Horticulture Australia

Horticulture Australia Recycled Water Tour to Israel and California 2001 VG00087

Craig Feutrill[*], *Jim Kelly,*[**]
Mardi van der Wielen[**], *and Daryl Stevens*[***]

[*] *South Australian Vegetable Industry Development Officer*
[**] *Adelaide University, Soil and Water*
[***] *CSIRO Land and Water*

The University of Adelaide

CSIRO Land and Water

WRSV
Water Reticulation Systems Virginia

NETAFIM AUSTRALIA

ARRIS
Australian Rural Research & Innovative Science

Contents

Figure 1 The Horticulture Australia Recycled Water Tour Group (photo by Dr Daryl Stevens CSIRO Land and Water)

Back: Allan Dawson, Fiandri P/L; Martin Sayers, Eastern Irrigation; Neil Brennan, CEO Central Highlands Water; Rick Desmier, United Water International; Bernie Sutton, City to Soil, Glen Templeman, Operations Manager Willunga basin Company; Peter Ebner, Lower Murray Services; Steve Letts, Reporter ABC; Jim Kelly, Arris P/L, Adelaide Univesity.
Middle: Graeme Cornish, Sound ABC; Michael Nguyen, PIRSA RS Horticulture Advisor; Mick Makestas, S.A. Water; Ray Ledger, SA EPA; Geoff Mabbett, CEO Western Water; Chris Davis, Executive Director of the Australian Water Association; Phil Jauncey, Matilda Farms, Colin Earnshaw, Wagga Wagga City Council; Eric Havnen, Camera ABC.
Front: John Mc Veigh, Executive Officer for Darling Downs Vision 2000; Majella Jackwitz, Jackwitz Gardens; Graham Clapham, Clapham Farm, David Armstrong, Yanco Farms; Craig Feutrill, IDO Vegetables SA; Colin Lewis, Tyco Water; Andrew Osborne, Fisher Stewart; Ron Leamon, CEO Lower Murray Water; Lisa Goodwin, Vivendi Water Australia; Dr Jim Sands, University of Queensland, Catton.

Background

The study tour of Israel and California was to examine the use of recycled water for the irrigation of horticultural crops, including non-processed raw produce. It was initiated to assist the water industry, irrigation engineers, users, and potential users, of reclaimed water to come to terms with challenges and issues relating to reclaimed water use in Australian horticulture. Continued competitiveness of horticulture depends on the ability of the growers to grow produce at nationally and internationally competitive prices. However, without a cost effective guaranteed supply of suitable quality water, this cannot be achieved. Reclamation of water from sewage treatment works offers a long-term viable option for our limited water resources in Australia. Economic viability of reclamation schemes primarily dictates its use on high value crops. However, Project VG97081 (Horticulture Australia Limited) and others in the water industry have identified that growers (especially vegetable growers) are cautious to adopt this new water source because of:

1. Their limited understanding of water reclamation and reuse.
2. Some potential management issues with reclaimed water use.
3. A lack of confidence in this new resource/technology.

An investigative tour involving Australian horticultural reclaimed water users, potential users, and advisers visited similar industries in America and Israel. The idea was firstly, to build confidence in the use of reclaimed water in the industry and secondly, to expose growers to the cutting edge in technology (irrigation, greenhouse, reclaimed water use, increasing opportunities and promoting diversity in horticulture) so that growers may develop these technologies in Australia. America and Israel were chosen because of the success of the reclamation schemes and the leading edge technology available to their growers. This new technology includes: processing and packaging, new plant species and cultivars (e.g. new salt tolerant salad vegetables), and proactive marketing and public relations of reclaimed water use.

The primary purposes of the study tour were to:

1. Observe and discuss technology first hand that might be appropriate for adoption by the Australian reclaimed water industry to improve their businesses.
2. Improve the understanding of overseas R&D and its relevance, encouraging growers to be more active in prioritising research in Australia.
3. Establish and promote linkages between Australian growers and overseas industry members and researchers,
4. Increase grower's knowledge base and understanding so as to reduce the inhibition to the use of reclaimed water and to promote further the demand for use of reclaimed water.
5. Increase public perception of the benefits and safety of using reclaimed water in agricultural production.

Water is essential for food production and to feed the worlds population as we progress into the 21st century, especially in states and countries where there are limited water resources (i.e. Israel; California, USA; Spain).

Irrigated agriculture is of paramount importance in the ongoing production of food and fibre. Today's world population of 6 billion is forecasted to reach 8.1 billion by the year 2030 and the demand for water of suitable quality and the associated technology for its use has never been greater. Globally, irrigation claims 70% of freshwater taken from rivers, lakes and aquifers, and in the last fifty years there has been a six-fold increase (Wolter, 2000). In the Murray-Darling Basin as much as 95% of the water is diverted for rural and irrigating purposes (Meyer, 2000). Some 26 countries already have more people than their water resources can support (Rowe and Abdel-Madig, 1995). Wastewater reclamation and reuse technology has been developed and is now available to meet some of the water requirements of these countries.

As the world population grows, the demand for urban water will grow at the expense of water available for irrigation purposes. To ensure continued supply of suitable quality water for urban and irrigation purposes, improvements in water use efficiency and new sustainable water resources are required. The development of water resources and new irrigation technologies must be undertaken to ensure that irrigators have the confidence to invest into their future. Reclaimed or recycled (reuse) water will become an integral part of water use in the future (Dillon, 2000). Reclamation schemes and interest in reclamation and reuse of effluent is increasing rapidly as Australia recognises the value and limitations to our natural water resources (highlighted recently at the Water Recycle Australia 2000 Conference; Dillon, 2000). Public/political pressure in Victoria recently, with the change of government, has lead to increased diversion of water from irrigation, to increase environmental flow down the Snowy River. Undoubtedly, conflicts about water availability, allocation and use will continue and intensify in the future (Meyer, 2000).

Increased environmental awareness and pressure by the Environmental Protection Authorities has recently produced a demand for land reuse of reclaimed water. This coupled with the increased demand for water of a suitable quality for irrigation, has seen the development, or proposed development, of several reclaimed water projects in Australia. Such projects where reclaimed water is, or will be, used specifically for horticulture in Australia are:

- The Virginia Pipeline Scheme, Northern Adelaide Plains, SA (recently commissioned);
- Willunga Basin Reuse Scheme, SA (recently commissioned);
- Richmond Sewage Treatment Works, NSW (recently commissioned);
- Toowomba City Council,
- Shoalhaven Reclaimed Effluent Management Scheme (Reclamation plant construction gone to tender);
- Gatton Shire Council, Lockyer Valley Reclamation Scheme (proposed);
- Melbourne East Waste Water Treatment Plant, Carrum, (proposed).

In theory, scientific and industry organizations may have the knowledge to ensure reclamation and reuse schemes will be environmentally and economically sustainable. However, in practice, if there is not successful adoption and use of the water by the end user, the economic success of the project will be questionable (Stevens et al., 2000). Consequently there needs to be an increase in knowledge of growers, legislators and the public so that the reclamation of wastewater can provide environmental benefits and also provide growers with a sustainable water resource.

REFERENCES

Dillon, P. 2000. Water Recycle Australia, 2000. (Editor) Conference, Adelaide, Australia. October 19-20.

Meyer, W.S. 2000. Irrigation and the Competition for Water: Will Improved Water Use Efficiency Delive Everyone's Aspirations. Paper read at Irrigation Association of Australia, 2000 National Conference and Exhibition, at Melbourne, Australia.

Rowe, D.R., and I.M. Abdel-Madig. 1995. Handbook of Waste Water Reclamation and Reuse. Boca Raton: CRC Lewis Publishers.

Stevens, D.P., M.J. McLaughlin, G. Owens, J. Kelly, and N. Maier. 2000. Agronomic issues when using reclaimed water: The Northern Adelaide Plains Experience. Water Recycle Australia 2000 Conference, Adelaide Australia, October 19 and 20.

Wolter, H.W. (FAO). 2000. Role of Irrigation For Food Security. Paper read at Irrigation Association of Australia, 2000 National Conference and Exhibition, at Melbourne, Australia.

ACKNOWLEDGEMENTS

Craig Feutrill, Jim Kelly and Dr. Daryl Stevens would like to thank Horticulture Australia (HA) for their support of this project. The tour participants were unanimous in their appreciation of HA’s foresight to fund this tour. We would also like to thank every participant for the unquestionable value they added to our tour.

EarthTech, Netafim and Tyco were invaluable in their on-ground assistance in both Israel and California, the tour ran smoothly because of their knowledge and input.

Many thanks also go to Keith Israel, from the Monterey Regional Water Pollution Control Agency in California and Dr. Gideon Sagi, Shaul Gillan, and Eli Vered from Netafim in Israel.

Arris Pty Ltd provided the exceptional administrational support and information transfer both pre and post tour.

EXECUTIVE SUMMARY

Between 22nd of April and May 4th 2001, 25 participants toured Israel and California on a study tour of reclaimed water use, new technology associated with it, and alternate crops and farming systems. The tour was lead by Jim Kelly, Craig Feutrill and Daryl Stevens, who also took three ABC staff with them to produce programs for the ABC's Landline program and other industry promotion videos.

The primary purposes of the Study Tour were to: 1. Observe and discuss technology first hand that might be appropriate for adoption by the Australian reclaimed water industry to improve their businesses; 2. Improve the understanding of overseas R&D and its relevance, encouraging growers to be more active in prioritising research in Australia; 3. Establish and promote linkages between Australian growers and overseas industry members and researchers; 4. Increase grower's knowledge base and understanding so as to reduce the inhibition to the use of reclaimed water and to promote further the demand for use of reclaimed water; and 5. Increase public perception of the benefits and safety of using reclaimed water in agricultural production.

The tour exposed participants to a wide range of issues and technologies. The majority of irrigation in Israel is carried out using drippers, either above or below ground, because of their high water use efficiency under the often very high evaporation rates experienced in the Israeli environment. The dire water situation in the western part of the USA is stimulating a shift from traditional furrow and sprinkler irrigation toward more water efficient dripper irrigation. Novel on-farm solutions have also been found for other difficult farming problems such as the high levels of soil salinity, boron and selenium coupled with high water tables found in the San Joaquin Valley.

Throughout the tour participants were continually reminded of the importance of relevant targeted research required to ensure the acceptance of non-potable use of reclaimed water, and to ensure of the sustainability of such reuse projects. Many of the world's reuse schemes have been assisted by the use of high quality research done for the Monterey scheme into the potential health risks and implications for agricultural production.

The study tour has developed research and grower/industry links with individual and organisation in the USA and Israel. For example, discussions are currently underway assess the feasibility of a tri-nation research project assessing the potential of reclaimed water for use in the hydroponic industry.

The contrasting practices in Israel or California provided opportunities for water industry representatives, growers and legislators to become increasingly aware of respective issues relating to water reclamation and reuse. Participants met groups that were committed to the adoption and use of a valuable and replenishable water resource (reclaimed water) that provided the user with security on which they could invest further in for the future.

Possibly the most significant outcome of the tour was the increased knowledge of the safe use of reclaimed water for food crops. In Israel and California the production of food crops using reclaimed water was accepted by growers, marketers and the wider public. However, it was also obvious that to provide the desired security adequate legislation, monitoring and controls needed to be in place. It was also obvious that the development of water reclamation and reuse schemes must be accompanied by effective communication and education programs to ensure that the wider community has confidence in the produce grown with reclaimed water.

Although there were distinctly different drivers for the use of reclaimed water between the USA and Israel, there were also two main themes common to all scheme. Firstly, reclaimed water is a valuable resource and secondly, high quality and value crops can be easily grown with reclaimed water.

Communication of the findings from this Study Tour has been at several levels. The general public have been educated through three landline articles. The industry has been educated through release of industry-based videos, presentation by the Tour leaders around Australia (on going) and through direct communication of participating growers with growers. Finally, the water industry has been educated by several industry reports/presentations to state water treatment authorities.

Israel – General Introduction

WATER RESOURCES IN ISRAEL

Sixty percent of Israel is classified as arid or semi-arid, with strong consequences for the availability of water for drinking, household use, industry and irrigation. The main source of potable water is the Sea of Galilee (Figure 2), otherwise known as Lake Kinneret.

Figure 2 View of the sea of Galilee overlooking the city of Tiberius, Israel's main supply of potable water.

Water is also obtained from aquifers, although many are too brackish for potable use and irrigation. Some aquifers have become saline due to over exploitation. Furthermore, many of the coastal aquifers are threatened by intrusion of seawater because of reduced ground water pressure as a result of increasing extraction. Reclaimed water is also used as a source of water for non-potable use only, particularly for irrigation of food and other crops.

The rapidly increasing population has placed increased pressure on very limited potable water resources, leading to more extensive use of reclaimed water for irrigation in order to reduce the use of potable water sources for these purposes. Purified reclaimed water can also be used for injection into coastal aquifers to protect them from saline intrusion. In summary, water reclamation and reuse in Israel is largely driven by the intense need to conserve potable water rather than for environmental concerns related to the disposal of wastewater.

WATER REGULATION

The Israeli Government now heavily regulates water use and management. This includes extraction and use of groundwater and surface water as well as allocation and use of reclaimed water. Regulations require that new developments must have a solution for management of sewage and wastewater besides ocean disposal, in acknowledgement of the potential for contamination of potable ground water supplies and for protection of the environment, as well as the potential for reuse. Mekorot, the national water carrier, is responsible for water resource management, supply and wastewater treatment. They also provide the water supply and the necessary infrastructure to bring water to a region. Regional water authorities usually then distribute pressurised water to the farm gate.

The government is responsible for allocation of water to growers, which is generally done on a family basis and depends on the enterprise. Allocations can also be reduced to ensure potable supply, as occurred in 2001 with 50% cuts in allocations to growers due to drought. Growers are now allowed to sell or trade their allocations but may not make a profit in doing so. The Ministry of Agriculture sets the price of water annually and it is more expensive in the much drier south of Israel than the wetter north. Price can also depend on use patterns of potable water in the cities. For example, in Jerusalem, the municipality pays Mekorot $0.80/KL for water, then on-sells it to the consumer for between $2.00/KL and $6.00/KL depending on use patterns. Because there are good profits to be made from municipalities selling water, there is little encouragement by the authorities for the city populace to minimise or economise water use.

REGULATION AND USE OF RECLAIMED WATER

The government is using several incentives to encourage farmers to use reclaimed water instead of potable water for irrigation, including:

1. Quantity – 20 to 25% more water offered, above allocation if reclaimed is used.
2. Price – 25% less paid for reclaimed water
3. Security – guaranteed supply of reclaimed water.

Reclaimed water is permitted for different uses depending on the level of treatment. Growers must seek permission every year for use of reclaimed effluent for irrigation and the type of crop irrigated from the Ministry of Environment and the Health Department. The highest class of water may be used for unrestricted irrigation (equivalent to South Australian Class A) and must conform to strict standards, which are equivalent to the model California Title 22 standards (less than 10 *E. coli*/100 ml, turbidity <2 and disinfection required). Meeting health requirements for reclaimed water is the responsibility of the reclaimed water supplier. The Ministry of Environment is responsible for environmental effects of reclaimed water reuse. xxx

During the tour, a variety of enterprises were visited which use reclaimed water of different classes for different uses. These include:

- Kibbutz Tzora (grapes, olives and almonds, Page 13);
- Kibbutz Yavne (olives, cotton and corn, Page 16),
- Steh Nizan (flowers, Page 19);
- Kibbutz Bet Kamada (potatoes, garlic and watermelon, Page 21);
- Arad (pistachio, almond and grapes, Page 22);
- Kibbutz Beit (citrus and pecan, Page 27) and
- Nir David (fish and sunflowers, Page 33).

A Kibbutz (plural Kibbutzim) is a very common type of settlement in Israel where a cooperative group of people live and work together and run all of their facilities, factories or agricultural enterprises in a cooperative environment.

WASTEWATER TREATMENT

The extensive use of reclaimed water and the need for efficient water use in Israel has resulted in considerable innovation and variation in wastewater treatment and agronomic management. Wastewater treatment in Israel ranges from the large scale Shafdan treatment plant (Figure 3) that treats the effluent of seven cities to a virtually potable standard using relatively modern methods and a unique aquifer treatment and storage system; down to very simple treatment schemes managed by farming collectives based on lagooning methods which need large areas but require little energy and maintenance.

The cost of the resulting water depends largely on the quality and level of treatment, with Shafdan water being relatively expensive (still cheaper than potable water) but still sought after because of its reliability and guaranteed low level of suspended solids and pathogens, low salinity and delivery at high pressure. At the other extreme, prices for water from many of the local reuse schemes are often only the cost of pumping and filtration. Plants treating effluent to a variety of levels were visited during the tour, including Kibbutz Tzora (Page 14), Shafdan (Page 15), Arad (Page 22), Emek Hefer (Page 28) and Emek Izrael (Page 30).

Figure 3 Aerial photo of the Shafdan wastewater treatment plant

After treatment, reclaimed water is generally stored in open dams that are often sealed with plastic to prevent losses through leakage rather than to reduce impacts on groundwater. Algae blooms are a common problem in such dams because of the high level of nutrients in the water, with consequences for blockages of irrigation equipment and potential health risks from the presence of toxin producing blue-green algae. A method for controlling algal growth in dams based on bio-control by fish is being used at Golan Heights, described on Page 32. The system at Golan Heights also uses a large-scale run-off harvesting scheme to capture and store rainfall from low permeability volcanic soils. Aquifer storage is sometimes used, with recharge taking place through sand dunes which also acts as filtration, treating the water to a tertiary level. This novel system is used at the Shafdan treatment plant, described on Page 15.

AGRONOMIC MANAGEMENT OF RECLAIMED WATER

Filtration is an essential step before use, particularly for less treated or algae bloom affected water, as much of the irrigation is carried out using dripper systems that are prone to blockages.

Arkal, the world's leading supplier of spin disc filters, has its origins in the need for efficient, low maintenance filtration of low quality water for irrigation in Kibbutzim. The operation of spin disc filters in use at Kibbutz Beit is described on Page 27.

The majority of irrigation is carried out using drippers, either above or below ground, because of their high water use efficiency under the often very high evaporation rates experienced in the Israeli environment. Netafim (Figure 4), one of the world's leading drip irrigation manufacturing companies, also had its origins in a Kibbutz. Netafim carries out a considerable amount of research into irrigation and agronomic practices at Kibbutz Magal, as discussed on Page 28.

Figure 4 Kibutz Netafim, Magal site of the greenhouse and irrigation research centre and irrigation equipment factory

Most of Israel's soil is of a limestone origin, making it less susceptible to problems associated with salinity than many Australian soils. However, care must still be taken to periodically use fresher water to flush salts out of the root-zone. This can coincide with switching to the use of potable water at berry set or equivalent in compliance with health and agronomic recommendations. Various trials and research have shown equivalent or higher yields and quality can be achieved using reclaimed water compared with other water sources provided good agronomic practices are used.

Around 80% of the irrigated land in Israel applies fertilizer via fertigation, which involves combining the application of water and fertilizers through drip irrigation systems. Fertigation allows an accurate and uniform application of nutrients to the wetted area, where the active roots are concentrated. Planning the irrigation system and nutrient supply to the crops according to their physiological stage of development, and consideration of the soil and climate characteristics, results in high yields and high quality crops with minimum pollution.

The following sections describe the various enterprises and treatment plants visited during the tour through Israel in detail, illustrating the potential for success through the use of reclaimed water for irrigation.

Day 1 Israel.

ZORA'A VINEYARD (KIBBUTZ TZORA).

Enterprise: 40 ha vineyard growing sauvignon blanc and cabernet sauvignon for own small boutique winery. The Kibbutz also has a 50 ha almond orchard, 200 ha of olives and a 900 cow dairy from which the off-run water is used directly for cotton growing.

Property manager/contact: Shaul Bondy – vineyard manager

Water source and quality: Secondary treated effluent delivered to the property via a creek system which runs 30 km from Jerusalem. Kibbutz Tzora has been using reclaimed water since the 1960s and was the first Kibbutz in Israel to do so.

Salinity TDS ~ 800 mg/L
Chlorides ~ 200 mg/L
Nitrate ~ 30 mg/L
Phosphate ~ 15 mg/L

Cost and allocation of water: There is a continuous agreement for a permanent allocation of reclaimed water from the national water authority, but the Kibbutz can get a short-term over allocation if required. To use the water, growers must have a registered and approved allocation and the quality must be tested twice yearly. The test is conducted by the reclaimed water supply company and the results are sent to the Ministry of Environment.

- Reclaimed non-pressurised – pumping costs only.
- Reclaimed water pressurised - \$0.40c/KL
- Potable -: 1st 60% of allocation \$0.45c/KL
  Next 20 to 25% of allocation \$0.70c/KL
  Remainder of allocation \$2.00/KL

Labour source: Occupied Territories, and with continued disputes the borders to these regions can be closed, restricting the labour getting to the Kibbutz.

Irrigation system: Irrigation starts with reclaimed water, a few weeks after bud-burst, and continues until berry set. Potable water is used from berry set until a few weeks before harvest to comply with Department of Health requirements. Shaul Bondy's research has indicated that continual irrigation with reclaimed water, compared with changing to potable water at bud-burst, has no effects on berry set and quality.

Above ground drippers (3.5 ML/ha/y) are used but are damaged by birds and jackals and are likely to be buried in the future. In order to reduce blockages, the drip-lines are flushed with chlorine at the end of each season and incoming water is screened with an 80-120 micron mesh. Irrigation scheduling occurs by manual assessment rather than with instruments. Winter rainfall is sufficient for plant requirements during this period, while summer pan evaporation is 9 mm/day.

Crop management

- Irrigation requirements for frost control are not needed in Israel
- Copper sulphate is sprayed for downy mildew (spraying is 10 – 14 days apart)
- Insecticide sprays are used in reduced amounts for light-brown apple moth
- Nutrient applications are adjusted for the amounts added in the reclaimed water

Experiences with reclaimed water: The grower recommended that the salinity and sodicity of reclaimed water be considered by users of reclaimed water. High soil sodicity (i.e. a high proportion of sodium compared to other cations like calcium and magnesium) can lead to degradation of soil structure, leading to soil crusting and reduced infiltration. The Kibbutz has been using reclaimed water to irrigate cotton for 30 years and grape vines for 15-18 years with no apparent degradation in soil structure and believe that their soil is able to tolerate reclaimed water with a sodium adsorption ratio (SAR) of 3.5. This SAR is low and wouldn't be a problem in any soil.

Work done by the Hebrew University on the health risks of drift from spray irrigation with reclaimed water has shown that there has been no increased incidence of disease in reclaimed water-user workers compared to other workers. Treatment levels are also considered to be high enough that there should be no issues.

Kibbutz Tzora Tertiary Treatment Plant

Contact/manager: Zahar

The Kibbutz has begun a trial to treat secondary effluent to tertiary level to a standard that permits unrestricted use for crop irrigation (i.e. meets standards for turbidity, bacterial content and chlorine level for the California Title 22 guidelines or the Israeli equivalent). The Kibbutz aims to be able to irrigate around 100 ha of vegetables with this water. The Kibbutz also distributes the tertiary treated water to other Kibbutzim in the Sorek Valley area which is used to irrigate around 900 hectares.

Water source: There are 2 sources of sewage water that run through the plant:

♣ Beit Shemesh, using a 30" diameter pipe draining into a compacted clay sealed artificial lake.

♣ Secondary treated water from Jerusalem, drained into a plastic lined dam by a 30km series of creeks

There is not much natural runoff in the region with approximately 30 rain days per year, so there is not much dilution of the sewage prior to reaching the plant.

Treatment method: The treatment plant utilises biomechanical activated sludge treatment, deep sand media filtration and chlorination (concentration of 1 mg/L required at emitter). An electrode based system has also been trialed, largely unsuccessfully. The plant also produces stabilised bio-solids by the addition of lime.

Treatment and water costs: The cost of tertiary treatment is around US $\$0.12/m^3$ (including capital costs). Farmers outside of the Kibbutz pay about double. The plant cost 70 million shekels to build (2 shekels ≈ $1 AUS).
Plant capacity: 500 m^3 (0.5 ML) per hour or 12 ML per day.

Storage: Irrigation is not used in winter so reclaimed water is stored during this season. Sixty percent of the irrigation requirement is held in reserve, so the capacity of the nine storage lakes is 160% of total irrigation usage (9000 ML). The storage lakes are from 8 km to 20 km from the treatment plant site and are fed by a 36" gravitational pipe. The lakes are sealed to retain water, not to prevent leakage into the ground as there is not a groundwater issue in the region. Underground water in the region is considered deep – the first aquifer is at 10 metres depth and the next aquifer at 30 metres, separated by a confining clay layer. They get algal blooms in the storage lakes and treated the lakes seven times last year with copper sulphate and a pesticide to contain the problem. There have been no toxic algae outbreaks.

Kibbutz Tzora sealed lined dam

The dam is a receiving and storage dam for secondary effluent received by the Kibbutz through the creek system from Jerusalem. The dam is preceded by a weir which is designed to stand up to the 1 in 100 year flow of 100 m^3/second. A small overflow occurs from the weir during the winter season. Land for 50 metres either side of the creek is owned by the State of Israel.

SHAFDAN MAIN RECYCLING WASTEWATER TREATMENT PLANT

Reclaimed water from the Shafdan wastewater treatment plant (WWTP) has been used for irrigation for the last 15 years and is currently used to irrigate around 750 ha. Under periods of extreme water shortage reclaimed water can be used for potable supply.

Water source: The Shafdan WWTP treats wastewater from seven large cities, including Tel Aviv, as required by Israeli law. The wastewater is mostly domestic, with some light food based industrial waste present also.

Treatment method: The Shafdan system was initially built in 1987, and had a major refit and overhaul in 1996. The treatment plant uses an activated sludge treatment for its sewage water. Treatment method is as follows: the sewage is run through 20 – 25 mm screens, then grease/oil is removed and then the water is subjected to the introduction of air and bacteria. There is a 15 hour detention time in canals, then it flows into an anaerobic centre that has a 1 hour detention time. The most important input is ammonia for nitrification and denitrification. A feedback control for ammonia is monitored in real time on line.

Plant capacity: 1.6 million inhabitants plus an industry base equivalent of another 0.5 million people. (2.1 million person equivalent). The plant can treat up to 340ML of wastewater per day.

Storage, further treatment and distribution: Further south, but still in the same system, there is another new storage and treatment method. This is aquifer storage which is achieved by seepage through sandy soils, with the sand acting as a giant filter for the water. The seepage area is surrounded by a number of recovery wells and has a detention time of 400 days in the aquifer. The Israel Health Ministry states that this water is deemed safe for "occasionally drinking".
The seepage and aquifer storage system is considered to provide tertiary treatment to achieve class A water requirements (unrestricted irrigation use).

There was a problem with saline (ocean) water seepage into the aquifer, so the engineers created a 'hill' of underground reclaimed water that minimises salt water contamination. 120 GL of reclaimed water is put into the recharge storage per year to a depth of 30 to 100 metres in a mostly sand substrate. The Shafdan system uses a wetting and drying cycle for the recharge – reclaimed water flows in for 1 day and the pond is left for 2-3 days 'drying' to minimise algae contamination. Three ML of effluent are infiltrated per day. The remaining sludge from the water treatment (up to 75 tonnes per day) is dumped into the Mediterranean Sea.

A pipeline for use of the reclaimed water is run down to the Negev desert and the pipe is painted red to signify the reclaimed water status. The Ministry of Agriculture and Department of Health monitor the environment impacts of the Shafdan plant, including the marine environment.

KIBBUTZ YAVNE OLIVE GROVE

Enterprise: 700 ha including olives, cotton, corn and silage all grown with reclaimed water.

Property manager/contact: Itali (farm manager)

Water source and quality: Effluent is from Ashdod city and is treated using the aerated lagoon method.

BOD level ~ 80 mg/L
Salinity TDS ~ 600 mg/L
Chloride ~ 185 mg/L
Nitrate ~ 40-50 mg/L
Phosphate ~ 12 mg/L

Domestic water supply is a mix of Sea of Galilee and ground water (TDS 80-150 mg/L).

Cost of water: There is an agreement between the Government and the town as to the cost of water – there is not one price, this is reviewed yearly.

Irrigation system: There is 500mm rain per year between October and April and another 600mm per year is irrigated depending on temperature. Evaporation pans are used for irrigation scheduling. There is no difference in irrigation for oil olives compared to pickling olives. The olive plantation is currently irrigated with above ground Netafim drippers, (4L/hour) with 5 drippers per tree at 1 metre spacings. Buried old-style in-line drippers were previously used for 22 years with few problems with blockages. The changeover from underground irrigation to dripper must occur during the winter season to minimise stress to the trees.

Cotton and corn are irrigated using subsurface drip irrigation at 45cm depth. Irrigation is started two weeks prior to planting, and planting follows a single surface irrigation.
In Israel, 95% of farmers irrigate by flow, rather than by time, and so therefore know if nozzles are blocked because flow is reduced. Water is supplied to both ends of the drip line, which minimises blockage problems and minimises risk of poor water distribution. The irrigation system requires a good pre-filtration system (120 micron

mesh) and chlorination to be efficient. The grower flushes the lateral ends with phosphoric acid 4 times per year.

Experiences with reclaimed water: Nitrogen content of the reclaimed water is actually beneficial to olive production on the Kibbutz. There is 350 kg of nitrogen applied per hectare per year via the reclaimed water. The olives need 550 kg of nitrogen per hectare per year, thus top up is only 200 kg per hectare per year. The grower stated “you can never have too much nitrogen for olives”. There can, however, be problems with cotton and citrus as too much nitrogen applied at the wrong time can lead to problems with budding and fruiting. There is insufficient potassium and phosphorus in the reclaimed water, so there is a need for supplementary use. The supplementary phosphorus applied (50L/ha) is from the phosphoric acid used to treat the dripper lines.

There is no difference between yield and quality of crops irrigated with fresh water compared with irrigation with reclaimed water. The grower saves money because there is a reduction in the fertiliser costs as described above.

Soil salinity testing to two metres depth has found 250 mm rain per year is sufficient to maintain suitably low levels of salinity in the root-zone. This is dependent on the intensity of the rainfall, in that a lot of small episodes are not as effective for leaching salts as fewer large ones.

Tour Delegates Comments Day 1 Monday April 30th 2001

The Kibbutzim and Shafdan Waste Water Treatment Plant

The [systems seen illustrate the] need for regulation in Australia to be co-ordinated, streamlined and output focussed. i.e. designed to facilitate an end result rather than restrict it. Perhaps risk management should be investigated rather than regulation.

Nearly all water is used in what presents as an arid environment, for example, underground irrigation rather than fixed overheads to feed lawns etc.

The aspects that interested me most were: …the fact that sludge from the Shafdan [scheme] is disposed of into the ocean. Also the radically different perspective to effluent waste – it's a part of everyday life.

Outcomes from this are: that it would be possible to have a treatment plant west of Brisbane capable of treating all of that regions' wastewater. There would be greater retrieval costs due to our lower population density.

[The].. consistent attitude to the use of recycled water, and the diverse attitude towards the environment.

ASR (aquifer storage & recovery) should be explored and exploited more in Australia – general conservatism is the barrier. Water prices in Australia should be higher, where the water resource is scarce – Politicians are reluctant to rock the boat.

[The] growers in Israel DO know what they are doing – they learn and practice under the supervision of a technician – their technicians or consultants adapt their technologies to the ground, soil, weather conditions (arid conditions), not depending on overseas technologies.

Day 2 Israel.

STEH NIZAN ("FIELD OF BUDS") FLOWER FARM

Enterprise: 3.5 ha of greenhouse grown flowers (lisianthus, Figure 5), of which 94% is exported daily to the US. Citrus and mangoes also grown on the 400 ha property.

Property manager/contact: Ido Korman (owner)

Water source and quality: From Shafdan Wastewater Treatment Plant – the enterprise would not be possible without this source. Runoff from the glasshouse roof is also recycled.

SAR ~ 2-3
Salinity TDS ~ 500-1100 mg/L
Chloride ~ 150-500 mg/L
Nitrate ~ 3 mg/L
Phosphate ~ <0.2 mg/L

Cost of water:

- Reclaimed non-pressurised – Pumping costs only
- Reclaimed water pressurised - \$1.00/KL (pressurised to 10 atm), prices reviewed annually
- Total farm uses 4,500ML, 50ML used over the 3.5 ha of greenhouses

Labour source: Thailand – 7 workers over the 3.5 ha of glasshouses (highest production expense).

Irrigation system and crop management:
Flower beds were 1.2 m wide with 3 rows of flowers (40-100 plant per m^2, Figure 6). Grown in a sandy soil, seedlings watered twice every day until root development and then every 3-6 days depending on conditions (monitored using sensors), over watering leads to root rot (Rhizoctonia). All drip lines have 1.6 litre per hour emitters, spaced at 20 cm and are used for fertigation. It takes around 70 days to get a flowering plant although this depends on the plant variety and time of year and may vary from 14-18 weeks. Flowerbeds have been sterilised in the past with methyl bromide, and are currently sterilised using a more environmentally friendly method of covering the moistened soil with plastic for 7 weeks and allowing the heat of the sun to sterilised the soil (Soil temp > 60 ^{o}C).

Figure 5 Lisianthus

The disadvantage of sun sterilisation is the 7-week waiting period, and some trials are being conducted with methyl iodine.

The farm uses a climate controller which monitors temperature, humidity, radiation and carbon dioxide. The grower can open/close apertures/screens on the greenhouse to alter any of the four parameters if needed. Reclaimed water is used for irrigation as well as for misting in shade-houses to keep humidity at acceptable levels, as lisianthus are susceptible to leaf burn in dry conditions. Heating pipes run around flower beds and heating is applied via water if required over the winter, although this is rarely needed here. Shading kept at around 65% during seedling establishment and then reduced back to 15% for the rest of the plant growth.

Figure 6 Greenhouse layout

Experiences with reclaimed water:
The grower is starting to use soilless culture as he is concerned about the long-term sustainability of soil when using reclaimed water. The farm has been using/trialing reclaimed water since 1988 and have seen no reduction in yields, but there are concerns for long-term use because of boron levels (0.63 mg/L). The reclaimed water supplier is trying to address this at the input side by identifying where this is coming from and try to reduce the input. Boron sensitivities vary greatly with plant species, and there is the potential to cope with high boron levels by growing tolerant plants.

20% of the farm's cost of production, is the water cost. The farm has grown 35 different crops over the last 12 years in order to remain competitive and keep ahead of the market. The internet has helped the owner to keep up with what is being grown around the world and where, and allowed him to select the flowers to grow, when to fill the niches the market is missing and to develop new novel crops for/with the market. The only opportunity for enlarging production is through development of export markets.

In Israel it is the responsibility of the water supplier to ensure that the water is of the 'correct' standard. Water quality is monitored by the supplier with regard to health standards, however there is no real control of quality with respect to agricultural irrigation quality and there have been some instances when agronomic quality has been poor. The Shafdan water is piped, channelled and stored in dams along the supply chain and there have been some dripper blockage problems with algae growth, sand infiltration and biofilms. There have been attempts to address algae growth by promoting fish growth in storage facilities; however, this has not been very successful to date in this region.

The number of farmers in the region is becoming less for many reasons. There is a perception that the Israel Government does not support farmers and applies difficult regulations on farmers.

For example, technical support for farmers is being rapidly withdrawn. There are Ministry of Health water checks every 2 years of farm equipment etc.

KIBBUTZ BET KAMADA (TOP OF THE NEGEV DESERT)

Enterprise: 900 ha of potatoes (Desiree, Mondiali and 2 other varieties) and cotton grown with reclaimed water and bore water over the last 10 years. Potatoes yield range from 45-60 tonne/ha. Cotton (4 bales /ha), garlic and watermelons are also grown.

Property manager/contact: Doron (farm manager)

Water source and quality: The Kibbutz uses 1.8 GL of water from Shafdan Sewage Treatment Plant and 600ML from bores. Shafdan water quality is similar to previous stop. Property is the last on the water distribution line and consequently has water supply difficulties during periods of high demand.

Cost of water: not given, assumed to be similar to previous stop

Labour source: not given

Figure 7 Drip irrigated potatoes, Kibbutz Bet Kamada

Irrigation system and crop management:
A five year rotation is used. Crops are drip irrigated and fertilisation through drip systems. This system is fully automated and applies the fertiliser near the end of the irrigation cycle so nutrients are washed out to the edge of the dripper zone. For potatoes, the dripper line is put on top of the bed after planting, with an emitter spacing of 10cm (Figure 7). Daily irrigation is used at the beginning of the season, moving to irrigation every three days towards the end of the crop so that the potatoes are not in constantly saturated soils. Drip lines are removed just prior to harvest and yield has been approximately 45 tonne/ha for the two years of trials. Cotton uses 6 ML/ha at a cost of $2000. Cotton is pre-irrigated with spray for germination and the dripper lines placed every second row, with row spacing is approx. 100 cm. The Kibbutz previously used sprinklers, but found that by using drippers they could save up to two thirds the water volumes they had been using while getting the same yield.

Pan evaporation at this site is approximately 9 mm/day and potatoes are thought to require irrigation equal to 100% of pan evaporation. The Kibbutz are currently trialing irrigation rates of 100, 80 and 60 % of this to see what differences there are. Visually it was difficult to tell the difference between any irrigation rate, but there were no yield data yet to compare.

ARAD

Enterprise: Orchards (stone fruit, pistachio and almond) and vineyards (quality cabernet, cabernet sauvignon, merlot and shiraz)

Water Source and Quality: The town of Arad (30,000 inhabitants) produces around 5 ML of effluent per day. The effluent is secondary treated through lagooning, which is a low maintenance and low ongoing cost system. The process train consists of parallel, covered anaerobic ponds, followed by paired facultative lagoons, then three parallel aerated lagoons (floating surface aerators) and finally, a 600 ML maturation-come-storage pond. Local farmers can tap into the pond where this effluent is stored, pump it across to their properties and use it for irrigation after filtration.

Salinity: 800-1200 mg/L TDS
BOD: 20 mg/L

Cost of water: treatment costs only

Labour source: not given

Irrigation system and crop management:
Irrigation is by drip and subsurface (almonds, Figure 8) about 15 cm deep and 1 m away from the trunks. Two drip lines are sometime used to ensure sufficient water supply to trees at peak demands. Irrigation scheduling is carried out on the basis of pan evaporation, weather station data and soil moisture, with vines requiring 65 –70% of pan evaporation.

Figure 8 Arad almond orchard showing surface drip irrigation layout.

When irrigating with secondary treated reclaimed water, it is very important to have a well designed system which allows good flushing and filtration to reduce blockages of irrigation equipment. Small flushing valves are placed along the lines for maintenance, which allow 4 L to flush out at high velocity each time watering begins. There are also check filters before water enters the system. Vines are watered with reclaimed water until budburst and then the water source is swapped to bore or potable water.

Experiences with reclaimed water:
This area is in the middle of a desert which has been brought to life with reclaimed water use. Winter rainfall is small and erratic (rainfall is around 25 mm /year) and the soils seal very quickly on rainfall and runoff causes erosion. Why would you have a farming area in a desert like this? In Israel the culture is that if you use the land, you possess the land and it becomes your countries (possession is $10/10^{th}$ of the law). Reclaimed water here is free to encourage its use in agriculture and hence possession of the land.

The soils are naturally slightly saline so there are salt management issues. Bore and potable water is used for leaching and flushing lines and soils to reduce the soil salinity. Soils have a high clay content but are fairly permeable due to their calcareous nature, so the managers are still able to apply a sufficient leaching fraction to manage their salinity issues.

The grapes are grown for quality, not quantity, and yield around 8 tonne/ha. There are experiments currently being conducted to assess the effect of reclaimed water through the whole season, but they want to be sure before they use this full scale as they have a great name for the wines and don't want to do anything to destroy this.

Tour Delegates Comments Day 2 Tuesday May 1st 2001

The system used at Arad is very similar to the proposed project for the Darling Downs. Storing the effluent in ring tanks is an effective & economic way of treating effluent

[It became apparent that] Australian irrigators are not paying, or even aware of, the full cost of water.

In Australia we have a lack of appreciation or value of the resource (water).

Australians need to appreciate the value of water and the potential for horticulture, but Australian soils are unlikely to be as resistant to damage as those in Israel.

There is the potential to develop things like this (the Arad treatment plant) in Australia – in terms of technology. However, the 'drivers' are not there at present in Western Australia. In Israel, the drivers are, Political, land ownership and necessity, and no other method of growing food.

The profitability of intensive horticulture is very much dependent on the continuous changing of varieties grown.

Day 3 Israel.

VISIT FROM DEAD SEA WORKS PERSONNEL

The Dead Sea Works (DSW) extracts minerals from the Dead Sea, such as magnesium chloride, industrial salts, anhydrous aluminum chloride, de-icers, table salt and bath salts and is one of the world's leading manufacturers of potash fertilisers. The potash division produces and markets potash products in a variety of grades and qualities. Potassium (as KCl), along with nitrogen and phosphorus, are the essential nutrients for plant growth, indispensable for sustaining modern high-yield agriculture. The DSW produces around 2.8 million tones of potash and 250,000 tons of salt annually.

Solar evaporation ponds are used to concentrate saline water (1,000-10,000 mg/L TDS) from the Dead Sea, saving fossil fuels. The source water is too saline for potable use. The annual amount of evaporation from the ponds is around 120 GL.

FLOODING IN THE DEAD SEA REGION

Figure 9 Flash flooding at the Dead Sea Resort

The tour delegates were fortunate enough to be present for a 'once-in-an-80-year' flood in the region. The flood illustrated the rapid run-off and flash-flooding capability of the area (Figure 9).

Unfortunately due to the delegates being trapped at the hotel for the duration of the flood, the days' agenda was modified.
Xxxx conference

Tour Delegates Comments Day 3 Wednesday May 2nd 2001

Why do we discharge recycled water to the sea? Almost 45% in South Australia. We should use all our reclaimed water for agriculture – we hear many complaints that we have not enough water for agriculture, while we are dumping the recycled water!

[The] conference displays were a good opportunity to see alternate technologies not normally available in Australia; plus the opportunity to see the background of systems that are imported to Australia.

I believe the future for many in Australasia [who work] in specialised horticultural activity will be based on what we saw today.

[A] Reverse Osmosis plant may be able to be used to treat smaller volumes of effluent to improve its quality.

Mixing farming and ideology seems to lead to different results – the more market driven approach in Australia still seems preferable.

Day 4 Israel.

KIBBUTZ BEIT

Enterprise: Citrus and pecan orchard

Property manager/contact: Omri (from Arkal) and Ziev Gattlee

Water quality and source: The water is secondarily treated to class B/C at Netanya where there are two treatment plants. The newer, larger plant can actually treat all of Netanya's wastewater and to a higher quality but at a higher cost. The local growers have a right to a certain percentage of the water and prefer the lower quality water from the older plant at a lower price.

BOD 60 – 80 mg/L originally (20% soluble, 80% non-soluble) but is a bit better now

Suspended solids 50 – 150 mg/L

The water authority has agreed to provide water with a salinity of less than 700-800 mg/L and chloride less than 250 mg/L. There are no problems with grease and oil as Netanya does not have significant concentration of industry.

Water costs and usage: operational costs only – essentially it is freely supplied (via gravity) so the Kibbutz only pays a few cents per KL. If they used water from the newer effluent plant at Netanya, the cost would be 35 cents per KL. The Kibbutz uses 600 ML per year.

Labour source: Kibbutz members and Arab staff

Irrigation system and crop management:
The Kibbutz filters their reclaimed water to avoid blockages of their irrigation system. They use ARKAL disc filters (Figure 10) with a throughput of 0.42 ML per hour. The system involves spirally grooved plastic discs clamped together to create a fine filter (typically around 20-50 microns). When clogging creates a high enough back pressure, the discs are released and a backwash flow causes them to spin rapidly (due to the spiral grooves), sloughing all the accumulated solids within a few seconds.

Experiences with reclaimed water: Periodically there are problems with blockages in the filter system from algae which grow well in the rich conditions provided in the secondary treated water.

Figure 10 Cutaway view of disc filter.

EMEK HEFER TREATMENT AND REUSE SCHEME

The Emek Hefer treatment plant is an example of a low cost and maintenance plant producing water of a relatively low quality for restricted use on orchards. A good filtration system is essential in order to minimise blockages of irrigation equipment as the low level of treatment does not remove all suspended solids.

Treatment method: Aerated lagoon – 250 ML capacity, 8 m deep (cheap investment). A long cylindrical screen filter is used which has a constant suction cleaning system, filtering 5 ML/hour (*Figure 11*).

Treatment costs: $40 - 50/ML (filtration costs).

Figure 11 Showing bank of screen filters with a capacity of 5 ML/hour

NETAFIM FACTORY AND RESEARCH, MAGAL

Netafim is the world's leading drip irrigation company, with an annual turnover of US $230 million. Five percent of their gross turnover is invested into research and development, much of which occurs at the sophisticated research facility at Kibbutz Magal. Research includes greenhouse design, irrigation systems and methods ranging from simple systems designed for no power areas through to highly sophisticated systems to deliver exactly the right amount of water to plants at exactly the right time. Several research projects seen during the tour are described below.

Netafim experiment with all different types of greenhouses (in all weather types), including Polyhouses (AZROM), other polycarbonate structures, tunnels and structures with opening and closing roofs, etc.

Research on drippers, both surface and sub surface is being conducted in all of the greenhouses on a number of crops.

Figure 12 Greenhouse tomatoes, soil-less culture using drip irrigation. Insert shows apparatus measuring fruit diameter.

Netafim also experiments with different irrigation designs and scheduling systems, with the aim of knowing how much and when the plant needs the water and to fulfil the requirement. For example, if there is water stress, the first noticeable change to the plant is to the leaves. Leaves are heavier when they have water, and a sensor can be used to check cell thickness in the leaves. Studies to this point have illustrated that most producers irrigate too much. Initial estimates have indicated that growers can save 30% in water costs and at the same time show a yield increase of 20% by watering to the plants needs. If the grower supplies water exactly when a plant requires it, it is easier for the plant to find it, therefore yield increases.

Netafim are also experimenting with low cost irrigation systems. The Family System is designed primarily for low income, third world countries. It uses one metre head pressure (200 L drum height), and 1 litre per hour flow rates and is ideal for areas that have little water and no power. Netafim are experimenting using low flow rates for this system and have found that to produce rice using the 'normal' growing method requires a total of 3 litres of water, while using the family system this is reduced to 1 litre for the same yield.

Figure 13 Hydroponic strawberries growing in suspended trays

Netafim is also experimenting using a recycled water system to grow tomatoes on a hydroponic system (Figure 12). This system uses 30% runoff from the hydroponic setup, the runoff water is filtered and UV treated and has resulted in huge crops. For the variety used a high EC is good for sweetness. The recycling system is gravitational, and feeds into 2 underground tanks. When a tank is full, it gives a pulse to the system using a cheap sensor, the water is sent to the filter, gets UV treatment and is then sent to a holding/mix tank. If the EC is higher than required, less fertiliser is used. Each greenhouse can be run on a separate recycling system fed through 1 filter/UV treatment system.

Some experimentation has also been carried out on hydroponic systems (Figure 13, previous page). For flower growing, two media are being trialled: coconut (which as a media can lower the pH of the water) and rockwool. For vegetables, volcanic stone (scoria) has proven the best media.

EMEK IZRAEL WASTE WATER TREATMENT PLANT

The Emek Izrael Waste Water Treatment Plant has been operational for three years. The reclaimed water is used to irrigate 400 ha, mainly cotton. Edible crops are not grown, even though the water is of sufficient quality, because the ground is not suitable for horticulture crops and the Kibbutz prefers to grow non-edible crops.

Water source and quality: Sewage is received from 80,000 people at the plant.
Sewage quality: BOD ~ 500-600 mg/L
TDS ~ 400 mg/L
Chloride ~ 300-350 mg/L
Final treated water quality: BOD ~ 20 mg/L
TDS ~ 30 mg/L

Treatment method:
First Stage:
Anaerobic pond – 3-4 days detention time (little energy or maintenance).
40% of BOD and 70% of dissolved salts removed.

Second Stage:
Aeration pond first stage - 1.5-2 days detention. 0.5 kW/m^3 of aeration.

Third Stage:
Aeration – 1.5-2 days detention. 0.5 kW/m^3
BOD 50 mg/L; TDS 30-40 mg/L at end of stage

Fourth Stage: 30-60 days detention – fed through three ponds, 400 000m^3 in the first solarisation pond, Second pond 400 ML, third 300 ML (1.1 GL in total).

Tour Delegates Comments   Day 4   Thursday May 3rd 2001

[For waste water treatment plants] – the cost of putting in large storage dams for winter flow should be looked at and justified rather than dismissed.

Israelis seem to be able to do things without the regulatory paralysis that besets Australians.

[Israeli] hydroponic technology would have many opportunities in Australia for people who are interested in improving growing outputs.

For my business it helped to confirm our probable entry into Greenhouse growing – it will be a very expensive change and the resulting premium price which should be able to be attained is the driver to justify the change in direction for us.

I was thinking that providing a consistent management framework for the provision of recycled water to customers was a key issue. The last few days have indicated the site-by-site method seems to suit the users – we need to make sure that the users have input therefore and how it [the system] is set up in the first place.

Reuse provides security of supply – If irrigators choose reuse they can negotiate a higher entitlement, provided at a lower cost than fresh water.

I shall write an article in Vietnamese for greenhouse growers regarding this issue [NETAFIM Magal research centre and leaf thickness/turgor measurements].

Drip irrigation technology has to be investigated for effluent reuse on the [Darling] Downs.

[We] need to define wastewater objectives in Australia (obviously different to Israel) and communicate them to Government's and communities.

Day 5 Israel.

GOLAN HEIGHTS RUN OFF AND IRRIGATION SCHEME

Contact: Ramat Hagolan (tour guide for Golan Heights)

Water for irrigation on top of Golan Heights is harvested from run-off water, as pumping water 800m up from the Sea of Galilee was going to be expensive and potentially difficult to maintain. Potable water is extracted from 500m deep bores.

A series of seventeen dams linked by 52” diameter pipes was constructed by a private water management company owned by farmers around 30 years ago. A series of big channels were dug in a combined operation with the military. The channels were constructed primarily acted as tank traps for the Israeli Military and secondarily to harvest and transport water. The heavy clay volcanic soils are ideal for surface run-off and result in low levels of sediment in the harvested water. Run-off occurs at rainfall of greater than 30mm (surface saturated) and it was found that 95% of run-off could be harvested. The system can store 7.5 ML and is used to irrigate 1500 ha.

The level in the dams was low in 2001 due to drought in 2000 and low rainfall in 2001, with only one rainfall high enough to produce run-off. Growers were forced to reduce crop size to survive.

Problems have been experienced with summer blue-green algae growth, causing blockage of drip irrigation systems. Injection of chlorine was found to help but was not entirely effective and there were concerns over the impacts of chlorine gas. An alternative system was developed that uses fish to control algae and water quality within the lake-like dams.

The first species introduced was common carp, which caused problems with turbidity by resuspending sediment while feeding in the bottom. The second introduction was a filter feeding carp (silver carp) which can take out all particles larger than 16 micrometres and act as a very efficient filter. Another type of fish introduced is the Grass Carp, which controls water weeds and terrestrial weeds when water level rises. Sixty to one hundred kilos of fry (small fish) were introduced into the dam in the first year. Fish will not spawn naturally in bodies of water such as this, so they are bred in hatcheries and annually released into the dam at stocking rates are 300 – 1,000 fish per ha. It is considered to be a cost effective, environmentally effective method of cleaning algae from dams. This type of management was started in the late 1980’s and within three years, fish were being used in most dams.

The fish system can also be used in dams supplying potable water. However, it cannot be used in effluent systems due to the high ammonia levels in effluent. Similar systems could be used in Australia but would have to use local fish species, as importation of exotic fish into Australia is not permitted.

NIR DAVID IRRIGATION AND FISH FARMING

This property uses water containing 1% effluent to farm fish using floating nets. The conversion rate of fish is one to one because the fish receive supplementary food from algae and other organisms present in the dam. Many species of fish are used, including low stocking rates of predatory fish. Infrastructure costs for dams are shared between the farmer and government.

Reclaimed water was also being used to irrigate sunflowers under a centre pivot. The circular spray pattern in the square paddock means that 25% of the area is wasted. The grower has addressed this by irrigating the corners with drippers (Figure 14).

Figure 14 Centre pivot irrigated sunflowers, in the corners of the paddocks area missed by the centre pivot is covered with drip irrigation.

Tour Delegates Comments   Day 5   Friday May 4th 2001

[From today, It helped me understand] the need to ensure that our water resources are not wasted and that we utilise them to the fullest.   Getting people to understand the true value and cost of water.

[There are} environmental restrictions to using introduced species [of fish – Silver carp] – a lack of research into capabilities of Australian species – they may be a suitable control of blue-green algae in reservoirs.

SA Water is to be encouraged to finance the research for control of blue-green algae in wastewater treatment plants.

We should consider using similar fish control techniques – but quarantine issues may stand in the way.

Australia needs to place a higher value on water and look to ways and means of value adding to every Mega litre.

[We need to investigate] total water cycle management.   Regulations would likely require immediate treatment between end users.

[The] use of fish for algae control [in dams] needs to be investigated in Australia

California, USA

General Introduction - California

Water Resources in California

Water recycling projects began in California in the early 20th century as a means of wastewater disposal. Today, 5-10% of water in California is recycled but the motivations behind reuse have shifted to a need for water supply and for environmental protection. The population of 34 million and extensive agriculture consume a great deal of water which is supplied in meagre amounts by the dry climate. Two thirds of the water used in southern California is imported from the north via the California Aqueduct and from the Colorado River in the south east (Figure 15). Ground water is also used for irrigation and potable use, but the water quality of many coastal aquifers is threatened by intrusions of sea water as a result of reduced ground water (aquifer) pressure from over-extraction. There are no new sources of water available, so reclaimed water is being increasingly turned to as an alternative water source for irrigation to allow expansion of agriculture and to free up potable water for urban use. There is also increasing interest in conserving surface and ground water resources for environmental benefits and in reducing discharge of wastewater into fragile habitats such as salt marshes.

Figure 15 California Aqueduct from the Colorado River (640 km long), the major supply of potable water to Southern California.

Regulation and use of reclaimed water

Governments encourage water recycling programs through the provision of federal grants to cover up to 25% of planning and construction costs as well as low interest state loans. The relatively arid climate and high level of agriculture make California the natural home of water recycling in the United States, and this is emphasised by the $1 billion of reuse development is currently underway in the state.

Water resources are mainly managed at the state level although operations generally occur at the level of the numerous Water Districts. The widely known California Title 22 Guidelines provide the standards and restrictions on use for reclaimed water and are held up as a model for Australian regulations. Many Californian treatment plants involved in reuse schemes treat effluent to the highest level, which allows unrestricted use for irrigation. Treatment plants visited during the tour include Camarillo (Page 37), Monterey (Page 51), San Jose (Page 57), San Ramon (Page 58) and Santa Rosa (Page 60).

Reclaimed water is used for a variety of purposes. Enterprises irrigated with reclaimed water visited during the tour included golf courses (Page 49), horticultural enterprises (eg. Page 49) including organically grown vegetables (Page 60) and an aquatic plant nursery (Page 62). There are also industrial applications of reclaimed water (eg. Page 57) including its use as a boost for a geothermal power station (Page 60).

Acceptance of reclaimed water

Acceptance of non-potable use of reclaimed water has generally been high. This has been assisted by the use of high quality research into the potential health risks and implications for agricultural production, particularly through the Monterey scheme (Page 51). There are also extensive education campaigns and demonstration programs, including the Guadalupe gardens site which allows the public to see the use of reclaimed water on locally grown urban plant species (Page 56). Acceptance of reclaimed water for potable use has been less successful. For example, a scheme designed to purify effluent to potable standard for injection into an aquifer used for drinking water was scuttled by a local campaign branding the scheme "from toilet to tap" (Page 58).

Other water use innovations

The dire water situation is stimulating a shift from traditional sprinkler irrigation toward more water efficient dripper irrigation. Such enterprises can be quite sophisticated, such as the Stamoules Ranch visited during the tour (Page 40). Novel solutions have also been found for other difficult farming problems such as the high levels of soil salinity, boron and selenium coupled with high water tables found in the San Joaquin Valley. The tour visited the Integrated on-Farm Drainage Management (IFDM) demonstration site at Red Rock Ranch where drainage water is sequentially reused on increasingly salt tolerant crops, allowing on-farm management of salt (Page 43).

DAY 1 USA.

CAMARILLO – CAMROSA WASTEWATER TREATMENT PLANT

The Camarillo reclaimed water plant supplies high quality water used to irrigate 650 acres of high value crops such as strawberries (Figure 16). The 650 acres is split between 6 customers, with the largest holding being 500 acres.

Figure 16 Camarillo Strawberries

The region has perched water tables with high salinity and chloride, so irrigation with the relatively fresh reclaimed water benefits both the growers and the environment.

Contact: Chris Smith, Engineering Services Manager, Camrosa Water District

Water source and quality:
Water quality leaving the plant:

TSS:	<1.2 mg/L
BOD:	2-4 mg/L
Turbidity:	<2 NTU
TDS:	850 mg/L (permitted limit for discharge to stream is 950 mg/L)

Chlorine is added at 10mg/L and has approximately 2 ½ hour contact time - down to about 4mg/L of chlorine when it enters the storage lake.

Treatment method: (Figure 17)
Activated sludge with extended aeration time. The plant denitrifies the reclaimed water because part of their license stipulates that they have to have less than 10mg/kg of total nitrogen to be able to discharge into the waterway. The strawberry growers also benefit, as they don't like to have too much nitrogen in the water.

Figure 17 Camrosa Water Reclaimation Facility

Plant capacity: Output of the plant is 6 ML per day. The scheme is still fairly new and is operating well below capacity.

Treatment and water costs:
Reclaimed water is sold for less than US $243 /ML, compared with potable water costs of US $625 /ML. The customers have an entitlement of 1.5 foot of water per acre per year (4.5 ML/ha/year). The reclaimed water cost is based on treatment costs only and is the "break-even" price. For new sewage customers, there is an initial connection charge of US $2,000 per

house, which is put into capital development. The philosophy is 'Whoever benefits from the facility pays'. The plant cost about US $7 million to build.

Storage: 100 million gallons or 70-80 days of plant output. Management of the reclaimed water plant try to ensure that the storage ponds are nearly empty going into the winter months.

There is a problem with Sago Pond Weed growing in the storage ponds. The reduced turbidity as a result of the tertiary treatment has allowed increased sunlight to penetrate to the bottom of the ponds, which has led to the increase in water-weed growth.

Management: The facility is required to test the effluent twice yearly for heavy metals, contaminants and organics, and levels have to comply with permit levels. There are not many heavy industries in the region, however there is a metal recovery plant but they have zero discharge from their facility.

A composting company trucks out the dried sludge produced by the plant at a cost of US $25 to $30 per ton. This compares favourable to the US $45 per ton that it would cost to put it in a landfill. The sludge is tested twice a year as well.

Issues: Acceptance of reclaimed water is perceived to be a bigger issue for growers than for the public, with a grower perception that the public may not wish to buy produce grown with reclaimed water. The Camarillo facility tests for Salmonella once per year to assist building grower confidence. The applied water does not contact the fruit at any time as it is drip irrigated and the crop sits above on plastic mulch.

Tour Delegates Comments   Day 1 USA Saturday/Sunday May 5th/6th 2001 – A very long day that included the crossing from Israel to West Coast USA.

Power costs were significantly more than in Australia @ US 6 to 10 cents per kilowatt hour – this should make it more feasible in Australia

We need to negotiate arrangements with regulatory bodies and end-users suitable to the circumstance for which the reclaimed water will be used. Class A for some crops and lesser quality (less cost) where the higher quality water is not required.

[The Camarillo strawberry growers is] another example of how the use of recycled water will need to be managed in the public arena when used on sensitive crops.   It appeared the fact that the crop was grown with RCW was not disclosed to the customer.

We need a change of thinking from the EPA – we need to engage the Federal Government to trade off options between fresh and reuse water.

We should aim for pragmatic, National guidelines – local control of the systems was an initiative that we could emulate.

The [Camarillo] plant itself demonstrated that recycled water can be used on market sensitive crops.

DAY 2 USA

STAMOULES RANCH

Enterprise: Stamoules Ranch is 9,300 acres (3765 ha) with 5,000 acres (2025 ha) currently under drip irrigation. Crops grown include, honeydew melons, bell peppers (capsicums), sweetcorn, cantaloupes(rock melon), and broccoli with future plans for artichokes and more bell peppers. Cotton is used as a rotational crop.

Company turnover (gross) is US $45 million, however the owner would like to increase profits to pay tax on $20 million through increasing efficiencies of production. The Ranch can produce a box of corn ready for market for US $3.00, broccoli for $3.40, loaded on the truck. All produce is field packed to reduce costs. In both of these examples, the box is the biggest expense. Cotton is produced at 4 bales per acres and costs US $800 to grow 1,800 pounds of lint.

Contact: Chuck

Water source, quality and cost: Total farm water use is 20,000 acre feet (≈24,000 ML). The farm has access to 5,000 acre feet (≈ 6,000 ML) from the ground water well. Allocated water from the aqueduct is 8,000 acre feet (≈ 10,000 ML) (US$72 per acre foot, $87 /ML) and the rest is purchased via water trading for about $150 US per acre foot ($182 /ML). Water can be directly traded between growers.

TDS: well water: up to 450 mg/L
aqueduct water: 300 -500 mg/L

Current water restrictions mean that the growers will only received 40% of their allocated water for this season. Therefore the importance of the use of drip irrigation to save up to 30% of water use can be seen.

Labour source: the ranch employs the same people every year from Mexico and Central America. They pay slightly above the award rate to ensure loyalty from their workers. They have 1,500 people harvesting at peak season. The company pays $6.75 to $7.00 per hour, where the 'normal' rate is $6.50 US per hour.

Irrigation system and crop management:
The ranch is changing to 100% drip irrigation to increase water use efficiency for the expensive water resource. The establishment cost of drip per acre is about $1,000 US and it pays for itself very quickly. It costs $200 US less per acre ($495 US per ha) to farm under drip irrigation (water, fuel, time, fertiliser). There is 13,000 feet of dripper tape per acre at a cost of 2 cents per linear foot (≈ 9,600m per ha at a cost of 6.7 cents /m). Maximum drip run is 1,300 feet (390 m). All the irrigation is manifolded off 10 inch lines (250 mm). Flow is 1,300 gallons (5,900 L) per minute to irrigate 40 acres (16 ha) with drip spacings at 18 inches (450 mm), 80 inch (2 m) beds, two tapes per bed and 28 inches (700 mm) between rows. The company owns a number of dripper laying rigs that can lay 80 acres (32 ha) per day (each) – that equates to 1 million feet (300,000 m) of tape with 1 driver and 3 labourers. The machine/rig capital value is US $180,000 (Figure 18).

The first 1,200 acres (485 ha) converted to drip had the drip lines buried at 14 inches (350 mm) deep and all drip lines since that time have been buried at 10 inches (250 mm) deep. The drip lines are buried permanently and are not recovered. The drip lines are replaced every 7 or 8 years. The ranch uses 'N'-phuric acid for cleaning the drip lines (this is made up of 14% nitrogen and sulphuric acid and is much safer than sulphuric acid alone). The lines are flushed once a month.

The drip irrigation is completely computerised for scheduling (pumping) and fertigation. This is accomplished by radio telemetry. The agronomist uses weather station data, which is put into the computer program – information includes: relative humidity, wind velocity and direction, rainfall and temperature. The decision of when to irrigate is still made by field inspection. The company agronomist/farm manager looks at plant stress and petiole analysis for fertiliser requirements.

Crops are germinated with overhead sprinklers, which also provide sufficient water to leach salts down. Very small nozzles are used ($5/64^{ths}$) at high pressures for overhead irrigation.

Figure 18 Caterpillar tractor used for laying drip irrigation

Rainfall is considered a 'pest' during the growing season as there is only 8 to 9 inches (200 – 225 mm) that fall annually and this usually falls at the wrong time to be an effective contribution to the irrigation requirements. Fourteen to sixteen inches (350 – 400 mm) of irrigation are used to irrigate a crop to harvest over the 75 to 90 day growing period (for honeydew, cantaloupe and sweetcorn). The ranch double crops some corn. Broccoli is planted twice a year, first planting in July, and then again in the fall. The farm cannot grow broccoli in the summer.

The ranch sprays pesticides every 4 days, usually via an aircraft or large boom sprayer. It would be possible to lose the entire crop if they did not spray pesticides during winter. A distinct advantage of using drip irrigation is that it allows the tractor to work on the land during or after irrigation. Previously, the pesticide spray rigs used to sink up to 18 inches in the winter months under conventional irrigation.

The soil ranges from sandy loam to clay to heavy clay. It has some micronutrient deficiencies but some of the well water contents can compensate for this.

The Ranch has a huge cool room, built in 1997 for US $18.5 million (Figure 19). Broccoli is brought in from the field, fan force cooled with covers and left for 3 hours to cool to 35 degrees F (0 ^{o}C), then moved out to be iced packed for shipment. Cantaloupes are also chilled in the cool-room. Peppers can only be chilled down to about 60 degrees F (15 ^{o}C). All labour/processing is done in the field to reduce handling and the time to the cool room and ideal storage temperature.

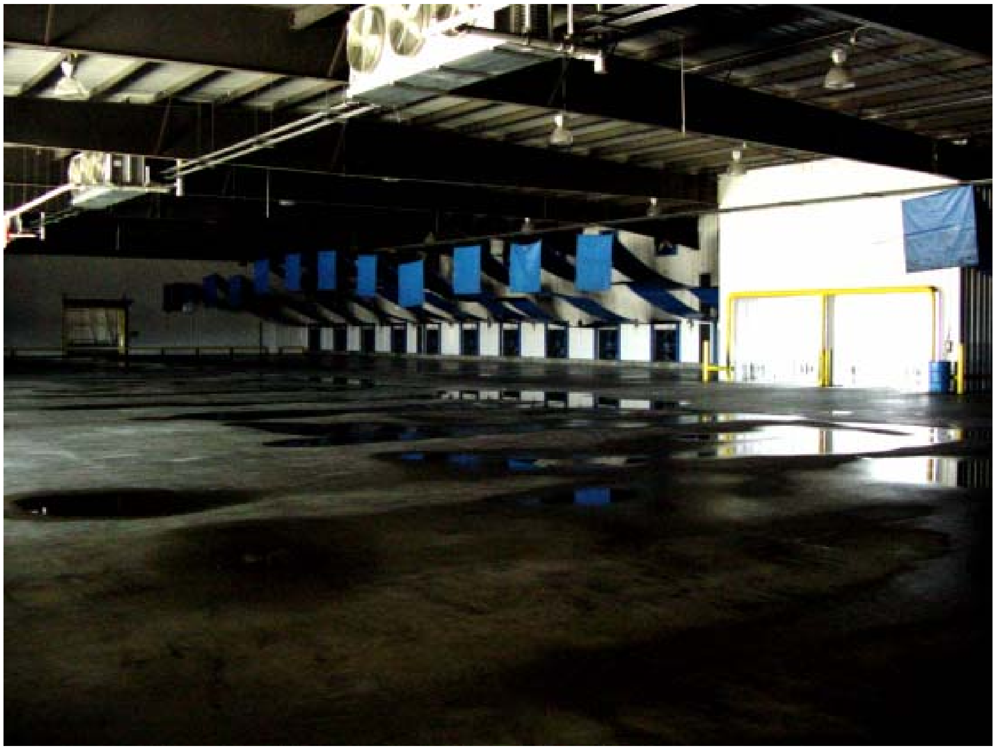

Figure 19 The Stamoules Ranch coldroom, showing half of the forced air produce cooling stations

Experiences with reclaimed water:

Chuck has seen significant savings in water and fertiliser usage by using drip irrigation. The ranch will be completely converted to drip during next year. Drip irrigation is no secret in the United States, but broad-scale convincing of growers of its effectiveness has been difficult.

The property has some perched water tables, which come to within 28 inches (700 mm) of the surface. Perched and rising water tables have been one of the major driving forces for sub-surface irrigation.

RED ROCK RANCH- INTEGRATED ON-FARM DRAINAGE MANAGEMENT (IFDM) 5 POINTS BRINE PROJECT DEMONSTRATION SITE

Introduction

The Westside Water District of the San Joaquin Valley suffers chronic problems from high water tables, soil salinity and high boron levels, limiting the choice of crops and yields. The salinity and boron are the result of a combination of natural soil conditions and importation of salt from irrigation water. Around one million acres (405 000 ha) of land in the region are affected by salt, and solutions are required to manage these issues and allow reclamation of land lost from production.

Water logging and soil salinity can be reduced and saline soils reclaimed through the use of subsurface or tile drains. The drains lower the water table and allow application of excess water to leach salts out of the root zone. However, the use of tile drains has been limited by environmental issues associated with disposal of saline drainage water, such as selenium poisoning of waterfowl at disposal basins, as well as a lack of drainage disposal infrastructure. Evaporation basins for drainage disposal are also expensive to operate and require large areas.

The Integrated on-Farm Drainage Management (IFDM) system is a low cost, sustainable strategy that sequentially reuses irrigation drainage water on increasingly salt tolerant crops in order to harness water use by plants to concentrate salts. All drainage water is managed on farm, permitting the use of leaching to reclaim saline soils without the need for off-farm disposal of the resulting drainage water. All fields involved are equipped with tile drains that permit collection and reuse of drainage water. The steps involved are described below.

Area A: high quality canal water is used to irrigate row crops. Good irrigation practice can be used to leach salt from the area, allowing a progression from low value row crops to high value, salt sensitive vegetable crops.
Area B: Primary drainage from area A is used to irrigate salt tolerant row crops such as sugar beets, cotton, alfalfa, wheat and canola.
Area C: Secondary drainage from area B is used to irrigate salt tolerant forage species.
Area D: Tertiary drainage water from area C is used to irrigate halophytes (generally non-agronomic but highly salt tolerant species).

The area dedicated to reuse is generally a small proportion of the total farm and its location is usually chosen on the basis of being the least productive area. The reuse allows little economic return in areas C and D, but allows the major benefit of use of subsurface drainage to control soil salinity and waterlogging and therefore increase productivity on the rest of the farm. Furthermore, research is being carried out into highly salt tolerant crops which may provide economic return, such as Salicornia as a salad vegetable (discussed further below). The concentrated drainage water may also be utilised as a resource for salt production.

Red Rock Ranch Demonstration Site

Enterprise: The ranch has been using the IFDM system since 1995 and is a demonstration to other farmers in the region of what can be achieved. The ranch is also used as a research site by the California State University (Fresno).

Contacts: John Diener (Owner) and Sharon Benes (Researcher: California State University)

Reclamation steps
The property was bought in 1984 with no drainage and a perched water table within 3m of the surface. The soils are vertisols with a depth of 450 feet (135 m) and potentially good for agriculture, but were highly saline and had high levels of boron (4-5 mg/kg) and selenium (1-1.4 mg/kg background level) as a result of their marine bed origin as well as input of salt from irrigation water.

The reclamation of the property began with the planting of two rows of high water use and relatively salt and boron tolerant eucalypts on the upslope part of the property, in order to intercept the incoming, laterally moving, regional perched groundwater table. The regional groundwater has a salinity of 2,000 – 3,000 mg/L. The trees are drip irrigated. Tile drains were then placed in the fields at a depth of six feet (1.8m) in parallel lines 100 feet (30m) apart, departing from the local practice of placing the drains at 8 feet (2.4m). This was done to reduce the amount of regional ground water intercepted, therefore reducing the amount of drainage water that had to be dealt with on the farm. This has lowered the percentage of time that free running groundwater was present in the drains from 80% down to 30%.

Agronomic Information. (Figure 20)
The property is divided into four 150 acre (approximately 60 ha) blocks, three of which are watered with local canal water (Area A according to the IFDM system described above). The remaining block is further divided into

- ♣ Area B (120 acres (50 ha) where the drainage water from area A is reused;
- ♣ 13 one acres blocks (0.4 ha) making up Area C;
- ♣ A small experimental plot comprising Area D; and
- ♣ A solar evaporator.

These areas are discussed in detail below.

Area A
Area A is watered with good quality canal water with a salinity of around 200 mg/L, supplemented by more saline well water when necessary. The quality of the canal water is almost too good, as the low level of salts promotes the collapse of the soil structure.

One of each of the three Area A blocks was tiled each year from 1995 – 1997. Alfalfa is the crop of choice for the first year after tiling because it is salt tolerant, needs frequent irrigation and has a relatively deep root system, allowing extensive and deep leaching. The soil salinity of the block tiled in 1995 was reduced to around 680 mg/L TDS by 1998, allowing the planting of salt sensitive, high value crops such as broccoli.

Irrigation is done using sprinklers, as is common in the region. Evaporation rates are very high so there is a need for a high water application rate, which often leads to bogging of the irrigator because of the combination of poor soil structure and very wet conditions. The grower deals with this by using temporary aluminium fluming.

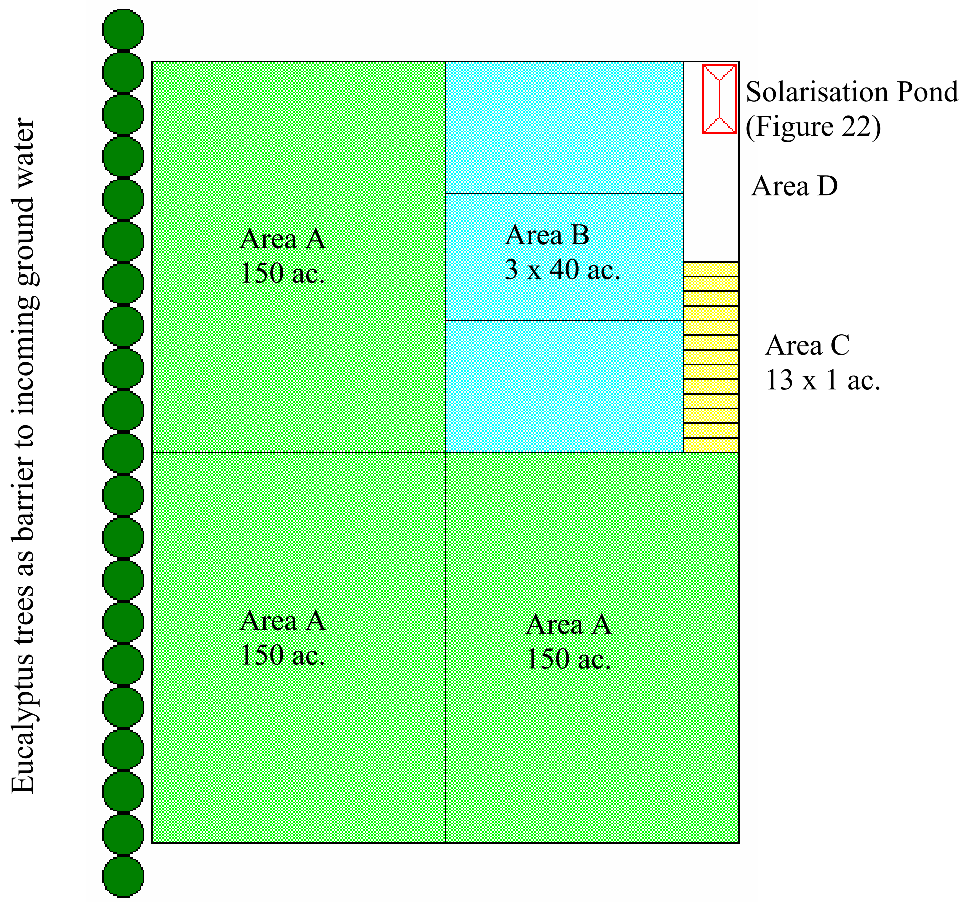

Figure 20 Red Rock Ranch research farm layout

Area B
Area B is irrigated with drainage water collected from area A with a salinity of around 3,000 mg/L. The 120 acres (50 ha) is divided into three 40 acre (17 ha) blocks where salt tolerant crops such as sugar beets, cotton, alfalfa seed, grains and some members of the mustard family are grown. Trials have also been carried out on other crops such as a salt tolerant variety of canola from India that is capable of extracting selenium from the soil. The crop can then be put to beneficial use as fodder for animals living on selenium deficient soils, providing both a financial return and bio-remediation of the soil.

Area C
Area C is irrigated with drainage water from area B with a salinity of 15,000 – 20,000 mg/L, although good quality water was used for the first two years to allow establishment. The main functions of areas C and D are to concentrate the drainage water, although there is considerable work going on at the property to trial potential crops with economic value. Examples include salt tolerant fodder crops such as Bermuda grass (*Cynodon dactylon*), Creeping Wild Rye (*Leymus triticoides*), Puccinellia (*Puccinellia ciliata / P. distans*), "Jose" Tall Wheatgrass (*Agropyron*

elongatum), Alkali Sacaton (*Sporobulus airoides*), "Salado alfalfa" (*Medicago sativum* var. "salado"), Tall fescue (*Festuca arundinaceae*) and Perla kolea grass (*Phalaris tuberosa* var. hirtiglumis).

Area D

Area D is irrigated with drainage water from Area C with a salinity similar to sea water, using a fixed pulse system. Soil salinity in the top 30cm is around 50 dS/m (saturated extract) or 32,000 mg/L TDS. The area is suffering from rising water tables and increasing surface salinity as the solar evaporator is too small to allow harvest of all of the drainage water.

Figure 21 Pickleweed (*Salicornia*) growing in highly saline soils at Red Rock Ranch.

This experimental plot has been planted by researchers with halophytes (salt loving plants) such as Pickleweed (*Salicornia bigelovii,* Figure 21), Saltgrass (*Distichlis spicata* var. stricta) and Salt bush (*Atriplex lentiformis*). The commercial value of some of these salt tolerant crops is currently being assessed. Pickleweed can be harvested as a salad vegetable and is currently being used in New York as a garnish for salads. It is an annual, which has to be reseeded each year after the previous crop has been mown. A research project on the property is evaluating whether pickleweed can be grown there commercially using hypersaline water with a high boron level.

Solar evaporator (Figure 22)

Drainage water from area D is sprinkled onto a two acre field of black plastic to evaporate the remaining water. The sprinkling is timed to quickly evaporate the water, leaving no standing pools to attract wild waterfowl. The salt left behind is mainly sodium sulphate and research is being done on how to turn it into a clean product for the domestic commercial sodium sulphate market which consumes three million tons annually. There is also a possibility that the salts with elevated selenium may have commercial value as a stock feed supplement in regions that are deficient in selenium.

Figure 22 Red Rock Ranch showing covered solarisation pond

Project costs and returns: Total project costs were US $376,000 or about $1,480 per hectare including infrastructure, research and consultants. Funding has come from a grant from the Bureau of Reclamation and from John Diener's private investment. The land value has increased from about $1,850/ha prior to the system to about $5,900/ha for the reclaimed land due to its higher productivity and ability to be used for higher value crops. Previous net returns from growing cotton, alfalfa, sugar beets and grains on saline land were around $430/ha, while returns from vegetables average around $3,330/ha.

Tour Delegates Comments   Day 2 USA Monday May 7th 2001

We need to establish the level of knowledge of our local producers and help to educate them to the benefits of using reuse water.

The only impediment is that if growers tried to emulate the size of production seen in the US, problems would occur with marketing. Our domestic market is easily oversupplied and exports markets returning 'payable' prices could be difficult to find.

We MUST sell the idea of drip irrigation to the current users of spray and flood irrigation & start 'ploughing' it in.

The side benefits of going to drip need to be demonstrated and the word spread. The potential to emulate the 5 Points model should be considered for analogous Australian circumstances.

Getting the message out i.e. 'cost benefits' amongst growers can generate change. Water savings on the cotton industry may lead to significant savings in water for environmental flows reducing pressure on potable water & allowing reuse.

The principle of 'polluter pays' is already happening but could be extended further in Australia

DAY 3 USA.

CARMEL AREA WASTEWATER DISTRICT – PEBBLE BEACH COMMUNITY SERVICES DISTRICT WASTEWATER RECLAMATION PROJECT

The Carmel Area Wastewater District on the Monterey Peninsular owns a wastewater treatment plant and distribution system that is producing high quality water which meets California Title 22 regulations for unrestricted irrigation use. The water is used for irrigating the seven golf courses in the region including the famous Pebble Beach course. (Figure 23)

There have been some problems with turbidity levels in the reclaimed water and the district is considering putting in a DAFF (Dissolved Air Flocculation and Filtration) plant. The water currently has a turbidity of 7 and a salinity of 800 mg/L TDS. In winter, the reclaimed water is not required for irrigation and is currently discharged to the ocean. In summer, the treatment plant cannot supply the full requirements of the golf courses, so the District is looking into taking over an abandoned 400 acre foot reservoir (485 ML) to provide storage of winter produced reclaimed water for summer use.

Figure 23 Pebble Beach greens are irrigated with reclaimed water

The District charges approximately US $1,300 per acre foot ($1,580 /ML) for reclaimed water, which is the same as potable water. The high price is feasible because of the high charges for use of the golf courses, of up to US $700 per round.

Mark Thomas, the irrigation manager at the Pebble Beach golf course, says the decision to switch to reclaimed water six years ago was based on freeing up more potable water for drinking by reducing the irrigation requirements for potable water at the golf course. A strategic watering regime has been adopted to maintain the quality of the greens and soils, which involves a monthly flushing with fresh (potable water) in order to move excessive salts out of the root zone. Mark believes that the greens are as good as they were under potable water irrigation.

T&A NURSERY & GREENHOUSES, SALINAS

Enterprise: The property mainly grows celery and broccoli seedlings in greenhouses which are sold to growers for transplantation and growing out. Thirty greenhouses (40x150 feet or 12x45m) are used to produce 12-1,400 boxes of seedlings per acre. The break-even point is $12/box. The company also crops 35,000 acres of cauliflower and lettuce.

Water source, quality and cost: from Monterey Scheme (page 51). The grower also recycles greenhouse run-off water.

Labour source: Mexican workers paid US $5.17/hour.

Irrigation system and crop management: The seedlings are grown in seed trays with 338 cells, with each cell holding 19.5 cm^3 of peat moss mixture at a density of around 145 plants/square foot (1,600 seedlings/m^2). The peat moss is imported from Canada as a high quality, custom blend. 600,000 plants are grown per greenhouse. The seeds are planted with a "Boots" seeder which uses a vacuum drum to pick up and drop seed, which is then ejected into the seed tray by water. Fertigation is used and the crops are also mown (tops taken off, Figure 24) to improve aeration and evenness of the crop.

Figure 24 Mowing of celery seedlings to increase root development whilst maintaining plant size necessary for in field automated planters.

OCEAN MIST FARM, CASTROVILLE

Enterprise: 6,000 acres (2,400 ha) of irrigated vegetables including artichoke, lettuce and sunflower.

Contact: Dale Huss

Water source, quality and cost: Half of the irrigation water used on the property comes from the Monterey Scheme (price and quality, page 51). The ranch is close to the ocean and previously used groundwater from an aquifer affected by intrusion of saline water. The grower has been using reclaimed water for about three years and the quality is a lot better than the available ground water. The reclaimed water is also available at a higher flow rate - 6,000 gallons/minute (27 KL/minute) from the reclaimed water project valves compared with 2,000 gallons/minute (9 KL/minute) from the ground water wells on the property.

Groundwater quality: SAR close to 15
Na, about 200 ppm
EC 2.5 to 3.0 (x640 for TDS)

Irrigation system and crop management: Reclaimed water is delivered to a dam on the property, from which it is pumped out onto the fields. The current power problems in California mean that most irrigation is done at night in order to avoid blackouts and spread the load. The reclaimed water has a higher sodicity than the ground water, which has implications for the slaking clay soils scattered throughout the region. The grower is considering using gypsum to address the impact of high levels of sodium on soil structure. Other than this, there have not been major changes in the farming practices at the property with the use of reclaimed water.

Experiences with reclaimed water: The grower found that there were initially some concerns with public perception of the use of reclaimed water for irrigating food crops, but these concerns have now eased. This is likely to be due to the large amount of research that has been done on the Monterey scheme, which has shown the health risks of eating produce irrigated with reclaimed water to be minimal. Furthermore, the reclaimed water is heavily monitored and it is made sure that the water is safe, unlike many other water sources.

The reclaimed water is more expensive than well water from the property. However, the well water needs to be pumped up from 1,700 feet (510m) and increasing electricity costs mean that well water will become more expensive. The grower also considers that the reclaimed water provides a more sustainable resource, allowing the farm to continue production in the long term.

MONTEREY COUNTY WATER RECYCLING PROJECTS

The Monterey scheme treats and distributes high quality reclaimed water for unrestricted irrigation use to 12,000 acres (4,800 ha) growing crops such as herbs, strawberries, lettuce, artichoke and celery. The scheme is held up as a benchmark for world's best practice. It was initiated in 1978, beginning with an extensive period of consultation, research into health and agricultural impacts, education and construction. The scheme began operation in 1998 and has grown to an annual distribution of around 13,000 ML of reclaimed water.

The motivation for the scheme was to provide a new source of water for agriculture as the groundwater used for irrigation in the region was threatened by seawater intrusion (Figure 25). Agriculture is seen as a very important part of the Californian landscape and economy, and if an alternative water source could not be found then agriculture was likely to become unfeasible in the region and the land taken over by urban development.

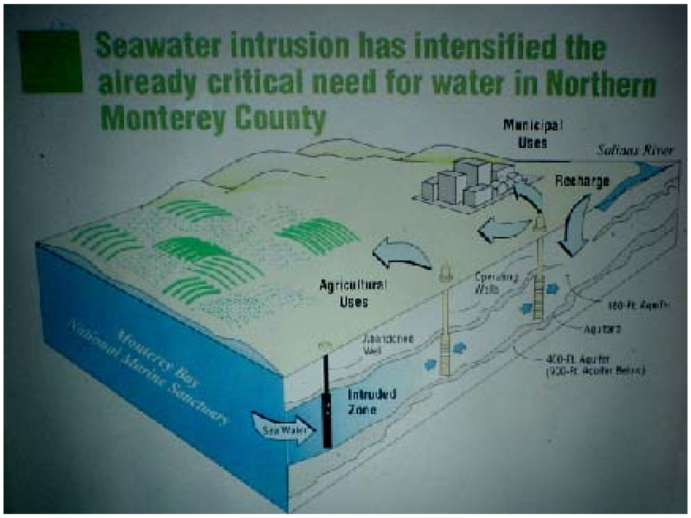

Figure 25 Representation of the Monterey region showing seawater incursion effecting the viability of irrigators in the region

Contact: Keith Israel (Monterey Regional Water Pollution Control Agency)

Water source: Largely urban effluent from the Northern Monterey County.

Plant capacity: The plant has an output of around 120 ML/day. Grower demand during the peak growth season of May to September is around 23,000 ML, based on an irrigation rate of 4.9 ML/ha. The reclaimed water is not sufficient to supply this demand so supplemental well water is added to make up the difference of up to 40% of requirements.

Treatment method and water quality: The treatment process consists of secondary facilities (headworks; primary clarifiers with anaerobic digestion of biosolids; trickling filters; bio-flocculation; secondary clarifiers), followed by tertiary treatment (coagulation, flocculation, multi-media filtration and disinfection). After treatment, the reclaimed water is directed to an 80 acre-feet pond (95 ML) which stores around one day of grower requirements. When reclaimed water is not required for irrigation during winter, the secondary treated water is discharged to the ocean two miles off-shore. The tertiary treatment is sufficient to meet the California Title 22 regulations for unrestricted irrigation use, requiring a seven-day median coliform limit of less than 2.2 MPN/100mL, a turbidity of less than 2.0 NTU and 5 mg/L of available chlorine as the reclaimed water enters the storage pond.

Chemicals used in well water treatment are the same as those used in potable water treatment.

- polymer and alum flocculation and filtration
- 4ft of anthracite coal with one foot of gravel
- functions similar to swimming pool filter (sand)
- add chlorine to disinfect
- 3 hours contact
- released to storage dam

A chlorine residual of 10 mg/L at the exit of the chlorine contact tanks is maintained as this was found to be effective in keeping the coliform count within compliance guidelines and helps to keep down algae growth in the storage pond. This translates to a chlorine residual in the water leaving the storage pond of around 4-6 mg/L. Testing on cauliflower seedlings has shown chlorine residuals of up to 15 mg/L did not cause adverse effects such as leaf burn. Covers on the chlorine contact tanks also help to keep the coliform count down by preventing settlement of coliform containing dust from agricultural areas. Pathogen monitoring has shown that the plant has always stayed within its compliance conditions. The County Health Department has approved the use of Clostridium testing as a quicker and cheaper surrogate for full pathogen testing. A five log pathogen reduction has typically been found across the whole treatment plant over two years of bi-weekly Clostridium testing.

The reclaimed water has a higher salinity and sodicity than the well water:

	Reclaimed water	Good quality well water
Salinity (mg/L TDS)	825	375
Chloride (mg/L)	250	60
Sodium (mg/L)	185	50
Sodium Absorption Ratio (SAR)	4.7	1.8

The reclaimed water – supplemental well water mixture delivered to irrigators has a average SAR of around 3.9, which is higher than the level of 3.0 preferred by many growers. However, it is not known how high the SAR can be in the long-term without significant impacts on yield and soil properties. The original project research did not indicate any salt build up problems over five years of pure reclaimed water application, so long-term research and monitoring of this issue is continuing. Attempts are being made to lower the sodium levels in the reclaimed water by reducing the input to wastewater, particularly from water softeners. For example, big salt users and the general public are educated on the benefits of a shift to more efficient softeners and from sodium to potassium based softeners.

The reclaimed water contains quite high nutrient levels, as the ocean dumping permit does not require their removal. Total nitrogen averages around 30 mg/L (most present as ammonia) while phosphorus averages around 2 mg/L.

The reclaimed water has very low levels of metals and trace organics because of the low level of heavy industry in the area. Commercial wastewater disposal customers are also regularly monitored and the general public educated to ensure that inappropriate wastes are not disposed of into the system.

Distribution: The distribution system consists of a rectangular grid with 72km of piping, 112 irrigation turnouts (of which 88 are in use), three pump booster stations and 21 supplemental wells located away from seawater intrusion. Backflow protection is used on the ground water wells to protect the aquifer. Each turnout is signposted with "Reclaimed water – do not drink" in English and Spanish, and similar signs are placed at 500m intervals along the distribution network. The treatment plant draws electricity from one power grid, while the wells are on a second power grid, so that at least one system is always on-line. This arrangement is necessary because of the current power restrictions in California.

There is a pressure minimum of 10 psi of head at the highest point in the system, with 30-40 psi in other parts of the system. Turnouts can supply 4-500 acre-feet per day. Growers have booster pumps with pressure regulating valves so they cannot capture more water than has been allocated. This system also protects the growers' infrastructure from pressure surges. Many growers on the system irrigate directly from the pipeline.

Treatment and water costs: The scheme is run as a non-profit operation, with a "user pays" philosophy. Current cost of the water to scheme participants is US $237 per acre foot xxx (US $128 /ML) (US $209 water cost, covering tertiary treatment costs; and US $28 delivery and infrastructure maintenance), and the cost is indexed with CPI. This is about twice the current price of extracting well water, although the cost of well water is likely to increase as pumping costs rise and aquifers get lower. Other water users in the region are also charged a levy because the scheme reduces saline intrusion into the ground water, which brings benefit to everyone. The costs of collection and secondary treatment are borne by the producers of wastewater (the local residents and businesses) through sewerage charges of around US$10/month.

The annual operating budget is around US $6 million, with around US $3.5 million for direct operating costs and the remainder for debt repayment. Initial funding for the US $75 million project came from low interest loans from the Bureau of Reclamation and the State of California as well as short-term bonds.

Experiences with reclaimed water: At the beginning of the project, the main areas of concern were public health and safety and public perception. Extensive research was carried out over 11 years by the $8 million Monterey Wastewater Reclamation Study for Agriculture (MWRSA) in order to address these issues. The research included five years of field trials using reclaimed water for irrigation to evaluate crop yield and quality, and the presence of pathogens on produce and in reclaimed water. It was found that there were no viruses present on any of the produce irrigated with reclaimed water, and that the level of naturally occurring bacteria on crops irrigated with reclaimed water was equivalent to that on crops irrigated with well water. Produce yields and quality were found to be as good as, or better than, crops irrigated with well water. Later research also looked at other emerging pathogens such as *E. coli, cryptosporidium, cyclospora, giardia* and *legionella* and confirmed that the reclaimed water was free of viable pathogens and of a high quality.

This research, together with a stringent monitoring program and a strong commitment to achieve 100% compliance with permit regulations, have provided the basis for the scheme to win public and commercial confidence and support. A proactive communication strategy was adopted which acquainted the produce industry and the local media and public with the project. A communications company was hired before the start of operation to develop a plan for education and to deal with potential crises with a three hour response time. Material was produced to educate local produce sellers, growers and workers for their own benefit and safety as well as to help answer any consumer questions about the safety of reclaimed water and produce grown with it. Marketability surveys were carried out in 1983 and 1997 and showed that industry buyers and sellers felt that there was no need to label or separate produce grown with reclaimed water, and that consumers would purchase the produce as long as the safety of the product was assured. A measure of the effectiveness of the strategies to address the public health and perception issues is that after three years of operation, the major issue of concern is now salinity.

Tour Delegates Comments Day 3 USA Tuesday May 8th 2001

Title 22 California standard for water treatment seems to be very high standard which has led to very easy acceptance and widespread re-use.

The results from the Monterey Scheme have direct applications for the Brisbane scheme – the need to be very professional in handling adverse media, and the concept of an area tax to assist paying for the scheme.

I intend to trial an area of both subsurface and above-ground drip on my farm in cotton production & possible horticulture trials.

…That given reclaimed water is of the right quality for each level of cropping, that public perception can be managed to allow this valuable resource to enhance our local regions

We need to better organise farming away from a lifestyle and more towards a business

Inherent cross subsidies in recycled water schemes in the USA do not exist in Victoria AUS – low interest loans are needed. Institutional boundaries (rural water companies and residential retailers inhibit the implementation of such schemes). The lack of the Victorian Governments clarity on policy is a major impediment.

The Government needs to review its policies in respect to committing to support of funding arrangements, regulatory etc, to foster re-use developments.

DAY 4 USA.

GUADALUPE GARDENS RECYCLED WATER DEMONSTRATION PROJECT, SAN JOSE

The Guadalupe Gardens (Figure 26) are a public demonstration site for the suitability of use of reclaimed water for a number of urban horticultural uses. The gardens are managed by South Bay Water Recycling (SBWR), which is Silicon Valley's regional water reuse scheme.

SBWR sell 40 ML of high quality recycled water per day, worth US $10 million PA, to over 300 customers for unrestricted irrigation use. 85% of the customers use the water for landscape irrigation (eg. large campuses, parks, golf courses) with some limited use for industry and agriculture. The SBWR operation is described in detail at the next stop. SBWR have found when marketing recycled water that customers are not generally interested in the success of recycling schemes carried out elsewhere, instead they want to see where recycled water has been used successfully locally. Their main issue of concern often seems to be about the impact of reclaimed water on local garden plants and soil rather than human health and safety issues. The Guadalupe gardens were created as a demonstration to the public on how reclaimed water can be used on locally grown species.

Figure 26 Guadalupe Gardens showing recycled water sign

The park was established for other purposes 12 years ago and was watered with potable water up until two years ago when SBWR took over. The irrigation system was not modified for use with reclaimed water as the intention is to demonstrate to the locals that reclaimed water can be used in virtually the same way as other sources of water. The gardens are open to the public and plants are labelled for ease of identification. Plants such as Star Jasmine, which was thought to be sensitive to reclaimed water, are doing so well under reclaimed water irrigation that they now need to be pruned more frequently.

SOUTH BAY WATER RECYCLING WASTEWATER TREATMENT PLANT, SAN JOSE

The major motivation of the South Bay Water Recycling (SBWR) scheme is to conserve a salt marsh environmental refuge in the bay which forms part of the flight path habitat of migratory wildfowl. Research has showen that freshwater discharges in excess of around 480 ML/day represented a hazard to the sensitive salt marsh community, necessitating diversion of 40 ML of the daily 520 ML/day discharge. Industry in Silicon Valley is largely skewed towards the computer industry rather than agriculture, providing a more limited market for use of reclaimed water in the region. As described above, the majority of the reclaimed water is used for landscape irrigation.

Contact: Eric Rosenbloom (City of San Jose)

Water source: Municipal wastewater is received from 1.3 million person equivalents, covering around 80% of the Silicon Valley.

Plant capacity: The plant receives around 167 million gallons per day (740 ML). The output of reclaimed water for reuse is currently 40 ML/day, with the capacity to expand up to 400 ML/day.

Treatment method and water quality: Primary sedimentation occurs in two batteries of tanks, with the solids pumped to three anaerobic digesters and then shallow solar beds. Around 30,000 tons of solids are processed annually and are put into landfill. The effluent passes into aeration basins which perform a combination of secondary treatment and biological nutrient reduction through alternating aerobic and anaerobic quartiles. The secondary clarifiers are peripheral feed, 150 foot diameter and 20 foot deep basins with baffling to prevent short-circuiting. Tertiary treatment to Title 22 standard is provided through chlorination with injection of gaseous chlorine and polishing through 16 multi-media filters incorporating sand, anthracite coal and garnet. A side stream leads to the distribution pump houses for the water to be reused and the remaining 90% of the treated water is disposed of into the bay.

Storage and distribution: The distribution system involves a line and branch system, with a 60 mile pipeline, four main pump stations and a reservoir.

Treatment and water costs: The wholesale cost of water is indexed to wholesale costs of raw, untreated potable water from the rivers coming into California, which is currently around US $350/acre-foot. The wholesale price of reclaimed water has been frozen at the 1996 indexed price of US $240/acre-foot (US $200 /ML) in order to be more attractive to customers. Industry and agriculture are offered a 90% rebate (reclaimed water cost of US $25 acre-foot) which lines up with price reductions on potable water supplied to these consumers. The subsidy is effectively paid for by the ratepayers, who pay for the collection and treatment of wastewater through sewerage rates. The water retailer adds a mark up of US $300/acre-foot (US $250 /ML), although the mark up is less when the user has a well but is using reclaimed water instead of well water.

Experiences with reclaimed water: SBWR is about to embark on a large scale program to use reclaimed water for the production of high technology computer parts, providing an important new market for reclaimed water in the area. The industry currently uses 60 ML of treated drinking water.

DUBLIN SAN RAMON ADVANCED WATER RECYCLING PROJECT

Contact: Dave Requa, WateReuse Association

The Dublin water recycling project currently produces around 3 million gallons per day (13 ML) of high quality reclaimed water for unrestricted irrigation of urban landscapes including parks, golf courses and commercial areas. The plant was originally built to produce potable standard water, using reverse osmosis technology, for injection into the local aquifer used for drinking water as well as landscape irrigation. However, the ground water injection side of the project was scuttled by a local campaign under the banner of "toilet to tap". The current scaled down operation uses micro-filtration and UV disinfection for its tertiary treatment plant while the reverse osmosis plant stands idle. Interestingly, the drinking water supplies of the area are largely drawn from the Sacramento River, which is used for disposal of treated wastewater by towns upstream. It has been estimated that 25% of the summer river flow at Dublin consists of treated effluent with a residence time of 5-10 days, whereas potable water used from the proposed groundwater recharge scheme would have consisted of 2% treated effluent with a residence time of 25 years. The importance of public perceptions to reclaimed water schemes, particularly where potable reuse is involved, cannot be overemphasised.

Tour Delegates Comments Day 10 Wednesday May 9th 2001

High levels of treatment do not necessarily translate into high value end-use. We need to have end-use agreed before expenditure is put in place.

Today reinforces the need for consistent development of policy for industry pricing. The non-transparent nature of the US experience has resulted in gross inefficiencies at the treatment end. Little has been said about the environmental pressures leading to these schemes though.

The true pricing for both existing water supplies and recycled water is paramount to achieving more use of recycled water.

There is a huge potential in inland Australia for local Governments to reuse effluent on parks & gardens. EPA license costs will eventually force the issue.

DAY 5 USA.

SANTA ROSA SUBREGIONAL RECLAMATION SCHEME

The Santa Rosa scheme provides high quality reclaimed water for unrestricted irrigation use on 6,200 acres including hay and fodder crops, horticulture, viticulture, turf farming and an aquatic plant nursery. Two of these properties are described in the following stops. A new project will supply 11 million gallon/day (49 ML) to local geothermal power stations which generate electricity with forced steam. Injection of the reclaimed water will increase the amount of steam and therefore the generating power of the plants, with a net increase of 85-100 MW expected.

Water source: Municipal effluent and storm water from the Northern Bay area.

Plant capacity: Flow into the plant is around 18 million gallons per day (80 ML) during summer, and 65-70 million gallons (290-310 ML) during winter.

Treatment method and water quality: The treatment train consists of: aerated grid chamber which removes grit; primary clarifiers; aeration basins with anoxic zones to reduce nitrate levels; secondary clarifiers; trickling anthrocite carbon filters; and UV disinfection. The plant switched to UV disinfection two and a half years ago and are very pleased with its effectiveness. UV disinfection also avoids having to deal with the regulations and health risks associated with use of chlorine. The tertiary treatment is sufficient to meet Title 22 standards. Bio-solids are composted with green waste and sold or directly land applied by farmers prior to fall planting. A single application at agronomic rates is used to ensure uptake of nitrate contained in the solids.

Storage and distribution: Reclaimed water is stored at the plant during spring to provide enough water for the irrigation season. There are problems with algal growth in the shallow storage ponds which are treated with hypochlorite to control algae. The plant also has a 15 million gallon (65 ML) concrete lined emergency storage basin. The water is distributed to growers at low pressure and is generally collected in on-farm storage dams and pumped out to the fields.

LEFT FIELD VEGETABLE FARM

Enterprise: Four acres of high quality, organically grown vegetables (Figure 27) including capsicum, tomatoes, onions, lettuce, cut flowers, winter squash, pumpkins and broccoli.

Water source and cost: Reclaimed water, provided for free from the Santa Rosa scheme, is used in the field. Growers are paid a bonus if they are able to get 18 inches of reclaimed water onto the land annually.

Figure 27 Left Field Vegetable Farm organic capsicum crop.

Irrigation system and crop management: The grower collects reclaimed water in a dam and uses a pump to boost the pressure up to 75 psi. A small filter system is used to prevent blockage of the irrigation system. A combination of drip and sprinkler irrigation is used. Rainfall is around 30 inches but largely falls outside the growing season.

Faba beans are used as a cover crop for nitrogen fixation (250 pounds/acre) and incorporation into the soil, or are maintained to suppress weeds such as bindweed. The grower uses a wide range of crops and is always trying new things to attract customers. Produce is generally marketed at "farmer's markets" which allow growers to sell directly to the public.

Experiences with reclaimed water: The grower believes the reclaimed water is "perfect" for agriculture, with small amount of nitrogen and phosphorus and fairly low salinity levels. The local groundwater, has lower salinity and relatively high iron and sulphur levels. The grower uses groundwater for raising seedlings in his greenhouse and has noticed that the seedlings react well to the neutral pH of the reclaimed water when transplanted outside.

The grower is satisfied with the safety of the reclaimed water based on the research done on the issue, including the Monterey work. He makes efforts to make it acceptable to customers through talking positively about the processes involved including disinfection. A survey of participants of a tour of the farm found that 83% would buy vegetables irrigated with reclaimed water and that very few would have problems with the quality of the resulting produce. The grower estimates that he might lose two customers a year as a result of use of reclaimed water irrigation through uncertainty of the health implications. However, most customers are not concerned and many believe that irrigation with reclaimed water is a good idea.

The use of reclaimed water by organic farmers is somewhat in limbo for some of the certification bodies which exist at state and national levels. At present it is allowed but may not touch edible portions of the crop. Federal regulations for organic certification will be introduced in 18 months and will permit use of reclaimed water.

Stop 3 Aquatic Plant Farm, Santa Rosa

The aquatic plant farm raises aquatic plants for nurseries to sell to the home pond market. Tertiary treated effluent from the Santa Rosa scheme is used in the ponds.

Slow release fertiliser tablets are the only form of fertilisation used. Two large greenhouses over shallow ponds are used to get a faster start to the growing season but most plants can grow outside by May. Shade houses are used for those species which prefer shady conditions. Waterlilies are grown in pots to keep the crayfish out of them.

The farm has been using reclaimed water for five years and has had no problems with infections or other health issues during this period. The only form of protection used is surgical gloves during potting. Drinking water is also provided to workers. The grower trusts the effluent more than other water sources because she knows that the quality of the water is monitored.

Tour Delegates Comments   Day 11 Thursday May 10th 2001

With respect to the Santa Rosa Treatment Plant – I hope this never happens in Australia. This is an example of inappropriate cross subsidy from residential users to agriculture. It won't create the incentive for farmers to be efficient water users.

Serious consideration needs to be given to incentives but not to be confused with the 'real' drivers of reuse schemes.

Santa Rosa is NOT the way to go – reclaimed water must have some value to attached to remind people of its value.