The Virginia Pipeline: Australia's largest water recycling project

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Abstract The need to conserve, reuse and recycle water is becoming increasingly important for both environmental and economic reasons. The Virginia Pipeline is Australia's largest water recycling project. More than half the output from (the capital of South Australia) Adelaide's largest wastewater treatment plant is further treated to achieve a product water quality fit for irrigation of vegetable crops with minimal public health restrictions. The project partners have a vision to achieve total reuse. To achieve this vision, recycled water will need to be stored during cool weather periods when the demand for water is low. Temporary storage of this water in poor quality aquifers is the subject of a major research project.

Keywords Agriculture; aquifer storage; commercial; treatment; water recycling

Background

Australia is a large and climatically diverse continent comprising tropical, arid, temperate and alpine regions. Some 90% of the continent's rainfall occurs in the tropical north which is inhabited by less than 10% of Australia's population of 19 million. Most of the population reside in the temperate areas and inhabit the large coastal cities of Brisbane, Sydney, Melbourne, Adelaide and Perth. Whilst infrastructure to provide water for each of these cities is well developed, the need to conserve, reuse and recycle water is becoming increasingly important due to both environmental and economic considerations. The water recycling project that is the subject of this paper is located near the City of Adelaide, the capital of the State of South Australia.

South Australia occupies an area of 984,000 square kilometres of which 80% is arid and semi arid terrain with average rainfall of less than 250 mm per year. The State's population is 1.5 million of which 1.1 million live in Adelaide. Adelaide and the coastal regions to the south experience average rainfalls of 600 mm per year, with most of this falling in the cooler months between May and September. Adelaide's climate is often described as Mediterranean, with cool, wet winters and hot, dry summers. The mean maximum summer temperature is 29°C, with occasional daily maxima over 40°C. Average annual evaporation exceeds 2000 mm. The State has a diverse and modern economy, but agriculture, food and beverage production continue to be important both locally and for exports. Consequently the efficient management of the State's water resources takes some prominence in social, environmental, economic and political forums. The State's water infrastructure is government owned through South Australian Water Corporation (SA Water). In 1995, operation of Adelaide's water infrastructure was contracted out to United Water International Pty. Ltd. (United Water), the major shareholders of which are Compagnie Generale Des Eaux and Thames Water International. More information on South Australia can be accessed at www.sacentral.sa.gov.au via the internet.

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History of water reuse and recycling

South Australia was formally colonised by the British in 1836. Water reclamation and reuse had been practised in South Australia since 1880 when a large sewage farm was established to meet the public health needs of the infant state capital. Settled sewage was used to irrigate pasture and vegetable crops until 1936 when the practice was stopped due to an outbreak of disease (Hammerton, 1986). In the meantime, the first activated sludge plant in the southern hemisphere had been constructed in Adelaide. During the 1950s and 1960s existing sewage treatment plants were expanded and new ones were built. This was a period of historic growth in the populations and economies of Australian cities as a consequence of a surge in immigration from Europe following World War 2. Marine discharge of secondary treated sewage effluent became dominant. Limited reuse occurred in and around the treatment plants on an opportunistic basis. Most city reuse was for irrigation of golf courses and recreation areas, particularly during the hot, dry summers. However reuse from Adelaide's largest treatment plant at Bolivar was primarily for pasture and limited vegetable production. The Bolivar plant, commissioned in the 1960s was situated on the northern Adelaide Plains, adjacent to an area of good alluvial soils and well away from the existing city. This farming area, centred on the town of Virginia was also endowed with a large, high quality source of underground water. During the 1950s the area attracted a large European immigrant population, augmented by south-east Asian immigrants in the 1980s. Virginia has become South Australia's largest and most diverse market gardening area. Virginia provides about 35% of South Australia's vegetable production and generates about AU$120 million in economic activity.

Support to increase reuse of sewage treatment plant effluent gathered momentum in the late 1980s due to increasing concerns about the effect that nutrients in the discharges were having on the ecology of the marine receiving waters. Water industry professionals were also beginning to recognise that many of the State's surface and underground water resources were reaching, or had exceeded their sustainable limits of exploitation. In 1993 the Government of South Australia endorsed a policy supporting the reuse of treated sewage effluent when and where sustainable. In 1995 a range of resource protection legislation was brought together with the proclamation of the Environment Protection Act. All of these events set the scene for a major increase in the level of water reuse and recycling to take place.

Project overview

Virginia is the hub of a major vegetable growing industry heavily reliant on a good quality irrigation water supply. The industry has historically relied on a major groundwater resource. This resource has provided about 18,000 megalitres per year, which is beyond sustainable limits. Despite some 12,000 hectares of good quality soil being available, the annual area of irrigated cultivation is limited by water to only 3,500 hectares. The Bolivar Wastewater Treatment Plant located adjacent to the area discharges an average 40,000 megalitres of sewage effluent per year. Until recently, this output, including an annual nitrogen load of 2,000 tonnes, was discharged to sea with adverse ecological impacts. This set of circumstances provided a clear opportunity to develop a holistic solution to reduce the mining of groundwater, reduce eutrophication of the coastal environment, sustain and expand the economy of the region and improve the return on taxpayers funds. These funds would have otherwise been spent on a non revenue generating upgrade of the Bolivar plant for nutrient reduction with continued marine discharge. Instead, taxpayers funds were expended on what is in effect a water treatment plant (Dissolved Air Flotation and Filtration, ie DAF/F) added to the end of the wastewater treatment plant. Consequently this project has been termed a water recycling project as opposed to a reuse project. The distinguishing factor is the specific objective to achieve a product water quality that meets a market requirement.

The Virginia Pipeline project commenced operation in 1999 after four years of promotion, investigations and negotiations, and an 18 month construction and commissioning period. The main elements of the project consist of a 120 megalitre per day DAF/F treatment plant, a disinfection contact and balancing storage reservoir, a pump station and 150 kilometres of distribution pipework ranging from nominal diameters of 850 mm down to 100 mm. The pipeline supplies water to about 250 vegetable growers operating within an area of 200 square kilometres. At the time of project commissioning in 1999, growers had signed contracts with the pipeline operator to purchase 28,000 megalitres per year of recycled water. Because most demand is confined to the drier part of the year, this volume of water is approaching the maximum that can be used without providing major storage for the winter flows through the sewage treatment plant. The AU$23 million pipeline project was negotiated on a Build, Own, Operate, Transfer (BOOT) basis with a private company, Euratech Ltd. Capital funding was a mixture of government equity and private equity and debt. All operating expenses are funded from water sales with initial buyers paying an average AU$120 per megalitre. The Virginia Pipeline was the first project of its type in South Australia. There was significant initial customer resistance to paying for the full cost of recycled water and the government equity effectively subsidised those that pioneered the water's use. As customer confidence in the scheme has increased, Euratech has made subsequent sales of water at commercial prices. More information on the Virginia Pipeline can be accessed at www.dehaa.sa.gov.au/testzone/watercare/database/bolivar.htm. Another similar scheme, which has been fully funded by private investors, has recently been completed to the south of Adelaide. This indicates how quickly the market can react to a new opportunity to secure access to a limited resource once pre-existing perceptions and other barriers are dealt with.

Public health, water quality and treatment

United Water operates and maintains six water treatment and four wastewater treatment plants in Adelaide on behalf of SA Water. The Bolivar plant is the largest of the four wastewater plants and treats an annual average 135 ML/d of domestic and industrial effluents contributed by an equivalent population of 1.3 million.

The wastewater treatment process at Bolivar consists of conventional primary sedimentation followed by secondary treatment through biological trickling filters. Further treatment is achieved through stabilisation lagoons from which the effluent was historically discharged to the marine environment.

In order to meet the requirements set by the South Australian Health Commission (SAHC) and the South Australian Environment Protection Authority (SA EPA) for water suitable for irrigation with minimal public health restrictions, the effluent from Bolivar was required to undergo further treatment. The key treated water quality requirements were set as follows:

- turbidity, less than 10 NTU (mean), 15 NTU (max)
- faecal coliforms, less than 10 FCU/100mL (median)
- pathogens, less than 1/50L (objective zero).

These requirements took into consideration the fact that detention time in the stabilisation ponds is no less than 16 days and on average 30 days. This provides a safety buffer before final treatment for recycling as well as allowing for further degradation of any potential toxins and pathogens that might break through the wastewater treatment processes.

Work on concept design for a 120 ML/d plant with post treatment disinfection started at the end of 1996. DAF/F was selected as the preferred process. A month later, a 3 month pilot plant program was developed to support the concept design and confirm the design and operating parameters. A 0.5ML/d DAF pilot plant fitted with three external 200 mm diameter filtration columns was used for that purpose. Pilot work showed that the DAF/F process was able to produce the water quality required by the SAHC and SA EPA. In broad outline, the raw water is pumped from the stabilisation lagoons and coagulant chemicals are added. The feed is then flocculated to promote the formation of larger flocs. In the flotation tank, the flocculated water is mixed with a recycle stream containing dissolved air. The pressure of the recycle stream is reduced when it enters the flotation tank, whereupon small air bubbles come out of solution. The bubbles and flocs agglomerate and rise to the surface where they are removed as sludge.

To further clarify the water the underflow from the flotation process is passed through a granular filter located under the flotation tank. Flocs and suspended matter not removed in the flotation process are removed in the filter. The filter is backwashed when its head loss reaches a predetermined level. A small proportion of the filtrate is used to provide the recycle stream mentioned earlier.

The construction of the AU$34 million DAF/F plant started in February 1998. The 150 ML/d plant has been built in two stages, Stage 1 (75ML/d) being completed at the end of 1998. Commissioning started in February 1999. Results obtained during the early commissioning period indicated that the performance of the plant was satisfactory. Suspended solids were reduced for 24 hour composite samples to 11 mg/L (average value) from values in the feed water of between 100 and 150 mg/L. Faecal coliforms were adequately removed with a 90 percentile of 38 coliforms/100 mL remaining.

During commissioning the DAF/F plant operating parameters were revised. In particular, suspended solids requirements were replaced with a need to achieve an average turbidity of 10 NTU in the treated water. This change was based upon improved operational control achievable through on-line turbidity measurement and monitoring at the plant. Strong correlation was demonstrated between suspended solids and turbidity during both initial pilot plant work and more recent full-scale plant commissioning work.

At the time of writing this paper (June 1999), the project partners were awaiting the arrival of warmer, drier weather, commencing in October 1999, to proceed with full operation of the scheme.

Associated monitoring and research

Various government approvals were necessary to enable the project to proceed. The key approvals from the public health and environmental sustainability perspectives were the final certification of the treatment process performance by the SAHC, and the approval of an Irrigation Management Plan (IMP) by the SA EPA. Certification by the SAHC was easily obtained as the treated water met or exceeded the quality requirements. The IMP submitted to the SA EPA for approval was based on an initial strategic assessment of potential environmental effects supported by strategic monitoring. This was coupled to an initial three year research, education and training program aimed at fostering improvements in irrigation practice and on-farm management by the region's irrigators. This proactive approach was successfully argued to be a more beneficial use of financial resources than a large investment in extensive monitoring sites, analyses, data capture, synthesis and storage. Instead, a better understanding of sustainability issues is leading to practices being modernised. Monitoring of soil and both surface and ground water continue to be an important part of irrigation management, but the monitoring is well targeted, cost effective and intended to provide early warning of any emerging issues. As the scheme is still in the early start up phase, it is too early to comment on this aspect of the project.

Key commercial issues

Discussed below are only a few of the commercial issues that needed to be managed throughout the course of the project.

An early step in developing the commercial elements of the project was to conduct preliminary market research to determine the potential demand for the product, its price sensitivity, and understand how the product would be received in the marketplace. Whilst the potential demand was good it was very sensitive to price. The product was generally perceived as being inferior because people associated it with sewage. This information allowed a marketing and project promotion strategy to be developed. The strategy was to physically show customers what the water would look like after treatment, thereby improving product perception, raising the perceived value of the product and improving potential demand. Recycled water samples were initially synthesised in a laboratory and later in a pilot plant. These samples were displayed extensively at public meetings. The South Australian Health Commission gave assurances that the treatment process selected was capable of producing a quality of water fit for a wide range of vegetables and other crops with minimal restrictions. The change in perception from the recycled water being considered inferior to almost as good as groundwater was successfully achieved over a period of about 3 years.

There were quite a number of risks associated with the project. One of the biggest risks to SA Water was that sufficient recycled water be sold to reduce its marine discharge sufficiently to achieve environmental compliance. A major issue for the pipeline owner, Euratech was for revenue to be sufficiently certain for it to proceed with building the project. To control these risks, long term “take or pay” contracts were negotiated with the irrigators in advance of the project proceeding, ie the irrigator would be required to pay each year for the contracted amount of water whether it was used or not. Because most irrigators also had access to groundwater, the practical effect of this initiative would be for the recycled water to be used in preference, with ground water being left for later in the season if required. This would maximise reuse, provide stable revenue and possibly reduce the demand on the aquifer.

The project was structured as a 20 year BOOT with Euratech returning the entire business including the assets to SA Water at the end of this period for one dollar. The project agreements were signed when water sales reached the minimum viable level. There was a conscious decision to share the upside of additional water sales between SA Water and Euratech in a manner that gave Euratech substantial incentive to maximise sales volume. SA Water would benefit in the short term by meeting or exceeding discharge compliance requirements. In the long term it would benefit by taking over a business with robust, inflation linked cash flows.

Due mainly to the groundbreaking nature of the scheme, the negotiations leading to the creation of the seven major project agreements took about two years to complete. This came at a cost of over AU$1 million for external consultants, including accountants, lawyers and engineers. This was in addition to another AU$1.5 million expended on the commercial and technical investigations necessary to promote and progress the project over four years. Many valuable lessons were learned over this time and subsequent similar projects have been able to benefit directly from this work. The promotion and development of a significant, groundbreaking project needs adequate resources and risk funds to deal with the inevitable challenges without loss of momentum.

Aquifer storage and recovery research

As mentioned in the Project Overview, the practical challenge to the vision of zero discharge to sea, and therefore total recycling, is an economical means of seasonal storage. For a range of reasons, surface storage was not considered viable. These facts were recognised when the project was first considered. However Aquifer Storage and Recovery (ASR) was a technique with which the government and others had, in other applications, enjoyed considerable recent success. One such success was at the town of Clayton on the western shore of Lake Alexandrina in South Australia. Here the town water supply has been traditionally pumped from the lake. In recent summers this supply has been under threat from toxic algal blooms caused by high nutrient loads. An ASR project was undertaken to inject high quality potable water, when available from the lake into an unconfined, high salinity (>40,000 mg/L) limestone aquifer beneath the town. This unique undertaking required the development of a lens of potable water within a buffer zone of mixed saline and fresh injected water. Testing confirmed that a lens of potable water was successfully established creating a safe potable water supply. This scheme is now in its third year of operation.

This success prompted the government and others to invest AU$3 million in a research project to explore the viability of recycled water ASR. The research is structured to address the issues that arise when considering the injection of water that is of a quality less than drinking water into an aquifer. A consortium comprising United Water, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Government of South Australia represented by SA Water, Primary Industries and Resources South Australia (PIRSA) Groundwater Program and Department of Administration and Information Services Major Projects Group have combined to undertake the research. The three year project is underway with the objective of determining the technical feasibility, environmental sustainability and economic viability of ASR using the Dissolved Air Flotation and Filtration (DAF/F) treated, recycled water from the Bolivar Wastewater Treatment Plant. The project is also intended to confirm and demonstrate that any potential health risks associated with the practice can be controlled effectively within a strict quality regulation and monitoring regime.

Before the project moved out of the laboratory and into the field, an extensive community liaison program was undertaken. The aim was to both educate the community about the aquifer and to consult them about managing the possible risks and benefits to be gained if the research was successful and a large scale ASR scheme could be implemented. The program was designed to overcome misconceptions that existed within the community about the aquifer, its physical make-up and the movement of water within it. The program also sought to overcome health related concerns given that groundwater was used by some for domestic supply as well as irrigation. This public health issue is addressed through the current Australian Water Quality Guidelines for aquifer storage and recovery of stormwater and recycled water. In summary, the guidelines recommend that the quality of injected water should be such that it preserves all potential beneficial uses of the existing groundwater. In keeping with the 1995 National Water Quality Management Strategy (NWQMS) Groundwater Protection Guidelines, this offers a higher level of protection to aquifers containing higher quality water or discharging into environmentally sensitive water bodies. The guidelines also allow for attenuation processes where these can be quantified in the aquifer (Dillon and Pavelic, 1996). If the aquifer is brackish, the recycled water injected need not be fit for drinking, so long as all existing potential beneficial uses eg irrigation and stock use, and ecosystem maintenance are protected. If the injectant does not meet NWQMS water quality guidelines for those beneficial uses, the attenuation of contaminants within the aquifer would need to be quantified to ensure that required water quality is achieved at all prospective extraction wells. If there are drinking water users in fresher parts of the same aquifer, an evaluation would be required on whether contaminants would have attenuated to drinking water standards within the minimum travel time to such wells to ensure they are not compromised. These guidelines are quite different to those currently applying in USA where groundwaters less than 10,000 mg/L total dissolved solids are considered to be potentially potable, and water needs to be treated to drinking water standards prior to injection (Dillon and Pavelic, 1998).

The question of injecting recycled water treated to a level that is fit for irrigation use raises the spectre of pathogens and nutrients that may be introduced to the aquifer as a result of ASR. For the Bolivar scheme injection will occur into the brackish parts of the aquifer where the groundwater is too saline for irrigation or domestic purposes. If pathogen attenuation is as expected, the travel time to a well that is used for domestic purposes would be such that all potentially harmful microorganisims originating from the injected water would have died off. Any conservative solutes in the recycled water that may lie outside drinking water guidelines will be sufficiently diluted by the time that the injected water may reach a domestic supply well such that the groundwater would still meet drinking water guidelines.

Artificial recharge of aquifers is an innovative technique that has significant prospects for beneficial application. Over the last decade a relatively small and specialised group of researchers and practitioners has met on three occasions at international symposia arranged to enable transfer of information. The first of these gatherings was in 1988 at Annaheim USA, the second in 1994 at Orlando USA and the third in 1998 at Amsterdam, The Netherlands. The next International Symposium on Artificial Recharge, ISAR 4 is being held in September 2002 at Adelaide, Australia. More information is at www.clw.csiro.au/cgs/conf /content.htm.

Conclusions

In Adelaide, the State capital of South Australia, a highly innovative and cost effective solution has been found to the dual problems of returning municipal wastewater to the environment and the over-exploitation of natural water resources for irrigation of crops. The solution is the outcome of extensive negotiations between government, private investors, developers and irrigators. Whilst details may vary from one region to the next, much of what has been learned from this project could be applied to other locations and circumstances. The level of water treatment required for recycling is dictated by the needs of the end user. In the case of this project, the quality required was quite high but still short of potable quality. Aquifer storage and recovery (ASR) of this quality water has not been previously identified in the literature as having been attempted. Storage and recovery of this quality water in a poor quality aquifer is the subject of a major research project which was about half complete at the time of writing. The local community is being kept informed of all aspects of the project and results to date indicate a good likelihood of the success of the technique. A satisfactory conclusion to the ASR research project will help this major water recycling initiative move one step closer to the vision of zero discharge of wastewater to the sea.

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