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Seawater desalination: an environmental regulator's perspective

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ABSTRACT

The Port Stanvac seawater reverse osmosis desalination plant will be capable of producing 300,000 m^3 of potable water per day when fully complete. This is the first large-scale desalination project in South Australia. A second desalination plant has recently received development approval for the Upper Spencer Gulf in South Australia. The Port Stanvac plant was initiated by the South Australian Government in response to a wide spread and prolonged drought in Australia. The plant was planned and built to drought proof Adelaide, a city of over one million people. The timescale for the plant from the first proposal to site selection, design and build was compressed due to the urgency of the situation. There were significant environmental concerns in the construction and operation of a desalination plant in the location chosen. These included protection of cliffs and high-value intertidal reefs during construction and energy use and the protection of the marine environment during the operating life of the plant. The environment protection authority was charged with regulating the environmental effects of the construction and ongoing operation of the desalination plant. This was the first such plant ever constructed in South Australia, so there were a lot of new concepts to understand to ensure the highest level of protection could be obtained. A lot of effort was made to ensure that the plant could operate in an environmentally sustainable manner in a sensitive location. Ensuring that this could be demonstrated to the public was an important factor in the way the plant was regulated. The plant is now operational and the monitoring system is in place. As the plant ramps up from producing 30,000 m^3 of potable water to 300,000 m^3 per day, the ongoing challenges of monitoring the discharge has been complex.

Keywords: Environmental regulation; Monitoring of desalination

1. Introduction

The Port Stanvac seawater reverse osmosis desalination plant will be capable of producing 300,000 m^3 of potable water per day when fully complete. This is the first large-scale desalination project in South Australia. A second desalination plant capable of producing up to 280,000 m^3 has received development approval for Point Lowly in the Upper Spencer Gulf in South Australia to provide water for industry.

There are significant environmental concerns in the operation of desalination plants in the chosen locations. The primary concern for the environment protection authority (EPA) was the protection of the marine environment from unacceptable impacts during the operating life of the plant.

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The EPA is charged with regulating the environmental effects of desalination plants that discharge into waters. The Port Stanvac plant was the first large-scale desalination plant ever constructed in South Australia, so there were a lot of new concepts to understand to ensure the highest level of environmental protection could be obtained.

A lot of effort was made to ensure that the plant could operate in an environmentally sustainable manner in its location. Ensuring that this could be demonstrated to the public was an important factor in the way the plant was regulated. The plant is now operational and the monitoring system is in place. As the plant ramps up from producing 30,000 m^3 of potable water to 300,000 m^3 per day, the ongoing challenges of monitoring the discharge has been complex. I will outline the processes and issues facing the EPA in the regulation of sea water reverse osmosis (SWRO) plants in South Australia with a particular focus on the Adelaide Desalination Plant in South Australia as that is the only plant that is operational.

2. Key challenges

The key challenges for an environmental regulator are obviously environmental concerns, but listening and responding to the concerns of the public is also very important. A regulator needs to be impartial and fair and have a high level of expertise in both scientific and regulatory matters. They also need to win the trust of the public. With many people sceptical of the environmental credentials of large-scale seawater desalination, this was a difficult task in itself.

The key environmental concerns with the proposals were similar to those of other seawater desalination plants. The primary concern for the EPA was the discharge of seawater concentrate and a variety of process chemicals into the sea. Other concerns included entrapment and entrainment of marine organisms in the intake, energy usage, chemical storage and handling on site, noise and odour.

Many in South Australia were sceptical of whether desalination was an appropriate way of providing water. They were also concerned about the specific locations of the two plants. In particular, the plant proposed for Point Lowly attracted a lot of public concern about its location adjacent an aggregation and spawning area for the iconic giant cuttlefish. During the Environmental Impact Study for this plant, there were over 3,000 submissions against the location of the desalination plant. Many form letters indicate a level of interest that people were concerned enough to comment against the proposal even if they did not have specific arguments (Fig. 1).

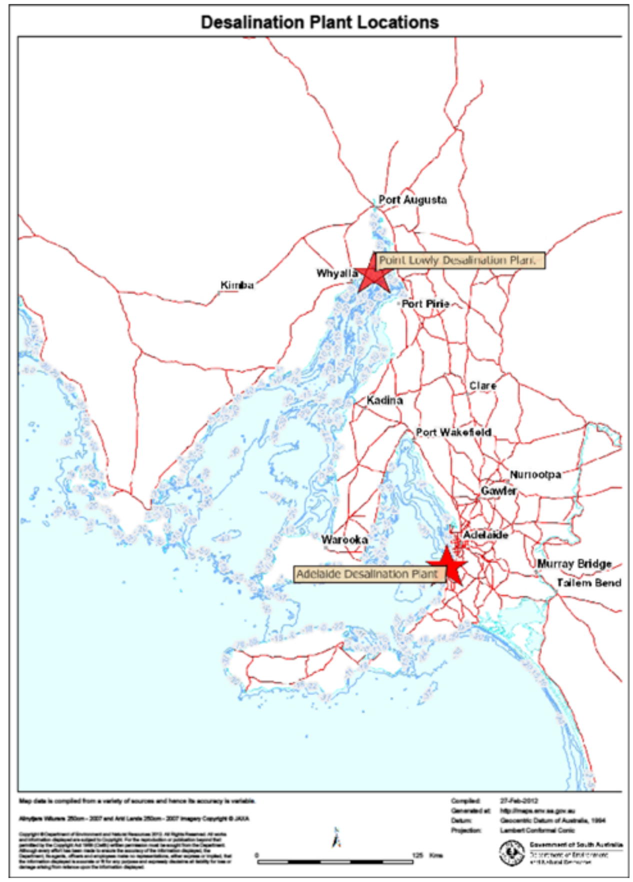

Fig. 1. Locations of two SWRO plants in South Australia.

It is not the role of the regulator to win the public over to the proposals, which is the role of the proponents. Our role includes ensuring whether we communicate appropriately so that the public can have surety that the plants will be properly regulated and scrutinised to ensure that environmental harm does not occur.

Probably, the biggest environmental concern other than discharge is energy usage; desalination has a reputation for being very energy intensive. As part of the environmental commitments in the development stage, the State Government committed the Adelaide Desalination Plant to use 100% renewable energy sources for power consumption for the plant. While electricity use falls outside the scope of the Environment Protection Act, we are still concerned that the plant be as energy efficient as possible. Luckily, the operators and owners of the plant are also very concerned to minimise energy use as electricity is one of the major costs of desalination.

The entrapment and entrainment of organisms in the intake is another concern for desalination. Low intake velocity was required as part of the development approval, and an intake structure was designed and installed to ensure that the velocity past the outer grill is always less than 0.15 m/s. This was backed up with licence conditions on the intake flow rate on the licence. Studies of the intake impact have been required as part of the development approval and licensing process.

While our focus as a regulator has been on the potential marine impacts, there are other potential impacts. For the Adelaide Desalination Plant, there are people living and working several 100 m away. Noise from large pumps is a potential problem that is required to be considered. All pumps were required to be installed in specially designed buildings for noise attenuation purposes. Audits of noise impact have been required under the licence requirements to demonstrate compliance with legislative requirements.

Large volumes of chemicals are stored and used on the site in the process of pretreatment, desalination and also post-treatment of water. Public concerns were raised over potential for leakages to air, water or land. Proper controls are required to ensure that all chemicals are properly stored, managed and used on desalination sites. Workplace health and safety regulations interact closely with environmental regulation in the use and storage of chemicals at desalination plants and contribute to a high level of control of this issue. Another concern is the odour from the chemicals and whether it will have an impact on neighbours. Other odour sources that needed to be considered are sludge from the pretreatment and any general waste sources.

3. Seawater concentrate discharge

The main issue of concern to the EPA and the public of South Australia is the return of seawater concentrate back into the sea. Given the reverse osmosis process that is to be used for both plants in South Australia, the concentration of salts in the discharge will be roughly twice that of the ambient seawater. The ambient salinity at Port Stanvac in Gulf St Vincent can vary between 35 and 38 ppt and at Point Lowly in the Upper Spencer Gulf can range from 37 to 40 ppt; therefore, the concentrate being returned could be 76 and 80 ppt, respectively. If these high salinity levels are not quickly and adequately dispersed, there is high potential for harm to species inhabiting the area. There has also been concern that if the concentrate is not adequately dispersed, it could form a seabed plume with low dissolved oxygen and smother marine life. As well as the salinity there will be doubling of any contaminants from the feedwater and the addition of any process chemicals used in the plant.

As a regulator, we need to know what chemicals will be used in the plant and how the residue will be disposed. For both desalination proposals at the development stage, there was no detailed information as final designs had not been made. Given the Point Lowly plant will not be built for another 5–7 years it will be some time before there is a detailed design. We had to assess the proposals often using only generic information on the processes involved which adds a layer of complication to an already detailed process. There was no particular reason why the discharge stream would be significantly different to other plants in Australia or other parts of the world. However, as each desalination company will have slightly different processes and use slightly different proprietary chemicals at different stages and doses, we could not have testing done on an actual discharge. The initial assessments were therefore made using information on the likely make up of the discharge stream. Even once the decisions had been made on what would be used and how we could not get testing done on the actual discharge until the process is operational. Therefore, all testing done prior to operation are only models based on facsimile discharges not the actual discharge. This is one reason for some ongoing effluent toxicity testing once the plants are operating.

4. Ecotoxicity testing

In order to determine the effect of the discharge of high salinity concentrate, ecotoxicity testing is required. Both proposals in South Australia had pilot plants operating to determine the operational needs of the main plants. These were able to provide concentrate similar to what would be discharged. Tests using locally relevant species of concern are required. Species chosen and protective concentrations would be derived in accordance with The guidelines for fresh and marine water quality (ANZECC [1]). For the Port Stanvac plant, the following seven species were selected for testing as indicator species:

(1) *Nitzschia closterium* (diatom)—sub chronic
(2) *Heliocidaris tuberculata* (sea urchin)—sub chronic
(3) *Mytilus edulis* (blue mussel)—sub chronic
(4) *Ecklonia radiate* (macroalgae)—chronic
(5) *Diopatra dentate* (polychaete worms)—chronic
(6) *Allorchestes compressa* (amphipod)—chronic
(7) *Seriola lalandi* & *Pagrus auratus* (yellowtail kingfish & snapper)—chronic

The results of this testing indicated that the toxicity of the concentrate was the main concern while the discharge of process chemicals (in the amounts likely to be in the discharge) did not have additional toxic effect. There were two exceptions to this which were sodium EDTA and sodium dodecyl sulphate (SDS) which were common in many cleaning and consumer products such as shampoo were shown to have potentially highly toxic effects. It was quickly resolved that these two chemicals could not be discharged to the marine environment and other disposal routes would be found.

Upon review of the data and results of the testing provided by the applicant, a number of issues concerned with the data appeared. These were mostly down to quality control on the results and reporting. Unfortunately, these quality control issues meant that the EPA could not be confident in the results and were not able to accept them as reliable. Despite the now short time frame on when the applicant would like to have a licence and start producing water, better quality data were required to enable the EPA to make a proper assessment and come to a conclusion that could be justified to all.

This meant that more testing was required and the testing needed to be done to the highest possible standard that could withstand tight scrutiny and the EPA could rely upon. One of the key challenges in doing this was finding indicator species that could be used and were available at the time so as to not delay the approval process. Eventually, snapper and kingfish were settled as representative, indicative and available. This round of testing would be conducted by experts from the Commonwealth Scientific and Industrial Research Organisation and a further level of review would be conducted independently of the proponents and the EPA by Professor David Fox of the University of Melbourne. Professor Fox, who was the lead author of the Adelaide Coastal Waters Study, had pioneered a new Bayesian analysis method and this would be used on top of the standard methods. Using such highly respected experts to undertake the additional study allowed the EPA to ensure that the best possible review of the best possible data would be undertaken.

The results of this round of testing, which could be accurately relied upon and defended, were actually similar to other results received i.e. generally the concentrate itself was the prime concern rather than the treatment chemicals. The results indicated that dilution of 14 times would be required at the outfall to provide the required level of protection. This was slightly lower than the 21 times dilution predicted by the previous testing and also significantly lower than the ratio of 58:1 that is required in the development approval.

5. Diffusion modelling

As part of the EIS process for the Adelaide Desalination Project, a ratio of 50:1 dilutions was required to be demonstrated at the outfall by the proponent. This ratio was chosen early in the process when there was not a great deal of experience of desalination in the EPA. This ratio was chosen to be protective of the environment and was subsequently increased to 58:1 when the plant designer was chosen and they increased the plant efficiency from the previously expected 42 to 48.5% while increasing the salinity of the discharge accordingly.

Modelling of the predicted dispersion of the saline plume was required to demonstrate that the required ratio could be met. When the proponents came back to the EPA with a design of an outfall of 140 m long, this caused consternation for some as the proposal in the Environmental Impact Statement suggested a 250 m long diffuser. To anyone without an understanding of diffusers, this meant a lessening of environmental protection. AdelaideAqua had proposed a 140 m long diffuser structure with six risers each with

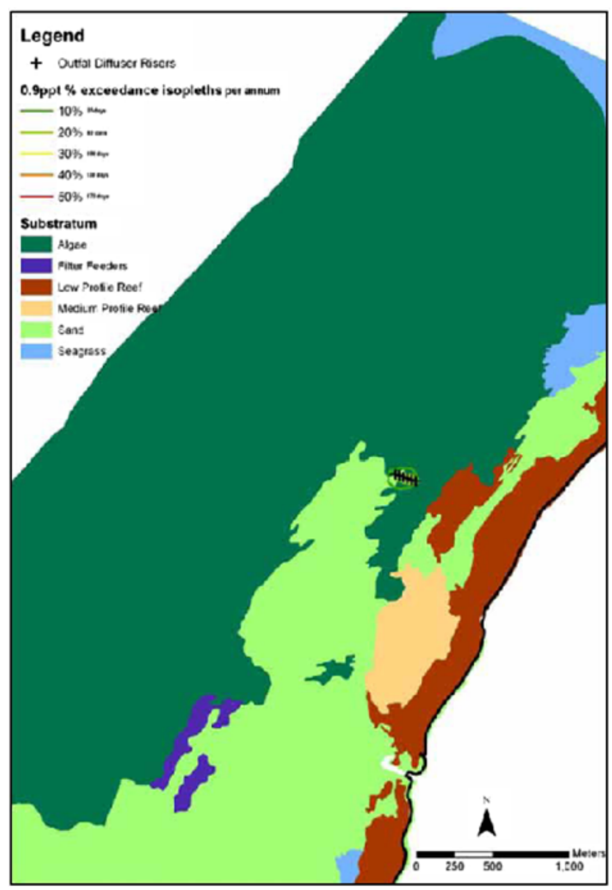

Fig. 2. Modelling output supplied with licence application for Adelaide Desalination Plant (percentage Exceedence of 0.9ppt Salinity Isopleths at the bed relative to substratum type).

Fig. 3. Photo of diffuser for Adelaide Desalination Plant.

four ports with duckbill diffusers. Modelling was required of near field, mid field and far field (Fig. 2).

The modelling provided showed that the 58:1 ratio could be achieved by the diffusers for all production levels of 40% and above. The ratio could be achieved for lower production levels with the use of a seawater bypass at the lower levels. The installation of a seawater bypass was a requirement of the development approval. The modelling was done on a steady state assuming no water movement or wind in the area around the diffuser, which is an artificial construct and unlikely to happen often. As an aside, it is interesting to me to note that even though completely still conditions of no tidal movement and no wind are rarely combined, I dived adjacent the diffuser during a neap tide and while there was enough wind and waves on the surface to make boating uncomfortable, there was almost no movement at the seabed at the time making good conditions for easy diving but less than ideal conditions for diffusion (Fig. 3).

The modelling demonstrated that the design chosen could meet the environmental requirements set and so the diffuser design was approved. Like the ecotoxicity testing, it is modelling and not a real-life example. AdelaideAqua are required as a condition of their licence to undertake plume dispersion testing to demonstrate the dispersion and ensure that it meets the requirements. A first plume dispersion test has been undertaken recently, though results are not yet available. The EPA will review it in detail when received. There is a requirement that if real-world results of diffusion do not meet the expectations of the modelling, the diffuser structure be capable of modification or extension to comply.

6. Compliance criteria

Once we had good quality information from the ecotoxicity testing on what level of salinity increase was acceptable within a framework causing minimal impact in the vicinity of the outfall discharge and an indicator of what could be achieved from the diffusers through the modelling, the next step was to work out the licensing criteria. The modelling showed that the diffuser could achieve a level of diffusion that would protect sensitive species from negative impact. We had to work out a licensing threshold in terms of numbers and locations of compliance point(s). As well as working out what to measure for and where, an important point was to work out what would happen if the criteria were not met.

All the feedback we received from the public indicated that they wanted to be assured that if the plant was to cause harm, it could be stopped there and then and not at some point in the future after potentially irreversible harm had occurred. Because of the wide ranging fluctuation in salinity in the ambient environment, it meant that setting a fixed salinity limit was not viable. We wanted there to be real-time feedback to the plant operators while they were discharging so that any environmental issues could be resolved as they occurred. The ecotoxicity testing revealed that up to about 2.6 or 2.7 ppt increase in salinity should be acceptable. The modelling showed that the diffuser design would mean that there should be no increase above 1 ppt at 100 m from the diffuser under almost all scenarios.

We settled on a limit of 1.3 ppt, averaged over 24 h, at 100 m from the diffuser as the licence criteria. These requirements led to a ring of monitoring stations at 100 m from the diffuser. Currently, there is a requirement for four monitoring points at 100 m for compliance monitoring, plus another four at 200 m to try and confirm any trend over distance. The four at the inner ring are required to be linked via telemetry to the operators control room at the desalination plant (although the operators have linked all monitoring points). This is used to provide feedback every hour for the plant operators. It should be noted that while this is a very high level of monitoring, it was never intended to be permanent. Once the plant has been proven and if it is shown that there is no environmental harm, the expectation is to lessen the requirements for monitoring. The outer ring does not have a compliance purpose but is a means of extra checking and a negotiated extra commitment of the owner and operator. It also provides a back up set of monitors should the marine environment take its toll on the instrumentation.

The limit was set at a level well short of where environmental harm would be expected. If the operator exceeds the limit it is not in itself a breach of the licence. If there is an exceedance, the requirement is to notify the EPA and cease discharge within 6 h. This is to ensure that salinity increase never gets to a level that might cause harm. As the 1.3 ppt is a limit for a 24 h average, the operator should have adequate warning of any impending exceedance and be able to take action to avert it. There is also a requirement to notify the EPA and take appropriate actions after exceeding 1.3 ppt for 6 h. Given this time period and the rapid feedback achieved from the monitoring, there is little likelihood of an exceedance of a limit that is highly protective. Using this type of adaptive management with instant feedback is expected to ensure that the plant operates within allowable levels at all times and provides a high level of environmental protection.

7. Ongoing monitoring and review

In order to provide this rapid feedback, the monitoring system needs to be fully functioning and capable of recording the data, transmitting and being received at all times. There is a ring of conductivity, temperature & depth's (CTD's) on the seabed surrounding the diffuser line and these need to record the conductivity, temperature and depth continuously (every 10 min), a modem on the seabed with the CTD talks to a modem on the surface buoy which talks with a receiver at a high point on the desalination plant which transfers the information to the operations control room. With sensors in the water for up to 2 months at a time, there is potential for growth on the sensors, batteries running flat, bad weather damaging equipment and other potential problems to occur. These are a range of the issues that have meant that so far the record of data recording and transmission has been far from complete. Part of the ongoing challenge of the monitoring is to find an acceptable system for providing ongoing real-time feedback. One potential solution is to have less monitoring points, therefore using the others as back up for a hot swap when servicing the equipment. This should lead to less down time and therefore more consistent data. The dashed lines in the salinity graph indicate gaps in the results available. The slight downward trend over the month shown is likely to be a result of fouling or calibration issues (Fig. 4).

As well as the real-time salinity monitoring there has been monitoring of the local reefs, fish life, plankton, intertidal areas and water quality profiling prior to and ongoing to provide a high level of background information of conditions pre-discharge and post-discharge. This monitoring will continue to demonstrate whether there is any impact on the receiving environment. These surveys have been conducted by organisations including universities and bodies such as the South Australian Research and Development Institute, the Australian Water Quality Centre and the Department for Environment and Natural Resources. Requiring the operator to pay for monitoring and surveys by

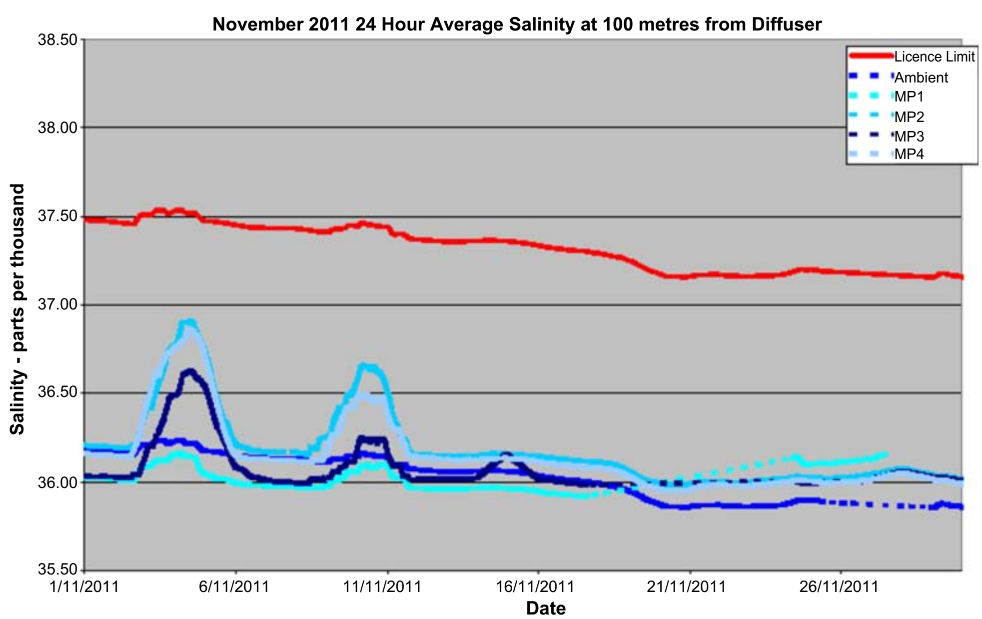

Fig. 4. Results of salinity monitoring at Adelaide Desalination Plant.

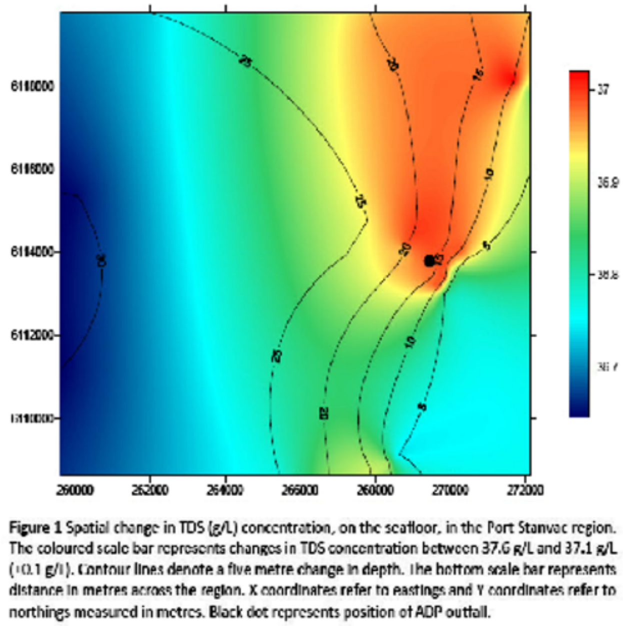

Fig. 5. Water quality profiling results for Adelaide Desalination Plant.

expert outside organisations means that South Australian taxpayers are not paying for the work and the public can be assured that it is done expertly and without bias. As an aside, it also means that this small section of coast will be extensively studied and may prove useful to a variety of marine researchers in the future. Plate 4 shows results of water quality profiling of an area extending up to 5 km from the outfall. This is from September 2011 and a slight increase in salinity extending northwards which is roughly consistent with the results of modelling (Fig. 5).

When the EPA was in the process of working on the licence, we communicated with the public and sought their views. The overwhelming feedback received at the time from the public was that there should be monitoring done of the impact of the plant and that the results should be made publicly available so that everyone could see. As a response to this, the EPA committed to making the results of monitoring available on the internet for the public to see. Making this decision ensures that we are open and accountable and helps the public to trust us in doing our job in protecting their environment. Monitoring results are available at http://www.epa.sa.gov.au/environmental_info/water_quality/projects/adelaide_desalination_plant EPA has not received much feedback to date on the publication of results, but the little it has received has been positive.

One more way that the public can trust that a thorough review of the monitoring will be undertaken is to require an independent scientific review of all monitoring. This will be to review the effectiveness of the monitoring, determine if there has been any environmental impact and make recommendations for the future. This is a one off the review to be undertaken by experts independent of the operators of the plant, the EPA and any of the experts undertaking the monitoring. It is to occur after 12 months of full production and include a review of all the marine monitoring undertaken. The review panel will be able to make any recommendations or comments as they see fit and this review document will be publicly available.

8. Conclusion

While these plants were set up first for South Australia, they were not first for Australia or the rest of the world. I was able to visit desalination plants in Queensland, Western Australia and New South Wales and learn from their experience. Discussions with the environmental regulators in these jurisdictions were also extremely useful. One thing I was able to ascertain from this network was that they had similar experiences that we had in South Australia. In those places, the public were quite sceptical of the ability of desalination plants to operate without harm but the environmental regulators had generally formed a different view based on their detailed experience and review of the monitoring data from the plants.

One thing that would make the role of an environmental regulator easier (and therefore may help a proponent get through the approval process quicker) would be if there was more research and data available worldwide on the impacts from some of the many plants already in existence. If there were good quality information readily available for regulators and the public to review and gain an understanding of the likely impacts, it could lead to better understanding and easier approval processes. There might be a role for desalination associations or other bodies to fund coordinated independent research into the impacts of the concentrate discharge at a number of desalination sites and making the results freely available.

Reference

[1] Australian and New Zealand guidelines for fresh and marine water quality. Volume 1, The guidelines/Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.