UPGRADE OF PORTOBELLO ROAD STORMWATER SCREEN

B. Scott, R. Els and Tim Matheson
Calibre Consulting: 8/666 Great South Road, Ellerslie, Auckland

ABSTRACT

The Portobello Pump Station forms a key component of the stormwater drainage network for the residential stormwater catchment of South Dunedin. Upstream of the pump station is a silt well and bar screen aimed at reducing the volumes of sediment and gross pollutants entering the pump station.

The area has recently been subjected to severe stormwater flooding. Blockages at the bar screen was identified by Dunedin City Council (DCC) to be a key contributor, with DCC's operations staff expressing concerns relating to elevated risks of blockage during high flow conditions, and a lack of suitable access to clear blockages during such flow conditions.

This paper describes the considerations for developing a new bar screen design (and rearrangement of the silt well) to maximise hydraulic efficiency, reduce risks of blockage, improve accessibility for operations staff, and reduce health and safety risks associated with working at heights above water, during severe weather. The paper also describes the range of design options considered (including automated and manual screen cleaning/ screen withdrawal arrangements) and the decision making process involved in arriving at the final solution.

The selected design offered a cost-effective and constructible design, with improved operability, and a 'worst-case' screen withdrawal option that can be enacted from the surface, via a basic pulley system.

KEYWORDS

Stormwater Management, Flood Risk, Operation and Maintenance, Silt Well, Bar Screen

PRESENTER PROFILE

Tim Matheson is an Auckland-based surveyor working for Calibre Consulting. He graduated with a Bachelor of Surveying (with Distinction) from the University of Otago in his hometown of Dunedin. Since joining Calibre, Tim has taken a keen interest in three-water infrastructure projects, and worked alongside the company's Water Infrastructure Team to deliver of a series of projects including the Portobello Road Screen Upgrade.

1 INTRODUCTION

In June 2015, The Dunedin City urban area, as well as other Central Otago regions, experienced heavy rainfall. The one-day total rainfall at Musselburgh (a suburb in Dunedin) was 142 mm with an estimated return period of exceeding once in 50 years (Palmer, et al., 2015). This event resulted in large scale flooding throughout the city, causing widespread disruptions and damage to infrastructure.

The South Dunedin stormwater catchment collects runoff from an area of 570 hectares and discharges into the Upper Otago Harbour via the Portobello Road pump station. The catchment comprises primarily of residential and commercial property.

The South Dunedin catchment can be described as low lying and flat. Stormwater management within the Catchment is therefore difficult, with reticulation networks comprising of minimal grades. The Portobello Road stormwater pump station and silt screen was built in 1962, to help deliver DCC's desired levels of service, by increasing discharge rates into the Upper Otago Harbour. The pump station is located south of Dunedin City Centre, approximately 500m east of the Upper Otago Harbour (refer Figure 1).

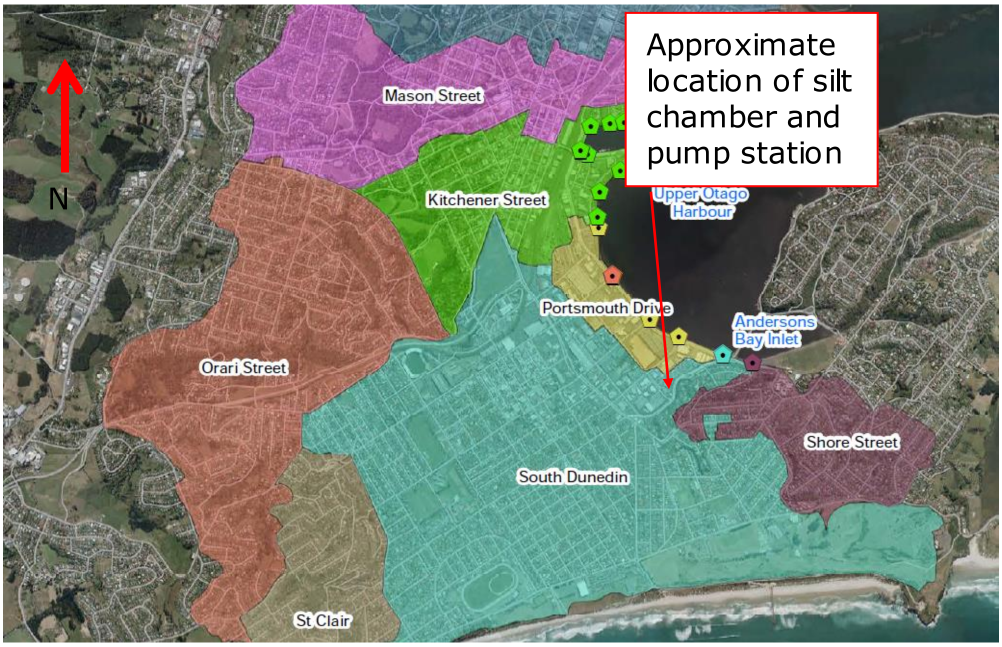

Figure 1: South Dunedin Catchment shown in light blue (Murray, 2010)

The original arrangement for the silt well at Portobello road requires Maintenance Personnel to regularly rake debris off the bar screen. This is labour intensive and poses a risk to the maintenance personnel, particularly under high flow conditions.

This paper discusses the challenges associated with the existing layout and how a number of improvement solutions were identified and assessed using a multi-criteria analysis.

1.1 DESIGN CRITERIA AND OBJECTIVES

The project objective was to develop a cost effective and safe solution to improve the operability of the silt screen, by reducing the risk of blockage, and enabling better access to the screen for maintenance personnel during severe weather. Key performance criteria targeted included:

- Enhancing the hydraulic performance of the stormwater screen, to enable a minimum flow through the silt screen of 6.5 m^3/s (to match existing pump station discharge capacity);
- Enabling safe, reliable and efficient cleaning of the screen without impeding the hydraulic performance of the stormwater screen;
    - Enable access for maintenance staff/equipment to all parts of the chamber, to remove settled material;
- Enabling the safe and efficient removal of the bar screen, out of the stormwater flow path, during extreme weather.

The option investigation and assessment process consisted of the following considerations:

- Assessment of existing system characteristics and performance;
- Review of Health and Safety risks associated with existing system, and identify desired improvements;
- Assess screen arrangement and alternative options (including inclination and location options) to optimise operation and ease of access for maintenance;
- Consider alternative screen materials to improve durability within the demanding and abrasive operating environment, which is typically submerged in stormwater;
- Consideration of options (such as a Gantry crane design to attach lanyards and harnesses for maintenance staff) to improve accessibility for maintenance staff.

2 ORIGINAL ARRANGEMENT

The existing silt chamber is a concrete structure located underground (refer Figure 2). The chamber is part of the stormwater infrastructure network and intercepts flows prior to reaching the pump station, removing debris via the bar screen. Aluminium lids were used to allow access into the chamber for maintenance purposes.

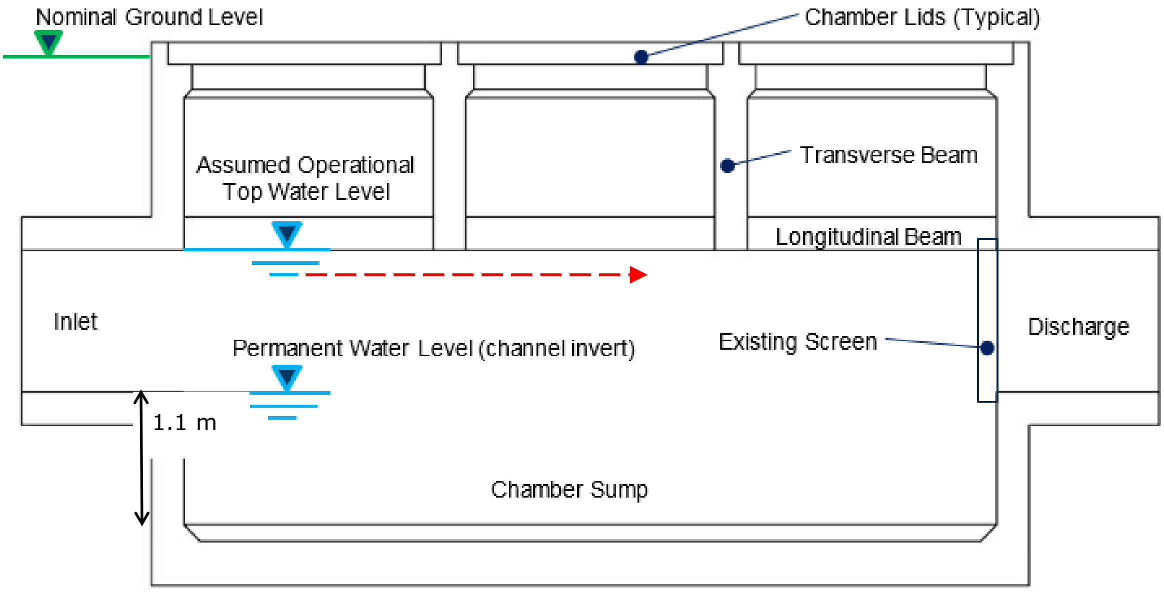

Figure 2: Schematic of original silt well elevation

Stormwater flows in and out of the chamber via 4.4m x 1.3m openings. The chamber floor is located 1.1 m below the entrance and exit channels. As water enters, there is a rapid reduction in bulk flow velocity, enabling coarser sediment to settle to the tank floor. A 50mm bar screen covers the discharge orifice as (refer Figure 3). The bar screen prevents debris and detritus material (i.e. waste packaging, drink bottles or large leaves) from flowing downstream to the pump station.

Figure 3: Existing silt well bar screen (50 mm spacing).

2.1 RISKS ASSOCIATED WITH ORIGINAL ARRANGEMENT

The current arrangement of the bar screen area (limited to that of the discharge opening) generates an inefficiency with respect to surface area available for flows to pass through the screen. This generates a higher risk of blockage at the screen than necessary.

Removal of debris built up on the screen is achieved through maintenance personnel attaching themselves to an existing gantry, and using a long handled rake to pull up debris via aluminium lids. This technique for cleaning the screen is effective during low flow conditions. However, as debris loadings and water pressures increase during extreme storm conditions manual raking becomes less effective (as debris is effectively stuck to the screen by higher flows). This method is also highly labour intensive.

3 PROPOSED ALTERNATIVE OPTIONS

A series of alternative design options were identified following the assessment of the original system, and a review of available screening technologies. However following discussions with DCC staff, maintenance contractors and equipment suppliers, a number of identified options were also discarded. These include:

- step screen solution (typically associated with finer screening systems);
- rotary trommel screen solution (associated with wastewater treatment and limited flow capacity);
- revolving chain raked bar screen solution (difficult to provide a backup if system was to fail during a storm event).

Three suitable alternatives to the original system were therefore identified for further consideration as follows:

- Self-operating inclined bar screen solution;
- Manual opening inclined screen;
- Cable operated bucket cleaner.

3.1 OPTION 1 – SELF OPERATING INCLINED BAR SCREEN

This option consists of an inclined bar screen and an actuator to raise and lower sections of the screen creating an opening whereby stormwater can pass through. The bar screen location also increases the surface area available for water to pass through, significantly improving the hydraulic inefficiencies associated with the original system. The incline also allows for a more ergonomic manual raking position. The actuators can move the bar screen without maintenance personal requiring access to the chamber. This option also allows for the bar screens to be remotely monitored and operated.

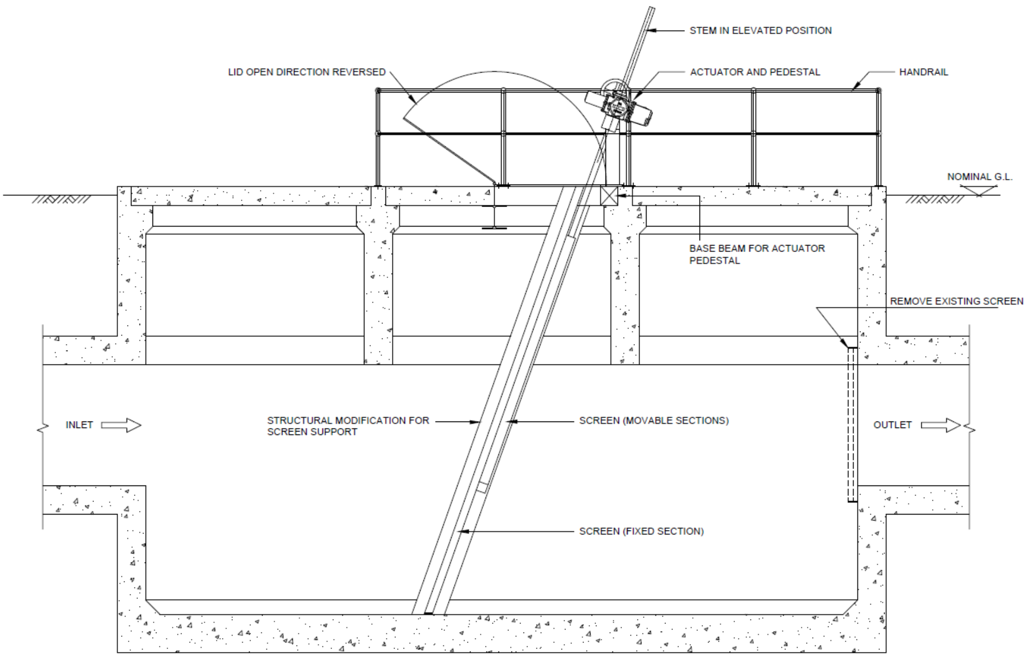

Figure 4: Schematic of Option 1 – Self Operating Inclined Bar Screen

3.2 OPTION 2 – MANUAL OPENING INCLINED SCREEN

This option consists of an inclined bar screen (similar to option 1) and manually operable bar screen sections. Sections of the bar screen can be lifted by chain hoists in the event of blockage. The screens can be raised to a point where buoyant debris is still intercepted and stormwater can pass through the submerged screen opening. This option is significantly cheaper to install than Option 1, but requires more time to lift the bar screen.

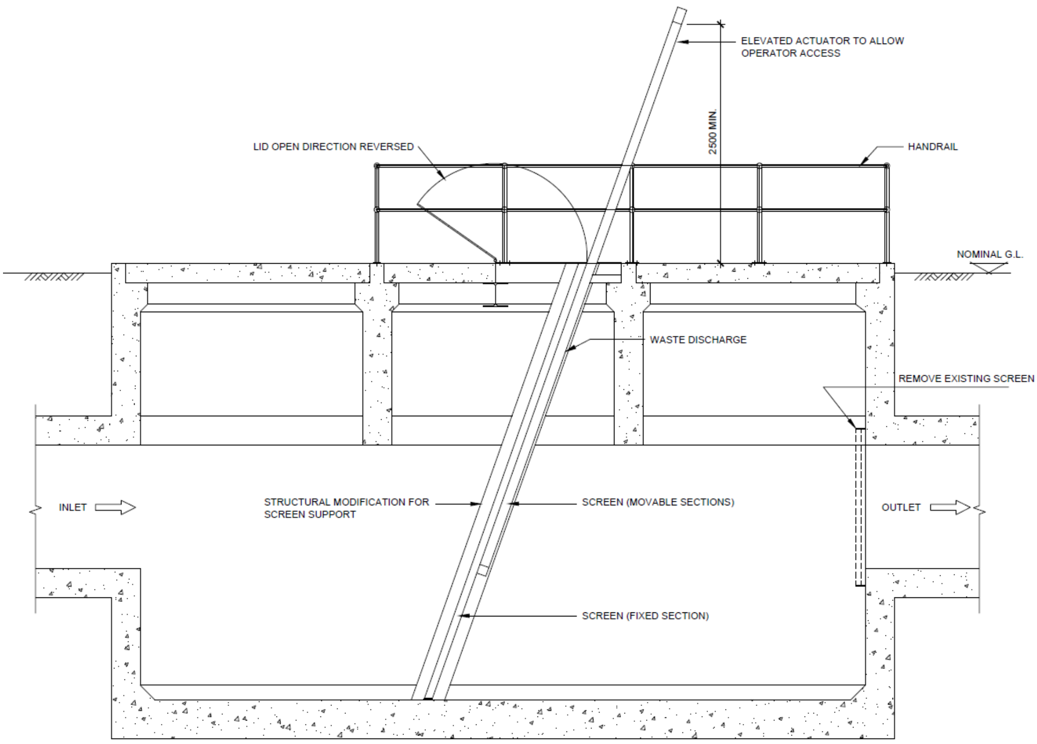

Figure 5: Schematic of Option 2 – Manual Operating Inclined Screen

3.3 OPTION 3 – CABLE OPERATED BUCKET CLEANER

This option consists of a vertical bar screen and an automated bar screen cleaner. This option provides the biggest improvement in terms of operator health and safety. This is a result of automating the cleaning process, which replaces the need to manually remove the debris. Liftable screen sections can be installed similar to Options 1 and 2. However, the likelihood of this requirement was deemed insignificant as the mechanical cleaning process can operate in all flow conditions resulting in less debris build-up on the bar screen.

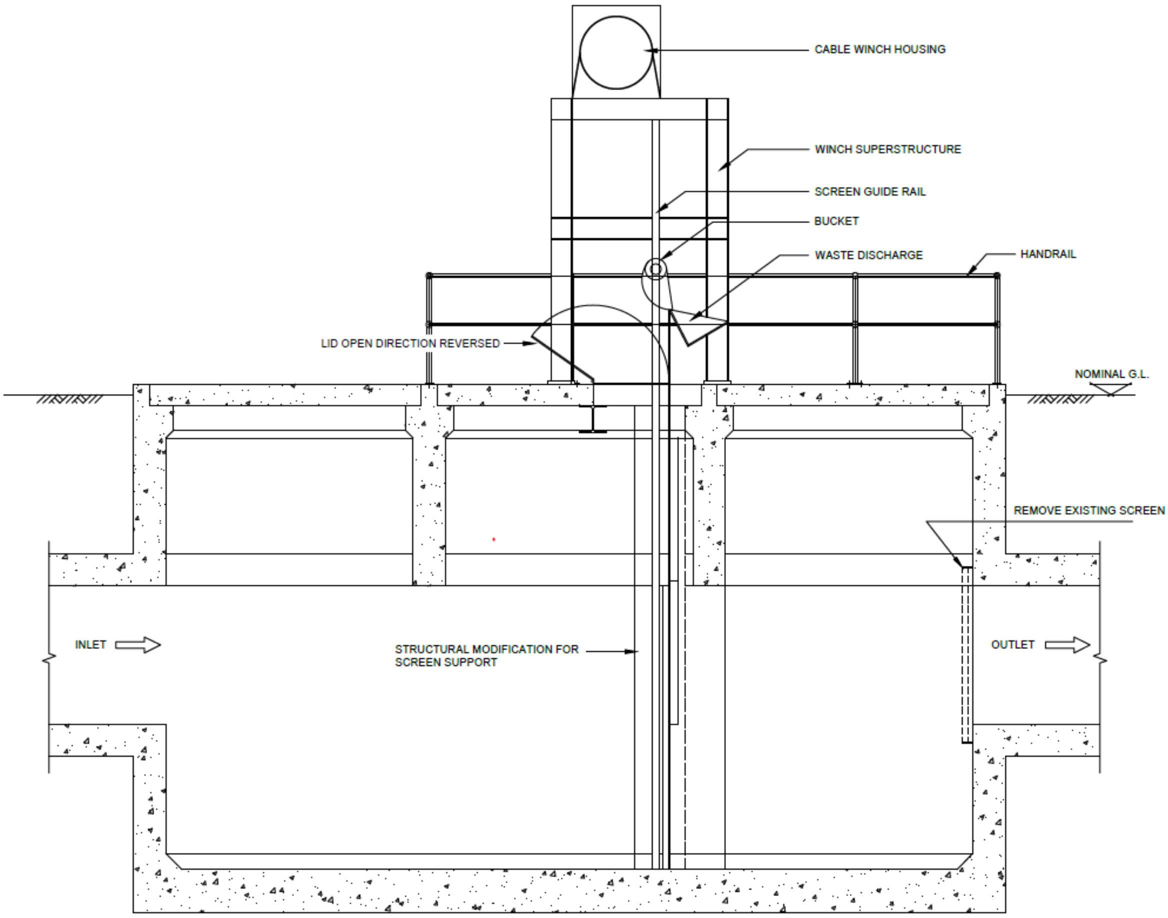

Figure 6: Schematic of Option 3 – Cable Operated Bucket Cleaner

4 OPTION ASSESSMENT

Each of the three options selected involve the relocation of the bar screen to the middle of the chamber, increasing the surface area available for flows to pass through the screen. This offers a considerable improvement to the hydraulic efficiency of the existing scenario. Each of the options also offer measures to lift out the screen during extreme weather.

Options 1 and 2 are similar in terms of design. Option 1 offers an actuated system for removing sections of the screen out of the flow path, with Option 2 offering a manual solution. Both Options 1 and 2 also offer improvements in safety over the existing system. Option 3 offers a significant improvement in safety while greatly reducing the likelihood of debris build-up during a storm event.

4.1 COST ESTIMATES

Cost estimates were prepared to provide an understanding of the capital and operational costs associated with each option. Cost estimates (refer Table 1) were developed using a number of sources of information including:

- Previous and current contracts of a similar nature;
- Data obtained from suppliers/ maintenance staff;
- The Rawlinsons Construction Handbook.

Table 1. Comparative Estimates and Net Present Value (NPV) Results

Option	Estimate CAPEX	Contingency Allowance (40%)	Total Estimate CAPEX	50 Year Annualised OPEX	50 Year NPV
1	$322,980	$129,190	$452,180	$18,820	$888,540
2	$217,390	$86,960	$304,350	$17,190	$679,420
3	$398,600	$159,440	$558,040	$16,900	$978,100

The above analysis showed Option 2 to be the most cost-effective of the three solutions considered, with Option 3 identified as the least cost-effective solution.

4.2 MULTI-CRITERIA ANALYSIS

A multi-criteria analysis was used to further evaluate the feasibility of the three options identified. A Critical Ranking (CR) was also applied to each of the criteria analysed (refer Table 2).

As safety and operational risks were considered significant, a high CR rating was applied to criteria relevant to such factors. The risk management philosophy adopted was based on the traditional hierarchy of controls approach; Eliminate, Isolate, Minimize.

Performance Gradings (PG) were assigned (from excellent to poor weighted 5 to 1 respectively) for each of the criteria assessed under each option. The overall ranking for a particular option was determined from the summation of the products of the CR and the PG over the full range of criteria considered (See Equation 1 below).

$$Overall\,ranking = \sum (CR \times PG) \qquad (1)$$

A summary of the multi-criteria analysis and overall rankings is provided in Table 3. Results identified Option 1 to be the most suitable of the options considered, with Option 2 a close second. Option 3 was identified as least preferable.

Each of the options considered presented significantly mitigated risks associated with screen blockage, and associated flood risk. The options presented also effectively addressed the safety concerns associated with the operation of the silt well, including offering the ability to raise screen sections out of the flow path, if blockage should occur.

Table 2. Criticality Ranking (Weighting)

Criticality Ranking	CR	Design Factors
Highly Significant	3	Factors associated with the causes or prevention of: • Reliability. • Robustness of equipment. • Availability of work-around / fall-back scenarios. • Removal or Mitigation of Safety Hazards. • Health and Wellbeing of Operators
Significant	2	Factors associated with the causes or prevention of: • Capital Cost. • Design Life / Durability. • Solution Complexity. • Security/Vandalism Risk.
Moderately Significant	1	Factors associated with the causes or prevention of: • Operational Cost and Manning. • Availability of supplier / OEM support. • Exposure to Other Risk Factors; Terrorism, Climate Change, Explosive Atmospheres, etc.

Table 3. Numerical Evaluation Outcomes

Criterion		Option 1		Option 2		Option 3	
Descriptor	CR	PG	CR x PG	PG	CR x PG	PG	CR x PG
• Reliability	3	5	15	5	15	4	12
• Robustness	3	5	15	5	15	5	15
• Availability of Work Arounds	3	4	12	3	9	3	9
• Mitigation of Hazards	3	4	12	2	6	5	15
• Operator Health	3	3	9	3	9	5	15
• Capital Cost	2	3	6	5	10	1	2
• Durability	2	5	10	5	10	4	8
• Solution Complexity	2	4	8	4	8	1	2
• Security Vandalism Risk	2	4	8	5	10	3	6
• Operational Cost	1	4	4	5	5	3	3
• Supplier / OEM Support	1	5	5	3	3	3	3
• Other Risks	1	4	4	4	4	3	3
Weighted Totals		110		104		93	
Overall Ranking		1		2		3	

Following the above analysis, Option 2 was selected by DCC as the preferred solution. The higher multi-criteria analysis rating for Option 1 was acknowledged, however the associated whole of life cost (compared to that of Option 2) was considered unjustifiable against the relatively limited additional benefits offered.

5 DESIGN

The multi-criteria analysis process and cost analysis culminated in Option 2 (Manually opening inclined screen discussed in 3.2 above) being chosen as the preferred option. Figure 7 below shows a 3D representation of a model developed for this design. This design solution involves the following:

- Relocating the bar screen to the central bay of the chamber and installing the screen at an incline, 20^0 to the vertical.
- Improved access to the silt well chamber and bar screens was achieved by locating the aluminium lids over the inclined screen, above the upstream and downstream bays to allow for maintenance access to any section of the chamber.
- The use of recovery gantries allows maintenance personnel to use harnesses and lanyards while chamber lids are open. This effectively removes the risk of falling.

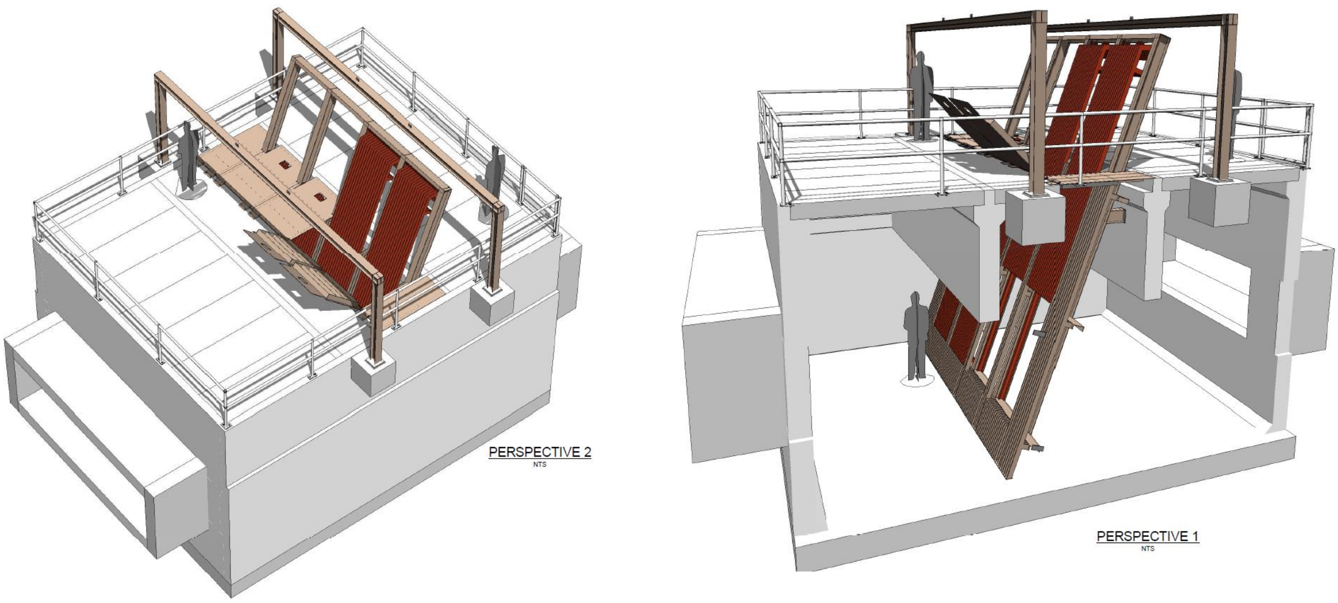

Figure 7: Perspective views of final design

5.1 HYDRAULIC ANALYSIS

A comparison was made between the existing silt well and the proposed upgraded silt well by analysing the percentage of the screen face area being blocked against the headloss or pressure differential generated. The impacts of screen blockage on head loss is shown in Figure 8.

The hydraulic efficiency of the existing chamber can be greatly compromised when the screen face becomes blocked. The increased head losses reduce stormwater flows to the pump station and thus less runoff can be discharged into the Upper Otago Harbour. The hydraulic advantage with the relocation of the screen is that the proposed position allows for a larger screen surface area. Larger surface area results in a lower pressure on debris perpendicular to flow, which results in vast improvements in the effectiveness of manual raking and maintenance ergonomics.

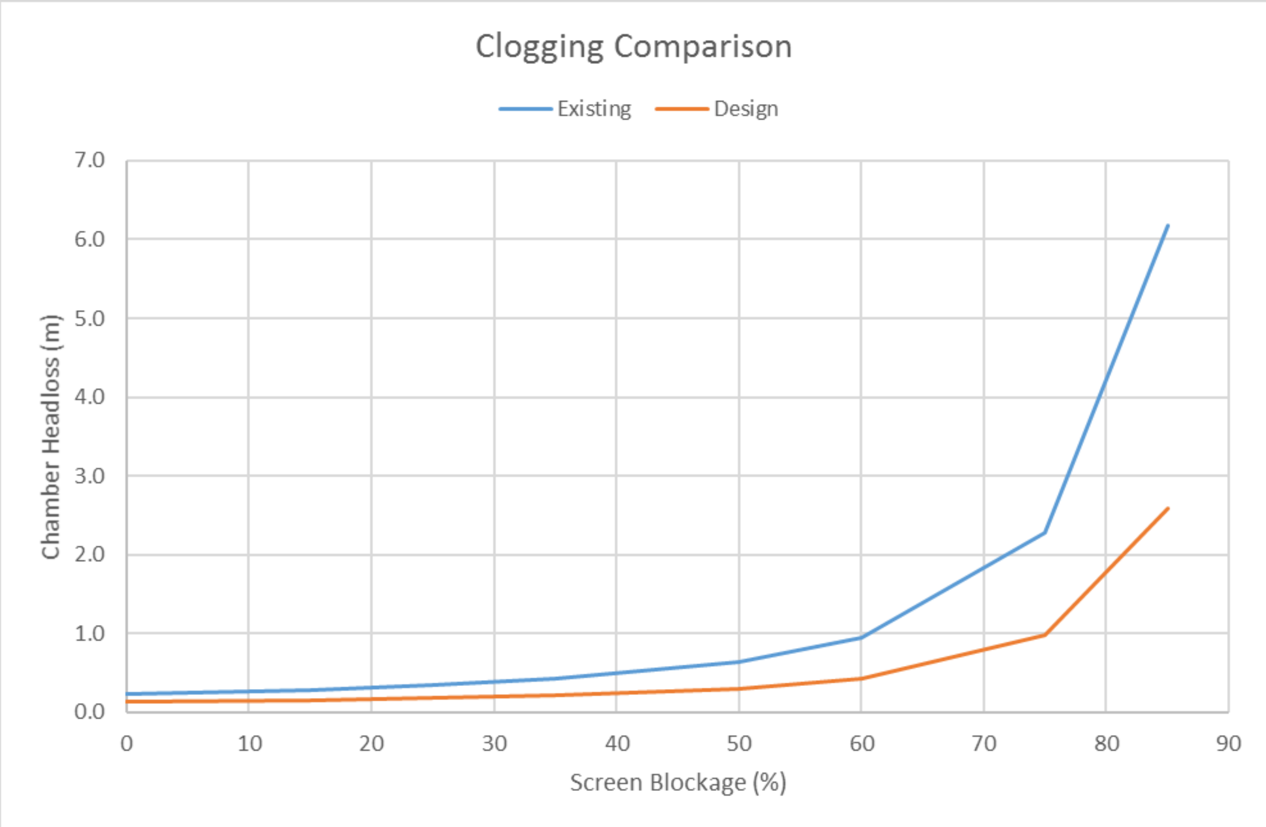

Figure 8. Comparison of Head Loss Against Screen Blockage

5.2 SAFETY IN OPERATION

Operator safety was considered paramount in the design process and many of the design features are associated with providing improvements in operational safety and ergonomics.

A high number of consequential risks are present at the silt well site. These consequential risks cannot be removed completely due to the nature of the site and are to be managed through the procedures discussed below.

5.2.1 OPERATOR ACTIONS

Access over the silt well lids, including the general public and operators have been considered and improved in the proposed design. The new reinforced concrete lids are designed with 'swift-lift' embedded lifting lugs to reduce significant trip hazards posed by the existing eyelet type lifting lugs. A permanent fence was proposed to surround the chamber to discourage public access and to remove the requirement for temporary coning-off of the area during raking operations.

5.2.2 STANDARD RAKING OPERATIONS

Prior to undertaking screen raking operations it is intended that the maintenance personnel will clip their harnesses into the recovery beam located directly above the access lids. They will then unlock and open the aluminium access lids that span the screen access aperture, to gain access to the screens for raking. Once the access lids are open, the screens can be raked. Other personnel should remain outside of the fenced area if they are not properly secured onto the recovery beam lanyards.

5.2.3 NON-STANDARD OPERATIONS

Where an excessive volume of debris accumulates on the screen (causing blockage) or higher water flow velocities result in debris being difficult to remove, the screens can be raised to allow flood flows to reach the pump station. DCC will need to prepare a standard operating procedure (SOP) to enable the decision to open the screens to be justified.

When the large concrete screens are to be raised, a (minimum) 5-tonne chain hoist will be positioned on the lifting lug (on the screen-lifting beam) of the movable screen. The moveable screen section can then be hoisted into its elevated position. Once elevated, the two screen locking pins can be positioned and locked in place and the screen lowered onto the pins. The hoist can then be moved onto the next movable screen section and the process repeated.

The screen sections can then be cleaned and lowered into the flow, or they can be retained in the elevated position until the flood has receded.

5.2.4 MAINTENANCE

Periodic maintenance of the facility will be required to ensure the performance of the facility into the future. A number of maintenance activities have been recommended and allowed for in the design.

Hydrostatic level instrumentation has also been provided to alert operational staff to events where head loss across the screen increases to unacceptable levels (an alarm is triggered on the pump station SCADA system to alert operators that screen raking is required).

All of the aluminium access lids are to be inspected regularly for damage, and the hinges lubricated every 6 months.

The movable screens are to be maintained by exercising the screen guides at times of low flow, at least once every 12 months as a minimum.

The program for the management of silt at the facility will remain unchanged, i.e. desilted on a five yearly rotation. This should continue, although there are additional access lids in the upstream and downstream bays. These lids can be used for access for desilting, but should only be used in strict accordance with confined spaces access equipment, training and procedures. The lids will have signage to this effect.

6 CONCLUSION

The main objective of this project was to enhance the hydraulic performance of the silt well and bar screen upstream of the Portobello Road stormwater pump station. A number of options were identified, and a multi-criteria analysis was used to assist with the selection of the best option for implementation.

A manual inclined bar screen was selected as the preferred option, which satisfied the main objected of improved hydraulic performance. The solution also offered the additional key requirements of reduced health and safety risks during maintenance. Additional operational and health and safety improvements were provided through a series of further modifications to the existing facility, including placing a fixed fence around the chamber openings, and replacing the existing cover slab lifting eyes to remove trip hazards.

ACKNOWLEDGEMENTS

Dunedin City Council (DCC)

Janan Nirainjanan (DCC Project Manager)

Charlie Schorr-Kon (Calibre Consulting Design Manager)

Navin Weeraratne and Dave Allen (Technical Reviewers)

REFERENCES

Murray, D. (2010). *Dunedin 3 waters Strategy.* Christchurch: URS. Retrieved Jan 12, 2017

Palmer, G., Goldsmith, M., Payan, J.-L., Morris, R., Valentine, C., MacLean, S., . . . Mackey, B. (2015). *Coastal Otago Flood Event 3 June 2015.* Dunedin: Ortago Regional Council. Retrieved Jan 12, 2017