# ASSESSING THE IMPACT OF WET WEATHER OVERFLOWS ON WATER RECREATION USING EFFECTS-BASED ASSESSMENT

***K. Chakravarthy (DHI Water & Environment), C. Jackson (Urban Utilities)***

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## ABSTRACT

With an increase in the urban water recreation aspirations for many cities, the receiving environmental aspects of Wet Weather Overflows (WWOs) have recently become focused. To address the limitation in historical sewerage system design of only targeting reductions in sewage spills onto land to reduce public health risks, Urban Utilities and DHI Water & Environment worked on developing a Receiving Environment Digital Twin Decision Support System (REDiT) tool that would enable an "Effects-based Approach (EBA)" to be implemented in sewerage system planning. An EBA is a data-driven decision-making approach that considers impacts from all pollution sources, quantifies the proportional impact of individual sources, such as WWOs, and tests mitigation options against modern performance metrics, such as ecological process or community benefits.

The REDiT tool was developed using an integrated catchment rainfall-run-off, hydrodynamics and water quality model of the Brisbane River Estuary to dynamically predict the sources, transport and fate of bacteria levels using Enterococci as the surrogate parameter. The tool was used to assess the impact of WWOs on available water recreation hours at several water recreation-sensitive receptor sites in the estuary. The community impact was assessed during two historical storm events with annual recurrence intervals (ARIs) of six months and two years. The assessment determined the percentage of permissible water recreation hours available for primary contact (e.g., swimming) and secondary contact (e.g., rowing) during the storm event (two days) and for seven days after the storm event (in total, nine days).

Results for the nine-day events showed that of the total number of hours available for water recreation, 87% and 69% were suitable for primary contact recreation for the 6-month and 2-year ARI events, respectively. 97% and 95% were suitable for secondary contact recreation for the 6-month and 2-year ARI events, respectively. The percentage of sensitive receptor sites supporting at least 80% primary contact recreation for a 6-month ARI event is 92%, decreasing to 8% for a 2-year ARI event.

Urban Utilities plans to use the REDiT tool and bespoke benefits-focused performance measures to drive cost-effective sewerage system investment that achieves its desired contribution to cost-effectively improving the beneficial uses of waterways.

## KEYWORDS

Wet Weather Overflows, Effects-based Assessment, Primary Recreation, Secondary Recreation, Swimmable Hours

## INTRODUCTION

During larger wet weather events, stormwater enters the wastewater system from inflow (illegal private plumbing, floodwater inundation) and infiltration (cracked sewerage pipes) when catchment conditions become fully saturated. Inflow and infiltration of stormwater significantly increase sewage flow in the system, which can cause flows to back up and overflow into private properties, causing significant public health risks and community disruption.

Water utilities in major New Zealand and Australian cities operate complex sewerage systems to protect public health and the environment. A critical control measure that reduces public health risks is to design emergency relief overflow structures (EROSs) that divert flows to receiving waters to minimise the spatial distribution and volumes of land-based WWOs. Although sewage flow is diluted more than two-fold with stormwater during WWO events, these WWOs can contain human pathogens that adversely impact recreational water use.

The effects of WWOs on recreational waters vary significantly based on WWO volume, spatial and temporal factors, and the size of the wet weather event (rainfall dependent). Misunderstanding the actual effects of WWOs on receiving environments may lead to capital expenditure that delivers very low measurable recreational benefits, potentially increasing financial and reputational risks.

When designing effective WWO mitigation strategies, water utilities should consider all sources of pathogen pollution to the waterway, how the waterway is valued and used by the community, and the desired future use of the waterway (e.g. swimming). Effective WWO mitigation strategies include Asset-based (bigger pipes), Containment-based (bigger pipes and storage), Outcomes-based (water quality targets), Risk-based (ecological, public health), and Effects-based (evidence/data/science/benefits) (WSAA 2023). Among these approaches, Effects-based Assessment (EBA) focuses on common environmental protection principles (shared responsibility, proportionality, importance of prevention) and takes a rigorous scientific approach to the WWO management strategy. It tests and compares the effectiveness of a wide range of WWO management responses so a water utility can achieve its desired outcomes for a local waterway. The EBA is data-driven and relies less on desk-top qualitative risk assessments or "expert" judgments. An EBA provides critical insight into how water quality will respond and how beneficial uses will be affected by future changes in sources of pathogen pollution and directly assesses the WWO proportion in the context of the total public health impact at a targeted recreational water site.

## BACKGROUND

Urban Utilities, one of Australia's biggest utilities, is responsible for delivering retail water supply and wastewater services across five local government areas in Southeast Queensland. Annually, Urban Utilities removes and treats around 124,600ML of sewage (UU 2024). In the urban footprint, Urban Utilities operates multiple sewerage schemes and Sewage Treatment Plants (STPs) that directly discharge into the Bremer and Brisbane River estuaries and Moreton Bay creeks (see Figure 1).


*Figure 1 - Location of the STP outfalls operated by Urban Utilities and extent of the associated sewer catchments. Background images' sources: Google Earth and OpenStreetMap.*

Urban Utilities' vision is to "play a valued role in enhancing the liveability of our communities". In this regard, Urban Utilities is taking a lead role in advancing science and engineering knowledge to - protect and enhance ecosystem health for current and future generations through excellence in water cycle management, strengthen relationships with local communities and regulators to deliver better environmental and social outcomes; and, communicate the complex aquatic ecosystem interactions effectively to internal and external stakeholders to justify required investments for infrastructure upgrades.

Urban Utilities is implementing an EBA approach for sewerage infrastructure planning to ensure investment targets improvements in beneficial uses of waterways through prudent pollution management actions. Urban Utilities plans to use an EBA to support a future transition towards more proactive management of its infrastructure, whereby different processes and systems can be operated in real time to mitigate disturbances before they adversely impact environmental values. An EBA can drive cost-effective investment, improve ecosystem services, and benefit local communities.

To support this environmental leadership goal, Urban Utilities is working with DHI to implement an EBA using an innovative digital solution called "Receiving Environment Digital Twin (REDiT)", a science-based decision support system to guide infrastructure investment (Huiban et al. 2023). REDiT is a cloud-based digital solution that allows Urban Utilities to simulate and visualise selected water quality parameter changes in River and Creek

Estuaries and Moreton Bay with various planning scenarios for an "average rainfall year" and allows high-level environmental assessments of these scenarios. REDiT can be used to optimise sewerage planning and operations to manage water emissions and reduce environmental footprints.

## METHODOLOGY

REDiT is a coupled catchment-wet weather overflow-hydrodynamic-bacterial decay fate and transport model suite to investigate/simulate the temporal and spatial impacts of WWOs on water recreation risks in the Brisbane and Bremer River Estuaries and Moreton Bay. The schematic diagram of the modelling framework is shown in Figure 2 –

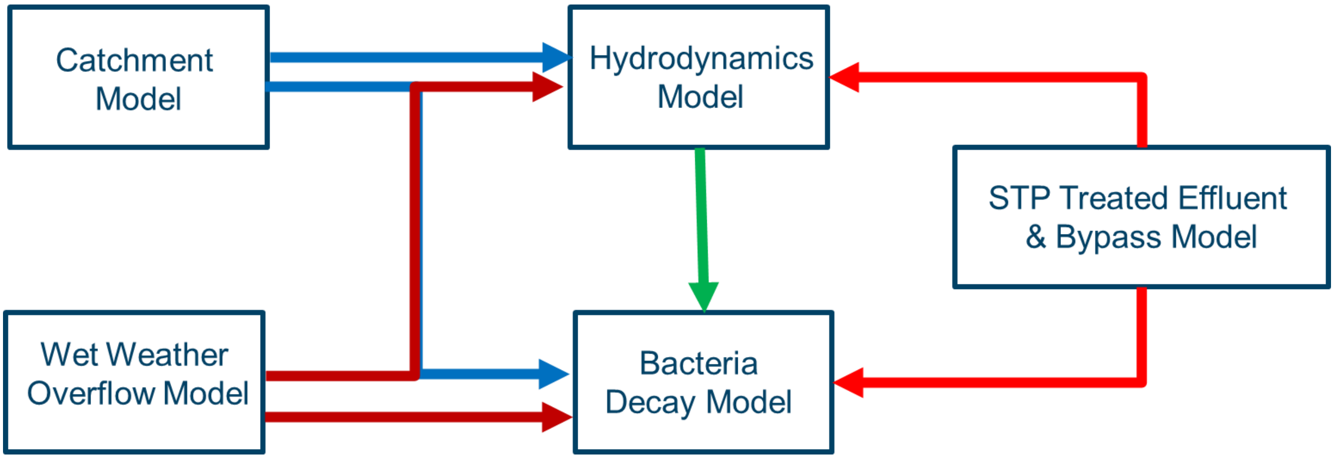


*Figure 2 - Schematic diagram of the model layout for EBA of WWOs in Brisbane River Estuary.*

- **Catchment Model** computes the nonpoint source freshwater diffuse flows and bacteria (Enterococci) loads from more than 101 sub-catchments over an "average rainfall" Baseline year.
- **Wet Weather Overflow Model** predicts the hydraulic and bacteria load of WWOs from the sewerage network over the Baseline year. The WWOs are aggregated to the sub-catchments in the Catchment Model
- **STP Treated Effluent & Bypass Data—Actual** STP effluent (treated and bypass) quantity and quality data were used.
- **Hydrodynamics Model** computes local currents and mixing characteristics due to the combined effects of catchment flows, tides, and wind under dynamic density effects. The hydrodynamics model predicts how catchment, WWO, and STP bacterial loads are dispersed throughout the river estuaries and the bay.
- **Bacteria Decay Model** computes the fate and transport of Enterococci bacteria using local water currents, temperature, salinity, sunlight, and turbidity.

## RESULTS AND DISCUSSION

Urban Utilities uses conservative Enterococci public health thresholds of 40 cfu/100ml and 200 cfu/100ml for primary contact (e.g., swimming) and secondary contact (e.g., rowing) when assessing risks in recreational estuarine and coastal waters (DEHP 2009). These thresholds were used in REDiT to assess Enterococci concentration levels at 12 recreational sites in Brisbane River Estuary and Moreton Bay.

A baseline financial year, July 2016 to Jun 2017, was selected for the modelling period as it approximates an "average rainfall year" (+/- 10% of long-term annual average rainfall). In this period, the models predicted the following proportion of discharges and Enterococci loads from the wet weather overflows to the receiving waters –

*Table 1 – Predicted WWO loads (as proportion of nonpoint source pollution) in 2016/17*

| Items | WWO (% of total catchment inputs) |
|---|---|
| Time (%) | 0.5 |
| Discharge (%) | 0.25 |
| Bacteria Load (%) | 11.6 |

Figure 3 shows the month-wise prediction of recreational hours exceeding primary contact and secondary contact thresholds as a proportion of the total available hours. It was assumed that each day has only 16 hours available for recreation (between 4 am and 8 pm).

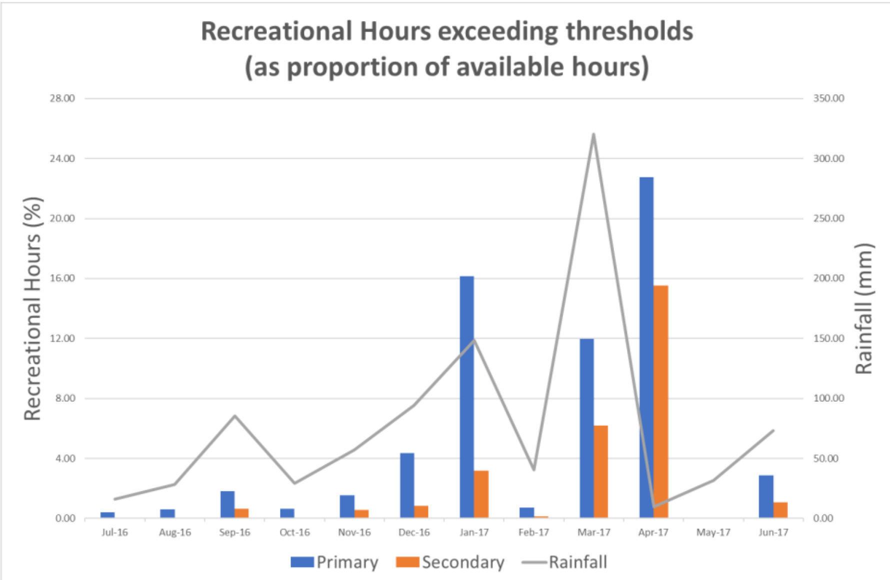


*Figure 3 – Recreational Hours (%) exceeding thresholds in FY 2016/17.*

As observed in Figure 3, January, March, and April 2017 showed a higher proportion of threshold exceedances for primary and secondary contact recreation in the receiving environment sites. These exceedances are only due to catchment baseline flows and WWOs, so they correspond well with monthly rainfall distribution. Due to high rainfall in

March, higher exceedances were observed in April, indicating that impacts on the receiving environment last longer than the event duration.

To understand the impact of WWOs on the recreational sites in the receiving environment for individual storm events, we selected two ARIs and quantified the discharges, and Enterococci loads over a 48-hour wet weather event duration –

*Table 2 – Predicted WWO loads (as proportion of nonpoint source pollution) for individual ARIs in 2016/17*

| 48-hr duration | WWO (% of total catchment inputs) | |
|---|---|---|
| **Items** | **6-month ARI** | **2-year ARI** |
| Time (%) | 5 | 11 |
| Discharge (%) | 0.1 | 0.7 |
| Bacteria Load (%) | 6 | 28 |

Figures 4 and 5 show the nine-day prediction of recreational hours exceeding primary contact and secondary contact thresholds as a proportion of the total available hours for the two ARI events. The first two days show the impact during the 6-month ARI event (Figure 4) and 2-year ARI event (Figure 5), and the remaining seven days show the impact after the event.

Results showed that the impact on the receiving environment continued after the event. The length of the impact depended on the amount of rainfall.

When the impact was quantified as threshold exceedances for primary contact recreation for more than 10% of the available time, the impact was observed for about 50 hours for the 6-month ARI event. This impact increased to 86 hours for the 2-year ARI event.

When the impact was quantified as threshold exceedances for secondary contact recreation for more than 10% of the available time, the impact was observed for about 20 hours and 32 hours for the 6-month and the 2-year ARI event, respectively.

Results for the nine-day events showed that of the total number of hours available for water recreation, 87% and 69% were suitable for primary contact recreation for the 6-month and 2-year ARI events, respectively. 97% and 95% were suitable for secondary contact recreation for the 6-month and 2-year ARI events, respectively.

The percentage of sensitive receptor sites supporting at least 80% primary contact recreation for the 6-month ARI event was 92%, decreasing to 8% for the 2-year ARI event.

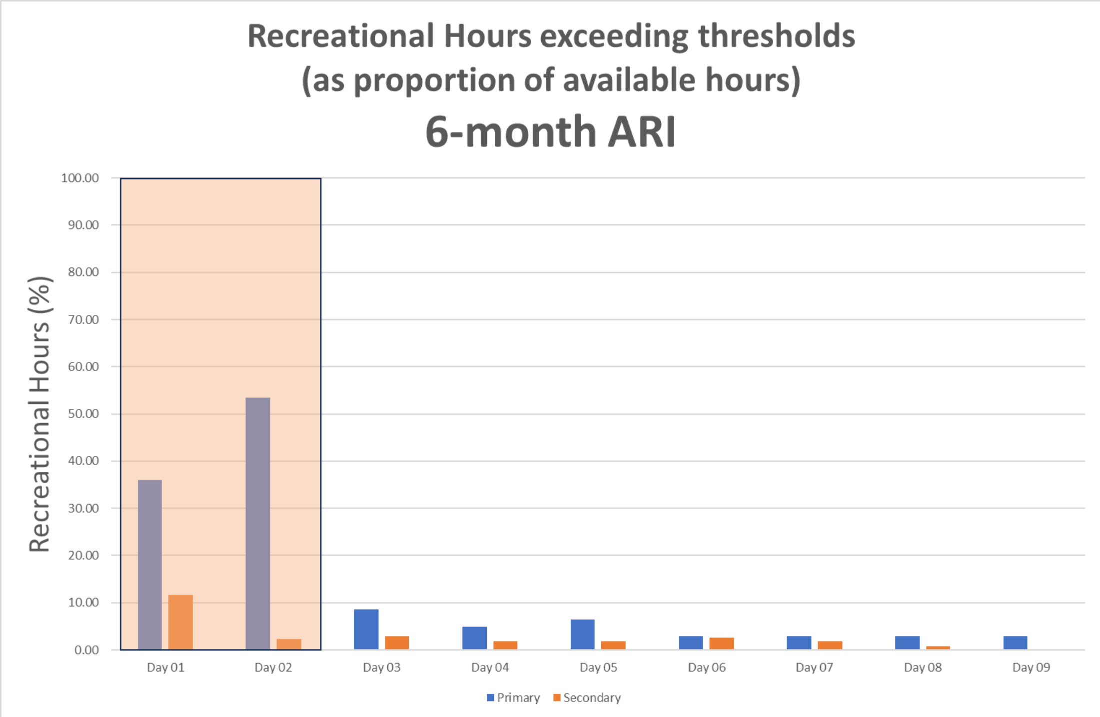


Figure 4 – Recreational Hours (%) exceeding thresholds for 6-month ARI event.

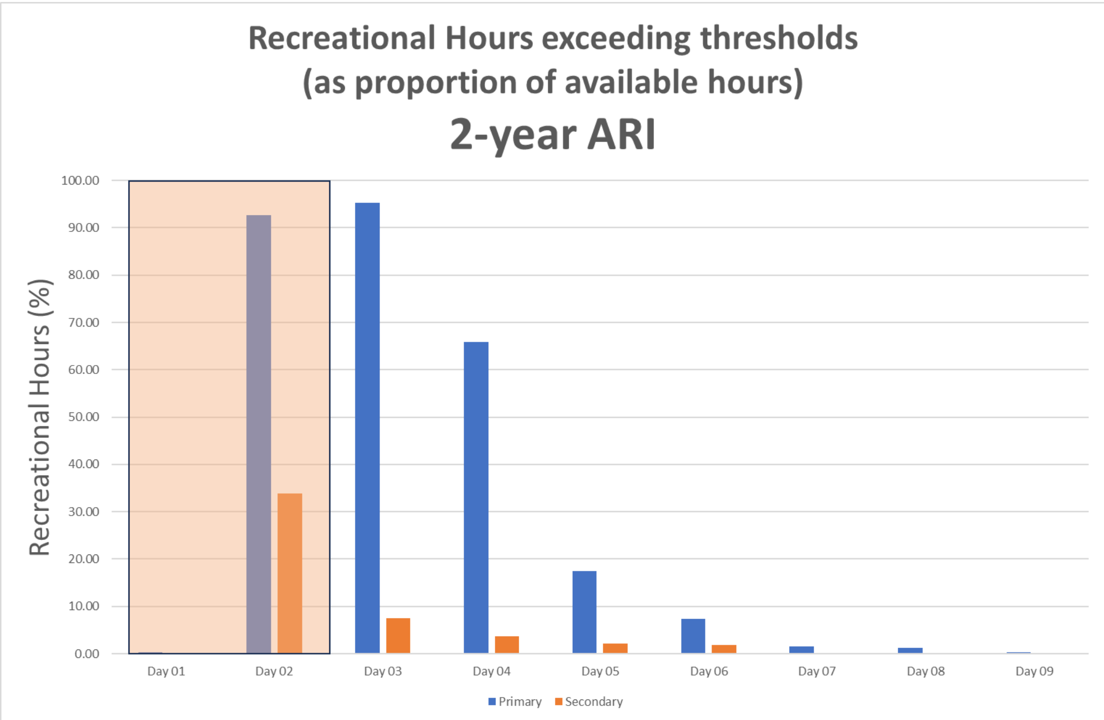


Figure 5 – Recreational Hours (%) exceeding thresholds for 2-year ARI event.

## SUMMARY

The Brisbane River Estuary experiences cumulative stress regarding bacteria loading primarily from catchment inflows and, to a much lesser extent, from sewerage assets (STPs and WWOs). Using an EBA, we addressed the questions about impacts from key sources of pollution and the cumulative impacts on water recreation in the context of total catchment pollution. We delineated the impacts on recreational primary contact and secondary contact hours from catchment inflows and WWOs only. Results indicated that for the assessed events, WWOs occur briefly, discharge an insignificant volume, and contribute less than 30% of total catchment bacterial loads.

With catchment loads dominating bacterial loads, an EBA using REDiT is being used to develop cost-effective WWO management strategies for community benefits. In the future, Urban Utilities plans to enhance REDiT to an operational model to support the transition towards more proactive management of its infrastructure. Real-time operational changes can mitigate WWOs, leading to more effective protection of water recreation values.

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## REFERENCES

DEHP (Department of Environment and Heritage Protection). 2009. Queensland Water Quality Guidelines, Version 3, ISBN 978-0-9806986-0-2.

Huiban, M., Chakravarthy, K., and Jackson, C. 2023. An online decision support system for the assessment of bacterial contamination in the Brisbane River Estuary. Australasian Coasts & Ports 2023.

UU (Urban Utilities). 2024. About Us. What We Do. URL - https://www.urbanutilities.com.au/about-us/what-we-do. Last Accessed – 15 April 2024.

WSAA (Water Services Association of Australia). 2023. Managing Wet Weather Overflows. Guidelines for the Australian & New Zealand Water Industry.