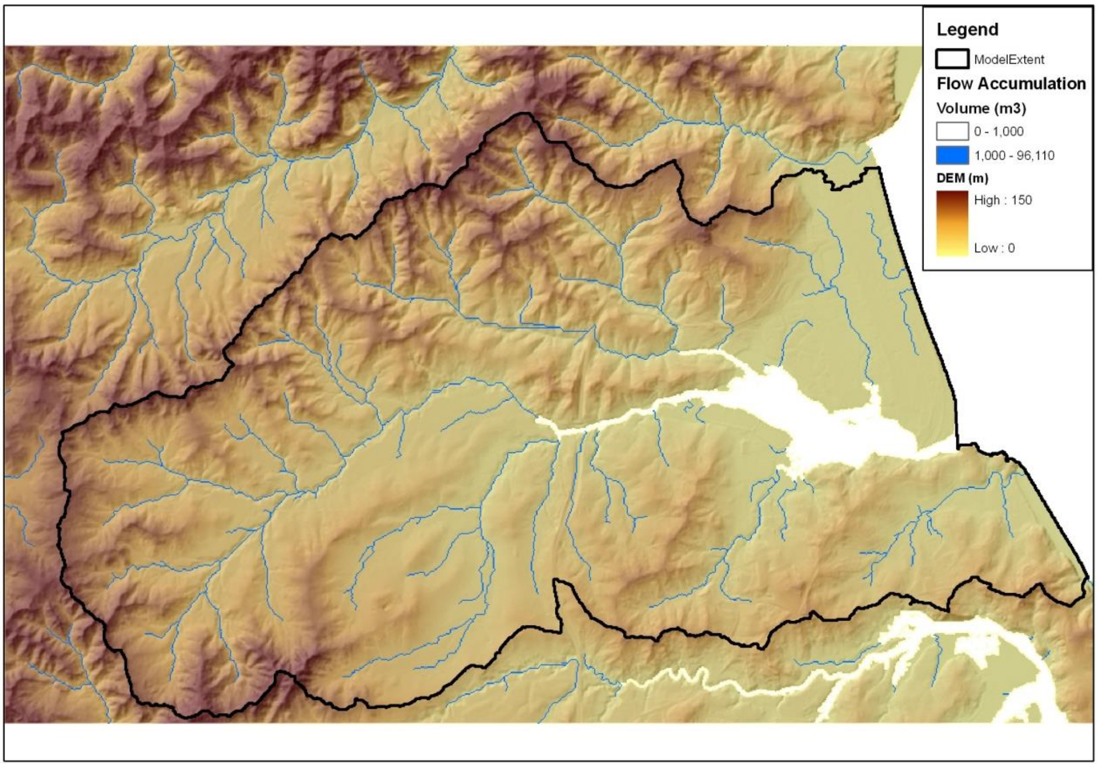

Figure 4-4 Example of hydrological catchment delineation using accumulated flow paths (Orewa River catchment)

4.4 Cross drainage structures

All cross drainage structures (e.g. bridges and culverts) on State Highways have been assumed to have sufficient hydraulic capacity pass the flood flow corresponding to the design 100 year ARI rainfall. The surface elevation model has been adjusted at locations of these structures to by lowering the ground levels to that of the approximate bed level of the drainage channel.

All other cross drainage structures have been assumed to have a lower hydraulic capacity than the flood flow corresponding to the 100 year ARI rainfall. No changes have been made to the surface elevation model at these locations.

In addition to the State Highway structures being set to have no limiting hydraulic capacity the Franklin District Council requested that a number of non State Highway structures be assumed to provide no hydraulic restriction. The digital elevation model in these areas has also been adjusted to represent a non hydraulic constriction case.

4.5 Surface roughness

The resistance to flow over the surface is composed of many forms of friction loss. The RFHM approach considers the resistance to be represented by Manning's friction loss defined at the same spatial resolution as the surface elevation grid used in the modelling (i.e. 10 m x 10 m for urban and 20 m x 20 m for rural). The spatial variation is derived from the LDCB2 land use classification from the MfE. Table 4-1 details the different land uses and corresponding Manning's roughness based on experience and generally accepted values.

Table 4-1 Manning numbers applied to different land use types (note M = 1/n)

Description (based on LCDB2)	Code	n	M
High Producing Exotic Grassland	40	0.050	20
Pine Forest - Closed Canopy	66	0.125	8
Manuka and or Kanuka	52	0.125	8
Pine Forest - Open Canopy	65	0.125	8
Indigenous Forest	69	0.125	8
Orchard and Other Perennial Crops	32	0.125	8
Built-up Area	1	0.100	10
Short-rotation Cropland	30	0.050	20
Vineyard	31	0.125	8
Broadleaved Indigenous Hardwoods	54	0.125	8
Other Exotic Forest	67	0.125	8
Urban Parkland / Open Space	2	0.033	30
River	21	0.020	50
River and Lakeshore Gravel and	11	0.020	50
Gorse and or Broom	51	0.125	8
Afforestation (imaged, post LCDB 1)	63	0.125	8
Deciduous Hardwoods	68	0.125	8
Lake and Pond	20	0.020	50
Major Shelterbelts	61	0.125	8
Surface Mine	3	0.050	20
Transport Infrastructure	5	0.100	10
Afforestation (not imaged)	62	0.125	8
Low Producing Grassland	41	0.050	20
Mixed Exotic Shrubland	56	0.050	20
Forest Harvested	64	0.125	8
Flaxland	47	0.050	20
Fresh water Vegitation	41	0.100	10
Saline Vegitation	45	0.100	10
Mangroves	70	0.100	10

4.6 Downstream Water Level Boundaries

The open boundary of each model is chosen to represent to outlet of the catchment discharging to the ocean or estuary. The ocean water level has been defined as a constant in time corresponding to mean sea level (MSL). Figure 4-5 presents the distribution of different MSL values around the Auckland Region. The different model areas therefore have different MSL boundary conditions depending on the location of their outlet.

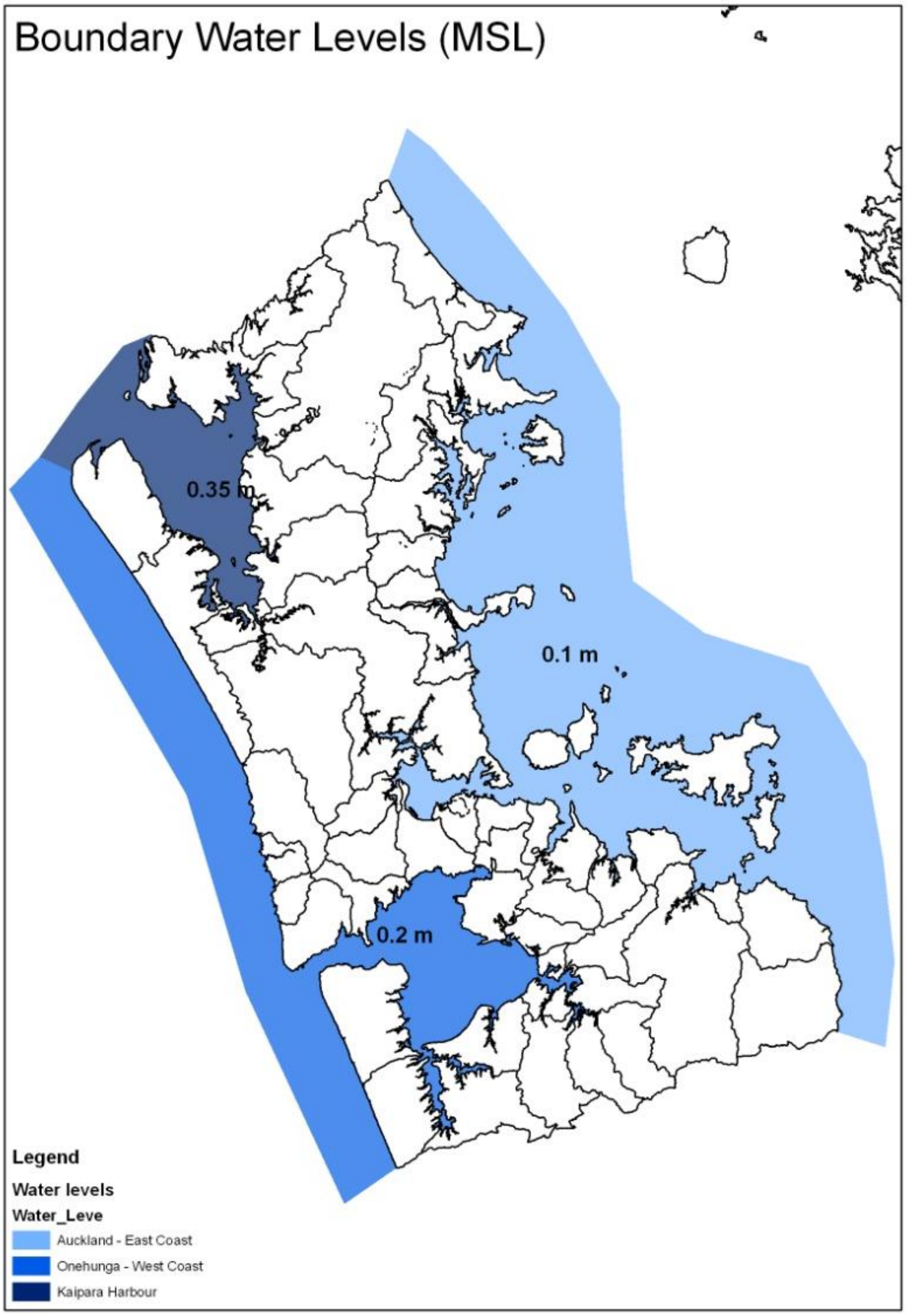

Figure 4-5 Boundary Water Levels

4.7 Initial Conditions

The initial condition for each model simulation assumes all surface depressions are filled with water and a horizontal backwater is defined from the open MSL boundary condition.

4.8 Simulations

The DHI MIKE 21 modelling software has been used for the hydrodynamic simulations.

The rainfall event being simulated is of 24 hour duration. The model simulation time is dependent on the simulation time step (the time interval at which a hydrodynamic calculation is carried out). The time step is dependant, amongst other things, on the spatial resolution of the model grid. Typically for model grids of the resolution used in this study (10 m by 10 m urban and 20 m x 20 m rural) the time step is of the order 1/5th second. At sub second time steps simulation times can become prohibitively long. As a result, each RFHM simulation was 6 hours into the 24 hour rainfall event and run until the peak levels and flows have been reached, and passed, at all locations within the catchment. Table 2-1, Section 2, provides details of the simulation time for each model area.

5 RESULTS

5.1 Post-processing

The model simulations produce results data that are stored as time series data values at a time interval of 5 minutes with a spatial distribution at a resolution equal to that of the input model grids (e.g. 10 m x 10 m for urban and 20 m x 20 m for rural catchments).

The model results produced include:

- Water levels;
- Water depths;
- Discharge; and
- Flow velocity.

For this RFHM study the maximum water depth values for each grid cell are extracted to produce a spatial map of maximum flood depths for each catchment. The maximum water depths have been filtered to remove any depths less than 0.10 m and erroneous flood depths at the vicinity of the open model boundaries.

The maximum flood depths have been superimposed on to the ARC aerial photography and a series of flood maps produced. The flood extent has been translated in to a GIS polygon shape file for each catchment.

5.2 Continuity checks

In order to ensure reliable simulation results continuity checks (volume balance) were carried out on each catchment. Continuity balances less than 20% have been defined as acceptable. Where the initial continuity check was above 20% the model has been rerun with a lower time-step (typically $1/10^{th}$ second).

5.3 Limitations

No quantitative or qualitative validation has been carried out for the flood events. Quantitative validation may prove difficult because of the fact that the simulation results represent an abstract design rainfall event. Some qualitative model validation may prove beneficial and it is recommended that this is carried out by the ARC.

The quantitative accuracy of the results from modelling is dependent on a range of factors, including the quality of the input data, the modelling methodology and the resolution of the model grids.

The following points should be noted when utilising the outputs from the RFHM:

- The LiDAR data has an absolute vertical accuracy of 0.25 m in urban areas and 0.50 m in rural areas. Significant deviations in vertical accuracy can occur in areas of dense vegetation. Below water ground levels are not reliably represented in the LiDAR data;

- Hydrological processes are represented in a simplified distributed way with losses pre-applied to the rainfall timeseries;

- The in-channel hydraulic routing for small water courses (typically of width of the order of less than 5 grid cells) is not accurately resolved in the RFHM models;

- The resolution of the model grids (10 m in urban catchments and 20 m in rural catchments) may not resolve the sub grid features that have an impact on the evolution of the flooding within the catchment (e.g. road embankments and narrow open channel drainage networks);

- Cross drainage structures on State Highways have been considered as providing uninhibited passage of the flood flows corresponding to the 100 year ARI rainfall (with the exception of the Franklin District models) models;

- Storm water reticulation capacity was not considered in the RFHM models;

- The initial condition fills all depressions with water at the start of the simulation. This can cause unrealistic water depths where areas have no overland drainage.

In conjunction with the ARC the following disclaimer was defined to accompany all the mapping outputs from the RFHM study.

Disclaimer

The information contained on this map represents rapid regional flood hazard mapping. It was produced for regional flood planning and civil defence purposes. Refer to the appropriate Territorial Authority for local flood maps and information about local habitable floor and property flooding.

The floodplain extents reflect application of the 100-year Annual Recurrence Interval (ARI) rainfall event (using updated rainfall depth-durations from 2008), use of topography generated from regional LiDAR data (flown in 2006) and simulated in MIKE-21 computer software. Computer simulations are based on initial rainfall loss, a constant loss of runoff due to infiltration and a 10 m x 10 m mapping grid. Culverts were assumed to be blocked, while major bridges crossings did not impede flow.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

A RFHM study has been undertaken for the Auckland Region. Separate hydrological catchments have been defined covering a total area of 4,600 km^2 which have then been simulated for the 24 hour, 100 year ARI rainfall event.

The RFHM approach uses a rectangular grid representing the surface ground levels and surface roughness combined with spatially distributed rainfall timeseries data to carry out hydrodynamic simulations for each of the hydrological catchments. Grid resolutions of 10 m x 10 m for urban catchments and 20 m x 20 m for rural catchments have been established in this study. Rainfall losses (initial and continuing) have been applied to the rainfall prior to simulation.

The model simulation results have been processed to produce a flood map of the maximum flood depth at each grid cell for all catchments.

The flood maps produced are suitable for use in:

- Strategic planning studies;
- Identification of areas at potential risk of flooding; and
- Prioritisation of scheduling of more detailed catchment flood studies.

6.2 Recommendations

It is recommended that the flood maps produced from this RFHM study be qualitatively validated to ensure that there are no erroneous predictions being made by the models.

It is recommended that the flood maps be regenerated following any significant hydrological, hydraulic, land use or topographical changes.

7 REFERENCES

van Kalken, T., Taylor, A., Davis, M. and Hellberg, B. (2009); *Rapid Two Dimensional Flood Hazard Mapping in the Auckland Region*, NZ Water Stormwater Conference, Auckland, 2009.

DHI 2008. *Rapid Flood Hazard Mapping for the Auckland Region, Sensitivity Tests (Draft Report)*, Auckland Regional Council, Auckland.

ARC. 1999. *Guidelines for Stormwater Runoff Modelling in the Auckland Region. (Technical Publication No. 108).* Auckland Regional Council, Auckland.

A P P E N D I C E S

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Sensitivity Report

Rapid Flood Hazard Mapping for the Auckland Region

Sensitivity Tests

September 2008

Auckland Regional Council
TE RAUHĪTANGA TAIAO

Final Report

Rapid Flood Hazard Mapping for the Auckland Region

Sensitivity Tests

September 2008

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CONTENTS

1 INTRODUCTION

The Auckland Regional Council has commissioned DHI to undertake a Rapid Flood Hazard Mapping (RFHM) assessment for a number of catchments in the Auckland Region. The assessments are based on the application of rainfall directly on to a 2D (MIKE 21) model grid of each catchment. This methodology applies rainfall directly to each grid cell in the model area but does not take into account losses from the rainfall such as ponding and infiltration. To include these losses in the model it is necessary to apply the losses directly to the rainfall input before applying to the model. The ARC has requested DHI to perform sensitivity tests to determine the effects of applying spatially varying losses on the predicted flood levels and extents. A comparison to an alternative flood mapping approach using hydrographs generated from a TP108 rainfall-runoff model has also been undertaken.

2 METHODOLOGY

The methodology proposed for the ARC RFHM project is based on a rainfall on grid approach, where net rainfall (gross rainfall minus initial and continuing losses) is applied directly to a MIKE 21 2D model grid. The sensitivity tests undertaken and reported here aim to quantify the effects of using spatially varying rainfall losses as a function of land use, ie to determine if differences in predicted flood levels and extents occur if different rainfall losses are applied in different parts of the catchment.

The model results are also compared to a different RFHM technique applied by North Shore City Council (NSCC) where rainfall is first applied to separate TP108 rainfall run-off models for individual sub-catchments (in NSCC these have a maximum area of 10ha), and the resulting outflow hydrographs are applied as a source inflows to MIKE 21.

Three different MIKE 21 models were developed to compare different modelling techniques for rainfall and runoff inputs. The Lucas Creek catchment in Albany was selected as a test case as the topography is fairly representative of many of the catchments in Auckland, but the land use is quite diversified with large areas of both pervious and impervious surfaces, see Figure 2-1.

Two models were set up for the rain on grid (ARC) approach, where a TP108 rainfall hydrograph is applied directly to the grid cells. Distributed losses were applied to one of these models (rainfall on grid, distributed loss model) while in the second model uniform losses were assumed – in this case these were assumed to be zero (rainfall on grid, zero loss model), corresponding to a fully impervious surface. A third model was set up using the NSCC approach, with source point inflows generated from a TP108 rainfall-runoff model (source points, TP108 runoff model). The same TP108 rainfall hyetograph was applied for all three models.

Each model used a constant roughness, Manning's M of 20, a storm depth of 220mm (corresponding to a 100 year ARI event) and identical bathymetry and initial conditions. A grid size of 10m was used.

2.1 Rainfall on Grid – Distributed Loss Model

For the pervious areas in the Lucas Creek catchment, a Horton loss approach was used to estimate the rainfall losses in the pervious areas. Horton losses are an integral part of many established rainfall-runoff models (including DHI's Model B) and are easily established from physical soil parameters. The Hortonian loss model assumes an initial infiltration rate which decays to a lower final infiltration rate over a period determined by an exponential time exponent.

The following Horton loss parameters were assumed for Lucas Creek:

Initial loss rate: 51mm/hr

Final loss rate: 2.5mm/hr

K exponent factor: 4.14/hr

In order to compute the accumulated losses at the start of the storm, a simple MOUSE model was established for a sample catchment from which the initial losses were computed as shown in Figure 2-2.

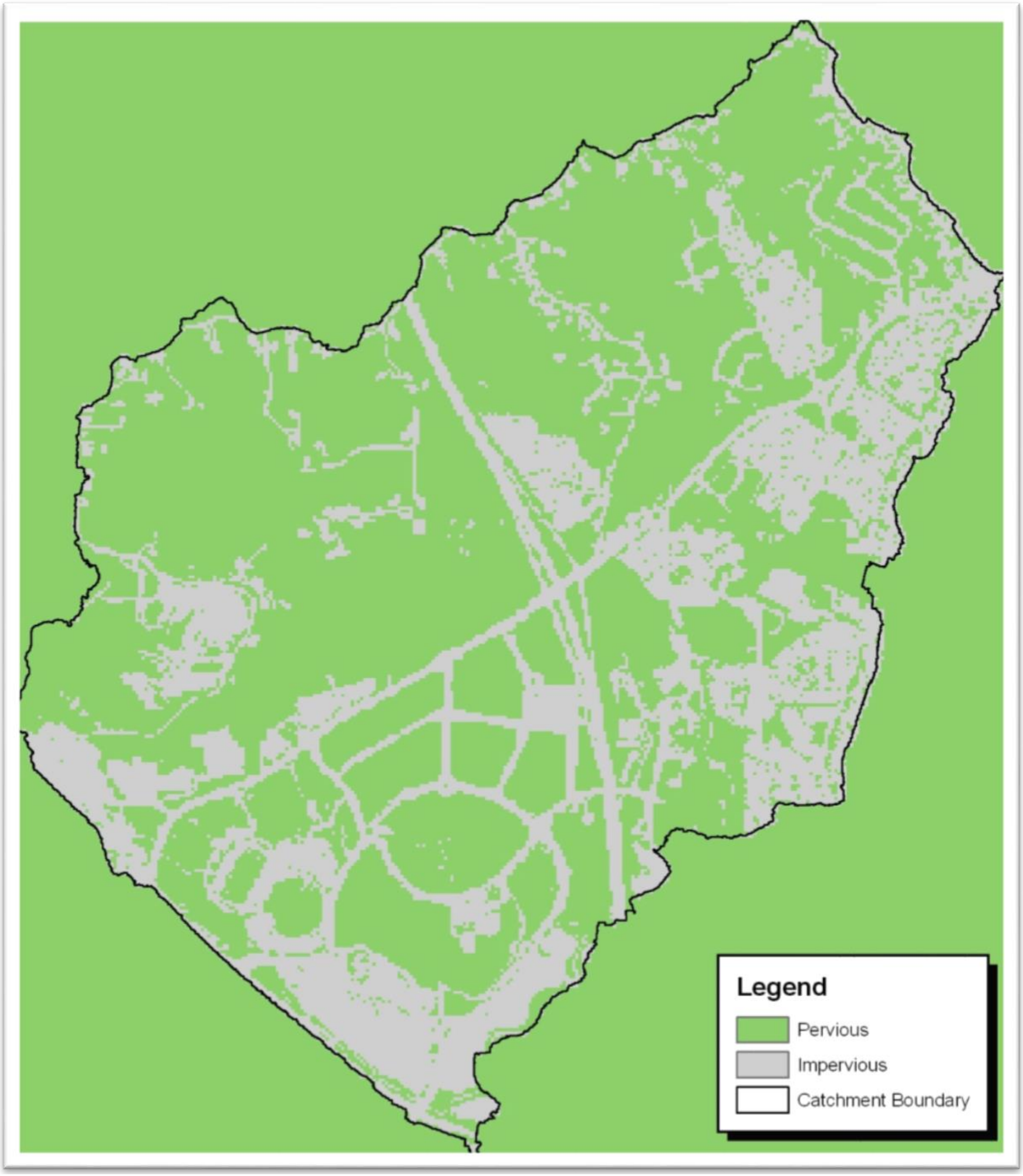


Figure 2-1: Land Type Classification for the Lucas Creek catchment

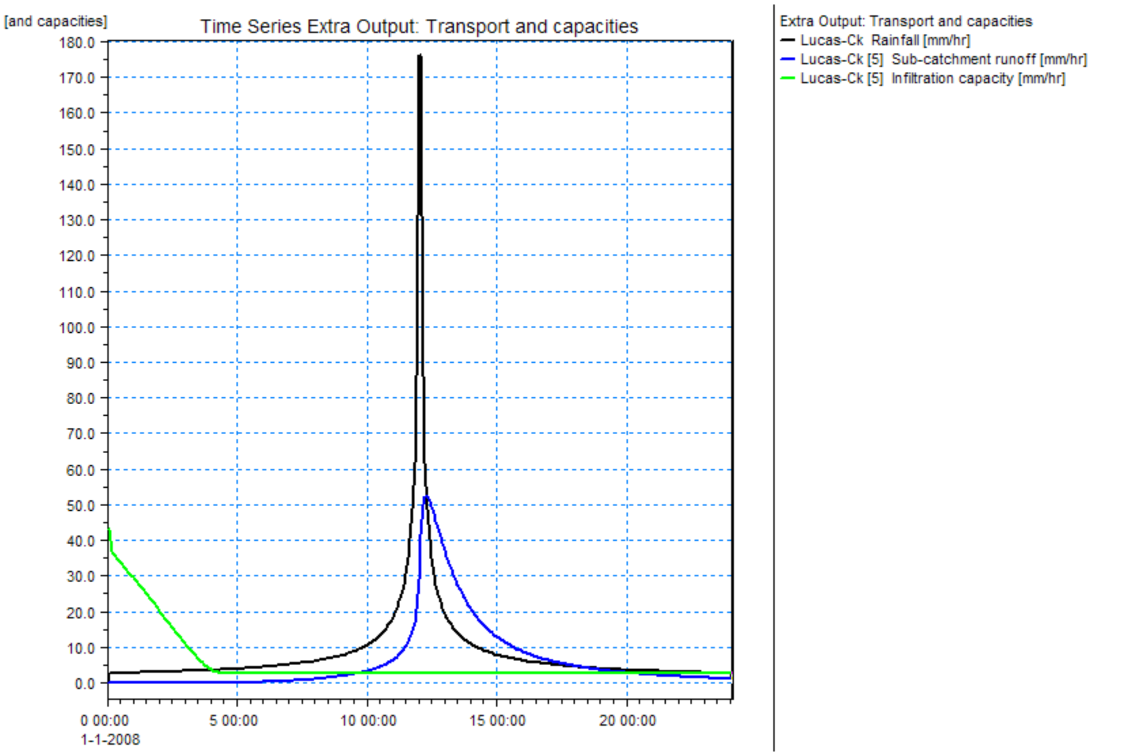


Figure 2-2 Horton Rainfall Losses computed from MOUSE

The rainfall loss rate (shown in the green line) can be seen to steadily decrease from its initial rate of 51mm/hr to the final value of 2.5mm/hr within the first four hours of the event. At the start of the storm this loss rate exceeds the rainfall rate (black line), so that the actual loss is simply the rainfall rate. The integrated Horton approach was used so that accumulated losses were taken into account. The total initial loss amounted to 2.1mm and the total loss during the storm (initial plus continuing) was 63.2mm, compared to a storm depth of 220mm.

For the rainfall on grid, distributed loss model, a rainfall profile was developed based on the revised TP108 (5 minute timestep) profile. The rainfall to be applied to pervious areas had a continuing loss of 2.5mm/hr subtracted, as well as an additional 2.1mm at the start of the storm.

2.2 Rainfall on Grid – Zero Loss Model

The rainfall input to this model was similar to the distributed loss model descried above, except that no losses were removed from the TP108 rainfall profile.

2.3 Source Points, TP108 Runoff Model

GIS tools were used to delineate the maximum number of catchments possible for the Lucas Creek catchment (MIKE 21 allows a maximum of 256 source inflows in the current version). The catchment is approximately 65% pervious with the remaining 35% assumed impervious. A catchment size of 3ha was considered, resulting in 239 sub-catchments.

For each catchment the following parameters were calculated:

- Length
- Slope
- Curve Number
- Area

For the curve number calculation the catchment pervious and impervious areas were assumed as shown on Figure 2-1. The pervious areas are assigned a curve number of 74 and the impervious areas assigned a curve number of 98. From this the average curve number in each sub catchment is calculated. The average curve number for the entire Lucas Creek catchment is 82, the range of curve numbers used in the model was 74 to 96. Note that NSCC have adopted a uniform curve number value of 91 for all catchments assuming maximum probable development. A second source point model was therefore run using an assumed curve number of 91 for all sub-catchments for comparison purposes.

The runoff for each catchment is calculated using the MIKE 11 rainfall runoff module, using the UHM method with the SCS dimensionless hydrograph (TP108 implementation). The time to peak is calculated separately using the following formula.

$$TLag = \frac{2}{3} \times 0.14 \times C \times Length^{0.66} \times \left(\frac{CN}{200 - CN} \right)^{-0.55} \times \left(Slope \right)^{-0.3}$$

Each runoff hydrograph is then applied as a source point in the MIKE 21 model. The model was run for the two hours between the peak of the storm using an initial condition where all depressions are filled with water.

The way in which losses are accounted for in TP108 differs from the Horton approach used in the rainfall on grid models. Figure 2-3 below shows the rainfall input and loss rate calculated by TP108 for the same storm as used in the tests (220mm) and assuming a curve number of 74, comparable to the Lucas Creek pervious areas. Compared to the Hortonian model it can be seen that peak infiltration in this case occurs at the peak of the storm, and falls to almost zero thereafter. Also before the peak occurs the loss rate is seen to be less than the rainfall rate, whereas in a Hortonian approach the loss rate would track the rainfall rate until the infiltration capacity was reached, after which it would decrease.

The total loss occurring during this storm computed by the TP108 method and assuming a curve number of 74 is 63.5mm, almost identical to that computed from the Horton approach (63.2mm). However the net (after losses) peak rainfall intensity is significantly less in the TP108 method: 143 mm/hr compared to the Horton approach where the peak net rainfall rate is 173.5 mm/hr. Based on this it would be expected the peak catchment discharge using the rainfall on grid approach with Horton based losses will be greater than the TP108 source point approach.

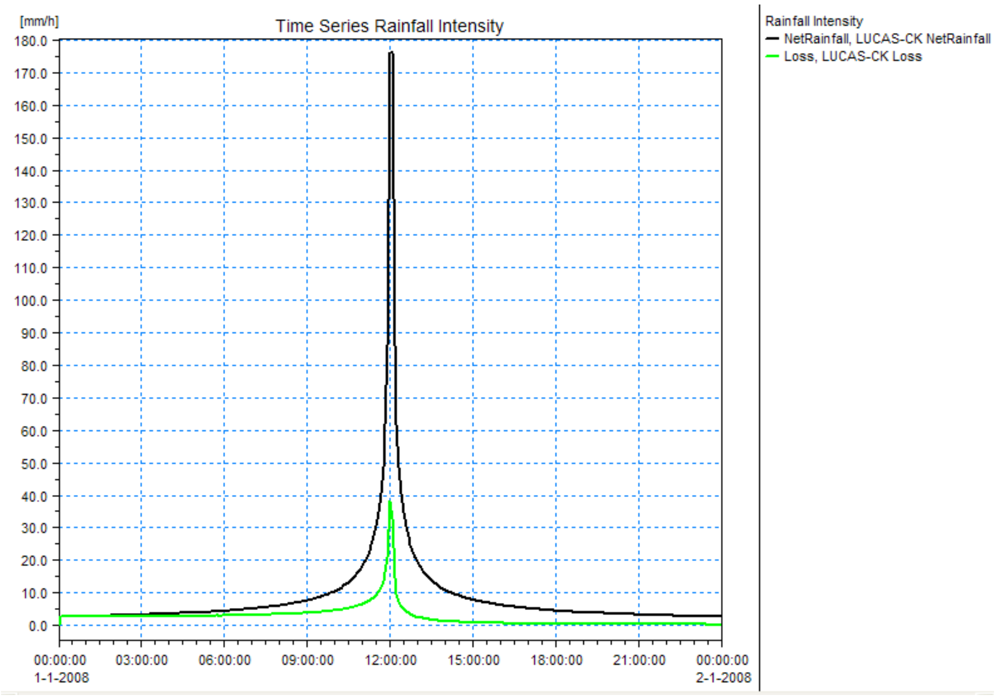


Figure 2-3 Infiltration losses (green line) computed from TP108 for CN=74 and Rainfall = 220mm

2.4 Summary of Model Setups

Table 2-1 summarises the different model setups investigated. The results are reported in the next section.

Table 2-1 Summary of Model setups

Model No.	Model type	Main parameters
1	Rainfall on grid	2.1mm initial loss, 2.5mm/hour continuing loss on pervious grid cells, zero loss on impervious grid cells
2	Rainfall on grid	Zero uniform rainfall loss
3	Source points, TP108 runoff	Varying curve number in sub-catchments
4	Source points, TP108 runoff	Uniform curve number=91 in all sub-catchments

3 RESULTS

The results of the rainfall on grid model with distributed rainfall losses were compared to the same model assuming zero uniform losses as well as the source point, TP108 runoff model. Figure 3-1 compares the discharge at the catchment outlet. As expected the rainfall on grid models generate higher peak runoff compared to the source point, TP108 runoff approach due to the higher net rainfall intensity.

The difference between two rainfall on grid models (distributed and zero loss) is small, with the peak discharge for the zero loss (totally impervious) catchment 5% higher than the distributed loss model. The reason for the small difference between the two rainfall on grid models is that the losses around the peak flow only differ by the value of the assumed continuing loss rate, in this case 2.5mm/hr, compared to the rainfall intensity at this time of around 176mm/hr.

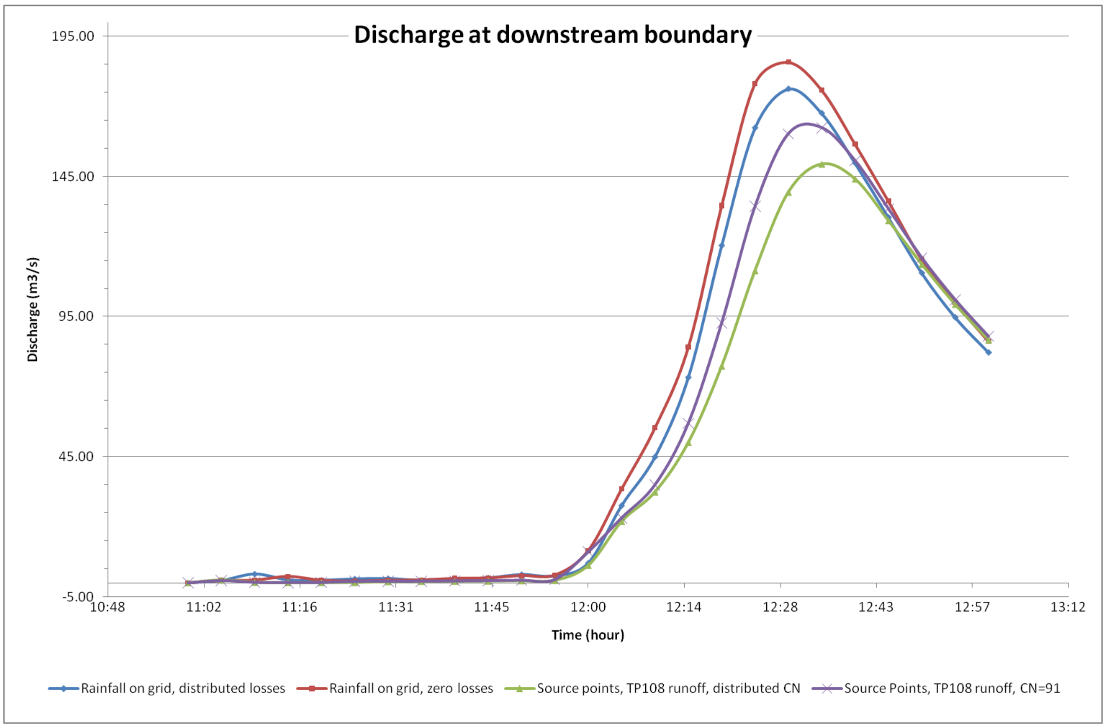


Figure 3-1: Discharge hydrograph at downstream boundary

The maximum flood depths and extents plots can be found in the drawings section at the end of this report. Difference plots between all three simulations are also presented. These indicate that the change in flood depths and extent between the two rainfall on grid approaches is minimal (less than 15cm) and in this case confined mainly to the Lucas Creek channel itself. Comparing the rainfall on grid simulations to the source point, TP108 runoff (distributed curve number) approach, it can be seen the maximum difference in water levels obtained is generally of the order of 5-15cm (higher) for the rainfall on grid, distributed loss model and up to 25cm higher for the rainfall in grid, zero loss model approach. Some deeper pockets of differences occur where the channel is confined.

The peak runoff for the source point, TP108 runoff model assuming a uniform curve number of 91 (as assumed by NSCC) lies closer to the rainfall on grid peak flow values; within 8% of the distributed loss and 13% of the zero loss values.

4 CONCLUSIONS

This sensitivity analysis has been undertaken to assess the effect of differing assumptions regarding land use and imperviousness on a Rapid Flood Hazard Modelling assessment being undertaken for the ARC. The ARC assessments are being undertaken using a rainfall on grid approach. The tests have quantified the potential effects on flood extent and levels in the rainfall on grid approach by applying spatially varying rainfall losses compared to a uniform zero loss approach. The results were compared to an alternative RFHM approach adopted by NSCC in which a TP108 rainfall runoff model is used to generate the catchment hydrographs as source point inflows.

The model results indicate that:

- There is little difference in the rainfall on grid models between applying a fully distributed loss model compared to applying a uniform loss model. A zero uniform loss was applied which has exaggerated any differences. As the simulated differences are minor the conclusion is that little is to be gained by applying distributed losses, considering the other uncertainties involved in the flood mapping process.

- The rainfall on grid approach generates higher water levels compared to the source point, TP108 runoff approach. Two source point, TP108 runoff models were run; one with different curve numbers in each sub-catchment depending on local land use and the other using a uniform curve number of 91 (as used by NSCC). The rainfall on grid models produce higher peak runoff than the source point, TP108 runoff models because the latter method focuses on the peak of the TP108 storm where the rainfall losses computed using TP108 generally reach a maximum. This compares to a more traditional Horton loss model applied in the rainfall on grid models where the losses at the peak of the storm would generally have reached a steady but lower value.

Considering the nature of the assessments being undertaken for the ARC RFHM study, it is recommended that a uniform loss approach is adopted. The assumption of uniform impervious areas is probably too conservative and therefore a pragmatic value for losses should be adopted. Although the Horton loss rates applied in this study relate to pervious land uses, similar values those used this study could conceivably be adopted region wide.

The justification is that the results may align more closely with the source point, TP108 runoff approach used by NSCC. In the NSCC approach a uniform curve number of 91 has been applied for all catchments, and the models are generally run one hour each side of the peak. The computed TP108 infiltration rates around this period are shown in Figure 4-1. The average rate between 11.00-13:00 hours is just under 2mm/hr, based on a 220mm rainfall depth. Throughout the region 24 hour rainfall depths vary from 130 -310mm. The spatial variability of rainfall depths will be taken into account in the RFHM assessments. Based on the findings of this analysis it is recommended a uniform loss of 2.0-2.5mm/hr is adopted for use.

The ARC flood hazard models will be run from 6 hours before the peak of the storm until such time after that a maximum flood level has been reached across the catchment. Initial losses will therefore occur primarily in the 6 hours before the start of the simulation.

Taking into account the lowest 24 hour rainfall depth in the region of 150mm, the accumulated rainfall at 6 hours after the start of the storm (ie coinciding with the start of the flood hazard mapping simulations) is 13.7mm. Therefore initial losses up to this value can be assumed to have occurred (as a minimum) in the ARC flood mapping models.

Note that comparable studies in Australia have assumed initial and continuing losses of 10mm and 2.5mm/hr respectively. The results of these studies have been closely compared to and validated against more detailed flood hazard mapping techniques.

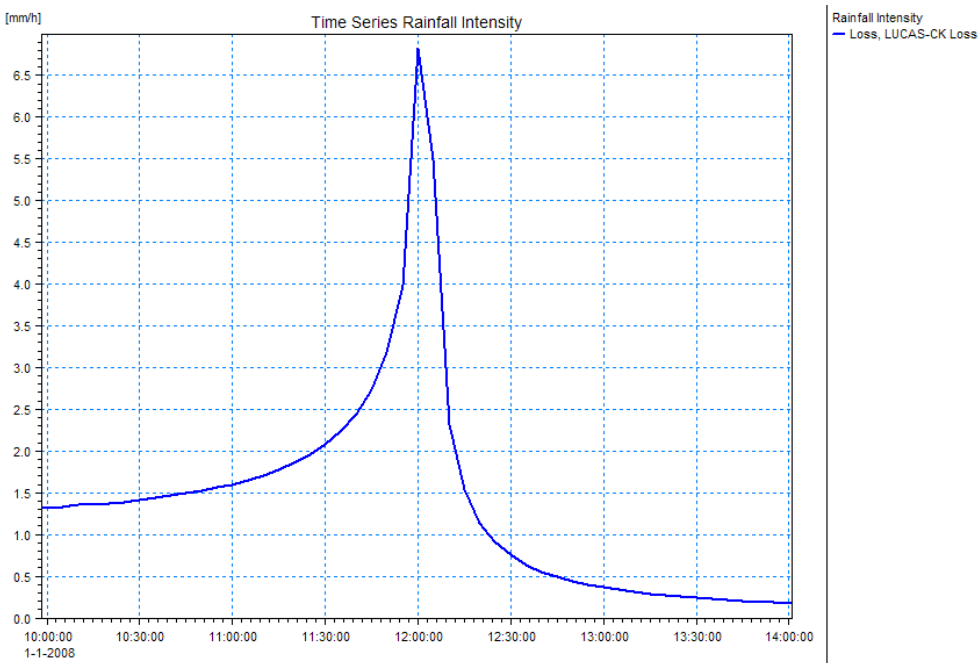
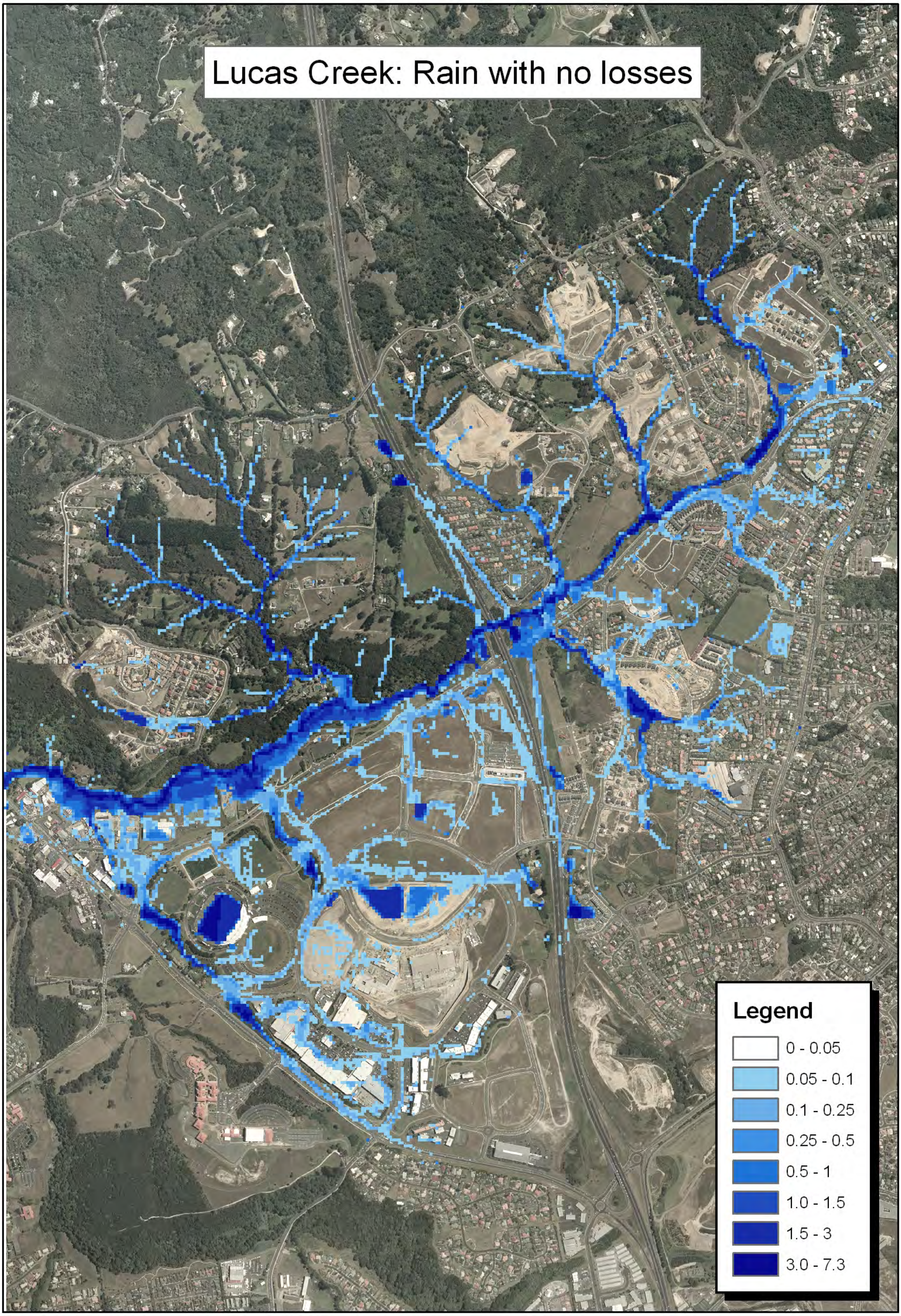
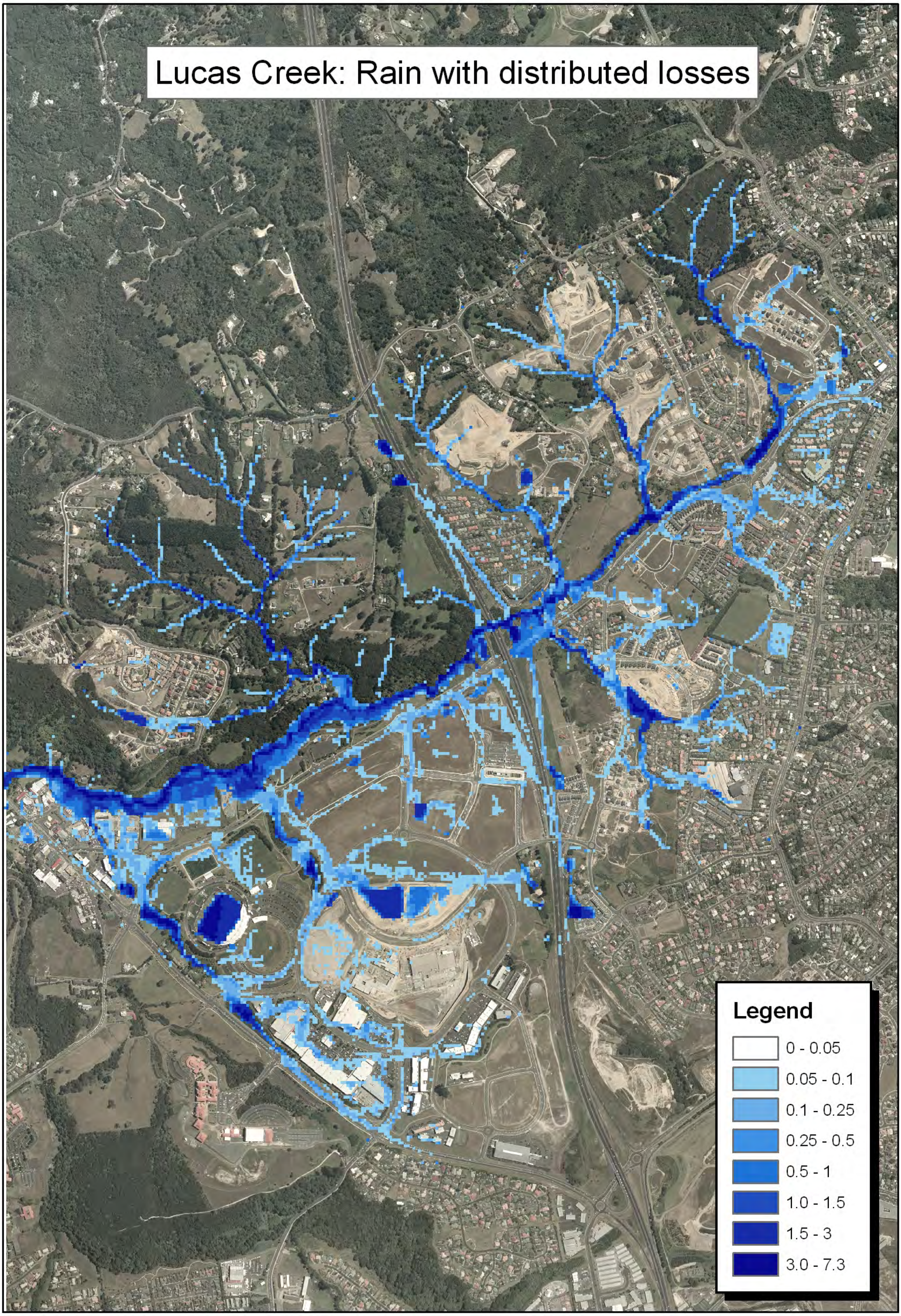
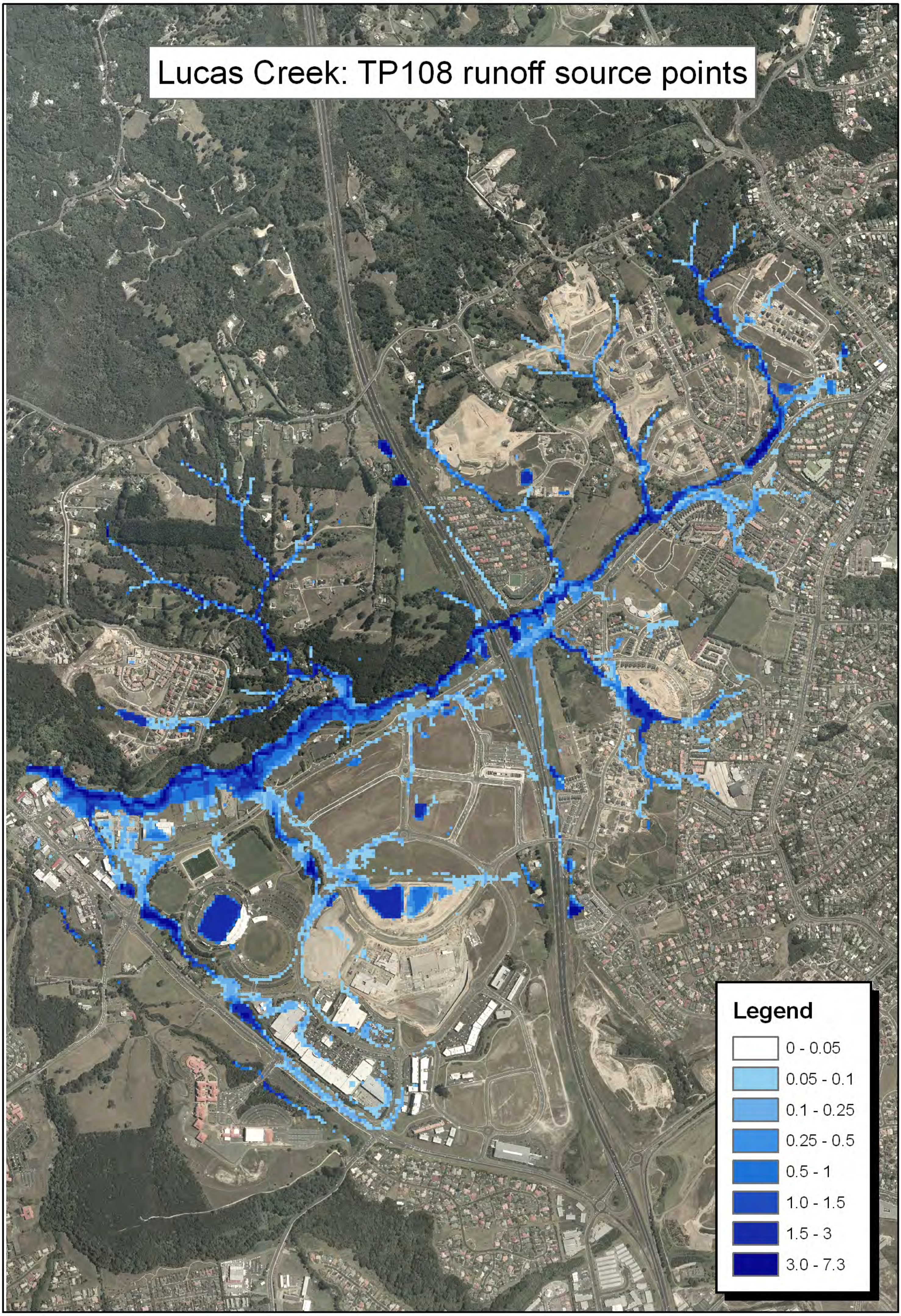


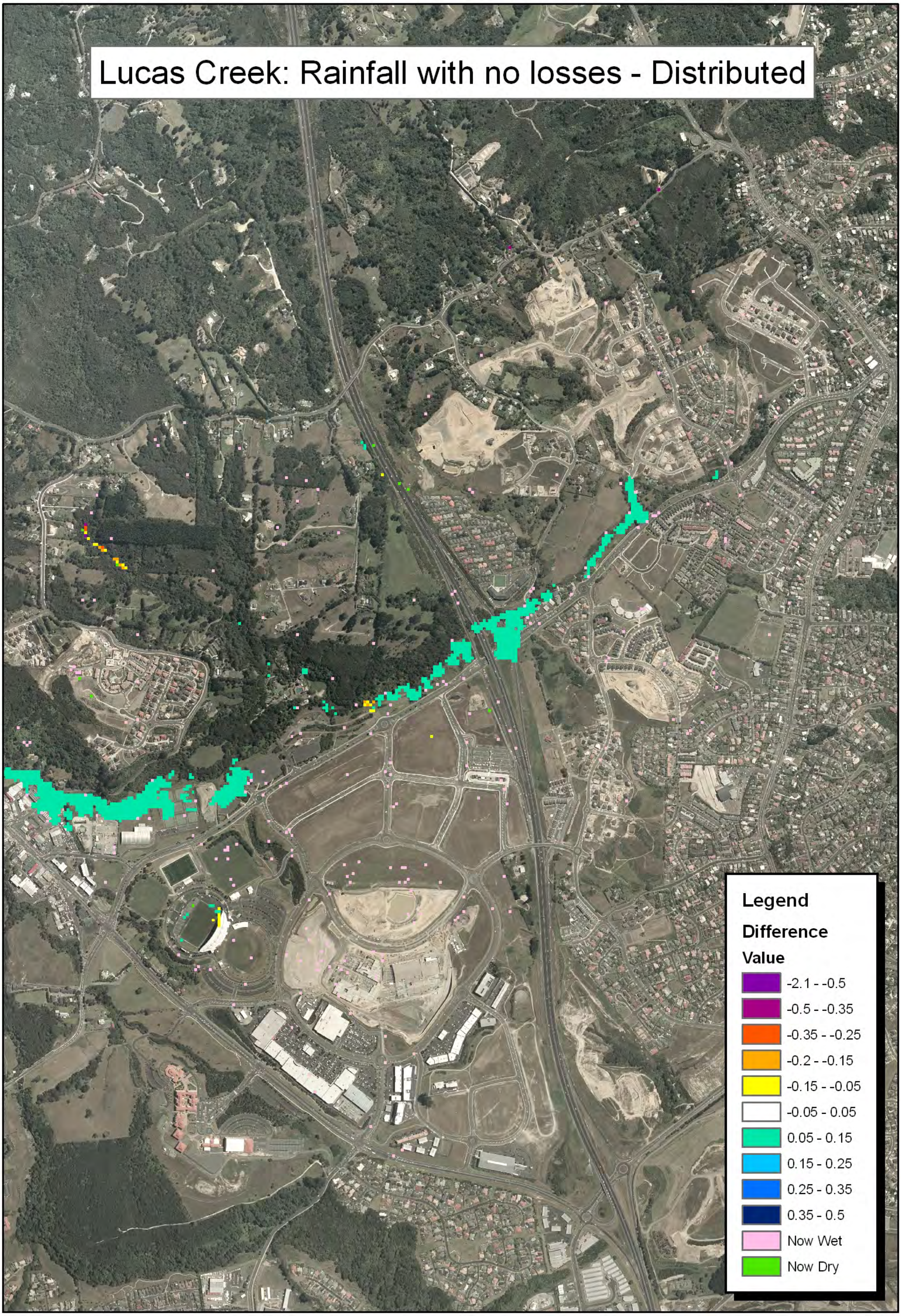
Figure 4-1 TP108 based infiltration rate for 220mm storm depth and CN-91

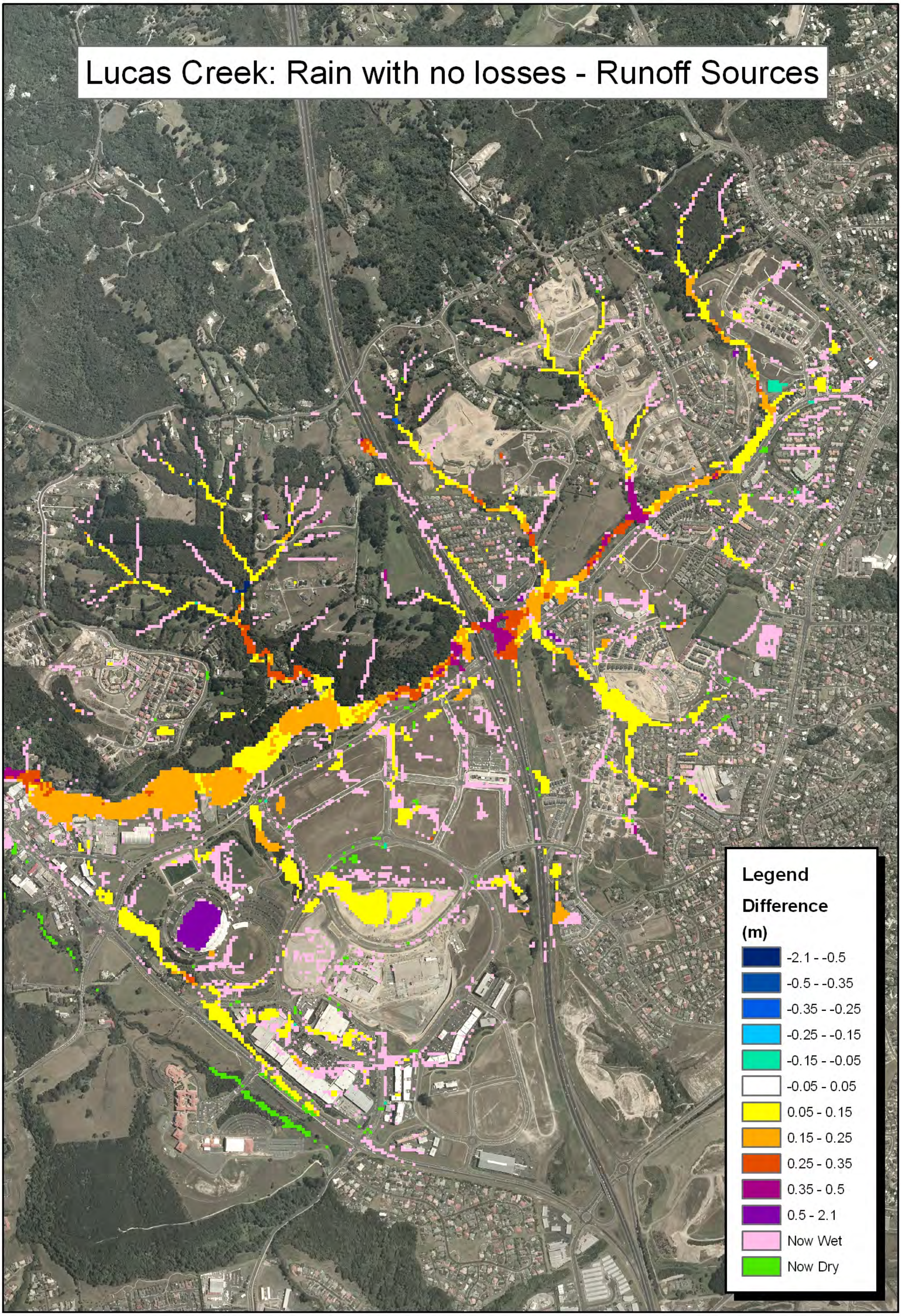
D R A W I N G S

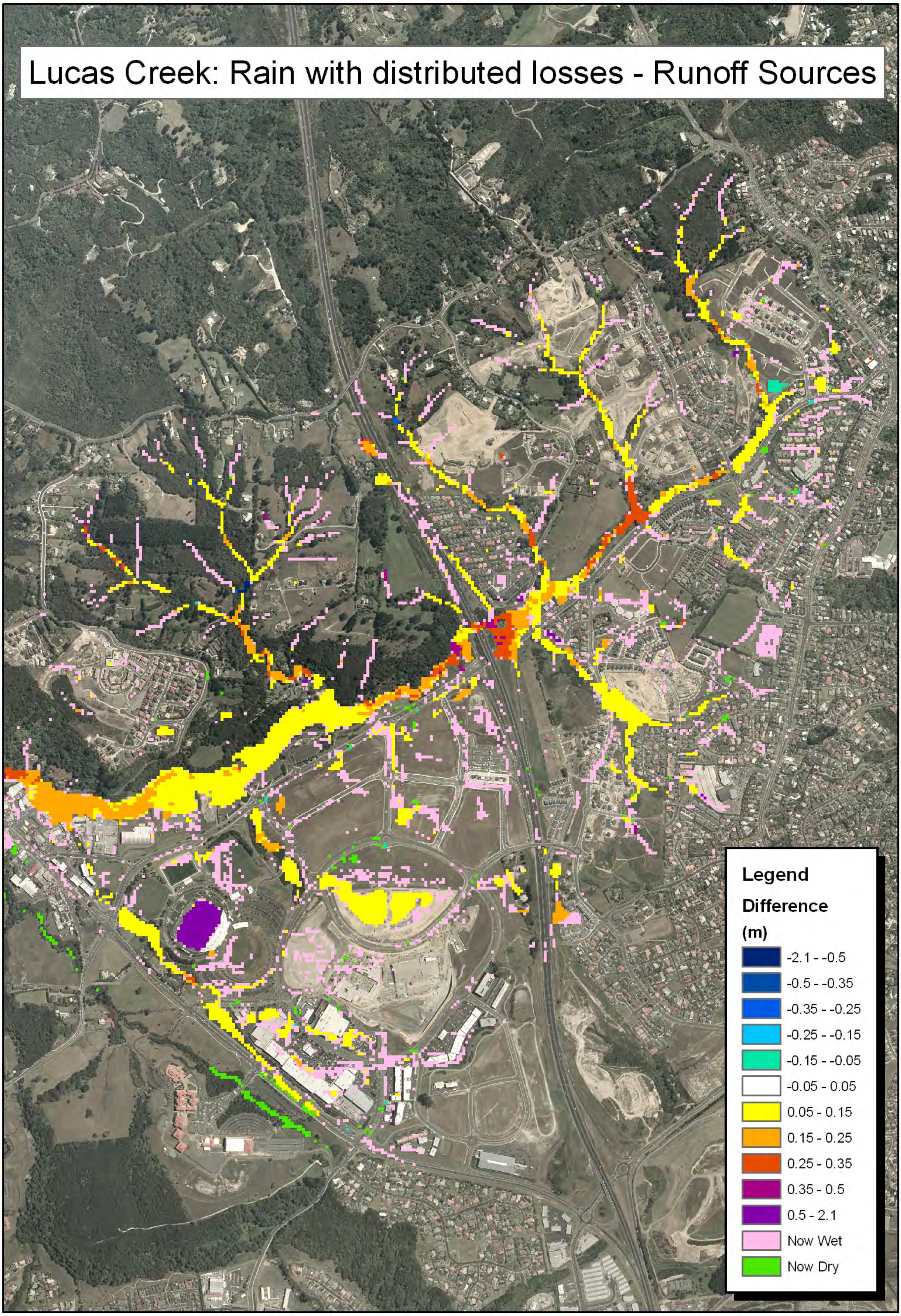

Lucas Creek: Rain with no losses
Legend
0 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1.0 - 1.5
1.5 - 3
3.0 - 7.3


Lucas Creek: Rain with distributed losses
Legend
0 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1.0 - 1.5
1.5 - 3
3.0 - 7.3


Lucas Creek: TP108 runoff source points
Legend
0 - 0.05
0.05 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1.0 - 1.5
1.5 - 3
3.0 - 7.3


Lucas Creek: Rainfall with no losses - Distributed
Legend
Difference
Value
-2.1 - -0.5
-0.5 - -0.35
-0.35 - -0.25
-0.2 - -0.15
-0.15 - -0.05
-0.05 - 0.05
0.05 - 0.15
0.15 - 0.25
0.25 - 0.35
0.35 - 0.5
Now Wet
Now Dry


Lucas Creek: Rain with no losses - Runoff Sources
Legend
Difference
(m)
-2.1 - -0.5
-0.5 - -0.35
-0.35 - -0.25
-0.25 - -0.15
-0.15 - -0.05
-0.05 - 0.05
0.05 - 0.15
0.15 - 0.25
0.25 - 0.35
0.35 - 0.5
0.5 - 2.1
Now Wet
Now Dry


Lucas Creek: Rain with distributed losses - Runoff Sources
Legend
Difference
(m)
-2.1 - -0.5
-0.5 - -0.35
-0.35 - -0.25
-0.25 - -0.15
-0.15 - -0.05
-0.05 - 0.05
0.05 - 0.15
0.15 - 0.25
0.25 - 0.35
0.35 - 0.5
0.5 - 2.1
Now Wet
Now Dry