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Nukuhau Plan Change

Stormwater Management

Contact Details

Andrew Boldero

WSP
Opus House, Princes Street, Hamilton 3204
Private Bag 3057, Waikato Mail Centre,
Hamilton 3240
+64 7 838 9344
+64 22 429 7262
andrew.boldero@wsp.com

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Prepared by
Rodrigo Gonzalez

Reviewed by
Andrew Boldero

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Disclaimers and Limitations

The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

In preparing the Report, WSP has relied upon data, Lidar, analyses, draft designs and other information (‘**Supplied Data’**) provided by or on behalf of the Client. Except as otherwise stated in the Report, WSP has not verified the accuracy or completeness of the Supplied Data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in this Report are based in whole or part on the Supplied Data, those conclusions are contingent upon the accuracy and completeness of the Supplied Data. WSP will not be liable in relation to incorrect conclusions or findings in the Report should any Supplied Data be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to WSP.

The recommendations in this report are based on a 0.5 m Lidar, pipe diameters from the Taupō District Council, and levels of approximately 5% of the stormwater pipe network provided by the Taupō District Council. 95% of the pipe levels and grades were assumed in the one-dimensional model. The stormwater analysis is high-level and further investigation would need to be carried out for detailed design and construction.

1 Introduction

1.1 Purpose

The purpose of this report is to inform a zoning change required to progress the proposed Nukuhau development (Taupō) in terms of stormwater management (treatment, conveyance and flood risk).

As part of the plan change application, a quantification of the effects of the proposed residential development needs to be assessed. Any increase in impervious area (residential development) will change the stormwater runoff characteristics and can impact flood levels and erosion risk. This report considers several options, outlines potential effects in terms of stormwater (drainage and flooding and recommends a stormwater management strategy for further development.

This report discusses stormwater management strategies and assesses the likely effects. It provides an overview of potential issues and opportunities in developing the Nukuhau area. This report also outlines risks, issues and opportunities for further consideration during the design development.

1.2 Background

Private land owners are applying for a district plan change in Nukuhau, Taupō to allow the development of 5 areas. Four of these are adjoining and are all up-catchment from the existing urban sprawl in the Nukuhau area (northern suburbs of Taupō).

The existing stormwater network allows for the conveyance of the road reserve and carriageway areas to discharge stormwater to the lake (Lake Taupō). The existing residential areas are drained via soakage or open channel. There are several overland flow paths through the proposed development area that connect with formal open channels through the existing residential area before also discharging to the lake.

The largest open channel is along the western side of the Nukuhau area. This has several large culverts under the road. Of note is Acacia Bay Road which doesn't have a culvert crossing so forms a basin. This basin provides infiltration for a significant catchment area. This culvert is proposed to be installed around a similar time to the development. The culvert is likely to reduce the water level in the open channel/basin in this area. As the proposed culvert is significantly downstream from the development it was thought to be hydraulically independent. It was included in the preliminary modelling to assess its hydraulic relationship which confirmed its independence. As such the proposed culvert has been excluded from the final modelling.

1.3 Methodology

This report utilised the existing data available. GIS information of the existing network provided pipe alignments and sizing but did not contain significant level data. LIDAR contours provided an approximate surface for modelling purposes as survey information for the development area (level data) is not yet available.

A manhole survey was undertaken in some critical areas to assist with invert level interpretation (estimation of existing manhole inverts). No specific site investigation works have been undertaken outside of the initial site walk over and the above mentioned stormwater manhole survey.

The report discusses the potential effects the residential development could have on the area. A number of potential mitigation strategies are discussed along with the results of meetings with Waikato Regional Council (WRC). This provides direction towards a recommended strategy which was hydraulically modelled. These modelling results for the recommended strategy are provided in this report.

WRC's recently released guidelines are also considered and discussed further in this report. This forms the basis of the recommended strategy. As well as outlining the recommended strategy this report also discusses safety in design, risks and further options.

1.4 Proposed Development Layout

The proposed development areas are shown below in Figure 1-1:

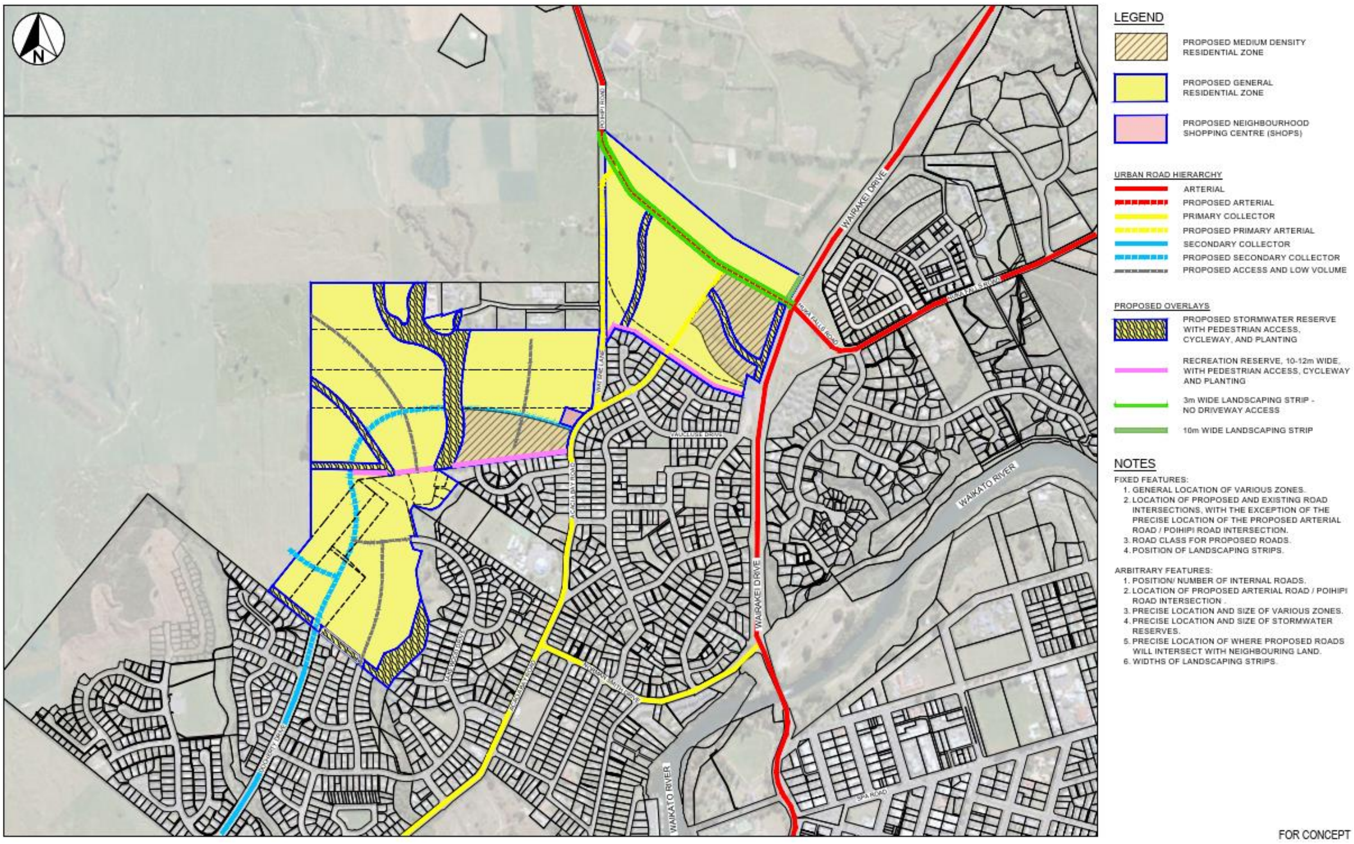


Figure 1-1 : Development areas including downstream catchment

1.5 Geology and geotechnical

The geology around Taupō contains several challenges in terms of Tomo *(a void/tunnel formed by the action of water on limestone or volcanic rock)* risk from concentrated stormwater flows. This risk is discussed further in section 10. The Nukuhau development area is located on sandy loam soil, which is well drained (Landcare research, 2019). This indicates the site is likely to be suitable for soakage pits and infiltration for disposal of stormwater. Significant characteristics of the area include the Brentwood Gully and the existing stormwater detention pond located on the North corner of Poihipi Road. and Wairakei Drive. For further information on the geotechnical characteristics refer to the geotechnical assessment report.

1.6 Topographical data

LiDAR was provided for Nukuhau and surrounding area. The LiDAR appeared to correlate well to the actual topography, however survey will be required to further develop the stormwater concept.

2 Taupō District Council (TDC)

2.1 TDC Design Requirements

The Taupō District Council Stormwater Strategy (Taupo District Council, 2009) states

1. *Primary stormwater systems will be designed to manage stormwater up to a 10% annual exceedance probability (AEP) rainfall event agreed for the catchment.*

2. *For higher intensity rainfall events (greater than 10% AEP), excess stormwater will be managed by secondary flowpaths, ponds and other suitable methods up to a 1% AEP event agreed for the catchment.*

2.2 TDC Consultation

Discussions were held with TDC on 2 October 2019 in Taupō to outline the assessment work to date and discuss TDC's preferences in terms of infrastructure (operations and maintenance) which included a discussion on tomo risk and the proposed culvert under Acacia Bay Road.

In summary:

- The Acacia Bay Road culvert is still in the land owner negotiation phase, although likely to proceed, the exact solution and downstream channel may change.
- Some existing subdivisions (examples given) have issues when a combined soakage pit is used (multiple houses connected to one large soakage pit).
- In terms of tomo risk, TDC expect that a single lot solution will disperse the infiltration across a large enough area with smaller flows which, based on Councils experience, should mitigate/reduce the risk of tomo.
- The solution of providing a sealed pipe conveyance of stormwater flows to the lake/river outlet is not considered a practical solution by TDC.
- Driveway entries (within the road reserve) shall be installed at the same time as the road (due to previous experience where land owners didn't provide a consistent standard or size of culvert).
- No surface water from lots to enter the road reserve for treatment or storage for all events up to and including the 10% AEP event.
- Dry periods combined with high infiltration rates requires additional consideration for planting specifications as there are known issues with plants dying from lack of water. Grassed swales are preferable to rain gardens as grasses are typically more resilient to dry conditions.

3 Waikato Regional Council (WRC)

3.1 WRC Guidelines Requirements

The revised (2018) stormwater management guidelines from WRC (WRC Guidelines) has evolved from the previous utilised Technical Publication (TP) 10. The focus of the new WRC Guidelines includes:

- Low impact design
- Prioritisation of stormwater issues
- The receiving environments
- A scoring matrix for stormwater management approaches
- Revegetation
- Soil conditioning and characteristics (i.e. compaction)
- Innovation
- Sustainability

WRC Guidelines uses a scoring matrix (Appendix B) to encourage low impact design and requires a minimum score of 15. Low impact design (LID) is based on disposing of stormwater efficiently and implementing natural processes. A minimum of 6 points is required for maximising source control and a minimum of 6 points is required for LID stormwater devices/practices used. The scoring matrix table in appendix B details how the point system works outlining the requirements including how minimum point scores (15 points) may be obtained for the recommended strategy.

3.2 WRC Consultation

WSP have discussed the proposed plan change with WRC (8 November 2019) to allow input from the Regional Council in terms of compliance with the recently revised development guidelines. A summary of this discussion is outlined below.

3.2.1 Discussion Summary

- The point system as per the WRC Guidelines is a guide and can be flexible if the outcomes are acceptable to WRC.
- Taupō area (specifically Nukuhau) is predominantly pumice sand which has an associated tomo risk (sub-surface tunnelling).
- Taupō groundwater is currently nitrogen banked. Treatment is required to reduce the nitrogen levels entering the groundwater.
- Private lot stormwater management is controlled by TDC.
    - Driveway runoff requires treatment prior to entering the groundwater. Runoff is not permitted to enter road/public drainage system
    - Using a grass grid type driveway system could reduce the on-lot infrastructure and maintenance requirements.
- Road Treatment
    - Swale with an infiltration base is unlikely to provide required treatment
    - Bio-retention swales being used elsewhere could provide a good solution
    - Planting specification requires robust plant selection
- Road Detention
    - Due to tomo risk wetland or pond options are likely to be lined
    - Oversizing piped network and using weirs within swale could be used to maximise storage volume
- Flood mitigation
    - Existing gullies being pumice sand are likely to be susceptible to erosion and therefore required peak flow management
    - WSP could proposed a solution that reduces the 10% AEP to pre-development conditions

3.2.2 Gully Realignment proposal

The potential realignment of some of the small to medium gullies were discussed with WRC. WSP proposed an option of re-aligning some of these (exact scenarios to be confirmed) to align to the larger gullies. This would allow the developer to maximise land use as the distance between the existing gullies would not enable significant development. The design strategy for this is as follows:

- No significant change in the hydraulics of either gully
    - The cross-sectional area of the existing gullies does not change
    - Gullies are still separated hydraulically (no hydraulic effects upstream or downstream)

- The location of the gully inlet and outlet at the boundaries will not significantly reduce
- Planting and landscaping options will not be affected

Figure 3-1 shows the existing scenario with Figure 3-2 showing the proposed scenario. These scenarios are examples of the concept. These are to provide a visual interpretation of the concept for further discussion.

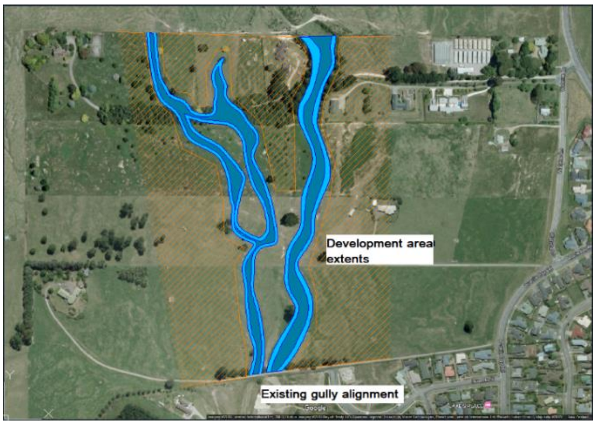


Figure 3-1: Existing Gully Layout

Figure 3-2: Proposed Gully Layout

The revised gully layout could potentially add approximately 10,000m^2 to the development area as this reduces the distance between the existing gullies. The percentage of land increase in this area is approximately 10-15%. This percentage increase will vary depending on the location of realignment. For example, the southern section could provide a more favourable cost benefit ratio in terms of the increase in development area as this requires less earthworks to achieve. This is estimated to be approximate a 15-20% increase in available area which would be specifically designed to keep the existing naturalisation of the gully (i.e. maintain similar curves and varying widths).

WRC have responded to this concept and given an informal recommendation that aligns with the Regional Policy Statement to not modify natural gully systems (email 2 November 2019). The informal comments from WRC is not a formal technical response.

4 Stormwater Strategy Options

A number of solutions (infrastructure/devices) were considered during the investigation for the conveyance, treatment and detention. These solutions were used to establish a number of developed scenarios for further consideration. These options (solutions and developed scenarios) are summarised in the following sections:

4.1 Conveyance Solutions

- PE/PVC pipe
- Concrete Pipe
- Box culverts
- Conveyance swales
- Combined treatment and conveyance swales
- Combined treatment, conveyance and infiltration swales

4.2 Detention Solutions

Due the sensitive receiving environment and development design criteria, detention will be required for the development. The following detention strategies for erosion and flood control are considered suitable for the development:

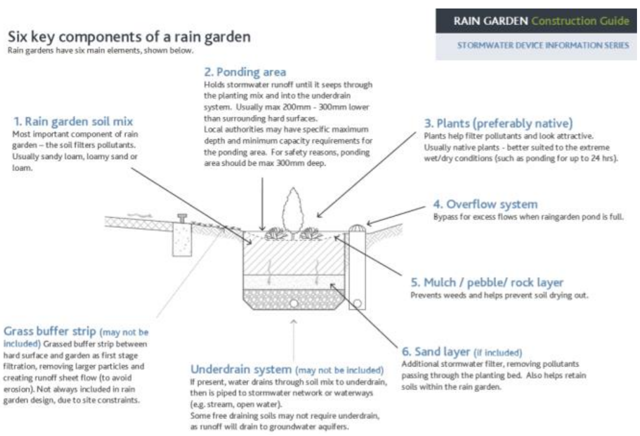
- Underground storage tanks
- Oversized piped network
- Road side swales with detention weirs
- Maximising infiltration in treatment swales throughout the road network

4.3 Treatment Solutions

The following sections provide an outline of the commonly used treatment options considered suitable for the area. The treatment strategy is to provide treatment for all pollutant generating surfaces (as per the WRC guidelines). This includes road carriageway and driveways. This excludes roof and footpath runoff. It is assumed that roofing materials used for housing in the area will not be contaminate generating.

4.3.1 Raingardens

- Provides treatment (limited storage)
- Can be located throughout the catchment
- Can be integrated with landscaping and open space designs



Images from Auckland Council's raingarden construction guide

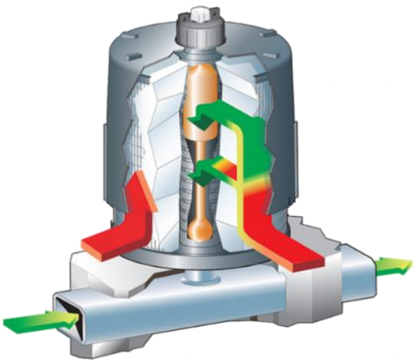
4.3.2 Vegetated Swales

- Provides treatment (storage can be increased with use of weirs)
- Can be located throughout the catchment
- Generally, a cost effective treatment option
- Can be integrated with landscaping and open space designs
- Specialist plants required due to extended dry conditions


Images from Whanganui District Councils environmentally friendly SW design guide

4.3.3 Filter Chambers (Stormfilter bank type systems)

- Provides treatment and some storage volume
- Can be located anywhere in catchment
- One point of maintenance
- Can be expensive if treating large flows/areas
- Generally, not integrated with landscaping and open space designs

Images from www.Stomrwater360.co.nz

4.3.4 Wetlands

- Provides storage and treatment
- End of catchment solution – not preferred by WRC
- One point of maintenance/single asset to be maintained
- Generally integrated with landscaping and open space designs

Image from www.Stuff.co.nz

4.4 Developed scenarios

From the design concepts a number of scenarios were developed that utilise varying components of Water Sensitive Urban Design (WSUD). These have been refined and modelled to provide a recommend strategy. These 'options' are outlined in the Table 4-1 below.

Table 4-1 Developed Scenarios Table

Developed Scenario	Location	Solution			Comments
		Treatment/ Conveyance	Detention	Disposal	Rainwater reuse tanks is an option for all scenarios
1	Lots	Filter device + pipes	Stormwater tank/chamber	Existing network	Existing network undersized
	Roads	Filter device + pipes	Stormwater tank/chamber	Existing network	
2	Lots	as per road solution	as per road solution	as per road solution	Does not align with TDC policy
	Roads	Filter device + pipes	Stormwater tank/chamber	Existing network	
3	Lots	Grassed driveways/filter strip	As per infiltration	Infiltration strip/soakage pit	No detention required if direct outfall to lake (assuming no erosion issues at outfall)
	Roads	Swales	n/a	Piped (PE/sealed) to lake	
4	Lots	Semi pervious paving	n/a	Infiltration	Designed for the 1% event + overflows into the existing overland flow path(s)
	Roads	Swale/filter strip	Swale	Infiltration	
5	Lots	as per road solution	as per road solution	as per road solution	Does not align with TDC policy
	Roads	Swale	Swale	Infiltration	

5 Hydrological Assessment

For the purposes of this hydrological assessment, peak flows have been determined using the (Waikato Stormwater Runoff Modelling Guideline, 2018) methodology. This has been applied within the HEC HMS modelling software for the whole catchment analysis. The method is commonly used throughout the Waikato Region to demonstrate the runoff characteristics of Greenfield and urbanised catchments as is considered industry best practice.

5.1 Catchment Analysis, Watershed Delineation and Information

The Catchment area was divided into 15 sub-catchments for the hydrological analysis.

- 4 upper catchments. These areas are characterized by high slopes, grass and bush cover with high infiltration rates.
- catchments inside the proposed development areas. The hydrographs from these catchments will varied between the existing and developed scenarios because of the change in the impervious surfaces.
- 4 catchments in the Taupō township, downstream of the proposed the developed areas. The hydrographs from these catchments will be distributed between all the existing manholes in the existing network inside each of the catchments.

Figure 5-1 below presents the sub-catchments modelled as part of this study.

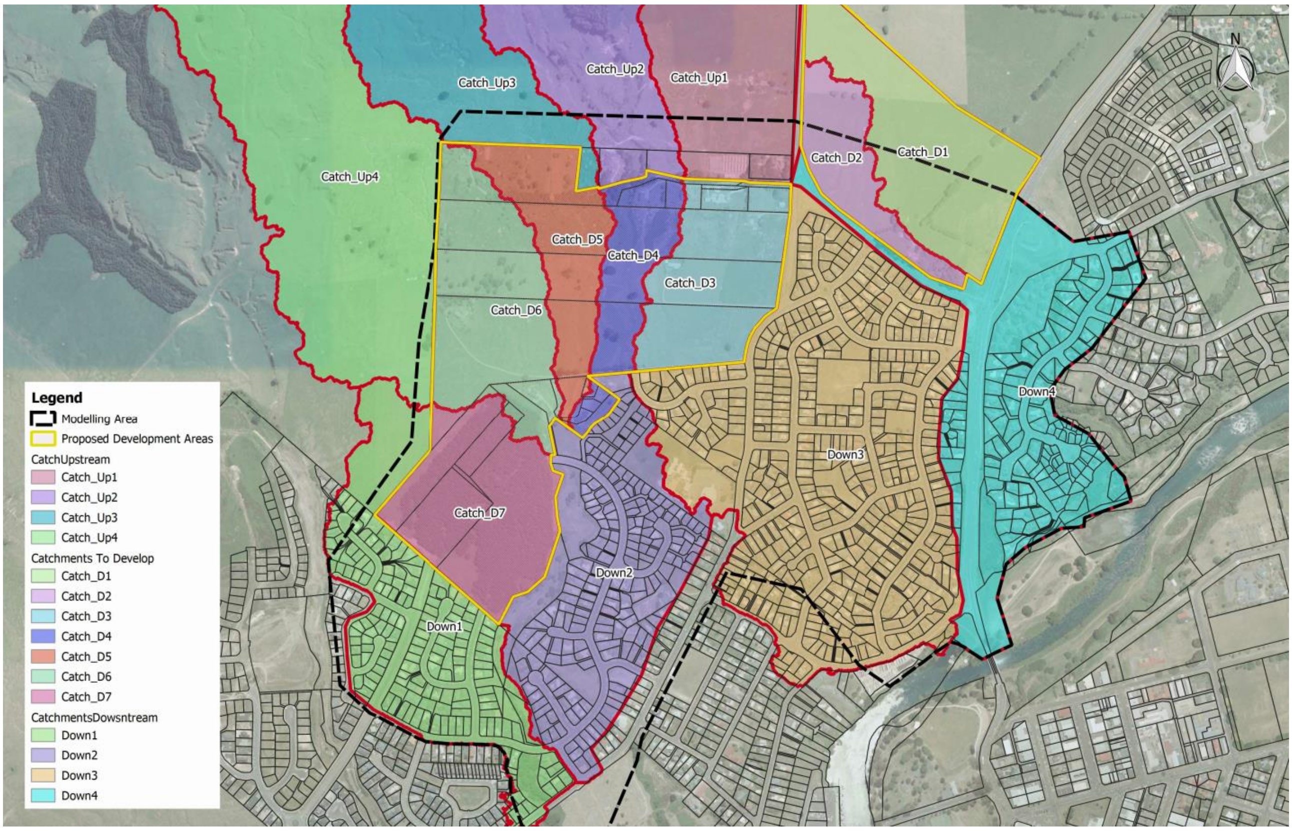


Figure 5-1 : Sub-catchment layout

The catchment delineation was developed with a watershed analysis in QGIS over the 1m x 1m (Grid) DEM.

The 24h Hydrographs were determined for 100yr ARI design rainfall events with Climate Change (2090) and were used as inputs into the hydraulic model. The inputs were modelled at the outlet of each sub catchment for the upper and developed catchments and distributed equally between the existing manholes of the network for the downstream catchments, in the urban area, with the objective to check the capacity of the drainage network.

5.2 Catchment Rainfall

HIRDS (version 4) existing rainfall depths for Taupo are presented in Table 5-1. The analysis includes a warming factor of RCP 6.0 (equivalent to a conservative 2.1 degree Celsius projection) to allow for predicted climate change, which is consistent with the temperature increase anticipated for the Waikato region by 2090 (NIWA Climate Change Scenarios for New Zealand, 2016).

Table 5-1 : HIRDS (V4) Design Rainfall depths (mm). (Current rainfall Taupo)

ARI (Years)	AEP (%)	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	50	7.8	11.4	14	19.7	26.9	41.9	53.6	66.8	81.2	90
10	10	12.6	18.2	22.4	31.1	42.1	64.7	82.1	101	122	135
50	2	18.3	26.3	32.1	44.3	59.5	90.3	114	140	167	183
100	1	21.1	30.2	36.9	50.7	67.9	103	129	158	188	206

The percentage of adjustment because of Climate Change is in accordance with the (Waikato Stormwater Runoff Modelling Guideline, 2018), which recommends a percentage of adjustment that differs for a range of average recurrence intervals.

Table 5-2 : Design Rainfall depths (mm). (Climate Change 2090

ARI (Years)	AEP (%)	10m	20m	30m	60m	2h	6h	12h	24h	48h	72h
2	50	9.1	13.2	16.1	22.5	30.4	46.6	59.0	72.8	87.7	96.6
10	10	14.7	21.2	26.0	35.9	48.5	73.9	93.3	114.4	137.6	151.7
50	2	21.4	30.7	37.5	51.7	69.5	105.5	133.2	163.5	195.1	213.7
100	1	24.6	35.3	43.1	59.2	79.3	120.3	150.7	184.5	219.6	240.6

5.3 Hydrological Analysis and Design Peak Flows

A weighted Curve Number (CN) was determined for each sub catchment for the hydrological analysis. The weighted CN is related to the percentage of area covered by each of the soil types. (Figure 5-2). The soil in Taupō is mainly pumice sand, which provides significant infiltration capacity.

The soil classes were determined with the S-Map layer from LRIS Portal. The CN from each of the soil classes are in accordance with the (Waikato Stormwater Runoff Modelling Guideline, 2018) and are presented in Table 5-3.

Table 5-3 : Soils Curve Number

Soil Class	Impervious	A (Bush/Grass in good condition	A (Pasture in good condition)
Curve Number (CN)	98	32	39

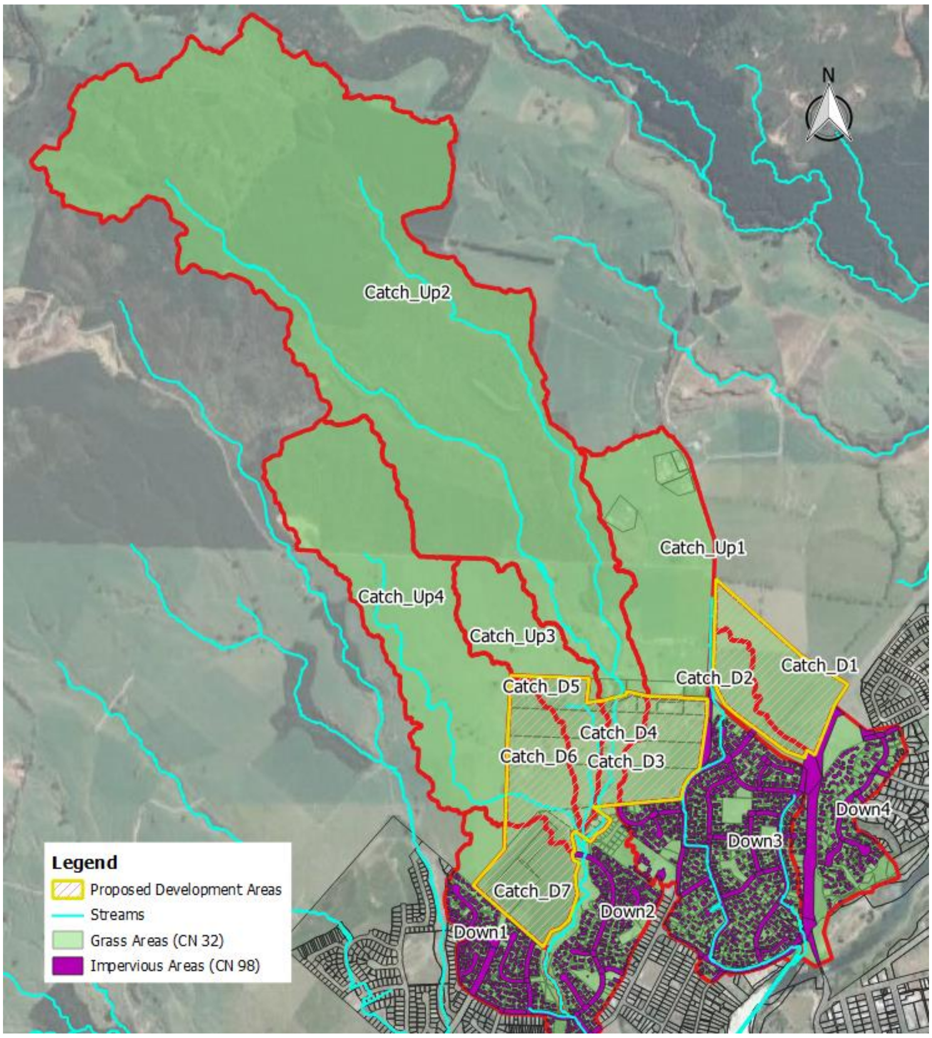


Figure 5-2 : Soil groups distribution

Hydrological modelling was undertaken in HEC-HMS 4.3 software to determine the existing catchments characteristic and response from the 1% AEP (2090) event. The resulting hydrographs from HEC HMS were used as inputs into the hydraulic model in each sub catchment.

Table 5-4 and Table 5-5 summarise the parameters of the sub catchments and peak flows for the 1% AEP (2090) event. The parameters of the Upper and Downstream catchments remain the same in the existing and developed scenario, whereas the proposed developed areas are modified because of the increase in the impervious areas.

Table 5-4 : Catchment parameters and peak flows in the upper and downstream catchments.

Catchment Name	Area (Ha)	CN	Ia (mm)	1% AEP Event (2090) Peak Flow (m3/s)
Catch_Up1	41.77	32	23	1.3
Catch_Up2	255.73	32	23	5.5
Catch_Up3	17.51	32	23	0.6
Catch_Up4	72.44	32	23	1.9
Down1	23.23	61.2	8.3	3.5
Down2	24.91	57.3	9.9	3.1
Down3	56.09	64.2	7.3	8.7
Down4	30	60.6	8.6	4.4

The proposed developed catchments are divided in Pervious/Impervious areas to allow for the design of mitigation devices. The mitigation scenarios were modelled as developments with infiltration devices able to cater the 1% AEP event (2090) from the new impervious surfaces (Shaver, Waikato Stormwater Management Guideline, 2018).

Table 5-5 : Catchments parameters and peak flows in proposed developed catchments

Catchment Name	Scenario	Area (Ha)	CN	Ia (mm)	1% AEP Event (2090) Peak Flow (m3/s)
Catch_D1	Existing	15.6	32	23	0.54
	Developed (60% Impervious)		60% CN98 40% CN39	60% Ia 1.0 40% Ia 18.8	2.55
	Developed with Mitigation				0.73
Catch_D2	Existing	6.67	32	23	0.28
	Developed (60% Impervious)		60% CN98 40% CN39	60% Ia 1.0 40% Ia 18.8	1.26
	Developed with Mitigation				0.31
Catch_D3	Existing	12.34	32	23	0.57
	Developed (60% Impervious)		60% CN98 40% CN39	60% Ia 1.0 40% Ia 18.8	2.51
	Developed with Mitigation				0.52
Catch_D4	Existing	7.12	32	23	0.3
	Developed (60% Impervious)		60% CN98 40% CN39	60% Ia 1.0 40% Ia 18.8	1.34
	Developed with Mitigation				0.33
Catch_D5	Existing	9.41	32	23	0.35
	Developed (60% Impervious)		60% CN98 40% CN39	60% Ia 1.0 40% Ia 18.8	1.62
	Developed with Mitigation				0.45
Catch_D6	Existing	15.38	32	23	0.63
	Developed (60% Impervious)		60% CN98 40% CN39	60% Ia 1.0 40% Ia 18.8	2.86
	Developed with Mitigation				0.68
Catch_D7	Existing	14.28	32	23	0.62
	Developed (60% Impervious)		60% CN98 40% CN39	60% Ia 1.0 40% Ia 18.8	2.78
	Developed with Mitigation				0.62

6 Hydraulic Modelling

6.1 Introduction

The flood assessment has been undertaken through a 2D hydraulic analysis using TUFLOW (Version 2018-03-AB). Modelling has been completed for 1% AEP events with Climate Change to 2090.

6.2 Lidar and Survey parameters

Based on the available data, the approach to the use of terrain data and use of LiDAR in the development of the hydraulic model is as follows:

- The LiDAR DTM provided had a resolution of 1m x 1m that forms the base information for the hydraulic model. These data were assumed to be correct and no adjustments have been made other than those required to improve the accuracy of the bottom of the channels.

- The 2D TUFLOW model uses a 4m x 4m grid with the ground level applied within each grid cell taken as the average of the LiDAR points within that cell.

6.3 Land use

The area was separated into land cover classifications in QGIS using 3 categories: Houses, roads, and bush. The "Houses" classification encompasses the proposed residential zones and proposed neighbourhood shopping centre zone of the proposed development layout (Figure 1-1). The CN values chosen for the "Houses" classification is appropriate for modelling the residential zones. The neighbourhood shopping centre zone is expected to have a higher portion of impervious area than the general or medium density residential zones, however the total area of the neighbourhood shopping centre zone only accounts for 2% of the total sub-catchment area (Catch_D3). Therefore, the impact of any increased runoff that was not accounted for in the assessment is considered to have a negligible effect on the overall hydraulic modelling results. Classifications will be refined during the next stages of stormwater design development.

The remaining areas of the catchment were assumed to be grass cover. For each of the categories, a Manning's "n" number was assigned with different fraction impervious values. Table 6-1 presents the Manning's.

Table 6-1 : 2D manning 'n' Values from Waikato Guideline

Land Use	Grass	Bush	Roads	Houses
Manning's 'n' values	0.3	0.4	0.011	0.5

6.4 Culverts and Pipes

Culverts were modelled as part of the 1D network in TUFLOW. Available GIS data was used for dimensions, length and inverts (where available). Where insufficient information was not available to define asset data (i.e. pipes inaccessible), informed assumptions were made for the modelled assets. There was limited information available for downstream culverts, but due to their location, there is no foreseeable hydraulic effects. Culverts were modelled using a manning number of 0.015 and entry/exist loss coefficients of 0.5/1.0 were adopted in all the structures.

6.5 Model Boundary Conditions

Boundary conditions within the models consisted on:

- Downstream boundary as a normal depth (1% slope).

- Hydrographs from upper catchment from the hydrological assessment in section 5.3.

6.6 Limitations

TDC's stormwater asset information did not include level data for a significant portion of the stormwater network. Therefore, we utilised the LIDAR derived ground model to the defined invert levels based.

Due to the limited information available of the existing pipe network and the inherent inaccuracies of LiDAR, the hydraulic modelling results provide information for strategy level discussion only. This enables us to provide an indication of performance and outline potential issues. However, for detailed design progression additional survey information will be required.

7 Modelling results

Due to the initial modelling results showing no issues in achieving pre-development flows for the 10% AEP (due to the high infiltration rates available). The refined modelling of the recommended strategy concentrates on the 1% AEP mitigation, as this will be the most challenging aspect of the stormwater management.

The 1% AEP event with Climate Change to 2090 for the 3 scenarios (existing, development and development with mitigation). Mapping of flood extent and depths are included in Appendix C.

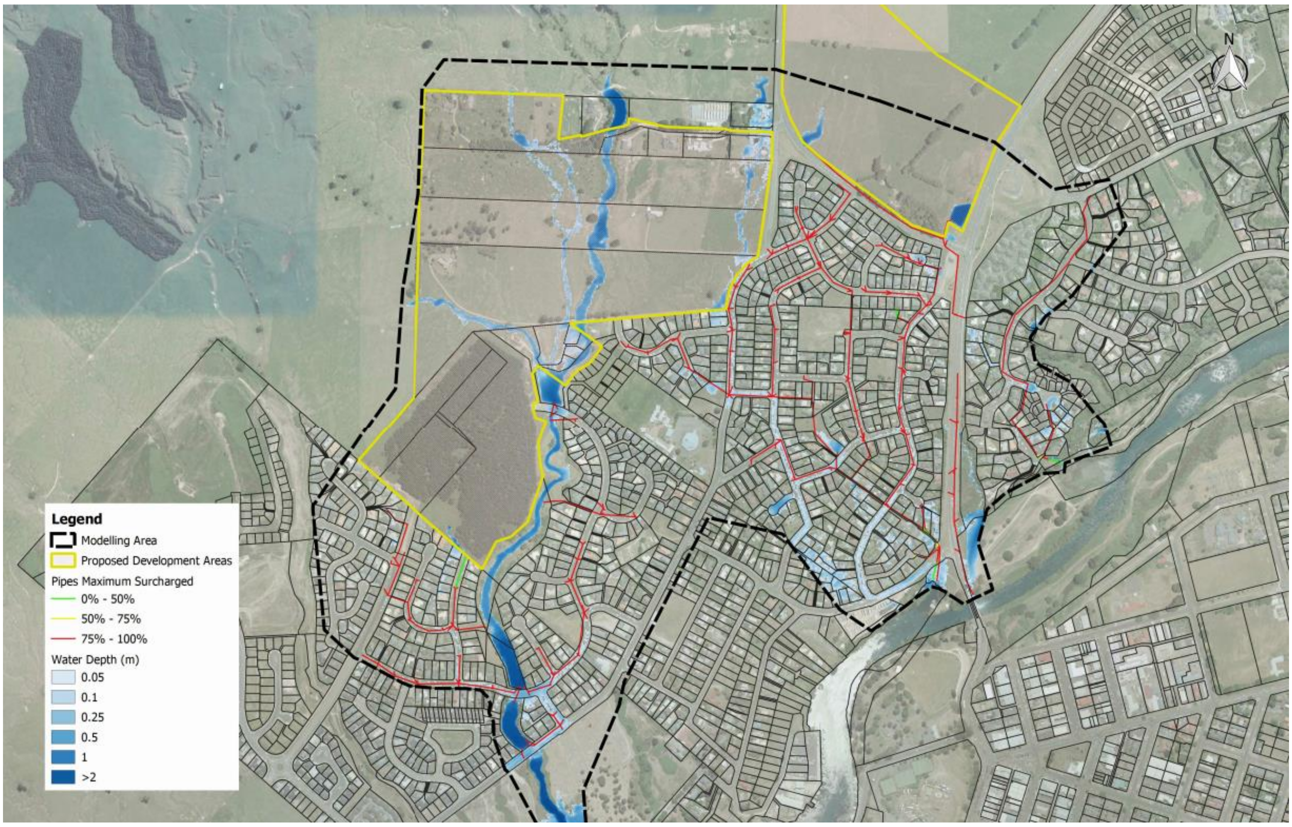


Figure 7-1 1% AEP Flood Extent (2090) – Existing Scenario

As the network design criteria is currently 10% AEP, as expected, the 1% AEP (2090) assessment shows no capacity in the existing drainage network with almost all the pipes being at a 100% surcharge state in any moment during the 1% AEP event. This results in overland flow paths in some roads in the urban area, mainly at the end of the network. The previous modelling of the 10% AEP showed mixed results between some available capacity and no capacity. It is likely that portions of the existing network were designed for the 50% AEP (2 year ARI).

There are also significant overland flow paths through the gullies in the proposed developed areas. The site visit showed that these gullies were well defined with steep edges on either side. The WRC guidelines for development outlines the importance of maintaining these gullies and overland flow areas. No modifications to the existing gullies were included in the hydraulic model.

The existing scenario has been used to assess the flood impacts related to modifications in the hydrographs because of the new developments. The results of the impact assessment show the results (increase/decrease) on the maximum water level in the gullies and roads in the lower catchment because on the discharge of water from the new developed areas.

The existing scenario has been compared to the developed scenario without mitigation (Figure 7-2), and against the mitigation scenario (Figure 7-3**Error! Reference source not found.**).

For the maps of the flood depths in the 3 scenarios, and the comparative in the water levels refer to Appendix 2.

7.1 Developed Scenario

As expected, the impact assessment predicts an increase in the flood extent and levels in the gullies and in the overland flows along the roads, with a maximum increase of 350mm in Woodward Street and 35mm in the gully upstream of Acacia Bay Road.

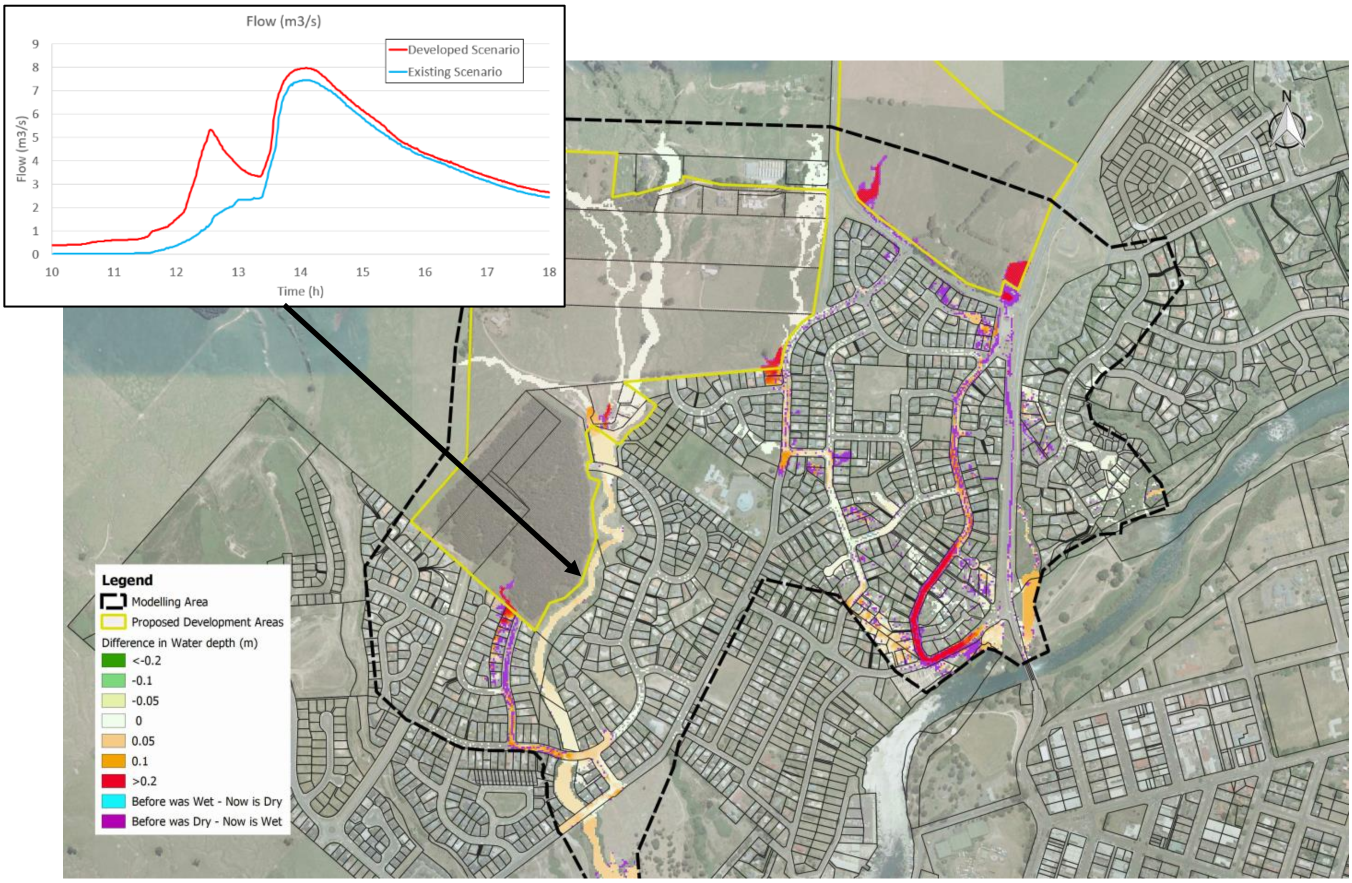


Figure 7-2 1% Flood depth impacts due to the new developments without mitigation

The new impervious areas from the proposed developments and it canalization induce a quicker drainage of the area, which results in a shorter time of concentration than the undeveloped catchment and provoke an additional peak in the hydrographs on the gullies.

7.2 Developed Scenario with Mitigation

To minimize the effect of the new developments on the flooding downstream a new scenario with mitigation has been modelled.

The mitigation scenarios were modelled as developments with infiltration devices able to cater the 1% AEP event (2090) from the new impervious surfaces. If the infiltration devices will be designed to convey only the 2% or 10% AEP events (2090) additional storage volume would be needed in the proposed developed areas. It is envisaged that the volume available in the proposed swales would attribute to minimising the need for formalised storage (underground tanks). The next table shows the additional storage volume required.

Table 7-1 : Additional Storage required in only infiltration for the 50% or 10% AEP events (2090)

Catchment Name	Additional Storage Volume if infiltration only for the 50% AEP event (2090) (m3)	Additional Storage Volume if infiltration only for the 10% AEP event (2090) (m3)
Catch_D1	4440	2850
Catch_D2	1900	1220
Catch_D3	3510	2255
Catch_D4	2026	1300
Catch_D5	2676	1720
Catch_D6	4374	2810
Catch_D7	4060	2610

The reduction in the peak flows from the developed catchments predicts a significant reduction to the flood extents when compared with the non-mitigated scenario (Figure 7-3). There is no significant increase in the water levels between the existing scenario and the mitigated scenario. In some isolated areas there are a slight increase in the water depth on the main gully (less than 10mm) which is considered outside the accuracy of the model and considered less than minor.

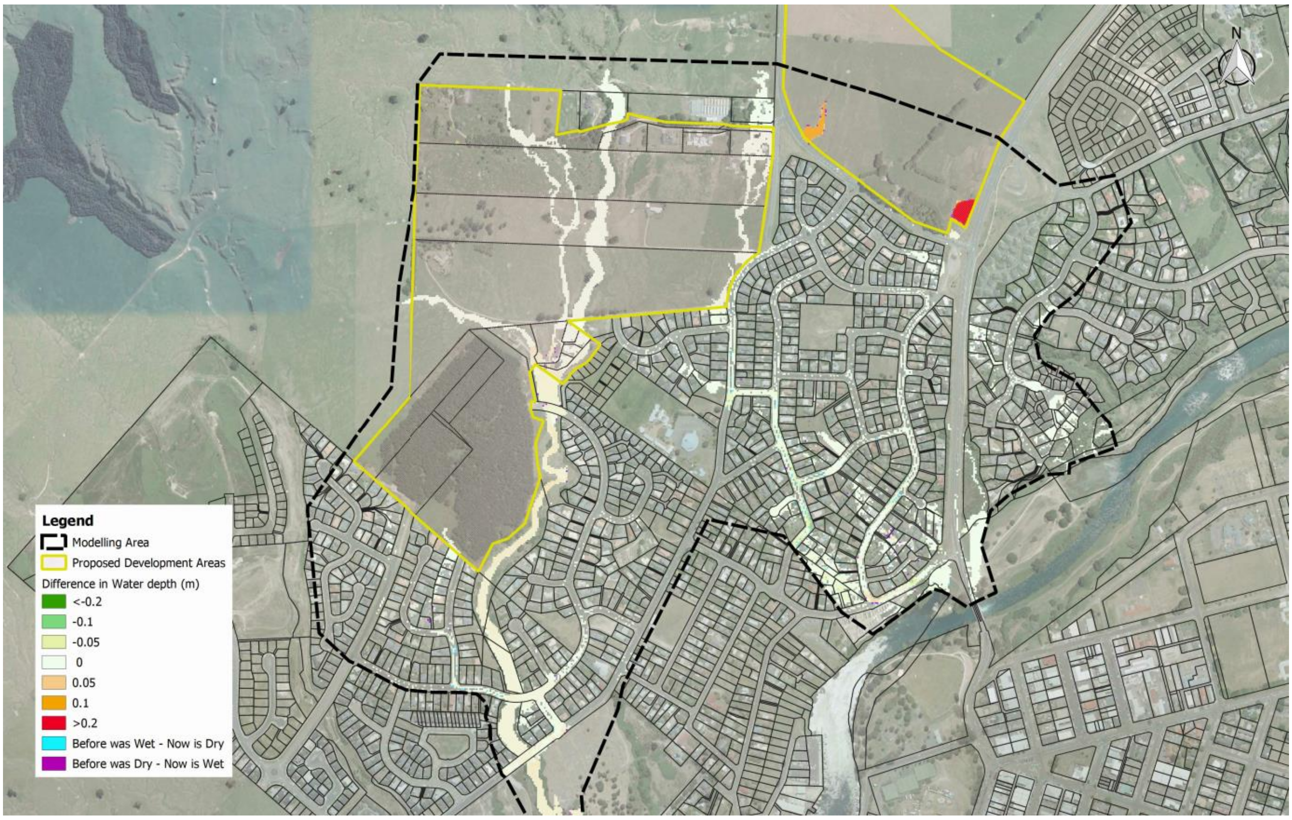


Figure 7-3 1% Flood depth impacts because of the new developments with mitigation

The results show that a storm water management approach, with devices able to manage the runoff from the new impervious surfaces during the 1% AEP event (2090), via infiltration or detention, mitigates the risk of increased downstream flooding.

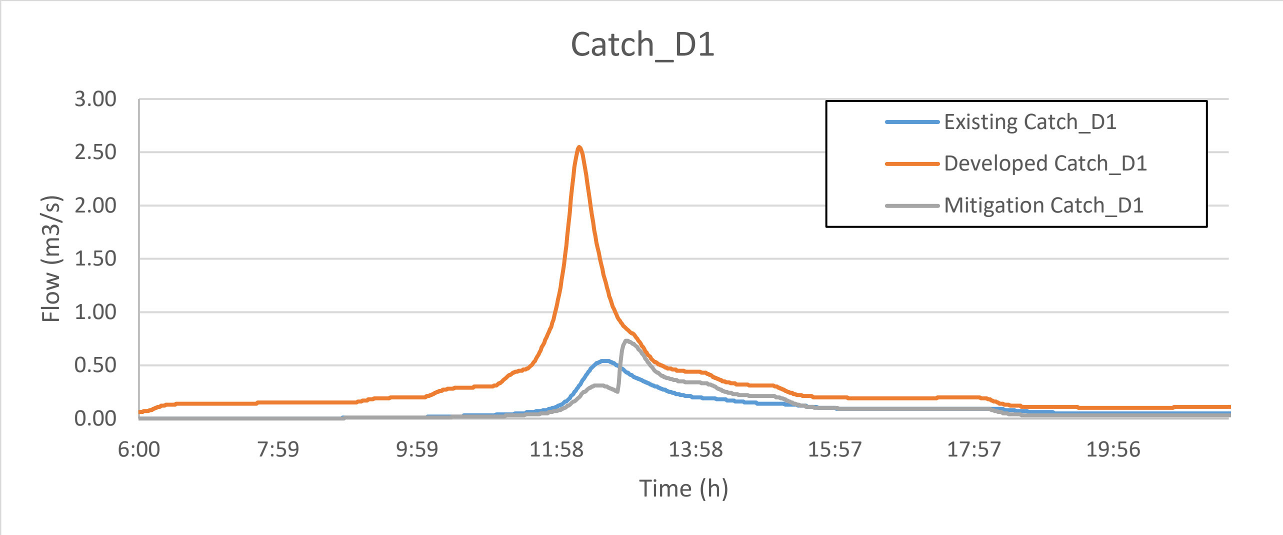


Figure 7-4 : Hydrographs from Catchment D1 (example)

8 Stormwater Strategy (recommended) and Conclusion

The goal of stormwater management strategy is to minimise effect on natural environment whilst maximising the benefits to the community. This strategy aligns with the WRC stormwater management guidelines. The recommended strategy is summarised in the following table which outlines the strategy and mitigation prioritisation(s).

Table 8-1 : Recommended strategy and prioritisation table

Location	Stage	Water Quality Event	50% AEP (2 year ARI)	10% AEP (10 year ARI)	1% AEP (100 year ARI)
Road	Conveyance	Swale	Swale	Swale	Swale
	Treatment	Filter Strip	Filter Strip	n/a	n/a
		Swale	Swale		
	Detention	n/a	Swale section	Swale section	Swale section
			Oversized pipes	Oversized pipes	Oversized pipes
			Underground tanks	Underground tanks	Underground tanks
	Disposal	Infiltration	Infiltration	Infiltration + Detention	Infiltration + Detention + Overflow
	Overflow	n/a	n/a	n/a	Existing overland flow path
Lots	Conveyance	Pipes	Pipes	Pipes	Existing overland flow path
		Slot drain	Slot drain	Slot drain	
		Surface drainage	Surface drainage	Surface drainage	
	Treatment	Filter Strip/semi pervious pavement (grass/pavement)	n/a	n/a	n/a
		Swale			
		Filter chamber			
	Detention	Underground storage tank combined with reuse tank	Underground storage tank combined with reuse tank	Underground storage tank combined with reuse tank	n/a
		Swale	Swale	Swale	
	Disposal	Infiltration	Infiltration	Infiltration	Infiltration + Overflow
	Overflow	n/a	n/a	n/a	Existing overland flow path

The recommended strategy also includes the following concepts:

- Compliance with the WRC Stormwater Management Guidelines
- Infiltration avoids significant concentrated (single lot or equivalent only)
- Oversized infiltration pits on each lot (or multiple pits) to ensure maintenance and performance contingencies
- Stormwater infrastructure is integrated into the development and landscaping design
- Plants are suitable for purpose (localised planting specification)
- Combination swales are used within the road reserve for Conveyance, Treatment, Detention and Disposal.
- The use of infiltration for up to and greater than the 10 year ARI to offset storage is considered further in the development of the design

8.1 Road Swale (conveyance, treatment, detention and disposal)

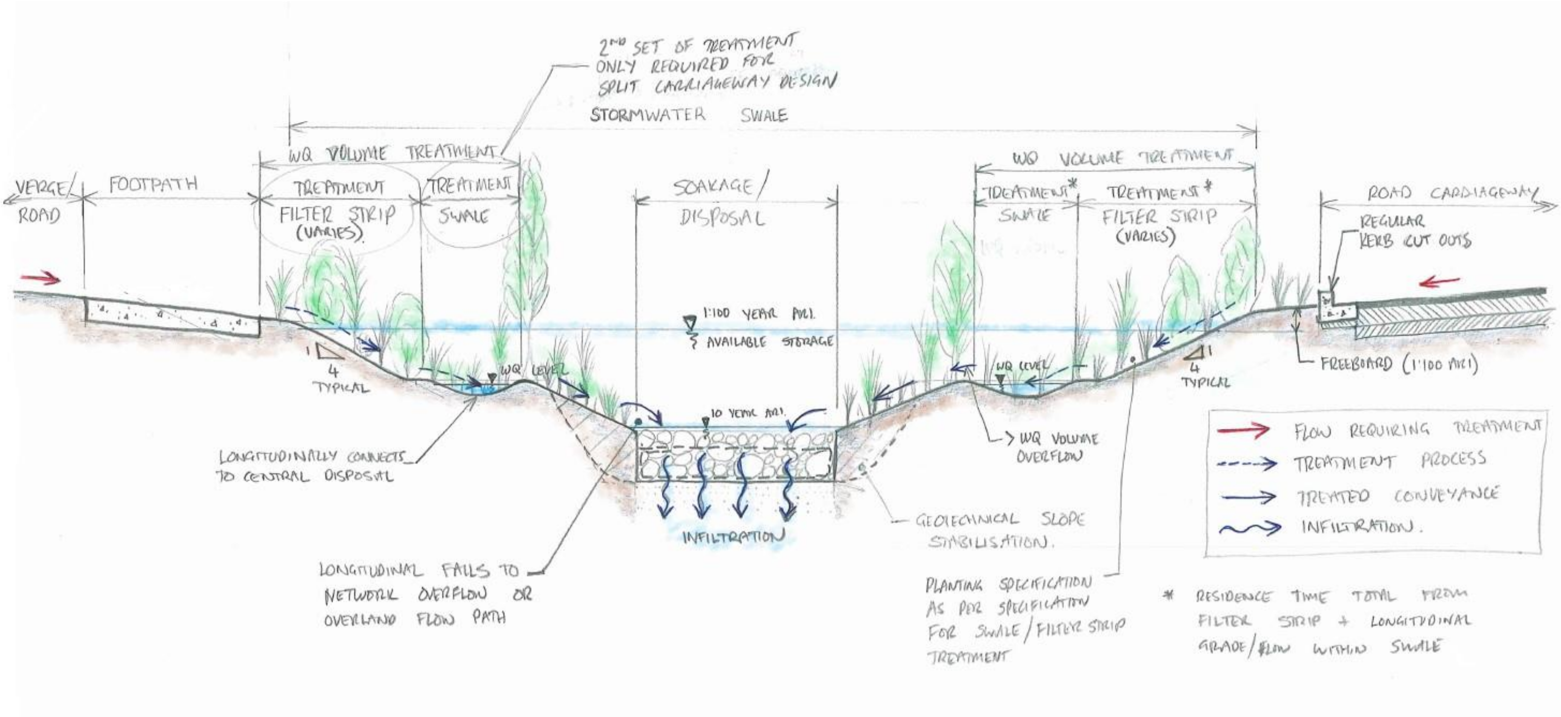


Figure 8-1 : Road stormwater management swale

8.1 On Lot Treatment, conveyance and detention

- Roof runoff contamination will be minimised by the use of non-contaminate loading materials.
- Driveway options include the use of semi-grass pavements to minimise the contaminated flows at the source. This paving type is shown in Figure 8-2. Standard concrete driveways are also an option but would require treatment devices to be installed and maintained (refer risk summary in section 10). It is proposed that the semi-grassed pavement will act as a filter-strip so no formal treatment device is required.


Figure 8-2 : Lot stormwater management (Driveway pavement)

8.2 Community Benefits

The recommended strategy aims to:

- Connect the community with Stormwater by utilising above ground conveyance, detention and treatment that can be seen.
- Connecting community with the natural environment by maximising green space and vegetation.
- Minimising impact to the environment through sustainable stormwater management practices.
- Reducing carbon footprint by utilising integrated stormwater management devices (road side swale) that undertake multiple functions (conveyance, detention, treatment and disposal) whilst minimise concrete and the construction effort which is likely to contribute significantly to development carbon footprint.

8.3 Conclusion

The modelling undertaken shows that maximising the use of infiltration, within Councils risk appetite in terms of pumice sand (Tomos), can provide a solution that aligns with WRC guidelines and provides good community outcomes. The modelling has shown that the are no major issues with the proposed development in regards to stormwater (meeting the pre-development flows). Further design work is required to ensure the recommended strategy will work within the developer’s parameters for the proposed development (i.e. space and layout).

9 Safety in Design Considerations

Safety in Design (WorkSafe 2015) requires the design to consider safety as part of the design process. Specific design elements for further safety in design consideration in subsequent design development are outlined below. It is envisaged that this report will be utilised as an initial template for development of the safety in design register. This will then lead into a full safety in design process through the design stages. A list of potential issues to be considered further are outlined below:

- Depth of pipes and manholes to be minimised (construction, maintenance and decommissioning)
- Flood areas to be minimised (operation/access)
- Geotechnical risks – slope stability
- Hydrogeology – ie Tomos - minimising concentrated infiltration areas by design.
- Hydrology – ie climate change predictions incorporated in the design model
- Maintenance considerations (ie access)
- Constructability considerations
- Communication plan (how will SiD considerations and decisions be communicated to contractors, operational staff and future users etc.

Stakeholder Consultation (PCBUs):

- Regional Council
- District Council
- Land owners
- Developer(s)
- Operations and Maintenance staff
- Engineers/designers
- Contractor(s)
- Local Iwi(s)
- Community (community associations and groups)

10 Development Risks

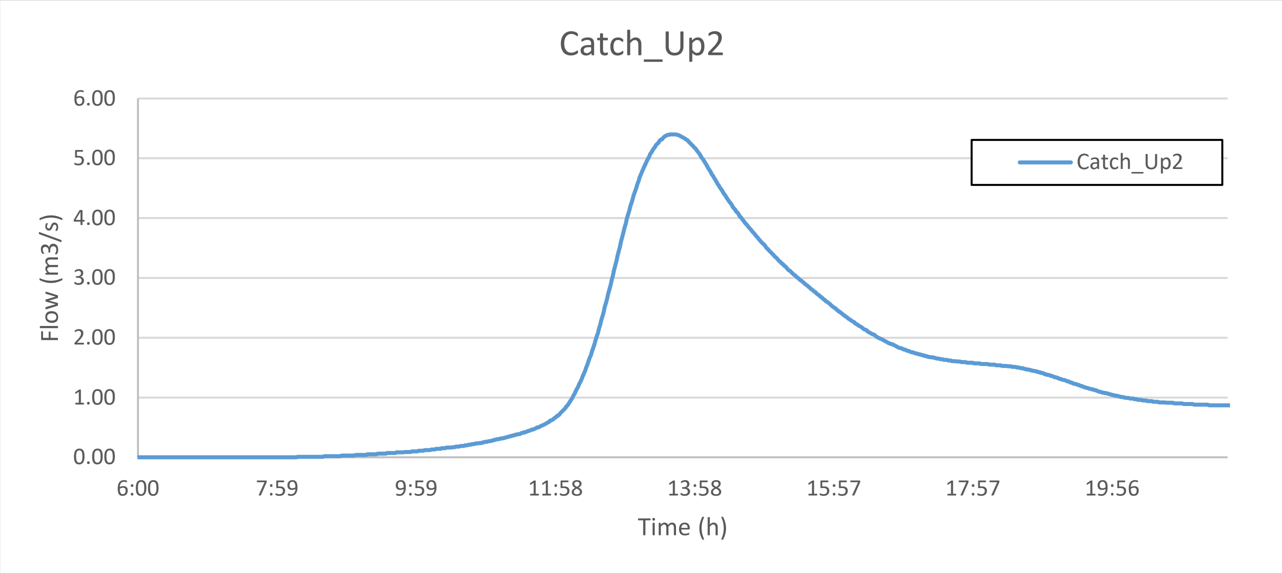
The following risk table outlines some high-level risks of the Nukuhau development in terms of storm water management (conveyance, detention, infiltration and treatment) and flood risk. This is not an extensive list of risks. It is envisaged that these risks will form an active risk register during the subsequent stages of development and be updated/revised throughout.

Table 10-1 : Risk Table

Item	Risk Category	Description
1	Hydrogeology (Tomo risk)	The sandy loam around Taupō provides excellent infiltration, however the associated Tomo issue is also common around the Taupō area. Further consideration is recommended. Specific investigations maybe required to enable quantification of this risk. Currently TDC have indicated they are comfortable with the strategy of on lot infiltration to ensure the infiltration is spread throughout the catchment and not concentrated.
2	Maintenance	Reliance on infiltration for stormwater disposal and to mitigate flood risk requires the infiltration/soakage pits to be maintained. Although TDC have maintenance procedures in place for the Road network, private land owners do not. Further discussion on how private infrastructure will be managed is highly recommended. Some options for further discussion include: - Requirements being placed on property via LIM reports/conditions - Council maintenance to include testing of private soakage pits - Council to allow private property stormwater to be management in the public stormwater system (this does not align with TDC policy)
3	Existing network capacity	Additional flows into the existing network reduce spare capacity in the system. Current system appears undersized for proposed development. Currently we are proposing to not utilise the existing network for conveyance of the design events.
4	Flood risk (>1% AEP)	Additional impervious areas increase flood risk in extreme events (greater than the design event). Currently we are proposing no increase in flood levels for the 1% AEP, however the additional impervious
5	Nitrogen banking	It is currently understood that the groundwater in this area is nitrogen rich. Discharging nitrogen rich groundwater to the lake could have environmental impacts. Currently aligning with the WRC guidelines is expected to minimise the nitrogen loading. Additional discussions/consideration maybe considered during subsequent stages.
6	Regional Council and District Council preferences not aligning	It is possible that the District Council and Regional Council preferences do not align on all aspects on the proposed plan change.

Appendix A Hydrographs from Sub-catchments

Existing, developed and developed with mitigation 1% AEP (2090)



Catch_Up2
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5.00
4.00
3.00
2.00
1.00
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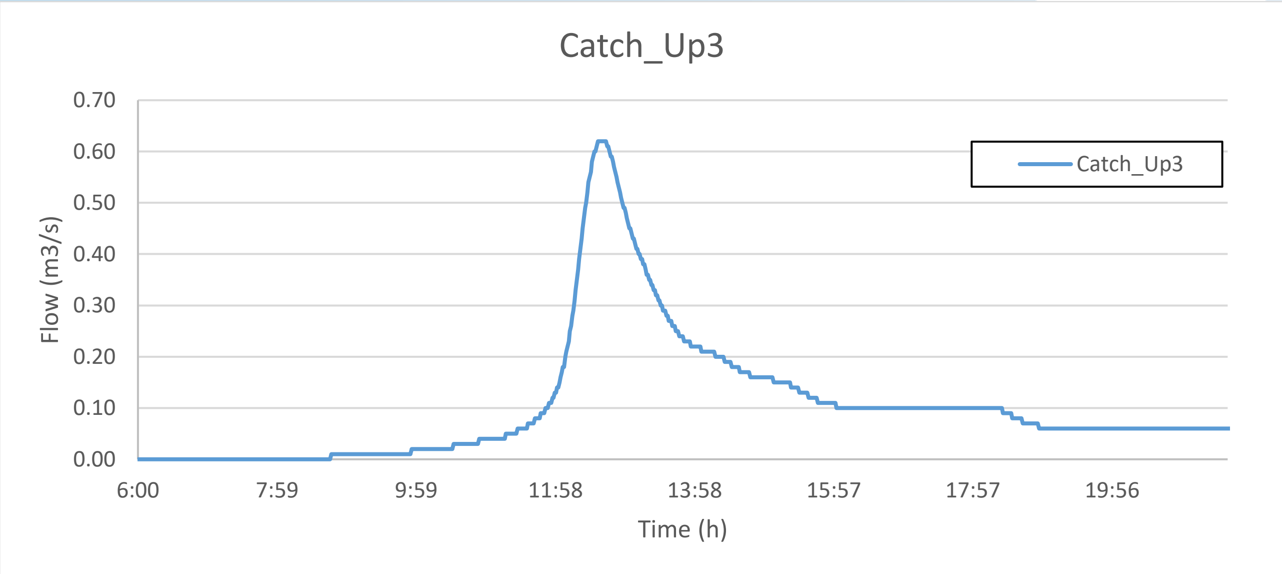
9:59
11:58
13:58
15:57
17:57
19:56
Time (h)
Catch_Up2



Catch_Up3
Flow (m3/s)
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0.40
0.30
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0.10
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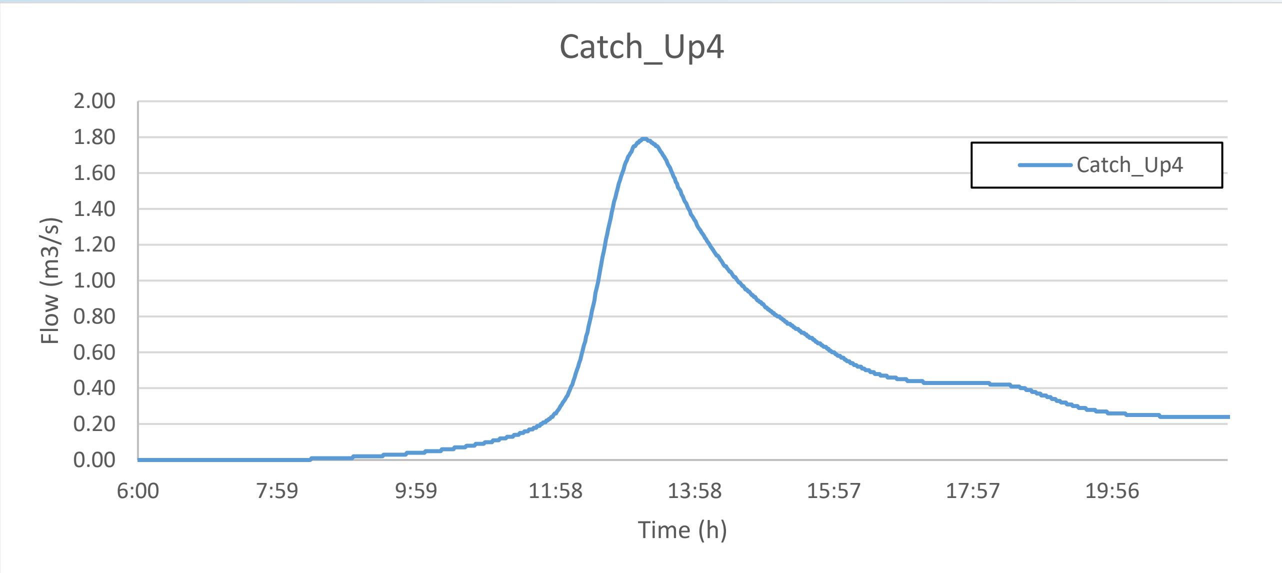
13:58
15:57
17:57
19:56
Time (h)
Catch_Up3



Catch_Up4
Flow (m3/s)
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1.20
1.00
0.80
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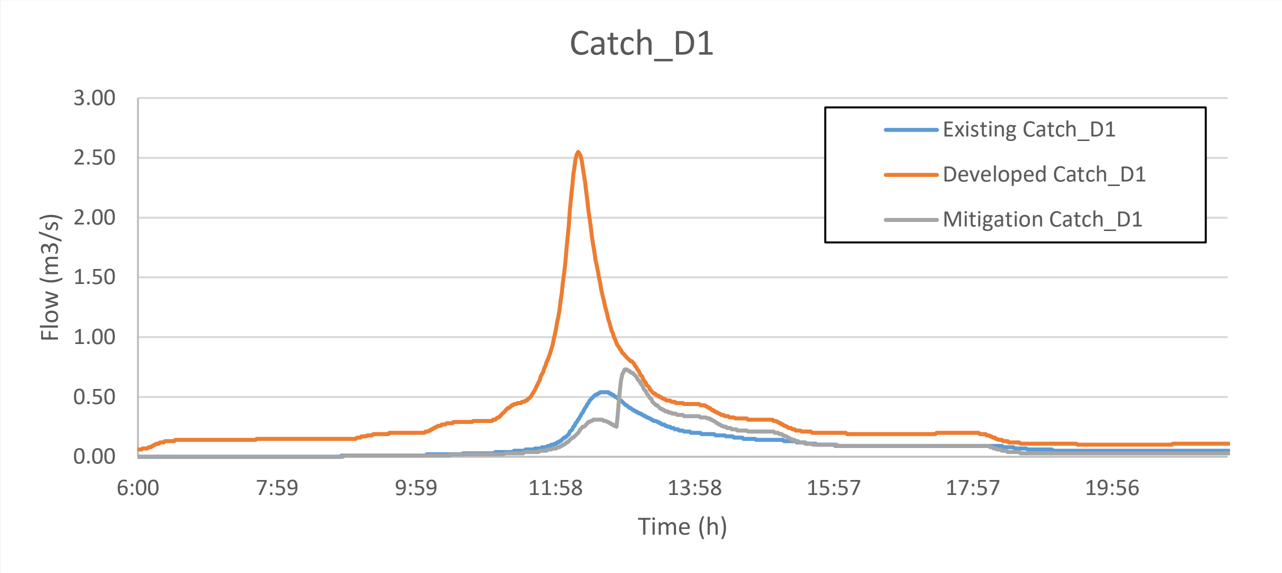
0.40
0.20
0.00
6:00
7:59
9:59
11:58
13:58
15:57
17:57
19:56
Time (h)
Catch_Up4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1.50
1.00
0.50
0.00
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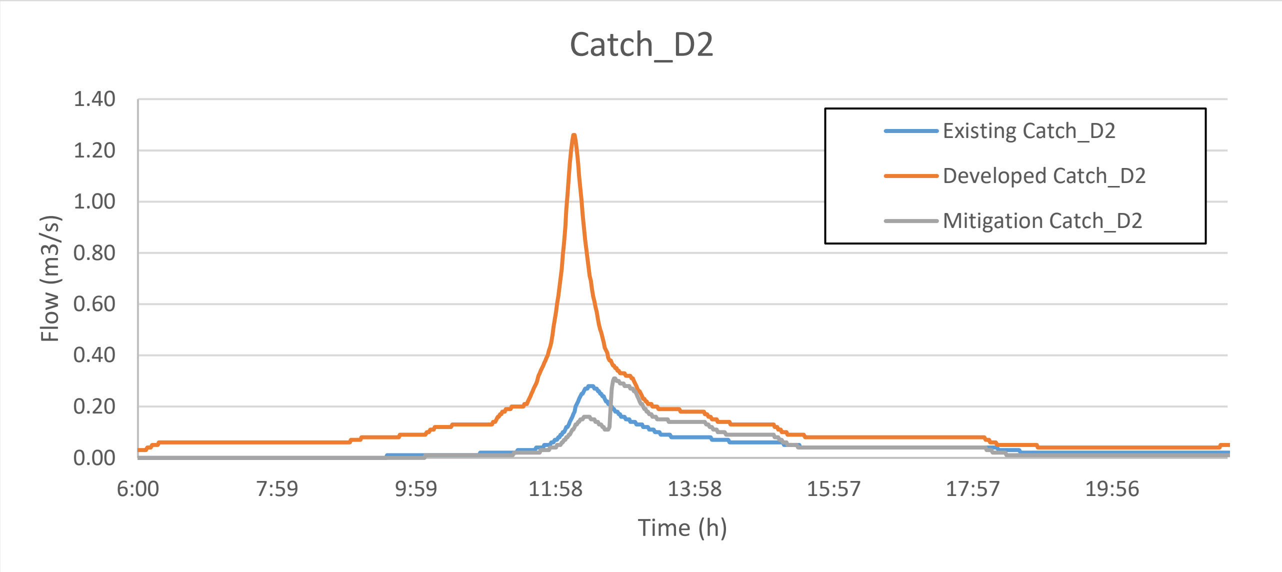
9:59
11:58
13:58
15:57
17:57
19:56
Time (h)
Existing Catch_D1
Developed Catch_D1
Mitigation Catch_D1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1.00
0.80
0.60
0.40
0.20
0.00
Flow (m3/s)
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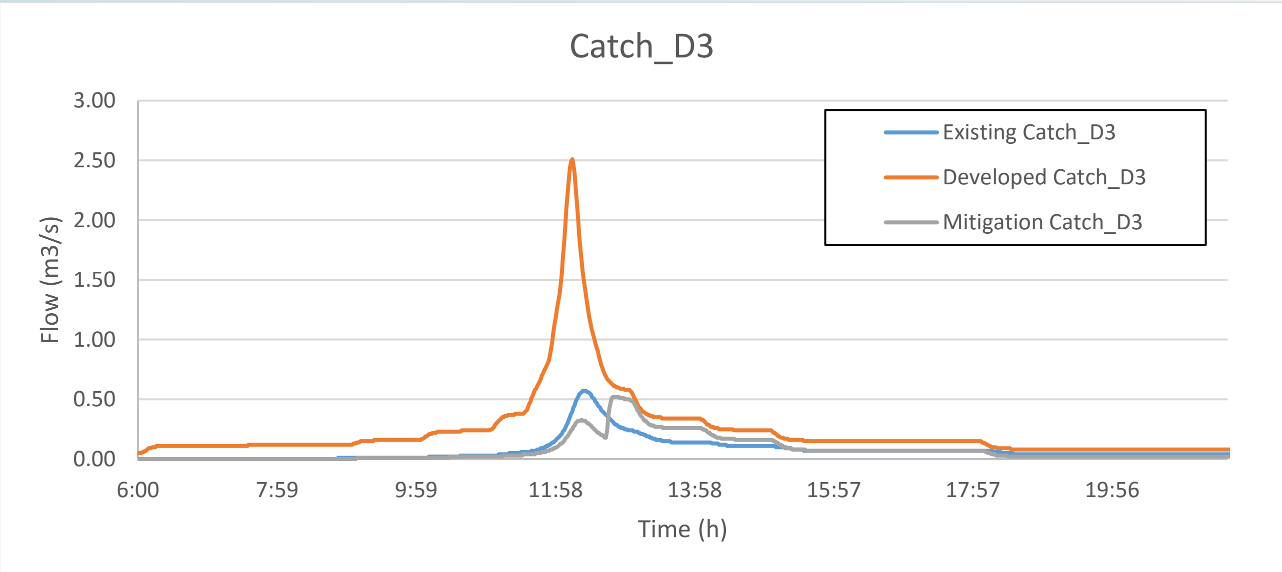
9:59
11:58
13:58
15:57
17:57
19:56
Time (h)
Existing Catch_D2
Developed Catch_D2
Mitigation Catch_D2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2.00
1.50
1.00
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0.00
Flow (m3/s)
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9:59
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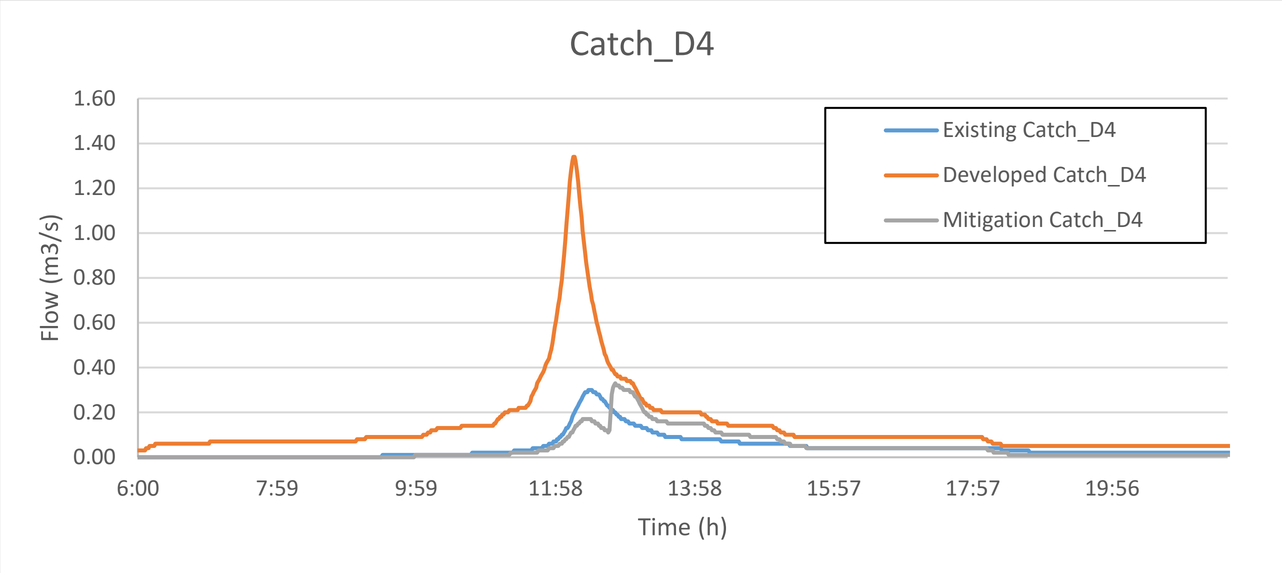
15:57
17:57
19:56
Time (h)
Existing Catch_D3
Developed Catch_D3
Mitigation Catch_D3


Catch_D4
Existing Catch_D4
Developed Catch_D4
Mitigation Catch_D4
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1.20
1.00
0.80
0.60
0.40
0.20
0.00
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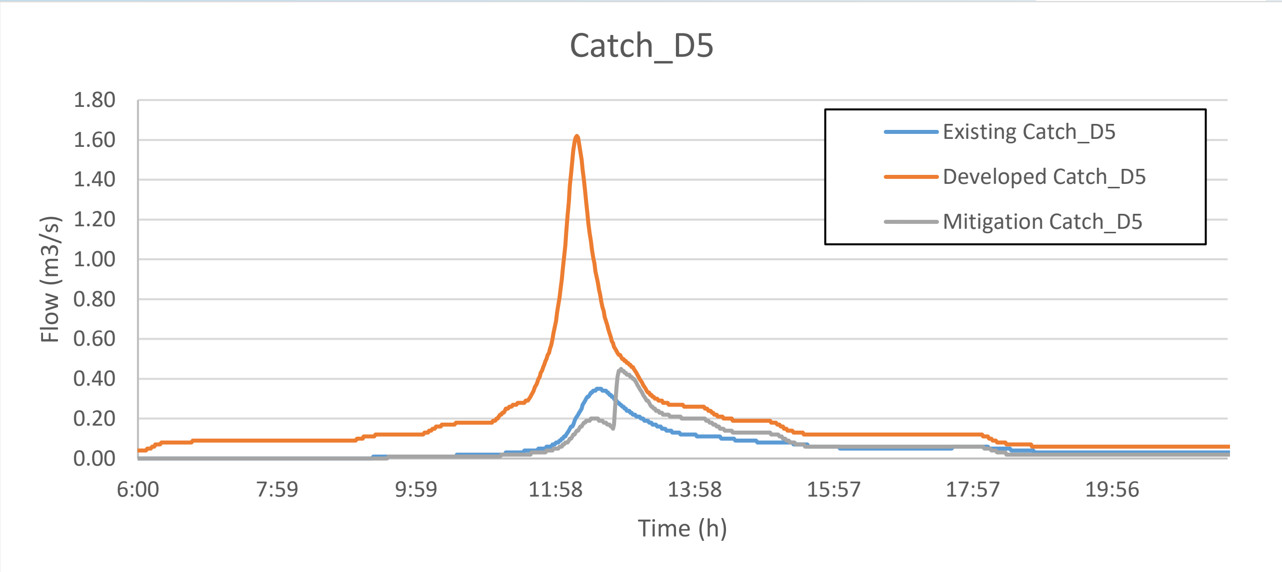
7:59
9:59
11:58
13:58
15:57
17:57
19:56
Time (h)


Catch_D5
Existing Catch_D5
Developed Catch_D5
Mitigation Catch_D5
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1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
6:00
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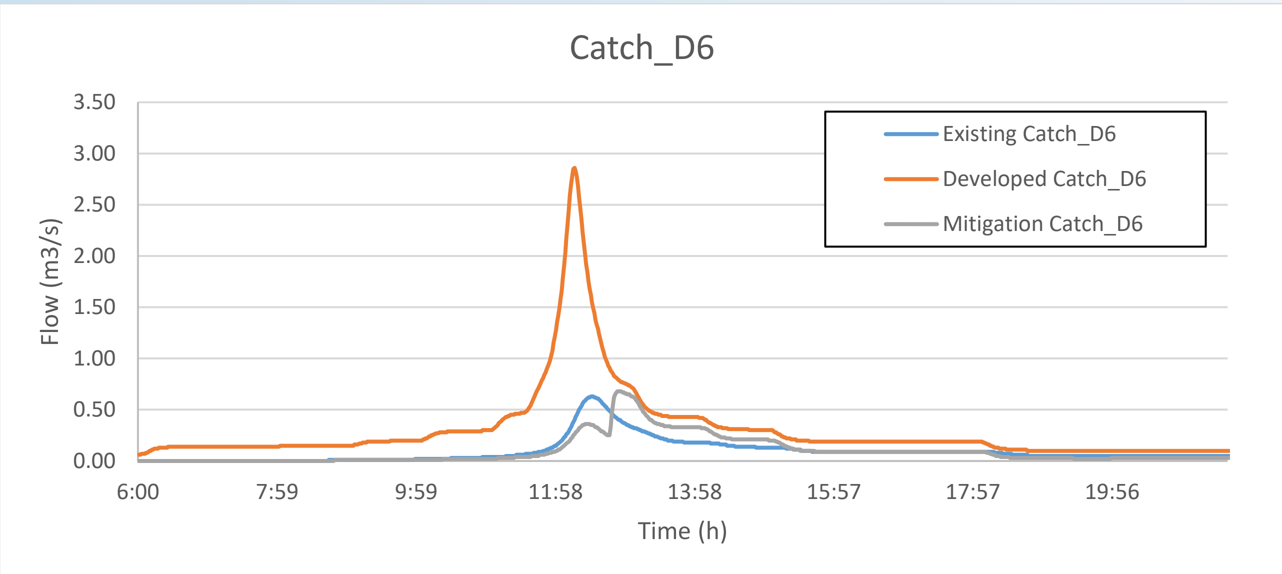
9:59
11:58
13:58
15:57
17:57
19:56
Time (h)


Catch_D6
Existing Catch_D6
Developed Catch_D6
Mitigation Catch_D6
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2.00
1.50
1.00
0.50
0.00
6:00
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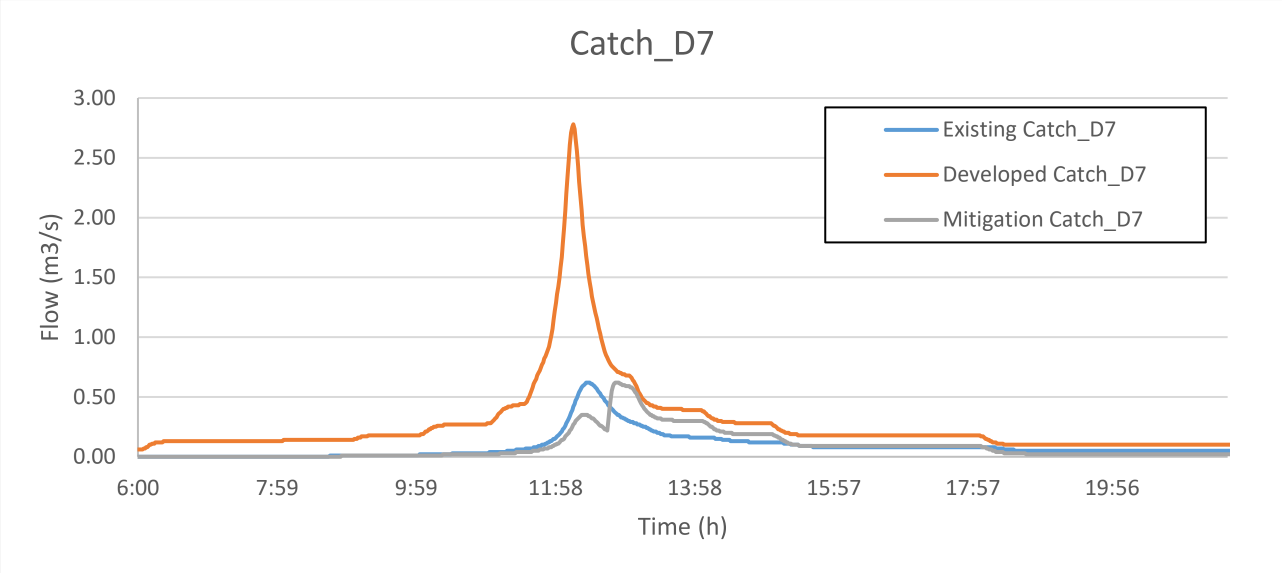
9:59
11:58
13:58
15:57
17:57
19:56
Time (h)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Flow (m3/s)
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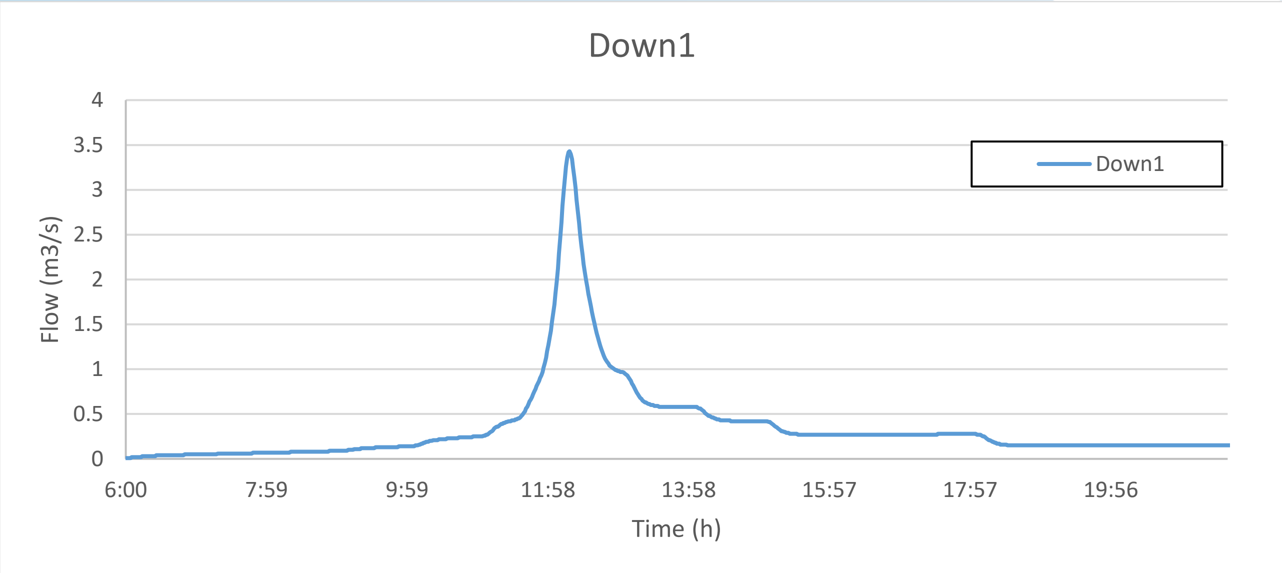
9:59
11:58
13:58
15:57
17:57
19:56
Time (h)
Existing Catch_D7
Developed Catch_D7
Mitigation Catch_D7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1.5
1
0.5
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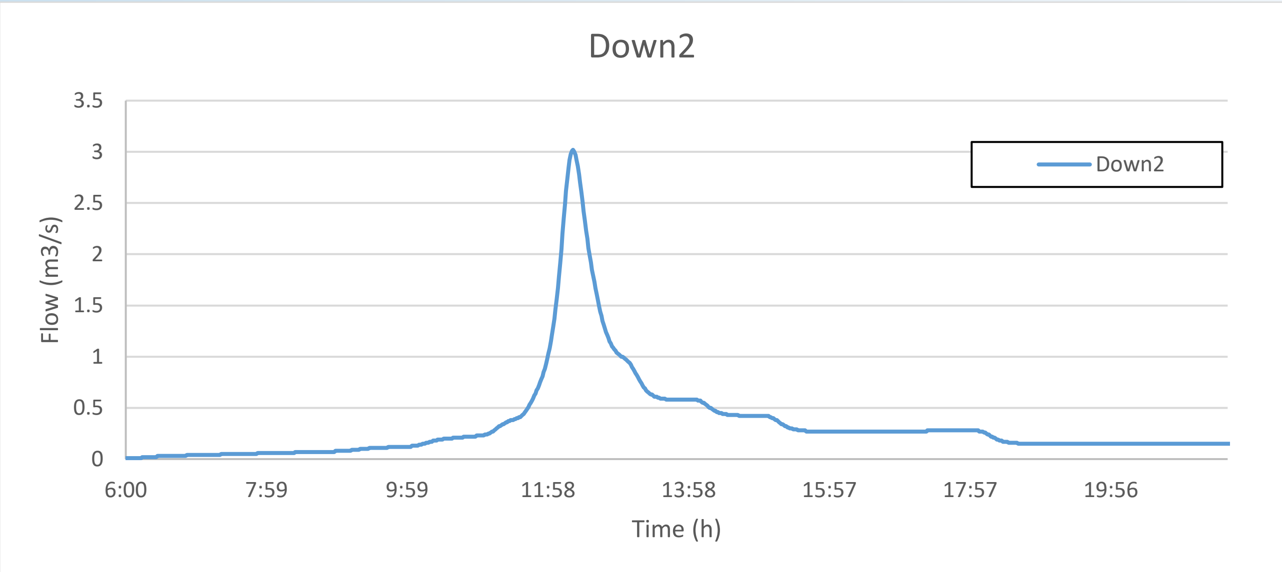
19:56
Time (h)
Down1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Flow (m3/s)
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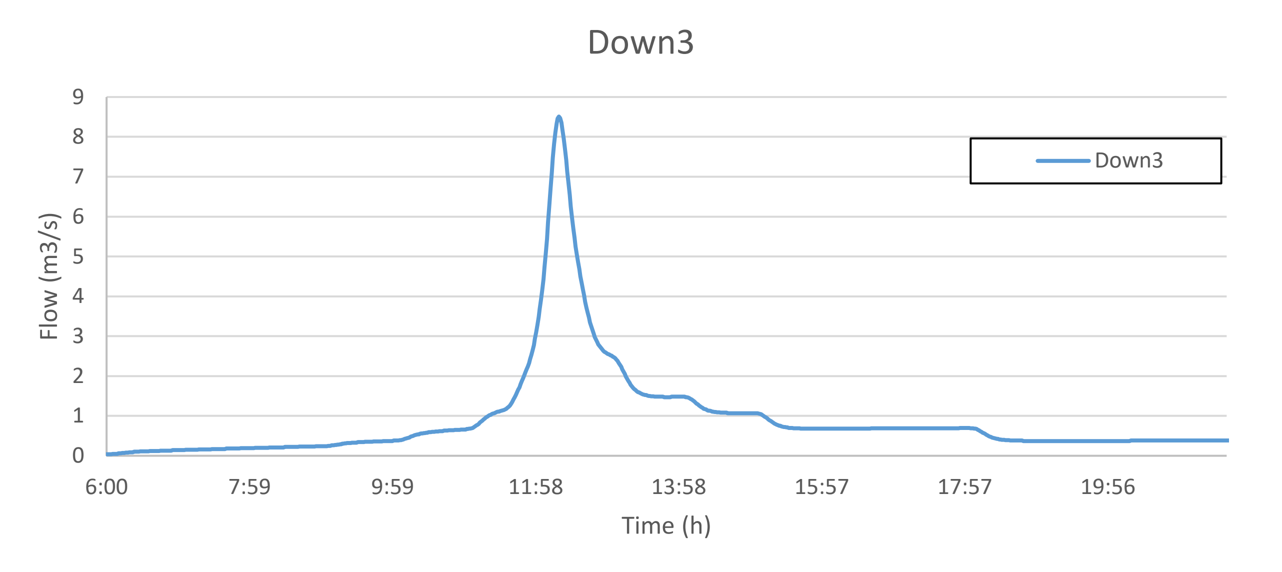
19:56
Time (h)
Down2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5
4
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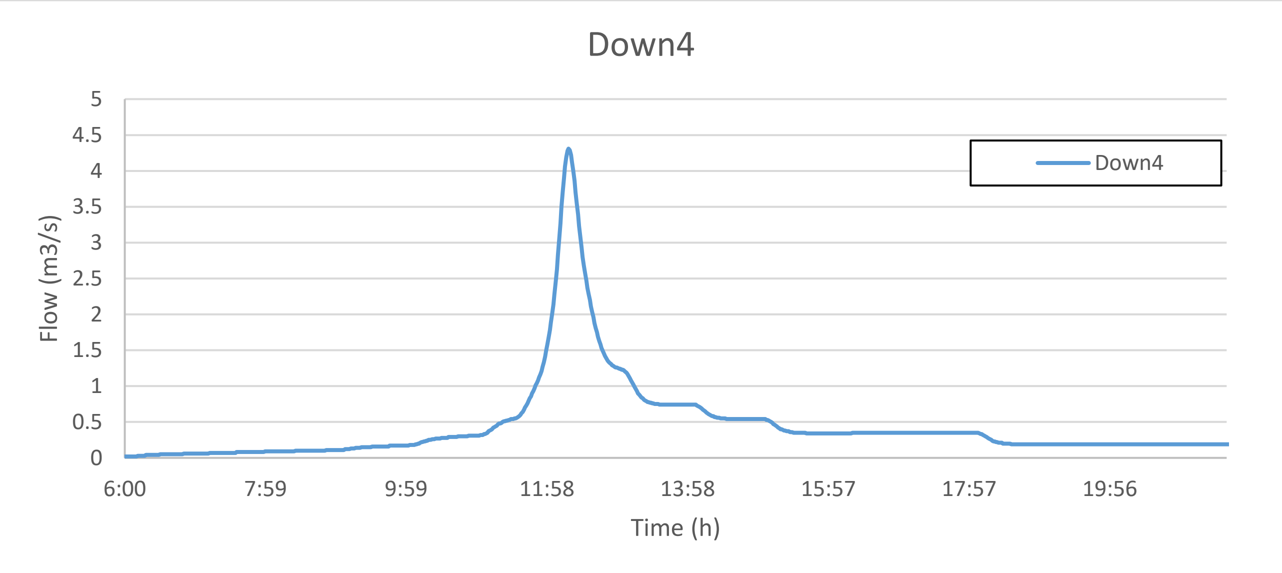
19:56
Time (h)
Down3


Down4
Flow (m3/s)
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1.5
1
0.5
0
6:00
7:59
9:59
11:58
13:58
15:57
17:57
19:56
Time (h)
Down4

Appendix B
Waikato Regional Council

Scoring Matrix

Matrix table with recommended strategy scores

Implementation elements	Typical components	Maximum Individual score	Scoring Matrix Values	Total Score for proposed concept
SC = Source control maximised (6 Points Minimum in the case of this develop)	Water re-use	0-4 depending on % of runoff capture	Flow detention only is 1 point.	
			Site use for garden watering is 2 points.	
			Site use for garden watering and for non-potable inside waters uses including laundry and toilets is 3 points.	
			Site use for full water supply is 4 points	
	Site disturbance reduced from a conventional development approach	0-3 depending on % of runoff capture	10 % reduction from a conventional development is 2 points.	2
			20% and greater reduction from conventional development is 3 points	
	Impervious surfaces reduced from a traditional approach	0-3 depending on % of runoff capture	5% reduction is 2 points.	2
			10% reduction is 3 points	
	Use of building or site materials that do not contaminate	0 or 1 for residential 0-3 for commercial or industrial	Residential roofs, gutters, down spouts made of non-contaminant leaching materials is 1 point.	1
			Commercial roof, gutters, down spouts made of non-contaminant leaching materials is 3 points	
	Existing streams and gullies located on site (including ephemeral) are protected and enhanced. The entire stream other than possible crossings shall be protected to qualify for points	0 or 3	Preservation and protection of natural streams and gullies is 3 points	2
	Riparian corridors are protected, enhanced or created	0-3	Riparian corridor protection scores depend on the width of corridor provided. 5 metres on either side of the stream is 1 point, 10 metres is 2 points and greater than 10 metres is 3 points	

	Protection and future preservation of existing native bush areas	0-2 depending on percentage of site area	Protection, preservation and, if needed, enhancement of native bush areas that exceed 10% of the site is given 2 points.	
LID stormwater device/practice used (6 Points Minimum)	Infiltration devices to reduce runoff volume	0-6 depending on % of runoff capture	Meeting the capture and infiltration requirements of the initial abstraction volume is given 2 points	
			Meeting the capture and infiltration requirements for the site water quality storm is given 3 points.	
			Meeting the capture and infiltration requirements for the 2-year ARI event for the site is given 6 points.	6
	Revegetation of open space areas as bush	0-3 depending on % of site covered	Planting open space and providing maintenance of planting for 3 years if open space is equal to or exceeds 10% of overall site area is given 3 points.	
	Bioretention	0-6 depending on % of runoff capture	Meeting the capture and retention requirements of the initial abstraction volume is given 2 points.	
			Meeting the capture and retention requirements for the site water quality storm is given 3 points.	
			Meeting the capture and retention requirements for the 2-year storm for the site is given 6 points.	
	Swales and filter strips	0-3 depending on % of runoff capture	All impervious surfaces draining to swales and filter strips that have capacity for conveying the water quality event is given 2 points.	
			All impervious surfaces draining to swales and filter strips that have capacity for conveying the 2-year ARI event is given 3 points.	
	Tree pits	0-6 depending on % of runoff capture		
TM = Traditional mitigation	Constructed wetlands	0-4 depending on % of runoff capture	Meeting the water quality design storm criteria is given 2 points.	
			Meeting extended detention and peak control requirements is given an additional 2 points. (this could be removed).	

	Wet ponds	0-1 depending on % of runoff capture	Use of a wet pond for stormwater quantity control and stream channel protection is 1 point.	
	Innovative devices	0-1 depending on % of runoff capture	Meeting water quality requirements using council accepted devices is given 1 point.	1
	Detention ponds (normally dry)	0	As this device provides negligible water quality benefit use of the device for quantity control is 0 points.	
UD = Urban design	Stormwater management is designed to be an integral and well considered part of the urban design	0-2	Stormwater management is designed to be an integral and well considered part of the urban design is 2 points.	2
Total Score = 15 for recommended option				Minimum = 15 Recommended = 21
Highly recommended				
Recommended				
Not investigated in this report				

Appendix C
Flood Maps and flood depth impacts

Existing, developed and developed with mitigation 1% AEP (2090)

Appendix D
Calculations

Generic infiltration device design and calculations for house lots and road sections

Project	Nukahau - Houses	Job No.	2-37400.00	Phase	0
Location	Taupo	Calculated by	RJG	Date	28-Nov-19
Developed or existing	1 developed House	Verified by	AB	Date	14/12/2019
Calculate curve number and catchment characteristics					
Soil name and classification	**Cover description**	**Curve Number CN**	**Area (ha) impervious**	**Area (ha) pervious**	**Product of CN * area**
Impervious	Impervious Surfaces	98	0.0250		2
A	Fiar - Grass	35		0.0	0
A	Well Drained - Bush	49		0.0	0
C	Poorly drained - Grass	70		0.0	0
C	Poorly Drained - Bush	79		0.0	0
		TOTALS	0.025	0.000	2
		Total area (ha)	**0.025**	**Total area (km^2)**	**0.00025**
		Weighted CN			**98.0**
Initial abstraction	5	**I_a (weighted) (mm)**			**0.3**
Storage				**S (mm)**	**5**
Channel characteristics					
Channelisation factor (natural = 1, engineered grass = 0.8, concrete = 0.6)					0.60
Catchment length along main channel (km)					0.10
Catchment slope (using equal areas method - refer slope worksheet)					1.00%
Time of Concentration				**t_c (hours)**	**0.170**
				scs lag time	**0.113**
Flood peak and volume calculation		**Storm 1**	**Storm 2**	**Storm 3**	**Storm 4**
Select A R I (years) or A E P (%)		2 Year	2 Year CC	5 Year	5 Year CC
Read 24 hour rainfall depth for that recurrence interval (mm)		67	73	87	96
c*		0.865	0.874	0.892	0.902
Read q* from chart		0.1629	0.1632	0.1638	0.1641
Peak Flow rate (m^3/s)		**0.0**	**0.0**	**0.0**	**0.0**
Runoff depth (mm)		**62**	**68**	**81**	**91**

Project	**Nukahau - Roads**	Job No.	2-37400.00	Phase	0
Location	Taupo	Calculated by	RJG	Date	28-Nov-19
Developed or existing	100m of Road (20m width) -70% impervious	Verified by	AB	Date	14/12/2019
Calculate curve number and catchment characteristics					
Soil name and classification	Cover description	Curve Number CN	Area (ha) impervious	Area (ha) pervious	Product of CN * area
Impervious	Impervious Surfaces	98	0.014		1
A	Fiar - Grass	39		0.006	0
A	Well Drained - Bush	49		0.0	0
C	Poorly drained - Grass	70		0.0	0
C	Poorly Drained - Bush	79		0.0	0
		TOTALS	0.014	0.006	2
		Total area (ha)	0.020	Total area (km^2)	0.00020
		Weighted CN			80.3
Initial abstraction	5	I_a (weighted) (mm)			3.2
Storage				S (mm)	62
Channel characteristics					
Channelisation factor (natural = 1, engineered grass = 0.8, concrete = 0.6)					0.60
Catchment length along main channel (km)					0.10
Catchment slope (using equal areas method - refer slope worksheet)					1.00%
Time of Concentration				t_c (hours)	0.170
				scs lag time	0.113
Flood peak and volume calculation		Storm 1	Storm 2	Storm 3	Storm 4
Select A R I (years) or A E P (%)		2 Year	2 Year CC	5 Year	5 Year CC
Read 24 hour rainfall depth for that recurrence interval (mm)		67	73	87	96
c*		0.326	0.348	0.391	0.419
Read q* from chart		0.0909	0.0955	0.1050	0.1104
Peak Flow rate (m^3/s)		**0.0**	**0.0**	**0.0**	**0.0**
Runoff depth (mm)		**32**	**37**	**48**	**56**

GENERIC DESIGN FOR INFILTRATION DEVICES - HOUSE

Sumary			
Event	Surface Area (m2)	Device Volume (m3)	Device Depth (m)
2yr	3.4	6.5	1.9
10yr	5.5	10.8	1.9
100yr	9.2	18.4	2.0

- Summary for a 250 m2 house. Roof 100% impervious.
- Infiltration rate suppose to be 210 mm/h (SAND) with Loamy sand the volume increases quite a lot

1) **Rainfall=**

2yr C.C. Rainfall depth (mm)= 73
10yr C.C. Rainfall depth (mm)= 114
100yr C.C. Rainfall depth (mm)= 185

2) **Volume=**

2yr C.C. V= 17 m3
10yr C.C. V= 27 m3
100yr C.C. V 45 m3

3) **Device Surface Area=**

Infiltration Rate= 210 mm/h

$$A_s = \frac{WQV}{(f_d)(i)(t)-p}$$

As 2yr= **3.4** m2
As 10yr= **5.5** m2
As 100yr= **9.2** m2

dmax= **14.4** m

$$d_{max} = f_d({}^{t}/_{V_r})$$

Where:
d_{max} = Maximum depth of trench
f_d = Infiltration rate (m/hr)
t = Time to drain from full condition (hours)

A_s = surface area of the trench (m^2)
WQV = water quality volume (m^3)
f_d = infiltration rate (m/hr) - rate reduced by ½ from measured
i = hydraulic gradient (m/m) - assumed to be 1
t = time to drain from full condition (hours) - maximum time 48 hours.
p = rainfall depth for water quality storm (m)

4) **Device Volume= (Storage from 37% of the volume)**

V 2yr= **6.5** m3
V 10yr= **10.8** m3
V 100yr= **18.4** m3

$$V = WQV + p({}^{A_s}/_{V_r})$$

Where:
V = Device volume with any aggregate added

Table 8-8: Infiltration rate for various soil textural classes

Texture Class	Approximate Infiltration Rate in mm/hour
Sand	210
Loamy sand	61
Sandy loam	26
Silt loam	13
Sandy clay loam	7
Clay loam	4.5
Silty clay loam	2.5
Sandy clay	1.5
Silty clay	1.3
Clay	1.0
	0.5

5) **Device depth and compare with maximum depth:**

V/A 2yr= **1.9** m Acceptable
V/A 10yr= **1.9** m Acceptable
V/A 100yr= **2.0** m Acceptable

V/A_s = depth of trench (d)
If $d < d_{max}$ the design is adequate. If $d > d_{max}$ then the surface area must be increased and depth decreased.

GENERIC DESIGN FOR INFILTRATION DEVICES - ROAD

1) **Rainfall=**

2yr C.C. Rainfall depth (mm)=	73
10yr C.C. Rainfall depth (mm)=	114
100yr C.C. Rainfall depth (mm)=	185

2) **Volume=**

2yr C.C. V=	7	m3
10yr C.C. V=	14	m3
100yr C.C. V	27	m3

3) **Device Surface Area=**

Infiltration Rate= 210 mm/h

$$A_s = \frac{WQV}{(f_d)(i)(t)-p}$$

As 2yr=	**1.5**	m2
As 10yr=	**2.9**	m2
As 100yr=	**5.6**	m2
dmax=	**14.4**	m

$$d_{max} = f_d(t/V_r)$$

Where:

d_{max} = Maximum depth of trench
f_d = Infiltration rate (m/hr)
t = Time to drain from full condition (hours)

A_s = surface area of the trench (m^2)
WQV = water quality volume (m^3)
f_d = infiltration rate (m/hr) - rate reduced by ½ from measured
i = hydraulic gradient (m/m) - assumed to be 1
t = time to drain from full condition (hours) - maximum time 48 hours.
p = rainfall depth for water quality storm (m)

4) **Device Volume= (Storage from 37% of the volume)**

V 2yr=	**2.8**	m3
V 10yr=	**5.6**	m3
V 100yr=	**11.1**	m3

$$V = WQV + p(A_s/V_r)$$

Where:

V = Device volume with any aggregate added

5) **Device depth and compare with maximum depth:**

V/A 2yr=	**1.9**	m	Acceptable
V/A 10yr=	**1.9**	m	Acceptable
V/A 100yr=	**2.0**	m	Acceptable

V/A_s = depth of trench (d)
If $d < d_{max}$ the design is adequate. If $d > d_{max}$ then the surface area must be increased and depth decreased.

Sumary			
Event	Surface Area (m2)	Device Volume (m3)	Device Depth (m)
2yr	1.5	2.8	1.9
10yr	2.9	5.6	1.9
100yr	5.6	11.1	2.0

- Summary for 100m.l. of road (20m width) and considering 70 % impervious.
- Runoff from roads needs treatment before infiltration.
- Infiltration rate suppose to be 210 mm/h (SAND) with Loamy sand the volume

Table 8-8: Infiltration rate for various soil textural classes

Texture Class	Approximate Infiltration Rate in mm/hour
Sand	210
Loamy sand	61
Sandy loam	26
Silt loam	13
Sandy clay loam	7
Clay loam	4.5
Silty clay loam	2.5
Sandy clay	1.5
Silty clay	1.3
Clay	1.0
	0.5

Table 5-2: Runoff curve numbers for most urban and rural lands[18]

Cover description					
Cover type and hydrologic condition	Hydrologic condition	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, reserves, etc.)					
Condition (grass cover < 50%)	Poor	68	79	86	89
Fair condition (grass cover 50%-75%)	Fair	49	69	79	84
Good condition (grass cover >75%)	Good	39	61	74	80
Impervious areas					
Paved parking lots, roofs, driveways, etc.		98	98	98	98
Streets and roads*					
Paved; kerbing and catchpits (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Pasture, grassland, or range – continuous forage for grazing	Poor Fair Good	68 49 39	79 69 61	86 79 74	89 84 80
Straight row crops	Poor Good	72 67	81 78	88 85	91 89+
Bush – bush-weed-grass mixture with bush being the major element	Poor Fair Good	48 35 30	67 56 48	77 70 65	83 77 73
Bush – grass combination (orchard or tree farm)	Poor Fair Good	57 43 32	73 65 58	82 76 72	86 82 79
Bush**	Poor Fair Good	45 36 30	66 60 55	77 73 70	83 79 77
Farmsteads – buildings, lanes, driveways, and surrounding lots		59	74	82	86

* As calculations for runoff volumes are undertaken separately for pervious and impervious areas, the generalised curve numbers incorporating pervious and impervious surfaces provided by NRCS are not included in the table.

Some of the cultivated agricultural land categories are not included and Table 2-2b of Technical Release No. 55 should be referred to which is located in Appendix A.

** Bush condition:

Poor: forest litter, small trees, and bush are destroyed by heavy grazing or regular burning
Fair: woods are grazed but not burned, and some forest litter covers the soil
Good: woods are protected from grazing, and litter and bush adequately cover the soil

Table 5-1: Initial abstraction values for runoff curve numbers

Curve number	I_a (mm)	Curve number	I_a (mm)	Curve number	I_a (mm)
40	19.0	60	8.5	80	3.2
41	18.3	61	8.1	81	3.0
42	17.5	62	7.8	82	2.8
43	16.8	63	7.5	83	2.6
44	16.2	64	7.1	84	2.4
45	15.5	65	6.8	85	2.2
46	14.9	66	6.5	86	2.1
47	14.3	67	6.3	87	1.9
48	13.8	68	6.0	88	1.7
49	13.2	69	5.7	89	1.6
50	12.7	70	5.4	90	1.4
51	12.2	71	5.2	91	1.3
52	11.7	72	4.9	92	1.1
53	11.3	73	4.7	93	1.0
54	10.8	74	4.5	94	0.8
55	10.4	75	4.2	95	0.7
56	10.0	76	4.0	96	0.5
57	9.6	77	3.8	97	0.4
58	9.2	78	3.6	98	0.3
59	8.8	79	3.4		

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