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Community engagement and technical collaboration leads to a greatly improved wastewater service for Whangarei.

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Affordable wastewater management for the residents of Whangarei was developed through consultation and understanding the community drivers alongside focussed technical investigations to identify a cost effective solution that would meet the community expectations.

Under significant budget constraints, the Whangarei DC engineering team embarked on a number of investigations to develop a more comprehensive understanding of both the catchment and harbour while also listening to the "voice" of the community.

A number of investigations allowed for a better understanding of the environment and provided tools to develop and assess cost effective solutions with this work undertaken in parallel to a substantial consultation program.

With a clear understanding of the community expectations the team at Whangarei were able to use the tools to develop a catchment wide master plan of improvements to the network and plant that would allow for growth, improved containment as well as meet the community expectations.

Solutions implemented included: sewer network treatment and offload systems, sewer capacity and configuration modifications, inline sewer repairs, direct disinfection of primary effluent, and implementation of accurate and timely communication systems specifically around sewer spills.

The capital works programme has taken 5 years to implement at an affordable cost of around $30m. It has exceeded expectations in terms of environmental outcomes. Customer satisfaction has increased from a low of 46% in 2010 to 76% in 2015. The final budget for the work established as part of the master plan is only 20 – 30% of the previously considered network amplification and storage proposed to meet the desired containment standard.

KEYWORDS

Community drivers, Harbour water quality, hydraulic modelling, quantitative microbial risk assessment, UVT.

1 INTRODUCTION

Whangarei is a city of some 60,000 residents two hours' drive north of Auckland in New Zealand, it has one of the country's deepest harbours and is a popular holiday destination known for its recreational amenity.

The city is serviced by a sewer system that began construction near the start of the 20th century, and progressively grew and provided a greater level of service over time. As is a factor of many sewer networks the Whangarei system suffers from a high rate of stormwater getting into the network via inflow and infiltration. This leakiness is exacerbated by the high rainfall the city receives and the heavy clay soils that most of the pipes are bedded in.

Figure 1: Construction of the Whangarei Septic Tank (1930)

The outcome of this leakage is that during heavy rain the sewer network discharged into the harbour. While this was a historic occurrence the community expressed that they no longer were willing to tolerate it, and in 2009, there were public marches through the town centre and a truck load of septic waste dumped on the Council steps.

To address these issues, under significant budget constraints, the Whangarei DC engineering team embarked on a number of investigations to develop a more comprehensive understanding of both the catchment and harbour along with listening to the "voice" of the community. Technical investigations including; long term (strategic) and short term sewer flow and rain fall gauging; development of a hydraulic model for the entire sewer network and treatment plant; hydrodynamic dispersion modelling of the harbour a quantitative microbial risk assessment (QMRA), ecological assessments for the marine environment targeted a specific locations; and UVT assessments for disinfection, were completed to better understand how the conditions across the catchment influenced water quality across the harbour.

In parallel to these technical investigations council embarked on a substantial consultation program with community, businesses and iwi/hapu stakeholder groups to fully appreciate and record their expectations as a driver for change.

With a clear vision around the community expectations and knowledge from the technical investigations and associated economic analysis, the team at Whangarei were able to use various modelling tools alongside conventional engineering to develop a catchment wide master plan of improvements to the network and plant that allow for projected growth as well as meet the community expectations around containment and harbour water quality.

The final budget for the work established as part of the master plan is only 20 – 30% of the previously considered network amplification and containment solution.

2 WHANGAREI NETWORK AND TREATMENT PLANT

The city's 500 km of sewer network consist of a mixture of earthenware, asbestos cement and PVC sewer pipes installed respectively from 1905 – 1950, 1950 – 1990, and 1990 to present. The pipe network, that has remained relatively unchanged since installed, has been laid predominantly in heavy clay soils that swell and shrink as the soil moisture changes. The city experiences New Zealand's highest urban rainfall with an average just over 1,600 millimetres per annum[1].

The sewer network has very high inflow and infiltration (I/I) of storm and ground water, increasing the flow of wastewater during wet weather to well over ten times dry weather. These high flows cause sewage spills and peak flows at the treatment plant. A large proportion of the pathogens that end up in the harbour during storm events come from sewage discharges. As a response to sewage spills the Northland District Health Board would impose restrictions on contact recreation and shellfish gathering the harbour.

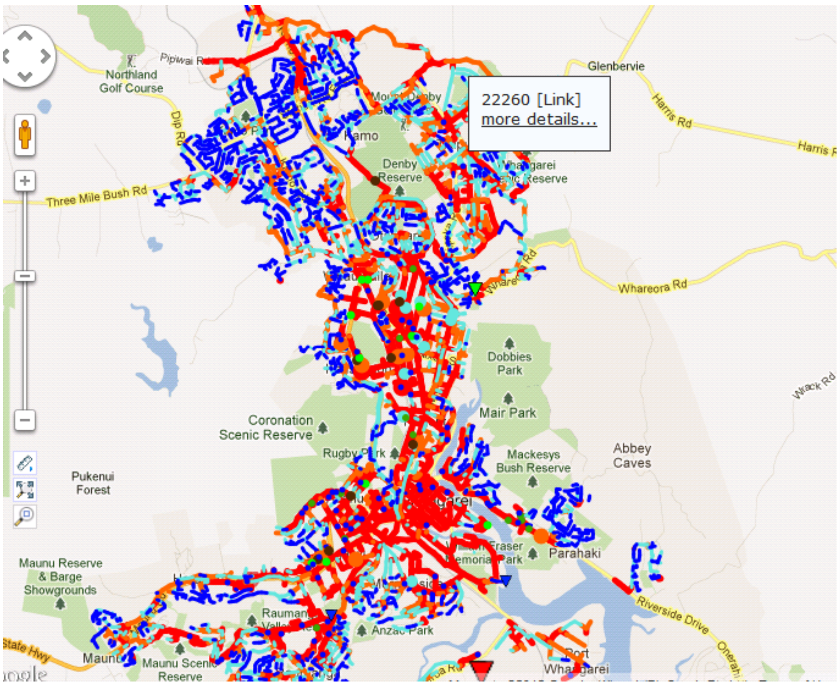

Figure 2: Whangarei Sewer Network – red indicates pipes at capacity in a 1 year ARI storm.

Figure 3: Network response to rainfall – quick rise after rain and slow regression indicates both inflow and infiltration issues

The overflow from the sewer network was identified as coming from a small number of large volume discharge sites, such as major pump stations and constructed overflow points, and many smaller sites, such as surcharging manhole sand gully traps. The overall discharge points were estimated at over 50 in an annual rainfall event.

The bulk of the flow from the sewer network is pumped from a terminal pumping station at Okara Park to the wastewater treatment plant on Kioreroa Rd.

The treatment plant, built in 1964 has gone through a range of upgrades in response to community concerns around water quality. When viewed over the life of the of the sewerage system each upgrade had greatly improved the public health risk posed from sewer discharges. Initially there was no treatment and then from 1930 to 1964 all wastewater received primary settlement and screening before discharge direct to the harbour. The treatment system in 1964 allowed for Biochemical Oxygen Demand (BOD) removal and then was upgraded in 1988 to include disinfection and ammonia reduction.

In 2009 the treatment plant could comfortably meet a 10mg/L solids, 10 mg/BOD, 5mg/L ammonia, and 200 Faecal coliform per 100mL standard during dry weather. During wet weather however the majority bypassed treatment.

Despite improving treatment levels the community perception was that water quality was deteriorating due to wastewater, as diagrammatically presented in Figure 4. This is likely due the improving ability to measure water quality and better ability to communicate this risk to the community.

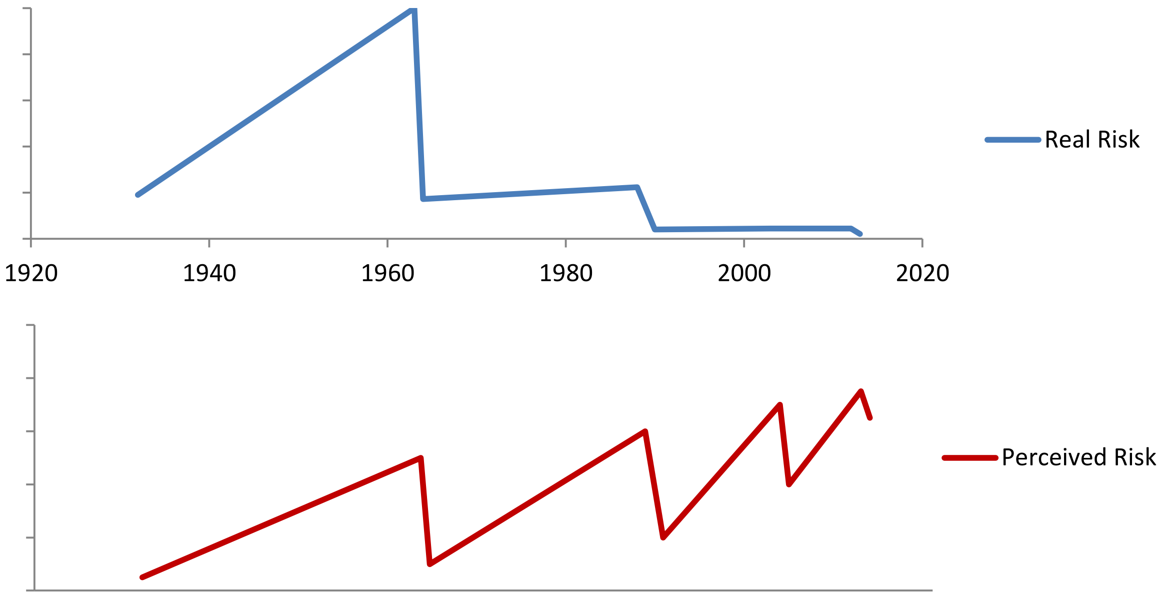

Figure 4: Top: Estimated risk from wastewater discharged to the harbour (annual load of faecal coliform bacteria). Bottom: Indicative community perception of risk from wastewater discharge.

3 TECHNICAL INVESTIGATIONS

To address the community concerns there were a number of questions to answer:

a. How much? – What volume of wastewater do we need to deal with
b. Where does it go? - What happens to the wastewater once it leaves the sewer network
c. So what? – What is the risk it poses
d. What can we do about it

3.1 HOW MUCH? - FLOW MONITORING AND HYDRAULIC MODELLING

To get a handle on sewer flows and overflow volumes council engaged AWT (now Mott McDonald) to build a sewer network model.

An initial monitoring campaign was conducted between March and June 2009 which revealed relatively large inflow and infiltration issues across the Whangarei catchment. The data obtained provided for an excellent calibration of 22 monitoring locations over a range of events [2]. However this initial monitoring period provided no baseline to differentiate base infiltration as a result of high ground water to actual dry weather wastewater production.

The implementation of strategic long term monitors allowed council to obtain a seasonal baseline for the network and better predictions for peak events across the seasons.

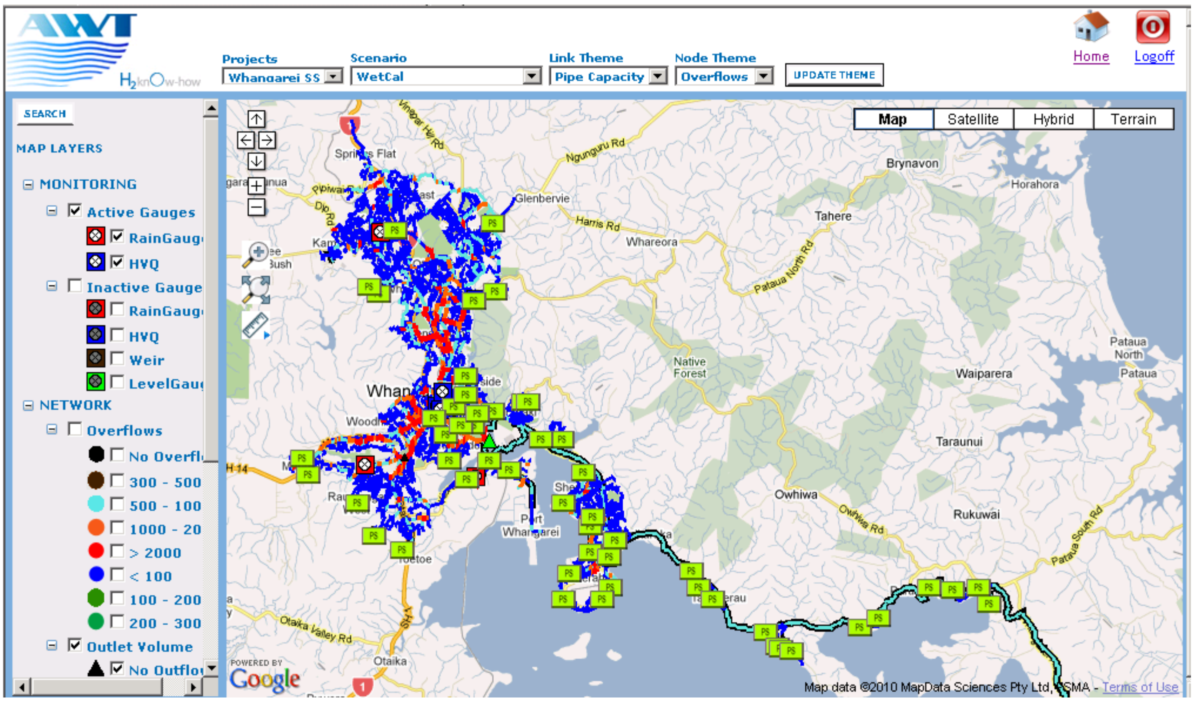

Figure 5: Overview of Whangarei City modelled catchment

Once the model was calibrated design storms could be imposed on the network model to see its response. Following a review of various rainfall models and actual data the standard HIRDs intensity distribution for Northland were used as the design rainfall pattern. Imposed on this was an allowance for climate change and growth. The forecasts were done for the year 2041, a 30 year horizon at the time the model was built.

Table 1 below presents the 2011 and predicted 2041 spill volumes based on the network modelling work.

Table 1 Spill Volumes

	Event Return period	Total overflow volume (ML)	Total to treatment plant (ML)	Overflow + Treated (ML)	% of wastewater generated during a storm that overflows to a stream catchment: Raumanga (%)	Hatea (%)	Wai-arohia (%)	Total (%)
Current (2011)	6mth	23	108	131	9.4	4.6	3.8	18
	1yr	33	131	164	9.9	5.7	4.2	20
	2yr	43	156	199	10.4	6.6	4.6	22
	5yr	63	181	244	11.9	8.6	5.2	26
Future (2041)	6mth	31	108	139	10.4	8.1	3.7	22
	1yr	42	131	173	11.1	8.8	4.1	24
	2yr	52	156	208	11.3	9.3	4.4	25
	5yr	75	181	256	12.8	11.4	5.0	29

Coupling the network model to a hydraulic model for the treatment plant allowed for a catchment wide approach to evaluate options that were focussed on harbour water quality and the associated public health risks as a key driver.

3.2 WHERE DOES IT GO? - DISPERSION MODELLING & QMRA ASSESSMENT

To understand what happened to the wastewater once it overflowed into the harbour, council, in conjunction with the Northland Regional Council and North Port, funded NIWA to develop a hydraulic dispersion model.

The model assessed that fate of contaminants into the harbour at volumes determined by the sewer network model and allowed for some differentiation around the impact of wastewater discharges (including overflows) and background or other sources. This model indicated that the path of contaminants in the harbour was complex, with tidal movement potential holding contaminants in the harbour for over 90 days.

The model was an extremely useful tool for communicating with the public, as it could be animated for various storm events, showing how the discharges affected (or didn't affect) water quality in the harbour. An example is presented in figure 6 which shows an untreated discharge from the treatment plant (bright orange) affect water quality. The mouth of the 18km long harbour is in the right hand bottom corner.

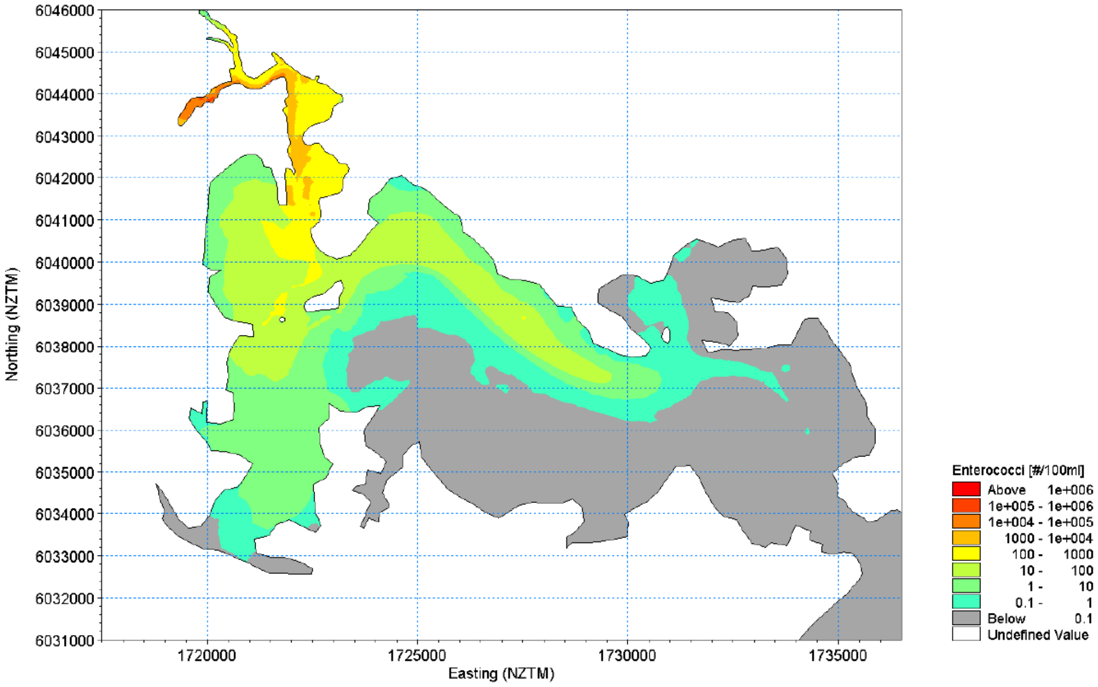

Figure 6: From NIWA Harbour dispersion modelling report – Spatial plot for WWTP extreme bypass scenario as a result of a 2-year ARI flood; showing the predicted maximum concentrations of enterococci recorded at any time over the 3-day data extraction period.

The model allowed for an open engagement with the community by providing a scientific basis and the first opportunity to quantify the effects on harbour water quality as a result of a storm event. The model predicted some disturbing results that indicated high bacterial levels in recreational bathing, and some shellfish gathering areas with a significant retention time for contaminants within the harbour.

3.3 SO WHAT? – QUANTITATIVE MICROBIAL PUBLIC HEALTH RISK ASSESSMENT (QMRA)

These modelling results where then used by NIWA, Northland Regional Council and council to undertake a quantitative microbial risk assessment (QMRA) to estimate the risk wastewater discharges pose to public health while people are swimming, undertaking recreational activities, and eating raw shellfish collected from the harbour for various modelled storm events.

The assessment estimated the probability of specific pathogen (in this case Rotovirus) making its way into the harbour and making people ill at either a contact recreation site or a shellfish gathering. The definition of "making people ill" was determined as a greater than 5% chance someone became ill as a result of the discharge.

The findings of the study indicated that the risk from recreation contact is very low, even without upgrades. The basis for this is that it was unlikely anyone would use the harbour for recreation during storms. The risk for shellfish collection was higher however as the pathogens remained after the storm event passed. The overall findings are presented in Table 2.

Table 2: QMRA findings for wastewater overflows in a five year storm event

Contact Recreation	Summer		Winter	
	Current	With Improvements	Current	With Improvements
Upper Harbour	Acceptable	Acceptable	Acceptable	Acceptable
Wider Harbour	Acceptable	Acceptable	Acceptable	Acceptable

Shellfish Gathering	Summer		Winter	
	Current	With Improvements	Current	With Improvements
Upper Harbour	Acceptable	Acceptable	Unacceptable	Acceptable
Wider Harbour	Acceptable	Acceptable	Acceptable	Acceptable

Ecological assessments at specific locations within the harbour were also completed to establish effects to marine environment as a result of the waste water discharge. This built on the work that had been undertaken for the treatment plant discharge in Lime burners creek and established that there is minimal ecological impact as a result of the peak (overflow & planned) discharges both in Limeburner's creek and at the other proposed off load locations. This and the previous ecological work confirmed that the effects to the harbour as a result of the peak flow / overflow discharges are related to microbiological contamination as opposed to nutrients, solids or organic load.

3.4 WHAT TO DO ABOUT IT?

To address the public health risk to shellfish collection Council established overall aims for an overflow reduction programme, that when tested with models achieved reduced public health risks. These were:

- Key infrastructure projects are developed so that they contain/prevent/treat spills from a 1 in 5 year return period storm.
- Network discharges are reduced such that 80% of spills that are predicted to occur in year 2040 are prevented or treated in an annual storm event.
- Integrated harbour management initiatives to improve non-wastewater contaminants

Using the network model it was evident conveying all of the wastewater plant to the treatment plant during storms was cost prohibitive. A sizing exercise indicated this would cost over $200M and end up with greater than 4,000 L per second entering the treatment plant.

A review of other council’s efforts in reducing I/I through sewer upgrades indicated this was costly and had mixed results.

Council identified that establishing planned discharge locations where wastewater overflows are disinfected prior to release was substantially more economic than containment through pipe amplification and storage. While this option contains less total volume in the system, it contains a greater portion of untreated wastewater and provides a substantially improved outcome in terms of water quality and public health risk for a given capital spend.

A key factor was determining if the stormwater diluted sewage could be disinfected with minimal treatment, this is further discussed below.

An optioneering exercise allowed the development of a master plan that included:

- Two network based off load sites. - This included a 1,000 m^3 storage tank with the ability to treat 450L/s at the Hatea pump station. This option included the ability to shut down sewer trunk lines and divert flow to the storage tank to free up conveyance capacity in the remaining network .A second 600 m^3 storage tank with a 260 L/s treatment capacity ((Tarewa). Again this option included the ability to throttle sewer trunk lines and divert flow to the storage tank.
- Treating all wastewater from the treatment plant – no bypass. This included building a 75 MLD (870 L/s) storm UV system and reconfiguration of the treatment plant to provide high flow treatment. This increased the treatment plant disinfection capacity to 125 MLD.
- Sewer network reconfiguration. The model identified sewers with spare capacity. Cross linkages to these sewers above bottle necks allowed the most to be gained for the existing sewer capacity. In some case larger pipes were needed to reduce network overflows.

3.5 ASSESSMENT OF DISINFECTION OPTIONS

To ensure effective disinfection, measurements of ultraviolet light transmittance (UVT) through the wastewater during storm events were undertaken. This allowed for the development an empirical model for sizing and costing treatment and disinfection requirements at constructed off load locations including the raw and primary treatment overflows at the treatment plant.

Figure 7 below presents the results that allow a relationship between solids in the wastewater and the associated change in Ultra Violet Transmissivity (UVT) to be developed for a storm (peak flow) event.

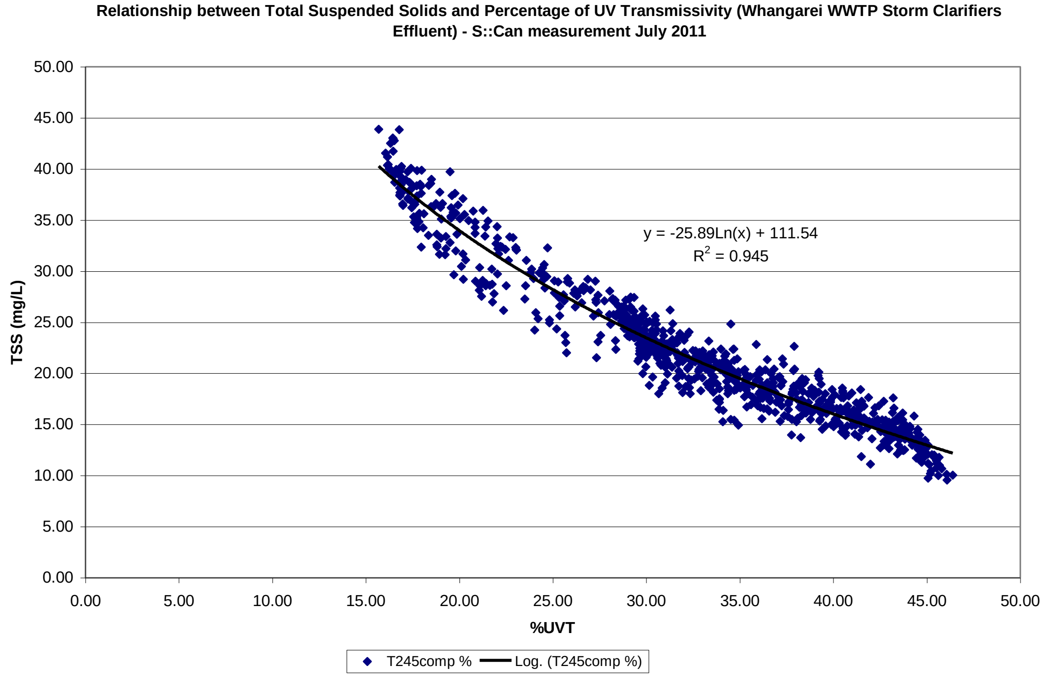

Figure 7: Trend for TSS / %UVT relationship (Storm Clarifiers S::can data – July 2011)

Both grab samples and measurements taken using an EScan (UV Spectrophotometer) at the treatment plant were used to evaluate the dynamics around the change in UVT through the course of a storm event including an assessment of the "first flush" and how the transmissivity improves over the duration of the event. Changes in UVT were related to solids concentration for a number of events and this information was used to size and specify the treatment requirements (both the chemical dosing, settlement requirements and UV plant) for each off load location.

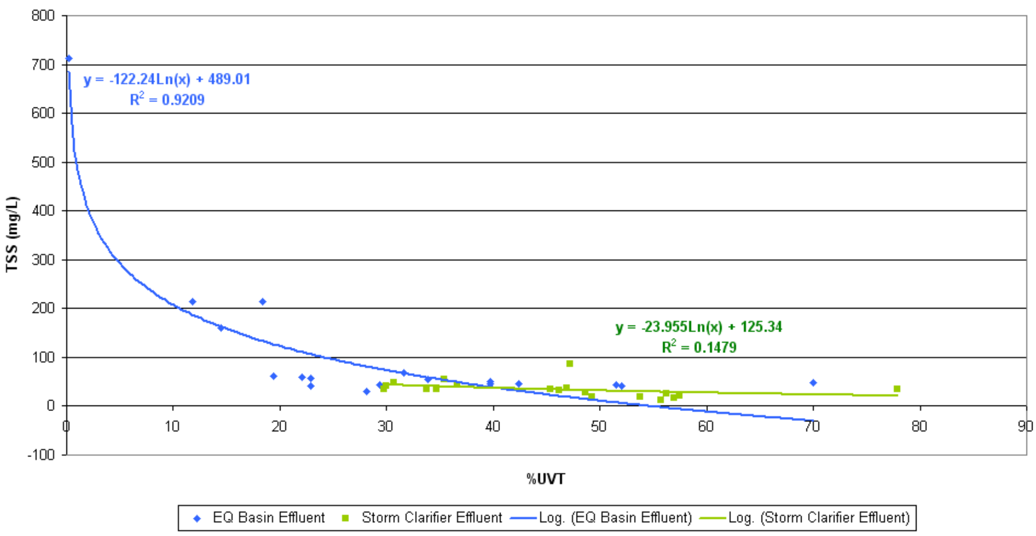

Figure 8: Trend for TSS / %UVT relationship (EQ Basin and Storm Clarifiers effluents Grab samples – December 2011 & March 2012)

Due to the variability of the water quality through the storm it was very difficult to determine the ideal design point. Selecting conservative design figures had huge implications on the size and power requirements of the UV equipment. It was very clear that choosing the worst case TSS and UVT and the highest flow rates would make the UV disinfection system unrealistically large.

Council reviewed its risks and selected typical design parameters, understanding that at times (e.g. first flush) the disinfection dose could be less than needed. To help mitigate the risk Council included civil works that allowed expansion of the disinfection system and process options, such as chemical settlement, that could be implemented if the treatment standards weren't achieved. The design parameters for the UV equipment included are presented in Table 2.

Table 3: Wet weather overflow UV design parameters

Site	**Flow** (L/s)	**Influent** E. Coli / 100mL	**Effluent** E. Coli /100mL	**% UVT**	**TSS** (mg/L)	**Min dose** (mJ/cm^2)
Whangarei – Storm UV	860	$5.0 X10^6$ (90% ile)	3,000 (90 %ile)	35	35	40 10 min average)
Hatea	450	$2.5X10^6$	250 (90 %ile)	40	30	40 (10 min average)
Tarewa	254	$2.5X10^6$	250 (80%ile)	40	50	40 (10 min average)

4 CONSULTATION & COMMUNITY ENGAGEMENT

During the early 2000's Council engineering staff had engaged with the community at large and directly with a number of key stakeholder groups including;

- Iwi and hapu representatives
- Commercial shell fish operators
- Northland district health board and Regional Council
- Water quality action groups

Council had spent substantial time working with these groups to understand what was of key importance and to provide feedback around the affordability of different solutions given the budget that had been allocated by the Council.

The community engagement came to a head in December of 2008 when about 500 people took part in a "save the harbour" march and presented the Mayor with a petition of 5,500 signatures. This direct community feedback provided a greater level of public awareness and discussion at both a community and political level around the balance of cost vs environmental protection. In essence the "people had spoken" and indicated that a greater focus needed to go on environmental protection.

From this point the Council and subsequent Councils placed a greater focus on this community value and worked more closely with the engineering team to identify an affordable solution.

Using the tools and outputs described in the above technical investigations and following a decision to eliminate all overflows at the Okara Park pumping station (and divert these peak flows to the plant), the team considered what could be undertaken across the wider network that would meet the harbour water quality requirements and provide and acceptable public health risk.

It also provided clear empirical information that could be shared with the community.

5 Development & Implementation of the Master Plan

The majority of the Master Plan has now been completed, with only the Tarewa tank to be built although it is currently being designed. The total cost of the projects will be around $20M.

Approximately $2.5M of sewer relocation works has also been completed. A brief overview of the treatment projects are presented below.

An integrated harbour group has been operating for over two years looking at improving back ground water quality in the harbour.

5.1 HATEA SEWAGE PUMP STATION, TREATMENT SYSTEM AND STORAGE TANK

The Hatea system cost $5M and has been operational since mid-2012. The storage system operates around every two months with the treatment system operating approximately every 6 months. The UV system utilises three WEDECO reactor units.

Water testing has indicated influent E Coli at around 2,000,000 per 100mL and effluent concentrations less than 100 per 100mL. It consistently achieves its consent requirement of better than back ground.

The largest volume treated was 18,000 m3 during a storm event in 2014.

Figure 9 Hatea Storage and Treatment Facility – Architecturally design to fit in with residential location

5.2 WHANGAREI TREATMENT PLANT STORM UV SYSTEM

The Whangarei Storm UV system cost $3M including the treatment plant reconfiguration and civil structures. It utilises a Trojan open channel UV system.

It operates on a monthly basis on average every month, however can run for days during extended rain events. It consistently meets its consent requirement of a median E. coli less than 1,500 per 100mL as indicated in Table 3.

Figure 10 Whangarei Wastewater Plant Storm UV System

Table 4 Monitoring data for Storm flow UV system

Analysis of performance of Storm Flow UV system at Whanagrei WWTP 10 - 12 June 201						
Sample time	**Flow through**	**UVT - Lab**	**TSS**	**Coliform Escherichia (97w) - MPN**		
	L/s	**% (unfilt)**	**mg/L**	**UV influent**	**UV effluent**	**% removal**
10-Jun 08:30	498	27.1	75	1014000	794	99.92
10-Jun 09:15	510	32	53	1223000	723	99.94
10-Jun 09:45	454	34.8	51	959000	345	99.96
10-Jun 10:12	488	32.6	55	1081000	201	99.98
10-Jun 10:40	529	32.7	55	1153000	480	99.96
10-Jun 11:12	650	31.4	60	1178000	301	99.97
10-Jun 11:40	717	31.6	55	253000	1145	99.55
10-Jun 15:00	751	34.6	66	744000	1296	99.83
11-Jun 09:00	303	67	18	201000	20	99.99
11-Jun 12:00	246	51.7	25	384000	10	100.00
12-Jun 09:00	76	67.5	12	269000	10	100.00
Composite sample						
Phage consent						
Median				918500	323	
Median - consent					1,500	
90%ile				1214000	1,145	
90%ile - consent					3,000	

6 CONCLUSIONS

A comprehensive understanding of the overflow issues, and the community's expectations, has allowed a cost effective master plan to be implemented that meets the goal of protecting public health from sewage spills during wet weather.

Key factors included:

- establishing water quality targets based on health risk assessments;
- development of a calibrated sewer network model to trial options and provide input into the health risk studies and to identify network constraints and opportunities;
- understanding the ability of UV disinfection to treat diluted wastewater;
- understanding the risks associated with UV disinfection treatment options to make the most effective use of capital expenditure;
- Keeping messages simple and open, allowing the community to be engaged in the programme.

Since implementing the sewerage master plan the council's customer satisfaction rating has increased from 46% to 76%. Wastewater issues are also no longer an issue for Councillor appointment. Strong relationships have been built with iwi and hapu, the district health board and the regional council, all whom have been able to have input into the programme.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the work and collaboration of; Whangarei DC staff, NIWA, Opus International Consultants, Northland regional council, and the associated community, Iwi and other stakeholder groups

REFERENCES

1. Managing wet weather sewage spills in a challenging environment - Andrew Carvell - Water NZ conference paper September 2011.

2. Seasonal Variation in Sewers, How it can affect your perception of system Performance; T Joseph - Water NZ Conference paper 2012

3. "Predictions of Human Health Effects Associated with Wet Weather Flows in Whangarei", G McBride and G Reeve, NIWA (2011). Report to Northland Regional Council.

4. "Whangarei Harbour Hydrodynamic and Dispersion Model", Reeve et al, NIWA (2010). Report to Northland Regional Council.