THE HAMILTON CITY STORMWATER MASTER PLAN, BIG DATA FOR SMART CITY PLANNING.

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ABSTRACT

In 2015 Morphum was commissioned to prepare a Stormwater Master Plan (SMP) for the City of Hamilton, in the North Island of New Zealand. The SMP project vision was "To provide a dynamic, well documented and geospatial platform to support the analysis, planning and management of stormwater for Hamilton City".

The SMP provides both a framework and a set of functional tools and processes to prioritise, plan and deliver on stormwater and environmental management objectives and help meet the conditions of Hamilton City Councils discharge consent. It also serves as an overarching document informing individual Integrated Catchment Management Plans (IMCPs) which are underway in the City. Through using GIS in every facet of the technical planning process the aim is to support Hamilton City Councils service delivery business processes and the 10 Year indicative stormwater funding programme through what is often referred to as 'SMART City Planning'.

Therefore the SMP is intended to be much more than simply a plan; it represents the new way Hamilton City intend to manage stormwater and its associated information sets. The SMP is not just a static print out or set of reports, but rather a complex set of GIS overlays, integrated information sets and "big data". The SMP enables analysis and interrogation of information about stormwater in a way that was previously unavailable to HCC and other stakeholders. Consequently numerous workshops were held with other stormwater, infrastructure, and planning teams and managers at Hamilton City Council to ensure that the objectives and outcomes of the SMP were fit for purpose.

One of the main deliverables and tools of the SMP is a Projects Database which represents how (and where) Hamilton City can better manage the stormwater network and its associated impacts. The Projects Database informs the 10 Year indicative stormwater funding programme. The projects identified include growth requirements, stream enhancement works (to improve ecological function), treatment improvements and investigations into flooding. The projects database has a spatial reference, to an associated polygon, indicating the site or area related to the project record.

As many of the tools and processes are new to Hamilton City Council, a comprehensive methodology development process was undertaken to ensure transparency and clarity around the technical tools such overland flow paths and geometric networks. This paper will aim to describe these methodologies and how they have been used to develop the SMP for Hamilton 2016.

KEYWORDS

Big Data, Geometric Network, Spatial Layers, Integrated Systems, Master Planning, Stormwater Planning, Long Term Plan,

PRESENTER PROFILE

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1 INTRODUCTION

1.1 OVERVIEW AND CONTEXT

Hamilton City is the largest urban area in the Waikato region with a census population in 2013 of 141,612. It is experiencing rapid growth, with its population expected to increase by at least 2,000 per year for the next 10 years (Hamilton 10 Year Plan 2015-2025) to over 150,000 within its 98 square kilometre boundaries. There are extensive undeveloped "greenfield" areas on the edge of the city which, along with infill development in the brownfield areas, are intended to provide for this population growth and future development. As this development occurs, it will put pressure on receiving environments and existing stormwater network. This requires enhanced management through the control of discharges to open watercourses, improved consenting, design and planning mechanisms as well as more stringent land use controls than previously required.

The Waikato River is an important asset and feature in Hamilton City, relied on both recreationally and as a source of food. Multiple stakeholders are concerned with water quality and the adverse effects of urbanisation on the Waikato River. Similarly the gully systems are also viewed as an important asset with ecological value (Clarkson *et al*. 2012).

The city is located on the banks of the Waikato River and is surrounded by rural plains typical of the Waikato Region. Several catchments straddle the city and discharge via streams, gullies and outfalls into the Waikato and Waipa Rivers (receiving environments). Hamilton City Council (HCC) is responsible for the management of stormwater including water quality and flooding.

Over time, research and guidelines have been developed requiring treatment (quality) and flow control (quantity) to reduce the impact stormwater has on flooding, property and our receiving environments. In approximately 2001, Hamilton began negotiation with Waikato Regional Council (WRC) for a Comprehensive Stormwater Discharge Consent (CSDC). This consent was granted in 2010, covering existing discharges, and allowing for new discharges subject to compliance with conditions (such as mitigation of effects, water quality improvements and obtaining approval for catchment management plans). Guidelines such as Auckland Regional Council TP10 (2003) were used as a standard for mitigation of effects, and in Hamilton, from about 2003 onwards, this generally resulted in soakage (where conditions were suitable), and 'ponds' for sub-catchment stormwater management prior to discharge to the receiving environment.

In 2015, the first catchment management plan was approved, and included best practical options of planted stormwater devices. Planted devices (e.g., swales and wetlands) are shallower than ponds and research shows they have numerous advantages over ponds, including increased treatment and reducing temperature effects. The Hamilton Infrastructure Technical Specifications (ITS) has been updated over time, and now provides specifications on a variety of planted stormwater management devices to reflect current best practice. A Stormwater Bylaw came into effect in September 2015 which

provided information as to what can enter the stormwater network and responsibilities around the discharge of stormwater. The Hamilton District Plan was updated in 2014 and requires on lot water efficiency measures. Three Waters Management Practice Notes are referred to in the ITS and detail on lot measures such as reuse tanks, bioretention (raingardens) and soakage. WRC are currently preparing Waikato Stormwater Guidelines, due mid-2017. These documents provide guidelines and requirements to ensure future development follows best practice and effects of stormwater on the receiving environment are managed.

Understanding the performance of the stormwater network, the effects of stormwater discharges and the requirements to service growth across the city, represents a significant challenge to HCC and the community. HCC has acknowledged that it is imperative that questions around stormwater effects are answered to meet future growth challenges and to quantify budgetary requirements to support the 10 Year indicative stormwater funding programme. But how will the City meet overarching objectives, achieve Levels of Service and deliver on discharge consent requirements? The answer is through the development of a comprehensive, data (evidence) driven, integrated assessment and planning platform: a master plan for stormwater to summarise the current state of play and provide direction into the future.

This SMP is a fast track approach to city-wide management planning for stormwater and its effects, and provides an information and planning framework to supporting financial forecasting that better informs Council and the community when considering long term obligations and decision-making.

It is envisioned that future versions will move the SMP in a more strategic direction based on reliable information, a good understanding of the stormwater network and its effects, reviewing and refining stormwater management objectives (including Levels of Service) and defining what is required to support future growth.

1.2 VISION

The SMP project vision is "*to provide a dynamic, well documented and geospatial platform to support the analysis, planning and management of stormwater for Hamilton City"*.

The SMP is in fact more than a plan; it generates information to support HCC to manage key stormwater infrastructure and projects. The SMP is not just a static print out or set of reports, but rather a complex set of GIS overlays, integrated information sets and "big data". The SMP will enable analysis and interrogation of information about stormwater in a way that was previously unavailable to HCC and other stakeholders. The document provides a review at a fixed point in time and it is recommended to be updated every 3 years to inform the 10 Year Plan funding request. The GIS deliverables have been developed as part of the initial masterplan process, and are useful as a static layer, or can be a live management tool for HCC to use on a day-to-day basis.

Using GIS in every facet of the planning process and to underpin the business processes of HCC's service delivery is often referred to as 'SMART City Planning'.

As many of the tools and processes are new to HCC, comprehensive methodology development was undertaken to ensure transparency and clarity around the processes followed to develop each chapter of the SMP.

1.3 DRIVERS

The CSDC and the business case for ICMPs provide the main drivers that describe the required outputs of the SMP and ICMPs for HCC. Hamilton is currently facing significant development pressure and HCC needs a flexible planning framework to manage growth in a responsible manner. Consequently, additional drivers for preparing a SMP include:

- Rapid development pressures,
- Complex planning processes,
- Statutory requirements[1] (including Healthy Rivers compliance),
- Legacy issues,
- Community expectations, and
- The need for efficient collation and analysis of data on a city-wide scale.

1.4 OBJECTIVES

The overarching objectives for the SMP support the vision, drivers and design philosophy set out above. The objectives are:

- Provide a high level understanding of stormwater quality and associated effects now and in the future for Hamilton City.
- Provide a dynamic, well documented and geospatial platform that is able to be updated and maintained, and supports analysis, planning and management of stormwater.
- To inform the stormwater planning required to facilitate growth and define compliance requirements and actions.
- Enable efficiencies to be achieved in carrying out stormwater management activities including the development of stormwater catchment plans.

2 GEOMETRIC NETWORK

The majority of the analysis of the SMP was done using the geometric network (also known as a connectivity network) in GIS, which was designed, built and quality assured as part of the SMP. The rationale for using a geometric network is to take advantage of its connectivity and directionality functions. These allow attributes to be accumulated along the network, in the downstream direction, so that impacts on receiving environments and the effects of mitigation measures may be evaluated. The geometric network was built from existing HCC drainage network features and additional drainage lines extracted from a DEM.

The network comprises six separate datasets which collectively make up the piped and open channel components of the drainage network. These include urban drainage elements as well rural channels which drain into and out of the HCC Boundary.

Catchments that drain to the geometric network were prepared in one of two ways, depending on their position in the network. For areas within the HCC boundary, catchments were delineated from the DEM using automated means in ArcGIS. For areas not covered by the DEM, catchments were taken directly from the River Environment Classification (REC) dataset. The catchments represent the surface area that drains to each node. This methodology assumes that the network allows water into it at each node point, which is commonly a manhole location.

[1] See ICMP Objectives (stormwater) for an outline of relevant statutory and planning documents.

The geometric network is a useful planning tool for a range of disciplines in the SMP as well other serving other planning requirements such as looks up functions at any point in the network (there are over 16,000 points in the network for which results are returned). Look up functions include contributing catchment size, length of upstream pipe/open watercourse and percentage impervious.

3 WATERCOURSE MANAGEMENT

The SMP describes the Hamilton streams and defines management priorities and principles. The network of open watercourses within the city limits has been compiled into a continuous network that takes into account the stormwater pipes and culverts that feed and convey stormwater. The network has been allocated a management type which was based on a decision tree methodology using available information such as channel type, potential upstream habitat, riparian width, erosion scarring and upstream impervious.

The Watercourse Management chapter provides details on how watercourses can be managed at the citywide scale. This is underpinned by the fundamental goal to protect, maintain and enhance the natural environmental values of Hamilton City's watercourses, while providing for social, cultural and economic values. This is intended to be achieved through compiling disparate existing datasets, modifying where appropriate and adding catchment context from outputs and analysis derived from the Geometric Network, such as upstream impervious catchment area. This information has then been used to develop guiding principles for watercourse management types (see Figure 1) and management actions. The guiding principles also assist the development of ICMPs (including the identification and prioritisation of enhancement opportunities) and ultimately the identification of capital work programmes and actions for the future.

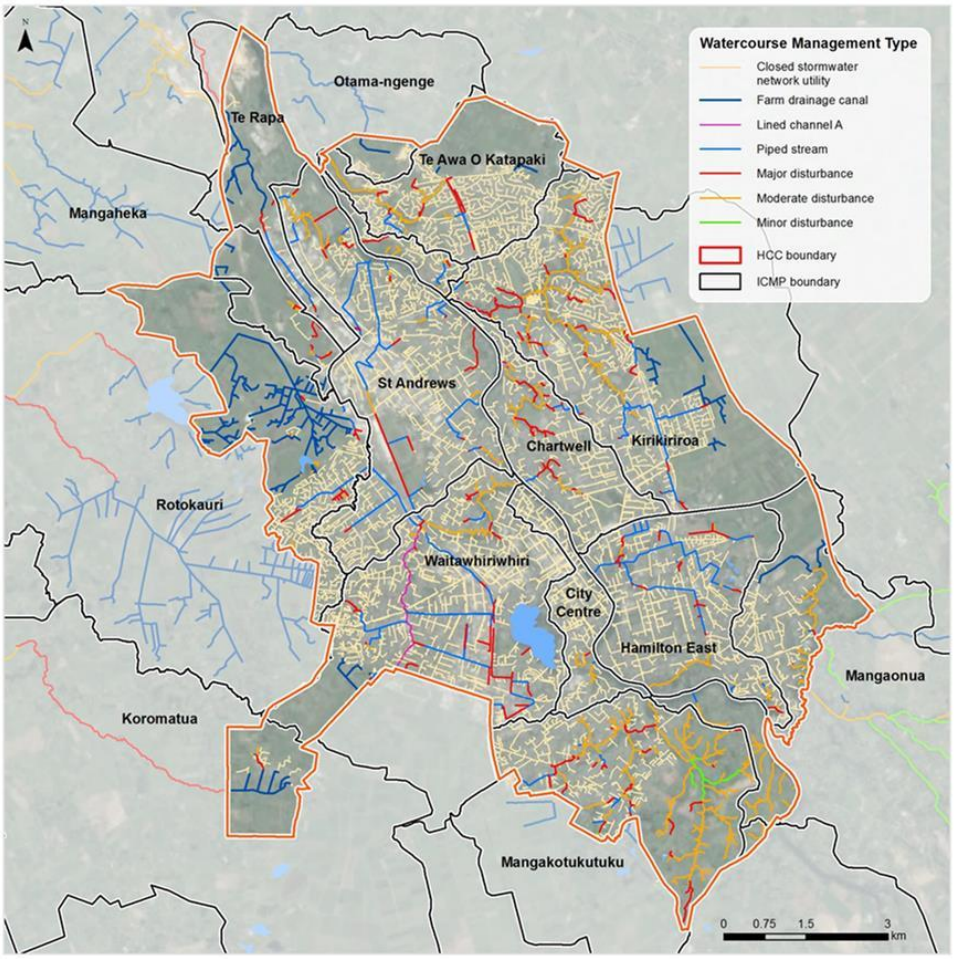

Figure 1: Hamilton City Watercourse Management Types

There is an estimated 168 km of streams in Hamilton City which range in type from rural drains through to minor disturbed natural channels which still retain high biodiversity values. Seventeen native and nine exotic fish species have been recorded within the ICMP Boundaries and MCI quality thresholds range from Poor (severe enrichment) to Good (mild pollution), with no sample results indicating Excellent water quality. The proportions of each watercourse type are shown in Table 1.

Table 1: Watercourse Management Types in Hamilton

Watercourse Management Type	Total Length in Hamilton (km)	As a % of total
1A Piped Stream	49.2	6%
1B Closed Stormwater Network Utility	636.8	72%
2A Lined Channel A	3.2	<1%
2B Lined Channel B	-	-
3 Farm Drainage Canal	41.0	5%
4 Minor Disturbance	3.6	<1%
5 Moderate Disturbance	75.7	9%
6 Major Disturbance	44.2	5%
1% of the network was not assigned a Watercourse Management type.		

Streams and waterways are vulnerable to the effects of land use change and their associated discharges. In order to support the healthy function of these waterbodies, it is important to improve their core functions such as riparian vegetation density, substrate

diversity and natural channel shape. Erosion, sedimentation and point source pollution discharges are of particular concern for waterways in Hamilton City. Guiding principles have been adopted for each watercourse type listed in Table 1 which can be used to inform remedial and/or enhancement actions and inform long term planning conducted through the ICMP process.

A number of watercourse related projects have been defined through the development of the SMP with a total estimated cost of over $17 million (including growth funded erosion prevention programmes). It should be noted that there are many more project locations to be identified for watercourse improvement, enhancement and restoration which will be done through the catchment management processes. The recommended 10 year indicative funding programme request includes riparian improvement as several parks which was supported by the Parks and Open Spaces team, Bank erosion prevention for greenfield areas and fish barrier remediation of 18 sites.

4 CONTAMINANT MANAGEMENT

Developed and developing catchments need to be managed to reduce the discharge concentrations and total loads of key contaminants such as heavy metals (zinc/copper), sediment and other chemicals such as nitrogen and phosphorous. These pollutants result in negative impacts on our waterways, lakes and wetlands. In order to manage these effects it's important to understand the relative contributions of key pollutants from their source land use types such as zinc and copper from our roadways.

The SMP has developed a citywide contaminant load model which utilises the geometric network and hydrology tools, to define total annual loads and relative annual average concentrations to target areas where water quality treatment could be investigated and implemented. It should be noted that further development of the model is required including monitoring inputs, calibration and refinement however the inputs to the model such as the land cover layer (Figure 2) and load values are immediately available for use to provide developers and HCC with a high level estimation of contaminants loads for defined areas. This is considered a major development, in particular the loads expressed through the geometric network that focuses attention towards high relative concentration locations.

In Hamilton City there are currently 21 council-vested stormwater ponds and wetlands which are designed to manage flows and/or remove pollutants from the stormwater passing through them. As per 2015 aerial imagery, 70% of the area confined within the boundary is developed or brownfield and the remaining 30% is undeveloped greenfield. There is a relatively low proportion of the City currently being treated – approximately 14% of the total land area. The considerable greenfield areas bordering the urbanised areas are earmarked for growth with proposed development areas to be treated to the ITS Standard and as required by the WRC Stormwater Discharge Consents. The SMP has accounted for the treatment of these growth areas and summarised the extent and other key details to help inform long term costing and catchment management planning. There are currently over 80 wetlands and ponds proposed to be built in the greenfield and structure planning areas.

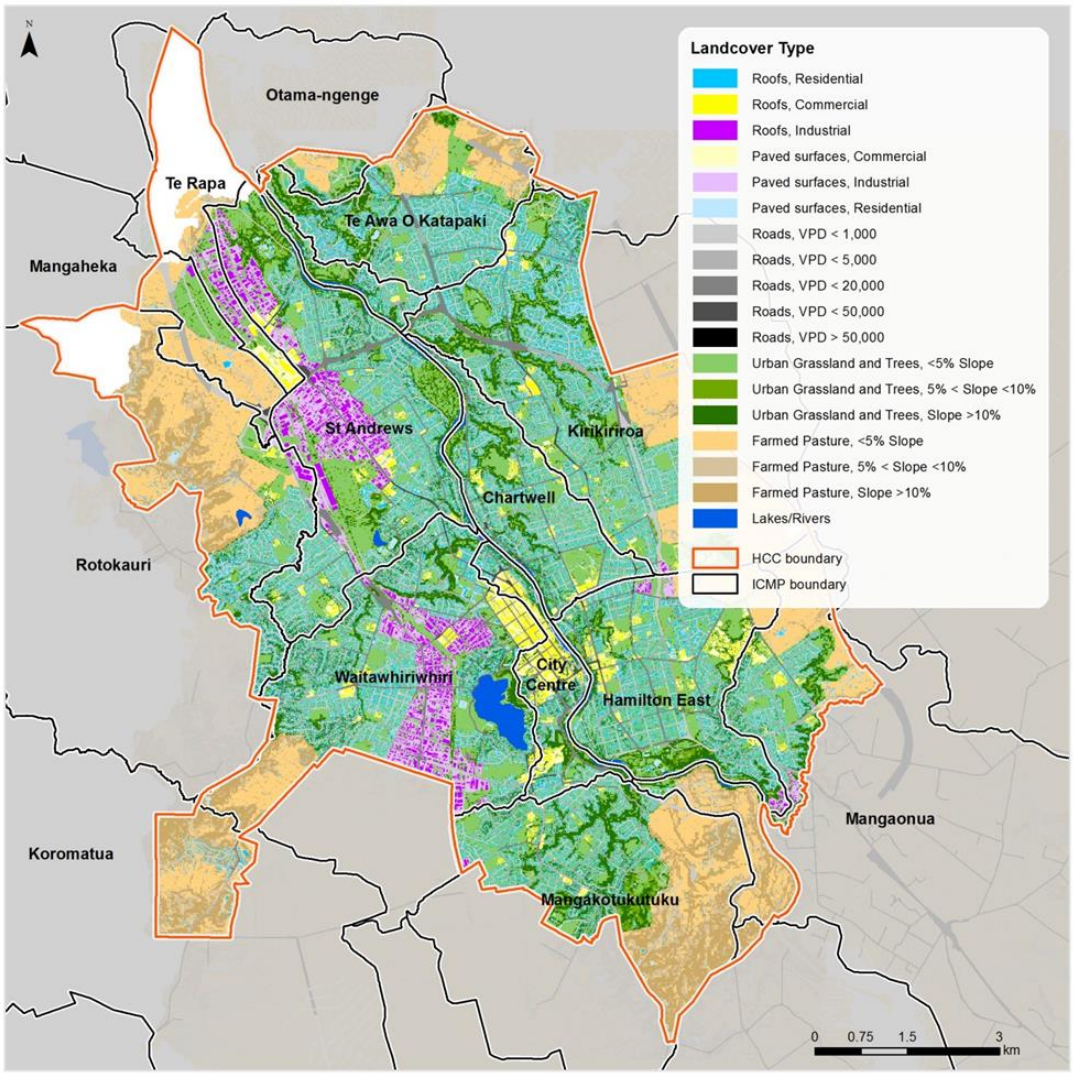

Figure 2: Hamilton Land Cover Layer (purple and yellow represent priority)

Most of the city drains to the Waikato River (within the city boundary) being 81% of the total with 19% draining into Waipa or Waikato District land before ultimately discharging to the Waikato River. Source annual total loads have been estimated in the contaminant load, from the Hamilton City Catchments. In kilograms, these are as follows:

- Total TSS 5,193,171
- Total Nitrogen 141,808
- Total Copper 175
- Total Phosphorus 18,075
- Total Zinc 1,781

Given that the greenfield areas are to be treated to a minimum of ITS standards and are undergoing catchment management planning and consenting application reviews, the SMP has given some particular focus to the brownfield areas where five catchments have less than 2% of the area managed through a recorded stormwater device. Less than 20% of the brownfield area is treated in Hamilton. The SMP had a particular focus on

identifying brownfield areas with commercial and industrial land use areas, highly trafficked roads[2], and isolated catchments at the headwaters of watercourses.

A total of 37 water quality projects have been identified for investigation/feasibility at a total estimated cost of $2.6 million (not including proposed treatment devices identified for growth). The analysis has focused on central commercial hub areas and high contaminant generating sub-catchments that drain to sensitive receiving environments such as the headwaters of low disturbance stream types. Many of these projects are at scoping stage to allow prioritisation and feasibility to be conducted. Into the future, as brownfield treatment projects become more frequent; the adoption of water sensitive features and continuing to follow the HCC ITS standards will likely result in improving the quality of stormwater that discharges to the receiving waters. The recommended LTP funding request comprises scoping of 37 projects, including on lot programme review, scoping of new brownfield devices at 20 locations and scoping for retrofit of existing devices at 13 sites.

5 FLOOD MANAGEMENT

Flooding caused by significant rain events is one of the most common types of natural hazards experienced in the Waikato. The consequences of flooding on people and property can be very significant for individual residents affected and for the community as a whole. Economic and environmental impacts can extend to disruption to the road network, malfunction of the wastewater system and wastewater overflows into the environment. Ongoing and repeated flooding of property and buildings can result in severe effects on health and safety of occupants, property values, productive use, and insurability.

HCC has a responsibility to manage for the effects of flooding through detailed assessment, setting standards for design and monitoring performance. The SMP has developed a number of citywide datasets which aid in the development of flood models. These include a Digital Terrain Model, OLFPs, an Impervious Surface Layer and Building Footprints.

The SMP used a rapid assessment tool for prioritising areas for further scoping. This was done by intersecting building footprints with the developed OLFPs and the available flood extents. All the information sets provide base inputs for further detailed ICMP processes. Having this information presents council with a significant step forward in best practice flood management. This analysis provides a conservative estimate which, through detailed modelling, is expected to reduce significantly.

The assessment of flood extent, frequency and impact is a complex and important management issue for councils. ICMPs and investment in detailed flood modelling make progress towards addressing some of these issues. At a citywide scale, 28% of buildings in Hamilton City are identified in the 100 year flood extent. Catchments of priority (based on number of buildings in the 100 year flood extent) include St Andrews with just over 5,000 buildings and Waitawhiriwhiri with over 4,200 buildings. Together these catchments represent 44% of the buildings in the city that have been identified as partially or fully within the 100 year flood plain extent. These catchments are considered priorities for future assessment and analysis.

[2] Highly trafficked roads; e.g., larger than 5,000 VPD are considered priority where thy may coincide with a high contaminant producing land use. The corresponding yields for roads are incorporated through the model run as per *Methodology for the Creation of the Hamilton City Contaminant Load and Treatment Model*.

The OLFP information layer is an invaluable tool to help define potential flooding locations and the impact surface terrain has on magnitude and course. An OLFP layer represents route for stormwater flow when the primary (piped) stormwater network becomes blocked or overwhelmed by high flows or the path followed before it finds the point of entry to the primary system. On a citywide basis 12% (approx. 8,700) of total buildings within the Hamilton City boundary intersect with an OLFP. Waitawhiriwhiri, St Andrews, Hamilton East and Kirikiriroa catchments collectively account for 62% (approx. 5,400) of the total buildings in the city intersected by OLFPs.

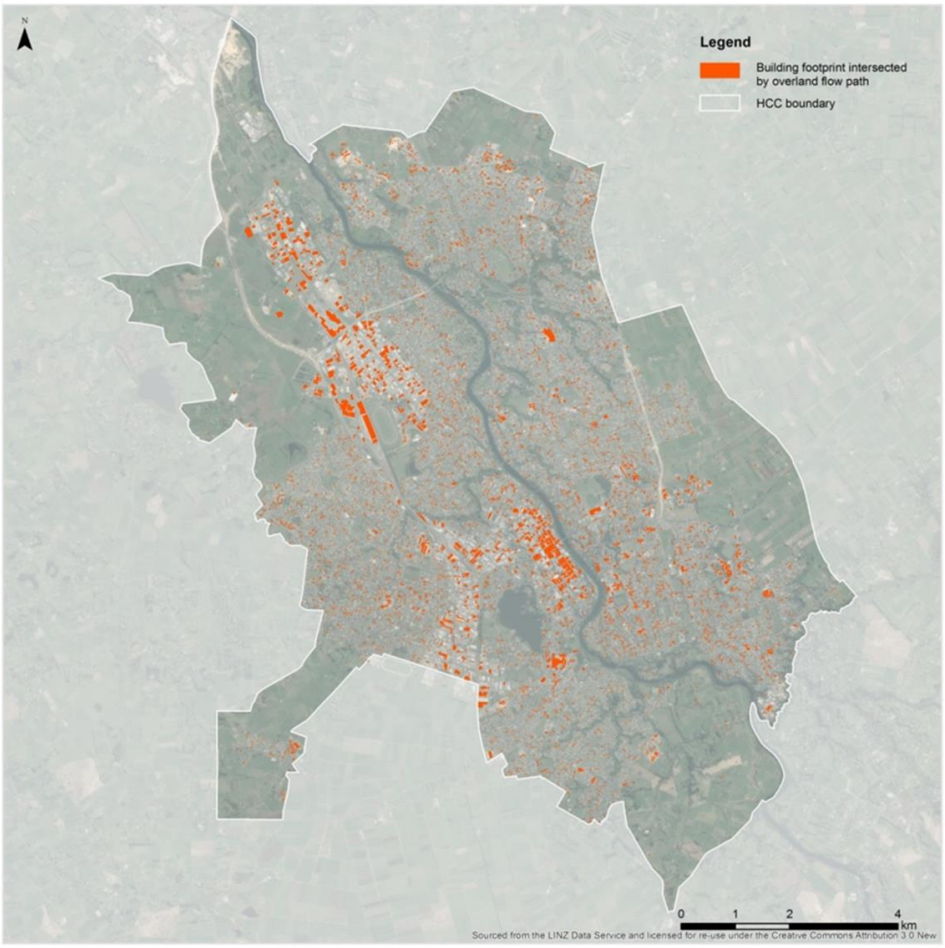

Figure 3: Building Footprints Intersected with Overland Flow

On the basis of building footprints affected from predicted floodplain extent or OLFPs, the following catchments are considered to have the highest potential flooding issues across Hamilton City:

1. St Andrews
2. Waitawhiriwhiri
3. Hamilton East
4. Mangakotukutuku
5. Mangaonua
6. Rotokauri
7. City Centre

Detailed flood modelling will be required in order to confirm the likely risk of inundation. This modelling would need to include system performance assessment to inform mitigation and network capacity upgrades to reduce the depth and frequency of inundation. Issues are likely to be dependent on several parameters such as road design, driveway crossings, building floor levels and the location and size of stormwater infrastructure. The HCC SW Modelling Methodology is currently being updated at the time of writing, and will begin to address these matters and consider mitigation options to

reduce inundation of habitable floors. Detailed modelling will continue through ICMPs in line with the updated SW Modelling Methodology.

Priorities to scope flood hazard and risk may also be influenced by other factors including proposed development, major infrastructure projects and frequency/severity of known (existing) flooding issues. With this in mind management steps and approach can be summarised as follows:

- Detailed flood modelling, system performance reporting and mitigation options assessments
- Policy, including land use change and long term retreat from flood prone areas.
- Major capital works projects as identified from mitigation assessments.
- Develop and implement risk assessment methodology.
- Increased funding to undertake flood assessments.
- Increased initial funding to mitigate flooding.
- Investigate effectiveness of related planning rules.

A flood scoping project has been included in the 10 Year indicative stormwater funding programme to assess citywide the nature of the risk to life and property, and the affordability of various mitigation strategies, to assist in setting objectives for level of service and priorities for mitigation.

6 NETWORK MANAGEMENT

Hamilton City is serviced by an estimated 14,565 underground pipes and culverts with a total pipe length of more than 675 km. These networks are designed to collect and convey surface waters to controlled discharge points such as lakes, rivers and stormwater devices. Understanding the capacity of these networks to discharge water is of primary importance, as they function to reduce any potential surface flooding during intense rain events. However, this is a very complicated process and at a city scale requires detailed information[3].

The intent at the outset of the exercise was to build a "City Scale" rapid pipe capacity assessment tool. In order to do this the runoff characteristics of the land cover and soils had to be determined and represented through a geospatial curve number layer. The methodology developed provides a calculation for returning peak discharge for each of pipe in Hamilton, and uses the Colebrook white formula to compare the pipe full value. The network capacity methodology was not undertaken to completion, however, the geospatial elements developed including curve numbers, existing imperviousness and future imperviousness (based on the partly operative District Plan and depicted in Figure 4) all form part of a wider objective for Hamilton City to ensure consistency amongst studies and models and provide inputs into catchment based hydraulic modelling tasks for each ICMP. This work along with the SW Modelling Methodology will ensure greater consistency amongst Flood Hazard Mapping.

[3] Hamilton's current level of service for Network Capacity is Residential 2 Year ARI, Industrial 5 Year ARI and Commercial 10 Year ARI

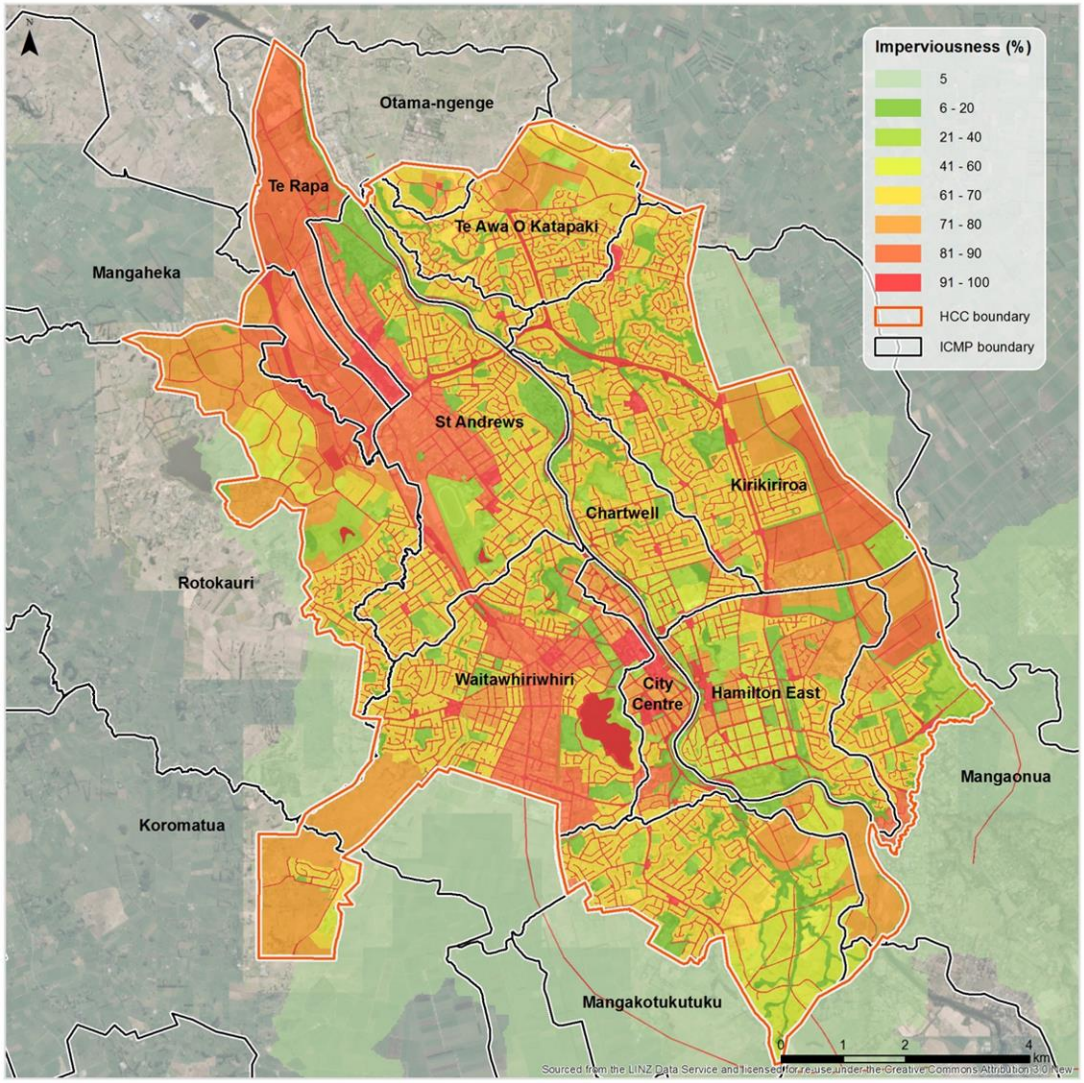

Figure 4: Future Impervious as per Hamilton City partly operative district plan

7 GROWTH PLANNING

Growth in Hamilton is one of the key drivers for the development of the SMP. As the urban boundary of Hamilton extends and existing development intensifies, the pressure on the existing infrastructure and natural systems intensifies. The SMP identifies growth through; infill and urban intensification (represents 50% of the expected grown in Hamilton), structure plan growth and associated transport growth (Southern Links). Additionally long term growth areas with strategic agreements have been identified but are not considered within the SMP Version 1 analysis. The long term growth areas may be considered during ICMP development for relevant catchments or within future versions of the SMP.

Hamilton is growing at a fast pace with new housing and developed areas either currently underway or being planned across the City. The SMP has brought together all of the Structure and development plans in order to predict the future level of development to inform the modelling of contaminants and flooding.

The areas identified for growth, within the Hamilton boundary, have been subject to the structure plan processes. As these areas are largely greenfield, they will be subject to

requirements stipulated in the ITS for stormwater treatment and design management, or the outcomes of ICMPs where they have been completed.

Poor design and construction of treatment devices can lead to high operational and retrofit costs, many of which are ongoing. To reduce this occurring, adherence to best practice design guidance, for stormwater management devices, is generally accepted. The HCC ITS has been updated to reflect current best practice, with a focus on planted devices and reduced open water. This helps with improved contaminant removal and acts to reduce discharge temperatures, in line with the requirements of the CSDC. Defects liability has also been increased to 24 months to ensure plantings are healthy and vigorous before they become the responsibility of HCC, to reduce operation and maintenance costs.

Further impacts of growth on downstream waterways have also been considered within the Kirikiriroa, Te Awa O Katapaki, Mangakotukutuku, Mangaonua and Mangaheka catchments. Watercourse assessments (as extensions of the SMP) have been or are planned to be undertaken to inform concept projects for erosion prevention, based on legacy stormwater and proposed increases from growth.

8 PROJECTS DATABASE

One of the main drivers, deliverables and tools of the SMP is a Projects Database which represents how (and where) Hamilton City can better manage the stormwater network and its associated impacts. The projects identified include growth requirements, stream enhancement works (to improve ecological function), treatment improvements and investigations into flooding. The actions against these projects range in status from scoping, options assessment and detailed concept design components. In order to manage this information and provide a robust reporting platform, a Projects Database has been designed and populated.

The projects database has a spatial reference, to an associated polygon, indicating the site or area related to the project record. At the time of writing, a total of 216 projects were identified, of which over 200 have been put forward for the 10 Year indicative stormwater funding programme. Projects are represented as line items with details such as type, scope, status, cost, funding split and duration. The projects database also has function to support programme spend across a 10 year financial window.

9 RECOMMENDATIONS

There have been substantial learnings from the development of the SMP. As part of the gap-analysis and data collation aspect of the SMP, several recommendations have been made with emphasis on planning for the SMP Version 2. The recommendations aim to provide a higher resolution and complexity of analysis to the SMP process and ultimately increase the quality of future SMP outputs. The recommendations provided in table 2 are a guide only and HCC are at liberty to adopt in part or not at all at their discretion. The listed recommendations do however provide guide for the development of Stormwater Master Planning projects and initiatives.

Table 2: Recommendations

Recommendation	Summary

Recommendation	Summary
Impervious layer	An impervious layer is a fundamental dataset to inform strategic planning and catchment specific analysis in urban areas. An accurate impervious layer has multi-benefits including essential input into flow calculations, degree of disturbance of watercourses, flood risk assessments, lot coverage consent assessments, etc. The HCC supplied layer Merged_Hard_Surface was used for the SMP analysis (following a large scale upgrade of manual correction and dissolving the building footprints as initially the layer was not of high enough accuracy for use. The updated layer was considered fit for purpose at a citywide scale for this version of the SMP. It is recommended that HCC invest in a new impervious layer during the next round of LiDAR procurement. This would increase accuracy of the Watercourse management type decision framework and estimates of stormwater runoff for the rapid pipe capacity analyses. Furthermore the growth HCC is experiencing on the city fringes and through intensification, means that the topographic and land cover will likely change substantially before the next SMP and for the use of future ICMPs.
LiDAR	Light Detection and Ranging Survey (LiDAR) provides the underlying input into many models and analysis completed by council and consultants, not just related to stormwater management. The stormwater related uses include: • Stormwater modelling, • OLFPs, • Catchment and watershed tracing through a DEM, • Depiction of a vegetation layer 2008 LiDAR was used for the SMP analysis and is not considered to reflect accurate topography on the fringes of Hamilton where growth has recently occurred.
Reach scale environmental data collection	Deliverables of Ecological reports by consultants have largely been in report format. This has created a silo between environmental data collection sitting with distinct areas within council. If not displayed geospatially there is less opportunity for data comparison. It is recommended that ecological and asset information is collected geospatially (and provided back to council as part of a consultant contract). It is recommended to align data collection with the ICMP Receiving Environment Module Methodology
Flow and rain gauge locations	Flow gauge information can provide input into runoff calculations and provide general runoff characteristic data of the upstream catchment. Flow gauge data is also an important input into calibration of flow models. It is recommended that HCC invest in flow gauge monitoring and ensure that this is consistent with the objectives for wastewater model management
Stream ecological valuation (SEV) collection	The SEV method assesses four broad categories of stream ecological function, including hydraulic function, biogeochemical, habitat provision and biodiversity. The SEV method was originally designed to assess the value, and potential impacts on streams to support resource consent applications. However, the method has been used successfully for stream ecological monitoring, catchment planning, and identification of effective restoration options (Storey et al. 2011). It is recommended that this assessment be considered for offset mitigation projects.
Asset consideration within AMPs such as plants and OLFPs.	It recommended to extend the scope of future AMP's to include additional consideration of natural assets such as riparian planting and critical OLFPs. The natural and modified assets are an essential part of the stormwater network but often are ignored in asset management practices and consequently management of these assets is out of scope and underfunded. There is also a financial implication by including these assets because assets such as plants will depreciate and need renewing where they serve a stormwater management purpose (such as erosion prevention or wetland treatment).

Recommendation	Summary
Estimate contaminant loads to the Waikato River.	Identifying the contributing contaminants to the Waikato River is an important parameter to understand the effect HCC has on the Waikato River. Currently there is no identification of the contaminant concentrations in the Waikato River upstream of Hamilton City. The way in which the geometric network was built means that the network and therefore the associated HCCLM can be further developed to include the full upstream catchment of the Waikato River (up to Lake Taupo). Although inputs would be required (e.g., LiDAR, Land cover information), the geometric network and *Methodology for the Creation of the Hamilton City Contaminant Load and Treatment Model* can be further developed to identify the effect Hamilton has on the Waikato River. Consideration of WRC Regional Ecological Monitoring Data (which includes several monitoring locations within the Waikato River) would provide data to corroborate and validate results. This could also include investigation into what other Councils have done in this regard
OLFP criticality	Overland criticality is used to identify OLFP reaches that pose significant consequences to economic, environmental, social or cultural values. It also provides prioritisation to inform management and operational programmes for the mitigation of flow paths. It is recommended that a study is considered to be included in the SMP Version 2 during scoping. This could follow the methodology developed for Auckland Council in 2014 by Morphum Environmental. It could consider policies such formalising critical OLFPs through physical works and easements.
Biotic indices	Biotic indices provide a means to infer the 'health' of a watercourse, or the disturbance from a reference condition (integrity). The watercourse management types developed in the SMP are based on available data of upstream impervious, erosion scarring, channel type and riparian latitudinal extent. The parameters infer disturbance of the stream but could be further developed to encompass biotic indices Calculated MCI and Fish Index of Biotic Integrity (IBI) scores should be compared to open watercourse management types to corroborate assessments of degree of disturbance. It is recommended that the SMP v2 incorporates MCI data to corroborate against watercourse management types provided in this SMP.
Channel erosion load model	Stream bank and bed erosion are a major source of sediment transportation which is controlled by the hydraulic and geotechnical processes operating on the channel boundaries. Increases of flow and volume (often caused by an increase of upstream impervious with urbanisation) cause bank and channel erosion and scour. Ultimately the result is an increase in mobilised sediment and an increase in total suspended solids for catchments with watercourses. Currently the HCCLM does not estimate or account for in stream erosion and scouring giving effect to the pollutant concentrations in the HCCLM. This has under estimated the actual values. A study is recommended to investigate how a channel model can be used and plugged into the HCCLM to infer loads per linear metre. It is recommended that the HCCLM adopt a similar approach to AKC 2010 using open watercourse identified in *Methodology for Assigning Watercourse Management Types*. Stream width is recommended to be based on real data which will be collected as part of the ICMP Receiving Environment module methodology data collection for the development of ICMPs. This should be considered during the SMP Version 2 scoping.

Recommendation	Summary
Culvert burning for the OLFP layer	The production of OLFPs from a DEM is an iterative process which requires repeated conditioning of the terrain surface such that a "hydrologically-correct" DEM is produced. This enables the delineation of continuous flow paths from the upper-most parts of a catchment and the ultimate drainage sink, in this case the Waikato River. The conditioning process requires "burning" through flow barriers on the DEM surface (such as road embankments which would in reality contain a culvert). Spatial infrastructure asset data in Hamilton currently provides limited extent of the Hamilton Network. It therefore recommended a data collection exercise is performed to provide locations of assets to support the DEM burning process. This includes: a. Process to receive NZTA Asset data under roads, railway etc. b. Process for the update of Inlet and outlet asset information exported from IPS and georeferenced. c. Culverts collected through the ICMP Receiving environment Module Methodology. Following this process, it is recommended that the OLFP layer undergo burning using these culverts.
Stormwater Management Devices – collection of data and updates to the proposed private stormwater device layer	A database of existing and planned private and public stormwater management devices (for water quality and quantity control) is required for strategic planning and ultimately to comply with the CSDC conditions. All management devices, whether public or private, need to be accounted for when accounting for mitigation measures in place to protect the receiving environment. If a device is vested, the data for these devices will be available on IPS and the public stormwater device GIS layer. However, there is often a significant time between approval for the device and vesting. There are also a significant number of private devices. A future and existing device layer was created through the SMP, along with a data schema of attributes required to be known for the devices. This layer will have information available through this database that will be displayed via GIS separately to the 'public devices' layer. It is recommended that the private device stormwater management GIS layer and database are updated, as detailed below a. Collection of critical information is budgeted within Data Gaps project (data schema for existing devices and the catchments they serve). b. Update the ITS datasheets to ensure new devices submit the required data schema information and catchment details and move to automated updates. c. Confirm the procedure for updating the private stormwater device layer including automation.
Flood Investigation Procedure	Assess citywide the nature of the risk to life and property, and the affordability of various mitigation strategies, to assist in setting objectives for level of service and priorities for mitigation. This could inform policy development and changes.
Land Acquisition for Stormwater Devices	A process for securing stormwater management device land in growth areas is required to ensure that proposed management of Stormwater is possible. The options include: a. Relying on land owners and developers to work together. b. Land designations. c. HCC procure land from developers and private land owners. d. HCC procure land from developers and private land owners and recoup development contributions through capital works
Education and Implementation of datasets	A specific recommendation was identified during the development of the SMP to up skill and educate HCC staff on the uses of geospatial data. The geospatial data produced in the development of the SMP and associated stormwater projects provides some important baseline datasets and tools to plan for growth and assess developments. This may be in the form of a series of workshops with key development engineers on for example OLFPs dataset and include uses and limitations of the dataset.

10 CONCLUSIONS

The management of stormwater and receiving waters has been changing rapidly over recent times in Hamilton City. It is now generally acknowledged that the wholesale piping of streams and uncontrolled discharges to rivers and lakes is not acceptable. There are multiple community, cultural and legislative drivers which demand best practice standards are developed and adhered to.

One of the main drivers to develop the SMP has been to respond to growth pressure alongside ensuring compliance with the Comprehensive Stormwater Discharge Consent (CSDC). The plan collates the necessary constituent information to allow Hamilton to assess existing and future scenarios against legal requirements (such as mitigating effects of stormwater) and upcoming obligations (Healthy Rivers WRC Plan change which focuses on contaminants entering the Waikato River). In approximately 2001, Hamilton began negotiation with Waikato Regional Council (WRC) for CSDC for the diversion and discharge of urban stormwater runoff in Hamilton City.

Multiple parallel projects have been completed as the SMP has been developed. These have been informed by new data requirements, the need for fit-for-purpose methods and guidelines that can be used to support best practice outcomes. Some of the methods and guidelines include the HCC Stormwater Modelling Methodology, Integrated Catchment ICMP Modules, an update to HCC Three Waters Management Practice Notes (on lot requirements) and an update to the HCC Infrastructure Technical Specifications (ITS). These documents can be used in tandem to minimise operations and maintenance by promoting at source treatment, sub-catchment solutions and optimisation of existing assets.

The development of more than 20 new or modified/collated datasets represents a significant step forwards for Hamilton City in stormwater and environmental management. A number of these represent best practice in stormwater management and can be used for future planning and operational activities, they include, at a citywide scale:

- Overland flow paths (OLFPs) generated from digital elevation model (DEM).
- Building footprints on a property by property level.
- A geometric network linking pipes and streams (combines all network related data).
- Enhancement and correction of the current impervious surfaces layer.
- Future Impervious Surfaces (District Plan zones and Maximum Probable Development values).
- Curve Number Overlay for rainfall runoff calculations.
- Watercourse Management Typing.

The SMP provides both a framework and a set of functional tools and processes to prioritise, plan and deliver on stormwater and environmental management objectives and help meet the conditions of Hamilton City Councils discharge consent. It also serves as an overarching document informing individual Integrated Catchment Management Plans (IMCPs) which are underway in the City. Through using GIS in every facet of the technical planning process the aim is to support Hamilton City Councils service delivery business processes and the 10 Year indicative stormwater funding programme through what is often referred to as ‘SMART City Planning’.

ACKNOWLEDGEMENTS

The very supportive staff from Hamilton City Council and in particular Andrea Phillips. Emily Reeves and Co-author for going above and beyond to get this job done.

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