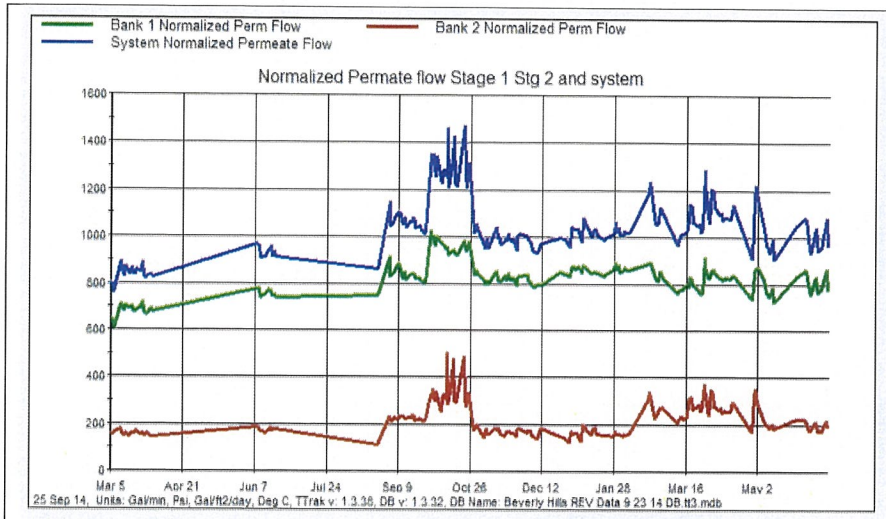
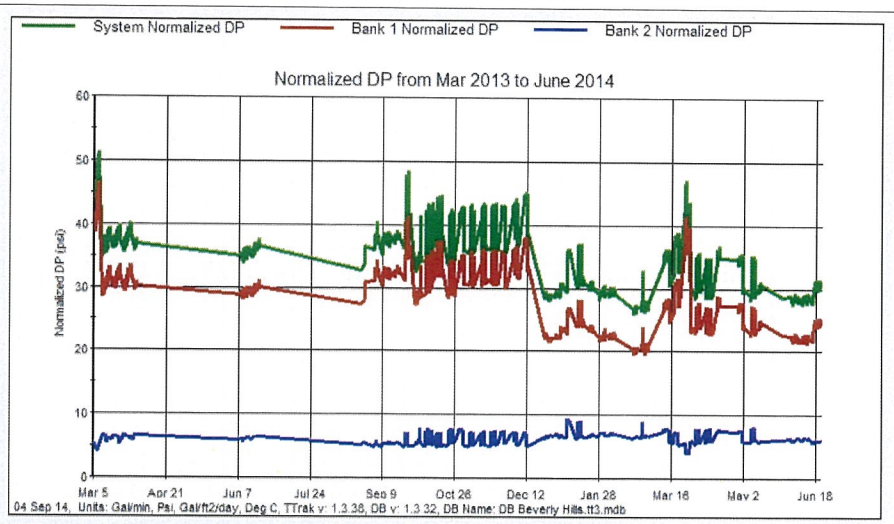
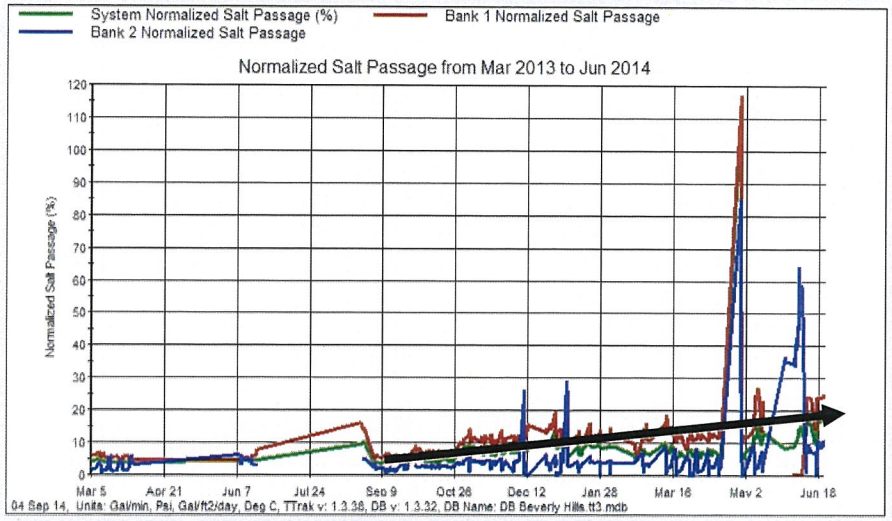
Table 4 - Normalized RO Data, Using Toraytrak Software







The three charts provided in Table 4 have been developed using data gathered from the HMI and using Toraytrak™ software from Toray Membranes. RO normalization can be performed using membrane supplier's software (usually available free on the internet) or developed independently on an excel spreadsheet. Ideally, the calculations for normalization can be included in the HMI/SCADA and trends appear here automatically.

We understand that the normalization software at site had fallen into disuse, and so Hazen and Sawyer have re-established trending using this software using historical data, installed it on a City machine, and provided a standard operating procedure for its use. The software we have used at this time is Toraytrak™, however if another model membrane is selected for membrane replacement we can work to establish normalization for that model.

The three graphs shown include:

- Normalized permeate flow – this provides a flow rate compared to the original baseline, corrected for temperature and feed salinity. It has been performed on both individual stages as well as the unit overall. Generally, a trend downwards indicates an increased resistance to flow usually from some form of fouling or scaling. In the case above, normalized flow appears variable but with no discernible reduction overall. In fact, there may have been a reduction in flow resistance over time.

  This is not typical performance, and one hypothesis is that a lower resistance to flow may be related to a loss of membrane rejection. The membrane material may have become damaged to the extent that it provides less flow impedance.

  An additional item to note is that the permeate flow from the second stage is quite low. Typically we expect a flow rate approximately 40% to 50% of the first stage permeate flow. The lower than expected flow may be due to insufficient driving pressure at the hydraulic turbocharger, that provides additional boosting pressure to the second stage membranes. The backpressure is provided by the concentrate valve, which is currently not in operation on the unit, but rather is replaced with a restricted pipe spool.

  .

- Normalized Differential Pressure – this provides an indication of any resistance to flow or blockage on the feed/brine channel of the membrane. Higher normalized DP is usually an indication of fouling.

  In this case, it appears that there has been a gradual reduction in normalized differential pressure. This usually only occurs in cases where fouling has been successfully combatted. In this case, it is unclear if this is a true reduction in fouling, or if as for normalized flow it is indicative of damage to the membrane systems – with RO

membranes providing less resistance to flow.

- Normalized Salt Passage – this provides an indication of the RO system salt rejection capability.

  In this case, there is a very large increase in salt passage through the membranes. This is most likely indicative of membrane damage, o-ring leaks or both. As noted previously with the increase in RO permeate TDS, the salt passage is 3 to 4 times higher than at the start of the logging run.

  We note that membrane autopsies are currently under way which may confirm the condition of the membranes and provide insight into what has caused the potential damage.

Recommendation: We strongly recommend that normalized data be logged regularly to provide a clear indication of RO performance. Hazen and Sawyer have provided software and a procedure for this to take place.

Weekly Operating Log Sheet

A weekly plant operating log sheet is completed by plant operators at each shift (we note that during our review on our recommendation the frequency was reduced from once per shift to once per day). The log sheet contains over 130 items that are required to be logged each day. We have previously mentioned this log sheet in our discussion on water quality monitoring.

In general, we believe that there is too much information required on this log sheet, and that while a great deal of data is gathered, there is no evidence of much analysis of the data. We do agree that a checklist of items per shift is very important, however with too much information key important areas are hidden beneath the piles of data. Additionally, much of the data that is recorded is (or should be) available at the HMI where some of the key parameters could be trended to provide an easier visual guide to performance.

The log sheet appears to be a remnant of an on line excel spreadsheet as there are a number of calculations in the sheet. These are typically not filled out currently, and display a "#DIV/0!" where a calculation would otherwise have been.

Rather than list each individual item, we have provided an updated log sheet which we believe is sufficient for operations. In it, we have recommended a reduced frequency and a reduced number of parameters. We have identified a number of parameters which can be trended on

the HMI, rather than gathered on the spreadsheet manually daily – we recommend the effort be put into reviewing trends rather than gathering numbers.

We have also removed the daily monitoring of each RO pressure vessel. This testing is typically only performed on a weekly or even monthly basis, as a follow up to normalized data observations which provide a review of overall plant performance. It is commonly used as a troubleshooting exercise to identify o-ring leaks or damaged membranes within vessels. This is time consuming, and regular testing does not provide sufficient value at the current frequency.

The proposed revised Weekly Operating Log Sheet has been included as an appendix to this report.

Recommendation: Review the recommended Weekly Operating Log Sheet provided and work to implement in lieu of the current worksheet.

Flow Meter Reading Form.

A flow meter reading form records major flow rates in and out of the plant on a daily totalized basis. This form includes:

- Plant influent Flow
- Plant effluent flow
- RO Feed Flow
- Brine Discharge
- First and Second Stage RO Permeate

These are recorded on to a master spreadsheet with monthly tabs.

Recommendation: We recommend that these totalized flows be configured on the HMI/SCADA to provide an automated flow balance record.

We further recommend that a regular trend of plant influent flow, plant effluent flow and brine discharge be recorded in trend format to provide good tracking of plant production and waste volumes.

Electrical Reads

Electrical power consumption is recorded on a daily Electrical Reads spreadsheet. This records all electrical consumption within the building, and separates the plant consumption from other

unrelated items in the building. Electrical power consumption is useful if calculated as a power per unit volume of water produced.

Recommendation – Include a calculation to produce a kWH/1000 gallons or kWh/AF for water produced to provide a useful target for power consumption.

Non Conformances and Corrective Actions

It is important that operations teams continually learn from any plant or process non-conformances, safety incidents, operational mishaps or other operational problems that may occur. It is also important in many cases to communicate the issue, and corrective actions taken, to various stakeholders including plant management, City administrators, regulators and customers.

During our visits, there did not appear to be any formal process for managing non conformances and documenting corrective actions.

Recommendation: We recommend that a system of non-conformance and corrective action processes and procedures be developed. In particular we recommend the inclusion of:

- An incident management procedure – this details how to manage the incident process for any incidents. It assists in classifying what kind of incident it is, who needs to be contacted and by when, what needs to be reported and by when, and how any follow up investigation must be conducted.

- An incident report form – this provides a format to report the incident, document immediate actions taken and record communications of the incident.

- An incident investigation procedure – outlining how we can learn from the incident, and what changes to procedure have resulted.

During one of our visits we have shared a possible incident reporting and investigation process used at another facility, which could be used as a basis for development of a process for Beverly Hills.

Safety and Emergency Management

During the site visit, we worked to identify safety and emergency management processes or information. Some facilities develop specific safety and emergency management plans, which provide details on managing various safety aspects throughout the facility.

The safety of site staff, and the general public, is always a first priority for any organization. At the RO Water Treatment Plant, and in the distribution system, there are a number of inherent safety hazards including:

- High operating pressures.
- Dangerous chemicals.
- Working in restricted, confined spaces.
- Driving, particularly to and from distribution sampling and maintenance locations.
- Trip and fall hazards.
- Lifting hazards.
- Flammable materials.
- Earthquakes.

During the site visits, there appeared to be limited safety information available and in use by operations, with no overall safety plan at the site. As discussed previously, there was a small amount of information contained within the OMMP, although this is inadequate to sufficiently cover all safety issues. Other various pieces of documentation are available at the plant, including chemical MSDS, some chemical spill management plans, and some procedures.

Recommendation: We recommend that a more comprehensive safety plan be developed for operations at the Beverly Hills facility. This could either be included as a portion of a revised OMMP, or as a stand-alone document that may be referenced by the OMMP. The intention is not to create a large and unwieldy document, but rather to make sure that operations staff understand safety hazards, understand how to manage them and are able to manage through a safety emergency. Elements may include:

- Responsibilities and accountability within the organization for safety.
- Safety policies and regulation.
- Safety behavior.
- Safety goals and target measurement.
- Job safety and hazard assessment.
- Managing visitors and external contractors on site.
- Personal Protective Equipment (PPE) requirements.
- Safety training.
- Communication and consultation.
- Management of Hazardous Chemicals.
- Emergency management (chemical spills, accident, fire, earthquake etc).

- Change management (ensuring that safety is considered in any changes to plant, infrastructure or procedures).

Safety Items Noted During the Plant Visit

There were a number of items that were identified during the site visit that we believe may present an additional safety hazard for plant staff and visitors alike. Safety is the responsibility of everyone, and we raise these items to your attention in the best interests of safety for all.

Item	Description	Suggested Remedy
1	**Chemical Storage Tank level indication is not clearly visible from outside platform during chemical loading.** The indicator for ammonium hydroxide, sodium hypochlorite and sulfuric acid storage tanks are obscured behind the storage tank and cannot be viewed without entering the containment area. This is not desirable during chemical fill. This increases the risk of tank overflow during filling.	Suggest either a relocation of the panel to be more visible, or providing a second indication that can be viewed directly by the chemical loader. Review the possibility of a high level tank alarm to sound an alarm and/or flashing light.
2	**Chemical dosing pumps are not all well supported in the containment area**. There is a risk of dosing line breakage/leaking, during maintenance. Additionally, there appear to have been significant maintenance and changes to the system over time, and it is unclear if pump capacities are matched to the existing system.	Review chemical dosing lines and supports to ensure systems are robust and do not leak. Conduct a review of each dosing pump to ensure it is correctly matched to the corresponding piping system.
3	**Cluttered storage areas**. There are trip hazards/access hazards around storage of various items within the plant (boxes of stripper packing,	We recommend that some material be reviewed to determine if it can be disposed of. We further recommend that equipment

	cleaning chemicals, softening salt etc).	that must be stored be done to minimize impedance of access to equipment and minimizes risks of trips and fall.
4	**Access to manual valves is difficult within valve trench**. We note that many valves required during the RO chemical cleaning cycle are in this trench.	Review intended operation of the valves and determine if operators must descend into the trench, or if an extension valve stem operator can be used through the grating.
5	**Temporary hoses are potential trip hazards**. These are running across the floor in a few places, and present trip hazards.	Recommend providing step over points for hoses and clear indication to alert plant staff and visitors of the hazard.

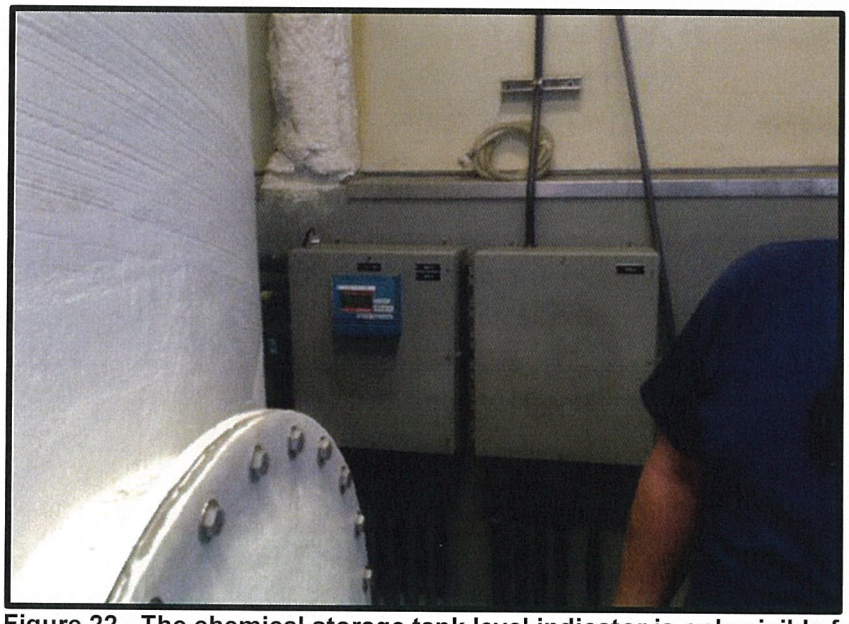


Figure 22 - The chemical storage tank level indicator is only visible from within the containment area. This is not desirable during chemical filling as a full tank cannot be identified easily by the tanker driver.

Interviews with Operators and Staff

During our visits we met with and interviewed two operators, the water systems production/operation supervisor and the water quality specialist.

In general, there were a few clear themes that emerged during these interviews:

- **Lack of knowledge sharing and training from the previous plant supervisor**. As an overall theme, most of the staff interviewed commented that there was not a great deal of training or information sharing under the previous plant manager. It appears that tasks were instructed or delegated, but without providing a good understanding or thorough knowledge behind that task. In general, there has not been sufficient capacity built for the remaining staff to fully understand plant operations as required.

  This was particularly evident when the most recent OMMP was located, but its existence was unknown to staff.

- **Knowledge of Plant Process is Weak**. In discussing plant and process with the operators and supervisor, it is clear that the plant process is not well understood. This is particularly true of the reverse osmosis system, where a few fundamental areas appear not to be understood. For example, the functions of the concentrate valve and hydraulic turbocharger did not seem well understood by operators.

  The RO membranes themselves appear to be in very poor condition. This is generally understood by staff at the plant, but not the degree of the problem nor a full understanding of what to look for. This is a pity, as lots of data has been collected in the field, however not correlated to performance in such a way that process decision making can take place.

  Additionally, there is not a thorough understanding of the impact of water chemistry through the plant, in terms of both impact to the RO condition and final treated water quality.

- **Log Sheets Takes Significant Time to Complete**. According to plant operators, it takes approximately 2 hrs to complete the Weekly Operation log for each shift. As previously noted, we have provided an alternative log sheet which we believe would improve the time required, and place greater focus on already collected on line data.

- **No good instructions for RO Cleaning**. This was a complaint by both operators interviewed, and is a very important issue. Effective cleaning of the RO is critically important, in terms of chemicals used, prevention of damage to RO membranes and cleaning effectiveness. Additionally, cleaning is a manual procedure and safety for

operators is very important.

- **Not many Standard Operating Procedures**. There are not many standard operating procedures produced for operators for any of the regular tasks that are performed. The majority of tasks are based on verbal instruction, memory and trial and error. There are some standard operating procedures within the OMMP, however these do not appear in use.

  There has been an initiative to produce a range of standard operating procedures, a list of which was provided during a site visit. This is a detailed list, and contains a number of important procedures. We note that there has been some very good progress with water quality sampling and analysis, however progress in other areas seems to be slower. We recommend that this list be reviewed, and key targets for completion agreed upon. We have further discussion below in our section on Standard Operating Procedures.

- **Water Quality Sampling and Analysis**. There appeared to be good knowledge of water quality sampling and analysis requirements by operators. This is no doubt in part due to the good work that has been done by the Water Quality Specialist in developing revised procedures and the Water Quality Sampling Plan. This area appears to have been bolstered following previous issues with regulatory sampling.

- **Inconsistency at Shift Handover**. There are different systems used by operators at shift handover. This is typically done in a combination of operator log book and email. It appears that different operators have set up a standard template, but there is not consistency across all. There is a one hour overlap between shifts and information is informally transferred with a run through operator's screens at that time.

- **Distribution System Trainees**. The plant operators discussed problems with distribution trainees coming to gain higher level accreditation by operating at the plant, but then returning to distribution once the required time has been completed. This appears to have been a significant drain on experience from the plant. We understand this practice may be discontinued.

- **Reservoir Management** – This appears to take a significant proportion of operator time at the site. During our visits to site, the RO unit was only operating at one time, and so we are unclear if the balance between plant and reservoirs is manageable. We recommend, based on the review of plant operations, to ensure the balance of plant to reservoir management is acceptable.

- **Key Plant Problem Areas**. The plant operators appear to have consistent problem areas within the plant that take time away from other duties. These include:
    - Air/gas locking of sodium hypochlorite dosing pumps.
    - Maintenance of dosing systems.
    - pH control of the bypass stream.
    - Stripping tower performance (in particular H_2S management).
    - Sand clogging cartridge filters.
    - Sand clogging RO elements.
    - Incorrect material selection at chemical dosing pumps for maintenance.

Recommendations: Overall, it is clear that significant training is required for the operations staff, in particular to properly understand the water treatment process as a whole and reverse osmosis in particular. We recommend that an operator training program be developed and executed as soon as possible. As a starting point, we recommend process training to understand the fundamentals of the treatment process – Hazen and Sawyer can provide this training in a short period of time.

Following this, we recommend a structured training of specific plant procedures, systems and processes in order to tie training to the particular requirements at the plant. During our visit, we did sight a training schedule that does include some required operator tasks. This is a good start, and building upon this document may be useful to produce a final training plan.

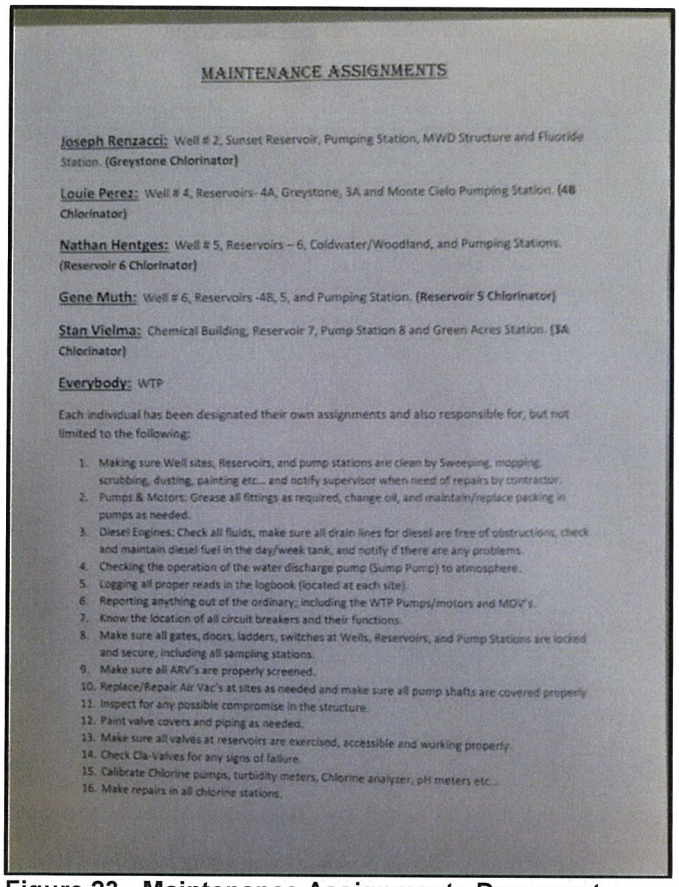
Standard Operating Procedures are clearly important, and we recommend that this be addressed urgently. We propose working with the City to identify priorities for procedures, and assist working with plant staff to complete them. We agree that the best way to gain acceptance and have ownership of these procedures is for operators to be directly involved in creating them.

Lastly, we recommend a review of communication protocols at shift change to ensure that information is consistently transferred from one shift to the next.

Maintenance Management and Asset Management

Maintenance Management

During our site visit, there did not appear to be a process for maintenance management. We found a posted list with maintenance assignments (shown below) along with items listed on a white board in the control room area.



MAINTENANCE ASSIGNMENTS

Joseph Renzacci: Well # 2, Sunset Reservoir, Pumping Station, MWD Structure and Fluoride Station. (Greystone Chlorinator)

Louie Perez: Well # 4, Reservoirs- 4A, Greystone, 3A and Monte Cielo Pumping Station. (4B Chlorinator)

Nathan Hentges: Well # 5, Reservoirs – 6, Coldwater/Woodland, and Pumping Stations. (Reservoir 6 Chlorinator)

Gene Muth: Well # 6, Reservoirs -4B, 5, and Pumping Station. (Reservoir 5 Chlorinator)

Stan Vielma: Chemical Building, Reservoir 7, Pump Station 8 and Green Acres Station. (3A Chlorinator)

Everybody: WTP

Each individual has been designated their own assignments and also responsible for, but not limited to the following:

1. Making sure Well sites, Reservoirs, and pump stations are clean by Sweeping, mopping, scrubbing, dusting, painting etc... and notify supervisor when need of repairs by contractor.
2. Pumps & Motors: Grease all fittings as required, change oil, and maintain/replace packing in pumps as needed.
3. Diesel Engines: Check all fluids, make sure all drain lines for diesel are free of obstructions, check and maintain diesel fuel in the day/week tank, and notify if there are any problems.
4. Checking the operation of the water discharge pump (Sump Pump) to atmosphere.
5. Logging all proper reads in the logbook (located at each site).
6. Reporting anything out of the ordinary; including the WTP Pumps/motors and MOV's.
7. Know the location of all circuit breakers and their functions.
8. Make sure all gates, doors, ladders, switches at Wells, Reservoirs, and Pump Stations are locked and secure, including all sampling stations.
9. Make sure all ARV's are properly screened.
10. Replace/Repair Air Vac's at sites as needed and make sure all pump shafts are covered properly
11. Inspect for any possible compromise in the structure.
12. Paint valve covers and piping as needed.
13. Make sure all valves at reservoirs are exercised, accessible and working properly.
14. Check Cla-Valves for any signs of failure.
15. Calibrate Chlorine pumps, turbidity meters, Chlorine analyzer, pH meters etc...
16. Make repairs in all chlorine stations.

Figure 23 - Maintenance Assignments Document

The list provides some specific and daily tasks required, however there does not appear to be a process of work order management, maintenance scheduling, maintenance prioritization or recording/follow up at the plant. We note that the distribution system is currently using Hansen work order management and that this may be employed for the plant also. We encourage that a system be developed for the plant, to ensure that maintenance is prioritized correctly, is conducted correctly and that the costs and time required to perform maintenance are tracked. A well-constructed work management system can provide very valuable information to improve maintenance performance.

One issue at site was illustrative of the problems with maintenance management. The RO concentrate valve has been out of service on the RO unit. Typically, and RO unit will not operate without this valve in service due to problems with controlling recovery effectively. It was noted at site that this valve was not in service during operation, and that there was a significant lead time on its replacement.

Secondly, chemical dosing pumps appear to have had maintenance conducted at different times in the past. There does not appear to be any record of materials used, replacement pump sizes or other information. This is critical, as it appears that dosing pumps of a different size to the original design have replaced originals, and there is no record of a check on piping and instrumentation suitability. Additionally, there may be incorrect and incompatible material used in its replacement.

Asset Condition Assessment

We recognize that GHD have currently provided or are providing an asset condition assessment for the plant. We recommend that a formal asset condition assessment be conducted on a regular basis following plant upgrades, to ensure that equipment is safe and reliable for operation. A simple assessment, with photographs and documentation can be conducted either in house, or with expert advice to both advise on safety and reliability of equipment as well as inform upcoming capital budgets.

Plant Availability/Criticality

We have noted whilst reviewing the plant, that there appears to be inconsistency in design with regard to plant availability. In some portions of the plant, there is redundancy such that the plant may either continue to operate automatically, or be available on line after a short period of equipment change over.

In other parts of the plant, however, there are process/equipment bottlenecks and "pinch points" which, in the case of failure, will shut down the entire plant.

For example, the RO unit itself has an entire standby feed pump to operate the unit if one of the pumps requires maintenance. Just slightly ahead in the process, there is only a single antiscalant dosing pump – itself a critical item which if unavailable will shut down the plant.

While this may be a deliberate decision (chemical dosing pumps can generally be procured quickly or cheaply kept as a spare on the shelf whereas a high pressure pump may require 12 – 18 weeks delivery on order) we recommend that an assessment be conducted to determine the

availability of the plant overall. This will help both set an expectation of reliability, as well as inform future capital upgrades with a basis of equipment selection and redundancy.

Recommendation: We note that there does not appear to be a current strategy to maintain a minimum plant availability in terms of spares inventory management or targeting of maintenance. We recommend that a criticality assessment be conducted to review critical components, identify critical spares and target maintenance tasks based on a targeted plant availability.

Operator Training

Effective training of operations staff is critical in the successful management of the plant and distribution system. As we have noted in our interviews with operations and staff, training particularly in process plant and operation appears to be significantly lacking. We recommend that a training program be developed as a priority both for the plant and process as well as the operations systems and processes that are being and will be developed.

An overall training program may consist of:

Topic Area	Contents
Permits and Regulations	Operating Permit. Environmental Discharge
Water Quality Sampling and Testing	Types of samples Proper sampling technique Labeling requirements Chains of custody Sample locations Sample frequency Process vs Regulatory Sampling and Testing Process Control Testing Procedures and Instrument Use
Safety	Safety (OSHA) requirements. Identify Safety Hazards Emergency Management Incident reporting and investigation City safety policies.
Instrumentation	Ability to read/record values from gauges and displays Understanding of units of measure Standardization/Calibration/Verification

Equipment and Maintenance	Ability to identify/describe components of equipment Start/Stop procedures Identify normal operation. Understanding of standard operating procedures
SCADA	Ability to navigate screens Ability to identify/acknowledge alarms Ability to select individual system components Ability to generate/select graphs and interpret results. Ability to Start/Stop a process or entire facility for planned or emergency shutdown.
Process Technology	Chemical dosing and Handling Reverse Osmosis (and pretreatment) Water chemistry and impacts to process. H_2S stripping Air scrubbing

We recommend that a training program be developed, with a training register to keep a log of which personnel have received which training.

Hazen and Sawyer are able to assist with training, and can provide process technology training rapidly for the city.

Standard Operating Procedures

As discussed, we have noted that there are not a great deal of standard operating procedures (SOPs) that are in use at the plant. These are critical, to ensure that there is consistency of operation and that systems can be passed on to new employees as other employees' transition to other roles within or outside the organization.

We recommend that the program of SOP development be continued to engage staff in the development of procedures that will incorporate all major, repeated operating tasks. We recommend a review of the current list, with a view to refining and prioritizing completion.

Importantly, we recommend that a system of document change management and revision control be adopted. This control ensures that operators and other staff are using the current

version of a document, and that any changes that have occurred are accurately captured. This is vitally important as the city launches into an upgrade of facilities.

We welcome the opportunity to assist the city in development of these procedures and a document change management process.

Other Process Items

Our report focused on operational systems and processes rather than a specific plant and process review. Nonetheless, we have identified some areas which we believe merit further review and discussion.

Reverse Osmosis Membrane Condition

As we have discussed in both Water Quality Monitoring and our RO Normalization review, the RO membranes are in a particularly degraded state. The chart below provides an indication of the severity of the condition in terms of the salt that is passing through those membranes.

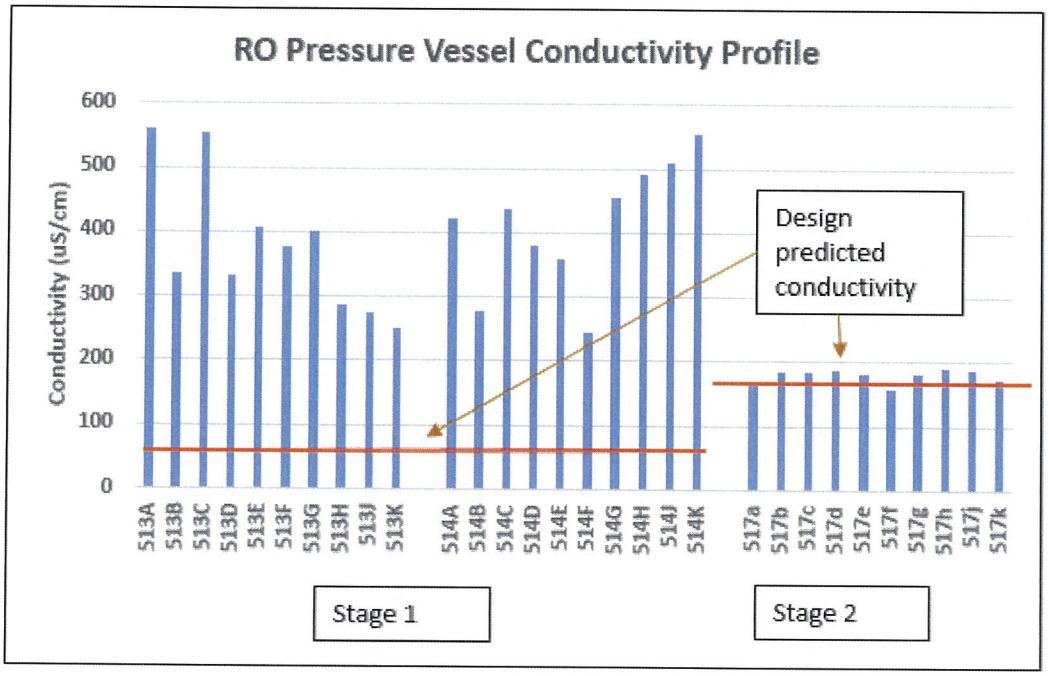


Figure 24 - Expected vs actual individual vessel conductivity

In Figure 22, we have compared individual RO vessel conductivity against what is predicted for the current feed water and membrane age. As can be seen, the first stage membranes appear to be in a very bad condition and in some cases are producing as little as 50% rejection in that stage of salt. There is significant variability between the vessels in the first stage, however all appear to be significantly worse than anticipated for membranes of that age. This may be due to membrane physical damage, membrane oxidation or chemical damage and/or leaks of membrane interconnecting o-rings. It is unusual to see membranes in this condition continuing to operate.

We note, that by contrast the second stage elements appear to be operating at close to their anticipated performance. This is consistent with the fact that second stage membranes have been replaced more recently than first stage (2 years compared to 7 years).

There are several reasons this may have occurred, and we understand that GHD are currently investigating with autopsies.

One significant concern is entrainment of sand from the wells into the vessels. The sand may have an abrasive effect, particularly on lead elements. We understand that options for sand removal from the wells prior to the cartridge filters is being conducted. Additionally, we recommend a particle size distribution of the sand particles to understand if these are passing through the cartridge filters, or are somehow bypassing.

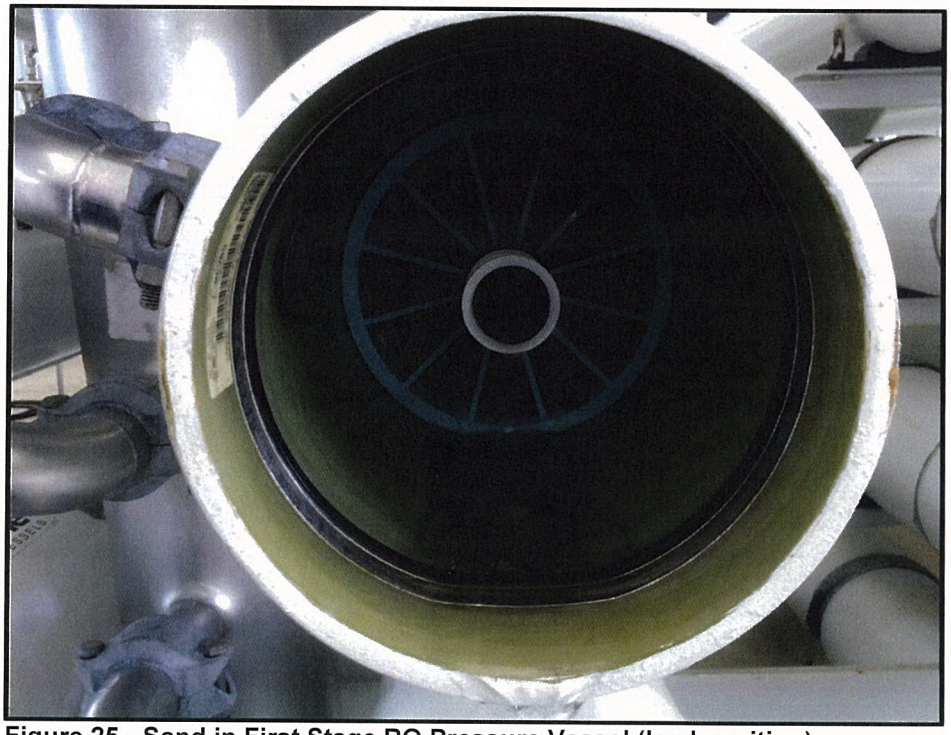


Figure 25 - Sand in First Stage RO Pressure Vessel (lead position)

Additionally, we understand that chloramine has been used on occasion to disinfect the membrane system as a result of adverse HPC and bacterial counts during sampling. While chloramine is a weaker oxidant than free chlorine, it can still oxidize membranes over time and can react with certain catalyzing agents (such as iron and manganese) in the water to have a stronger oxidant effect.

The RO Cleaning procedure is a potential area of risk to membranes. During the sequence, there is a risk of applying back pressure to the membranes that may cause a detachment of the membrane layer from the backing surface. A backpressure event is reasonably common in this situation, and if a manual valve is placed in the wrong position during this cycle backpressure can occur. We recommend strongly that the cleaning sequence is thoroughly reviewed and a solid procedure developed to ensure that this cannot occur.

One last consideration is the shimming of membrane elements. Standard membrane elements do not always exactly match the length of the pressure vessel, and as a result there can be some forwards/backwards movement of the membranes during start up and shutdown. Shims simply use small plastic annular spacers to take up any space between the membrane end connector and the vessel connector to minimize this movement. We recommend that the city ensures shimming be conducted on membrane replacement.

RO Concentrate Valve and RO Recovery Control

An RO unit is typically controlled by providing a variable frequency drive on the feed pump to produce a desired permeate flow rate, and a controlled concentrate valve to control concentrate flow (and hence RO recovery).

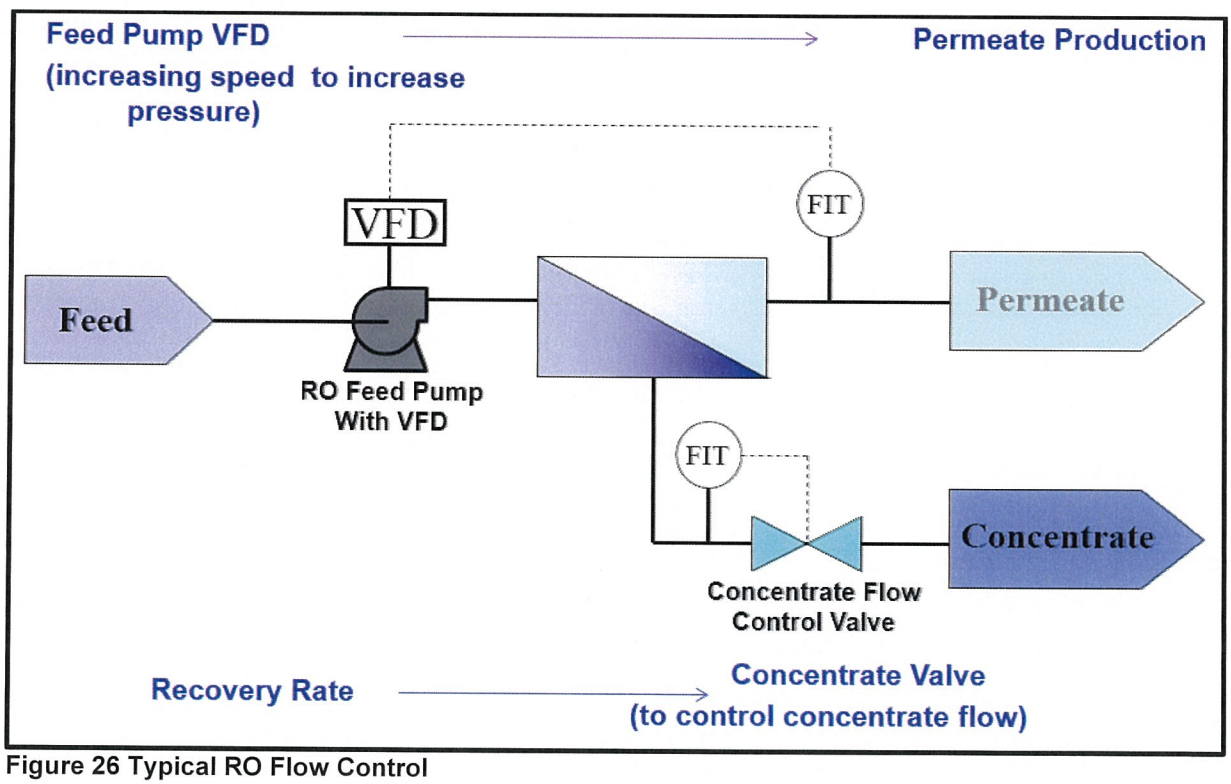


Figure 26 Typical RO Flow Control

The RO recovery is critical, as it will impact both the risk of scaling, and also to an extent the final treated water quality that is produced.

It is important that the concentrate flow is controlled effectively to minimize this risk.

We note that at the plant currently, the concentrate valve has been removed from the unit for maintenance, and in its place a smaller diameter section of pipe, acting as an orifice plant, is being used to provide some backpressure, however it cannot control to a set recovery.

Figure 27 - RO Concentrate Valve is out for maintenance. The section of pipe in use is located behind the actuator.

The impact of this valve absence is an inability to control recovery. As the graph below shows, the RO recovery has been fluctuating during periods of operation. Typically, as the membranes operate and become more fouled, the recovery tends to reduce with time, as can be seen in the Figure 28 below.

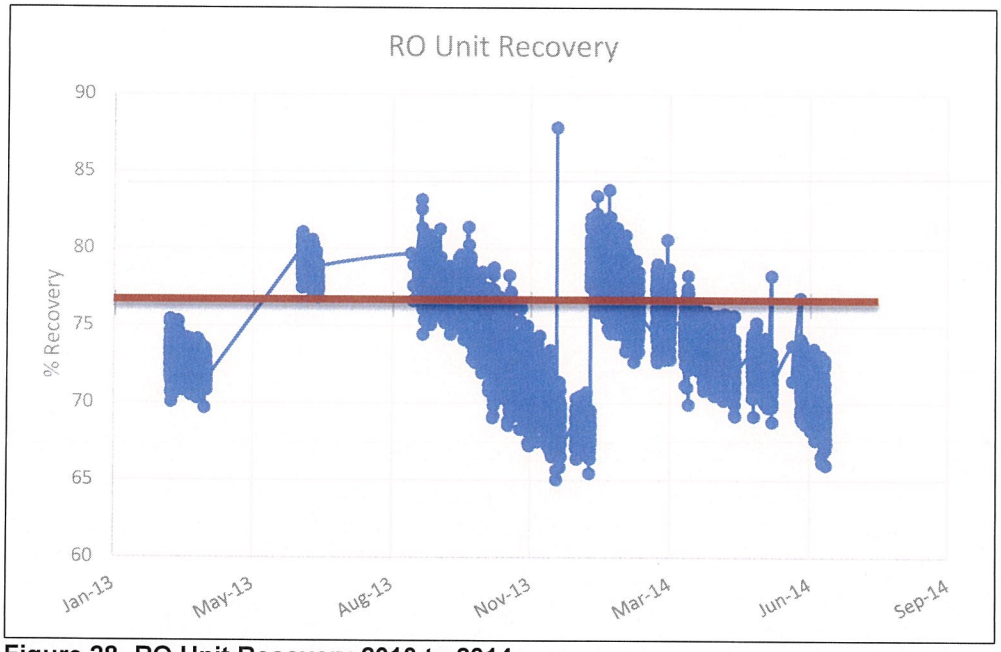


Figure 28- RO Unit Recovery 2013 to 2014

AS we can see, the RO recovery begins high, then reduces with operating time. It appears that this valve may have been out of service for some time. It is undesirable to operate without this control in place. Given the current configuration, it is difficult to adjust this manually, and we recommend that this valve be returned to service as soon as possible.

Hydrogen Sulfide Removal

We have noted at site that there have been some difficulties in achieving removal of hydrogen sulfide.

Hydrogen sulfide is removed from the RO permeate, and bypass streams by stripping H_2S in the gas phase from the water. In order to ensure that H_2S is in the gas phase, the pH must is reduced to approximately 6.0 or below. In Figure 29, the equilibrium of hydrogen sulfide in the gas phase and dissolved phase (sulfide) is shown with pH. By driving the pH lower than 6.0, more hydrogen sulfide is in the gas phase available for removal.

As previously discussed, the RO has significantly compromised membranes which are leaking significantly more dissolved salts into the permeate than anticipated. Often, the pH across an RO unit reduces as compared to the feed. This is because the RO will remove dissolved alkalinity (in the form of bicarbonate and carbonate) but not dissolved carbon dioxide as it is a gas. The change in ratio between bicarbonate alkalinity and carbon dioxide results in a reduced pH. At the plant, the operators have noticed that it requires a much higher dose of sulfuric acid

to drop the pH in the RO permeate compared to earlier in operation. This is most likely due to the fact that the RO is no longer rejecting sufficient bicarbonate, and consequently the pH reduction across the RO is less.

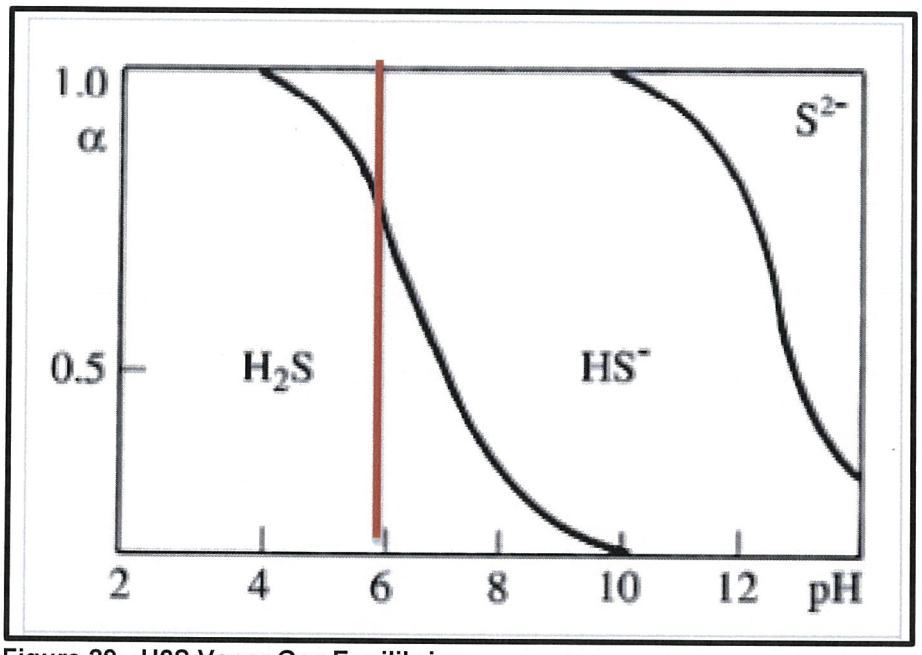


Figure 29 - H2S Vapor Gas Equilibrium

When the RO system is returned with new membranes in the first stage, we anticipate less acid will be required to lower pH across the RO unit.

At the bypass stream, a high acid dose is injected to meet the requirement of pH 6.0. We note that there have been problems with mixing of the acid dose prior to the stripper in the past, however these may have been resolved.

An additional areas that should be reviewed is the exchange of air across the strippers to ensure that this is consistent with design. This may need to be deduced from fan speeds.

Concrete Corrosion

As we have mentioned in our discussion on water quality monitoring, the RO permeate is not chemically stable with respect to hardness, alkalinity and pH, and can be corrosive to cement and copper services. Given the current blending regime, with a lower than original design bypass flow, the overall plant effluent may be at a lower than desired stability and consequently impacting infrastructure such as the clearwell tank. We note that many drains around the plant also show signs of concrete corrosion.

As discussed previously, we recommend measuring hardness, alkalinity and pH regularly to both target and trend a stability index (either LSI or CCPP).

Conclusion

The city has some significant operational challenges ahead in terms of operational systems and processes, as well as plant performance. There are some major shortcomings that put the utility at risk of non-compliance to plant permits, risk of damage and degradation to plant and distribution assets, and importantly risks to the safety of site personnel.

But these challenges are not insurmountable. The staff are dedicated, enthusiastic and committed to successful operation. With some assistance, we have no doubt that the will be able to return the plant to a very high level of performance. There are already some great strides in achieving this, notably in the management of water quality.

We stand ready to assist the city in working towards this goal. Our major findings and recommendations are as follows:

Our major findings are as follows:

- **Plant Performance Targets should be clearly defined**. Targets for operations staff in terms of production, quality, safety and other regulatory requirements are not clearly defined. We recommend this so that staff can compare performance against targets.

- **Operating Performance is not correctly analyzed.**. There is a vast amount of information recorded on the HMI/SCADA and operating log sheets, however it is not presented or reviewed adequately to gauge plant performance. We recommend that trending of important parameters be set up and regularly reviewed to measure performance against overall plant and process unit specific targets. This is important for water quality targets and internal process performance targets.

- **Water Quality Management and Monitoring has shown great improvement.** This area in particular is advancing well, with robust procedures and a sampling plan being developed. We recommend using this work as a basis for a comprehensive water quality management plan for the facility (which could be incorporated into a revised OMMP).

- **The Reverse Osmosis (RO) system is not correctly analyzed**. The RO system performance data is not normalized, and consequently performance has not been reviewed adequately, leading to a substantial worsening of condition.

- **The RO system membranes (first stage in particular) are in very poor condition**. These membranes are leaking salt an order of magnitude above what is anticipated for membranes in this operation. The overall cause for poor condition must be investigated and resolved, followed by the installation of new membranes.

- **The RO Unit is not operating correctly, and requires a concentrate valve to be replaced as a matter of urgency**. This is critical for controlling RO recovery, which is itself critical for successful unit operation.

- **A concentrate reduction strategy should be considered**, with a review of current RO feed water chemistry, membrane selection and antiscalant to determine an optimum RO unit recovery. A higher recovery, if possible, can reduce brine production from unit and increase overall treated water yield from the plant.

- **Provide options for lower RO unit throughput, based on lower well yields.** This review (combined with the concentrate reduction strategy) may provide operating cost savings in terms of membrane costs, pumping energy costs and chemical dosing) as well as provide more suitable system hydraulic operating conditions.

- **Final Treated Water blend may be corrosive to concrete**. We recommend a review of water chemistry and blending along with monitoring of water stability indices to ensure protection of plant concrete infrastructure such as cement lined pipes and the concrete clear well

- **Arsenic Management Plan, a regulatory requirement outlined in the OMMP, does not appear to be followed**. This is a requirement of the permit, and included in the OMMP, however does not appear to be entirely operational. We recommend this plan is checked for compliance.

- **The Operations Maintenance and Monitoring Manual (OMMP) is not known to operators and is not in use. We recommend creating a revised, updated OMMP**. This is a major risk of non-compliance to the plant operating permit and in itself may constitute a non-compliance. We recommend as a matter of urgency that the city confirm with the State Regional Water Quality Control Board (formerly CDPH) if the version found during our visit is the current lodged with the regulator. Further, we recommend that this form the basis of a thorough revision to include important

shortcomings as well as updates to reflect existing operation.

- **Plant Weekly Operator Logs are Unwieldy and Unhelpful.** We have recommended a revised log sheet, as the current log contains a lot of data recorded but the key trends are not reviewed to determine plant performance or identify operational risks. It is data rich, but knowledge poor.

- **A non-conformance/corrective action process is recommended.** In order to capture learnings from problems or incidents, we recommend a non-conformance and corrective action system. This will involve reporting incidents, managing incidents and effectively taking from lessons learned to improve operations into the future.

- **A Safety and Emergency Management Plan is recommended.** We could not find a comprehensive safety plan on site covering the multiple safety issues that are encountered at an operational facility. We recommend that a plan be developed, to ensure safety hazards are effectively managed.

- **An Operator Training Program is recommended as a matter of urgency.** Operators are currently not sufficiently familiar with water chemistry, RO unit operation and other plant processes. We recommend a training program be developed to encompass process, operational procedures, safety and other necessary operational elements to ensure operators are well equipped to manage the plant.

- **Development for Standard Operating Procedures is recommended.** Leveraging from work already begun by the city, we recommend developing a number of robust operating procedures, developed with and by the operators themselves, to cover operation of all aspects of the plant. There are currently few procedures in use, and much operation is performed by memory and word of mouth. We additionally recommend a document change management system be established to keep track of version control and ensure changes to plant, process and operations are captured in the procedures.

- **More use of trending from the HMI should be adopted to keep track of process and water quality performance**. There is an abundance of data reported, however trends are more useful for performance monitoring, diagnostics and decision making. We recommend that a set of standard trends be developed.

- **Develop a high level plant Dashboard Report, to define key performance requirements at a glance. This will be helpful to track performance against targets.**

Conduct a criticality and condition assessment to determine appropriate spares and maintenance strategy to meet a desired plant availability.

Appendix 1 – Revised Weekly Operations Log Sheet