The growing problem of Seeps across SA - What can be done about it?

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Key messages

- Seeps are rapidly growing as a result of modern farming systems, landscape and seasonal factors (both very wet and extended dry periods).
- Early identification and action is imperative and can be assisted through satellite NDVI imaging.
- Specific management strategies must be applied within Recharge, Discharge and Interception Zones to prevent this initial *unused fresh water* problem resulting in large unproductive saline scalds.
- Take action early to keep land productive and prevent degradation occurring.

Why do this trial work?

This work aims to give farmers practical solutions for managing the growing problem of Mallee Seeps, and is based on 5 years of investigative monitoring and trial work in the SA Murray Mallee.

Seeps resulting from localised perched water tables have become a degradation issue across the cropping zones of SA and Victoria over the last 20 years, and have rapidly increased over the last decade. This was highlighted in a recent survey involving 80 landholders across the Mallee region (McDonough 2017). The emergence of a seep is due to a combination of landscape, seasonal and farming system factors that led to waterlogging, scalding and salinisation of farmer's most productive cropping ground. They also reduce paddock efficiencies and increase risks of damage to machinery.

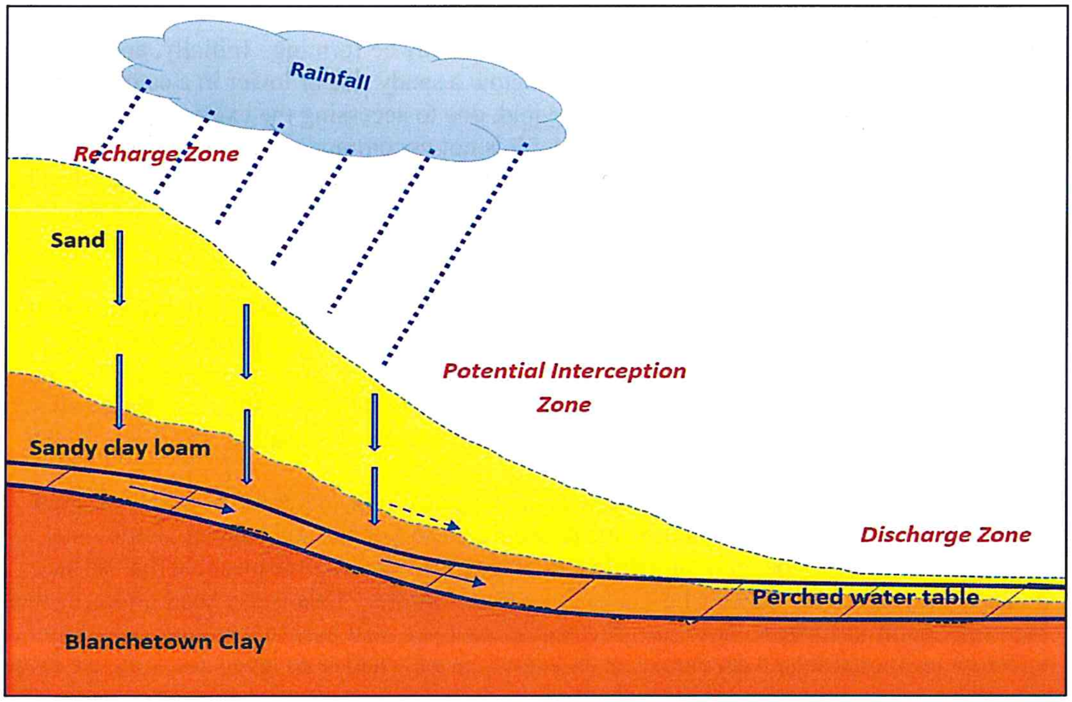

Figure 1. The formation of Mallee Dune Seeps, adapted from Hall (2017) p31, showing the three key zones of recharge, interception and discharge.

Modern farming systems which are dominated by no-till and intensive cropping have led to almost complete control of deep rooted/perennial summer weeds such as skeleton weed which use to dominate mallee sand dunes. This has led to a greater amount of summer rainfall passing through sandy rises that have very low water holding capacity. This results in the formation of perched water tables above areas of impervious clay layers (such as Blanchetown Clays) and water moving laterally toward lower lying areas (as demonstrated in Figure 1) to find surface expression where the clay comes close to the soil surface in mid-slopes or at the base of swales. This leads to waterlogging, capillary rise, evaporation and a process of surface salinisation over time.

These seeps generally begin as areas inundated with too much fresh water but this will lead to permanent salinisation and land degradation if no remediation takes place. The key to managing seeps is to identify the problem early, assess and apply appropriate management into the three key zones of Recharge, Intercept and Discharge areas (see Figure 1).

How was it done?

This paper presents findings and strategies resulting from a number of seep monitoring projects conducted over the last 5 years funded through NLP, NR SAMDB, GRDC and MSF, involving 7 sites over 6 farms. Each site has involved the use of moisture probes, piezometers and rain gauges with continuous data loggers, along with detailed landscape soil testing and treatment monitoring to more accurately assess the dynamics of the catchments and impacts of rainfall events and various management strategies. The farmers have been directly involved in developing and applying practical strategies to remediate the problems in each catchment.

While results and new approaches will continue to develop, there are already many important understandings, outcomes and strategies that farmers and advisors can use now to deal with this growing land degradation issue.

What happened and what can be done?

Identifying the problem

There are a number of key indicators that a seep area may be forming. Initially, and often more evident through drought years, the crop below a sandy rise or lower in a catchment area may produce substantially higher growth or yield, due to accessing the extra moisture from the beginnings of a perched fresh water table. It is not uncommon to find a distinct saturated layer of soil within the top 1m (sometimes slightly deeper) where this is happening. Ideally, this is the time to commence remedial action, well before it turns into an expanding and degraded soil area.

This early phase is usually succeeded by ryegrass becoming very thick and dominant through cereal or pastures. Ryegrass tends to be more tolerant and responsive to these conditions, persisting well into summer with a very large seed set (likely to have a high percentage of hard seed). It is not uncommon for farmers to find tractors suddenly sinking to their axles and major operational disruptions occurring around these sites by this stage.

As the seep area grows and the perched water table gets closer to the surface, bare scalded areas will start to emerge, essentially due to anaerobic soil conditions that are detrimental to most plant growth. Depending on rainfall and landscape factors, it is possible that surface ponding may occur for extended periods after rainfall events. This is a critical phase, as these bare soil conditions, particularly over the heat of summer, will lead to capillary rise of the moisture, evaporation and accumulation of salt at the soil surface to levels too toxic for crop growth.

In recent years it has become evident that while the wet years (such as 2010/11 and 2016) have resulted in much of the excess water issues occurring in these catchments, it is the drier years with less plant growth and longer periods of heat and evaporation that greatly exacerbate the spread of surface salt accumulation.

The use of NDVI satellite imaging to identify seeps and their potential growth areas.
Normalised Difference Vegetation Index (NDVI) has grown in prominence in recent years as a way of monitoring crop and pasture growth in precision agricultural management. NDVI images can be obtained from both drones and satellites, and essentially indicate areas of higher or lower vegetative growth through spatial colour images of targeted paddock areas. In 2017 a NR SAMDB project (McDonough 2018a) found that strategic use of NDVI imaging can identify both the early formation of mallee seep areas as well as the potential threat to surrounding areas.

There are numerous NDVI satellite monitoring programs being used by consultants and farmers, such as *Data Farming* and *Decipher*. These satellite images are convenient and free to access for the levels required for this purpose, and have now become a vital tool for seep management. A guide to the use of an NDVI mapping program is available on the MSF Mallee Seeps Website at http://www.malleeseeps.msfp.org.au/.

The key principle is to look at multiple cloud free images through the Oct-Dec periods. A perched water table has areas of soil that remain wetter for longer, resulting in extended periods of plants growth, particularly in annual species and this clearly shows up as greener and greater plant growth within these areas, contrasting with normal crop areas that have already dried out at this time point. These sites can then be analysed to assess the extent to which the seep is impacting the landscape. The main advantage of using NDVI imagery is that it will show the extent to which the seep areas are likely to grow to if nothing is done. In many cases it has been revealed that an easily identified bare patch of 0.2ha has the potential to develop into 5ha or more, due to the clear indication of excessive water and growth in the surrounding area. This helps provide far stronger incentive for a farmer to take remedial action immediately, rather than just watch the degradation develop over time.

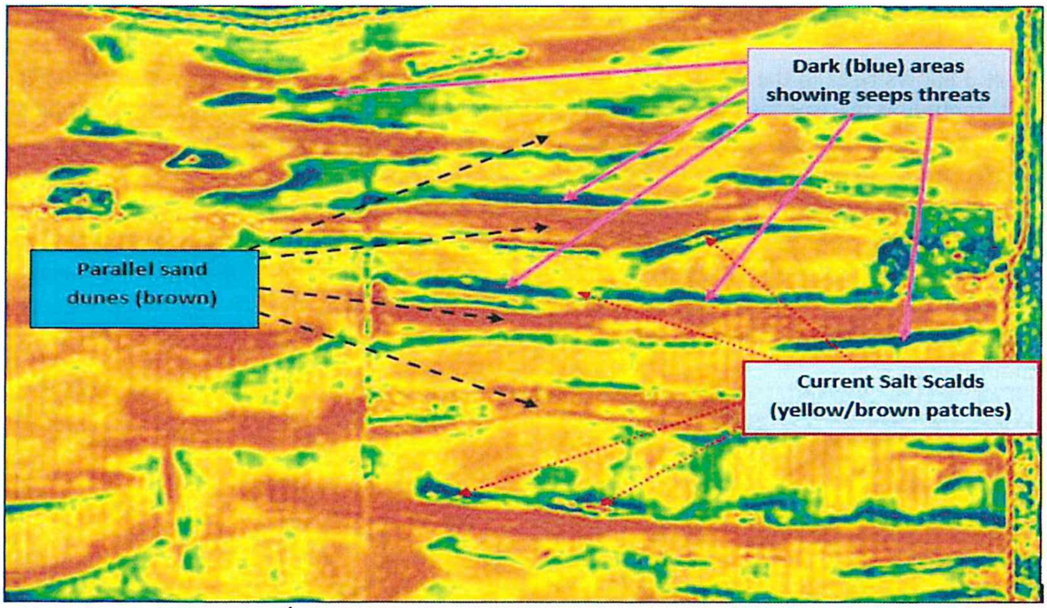

Figure 2. NDVI Map 16th Oct 2017 showing large areas under threat from seep degradation.

Viewing images throughout the growing season may also identify specific areas of poor crop growth which may be directly contributing to recharge after rainfall. These areas can then be targeted for specific management options. Ground truthing of images, along with local farmer knowledge is vital in ensuring an accurate assessment of the satellite images is made. For instance, frost events can lead to crops reshooting late and staying greener longer in low lying areas. Summer crops or uncontrolled summer weeds may also lead to similar NDVI image colours as seeps, as can trees or other perennial vegetation. Cloud cover and shadows from clouds can also cause distortions and misinterpretations, which is why it is often important to view multiple images.

Key management zone strategies

Once areas with seeps and those areas threatened by seep formation have been identified, it is important that management strategies are implemented as soon as possible. Ideally, these should be designed to best fit within the farmer's systems with minimal disturbance to the normal paddock activities. Some strategies may even lead to higher paddock productivity. However, some less convenient changes may be necessary in order to protect a greater area of productive land heading towards problems and total degradation if nothing is done.

There are three main areas within these local catchment systems that need to be identified (see Figure 1). These are:

1. *Recharge Zones* – where most of the excess water is entering the system;
2. *Discharge Zones* – where the problems are developing at the soil surface (often in midslope or lower lying areas); and
3. *Potential Interception Zones* – where higher water use strategies can utilise the excess water before it reaches the discharge zones.

It is generally a combination of management strategies targeted in each zone that is required to stop the spread of these seeps and possibly bringing these areas back into normal production.

Recharge Zones

Deep sands (often non-wetting) are the main source of extra water moving into the discharge zone. This is because they have very low water holding capacity and soil fertility, and are often suffering compaction to levels that prevent plant root penetration below 20 cm. This means that even relatively small rainfall events can quickly pass through the root zones to contribute to the perched water table below.

Figure 3 shows rises in the water table at a mid-slope piezometer between Nov 2015 and May 2018 (including the wet Spring of 2016 of 130 mm) at Wynarka. The perched water table at this site is below the crop root zone, so any rise is a direct impact of rainfall contributing recharge from the 60m of sandhill slope above the piezometer. Any fall in levels is likely due to discharge, evaporation or transpiration of the water lower in the system (particularly in the hotter summer periods), or in some cases a bulge of water may be moving down the slope after a larger rainfall event. It reveals that a 40 mm rainfall event raised this midslope water table by over 40 cm. Smaller events of 12 mm and 15 mm during the 2017 growing season led to rises of 15-20 cm. Even a sudden 7 mm rainfall event in Dec 2016 caused a 10-15 cm water table rise.

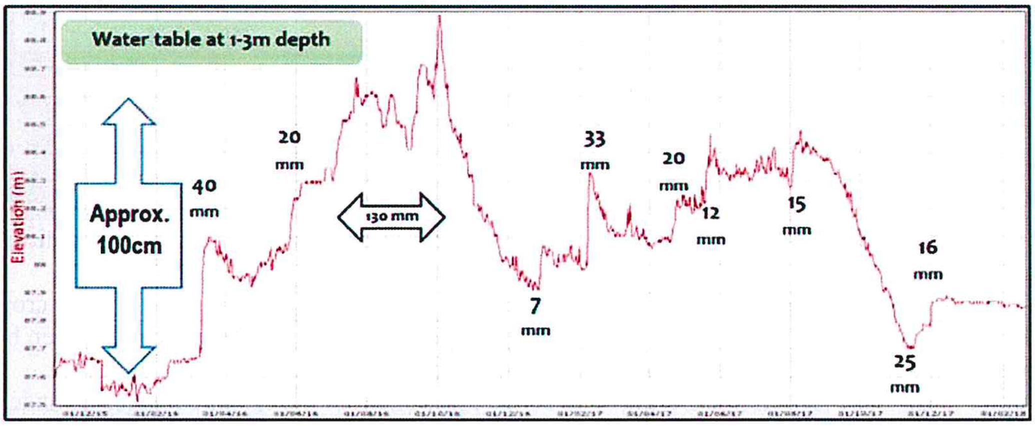

Figure 3. Midslope (RO2 Piezometer) water table rises after specific rainfall events in mm, as stated along the line (Nov 2015-May 2018) at Wynarka

The key principles for managing these areas is firstly to break any soil compaction, as this will increase plant root zones from around 20 cm of depth to *as much as* 150 cm (as observed at one site). This also allows crops to dry out these new rootzones to wilting point, meaning that any summer rainfall will have a larger bucket to fill before it starts contributing to recharge. This will also lead to greater crop yields and water utilisation.

Further to this, any soil amelioration that incorporates clay or nutritious forms of organic matter such as manures into the top 40 cm has been shown to greatly improve soil water holding capacity within this rootzone. This was clearly evident at a Karoonda seep monitoring site, where the spading in of chicken manure has produced well over double the crop yields over a 4 year period, and soil moisture probes showed excellent soil water retention within the 40 cm spading depth which was utilised by the crop. This was in direct contrast to the control plot which had low yields, very little soil moisture use by crops below 30 cm depth and numerous rainfall events contributing to recharge (McDonough 2018b).

Any practical, effective and safe method of achieving sand amelioration through deep ripping, delving, spading, clay spreading or manure/organic matter/nutrition incorporation will be beneficial in remediating these sandy recharge zones. Current research is developing more options for farmers in this pursuit.

Some farmers have decided their deep sands are not worth cropping and have chosen to establish them with permanent perennial, deep rooted pasture options such as lucerne or veldt grass. This becomes more of a viable option for farmers with livestock in their systems, providing valuable feed options at critical times. However, care is needed in establishing these pastures into adequate soil cover within favourable seasons. One cooperating farmer in 2019 chemically fallowed his sandhill until sowing lucerne in August, avoiding the dry May-June period with high wind events, and achieved an excellent stand as the soil warmed up in Spring.

<u>Discharge Zones</u>
The main principle for discharge zones is maintaining living soil cover all year around if possible. This greatly reduces capillary rise of moisture to the surface, and evaporation leading to surface salt accumulation, because plant roots will be drawing the moisture from deeper in the profile. Bare soil, over the summer months and dry seasons, will lead to a rapid deterioration of these soils into unproductive saline scalds. However, the strategies used to best manage this will depend on the development stage of the seep.

When a perched watertable is in its early stages and is mainly resulting in increased yields with some patches suffering from saturation, it is important to maintain cropping through these areas, without getting machinery bogged. As soon as practical after harvest a summer crop should be sown in these zones. A mixture of sorghum and millet has been successfully used over 3 seasons by farmers at the monitoring site near Mannum. These crops will only grow well where the excess moisture is accumulating, and soon die out in the dry sandy soils surrounding the seeps (there has been very little summer rainfall through this period). The summer crops are either cut or harvested prior to seeding the winter crop. This has not led to any loss of crop yield as a saturated soil layer is still evident despite the growth of the summer crop. While this technique does not address the problem at its source, it does greatly reduce the soil degradation, with minimal impact on the farmer maintaining their normal cropping program. However, this method will only be affective long term if management strategies are also employed to address the excess water emanating from the recharge and moving through interception zones.

It is important that all sites are soil tested to guide the type of remediation action appropriate for each specific site. If the scald is already established surface salinity or waterlogging to severe for crop growth, then perennial salt tolerant pastures such as puccinellia or tall wheat grass should be established. Success has been achieved using airseeders where possible. Dragging harrows behind a four wheeled motorbike and seed spread through a rabbit baitlayer has been used successfully where heavier machinery has been too risky. While it has been reported that puccinellia is suitable for areas with moderately high to very high soil salinity of 8 to >32 dS/m, and tall wheat grass being slightly less salt tolerant at low to moderate levels of 0-8 dS/m (Liddicoat and McFarlane 2007), current trial demonstrations have shown good and poor establishment in a variety of sites and salinity levels, highlighted by some excellent puccinellia establishment on a crystalline salt covered scald at Wynarka. In some cases, tall wheat grass has established later in the season where puccinellia has not grown, even though they were sown together in the same seed mixture. The salt tolerant annual legume variety Messina has also been tried but has generally not established well on bare scalded sites. Saltbush has been grown and grazed successfully in some seep areas, but has not survived well in the most saturated areas that are subject to periodic water inundation.

It is becoming apparent that successful establishment of these pastures can sometimes be dependent on seasonal factors and more specific soil parameters, which may not have been considered in previous work based more on saline water table sites. Even slight raises in surface soil levels or organic matter content have been shown to make a difference. For example, current monitoring of scald sites have been found some to have extremely high pH, approaching 11, which is toxic to most plant growth.

The MSF Seeps project is aiming to better understand these various parameters. This will provide more accurate and relevant information for managing these scalded areas. Soil qualities at different time throughout seasons, and where plants have and have not established need to be measured. The surface crust (often black) is being measured along with 0-10cm samples, as they may provide important insights into critical soil issues. Initial success has been achieved with a front end loader to add 10cm layers of sand, straw and manures to bare scalds and to get salt tolerant grasses established and even a cereal crop at one site. These sites will be monitored over coming seasons to see if they deteriorate over time, or continue towards greater soil improvements.

In areas that already have salt scalds and are too toxic for re-establishing crop growth, it is still important to employ these strategies on the edge areas to help stop the growth of these bare seep scalds.

Potential Interception Zones

There are often areas below recharge zones where there is lateral subsoil flow of excess water above the impervious clay layers (Figure 1). They provide the opportunity for water interception and utilisation before it causes problems in the discharge areas. The most successful strategy applied within all monitoring sites has been the strategic establishment of lucerne in this zone to produce hay or pasture, as its roots penetrate deep into the perched water table layer throughout the year. Lucerne especially takes advantage of large summer rainfall events that are usually a key source of recharge water and is a versatile option that is familiar to many. Figure 4 shows that each major rainfall event in a lucerne area was quickly utilised and there was no evidence of recharge happening. This is in contrast to the continuously cropped side which regularly has 60-70mm more water in the top 1 m soil profile and water passing beyond the rootzone. In the extremely wet season of 2016, the midslope piezometer in the lucerne was the only site to experience a reduction in water table.

Farmers are targeting strips of lucerne (often 30-50 m wide) above seep areas to intercept the lateral water flows. Even cropping farmers can gain profits from this by selling lucerne hay and through prevention of seeps to maintain crop yields. Crops can be sown through these lucerne strips, so establishing lucerne in the same direction as cereal sowing may be worthwhile, even if it takes more initial effort. While encompassing these lucerne strips within cropping paddocks will present some compromises, it is still better than losing greater areas of highly productive land to spreading seeps.

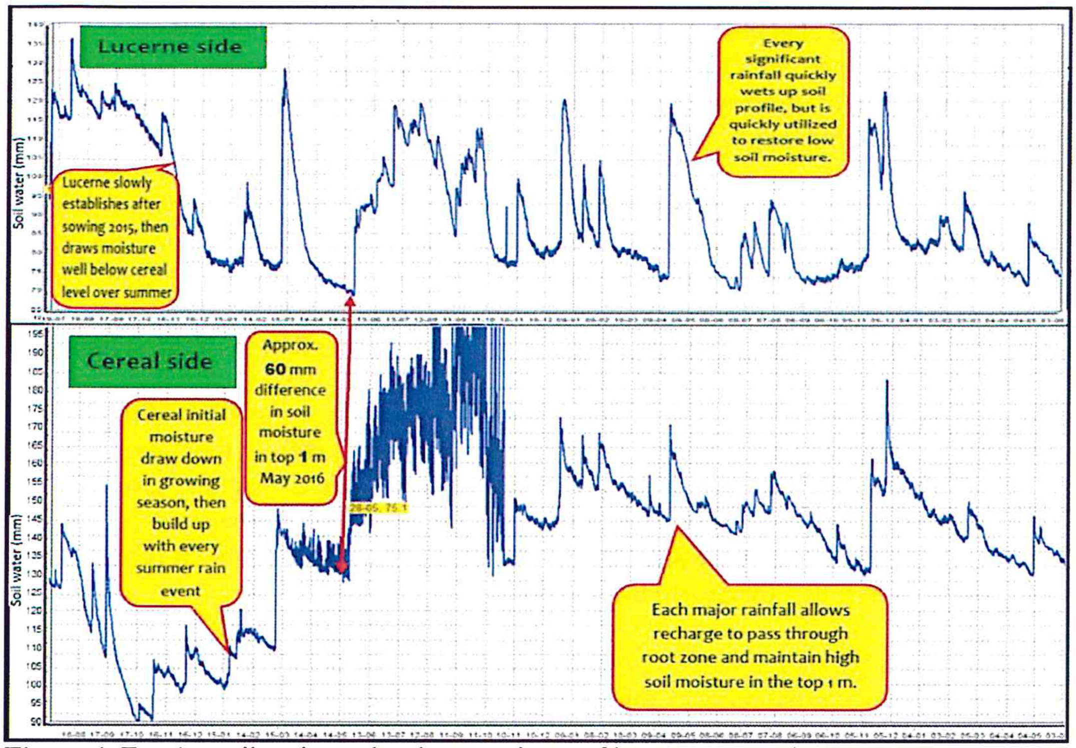

Figure 4. Top 1m soil moisture level comparisons of lucerne & cereal treatment areas (July 2015-May 2018)

While most farmers do not wish to plant trees in the middle of cropping paddocks, it may still be an option to consider, particularly where a fenceline or laneway already exists, and where a large amount of water use is required to reduce an emerging seep. If planting close to seeps, it may be worth testing the water quality to assess whether more salt tolerant species may be required. This project found greater success where tree guards protected the seedlings from vermin and some early watering was done to ensure summer survival on the deeper non-wetting sandy soils.

New innovative strategies being tested

The MSF Seeps Project is currently exploring a number of trials and demonstrations including the use of a subsoil extruder on deep sands above a seep at Alawoona. This machine profiles a manure slurry behind its multiple deep ripping tines. This is much safer for wind erosion than spading in manure, and initial results have been promising for improving crop production and water use. Other trials are assessing the use of other subsoil amelioration techniques, alternative pasture species, methods to maximise crop water use and longer season varieties.

Another site will assess the practicality of establishing an in-ground sump just above a seep scald area to pump water out to be stored and used for either spraying, livestock or liquid fertiliser application. Early water quality measurements at the particular site has presented some challenges, but work is ongoing.

What does this mean?

Localised seeps are a growing land degradation issue across cropping zones of southern Australia, and come about through a combination of landscape and seasonal factors as well and changes associated with modern farming systems. New technologies such as NDVI Satellite imaging are providing important resources for the identification of developing seeps and the potential threat posed to farmers' paddocks if left unmanaged.

There are a variety of strategies that have been identified though a number of seep projects in the SA Murray Mallee in recent years that provide practical options for farmers to apply into the 3 critical areas of Recharge, Discharge and Intercept Zones. More work is currently refining these strategies through the MSF Mallee Seeps project that aims to improve water use efficiencies and remediation of these issues.

This information is highly relevant and adaptable to seep forming areas of the Eyre Peninsula. However, it is important to make a distinction between the more localised perched water table issues associated with mallee seeps, and the salinity issues directly caused with often saline water tables within existing river systems. The latter can be very different in cause and effect, with the source of the problem often emanating from much further up the catchment.

There is currently an application to apply monitoring and demonstration sites within local EP areas to assist in providing local answers to the early detection and management of seeps in that region.

References

Hall , J. (2017). Mallee Dune Seepage in the SA Murray Mallee - Summary Report. Natural Resources SA Murray Darling Basin, Dept of Environment, Water & Natural Resources, Government of South Australia, Murray Bridge. https://data.environment.sa.gov.au/Content/Publications/REPORT_NRSAMDB_Mallee%20Dune%20Seepage_Summary%20Report_2017.pdf

Liddicoat, C. and J. McFarlane (2007). Saltland Pastures for South Australia, Dept of Water, Land and Biodiversity Conservation (South Australia). https://www.environment.sa.gov.au/files/sharedassets/public/science/kb-saltlandpasturessamanual.pdf

McDonough, C. (2017). Mallee Seeps Farmer Survey 2017 Report for Mallee Sustainable Farming. https://www.naturalresources.sa.gov.au/files/sharedassets/sa_murray-darling_basin/land/reports_and_case_studies/mallee-seeps-farmer-survey-2017-rep.pdf

McDonough, C. (2018a). The Use of Normalised Difference Vegetation Index (NDVI) to Manage Seeps. Martins Report, Karoonda. SA Murray Darling Basin Natural Resources Management Board https://www.naturalresources.sa.gov.au/samurraydarlingbasin/land-and-farming/soils/mallee-seeps.

McDonough, C. (2018b). Monitoring Mallee Seeps Summary, Project 1569C for the South Australian Murray Darling Basin Natural Resources Management Board. https://www.naturalresources.sa.gov.au/files/sharedassets/sa_murray-darling_basin/land/reports_and_case_studies/monitoring-mallee-seeps-jun18-rep.pdf

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Locations:
Various demonstration/monitoring sites across the SA Murray Mallee.
Bow Hill: Kevin and Geoff Bond;
Wynarka: Peter Rose, Andrew Thomas, David Arbon
Karoonda: Stuart Pope, Simon Martin
Alawoona: Lachie Singh
Rainfalls
Av. Annual: 285-342mm
Av. GSR: 194-235mm