DEVELOPMENT OF MULTI-CATCHMENT FLOOD REDUCTION ALTERNATIVES IN AUCKLAND

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ABSTRACT

Auckland faces major stormwater drainage issues including flooding, growth pressures and ageing infrastructure. Historically, stormwater management within the Auckland City isthmus has been undertaken on a catchment-by-catchment basis. Development of multi-catchment solutions to address existing and future drainage issues requires a shift from the individual stormwater catchment management approach. A major strategic objective is to protect all habitable floors from flooding in a 50 year average recurrence interval (ARI) event by 2043 and as a significant portion of the City relies on soakage for the primary stormwater disposal method, this will be difficult to achieve without consideration of crossing drainage basin divides. Some of these soakage catchments are centrally located within the City and are closed basins. A GIS-based City-wide flood map was developed as a tool to investigate potential, holistic, multi-catchment stormwater solutions. The mapping effort included compilation of known flooding problems and complaints, field observations, flood hazard mapping results, soakage potential, planned and conceptual improvements, and other available information. Stormwater flows and initial pipe sizes were based on a simplified and verified design storm flow calculator which provides the ability to assess at a strategic level what flood protection can be achieved.

KEYWORDS

stormwater, flooding, regional, catchment, management, modelling, mapping

PRESENTER PROFILE

Paul Miselis is a Principal Engineer with the Three Waters Team at Maunsell AECOM in Auckland. He joined Maunsell AECOM after working for 17 years in the United States with watershed management. Paul also has expertise in stormwater treatment alternatives analysis, flood risk assessments and wetland and stream restoration design.

Xeno Captain started his career in 1979 at Auckland City in the Drainage Design Office and when Metrowater was formed in 1997, Xeno took over the management of the drainage networks across the city. He is presently involved with management of City-wide Flood Hazard Mapping efforts and flood mitigation studies.

1 INTRODUCTION

Auckland City faces major stormwater drainage issues including flooding, growth pressures and ageing infrastructure. Historically, stormwater management within the Auckland City isthmus has been undertaken on a catchment-by-catchment basis with narrowly-focused solutions to stormwater and flooding problems. Development of City-wide solutions to address existing and future drainage issues requires a shift from the individual stormwater catchment management approach. For example, approximately 40% of the City relies on soakage for the primary stormwater disposal method, but some of these soakage catchments are closed (landlocked) basins, centrally located within the City and have no natural overland flow path to the sea for drainage. A major strategic objective is to protect all habitable floors from flooding in a 50-year Average Recurrence Interval (ARI) event by the year 2043, which will be difficult to achieve without consideration of crossing drainage basin divides.

The primary objective of this project is to develop an up-to-date understanding of City-wide stormwater flooding issues and how these issues can be addressed through regional solutions. This project is divided into four main components. Key outputs include: (1) the compilation and a high-level audit of existing flood-related information; (2) the construction of a City-wide stormwater flooding issues map; (3) the development of a planning-level design storm flow calculator to calculate flows from large catchments, and (4) an initial assessment of potential regional stormwater solutions. Originally, this project was intended to be undertaken in a stepwise fashion; however, each task of the project contributes to the comprehensive nature of the other components. For example, a data audit could not be completed without production of various components of a flood issues map, and potential regional stormwater solutions could not be assessed without the design storm flow calculator.

A GIS-based City-wide flood issues map was developed as a tool to identify existing flooding problems and to investigate potential holistic, multi-catchment stormwater solutions. In doing so, a number of potential single-catchment flood relief solutions were also identified. The flood issues mapping effort included compilation of known flooding problems, stormwater and wastewater complaints, overflow data, catchment-level flood hazard mapping results, aquifer data, soakage potential, topographic data, stormwater networks, and other available information. Related reports, such as Drainage Strategic Plans (DSP), Asset Management Plans (AMP) and studies on soakage alternatives, catchpit design and roadway contaminant removal options, were also consulted to assist with the development of the City-wide flood issues map. Compilation and review of the existing information was done to identify where significant data gaps exist.

A spreadsheet-based stormwater design storm flow calculator was developed and empirically adjusted specifically for Auckland catchments. The calculator was used to generate preliminary estimates of pipe sizes needed to drain stormwater flows away from specific catchments and to quickly check if certain existing conveyances are adequately sized to accommodated expected flows for a given storm event.

The City-wide flood issues map and the design storm flow calculator are tools that can be used to assess at a strategic level what flood protection can be achieved. These tools were used to identify a number of potential concept-level flood relief alternatives. Alternatives initially considered multi-catchment scenarios across the City but during their development, a number of single-catchment solutions were also identified. In some cases, multi-catchment solutions did not appear to be practicable, and so only single-catchment solutions were considered. This is often the case for flood hazard areas located near the downstream limits of catchments.

Typical multi-catchment solutions consist of constructing a network of inlets (or utilising existing networks) to collect the stormwater from flood problem areas and route it through new stormwater pipes or tunnels to discharge at either Manukau or Waitemata Harbour. Multi-catchment options are especially attractive for centrally-located Drainage Management Areas such as Epsom, Ellerslie, Oakley, parts of Meola and the northern reaches of Mt. Wellington South.

A number of mapped flood hazard areas are located upstream of drainage networks that throttle down from larger pipes into smaller pipes or where pipes may be undersized for the expected flows. Accordingly, stormwater solutions also include investigations of the existing stormwater network to identify choke points and constrictions in the drainage system.

Opportunities for creation of flood detention areas and restoration of floodplain storage capacity are identified. This concept is especially applicable in areas adjacent to existing open channels, streams and wetlands. Additional storage can also be created within select existing reserves near flood hazard areas. DMAs with such opportunities include Ellerslie, Meola, Avondale, Oakley, and Glendowie. The combination of increased flood storage capacity with better drainage can reduce flood potential.

Areas where additional efforts are needed to refine viable solutions are identified. When designing any stormwater solution, in particular multi-catchment solution, care must be taken to avoid solving one flood issue by displacing it into another area.

2 FLOOD HAZARD MAPPING IN AUCKLAND

2.1 BACKGROUND

Auckland City Council has a responsibility under both the Resource Management Act 1991 (RMA) and the Building Act 1991 to avoid, remedy and mitigate flood hazards. A flood hazard is one or a combination of the following aspects:

- Flood water depth;
- High velocity overland flow; and
- Flood water contaminated by wastewater.

Historically, stormwater management and flooding issues within the City of Auckland have been addressed on a single-catchment basis. Doing so provided a good assessment of potential flood hazards within a specific area; however, regional solutions to flood problems become obscured when viewed from a narrowly-focused local perspective.

The City of Auckland isthmus has been divided into 38 Drainage Management Areas (DMA) based mainly on stormwater catchment delineations. The Integrated Catchment Study (ICS) Programme further grouped the DMAs into five ICS Areas. Figure 1 shows the locations of the DMAs and the ICS Areas. The DMAs are outlined in red and the ICS Areas are outlined in black. The DMA abbreviations and their full names are listed in Table 1. ICS Areas are listed in Table 2.

To date, three main rounds of flood hazard mapping have been conducted across the Auckland isthmus and in parts of Waiheke Island. Specifically, they are:

- Pre-Integrated Catchment Study (Pre-ICS) flood mapping (Type A and B flood areas);
- ICS flood hazard mapping (FHM); and
- Post-ICS flood hazard mapping.

Summaries of each the three flood mapping efforts follow. Although conducted across the City, these mapping efforts were focused on single stormwater catchments and to date, most flood relief alternatives have been similarly focused on single-catchment solutions. Some flood hazard maps have not been completed, and those that have been finished will require periodic updates as stormwater infrastructure is replaced, upgraded or added, or when new asset information is obtained.

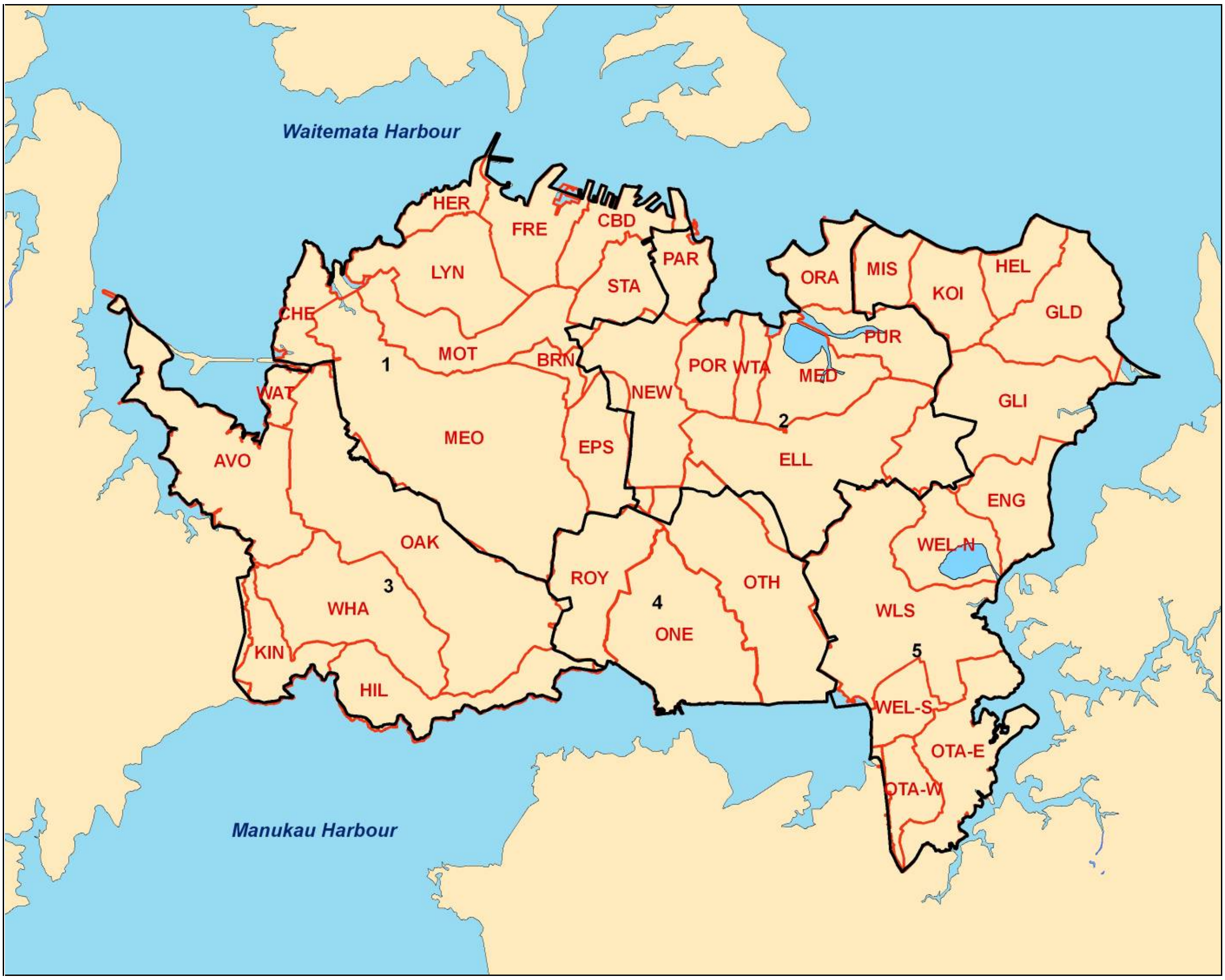

Figure 1: Auckland Drainage Management Areas and ICS Areas

Table 1: Drainage Management Areas within Auckland

No.	DMA / Catchment	Catchment Identification	No.	DMA / Catchment	Catchment Identification
1	Avondale	AVO	20	Motions	MOT
2	Brentwood Avenue	BRN	21	Newmarket	NEW
3	Central Business District	CBD	22	Oakley	OAK
4	Point Chevalier	CHE	23	Onehunga	ONE
5	Ellerslie / Waiatarua	ELL	24	Orakei	ORA
6	Point England	ENG	25	Otahuhu East	OTA-E
7	Epsom	EPS	26	Otahuhu West	OTA-W
8	Freemans Bay	FRE	27	One Tree Hill	OTH
9	Glendowie	GLD	28	Parnell	PAR
10	Glen Innes	GLI	29	Portland / Hapua	POR
11	St. Helliers	HEL	30	Purewa	PUR
12	Herne Bay	HER	31	Royal Oak	ROY
13	Hillsborough	HIL	32	Stanley	STA
14	Kinross	KIN	33	Waterview	WAT
15	Kohimarama	KOI	34	Mt. Wellington North	WEL-N
16	Grey Lynn	LYN	35	Mt. Wellington South	WEL-S
17	Meadowbank	MED	36	Whau	WHA
18	Meola	MEO	37	Mt. Wellington Southdown	WLS
19	Mission Bay	MIS	38	Waiata	WTA

2.1.1 PRE-ICS FLOOD MAPPING

The pre-ICS flood mapping effort was undertaken in the late 1990s in two stages. The first stage was a high-level assessment of flood risk areas, or "Type B" flood areas. This was followed by a more detailed investigation of floodplain areas or "Type A" flood areas. Most of the pre-ICS flood mapping information has been superseded by the newer FHM studies. Definitions of Type A and B flood areas are as follows (Wilson, et al., 2005):

- Floodplain Areas (Type A): These areas indicate the extent of land that is potentially at risk of flooding during heavy rainfall events as identified by detailed hydraulic analysis and computer modelling of the stormwater system under simulated rainfall conditions.

  Floodplain areas correspond to Maximum Probable Development (MPD) and a 100-year return period storm (100-year Average Recurrence Interval (ARI), or 1% Annual Exceedence Probability (AEP)) based on model rainstorms developed by Auckland City in 1989. The predicted floodplain areas may be supplemented by detailed catchment reports held by Auckland City Council (ACC) which provide flood levels and flows.

- Flood Risk Areas (Type B): These areas indicate the extent of land that may be at risk of flooding during heavy rainfall events. Flood risk area delineations were based on knowledge of past flooding, two-metre land contours showing low-lying areas, site observations and other relevant catchment information. They are considered indicative only and have not been subject to a detailed review or analysis.

2.1.2 INTEGRATED CATCHMENT STUDY FLOOD HAZARD MAPPING

The ICS programme was initiated by Metrowater and Auckland City Council in 2001 and finished in 2005. The intent of the ICS programme was to develop a comprehensive understanding of the drainage system and receiving environments within the Auckland isthmus (Kinley). The ICS programme divided the Auckland isthmus into five supercatchment areas (Figure 1 and Table 2) based on groupings of the original 38 DMAs or stormwater catchments and the common receiving waterbodies. Key products of the ICS programme include development of models of the stormwater and wastewater networks and flood hazard maps.

Table 2: *ICS Areas*

ICS Area	ICS Name
1	Waitemata / Point Chevalier
2	Hobson Bay / Waitemata
3	Western Bays
4	Central Manukau
5	Tamaki / Eastern Bays

There are three main types of drainage systems operating in the City of Auckland: (1) stormwater only; (2) wastewater only; and (3) combined stormwater and wastewater. Stormwater systems also include the use of streams and soakage for drainage of runoff. One of the main goals of the ICS programme was to better define how the City's stormwater and wastewater systems are related so that wastewater overflows could be reduced. Accordingly, a significant portion of the ICS programme focused on modelling of the existing networks. Since combined systems traversed multiple catchments and significant volumes of stormwater entered the combined systems, the ICS also helped to initiate a quantitative understanding of regional drainage issues, including wastewater overflows.

Flood hazard maps were a key product of the ICS programme. The objective of ICS FHM effort was to delineate flood hazard extents. FHMs were also intended to identify flooding issues. FHMs were created for most of the 38 drainage management areas (DMA) in the City's isthmus and efforts to complete the mapping continue.

2.1.3 POST-ICS FLOOD HAZARD MAPPING

Flood hazard mapping conducted after the conclusion of the ICS programme in 2005 was intended to fill in data gaps in catchments that had not been modelled during the ICS. Out of the original 38 DMAs on the Auckland isthmus, 14 FHMs remain to be completed as part of the post-ICS group. Presently, two FHMs from this group have been completed and approved, five are nearing completion or in final draft form, four are in progress or in early draft form, and three are in the planning/scoping phase. A compilation of the ICS and the post-ICS flood hazard mapping forms the basis for the City-wide flood issues map.

The post-ICS flood hazard mapping guidelines follow the modelling framework established for the ICS programme (Wilson, et al.), which are appropriately considered to be living documents to accommodate evolving technologies. Similarly, the FHM models and the associated GIS databases will need updating as changes within the drainage networks occur.

2.2 PRESENT CITY-WIDE FLOOD ISSUES MAPPING

For this project, a GIS-based City-wide flood issues map was developed as a tool to investigate holistic, multi-catchment stormwater solutions. The mapping effort included compilation of known flooding problems and complaints, field observations, catchment-level flood hazard mapping results, soakage potential, existing infrastructure, key planned and conceptual improvements, and other available information related to stormwater management in Auckland.

This information was used to develop initial assessments of potential multi-catchment stormwater solutions with flows and pipe sizes based on a simplified and verified design storm flow calculator. This provides the ability to assess at a strategic level what flood protection can be achieved.

3 DESIGN STORM FLOW CALCULATOR

A simplified method for calculating stormwater flow from large catchments during planning and the early design phase was required. In assessing the most appropriate formula-based method, the following criteria were considered:

1. Ease of use – In order to allow non-technical staff to easily calculate flows, the interface needs to have easily acquired catchment parameters (catchment area, coverage, etc).

2. Reasonable degree of accuracy – An accuracy of ± 25% was considered satisfactory and would allow for a 'first cut' of flows and likely infrastructure requirements.

3. Must be calibrated – To ensure the design calculator would give some degree of certainty it needs to be compared to known modelled flow. The calculator was calibrated against ten existing flood hazard models within Auckland City of varying catchment sizes.

A modified rational method for estimating flows was considered most suited to the above criteria. Traditionally, the rational method has been restricted to catchments no greater than approximately 10ha due to the inherent assumptions that the watershed is homogenous and evenly graded. However, by calibrating the results from the rational method to accurate model data, a coefficient was calculated that makes allowance for non-homogenous surfaces with depressions and varying grades.

The coefficient varies for different storm events because the influence of the catchment characteristics decreases as storm flows increase. Depressional storage is very quickly filled during a 100yr storm and has little effect on the overall flow, whereas depressions significantly affect peak flows during small storm events.

The process by which the formula was calibrated is as follows:

1. Catchment parameters (area, impermeable coverage) were determined from the FHM models to ensure consistency between calculated flows from the calculator and model.

2. Time of concentration (T_c) was determined using Auckland Regional Council's (ARC) Technical Publication (TP) 108 approach and ArcGIS contours and length. The channelisation factor was assumed to be 0.6.

3. Peak flows using the storm duration closest to the Tc calculated above was used to calculate the peak flow.

4. A linear relationship was drawn between the rational flow results and modelled results. This linear function then determined the adjustment coefficient (refer to Figure 2). The R^2 value of the relationship between rational flows to modelled flows is approximately 0.95 showing a strong correlation for all storm events.

5. A transitional coefficient (Figure 3) was calculated to allow the unaltered rational method to be used up to 10ha before transitioning smoothly to the calibrated coefficient.

6. This process was undertaken for 10yr, 50yr and 100yr return period storm events.

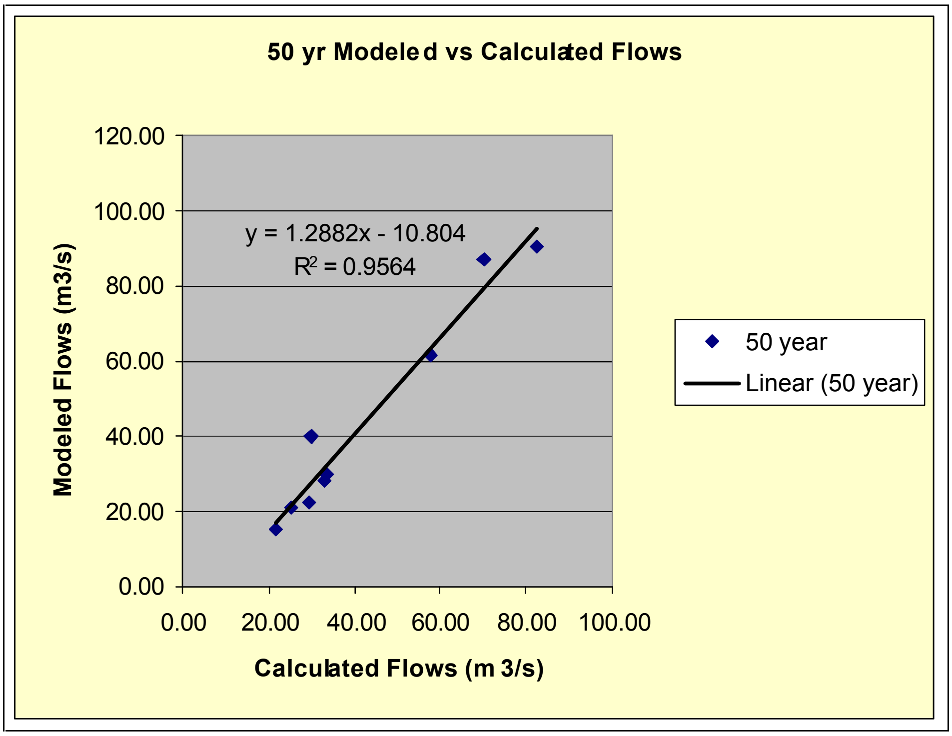

Figure 2: Linear relationship between rational calculated flows and modelled flows

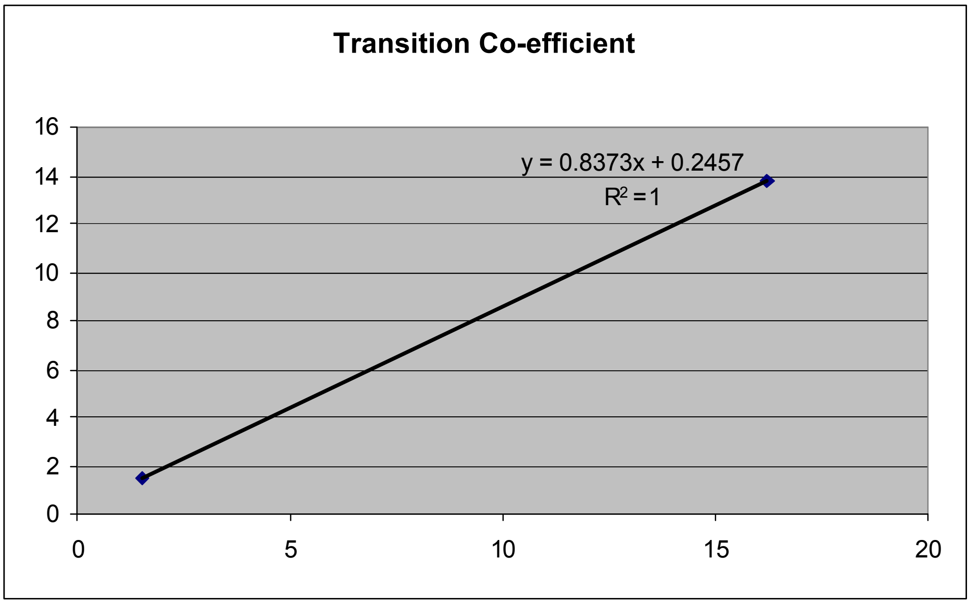

Figure 3: Linear transition between 10ha flow to minimum calibrated flow (Mission Bay)

The result is a design storm flood calculator that is simple to use and can be used to calculate stormwater flows from large catchments with a degree of accuracy acceptable for high-level planning and conceptual design purposes.

The interface (Figure 4) is designed to guide the user through a three phase step-by-step process to calculate flows. The extent of roads, roofs and permeable areas that are captured by the stormwater drainage network are user-defined. The output is a total flow, a captured flow (i.e., in the conduit, either pipe or open water course) and an uncontrolled overland flow.

Peak Flow Estimator - Calculation Sheet

Cells for User to Complete

Step 1 - Define Catchment Parameters		
Area (Ha)	400	Ha
% Impervious	50%	
C impervious	0.90	
C pervious	0.35	
Design Storm	10 yr	

Step 2 - Determine Time of Concentration		
% Impervious		50%
Catchment Area - ha	Perv	200.00
	Imp	200.00
	Total - ha	400.000
	A - km2	4.0000
SCS Curve Number	Perv	74
	Imp	98
CN	Weighted	86
Channelisation factor (C)		0.7
Catchment length (L)	km	7.500
Catchment slope (Sc) using equal area method	m/m	0.01000
Runoff factor (Rf)		0.754
Time of Concentration (tc)	hours	**1.72**
Time of Concentration (tc)	mins	103.33

Step 3a - Determine Total Runoff	
Storm Duration (closest equal to Tc)	15 min
Intensity Lookup	87mm/hr
TOTAL RUNOFF	**68.51m3/s**

Step 3b - Determine Breakdown of Runoff					
Total Pervious Coverage	50%				
Total Residential Impervious Coverage	30%	Total 100%			
Total Road Coverage	20%				
Enter assumed % Capture Rates below:					
% Capture of Pervious	30%				
% Capture of Residential Impervious	40%				
% Capture of Road Runoff	75%				
	Res Imperv m3/s	Perv m3/s	Road m3/s	Total m3/s	
Calculated Overall Splits					
Captured	8.22m3/s	10.28m3/s	10.28m3/s	**28.77m3/s**	
Overland	12.33m3/s	23.98m3/s	3.43m3/s	**39.74m3/s**	
Total				68.51m3/s	

Figure 4: Storm Flood Calculator Interface Figure

The front end of the calculator also has a table to determine the size and slope of pipe that will adequately cater for the predicted flows (Figure 5). This has been formatted to automatically show the size and slope of pipe that will cater for both total flow and captured flow (i.e., the green shaded areas). The calculator also allows for different pipe material by adjusting Manning's n.

Insufficient Pipe size of grade
Sufficient for partial capture only
Sufficient for full flow

Pipe Capacity Estimator

Manning's Formula for Pipes Flowing Full Mannings n = 0.013

Slope

Pipe diameter	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1
0.150	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05
0.225	0.04	0.06	0.08	0.09	0.10	0.11	0.12	0.13	0.13	0.14
0.300	0.10	0.14	0.17	0.19	0.22	0.24	0.26	0.27	0.29	0.31
0.375	0.18	0.25	0.30	0.35	0.39	0.43	0.46	0.50	0.53	0.55
0.450	0.29	0.40	0.49	0.57	0.64	0.70	0.75	0.81	0.86	0.90
0.525	0.43	0.61	0.74	0.86	0.96	1.05	1.14	1.22	1.29	1.36
0.650	0.76	1.07	1.32	1.52	1.70	1.86	2.01	2.15	2.28	2.40
0.900	1.81	2.56	3.14	3.62	4.05	4.43	4.79	5.12	5.43	5.72
1.050	2.73	3.86	4.73	5.46	6.11	6.69	7.22	7.72	8.19	8.64
1.200	3.90	5.51	6.75	7.80	8.72	9.55	10.32	11.03	11.70	12.33
1.350	5.34	7.55	9.24	10.67	11.93	13.07	14.12	15.10	16.01	16.88
1.650	9.11	12.89	15.79	18.23	20.38	22.33	24.11	25.78	27.34	28.82
1.800	11.49	16.26	19.91	22.99	25.70	28.16	30.41	32.51	34.48	36.35
2.100	17.34	24.52	30.03	34.68	38.77	42.47	45.87	49.04	52.02	54.83
2.400	24.76	35.01	42.88	49.51	55.35	60.64	65.50	70.02	74.27	78.28
2.700	33.89	47.93	58.70	67.78	75.78	83.01	89.67	95.86	101.67	107.17
3.000	44.88	63.48	77.74	89.77	100.36	109.94	118.75	126.95	134.65	141.94
3.300	57.87	81.84	100.24	115.75	129.41	141.76	153.12	163.69	173.62	183.01
3.600	72.99	103.22	126.42	145.97	163.20	178.78	193.11	206.44	218.96	230.81
3.900	90.35	127.78	156.50	180.71	202.04	221.32	239.05	255.56	271.06	285.72
4.200	110.10	155.70	190.69	220.19	246.18	269.68	291.29	311.40	330.29	348.15
4.500	132.33	187.15	229.21	264.67	295.91	324.15	350.12	374.30	397.00	418.48
4.800	157.19	222.30	272.26	314.37	351.48	385.03	415.88	444.59	471.56	497.07

Pipe diameter	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.2
0.150	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.07
0.225	0.15	0.16	0.16	0.17	0.17	0.18	0.19	0.19	0.20	0.20
0.300	0.32	0.33	0.35	0.36	0.37	0.39	0.40	0.41	0.42	0.43
0.375	0.58	0.61	0.63	0.66	0.68	0.70	0.72	0.74	0.76	0.78
0.450	0.95	0.99	1.03	1.07	1.10	1.14	1.18	1.21	1.24	1.28
0.525	1.43	1.49	1.55	1.61	1.67	1.72	1.77	1.82	1.87	1.92
0.650	2.52	2.63	2.74	2.84	2.94	3.04	3.13	3.22	3.31	3.40
0.900	6.00	6.27	6.53	6.77	7.01	7.24	7.46	7.68	7.89	8.10
1.050	9.06	9.46	9.85	10.22	10.58	10.92	11.26	11.59	11.90	12.21
1.200	12.93	13.51	14.06	14.59	15.10	15.59	16.07	16.54	16.99	17.44
1.350	17.70	18.49	19.24	19.97	20.67	21.35	22.01	22.64	23.27	23.87
1.650	30.23	31.57	32.86	34.10	35.30	36.46	37.58	38.67	39.73	40.76
1.800	38.12	39.82	41.44	43.01	44.52	45.98	47.39	48.77	50.10	51.41
2.100	57.51	60.06	62.52	64.88	67.15	69.36	71.49	73.56	75.58	77.54
2.400	82.10	85.76	89.26	92.63	95.88	99.02	102.07	105.03	107.91	110.71
2.700	112.40	117.40	122.19	126.81	131.26	135.56	139.73	143.78	147.72	151.56
3.000	148.87	155.48	161.83	167.94	173.84	179.54	185.06	190.43	195.65	200.73
3.300	191.94	200.48	208.66	216.54	224.14	231.49	238.62	245.53	252.26	258.82
3.600	242.07	252.83	263.16	273.09	282.68	291.95	300.93	309.66	318.14	326.41
3.900	299.67	312.99	325.77	338.07	349.94	361.41	372.54	383.34	393.84	404.07
4.200	365.15	381.38	396.96	411.94	426.40	440.38	453.94	467.10	479.90	492.36
4.500	438.90	458.42	477.14	495.15	512.53	529.34	545.63	561.45	576.83	591.82
4.800	521.33	544.51	566.75	588.14	608.78	628.75	648.10	666.89	685.16	702.96

Figure 5: Pipe Capacity Estimator (automated colour coding)

4 FLOOD ISSUES MAP

A detailed City-wide flood issues map for the Auckland isthmus has been assembled from the available information provided to Maunsell AECOM. The flood issues map is a GIS-based tool containing stormwater-related information. The flood issues map should be considered a living document since it will require regular updates with new information as it becomes available, including flood hazard map revisions, new asset information, new construction, system improvements, survey or maintenance, etc.

Maunsell AECOM staff worked closely with Metrowater staff to compile a comprehensive list of information related to stormwater flooding and other relevant data across the Auckland isthmus. Data used in this study resided in many different formats and software platforms (e.g., MapInfo, Hansen, Excel, PDF maps, databases and reports). A significant amount of work was required to collect, review and process this information into a format useable to generate a comprehensive flood issues map. Through this effort, data was migrated to an ArcGIS platform containing one Auckland City/Metrowater master dataset. This included assembly of the individual flood hazard maps for each of the DMAs into one merged layer with common symbology. This also included incorporation of other stormwater data into the GIS platform that had previously existed only in spreadsheet or database format. The quality and comprehensiveness of the City-wide flood issues map is dependent on the quality of the inputs. It is imperative to have good, accurate data.

A key element of the GIS-based flood issues map includes the merging of the available FHM results for each of the 38 DMAs across Auckland. Merging the FHM study results into one master data set provided valuable insight into the completeness of the existing FHMs for each of the 38 DMAs. The assembly and merging the flood data was a lead-in to the creation of a comprehensive flood issues map for the City of Auckland. Each FHM study consists of a number of layers depicting flood scenarios for various storm events. FHMs typically incorporated the following as key deliverables for both the existing development (ED) scenario and the maximum probable development (MPD) scenario:

a. 10-year ARI flood plain
b. 50-year ARI flood plain
c. 100-year ARI flood plain
d. 10-year ARI significant overland flow path
e. 50-year ARI significant overland flow path

As previously mentioned, one strategic goal of the City-wide stormwater management plan includes safeguarding all finished floors from flooding for up to the 50-year ARI flood. The numbers of floors below this flood event are tabulated below in Table 3 (Auckland City Council). This table can help to identify and prioritise flood relief projects.

Table 3: Number of floors below 50-Year ARI Flood (MPD)

Catchment	Number of Floors Below 50-Year ARI Flood (MPD)	
	2006 Estimate	2008 Estimate
Avondale	41	18
Central Business District	0	0
Ellerslie / Waiatarua	95	106
Epsom	82	58
Freemans Bay	17	17
Glen Innes / Point England	25	25
Glendowie	48	48
Grey Lynn	40	32
Herne Bay	14	1
Hillsborough	3	0
Kinross	6	6
Kohimarama	103	60
Meadowbank	35	35
Meola	38	38
Mission Bay	46	140
Motions	10	10
Mt Wellington - North	44	44
Mt Wellington - South	10	10
Mt Wellington - Southdown	26	41
Newmarket	71	71
Oakley	268	268
One Tree Hill	35	35
Onehunga	26	14
Orakei	4	4
Otahuhu East	6	6
Otahuhu West	2	1
Parnell	2	2
Portland / Hapua	21	12
Point Chevalier	5	3
Purewa	12	12
Royal Oak	33	33
St. Heliers	36	36
Stanley	0	8
Waiata	3	3
Waterview	5	0
Whau	38	17
Totals	**1250**	**1214**

Source: ACC SWAMP, March 2009.

The flood issues map along with the design storm flow calculator was used to assist with the development of regional stormwater solutions. An example of where the design storm flow calculator was applied is in the Epsom DMA. Flood areas in Epsom are of special concern since much of the catchment is considered a closed basin and it significantly relies on soakage for disposal of stormwater. Figure 6 shows the closed basin characteristics of the Epsom area. Flood areas are shown in blue.

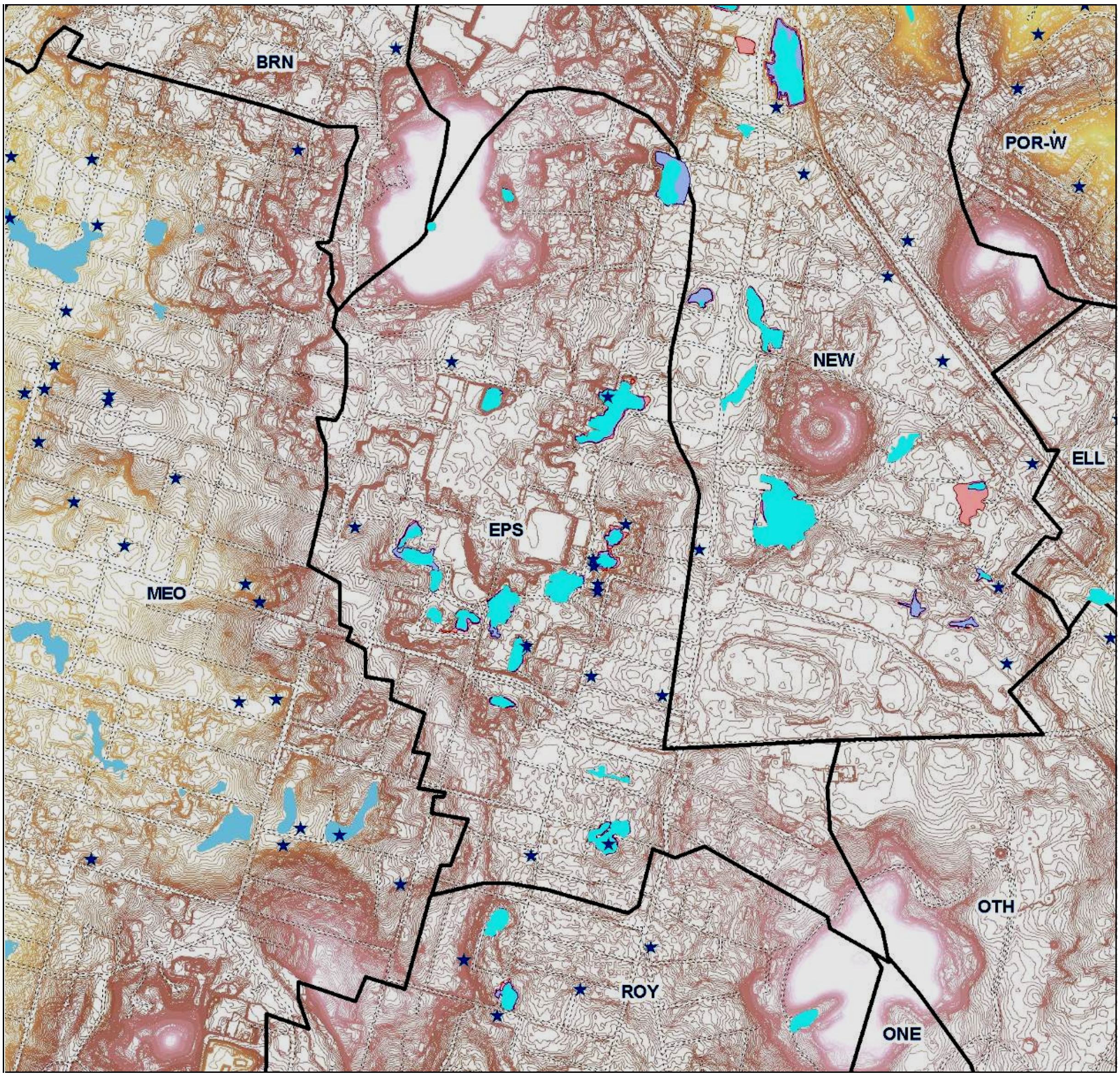

Figure 6: Flood Risk Areas, Stormwater Complaints and Contours in the Epsom DMA

Disposal of stormwater in Epsom relies heavily on soakage; however, not all of the flood hazard areas coincide with zones of good soakage potential (Figure 7). Blue circles indicate Metrowater soakhole locations. High soakage potential areas are indicated in green, medium soakage potential areas in dark yellow, low soakage potential in red, and no soakage potential in white. Flood areas are sown in blue. A significant number of buildings prone to flooding in the Epsom DMA are located in areas of no, low or medium soakage potential.

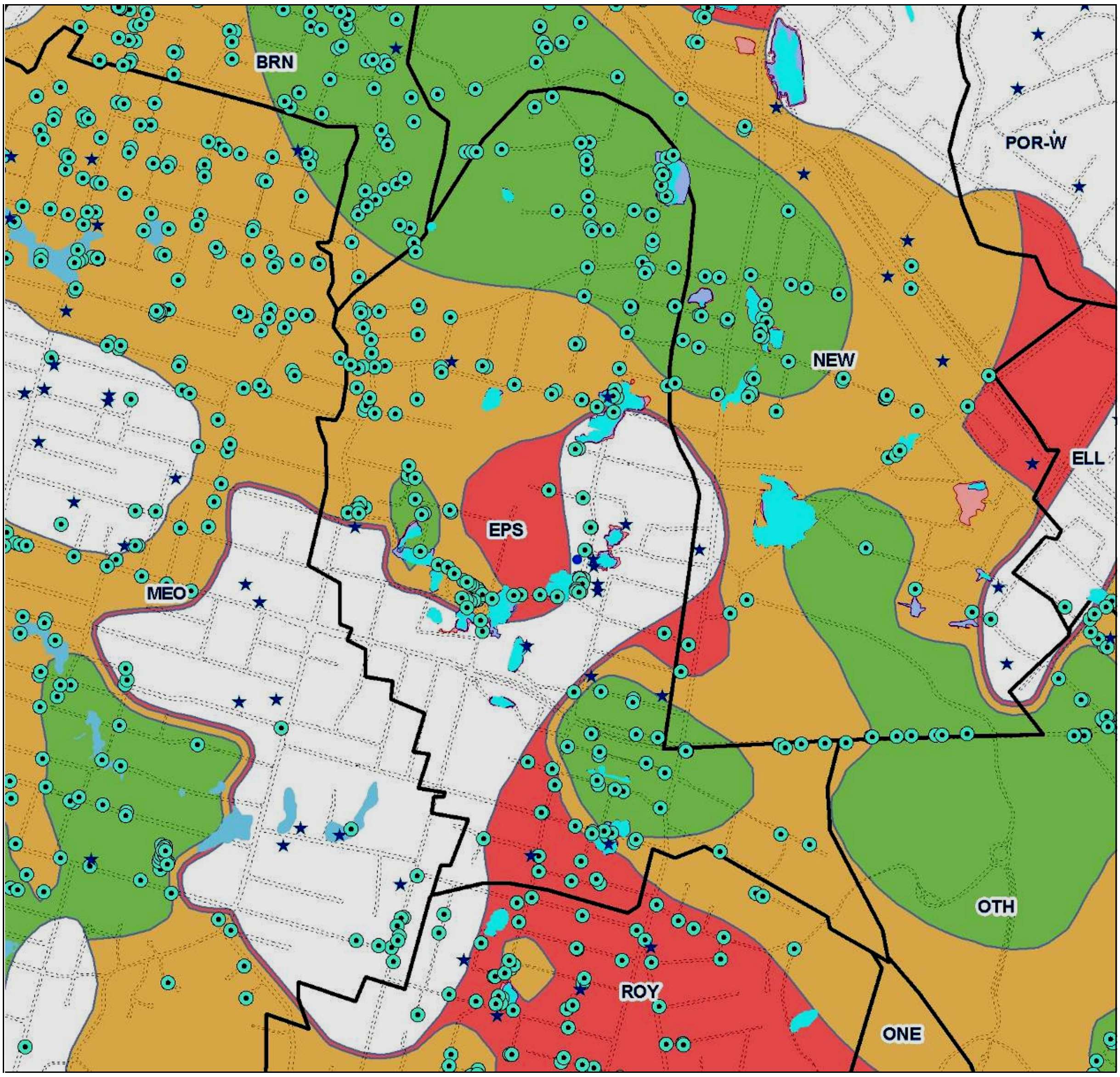

Figure 7: Soakhole Locations, Soakage Potential and Stormwater Complaints in the Epsom DMA

5 POTENTIAL STORMWATER FLOODING SOLUTIONS

An initial assessment of potential regional stormwater solutions was undertaken by utilising the tools developed specifically for this project, namely the GIS-based City-wide flood issues map and the design storm flow calculator.

During the review of flood issues it was noted that a number of DMAs could benefit from regional solutions where stormwater drainage schemes cross catchment divides (i.e., multi-catchment solutions). Further, a number of other catchments were identified that could benefit from more traditional localised flood relief schemes focused on solutions within the same catchment (i.e., single-catchment solutions).

5.1 MULTI-CATCHMENT STORMWATER SOLUTIONS

Multi-catchment stormwater solutions consist of addressing flood issues in more than one DMA with common drainage networks, such as pipes or stormwater tunnels. Several examples of multi-catchment and single-catchment solutions are shown in Figures 8 and 9.

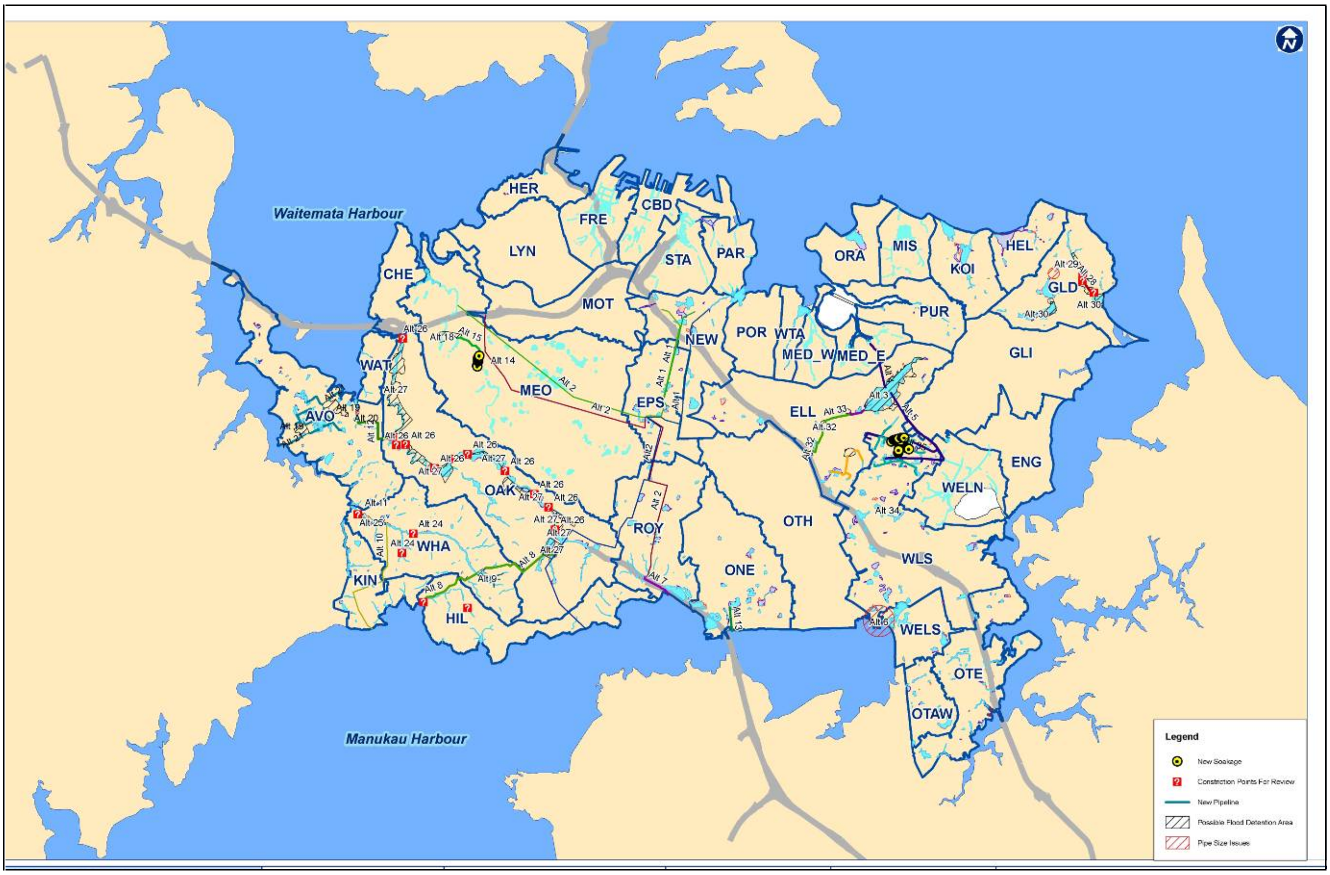

Figure 8: Potential Multi-Catchment City-Wide Stormwater Solution Alternatives

Epsom and Newmarket

Flood problems in Epsom are characterised by lack of drainage from closed catchments. While this area relies heavily on soakage for drainage, soakholes are relatively quickly overwhelmed during larger rain events. Further, a number of flood problems are located in areas with little or no soakage potential. Stormwater solution alternatives for Epsom and surrounding areas are shown in more detail in Figure 9.

Alternative 1: This stormwater drainage alternative is aimed at capturing floodwaters in some of the closed catchments in central Epsom and draining them away via gravity pipes or a stormwater tunnel that ultimately discharges Hobson Bay via Newmarket Stream. This alternative could benefit from coordination with the drainage works presently under construction in Newmarket.

Epsom, Meola and Newmarket

Alternative 2: The EPS, MEO and NEW alternative builds on the above option by adding lateral branches to the stormwater tunnel to capture flood areas located in Meola. The pipes would discharge to Newmarket Stream as above or to Manukau Harbour via the Hillsborough or Royal Oak DMAs. Depending on the final route, stormwater solutions may have the potential to tie into other proposed regional water management solutions such as the Central Interceptor.

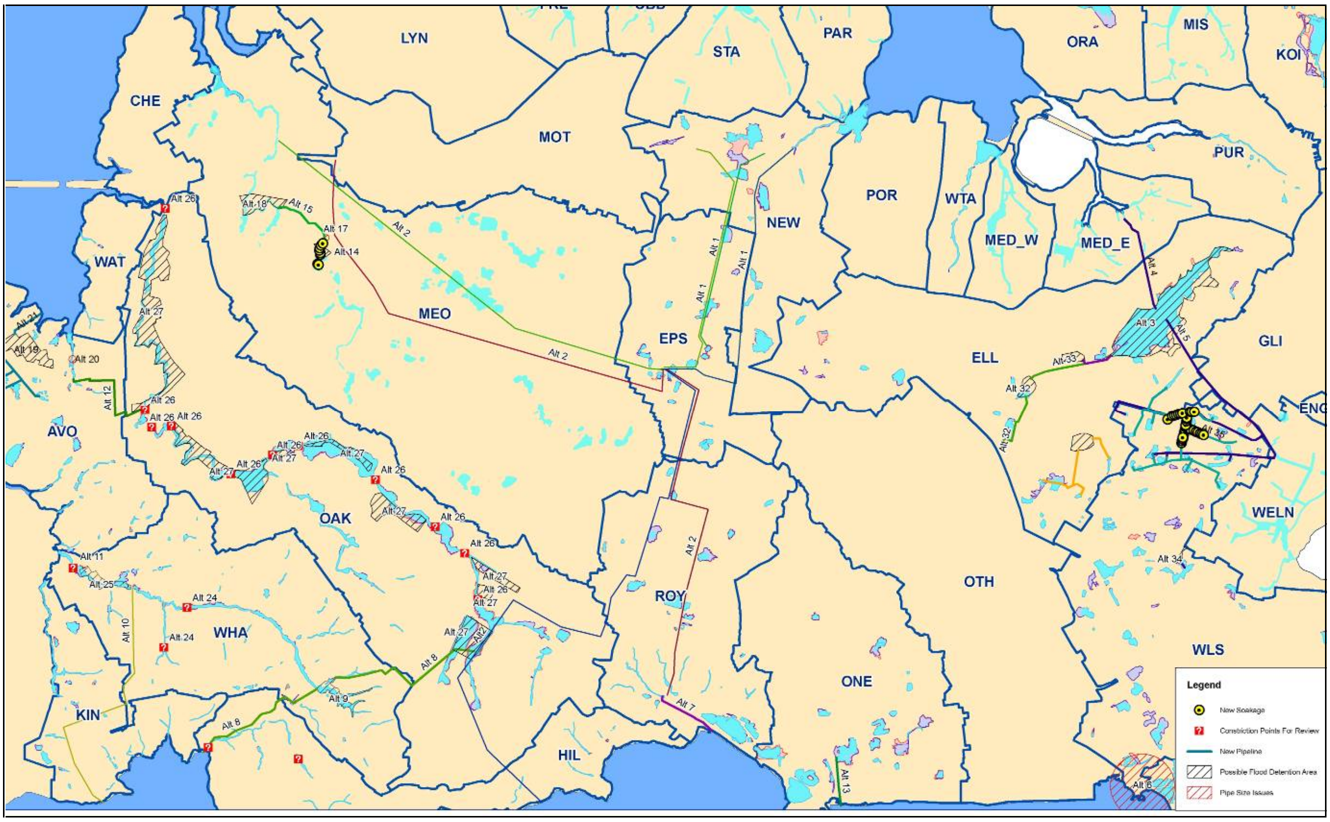

Figure 9: Potential Epsom, Meola and Oakley Regional Alternatives

Ellerslie and Meadowbank

Several homes in the southwest corner of the wetland in Waiatarua Reserve are threatened by flooding even though the 1200 mm diameter Waiatarua Tunnel already exists as a multi-catchment solution in Ellerslie and Meadowbank. It extends from the large depressional area at Waiatarua Reserve in northeast ELL and discharges to a stream in eastern MED after capturing a number of lateral drainages along the way.

Currently, drainage improve work is underway in the western portion of Ellerslie DMA. A multi-catchment scheme is proposed to tunnel under the motorway to convey flows from the west side of ELL to a tunnel under Ladies Mile, then down the storm sewers along Abbots Way and out the Waiatarua Tunnel. In addition, the Ellerslie FHM is due to be updated in the near future.

Alternative 3: It appears that lowering some areas within or around the wetland and golf course would create additional flood storage.

Alternative 4: Another alternative would be to increase the diameter of the existing Waiatarua Tunnel or construct a new one parallel to the existing one to provide flood relief benefits for Ellerslie. Caution is needed in this case to ensure that flood issues are not displaced onto the downstream receiving areas.

Ellerslie and Mt. Wellington South

Alternative 5: Many of the flood issue areas in WLS are characterised by small closed basins that rely on soakage to a large extent. One flood relief option in this case would be construct a network of catchpits and drain pipes that feed into a larger tunnel extending from northern WLS and discharge into the Waiatarua wetland in ELL. This option may require creation of additional flood detention volume in ELL and upsizing the Waiatarua Tunnel. Water quality treatment benefits can also be added in the Waiatarua Reserve wetland expansion.

Mt. Wellington South and Mt. Wellington Southdown

<u>Alternative 6</u>: Numerous flood areas in WLS are located in commercial centres and correspond to documented customer stormwater flooding complaints. The flood relief alternative in this case focuses on increasing the capacity of the existing network that captures stormwater runoff along the WLS (Mt. Wellington South) and WEL-S (Mt. Wellington Southdown) DMA boarder and discharges to Manukau Harbour.

Onehunga and Royal Oak

One flood problem area is located near the boundary of the ONE and ROY DMAs. It appears that the infrastructure is in place to drain off the areas but the discharge is to tidal areas and it may be further limited by the size of the existing drainage pipes. Discharging to tidal areas on a high tide can cause adverse tailwater conditions which may lead to upland flooding.

<u>Alternative 7</u>: One solution for consideration includes an investigation to confirm if the pipes under Hugh Watt to Manukau Harbour are blocked (or biofouled if in tidal waters) or if they could be upsized to accommodate greater flows.

Oakley, Whau, Hillsborough and Kinross

Flooding appears to be an issue for many building along the main drainage systems located in central OAK and central WHA.

<u>Alternative 8</u>: Connect flood prone areas with a network of collection and drainage pipes in OAK and WHA, which subsequently discharges through either HIL or KIN. Flood areas in HIL and KIN should also be included by reviewing downstream constrictions in these DMAs.

<u>Alternative 9</u>: Review the potential of creating additional flood plain storage in the golf course in WHA to detain floodwaters from OAK, which subsequently discharges through HIL to Manukau Harbour during flood conditions.

Whau and Kinross

As mentioned, flooding appears to be an issue for many building along the main drainage systems located in central WHA.

<u>Alternative 10</u>: Construct a stormwater collection and drainage network along Blockouse Bay Road from WHA through KIN to Manukau Harbour picking up flood problem areas in KIN at the same time.

<u>Alternative 11</u>: Review the capacity of the existing stormwater network in downstream areas of the cannel in WHA, especially for constrictions in the culverts under Wolverton Street where they appear to be a choke point thus causing flooding in upstream areas. This alternative and network review also applies to the open channel drainage that flows through KIN under Wolverton Street. This alternative should also include a review of the drainage network as it flows through AVO to the Whau River and ultimately out to Waitemata Harbour.

Oakley and Avondale

Alternative 12: This solution has the potential to relieve some flooding in OAK by creating a high water pop off from OAK to AVO where presently none exists. Specifically, a pipe or tunnel could be constructed to connect the open channel in OAK near Methuen Road to the open channel in AVO near Great North Road and ultimately discharge to the Whau River. A control structure could be installed on the OAK side to ensure that during most events, water flows in a normal fashion; however, during storm conditions that generate high waters, floods flow could bypass the downstream third of the OAK catchment. Care must be taken during the design of this option to ensure that new or existing flood problems in AVO are not created or exacerbated.

5.2 SINGLE-CATCHMENT STORMWATER SOLUTIONS

The identification of potential, concept-level single-catchment solutions resulted from a search for potential multi-catchment solutions. Examples of single-catchment solutions, also shown in Figures 8 and 9, include the following examples of alternatives in the Meola DMA.

Flooding around Parish Road in Meola is in an area of little or no soakage and it appears to rely on a combination of soakage and a combined stormwater/wastewater drainage network. Flooding also occurs at Wairere Avenue near New North Road and affects approximately 18 residential buildings upstream of the railroad tracks. Based on the configuration of the existing storm drain network, it appears that a number of the flood problem areas in MEO have been know for sometime and that the infrastructure is in place to provide drainage. The following identifies a number of single-catchment alternatives:

- Flooding occurs at approximately 24 residential structures located south of the golf course and along two depressional areas (former stream tributaries) between Martin Avenue and Rawalpindi Street. It appears that the ditch though the Chamberlain Park golf course is a constriction point and may be too small to adequately convey flood flows. It may be possible to create flood detention areas within the golf course adjacent to the motorway.

- Create additional floodplain storage near the Mt. Albert War Memorial Reserve with a combined flood detention and wetland treatment pond.

- Increase the capacity of the downstream stormwater conveyances being careful not to increase the potential for downstream flooding.

- Add more soakholes, but since the flood problem areas are in "poor" soakage areas, this may not be the best alternative.

- According to the GIS records, the pipe size decrease as one travels downstream in this area. Specifically an oval 2200 mm high by 2400 mm wide pipe (NI3521) goes into 2200 mm high by 1800 mm wide pipe (NI3517) located under the railroad tracks. A review of the pipe system in this area is warranted and pipes need upgraded accordingly to accommodate flows without displacing flood problems onto downstream areas.

6 CONCLUSIONS

This project will help support Metrowater's development of integrated City-wide stormwater solutions to address current and future drainage needs. Auckland City faces major stormwater drainage issues including flooding, growth pressures and ageing infrastructure. Proper planning is critical to providing good drainage solutions and with the right tools, significant headway can be made to reduce flooding of homes and businesses. Tools developed through this project will facilitate stormwater planning in Auckland.

A City-wide flood issues map was developed as a tool to investigate holistic, potential multi-catchment stormwater solutions. The mapping effort includes compilation of known flooding problems, stormwater and wastewater complaints, overflow data, catchment-level flood hazard mapping results, aquifer data, soakage potential, planned and conceptual improvements, and other available information. Related reports, such as Drainage Strategic Plans, Asset Management Plans and studies on soakage alternatives, catchpit design and roadway contaminant removal options were used to assist with the data audit and development of the flood issues map.

A number of potential, high-level stormwater flooding solutions are identified. Stormwater solutions include single- and multi-catchment scenarios. Areas where additional efforts are needed to refine viable stormwater solutions are identified. Multi-catchment drainage schemes have the potential to provide flood relief to a number of areas and can also be tied into regional drainage networks for storage or water quality treatment.

A number of mapped flood hazard areas appear to be located upstream of choke points and constrictions in the stormwater drainage network. Therefore, more formal investigations into the stormwater system capacity is recommended at several key locations, but a more detailed City-wide investigation should be undertaken to compile a comprehensive list of the locations of stormwater pipe capacity reductions and to identify potential alternatives.

Across the City, many historic floodplains and flow ways have been filled in, channelised or developed. Encroachment into such areas often manifests itself as flood problems. Creation of flood detention areas and restoration of flood plain storage capacity is recommended in several locations (Ellerslie, Meola, Avondale, Oakley, Glendowie), especially adjacent to existing open channels and wetland areas and in existing reserves. An added benefit of a properly designed and constructed wetland or flood detention area is the treatment of stormwater runoff. Combining flood storage capacity with better downstream drainage can also help reduce flood risks.

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