Adapting water infrastructure for an uncertain climate

Researchers from the Deep South National Science Challenge are exploring options to ensure wastewater infrastructure can cope with advancing sea levels and extreme rainfall events.

The Adaptive Tools for Decisions on Compounding Climate Change Impacts on Water Infrastructure project has been applying decision making under deep uncertainty (DMDU) tools to inform adaptation planning for wastewater treatment plants, trunk sewers, and outfall pipelines that face a changing climate and increasing demand for service.

The majority of our population lives near the coast, which means our infrastructure is mostly in areas susceptible to compound coastal hazards – the interaction between different hazards that occur simultaneously.

Wastewater infrastructure is particularly vulnerable because it is often gravity-fed, and therefore very low-lying. Coupled with increasing influent volumes and communities that expect current levels of service to be maintained into the future, wastewater systems are highly vulnerable to changes in climate and land use. Ensuring the safe and effective provision of wastewater is a critical societal need and has significant health implications.

"Wastewater isn't glamourous," says project lead and NIWA scientist Dr Andrew Allison, "but losing critical wastewater services, even for a short time, is much less glamourous."

Applying deep uncertainty tools to compound hazards

The Adaptive Tools research team used a robust decision-making (RDM) approach to inform wastewater infrastructure adaptation options by partnering with Watercare and Wellington Water at two locations.

RDM is one of several DMDU tools. RDM seeks to find the adaptive actions that perform well across as many scenarios as possible. In contrast, the commonly used optimisation approaches try to find the solution that works best for a single scenario which, in conditions of uncertainty, provide least flexibility and can create lock-in of decisions and thus maladaptation.

The use of Dynamic Adaptive Pathways Planning (a DMDU approach) is recommended in the MfE's Coastal Hazards and Climate Change Guidance for Local Government (2017). However, few examples exist in practice of DAPP implementation. This research sought to fill this gap for compound hazards coastal settings.

DAPP requires the adaptation thresholds (things that need to be avoided), indicators (things that need to be monitored), and triggers (the time when action needs to be taken) need to be developed, so that the actions decided can be monitored for their performance as the climate changes. Councils and water service providers have only begun to address implementation of the DAPP analyses.

Accordingly, the researchers used seven methods – scoping workshops, system mapping, dynamic adaptive pathways planning (DAPP), exploratory modelling, RDM, real options analysis and validation workshops – to simulate future pressures and potential adaptive actions for two wastewater treatment plants (WWTP), at Helensville and Seaview.

Two implementation examples

The Helensville example focused on how Watercare could implement a Dynamic Adaptive Pathways Plan that had been developed previously. The Helensville WWTP sits on a bend of the Kaipara River just north of the town of Helensville in north Auckland. The plant is less than four metres above mean sea level and is vulnerable to high river flows, sea level rise and high tides – particularly so when these occur simultaneously.

The research team found that an adaptation threshold exists at 31cm of Relative Sea Level Rise (RSLR), at which point the plant would be inundated in a one percent Annual Exceedance Probability (AEP) event. An AEP event is a one percent chance of an event occurring in any given year.

In this case, the trigger point exists at a sufficient lead time to enable relocation of the plant without it being impacted by a flood, while the asset owners can monitor the rate of RSLR (the indicator). Sea level rise is occurring faster than usual at the Helensville WWTP site due to land subsidence.

The Helensville example quantitatively shows how a DAPP

Terminology

Adaptation thresholds are critical points of failure to be avoided, such as inundation.

Adaptive actions are engineering actions designed to avoid an adaptation threshold.

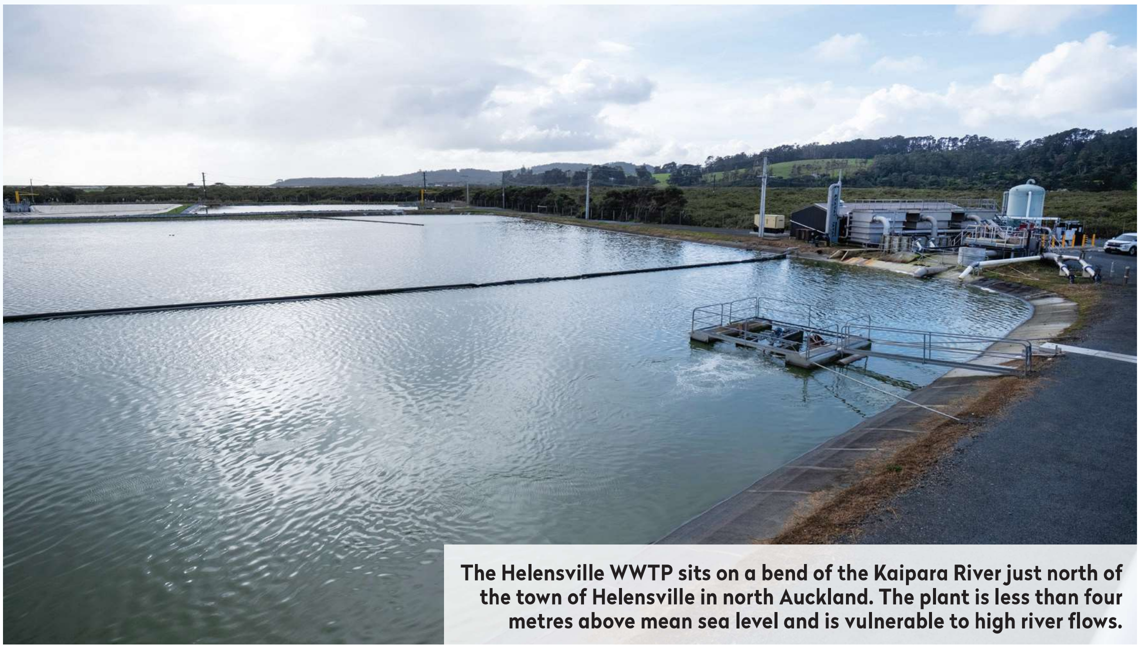
Triggers are a decision point when the efficacy of current and future actions are reviewed and new adaptive actions chosen and implemented to avoid an adaptation threshold.

Indicators are factors that are monitored to warn that a trigger is approaching. For example, near-miss events.

Lead time is the time it takes to plan for, obtain consent and implement a new adaptive action.

Nuisance flooding is flooding that occurs on site but does not impact plant operations or wastewater processing.

RSLR is the rate of sea level rise observed at a specific site. Comprised of global sea level rise and local land subsidence/uplift.



The Helensville WWTP sits on a bend of the Kaipara River just north of the town of Helensville in north Auckland. The plant is less than four metres above mean sea level and is vulnerable to high river flows.

could be implemented by a water service provider, in practice. The Helensville study was completed in September 2021.

The second example was conducted at the Seaview WWTP in Petone. The plant was built on reclaimed land at the mouth of the Hutt River, and existing analysis showed that the plant was susceptible to inundation in a one percent AEP compound hazard event after 60cm of RSLR as well as being exposed to sea level rise and related groundwater rise and liquefaction hazards.

Working with Wellington Water, the researchers developed a prototype DAPP for the Seaview WWTP, the trunk network and outfall pipeline, including indicators, triggers and adaptation thresholds to be avoided. Modelling showed that after 26cm of RSLR, 'nuisance flooding' would begin to occur at the site, and after 56cm of RSLR plant assets could be inundated in a one percent AEP flood – this could happen as soon as 2060, while the plant has a design life of 2080.

If changes were implemented to plant layout, including raising electrical systems, the plant may be able to remain on site for its design life.

In practice

Four months after this research was complete, the Auckland Anniversary weekend floods occurred, with 265mm of rain falling in 24 hours and 211mm in less than six hours. The floods provided a rare opportunity to observe an extreme event occurring in a location that had very recently been modelled.

Infiltration of water into the trunk network meant that influent volumes to the plant were so high that even after plant upgrades in 2022 (which increased processing capacity by 50 percent), the plant could not handle the flow. Mobile pumps were trucked in to bypass the ultrafiltration treatment system by lowering pond levels, which resulted in partially treated sewage being discharged into the Kaipara River.

The Kaipara River burst its banks and flooded large areas of farmland upstream from Helensville, which helped to reduce the river flows. Additionally, the peak river flows occurred during the lower half of the tidal cycle, so the Helensville WWTP was not inundated by the river.

The Auckland floods were a one-in-220-year event, meaning that they were far outside the design standard of the plant, and larger than the largest flood modelled by the research team. Re-running the model to simulate the event showed that the plant would have been inundated if the river flows had peaked at high tide, rather than low tide.

Lessons learned

The research team says that as extreme weather events become more frequent and severe, and ongoing sea levels and groundwater rise progresses, water service providers need to consider the planned relocation of wastewater assets and other water vulnerable infrastructure.

"It's not really a matter of if, but when," says Andrew. "Our infrastructure systems are not located or designed to cope with these increasingly large compound hazard events compounded by ongoing sea level rise, and they're simply not going to be able to continue to operate where they are as the sea continues to rise."

"Furthermore, our land use planning needs to consider where further development and associated infrastructure is located, how it is designed to accommodate and avoid the impacts of the ongoing changing climate."

The approach developed in the Adaptive Tools project is already being applied more widely to infrastructure adaptation, including for freshwater supply and transport networks. It provides a way to stress-test DAPP derived near-term actions and long term options and to ensure that the components of a DAPP (indicators, signals, triggers and adaptation thresholds) can be measured, and to simulate how a DAPP would play out across a range of future scenarios. This can give infrastructure providers greater confidence in decision-making, in the face of a deeply uncertain future.

Next steps

With the project completed, Deep South have commissioned the researchers to draft guidance for the use of their approach more widely for infrastructure adaptation, including non-water infrastructure. This guidance shows how the seven methods can be used within a 10-step planning cycle that complies with MfE guidance and allows for robust decisions to be made to adapt infrastructure under deeply uncertain futures.

Research team: Andrew Allison, Scott Stephens, Paula Blackett, Shailesh Singh (NIWA), Judy Lawrence (PSConsulting), Adolf Stroombergen (Informetrics), Jan Kwakkel (Delft Technical University).

Article supplied by NIWA