ISD Trial: Swan Valley, Western Australia
November 2006 to March 2007

Location: The trial was carried out on a smallholding (Horse Stud Farm) at West Swan, within the Swan Valley wine region in Western Australia. The site is situated on the eastern edge of the Swan Coastal Plain, and approximately 2km west of the Swan River.

Geology: A new bore was drilled into the Superficial Aquifer at the site to a depth of 26m below ground level (bgl). The upper 15m of Superficial deposits were heavy clays, typical of the eastern part of the Swan Coastal Plain close to the Darling Scarp and within the Swan Valley. The driller's log record clay to 15m bgl, clays with sand to ~18m bgl and then approximately 7m of sand and coarse rock to 26m bgl underlain by clay.

ISD bore: The drilled bore was cased with 155mm id PVC casing and two sections of 3m-long slotted casing (20 thousandths inch slots). Pea gravel was run into the annulus around the cased and screened section of the bore. The bore configuration was as follows

Depth	Casing / screen
0 - 17m	Blank casing
17-20m	Slotted casing
20-23m	Blank casing
23-26m	Slotted casing

Initial information on a bore drilled close by the site indicated the confined sand aquifer occurred between 17-26m bgl. However, later testing suggested low permeability sands/clays between 17m and 20m depths bgl. Thus the main ISD trial was carried out using the lower 3m screened section. The tested aquifer was thus effectively only 3m thick at this site, which is the absolute minimum thickness for this type of system.

Groundwater: Rest water levels at the start of the testing were around 5.5m bgl, well within the clay sediments. Initial groundwater salinities within the upper screened section were just over 2000mg/L, and just over 3000mg/L when groundwater from both screened sections were pumped. Groundwater from a monitoring bore (the farm bore) within the same aquifer and 6m east of the ISD bore showed total dissolved salts (TDS) of 3300mg/L. Background groundwater within the sand aquifer from 20-26m bgl was assumed to be close to the latter concentration.

Groundwater at the site is a sodium-chloride dominated water with pH value around 6.2-6.4; it is anoxic and reducing in nature (redox potentials negative at approximately -100 to -120mV) and containing high concentrations of dissolved iron, varying from 10-15mg/L in background groundwater.

ISD system: The prototype ISD system used in the trial consisted of three main elements or modules connected within the bore by 3m lengths of 2.5mm (1 inch) stainless steel drill rods. The modules consists of

- an upper pump housing, permeate and feed line (~1.5m in length)
- an RO treatment vessel constructed of stainless steel, 100mm in diameter and 4m long, containing 4 x 1m long, spiral-wound Reverse Osmosis (RO) elements
- An inflatable packer emplaced somedistance below the main treatment vessel to isolate an upper section of bore screen through which groundwater feed is pumped

The packer also isolates a lower section of bore screen through which concentrates (fluids and salts rejected by the RO membrane elements) are discharged back into groundwater at the base of the aquifer.

Considerable efforts were made to find the optimum configuration of the ISD modules (pump, main treatment vessel, packer) within the bore. Initial tests carried out with the inflatable packer situated between the two screens gave rise to significant drawdown within the top section of the bore (~6m) which led to instability of the sand/clay sediments and a feed groundwater to the ISD system which had high turbidity. The drawdown was caused by the unexpected low permeability of the upper clay/sand sequence mentioned above. Hence the initial tests were stopped, the system removed from the bore and the RO elements backwashed to remove accumulated clay sediments. The bore was also pumped and redeveloped using air to stabilise the formation and obtain a clarified feed groundwater.

The downhole configuration of the ISD unit used in the main testing in relation to the location of the screened sections of borehole was as follows:

Depth	**ISD module**	**Screens**
0-17m	drill rods	
17-18.5m	Pump housing and feed tubing	
18.5- 23.5	Main treatment vessel, connecting flanges	17-20m
23.5-24.5	drill rod plus flow control valve	
24.5- 25.2	Inflatable packer	23-26m
25.2-26m	Lower screen for concentrate return	

Thus feed groundwater was obtained by pumping from the upper screen and from the upper part of the lower screen between 23 and 24.5m where aquifer sediments had high hydraulic conductivity. Re-injection of concentrates was through a 0.8m length of screen below the inflatable packer.

The main modules of the ISD system are shown below in Plates 1-5.

Trial results: The main trial of the ISD system was carried out between 4 November 2006 and 12 March 2007. A licence to carry out the trial over this period was obtained from the Western Australian Department of Water, with conditions that groundwater be monitored near the ISD bore during testing, and that the environmental impact of ISD be assessed.

The trial was carried out in order to

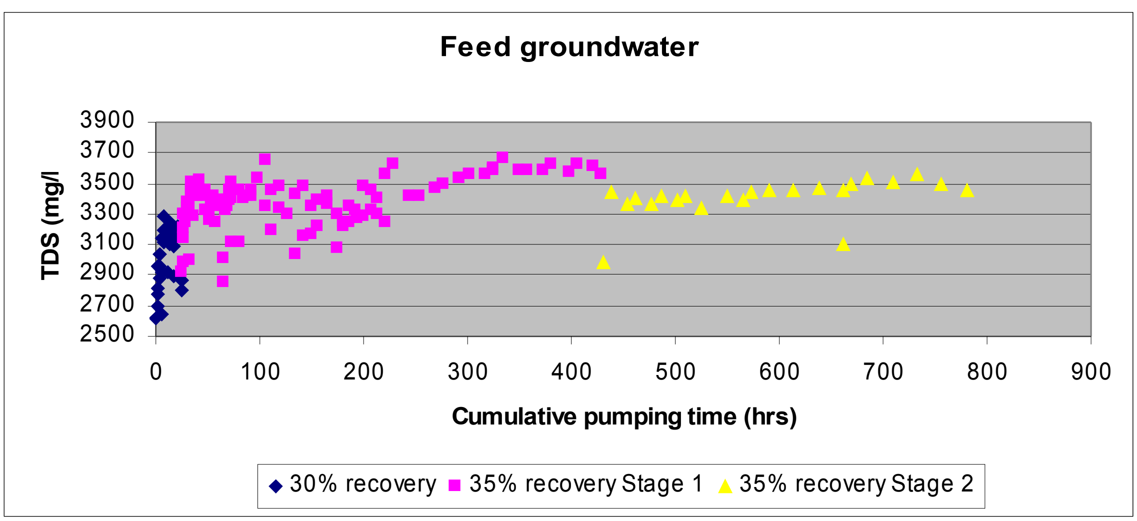
- Evaluate the operation of the prototype design
- Assess the efficiency and cost-effectiveness of ISD-RO treatment
- To identify potential for membrane fouling and assess ways of overcoming this
- To obtain information on hydraulic behaviour and impacts of ISD within the aquifer, and using this data to develop numerical (predictive) models which would provide a basis for determining long-term environmental impact of ISD application
- To define designs for next-generation prototype ISD devices.

The Swan Valley test site was considered to be a significant challenge, given the very limited thickness of the confined aquifer, and the very high concentrations of iron and possible clay mobilisation during pumping which potentially could give rise to membrane fouling.

The trial commenced with a short period of pumping with inlet pressure to the RO treatment vessel at 700KPa, giving a permeate flow of around 550L/h, and recovery (% of feed which is recovered as permeate) at 30%. Subsequently, pressures were increased to 800KPa, giving a recovery of 35% and flowrate of permeate of 600L/h. This proved to be the optimum operating conditions for this bore. The following results were mostly obtained under these conditions.

Feed groundwater

The salinity of groundwater feed over the trial remained reasonably constant at 3500mg/L TDS (see below) and pH of 6.1-6.4. Feed TDS showed highest variability in the early stages of the trial when ISD was run for 5-7 hours each day during weekdays. The lowest TDS concentrations in feed groundwater were always recorded when the pump was switched on after 2-3 days of system downtime.



Later in the trial (from ~250 accumulated runtime hours) the system was run continuously, apart from two breaks (~430 hours, and 670 hours) when the system was shut down for ~ 2 weeks for logistical reasons. At both these breaks, the TDS of groundwater on commencement of pumping was ~3000mg/L, close to the background groundwater salinity (as TDS).

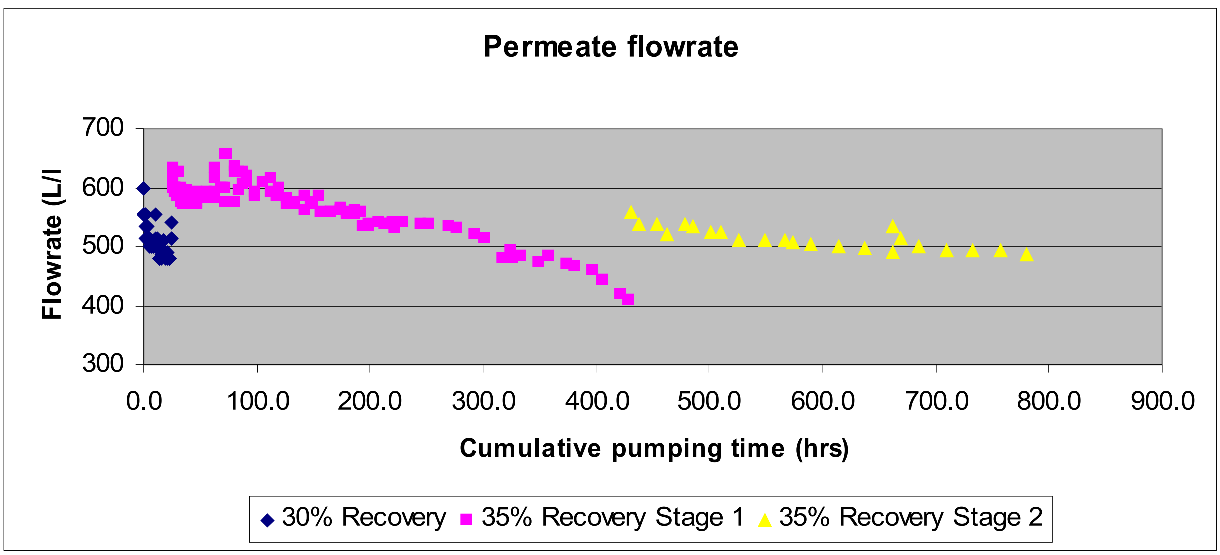
The latter indicates that

- there is some concentrate return into the feed groundwater stream (estimated to be about 25% of feed)
- injected concentrates rapidly dissipate within the aquifer, particularly when ISD is switched off.

The near-constant feed salinity indicates that injected concentrate fluids mainly remain at the base of the aquifer, presumably as these are more dense than groundwater feed to the ISD system.

Permeate flowrates and salinity

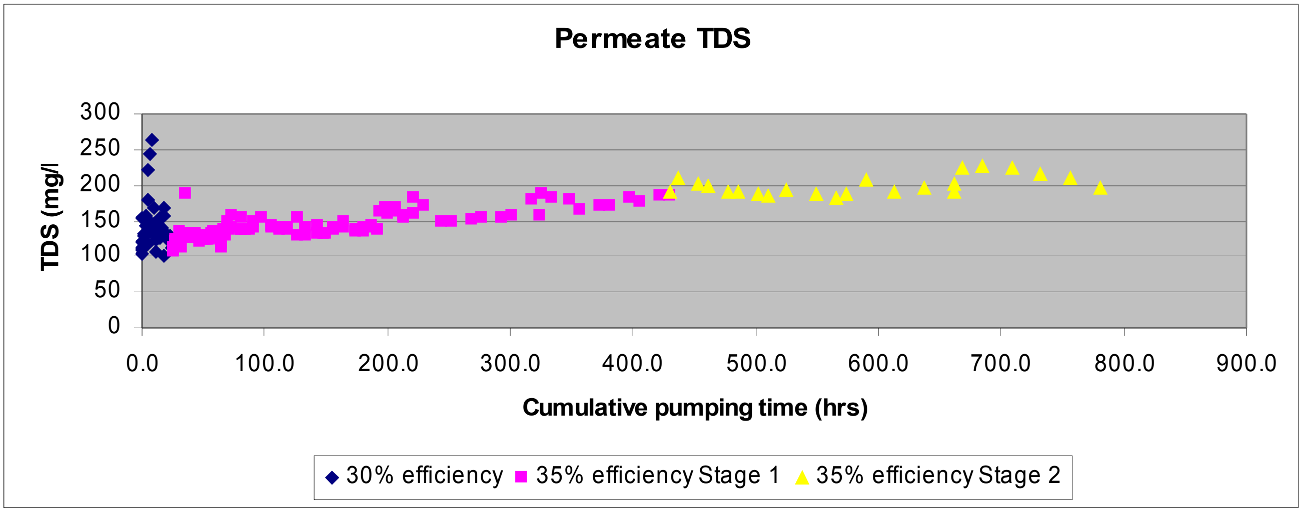
Permeate flowrates are shown below for the trial period. These show the initial flows of around 600L/h which decayed over the first 420 hours of cumulative pumping, mostly over the period from 300-420 hours. Removing the ISD system from the bore and backwashing and antifoul washes of membrane elements restored flows to around 550L/h once the system was re-installed (shown by the jump in flows at ~450hrs).



Measures taken to reduce formation of iron flocs (fine suspended particles produced when iron is oxidised and precipitated as an oxyhydroxide) resulted in a much lower membrane fouling from 450-800 hours of pumping.

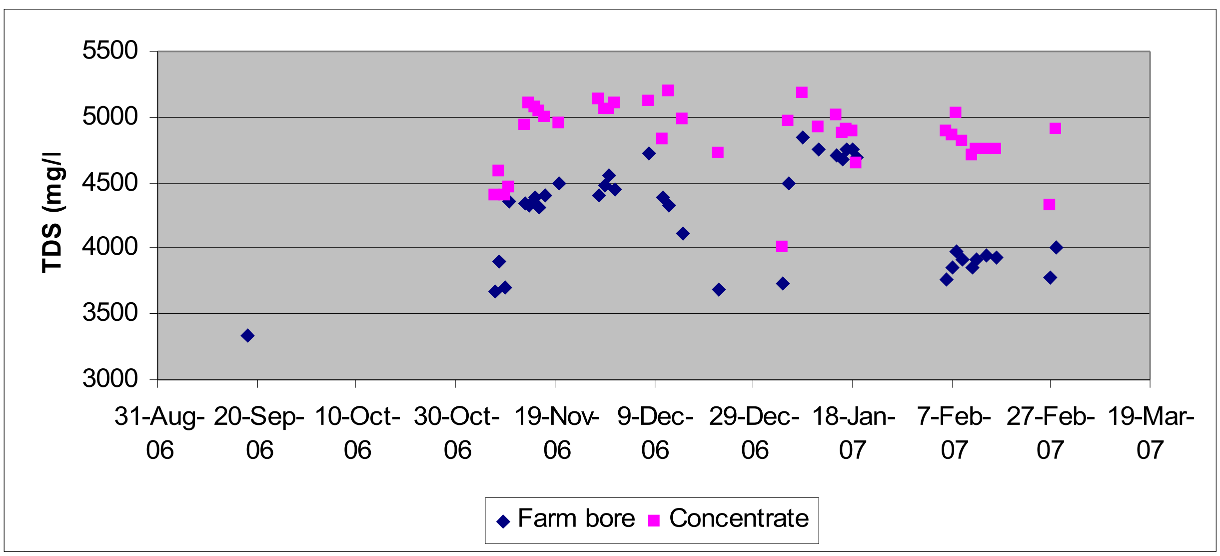
Permeate quality has been excellent throughout the tests. Permeate salinity was generally 200mg/L or less. The pH value varied from 5.1-5.5, but increased to 5.8-5.9

on standing in the balancing storage tank, as the permeate was exposed to air. Concentrations of iron in permeate were <0.3mg/L at all times. The gradual increase in TDS is considered to be partly related to membrane fouling.



Concentrate fluids and impacted groundwater

The salinity of concentrate fluids returned into groundwater after RO treatment are shown below, compared with salinities of groundwater pumped from the monitoring (farm) bore which is 6m downgradient of the ISD bore.



In the figure above, salinities of concentrate vary from 4500 to 5200mg/L TDS. There is a slightly delayed response to injection of concentrates on salinities of groundwater from the monitoring bore, with salinities generally being lower than those in concentrate fluids (generally being below 4500mg/L). Salinities of groundwater pumped from the monitoring bore decreased rapidly over the Christmas / New Year period when the ISD system was not operational. Likewise, this also occurred around 18 January 2007 when the system was removed for membrane cleaning.

In the latter two cases, groundwater salinities at the monitoring bore reduce to around 3600mg/L, compared with the initial background salinity of 3300mg/L in September 2006 (see the Figure above), indicating minimal overall local impact of ISD on groundwater.

Results of the numerical modelling of groundwater impacts broadly mirror the above conclusions. These also indicate salinities dissipating through dispersion in groundwater so impacts over 10 years of continuous ISD operation are within 50m of the ISD bore, and the more saline concentrates within the region of the bore remain at the base of the aquifer, as found during the trial.

Power requirements and costs of water supply

The whole ISD system is run from a small (1200Watt) submersible pump. Hence power costs are quite low. Assessment of power consumption for full operation of the system (feed, treatment, permeate delivery to surface and concentrate disposal) was estimated to be ~2KWh/m^3 of delivered permeate for the system used in the Swan Valley. This is probably higher than expected due to the relatively low permeate volume delivered at the Swan Valley site, caused primarily by hydrogeological constraints (minimal aquifer depth limiting groundwater feed flow, high iron concentration, high concentrate return into feed flow). Desaln8 feels that power consumption can be significantly improved above that found at this first trial site.

Desaln8 estimates the costs of delivering water, including plant operation, assessment etc to be comparable with current costs of urban water supply in Australia.

Further trials will be used to more fully define the operating and maintenance limitation of the device and the subsequent impact of this on the delivery cost of the permeate.

Acknowledgements.

Desaln8 acknowledges Land and Water Australia for provision of funding for development of the numerical models and for part funding of the trial in the Swan Valley, and the University of Western Australia School of Environmental Systems Engineering [Dr David Reynolds] for research expertise relating to modelling of the ISD process and groundwater impacts.

We also acknowledge the kindness of the Bray family, for allowing the trial to be carried out on their property at West Swan, and for assistance with emplacing ISD downhole and for other material assistance. Without this assistance, the trial would not have taken place.

The Department of Water is also thanked for allowing the trial of ISD to proceed through granting of a conditional bore licence.