DECISION SUPPORT SYSTEMS OPTIMISING EFFLUENT RELEASE IN A SUB TROPICAL ESTUARINE ENVIRONMENT – AN AUSTRALIAN CASE STUDY

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Abstract

Gold Coast Water is responsible for the management of the water and wastewater assets of the City of the Gold Coast on Australia's east coast. Treated wastewater is released at the Gold Coast Seaway on an outgoing tide in order for the plume to be dispersed before the tide changes and renters the Broadwater estuary. Rapid population growth over the past decade has placed increasing demands on the receiving waters for the release of the City's effluent.

The Seaway SmartRelease Project is designed to optimise the release of the effluent from the City's main wastewater treatment plant in order to minimise the impact of the estuarine water quality and maximise the cost efficiency of pumping. In order to do this an optimisation study that involves water quality monitoring, numerical modelling and a web based decision support system was conducted.

An intensive monitoring campaign provided information on water levels, currents, winds, waves, nutrients and bacterial levels within the Broadwater. These data were then used to calibrate and verify numerical models using the MIKE by DHI suite of software. The decision support system then collects continually measured data such as water levels, interacts with the WWTP SCADA system, runs the models in forecast mode and provides the optimal time window to release the required amount of effluent from the WWTP.

The City's increasing population means that the length of time available for releasing the water with minimal impact may be exceeded within 5 years. Optimising the release of the treated water through monitoring, modelling and a decision support system has been an effective way of demonstrating the limited environmental impact of the expected short term increase in effluent disposal procedures.

Introduction

As one of the fastest growing regions in Australia, the Gold Coast City's population is expected to increase from just over half a million to 1.2 million by 2056. Ideally located in South East Queensland, the Gold Coast also supports an additional tourist population of approximately 10.1 million visitors per year. This unprecedented population growth is placing much pressure on the City's infrastructure.

Gold Coast Water holds primary responsibility for the collection and treatment of wastewater within the city. Gold Coast Water's wastewater treatment plants (WWTP) have a combined capacity of 176 ML, with wastewater typically being treated to a secondary level Class B Recycled water. Currently, the Gold Coast reuses approximately 18 ML of recycled water a day for irrigation and other beneficial uses. 110 ML per day of excess recycled water is subsequently released to the City's principle release site - the Gold Coast Seaway. The Gold Coast Seaway is a man-made navigation channel that connects the Gold Coast Broadwater to the Pacific Ocean.

The main release is along the northern wall of the Gold Coast Seaway and discharges recycled water from the Coombabah WWTP, the City's largest WWTP, with 60 ML discharged daily. A further 48 ML is discharged at the southern wall. The overall system is based on an ebb-tide staged release where the recycled water is discharged on the outgoing tide, allowing mixing and dilution of the recycled water with the ocean waters of the Pacific Ocean before the return of the incoming tide.

The system is controlled through a licensing agreement with the Queensland Department of Environment, Resources and Management (the former Environmental Protection Agency). Given that the tidal conditions at the Gold Coast are semi-diurnal (i.e. twice daily) two release periods are carried out each day. The release period for the recycled water is from 10 minutes after the high tide to 50 minutes after the following low tide, a total of 13.3 hours per day.

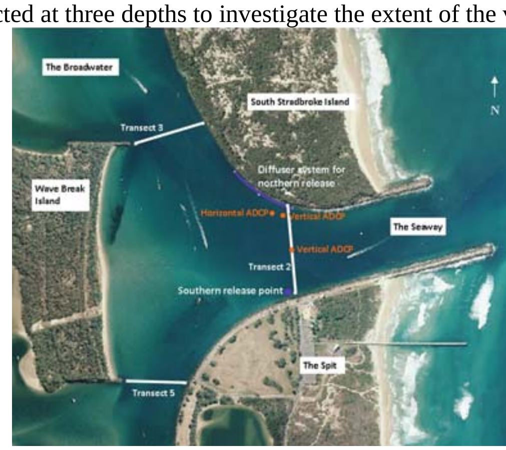
Given the current rate of population growth, the volume of wastewater to be released into the Gold Coast Seaway is expected to increase by up to 46% over the next decade to 160 million litres. Therefore a cost effective solution was required. An initial investigation of the capacity of the Broadwater to assimilate a greater quantity of recycled water over a longer release period was undertaken in 2007 [1,2]. This study concluded that additional recycled water could be released into the Gold Coast Seaway without having a negative environmental impact to the Broadwater. The Seaway SmartRelease project was therefore designed with the aim of optimising the release of the recycled water from the northern discharge point to allow for the maximum discharge of recycled water in order to minimise the environmental impact and also to maximise cost efficiency of the system. The project consists of three major elements: hydrodynamic and water quality monitoring, numerical modelling and the development of a decision support system.

Monitoring

Monitoring of the hydrodynamic characteristics of the Seaway Channel was an important component to further understand the nature of the discharge zone and to calibrate the numerical models. This monitoring program characterised the flow dynamics, namely the water direction and rate of flow. A further aim of the hydrodynamic monitoring was to verify and detail the time lag between the water level and the change in flow direction. This time lag was initially described during the Broadwater Assimilative Capacity Study [1,3].

This was achieved through the deployment of one horizontal Acoustic Doppler Current Profiler (ADCP) and two vertical ADCP's. The deployment was carried out over varying time frames between February and June 2009. Further velocity data was collected using a boat mounted ADCP (where the ADCP points from the surface looking down through the water column to the seabed). The boat traversed a series of transects (Transect 2, 3 and 5) which were in line with the water quality monitoring program (see below). One transect was position across the Seaway Channel and the other two across the approach channels adjacent to Wave Break Island (Figure1) to characterise the volume of flow from both the north and the south of the Broadwater. Transects were carried out over three field days in line with the water quality monitoring program. Flow data was collected along each transect hourly throughout the semi-diurnal tide starting one hour prior to the release of the recycled water which commences 10 minutes after high tide (i.e. -1 hr before high tide to +11 hours).

The water quality monitoring program was undertaken to quantify the impact of the recycled water release and to investigate the extent of the discharge plume. Three field days were carried out in February, March and April 2009 ensuring that varying tidal and environmental conditions were assessed. 13 sample points were defined in addition to samples collected directly from outlets along the recycled water transfer pipes (Figure2). Transects 1 and 2 were selected to assess the dilution of the recycled water plume while Transects 3 and 5 were selected to assess for dispersion of recycled water along the approach channels adjacent to Wave Break Island. Transect 4 was in line with a site of the long term water quality monitoring program, the Ecosystem Health Monitoring Program. Water samples were collected hourly and bi-hourly throughout each semi-diurnal tide, from -1hr to +11hrs relative to the release of the recycled water commencing at 10 minutes after high tide. Samples were also collected at three depths to investigate the extent of the vertical mixing of the plume.



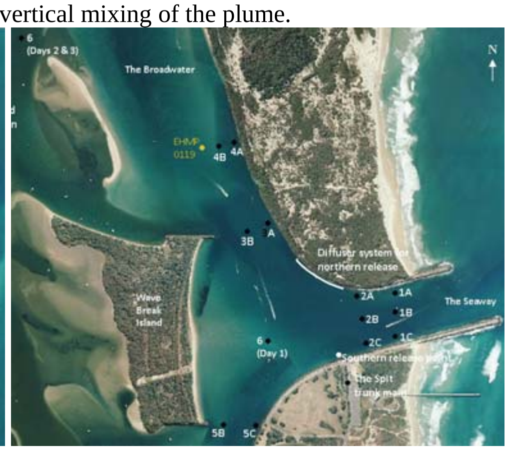


Figure 1. Location of ADCPs (Source: Gold Coast City Council). Figure 2. Water quality monitoring sample points (Source: Gold Coast City Council).

Water samples were analysed for the following water quality parameters: Total Nitrogen (TN), Total Phosphorous (TP), Nitrate + Nitrite (NO_X), Ammonia (NH_3), faecal coliforms and Enterococci. Conductivity temperature depth casts (CTD) were also carried out at each sample point to assess for vertical stratification in additional to mixing of the plume.

Modelling

Numerical modelling formed a large component of the Seaway SmartRelease Project and was the basis for the development of the SmartRelease decision support system (DSS). The DHI MIKE 21 and MIKE 3 suites of software were used in the development of the hydrodynamic, advection-dispersion and spectral wave models. The overall purpose of the modelling component of the project was to predict the fate of the recycled water plume discharged along the northern Seaway wall.

The models are based on current environmental conditions and winds and waves were included to better understand the impacts of the mixing of the recycled water plume. The previously discussed monitoring program provided the data for the model calibration in addition to data available through the Government's Bureau of Meteorology.

Detailed and calibrated flow, wave and advection-dispersion models form the platform that allows a range of release scenarios to be investigated and the simulation of the following important processes:

- the lag between water levels and changes in flow direction
- impacts of wind and waves on flow regime and mixing ability
- the resulting return of nutrients into the Broadwater during the flood tide

The resulting calibrated models were incorporated into a forecast DSS that provides an optimised pumping schedule based on the conditions within the receiving waters and WWTP just prior to the release of the recycled water.

Decision Support System

The decision support system developed as part of this project provides a fundamentally new way of managing the release of recycled water from the Coombabah WWTP. Prior to this project the treatment plant operators only had reliable information regarding the condition of the plant, without information regarding the local environmental conditions of the receiving waters. The DSS provides the integration of all the previously discussed components of the Seaway SmartRelease Project and offers a real-time simulation tool to guide the optimal release of excess recycled water from the Coombabah WWTP.

The DSS is built on technology that allows a central PC to communicate with the SCADA (Supervisory Control and Data Acquisition) system at the WWTP, internet-based data sources and numerical models to simulate the outcome of each release based on the most accurate and up to date input conditions. The aim of the DSS is to provide the operators of the Coombabah WWTP with sufficient information to optimise the release of recycled water based on the following constraints:

- Water levels and tidal currents in the Gold Coast Seaway
- Extent and concentration of recycled water plume in the Broadwater
- Water levels in the recycled water storage lagoons at the WWTP
- Power usage and tariff costs

The main components of the DSS include (Figure 3):

- Inputs – water levels (in the WWTP and the Seaway), currents, winds, waves etc.
- MIKE 21 and MIKE 3 – numerical models
- DIMS – the hub for linking SCADA systems and models.
- Dashboard Manager – the presentation layer/user interface that displays the optimised release window.

An important component of the DSS was to create a user-friendly interface to be utilised by a range of WWTP operators. This was constructed using the Dashboard Manager™ (example shown in Figure 4 below). This provides a series of customised web pages showing relevant information such as the results of the pumping schedule and model results. Prior to the commencement of the recycled water pumping period, a detailed program is run that includes a series of tasks which are completed 30-60 minutes prior to the start of the permitted discharge period. This ensures that the most up-to-date data is applied to the system. These tasks are completed twice daily prior to each release period.

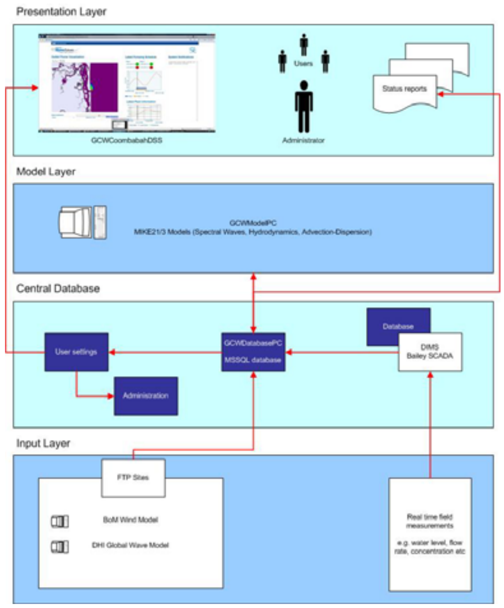


Figure 3. Components of the SmartRelease decision support system.

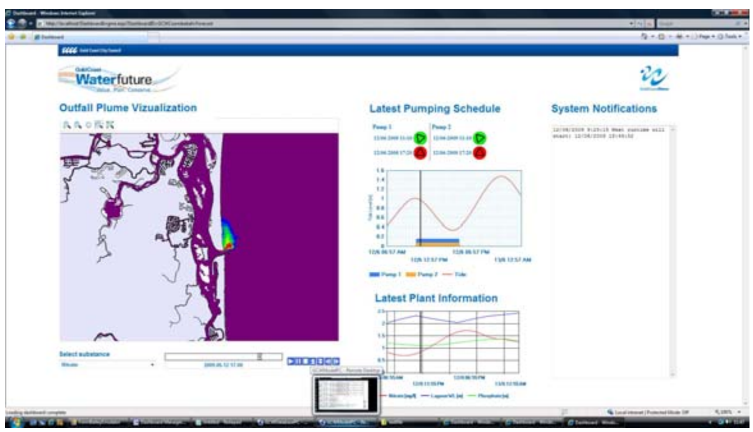


Figure 4. SmartRelease decision support system operator's page output.

An important consideration for the DSS is for the water level of the storage lagoon at the WWTP to be drained to a specific level by the end of the discharge period. This avoids overflowing of the storage lagoon into Coombabah Lake. Therefore the volume of the water needed to be discharged during the next permitted discharge periods needs to be calculated. This is completed using forecasted inflow, current water level in the lagoon, the relationship between the volume and water level in the lagoon and the period until the end of the next end of permitted discharge.

A base case scenario is then developed using the advection dispersion model and assumes the maximum allowable discharge for that release. That is, two pumps operating at full speed over the entire release window (10 minutes after local high tide until 50 minutes after local low tide) or until the minimum water level at the WWTP lagoon is reached. The DSS is then based around finding the optimum improvements to water quality and pumping costs compared to this base case by varying the start and finish times of the release and the use of one pump versus two.

The primary concept behind the optimised strategy is based on the start and finish times of the recycled water release. Sensitivity testing has shown that significant improvements in water quality can be gained by shifting the start of the release period to coincide with the maximum discharge into the Broadwater. The release period begins when the flood tide starts to decelerate, during this period an eddy forms on the northern wall in the vicinity of the recycled water diffusers. The optimised strategy allows the release to be stored near the discharge points during slack water and be flushed rapidly as the ebb flow increases. By finishing earlier relative to the low tide than the base case, there is more time available for dispersion of the nutrients outside the Broadwater before the flood tide returns any residual nutrients to the Broadwater. This optimised pumping schedule has the effect of reducing the median nutrient concentration within the estuary thereby significantly improving the water quality by up to 50 - 60%.

While this provides the best outcome for water quality within the Broadwater, pumping costs have not yet been taken into consideration. An optimum pump cost case is therefore included where a weighting factor is applied. In other words, if the optimum water quality results show decrease in nutrient concentrations by 25% it may be acceptable to aim for a 15% decrease in nutrient concentrations to save 20% in pumping costs.

The database in the DSS then stores the results from the base case, optimum water quality case and the optimum pumping cost case. Animations of the resulting plume and a pumping schedule are provided for the WWTP operators to determine which case is most appropriate for that release.

The DSS guides the release operation utilising real-time tide data and release rules developed from forecast hydrodynamic and advection dispersion models taking into consideration the lagoon water level, storm prediction, optimisation of day and night time release etc. The ultimate goal is to release in the best possible time window to avoid any adverse environmental effects and reduce operational cost through knowledge-based real-time decision making and operational automation.

Conclusion

Population growth on the Gold Coast has lead to an increased demand on the City's infrastructure. Recycled water is currently managed by Gold Coast Water and released during each ebb tide into the Gold Coast Seaway (which flows into the Pacific Ocean). The Seaway SmartRelease Project has developed an optimisation strategy to allow for the maximum volume of recycle water release without creating a negative impact on the surrounding waters of the Broadwater while minimising operational costs. The outcome of the optimisation strategy was the development of a decision support system consisting of a user-friendly web based interface. The system links water quality and hydrodynamic monitoring, numerical modelling and real-time analysis of lagoon levels at the WWTP and prevailing tidal, meteorological and oceanographic conditions to provide an optimised pumping schedule for each individual release period.

The SmartRelease Project has provided an increased understanding of the behaviour of the recycled water plume within the Gold Coast Seaway and adjacent Broadwater and the impacts of this release. The Project has provided a cost effective, short term solution to meet the demands of our growing City while ensuring the goals of environmental sustainability are achieved by optimising the release system and protecting the environmental integrity of the receiving natural waters.

References

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