A FLOOD TWO MONTHS IN – A WAIĀRI RESILIENCE STORY

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ABSTRACT (500 WORDS MAXIMUM)

Tauranga City Council encountered challenges that are widespread among water utilities while selecting and planning the new Waiāri Water Treatment Plant's location. The site's stream intake works were influenced by factors beyond just the physical characteristics of the area. This paper presents the strategy used in this project for enhancing resistance against multiple natural hazards and explains how the intake system performed in a real-life scenario involving an extreme natural event.

The Council commissioned its new Waiāri Water Treatment Plant, with water first being delivered to customers in December 2022. The plant treats water from the Waiāri Stream, a pristine waterway with typical turbidity less than 1 NTU and an average summer flow of approximately 4m³/s.

The intake site is susceptible to several natural risks such as liquefaction, slope instability, flooding and debris impacts. Significant effort was therefore placed on balancing resilience while maintaining affordability during the intake design.

Within the first two months of operation, a significant rainfall event occurred within the catchment, causing the stream flows to peak at approximately 250 m³/s and flood levels to rise 5m above normal stream level. The flood also carried significant amounts of silt and debris and changed the stream bed significantly around the intake site. The event occurred between midnight and 1am. Although the plant was offline at the time, the proof of performance of the intake lies in how well it survived the impact of the event and its ability to be brought back online.

Photograph 1: post-flood photo showing indicative typical stream level (blue) and flood level (red)

During the design process, designers and plant operators worked collaboratively to consider natural hazard risk and resilience. Not all risks carried the same impact on the plant's ability to operate post a natural disaster, and a weighted resilience rating was developed to inform the design. This methodology and collaborative approach can be applied to any similar infrastructure design.

This paper also discusses the effects of the flood on the plant, immediate measures taken to maintain operation and then to restore the stream. It also compares the design versus actual resilience performance during and after the extreme event. The key consequence from this event was silt management. The steps taken to be better prepared to manage this into the future and practical actions to be implemented will be presented.

KEYWORDS

Waiāri Stream, Water Supply, Resilience, Intake, Pump Station, Flood

PRESENTER PROFILE

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Rodney has been in the water industry for 16 years and has been involved with the Waiari Water Scheme when the design process was kicked off in 2016 and has been a key player right through to its operation today.

Chris Olivier

Chris is a Technical Director in Beca Ltd. undertaking the role of Design Manager for the Waiāri Water Treatment Plant delivery.

He holds a B.Sc. Eng. (Civil) degree obtained from the University of Natal in South Africa.

INTRODUCTION

Tauranga city is situated on the east coast of New Zealand. It is surrounded by rural areas and intense horticulture/agriculture interspersed with small settlements and semi-urban development areas. The urban area is administered by Tauranga City Council (TCC) and the surrounding rural areas by the Western Bay of Plenty District Council (WBoPDC).

Tauranga is one of New Zealand's fastest growing cities and has been so since the 1960s. It experienced a 14 % increase in population between the 2001 census and the 2006 census, though that number slowed to 11% between the 2006 Census and the 2013 Census. This population growth has made Tauranga New Zealand's 5th largest city with a urban population of 137,000 in 2018 (StatsNZ 2021).

To meet the demands created by this growth a new green field river take and water treatment plant (WTP) has been constructed in the Waiāri Stream catchment to the south-east of Tauranga.

In 2007 TCC appointed CH2M Beca Ltd (Beca) as its delivery partner to provide engineering services for the consenting, design, and construction of the intake and WTP.

As a result of its geographic situation TCC needs to draw its water supply from outside the Tauranga district. TCC and WBoPDC undertook several joint water supply studies and, in 2004, both councils signed a Memorandum of Understanding to jointly develop the water supply resource in an integrated and sustainable manner. The water source was selected as the Waiāri Stream.

Figure 1: Location plan (background Tauranga city council 2023)

Although the Waiāri Water Supply Scheme included the development of the water source, abstraction facilities, water treatment plant and the 21 kilometers of water pipeline to convey the treated water to the supply network, this paper will focus on the water source development and intake facility.

WAIĀRI STEAM AND CATCHMENT

The Waiāri Stream is primarily a groundwater fed stream (base flow). It has a narrow steeply incised catchment over much of its reach (approximately 20km) before opening to a flatter flood plain area over its lower 7km. As a result, it has a reasonably consistent and reliable base flow but responds rapidly to rainfall events in its catchments.

The upper catchment areas are covered by a mix of forestry, recreational and horticulture.

Photograph 1: Typical land use of Waiāri catchment.

SELECTING THE LOCATION FOR THE WAIĀRI INTAKE

As is case with much water infrastructure, constraints and demands based on peripheral factors often outweighs the choice or availability of sites with ideal physical attributes.

In the case of Waiāri, the site for the stream intake was selected at the location just after the stream transitioned from its steeply incised river valley to its flatter flood plain.

The selection of this site was driven by several factors including:

- Base flows at this location were sufficient to service the expected demand required of this water source to 2050.
- Access to any site higher up the catchment would have been equally if not more difficult.
- A reasonably flat plateau area, at an appropriate elevation, was identified adjacent to this site that would enable the establishment of the water treatment plant and bulk treated water storage and be able to gravitate this supply the 21km to the TCC storage and reticulation network.
- A willing seller who owned both the proposed intake facility site and the plateau area for the water treatment plant.

Figure 2: Site locations for the water treatment plant and the intake.

NATURAL HAZARDS RISK AND RESILIENCE

Although this site selection ticked many boxes it came with its own particular hazards and challenges.

The intake structure is located within a flood plain with soft, liquefiable alluvial materials, underlain by ignimbrite at about 12m below ground level, at the base of a steep, 80m deep gully. The alluvial materials are interspersed with organic materials, logs, and tree stumps to depth.

Photograph 2: Intake site - pre-construction.

The gully slopes are formed of residual volcanic soils overlying older ignimbrite flows. The slopes are marginally stable with much evidence of historic landslides. The permanent access to the intake site had to be established via this steep gully slope.

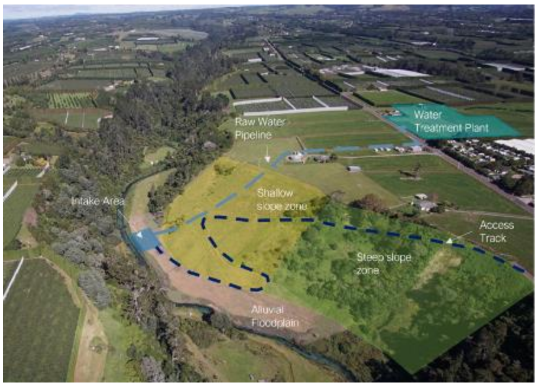

Figure 3: Intake site-topography.

RISK ASSESSMENTS FOR THE INTAKE SITE

At an early stage it became obvious that all hazard and risk would not be able to be economically addressed to the same level of resilience. From an early stage therefore Tauranga and Beca worked closely together to share knowledge and perspectives on the various natural hazards, their likely impact, and operational ability to be able to recover from potential impacts

To facilitate understandings, level of risk and impacts and achieving decisions Beca developed a risk matrix showing the impact of different natural hazards and present the results in a graphical format. The risk matrix was supported by developing a scoring system for the risk assessment where we considered the impact of each natural hazard in terms of:

- Time to bring the intake facilities back to operational level,
- Cost to bring the component back to operation.

The scores given to the time and cost were combined to give an overall risk score for each of the components. The scoring system is presented in Figure 4

The natural hazards considered were:

- Earthquake
- Landslide
- Flood
- Debris
- Silt

Typical graphical representations that were developed for workshop presentations are shown below.

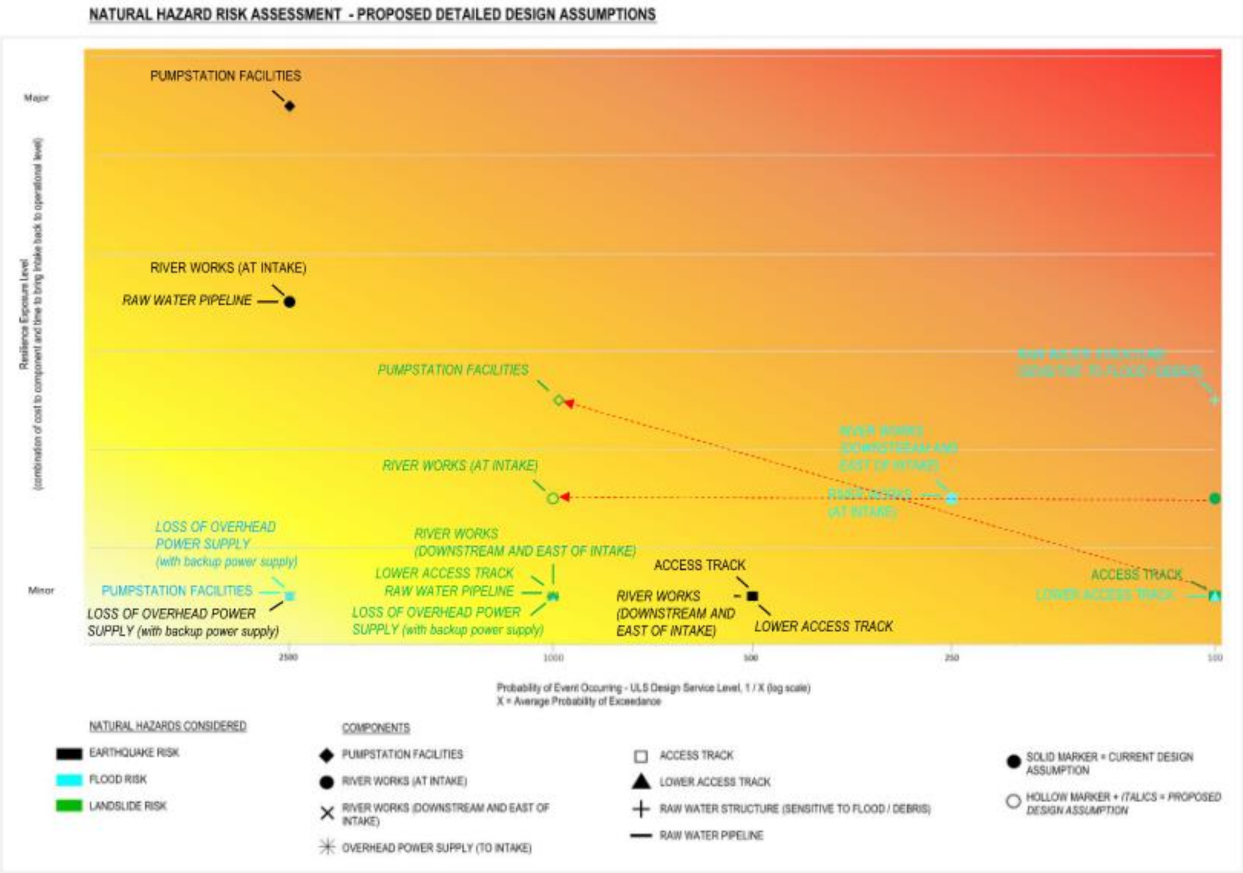

Figure 4: Graphical representation of risk assessments.

This facilitated decision making and the setting of importance levels and design standards for each component of the intake facility which provided the best outcome from an economic and resilience perspective.

Table 1: Recovery period targets from serviceability level 2 event.

Table 1: Acceptable period to bring infrastructure back to a fully operational state – SLS2 event

Natural hazard	Extend of Effect	Infrastructure Group					
		River works	Screens/Sheetpiles	Wet wells	Building	Deflector wall	Raw water pipelines
Earthquake	Regional	2 days	2 days	2 days	2 days	2 days	2 days
Flood	District	1 day	1 day	1 day	1 day	1 day	1 day
Landslide	Local	2 days	2 days	2 days	2 days	2 days	2 days

Table 2: Design standard annual probability of exceedance set for the intake.

Table 3: Annual Probability of Exceedance relating to Service Level

Service Level	Extent of Effect	Annual Probability of Exceedance						
		Earthquake IL:3 Design Life:100 years (Intake Building, River Works at Intake, Raw Water Pipeline)	Earthquake (Lower Access Track, River Works Downstream + East side of Intake)	Flood: River works (scour protection)	Flood: Raw water structure (sensitive to flooding/debris)*	Flood: Building	Flood: Lower Access Track	Landslide
SLS1	Adopted	1/25	1/25	-	1/25	-	-	1/10
	Final	1/25	1/25	-	1/25	-	-	1/20
SLS2	Adopted	-	-	-		-	-	-
	Final	1/250	1/250	-	1/50	1/50	1/50	1/100
ULS	Adopted	1/2500	-	1/250	-	1/2500	1/100	1/100
	Final	1/2500	1/500	1/250	1/100	1/2500	1/100	1/1000

Note: * The design criteria for the raw water structure (non-sensitive to flooding/debris) adopted for the Intake Preliminary Design = 1 : 10 year flood event

The importance of this coordinated and collaborative assessment ahead of detail design commencing cannot be underestimated and was a fundamental cornerstone of the design philosophy and final outcomes of the success of the project.

INTAKE FACILITY DESIGN FEATURES

The outcome of the risk assessment and design standard exercise resulted in an integrated design philosophy being applied across the various intake facilities.

The intake facilities were grouped into separate components to which resilience levels, levels of importance and design standards were applied. Each with the objective of maintaining plant operability or return to operability post a natural disaster event. The inter-relationship on operability is such however that resilience decisions made on one component influenced design features applied to other components.

GULLY SLOPES

The overall gully slopes were assessed as being only marginally stable which was borne out by the evidence of historic slips. The decision was however made that it would not be economically viable to implement global slope stability works across the full extent of this slope.

This decision then had knock on effects to the design features implemented across the remaining intake components.

ACCESS TRACK

The access track was designed to standards less than those applicable to public roads. Geometric design was for an eight-meter-long fixed bed truck and HO loads. ULS annual probability of exceedance were set as 1:500 and 1:1000 for earthquake and landslide respectively.

It was accepted that the intake track might not be available post an earthquake or landslip event. This was compensated by increasing the resilience of other components of the of the intake facility to be able to operate or bring back into operation without the need of vehicle access down the access track for events of a similar nature.

Photograph 3: Waiāri access track.

IN-STREAM WORKS AT INTAKE

For the in-stream river works protection earthquake design was based on IL3, Design Life of 100 year with a ULS of 1:2500 annual probability of exceedance.

The intake consists of a set of six passive intake Tee Screens. Particular care was taken in the design to avoid the possible entrapment of flood debris. While scour protection of the in-stream training works was based on a flood of annual probability of exceedance of 1:250 year.

Photograph 4: River training works and intake screening structure.

SCREEN ACCESS PLATFORM

A working platform had to be provided for access to the in-stream river training works and to the intake screens. Because of the form of the foundation/ground improvements to the main building this area has the same structural design standard as the main pump station building.

During the resilience workshops it was agreed that this area be categories as being non-sensitive to flooding. This was on the basis that during a flood event this area would not need accessed by operators and that the flooding of this area would also not inhibit the ability of the intake to operate. To achieve a balance between minimizing impacts on adjacent properties, achieving operational maintenance reach, and flood impacts, an annual probability of exceedance against flooding was set as 1:10 years. A focus on keeping the area clear of protrusions to avoid debris hang-up was implemented although a solid parapet wall was set as a prerequisite by the operational team as an operational H&S requirement.

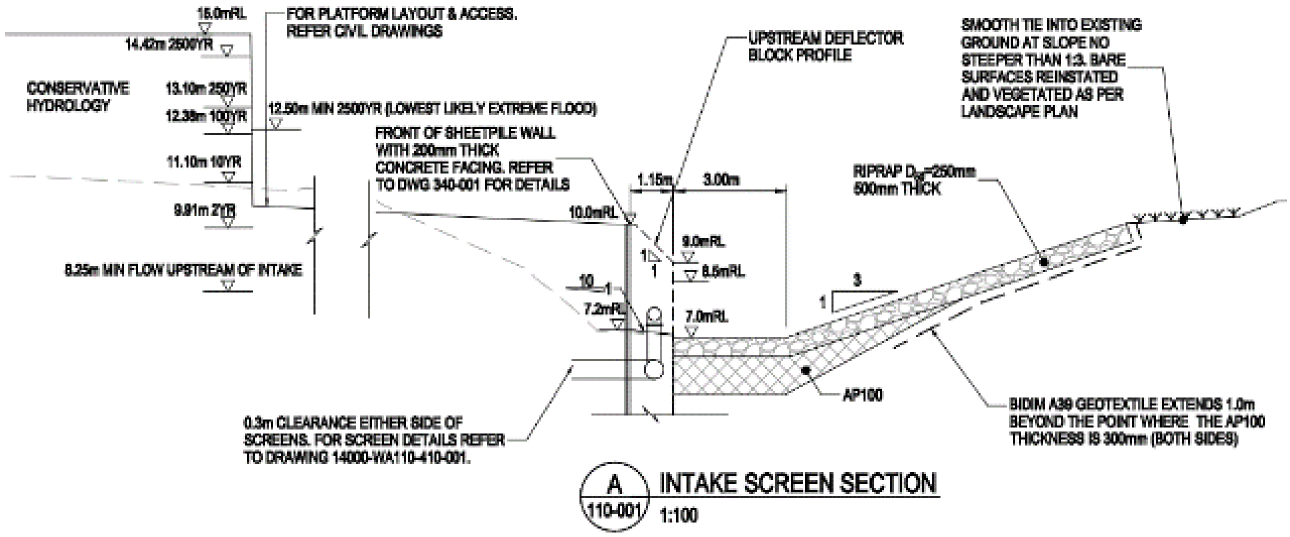

Figure 5: Flood level design criteria for intake and platforms.

Photograph: Lower access platform.

INTAKE PUMP STATION BUILDING

The intake pump station building consisted of a pump room, electrical switchboard room, standby generator room and transformer platform. It also incorporated a deflector wall to protect it against landslip from above.

Resilience levels for the pump station structure were selected as:

- Earthquake – IL 3, design life 100 years, ULS annual probability of exceedance 1:2500
- Landslide – The deflector wall was designed to withstand a 1:1000-year landslide
- Flood – The pump room floor level was set at a 1:250-year flood level while the transformers, electrical switch room and generator room were set at 1:2,500-year flood level.

Significant ground improvement and foundation work was required to achieve the design standards with a lattice of CFA piles installed to prevent liquefaction.

Photograph 5: Ground improvements and deflector wall under construction.

RAW WATER PIPELINES AND SERVICE DUCTS

The water treatment plant is fed by twin 630mm diameter pipelines. Although early concepts proposed these pipelines to be surface mounted to traverse the gorge slope, it was decided to directionally drill these pipes to improve the resilience of this critical component of the infrastructure. It was also decided that the site services (355mm electricity and communications service duct) would be fed to the site in a similar fashion

Three directionally drilled pipes were installed at a depth and profile such that they were within more competent material as indicated in Figure 3

Notwithstanding the significant ground improvements and foundations to intake building it was still anticipated that the building could have a movement of in order of 500mm towards the stream in a 1:2,500 earthquake event. The pipelines and services ducts were therefore designed with "soft connections" between the building and the directional drill exists, providing the pipelines the same resilience standard as the main pump station building.

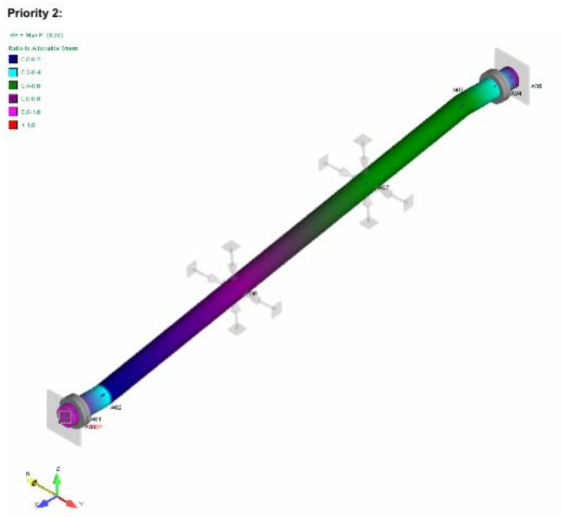

Figure 6: Pipe stress analysis of "soft connections".

FLOOD EVENTS

The Waiāri Water Treatment Plant and Intake was commissioned in November of 2022, going into full operation with water being delivered to its customers in December 2022.

Like much of the North Island, Tauranga and the Western Bay of Plenty region experienced an exceptionally wet summer over 22/23, with reports that Jan to March rainfall figures were over 200% of average for those months. These saturated soil conditions caused the Waiari Stream to respond with high flow with even low intensity rainfall events.

In the early hours of the morning of 29 January 2023 a significant rainfall event fell in the upper catchment area of the Waiāri Stream causing the stream to come down in flood.

Dry weather flows in the stream adjacent the intake works would normally be in the order of approximately 8.5mRL. At the peak of the flood river levels were recorded as 13.17mRL, estimated to be equivalent to a 1:250 flood event and sufficient to flood the pump room.

A second flood event occurred between the hours of 5pm and 7pm on the evening of 23 May 2023. Peak flood levels reached 12.8mRL, again being deep enough to enter the pump room with a floor level of 12.7mRL.

Photograph 6: Time lapse photographs of flood event of May 2023.

EXPERIENCE AND PERFORMANCE

A resilience target of being able to bring the intake screens and pumps back into full operational state following a serviceability level 2 (1:50 year return period) flood event set during the design stage was one day.

These events were far greater than that predicted 1:50 year event, and the impacts took more than the one-day recovery period to overcome. However, the core structures and design intent withstood flood effects well and the experience and learnings picked up from those events will enable improvements to be made that will assist with more rapid recovery in the future.

Photograph 7: Jan 2023 flood level.

FLOOD INUNDATION

Clean up was required after both events, but all electrical switch gear, motors etc. were positioned above the 1:2,500 flood level and suffered no damage. The effect of flood waters themselves did not cause any lasting or permanent damage preventing the operation of the intake.

Photograph 8: Height of flood within the pump room.

DEBRIS

The intake structure, building and platform forms worked well in not providing protrusions that would cause the hang-up and accumulation of debris. There were some large logs that were deposited in the stream bed and beneath the screens, but these were limited, did not prevent the operation of the intake and were easily removed in the days subsequent to the flood event.

Photograph 9: Typical debris residue following the flood events.

SILT

However, in both events the quantity and consistency of the slit deposits remaining after the flood subsided were not anticipated, and it was the impact of this and their ongoing effects that have had the most impact on the recovery and operation of the intake.

IN-STREAM SEDIMENT LOAD

Since the two flood events a significantly increased silt load and movement has been experienced in the stream. A flight over the catchment after the January flood identified 13 major slips had occurred during the rainfall event. These slips will take time to recover and stabilize so an increased silt load in the stream can be expected for some time to come.

Photograph 10:Typical slip in the upstream catchments.

Although the intake structure was designed with a downstream control weir and notch to control silt levels, the sheer quantity of silt was such that the passive intake Tee screens were becoming submerged in silt. The risk of silt build-up had been identified during the design and spool pieces had been order with the screens when they had been purchased. These 300mm spool pieces have been installed and have enabled the intake to operate effectively since the January event.

Photograph 11: Divers installing spool pieces to the TCC screens.

This is not expected to be a permanent solution. At some stage the stream flows will reduce back to their pre 22/23 levels and at that time it will be necessary for the screens to be returned to their design level.

In-stream sediment levels are being monitored and plans have been developed for the installation of further flow training weirs, with the intent to increase scour velocities immediately adjacent the screens. By July 2023 silt levels measured along the line of the intake screens had started to return to pre flood levels. An implementation decision will be made on this subject to the ongoing sediment monitoring and stream flows.

SILT DEPOSITS TO WORKING PLATFORMS

The quantity of silt deposition remaining on the access platforms as the flood has receded has been greater than anticipated. There have been areas where this is greater than 300mm thick.

Photograph 12: Partly cleared silt from lower platform.

Although the silt deposits to the working platforms do not in themselves prevent the operation of the intake facilities, they hinder the ability to be able to move around the site to be able to complete tasks that are operationally critical. To that extent therefore this was a risk that was not fully appreciated. Clean-ups have proved to be relatively expensive and disruptive, taking well over a day to complete.

Photograph 13: Clean-up operation in progress.

TCC have a catchment management specialist who through collaborative and consultative interactions with upstream landowners strives to achieve good catchment management practices. However, there are no guaranteed initiatives that can be implemented to assure limiting the silt load in flood conditions.

Actions for the Waiāri Intake are to implement minor modifications and to document clean-up procedures that will make the clean-up operation more streamlined and efficient. It is also intended to upgrade the platform from a chip seal finish to asphalt to make clean-up easier.

WET WELL SILT BUILD-UP

The greatest impact of the January 23 flood has been on damage to the pumps as a result of pump start up with the bowls submerged in silt.

Notwithstanding that the pumps were not in operation during the flood of January 23 a considerable amount of silt entered the wet wells and settled there. This was to an extent where the inlet and bowl of the pumps were submerged in silt.

Photograph 14: Silt build-up in wet well.

The original design did not include instrumentation for monitoring silt levels in the wet wells. Operating and maintenance manuals were still in the course of preparation from recently completed contracts, and functional descriptions and standard operating procedures that were available did not cover the procedures following an event of this magnitude.

The operators who were themselves still learning and coming to grips with a completely new facility therefore unknowingly started the pumps under this critical condition.

Although the design philosophy for the intake and treatment train is for silt passing through the 3mm screens to be conveyed together with the pumped flow to the treatment plant for removal, the pumps were never designed or specified for this sort of submerged start up.

This resulted in the blocking of gland water discharge ports, seal failure, wear rings worn, and column shaft bearings being worn. Although the pumps have been able to be nursed through a period to continue to deliver flow to the treatment plant all three pumps have had to be refurbished.

Instruments are now being installed that will prevent pump start up if the silt levels get to close to the pump bowl entry.

Operational procedures to be followed after a flood event are being documented. These will include a two stage pump initiations procedure post such an event but will also include for the manual pumping out of silt from the wells in the event that the new instrumentation has locked the pumps out from starting.

SCOUR

The river training works withstood the flood effects well. The only sign of scour damage was to the screen servicing platform behind the parapet wall and that had no effect on the intake and pump station operation.

Photograph 15: Scour damage on downstream face of parapet wall.

CONCLUSIONS

The project demonstrated the significance of early-stage collaboration with the client and broader design team to address various risks. Through this collaborative effort, robust and sustainable standards and solutions were cultivated.

Understanding of the components that are critical to the ongoing operation of the facility, acceptable durations for loss of service and the susceptibility of the various components to natural hazards allows a sound design basis to be established.

The decision to classify the lower access platform to the screens as non-sensitive to flood inundation, although technically correct, has led to costly cleanups. By tweaking the pavement design in this area, we can deliver an environment that is easier to clean up and more resilient to these storm events.

Both Tauranga City Council and Beca are in agreement about the top priority being the enhancement of wet well operations and mitigation of silt buildup. We are focused on developing a sustainable, long-term solution to safeguard the infrastructure and creating a well-documented strategy for instances beyond normal operation.

While some might view dealing with these occurrences within the initial six months of constructing a new water plant as highly unfavorable, it actually presented a valuable opportunity. Despite the formidable challenges faced by the operations team during this period, there's a silver lining. Experiencing these challenges while information is fresh, consultants are engaged, contractors are available, and capital budgets are approved provides an ideal opportunity for learning and implementing improvements that will benefit the operation down the line.

In general, all projects should consider booking in a severe weather event to assess their newly constructed systems. At the very least, there should be a process for revisiting infrastructure following such events, with necessary improvements being implemented based on actual impacts.

REFERENCES

Bahrs, P. and Olivier, C. (2018) *Waiāri: Planning the water supply for a growing city*. Water New Zealand Annual Conference 2018.

Argyriadi, D. Griffiths, J. and Wahab, H. (2023) *Waiāri water supply project – design and construction challenges.* Australia and New Zealand Conference on Geomechanics, Cairns 2023