REAL TIME CONTROL – INFORMING POLITICAL DECISION MAKING

T. Lockie (Hydraulic Analysis Limited)
N. Brown (North Shore City Council)

ABSTRACT

This paper discusses the application of the North Shore City Council's (NSCC) calibrated trunk wastewater model to assess the performance of the NSCC Real Time Control scheme and the use of the model to develop a range of RTC operational scenarios to achieve differing objectives i.e. minimise spill frequency, minimise spill volume or control of spills to preferential locations.

The NSCC trunk sewer model and RTC scheme were developed as part of the Project CARE Review study, which was an update and extension of an existing strategic wastewater model to aid in infrastructure planning. The current operation of the NSCC wastewater network includes the control of number of gates and pumps to minimise spill volumes and to preferentially spill at certain locations. MOUSE User Written Controls (UWC) were developed to simulate these controls appropriately. The UWC module deals with local PLC operations and remote SCADA operations of the control structures. The implemented control logic ranges from simple gate operations to more complex storage synchronization.

NSCC's RTC provides flexibility in how the system is operated. Model analysis of the NSCC's RTC operation informed a clear understanding of the RTC's operational flexibility and potential impact on system performance. However with that flexibility comes choice, requiring political decisions to be made in the selection of the preferred operational strategy.

This paper briefly outlines the development of the model RTC, and discusses the option assessment performed on the RTC scheme to develop a range of operational RTC scenarios and the implications of these schemes to network performance.

KEYWORDS

MOUSE, Wastewater Modelling, Real Time Control, RTC, User Written Control, UWC.Introduction

1 INTRODUCTION

This paper discusses the application of the North Shore City Council's (NSCC) calibrated trunk sewer MOUSE model (developed as part of Project CARE) to assess the performance of the NSCC Real Time Control scheme and the use of the model to develop a range of RTC operational scenarios to achieve differing objectives i.e. minimise spill frequency, minimise spill volume or control of spills to preferential locations.

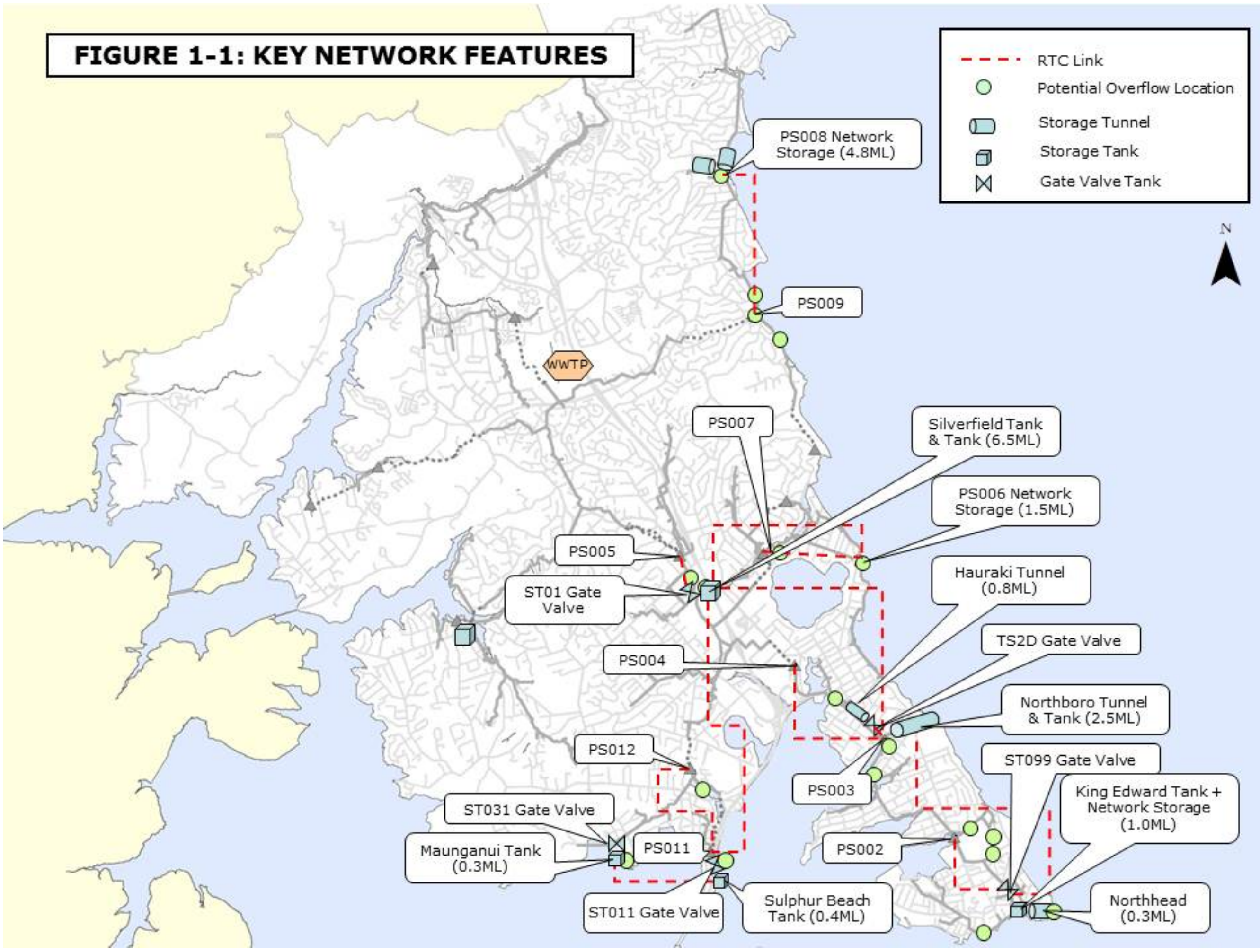
The outline of this paper is as follows:

1. Description of the NSCC's wastewater network
2. Description of NSCC's Project CARE, from which this RTC analysis builds upon
3. NSCC's existing RTC scheme
4. Model implementation of the NSCC's RTC scheme
5. Model RTC analysis and findings

2 THE NSCC'S WASTEWATER NETWORK

2.1 NETWORK STATISTICS AND EXTENTS

The NSCC's wastewater network covers 11,000 hectares and services ~220,000 residents, the below figure shows the catchment extents and key network features.



2.2 NETWORK DEVELOPMENT

Prior to the 1960s, wastewater within the NSCC catchment was disposed via sedimentation tanks and coastal outfalls which serviced pockets of development. In the 1960s the wastewater system was centralized with the construction of a trunk sewer network and the Rosedale Wastewater Treatment Plant (WWTP). At which time the sedimentation tanks and outfalls were abandoned. In the late 1990s and early 2000s, a number of these abandoned tanks and outfalls were recommissoned and adapted to provide offline and online storage. In addition to these historic structures new storage facilities were provided as part of NSCC's capital improvement works program. To utilize this network storage efficiently a Real Time Control scheme was developed, from the late 1990s.

3 THE NSCC'S PROJECT CARE

3.1 PROJECT CARE OVERVIEW

Project CARE is a program to improve beach water quality in North Shore City by reducing the number of wet weather overflow events from well over 12 times per annum down to no more than two per annum by 2021. To achieve the targeted overflow frequency as of 2008 the proposed capitals works program is estimated at $303 million.

The findings and recommendations from the Project CARE process was used to support resource consent applications and reporting requirements for the Auckland Regional Council. Where NSCC's proposed wastewater network consent condition is:

A design target for all of the network, of an average of no more than two wet weather overflow events per year by 2021, as assessed by computer modelling.

3.2 PROJECT CARE TIMELINE

1998 and Prior:

- Frequent spills to beaches and associated beach warning signs – substantial public awareness of issues particularly as beach water quality is important to the community
- Councilors elected on platform to resolve spilling and impact on beach water quality
- Project CARE initialized

1998 – 2002:

First iteration of the Project CARE strategic planning program carried out in four phases, starting in 1998 and completed in 2002 (by NSCC, Worley Consultants (AECOM) & Sydney Water):

- Phase 1 was the planning phase, when existing data were collected and reviewed in order to carry out the scoping of the project
- Phase 2 involved the identification of all sources of bacterial pollution, quantifying them to establish a clear understanding of the performance of the wastewater and stormwater systems and the treatment plant outfall and their effect on beach water quality. Computer simulation tools were utilized to assist in the assessment
- Phase 3 involved development and assessment of options to improve the wastewater system, divided into two functional phases:
    - 3a - Identification of the most cost effective solutions for system improvement by cost optimization for a number of different levels of improvement
    - 3b - Cost benefit analysis of options in order to agree on a level of improvement (using a containment standard as a design target) for 2050
    - The output of this phase was that a design standard of two wet weather overflows events per annum (annual average, based on computer modeling) was recommended and adopted
- Recommended Level Of Service (LOS) agreed with community and councilors. Also agreed to 6 yearly review of Project CARE to ensure on track.
- Phase 4 covered the development of a detailed program of works called the Wastewater Network Strategic Improvement Plan (WNSIP) to meet the target.
    - Final capital works program was generated to achieve LOS of by 2021
    - Optimized with Sydney Waters SEWCOM
    - 2002 WNSIP = $231 Million (2001 Dollars), $504 Million (2008 Dollars))

2002 – 2006:

- Number of projects built from the capital works program ($145 Million Spent (2008 $) from 2001 to 2008)
- RTC implemented to improve system performance until 2021, by utilizing network storage.
- Detailed network investigations completed, for a number of catchments to ensure local network achieves LOS by 2021

2006 – 2010:

First Review of Project CARE undertaken, which involved:

- The rebuild and calibration of a strategic model (in DHI's MOUSE 2007) of the NSCC's Trunk wastewater network, model extents includes:
  - 11,000Ha of catchment
  - ~100km of sewer
  - ~20 Pump stations
  - ~9 offline storage tanks (19ML of storage)
  - 5 Online gate valves
  - Representation of RTC
  - The model was calibrated against:
    - 47 long term flow gauges (in operation for 1 year)
    - 12 short term gauges (3 months of gauge data)
    - 18 pump station Magflow and wetwell level gauges
    - 14 rain gauges
- System Performance for existing and future development scenarios
- Review of the 2002 WNSIP progress and performance, to identify whether the completed WNSIP has achieved the targeted LOS.
- Revised WNSIP (2008) to meet LOS by 2021 and maintain LOS to 2051, to $303 million ($ 2008).
- Sensitivity Analysis
- Optimization of WNSIP
- Review and update of RTC operation, discussed in this paper

4 THE NSCC'S REAL TIME CONTROL (RTC) SCHEME

By 2007 the NSCC's existing RTC scheme had been developed to:

- Prevent (Minimise) overflows
- Maximise storage utilisation
- Preferentially spill

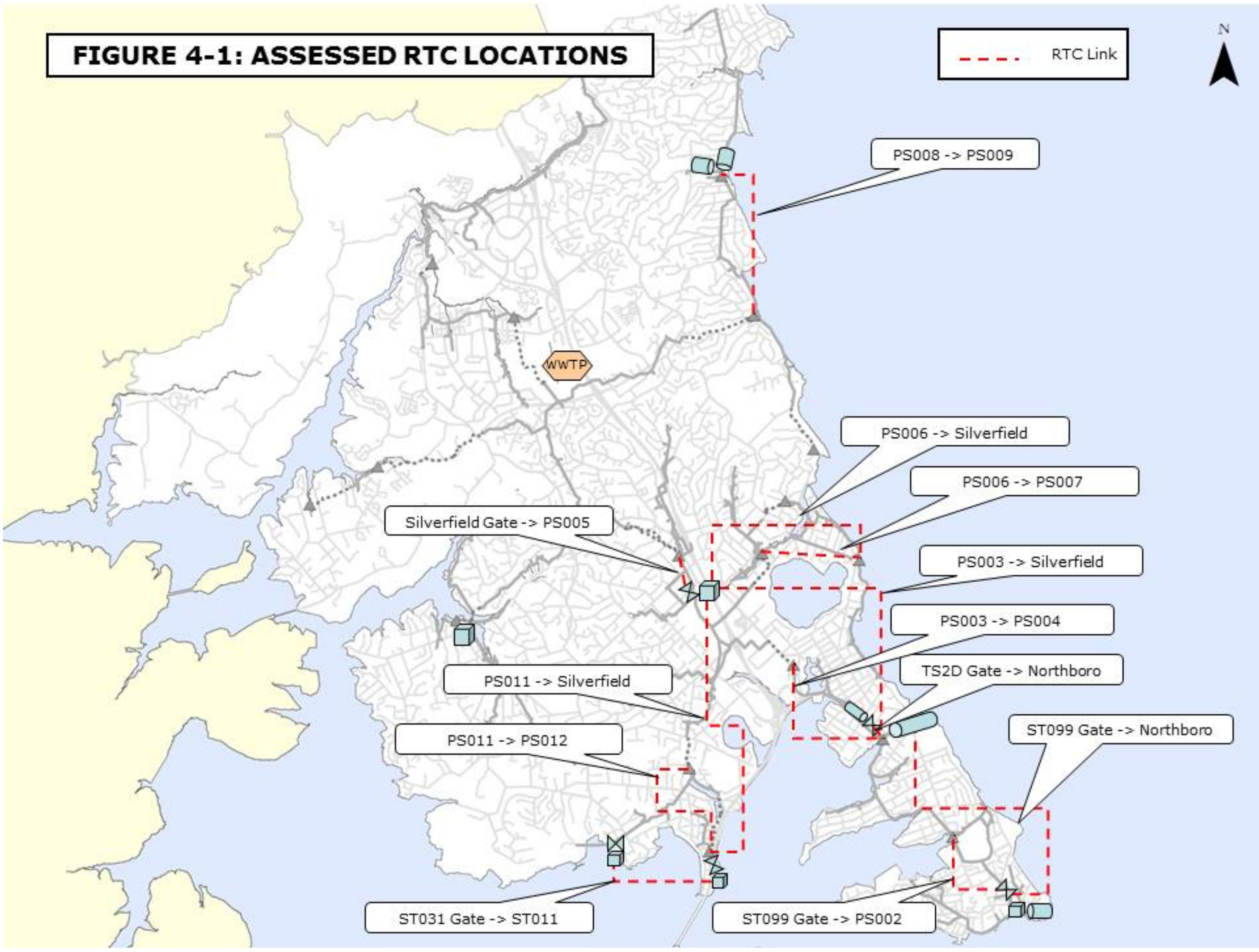
With RTCs implemented for a number structures including:

- Gate Valves
- Pump Stations (Inhibit / Enable)

A number of RTC operational strategies were in operation, such as:

- Predictive controls to forecast system states and preempt network failure
- Storage coordination, to ensure closely related storage tanks were filled and emptied in coordinate manner so as not adversely affect network operation i.e. emptying all storages simultaneously

The NSCC's 2007 RTC scheme had been developed on an ad-hoc basis, therefore NSCC were unsure whether it was achieving the overall strategic objective. The below figure details the key RTC's assessed during this analysis.



5 MODEL IMPLEMENTATION OF NSCC'S RTC SCHEME

5.1 OVERVIEW

This section describes the model (Network and RTC) setup which was utilised to assess RTC performance. Where the model representation of the NSCC RTC scheme was developed during the Project CARE review model build and calibration phase in 2007 / 08.

5.2 MODEL RTC SETUP

MOUSE User Written Controls (UWC) were constructed to simulate the Real Time Controls implemented in the NSCC wastewater network. These controls were coded in Delphi7 and compiled into a Dynamic Linked Library (DLL) which the MOUSE HD engine accesses during simulations. Control values and set points are read from a text file (PFS) where the following variables for each control are defined:

- Set-points for sensors
- Polling interval (simulates interval at which the SCADA interrogates each control)
- Storage coordination parameters

5.3 MODELLED CONTROLS

The below table summarize model implemented controls.

Table 1: Modelled RTC

Control ID	Location	Type	Description
ST001_Gate	On TS4 near Silverfield Tank.	Gate	Closes Gate which diverts flows to ST01 when level at PS005 wet well is high.

Control ID	Location	Type	Description
ST001_PS	Silverfield	Pump	Empties Silverfield Tank
PS003	**Northboro**	**Pump**	**Shuts down pumps incrementally for high level at either ST001 or PS004.**
ST03_PS	Northboro Tank	Pump	Empties Northboro Tank
ST03_GATE	Northboro Storage Tunnel	Gate	Gate is opened to drain the Northboro Storage Tunnel to the Northboro tank.
STLEONARDS_GATE	Northboro Storage Tunnel	Gate	Opened to drain the Northboro Storage Tunnel to the coast. Manually operated in reality.
TS2D_GATE	Hauraki Tunnel	Gate	Closes gate when ST03 level high which diverts flow away from PS003 to TS4 -> PS004 via a high level overflow.
PS006	**Black Rock**	**Pump**	**Shuts down pump station incrementally due to high level in ST001 or PS007.**
PS008	**Browns Bay**	**Pump**	**Shuts down pump station due to high level at PS009, utilise storage at PS008, pumps to PS009 when storage full.**
PS011	**Sulphur Beach**	**Pump**	**Shuts down pumps incrementally for high level at either ST001 or PS012 and utilises storage at ST11.**
ST011_GATE	Sulphur Beach	Gate	Empties ST11 back to PS011
ST031_PS	Maunganui Tank	Pump	Empties ST31
ST015_PS	Kahika Storage Tank	Pump	Empties ST15
ST031_GATE	Maunganui Tank	Gate	Diverts flow to ST31, at high ST011 level.
NORTH HEAD_PS	North Head Storage Tunnel	Pump	Empties North Head Tunnel into sewer network
ST099_Gate	**King Edward Tanks**	**Gate**	**Closes gate when level at PS002 is high. Holds back flow and utilises storage at PS99 and then Torpedo Bay and North Head tunnel. Gate operation can also be controlled by the level in the Northboro Tunnel.**

Note: Bold Indicates controls assessed in the RTC Option Analysis

5.4 MODELLED RTC VERIFICATION

Development and verification of the existing RTC's was a complex process. Most of the controls have multiple variables affecting its operation, to which they are sensitive where a small difference in simulated values from those observed can vastly alter the operation of the control. To reduce this interference, where possible, the controls were initially verified with the recorded telemetry variable controlling its operation as a boundary condition.

Table 1: RTC Verification Model Setup

Control	Model Setup
ST001 Silverfield Gate	TS04 telemetry water level sensor set as boundary condition to model gate sensor.
PS099 King Edward Tank	Northboro Tunnel and PS002 Wetwell telemetry water level sensor set as boundary condition to model gate sensor.
PS003 Northboro Pump Station	Silverfield Tank and PS004 Wetwell telemetry water level sensor set as boundary condition to model gate sensor.
PS006 Northboro Pump Station	Silverfield Tank and PS007 Wetwell telemetry water level sensor set as boundary condition to model gate sensor.
PS008 Northboro Pump Station	Browns Bay PS Storage Tank and PS009 Wetwell telemetry water level sensor set as boundary condition to model gate sensor.
Hauraki Tunnel Gate (TS2D)	Northboro Tunnel and PS003 Wetwell telemetry water level sensor set as boundary condition to model gate sensor.
PS011 Northboro Pump Station	Silverfield Tank and PS012 Wetwell telemetry water level sensor set as boundary condition to model gate sensor.
ST31 Maunganui Tank	PS011 Wetwell telemetry water level sensor set as boundary condition to model gate sensor.

The below table summarises the modelled Real Time Control performance (source Project CARE, Model Build and Calibration Report, NSCC 2008).

Table 1: Model RTC Performance

Control	Performance	Comment
ST001 Silverfield Gate	Acceptable	Reasonable representation of gate movement.
PS003 Northboro Pump Station	Acceptable	Some anomalies from PS004 level control

Control	Performance	Comment
PS006 Northboro Pump Station	Acceptable	Some short pump starts not simulated in model.
PS008 Northboro Pump Station	Acceptable	Model shuts PS008 for slightly longer period than indicated in telemetry.
Hauraki Tunnel Gate (TS2D)	Poor	No gate position data available to verify model performance.
PS011 Northboro Pump Station	Moderate	Model represents PS011 throttling timings poorly.
ST031 Maunganui Tank	Poor	Limited gate position data available to verify model performance.
ST099 King Edward Tank	Moderate	Good model representation of gate movement for some events but for other events poor estimation.

It is expected that the current model RTC, contains the core logic and functionality of the NSCC RTC, which will enable the assessment of the RTC operation and to qualify the adjustment of set points to improve operation.

6 MODEL RTC ANALYSIS AND FINDINGS

6.1 MODEL RTC ANALYSIS OBJECTIVE

As described previously in the introduction the objective of this analysis was to develop improved trunk sewer network performance through:

- Adjustment of ProjectCARE Review calibrated model RTC set points and assessment of the model performance
- Review of RTCs and logic to develop improved control logic
- Improve understanding of RTC operation, through what if analysis to quantify of sensitivity of system performance to changes in RTC operation.

6.2 MODEL RTC ANALYSIS SCOPE

This study utilizes the calibrated strategic model (developed as part of the Project CARE review) for the NSCC trunk sewer network to assess system performance for a number of different RTC set point arrangements. The following controls were analysed:

- PS008 RTC (Browns Bay)
- ST001 RTC (Silverfield Gate)
- PS011 RTC (Sulphur Beach)
- ST099 Gate RTC (King Edward)
- PS003 RTC (Northboro)
- PS006 RTC (Black Rock)

6.3 MODEL RTC ANALYSIS ASSUMPTIONS AND LIMITATIONS

The core assumptions and limitations that apply to this analysis are:

- The current model RTC operation is an adequate representation of actual RTC
- In general the current RTC logic will be adopted i.e. Only set points were adjusted to determine an improved RTC operation. However in addition some consideration and recommendations were given to obvious logic and control changes.
- Results from this study are estimates and give a relative indication of RTC performance. Where differences between schemes are assumed to give an indication of the relative performance of each option, rather than an extract representation of the actual operation

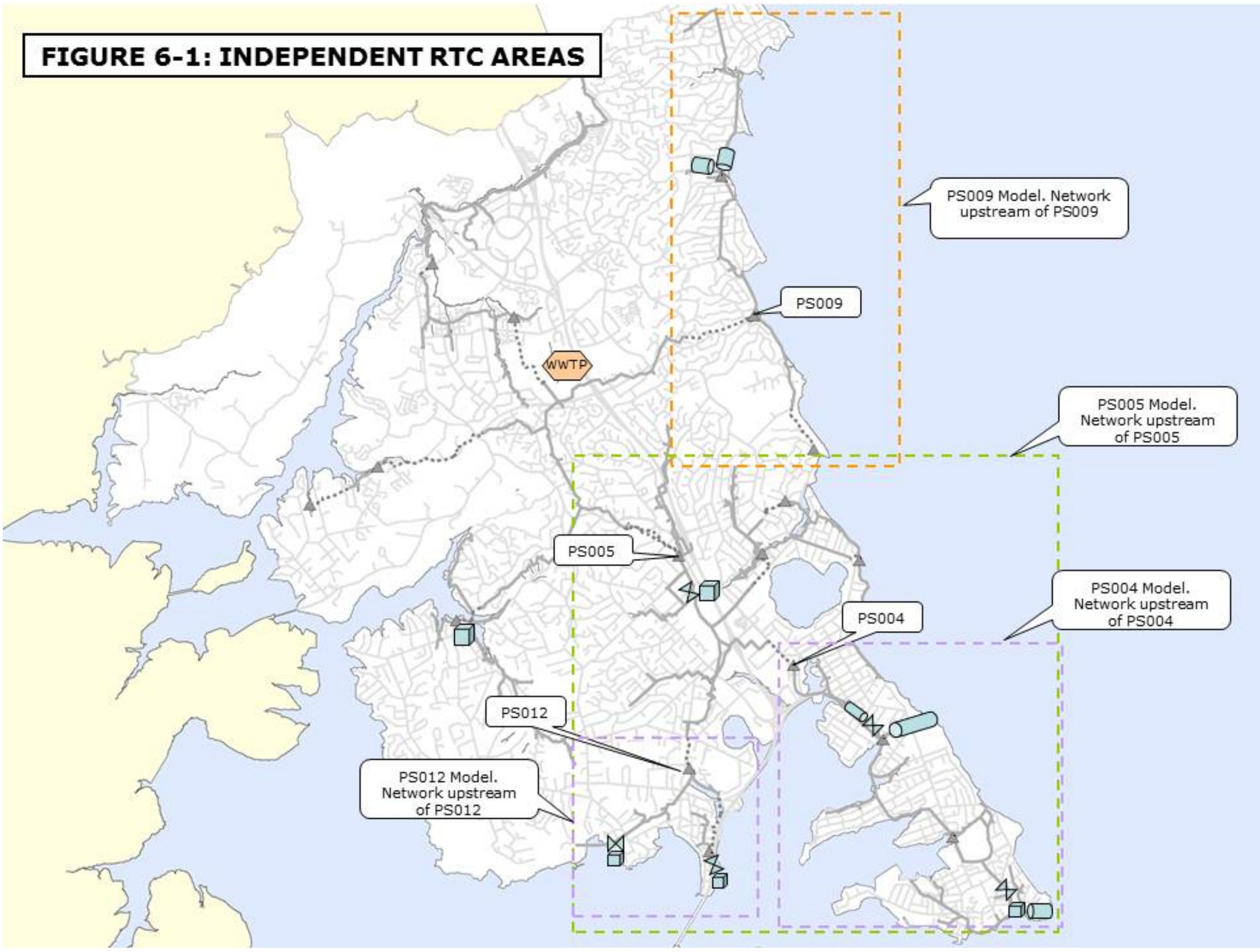
- An exhaustive search has not be been performed with all possible set point permutations therefore recommended set points may not be optimal and are considered the best performed of the options assessed

6.4 MODEL RTC ANALYSIS METHODOLOGY

The methodology adopted to assess RTC performance is as follows:

- RTC logic remained unchanged with only set points adjusted
- Each RTC was assessed initially in isolation, e.g. PS003 -> ST001 control level will be assessed separately from the PS006 -> ST001 control level.
- The parameters which give the 'best' performance were combined to assess the joint RTC operation.
- RTC logic performance was assessed with a 9.5 year (1999-2008) rainfall time series. Note: To take account of spatial variation rainfall across the NSCC catchment, 8 long term rain gauges records were applied to the model.
- The Project CARE model was split into four separate models covering the network upstream of the pump stations which formed the downstream boundary condition):
  - PS009 (independent of the RTC scheme upstream of PS005)
  - PS005, which was split into two sub areas for some analyses:
    - PS004
    - PS012

See the below figure for model extents.



To assess network performance associated with each RTC scheme, system release points (overflow locations within the PS009 and PS005 networks) affected by the RTC operation have were identified and classified into the following:

1. Primary locations (spilling directly to coast)
2. Secondary locations (spilling directly to estuaries, watercourses)
3. Tertiary locations (uncontrolled spills through manhole lids in roadways, reserves)

See the below figure for overflow classification location.

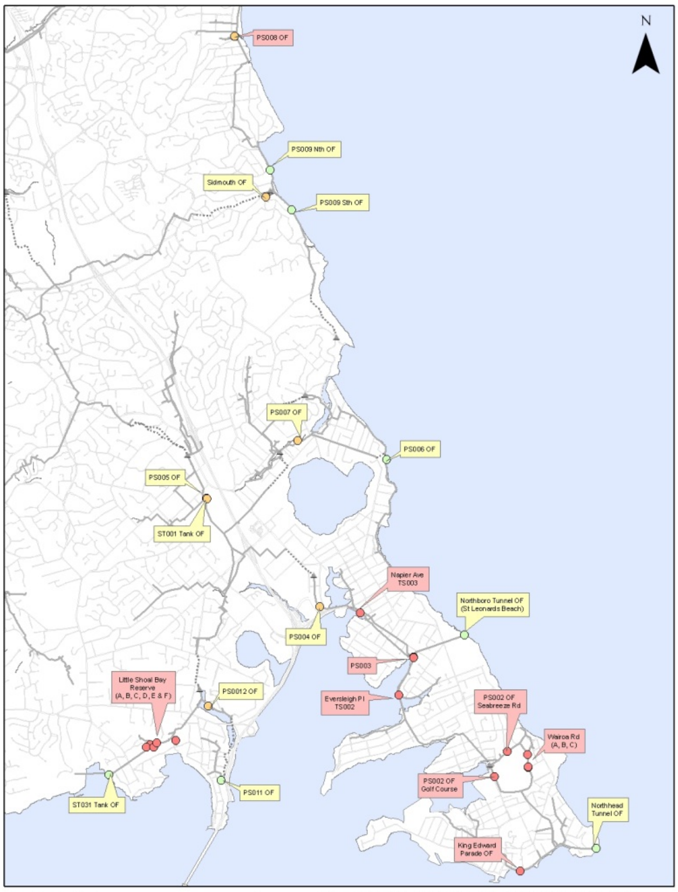


FIGURE 6-2: OVERFLOW CLASSIFICATION

Simulated network performance was assessed on the following criteria:

- Reduction of spill frequency
- Reduction of overflow volume
- Preferential spills through constructed overflows to coast (Primary locations)
- Reduce uncontrolled spills

RTC set point adjustments were based on the percentage of network storage utilization. A stage storage relationship was generated for the network upstream of each control point. This relationship enable to the RTCs to be assessed in uniform steps i.e. 10% increments. Which was converted back to a reduced level for simulation within the model and for provision to the NSCC operations team for implementation.

6.5 MODEL RTC ANALYSIS SIMULATED SCENARIOS

The below table identifies the proposed controls assessed and the associated set point/s. For each control set points were assessed in 5-10% increments, which for 22 individual set points results in a significant search space. This search space was reduced, as described above, by splitting the network into independent areas(e.g. networks upstream of PS009 and PS005) and by applying engineering judgment and some simple logic such as that pump station inhibit levels occur consecutively i.e. the level 2 inhibit occurs at or after the level 1 inhibit has been triggered. Still a significant amount of computer processing was spent simulating each of the RTC schemes with a total ~2,500 model simulations completed which represented approximately 2 months of computer simulation time.

With the extensive number of simulations required and associated post processing required, a model 'user interface' was built in an Excel spreadsheet to track each scenario details and to automatically generate and simulate model scenarios. This allowed a range of scenarios to be setup and automatically simulated which greatly improved the project efficiency and reliability (reduced human error). In addition to the user interface a series of tools were developed to automate extraction of results from completed simulations to rapidly assess each RTC schemes performance.

Table 1: Assessed Control Locations and Associated Set Point/s

Control	Set Point
ST001 Gate	PS005 level as recorded at MH 241067
ST031 Gate	ST11 Level
TS2D Gate	PS003 Wetwell Level
	ST03 level
ST099 Gate	PS002 Wetwell Level
PS003	PS004 Wetwell Level
	ST001 Tank – Level 1
	ST001 Tank – Level 2
PS006	PS007 Wetwell Level
	ST001 Tank – Level 1
	ST001 Tank – Level 2
	ST001 Tank – Level 3
PS008	PS008 Wetwell Level
	PS009 Wetwell - Level 1
	PS009 Wetwell - Level 2
	PS009 Wetwell - Level 3
PS011	PS012 Wetwell - Level 1
	PS012 Wetwell - Level 2
	PS012 Wetwell - Level 3
	ST001 Tank - Level 1
	ST001 Tank - Level 2
	ST001 Tank - Level 3

6.6 MODEL RTC ANALYSIS FINDINGS

6.6.1 OVERVIEW

This section describes findings of the completed model analysis and recommended operational strategies, where the preferred strategy was developed on a case by case basis. In many cases the recommended operational was not straightforward and required extensive discussion to develop a consensus as to the preferred operational strategy. To achieve agreement over the strategy these findings were presented and discussed with relevant stakeholders within the NSCC, including operations, planning and projects team members. The completed model analysis allowed the presentation of the pros and cons of each proposed scenario e.g. the adopted RTC scheme can allow spills to be increased while reducing spill volume or preferentially spill to primary locations which would result in an increase in spill volume and frequency.

6.6.2 PS008 TO PS009 RTC SCHEME

The below table summarizes the model analysis completed for the PS008 to PS009 control. As described below three alternative operational strategies were identified from the completed model scenarios, these scenarios were identified to minimize spill volume or frequency (which is expected to result increased spills from PS009) or minimize spill frequency with no change in spill frequency from PS009.

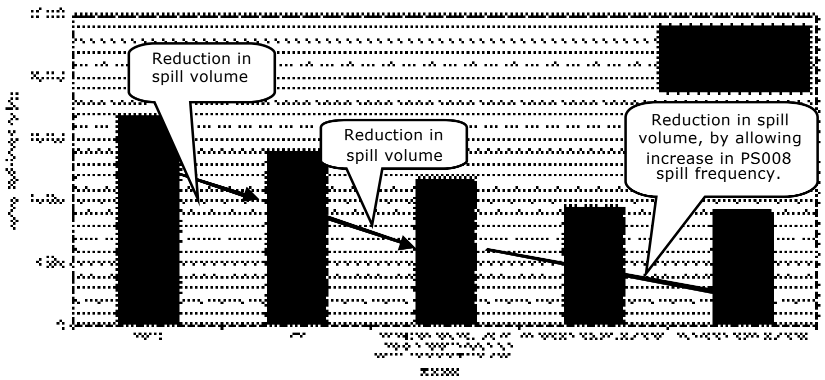
The following are the key network features associated with the PS008 to PS009 RTC:

- PS009 (Sidmouth) overflow is through a constructed overflow and discharges direct to the sea
- PS008 (Browns Bay) overflow is through a manhole lid and discharges over a concrete slab into the Taiaotea Stream close to the outlet to the sea – a project is currently looking into changing this overflow location into a constructed overflow.
- PS008 has a 4.5ML online tank directly upstream of the pump station
- Overflows at PS008 effect Browns bay Beach and Rothesay Bay
- Overflows at PS009 effect Mairangi Bay, Murrays Bay and Campbells Bay

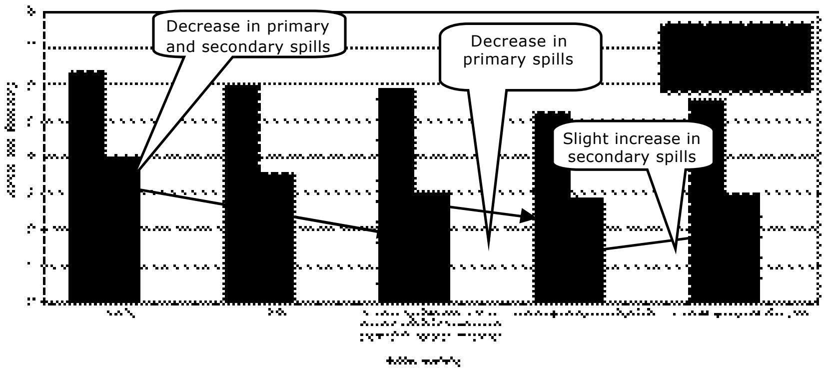
Table 1: PS008 to PS009 RTC Analysis Findings and Recommendations

RTC Control	RTC Scenario	Performance Summary	Result Figures	Current Recommendations
PS008	Current RTC	Current simulated RTC operation shows a significant bias to minimising overflows from PS008.	Figure 6.1 to 6.6	It is recommended that the set points from Run 2193 be implemented which are expected to increase spill frequencies at PS008 while improving PS009 overflow performance. Where: • Simulated overflow volumes decreased by 30% from 14,000m3/annum (Existing) to 9,500m3/annum (Run 2193) • Simulated overflow frequency decreased by 13% overall and by over 40% at the most influenced overflow • Simulated number of overflows at PS008 increased from 0.8/annum to 1.2/annum (beneath the 2021 LOS of 2/annum)
	Run 2195 – Minimise Spill Volume	Run 2195 indicated the least spill volumes from the Primary and Secondary overflows upstream of PS009, with a reduction of 4.8ML from the 14ML spill volume simulated with the current RTC setpoints. This simulation also simulated the least PS009 North spill frequency with 2.1 spills/year compared with the current RTC simulation of 4.1 spills/year, however with this scenario spill frequencies are increased for PS008 from 0.7 (Current RTC simulation) to 1.4 spills/year.		
	Run 2193 – Minimise Spill Frequency	Run 2193 when compared with the current simulated RTC showed the greatest overall reduction in spill frequency (from 6 to 5.2 spills/year for the combined PS008 and PS009 overflows) with the most significant improvement occurring at the PS009 North overflow with a reduction in spill frequency from 4 to 2.3 spills/year. This option is simulated to incur an increase in spill frequency and volume at PS008, from 0.7 to 1.3 spills/year and 1.7 to 2.4ML/year.		

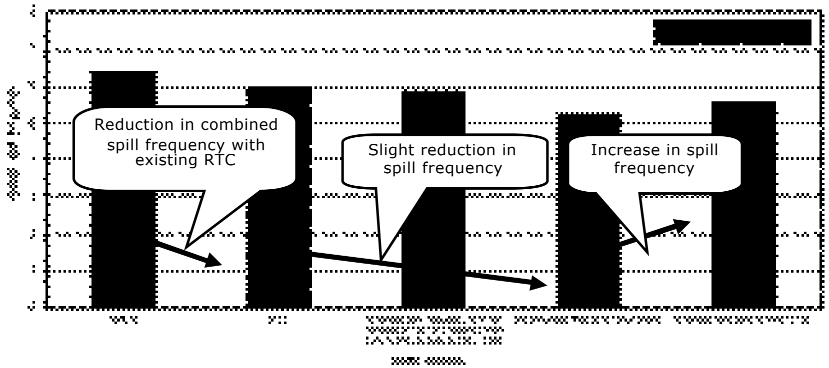
RTC Control	RTC Scenario	Performance Summary	Result Figures	Current Recommendations
	Run 2188 – Least Frequency and Volume with No Increase in PS008 Overflow Frequency from Current RTC Operation	Due to the sensitive nature of the PS008 overflow and the fact that PS008 spills through a manhole lid, it is potentially desirable to not increase spills from this location. Run 2188 simulated the least combined (PS008 and PS009 overflows) overall spill frequency and volume with no increase in PS008 overflow frequency (0.7spills/year) from the current simulated RTC. This option simulated a slight reduction in the combined PS009 & PS008 overflows spill frequency from 6.0 (current RTC) to 5.9 spills/yr and spill volume from 14 ML/yr to 11.8ML/yr. Spill frequency from PS008 is maintained at 0.7 spills/yr, while spills from the PS009 North overflow reduced from 4.1 to 3.6.		



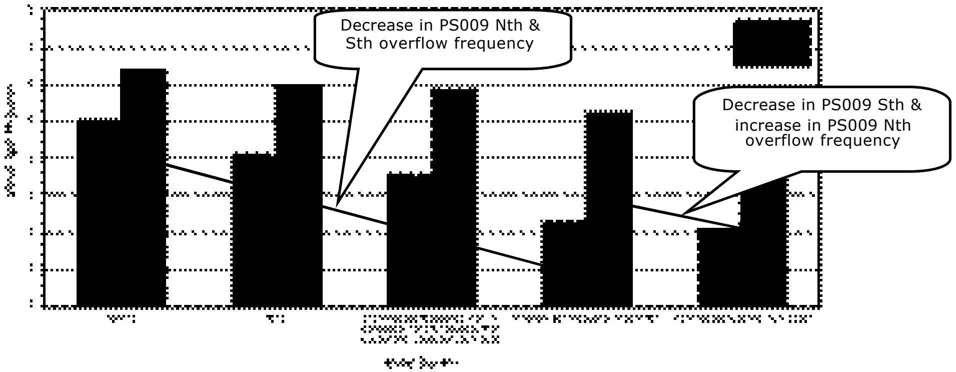
Reduction in spill volume
Reduction in spill volume
Reduction in spill volume, by allowing increase in PS008 spill frequency.



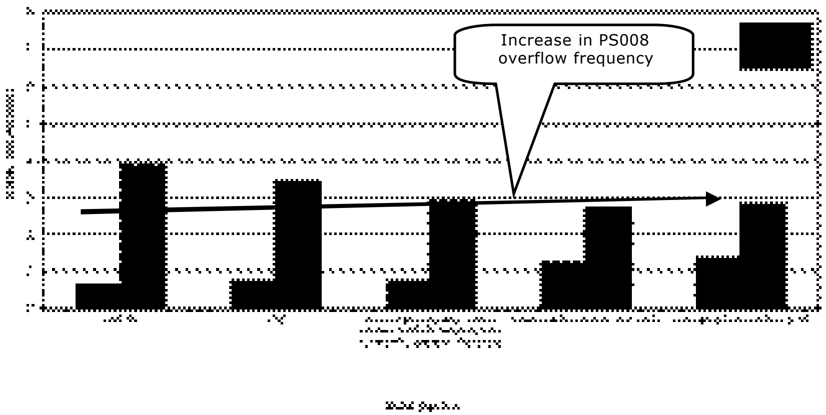
Decrease in primary and secondary spills
Decrease in primary spills
Slight increase in secondary spills



Reduction in combined spill frequency with existing RTC
Slight reduction in spill frequency
Increase in spill frequency



Decrease in PS009 Nth & Sth overflow frequency
Decrease in PS009 Sth & increase in PS009 Nth overflow frequency



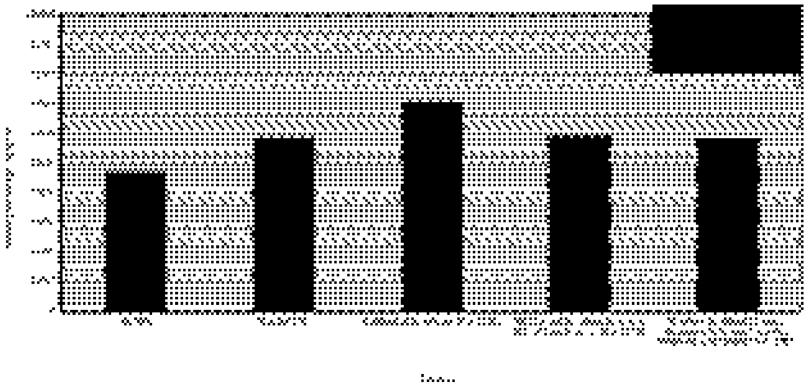
Increase in PS008 overflow frequency

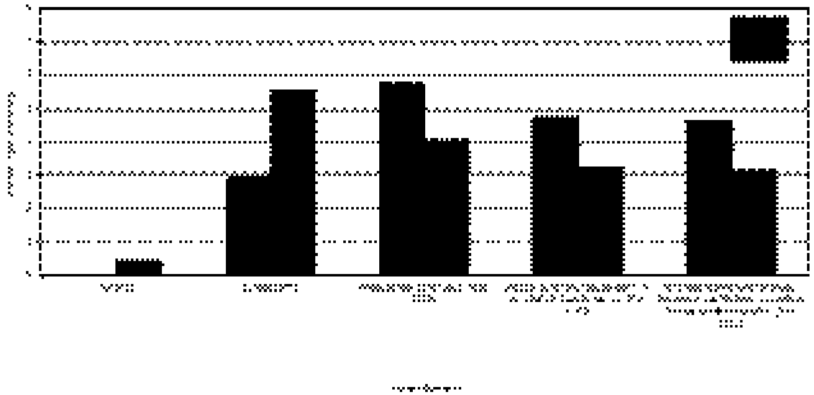
6.6.3 PS011 RTC SCHEME

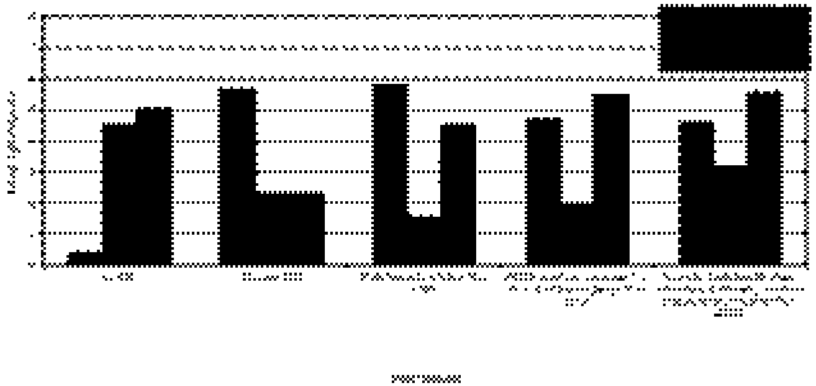
The below table summarizes the model analysis completed for the PS011 control. As described below four alternative operational strategies were identified from the completed model scenarios, these scenarios were identified to minimize spill volume, frequency or preferentially spill or allow PS012 spill at ~2 spills per year (NSCC's targeted LOS).

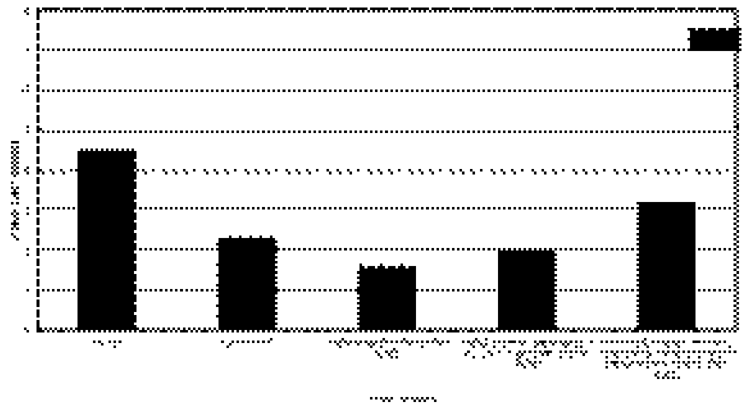
Table 1: PS011 RTC Analysis Findings and Recommendations

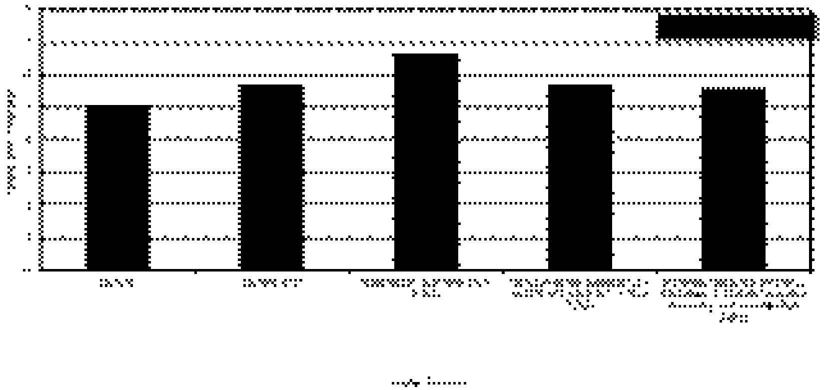
RTC Control	RTC Scenario	Performance Summary	Result Table and Figures	Current Recommendations
PS011 – Silverfield Control		Review of model simulations indicates that the utilisation of the available storage at PS011 and ST031 has a minor impact in the reduction of spill volumes from Silverfield with a significant increase in spills from PS011 & ST031.		The control of PS011 from Silverfield should be discontinued with PS011 only controlled by the level at PS012
PS011- PS012	Current RTC Simulation	The current simulated RTC produced the highest spill volume and frequency of the scenarios assessed, for the combined PS011, ST031 & PS012 overflows. It is noted that the Tertiary overflow frequency in the Little Shoal Bay Reserve is simulated to increase from the current RTC, due to disabling of the PS011 -> ST001 which restricts PS011 operation. As there is no direct relationship between ST001 and the Tertiary spills this link is not considered suitable to control these spills. In addition further confirmation of these spills is required.	Figure 5.19 to 5.24	It is recommended that Run 2172 set points be adopted. This set point arrangement is expected increase the PS011 preferential spill frequency and volumes with a reduction in ST031 and PS012 spill frequency and volume from the current RTC. This option achieves a spill frequency similar to the NSCC LOS of 2 spills per year from PS012. It is also noted that Run 2172 RTC operation increases tertiary spills to the Little Shoal Bay reserve, which is due in large part to disabling of the PS011 -> ST001 which previously restricted PS011 operation. As there is no direct relationship between ST001 and the Tertiary spills this link is not considered suitable to control these spills. In addition further confirmation of these spills is required. It is recommended that locations for these uncontrolled spills are closely monitored following the adoption of this control to ensure that no significant degradation in system performance occurs at these locations. Note: These are known confirmed spill locations with capital works programmed to resolve network capacity constraints.
	Run 2180 – Preferential Overflows	Scenario 2180 simulated the least number of spills from PS012 (Secondary) and Tertiary (with the exception of the current RTC set points) locations, this is achieved by increasing spills from ST031 & PS011.		
	Run 2172 – PS012 with ~2 spills per year	Scenario 2172 allows PS012 to spill ~2 spills per year, which is similar to NSCC Level of Service of 2 spills per year. This scenario simulates a reduction in spills from PS011 and ST031, with an increase in tertiary spills.		
	Run 2182 – Minimise Tertiary, Secondary and Primary Overflows	Scenario 2182 simulated the least number of combined spills from Tertiary, Secondary and Primary locations. Where this scenario simulated an increase in tertiary overflows and PS012 overflows (3.1 spills per year, which exceeds NSCC's targeted LOS) with a decrease in spills from primary locations.		

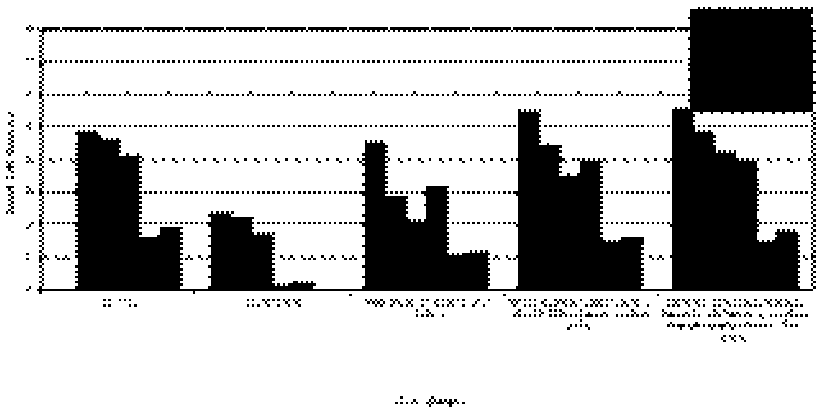












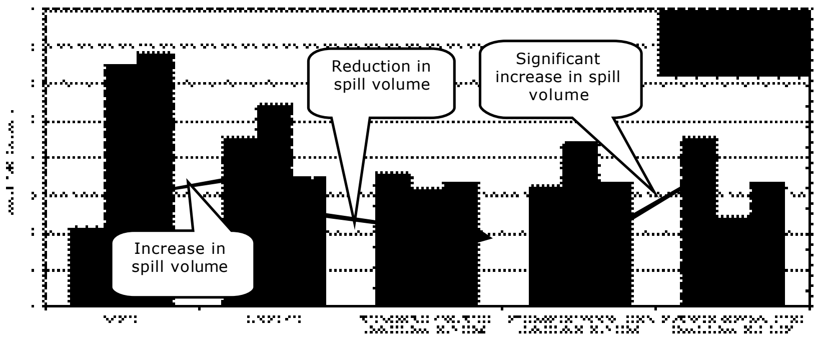
6.6.4 PS003 & PS004 RTC SCHEME

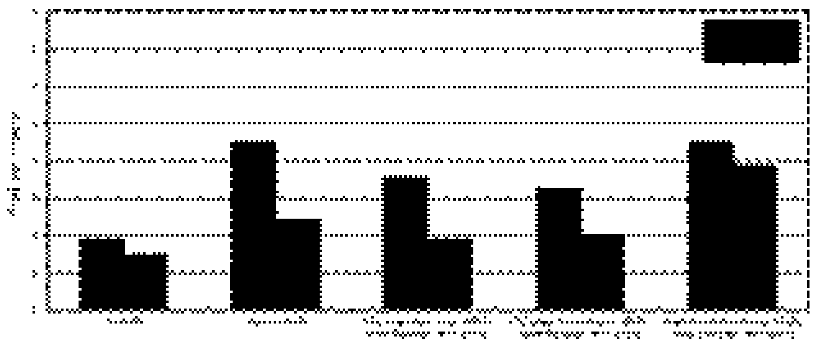
The below table summarizes the model analysis completed for the PS003 & PS004 control. As described below three alternative operational strategies were identified from the completed model scenarios, these scenarios were identified to minimize spill volume, frequency or preferentially spill. In addition the operation of the Silverfield gate by RTC is recommended to be discontinued.

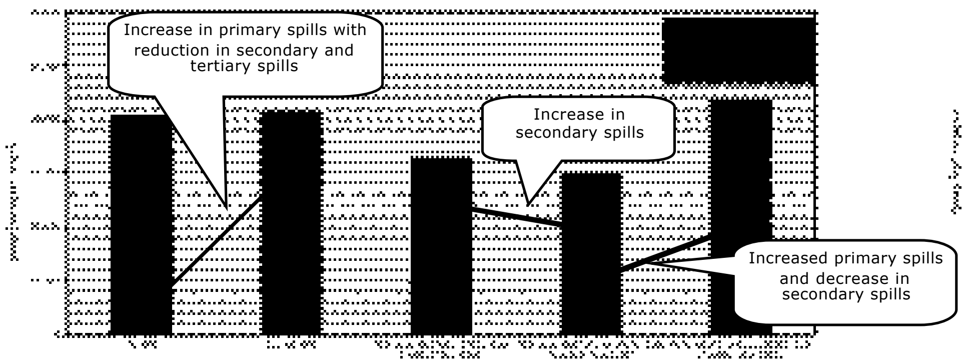
Table 1: ST001 Gate, PS003 & PS006 RTC Analysis Findings and Recommendations

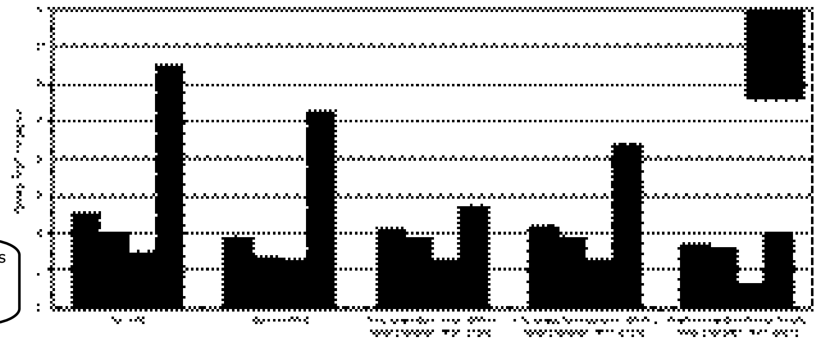
RTC Control	RTC Scenario	Performance Summary	Result Table and Figures	Current Recommendations
ST01 Gate Control		Simulation of the three differing RTC scenarios with the ST001 in operation and disabled indicated that the simulated operation of this gate has no significant impact on system performance.		It is recommended that the ST001 gate operation should be discontinued.
PS003 & PS006 -> ST001	Current RTC	The current simulated RTC operation minimises overflows at ST001 through the use of the Northboro storage and PS006 network storage and achieves a limited reduction in PS004 spill frequency.	Figure 6.6 to 6.11	Set points from Run 2164 are recommended to control PS003 and PS006. Selection of the 'best' RTC set points scheme is dependant on the preference for spill locations, where it is considered acceptable to allow the increase, from the current RTC, in spills from the Silverfield Tank from 1.9 spills/yr (current RTC) to 2.1 spills/yr (which is similar to NSCC's LOS requirement) which allows a reduction in spill volumes and frequencies from Northboro, PS006 and PS004.
	Minimise Spill Frequency	To minimise spill volume from the release points upstream of PS005, it was found necessary to inhibit (stop) all 2 PS003 & 2 of 3 PS006 pumps when Silverfield is almost full (~90%). In addition the PS006 -> PS007 control was disabled and the PS003 -> PS004 inhibit was set at 50% of the PS004 Network storage. This control, was assessed with the following refinements: ▪ Disabling the ST001 gate Control ▪ Restarting PS006 & PS003 operation as soon as the level in the Silverfield tank starts to drop, rather than the default operation which waits until the level drops by >=10% of the Silverfield tank volume ▪ Disabling the PS011 -> PS012 control Scenario 2164 simulated the minimum number of spills and spill volume from the combined Primary, Secondary and Tertiary locations.		

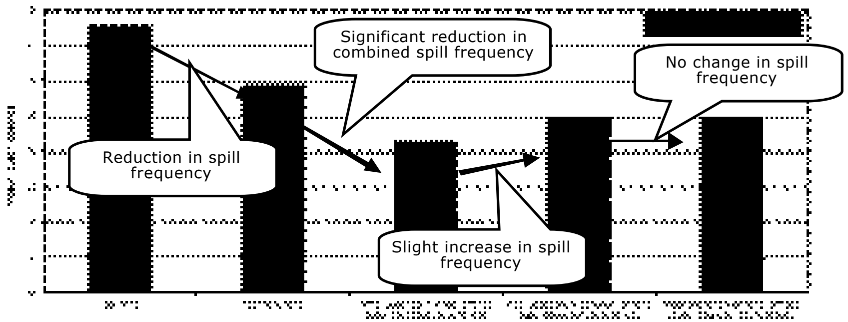
RTC Control	RTC Scenario	Performance Summary	Result Table and Figures	Current Recommendations
	Minimise Spill Volume	To minimise spill volume from the release points upstream of PS005 it was found necessary to disable the PS003 -> ST001 control and control the Level 2 & 3 pumps at PS006 on the Silverfield Tank (pump inhibited at 90% full), the remaining Level 1 pump Silverfield controls were disabled. In addition the PS006 -> PS007 control was disabled and the PS003 -> PS004 inhibit was set at 60% of the PS004 Network storage. As described previously this control, was assessed with the following refinements: ▪ Disabling the ST001 gate Control ▪ Restarting PS006 & PS003 operation as soon as the level in the Silverfield tank starts to drop, rather than the default operation which waits until the level drops by >=10% of the Silverfield tank volume ▪ Disabling the PS011 -> PS012 control Scenario 2168 simulated the minimum number of spills from the combined Primary, Secondary and Tertiary locations.		
	Preferential Overflows	To preferentially spill to primary overflow locations from the release points upstream of PS005, it was found necessary to restrict PS003 and PS006 pump operation based on low levels at Silverfield (20 – 30% full) As described previously this control, was assessed with the following refinements: ▪ Disabling the ST001 gate Control ▪ Restarting PS006 & PS003 operation as soon as the level in the Silverfield tank starts to drop, rather than the default operation which waits until the level drops by >=10% of the Silverfield tank volume ▪ Disabling the PS011 -> PS012 control Scenario 2169 simulated a minimum number of spills from the combined Primary, Secondary and Tertiary locations.		

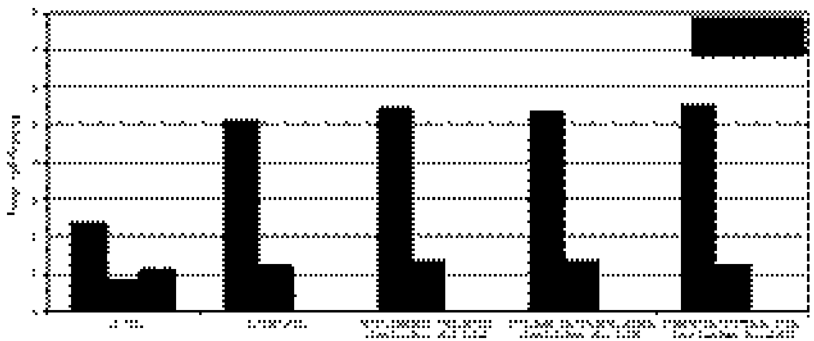

Reduction in spill volume
Significant increase in spill volume
Increase in spill volume




Increase in primary spills with reduction in secondary and tertiary spills
Increase in secondary spills
Increased primary spills and decrease in secondary spills




Significant reduction in combined spill frequency
No change in spill frequency
Reduction in spill frequency
Slight increase in spill frequency



6.6.5 GENERAL FINDINGS

In addition to the specific findings discussed above, the broad areas identified for improvement as a result of the model analysis and review of the RTC operation were:

- Utilization of storage tanks, at which level the RTC should cause operational changes to the system
- In the existing RTC storage tanks are drained to less than 50% full prior to upstream pumps being allowed to restart, this RTC decision increased the volume and number of overflows compared to if the pumps were restarted while the tanks were almost full.
- Currently significant volume overflowing due to pumps not being allowed to restart until long after the peak has passed
- In some locations a significant reduction in spill frequency can be achieved.
- Removal of the use of the Silverfield gate from the RTC scheme, the gate causes the tank to be utilized prematurely during storm events, the gate is also slow to respond to changes which causes additional tank volume to be used than if the gate were not used. The gate is not necessary as PS005 causes backup into the Silverfield tank when the inflow is greater than the pump forward rate.

7 CONCLUSIONS

In summary for all areas assessed in this RTC analysis three operational strategy have been developed to achieve the following objectives:

- Lowest frequency of overflow
- Lowest volume of overflow
- Preferential locations of overflow

Through use of the model the expected impact on system performance of each strategy was able to be clearly quantified. This allowed a robust and transparent debate as to the preferred strategy from all NSCC stakeholders.

The use of a calibrated hydrologic and hydraulic model assess the NSCC's RTC operation provided the following benefits:

- A quantifiable assessment of the RTC was possible
- The difference between running the system with and without RTC was assessed
- Rainfall is variable month to month and year to year, the use of a model allows the same rainfall to be used for different RTC settings to assess performance and the optimal configuration of settings.
- If necessary the regulator can be shown the quantitative assessment of RTC performance to justify NSCC's operational decisions
- The predicted frequency, volume, location, and receiving environment of overflows can be assessed citywide including the influence of different RTC decisions
- The modelled results are reproducible and transparent
- A systemic approach can be undertaken to assess a signficant range of operational scheme
- Identifies the areas of the network that the RTC influences

ACKNOWLEDGEMENTS

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