Draining groundwater for salinity control in Pithara, Wheatbelt, Western Australia

Department of Water
Government of Western Australia

The salinity of agricultural land within the valley floors of the Wheatbelt is due to groundwater being at or near the land surface in these lower parts of the landscape. Infiltration to groundwater systems has increased following clearing of deep-rooted perennial vegetation. Low gradients along these valley floors mean that groundwater can only drain away slowly. As the groundwater rises it dissolves salts stored in the soil profile, and brings the salt to the surface.

Broadly speaking, there are two ways to control dryland salinity. The first is to lock salt up in the soil, which is an effect of tree-planting programs. The second is to drain or pump water and salt out. This involves lowering the groundwater level and keeping it far enough below the soil surface to stop salinisation.

Drainage at Pithara

The Pithara site is one of four drainage projects being conducted by the Engineering Evaluation Initiative across the Wheatbelt. The main aim of the projects is to evaluate the usefulness of groundwater drains in reducing watertable and soil-salinity levels. The second aim is to contribute to the development of useful tools and methods that can be used to predict how effective drainage might be, before construction.

The site is 22 km east of Pithara (300 km NNE of Perth) on Kingsley and Paula Roach's property. The topography of the site is typical of the north-eastern Wheatbelt: low relief and broad valley floors, with poorly defined natural drainage. The average annual rainfall is around 320 mm. Groundwater, with salinity greater than 30 000 mg/L, is within 1 m of the surface over most of the valley floor.

Planning the Pithara drain and monitoring program

Planning the Pithara groundwater drainage scheme started by drawing lines on a recent aerial photograph and a contour map. The aerial photograph provided the best overview of the layout of the property as well as of topographical features and the current extent of salinity. Once a preliminary drainage plan was proposed, its suitability was discussed with the landowners: it was important to ensure that the drain did not interfere too much with the management of their property and would provide the greatest possible drainage benefit.

Backhoe pits were excavated at intervals of approximately 1 km along the proposed drainage alignments. The purpose of the pits was to:

- examine the materials and the likely excavation conditions
- get an indication of how fast groundwater might flow into the drain
- measure the groundwater salinity and pH for an indication of the likely drainflow water quality
- see the depth of groundwater in the pits.

Information from the pits was used to decide the most appropriate depth to dig the drain and work out the permeability of the soil (hydraulic conductivity). Some pits were also excavated alongside and away from the proposed alignment to check for better drainage or excavation conditions. If better conditions had been found, the alignment could have been altered or spur drains constructed to intercept the groundwater beneath those areas.

Soil profile of backhoe pit showing groundwater

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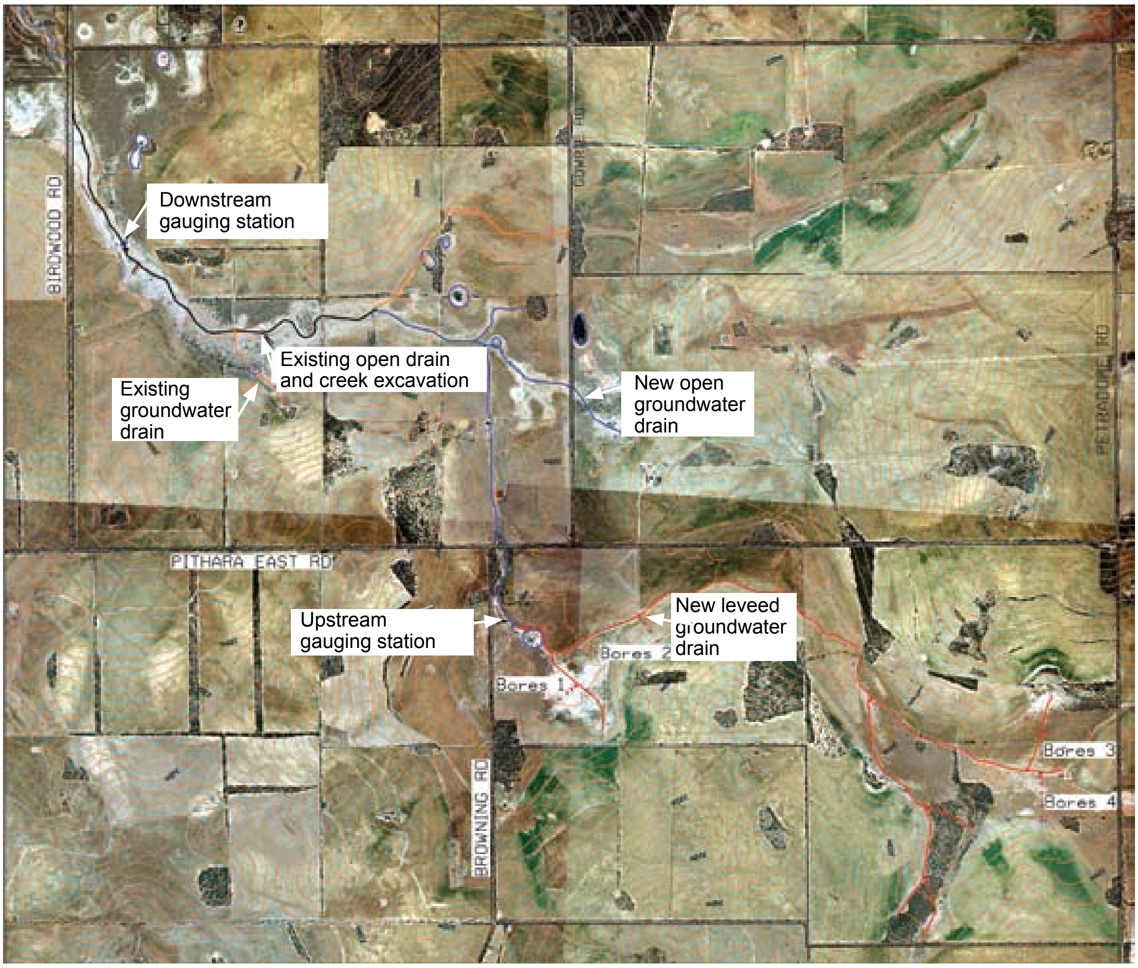

Figure 1 Aerial photograph and illustration of the drain alignment and main features of the Pithara drainage site

The drain alignment was then surveyed for position and elevation along its length. Planning was then finalised and included the following tasks:

- Seek the necessary approvals for construction of the works (e.g. Notice of intent to drain).
- Work out the most appropriate specifications for various sections of the drain and prepare detailed plans of more complex elements of the scheme, such as road crossings.
- Plan the management of surface water runoff and flood management in and around the proposed drainage scheme. This included designing the appropriate placement of drain spoil banks and checking the adequacy of floodways affected by the drain.
- Identify the need for and location of farm and floodway drain crossings. This included negotiating with the shire about two road crossings, and the Water Corporation about a pipeline crossing.
- Drill four transects of groundwater monitoring bores alongside sections of the proposed drain channel.
- Plan and construct the upstream and downstream drainflow gauging stations.
- Seek quotes for construction from various drainage contractors and order the required materials such as culverts.

What was constructed?

The Pithara drain was constructed and monitored in two distinctly different sections. The 9070 m long upstream section is all 2.5 m deep and the channel is completely enclosed within spoil banks formed from the excavated material. No surface water, except rainfall, can enter the channel between the banks. The works are contained within a catchment of about 6500 hectares (ha).

A completed section of the upstream Pithara drain

The upstream drain discharges into the downstream section. The downstream drain consists of 6815 m of 2.5 m deep and 2610 m of 1.25 m deep 'open' channel. This means that surface runoff can enter and be carried within the channel. A portion of the downstream section of the scheme was constructed two years before the project started. The total catchment area of the downstream drain at the measuring station is 14 000 ha.

The drain being constructed across Pithara East Road

What are we trying to achieve?

As groundwater levels rise and approach the ground surface, water begins to evaporate from the soil surface. Significant losses start when groundwater is several metres below the surface as water is carried upwards by capillary action. The closer the watertable is to the surface, the faster the rate of capillary rise and higher the rate of evaporative loss. This is illustrated in Figure 2 which shows the amount of water in mm/day evaporated from the surface of different soil types. For example, if the watertable beneath a loam soil is at 2 m (200 cm), approximately 1 mm per day of groundwater could be lost from the soil surface.

The saltier the groundwater and the higher the rates of evaporation, the more rapidly the salt can accumulate near the surface. If, in the case above, the groundwater had a salt concentration comparable to seawater (35 000 mg/L), 1000 litres (1 kL) would contain 35 kg of salt. If 1 mm evaporative loss per hectare is equivalent to 10 kL of water, this would mean that 350 kg of salt could accumulate in 1 ha of soil per day.

The main aim of drainage is to lower the watertable. In doing so, the rate of evaporation and salt deposition will be reduced and there may be some leaching of the salt. Figure 2 shows that, when the watertable is near the surface, small falls in the watertable are enough to significantly reduce evaporative loss from the surface and so reduce soil salinity. This is one reason why the impact of small groundwater-level reductions on plant growth is so evident on saline land.

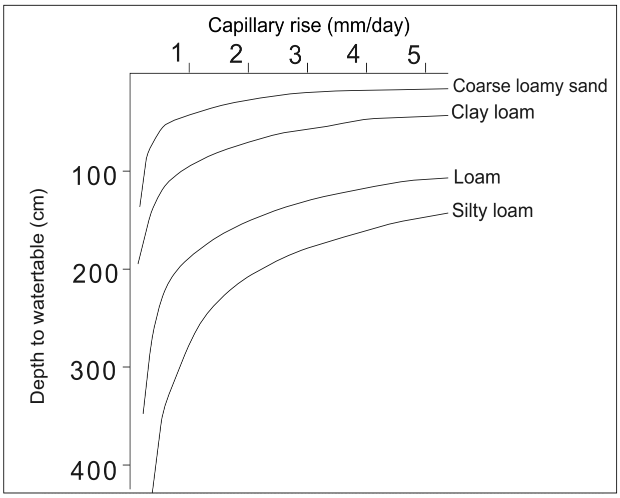

Figure 2 Rates of evaporative loss from different soils with watertables at various depths

How do we achieve watertable reduction?

To have a direct effect on lowering the watertable the drain channel must be below the watertable depth. This allows the groundwater to flow into the drain from the surrounding saturated soil. The furthest extent of lowered watertable to either side of the drain is termed the 'zone of influence' of the drain. The deeper the drain is below the watertable the greater its zone of influence. This is illustrated in Figure 3.

Small reductions in the watertable at great distances from the drain may be insufficient for any beneficial impact in terms of reclaiming saline land. The 'zone of benefit' is where the watertable falls enough to allow salts to be leached, waterlogging to be controlled, and land to be recovered to productivity. The zone of benefit is always narrower than the zone of influence.

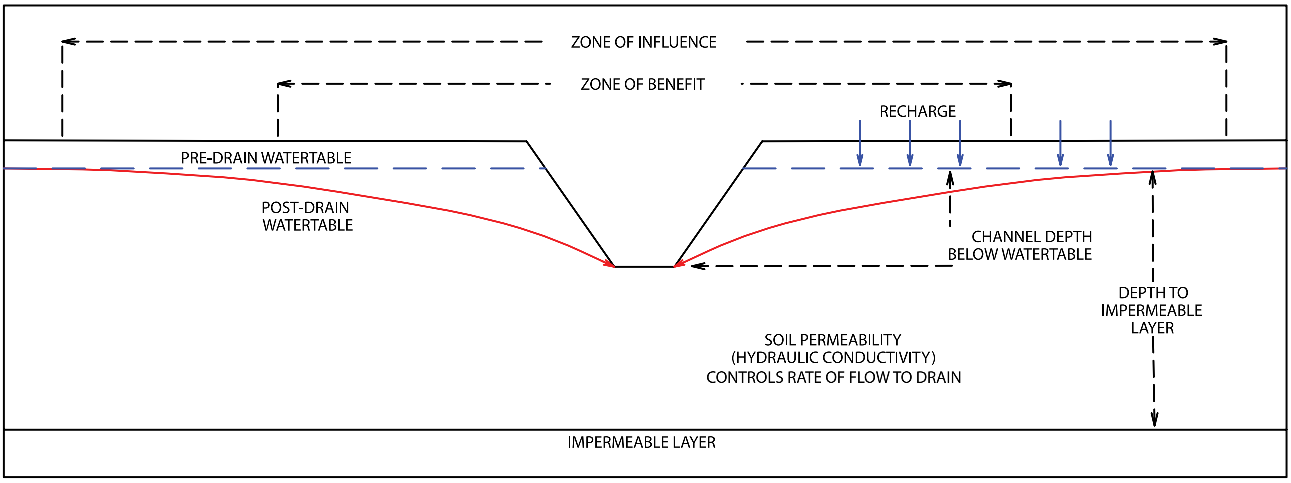

Figure 3 The main variables affecting the performance of a groundwater drain

What makes an efficient drain?

The depth to which the channel is excavated below the watertable is the only optional design variable that will affect drain performance. Once the channel alignment has been chosen, all the other factors affecting drain success are determined by soil and climatic conditions.

Given that the measure of success of a drain is a wide zone of benefit, these variables (see Figure 3) are:

- Permeable soil (high hydraulic conductivity) allows groundwater to migrate to the drain channel rapidly and from large distances. Soils that are not permeable will not allow the soil to drain.
- A greater depth to an impermeable layer beneath the drainage site will enable groundwater to flow 'radially' towards the channel rather than just horizontally. This allows groundwater to migrate towards the channel from greater distances.
- Recharge is infiltration that adds to the groundwater level. A rate of recharge lower than the drainage rate will allow the groundwater level to fall. If the recharge rate is higher than the drainage rate, the watertable will not fall as much because it is being constantly 'topped up'.

What do we measure?

At the Pithara site, we primarily want to measure the impact of the drain on the watertable alongside the channel. Together with information from the Murdoch University soils research project this gives us an indication of the zone of benefit of the drain in various soil conditions along its length.

Four sets of bores were drilled perpendicular to the drain channel (as Bores 1 – Bores 4 in Figure 1). In each transect the furthest bore is 400 m from the channel. These new bores, as well as existing bores, are monitored to assess drain effectiveness. The groundwater salinity and pH in the bores are measured regularly. Each year in April and September there is a groundwater chemical sampling program for the concentrations of major ions and heavy metals in 10 selected bores close to the drain.

Two gauging stations measure the volume and salinity of discharge from the drainage scheme. One is at the end of the upstream section and the other at the outlet of the scheme. The volume and salinity of the discharged water are automatically recorded every 10 minutes while the pH and chemistry of the discharge measured at the same frequency as the bores.

Sylvia Tetlow measuring the salinity and pH of the water at the downstream gauging station at Pithara. The orange staining on the flume and drain is due mainly to precipitation of iron from the groundwater.

Groundwater changes due to drainage

Before construction, an investigation of potential drain performance by measuring the rate of groundwater inflow into the backhoe-excavated test pits indicated that the zone of influence was likely to be around 300 m (150 m each side of the channel). A key contributing factor to this rather narrow zone of influence is the high silt content of the clay subsoil, which means the soil has a low permeability. The average hydraulic conductivity of the soil across the site was calculated to be 0.07 m/day — a conductivity of 0.25 to 1.0 m/day is the range for responsive drainage.

Figure 4 illustrates the groundwater level changes for two bores in transect 3 over nearly two years. The solid horizontal line represents the ground level at the drain. The black vertical line shows when the drain was constructed (day 0). The waterlevel in the 400 m bore is not above ground level. Due to the slope of the valley, the ground surface at this bore is much higher than at the drain.

Figure 4 shows that the groundwater in the bore 20 m from the drain started to fall as soon as the drain was constructed. This response was not seen in the bore 400 m from the drain, indicating that the drain has not affected the watertable this far away. The sharp decline in the waterlevel of the 20 m bore during October 2005 was due to pumping from a production bore 500 m away.

Figure 5 shows the average of all groundwater levels in the four transects and illustrates more clearly that groundwater levels closer to the drain have changed significantly. The changes in groundwater level 300 to 400 m from the drain are probably caused by natural fluctuations.

A measurement of the cross-section area of groundwater change between days 0 and 120, minus natural variation, can be used to calculate the volume of soil drained. The result is 179.5 m^3 of soil dewatered per linear metre of drain. Multiplying this by the 9070 m length of the upstream section of drain indicates that approximately 1.63 million m^3 of soil were drained in the first 120 days. With an average soil specific yield of 0.01, drain discharge during the period should have been approximately 16 300 kL.

The salinity of the groundwater across the site varies quite significantly according to bore location, seasonal dilution and evapoconcentration but, on average, is similar to that of seawater (35 000 mg/L).

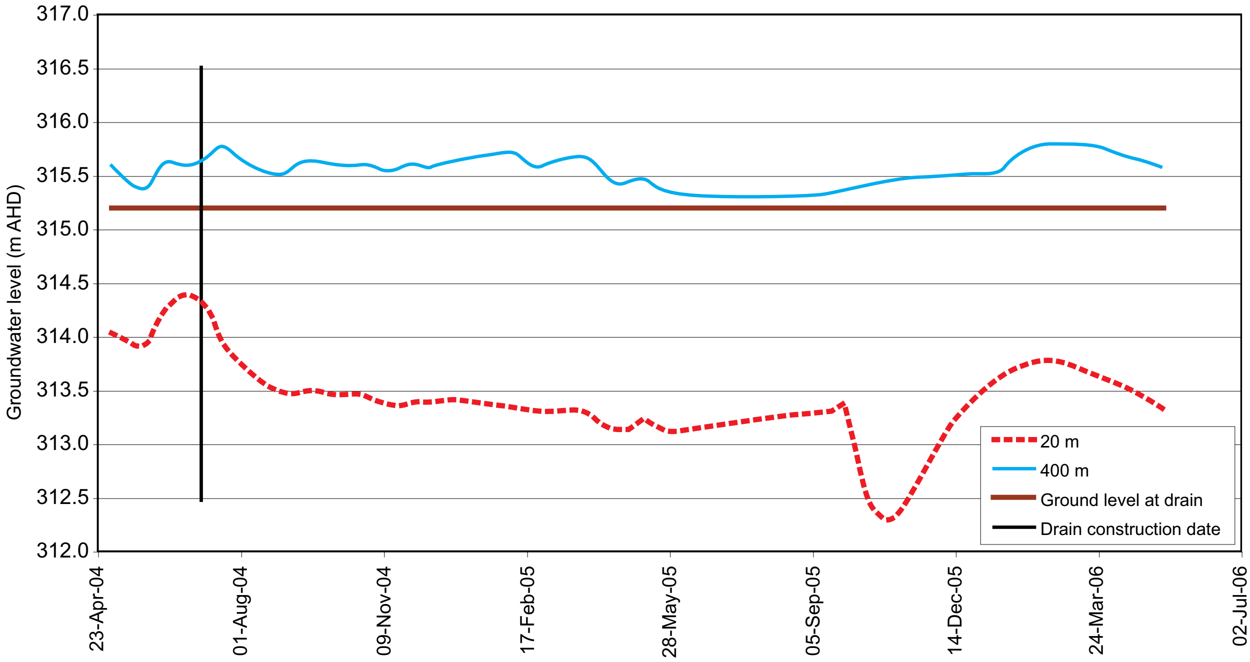

Figure 4 Time series groundwater level responses to drainage in bore transect 3

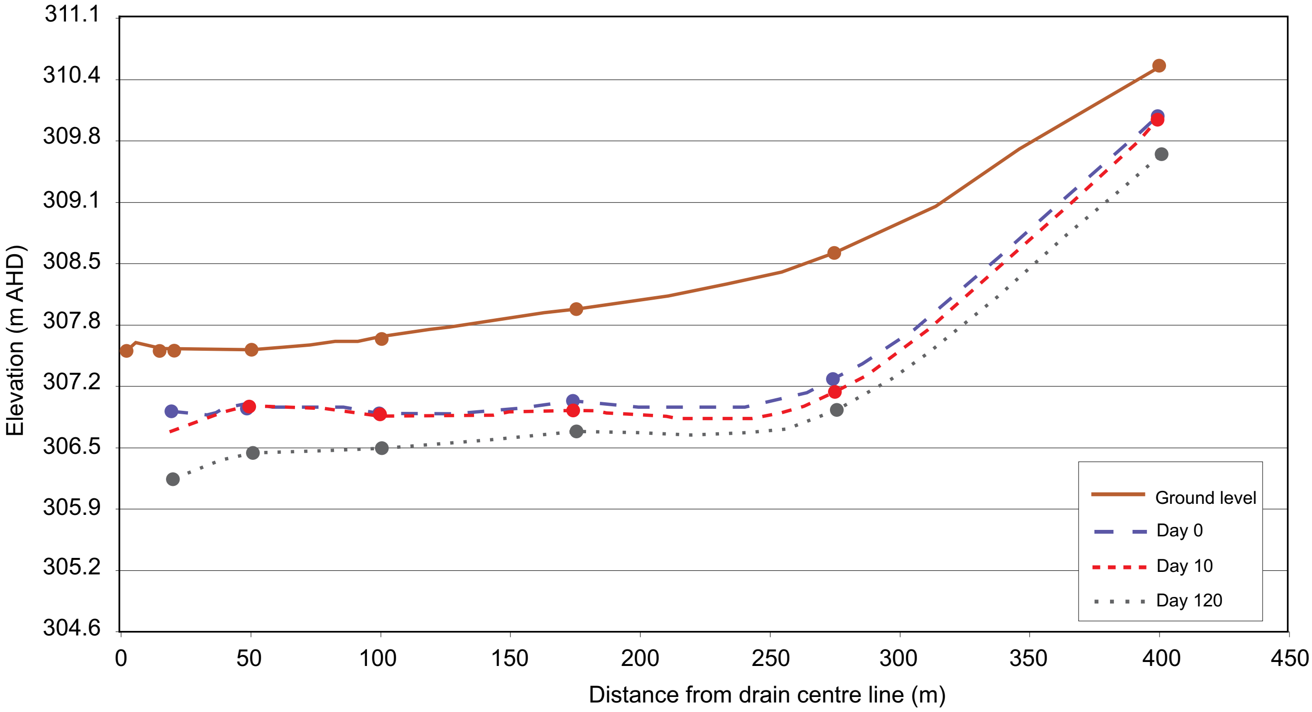

Figure 5 The average groundwater profiles for all transect bores in the Pithara drainage site for days 0, 10, and 120

Drain discharge

Figures 6 and 7 show the total daily discharges and salt loads for the upstream and downstream gauging station data loggers. The peaks in the discharge are due to rainfall events contributing to drainflow. The upstream leveed drain does not produce flows of the same magnitude as the downstream drain. The upstream drain only needs to accommodate runoff from within its spoil banks while the downstream drain needs to accommodate this and runoff from the surrounding landscape.

The onset of increased drain discharge from rainfall causes a 'spike' in the salt load caused by fresh runoff entering the drain, displacing the salts accumulated within the channel. Typical groundwater discharge rates to the drain in winter range from 0.15 to 0.30 L/s per kilometre.

Further evaluation of the drain is planned to include separating the drainage flow into components of:

- total discharge and salt load
- discharge due to groundwater only
- discharge due to rainfall.

This can assist with estimating the volume of soil dewatered and the volume of discharge from the drain.

The pH of the discharge is routinely monitored at both stations. Upstream discharge is neutral to slightly acidic. Downstream discharge varies widely depending on the dominant source of water at the time. While the whole of the scheme is flowing, pH tends to be neutral to slightly acidic. When the flow decreases, it is dominated by groundwater discharge from land closer to the drain outlet. The pH of this iron-rich groundwater can fall to less than 3.0 (very acidic).

The silty soils of the Pithara upstream drain have low permeability and erode quite easily. The channel is only 2 years old.

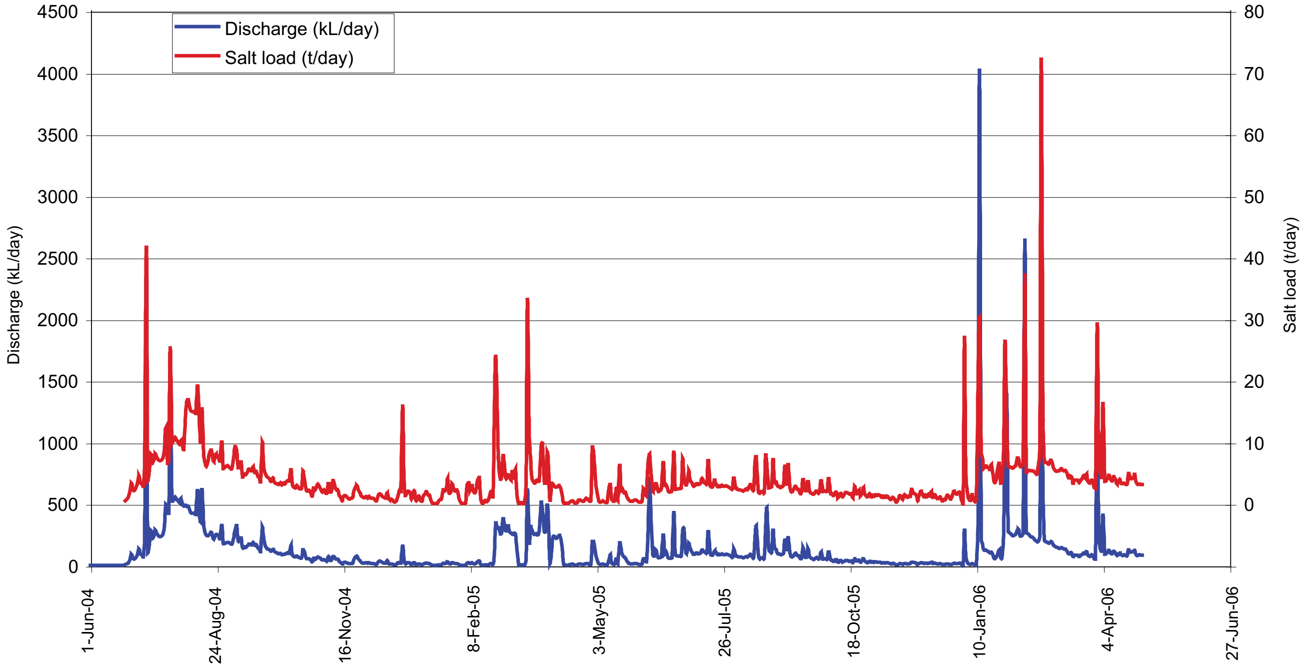

Figure 6 Discharge and salt load for the upstream gauging station

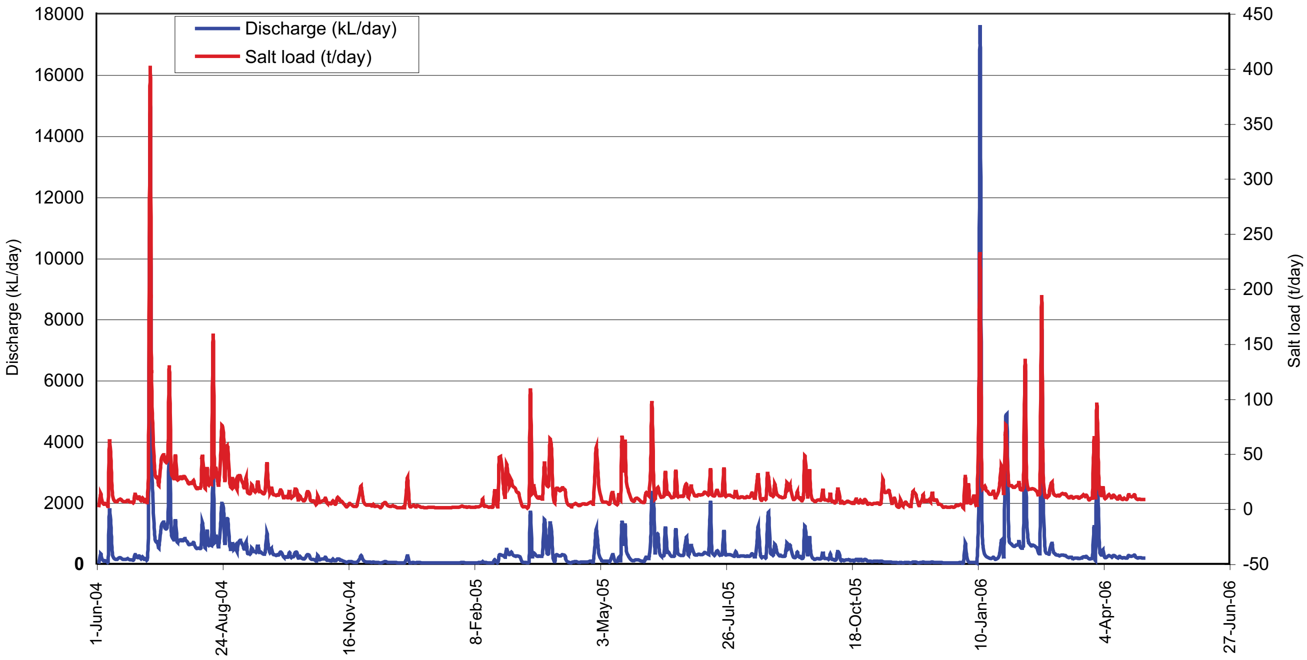

Figure 7 Discharge and salt load for the downstream gauging station

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Table 1 Drain discharge summary for the Pithara monitoring stations

	Measurement period			Upstream drain		Downstream drain [a]	
				Total	Value per linear metre	Total	Value per linear metre
Discharge volume (kL)	24 June 2004	–	24 Sept 2004	27 900	3.1	58 300	6.2
	1 Jan 2005	–	30 May 2006	58 500	6.5	105 600	11.2
Salt load (t)	24 June 2004	–	24 Sept 2004	750	0.8	2 300	0.25
	1 Jan 2005	–	30 May 2006	1 700	0.18	4 600	0.49
Flow-weighted mean salinity (mg/L)	24 June 2004	–	24 Sept 2004	27 000	27 000	35 900	35 900
	1 Jan 2005	–	30 May 2006	28 300	28 300	38 100	38 100

[a] The values of the discharge from the upstream station have been subtracted from the downstream values.

Where to from here?

The extreme variability across and interactions within a drainage site creates a level of complexity that makes proper evaluation of the drain difficult. It is often not until the data is properly collated, processed and looked at as a whole that the interactions and impacts can be quantified. Then, to compare the performance of one drain to another, computer models need to be created for each site. The data collection period for this site has finished.

The interactions between the measured variables are currently being analysed to work out the effectiveness of the drain.

At present, it appears that the drain may have a zone of benefit of 200 m. Excluding the area occupied by the drain structure, this equates to an area of about 275 ha. The cost of constructing the drain was approximately $120 000. This equates to a cost of $436/ha.

The paddock before cropping in May 2005

The paddock in December 2005 after cropping and harvesting

Where can you go for more information?

Contact Nick Cox on (08) 6364 7804 or email eei@water.wa.gov.au.

For copies of salinity related publications contact the Department of Water (08) 6364 7600 or view and download the latest EEI information at http://salinity.water.wa.gov.au.

August 2007

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