OPERATING WATER AND WASTEWATER PLANTS ON BARROW ISLAND

Paper Presented by:

Stephen Martin

Author:

Stephen Martin, *Project Manager, Operations & Maintenance*

Monadelphous Engineering-Water BU

37th Annual Qld Water Industry Operations Workshop
Parklands, Gold Coast
5 June to 7 June, 2012

OPERATING WATER AND WASTEWATER PLANTS ON BARROW ISLAND

Stephen Martin, *Project Mgr, Ops & Maintenance*, Monadelphous Engineering-Water BU

INTRODUCTION

The Gorgon project is one of the world's largest natural gas projects and the largest single resource natural gas project in Australia's history. It includes the construction of a 15 million tonne per annum (MTPA) Liquefied Natural Gas (LNG) plant on Barrow Island and a domestic gas plant with the capacity to provide 300 terajoules per day to supply gas to Western Australia.

Gorgon LNG will be off loaded via a four kilometre long loading jetty for transport to international markets. The domestic gas will be piped to the Western Australian mainland.

At the height of construction, in 2012, there will be 6,000 workers on the island. Those people need to be fed, watered, housed and entertained. Barrow Island is 130km off the WA coast so all the potable water needs to be generated on site and wastewater needs to be treated and disposed of on site. To make things more difficult, Barrow Island is an A-Class nature reserve and therefore the license conditions for all plants are quite onerous.

Water is produced through two different treatment plants:

- A 500kL per day brackish water RO Plant which is fed by 3 inland bores;
- A 3.8ML per day sea water RO plant (SWRO).

Discussion will focus on the SWRO plant. The main issues can be summarised into the following

a. The feedwater characteristics were outside of the design parameters for the plant – temperature, pH and turbidity were all above the limits given to the plant designers;
b. MF and RO filters have been failing prematurely;
c. High pressure pumps have failed prematurely – mainly due to excessive vibration with the pumps being housed in containers;
d. Hardness of the permeate water has been difficult to correct because the high pH is affecting the calcite filter processes.

There are two separate wastewater treatment plants on the island:

- A 600EP modular MBR plant supplied by CRS;
- A 3750EP modular MBR plant supplied and built by Tristar.

Both plants have had similar problems so for most of the issues we will have a couple of examples to work through. The issues can be summarised in the following categories:

a. High MLSS results mainly due to sludge treatment processes that were not working, creating an inability to waste. Sludge age problems are also associated with this issue;
b. Difficulty with phosphorous removal;
c. Denitrification issues, mainly from over-aeration which also causes alkalinity problems;
d. Equipment failures.

Operating in this harsh and remote location creates some unique problems that are common to both water and wastewater – mainly logistics, access to people, skills, information and plant, and premature equipment failure. The lessons learnt from dealing with these issues in a remote and harsh location are discussed below.

1.0 3.8 ML/DAY SEAWATER RO PLANT

The main water supply for Barrow Island is through a modular seawater Reverse Osmosis plant. The plant was constructed in two phases, with two different specifications, but essentially all commissioned at the same time in January 2011. The modular MF/RO Treatment plant consists of:

- A seawater intake system, including 5 x 70kW submersible pumps;
- A pre-treatment system with hydro-cyclones and 70 micron disk filters;
- 5 x containers with Siemens Memcor UF filters, each capable of treating 1,556 m3/day;
- 5 x containers with RO filter systems, producing up to 3.8ML/day of permeate;
- Post Treatment systems consisting of CO_2 injection and calcite filters and Sodium Hypochlorite dosing for disinfections.
- A brine treatment and disposal system, utilising Baleen Screens.

Monadelphous have two operators stationed at this plant during the day shift (5:30am to 5:30pm) and one on the night shift.

There have been a number of "lessons learnt" in the building and operation of these plants that I would like to share:

1 ***Logistics in such a remote location make all phases of the contract more difficult and more expensive.*** Chemical deliveries, for example, need to be carefully planned and managed to ensure that sufficient chemicals are available for the treatment process. Sodium Hypochlorite is a good example – it takes about 3 weeks from the time the chemical leaves our suppliers in Perth to the time it reaches Barrow Island. It was transported on open trucks, uncovered and exposed to temperatures of 35 to 45^{o}C. By the time the Hypo reached the island it was 3% in strength or lower, instead of the required 12.5%. Hypo is now transported in refrigerated containers and the turn-around has been reduced to 2 weeks. Chlorine strength is still around the 9% mark by the time it is used at the plants, but it's a vast improvement for us.

2 ***More care needs to be taken with the transportation and storage of membranes.*** Because of the stringent quarantine rules for the island, the preserving fluid was drained from every membrane before they were allowed to send them to the island. The membranes then sat in un-refrigerated containers waiting for the plants to be commissioned for up to 3 months. As a consequence nearly every UF and RO membrane on the site has already been replaced and the replacement membranes are also failing prematurely. We now have procedures in place to bring the membranes to the island in refrigerated containers, with the preserving fluid in place. We have membrane "maps" and we conduct sonic tests and salinity tests regularly to ensure the membranes are operating to specification.

3 ***Cleaning should be done on a time basis not waiting for alarm conditions to be met.*** Because of the difficulties with logistics and chemical handling on the island, CIP cleans were not being carried out on a regular basis. Operators were waiting for high Differential Pressure (DP) alarms before thinking about doing a CIP. It would then take 2 to 3 days before a CIP could be completed, by which time the plant was faulting out on High-High DP alarms. Now we have a CIP schedule across all plants

where the cleans are carried out by a dedicated crew, regardless of the DP readings. Overall performance of the plants has improved considerably since taking that move.

4 ***High temperature and high salinity sea water is much more difficult to treat.*** The rate of water permeation through the membrane increases as the feed water temperature increases, since the viscosity of the solution is reduced and higher diffusion rates of water through the membrane is obtained. Increasing feed water temperature will yield lower salt rejection or higher salt passage due to higher diffusion rate for salt through the membrane. Figure 1 (below) shows the variation of water flux and salt rejection as function of temperature 1. Temperatures of the feed water on Barrow Island are exceeding 35°C which is causing the plant to operate out of specification. Higher salinity rates and reduced membrane life are the two most concerning aspects for this project. We have tried to overcome the salinity problem by increasing the feed pressure, but that also exacerbates the membrane longevity problem.

5 ***We have had major problems with all RO High Pressure Pumps due to excessive vibration.*** The pumps are mounted in normal sea containers that were not stiffened to counteract the vibration caused by the pumps and the 70 or 90kW motors that run them. We have already changed out 3 of the 5 pumps which is an expensive and time consuming task. We are now stiffening these containers using a combination of concrete blocks, steel beams and stainless steel pins. The moral of the story is that equipment of this type cannot be housed in ordinary sea containers.

6 ***Very fine sand is difficult to filter.*** Pre-treatment for the MF filters consists of hydro-cyclones and 70 micron disk filters. The sand being drawing into the inlet lines is so fine that it is passing straight through the hydro-cyclones, remaining in suspension through the balance tank and being caught in the disk filters. The disk filters were backwashing continuously and they had to be changed out on a daily basis to soak the filters in solution and clean them by hand. We have instituted some maintenance on the inlet pipe – dredging around the openings and regular cleaning of the pipe upstream of the pumps - and this has drastically reduced the problem for the majority of the year. But there is little that can be done during the storm season, when turbulent conditions make the feed water turbidity very high. At those times we are resigned to the fact that the disk filters will need to be changed out twice a day. This manual process takes 2 operators more than 4 hours to complete which has a large impact on our resources.

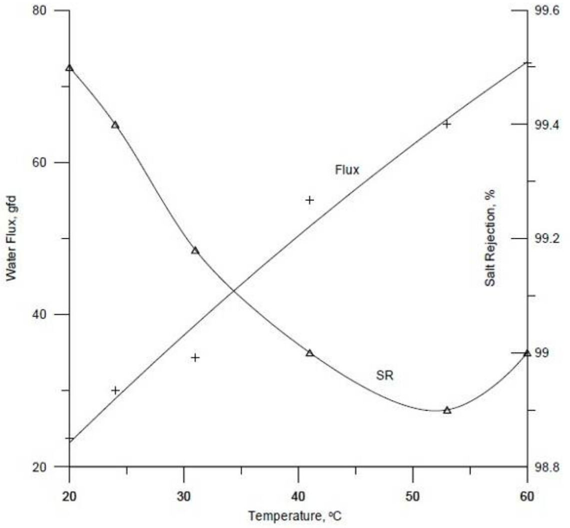

Figure 1: ***Water Flux and Salt Rejection as Function of Temperature***

Even temporary plants need protection from sea water corrosion. The plants have had numerous outages due to equipment breakdown, with the main cause being corrosion. Balance tanks, pumps, pipelines, fittings have all been affected at some stage by corrosion due to connection with sea water or RO permeate. The lesson learnt is that it is cheaper in the long run to spend more in the construction phase of the project and specify 316SS or other corrosion resistant material whenever contact with seawater, RO permeate or chemicals is involved.

2.0 MRB WASTEWATER TREATMENT PLANTS

Monadelphous are operating and maintaining two different MBR plants on Barrow Island:

- A 3750EP containerised MBR using Toray flat sheet membranes;
- A 600EP packaged MBR using 7 x Memcor MBR modules.

Whilst both plants are quite different, they have suffered from the same problems:

1. Equipment breakdowns due to the "temporary" nature of the plants;
2. Lack of redundancy in the system makes operations much more critical;
3. Low chemical strength affecting chemical cleans and disinfection;
4. Influent strengths well above design limits;
5. Poor denitrification due to over aeration;
6. Insufficient solids handling.

As with the water treatment plants, the wastewater plants have suffered a series of breakdowns and problems due to the "cheaper" specifications used during the construction phase. It has meant that we need to keep spares on site for all critical elements of the plant (Pumps, Blowers, Screens, On-line monitors, etc) which is a very expensive exercise in itself. If the plants are only going to be temporary, it is not economically viable to carry thousands of dollars of spares that somehow need to be sold off once the plant is no longer in use. But with the logistic problems discussed above, and the lack of redundancy discussed below, it is vital that we have ready access to all major components so that we can keep the plants running. These types of considerations need to be made at the design or purchase phase of the project. However project managers seem to be convinced that reducing the up-front costs, especially for "ancillary" items such as water and wastewater plants, is the best course of action. Hopefully experiences with projects like this one will convince project managers that better specifications up front will reduce the life cycle costs of the plants and improve outcomes for the project as a whole.

A good example of the above discussion can be found in the following the scenario. The 600EP plant services an area on the island that houses about 500 personnel and a number of offices for WA Oil and various contractors on the project. There is only one biological air blower servicing the plant. That blower is slightly undersized for this plant and basically runs between 90 and 100%, 24/7. If this blower were to break down it would take over 2 months to either get a replacement on site or to send that blower away for repair. In that time the offices would all need to be relocated or tankers used to transport the sewage to the other WWTP which is roughly 10km away. The residents would definitely need to be rehoused as there isn't sufficient tanker capacity to transport that amount of sewage. As there are not 500 beds available in the alternate accommodation

area, up to 300 people would need to be removed from the island which will cost thousands in air fares and lost wages, and slow the progress of the whole project.
Redundancy is an important issue for any operating plant. Redundancy allows the operator time to rectify issues and to carry out routine shut-down maintenance. But redundancy costs money and therefore, on projects such as the Barrow Island one, very little redundancy is built into the system. Smaller balance tanks allow very little down time for CIPs or shut-down repairs. Critical components like inlet pumps, recirculation pumps and screens, that do not have a duty/ standby arrangement, could lead to lengthy down time and necessitate the carrying of expensive spares. Building redundancy into any plants will improve reliability and allow the operators to focus on the correct operation and maintenance of the plants.

Elevated Trans-Membrane Pressures (TMP) have been a constant battle with both the MBR plants. Investigations showed that the CIP process at both plants was an automated procedure, with a defined amount of chemical being delivered to the filters. With the low chlorine strength problem mentioned above, the CIP process was not sufficiently cleaning the filters and biological growth build up was severely affecting the filters. When we increased the chemical doses for CIP to 3 times their original settings we noticed a vast improvement in performance. We now run the CIP processes manually and test the strength of the chlorine before starting a CIP, adjusting the dose rate to suit.

The table below shows the influent specification for the larger WWTP and the average actual figures being received at that plant.

Influent Specification	Average Results
BOD Concentration = 214 mg/L	380 mg/L
TSS Concentration = 200 mg/L	544 mg/L
Total Nitrogen = 40 mg/L	120 mg/L
Total Phosphorous = 14 mg/L	18 mg/L

We have had to make a number of adjustments to the plant's operating parameters to achieve the effluent standards that we are required to meet (see table below).

Total Nitrogen	< 20 mg/L
Total Phosphorous	< 6 mg/L
E.Coli	< 10 CFU/100mL
BOD5	< 20 mg/L
Total Suspended Solids	< 30 mg/L
pH	6.5 to 8.5
Turbidity	< 5 NTU (95%ile)
Chlorine residual	< 2 mg/L

Poly Aluminium Chloride (PACL) is added to the influent to aid Phosphorous removal. We have increased dosage rates 3 fold to achieve the required effluent limits. This amount of PACL dosing comes with its own problems, such as increased settling and thickening of sludge. We have increased the efficiency of the screens to remove as much up front as possible and we have increased wastage at the plant.

The massive increase in influent TSS has meant a lot more wasting than design and the limitations of the sludge handling system have made that end of plant difficult to manage (see below). But the hardest parameter to manage has been Total Nitrogen. We have reduce air input to 1.5 mg/L in an effort to reduce the amount of Dissolved Oxygen (DO) being transferred to the anoxic zone through the Return Activated Sludge (RAS) line. Effluent ammonia is virtually zero, even at the lower DO settings. The MBR tank is also agitated by air so the mixed liquor receives a second burst of oxygen there.

We made the mistake of reducing recycle rates from 6.5 times the inflow to 5.5 times, in an effort to reduce the DO in the anoxic tank. Nitrogen results actually worsened on these settings, probably due to a lack of food in the anoxic zones. Nitrogen results are currently averaging around the 20 mg/L mark but we are going to trial some sucrose dosing in an attempt to get below that mark.

Solids handling is an issue at both plants and it is an area of wastewater treatment that often gets neglected. But if your solids handling is not working well it can affect the whole system upstream. One would image that, being on a remote island, the designers would have opted for a solids handling solution that would give the least amount of dry solids so that transportation and handling costs would be minimised. However, the 600EP plant relies on a geobag and the 2500EP has one small centrifuge. We have had various problems with both systems over the past 12 months which have prevented us from wasting for periods of up to 2 weeks at a time. Both plants also have relatively small digesters, which again reduces the redundancy required at that end of the plant. The result has been that the plants have been running with very high MLSS concentrations and sludge ages.

We have increased to 2 geobags on duty at the 600EP plant, alternating between the two so that the drying time is effectively doubled. We have also introduced a polymer into the waste stream to speed up the dying process.

A second centrifuge is being installed at the 2500EP plant to provide more capacity and give us some time for maintenance and breakdowns at that plant.

These MBR plants can run at quite high MLSS figures because of the high influent TSS being received. We aim to maintain a sludge age of 25 to 35 days. This may seem a wide range but the reality is that there is a wide range for influent rates experienced at both plants. The numbers of workers on the island can change by up to 1,000 over a couple of days and flow rates are also affected by roster days and the infamous half day Sundays. With these large fluctuations in flow rates and influent quality the operators need to be diligent in monitoring their plants and adjusting the settings to suit the current conditions.

3.0 CONCLUSION

Large water and wastewater plants are becoming much more common on mine sites throughout Australia and therefore members from WIOA will become more and more involved with such facilities. It is important that we learn the lessons from the projects that are currently in operation so that we can improve these plants, ensuring safe drinking water for the people on site and improved environmental outcomes.