

BEDFORD GROUNDWATER INTERCEPTION SCHEME

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ABSTRACT

The Bedford Groundwater Interception Scheme (BGIS) is located near Cooke Plains in South Australia within the Coonalpyn agricultural region that contains 57,000 ha of land affected by dryland salinity. Oceanic equivalent saltwater (35 ppt and higher) from the shallow (1-2m) saline ground water aquifer has been used at BGIS to grow a range of marine organisms and the depth of the saline aquifer has been lowered by 600mm.

The Natural Heritage Trust (NHT) has provided funding to remodel and further expand the project to develop a robust nil-discharge integrated aquaculture production system. This will become a demonstration facility that will be used to assess technologies and species and develop aquaculture systems suitable for commercial exploitation of saline groundwater. The pilot-commercial scale semi-intensive system installed will produce 1.5 tonnes pa marine finfish and nutrient rich discharge water will be used for production of brine shrimp, bivalves and seaweeds which will also perform a bio-mechanical filtration role in the system. Once the water has passed through the system it can either be reused for fish production, or evaporated within a small-scale saltworks (1.7 ha) to produce salt and bitterns.

INTRODUCTION

Since 1996 the Coorong District Council (CDC) has operated the Bedford Groundwater Interception Scheme (BGIS) at Cooke Plains, South Australia. Cooke Plains is 1.25 hours drive east of Adelaide. An open excavation 3-4m into the ground adjacent salt pans on site allows oceanic equivalent (35 ppt and higher) saltwater to be obtained from the shallow (1-2m) aquifer (figure 1). The initial objective of this project was to develop an aquaculture based salt interception system with pumping costs covered by revenue generated through sale of cultured products. The BGIS has demonstrated that saline groundwater is suitable for the culture of snapper (*Pagrus auratus*), black bream (*Acanthopagrus butcheri*), and King George whiting (*Sillaginodes punctata*). In addition, brine shrimp (*Artemia sp*) have proliferated in ponds on



Figure1: Saline groundwater (36-42ppt) is obtained by excavating into the ground at the BGIS, which is pumped to storage tanks for aeration.

Site (figure 2) and the microalgae, *Dunaliella salina* has been cultured within a polytunnel achieving β -carotene concentrations 300% greater than that grown in open salt ponds.



Figure 2: Lined brine shrimp pond inside polytunnel at the BGIS.

The BGIS addresses the concern of Australia's rural industries for the growing problem of dryland salinity. Primary production in the Coorong district in 2001/02 was valued at \$180 million. The council area comprises 883,500 Ha of low average rainfall (350-500 mm pa) land of which 57,000 Ha is currently affected by dryland salinity with a further 70,000 Ha at risk. Affected land is characterised by shallow saline groundwater tables of varying salinity. This project offers a method to use saline groundwater in a productive manner while reducing the level of aquifers to remediate effected land through an aquaculture based salt interception system.

In 2001, the project was successful in obtaining further funding from the Natural Heritage Trust (NHT). Using this NHT funding, the emphasis of the project is now directed towards demonstrating the economic and environmental potential of a pilot-commercial scale system that can use and evaporate more saline groundwater while producing a wider range of products. This demonstration system will integrate production of finfish, brine shrimp, bivalves, seaweeds and salt. The existing infrastructure has been redeveloped to allow increased production capacity and increased water usage through installation of a small-scale salt works (1.7 ha) for disposal of up 20ML pa of saline groundwater through evaporation.

A report prepared by PPK E & I Pty Limited for the National Dryland Salinity Program (NDSP) titled 'Options for the Productive Use of Salinity' (OPUS, 2001) has identified aquaculture as a means of productivity utilising dryland saline water. However, it states that the industry needs to further develop to become a viable commercial option. This report supports the importance of the project such as BGIS, which is attempting to conduct research to develop commercial systems suitable for producing a variety of marine species while having a positive affect on the local saline aquifer.

The use of aquaculture for reclamation of saline land is not a new concept having been used in the Northern delta region of Egypt over many years as the first stage of agricultural development in over 50,000 hectares of highly saline soils (Cross, 1981). The aquaculture technology that underpins this project has been proven to be successful overseas (ie. Israel and USA) where a range of species (ie. Pacific white shrimp, clams, marine ornamental fish, tilapia, carp, sea bream) are cultured within aquaculture systems housed in polytunnels similar to those constructed at BGIS.

DESIGN AND METHODOLOGY

The fundamental strategy of this project is to develop a system that is compatible with environmental sustainability, while delivering viable economic outcomes to stakeholders. Aquaculture is being investigated as a means to offset the pumping costs incurred and derive profit directly through sale of products (ie. fish, brine shrimp, bivalves, seaweeds, salt and others) and indirectly through remediation of salt affected land. Based upon previous research, an expanded and remodelled integrated aquaculture system has been installed at BGIS (Figure 3). Within this system water flows sequentially through a series of lined ponds housed

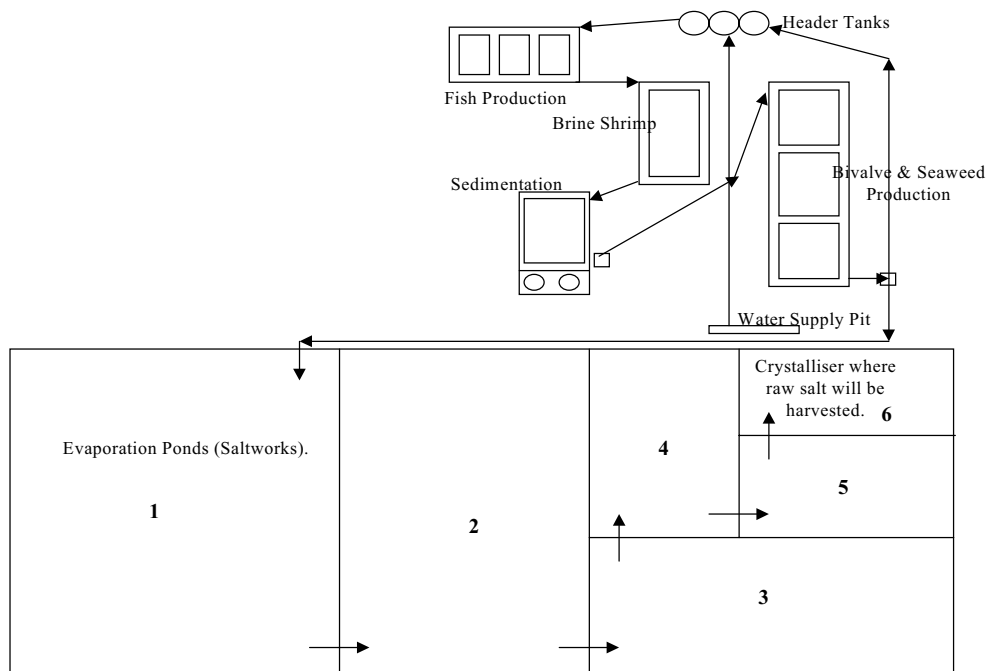


Figure 3: Layout of integrated aquaculture system for production and bio-mechanical filtration at BGIS.

within poly-tunnels. This system incorporates production and bio-mechanical filtration elements and provides the opportunity to discharge or reuse water as required to take advantage of climatic conditions (ie. high evaporation, elevated temperature) and changing demands of the production cycle (ie. increased water flow requirements).

Water Usage and Aquifer Monitoring

A core objective of this project is to maximise the use of saline groundwater within the integrated aquaculture system and ultimately remove as much of this as possible from the aquifer through evaporation in salt ponds.

Saline water is pumped from an open pit excavated into the shallow aquifer on site. At the BGIS, available saline groundwater ranges from 36-42ppt at ambient soil temperature. This water has proven suitable for production of a range of marine finfish species, brine shrimp and microalgae. Groundwater is periodically high in iron (e.g. up to 2.35 mg/L at BGIS) that is easily treated through aeration (oxidation of iron), settlement and filtration. To achieve this water is pumped from the pit into the first of a series of three linked 9,000L plastic storage tanks. Very vigorous aeration is installed in the first of these tanks to accelerate the change of

iron from soluble ferrous (Fe^{2+}) to insoluble ferric (Fe^{3+}) due to oxidation. Water is allowed to settle in the next two tanks before being sand filtered and pumped to a 20 KL fibreglass header tank that supplies water to the aquaculture system.

Monitoring bores (4) at the BGIS site will be extended and piezometers installed to allow the level of the saline aquifer to be monitored. This is an important component of the project as it is essential to know how the aquifer is changing in response to increased water usage by the aquaculture system.

Research outcomes from this aspect of the project will involve collection of data on total water usage and water quality in all parts of the system as a measure of suitability of water flow/exchange rates used. The suitability of commercial fish culture protocols for operation of ponds located in polytunnels will be assessed as will the level of the saline groundwater aquifer in response to pumping.

Integration of pilot-scale commercial aquaculture production.

Integrated aquaculture will provide a number of advantages to the profitability of this system through the efficient use of inputs and reductions in production costs (i.e. nutrient recycling, low cost lined pond and polytunnel technology). This project is assessing the production of marine finfish, brine shrimp, bivalves, seaweeds and salt to provide possible income generating streams and water treatment functions in a managed aquaculture system (Figure 3).

Fin fish production

A new polytunnel has been constructed (21m X 10m x 1.2m) which contains three lined 48m³ above ground ponds to grow fish. Water gravity feeds from the adjacent header tank. Initially fish production ponds have been stocked with advanced black bream and mullet (*Argyrosomus japonicus*) at less than 10 kg/KL to provide adequate production to assess performance and minimise risk. Finfish will be fed commercial pellets and supplementation of these with excess brine shrimp will be evaluated during early growth stages.

Discharge water will flow by gravity from this tunnel, through the brine shrimp tunnel and on to the sedimentation tunnel. A desk top model will be developed to match the evaporation profile at the site with the water required at different times of the production cycle. From previous research it is anticipated that a 12 month finfish production cycle will be achievable with autumn stocking (i.e. minimum water usage), so that low density of small fish within the system coincides with the time of minimum evaporation. Growth of these juvenile fish will be enhanced at elevated water temperatures maintained within polytunnels through winter. As water demands increase (i.e. flow rate and exchange%) with growth this will align with increases in water disposal potential through the increasing evaporative losses due to increasing temperatures experienced during spring and summer at Cooke Plains. Ultimately it is expected that this project will develop a model for productive capacity per unit of saline groundwater used within the system and balance this with the amount of water that can be disposed of onsite during the production cycle.

Ideally the ponds will be stocked with 10-50g fingerlings in late March- early April (2003) to provide the growing season required to reach market size at the end of the following summer. Species selected include mullet as a target species for this type of system as it is relatively easy to culture, is available from hatcheries, has good growth rates, adapts to a wide range of salinity and water temperature conditions, and is believed to have good economic prospects if appropriate marketing can be undertaken.

Brine Shrimp

Brine shrimp (*Artemia sp.*) are small hardy crustaceans that inhabit a wide range of salinities that make them an ideal candidate for a role in this type of integrated system. They are non-selective filter feeders that utilise a range of organic particles as an energy source. Initially organic matter in the form of fish waste will be the only feed source given to them. To achieve nutrient recycling, adult brine shrimp (14+ days old) will be harvested and fed back to the fish. Nutrient removal will also be achieved with any excess sold live to the lucrative aquarium market, or as dried biomass for feed manufacture. It is expected that the nutrient harvesting ability of brine shrimp (together with bivalves and seaweeds) may also enhance the quality of salt produced.

Sedimentation

A 13m X 10m X 1m lined sedimentation pond has been installed in an existing 10m x 21m polytunnel. This process will help reduce the sediment collected in the oyster/seaweed tunnel, as no mechanical filtration will be used in the system.

Bivalves and Seaweeds

After settlement water overflows into a sump from where it is pumped to a 10m x 46m x 1m polytunnel segregated into 3 equal sized lined ponds to hold Pacific oysters (*Crassostrea gigas*) and macroalgae. Water can supply each pond individually, or the water can cascade between all ponds.

Bivalves improve water quality by removing particles through filter feeding and by increasing particle sedimentation by production of faeces and pseudofaeces which is the indirect result of removing particles by filtration (Mariojous and Kusuki, 1987 as cited in Shipigel *etal*, 1997). Pacific oysters will be initially stocked within the system as they have high tolerances to changes in salinity and temperature. The oysters will be held in PVC trays (dimensions 1m x 2m), which are light weight, Australian designed and stackable. Oysters of varying sizes (10-40mm) will be trialed and each tray will have 100% coverage to help shape the oysters during growth. We are expecting to produce around 50,000-60,000 individual oysters (4,167 – 5,000 dozen) per annum. Small doses of sodium silicate will be supplied to the system to encourage the growth of diatom species of microalgae. Shpigel *etal* (1993) found that Pacific oysters performed better on a diet consisting predominantly of diatoms using a semi-integrated culture system incorporating fish and bivalves. In France, oysters (*C. gigas*) are fattened in ponds that contain populations of diatom species for 1-2 months prior to selling (Soletchnik *etal*, 2001).

Seaweeds are capable of removing ammonia and nitrates within the system. They will be grown concurrently with the oysters in the large polytunnel and continually harvested to promote growth. The wet weight of the seaweed will be recorded and various species of seaweed (eg. *Ulva* and *Gracilaria*) will be explored for production of high valued products (eg. alginates, carageenans, agricultural and biomedical uses).

After the water has passed through the oyster/seaweed ponds, it will be diverted through to the evaporation ponds, or pumped back to the header tanks to be reused.

Salt production

There is a discrepancy between rainfall and evaporation at the Cooke Plains site of 1.35 m pa that the disposal of saline groundwater through evaporation and accumulation of salt. The salt ponds currently used at Cooke Plains have been upgraded to accommodate the increased water use of the pilot-scale commercial aquaculture system and balance this with the evaporation

profile at this site. Pond design has been improved to maximise evaporation through the combined effects of heat, wind and pond water characteristics.

The expanded evaporation ponds have been modelled to simulate a small-scale salt works covering 1.7 hectares, using annual rainfall and evaporation data available for the Cooke Plains region. Six evaporation ponds will be constructed to manage salt water at a range of concentrations. The last pond in the series will be the crystalliser from which salt is harvested. The pond prior to the crystalliser will be used to collect bitterns (magnesium chloride) that will be used by the council for spraying on to unsealed roads. The evaporation pits will be clay lined to prevent water seepage back into the ground.

Research conducted on salt production will focus on the impact of upstream aquaculture operations on the formation and quality of salt produced.

FUTURE WORK

The upgrade of this project is expected to be completed and with stock introduced by early October, 2002, when collection of performance data will begin. In future, options for utilising alternative energy sources at the site will be explored, with the aim of reducing power costs. Use of highly saline water for irrigation of halophytes is also an option for consideration to further increase the volume of groundwater that can be disposed of without increasing area of evaporation ponds.

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