MBNRU: PROGRESSIVE SAFETY IN DESIGN – CONCEPT DESIGN THROUGH DESIGN BUILD

Roddy Copeland (Beca) and Sven Harlos (Watercare Services Limited)

ABSTRACT

An intentional culture of continuing safety in design has shaped the success of the largest wastewater treatment plant (WWTP) constructed in New Zealand in the last 15 years. Commencing in 2013, safe operation was at the forefront during design development and was the focus during construction. The collaborative approach between Watercare's Operation and Maintenance team and CH2M Beca designers set the stage for success which was progressively expanded through the next stage of the resulting design build construction contract. The culmination of these efforts was a safer construction and operational environment for many years to come.

Designed by CH2M Beca and constructed by a McConnell Dowell - HEB Joint Venture (JV), the new $140M Biological Nutrient Removal (BNR) upgrade to Watercare's Mangere WWTP will add capacity for an additional 250,000 people, meeting Auckland's projected growth and improving the water quality discharged to the Manukau Harbour.

The resulting construction contract contained a nested structural design-build component. Once the project had progressed to tender phase it was paramount that the communication and protection of Safety In Design (SID) functionality within the Principals' requirements related to these elements was maintained, and where possible, improved. Within the contract Watercare included workshops with CH2M Beca and the JV structural designer – Holmes Engineering – to continue the collaborative working approach to reduce risk and improve safety. As a result of the reviews and SID sessions, several key elements were included that not only improved the long term operational safety, but also improved safety from a construction perspective. This involved items such as access doors through external walls at base and ground levels, and internal access ways through long baffles to facilitate safer access for people and equipment.

JV led the construction phase from June 2015 to October 2017, engaging over 2000 staff on site. Throughout this phase Watercare, CH2M Beca and JV's progressive approach to maximizing construction and long term operational safety continued. As a result, several improvements to both the safety during construction as well as operation were achieved during this stage.

The commissioning phase was completed in March 2018. As part of Watercare's procedures and its emphasis on safety reviews, the Watercare Health and Safety team gave continual inputs during the construction phase and provided the final sign-offs prior to takeover.

This paper will discuss the collaborative safety in design approach, contracting approach and the breakdown of traditional barriers, from concept design through the six major phases to operational handover.

KEYWORDS

Wastewater treatment, safety in design, contract strategy, collaboration

PRESENTER PROFILE

Roddy Copeland is a Technical Director at Beca with 20 years' experience in delivering a wide range of multidisciplinary water, wastewater and infrastructure projects, both in New Zealand and the United Kingdom. Roddy was the Design Lead for the BNR upgrade and is currently the Project Manager responsible for the Pukekohe WWTP Upgrade.

Sven Harlos is a Chartered Professional Civil Engineer with more than 20 years' experience in delivering multidisciplinary, large Three Waters projects in the Asia Pacific Region, Middle East, Europe and Africa.

He has been with Watercare for 13 years, and is currently the Project Manager responsible for several $50M+ projects: the Mangere WWTP BNR and Solids Upgrades, the Pukekohe WWTP Upgrade and the Rosedale WWTP Upgrade.

1 INTRODUCTION

An intentional culture of continuing safety in design (SID) has shaped the success of the largest Wastewater Treatment Plant constructed in New Zealand in the last 15 years. Commencing in 2013 at the concept stage, safe operation was at the forefront of the development of the design. The collaborative approach between Watercare's Operation and Maintenance teams and CH2M Beca designers set the stage for success which was progressively expanded through to the resulting design build construction contract. The culmination of the efforts was a safer construction site and an operational environment suitable for the H&S requirements going into the future.

What is SID

"Safety in Design is the integration of hazard identification, risk assessment and control methods in the design process to eliminate or minimise risks to health and safety throughout the construction and life of the element being designed"

This paper will discuss the collaborative SID approach and break down of traditional barriers, from concept design through six major phases to operational handover. It will also look more closely at one of the design features from the SID process and how it offset the implementation costs through efficiencies during construction.

2 WHAT IS MBNRU ALL ABOUT

Watercare's Mangere WWTP is Auckland's main wastewater treatment facility. Already the largest wastewater treatment facility in New Zealand, the $144M development to address current and future population growth in Auckland is the largest single-site capital works delivery of wastewater infrastructure in New Zealand since Project Manukau circa 2000. MBNRU was a complex, multifaceted international project that utilised a strong New Zealand team with significant global technical input over five years. The Project was a programme of works that included four early works construction contracts, four supply contracts and a main construction contract.

The international design team, engaged from June 2013 to September 2014, delivered more than 40,000 hours of design and procurement efforts across four countries. The construction phase, from June 2015 to October 2017, engaged over 2000 staff and incorporated over 800,000 hours on site. The commissioning phase was completed in March 2018.

Photograph 1: View of completed MBNRU site from the west

The centerpiece of the upgrade was the construction of a Biological Nutrient Removal (BNR) facility adjacent to the Mangere WWTP. This modern biological facility, designed by CH2M Beca and constructed by a McConnell Dowell - HEB JV, is sufficient on its own to provide secondary treatment of wastewater for 250,000 people. At the heart of the facility is the bioreactor which is one of the largest concrete water retaining structures in the country, fed from the existing plant by a large process pump station. The main process components comprise:

- 14m high flow splitter box
- secondary treatment from two four-stage Bardenpho bioreactors (28,000 m^3 each)
- two 52 m diameter clarifiers
- an aeration system with new state of the art blowers housed in a new building, and removable disc diffusers
- two process pump stations
- 1.4 km of discharge pipework and tie-ins to the existing treatment plant

The procurement strategy was established in the first project phases after consideration of a variety of project delivery strategy options. NEC3 suite of contracts was utilised for Professional Services, Engineering & Construction and Goods & Supply contracts. NEC3 was the chosen approach as it provided Watercare with a high level of collaboration and transparency on risk management throughout the project.

Photograph 2: Installed disc diffusers on removable grids

Four early enabling contracts were developed to minimise time impacts of the main BNR construction contract, including access roads, earthworks rising mains and planting. Separate procurement packages for key equipment (Aeration Blowers and Diffusers, Interstage Pumps, Return Activated Sludge pumps) allowed Watercare to retain control of selection and ensure the concurrent design was tailored to the selected equipment.

The main contract for the BNR Upgrade (C5893 - Mangere WWTP BNR Upgrade Design & Construct) was an NEC3 Engineering and Construction contract with an embedded Contractor's Design component for the structural aspects of the water retaining splitter box, reactors, and clarifiers. The inclusion of the Contractor's Design allowed Watercare to maximise the Contractor's selected structural methodology insights to reduce price, programme and risk. The inclusion of the Contractor's Design added to the complexity of both the contract documentation required and how SID was applied and followed through on the project.

3 DELIVERING A SAFE DESIGN FOR MBRNU

3.1 INSPIRATION FOR SID

From the outset of the project, Health and Safety was always at the forefront of the project team's mind. Following a full day workshop a Project Charter was developed to help guide behaviors through the project. One of the core principles that came out of this session and included in the Charter was "We will take responsibility for our **safety** and the **safety** of others."

The attitude and culture towards SID on the project was shaped significantly by the individuals involved in the project and the wealth of knowledge, experience and personal commitment they brought from their international experience, backed up by the procedures and processes of the Watercare and CH2M Beca. This kept the project ahead of the game as the SID culture and context in New Zealand continued to mature with new supporting legislation changes such as the Health and Safety at Work Act and the publishing of the updated Watercare SID guide in 2017.

3.2 TAILORING SID FOR MBNRU

With an increasing number of projects in New Zealand adopting different delivery approaches it is important that the SID process is flexible and can be adapted to those delivery structures. This includes projects such as the MBNRU where there were design/build elements embedded within a traditional design, build and construct contract.

The starting point for the SID risk assessment methodology applied over the course of the project was the Watercare's SID requirements along with Beca's Safety in Design work instruction WI27/02, which was developed in accordance with AS/NZS ISO 31000:2009. It was identified early on that a unique project delivery model with an embedded contractors structural design component would require special consideration and planning in terms of how the SID methodologies would be delivered. Principles that influence achieving a good SID outcome were used and applied throughout the project design life cycle, taking into account the project delivery structure along with other factors such as:

SID Principles

1. Persons with control of the design should promote health and safety at source.
2. Eliminate risks as early as possible in the lifecycle.
3. Apply systematic risk management techniques.
4. Demonstrate and use safe design knowledge and capability.
5. Transfer the safe design information.
6. Coordinate, communicate and cooperate

- scale of project
- complexity of construction

- significant operational/maintenance tasks
- client specific philosophies
- project objectives

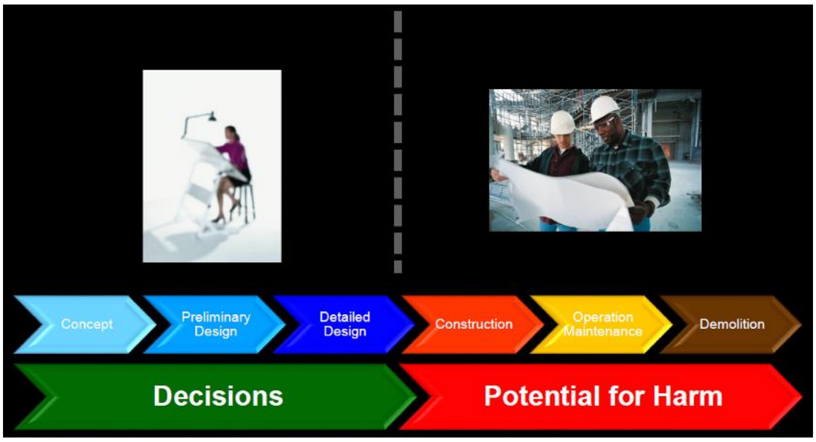
Two particular principles of communication/collaboration and information transfer were identified as being critical to providing a successful SID outcome for this project. Collaboration was important to get the most out of the differing backgrounds and viewpoints of the team. Information transfer and communication was especially important with differing levels of design being completed by different parties. It was critical that hazards and the associated mitigations identified by one designer were effectively communicated to the designer completing the final detailed design so that they were not lost.

The following sections provide a description of how the application of the SID method progressed through the major stages of the project cycle to contribute to a safer outcome for the construction and O&M teams.

4 PROGRESSION OF SID THROUGH THE PROJECT LIFECYCLE

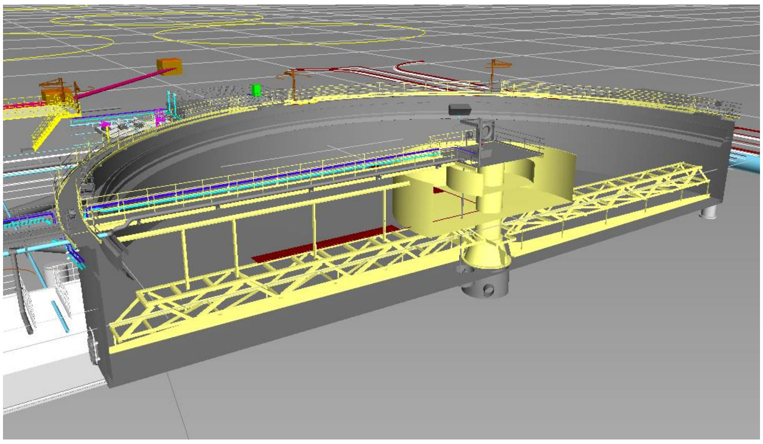
4.1 DESIGN STAGE

The design stage of the MBNRU project spanned a period of approximately 2 years between 2013 and 2015 and had three major stages: Concept Design, Preliminary Design and Complete Design. The output of the Complete Design stage included full detailed designs produced by CH2M Beca for all elements except the geotechnical and structural design for the major water retaining structures including the splitterbox, reactors and clarifiers. The final design of those elements was completed by the McConnell Dowell – HEB JV and their structural designer Holmes Engineering. The Complete Design produced by CH2M Beca for the water retaining structures included the process and geometric design for these structures, and a set of Principals Requirements which together captured the design requirements and brief to the JV.



The implementation of the SID methodology during the three major stages of design followed the principles of good SID delivery with a particular focus on collaboration to take advantage of the design experience of the CH2M Beca team along with the practical experience of the Watercare operators. A significant amount of effort was invested during this stage with almost 50 individuals from CH2M Beca and Watercare taking part in safety workshops. During the Concept Design phase there was a specific focus on identifying and understanding Watercare requirements and philosophies around access and maintenance, and then eliminating the risks as early as possible to allow the maximum benefit to be gained.

Throughout the design stage there was an intentional focus on Health & Safety (H&S) until it was part of the culture of the project. With safe operation at the forefront of the teams mind, a layered approach was used through the inclusion of SID criteria in the day to day design decisions, H&S moments at start of workshops, and having it at the top of each agenda for all meetings. A particular emphasis on obtaining a broad view on decisions was achieved through joint fortnightly design meetings which included the Watercare Projects and Operation and Maintenance teams. These meetings allowed key design decisions, including the assessment of operational H&S impacts, to be made as the design progressed rather than waiting until the end of the design stages.



These more informal sessions were backed up by the use of more systematic workshops which were facilitated and documented for formal tracking and managing as the design progressed. The 3D design model formed the main platform for communicating the design and reviewing the associated risks, providing a powerful tool for the operators to understand the design and the associated access, spatial and ergonomic implications of the design. These workshops included eight separate sessions dedicated to safety topics, including the following HAZOP, O&M, Constructability, Electrical, CHAZOP, and SID. Given the size and complexity of the project, the workshops were separated out by topic and project phase for a more focused approach. The output of each of these workshops was fed into a PHA Pro database where they could be captured and managed as the design progressed.

CH2M Beca

Safety in Design Register #1

Project Name: **MBNRU**

Author (Role): **Hayden Porter (Scribe)** Job No: **6518575**

Approved By: Date: **6 March 2014**

Stage of Design / Project: **Preliminary Design**

RISKS ASSOCIATED WITH DESIGN ELEMENTS			Risk Matrix			PROPOSED & APPROVED MITIGATION MEASURES		Mitigated Risk & Resolution				RESIDUAL RISK				
Ref	Hazard (Guideword)	Cause / Outcome	C	L	LR	Risk Owner	Proposed Control (1 Eliminate, 2 Substitute, 3 Reduce, 4 Control)	C	L	LR	Client Approved	Design Status		Date	Risk Owner	Action Required
1	*CONFINED SPACES*	Limited ventilation in IPS2 Wetwell. During maintenance activities this could lead to a danger of suffocation.	4	2	M	CH2M Beca	IPS2 Wetwell ventilation openings are required for maintenance access. Design team to ensure this is provided. Maintenance to supply own ventilation fans.	4	1	L		IPS2 Wetwell access for maintenance is shown on Drawing 2010893.002 rev1 (for Preliminary Design)	Closed	15/09/14	Watercare	Maintenance operating procedure to ensure that forced ventilation is in operation during maintenance
2	*CONFINED SPACES*	Hatches for access and ventilation/other services around the site.	NA			CH2M Beca	Review on sizing and location of all access and ventilation hatches provided for enclosed structures. (sitewide)	NA				Ventilation is provided to ensure fresh air is available where foul air extraction occurs. Access is provided throughout site including at floor level for Reactors and Clarifiers and through internal reactor walls.	Closed	15/09/14		
3	*CONFINED SPACES*	Various confined spaces throughout the site. (Especially in regard to the dry well of IPS2). Reduction of areas which are considered confined spaces is desired.	NA			CH2M Beca	Design team to eliminate confined spaces where possible, by incorporating access/egress which comply with the WSL codes (with AS 2865:2009 Confined Spaces). Watercare to confirm this policy. Peter Trafford emailed 07/03/14 confirming Watercare OH&S Manual Guidelines.	NA				Confined Space list confirmed with Watercare as per NTE 0034 and included as Appendix to this Report	Closed	15/09/14	Watercare	Confined space list to be used during development of SOPs
4	*CONFINED SPACES*	Access hatches for reactor are at ground level this requires internal scaffolding to get to reactor floor during maintenance. There is a risk of injury during the construction and use of the scaffolding.	3	3	M	CH2M Beca	Provide external access for reactor floor. i.e. access hatches placed at reactor floor level with a staircase down to them (below ground level). This will simplify access/egress to reactors. This staircase will be a confined space. Space at the bottom of this staircase needs to be sufficient to turn etc.	1	1	L		Included in Design, refer 2010896.008 rev4 (for Complete Design)	Closed	15/09/14		
5	*CONFINED SPACES*	There are no side wall penetrations in clarifier thus access to floor only via scaffolding. There is a risk of injury during the construction and use of the scaffolding.	2	2	L	CH2M Beca	Review external access for clarifier floor. i.e. access hatches placed at clarifier floor level with a staircase down to them (below ground level). . (consideration of post tensioning of clarifier in terms of access hatches). Both clarifiers could be accessed by a single set of stairs.	1	1	L		Included in Design, refer 2010896.017 rev2 (for Complete Design)	Closed	15/09/14		
												Will not be a confined space				

Figure 1: Extract from SID register

At the end of each design stage formal reports were produced, communicating the current status of all the risks and hazards identified. As shown in Figure 2 below, at the end of the Complete Design stage 587 actions had been raised and of those 560 had been addressed and closed during the design stage. The remaining 27 actions were carried forward and closed during the procurement, construction and commissioning phases.

Table 24.2: Action Item Status

	All Items			Watercare		Watercare & CH2M Beca		CH2M Beca	
	Closed	%Closed	Open	Open	Closed	Open	Closed	Open	Closed
HAZOP1	164	100%	0	0	8	0	4	0	152
SiD1	35	100%	0	-	-	-	-	0	35
CHAZOP	27	93%	2	1	4	1	6	0	17
O&M	106	98%	2	2	0	0	1	0	105
Constructability	31	79%	8	8	0	0	5	0	26
HAZOP2	111	90%	12	11	1	1	1	0	109
SiD2	46	100%	0	-	-	-	-	0	46
Electrical SiD	40	93%	3	3	0	-	-	0	40
Totals	**560**	**95%**	**27**	**25**	**13**	**1**	**17**	**0**	**530**

Figure 2: Extract of SID monitoring report at Complete Design

The registers and SID reports formed the backbone of the identified risks communication and were supported by a wider dissemination, passing the relevant information to those in control of managing the risk going forward. The means for passing on the relevant information included registers, contract documents, PRs, drawings, tenderer interactives, contract meetings, O&M manuals and training sessions.

4.1.1 A SAFER DESIGN

Through the dedication of the team and the commitment to health and safety, a safer design was delivered for the contractor to build and the operators to run and maintain. The registers captured a range of improvements as the project progressed, a small selection of which have been captured in Figure 3 below. One of the feature elements of the SID process was the inclusion of external low level stair access points to the base of the major tanks, combined with ground level and top of wall access providing much safer entry to the tanks. This SID innovation resulted in significant benefits for both construction and operations, and is described in greater detail in Section 4 of this paper.

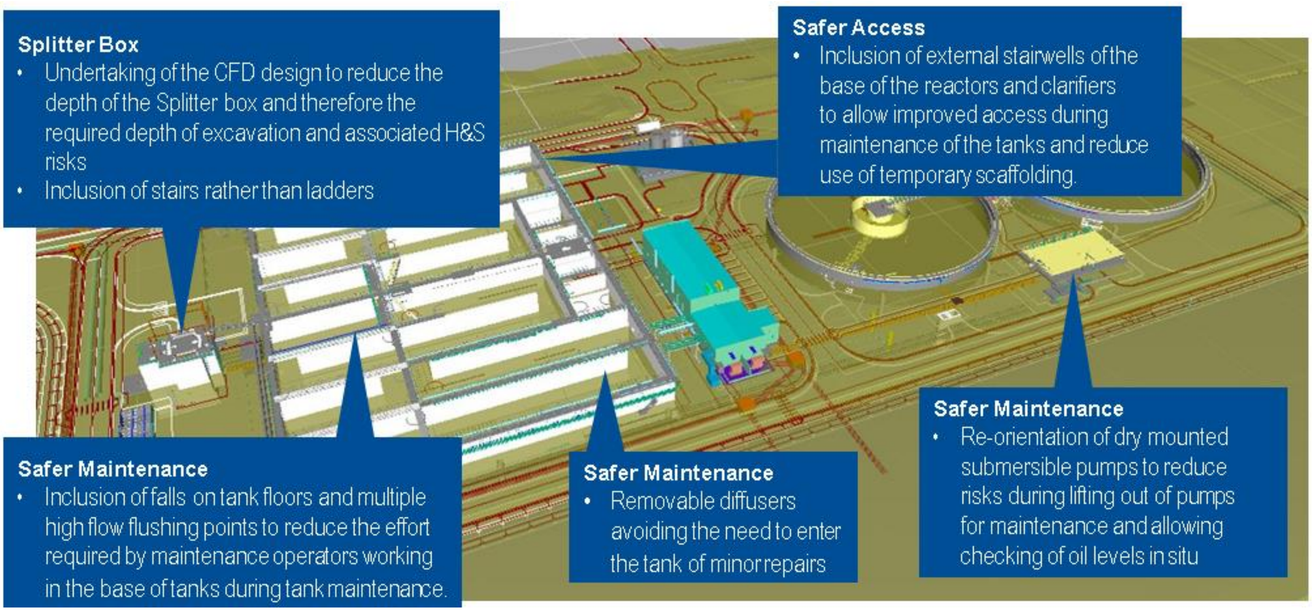


Figure 3: Examples of SID features identified during the design

4.2 PROCURING SAFE SOLUTIONS

The procurement strategy of a project sets the direction for the project and has a significant influence on the outcome of a project in many ways including safety. The procurement phase of the project was therefore a critical time for considering how we could influence the SID outcomes of the project. The approach to purchasing and designing around equipment was one aspect of this, and the way SID was integrated into the Design Build aspect of the project was another.

4.2.1 EARLY EQUIPMENT SUPPLY PACKAGES

One of the significant potential hazards on a wastewater treatment plant site is operating equipment such as pumps, blowers and other mechanical machinery which can have a range of risks including rotating parts, high levels of noise, require heavy lifting and starting automatically. The selection and design around mechanical equipment is therefore a critical part of SID on wastewater projects and the procurement of that equipment is the period during which there is significant opportunity to influence the H&S outcomes.

Following the development of a procurement strategy for the project, four different key equipment supply contracts were identified as being required and were tendered during the design phase. These were procured directly by Watercare to obtain supplier information needed to complete the design and to allow increased control over the selection. This helped to better match the process equipment to project drivers of efficiency, flexibility, and safety. The early equipment supply packages included:

- Aeration Blower Supply – 8 High Speed Turbo Blowers – 5600 Nm^3/s
- Diffuser System – 11,900 fine bubble membrane diffusers
- Interstage Pumps – 5 Centrifugal Pumps – $4.8m^3/s$ total flow
- Recycled Activated Sludge Pumps – 7 Centrifugal Pumps

The early selection of this equipment prior to the construction phase allowed the design to be more easily tailored around the equipment’s particular requirements for installation, operation and maintenance. This was done during the preliminary and detailed design phases, early in the project life cycle, allowing a greater level of flexibility for the design to incorporate safety considerations. With the development of the equipment procurement contracts being undertaken by Watercare and CH2M Beca, there was an opportunity to continue the collaborative approach with suppliers to produce better H&S outcomes. This started with including the relevant SID risks by in the tender documentation and was followed up by working with the suppliers to optimise the environment around the equipment.

An example of this is the early selection of the blowers which provided the opportunity for the selection of quiet and efficient blowers and for the blower building to be designed around the units that were purchased. We worked with the blower supplier to improve the temperature control in the building and for the process air by ducting air directly into the blower intakes and exhausting the cooling air outside the building. As a result the blower building has a relatively quiet and temperature controlled environment which is more pleasant and safer for the Watercare operators to work in.

4.2.2 SETTING THE SCENE IN THE MAIN WORKS CONTRACT TENDER

The design and production of tender documents is a major milestone for a project, and in terms of SID it is a period of focus on communication of any residual construction risks that couldn’t be fully designed out. The residual risks and hazards need to be managed in such a way that the key information compiled is passed on to our client and through our client to other stakeholders, vendors and constructors.

With the MBNRU project and the structural design that was embedded in the construction contract there was a need for attention to be given on how the SID process would be managed during the design phase of the construction contract. This included promoting continual improvement for safety with a particular focus on constructability, while also protecting the operation and maintenance or improvement of SID functionality already incorporated into the design.

The communication of residual risks was passed on through the traditional use of design risk registers, SID Reports, technical specifications, drawings and interactive constructor briefings during the tender process.

In addition, the Principals Requirements section within the tender documents was a point of focus. It included tables of critical design requirements which assisted in communicating the key aspects with which the contractors design needed to comply and where there was room for development to suit the structural design.

The tender document also included requirements for the SID process during the contractor's design. This required that the contractor's designer meet the full Watercare standard SID requirements and was centred on the need for an integrated SID workshop. This included the contractor's construction team and designer, as well as Watercare's Projects and Operations staff and CH2M Beca.

4.3 MOBILISING SID INTO THE CONSTRUCTION AND COMMISSIONG PHASE

The McConnell Dowell-HEB JV led the construction phase from June 2015 to October 2017, and engaged over 2000 staff on site. Throughout this phase the Watercare, CH2M Beca and the JV's progressive approach to maximizing construction and long term operational safety continued. Early in this phase, the JV implemented the required SID workshops with CH2M Beca and the JV structural designer, Holmes Engineering, to continue the collaborative working approach to reduce risk and improve safety.

With the final design responsibilities for the water retaining structures passed over to the JV and their designer under the design/build contract, new challenges and opportunities around SID were identified. The project was coming out of the design phase during which Watercare had a high level of control and collaboration with the design into a design/build phase with the risk of less opportunity for influencing the outcomes.

Photograph 3: Clarifiers during construction

At the start of the design build phase some of the design solutions that focused on safe operation and maintenance of the plant were challenged. The JV looked to tailor the design to reduce cost and make the structures easier and safer to build. In some cases the H&S features that Watercare Operations were expecting began to be eroded. The design went through a series of robust reviews and the collaborative working resulted in maintaining and improving both construction and operational safety for the project.

A few of the key SID outcomes included:

- All remaining access ladders were eliminated for primary ingress/egress and replaced with stairs

- 1.4km of buried pipeline was changed to avoid handling long strings of heavy PE pipe in deep trenches and under the existing infrastructure. Unlike PE pipe, the 12-metre FRP lengths could be pushed together, requiring no welding in the trench, significantly reducing health and safety risks and as a by-product, saved the client money

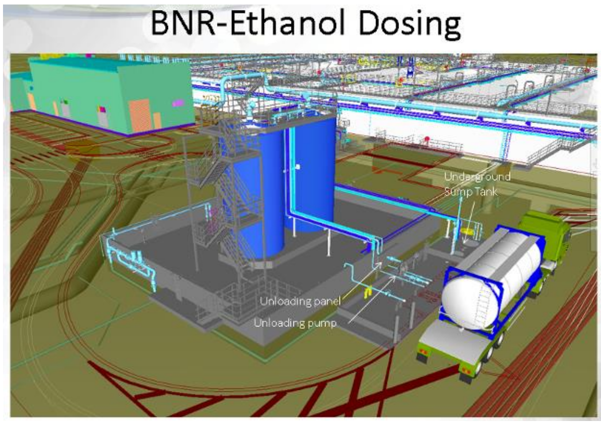
- Identification and utilization of the access doors through external walls at base and ground levels, and internal access ways through long baffles to facilitate safer access for construction personnel

- Relocation of handrails along the reactor walkways from the sides of the walkways to being top mounted to avoid the need for scaffolding during installation

With many of the ideas raised by the JV at this stage there were tradeoffs between the cost/constructability as compared to the operational outcomes. An example of this was the proposed relocation of the handrails to the top of the walkway slab by the JV. There were significant construction safety and cost benefits from mounting the rails on the top, however it also resulted in the effective width of the walkways being reduced from 1200mm to 900mm. Through discussions with the JV and Watercare Operations, the 900mm width was confirmed as being adequate. This also meant that future maintenance or repairs of the railings would be easier as the fixtures are easily accessible: a win/win for safety during construction and for maintenance.

One aspect of the SID Principle of Project Lifecycle is to minimize risks as early as possible as the level of influence is greater and the cost impact less. However, that should not prevent the continual review of safety improvements later on in the project. A good example of that is the complete removal of the ethanol dosing system from the design during the construction phase which came about following a holistic look at the process design of the wider Mangere plant and the BNR upgrade.

The Mangere BNR project design included an ethanol dosing facility to provide a source of carbon. This was to be dosed into the reactors to provide sufficient readily biodegradable carbon for effective denitrification. In response to wider drivers for the existing Mangere plant around efficiency and reducing energy, chemical consumption and creating a more stable process, CH2M Beca reviewed options for undertaking process improvements with a focus on Nitrate Shunt. These planned changes to the Mangere WWTP process would reduce the need for an ethanol carbon source for the MBNRU in the future. The project therefore elected to put the ethanol facility on hold and in its place tie-in to the existing carbon dosing source at the Mangere WWTP. The complete removal of the ethanol facility and associated risks came with significant H&S benefits. Whilst the design process worked through and reduced the risks around the ethanol facility to an acceptable level, the elimination of the entire facility scores much higher on the hierarchy of controls.



As the construction and commissioning phase was coming to an end, the focus was once again on communication of residual risks and passing on all ideas and proposed mitigations that had been captured over the previous five years. This was achieved in the first instance by having the operators involved in the design at the start and all the way through the design process, and followed up with a comprehensive set of O&M documentation, involvement in commissioning and multiple training sessions to pass on knowledge.

4.3.1 BREAKING DOWN ORGANISATIONAL BARRIERS

Continuing with the CH2M Beca led design phase approach to risk management, including SID, the team wholly committed to a unique approach for the construction and commissioning phases. The approach to risk management and the project risk register that it encompassed became the heart of communication and collaboration throughout the delivery of the project. CH2M Beca provided a Risk Manager to establish one over-riding risk management approach. The living risk register provided the JV with immediate insight into the mitigation and allocation of risks regardless of the owner, and the identification of opportunities for value engineering and cost savings. The emphasis was on developing processes to support communication, collaboration and a culture of mutual trust to ensure proactive risk management throughout all phases of the project and alignment across all parties: 'Together Doing It Better'.

5 OPERATIONAL IMPROVEMENTS PAYS OFF DURING CONSTRUCTION

During the design phase several collaborative SID sessions with Watercare's Operation and Maintenance team highlighted key areas of operator H&S risk that needed to be addressed. One innovative approach was to not only ensure stair access was provided to areas requiring access at height but to also provide similar access to buried structures, such as the bioreactors and clarifiers – two water retaining structures that do not normally include such features. This section of the paper shines a light on this idea and discusses it in more detail.

Operation of both bioreactors and clarifiers require routine cleaning of sludge deposits. This task can be particularly onerous for operators due to the difficulty in accessing the deep structure, the difficult working conditions due to the slippery, dirty and biologically active materials and the associated equipment and water required to remove the solids from large areas. The maintenance cleans of the reactors and clarifiers was therefore an important activity to focus on for improving safety and several features were included in the design including:

- Providing direct access to both ground level (at grade) and the bottom floor (3m below grade) in addition to the top of the reactors (5m above grade)
- removable aeration grids
- low/high pressure cleaning water
- falls on the floor and sumps and pumps for solids removal

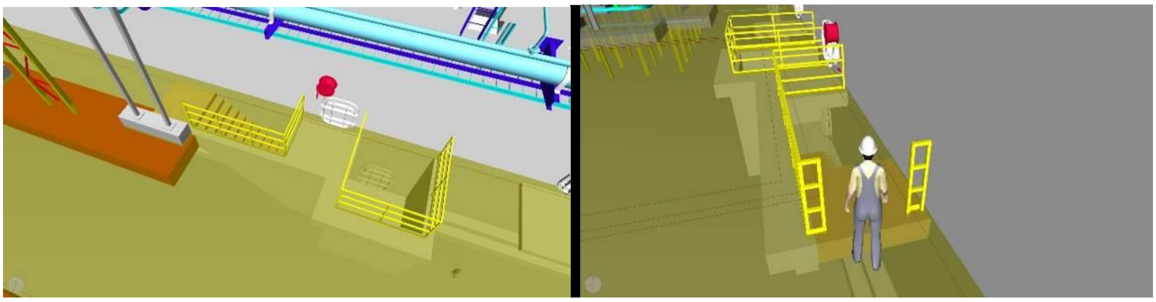
These features were not currently included in existing Mangere plant reactors and were added to further reduce potential injuries accessing the drained water retaining structures.

5.1 INNOVATION THROUGH COLLABORATION

Inspiration for improving access to the base of the large tanks was taken from discussions with the operators and a continual improvement approach with further development on access improvements implemented with Watercare and CH2M Beca on Digester No 8 at Mangere. On the existing reactors and clarifiers at Mangere and typical for other sites, access is only provided from high level or the top of the tank. Often no dedicated access is provided requiring improvised solutions by operators until a temporary scaffold with ladders can be installed. The solution for this project was to provide improved access at three levels to the tanks, the main feature being the external concrete stairway access to the bottom floors of the reactors and clarifiers. At the base of the stairs was a 1500mm by 2000mm bolted submarine door. The Watercare/CH2M Beca collaborative approach to design ensured that the low level stairway access facilitated the usage of stretchers and associated recovery equipment should they be required in accordance with the Watercare emergency procedures.

In the case of the reactors 4 separate stairway access points were provided to the bottom of the tank. Corresponding to each of those low level access points was an adjacent access port at ground level. This port provided an easy route for services such as hoses, ventilation, and power to enter the reactor keeping the personnel access route free and clear, reducing the risk of trips and falls. A further 4 dedicated access points were also provided to assist with access down from the walkway level. These included hatches in the floor allowing the operators to use standard tripod and harness techniques rather than having to climb over the walkways like at existing structures. Once inside the reactor doors were also provided in the long baffle walls significantly reducing the walking distance required to reach the different zones.

Each Clarifier also included separate access stairs to the bottom elevation in addition to a corresponding ground level port and separate elevated platform access staircases with a bridge between the two.



The safety benefits were apparent to both operator and designer from the onset. The collaboration also noted the potential for further mitigation of health & safety risks during construction providing further drivers to include them in the design.

The joint venture of McConnell Dowell and HEB Construction fully picked up on the availability of these doors and realized the benefits of the innovative approach from both a reduction in health & safety risk during the delivery of the constructed works and an inherent efficiency benefit to the program. Constructed as permanent solutions the combination of steel structures and concrete staircases contributed to the successful delivery of the project, planned from the onset to reduce efforts associated with the installation of the labour intensive aeration and clarifier equipment, the JV fully utilised the improved access to deliver a safer more efficient approach.

The secondary treatment expansion included the installation of 64 grids of over 11,500 membrane disc diffusers. The installation of the diffusers was needed on a tight timeframe at the completion of the construction phase and required over 7000 man hours. The usage of permanent floor level access in conjunction with plant and equipment access at grade reduced the movement effort by 80%, having a commensurate risk reduction. Furthermore the follow-on quality bubble testing phase gained similar benefits as temporary scaffold towers could not be utilized due to the density of aeration grids on the floors. Over 100,000 man hours were utilized for the mechanical fit-out of the reactors and clarifiers with no related health and safety incidents.

As noted above the innovation grew from Safety-in-Design process of the overall BNR project. The cost to develop the innovative approach to additional access was inconsequential to the overall BNR design and engineering costs.

The JV recognized during the tender phase the inherent reduction in risk with the more efficient use of permanent staircases as part of the works which enabled them to reduce significantly the use of temporary staircase towers. At an average of $5000/month each the removal of four towers over the 8 month period easily covered the cost of constructing the concrete staircases.

With direct costs on the low level access points being offset by the reduction in temporary facilities the overall project costs was reduced by the indirect increase in construction efficiency rewarding both Watercare and the JV in ability to meet budget objectives.

6 CONCLUSIONS

With the delivery models for projects continuing to evolve and become more complex, the approach to SID on projects needs to adapt and evolve along with them. By bringing an intentional culture and emphasis on safety in design along with a culture of collaboration be it through the form of contract or having the right leadership team, the H&S outcomes from the SID process can play its part in making infrastructure industry a safer place to work within.

During the planning for any project the approach to SID should be considered and the methodology for its implementation tailored to suit the project. The delivery or procurement model for the project is a critical aspect to consider and how the SID outcomes might be impacted through the characteristics of that approach such as through differing levels of control over the design, the incentives to try to reduce costs, to the opportunities for increased collaboration. The risks and opportunities of the project model in relation to providing a good SID outcome should be considered and a strategy for implementing a robust SID response implemented.

The success of the SID outcomes for the MBRNU project came out of several factors including: strong leadership and a wider team commitment to improving H&S in all aspects of the project, a willingness of the main parties bring a collaborative approach to solving problems, a form of contract that supported the desire for collaboration, integration of the operations teams into the design and the use of 3D models to effectively communicate the design.

REFERENCES

Watercare Safety in Design Guide V1.0, DP-10 1/3/2017

Beca Introduction to Safety in Design Training Presentation

Beca's Safety in Design work instruction WI27/02

Photograph 8: View through internal access port/door in reactor