Surface Water Management

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Water Erosion

Water erosion is a two-stage process:

- Stage 1 occurs with raindrop impact and broad overland flow on slopes, before that flow becomes concentrated into channels and streams.
- Stage 2 occurs within the channelised flow of gullies, streams and rivers.

Most sediment is delivered to watercourses from gullying, stream bank and bed erosion, but the direct costs to agriculture emanate mostly from hillside erosion

Severe hillside erosion in lower left hand corner progressing to gully erosion in upper right-hand corner.

Report Card on Sustainable Natural Resource Use by Agriculture

Water Erosion

Good cover prevents erosion. This paddock near Hyden did not erode after an intense summer storm dumped more than 150 mm rain, causing damage to infrastructure including this fence.

Water repellence contributes to water erosion by sheetflow and wind erosion in this bare paddock, West Midlands zone.

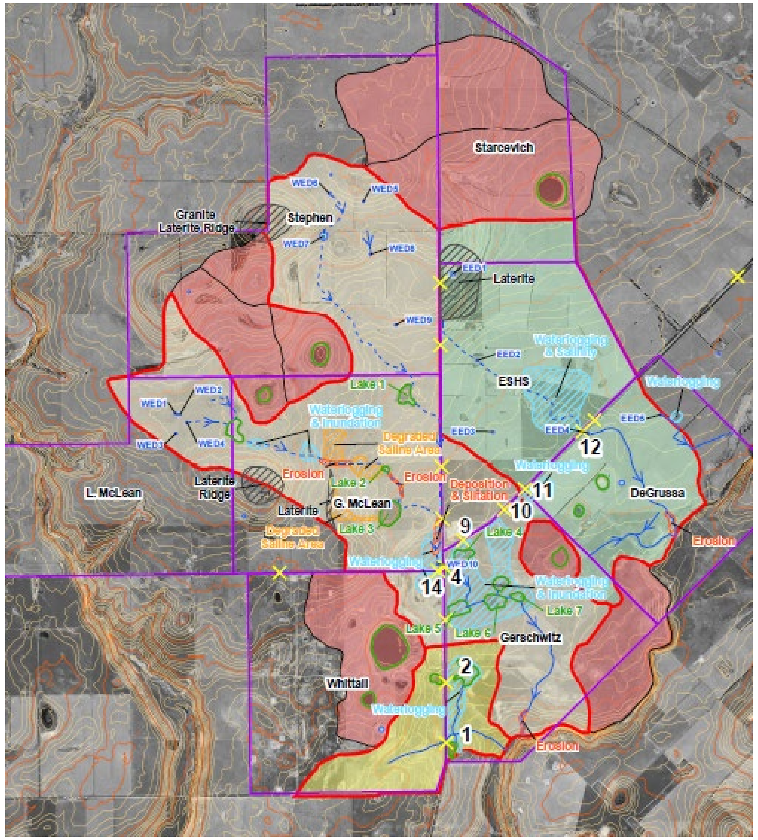
Sodic subsoil contributes to waterlogging and water erosion in this paddock, Stirlings to Ravensthorpe zone.

Need for Surface Water Management

Surface water management is needed to:

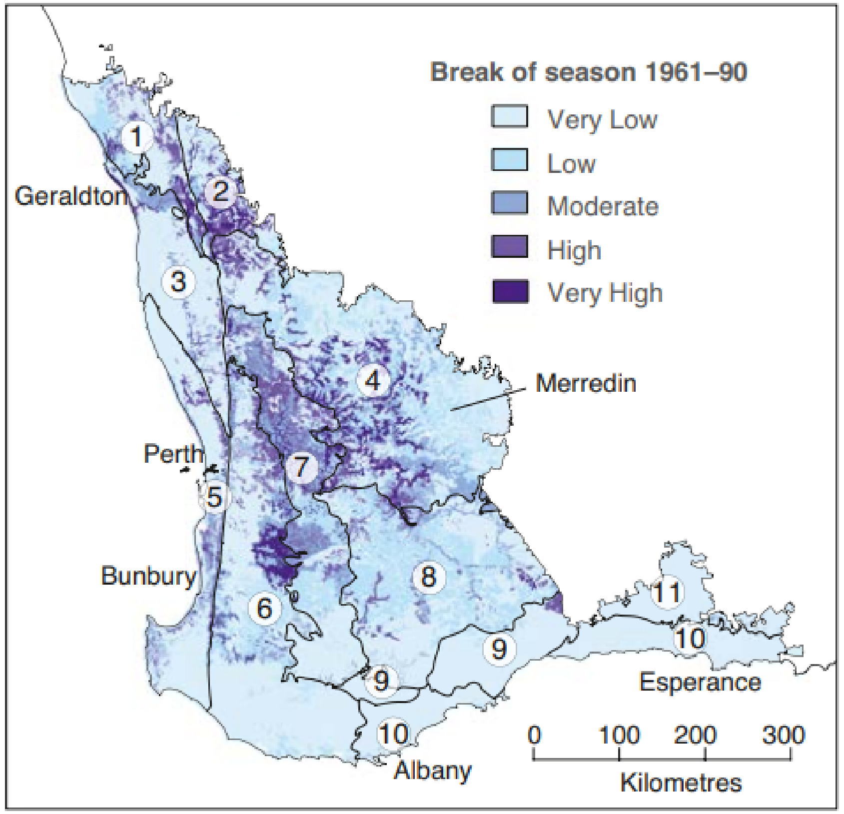
- Manage water erosion
- Maintain productivity
- Reduce waterlogging
- Water harvesting
- Manage salinity
- Downstream impacts

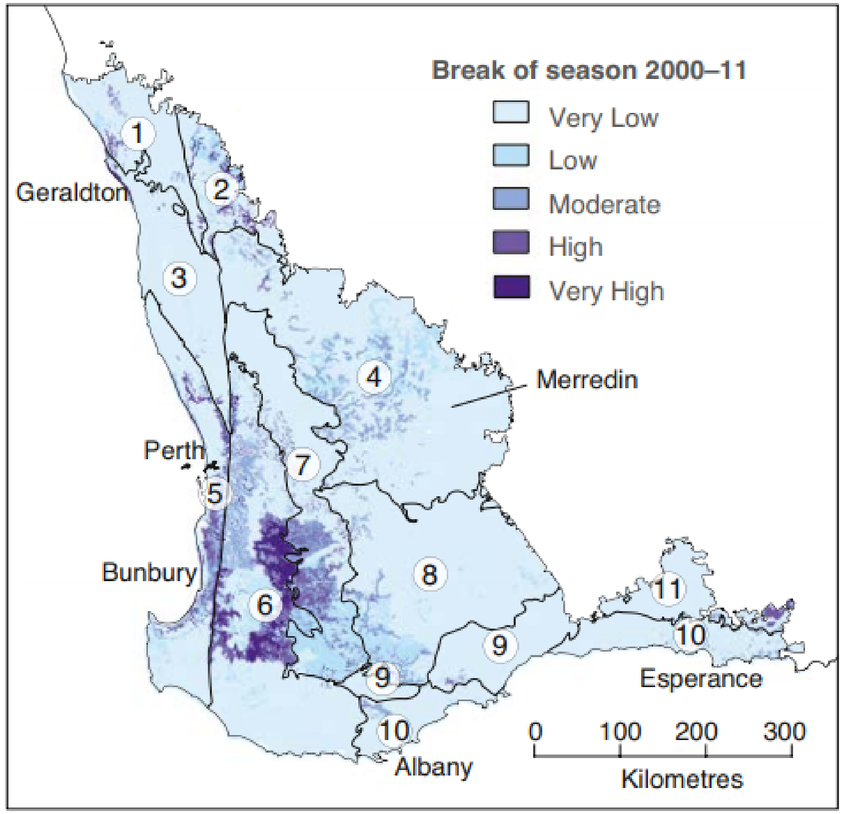
DAFWA website



GHD Report – Bandy Creek Surface Water Management

Erosion Hazard – Break of season

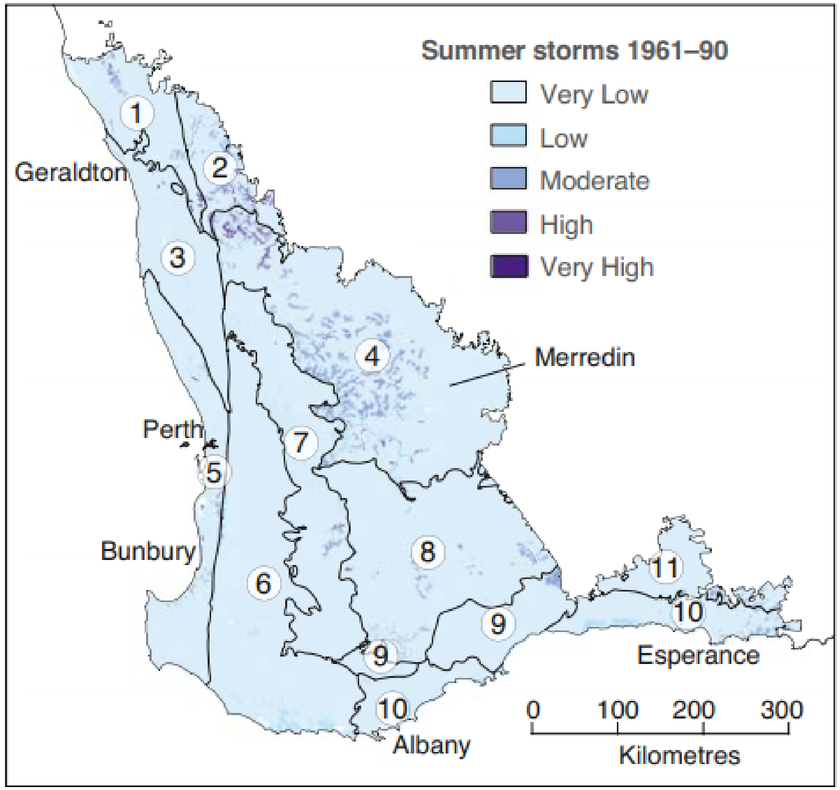


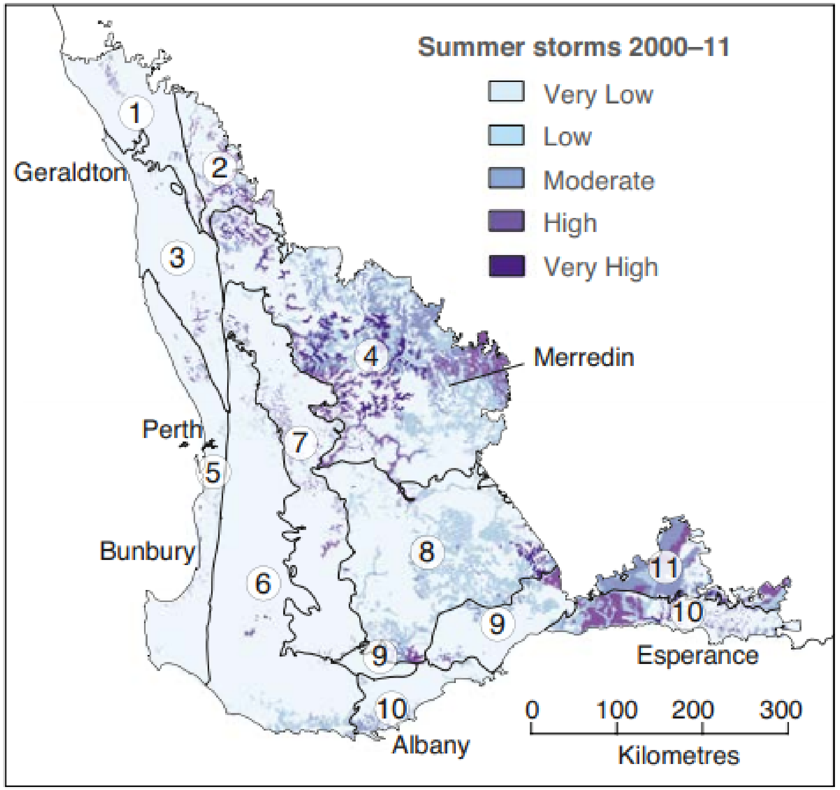


Break of season storm events, which were defined as: 20 mm or more of rain falling over a standard BoM (Bureau of Meteorology) 24-hour period (9.00 am to 9.00 am the next day) between April and July inclusive AND where there had been less than 30 mm of cumulative rain in the previous two months.

From Report Card on Sustainable Natural Resource Use by Agriculture

Erosion Hazard – Summer Storm





from Report Card on Sustainable Natural Resource Use by Agriculture

Summer storm events, which were defined as: 20 mm or more of rain falling over a standard BoM 24-hour period between December to February inclusive.

Water erosion - Key messages

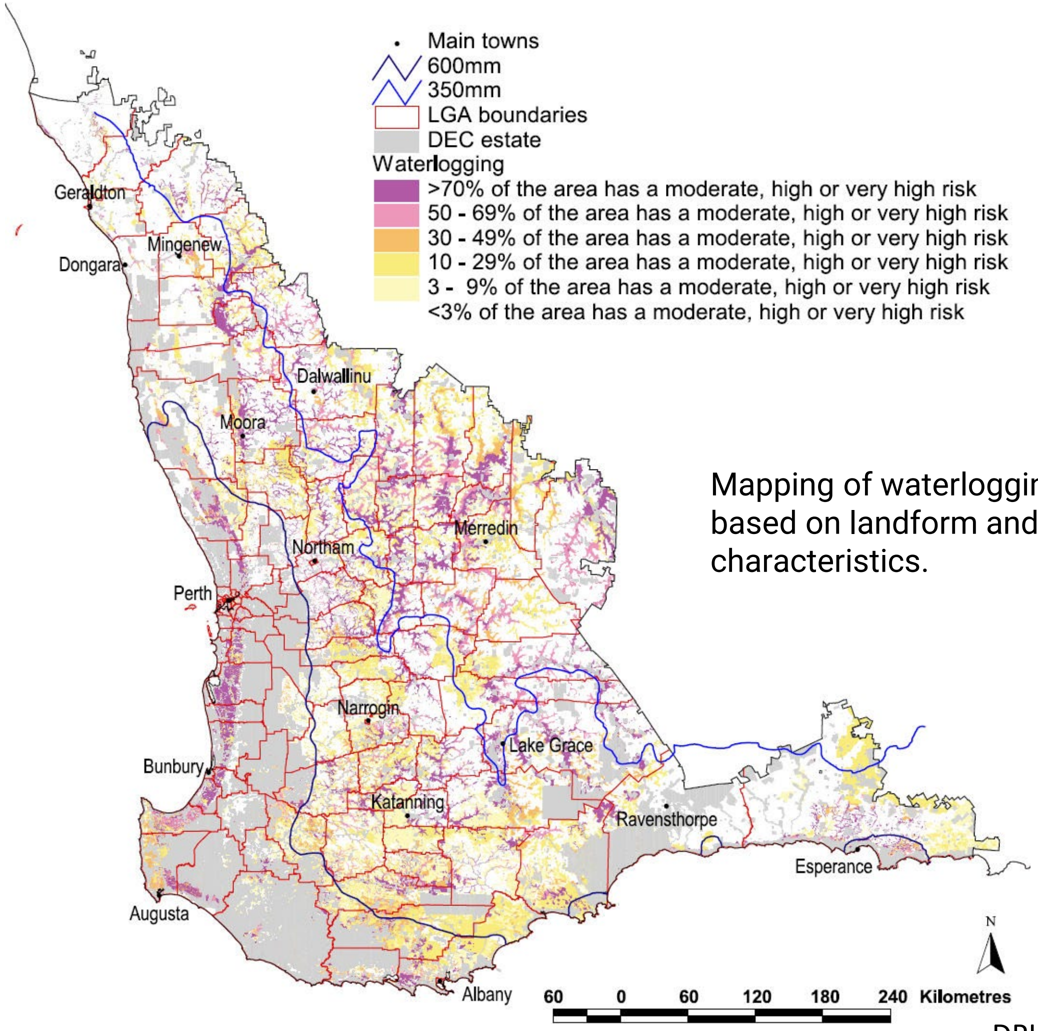
Condition and trend

Water erosion hazard across the south-west of WA – during the growing season – has diminished because of declining winter rains, increased stubble retention and adoption of reduced tillage practices.

- Water erosion events are mainly caused by intense, localised summer storms.
- There appears to be a trend towards more frequent, potentially erosive summer storms in the eastern wheatbelt and south-eastern coastal areas, and relatively little change in other areas

Ag Soil Zone	Summary	Hazard / Trend
Zone of Rejuvenated Drainage	Excessive grazing pressure on sloping land in some parts perpetuates risk of erosion. Cropping land is largely stable.	Moderate / Stable
Southern Wheatbelt	Good condition but increasing intensity and frequency of summer storms in the east remains a concern.	Low / Deteriorating
Stirlings to Ravensthorpe	Episodic events in the east have driven recent decline; this trend is expected to increase in future.	Low / Deteriorating
South Coast – Albany to Esperance	Condition continues to gradually decline due to insidious sheet erosion of shallow topsoil and sodic subsoil.	Low / Deteriorating
Salmon Gums Mallee	Largely stable at present.	Low / Stable

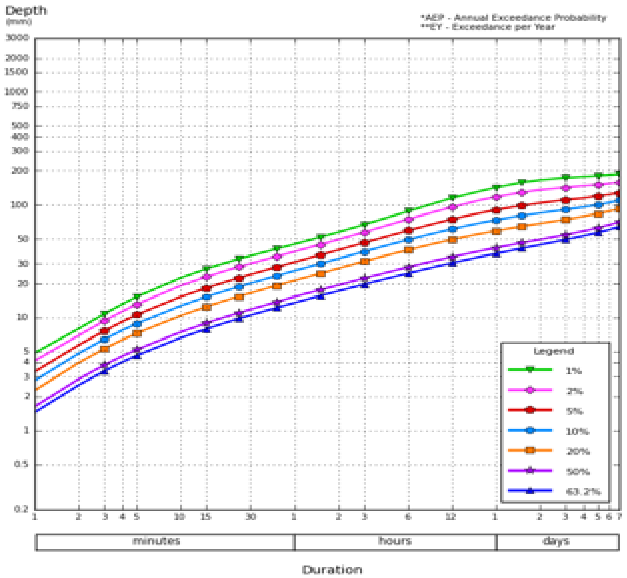
Waterlogging Risk



Mapping of waterlogging risk is based on landform and soil characteristics.

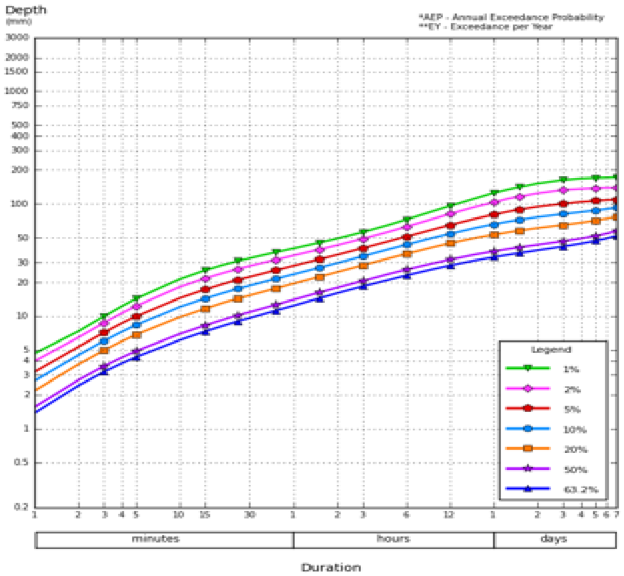
DPIRD/agric.wa.gov.au website

Rainfall Intensity



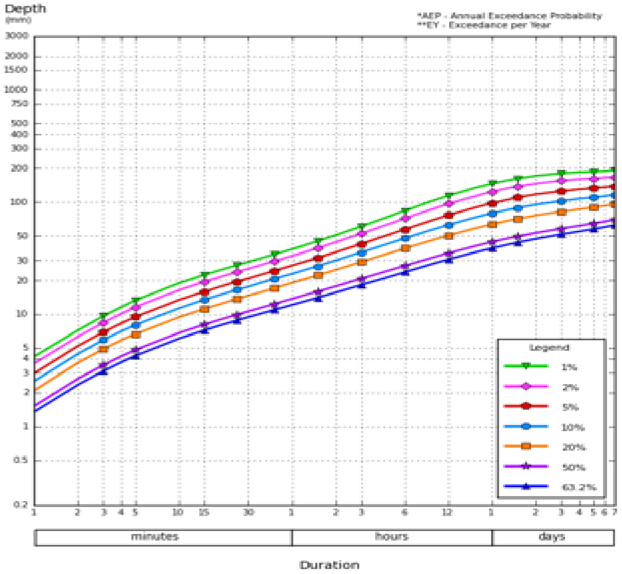
Williams

ARI	1hr (mm)	24hr (mm)	5 days (mm)
1-in-10	26	73	100
1-in-100	45	143	181
1-in-2000	106	339	411



Cranbrook

ARI	1hr (mm)	24hr (mm)	5 days (mm)
1-in-10	23	67	90
1-in-100	39	126	174
1-in-2000	82	261	405



Esperance

ARI	1hr (mm)	24hr (mm)	5 days (mm)
1-in-10	24	77	106
1-in-100	38	140	181
1-in-2000	70	259	319

Oz Lotto

Jackpot (7 numbers)	1-in-45,000,000
Division 5	1-in-3340

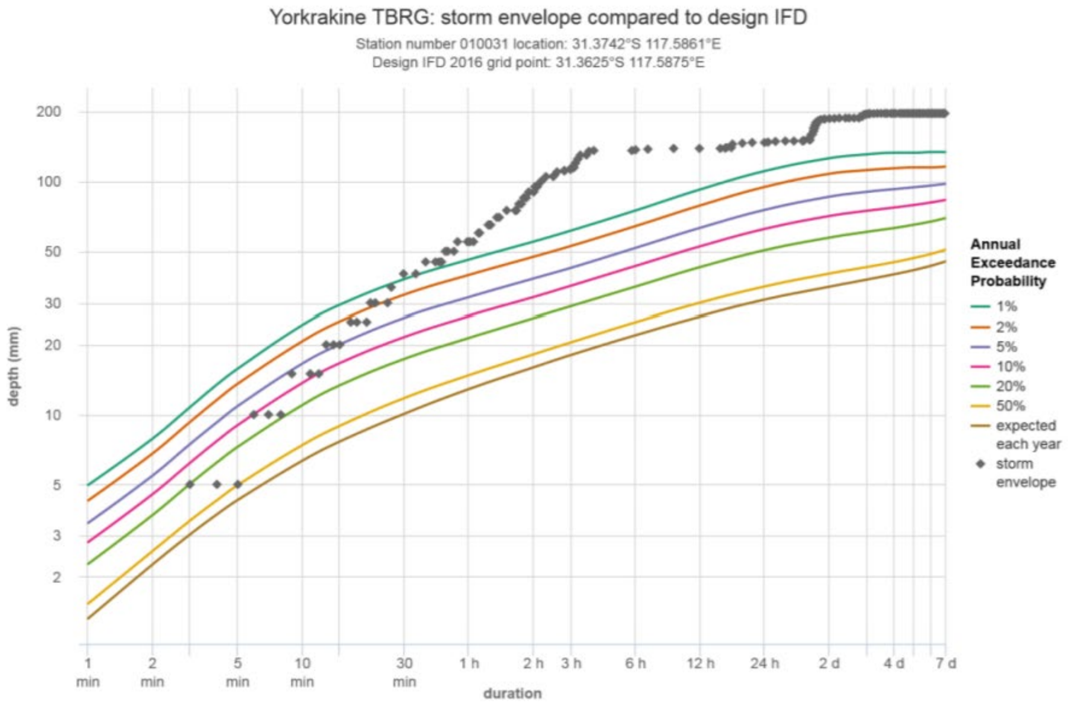
2017 Flood

2017 Flood damage estimates

Shire of Lake Grace / Ravensthorpe

Crop Production	$13.83 M
Livestock Production	$3.88 M
Land rehabilitation	$29 M
Fencing replacement	$7.78 M
TOTAL	**$54.49 M**

+ City of Swan - $26.10 M Grape & Wine production



Rainfall totals from 29 January to 1 February 2017 for Yorkrakine (North Tammin)

Economic costs

Waterlogging & Water Erosion

- In 2008 it was estimated 0.2m ha was at extreme risk, 0.4m ha was at very high risk, and 0.6m ha was at high risk of water erosion
- This totals to 1.2m ha at risk of lost production.

Soil constraint	Estimated annual opportunity cost 2003/04 to 2008/09	Estimated annual opportunity costs 2009/10 to 2013/14
Waterlogging/ inundation	$29m	$35m
Water erosion	$10m	$3m

Report Card on Sustainable Natural Resource Use by Agriculture

Transient Salinity

- Approximately 11% of croppable land in south-western Australia is affected by transient salinity (two million hectares).
- Yield penalties range from negligible up to 65% depending on the severity of susceptibility and crop type, with an average of approximately 15%.

AgZone	Lost production ($M/year)
East Moora to Kojonup	6
Southern Wheatbelt	33
Stirlings to Ravensthorpe	3
South Coast	3
Salmon Gums Mallee	7

DPIRD principal research officer Dr Ed Barrett-Lennard (left) and Southern Cross farmer and inventor, Callum Wesley, inspect wheel furrow and mound formation systems at Merredin to channel water towards plant roots to reduce the impact of transient salinity on plant growth.

Runoff mechanisms in agricultural areas

In typical years, winter runoff is generated by a combination of shallow aquifer throughflow, saturation excess rainfall (particularly in the wetter regions near the coast) and some infiltration excess generation due to non-wetting soils and from soils with low hydraulic conductivity in cleared country.

George & Conacher (1993) found that:

- 37 percent of streamflow arose from saturation-excess overland flow, and 52 percent was from throughflow.
- saturation-excess overland flow still occurred, but with a much reduced variable source area and a longer lag following rain.
- infiltration excess overland flow due to soil compaction and hydrophobicity (up to 70 percent of summer streamflow).

Summer runoff can be generated by intense cyclonic events and is then dominated by infiltration excess processes.

Much of the runoff that enters into the main channels is generated by rainfall directly on the valley floors themselves.

Infiltration-excess overland flow is considered an important mechanism in fine textured soils, surface sealing soils, non-wetting soils and surface compacted soils (McFarlane & Davies 1988).

However, saturation-excess overland flow is considered more important in duplex soils, soils in groundwater discharge areas, and fine textured soils in valley flats (McFarlane & Davies 1988).

Runoff following heavy rain in the Ferguson Valley (Forested Hills).

Tille et al 2001

Rainfall Excess

Heavy textured soils.

These soils have low infiltration capacities to begin with and these become progressively lower as the soils wet. Heavy textured soils are estimated to occupy about 11 per cent of the agricultural area.

Surface sealing soils.

Whether a soil develops a surface seal depends particularly upon the dispersive nature of the clay on the soil surface. Factors which affect soil structural properties (e.g. minimum tillage, cropping frequency, gypsum etc.) will affect the development of a surface seal.

Non-wetting soils.

Soils become non-wetting if water-repellent organic matter coats the surfaces of soil particles. Sandy soils are more predisposed to becoming non-wetting.

Surface compacted soils.

Surface compaction by vehicle tires and stock can result in decreased infiltration capacities and low surface storage capacities.

Saturation Excess

Duplex soils.

Duplex (texture contrast) soils are likely to become waterlogged due to:

- the high infiltration capacity and low soil evaporation characteristics of the sandy topsoil;
- poor internal drainage due to the clay sub-soil;
- the low water storage capacity of the shallow top-soil.

Soils in groundwater discharge areas.

Where there is a permanent groundwater system that discharges in an area of upward hydraulic heads, soils may remain saturated throughout the year and, due to the upward heads, infiltration rates are negligibly small.

Heavy textured soils in valley flats.

Water may pond on heavy textured soils in valley flats due to slow rates of internal and external drainage.

Water Erosion - On-farm Management

Management Option	Approximate cost	Longevity	Mechanism	Suitable locations and soils	Likelihood of Success / reliability	Associated benefits/ disbenefits
No till or minimum till	Standard practice	Annual	Knife point seeding, disc seeding or direct drill.	All	High	Can result in increased water repellence, higher levels of organic matter, less labour fuel and machinery costs, reduced soil compaction.
Winter and summer active components in pastures or perennial pastures. Waterlogging tolerant pastures.	Dependent on cost of seed	Annual	Sow a pasture with a mix of winter and summer active species	All	High	Can help to increase soil organic carbon, reduce risk of wind erosion, can create increased soil biodiversity. Longer pasture phases can have a cost of forgone crop income.
Managing stocking rates to carrying capacity	Depending on quality of stock and current market prices the grower may make or lose money	Annual	Reduce stocking rates to ensure minimum cover of 70% is maintained.	All	High	May need to purchase livestock when there is adequate ground cover.
Feedlots	Cost of transporting animals to feedlot	Annual	Move animals to feedlots during periods of low feed availability	All	High	
Sacrificial paddock	Lost soil nutrition from eroding paddock	Annual	Put aside one paddock (usually a low productivity paddock) where stock can be moved in high risk erosion years.	Paddocks that are already extremely degraded or have a greater resistance to water erosion due to soil type.	High	Increased risk of erosion in the sacrificial paddock.

From DAFWA report

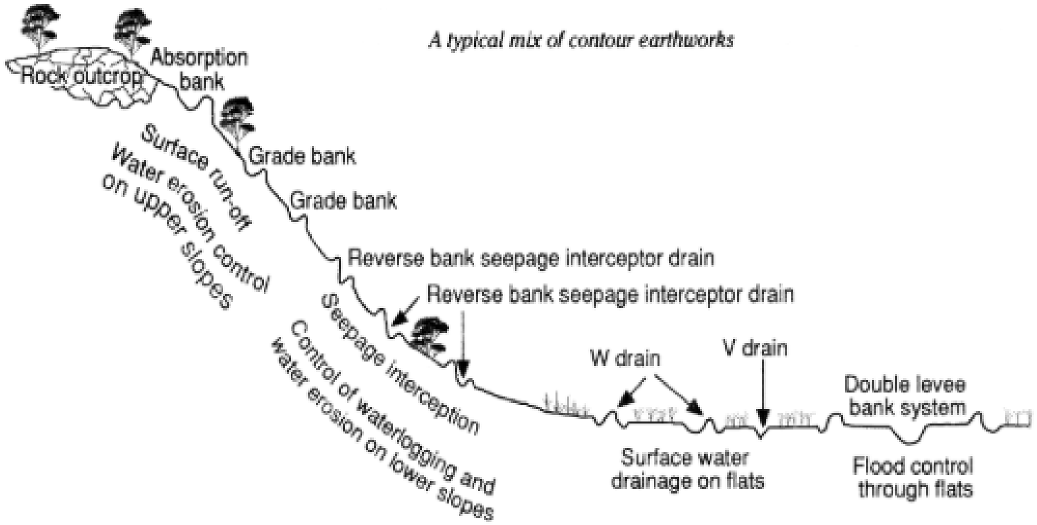
Water Erosion - On-farm Management

Management Option	Approximate cost	Longevity	Mechanism	Suitable locations and soils	Likelihood of Success / reliability	Associated benefits/ disbenefits
Banks	Significant costs of earth moving	10-15 years	Earth is moved to make banks according to the contours of the paddock to slow or stop water flow.	Those areas with higher rainfall. Steep slopes and a livestock focus.	Moderate	Can make controlled traffic farming more difficult. Stops water gaining high speed, however does not fix the problem. Removing banks can increase future risk of water erosion, particularly with livestock.
Vegetated water courses	Cost of replanting vegetation and excluding stock	As long as the vegetation remains	Plant vegetation	Water courses at high risk of water erosion that no longer have perennial vegetation surrounding them	High for the water course	
Controlled traffic farming	$40,000 Auto-steer technology and equipment standardisation. Cost of $2000 - $10,00 for equipment standardization alone	Long term	Maintains soil structure and channels water along hard wheel tracks	All soils	High	Less crop damage, 3-10% reduction in inputs, 5-15% increase in crop yield increased longevity of deep ripping, improved traction in wet conditions and less fuel use. Minimise compaction.
Contour tilling versus up and back	Maybe slightly higher time costs	Annual	Paddocks are tilled according to their contour lines	All paddocks with a gradient	Low to moderate	

From DAFWA report

Surface Water Management Options

- Absorption banks and level banks
- Grade bank
- Dams (Excavated earth tanks)
- Roaded catchments
- Grassed waterways
- Seepage interceptor bank
- Broad-based banks
- Shallow relief drains
- Levee waterways
- Raised beds
- Evaporation basins



From DAFWA website

Design

Good design

- Experienced contractor
- Rules of thumb
- Poor design can be worse than doing nothing
- Look at the catchment, soils etc
- Design first then construct

Design Steps

- Define problem/issue
- Set objective
- Identify options
- Evaluate options
- Design
- Construct
- Maintain & Monitor

Design

Earthwork	Land slope (%)	Soil type	Grade(%)	Landscape position	Purpose
Absorption banks and level banks	up to 10	clay, clay loam, rocky		upper slope, below areas producing a lot of run-off	controlling run-off water where a grassed waterway cannot be safely maintained
Grade bank	up to 10	shallow duplex, loam	0.2 to 0.5	upper and mid-slope	controlling surface water erosion; harvesting water from slopes
Dams (excavated earth tanks)	up to 10	clay, shallow duplex, deep duplex, loam	up to 10	not in valley watercourse	storing and providing access to water for agricultural or household use
Roaded catchments	up to 6	clay, shallow duplex	up to 6	good clay required close to surface	improving water run-off from reduced catchment areas into dams
Grassed waterways	up to 10	most soils	up to 10	running downhill on a natural water accumulation line	providing safe disposal of overflow from dams or discharge from the end of grade banks
Seepage interceptor bank	up to 10	shallow duplex, deep duplex, sand		lower and mid-slope	controlling shallow seepage and waterlogging
Broad-based banks	2 to 6	shallow duplex, loam	0.15-0.3	upper, middle and lower slope	controlling surface water erosion; allowing easy vehicle traffic across banks
Shallow relief drains	up to 0.2	clay, shallow duplex	up to 0.2	valley floor	removing surface water from flooded areas
Levee waterways	up to 10	clay, sand, deep duplex, shallow duplex	up to 10	valley floors and hill slopes	guiding and controlling the spread of water in drainage lines
Raised beds	0.1 to 2		0.1 to 2	valley floors and fairly level waterlogged areas	raising seed beds above the saturated soil of waterlogged areas
Evaporation basins	site specific				holding saline discharge and preventing salt discharge to environmentally sensitive areas

From DAFWA website

Water Management Structures

Structure	Water management issue		
	Groundwater (salinity)	Water erosion or flooding	Waterlogging or inundation
Banks		✓	✓
Waterway		✓	✓
Shallow relief drain		✓	✓
Deep drain	✓		✓
Detention structures	✓	✓	
Groundwater pumping	✓		

DAFWA website

Absorption & Level Banks

Aspect	Absorption & Level Banks
Use	Control surface water where there is no safe disposal
Landscape position	Up to 10% slope
Long section	Flat grade Channel blocks alng channel to retain water & alleviate damage in case of overtopping
Cross-section	Channel depths can up to 1m Level bank has 1 or both ends left at ground level to allow overflow in high runoff Absorption bank has both ends turned up to allow max storage.
Other design features	In porous soils, banks should be clay or plastic sheeting lined to prevent waterlogging below bank
Build with	Dozer on slopes up to 10%
Risks	Overflow or overtopping from banks can cause erosion, including overflow from top bank can lead to system failure Stored water in bank can add to recharge of waterlogged or saline areas below.

Grade Banks

- Grade banks are suitable to intercept and divert surface water run-off into storage or waterways, to limit soil erosion.
- Grade banks are usually designed as a set in the middle and upper slopes of hills that have a slope of 2% to 10%.
- Where possible, broad-based banks are preferred, to allow cropping and other machinery to work across them.

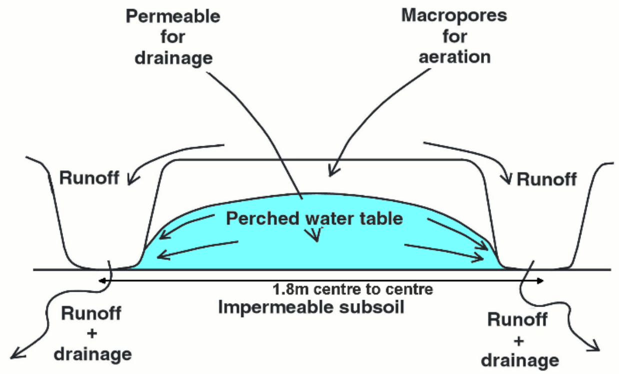
Grade Banks

Aspect	Advice
Benefits	• reduce erosion from surface water run-off • reduce sediment content in run-off • reduce waterlogging at the base of slopes • allow collection and re-use of surface water • lead to increased crop and pasture yields where seasonal waterlogging occurs • reduce flood peak flows.
Concerns	• obstructing traffic movement (broad-based banks may overcome this) • limiting the efficiency of precision cropping (odd-shaped cropping areas may increase overlaps or gaps) • increased maintenance requirements, especially where livestock of machinery cross, to prevent overflow • finding safe disposal points.
How grade banks work	Grade banks are designed to intercept run-off before it reaches a depth and speed likely to cause erosion.
Planning considerations	Grade banks may not be suitable: • on land sloping less than 2%; or on slopes greater than 10% because of the depth of cut of the uphill side slopes of the channel; stable construction of the bank is also difficult to achieve on these slopes.
Design Characteristics	• Grade banks on long slopes are usually spaced 50 to 220m apart. Banks are closer on steeper slopes, where storm events are more common, and if the soil is more erodible. • For general erosion control, the capacity of the bank is to carry the run-off expected in a 1 in 10 ARI. • Grade banks should have a flat channel floor up to 3.5m wide, with sloping batters between 1:3 and 1:6, depending on slope and soil type. Broad-based grade banks allow cropping and vehicle movement across the banks which may mean that more maintenance is required. • On land slopes of about 2%, channel depth of the bank should be 0.4m from the water level (when the bank is full) to the floor of the channel. For slopes between 2% and 5%, the depth should be 0.5m, and for slopes between 5 and 10%, the depth should be 0.6m. • The bank (on the lower side) should have a freeboard of 0.2m above water level when the channel is full.
Operation and maintenance	Grade bank channel, bank and/or sideslopes damaged by livestock or run-off should be repaired to original construction standards.

DAFWA website

Raised Beds

- Permanent raised beds are a practical and economic means of managing some waterlogged sites in wetter areas of the Western Australian grainbelt.
- Raised beds allow excess water to drain out of the beds (horizontal drainage) into open collector drains which then discharge off the paddock.



Raised Beds

Aspect	Design advice
Use	The probability of waterlogging is 50% when the emerging crops are most susceptible. Soils are most commonly shallow sand, high gravel t soils and loam over clay soils Where there are shallow watertables.
Landscape position	Hillslopes are less than 3%.
Bed	Orienting raised beds approximately north–south where possible. A north–south orientation allows for an even exposure of the bed to sunlight, which maximises the chances of uniform crop development across the full width of the bed.
Drains	**Cross drains** Cross drains remove water from small areas within a field where water ponds. **Catch drains** Catch drains collect the water flowing from the end of all the furrows in a field or section of a field. **Waterways** Waterways are broad-channelled, large capacity drains that carry water from upstream past and/or from an area of raised beds back to the natural drainage course.
Build with	Bed-formers can be supplied as three-point linkage or trailing models. Grader or scraper for drain / waterway
Risks	Erosion of the channel of catch drains and waterways is a major challenge for sustainable raised bed farming.

Shallow Relief Drain

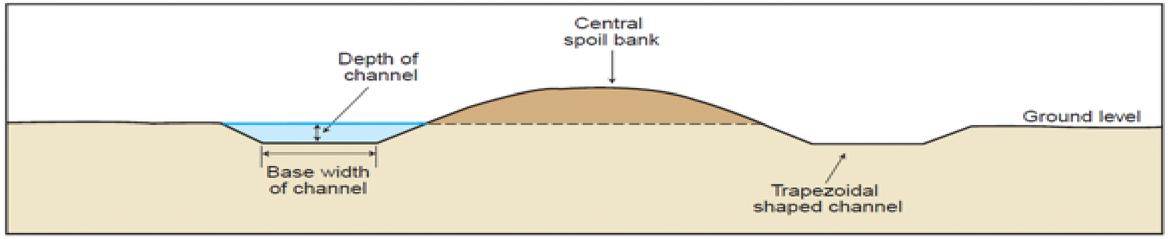
- A shallow relief drain is a shallow channel designed to manage run-off on flat, low-lying farmland and to remove water from areas affected by inundation, waterlogging or flooding.
- Shallow relief drains are easy to construct and a cost-effective means to:
  - remove surface water to a safe disposal area, to reduce the length of time the land is inundated or flooded
  - reduce the potential for localised recharge and the development of secondary salinity
  - remove accumulated surface water from depressions and low-lying land
  - improve the continuity of flow within the catchment along the valley floor
  - divert run-off from land that is prone to inundation or flooding.

Shallow Relief Drain

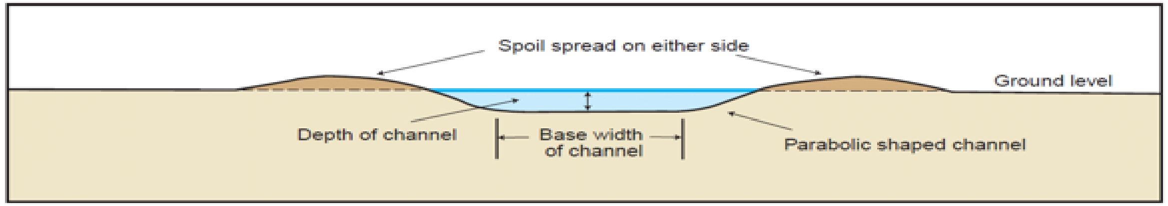
- There are different types of shallow relief drains and they are defined by the shape of their channel. These are the:
  - W-drain
  - U- (or spoon) drain
  - V-drain

Best time to mark channel lines

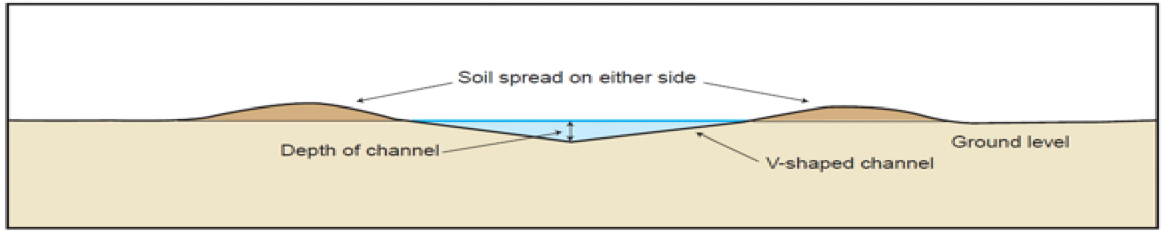
- The best time to plan shallow relief drains is after heavy rain, when inundated areas are easily seen and the lowest points in the landscape can be located. These points can be pegged and levels surveyed later to work out the best layout and drain depth for the scheme.



W-drains collect water from both sides and remove the problem of spoil blocking water movement into the channel



U- (or spoon) drain cross-section showing the broad, rounded channel with spoil on both sides



V-drain cross-section showing a single channel and spoil on either side. The spoil heaps are not continuous to allow water easy access to the channel from either side

Shallow Relief Drain - (U or V Drain)

Aspect	Shallow relief drain (U or V drain)
Use	Move water away from flooded or waterlogged areas Layouts – simple, parallel, herringbone
Landscape position	Lowest part of the receiving landscape Paddock scale Clay and shallow duplex soils
Long section	Less than 0.2% grade Paddock scale
Cross-section	Shape is calculated for receiving catchment (runoff calc & Manning's equation for velocity calc) Batter slopes 1:6
Other design features	Connect to waterway Seed batter to improve stability
Build with	Scraper, excavator, grader or dozer
Risks	Channel base erosion Construction in sandy soils will limit effectiveness at controlling waterlogging

Shallow Relief Drain - (W Drain)

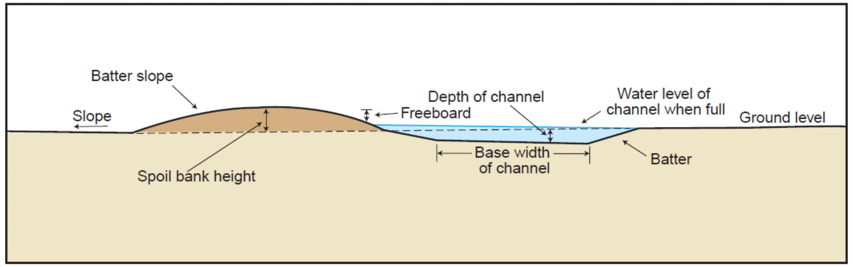
Aspect	Shallow relief drain (W drain)
Use	Move water away from flooded or waterlogged areas Use instead of leveed waterway along flat (<0.2% grade) undulating slopes
Landscape position	Lowest part of the receiving landscape Paddock scale Clay and shallow duplex soils
Long section	Less than 0.2% grade Paddock scale
Cross-section	Cross section is calculated for receiving catchment (runoff calc & Manning’s equation for velocity calc) Batter slopes 1:6 – Flat base
Other design features	Connect to waterway Seed batter to improve stability
Build with	Grader or dozer
Risks	Channel base erosion Construction in sandy soils will limit effectiveness at controlling waterlogging

Leveed or Artificial Waterway

Aspect	Design advice
Use	Banks used to confine flows to prevent wide areas of flooding and waterlogging Receive and safely dispose of runoff from banks where no natural channel exists
Landscape position	Usually in lowest part of the receiving landscape – but not always Up to 10% slope (with planning and design) Clay, sand, shallow and deep duplex soils
Long section	0.14 to 10% grade Hydraulic gradient defines flow in flat areas
Cross-section	Single or double levee Cross section is calculated for receiving catchment (runoff calc & Manning's equation for velocity calc) Max channel batter slopes 1:2 / Max levee batter slope 1:2 inside, 1:6 outside
Other design features	Connect to waterway Seed to improve stability, should not be cultivated Vegetation kept to a height of 0.1 – 0.2m Shouldn't be used as can access track or firebreak
Build with	Grader or dozer
Risks	Channel base erosion (levees should be used where grades >0.2%) Construction in sandy soils will limit effectiveness at controlling waterlogging

Broad-based Banks

- Bank with uphill channel constructed to control surface water flows from sloping land.
- Can be used to control run-off causing erosion flooding and waterlogging. Low profile allows tillage along the length of the bank batters and channel.
- Constructed in the lower and middle parts of the landscape.



From DAFWA website

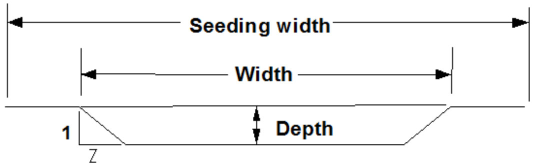
Broad-based Banks

Aspect	Design advice
Use	Catch and safely move runoff downhill Usually system of banks Low profile bank aims to allow tillage along bank, batters and channel
Landscape position	Usually in middle and shedding landscapes Usually 2 to 4% slope Shallow duplex and loam soils
Long section	0.14 to 0.3% grade Up to 1km long
Cross-section	Channel uphill of bank Flat base – 5m or wider – 1:6 batters Up to 1m deep
Other design features	Spaced 100 to 250m apart Connect to waterway or dam
Build with	Grader or dozer
Risks	Channel base erosion Overtopping or breach Leakage downhill in sandy soils

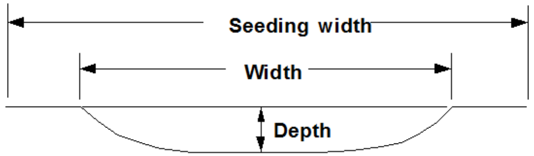
DAFWA website

Waterway

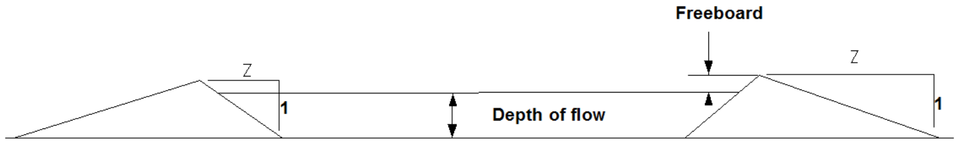
- Use a natural or constructed grassed waterway to allow safe movement of surface water across the natural landscape, and from dams, the end of grade banks and other surface water disposal structures.
- Grassed waterways should be part of an integrated water management program.



Trapezoidal shaped cross section



Parabolic shaped cross section



Freeboard on a Leveed Waterway

DAFWA website

Waterway

Aspect	Advice
Benefits	Effective and cost-efficient way of safely moving surface water from the ends of grade banks, diversions, dam overflows or other water concentrations to a stable discharge point.
Concerns	Flows of poor quality water can degrade downstream channels, watercourses and wetlands. Eroded material from poorly planned, constructed or maintained waterways, can reduce flow capacities when deposited in downstream channels.
Planning considerations	Waterways should be fenced on both sides of the channel or outside of levees, leaving adequate room for maintenance machinery. Provide livestock and vehicular crossings as necessary to prevent damage to the waterway and its vegetation.
Design Characteristics	**Channel slope** – can be on any slope or combination of slopes up to 10%. **Catchment run-off peak flow** – to be determined by a recognised method, such as in ARR **Channel cross-sectional shape** – is trapezoidal or parabolic in shape. Sideslope ratio of waterway bank should be no steeper than 2:1. **Capacity** – sufficient to contain the peak flow run-off from a 20-year ARI
Operation and maintenance	Grassed waterways greatly reduce the risk of water erosion – if they are effectively maintained! Do not cultivate grassed waterways. Maintain vegetation cover at 10–20cm high. Mow or periodically graze vegetation to maintain flow capacity. Reconstruct damaged channel floors and levees to original specifications. Do not use waterway as an access track or firebreak.

Waterway

Table 6.2. Maximum permissible average velocities of flow for waterways with uniform vegetative cover

Soil texture	Vegetation	Ground cover	Permissible velocity *(ms-1)
1. Sand	Bare	< 40%	0.5
2. Sand	Sparse grass cover	< 60%	0.6
3. Sand	Well grassed annual pasture with sub. clover	> 60%	0.75
4. Loamy sand	Vigorous sub. clover and grasses	> 80%	1.2
5. Sandy loam	Bush waterway	< 40%	0.75
6. Sandy loam	Annual pasture	< 60%	1.0
7. Sandy loam	Annual sub. clover and grasses	> 60%	1.0
8. Sandy loam	Annual sub. clover and grasses	> 80%	1.0
9. Sandy loam	Parkland cleared with sub. clover and grasses	> 60%	0.9
10. Sandy clay loam	Well-grassed with sub. clovers or medics	> 80%	1.2
11. Clay-loam	Sparse grass cover	< 60%	1.0
12. Clay-loam	Well-grassed with sub. clovers or medics	> 60%	1.2
13. Clayey soils	Well-grassed	> 60%	1.2
14. All soils	Densely-grassed with a component of perennial pasture	> 95%	1.5

* Based on values obtained from 'Soil and Water Conservation Engineering'; (Schwab *et al.* 1981), and 'Soil Conservation' (Hudson, 1981), and interpolations based on local experience provided by D.J. Stanton (WA Department of Agriculture).

Summary

Earthwork	Land slope (%)	Soil type	Grade (%)	Landscape position	Purpose
Absorption banks and level banks	up to 10	clay, clay loam, rocky		upper slope, below areas producing a lot of run-off	controlling run-off water where a grassed waterway cannot be safely maintained
Grade bank	up to 10	shallow duplex, loam	0.2 to 0.5	upper and mid-slope	controlling surface water erosion; harvesting water from slopes
Grassed waterways	up to 10	most soils	up to 10	running downhill on a natural water accumulation line	providing safe disposal of overflow from dams or discharge from the end of grade banks
Seepage interceptor bank	up to 10	shallow duplex, deep duplex, sand		lower and mid-slope	controlling shallow seepage and waterlogging
Broad-based banks	2 to 6	shallow duplex, loam	0.15-0.3	upper, middle and lower slope	controlling surface water erosion; allowing easy vehicle traffic across banks
Shallow relief drains	up to 0.2	clay, shallow duplex	up to 0.2	valley floor	removing surface water from flooded areas
Levee waterways	up to 10	clay, sand, deep duplex, shallow duplex	up to 10	valley floors and hill slopes	guiding and controlling the spread of water in drainage lines
Raised beds	0.1 to 2		0.1 to 2	valley floors and fairly level waterlogged areas	raising seed beds above the saturated soil of waterlogged areas

DAFWA website

Planning a Water Management System

What is the source of the water?

- Groundwater – discharge, salinity
- Surface water – erosion, flooding, waterlogging, inundation

Managing water at its source is the most efficient & economic system.

Managing surface water is easier & less expensive than managing groundwater.

Planning

- Collect baseline data
- Select possible management options & evaluate the costs and benefits
- Design the options using standards
- Implement the option/s
- Maintain, monitor & evaluate the option/s
- Water management is a land use in its own right, and it may require that areas of land be set aside solely for this purpose

Water Management Structures

- Each design has a specific use and location in the landscape
- One structure cannot alleviate all degradation types
- An inappropriate structure may result in a greater degradation risk than the structure was meant to alleviate

Each structure has a set of design criteria for minimum risk planning design criteria relate to:

- maximum grade
- minimum cross-section
- maximum allowable rate of flow in the channel
- landscape position

DAFWA website

Designing a Water Management Structure

Collecting the physical details about a site

- catchment area of the proposed structure
- average annual rainfall
- landscape slope
- soil type
- percentage of the catchment that is cleared
- the average recurrence interval (ARI):
  - banks, shallow relief drains – 10 year ARI
  - dams, waterways, deep drains – 20 year ARI
- *Land managers can collect or will know this information*

Monitor, Maintain & Evaluate

Monitoring

- Collect baseline data BEFORE construction (ideally 12 months)
- Collect reliable data rather than subjective assessments
- Keep clear and easily accessible records to enable short and long term trends to be identified

Maintaining

- regular checking & maintaining is necessary to keep structures operating at capacity

Evaluating

- assessing all the information helps you to decide if the surface water management was effective. You are then in a better position to repeat or change the system in other areas.

In Summary

Planning a surface water management system involves:

- defining the problem
- considering alternatives
- estimating costs & benefits
- designing & implementing the most appropriate option/s
- maintaining, monitoring & evaluating

Structures have a set of design criteria for minimum risk planning

Each structure has a specific use & location within the landscape

Open communication channels between stakeholders & obtain development approvals before construction begins

Managing Subsurface water

- Managing subsurface water can help to lower watertables and alleviate problems with waterlogging, rising salinity, and infrastructure damage.
- Many of the technologies on this page require the Commissioner of Soil and Land Conservation to be notified, especially when the subsurface water is discharged in a way that is likely to cause concern off-site.
- Subsurface water management should be part of an integrated water and salinity program.

DAFWA website

Managing Subsurface water

Option	Land slope	Soil type	Fall grade	Landscape position	Purpose
Open deep drain	less than 0.2%	Heavy clay is less permeable and less suitable for deep drainage.	less than 0.2%	lower landscape, valley floors	A channel used to intercept groundwater and discharge that water to a safe point. Open deep drains also allow inflow of surface water. Usually constructed to 1 to 3m deep to manage salinity and waterlogging.
Leveed deep drain	less than 0.2%	Heavy clay is less permeable and less suitable for deep drainage.	less than 0.2%	lower landscape, valley floors	A channel used to intercept groundwater and discharge that water to a safe point. Leveed deep drains prevent inflow of surface water which reduces erosion of the drain batters. Usually constructed to 1 to 3m deep to manage salinity and waterlogging.
Pumping groundwater	site specific	site specific	site specific	site specific	Used to drawdown the watertable (saline or fresh) to manage salinity and waterlogging under potentially productive land.
Desalination of groundwater or surface water	site specific	site specific	site specific	site specific	Used to produce product water of lower salinity level and brine discharge.
Siphon	1.5–2%	Upslope seepages	1.5–2%	In or below seepages in the higher landscape	Used to safely move saline or fresh water from higher in the landscape to safe disposal points lower in the landscape.
Relief well / bore				lower landscape	Used to release artesian pressure in groundwater that is leading to saline discharge.
Mole drain	less than 2%	clay / heavy loam	same or less than landslope	waterlogged heavy soils	Used for removing water from saturated clay soils. These drains are practical and relativel cheap for the close spacing required on saturated clay soils.
Evaporation basin and pond	site specific	clay	no fall	site specific	Used to hold saline discharge and prevent salt discharge to environmentally sensitive areas. They are part of a salinity management system.

DAFWA website

Deep Drain

Deep Drain – Open or Leveed

- Site Assessment
  - With a backhoe, put in about 5 five pits per kilometre of the intended drain alignment to 2.5–3m depth.
  - In each pit observe:
    - Soil horizons and soil type:
    - Soil characteristics which will give you an idea of the drain's effectiveness:

DAFWA website

Deep Drain

Depth

- Beynon: 3 m more effective than 2 m
- YYCMG reported 2.5 m more effective than 2.1 m
- 2.5 m depth is most common

Side slopes

Batter trials at Wubin found flatter slopes 1(H):1(V) more stable than 0.5(H):1(V) but dependent on soil type (e.g. Hillman R. South)

0.5(H):1(V) has lower combined construction and maintenance cost than 1(H):1(V)

Dependent on soil type

Levees

Excluding surface water with well constructed and maintained levees minimises damage and maintenance

Modelled effective drain spacing

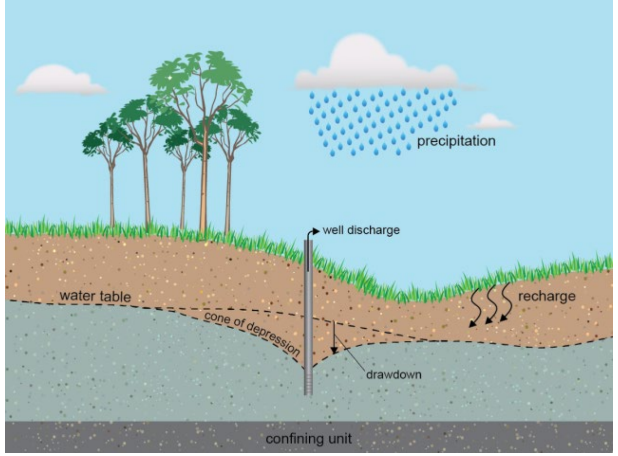
Pithara	– 160m
Morawa	– 270-660 m
Beacon	– 283 m

DAFWA website

Groundwater Pumping

Site investigation by a hydrologist to determine the:

- nature of the aquifer
- expected yield
- water quality
- disposal options
- the most appropriate pumping system
- pump location/s.



DAFWA website

Pump type	Power supply	Comments
Submersible	Mains electric or solar	Depend on proximity of power, pumping rate required and total working head. Typically require high yielding aquifers (more than 2–3L/s).
Compressed air systems	Mains electric or solar	As above, air compressors can be remote from the site. Water can be reticulated 5–10km from the power source. Typically pump at rates less than 2L/s.
Piston, rotor	Wind, solar or mains electric	Low yielding system

Siphons / Relief Wells

Siphons work best on natural hillside seeps where the landscape has a good fall to a disposal point and the aquifer has good transmission.

Sites most likely to suit siphons

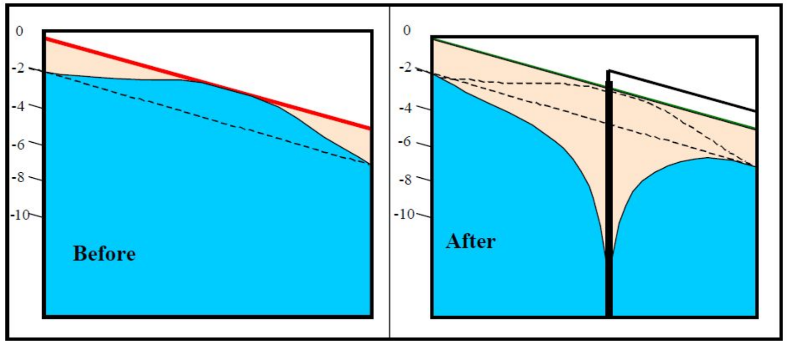
- that are in the middle of a large, natural hillside groundwater seepage
- that have a gradient from the seepage area of at least 1.5–2% to maintain the siphon vacuum
- where the seepage area is more than 5m above a safe disposal point
- where groundwater yield from the siphon is greater than 0.2 litres per second (L/s)
- where the bore is drilled to basement in weathered granite or fracture zones, not dolerite dykes
- where groundwater levels in bores are at or above the ground surface

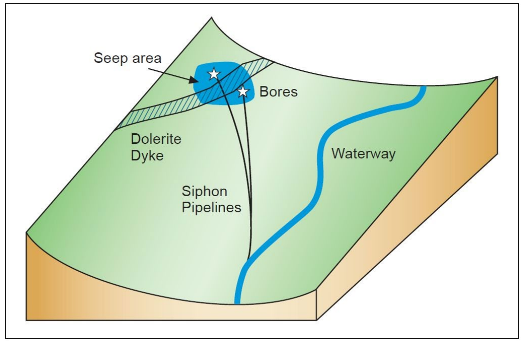
A relief well is a 'free-flowing' groundwater bore driven by artesian pressure. Such a bore allows groundwater to flow continuously up to the surface by releasing confined pressure stored within the aquifer at depth.

The best site is where there is sufficient artesian pressure. Groundwater discharge areas are more likely to be artesian where local surrounding slopes are greater than 1.5–2%, to provide the hydraulic head.

Finding sites with artesian pressure sites can sometimes be a problem; groundwater discharge can be a guide:

- saline areas that appear out-of-place in the landscape, such as in undulating terrain where isolated groundwater discharge (salt-affected) areas are located on a hillside
- areas containing isolated seepage eyes, which may have a significant perennial or seasonal flow
- upslope from dolerite dykes or other constrictions
- in faults and sloping sedimentary valleys in medium to high rainfall areas.





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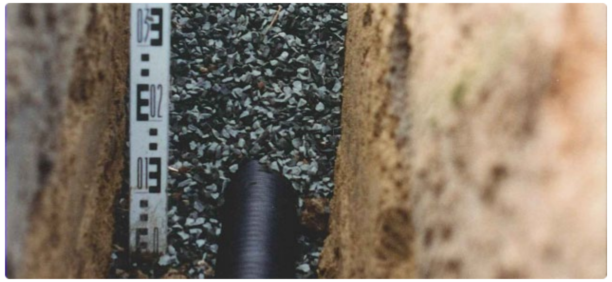
Slotted pipe

Subsoil drainage is a method of draining clay soils that experience regular waterlogging from irrigation or high rainfall.

Specifically designed drainage trenchers, dig the trench, lay the slotted pipe and place permeable backfill into the trench on top of the laid pipe.

General guidelines include drain depth of > 1.2m (to 2 m), and spacing depending on soil texture:

- 100-150 m for light-textured
- 50-100 m for medium textured
- 30-50 m for heavy textured soils



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Larger scale water management

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

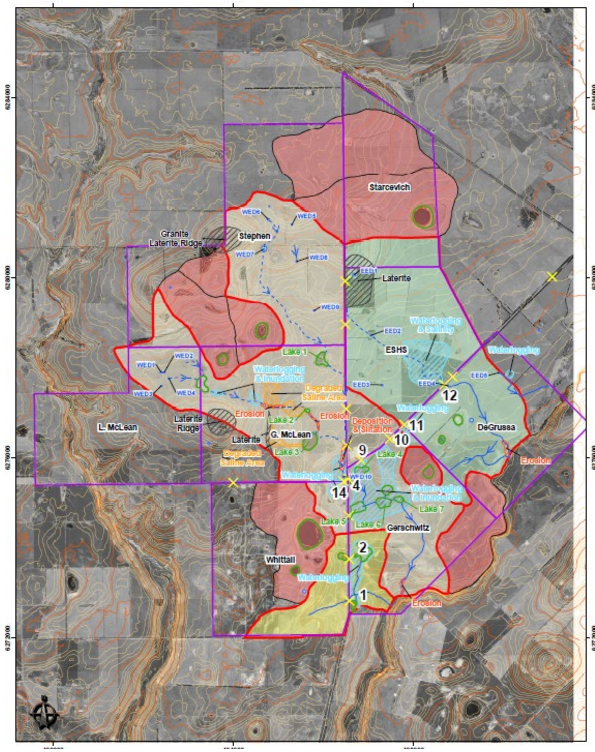
SOUTHCOAST NATURAL RESOURCE MANAGEMENT

Case Studies

- Hillman River
- Jibberding
- Bandy Creek
- Lake Magenta

Jibberding flooding 1999 - GHD

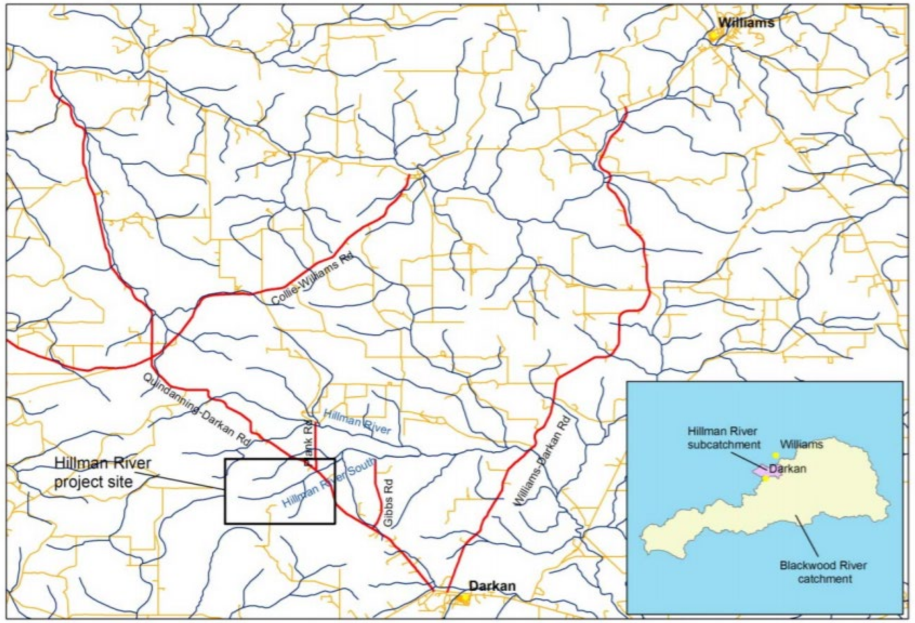
Lake Magenta – drainage channel monitoring - GHD



Bandy Creek Water Management Plan - GHD

Hillman River

- The Hillman River South drainage project evaluated the performance of deep drains in an area of higher rainfall and moderate relief, compared with the low rainfall low relief areas of the wheatbelt where most deep drainage trials.
- The project site is along the upper reach of the Hillman River South, a tributary of the Blackwood River, and located 11 km north-west of Darkan.
- The site is in a flat relatively narrow valley floor set within an undulating landscape. The Hillman River South is typically ephemeral.
- The valley floor is characterised by duplex soils, with sands and gravels overlying medium to heavy clay subsoil.
- Groundwater under the site is saline, with an average salinity of 9,000 mg/L.



McDougall 2012

Hillman River

Design and construction

- The Hillman River South project included the construction of approximately 8.7 km of deep drain with the objective of reducing the incidence of waterlogging and salinization along the valley floor.
- The drain was 2 m deep (on average) with a base width of 0.9 m and 1:1 batter slopes.
- The drain was enclosed by 1.2 m high levees over most of its length to prevent surface flows entering the drain, other than flows from the creek that discharged to the lower section of constructed drain.

McDougall 2012

Hillman River - Key Findings

- Deep drains at Hillman River South had no measurable effect on waterlogging or watertable levels because the recharge adjacent to the drain exceeded the capacity of drain.
- The downstream impact of the drainage discharge was unlikely to be detrimental and were not detected 10 km downstream.
- Typically used batter slopes (e.g. 0.5(H):1(V) or 1:1) may be too steep in sandy soils with high groundwater discharge but flatter batter slopes are impractical and costly.
- Increased drainage density is needed to lower the watertable at Hillman River. Parallel drains at a spacing of 239 m could manage the average recharge but the steep landscape and unstable side slopes present challenges
- Buried pipe drains could be more cost effective in unstable and saturated soils and would retain access and use of the land at higher drainage densities.
- The relatively steep landscape and sandy soils of the Hillman River catchment appear to make the site suitable for siphons.

Drain spacing scenarios (m each side of the drain)

	Drain spacing (m each side)	
Aquifer material	At average recharge (50 mm/yr)	At peak recharge (202.6 mm/yr)
Sand	239	118
Clay	8	3

McDougall 2012

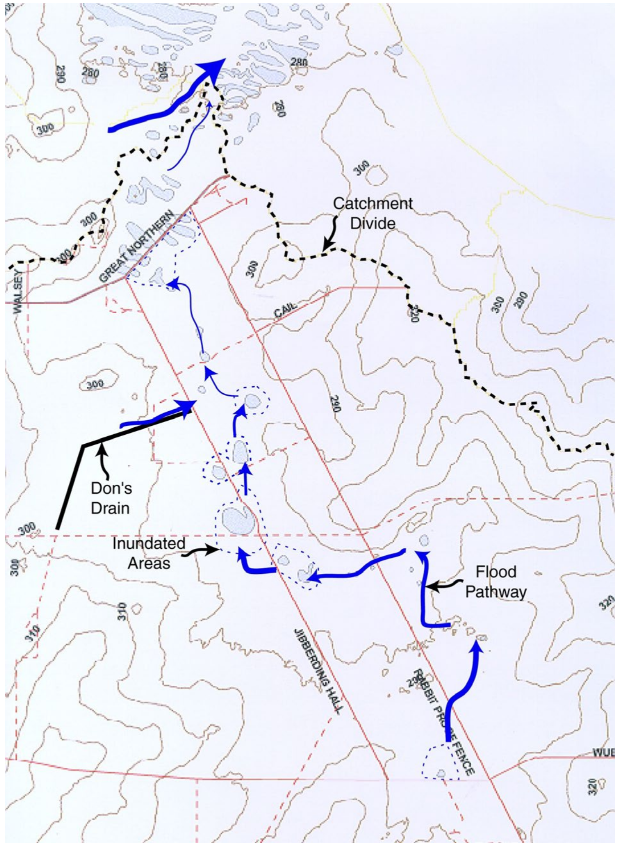
Jibberding

- Jibberding Catchment is a 270 km^2 sub-catchment of the Yarra Yarra catchment located in the northeastern wheatbelt, 15km northeast of Wubin
- The aim of the project was to design a channel (surface water relief drain) to connect the most significant lakes in the chain in order to promote the removal of floodwaters.
- The identified benefits were:
  - Reduce the time of the flood recession and thereby the period over which farmland and remnants are under water (waterlogging) and access roads unusable;
  - Limit the areas of arable land and native vegetation left unproductive from salinity as a result of flood-induced recharge. Removing floodwaters more quickly limits groundwater recharge.

Jibberding

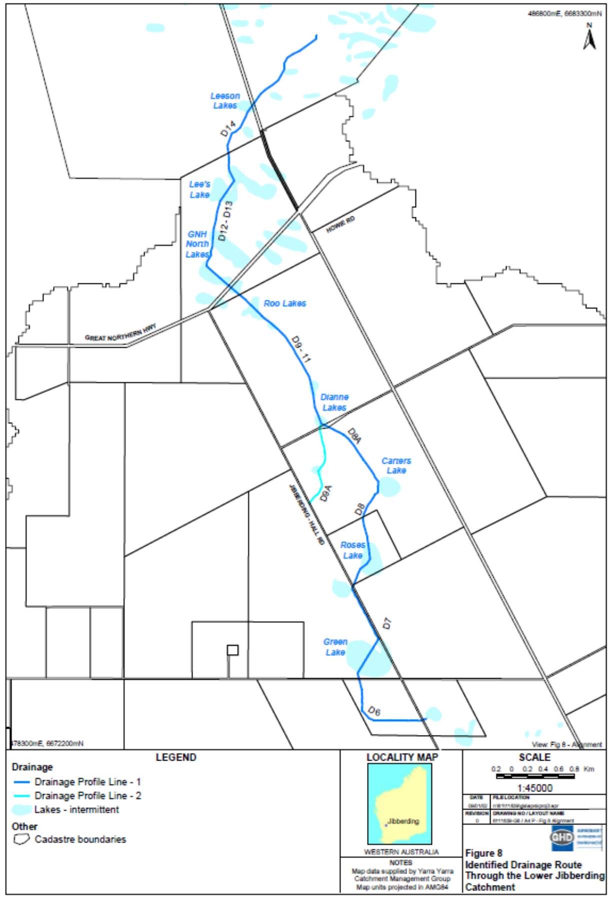
- Approach required:
    - assessment of catchment hydrology,
    - assessment of hydraulics of drain
    - detailed design specification of the drainage works.

- The design was for a 10 km relief drain to remove surface flows from the Yarra Yarra catchment
- The drain was designed (by GHD) on the basis of conducting flows up to the 15 year ARI event within the channel without overtopping, and for the 100 yr ARI flood to be contained within the floodway.
- The design also involved connecting a series of salt pans / lakes with low level maintaining the role of the lakes as important flood storages.



Jibberding

- The drain alignment was reviewed in consultation with the YYCMG and local landowners, and provision has been for controlled access points along the chosen alignment.
- The alignment was determined based on flood routes identified from the March 1999 event, and to best conform with existing land and infrastructure uses.
- Calibration was completed on the catchment hydrology to 1999 flood events (20 and 40-50 Year ARI storm events).
- Hydraulic design of the drainage channel was prepared using HEC-RAS so as to limit channel velocities to below 1.5 m/s (nominal scouring velocity) and minimise the channel capacity thereby reducing excavation costs.
- From the preliminary design the drain is typically excavated to between 0.75-1.25 metres deep, 1-2 m base width, with batter slopes of 1 in 4.

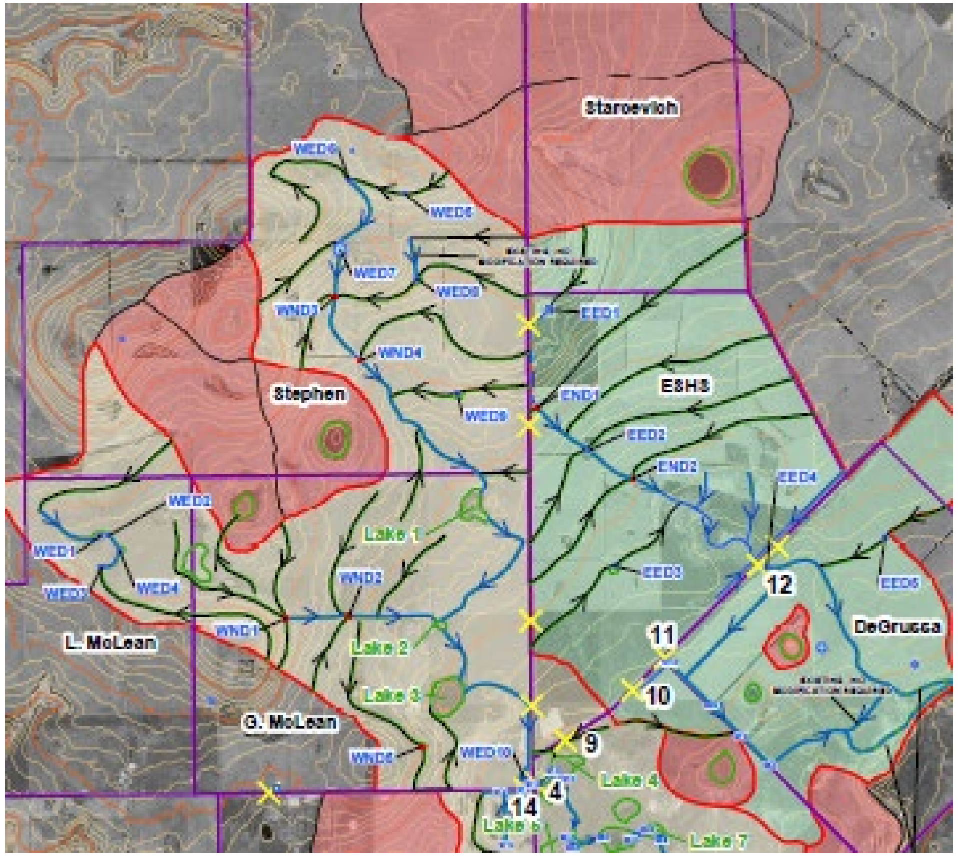


Bandy Creek

- The Bandy Creek subcatchment is one of four subareas draining into the Ramsar listed Lake Warden Wetland System (LWWS). The Lower Bandy Creek subarea (5,400 ha) some 25 km northeast of Esperance.
- GHD worked with Esperance LCDC to produce a surface water management plan for the Lower Bandy creek subcatchment given issues such as excess surface water runoff and accumulation, waterlogging, erosion and salinity.
- This included consultation with local owners, a detailed site assessment and the identification of appropriate best practice surface water management options.
- The development of the surface water management plan was supported by hydrologic modelling and included an evaluation of likely costs and benefits of the proposed works.

Bandy Creek

- Simply addressing the issues on a farm by farm basis would not be sufficient to mitigate the problems.
- As a result, the most appropriate surface water management plan was developed based on a combination of:
    - grade banks and overflow drains to link existing storages,
    - revegetated conveyance drain corridors,
    - more efficient use of the lakes and farm dams within the
    - project area,
    - construction of additional farm dams, and
    - revegetation of selected areas adjacent to the grade banks and overflow drains



Graded banks & conveyance drains

Lake Magenta

- GHD worked with CALM (now DBCA) to design improvements to an existing degraded drainage channel through the Lake Magenta Nature Reserve, outside Katanning WA.
- The project required hydraulic modelling of the existing and proposed drainage channels, as well as hydrologic modelling of the catchment upstream of the reserve.

Questions?