Regional Policy Statement Modelling for Selwyn District Council - District Plan

Selwyn District Council

Report

November 2019

The expert in **WATER ENVIRONMENTS**

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Regional Policy Statement Modelling for Selwyn District Council - District Plan

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CONTENTS

1 Introduction

1.1 Background

The aim of this project is to provide district wide flood hazard mapping for the Selwyn District. The Selwyn District area is bounded in the North East by the Waimakariri River and in the South West by the Rakaia River, foothills to the north set the boundary between Selwyn and the Hurunui district, and the District is bound by Christchurch City, Te Waihora/Lake Ellesmere and the coast to the South. Environment Canterbury (ECAN) are also a stakeholder in the project and have been involved at key stages.

1.2 Project Scope

The scope of the project comprises of the building of a flood hazard model that can simulate overland flooding from rainfall events at a suitable resolution for SDC's purposes. The following is required by SDC.

- The 0.5% and 0.2 % AEP design rainfall events should be modelled
- Selwyn river stopbanks should be represented in the model
- Hydrological loss factors should be agreed with the client
- Design rainfall events should have an allowance for climate change incorporated
- Suitable validation processes should be considered
- Limitations of use of the results and any possible future enhancements/refinements should be described.
- Deliverables should include raster files in a geodatabase
- A report should be produced outlining the methodology used, assumptions, limitations and recommendations.

2 Data

2.1 Ground levels

A number of different ground level datasets were combined together to create the master terrain used in the modelling. These datasets were given different priority to allow for the most accurate data to be used where available. The data and the priority are listed below, where 1 is the highest priority. The data coverage is shown in Figure 2-1. All data was provided and processed in the NZGD 2000 New Zealand Transverse Mercator projection.

1. LiDAR survey 2018
2. LiDAR survey 2016-2017
3. LiDAR survey 2015-2016
4. LiDAR survey March 2011
5. LiDAR survey September 2010

Datasets 1-5 were sourced from ECAN.

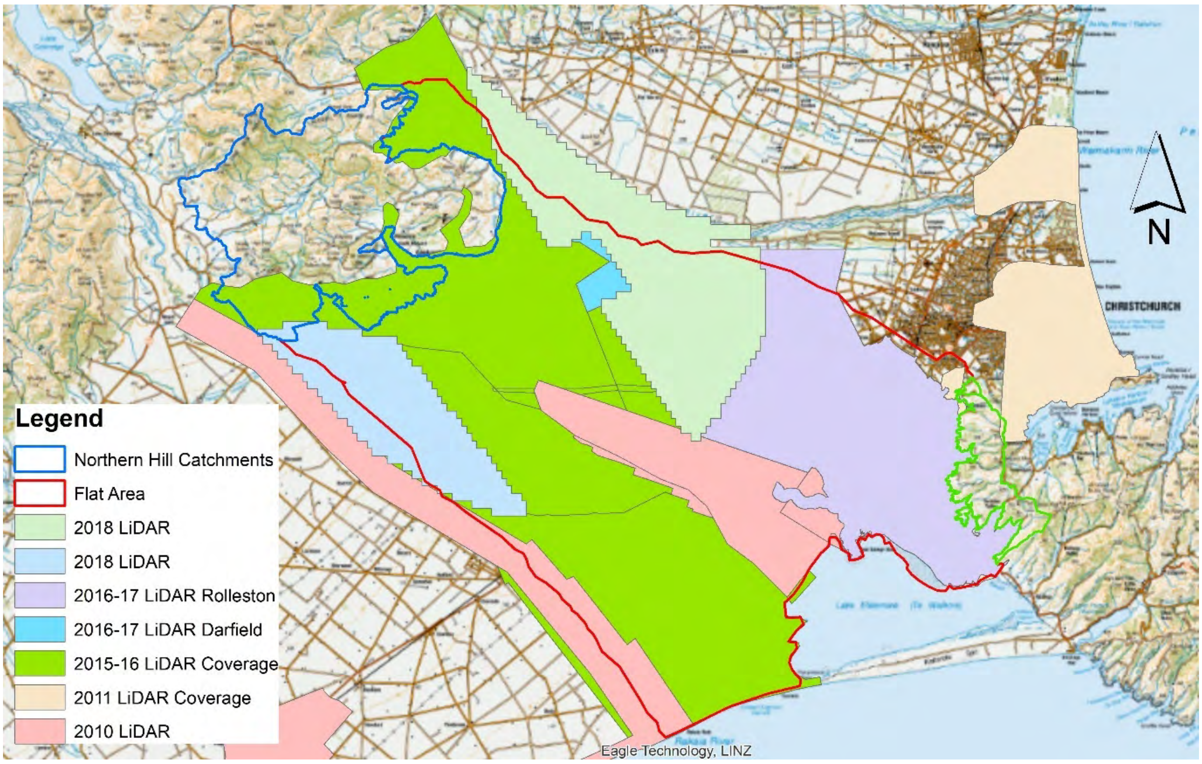


Figure 2-1 - Ground Level Data Coverage

2.2 Shapefile data

The following shapefile data was used in the project:

- Shapefile of the “Stormwater Lims and Pims” information showing the areas within the district where houses drain to ground.
- Building footprint data, shapefile from SDC
- Shapefiles of indicative flood extents, from SDC
- Shapefile of Selwyn model stopbanks from ECAN
- Shapefile of the LCDB 4.1 dataset from Landcare Research
- Shapefile of the s-map soil drainage layer, September 2016 release, from Landcare Research
- Shapefile of infiltration area to be modified, which is discussed in Section 3.2.4
- Shapefiles of river, road centrelines from the 1500k Land Information New Zealand (LINZ) topo dataset

2.3 Design Rainfall

Design rainfall data were taken from the NIWA HIRDS v.4 data series. Gridded rainfall intensity and depth data were downloaded from the NIWA website.

NIWA (2018) describe HIRDS v.4 as a *“set of tables containing either rainfall depths or rainfall intensities for given storm durations and recurrence intervals (ARI). The tables also provide the annual exceedance probability (AEP) which is the probability of a given rainfall being exceeded in any one year.”*

HIRDS v.4 has gridded data for the entire country at a national scale for the following recurrence intervals: 1.58, 2, 5, 10, 30 ,30, 40, 50, 60, 80, 100 and 250 years. Storm rainfall depth data are available for 10m, 20m, 30m, 1h, 2h, 6h, 12h, 24h, 48h, 72h, 96h and 120h events.

HIRDS v.4 has climate change scenarios built in. These are based on the 4 scenarios from IPCC 5th Assessment 2nd Edition, which are known as representative concentration pathways (RCPs), 2.6, 4.5, 6.0 and 8.5. From discussion with SDC it was decided to use two of these scenarios for this study, RCP 4.5 and RCP 8.5, for each AEP event.

2.4 Validation Data

Aerial photographs of previous flood events are available from the Flood imagery register at https://apps.canterburymaps.govt.nz/FIR. The site shows photos taken in various flood events.

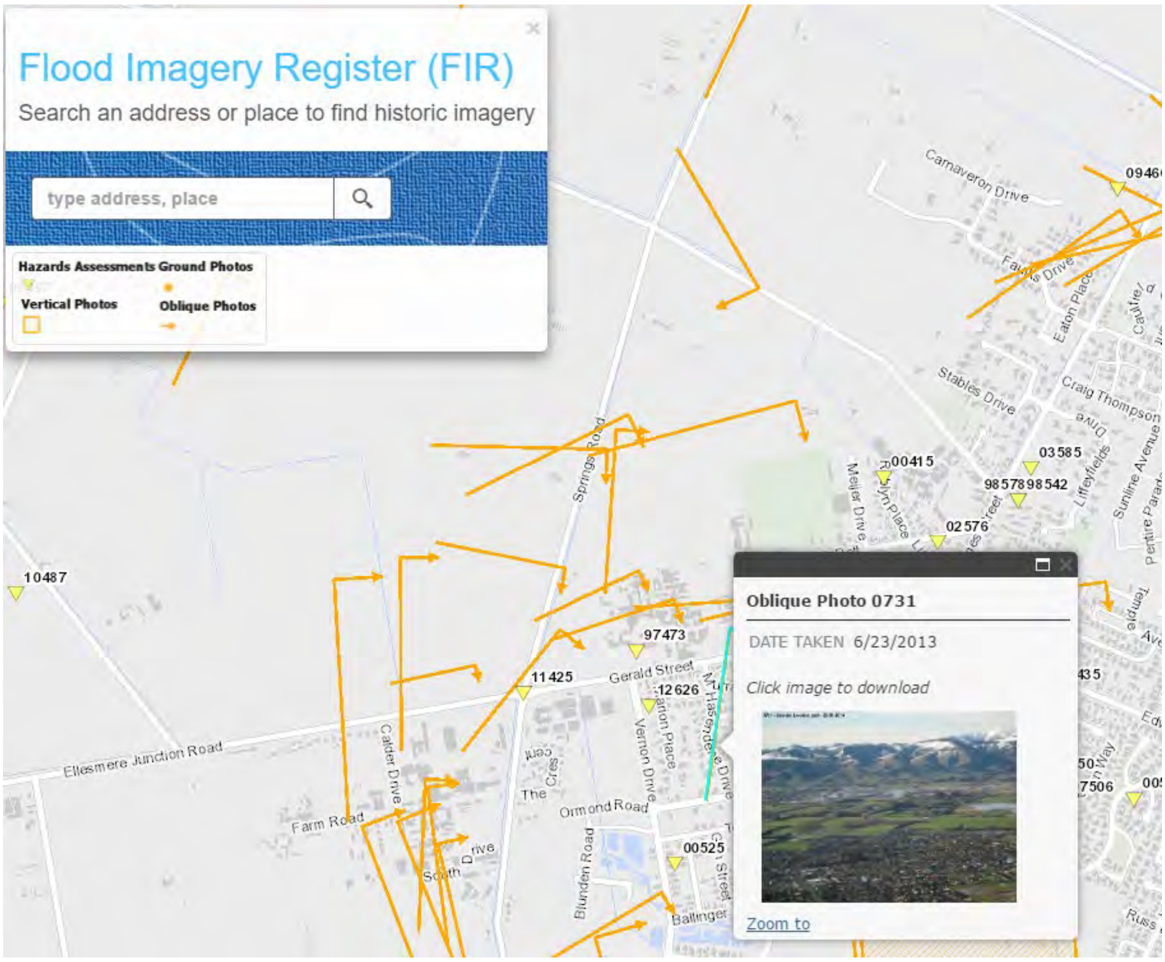


Figure 2-2 - Flood Imagery Register

Geo-referenced flood photos were also provided for the July 2017 event.

3 Model Build

3.1 Schematisation

The Selwyn District was separated into rainfall runoff models that represent the hilly areas and one MIKE 21 model to represent the flat area. Figure 3-1 shows the layout of these components. The rainfall runoff models in the North, and East hilly areas are modelled in MIKE 11 using the Urban B – Kinematic Wave runoff formulation. This rainfall runoff models represent a total of 31 sub-catchments. The resulting runoff from these models is incorporated into the 2D model as source point flows.

The MIKE 21 model uses a 10x10m quadrilateral grid with the model out-falling into Te Waihora/Lake Ellesmere having a water level boundary, and the ocean having a coastal boundary.

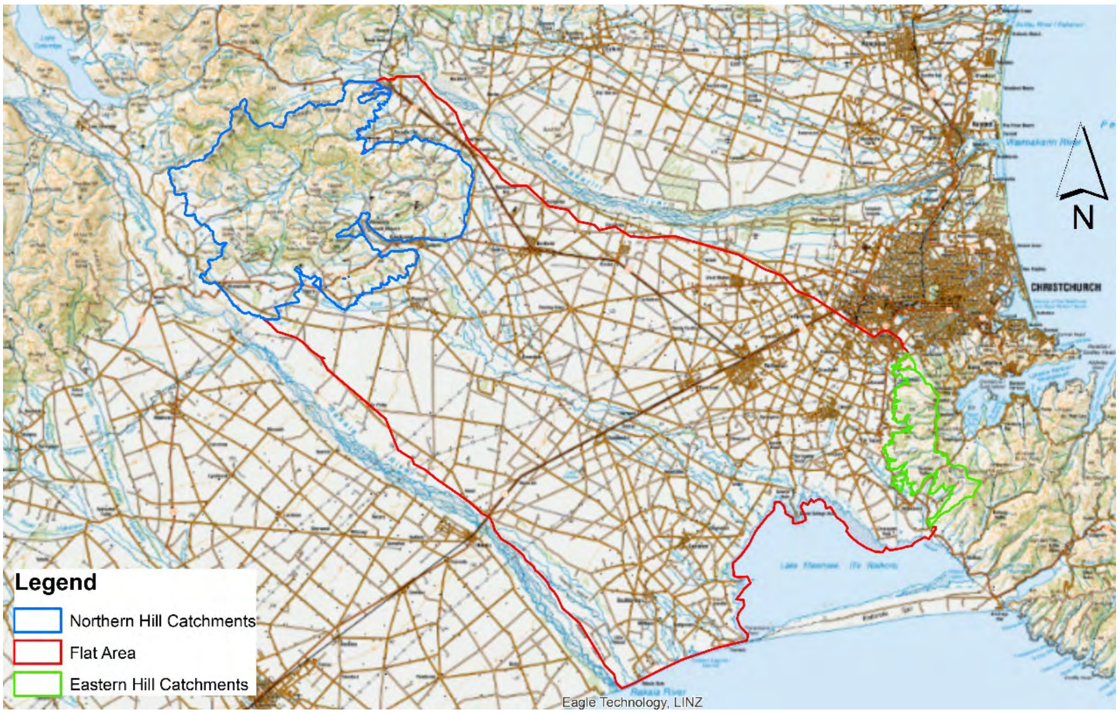


Figure 3-1 - Model and Catchment Layout

3.2 Hydrology

3.2.1 Catchment Delineation

Catchments were delineated for the study area using GIS hydrology tools. The delineation surface was derived from the LiDAR and contour data. The delineated catchments were lumped together to simplify the number of inputs into the MIKE 21 model and the number of MIKE 11 rainfall runoff sub-catchment models.

3.2.2 Rainfall Runoff Model

The rainfall runoff catchments were modelled using MIKE 11 Urban B (Kinematic Wave). The impervious area for all catchments was set to 1%, reflecting the rural land use. The length and slope were calculated from the underlying terrain, which for the most part came from the LINZ 8m DEM. Catchment parameters are shown in Table 3-1. Soil data was not available for the entire rainfall runoff model catchment area, so it was necessary to make some estimates on the soil type in this area. Imperfect drainage rates were used for the foothill catchments, and poor drainage rates used for the port hills catchments. See section 3.2.4 for more information on the infiltration rates used for each soil type.

Table 3-1 - Rainfall Runoff Catchment Parameters

Catchment	Purpose	Area (Km^2)	Length (Km)	Slope (per 1000m)	Infiltration type
E_1	Inflow to East	9.58	3.66	146	Poor
E_1a	Inflow to East	1.99	1.85	111	Poor
E_10	Inflow to East	2.54	2.10	133	Poor
E_11	Inflow to East	7.72	3.05	148	Poor
E_12	Inflow to East	0.74	0.76	46	Poor
E_13	Inflow to East	11.52	4.03	133	Poor
E_2	Inflow to East	4.12	2.18	161	Poor
E_3	Inflow to East	5.96	3.20	164	Poor
E_4	Inflow to East	8.29	3.35	167	Poor
E_5	Inflow to East	2.91	2.35	115	Poor
E_6	Inflow to East	3.12	3.40	112	Poor
E_7	Inflow to East	4.46	3.74	135	Poor
E_8	Inflow to East	2.16	3.60	126	Poor
E_9	Inflow to East	0.61	0.68	51	Poor
N_C	Inflow to North	32.65	9.86	61	Imperfect
N_CE	Inflow to North	2.21	2.94	116	Imperfect

Catchment	Purpose	Area (Km^2)	Length (Km)	Slope (per 1000m)	Infiltration type
N_CES	Inflow to North	3.66	3.76	97	Imperfect
N_CS	Inflow to North	28.09	11.37	41	Imperfect
N_E_1	Inflow to North	12.06	3.55	103	Imperfect
N_E_2	Inflow to North	6.18	2.35	115	Imperfect
N_ES	Inflow to North	76.05	17.70	29	Imperfect
N_NE_1	Inflow to North	37.82	9.82	57	Imperfect
N_NE_2	Inflow to North	2.10	4.02	84	Imperfect
N_NE_3	Inflow to North	7.21	6.35	67	Imperfect
N_SE_1	Inflow to North	6.75	3.14	75	Imperfect
N_SE_2	Inflow to North	11.80	3.50	55	Imperfect
N_SE_3	Inflow to North	5.68	4.27	55	Imperfect
N_SSW_1	Inflow to North	42.47	11.50	69	Imperfect
N_SSW_2	Inflow to North	25.33	8.55	68	Imperfect
N_W	Inflow to North	150.55	33.15	41	Imperfect
N_W_S	Inflow to North	5.94	3.28	46	Imperfect

3.2.3 Design Rainfall

The design rainfall depths to use for the district were generated from the national scale NIWA HIRDS v.4 gridded data sets. SDC required two 72 hour design storm ARI events to be modelled, 200 year and 500 year respectively. Neither of these recurrence intervals are available from HIRDS v4.

To create the design events, the HIRDS v4 data was interpolated and extrapolated in Gumble Space to generate the required recurrence interval equations. Once the appropriate equations had been generated, they were applied to the gridded datasets using raster maths to generate the storm duration depths under RCP climate change scenarios 4.5 and 8.5.

Following generation of the gridded rainfall depths, a Chicago nested storm event was created for each ARI storm. Chicago nested storms are commonly used in New Zealand due to the absence of historical records. In simple terms the approach is a method of creating an artificial hyetograph featuring nested storms of the rainfall intensities from the shorter duration events that may occur within the total storm duration event, in this case 72 hours.

For the 2D model the rainfall was spatially distributed as time varying rain-on-grid across the model domain. For each of the rainfall runoff catchments, the average weighted depth of rainfall within their respective catchments was used to generate the total rainfall depth. A Chicago nested design storm hyetograph was then generated for each catchment and applied to the rainfall-runoff model.

3.2.4 Infiltration

Infiltration was represented in the MIKE 21 FM infiltration module as a 10x10 metre 2-Dimensional (2D) grid. The spatial variation of infiltration rates was derived from the LRIS s-map (soil drainage) release September 2016. As buildings and roads are not included in the s-map it was necessary to add in the road and building footprint data separately. The road data was incorporated into the infiltration map by applying a 10 metre buffer to the 1:50,000 road centreline data from LINZ. The building footprint data was incorporated using the building polygons provided by SDC in combination with the discharge information recorded on the Council LIMS and PIMS database. Where buildings are in soakage areas these have been assigned an infiltration rate based on a 10% AEP rainfall intensity from the OPUS 2009, Development of Design Rainfall for Selwyn District. This allows the 10% rainfall to be removed from the runoff while any rainfall above this will accumulate in the model. For all other areas a time varying infiltration rate was used based on the Horton's decay curve, Table 3-2 details the different soil types and corresponding infiltration rates use in the model.

Table 3-2 - Infiltration Categories

Drainage type	Start Infiltration (mm/hr)	End Infiltration (mm/hr)	Horton's Exponent
Well drained	18.65	5.65	$5.8e^{-5}$
Moderately well drained	6.25	1.85	$6.5e^{-5}$
Imperfectly drained	2.5	0.75	$7.1e^{-5}$
Poorly drained	1.25	0.4	$8.2e^{-5}$
Very poorly drained	0.4	0.1	$1.2e^{-4}$
Roads	0 (impervious)		
Buildings in soakage areas	10% AEP rainfall intensity		

3.3 Hydraulics

3.3.1 Model Grid

The model terrain comprises a number of datasets as described in Section 2 of this report. These were processed and merged together to create an overall Master Terrain of the Selwyn District. Smoothing along the different LiDAR dataset boundaries were also carried out to ensure a good quality Master Terrain, from which the 2D surface consisting of a 10x10m quadrilateral grid was derived.

The grid was not modified to allow for: flow though culverts under major roads or the high overflow point of roads and the railway line.

3.3.2 Simulation Parameters

The following simulation parameters were used in the model:

- Eddy Viscosity; constant formulation, value of 0.5m^2/s
- Wetting, flooding and drying values of 0.01, 0.007, 0.003 m were used, and the advanced flooding and drying methodology was used.
- Timestep, maximum 2 seconds, minimum 0.1 seconds.
- Results saved every 15 minutes.
- Depth correction was applied to the grid, to ensure better accuracy of ground levels.
- Low order time and space calculations were used
- MIKE 2017 Service Pack 2 software was used for the modelling.

3.3.3 Roughness

The surface resistance to overland flow is made up of many forms of friction loss. The resistance is represented by a Manning's friction loss defined at a 10x10m resolution. The spatial variation is derived from the LCDB v4.1 land cover database from Landcare Research. Roads are not included in the LCDB but were added based on road centreline data from LINZ and the use of a fixed width buffer. Table 3-3 details the different land uses and corresponding Manning's roughness, based on experience and generally accepted values.

Table 3-3 - Roughness Values

Description on LCDB2	Landuse type	Manning's M
Alpine Grass/Herbfield, Depleted Grassland, High Producing Exotic Grassland, Low Producing Grassland, Urban Parkland/Open Space	Grassland and open spaces	20
Broadleaved Indigenous Hardwoods, Deciduous Hardwoods, Exotic Forest, Fernland, Flaxland, Forest – Harvested, Gorse and/or Broom, Herbaceous Freshwater/Saline Vegetation, Indigenous Forest, Manuka and/or Kanuka, Matagouri or Grey Scrub, Orchard, Vineyard or Other Perennial Crop, Short-rotation Cropland	Crops, shelterbelts and other vegetation	8
Built-up Area (settlement), Transport Infrastructure	Built-up area	12
Estuarine Open Water, Lake or Pond, River	Waterbodies	32
Gravel or Rock, Landslide, Surface Mine or Dump	Gravel and wasteland	25

3.3.4 Boundaries

The 2D rainfall was spatially distributed and applied directly to the rainfall grid. Where rainfall runoff catchments enter the 2D model area the pre calculated runoff from these catchments was applied as source points in the 2D model. Figure 3-2 and Figure 3-3 show the Northern and Eastern Hill sub-catchments

Te Waihora/Lake Ellesmere and the coast to the South act as the downstream boundaries for the model. A water level time series is applied for Te Waihora/Lake Ellesmere starting at RL 1.1m and increasing to RL 1.8m over a 36 hour period, as recommended by Environment Canterbury. A constant water level of RL 0.67m and RL 1.06 m is applied at the coastal downstream end of the model for the RCP4.5 and RCP8.5 scenarios respectively, as per Ministry for the Environment guidance. These levels account for sea level rise out to 2120.

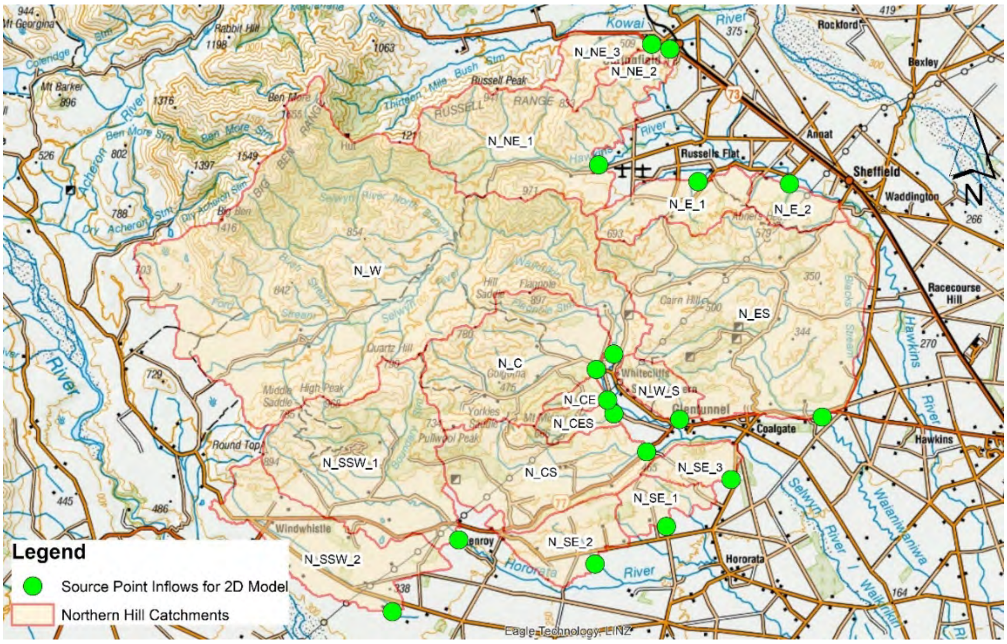


Figure 3-2 – Northern Hill Sub-Catchments

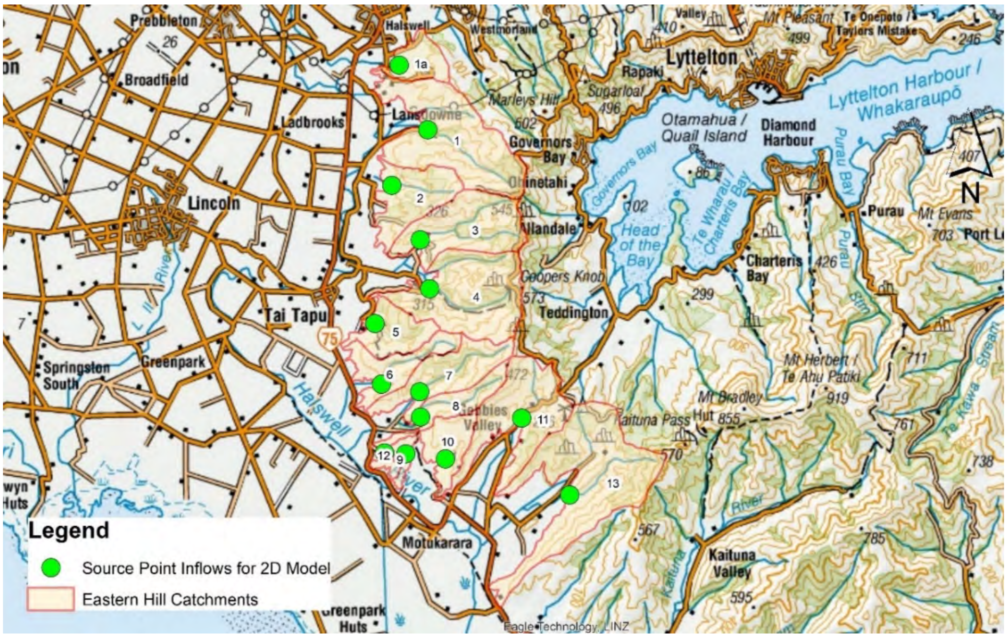


Figure 3-3 – Eastern Hill Sub-Catchments

4 Validation

The July 2017 event was used as a validation event for the model. This stage of the project was carried out in close collaboration with ECAN.

The first stage was to focus on the flooding in the flat section of the catchment. This aspect of the validation related directly to the rain on mesh approach, and the associated infiltration losses applied, in order to achieve enough runoff compared to observed. From initial simulations, overall, there was insufficient runoff from the previously "validated' infiltration rates used for SDC study modelling the 10% and 2% AEP design rainfall events. All infiltration rates were then halved which produced a more realistic amount of runoff compared to what was observed during the July 2017 event.

After several further iterations it was agreed that some changes needed to be made to the S-Map derived infiltration in river beds and below State Highway One. ECAN provided a map as shown in Figure 4-1. Infiltration in these areas was reduced to represent poorly drained soils because of the potentially shallow depth to groundwater.

Figure 4-1 – Area to change infiltration

The second stage of the validation investigated the runoff from the Northern Hill sub-catchments. Some of the Model B, rainfall runoff parameters needed fine tuning to achieve a better result at the recorder site at Whitecliffs.

As a final overall check, discharges were extracted at 17 locations across the model domain looking at peak flows, timing and flood volumes. Appendix A shows the locations investigated, with the associated peak flows and time to peak.

After a considerable effort to improve the model performance ECAN agree (email 31 Oct 2019) that the model is suitably validated and can be used to make flood hazard related predictions.

5 Model Results

The model has been run for the 0.5% and 0.2% AEP design rainfall events. The deliverables for this study are rasters supplied in an ArcGIS database. Maximum depth, velocity and water level have been processed for each of the four design simulations. The July 2017 validation event results have not been included. The maximum depth and hazard (velocity x depth) have also been processed into ArcGIS grid format for the 0.2% AEP events and is also provided as a deliverable in an ArcGIS database.

The naming convention for the rasters supplied in the ARCGIS database is:

- SD – Selwyn District
- 200 or 500 – 0.5% or 0.2% AEP design rainfall events
- 4p5 or 8p5 – RCP climate change scenario
- SE, WD or HZ – Surface Elevation or Water Level, Water Depth or Hazard

Figure 5-2 to Figure 5-4 are sample maps of the type of output that SDC may want to produce. DHI have filtered the depth results so any depths less than 50 millimetres are not shown. When using the rain on grid methodology every mesh element will become “wet” which can become confusing to interpret, by filtering the depths it is assumed that any depth below 50mm is insignificant and can be ignored when assessing the model results. A mask of the filtered depth area was also used to filter the area for which water level and flood hazard were calculated.

The following Flood hazard classification from the Australian Rainfall Runoff (ARR) guidelines is recommended to be used to describe the flood hazard in any flood mapping or display of information SDC choose to undertake. The sample map symbology has been categorised to show hazard for Adults as per Figure 5-1.

Table 5 Flow hazard regimes for infants, children and adults

<table>
<tr><th>DV (m^2s^{-1})</th><th>Infants, small children (H.M ≤ 25) and frail/older persons</th><th>Children (H.M = 25 to 50)</th><th>Adults (H.M > 50)</th></tr>
<tr><td>0</td><td>Safe</td><td>Safe</td><td>Safe</td></tr>
<tr><td>0 – 0.4</td><td rowspan="5">Extreme Hazard; Dangerous to all</td><td>Low Hazard[1]</td><td rowspan="2">Low Hazard[1]</td></tr>
<tr><td>0.4 – 0.6</td><td>Significant Hazard; Dangerous to most</td></tr>
<tr><td>0.6 – 0.8</td><td rowspan="3">Extreme Hazard; Dangerous to all</td><td>Moderate Hazard; Dangerous to some[2]</td></tr>
<tr><td>0.8 – 1.2</td><td>Significant Hazard; Dangerous to most[3]</td></tr>
<tr><td>> 1.2</td><td>Extreme Hazard; Dangerous to all</td></tr>
</table>

[1] Stability uncompromised for persons within laboratory testing program at these flows (to maximum flow depth of 0.5 m for children and 1.2 m for adults and a maximum velocity of 3.0 ms^{-1} at shallow depths).
[2] Working limit for trained safety workers or experienced and well equipped persons ($D.V < 0.8\ m^2s^{-1}$)
[3] Upper limit of stability observed during most investigations ($D.V > 1.2\ m^2s^{-1}$)

Figure 5-1 - Flood Hazard categories from ARR

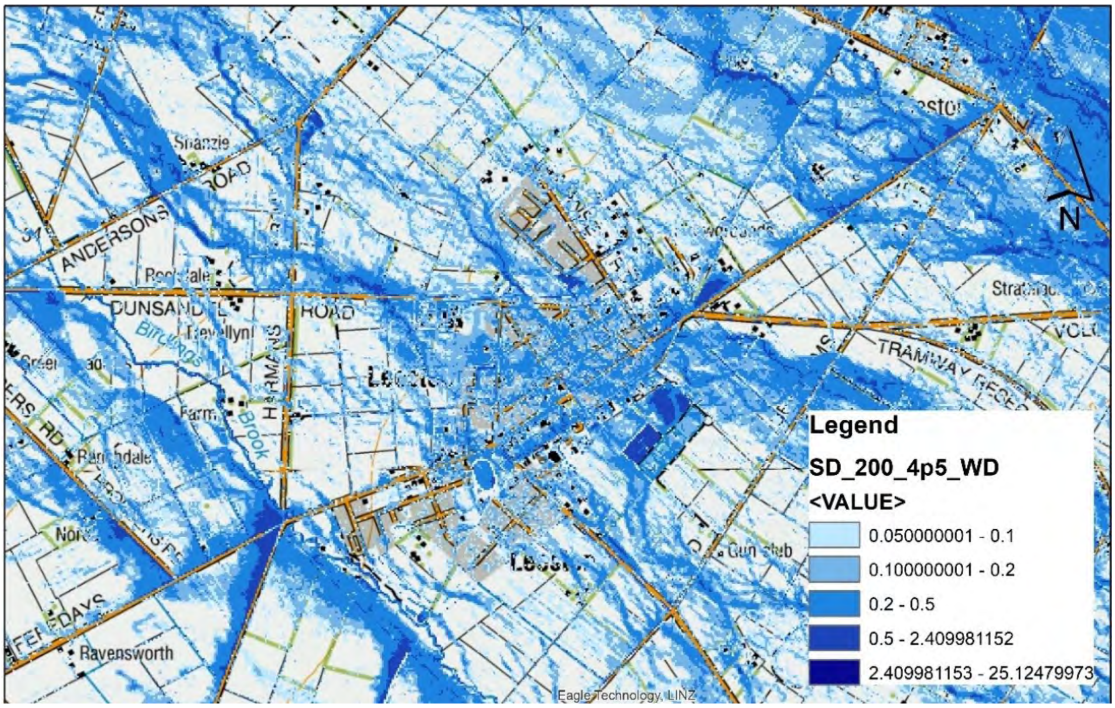


Figure 5-2 – Sample Max Water Depth Output for Leeston for 0.5% AEP/RCP4.5 Event

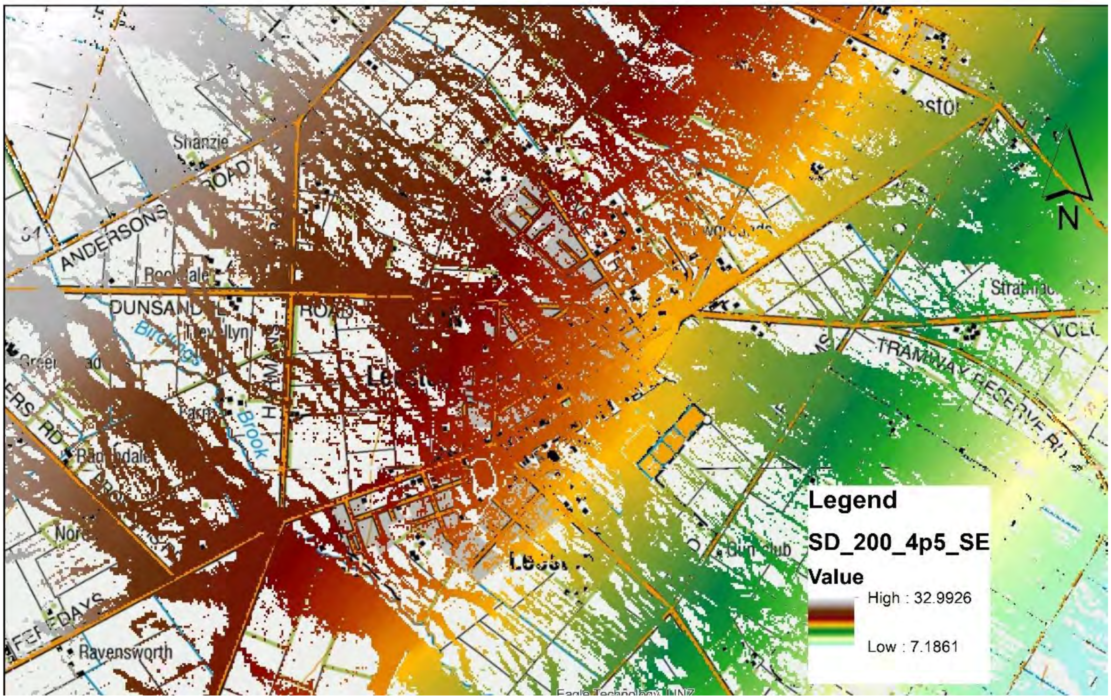


Figure 5-3 – Sample Max Water Level Output for Leeston for 0.5% AEP/RCP4.5 Event

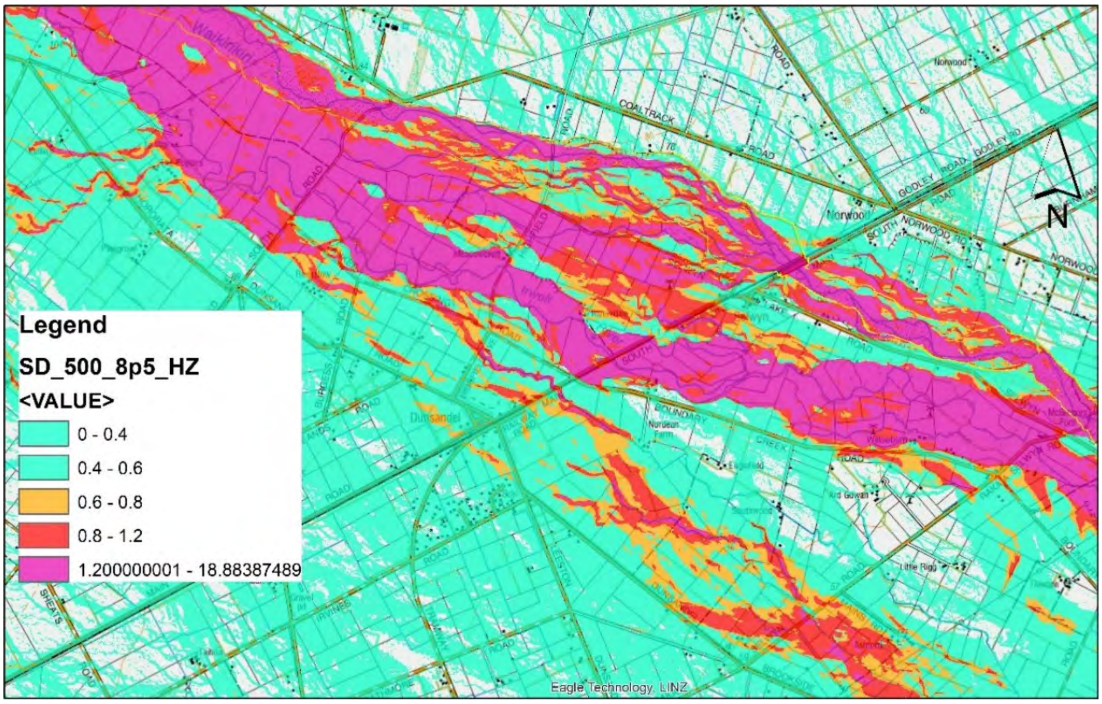


Figure 5-4 – Sample Flood Hazard Output near Dunsandel for 0.2% AEP/RCP8.5 Event

6 Limitations and recommendations

The following limitations have been identified:

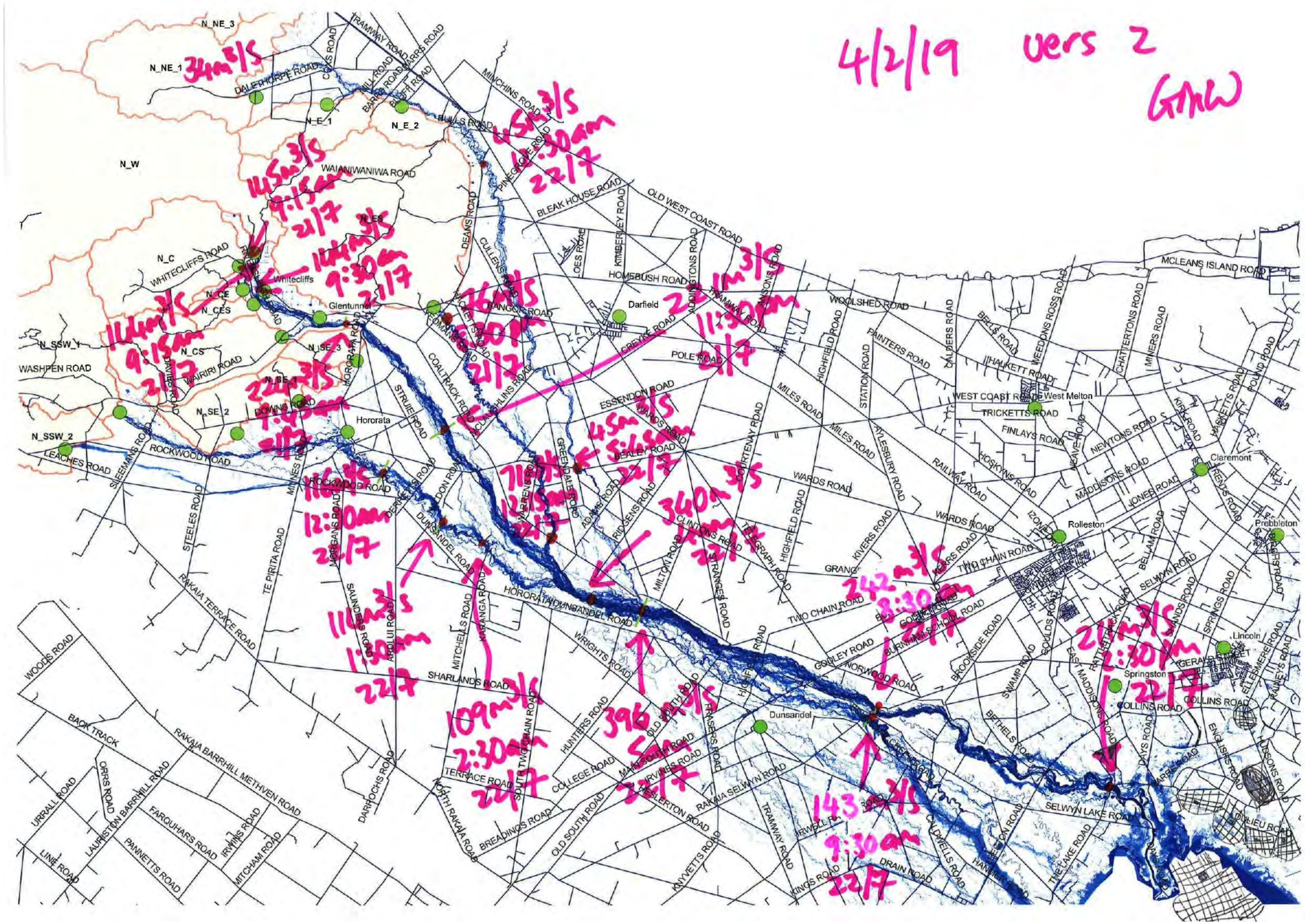
- Only some calibration/validation has been carried out for the July 2017 event and no other storm events were assessed.
- The ground levels are of varying LiDAR resolution throughout the model domain. Some care should be taken especially when interpreting results across different data sets.
- Infiltration is based on estimated rates based off spatial soil data. Thus, the accuracy of the rates is dependant both on the accuracy of the soil data, and the estimated rates assigned to each soil type.
- In channel routing for water courses smaller than the grid size of 10m will not be accurately resolved in the model.
- The location of hydraulic structures, such as culverts, was not estimated or included in this modelling. Ponding may be overestimated in some areas that, in reality, would allow some through flow to occur.
- It is expected that the 10m resolution of the grid will be adequate enough to pick-up flow obstructions such as road embankments, however structures such as fences or walls will not be resolved in the model, although some consideration is made for this in the “built up area” roughness value.
- Stormwater reticulation networks were not included in this model.
- It expected that the more detailed ECAN Selwyn River MIKE FLOOD model would be used to analyse the area in and near the Selwyn River.
- The rainfall used is a 72 hour nested storm, this assumes that the critical duration for the models is at or less than 72 hours. It is possible that in some areas the critical duration may be longer than this, in which case flood levels may be underestimated.

The following recommendations for future work on the project are:

- If further validation data is available for the catchment, further validation should be undertaken to better understand the accuracy of the models
- If further LiDAR data becomes available, the model should be updated
- Important structures such as culverts, bridges and roads should be considered to be added into future versions of the model
- With future advances in software and hardware it will be possible to run a finer scale model such as a 5x5m grid.

APPENDICES

APPENDIX A – July 2017 Validation


4/2/19 vers 2
GMW
34m³/s
145m³/s 10:30am 22/7
145m³/s 9:15am 21/7
144m³/s 9:30am 21/7
144m³/s 9:15am 21/7
76m³/s 6:30pm 21/7
221m³/s 11:30pm 21/7
224m³/s 7:45am 21/7
45m³/s 5:45am 22/7
116m³/s 12:30am 22/7
111m³/s 1:30am 22/7
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396m³/s 5am 22/7
242m³/s 8:30am 22/7
211m³/s 2:30pm 22/7
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Whitecliffs
Glentunnel
Hororata
Darfield
West Melton
Rolleston
Claremont
Prebbleton
Springston
Lincoln
Dunsandel