WHAT IS SO EXCITING ABOUT THE DELIVERY OF A 60MLD FLOATING PUMP STATION? DURING A DROUGHT & PANDEMIC? WITHIN 12 MONTHS?

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ABSTRACT

Why did we design, build and commission a 60MLD floating pump station in the Waikato River?

Watercare have commissioned a Water Treatment Plant (WTP) as part of the Waikato River to Redoubt (R2R) programme to deliver an additional 50 million litres of treated water per day (MLD) from the Waikato River to Auckland as urgent drought mitigation. This plant needed to be designed, constructed, and commissioned within a 12 months' timeframe – to enable water delivery to Auckland by Winter 2021. A conventional pump station with fixed intake screens, tunnel and wet well with raw water pumps could not have been completed within the drought response timeframe – an acceptable alternative solution was required.

What are the challenges associated with a floating pump station in the Waikato River?

The items below are some of the major challenges we faced during the design and execution of this project – a combination of stakeholder management, engineering and operational continuity:

- The downstream intake of the existing 175 MLD water treatment plant (20m) always had to be kept operational and protected during investigation and construction
- Finding an acceptable and least intrusive solution with Waikato Tainui and the Te Taniwha O Waikato
- Varying river levels from 0.5m (minimum river level) to 5.65m (flood condition)
- River flows of up to 2m/s
- Pump station debris loading with frequent "floating islands"
- Wave & seismic actions
- Unwanted visitors, operator / maintenance safety

How can you meet all these requirements and deliver this project on time?

In a nutshell – it took an integrated approach between floating pump station design, operational and maintenance requirements, partnering with equipment suppliers & procurement fast tracking, continuous contractor and fabricator design input and focused interface management with the downstream water treatment plant process components.

Procurement focused design

From the early stages the team had to focus on program, starting with the selection of robust equipment. Our design focus was the early procurement definition of these long-lead time items:

- The pump station design relied heavily on a well-established marine pontoon structure – Linkflote™ pontoons made by Volker Brooks (UK)
- Intake screens were sourced from a supplier with a proven operational track record in New Zealand – AWMA (Australia)
- Submersible pumps were sourced out of Germany by KSB
- Hoses to achieve the required pump station river level variation were sourced by HCD out of Australia
- Access gangways were designed and fabricated locally by Manson Engineering in Henderson
- The pump hoist was supplied by Monocrane

What ties this all together?

A well set up local fabricator (JP Marshall - Hamilton) with in-house fabrication support provided design input before construction drawings were issued mid-November 2021.

In-depth and agile collaboration between the supplier, designer, and constructor (Brian Perry Civil), regular factory and site inspections, were key to this successfully implemented project.

KEYWORDS

Engineering, Agile Design, Project Collaboration, Smart Procurement, Floating Pontoons

PRESENTER PROFILE

Sven Harlos is a Fellow of Engineering New Zealand and Programme Manager for the Waikato River to Redoubt (R2R) new water supply scheme. He has 26 years experience in the water industry both in New Zealand and overseas delivering mainly large and complex water and wastewater treatment projects.

Gregory Cameron is a Structural Engineer with a proven track record of delivering successful projects within multi-discipline team environments. He has strong communication and technical skills which he has developed through working on heavy industrial projects.

Gregory provides engineering solutions with a high level of detail, ensuring the contractor has enough information to build structures safely.

Holger Zipfel is a Project Design Manager with over 22 years' experience in the consulting, product development industries as well as the EPC business.

Holger has excellent leadership qualities, attention to detail and excellent client focus with the aim to achieve success for the project.

INTRODUCTION

Watercare Services Ltd and MTL started this journey in August 2020 with the aim to deliver drinking water to Auckland by Winter 2021. Our team was comprised of designers, and mechanical, process, civil and structural engineers, all with the core objective of delivering this project safely and to the required timeline.

1. PROGRAMME DRIVEN DESIGN SUPPORTED BY EARLY PROCUREMENT DECISIONS

The tight twelve-month timeframe, from inception to commissioning, necessitated appropriate selection of the main pump station equipment. This includes:

Pontoons - Linkflote™

The primary part of the structure was selected for its track record and its design verification support out of the UK. Refer to Section 2.1.1 for more details.

Pumps - KSB

Process pumping requirements, such as the pump system curve, were used to make the pump selection. KSB submersible KTR pumps matched the design envelope and have a proved track record within Watercare.

Photograph 1- Pump lift to verify centre of gravity

Hoses – HCD Flow Technology

Robust, 16bar pressure rated, corrugated, abrasion- and weather resistant, spring steel reinforced flexible flanged hoses were selected to provide the necessary flexibility (river level changes from RL 0.5m to RL 5.65m). Hoses with this specification are predominately used in the mining industry. MTL have previously specified hoses from the manufacturer HCD for the Hamilton WTP, just upstream from the Waikato 50 plant intake.

Photograph 2 - HCD Hoses on pallet

Gangways – Manson Engineering

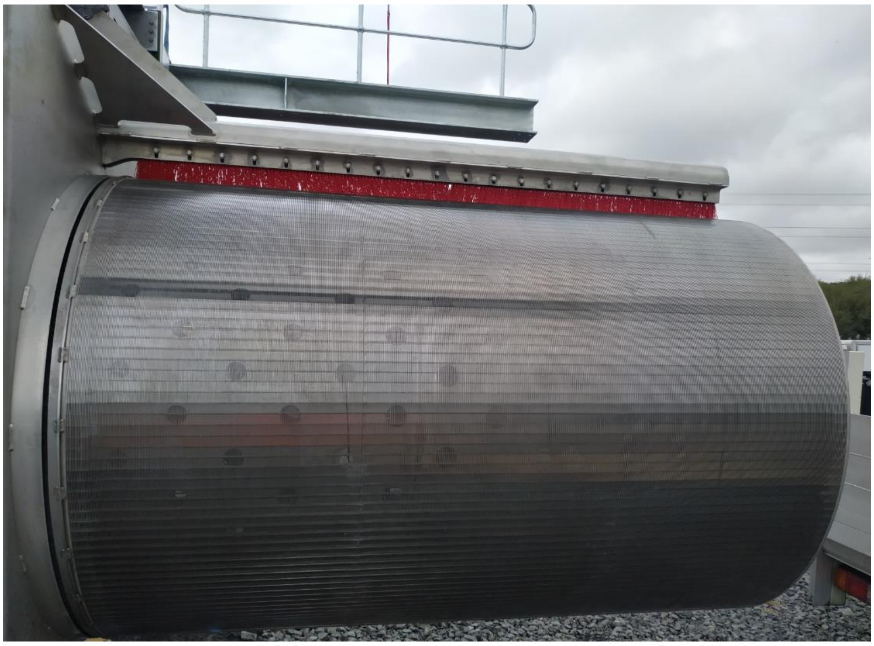
Manson Engineering Ltd supply gangways to the marine industry, including gangways for passenger ferry terminals. Manson gangways are used all over New Zealand and were the appropriate choice for the Waikato R2R project.

Photograph 3 - Gangway during manufacturing process

Screens - AWMA

Consent requirements were rigorous for the intake screens, as they were required to protect all Waikato River aquatic life. With this in mind and the vision from Te Taniwha of Waikato, the Wedge Wire intake slot velocities and slot width were critical to the project success. Ease and safety of operation and maintenance were additional selection parameters. The wider project teams positive experience with AWMA screens led to the final procurement of the screens.

Photograph 4 - Screen after on-site assembly at Winstone Quarry



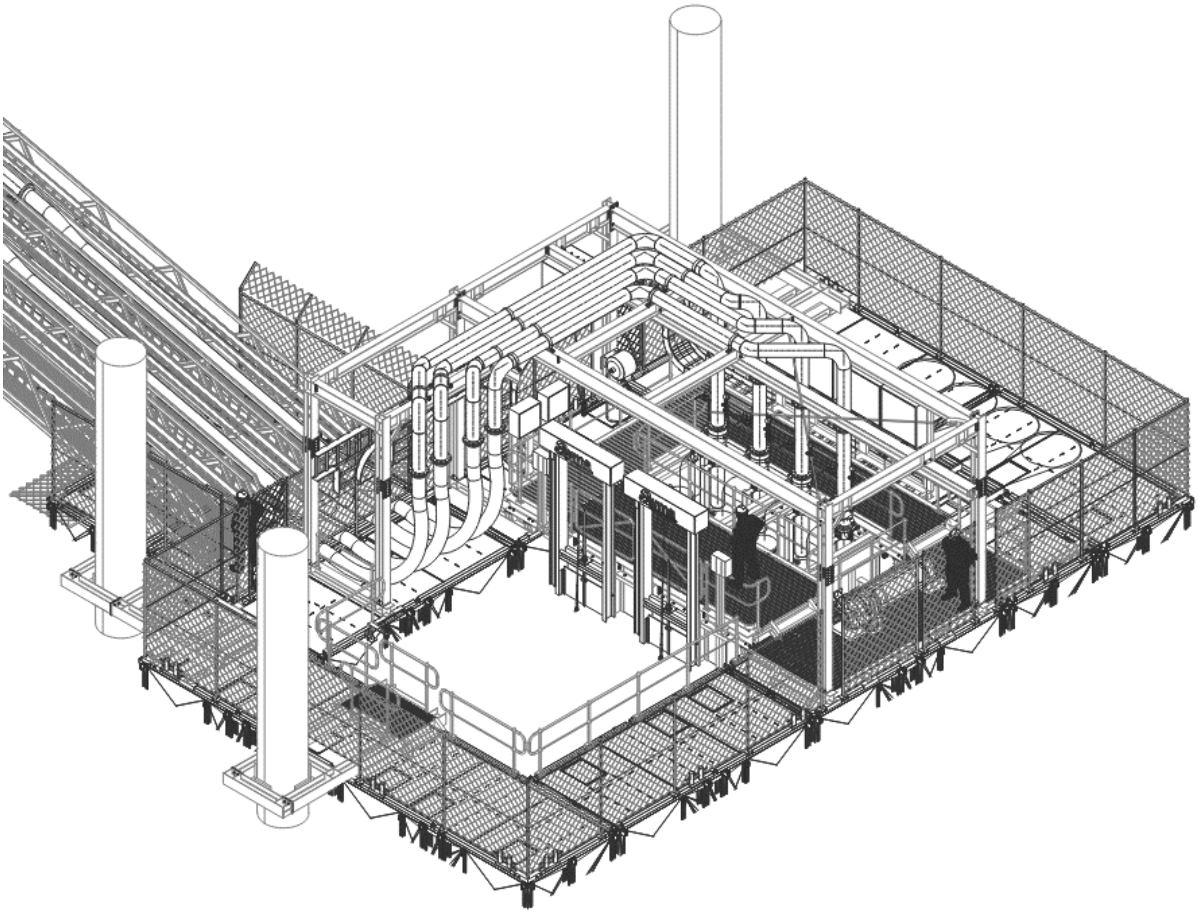
2 STRUCTURALLY DRIVEN CONCEPT

Engineering design of floating structures presents a range of different challenges compared to building on solid ground. Particularly when dealing with weights in excess of 100tonne, which was the case for the Waikato River floating pump station. Buoyancy and stability requirements must be satisfied while also ensuring adequate structural integrity of the pontoon and superstructure. Vibration and wave action on equipment also had to be considered. This calls for bespoke and innovative structural solutions.

2.1 STRUCTURAL SCHEME/OVERVIEW

Figure 1 shows the layout of the floating pump station and its main structural components, which includes: Linkflote™ pontoons, reinforced concrete river piles, steel pile clamps, steel gantry frame and monorail, steel framed wet well to support the pumps and intake screens, and gangways to provide pedestrian access as well as routes for the raw water hoses and electrical / communication supplies.

Figure 1- Floating Pump Station 3D model



The various structural elements that comprise the floating pump station are discussed in detail in sections 2.1.1-2.1.4.

2.1.1 LINKFLOTE™ PONTOONS

Linkflote™ pontoons form the basis of the floating pump station's structure. Linkflotes™ are modular flotation pontoons used for both temporary and permanent marine infrastructure applications and marine developments. They are comprised of a steel plated shell with a stiff internal steel frame which provides a robust and watertight construction. Location lugs and couplers are fixed to the sides and ends of each Linkflote™ element which allow the units to be easily connected to form almost any pontoon shape or configuration. Due to their flexibility and strength, they were the apparent choice for the floating pump station platform. Refer to photograph 5, showing the pontoons prior to dispatch.

Photograph 5 - Linkflote™ pontoon

The Linkflote™ pontoons are designed and manufactured in the United Kingdom by Volker Brooks. Meaning that swift procurement of these items was critical to the timely completion of the project.

The strongest part of the units is along the perimeter where the gunwales are located. Through the use of steel beams and saddle plates this is where the vast majority of the imposed loading was distributed to.

2.1.2 RIVER PILES & PILE CLAMPS

Lateral stability of the pontoon is provided in the form of three 1200mm diameter reinforced concrete piles. These piles span an impressive length of approximately 20-30m and are bored deep into the rock below the riverbed. A strong desire of minimising the number of piles and impact on the Awa led to the reduction of 5 smaller to 3 larger piles loading the floating pump station in position. A general view of the river piles and the floating piling rig can be seen below in photograph 6.

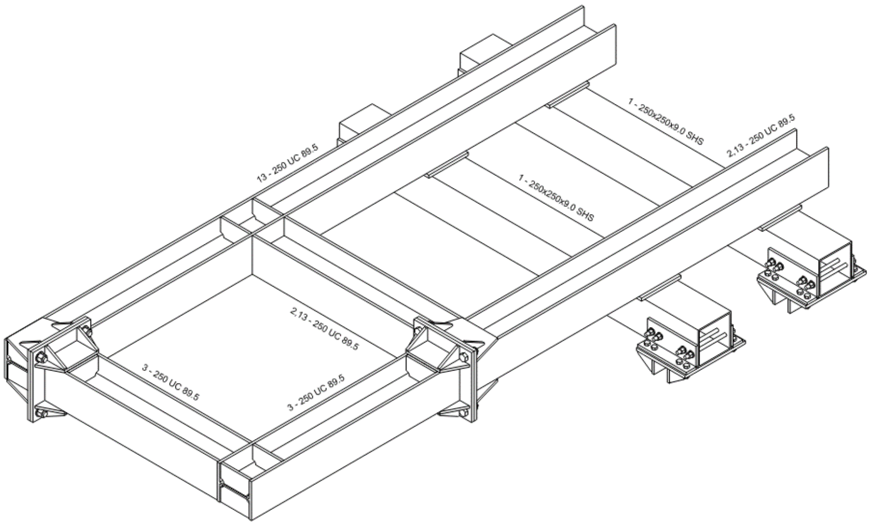
Photograph 6 - River piles and piling rig

The installation of the river piles was a precision exercise, as the alignment of the pontoon and the land-based construction was critical to the functionality of the gangways. The piles had to be installed within a small tolerance to allow for large deflections under horizontal loading conditions while still maintaining an acceptable installation angle of the gangway.

Installation tolerances of within 75mm horizontally and 1:75 vertically were required in accordance with ICE Specification for Piling and Embedded Retaining Walls, Third edition.

The river piles were designed to resist a combination of current/debris loading and wind loading, which are discussed further in section 2.2. Bespoke steel frames or "pile clamps" were engineered to enable the piles to be connected to the pontoon and ensure an adequate load path between the two elements. The bolted L-shaped connection at the end of the clamps was required so the pontoon could be rotated about the piles and easily fitted into position.

Figure 2 - Pile clamp



2.1.3 WET WELL

The wet well forms the heart of the floating pump station. It supports the intake screens and houses the raw water pumps. As these items are critical for the functionality of the river intake pump station, significant thought was required for the structural design of the wet well. With the combined weights of the pumps and screens being approximately 20tonne and due to the presence of high vibrations from the pumps an extremely stiff and heavy steel structure was required.

Photograph 7 - Wet well structure

2.1.4 STEEL GANTRY FRAME AND MONORAIL

A large steel frame was constructed on the pontoon to serve two primary functions; to support the stainless-steel pipes and feed them into the wet well where they connect to the pumps, and to support a monorail beam that was designed to lift the pumps out of the wet well for maintenance purposes. The monorail beam was a very practical addition to the floating pump station, as without it the removal of the pumps would be very difficult, less safe, expensive and time consuming.

Photograph 8 - Steel gantry frame and monorail

2.2 DESIGN LOADING

Various design loads had to be considered when designing the floating pump station. A collaborative use of various design standards was required for this unique structure. These are discussed in sections 2.2.1-2.2.2.

2.2.1 CURRENT LOADING AND DEBRIS ACTION

The design strength of maritime structures needs to allow for the combined effects of tidal and/or river/estuarine flood currents. The following standards provide guidance for deriving these loads and were used for the structural design of the floating pump station:

- AS4997 – Guidelines for the design of maritime structures
- AS3962 – Guidelines for design of marinas
- NZ Transport Agency’s Bridge Manual

Flow data for the river was obtained from an engineering feasibility report. Flows had been modelled at two cross sections (respectively 250m upstream and 100m downstream of the Waikato Water Treatment Plant intake) to assess peak flow velocities in the intake.

The analysis considered sensitivity of results to the following water levels:

- For flood flows, water level between RL 4.5m and RL 5.5m
- For low flows, a tidal range between RL 1.0m and RL 1.8m

For flood conditions, the modelling showed that mean peak flow velocities may be in the following range through the intake for two Annual Recurrence Intervals (ARI):

- 0.8m/s for 10-year ARI
- 1.7m/s for 200-year ARI

Due to the high importance level of the floating pump station, ensuring continuity of Auckland's water supply during flood conditions, the flow rate required for the design was for a 1000-year ARI. The NZTA Bridge Manual provides guidance on extrapolating flow rates to the desired ARI, and this was used to determine the appropriate design flow rate of 2m/s for the pontoon.

Once the design flow rate was determined the equivalent force applied to the pontoon due to the river current and debris action could be determined from AS4997 and AS3962. The total load applied to the pontoon due to current & debris action was determined to be equivalent to approximately 140Tonne.

2.2.2 WIND LOADING

Due to the floating pump stations highly exposed location wind loading was a considerable force that had to be designed for in conjunction with the current and debris loading.

Design wind loading was calculated in accordance with the following standards:

- AS/NZS 1170.0 – Structural Design Actions – General Principles
- AS/NZS 1170.2 – Structural Design Actions – Wind Actions
- AS 4997 – Guidelines for the design of maritime structures

The derived wind speeds used for the design of the floating pump station are summarised below in Table 1.

Table 1 - Design Wind Speeds

Return Period	**Design wind speed (m/s)**
Ultimate Limit State (ULS)	47
Serviceability Limit State (SLS)	37

The total load applied to the pontoon due to wind was determined to be equivalent to approximately 120tonne.

2.3 DESIGN DEVELOPMENT

In the early stages of design, the structural steel requirements were still being developed, as such the total imposed weights on the pontoon were not entirely known. Imposed weight is critical information when it comes to the design of floating structures as weight directly effects buoyancy. Therefore, before a final workable solution was reached the layout of the pontoon was developed gradually as the imposed loads become more apparent.

Figure 3 shows the development of the pontoon layout for the floating pump station, initially comprised of seven Linkflote™ units and a pontoon spacer. This preliminary layout posed issues in the form of access across the pontoon and concerns were raised around the racking of the pontoons at the open end and debris impacting and putting undue stresses on the couplers. As such the spacer frame was removed and two additional pontoons were added, providing extra buoyancy in the way of pedestrian access and better serviceability. Initially, this was viewed as a very practical and workable solution.

Once the structural requirements were finalised and the total imposed loads were defined, the pontoon increased from nine Linkflotes™ to the final layout of twelve. The three additional Linkflotes™ were required to satisfy the buoyancy and stability requirements.

It was also important to ensure that the Linkflote™ couplers were not overstressed by distributing the heavy loads as evenly as possible across the pontoon. This saw the introduction of the large steel spreader frame seen below in photograph 9. The wet well, which contained a high percentage of the imposed weight was bolted to this frame and lifted into position during construction. This frame also provided benefits in terms of more even freeboard measurements at each end of the pontoon as the frame reduced the eccentric loads on the pontoon.

Photograph 9 - Steel spreader frame

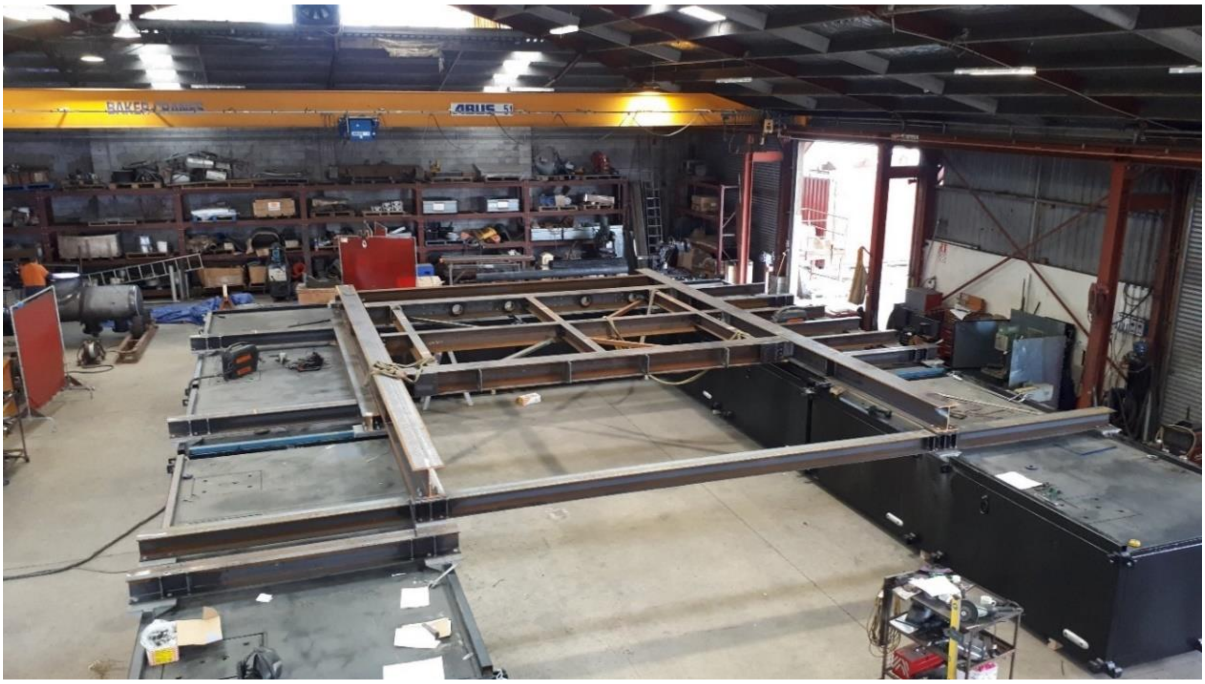
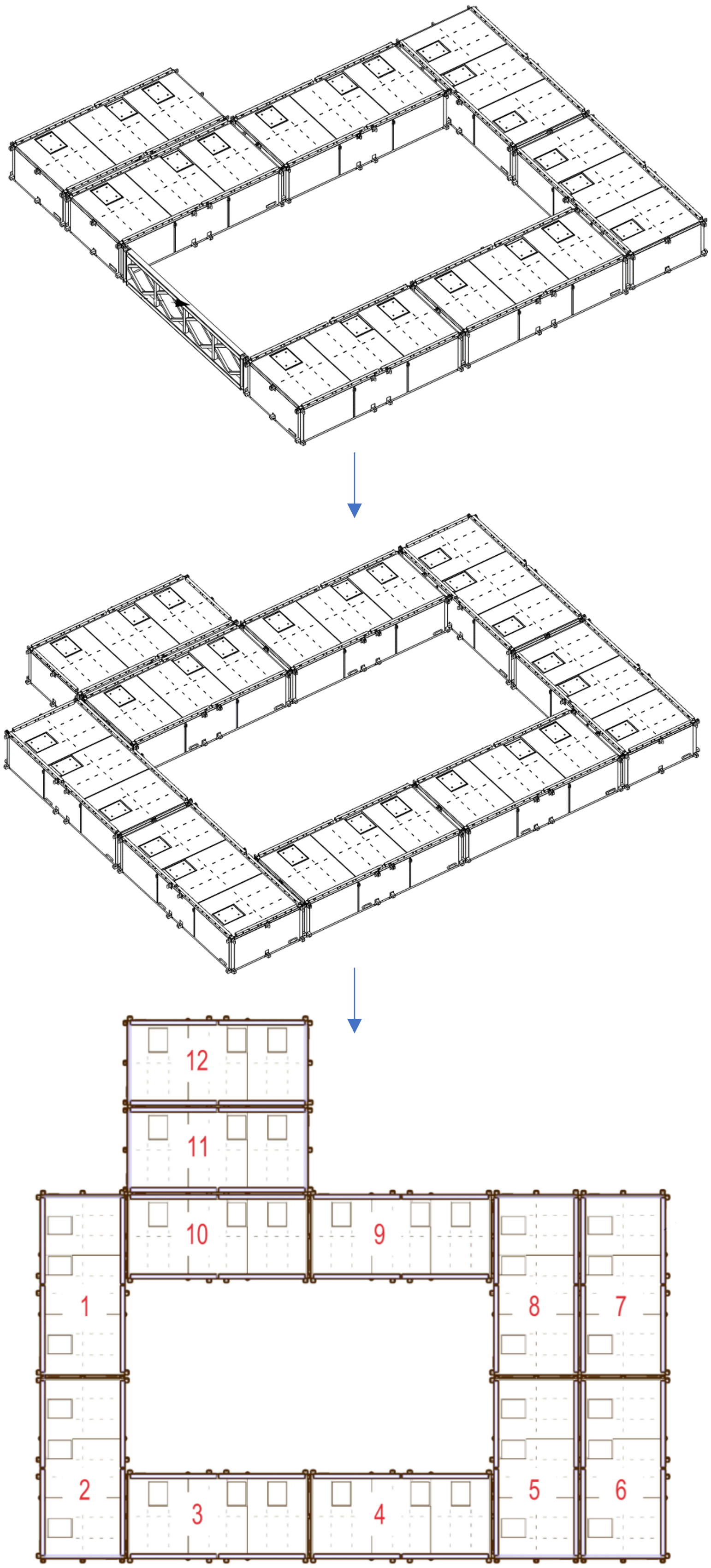


Figure 3 - Pontoon layout development



2.4 MECHANICAL DESIGN INTEGRATION

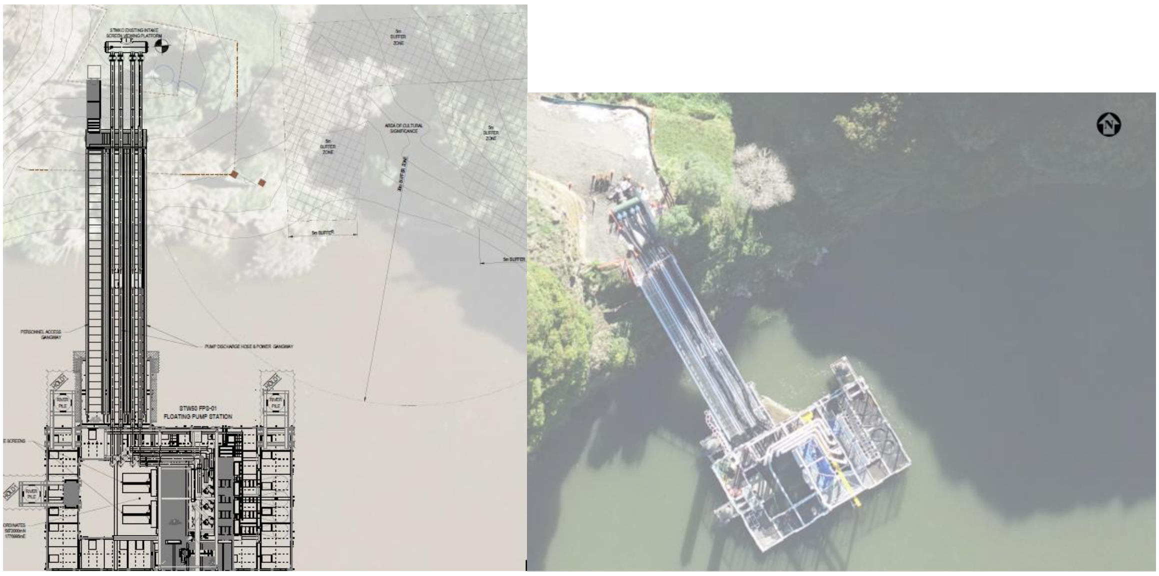
2.4.1 STAKEHOLDER INTERFACES

From the onset of the design process, as we were constructing close to a culturally sensitive area, our main attention was focused on final site set-out. Photograph 10 below, shows the serenity of this site after construction.

Photograph 10 - Culturally sensitive area near the construction site

To ensure we protected this tapu site we followed resource consent conditions. Watercare also conducted regular Hui with Iwi to discuss project issues and progress. The screenshots below show the consent drawing section.

Figure 4 - Consent drawing and final product



2.4.2 MECHANICAL CONSIDERATIONS

Our main challenge during the design phase was to cater for varying river levels from RL 0.5m to RL 5.65m and to provide safe access for operators and maintenance crews. The land-based access platform was installed above flood level, to provide pump station access in all river conditions. The gangway is hinged from this platform, and with fluctuating river levels, the gangway's horizontal movement varies by +/-1m. This movement, and piling deflections needed to be compensated with the use of flexible hoses and sliding gangways.

The superstructure has two main uses:

- Support of pump lifting monorail & gantry crane
- Support of pump discharge pipework

The pump discharge pipework needed to be at a raised level to provide a sufficiently long vertical loop for hose flexibility. The elevated pump discharge pipework also allowed for optimal maintenance and operational access.

The monorail has been cantilevered outside the pontoon structure for ease of pump removal by a floating barge.

All pipework, including the header manifold were designed to AS4041 – Pressure Piping. With the use of non-destructive testing methods and factory hydrotesting, site leak testing could be reduced to an in-service leak test.

Getting the relevant Watercare operations and maintenance personnel involved early in the design development process was key to understanding the operation and maintenance requirements as core design elements.

Right from the start of the project equipment was specified with a high level of detail, outlining lubrication details, flange connections and instrument alarm settings. This high level of detail reduced fabrication and construction queries and enabled a fast-commissioning process.

Our Inspection and Test Plans (ITPs) were used as a step-by-step guide during commissioning, incorporating all Site Acceptance Testing (SAT) requirements. This simplified the handover documentation to Watercare and acceptance to service.

2.5 PROJECT SUCCESS FACTORS

Early contractor involvement (ECI) with Brian Perry Civil was implemented right from the first project concept meeting. ECI and Beca interface management were paramount to the success of this project. On a weekly basis project interface meetings were conducted in the co-located Beca offices, where Watercare implemented an agile project delivery approach with daily stand-up sessions to update the teams. Using this approach, the project could be delivered from inception to construction issue within a sixteen-week timeframe, with fabrication starting before Christmas.

Once the design concept was developed sufficiently, both traditional face to face and online coordination meetings were held with the fabricators, J.P. Marshall. They stress tested the design, adding relevant fabricator input simplifying fabrication and site installation. This allowed elegant and efficient construction solutions to be developed.

As installation was in an aquatic river environment, any rework would have been very costly. Construction monitoring by the relevant discipline kept rework to a minimum and enabled the challenging construction timeline to be met.

Clear communication, use of digital cloud tools and teamwork across disciplines, companies and entities contributed to the project success. Where challenges arose, whether during the design stage or during construction on site, solutions were sought and implemented in a collaborative environment.

Digital technologies contributed to the project's success and were used by all parties. Including the client, contractors, suppliers, designers, and all remaining stakeholders. Utilising Microsoft Teams to conduct design reviews, HAZOP and Safety in Design Workshops, even during the Covid 19 lockdown ensured that the design delivery program was not impacted. With online 3D model viewing tools, ideas could be readily shared across teams, time zones and technology platforms.

2.5.1 FABRICATION

Regular inspections to J.P. Marshalls fabrication workshop were undertaken to ensure a high quality of works was maintained and that the structural items were being fabricated in accordance with the drawings. Refer to photographs 11-14 below for views of some of the steelwork in fabrication.

Photograph 11 - Wet well

Photograph 12 - Steel framing

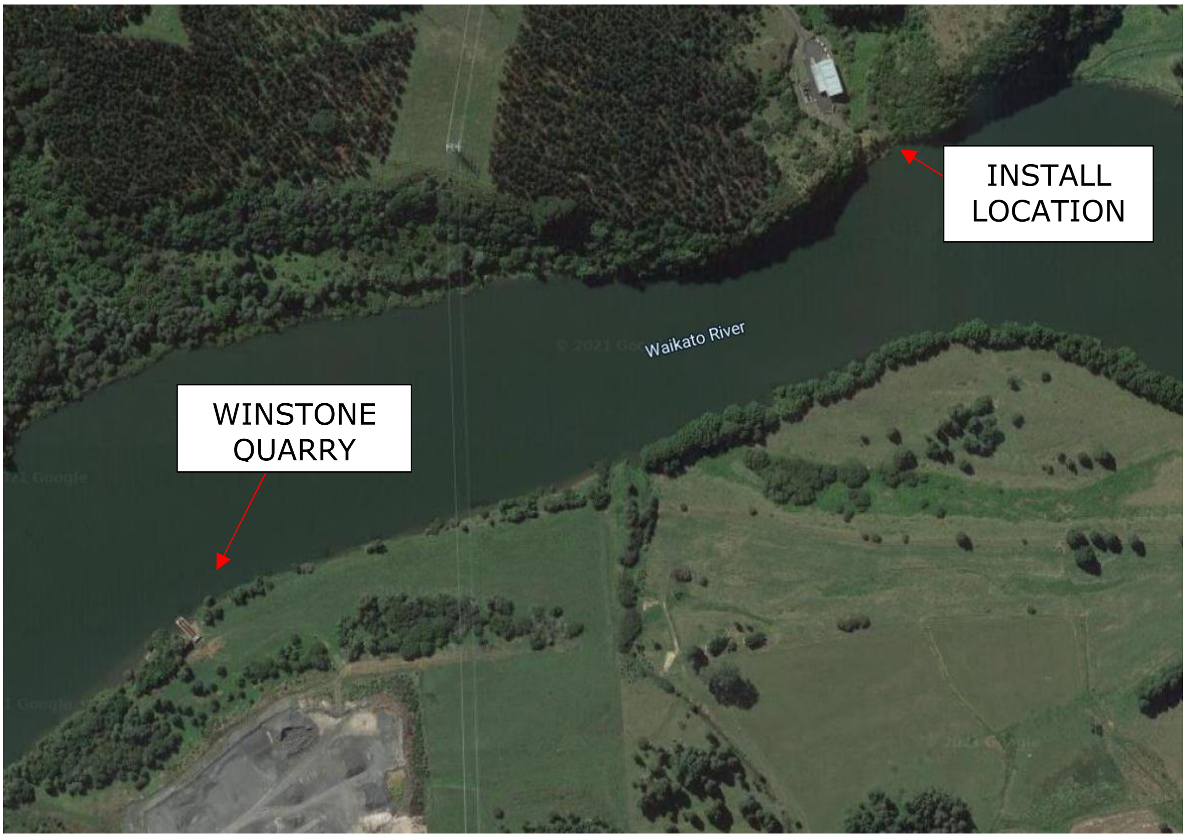
Photograph 13 - Saddle plate

Photograph 14 - Header

2.5.2 SITE INVOLVEMENT AND CONSTRUCTION MONITORING

The assembly of the twelve pontoons and majority of the construction of the floating pump station was completed 500m downstream of its install location at Winstone Aggregates Quarry (Figure 5). Once construction was completed the pontoon was floated upstream by tugboats and attached to the river piles that were bored and cast in advance from the BPC barge. Regular site inspections were completed to monitor the construction.

Figure 5 - Pontoon construction and install sites



An itemised list of the construction sequence is provided below:

- Land piles supporting the gangway access platform surveyed, bored, and cast. Gangway access platform installed.
- River piles surveyed, bored, and cast.
- Linkflote^{TM} pontoons assembled on the river with the location lugs and couplers (photograph 15).
- Lower half of the steelwork assembled on pontoon.
- Wet well (with intake screens attached) crane lifted onto pontoon and fixed into position.
- Upper portion of the steel frame, which was preassembled with the stainless-steel piping attached (photograph 16), crane lifted onto the pontoon, and fixed to the lower half of the frame.
- Monorail beam fixed to steel frame.
- Cable ladder structural supports installed on pontoon.
- Pile clamps fixed to the pontoon in accordance with pile locations.
- Pontoon floated over to install location and fixed to the piles.
- Gangways installed between landing platform and pontoon.
- Pumps installed in wet well.
- Hoses, remaining piping and power cables installed.

In the very early stages of the project, bathymetric surveyors were engaged to measure the depths of the riverbed between the assembly and final install locations. This concluded that the wet well needed to be temporarily raised while the pontoon was transported to avoid it from bottoming out on the river sandbanks. Photograph 17 shows the wet well lifted into position on the temporary props.

Photograph 15 - Assembled Linkflotes™

Photograph 16 - Preassembled upper half of steel frame with piping

Photograph 17 - Wet well installed on temporary props

A view of the final construction can be seen in photo 18 below.

Photograph 18 – Completed construction.

2.6 LESSONS LEARNT

Work can be very challenging in a river aquatic environment. This became all the more apparent during the monorail crane certification process. This included the provision of 3.6t weights to load test the monorail and lifting the SGS inspector via a bosun's chair held by a crane to inspect all fixings.

As discussed previously, late in the design process a spreader frame had to be added to distribute the wet well point loads across the pontoons. What hadn't been considered was the proximity of this frame to the flexible hoses. The solution was the use of hosebuns tied to the superstructure to move the hoses away from the beams to avoid rubbing and vibration damage. During the development of the spreader frame, any downstream design impacts should have been challenged. The design fix was subsequently scrutinised by a wider team and implemented successfully.

Photograph 19: Hosebuns in action

CONCLUSIONS

This rapid delivery project was successfully completed from inception to commissioning within a twelve-month timeframe. This could only be achieved in a collaborative and agile environment, where all stakeholders were involved right from the start and were able to make bold and fast decisions. Major project stakeholders involved were Iwi, Watercare's project, operations and maintenance teams, contractor, fabricator, site personnel, suppliers and head project (water treatment plant) designers.

The project success was simply measured by one parameter – 60MLD raw water delivered to the Waikato A WTP for treatment and delivery of 50 MLD to Auckland in Winter 2021.

ACKNOWLEDGEMENTS

We would like to thank all involved in this exciting project, including our families and friends, who saw less of us during this project.