GIS based Route and Asset Optimisation for the Western Dams Water Raw Water Supply Infrastructure

Margaret Cobeldick CPEng, Aurecon New Zealand Ltd, Nick Holden CPEng, Aurecon New Zealand Ltd, and Nikhil Susarla CPEng, Watercare Services Ltd

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ABSTRACT (500 WORDS MAXIMUM)

The existing Huia Water Treatment Plant in Auckland is almost at the end of its operational life. A project is currently underway for the planning, design and construction of a replacement plant at a neighbouring site. As part of the new Water Treatment Plant project works, the capacity and resilience of the supply infrastructure from the source dams to the Water Treatment Plant are also being assessed. The existing assets are located through rugged, isolated country of high environmental value, and it is critical that the raw water supply assets will be resilient and able to provide raw water flows to the new Water Treatment Plant for the next 100 years, whilst withstanding potentially worsening adverse weather events that have recently caused severe flooding and land instability issues in the area.

This paper describes the asset selection and optimisation process that is being used to quantitatively select the preferred raw water supply routes. Development of a GIS-based digital tool to follow an adaptive planning type process was required to coordinate and map out the interlinked decisions required on each component of the raw water supply. Some portions of the existing supply pipelines are over 100 years old and require renewal or upgrade for the future Water Treatment Plant. In addition, other key constraints apply to the project including constructability and safety issues, environmental impacts as well as stakeholder expectations. This GIS tool has several key benefits:

- It is allowing Watercare to optimise what components of the existing headworks and raw water system require upgrades or renewals.
- It is allowing Watercare to confirm the timeline and sequence of the asset construction works, which in turn has provided confidence over the forward capital works programme.
- The resiliency of the system components and overall system can be assessed and accepted by Watercare.
- The tool provides a graphical presentation of the options assessment which can be used to explain and share the outcomes of the decision process with internal Watercare and external stakeholders in a technical or non-technical manner.

- The tool has ensured that the collective historic data and decisions made on the project are incorporated into the decision-making process and this collective knowledge is not lost.

In development of this tool Watercare now have access to a project level digital adaptive planning tool that can be used to navigate and support decisions where the input data is complex.

KEYWORDS

Adaptive Planning, Digital Optimisation, Water Supply

PRESENTER PROFILE

Margaret Cobeldick is a Principal Engineer with over 23 years of experience in design and construction of water infrastructure. She is Aurecon's Project Manager for the Watercare Enterprise Model and is deeply involved in establishing digital design and adaptive planning into the Strategy and Planning stages of the works programme.

Nick Holden is an Associate Water Engineer with Aurecon. With over 16 years of design and construction experience in water engineering, Nick is the Project Manager for the Huia Raw Water Supply project and has been key in applying adaptive planning analysis to optimise the best capital works programme for Watercare.

Nikhil Susarla is a Planning Engineer at Watercare responsible for managing feasibility studies and delivering business cases for water treatment projects in Auckland. He has held various roles at Watercare ranging from Operations to Commissioning. Nikhil is the project manager for the Huia Raw Water Supply and replacement Huia WTP projects.

INTRODUCTION

The existing Huia Water Treatment Plant in Auckland is almost at the end of its operational life. A project is currently underway for the planning, design and construction of a replacement plant at a neighbouring site. As part of the new Water Treatment Plant project works, the capacity and resilience of the supply infrastructure from the source dams to the Water Treatment Plant are also being assessed.

The existing Water Treatment Plant is supplied raw water from four large dams located further west within the Waitākere Ranges, as shown in Figure 1. These convey raw water via a number of gravity pipeline systems to the existing plant for treatment and distribution into the transmission and network system to the east. Due to the rugged hilly nature of the Waitākere Ranges these gravity pipelines pass through various sections of tunnels, and pass over numerous pipe bridges and aquaducts as well as long sections along the ground surface.

The pipelines are a mixture of diameters (from 610mm through too 1500mm) and materials vary from cast iron, through concrete to concrete lined steel. Some sections have been recently replaced and other sections are over 100 years old.

These four dams and the water treatment plant supply around 20% of Auckland's water and are a key component of the overall supply strategy for the city.

The recent extreme weather events in Auckland including the 2020-2021 drought and the 2023 Anniversary Weekend floods, have resulted in sections of the raw water pipelines being damaged due to ground settlement and land movement and highlighted the vulnerability of the system in this area.

Figure 1: Location of four storage dams and water treatment plant (data source: Watercare GIS)

Watercare has commenced work on the design for the new Huia Water Treatment Plant in Titirangi that is to be located at a site near the existing treatment plant. As part of the wider project works a condition assessment and upgrade assessment for each of the four raw water supply systems was also required. The objectives were too:

- Ensure the upgraded raw water conveyance systems were able to supply the increased flow rate to the new water treatment plant which is also located at a slightly higher elevation. (The existing gravity conveyances would not be able to convey raw water at sufficient flow rates to the new treatment plant).

- Ensure the condition of the pipelines and integrity of the structural supports would ensure an operational life of 100 years whilst enduring future extreme weather events.
- Ensure continuity of supply to the existing water treatment plant while the replacement water treatment plant is being constructed and commissioned.

This paper describes the asset selection and optimisation process that was used to quantitatively select the preferred raw water supply routes.

DATA GAP ANALYSIS

The initial stages of the project involved an assessment of the work completed to date on this raw water system. Historically, Watercare and a number of consultants had worked on various aspects of the system and the data and assessments were accumulated and reviewed.

It became apparent that the work to date was thorough but had been limited to inspection and reporting on individual components of the raw water system and had not determined a method to determine what *combination* of asset upgrades were required to provide the level of service expected. Similarly, the timing of the upgrades had not been determined – noting that there are time constraints associated with the works with the new Huia Water Treatment Plant due to be commissioned in 2032.

In summary, Watercare needed to know that of the approximate 27 km of existing pipeline:

1. What sections have to be upgraded?

2. In what order should the sections be upgraded?

3. When should the upgrade occur to ensure the new treatment plant is supplied with flows as required?

ADAPTIVE PLANNING APPROACH

An Adaptive Planning Approach was identified as providing the means to determine the optimal pathway of works. To understand this, a schematic of the system is in Figure 2. This has been marked up to show some of the specific challenges associated with some of the existing system components [1].

In particular, the Upper Nihotupu pipeline in red operates almost independently from the other pipelines in blue – so upgrade of Upper Nihotupu would mean that upgrades of the lower blue system could be delayed. Or vice versa.

How could Watercare decide which of these upgrades should proceed first?

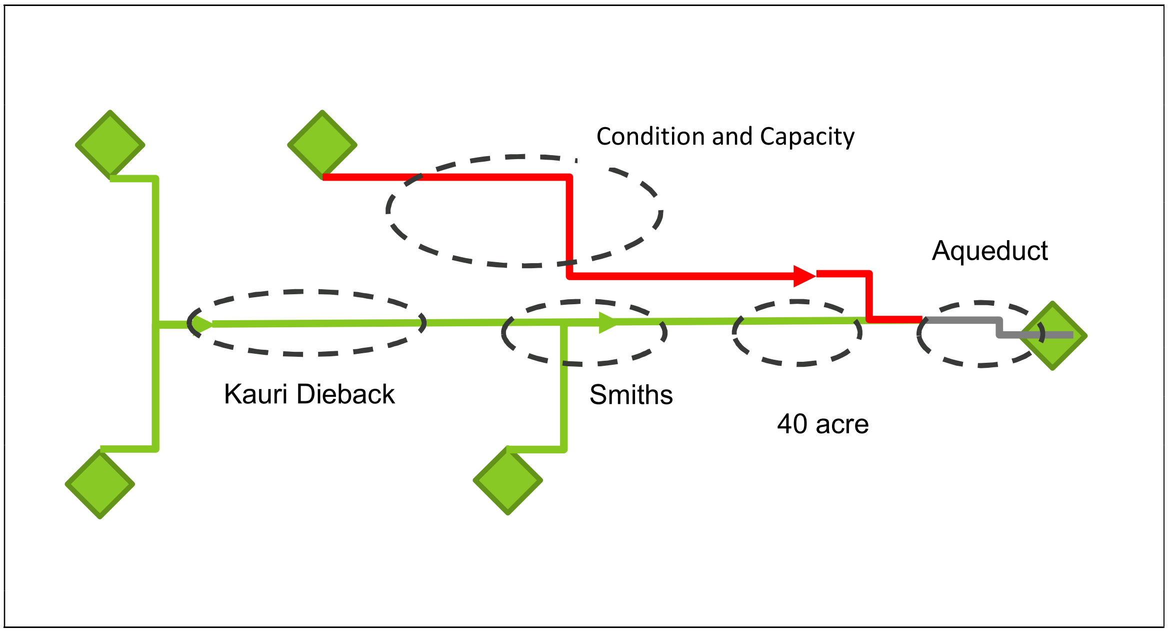

Figure 2: Existing system schematic and key issues

MULTI-FACETED CONSTRAINTS

The pipelines are located in areas with many constraints on future works, all of which impact on the decision process of what to build and where. Key constraints include the following:

-The areas the pipelines are located are on generally steep topography through remnant kauri forest that is currently being severely impacted by Kauri Dieback disease. Movement of soils over a wide area would not be approved by the local Council.

-This area is precious to local tangata whenua and to local residents – so creation of wide construction corridors through the forest by removal of large trees to move machinery and equipment would not be regarded as acceptable.

-There are large areas of land instability that require new support structures to ensure a further 100 years of service.

-40 Acre Slip is a known area of geotechnical instability and movement and receives ongoing monthly monitoring. After recent Auckland heavy rainfall events

[1] Note that the schematic presents just a few of the issues, including all of them would be a challenge at this scale.

monitored slippage has increased from approx. 1mm per year to over 90mm in 3 months.

-Some existing tunnel sections are too small and require construction of additional tunnels to ensure sufficient flow capacity.

-The existing pipeline convey water via gravity. However, would this still be possible with the new treatment plant located some 15m higher in elevation?

- Does the new system remain gravity with a new lift station at the treatment plant or does the system get retrofitted to allow a pressurised system?

-Due to the physically challenging area construction works could be difficult and expensive. What are the relative costs of various upgrade options and how does this influence the proposed works?

Due to the complexity of the decisions that were needed, how can this process and the final preferred solution be easily communicated to others within Watercare and in the wider community?

STEP 1: MULTI-CRITERIA ANALYSIS

The first step undertaken was to prepare a detailed Multi-Criteria Analysis (MCA) for each of the pipeline elements. Some 35 number of individual elements were analysed and provided an MCA scoring. An example of the list of the components scored in the MCA process is in Table 1.

OPTION 1		X		
OPTION 2		X		
OPTION 3			X	X
Element	A1a	A1b	A1c	A1d
Segment Description	U. Nihotupu Dam to Greenwoods Corner - TBM	U. Nihotupu Dam to Torrens Taper via Greenwoods Corner - Pipejack	U. Nihotupu Dam to Jacobsen's Tunnel - HDD	U. Nihotupu Dam to Jacobsen's Tunnel - Existing alignment
Contaminated Land	3	3	3	3
Stakeholders / Consenting	1	2	3	1
Kauri Dieback	2	2	2	4
Hydraulics	3	3	3	3
Structural / Tunnelling	3	3	2	2
Geotechnical	3	3	2	2
Planning				

Table 1: Example MCA Scoring

At this point a GIS-based map was created to illustrate the outcomes of the MCA process. This is shown in Figure 3.

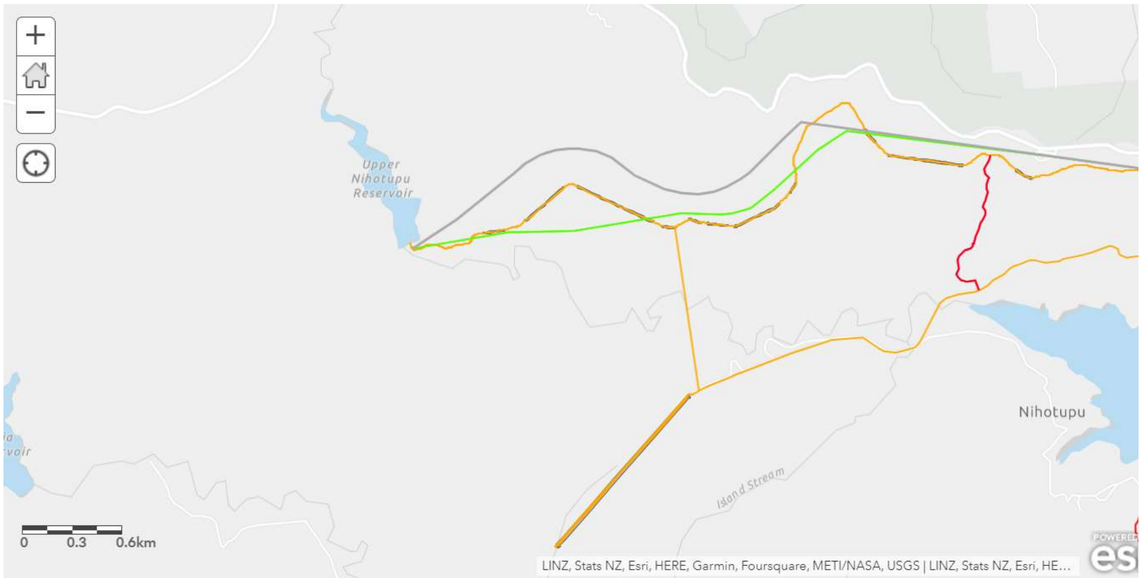

Figure 3: Initial mapping of MCA Element scoring

Development of this GIS-based map allowed the relative scoring of each element to be shown so that it was clear from Point A to Point B what the optimal combination of element upgrades was based on the MCA scores for each option. Specially, each alignment would have a range of elements with various constraints and costs and the GIS mapping tool was used to calculate what the highest-scoring combination of elements was for a specific pipeline.

This was a very productive first step in the process, as a number of less favourable options for upgrades could immediately be discounted. Watercare was now in a position to understand and start works on the upgrade works as recommended via the GIS optimisation and MCA analysis.

However, this tool did not answer the questions above regarding the order of the works and the timing the works had to be carried out. More advanced GIS programming was used to form this Adaptive Planning approach as explained in Step 2.

STEP 2: DYNAMIC ADAPTIVE PLANNING APPROACH

The new raw water conveyance system should operate so that with any one dam out of service then at least 80% service level can be achieved at the Water Treatment Plant. This means that if the Upper Nihotupu pipeline (red in Figure 2) was upgraded and operating at peak capacity then the remaining pipeline upgrades (blue in Figure 2) could be delayed.

The opposite was also the case: if the lower (blue) upgrades were carried out then the upper (red) pipeline upgrades could be postponed.

Further complexity was involved due to cross-connections between the pipelines.

The quandary faced was which set of upgrades should proceed first – the red or the blue? And where should the cross connections be located and when did they need to be constructed?

The solutions to these questions were provided using further GIS programming. A scoring attribute was applied to each element with a coupled-score. This meant that if one system (i.e. red) was scored highly on the 'construct early' attribute then this score was automatically scored lower for the other system (i.e. blue). This scoring could be switched around by the GIS user to compare optimal combinations of element upgrades.

STEP 3: SENSITIVITY ANALYSIS

Due to the long history of this project, there were many solutions, and ideas and options that had been raised and discussed. Some were considered highly, and others viewed more critically. Using a quantitative GIS process has meant that all of these solutions could be built into the option selection process described above.

It was important therefore that all of these solutions and ideas were represented clearly in the GIS map, and the MCA scoring associated with each of these elements was also clear. For this reason, the map included a link back to the MCA data table. The GIS map has been set up so that users of the tool could open the MCA data table and adjust the scores based on their personal preference. The GIS map would automatically update the optimal solution based on the new MCA scores [2]. Repeated changes to the MCA scoring by the project team were used to confirm how sensitive the optimal solution was to various constraints, and the selected combination of elements and upgrade works was selected.

STEP 4: PRESENTATION TO STAKEHOLDERS

This portion of the planning process is still underway, but it is a key part of the process. Sensitivity checks of the MCA scoring are being carried out, and the best-scoring selected combinations of works are being reviewed by the project team. Further engagement with internal and then external stakeholders will also be undertaken so that parties with a current interest in the project can understand the reasoning behind the preferred option selection.

CONCLUSIONS

Using GIS also takes away the human bias in decision making process a much more comprehensive and robust outcome. Watercare can be confident that the

[2] Note that this was for a 'user' version of the MCA analysis. A master version was retained by Watercare as the sole source of truth with the MCA scoring in the master version a summary of the outcomes from a number of project MCA assessment workshops.

multitude of all possible combinations of solutions have been included in the scoring assessment, including all those from the many years of history on the project, and that they have a visually clear tool to communicate with a broad audience about the proposed programme of capital works for the Huia Raw Water Supply.

This GIS adaptive planning tool has several key benefits for the Huia Raw Water Supply project:

- It is allowing Watercare to optimise system upgrades.
- It is allowing Watercare to confirm the timeline and sequence of the asset construction works.
- The resiliency of the system can be confirmed.
- The tool provides a graphical presentation of the options assessment for stakeholders.
- Historic and collective knowledge has been retained.

In development of this tool Watercare now have access to a project level digital adaptive planning tool that can be used to navigate and support decisions where the input data is complex.

ACKNOWLEDGEMENTS

We would like to acknowledge the many multidisciplinary and skilled staff from both the Aurecon and Watercare teams that have worked on and provided input and direction to this piece of work.

With the long historic background leading up to the decision making process we would like to acknowledge and appreciate all of company's and staff that have had input over time.

With a special acknowledgement to *Jon Reed of Beca* for his involvement and willingness to share his deep understanding of the project.