Refurbishing Outlet Valves utilising Shutdown Periods

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Awoonga Dam is the sole source of water for the City of Gladstone and the heavy industries in the region. The area's distribution reservoirs hold little more than a day's supply. Extended water supply disruption could have severe economic impacts.

The nine large valves in the inlet tower and river outlet of the dam cannot be inspected or maintained without shutting down the entire water abstraction system. Consequentially limited maintenance has been carried out in the 25 years since the valves were installed.

Recent Dam Safety inspections carried out for the dam owner, the Gladstone Area Water Board (GAWB,) noted some deterioration of the valves and recommended that the valves should be removed, inspected and refurbished as necessary

GAWB was thus presented with a daunting challenge to refurbish valves at Awoonga Dam, as it was generally believed that their removal for refurbishment would not be possible within the time limitations imposed by the system and customer requirements.

In 2008 GAWB commissioned GHD to develop a strategy to refurbish the valves within a 12 hour shutdown period. The strategy proposed and adopted required a rigorous risk management approach and close collaboration between GAWB's operational staff, two contractors and the consulting engineers. The work was successfully completed during 2011.

This paper discussed the strategies and processes developed and how the project planning, supervision and execution was driven by the risk management based approach. It also highlights some of the experiences and lessons learnt during the project.

Keywords: *Refurbishment, valves, risk management, outlet works, dam, maintenance.*

Introduction

Awoonga Dam is the sole source of water for the City of Gladstone and the heavy industries in the region which include alumina refineries, power stations, an aluminium smelter and a large port. The area's water distribution storage reservoirs hold little more than a day's supply. A disruption to the raw water supply from the dam extending more than 24 hours could therefore have severe economic impacts.

The current outlet works comprise a multiple inlet dry well Inlet Tower constructed during the 1985 raising, a wet well Auxiliary Inlet completed during the 1993 raising and a river discharge works.

The Inlet Tower has 6 operational inlets of 1.5m diameter at various levels leading into central pipe stack. Each inlet can be isolated using a DN 1500 butterfly valve. The outlet pipe leads via bifurcations to the Awoonga-Callide Pump Station, the Awoonga-Gladstone pump station and the river discharge works - refer to Figure 1. At the river discharge works the pipe bifurcates into a DN 900 and DN 2000 line. The DN 900 line is equipped with a DN 900 butterfly isolation valve and DN 300 needle valve. The main outlet has a DN 2000 butterfly valve for isolation and a DN 1900 fixed cone dispersion valve.

The outlet pipe layout precludes any section being isolated for maintenance while water is being extracted.

The 2007 Dam Safety Inspection Report recommended that the river outlet valves should be refurbished due to their corroded condition.

GAWB was thus presented with a seemingly unsurmountable challenge to refurbish valves at Awoonga Dam, due to the belief that their removal for refurbishment would not be possible within the time limitations imposed by the system and customer requirements.

In 2008 GAWB commissioned GHD to develop a strategy for the refurbishment of all the Inlet Tower and River Outlet valves limiting shutdowns to 12 hours.

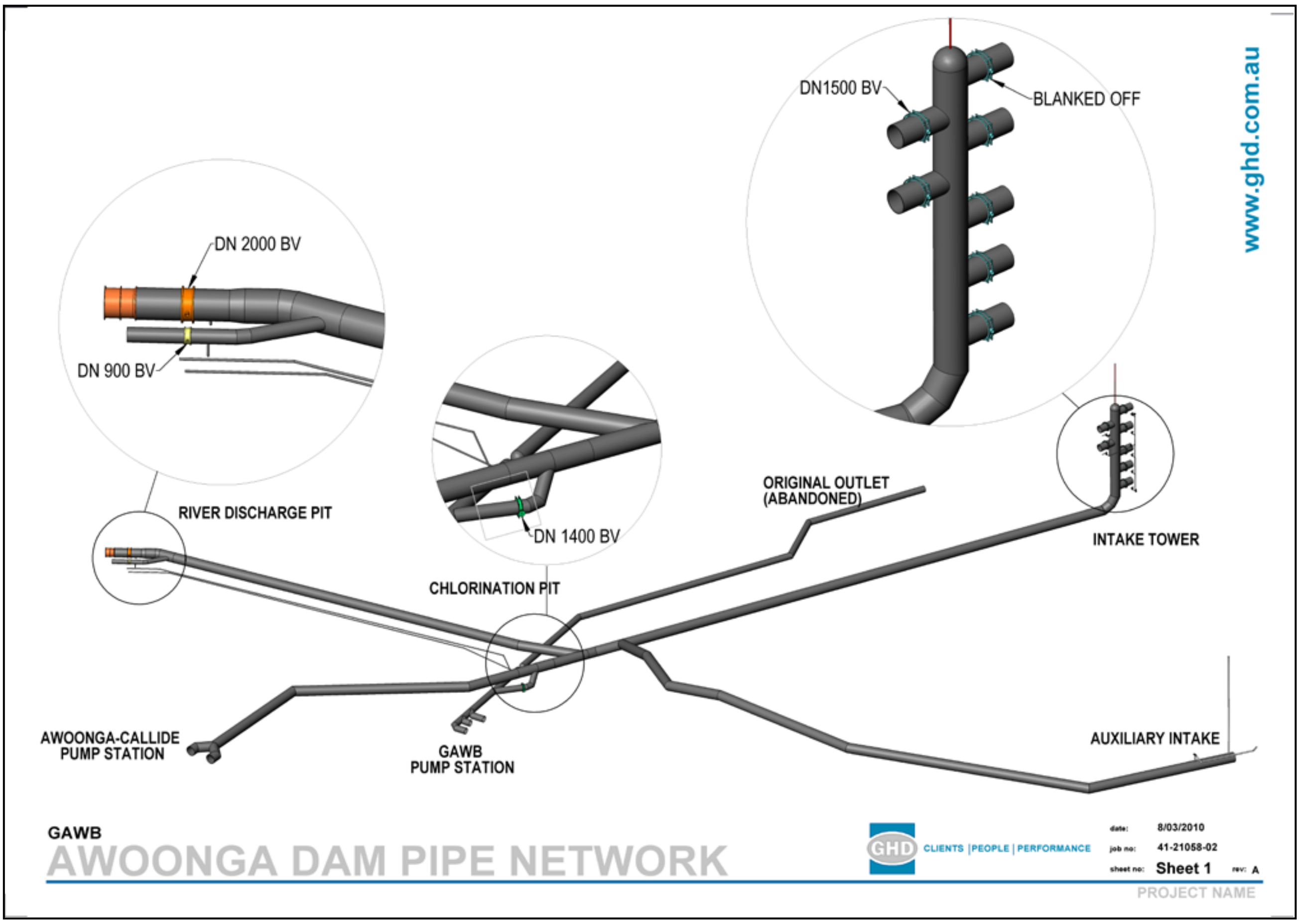

Figure 1: Layout of outlet pipe work

Equipment to be refurbished

The valves to be refurbished were located in 3 areas, namely the River Discharge Pit, the Chlorination Pit and the Inlet Tower. The River Discharge and Chlorination Pits are located downstream of the dam wall and the Inlet Tower upstream of the dam wall.

River Discharge Pit

The River Discharge Pit is at the end of a DN 2200 pipe that branches from the main outlet pipe. The smallest (DN 900) and the largest (DN 2000) butterfly valves to be refurbished are located in the River Discharge Pit. The DN 300 needle valve and DN 1900 fixed cone dispersion valve, located downstream of the two butterfly valves , could be removed without influencing pumping operations.

Chlorination Pit

A DN 1400 butterfly valve is located in the old chlorination injection pit and is used as an emergency isolation valve for the Awoonga-Gladstone pump station.

Inlet Tower

The Inlet Tower has a central pipe stack with 6 inlets; each isolated by a DN 1500 butterfly valve. A lift provides access to the eastern side of the valve platforms in the tower. The western side of each platform is open for overhead crane access to the platforms.

Valve Refurbishment Strategy

A detail work method statement for each valve, with estimated task durations, showed that all the valves could be removed and replaced with a blank flange, spool piece or refurbished valve within the 8 hour shutdown period. It was estimated that the DN 2000 valve and those in the tower where access is severely restricted, would be the most critical, placing the 8 hour shutdown period under pressure.

Detail analysis of the Operating Procedures in place at the time for draining and isolating the pipe work revealed that the 4 hour period previously used could be reduced to 1.5 hours by optimising the procedures and use of personnel. A 2.5 hour float in excess of the 8 hour shutdown period was thus created.

Having established that the allotted time was sufficient, the following strategy was developed:

- The contract would be performed in two parts, Part A for all the site work and Part B for refurbishment of the valves and supply of all replacement parts. Two separate contractors could be used.
- Risk Assessment Workshops were conducted prior to contract start to include the identified mitigation measures in the contract.
- Identify all long lead line items – seals, couplings, blank flanges and/or spool pieces. The Client was required to purchase these items before letting the contract.

- Each Contractor was to supply detail work method statements with estimated durations of each task before the shutdowns.
- The Superintendent would prepare a check list of all major tasks and preparations to be performed for each shut down.
- Schedule the site work to start with the easiest valves first to familiarise the Contractor with the work and to help identify unforeseen problems.
- The Client was to conduct practice shutdowns to streamline the pipe isolation, draining and refilling procedures.
- As much as possible pre-work to be done before the shutdown period. This included removing and greasing all flange bolts one at a time and removing all ancillary equipment not required the day before the shutdown, i.e. counter weights and actuators.
- Where possible, improve access to valves e.g. by enlarging the valve pit openings and widening the access way.
- Provide back-up for all critical equipment, including mobile cranes, generators and hydraulic torque wrenches.
- Make a detailed list of all the tools and equipment required during the shutdown, including correct size sockets for impact and hydraulic torque wrenches.
- Test all equipment the day before the shutdown.
- Provide spare bolts, nuts and washers, as well as spare gaskets for all flanges to be joined.

Scheduling of Work

Where possible, sequencing was arranged to reduce the site establishment costs. Only one valve was removed per shutdown, but generally 2 shutdowns were scheduled per week. The shutdowns were done on Tuesdays and Thursdays, with the pre-work on Mondays and Wednesdays. Fridays were for clean-up and valve despatch.
Due to all 6 tower valves being identical, the following sequence helped to reduce the overall number of shutdowns:

- Remove the lowest two valves and replace with blanked off spool pieces – this allows the system to be returned to service,
- Send the valves for refurbishment,
- Once the valves are refurbished, the next two valves are removed and replaced with the refurbished valves,
- The last two valves refurbished are then installed in place of the blanked off spools.

For the downstream valves the sequence was different as all these valves had different sizes:

- Remove valve and replace with blank or spool piece,
- Send for refurbishment,
- Replace valve once refurbished and commission.

Risk Management

Apart from technical challenges, the most difficult aspect of the work was the management of risk. Risks were identified, assessed and mitigation measures developed through a rigorous approach including the development of a Project Risk Register.
GAWB policy is that no work should be carried out unless all risks have a Low rating. Workshops were held to identify all project risks and all practical mitigation measures to reduce all risks to a Low rating. It was however not possible in all cases to achieve better than a Medium rating.
The first workshop was held prior to finalisation of the tender documents and further Risk Workshop was held jointly with the successful tenderers, GAWB and GHD personnel who were to be involved in execution of the project.
The most significant risks identified were:

Serious Injury or Fatality on Site

Should a serious injury or fatality occur on site during a shutdown period, various protocols required by Workplace Health and Safety (WPHS) would have to be followed. These could cause considerable delays while inspectors are mobilised to site carried out the subsequent investigation. Delays could be as long as a few days which would result in significant water supply interruptions. Mitigation measures identified included notifications to WPHS and having their inspectors on short notice standby. Rigorous Safe Work Methods were compiled and implemented for all sections of the work. With the above measures in place the possibility of a serious injury became remote and although the consequences were high, the risk was reduced to moderate.

Principal Supplied Items

The long lead line items, including new couplings and main valve seals sourced from Spain and Japan, were imported in advance by GAWB.
Risks associated with the couplings were that they were ordered from measurements taken on the existing pipes and were specifically made for each installation. Should these items not fit, they could cause significant delays during the shutdown period. Mitigation measures included dimensional checking of the pipe diameters.
The seals for the valves were imported from Kubota in Japan who was the original valve supplier. The seals could not be test fitted until the valves had been removed which could potentially have delayed the valve refurbishment. It was decided that the Part B contractor would identify Australian companies who would be able to manufacture these seals on short notice should it be found that they do not fit.
The above mitigation measures reduced the risks to medium in both cases.

Power Supply Interruption

Power supply interruptions had different consequences for the various work sites. In general the potential consequences were greater for the outlet tower work than for work at the valve pits downstream.

Outlet Tower Works

Grid power failure during the shutdown period would have resulted in the functional loss of the overhead cranes, lifts, lights and sump pumps. This would have resulted in personnel or equipment becoming trapped in the lift, or the load on the overhead crane being suspended in mid-air. A backup power generator was therefore wired to the tower distribution panel for quick changeover in case of mains failure.

As and additional measure, a schedule of planned power outages was obtained from the power company and shutdown work planned around these.

Downstream Works

No mains power supply was available at any of the two downstream valve pits. The contractor supplied a generator for lighting and power tools. He also provided a backup generator for standby.

Mobile Crane Breakdown

Breakdown of a mobile crane during the shutdown period was identified as a significant risk. A backup mobile crane was therefore positioned so that the primary crane did not restrict its ability to handle the load in case the primary crane broke down.

Figure 2: Access restrictions to Outlet Tower

Shutdown Time Overruns

A strict limit of 12 hours for the shutdown was set by GAWB to minimise the risk of water shortages to customers. The following control measures were implemented to reduce the risk to moderate.

- As much pre-work as possible was performed to limit the amount of work required during the actual shutdown period. Only work that could not be done in advance was performed during the shutdown.
- A detailed work plan with activities scheduled to 10 mins intervals, clear go, no-go control points and identified float for each shutdown period was prepared. The Superintendent would monitor progress closely for compliance with the plan.
- Competent staff were used for all aspects of the work. Shut down pre-work components would provide site specific training and result in more efficient and safer work during the shutdown period. The same work crew would be retained for the duration of the contract.
- Backup for critical elements was provided to ensure that minimum time was lost in case of break downs, e.g. hydraulic torque wrenches and sockets.
- Key backup personnel, familiar with the site and project, were on short notice standby.
- All GAWB and Council reservoirs had to be full at the start of each shutdown. The reservoir levels were monitored at hourly intervals during shutdowns.
- Key customers were given advance notice of planned shutdowns to enable them to take precautionary measures, reduce consumption during the shutdown and make their own emergency response planning.
- Contingency plans were put into action to ensure the availability of additional resources should the work force on site become overwhelmed or otherwise unavailable.
- Responsibilities and lines of communications were clearly allocated.
- Fatigue management plans were in place, part of which was that a full day break was required between shutdowns.
- Weather conditions were monitored against the possibility of rain or thunderstorms developing during the day.
- The facilities at the dam including the overhead crane and lift were refurbished prior to the works commencing.

Single Isolation, Risk of Engulfment

Working in the tower and valve pits with only a single point of isolation was considered a severe risk. All the valves fell in this category. Control measures included:

- Strict adherence to the GAWB shut down, isolation and lock-out procedures.
- Emergency evacuation plans were put in place and all personnel informed.
- Personnel in the valve pits restricted to the minimum required.
- An efficient warning system was put in place.
- Work was not permitted on upstream equipment during the shutdown period.
- All downstream discharge valves were maintained in the fully open position.

The above measures reduced the risks to moderate.

Contract Provisions

Appointments

Due to the start stop nature of the contract, only companies located within the Gladstone area were considered. Rigorous selection criteria were employed to ensure that the contractor selected was capable, experienced and had the necessary resources to complete the work within the time constraints. RCR Resources Pty Ltd was selected for the site work. The valve refurbishing contract, Part B, was let to TEMMCO Pty Ltd, based in Rutherford, NSW. Both these companies impressed with their experience, capability and commitment to provide high quality service and their willingness to work together.

Description of Works Progression

All the shutdowns followed the same basic procedure, with minor variations depending on which valves were removed or installed. The long lead items were procured prior to the shutdown. The day before the shutdown the cranes were set up, bolts removed, greased and replaced, backup equipment tested and all other preparations completed. The shutdown day would start once the contractor was present on site and had indicated readiness to proceed. The pumps would then be stopped, the pipes drained and all equipment locked and tagged. The shutdown work would then commence according to the work method statements prepared. On completion of the work, the Superintendent would sign off on the Quality Control Plan and the system would be re-filled. Whenever possible, two shutdowns were done in one week, on a Tuesday and Thursday, allowing Mondays and Wednesdays for pre-work.

The removed valves were transported to the refurbishment workshop where they were stripped and inspected. A refurbishment specification was prepared based on the problems identified. The aim of the refurbishment was to improve the corrosion protection system applied to each valve and prevent the need for major valve works in future. To this end high corrosion areas were filled with an epoxy based mastic – Belzona 1111 – which is machineable and extremely hard wearing. Interfaces between stainless steel inserts and mild steel were machined to provide a key and also sealed with Belzona. A high performance paint system was then applied after which the valves were assembled, pressure tested and returned to site.

Figure 3: DN 1900 cone valve removal

Difficulties Encountered

Weather conditions

- High rainfall filled the dam to overflowing in a matter of days. The large flow over the spillway resulted in high tail water levels, flooding the river discharge pit and delaying the removal of the DN 2000 butterfly valve and DN 1900 cone valve by 3 weeks. A coffer dam was eventually constructed to allow removal of the cone valve.
- Extended wet and cold weather delayed painting of the refurbished valves on a number of occasions.

Supplies and Equipment

- Some of the valve seals could only be ordered once the valves had been stripped. Supply of the seals however took much longer than initially indicated by the suppliers. This was accommodated by changes to the contract programme as the end date was not fixed.
- Notwithstanding the actuators having been sent to the agent for servicing, during the Factory acceptance test on the first valve it was discovered that the actuator did not work. Investigations revealed that the phase protection relay in the actuator had become brittle and that vibrations during transportation had caused it to disintegrate. The relay units on all the subsequent valves had the same problem.
- Rented hydraulic torque tools for flange bolt tightening were used and initially worked well but during a longer valve installation the machine overheated and the backup unit had to be used. More robust machines that did not suffer from overheating during continuous use were subsequently sourced.
- Incorrect adjustment of the hy-torque machines resulted in bolts shearing during second stage torqueing. It was decided forthwith to machine the ends of 4 bolts per flange and set the hy-torque machines according to the extension measured.

General

- During original construction works the valves were installed before the concrete works were completed. Valve pit openings provided were not large enough to get the valves out and these had to be enlarged before the shutdowns could commence.
- In preparation for the DN 1400 valve removal in the Chlorination Pit, baskets containing all the new bolts and hydraulic torque wrenches were placed inside the valve pit in readiness for the spool piece installation. When the lines were drained the valve pit partially filled with water, drowning both hy-torque machines rendering them inoperable. Fortunately the electric impact wrenches produced approximately the required tightening torque, allowing the spool piece to be installed and the pipe refilled without time delays.
- Grit blasting of the valves revealed more corrosion damage than anticipated. In most cases this could be successfully repaired by welding or epoxy type filler. The edge of the DN 1400 butterfly valve was however corroded beyond repair. The valve had to be scrapped and a new one with a 6 month lead time procured.
- The tower valves are installed with the actuator mounted on the opposite side of the valve to which it had to be removed. The platform spacing is so confined that parts of the actuator and hand wheel protrude between the next platforms beams. To remove and install the valves the actuators had to be removed from the reduction gearboxes. During one

shutdown the actuator hand wheel assembly had been misaligned by 15 degrees during servicing. This was not noticed until the valve was being installed. The misalignment resulted in the actuator and hand wheel interfering with the platform beams above. This unforeseen problem resulted in the shutdown extending to nearly 10 hours.

Figure 4: Restricted space during tower valve installation

Lessons Learnt

The following lessons were learnt from the project:

- The contractor was required to produce a detailed construction work method statement and programme for each shutdown period. These were compiled by the site supervisor and helped him to logically sequence and plan the work and identify any additional resources required. It also promoted a buy in into the planning process by the people who would do the actual work. Means of streamlining the process noted during the shutdowns were fed back into the next work method statement.
- A check lists was used to keep track of all major tasks to be completed prior to and during the shutdowns. This was circulated before each shutdown to all affected parties. No work would commence unless all tasks had been completed.
- Planning and preparations cannot be too detail. It was found that seemingly minor matters could result in significant delays, e.g. gasket joints were incorrectly assembled or shifted during installation and were only noted when placed under pressure, studs used on one valve were different size to those on other similar valves resulting in the correct size socket for the torque tool not being available. With better preparations or planning, these issues could have been prevented. Removing and greasing the flange bolts before the shutdown speeds up dismantling during shutdowns. In some instances it also revealed bolts that could not be accessed with the valve in a closed position. This could have caused delays as the actuators are disconnected for the shutdown work.
- Infrequently used older equipment (lifts, overhead cranes) when subjected to repeated use often result in break downs. Even though the overhead cranes were serviced and inspected prior to the project start, old electrical equipment failed due to repeated use. The control system for the lift had similar problems and the electrical gear on both had to be upgraded.
- The use of 3D rendering of the pipe layout improved the understanding of all processes involved. A 3D model of the tower, pipe stack and platforms also facilitated the simulation of the valve removal procedures to determine space requirements and the most effective work methods.
- Developing a team approach with good co-operation and mutual respect involving the Client, Contractors and Superintendent contributed immensely to the successful completion of the contract.

Conclusion

Although it was initially thought by the Client that the valve refurbishment works could not be done with the existing time constraints, it was shown that this was possible. Careful planning and risk management reduced unforeseen problems to a minimum and allowed them to be handled in an orderly and efficient manner.

The participation of all affected parties – especially the dam operators and contractors – during risk management and planning resulted in a buy-in into the process and a shared understanding of the risks. It also resulted in a better understanding of how the system operates in practice.

The successful completion of a contract depends to a large extent on the maintenance of good relationships between the Contractor, Client and Superintendent.

Implementing a regular inspection and maintenance plan together with the improved corrosion protection system should reduce the need for major valve refurbishment works in future.

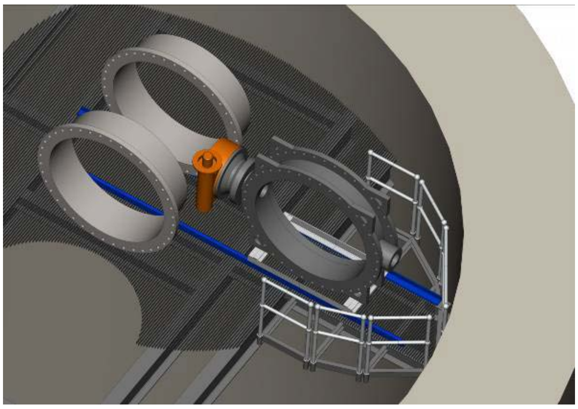

Figure 5: 3D simulation of tower valve removal

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