# PROJECT STORM - COLLECTION SYSTEM MODELLING AND OPTIMISATION IN AUCKLAND

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**ABSTRACT**

The control and elimination of overflows from wastewater collection systems is of concern to many wastewater authorities. It requires a comprehensive understanding of the system's existing and future performance. Whilst isolated discharges can occur for various reasons, it is excessive stormwater infiltration and inflow (I/I) entry during wet weather which gives rise to the largest number of overflows across Auckland.

Watercare Services Ltd (Watercare) commenced Project Storm with the goal of developing the most cost-effective combination of system-wide options to manage the wastewater system to meet the needs of future growth, community and environmental objectives. The project involves firstly developing a calibrated dynamic hydraulic model of the trunk wastewater collection system to ascertain the performance of the network under predicted growth and various wet weather scenarios. The model will also simulate the quantity and quality of overflows from the system. An assessment of the impacts that these overflows have on the receiving environment relative to other discharges (such as urban stormwater runoff) is essential together with the potential for environmental improvements.

Following a thorough understanding of system behaviour and its impacts, various upgrading options will be developed and optimised to meet future growth, public health, environmental and customer service objectives.

**KEYWORDS**

Watercare, modelling, overflows, system performance, system optimisation, consultation

## 1. INTRODUCTION

### 1.1 SYSTEM DESCRIPTION

The trunk wastewater collection system and Mangere Wastewater Treatment Plant (WTP) owned and operated by Watercare serves a connected population of 780,000 people and associated commercial and industrial wastes. The catchment includes the metropolitan area south of Auckland's harbour bridge which includes the sewered areas of Auckland, Manukau and Waitakere Cities and Papakura District. The local (retail) reticulation networks in these areas are operated by four local network operators (LNOs), namely MetroWater Ltd, Manukau City Council, Waitakere City Council and United Water Ltd respectively.

The trunk (wholesale) collection system comprises 287km of interceptor and branch sewers and 52 pumping stations (with peak pumping capacities of 7 to 3,700 l/s). It conveys an annual average flow of 3.5 $m^3$/s to the Mangere WTP.

The two principal sub-systems serviced by the Mangere WTP include a partly combined/separate sewer system covering the older parts of Auckland (comprising approximately 8% of Watercare's catchment and constructed in 1910-14) and a separate sewered area serving the remainder of Auckland (constructed in the 1950s-1960s).

Watercare's collection system has over 100 engineered overflow structures located at pump stations (PSOs), on combined sewers (CSOs) and separate sewers (SSOs), and upstream of siphons. This system receives wastewater from the four LNOs through over 1,500 connections. Each LNO has emergency PSOs, SSOs and Auckland City Council (operated by MetroWater) has some 350 CSOs from its local upstream reticulation. These overflows may impact a common area along a stream or length of coast line.

### 1.2 SYSTEM PERFORMANCE

Watercare has a number of trunk sewers which are close to or under capacity, based on theoretical wastewater flow rates. A large project is currently underway to provide increased capacity to the southern interceptor, through construction of a parallel interceptor at a cost of some $30 million.

During wet weather events in the July 1996 - June 1997 financial year there were 97 PSOs (of which 83 were caused by stormwater I/I) and 76 overflows from manhole lids (of which 70 were caused by I/I). However, during the month of September 1997 alone some 71 manhole lids overflowed (70 due to I/I) and 33 PSOs occurred (32 due to I/I). A large number of manholes in Watercare's system regularly overflow due to excessive I/I entry from LNO catchments.

A large number of wet weather overflows also occur from the upstream LNO systems, particularly when Watercare's system is full to capacity, but also from excess I/I within local catchments.

## 1.3 STATIC NETWORK MODEL

During the Wastewater 2000 project in 1994-95 Watercare developed a strategy for upgrading the collection system to meet the demands of predicted future growth across Auckland. This was the basis for identifying projects totalling $96 million over the next 20 years, and included several capacity upgrades, flow diversions and a new satellite treatment plant in West Auckland.

The current strategy was derived using theoretical design peak flows and static modelling of various combinations of upgrading options using an Excel spreadsheet representing the collection system. The flow rates were calculated using a peak flow of 900 litres / head / day and population forecasts with an allowance for commercial and industrial wastewater and combined area stormwater flows on a standard litres / day / hectare basis.

This static flow model has a number of deficiencies including:

- It assumes uniform flow conditions across the system to simulate system performance. This ignores hydraulic effects such as attenuation and backwater, which can have a significant effect on "real" system capacity.
- It does not use actual flows to calibrate the model and therefore it does not simulate actual performance.
- Catchments with excessive stormwater I/I entry cannot be identified, and therefore the effects of I/I cannot be accurately assessed as this is a very dynamic process. Therefore it is difficult, if not impossible, to understand system problems relative to I/I sources and to prioritise catchments.
- The frequency, duration and volume of overflows from the combined and separate systems cannot be considered. Appropriate wet weather containment standards, based on the location and effects of specific overflows is a key driver of any system upgrading strategy.
- It does not provide a basis for considering options such as real time control, stormwater I/I reduction and additional system storage.

In summary, the existing strategy, based on traditional static modelling, does not accurately reflect the way the system actually performs and cannot simulate system response during wet weather

This means that an optimal solution for overall system management, in terms of cost, programme and minimising environmental effects, cannot be developed until a calibrated dynamic hydraulic network model is fully developed and an integrated system-wide approach is adopted to wet weather flow management.

## 1.4 OBJECTIVES & OUTLINE OF PROJECT STORM

The main objective of Project Storm is to produce an optimal collection system upgrading and management strategy which:

- ensures sufficient system hydraulic capacity for conveying flows from existing and future population growth
- eliminates or minimises the adverse effects of overflows from the system on the environment
- evaluates a wide range of options and determines the most cost-effective combination of options for infrastructure improvements
- determines an appropriate and prioritised programme for system upgrading and regional wastewater management.
- manages delivery of wet weather flows to the Mangere WTP to protect treatment processes and comply with consent conditions

- provides a basis to undertake public consultation and obtain necessary regulatory approvals based on clearly defined wet weather containment standards which address environmental effects.

An outline of the phases of Project Storm is shown below in Figure 1.

## 2. DISCUSSION

### 2.1 PHASE 1 - COLLECTION SYSTEM MODEL

Phase 1 of Project Storm commenced in September 1997 with a major enhancement to Watercare's existing Intergraph GIS system, model development and data collection. The outputs of this Phase will be a calibrated model and a system performance report. These will be completed in October 1998. The main components of Phase 1 are described below in further detail.

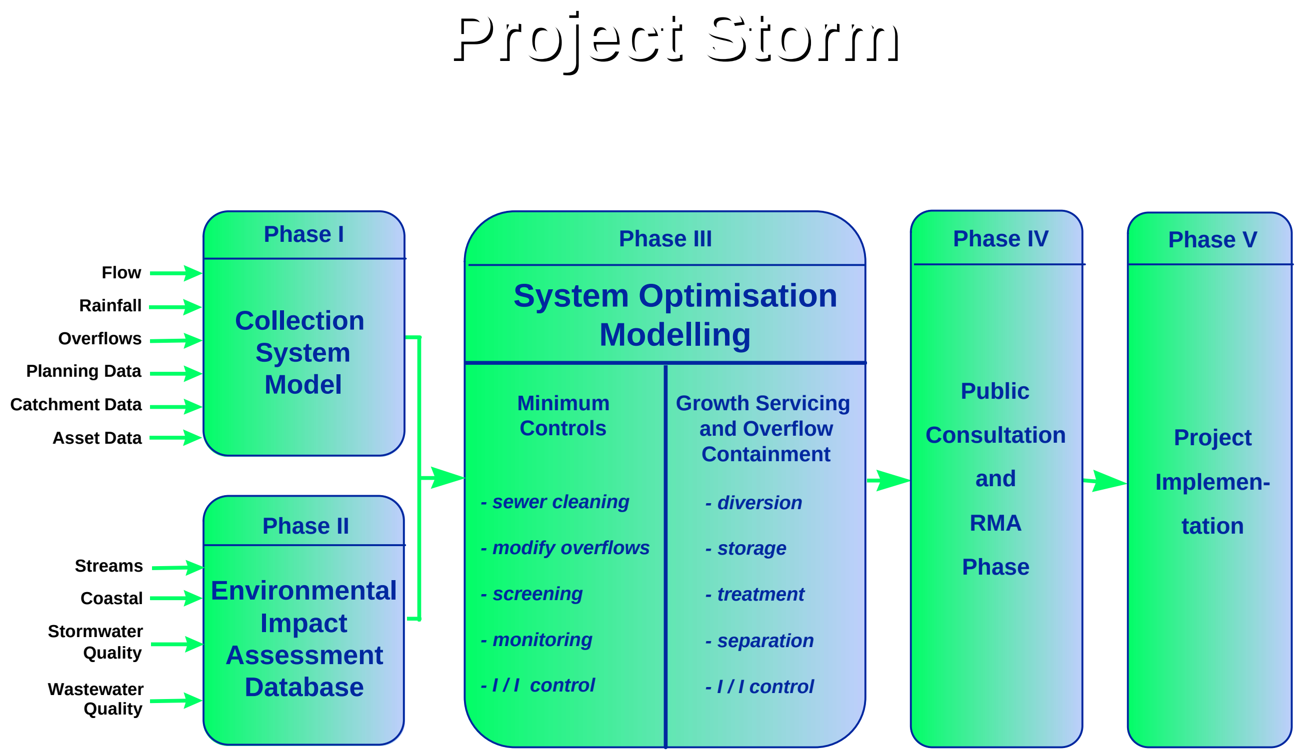


*Figure 1: Outline of the Phases in Project Storm*

#### 2.1.1 GIS METHODOLOGY

A critical aspect of any large collection system analysis project is the development and implementation of an efficient system for managing and manipulating data. As part of Project Storm, a significant quantity of data was collected and organized into a seamless digital environment to support model building and assessment of model results. This data was obtained from multiple sources, including the Auckland Regional Council, the four territorial local authorities and Statistics New Zealand, and in multiple formats. Categories of the data types collected and input into this system include:

1. Sewer asset data (e.g. pipe diameters, invert elevations, pump characteristics, etc.).
2. Spatial data such as sewer subcatchments, landuse types, and census population data.
3. Point features such as the location of rain gauges and flow meters.
4. System connectivity to establish the collection system topology and the linkage between sewer subcatchments and model load points.
5. Geographic background features and cadastral information such as roads, property and political boundaries.

Additional aspects of the Project Storm GIS system include the development of applications to handle the following project elements:

1. Quality assurance audits of input data. An example of this is a tracing routine that can route through digital sewer system data to ensure that a proper system topology exists (i.e. no missing links or nodes).
2. Routines to link the GIS system to the hydraulic model (both to create model input data and to import model results into the GIS).
3. Routines to assist in model calibration efforts, such as the adjustment of catchment routing parameters based on a comparison between recorded flow data and model results.

Additional applications are currently being developed to support other uses of the GIS data such as ad hoc queries. Applications have been developed using an interface software to the full GIS platform (MapInfo) that makes the applications simple and easy to use by non-GIS experts.

Figure 2 presents a sample of output from the Project Storm GIS system. This graphic is intended to show the structure and content of data and information contained within the Project Storm GIS, pointing out significant features such as land use and land use type codes (designated by the numbers inside of the polygons), sewers, CSOs, pumping stations etc.

The development of the Project Storm GIS to date has yielded a system which ensures the quality of data and greatly minimises the effort required to organise and construct the hydraulic models. Ultimately this system may have significant detail added to it (in terms of the reticulation sewers upstream of Watercare's network) as a more regional understanding and holistic approach is adopted for wastewater and stormwater management.

### 2.1.2 MODELLING METHODOLOGY

The hydrology and hydraulics of combined and separate sewer systems are highly complex, and therefore require a reasonably sophisticated technical basis for developing sufficient understanding of how these systems operate and can ultimately be optimised. As such, a detailed hydrodynamic and hydrologic model of the Watercare wastewater collection system is currently being constructed. This model is inclusive of areas served by combined sewers, partially separate sewers, and fully separated sewers. The purpose of this model is to provide a detailed system performance understanding, and to develop a foundation for assessing the most cost-effective solutions to mitigate wet weather impacts.

The model that is being developed for Project Storm is dynamic and fully capable of simulating the base flow and wet weather hydrologic characteristics of wastewater collection systems including:

- Dry weather flow
  - Base infiltration
  - Multiple diurnal patterns (e.g. residential, commercial, industrial)
  - Weekday and weekend flow patterns
  - Tidal boundary effects
- Wet weather flow
  - Direct runoff from impervious areas
  - Inflow and infiltration

The hydraulic model is being established to incorporate the details of complex pumping systems (including variable speed pumps) and sewer overflow/diversion structures. The model can simulate such complex hydraulics as surcharge, backwater conditions, and the effects of hydraulic attenuation.

During the initial phase of Project Storm, approximately 70 rain gauges, 60 flow meters and 20 overflow monitors were installed to collect data for dry weather conditions and multiple wet weather events. The collection system model is currently being fully calibrated to dry weather conditions and to multiple storms and verified against independent storms to ensure accuracy. Calibration is being done in three phases to account for summer, winter and seasonal variations in the groundwater influence. To support this effort, a subset of the monitoring system was left on line to collect representative winter and seasonal data.

Figure 3 presents a depiction of output from the fully dynamic model.

This graphic shows a profile view of a LNO combined sewer draining through an overflow structure prior to connecting to the Watercare Orakei trunk sewer. In this case, the model has shown that there is significant interaction between the hydraulics of the main trunk sewer and upstream overflow performance.

Worldwide, it has been clearly demonstrated that application of dynamic models to wastewater collection system management results in a more informed understanding of problems and the relative causes. Only through this understanding is it possible to derive the most cost effective solutions that will achieve the desired targets. The dynamic hydraulic model of Watercare's trunk sewer system will ultimately ensure that wastewater collection system performance is managed properly and in a cost effective manner.

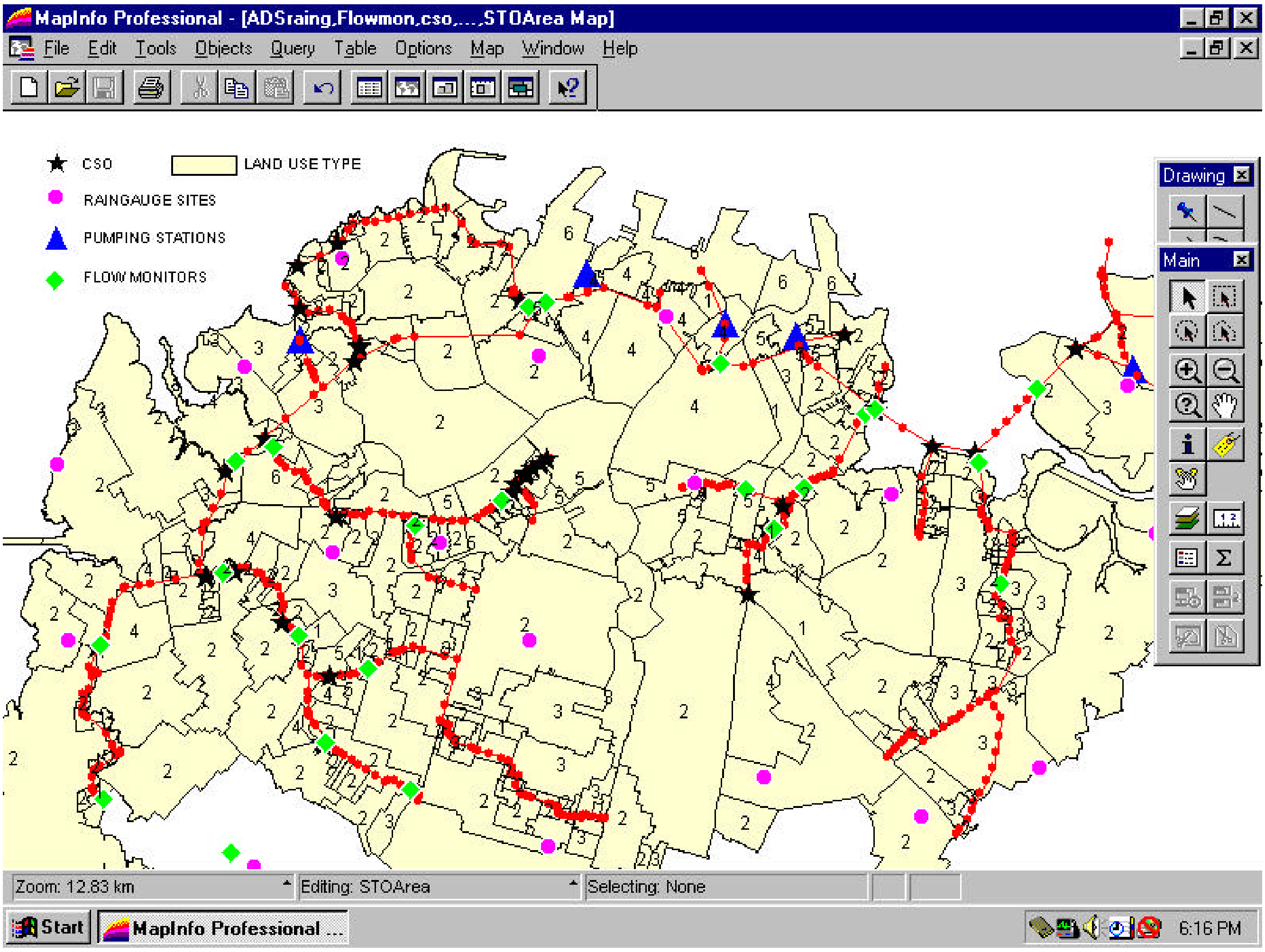


*Figure 2: Sample Output from Project Storm GIS System*

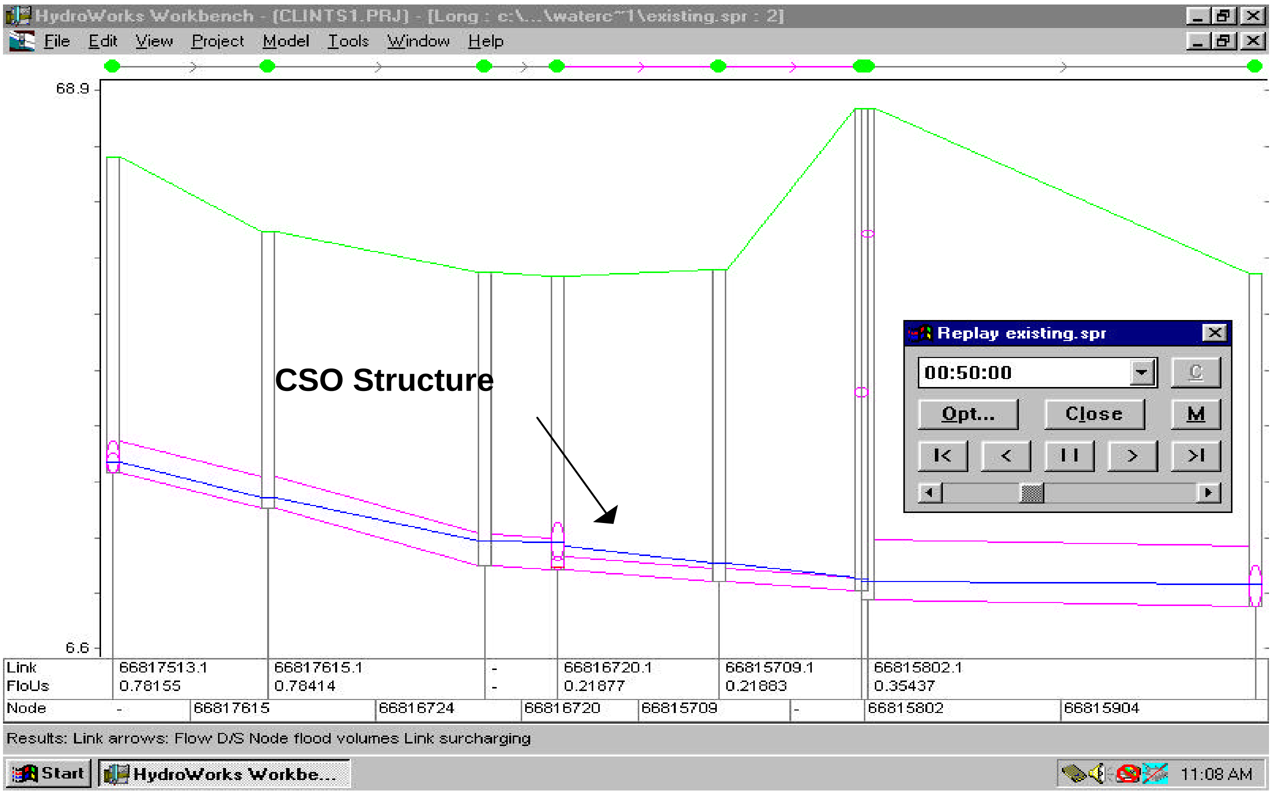


*Figure 3: Output from the Dynamic Model*

### 2.1.3 SYSTEM PERFORMANCE ANALYSIS

Once fully calibrated and verified, the model will be used to assess system performance against a series of design storms (e.g. 1, 5 and 10 year Average Recurrence Interval events of various duration). Additionally, the model will be subjected to time series rainfall data (i.e. continuous simulation). During this process, 20 years of detailed rainfall data will be statistically analysed and three characteristic wet, average and dry years will be applied to the dynamic model, together with predicted future population, to obtain a range of typical overflow frequencies and volumes. As detailed long-term rainfall data is only available at one or two sites, areal reduction factors will be applied to the storm prior to simulation on the dynamic model.

Output from the system performance analysis using the calibrated wastewater models will include:

1. System flooding analysis under various design storms
2. Characterisation and prioritisation of I/I from various wastewater catchments
3. Annual frequency and volumes of overflows based on time series analysis
4. Analysis of interaction between Watercare and LNO sewers
5. Identification of obvious hydraulic bottlenecks
6. Hydraulic impacts on the Mangere treatment plant under various conditions

As part of future phases of Project Storm, the model will be used to develop a basis for optimising system performance with the existing infrastructure (e.g. adjustments to overflow weir levels), and will ultimately serve as the foundation for development of cost-effective solutions. Additionally the modelling approach includes the basis for assessing the potential of real time control systems as a means to improve the overall system performance.

## 2.2 PHASE 2 - ENVIRONMENTAL IMPACT ASSESSMENTS

A critical objective of Project Storm is to establish the relative effect of untreated wastewater/stormwater discharges on the receiving environment. This understanding will serve as a basis for prioritising upgrading works in various catchments and the extent to which current environmental conditions can be improved by various levels of overflow mitigation.

The initial phase of the environmental impacts assessment was a pilot study of the Newmarket catchment. This study included field reconnaissance of the Newmarket stream from the headwaters to discharge in the Waitemata Harbour, as well as an analysis of pollution loads discharged to the catchment from untreated wastewater overflows and stormwater runoff. Results of this analysis show various levels of environmental impacts in terms of potential human uses, the aquatic habitat and obvious aesthetic effects. Additionally pollution “pie charts” have been developed which show the relative contribution of pollutants from various watershed sources (e.g. LNO and Watercare overflows, stormwater runoff, etc.). This pilot study is being used as a template for assessment of other critical catchments.

Results from the environmental impact analysis will be used to rank overflow effects and help prioritise where control efforts are applied to the wastewater collection system. Additionally this effort will provide the required information on cause/effect relationships to ensure that capital investments will result in desired benefits. In some areas it may be determined that any level of pollution load reductions will not result in the desired improvements until certain physical constraints are removed. Examples of this include paved channels, areas with improper levels of surface shading, or stream systems that do not have sufficient water during dry weather to support an aquatic habitat.

## 2.3 PHASE 3 - SYSTEM OPTIMISATION

A primary objective in the overall project approach is the development of a system whereby solutions can be iterated to find the optimum control scheme in order to manage the impact of wet weather flows.

The phasing of Project Storm enables a pragmatic means of implementing control schemes in a cost-effective manner. The development of a system performance understanding coupled with an assessment of the relative environmental impacts/objectives provides the foundation for prioritisation of control schemes.

The first step is to define an envelope of environmental objectives. These will reflect a range of possible outcomes for mitigating each environmental impact, and provide the basis for developing the costs and benefits of various control options. The benefits are expected to cover protection of public health, attaining desired environmental outcomes and various human uses.

The second step is to assess and implement options that are part of a minimum control plan. Examples of this include optimisation of the existing infrastructure (e.g. pump control improvements, raising of overflow weir levels, overflow screening systems, balancing of the trunk sewer hydraulic grade lines, etc.). These options are typically lower-cost in nature, and quite often provide a substantial step towards the targeted goals and objectives.

The final step in the optimisation process will be to evaluate the performance of minimum control measures relative to the overall objectives, and to decide what, if anything, is necessary beyond implementation of the minimum controls. The assessment and ultimate optimisation of these long-term control measures will be facilitated by the application of software tools designed to assist in this iterative process. Relative weighting factors will be developed (e.g. costs, options, environmental improvements, iwi issues, consentability etc.) and fed into the iterative process to ensure that recommended options are truly optimised to both engineering and non-engineering issues.

A wide range of technologies will be considered as inputs to the optimisation process. These include additional sewer and pump station capacity, relief sewers, storage tanks, treatment of wet weather overflows, system rehabilitation techniques to reduce stormwater I/I, sewer separation, relocation and elimination of overflow outlets and real time flow control. Local conditions will dictate, but it is expected the optimal strategy will include some combination of these options.

In some areas it will be necessary to model both Watercare's and the LNO systems together in order to understand their interaction and develop the optimal blend of improvements to meet environmental objectives. This is currently being undertaken in the Freemans Bay/Viaduct Basin catchment with MetroWater. An integrated approach is necessary so that a holistic management strategy is for wastewater and stormwater is the outcome.

## 2.4 PHASE 4 - PUBLIC CONSULTATION AND RMA

Once draft outcomes are available, Watercare will actively manage a programme to educate, inform and consult the general public. Initially, this will be on the basis of issues and options for system upgrading and overflow control, with more detailed consultation with tangata whenua, interest groups, regulatory authorities and directly affected parties.

It is anticipated consultation would be undertaken on an area or catchment basis. Coordination with territorial local authorities and LNOs will also be essential, as stormwater I/I reduction programmes will require co-operation and funding.

A goal of this Phase is to finalise the preferred combination of options and agree an overall management plan and programme. Phase 4 is programmed to commence mid 1999.

### 2.5 PHASE 5 - PROJECT IMPLEMENTATION

It is anticipated that a number of low cost minimum control initiatives will be undertaken and piloted during the Project to demonstrate immediate environmental and community benefits.

The remainder of the projects will be implemented on a priority basis and according to appropriate funding arrangements.

## 3.0 CONCLUSIONS

Watercare's current collection system upgrading strategy does not take into account the need to control overflows based on their environmental impact.

Watercare has embarked on a strategic modelling and system upgrading optimisation project to take account of future growth and the control of wet weather overflows caused by excessive stormwater I/I entry. A range of containment levels to meet environmental requirements within the collection system will be developed. It is expected the optimal solution will include a combination of technologies applied both within Watercare's and the LNO wastewater systems. The project requires a high level of co-ordination between Watercare and its LNO customers both during Project Storm and its future implementation. The prioritisation of LNO catchments with high stormwater I/I entry together with option optimisation will greatly assist with implementing beneficial system rehabilitation programmes in upstream catchments.

Knowledge of the impact of wastewater overflows along streams and the coastline compared to urban stormwater and other physical constraints will be a key driver for option development and evaluation.

Project Storm provides a robust strategy to manage the Auckland regional wastewater system effectively well into next century.

## DISCUSION

Comment Brian Sharman North West Water

Nice to see you paint the envelope , we paint the cucumber !!!

Question Tim Webster Severn Trent Water

If you have a defined target it saves you having to think about things so much . In your study you had to look harder does it give a better result?

**Answer**

Thinking "outside the box" meant we had to be careful about how we analysed the problem. It is very refreshing to consider issues other than set point targets. e.g. are we really being cost effective from the public perspective ?

You have to remind yourself this is not the UK or the Us with their standards

**Question Brian Reed CIRIA**

How much did you have to alter UK /US modelling methodologies ?

**Answer**

We did not really alter data input or modelling methodologies . It was how we used the validated model.