Appendix I

Database

Database Management

Lisa Pocock, database manager, Yarra Yarra Catchment Management Group, Kalannie

The Yarra Yarra Catchment Management Group's database has been created in Microsoft Access and is managed by the database manager. All data collected within the Yarra Yarra Catchment is sent to the database manager for entry into the database. This ensures accuracy of data entry and no duplication of data.

The database is currently set up to accommodate data from bores, observation pits and remnant vegetation assessments. Further data from new subjects can easily be added to the database. Every table within the database is related in some way and each record is then related back to the specific property a bore, observation pit or remnant vegetation site is located on, see Figure 1.

Static data collected from bores and observation pits has been entered into the database. This data includes colour properties, soil classification, moisture and hardness for each soil profile. Monitoring data is entered into the database and is related to each specific bore or observation pit that the data was collected from.

All monitoring data is entered easily through formatted forms. Drop down menus have been created for easy entry of data types and specified units used to measure the data.

Existing data sets collated by the Yarra Yarra Catchment Management Group (YYCMG) over several years was transferred into the new database. This involved editing data to ensure its compatibility to be imported into the new database. Editing involved changing the formats and names of existing fields. During this process faulty data was found and removed from the database.

Static data such as property pin numbers and the corresponding property owner's names are still being entered into the database. This does not effect the abstraction of data from the database. The database is however regularly updated when new data has been received.

Future plans for the database include adding all photographs into the database. This will be done by linking the files of each photo to the database. The photo will be accessed using a live link from the database.

The database is regularly backed up by creating a whole new file. Each database is identified by the date the file was created on. A copy of each database is also burnt to CD and stored.

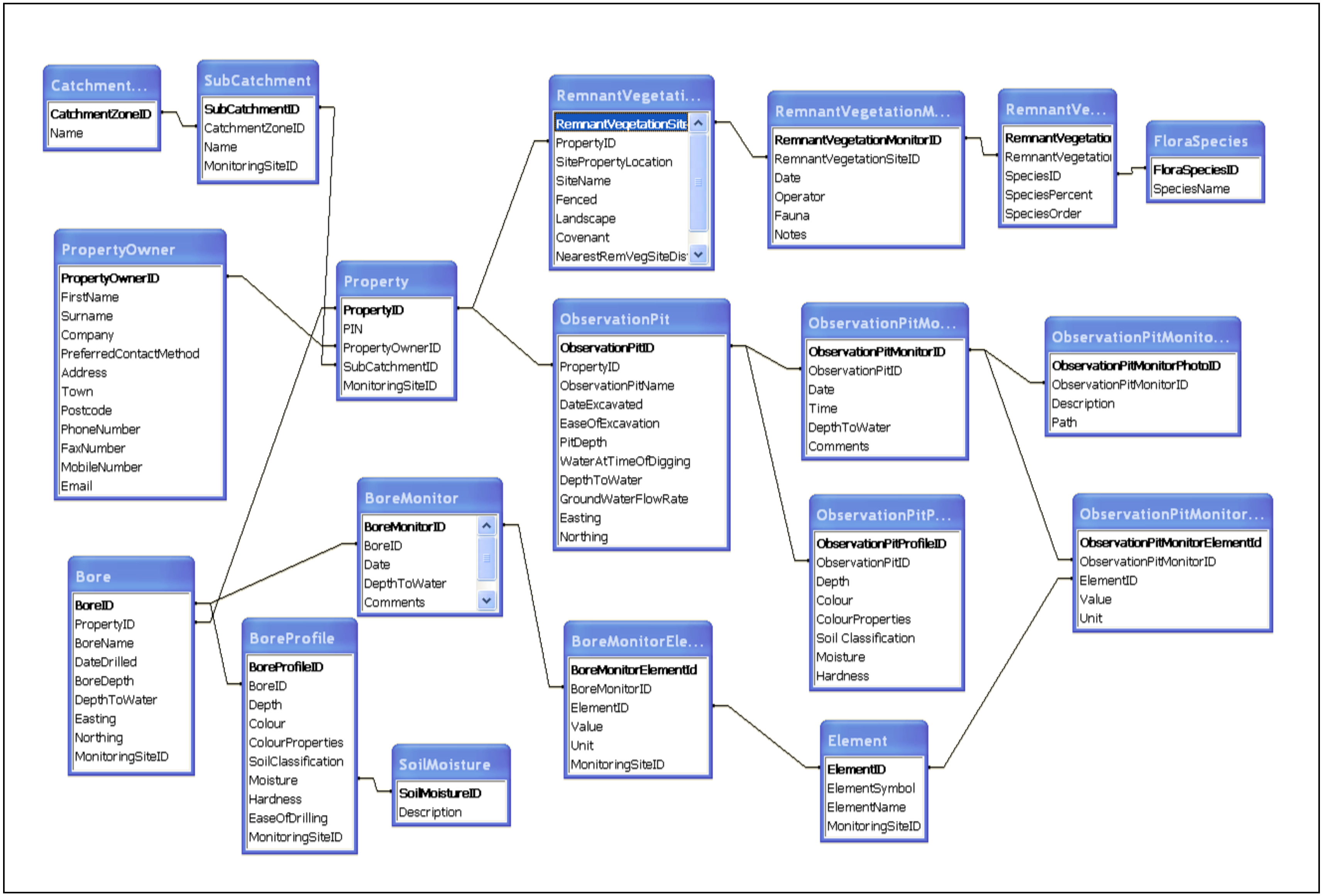

Figure 1: Relationships of the YYCMG Database.

Appendix II

Governance

Governance

Max Hudson, project manager, Yarra Yarra Catchment Management Group

1. The Current Situation

1.1 Our Philosophical Position

We recognise that if the community is to accept the responsibility of management, then they also need to have ownership of that process, and that all stakeholders need to be involved.

We also recognise that all those who live and work in a catchment need to be responsible for the management of that catchment. It is therefore imperative that all management boundaries should be aligned with actual catchment boundaries, even at a regional level.

1.2 Management Structure

Using topographical information provided by the Department of Land Information, the whole Yarra Yarra catchment area (west of the clearing line) has been divided into 60 minor subcatchments (Fig. 1), which can then be assessed and managed at their own level. We have amalgamated these minor subcatchments into 11 management zones (Fig.) and engage the community at this level. Elected representatives from each of the zones form the basis of the Yarra Yarra management committee. Two members of the Yarra Yarra committee are elected to represent the sub region on the Regional Northern Agricultural Catchments Council (NACC).

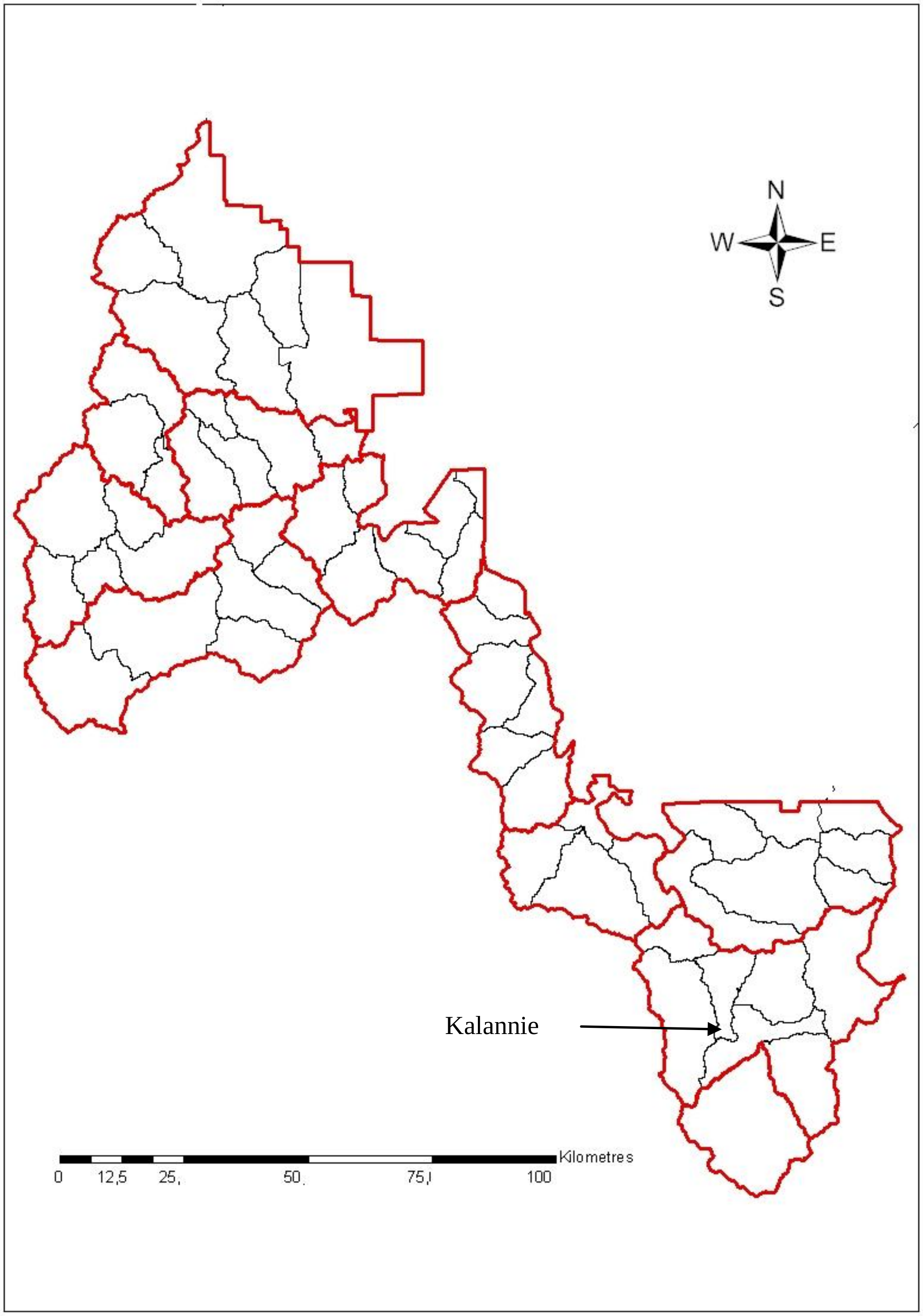

Fig. 1. The 60 minor subcatchments in the Yarra Yarra subregion.

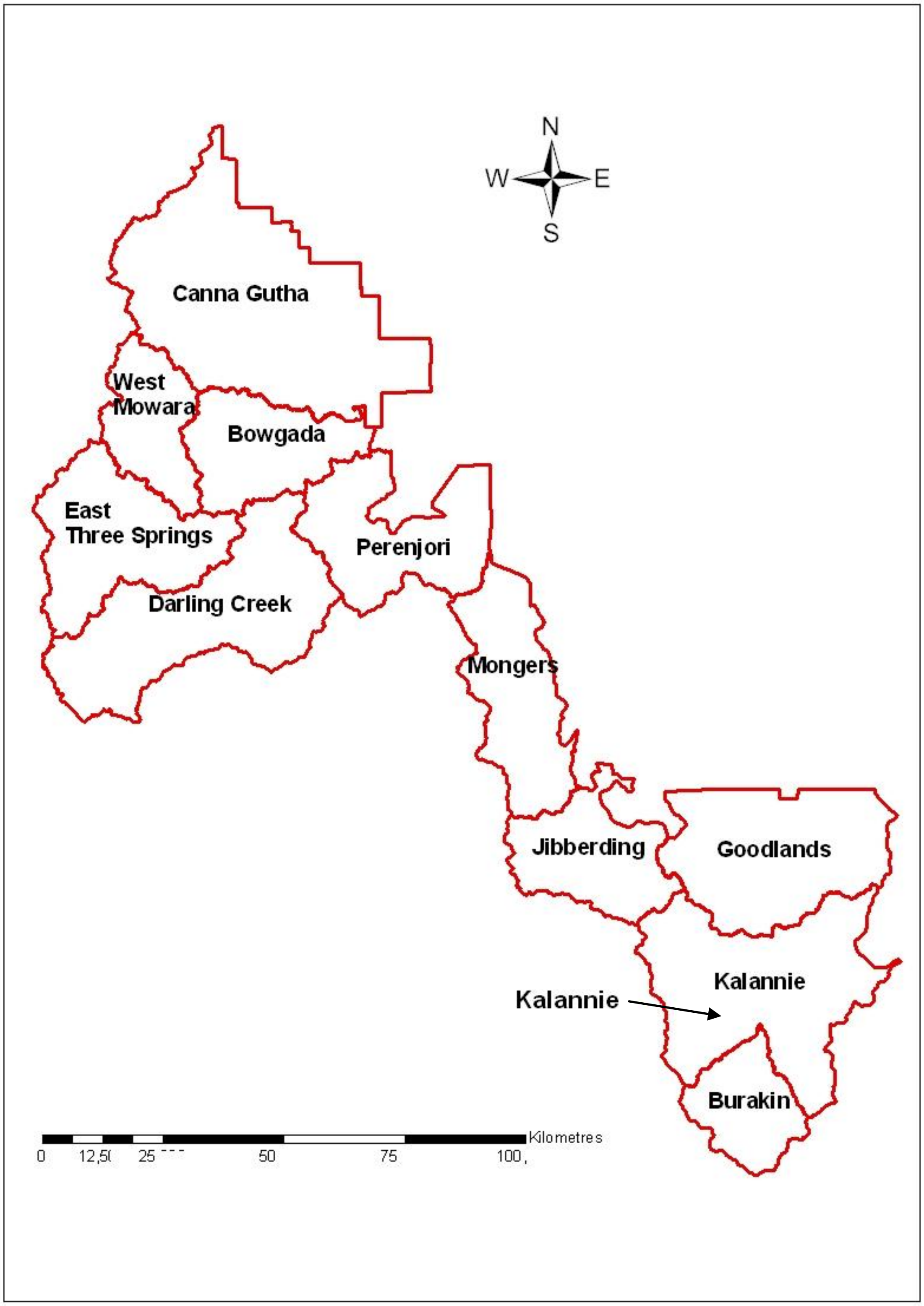

Fig. 2. The 11 management zones

2. Proposed Restructuring

2.1 Background

Since the initial development of farming land in the Northern Agricultural Region, federal, state and local governments have legislated to provide services such as road, rail, communications and water supplies for farming communities. However, no government body or organisation has ever taken responsibility for drainage in the region. Consequently, drainage of the landscape has deteriorated. This situation needs to be urgently addressed.

We aim to set up two complementary organisations –

1. a Yarra Yarra Catchment Regional Council (YYCRC), and
2. a Yarra Yarra Land Conservation District (YYLCD)

2.2 Regional Council

At the present time, the Yarra Yarra Catchment Management Group and others like it are in an extremely vulnerable position, as there is no statutory recognition of their existence, or any guaranteed continuity of funds for administration. On investigating all avenues of regional catchment control, the Yarra Yarra Group became aware of provision in the Local Government Act for the formation of Regional Councils to deal with specific issues. The formation of such a council to manage natural resources within the boundaries of the Yarra Yarra Subregion would be extremely advantageous, both to the shires in the region and to the Catchment Group. Under this arrangement, the Yarra Yarra Catchment Management Group would combine with those shires with land in the catchment basin to form a statutory catchment authority under the Local Government Act. This authority would be administrated by stakeholders within the catchment and would have the power to set rules relevant to local conditions. The seven shires involved and the Yarra Yarra Catchment Management Group resolved, at a combined meeting in April 2003, that such a statutory body should indeed be formed. A number of versions of an 'Establishment Document' have been drafted and the final draft was compiled with the assistance of solicitors "Watts and Woodhouse". This document now awaits final ratification by the Shires before signing and presenting to the Minister for Local Government and Regional Development for approval.

The establishment agreement sets out the following objectives for a statutory body to be known as Yarra Yarra Catchment Regional Council (YYCRC):

(a) with the exception of the cost of employing a chief executive officer, to incur costs only to an extent that the YYCRC has obtained grants or monies other than contributions by the Participants;

(b) to encourage cooperation and resource sharing, on a regional basis, in relation to the drainage and management of the Yarra Yarra Catchment Basin and its natural resources;

(c) to support the relationships that the Participants have with their communities, State and Federal Governments and others in relation to the drainage and management of the Yarra Yarra Catchment Basin and its natural resources.

2.2.1 Organisation of the Proposed Regional Council

To establish a Regional Council, the Act states that it must indicate that it can support a Chief Executive Officer to oversee the protocol and audit system, in the same as any other local government council. The Yarra Yarra Catchment Management Group can provide all other facilities, such as office space and equipment, with support from the Perenjori Shire Council. The Yarra Yarra LCD committee would direct the CEO as to what projects need to be implemented

Project coordinators, funded through NACC and/or funds generated by Yarra Yarra's own fundraising enterprises, would be required to work under the CEO. The CEO would oversee and put forward projects to the Regional Council and liaise between the catchment group and the Regional Council.

Funding from the shires to support the CEO position would be pro-rata, according to land holdings in the Yarra Yarra catchment (Fig. 3), viz.

Dalwallinu	28%
Perenjori	26%
Morawa	23%
Three Springs	8.0%
Carnamah	7.0%
Koorda	4.8%
Wongan/Ballidu	3.2%

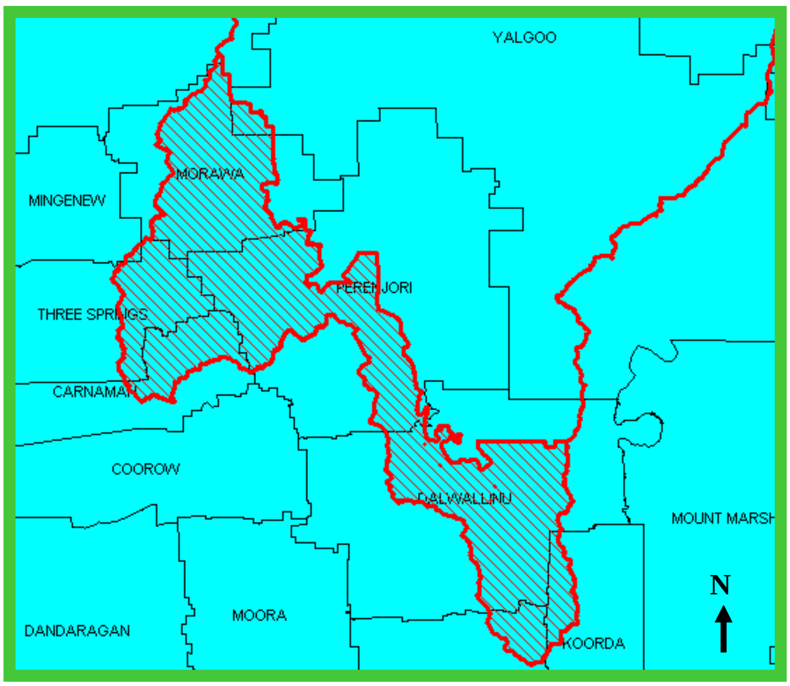

Fig. 3. Shire boundaries in the Yarra Yarra region. The agricultural part of the Yarra Yarra catchment basin (i.e. the proposed Yarra Yarra Regional Council) is highlighted.

The organisation of the proposed Regional Council is summarised in the accompanying flow chart (Fig. 4). Solid lines indicate interactions between groups; dashed lines show the flow of funds.

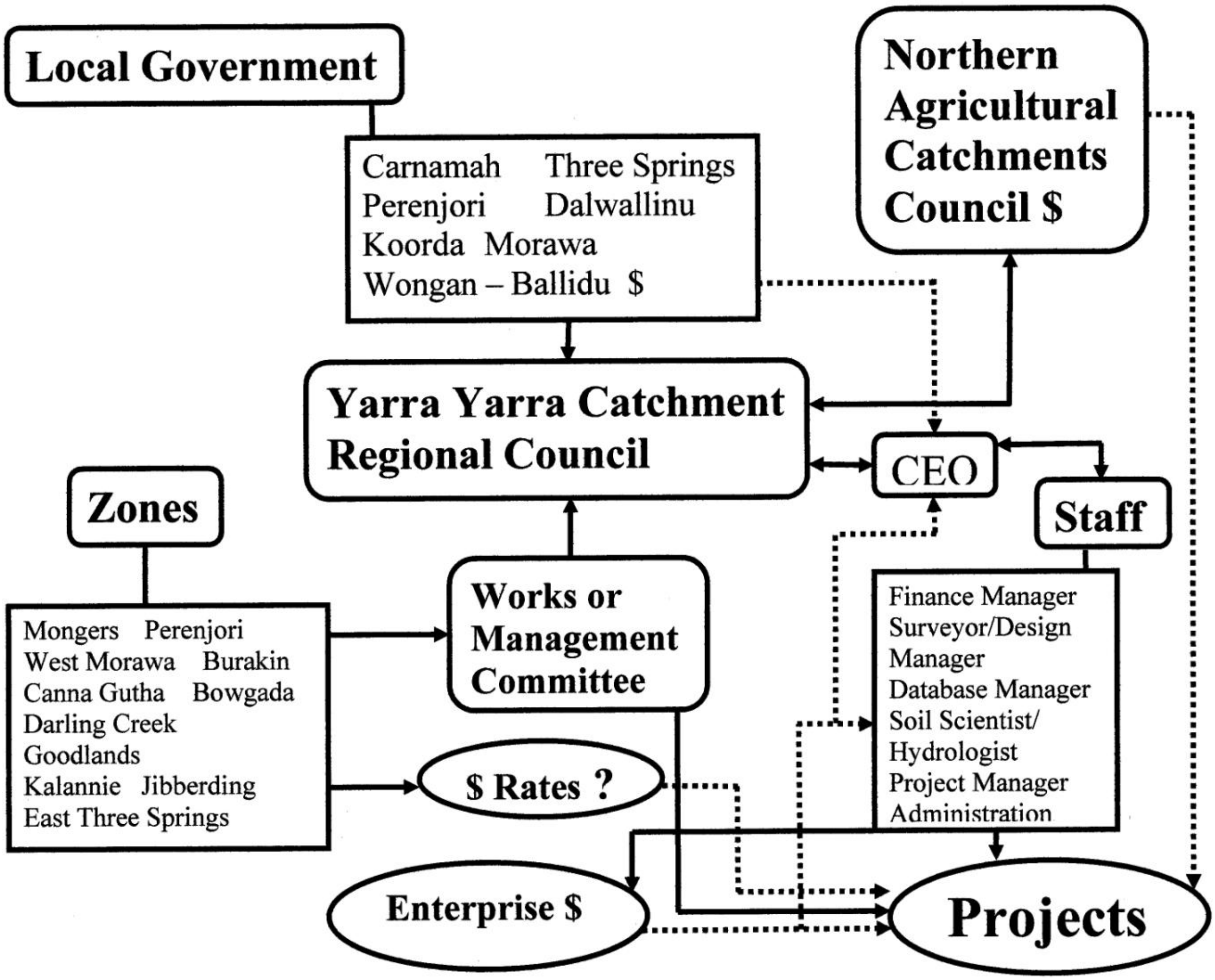

Fig. 4 Flow chart showing proposed structure of the Regional Council.

2.3 Land Conservation District

Since the initial meeting with the seven shires, a series of presentations has been delivered to the individual shires to promote the concept of a Regional Council. Maps were displayed at these presentations, indicating the relationship between existing Land Conservation District (LCD) boundaries the Catchment Basin boundary. We discussed the possibility of transferring statutory rights from these smaller landcare groups to a single, catchment-wide LCD. LCD boundaries are gazetted under the Soil and Land Conservation Act, which is administered by the Department of Agriculture through the Commissioner of Soil and Land Conservation. There has recently been consultation between the Yarra Yarra Committee and the Department of Agriculture regarding the amalgamation of all LCDs in the Yarra Yarra Catchment to form a single LCD, using existing boundaries of the Yarra Yarra Subregion of the Northern Agricultural

Region. The Yarra Yarra Catchment Management Committee would then assume the role of a Land Conservation District Committee and effectively become a works committee under the management of the Regional Council.

The state government would be directly involved with such a Subregional LCD through the appointment of a commissioner's nominee to the management committee. The identification of the new statutory boundary would give the group significant authority under the Soil and Land Conservation Act, with accompanying statutory rights that include the authority to strike a rate to support administrative costs if this was appropriate. Official recognition of this LCD boundary would be very useful when describing boundaries for a Regional Council.

The formation of a new catchment-wide LCD requires the winding-up and realigning of all existing LCDs, most of which are no longer active. Catchment zones will then be formed to replace of the old LCDs and also to establish administration areas where no LCD existed before. The new zones can then be form subcommittees of the greater Yarra Yarra LCD committee. One elected representative from each of these zones will sit on the Yarra Yarra LCD committee

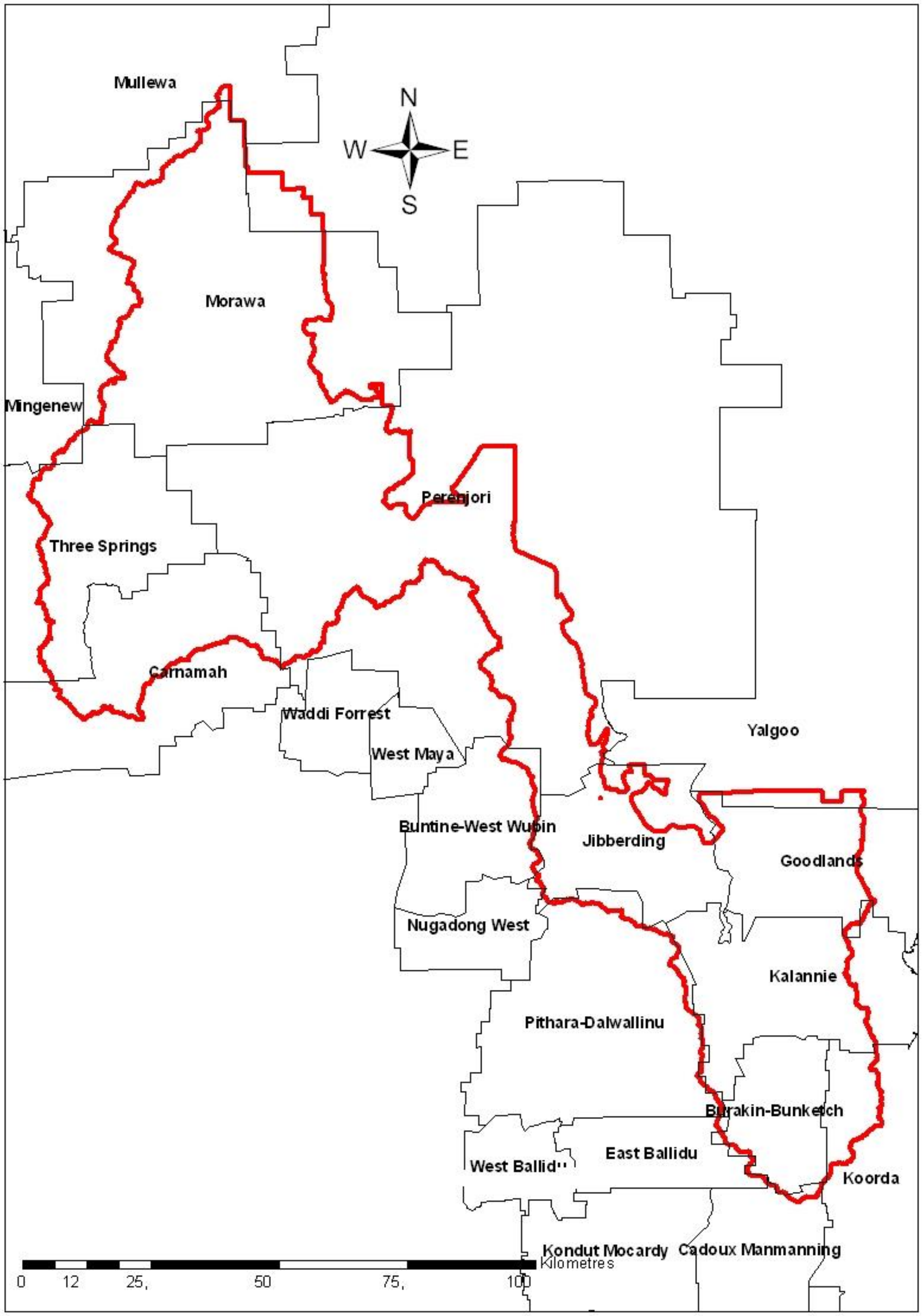

Fig. 5. LCD boundaries. The agricultural part of the Yarra Yarra catchment basin (i.e. the proposed Yarra Yarra LCD) is highlighted.

Background Reading

The State Sustainability document. 'The Western Australian State Sustainability Strategy 2002', Section 5, p. 94-97.

White Paper February 2004 'Moving Towards Total Water Cycle Management in Western Australia, Appendix 3 (Case Study- Yarra Yarra; new drainage in rural lands), p. 30-34.

Appendix III

Surveyor's Report

Survey of Yarra Yarra Catchment Basin 618

September 2005

By Dene Solomon

Surveyor and Planner

Yarra Yarra Catchment Management Group

Perenjori

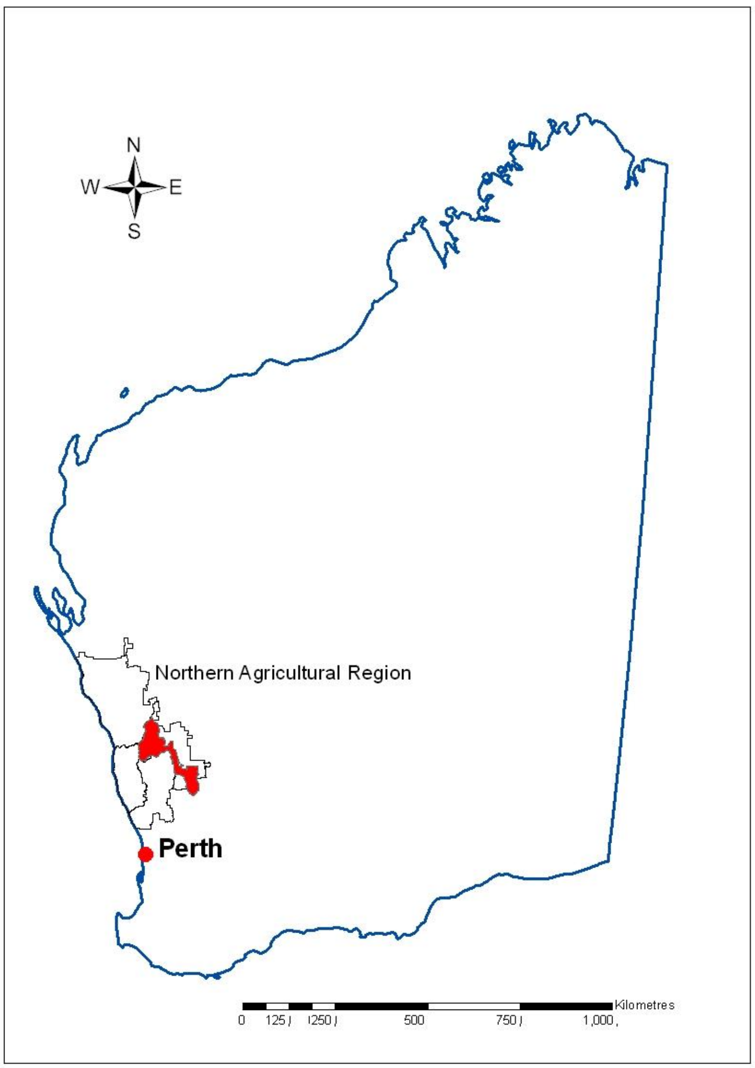

Fig. 1. Location of the Yarra Yarra Catchment Basin (Basin 618)

Background

The Yarra Yarra Catchment Management Group has extensive Geographical Information System (GIS) coverage within Basin 618.

This basin consists of

- In excess of 1 million hectares of agricultural land.
- 3086 kms of identified streamlines.
- 808 local road crossings of these streamlines

Within this basin, GIS data enables the Yarra Yarra Catchment Management Group to interpret and expand on its knowledge base with Arcview software. Existing topographic data for valley floors, provided by the Department of Land Information (DLI), has proved inadequate for an accurate assessment of streamline gradients. Using existing 2 m contours, low gradients within valleys make it impossible to identify natural creeklines or the lowest point on valley floors. This does not allow for meaningful hydrological assessments or on-ground decisions.

The significant survey products required to conduct a hydrological assessment in each subcatchment include

- area of catchment
- length of streamline
- gradient of streamline
- disposal point

Using the survey marks supplied by DLI makes it possible to gather information on the same coordinate system currently in use through our GIS system. Matching data can be imported into our GIS system and used immediately with existing GIS files. The data is then available now and at any time in the future. It can also be transferred to outside organisations. In conjunction with both Main Roads and BG&E (consulting engineers), we used this survey data to calculate volumes of runoff during given rainstorm events. This enables floodway and culvert dimensions to be determined for each road crossing.

We also produced long-section graphs along valley floors after accurate surveying (see example attached -- Fig. 2). Graphs of this kind are valuable tools to visually assess the possibilities for drainage within each subcatchment

Objective of Survey Component

The purpose of the survey was to construct detailed Digital Elevation Models (DEMs) for valley floors in the Yarra Yarra Catchment. The DEMs then allow GIS shape files to be developed, such as

- contour maps
- long-sections
- valley cross-sections
- gradients
- maximum and minimum stream elevations

Table 1. Summary of valley-floor survey in the 11 zones of the Yarra Yarra Catchment.

Zone	**Area (ha)**	**Length of main streamline (km)**	**Average grade of streamline (%)**	**Fall from top of streamline to disposal (m)**	**RTK points in subcatchment survey(s)**
Burakin	44 979	32	0.23	74	8 963
Kalannie	137 688	27	0.25	68	3 283
Jibberding	64 974	21	0.26	54	4 326
Mongers	78 584	23	0.28	64	18 753
Goodlands	109 305	27	0.21	56	6 241
Perenjori	83 684	17	0.21	35	12 236
Darling Creek	128 891	56	0.12	67	2 308
Bowgada	65 509	45	0.22	98	3 994
E. Three Springs	91 222	17	0.27	46	2 236
Morawa	50 161	26	0.24	62	4 217
Canna Gutha	202 019	34	0.24	82	754

Surveying Method

Surveying was carried out using the Real Time Kinematic (RTK) method with Sokkia instrumentation (Sokkia Radian, Sokkia Co. Ltd, Japan). This involved sending continuous positional corrections, via a radio link, from a base station at a known point to a roving instrument.

A four-wheel motorbike (quad) was used as the rover (Fig. 3), with obvious access advantages over other vehicles. The bike's stability also made accurate measurements possible. Survey points were picked up every 25 m, either on grid system or along topographic breaks. Figure 4 shows an example of a survey layout. Each survey (i.e. each subcatchment) required between 1 000 and 20 000 points. Minimum accuracy was 50 mm in both horizontal position and height.

All points were recorded in relation to the Australian Geodetic Datum 1984 (AGD84) and the Australian Height Datum (AHD). Each survey was closed to a known location, using the established national network of Standard Survey Marks (SSMs) and Bench Marks (BMs).

Using this system, rather than a series of local grids, allows the processed data to link with our GIS. It also means that new survey data can be incorporated into an existing DEM at any time. The DEMs created by this process are a long-term asset to the Yarra Yarra Catchment Management Group – they are in a format that readily permits calculations, they are accessible to outside organisations, and they allow for future control surveys and checks.

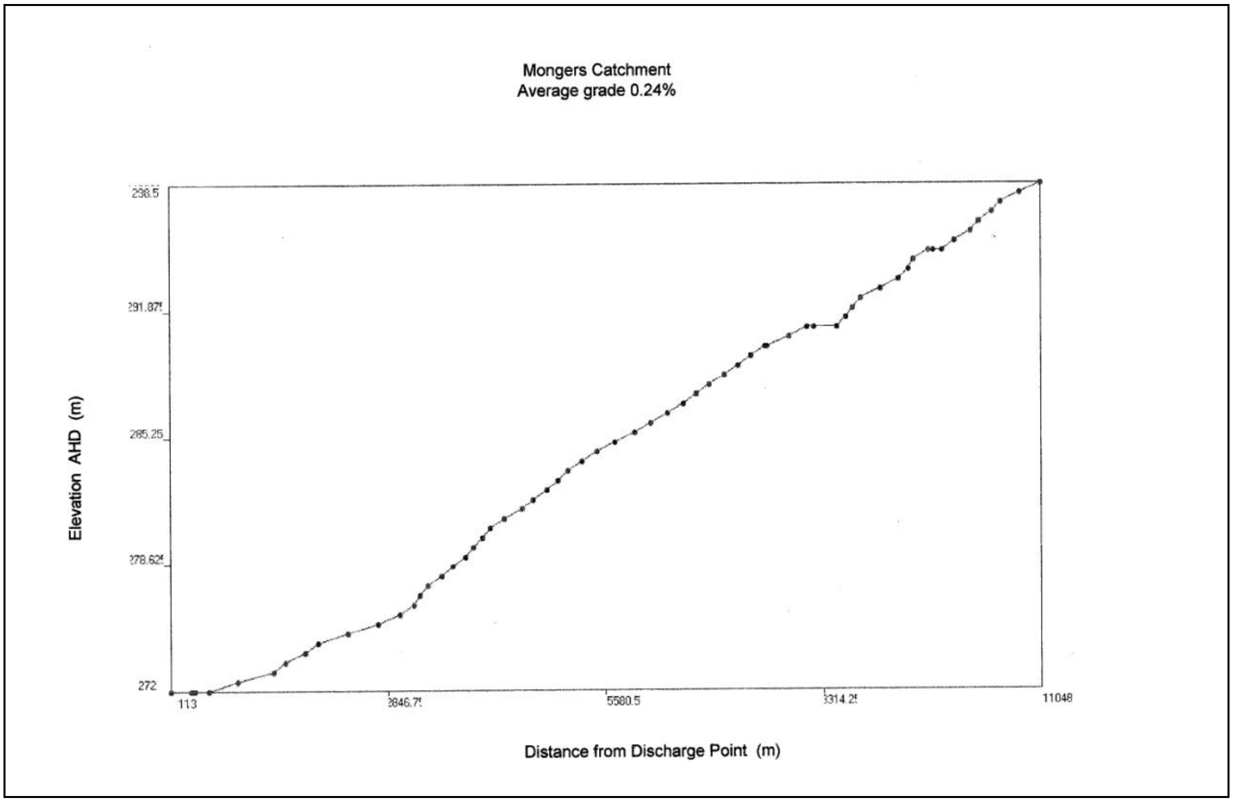

Fig. 2. Long-section view of a proposed drain, redrawn from the Digital Elevation Model (DEM).

Fig. 3. Four-wheel bike set up as a rover with RTK survey equipment.Explaining to local farmers how and why we are doing the survey.

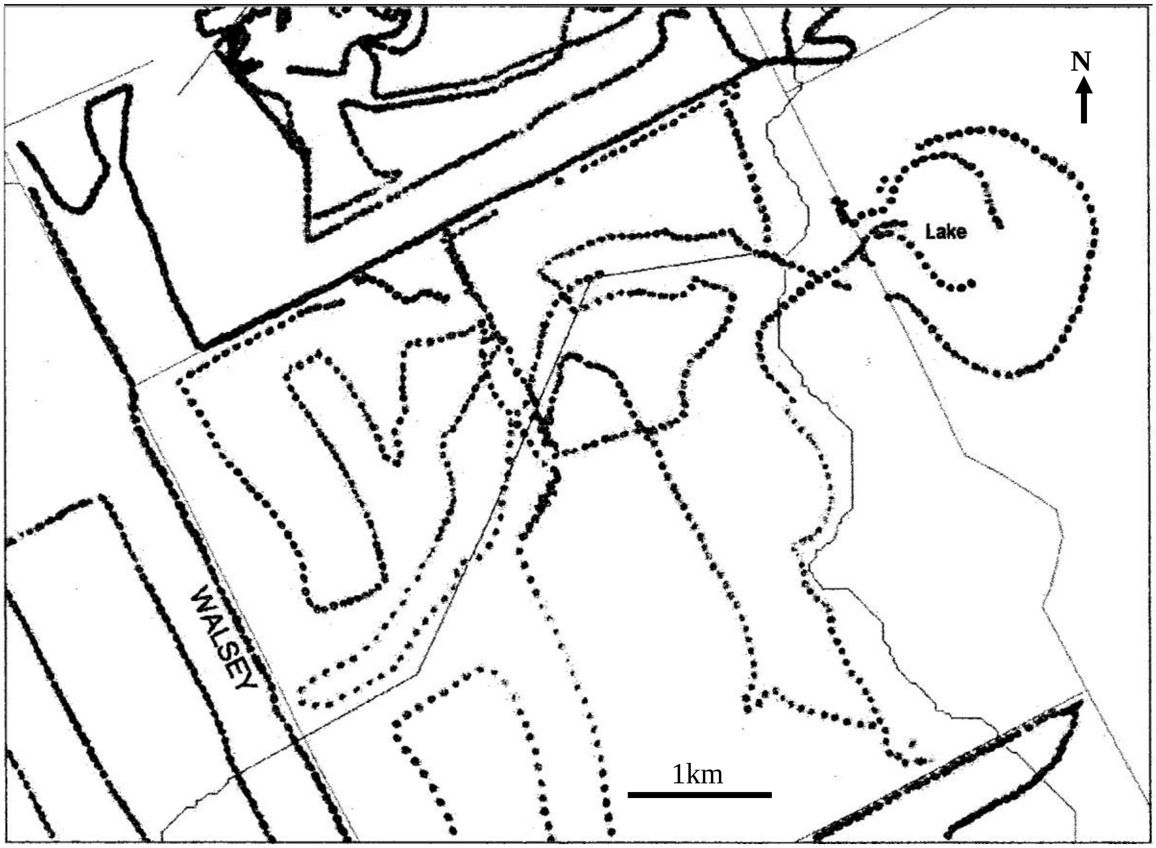

Fig. 4. Points picked up in a typical subcatchment RTK survey.
Each dot represents a point with known coordinates and height to an accuracy of 50mm or better.

Conclusions

1. Although gradients are very low at times, the overall gradient in each of the investigated subcatchments makes delivery to the lake system an engineering possibility.

2. The horizontal (positional) accuracy of the survey exceeds the needs of our group. However, alternatives (such as the publicly available Landmonitor DEM) lack the precision required for height.

3. It will take an additional 6-12 months to fully survey each valley floor within the relevant zones.

4. The survey gave landholders over the whole region an opportunity to meet Yarra Yarra staff and to discuss their concerns. The general consensus was that it was good to see us achieving something in the field and they hoped to see more of it.

5. Data is easily transferred to outside sources for further investigation, making it valuable as a planning tool for the Yarra Yarra Catchment Management Group.

Appendix IV

Engineer's Report on proposed MU55 drain

BG
&E
CONSULTING
ENGINEERS

PERTH
SYDNEY
DUBAI

PERENJORI DRAINAGE STRATEGY

WATERWAYS INVESTIGATION OF YARRA YARRA LAKES SUB-CATCHMENT

Prepared for:

Yarra Yarra Catchment Management Group
Perenjori

Date: 7 September 2005

Ref. P05042 Report No. 01 Rev 0

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TABLE OF CONTENTS

Date	Rev	Reason for Issue	Author	Review/Approval
7/09/05	0	Issue for client review	Patrick Thompson	

1 INTRODUCTION & BACKGROUND

BG&E Pty Ltd have been engaged to carry out hydrological and hydraulic analysis to complement the drainage strategy being prepared by the Yarra Yarra Catchment Management Group (YYCMG) for the Perenjori area.

The drainage strategy involves cutting drainage channels and constructing earth levees to separate groundwater and surface water flows. A typical cross section has been provided by the YYCMG. The groundwater flow is carried in a central channel, cut below the existing ground level, which follows the main steam channels. Levees are constructed either side of the central channel, forming two side channels that carry the surface flow.

Where the proposed channels and levees cross existing roads, waterways structures are required to carry the flow over / under the road. The scope of this report includes seven road crossings within a limited catchment area nominated by the YYCMG.

Hydrological analysis has been carried out to determine design flows for each crossing. Hydraulic analysis is then carried out to determine culvert sizes, floodway lengths and minimum levee heights.

2 SURVEY INFORMATION

The catchment area to be investigated was nominated by the YYCMG. Survey consisting of a ground model with a 2.0m contour interval was provided. Cross sections at each of the seven road crossings in the catchment were also provided. The crossings considered are listed below. A locality map is provided in Appendix A.

Crossing 1 Barker Road between Wilder Road and Maya East Road

Crossing 2 Richards Road between Wilder Road and Dinnie Road

Crossing 3 Wasley Road between Wilder Road and Dinnie Road

Crossing 4 Dinnie Road between Richards Road and Wasley Road

Crossing 5 Richards Road between Dinnie Road and Buntine East Road

Crossing 6 Dinnie Road between Richards Road and Wasley Road

Crossing 7 Wasley Road between Dinnie Road and Buntine East Road

3 HYDROLOGICAL ANALYSIS

Catchment areas for each crossing were identified using the ground survey provided, and were also checked using 1:100,000 scale topographic maps.

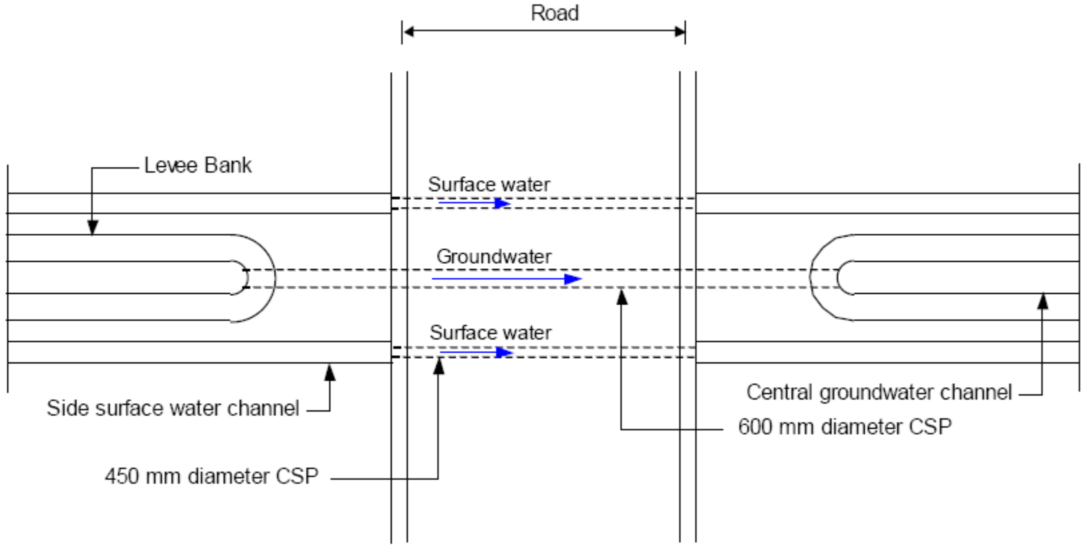
Design flows for each catchment were calculated using the Rational and Index Flood Methods in accordance with Australian Rainfall & Runoff (1987).

As the proposed drainage channels and levees effectively split the catchment into two separate sections, catchment areas were identified and design flows calculated separately for each sub-catchment (labelled as 'left' and 'right'). Design flows for each catchment are tabulated in Appendix B.

4 DRAINAGE SYSTEM GEOMETRY

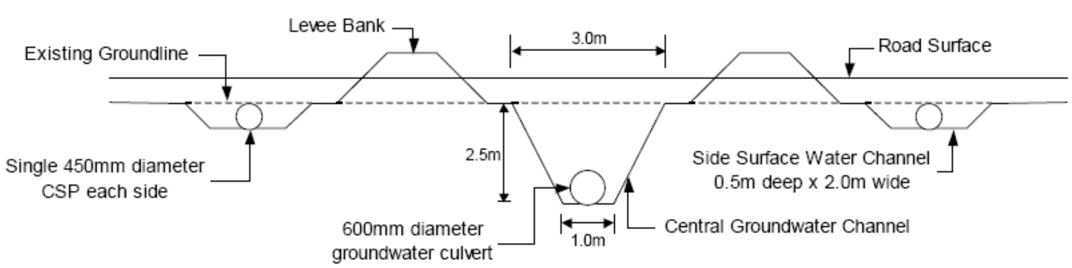
Typical sections and crossing configurations were provided by the YYCMG and are presented below. The levee banks terminate in a closed loop approximately 10m upstream and downstream of each road crossing. A single 600 mm diameter CSP culvert carries the groundwater under the road. Surface water flows under the road through 450 mm diameter CSP culverts for small flood events, and flows over the road (in a floodway situation) for larger flood events.

Where two groundwater drainage channels merge at a stream junction, a groundwater culvert is used to join the channels (similar to above), without hindering flow in the surface water channels.

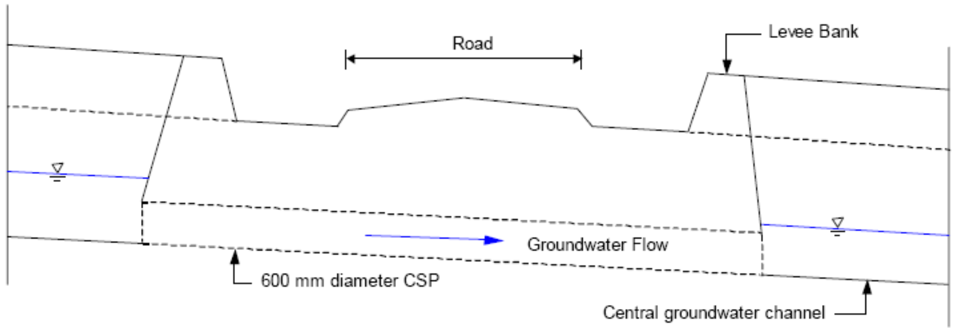


Plan view: showing separation of groundwater and surface water flow

(Levee banks keep groundwater and surface water separate)

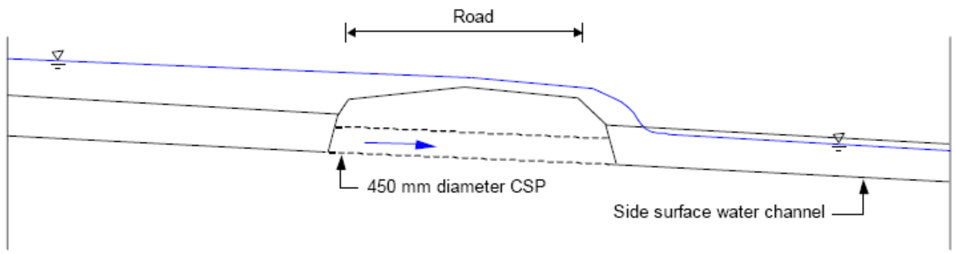


Typical section at road crossing



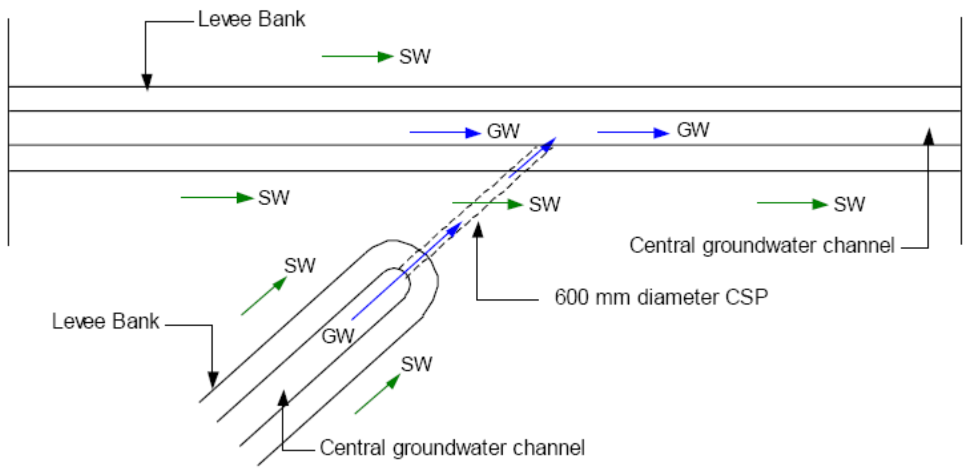
Long section through central groundwater channel

(all groundwater flow is through 600 mm culvert)



Long section through side surface water channel

(Flow is partly through 450 mm culvert and partly over floodway)



Plan view: showing junction of two groundwater channels

(GW = Groundwater, SW = Surface Water)

5 DESIGN CRITERIA

The YYCMG highlighted the importance of avoiding mixing of the groundwater and surface water flows. Minimum levee heights were calculated based on surface water levels not overtopping the levee for flood events up to and including the 100-year average recurrence interval (ARI) event.

Culverts sizes at each crossing were nominated based on providing a serviceability level of 2 years. A crossing is considered to be serviceable when the critical depth of flow over the road is less than 200mm (equivalent to a floodway head of 300mm). For larger flood events the crossing is considered to be impassable, however given the relatively small size of the catchments, the roads would only be closed for short periods (around 2-6 hours).

450mm was adopted as the typical culvert size based on minimising changes to the existing road levels.

6 HYDRAULIC ANALYSIS

Hydraulic analysis was carried out to determine the water levels at each crossing, the number and size of culverts required, and the minimum levee heights to prevent surface water from overtopping the levees and mixing with the groundwater flow.

The analysis was based on survey cross sections provided by the YYCMG, and was carried out using the software program HEC-RAS Version 3.1.2. Boundary flow conditions were calculated using the software program AFFLUX.

Simple HEC-RAS models were used to assess the flow at each crossing and included the road, culverts, immediately adjacent cross sections, and levees. The water levels were calculated for two cases. Firstly, for the design flows for the left and right sub-catchment, flowing in their respective channel (ie. all the left side flow in one side channel, and all the right side flow in the other side channel). Secondly, as the left and right flows merge immediately upstream of each crossing, the water levels were also calculated for the combined total flow. This covers the case a small distance upstream of the crossing (prior to the flows merging), and also the case at the crossing (where the flow has merged), ensuring that the levees are high enough for both cases. Levee heights of between 1.0 and 1.8m are required at the crossings investigated.

The analysis indicated that a single 450mm diameter corrugated steel pipe culvert was required for each side surface flow channel (ie. two pipes at each crossing). No changes to the existing road levels are required to achieve the adopted 2-year serviceability level. Floodway water depths up to 180mm for the 2-year ARI flood event were calculated. It is assumed that a 500mm deep surface flow channel will be excavated on each side of the central groundwater channel.

Velocities for the surface water channels were calculated to determine if any scour protection was required. Due to the shallow grades at all crossings, the 100-year ARI flood event velocities were typically found to be less than 2.5 m/s, and thus scour protection is not recommended.

At Crossing 6 the stream consists of a small channel on the side of a larger valley. When the capacity of the small channel is reached, any excess will flow over the banks and into the larger valley below. At this location, the levee banks need only be higher than the stream banks, and detailed analysis has not been carried out. As the road is higher than the stream bank, flow over the road is extremely unlikely.

At Crossing 7, the ground survey provided was insufficient to carry out the analysis as performed on the other crossings. However, sufficient road survey was available to conduct a simple floodway analysis. Water levels were calculated based on the assumption that the crossing acts as a broad-crested weir.

Results for the seven crossings considered are tabulated below, and presented in Appendix C.

Crossing 1	Q_2 Floodway Depth:	180 mm
Barker Road	Q_{100} Water Level:	293.84 m RL
	Existing Ground Level:	293.02 m RL (Approx.)
	Levee Height:	1.0 m Nominal (0.82 m min.)
	Culverts:	1 x 450 diameter CSP each side
Crossing 2	Q_2 Floodway Depth:	90 mm
Richards Road	Q_{100} Water Level:	298.21 m RL
	Existing Ground Level:	297.74 m RL (Approx.)
	Levee Height:	1.0 m Nominal (0.47 m min.)
	Culverts:	1 x 450 diameter CSP each side
Crossing 3	Q_2 Floodway Depth:	170 mm
Wasley Road	Q_{100} Water Level:	283.01 m RL
	Existing Ground Level:	281.39 m RL (Approx.)
	Levee Height:	1.8 m Nominal (1.62 m min.)
	Culverts:	1 x 450 diameter CSP each side
Crossing 4	Q_2 Floodway Depth:	70 mm
Dinnie Road	Q_{100} Water Level:	302.37 m RL
	Existing Ground Level:	301.80 m RL (Approx.)
	Levee Height:	1.0 m Nominal (0.57 m min.)
	Culverts:	1 x 450 diameter CSP each side
Crossing 5	Q_2 Floodway Depth:	60 mm
Richards Road	Q_{100} Water Level:	309.28 m RL
	Existing Ground Level:	308.81 m RL (Approx.)
	Levee Height:	1.0 m Nominal (0.47 m min.)
	Culverts:	1 x 450 diameter CSP each side
Crossing 6	Levee Height:	1.0 m Nominal
Dinnie Road	Culverts:	1 x 450 diameter CSP each side
Crossing 7	Q_2 Floodway Depth:	120 mm
Wasley Road	Q_{100} Water Level:	285.11 m RL
(Approximate only due to limited survey data)	Existing Ground Level:	284.37 m RL (Approx.)
	Levee Height:	1.0 m Nominal (0.74 m min.)
	Culverts:	1 x 450 diameter CSP each side

7 CONCLUSION

This report has investigated the proposed Perenjori Drainage Strategy. For a nominated catchment area, hydrological analysis has been carried out for each sub-catchment to determine design flows at seven road crossings. Hydraulic analysis has been carried out to determine culvert requirements, floodway depths, and minimum levee heights, with the aim of avoiding mixing between groundwater and surface flow for floods up to and including the 100-year ARI event.

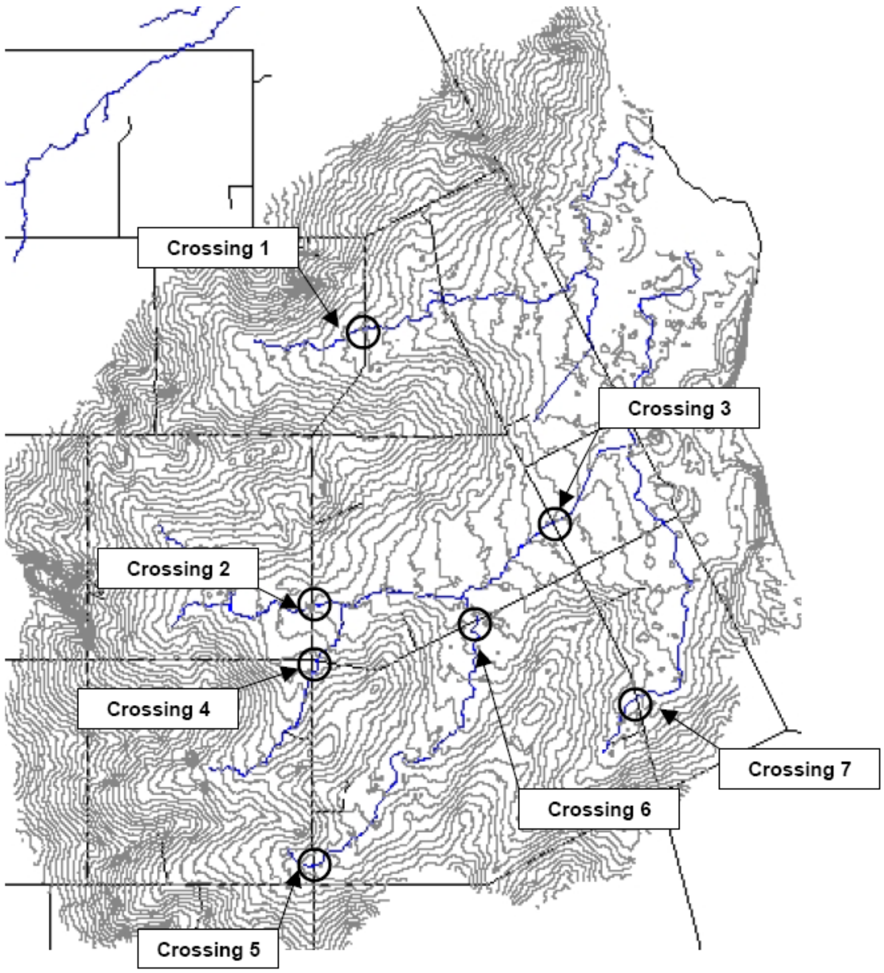
The investigation has shown that the proposed sub-surface drainage system is able to be implemented without adverse implications on the existing surface water flow conditions or existing road crossing serviceability levels.

APPENDIX A

Locality Map & Contour Plan

Locality Map

(Not to scale)



Contour Plan

(Not to scale)

APPENDIX B

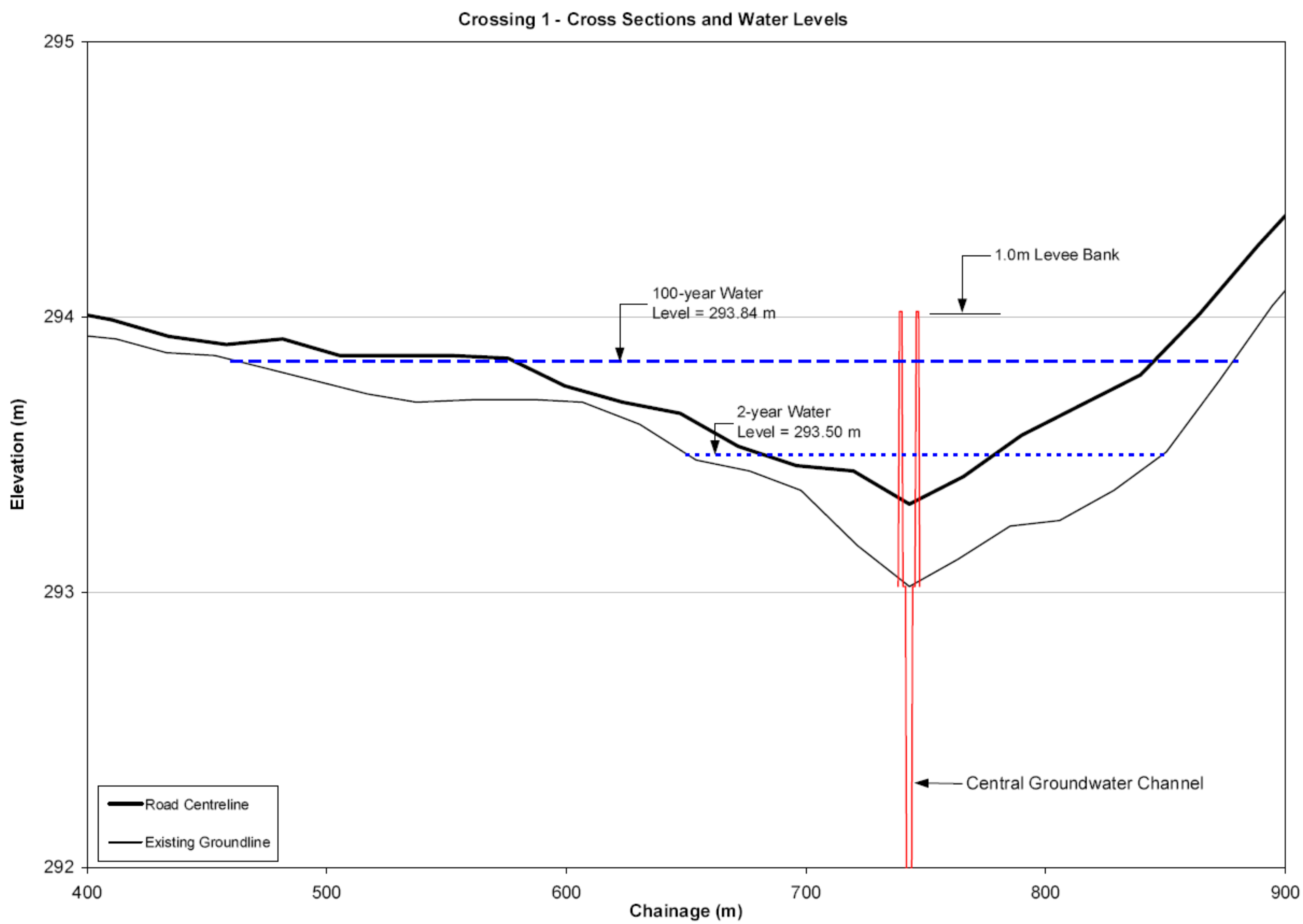
Hydrological Analysis

Hydrology Summary - Perenjori Drainage

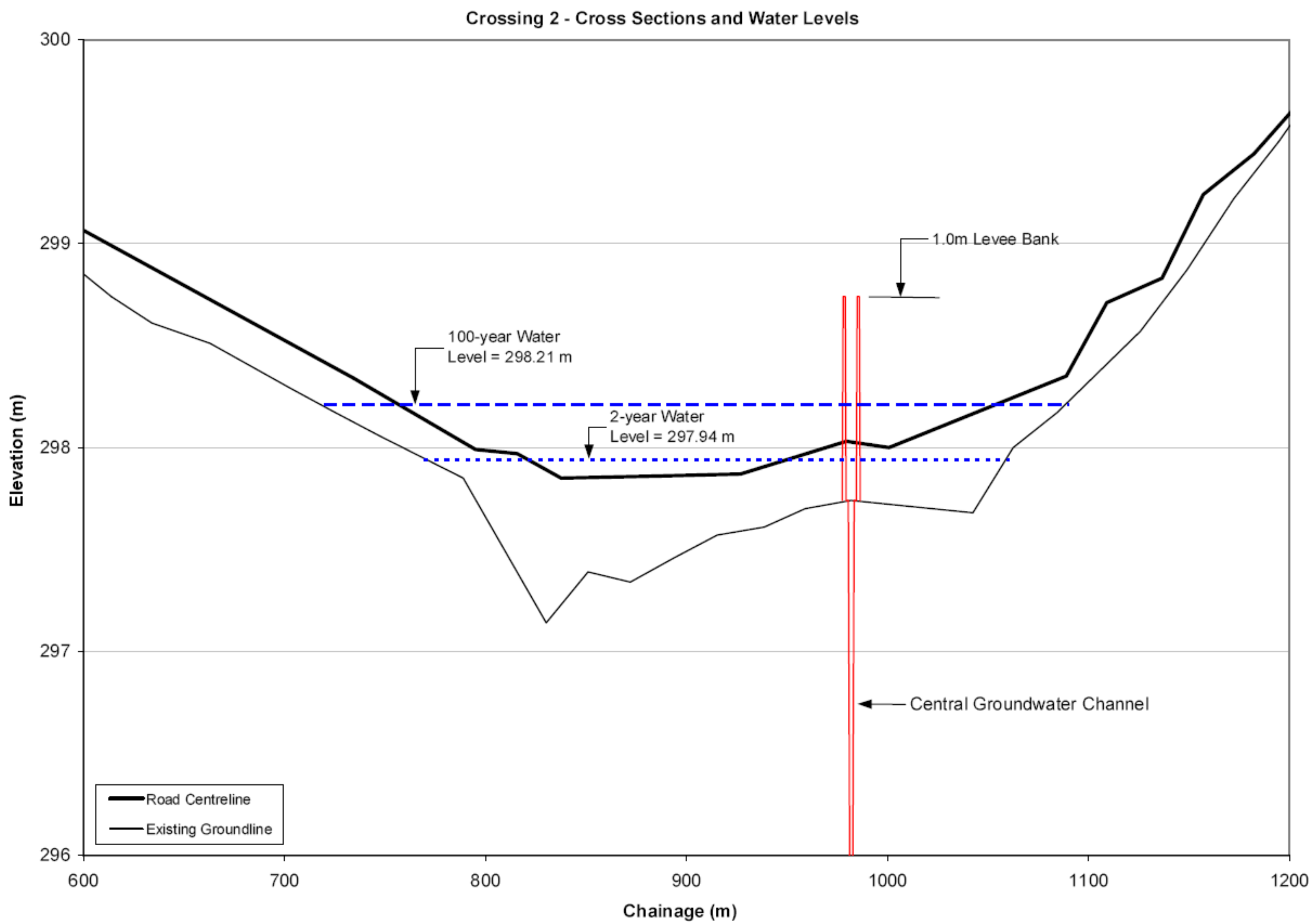
Catchment	Method	Left						Right						Total					
		Q2	Q5	Q10	Q20	Q50	Q100	Q2	Q5	Q10	Q20	Q50	Q100	Q2	Q5	Q10	Q20	Q50	Q100
		2	*5*	*10*	*20*	*50*	*100*	*2*	*5*	*10*	*20*	*50*	*100*	*2*	*5*	*10*	*20*	*50*	*100*
1	Rat 1	1	2	3	6	10		2	4	8	14	25		3	6	11	20	35	
	Rat 2	1	2	3	5	8		2	4	7	13	21		3	6	10	18	30	
	Ind 1	1	1	2	4	8		1	2	4	7	12		2	3	6	11	20	
	Ind 2	1	2	4	7	14		2	4	7	13	25		3	6	12	21	39	
	DESIGN	**1**	**2**	**3**	**6**	**10**	**15**	**2**	**4**	**7**	**13**	**25**	**41**	**3**	**6**	**10**	**19**	**35**	**56**
2	Rat 1	1	2	3	6	10		3	6	11	19	34		4	8	14	25	45	
	Rat 2	1	2	3	5	9		3	6	10	18	30		4	8	13	23	39	
	Ind 1	1	1	3	5	9		1	3	5	9	17		2	4	8	14	26	
	Ind 2	1	3	5	9	17		3	6	11	19	35		4	9	16	28	53	
	DESIGN	**1**	**2**	**4**	**6**	**10**	**15**	**3**	**6**	**11**	**19**	**34**	**53**	**4**	**8**	**15**	**25**	**44**	**68**
3	Rat 1	1	3	6	10	18		5	10	19	35	61		6	14	24	45	79	
	Rat 2	2	3	6	10	17		5	11	20	34	57		7	15	25	44	74	
	Ind 1	1	3	5	9	17		2	5	9	16	31		4	8	14	25	48	
	Ind 2	3	6	10	18	35		6	12	22	38	72		8	17	32	56	107	
	DESIGN	**2**	**3**	**6**	**10**	**20**	**34**	**5**	**11**	**20**	**35**	**60**	**90**	**7**	**14**	**26**	**45**	**80**	**124**
4	Rat 1	1	2	4	7	12		1	2	3	6	11		2	4	7	13	24	
	Rat 2	1	2	4	6	11		1	2	3	6	10		2	4	7	12	21	
	Ind 1	1	1	3	5	9		1	1	3	5	9		1	3	5	9	18	
	Ind 2	1	3	5	9	17		1	3	5	9	16		3	6	10	18	34	
	DESIGN	**1**	**2**	**4**	**7**	**12**	**18**	**1**	**2**	**3**	**6**	**12**	**20**	**2**	**4**	**7**	**13**	**24**	**38**
5	Rat 1	1	2	4	7	12		1	2	4	7	13		2	4	8	14	25	
	Rat 2	1	2	4	6	10		1	2	4	6	11		2	4	7	13	21	
	Ind 1	1	1	2	4	8		1	1	3	4	8		1	3	5	9	17	
	Ind 2	1	3	5	8	15		1	3	5	8	16		2	5	9	16	31	
	DESIGN	**1**	**2**	**4**	**7**	**12**	**18**	**1**	**2**	**4**	**7**	**13**	**21**	**2**	**4**	**8**	**14**	**25**	**39**
6	Rat 1	1	3	5	9	17		2	4	6	12	20		3	6	11	21	37	
	Rat 2	1	3	5	9	15		2	4	6	11	19		3	7	12	20	34	
	Ind 1	1	2	4	7	13		1	2	4	8	15		2	5	8	15	28	
	Ind 2	2	4	8	14	27		2	5	9	16	30		4	9	17	30	57	
	DESIGN	**1**	**3**	**6**	**10**	**18**	**28**	**2**	**4**	**6**	**12**	**20**	**29**	**3**	**7**	**12**	**22**	**38**	**58**
7	Rat 1	1	2	4	7	13		1	3	5	9	16		2	5	9	16	29	
	Rat 2	1	2	4	7	11		1	3	5	8	13		2	5	8	14	24	
	Ind 1	1	1	3	4	8		1	2	3	5	9		1	3	5	9	18	
	Ind 2	1	3	5	8	16		1	3	5	10	18		3	6	10	18	34	
	DESIGN	**1**	**2**	**4**	**7**	**13**	**21**	**1**	**3**	**5**	**9**	**16**	**25**	**2**	**5**	**9**	**16**	**29**	**45**

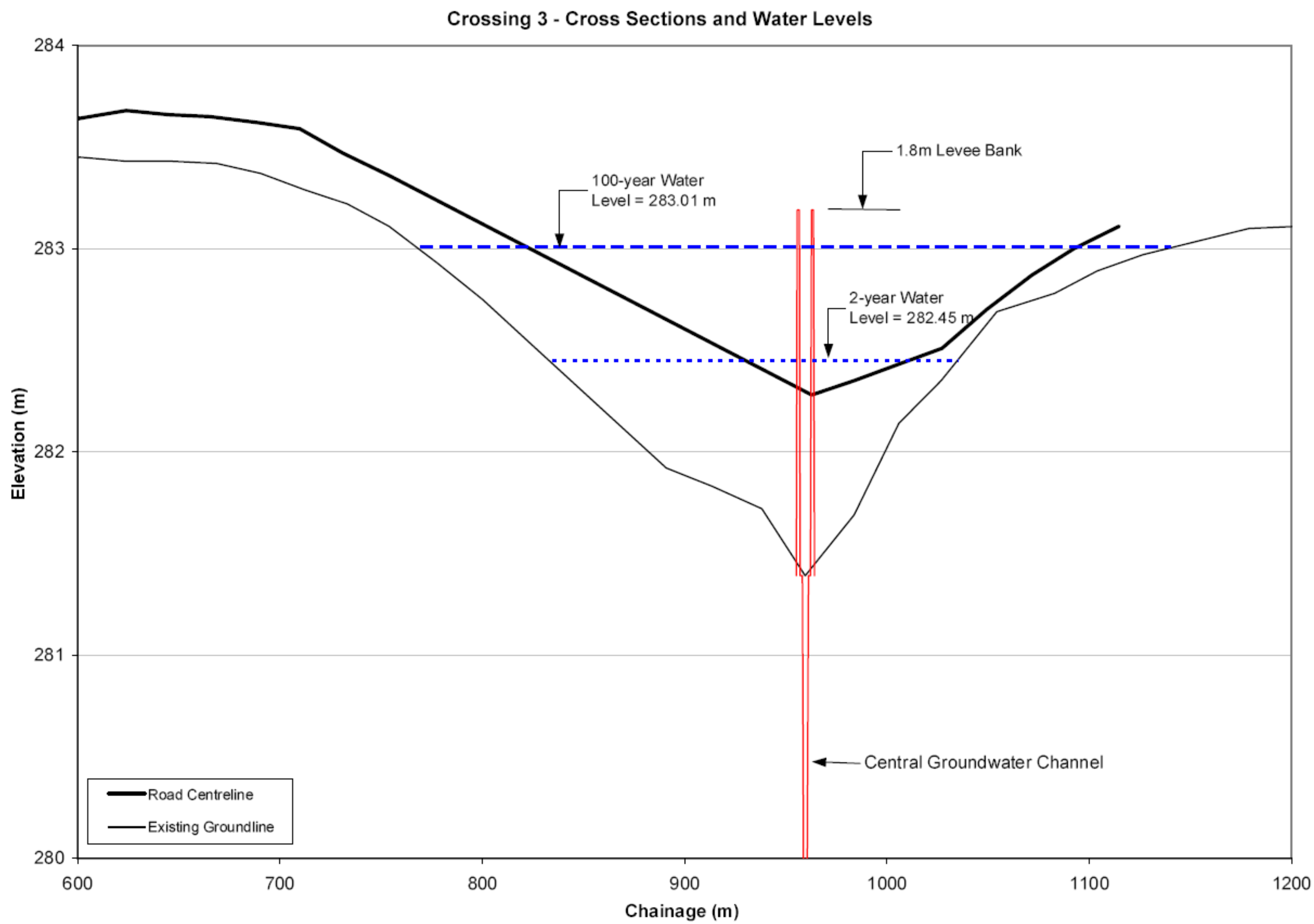
APPENDIX C

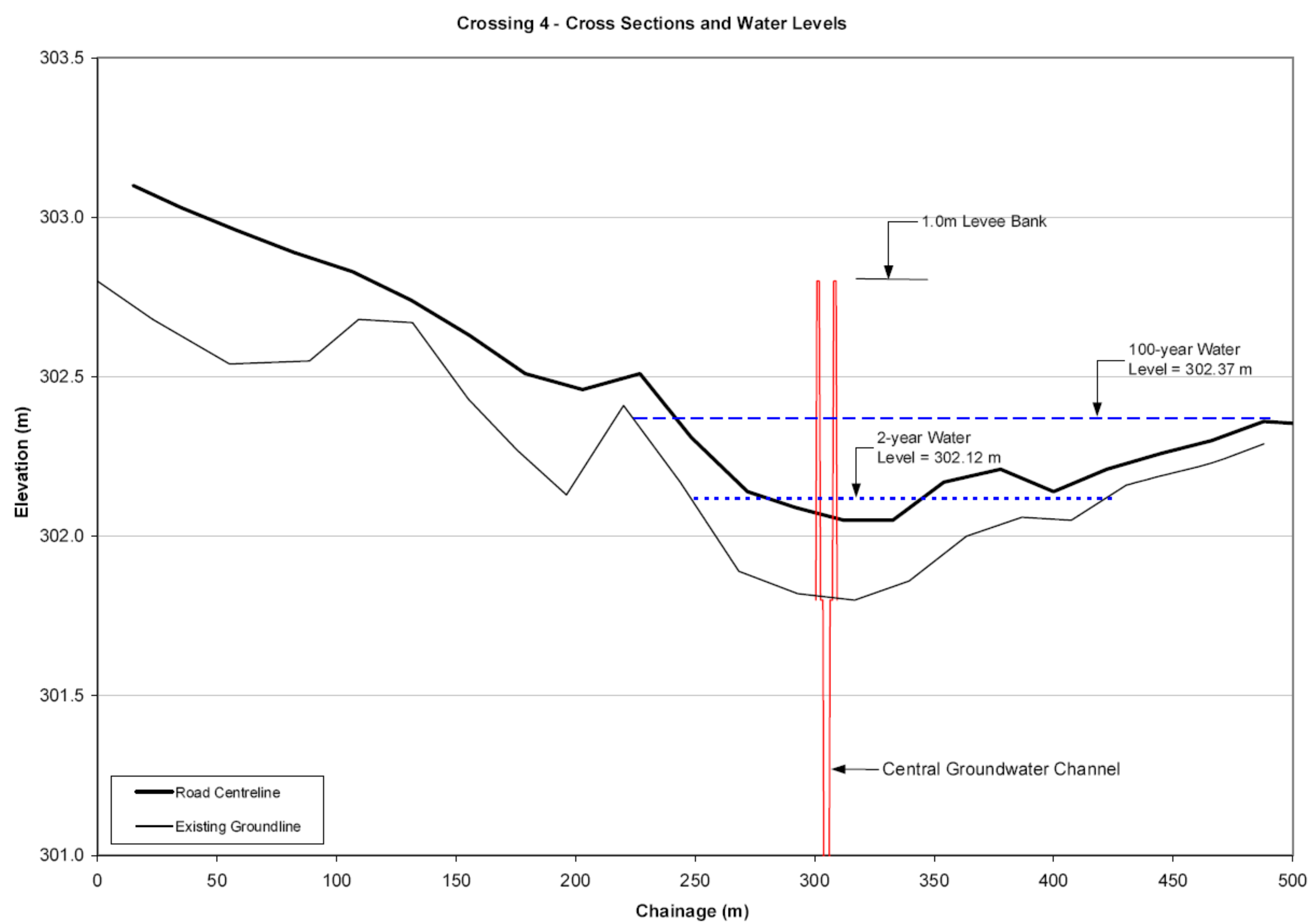
Hydraulic Analysis

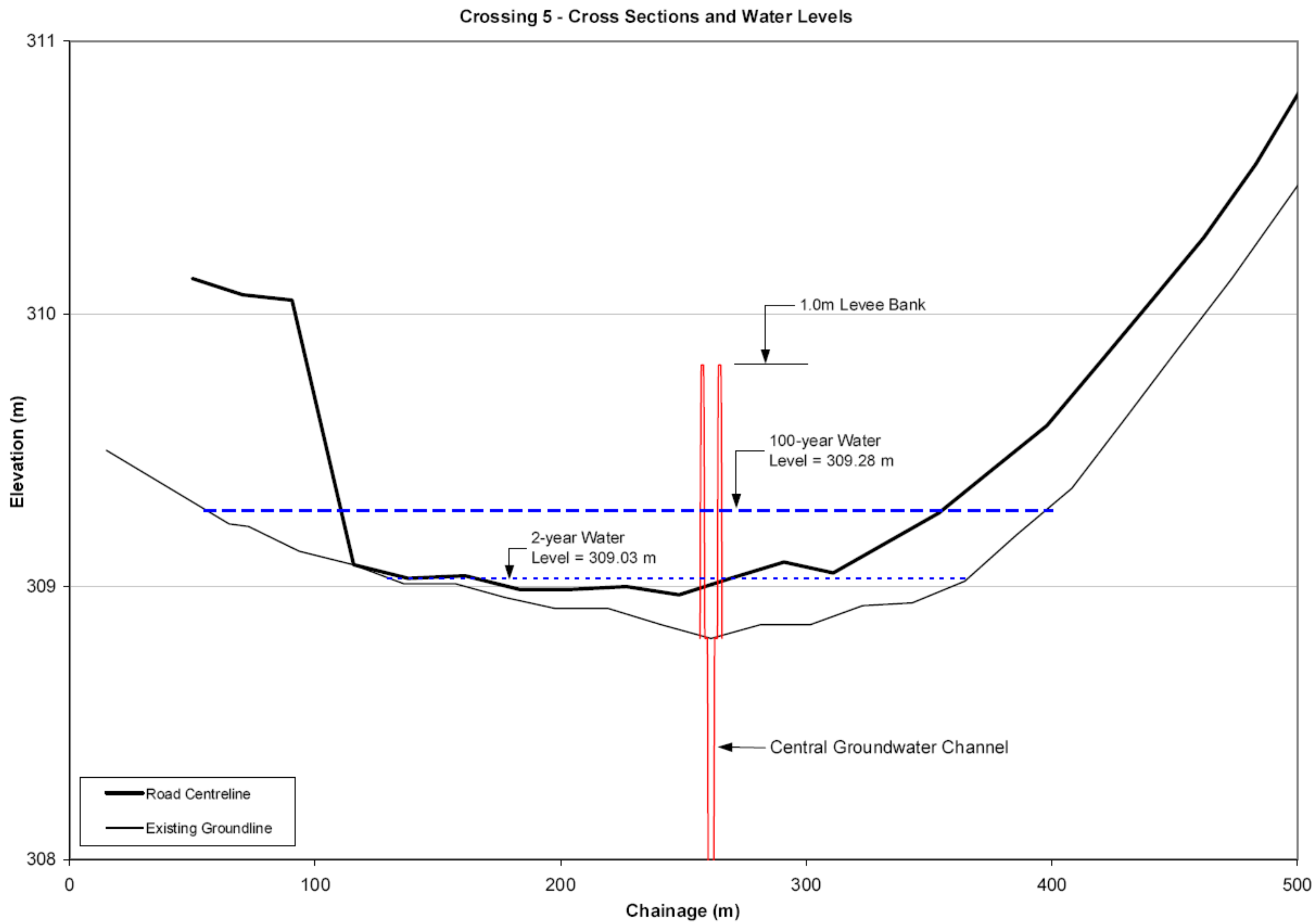


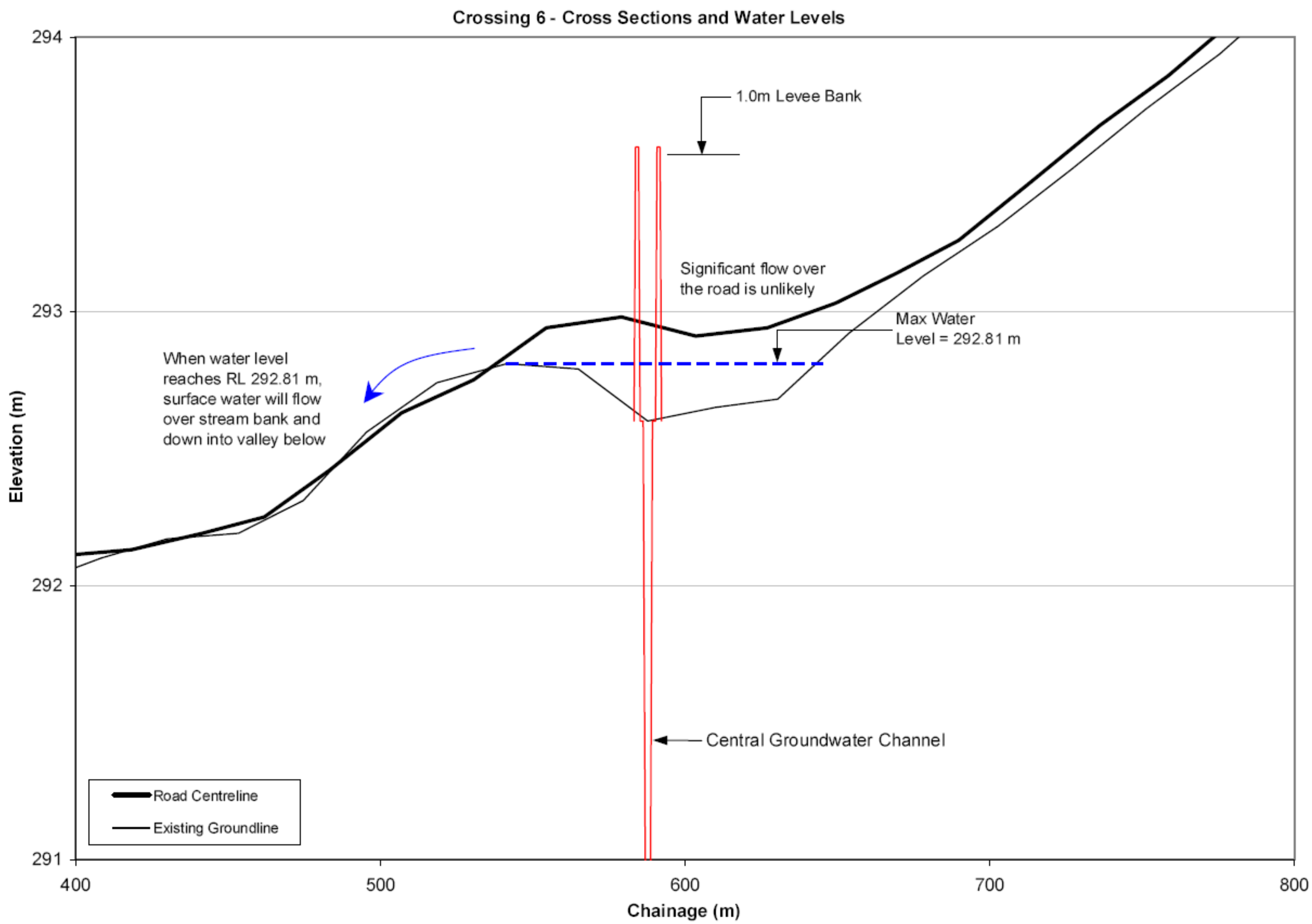
Crossing 1 - Cross Sections and Water Levels
295
294
293
292
Elevation (m)
400
500
600
700
800
900
Chainage (m)
100-year Water
Level = 293.84 m
2-year Water
Level = 293.50 m
1.0m Levee Bank
Central Groundwater Channel
Road Centreline
Existing Groundline

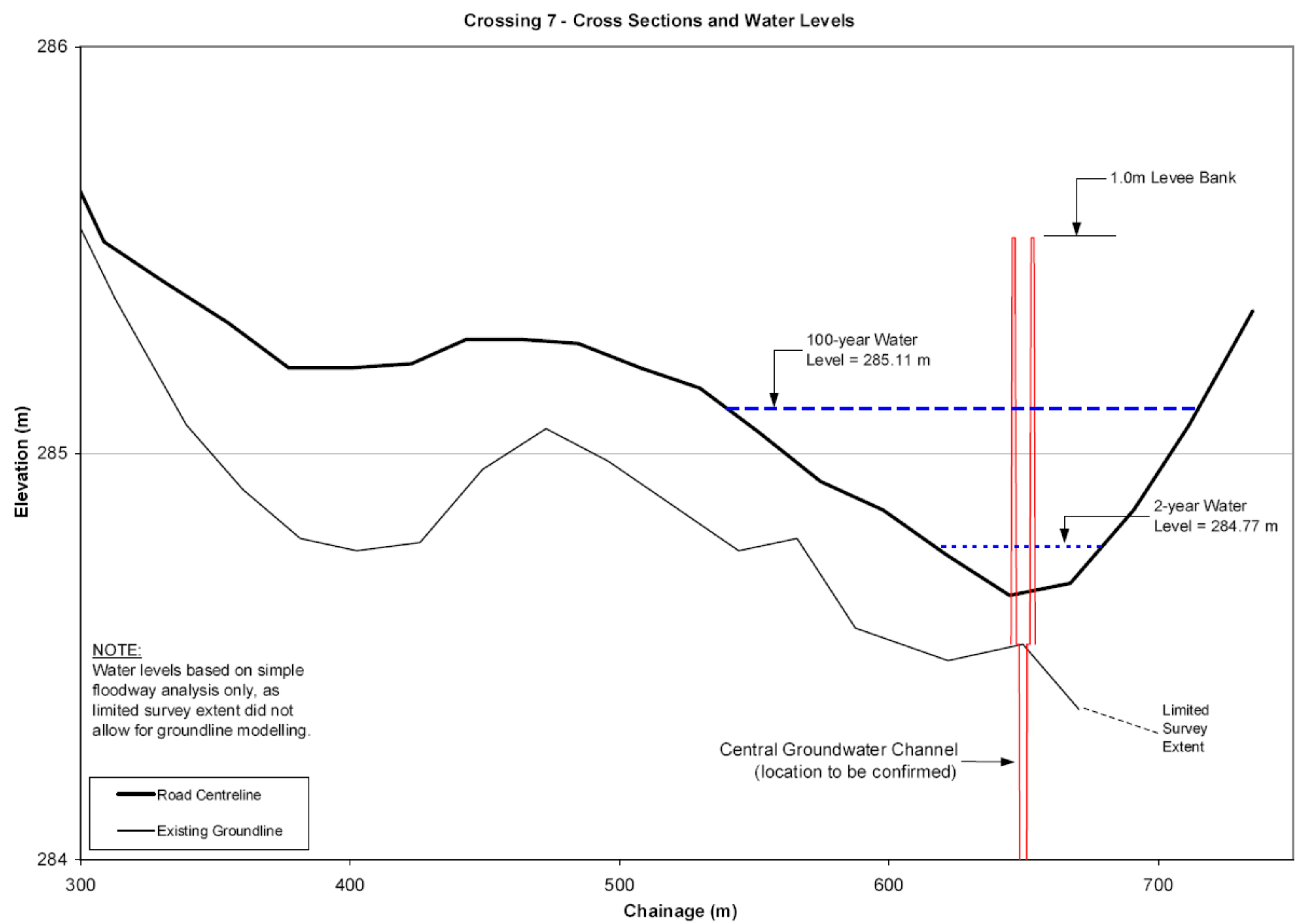

Crossing 2 - Cross Sections and Water Levels
300
299
298
297
296
Elevation (m)
600
700
800
900
1000
1100
1200
Chainage (m)
100-year Water
Level = 298.21 m
2-year Water
Level = 297.94 m
1.0m Levee Bank
Central Groundwater Channel
Road Centreline
Existing Groundline


Crossing 3 - Cross Sections and Water Levels
284
283
282
281
280
Elevation (m)
600
700
800
900
1000
1100
1200
Chainage (m)
1.8m Levee Bank
100-year Water
Level = 283.01 m
2-year Water
Level = 282.45 m
Central Groundwater Channel
Road Centreline
Existing Groundline

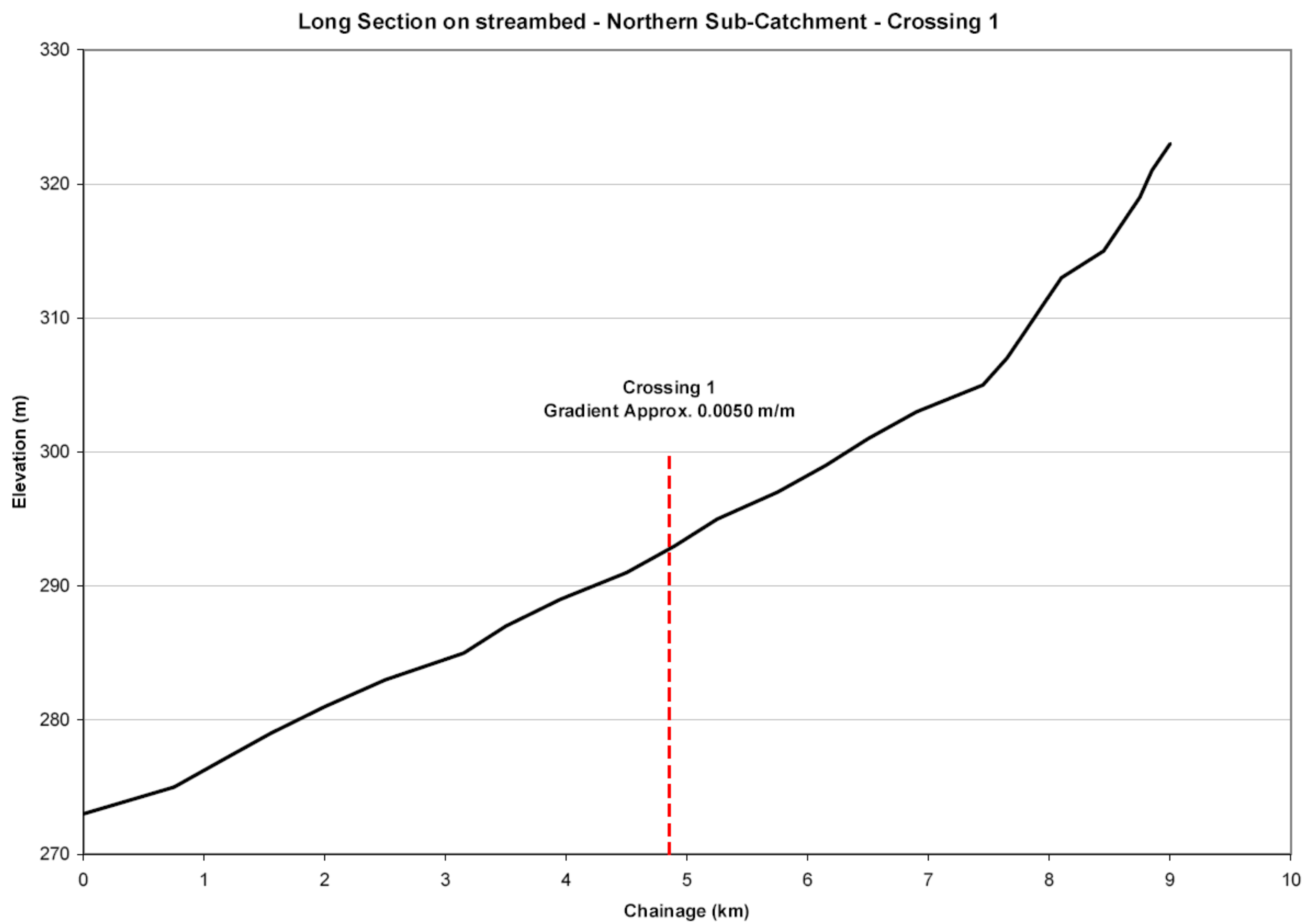

Crossing 4 - Cross Sections and Water Levels
303.5
303.0
302.5
302.0
301.5
301.0
Elevation (m)
0
50
100
150
200
250
300
350
400
450
500
Chainage (m)
1.0m Levee Bank
100-year Water
Level = 302.37 m
2-year Water
Level = 302.12 m
Central Groundwater Channel
Road Centreline
Existing Groundline

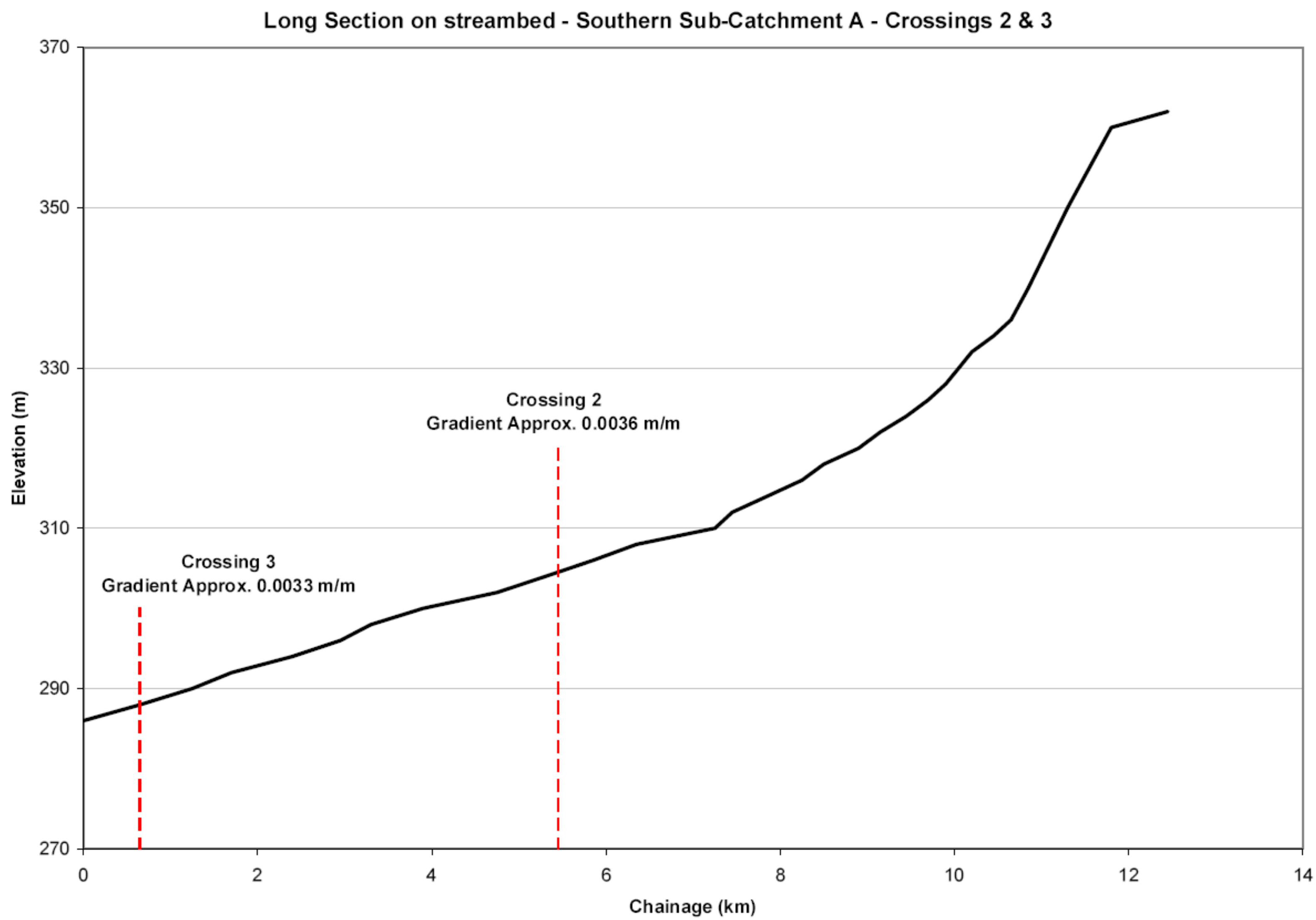

Crossing 5 - Cross Sections and Water Levels
311
310
309
308
Elevation (m)
0
100
200
300
400
500
Chainage (m)
1.0m Levee Bank
100-year Water
Level = 309.28 m
2-year Water
Level = 309.03 m
Central Groundwater Channel
Road Centreline
Existing Groundline

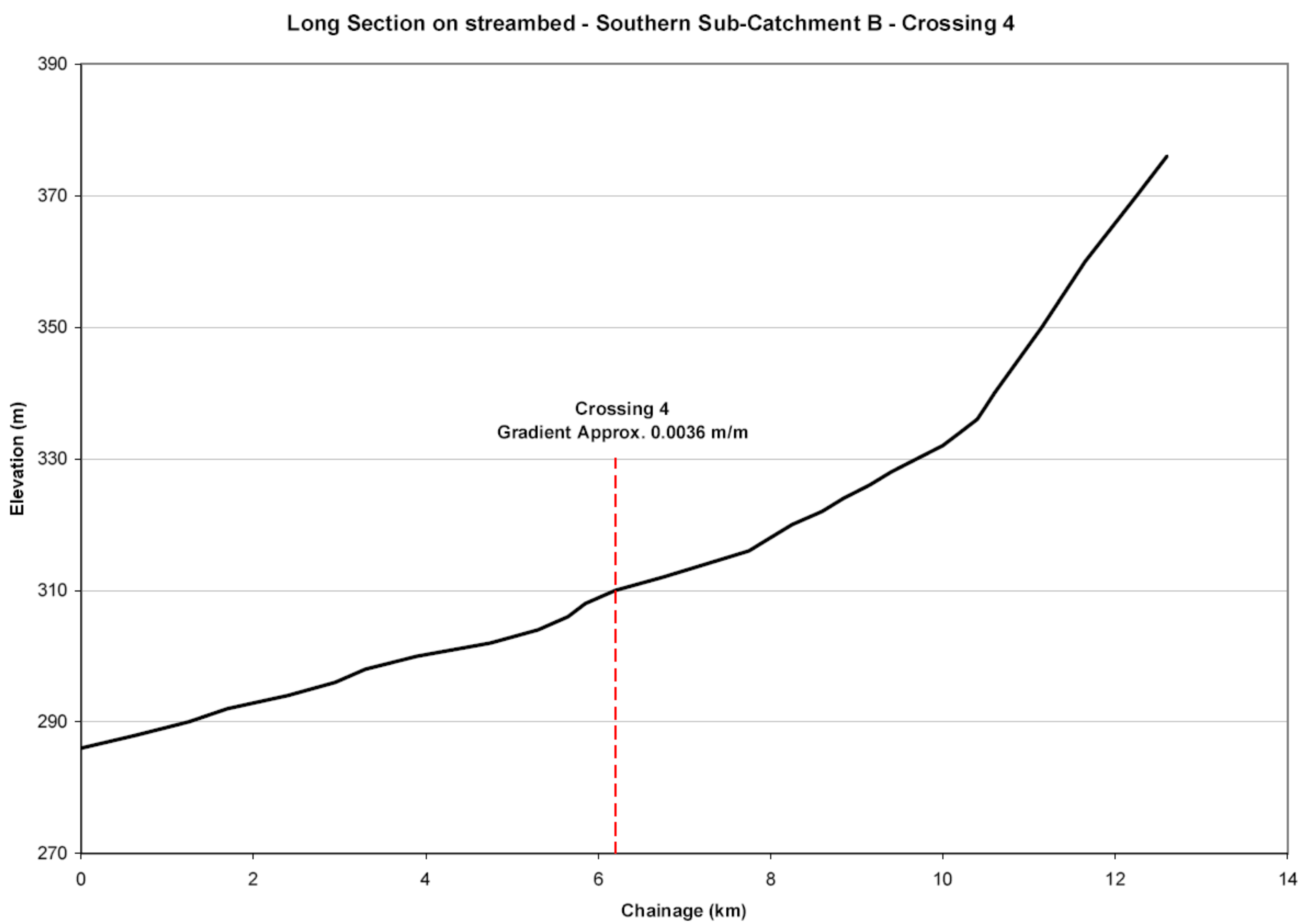

Crossing 6 - Cross Sections and Water Levels
294
293
292
291
400
500
600
700
800
Elevation (m)
Chainage (m)
1.0m Levee Bank
Significant flow over the road is unlikely
Max Water Level = 292.81 m
When water level reaches RL 292.81 m, surface water will flow over stream bank and down into valley below
Central Groundwater Channel
Road Centreline
Existing Groundline



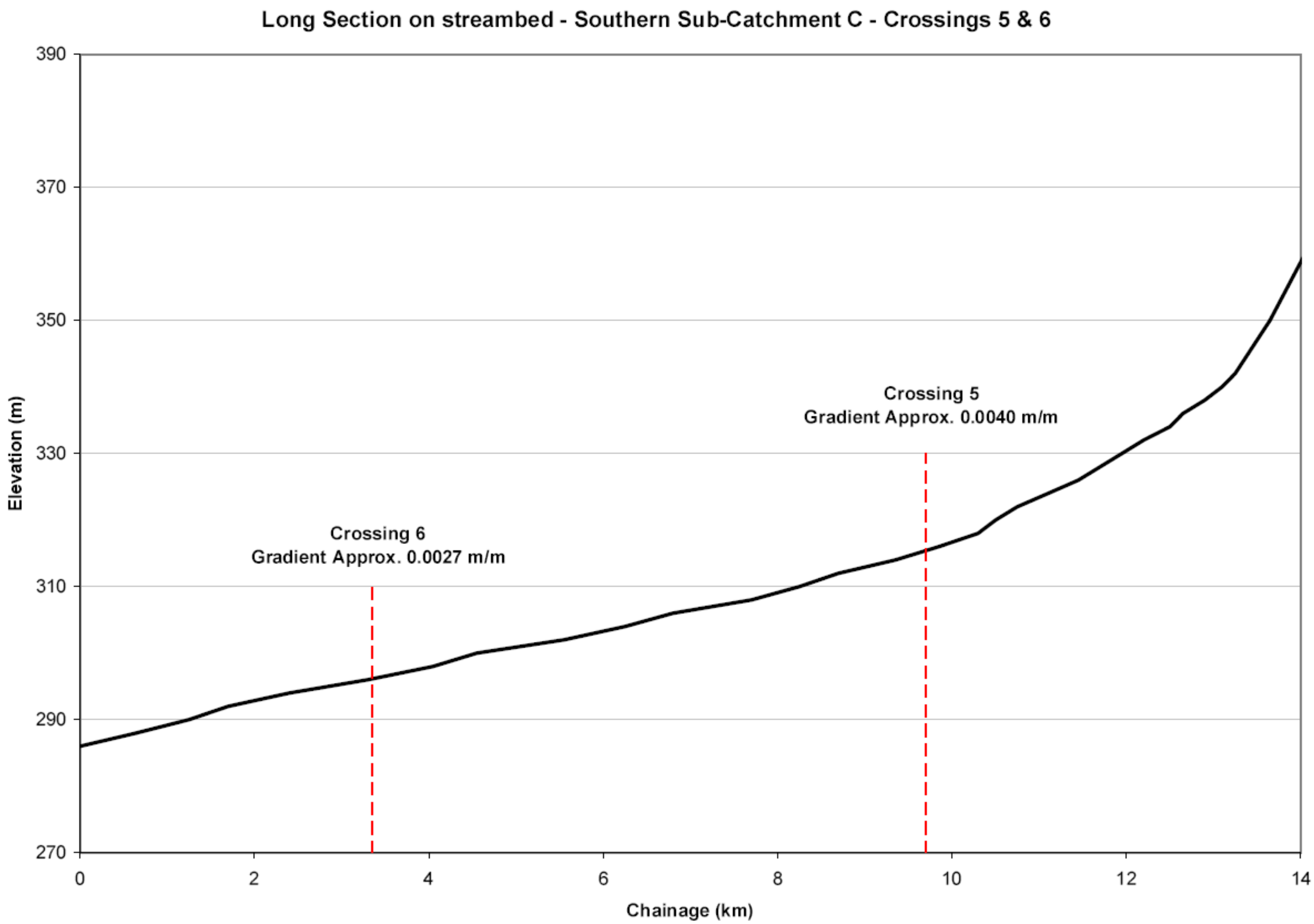
Crossing 7 - Cross Sections and Water Levels
286
285
284
Elevation (m)
300
400
500
600
700
Chainage (m)
1.0m Levee Bank
100-year Water
Level = 285.11 m
2-year Water
Level = 284.77 m
Limited
Survey
Extent
Central Groundwater Channel
(location to be confirmed)
NOTE:
Water levels based on simple
floodway analysis only, as
limited survey extent did not
allow for groundline modelling.
Road Centreline
Existing Groundline

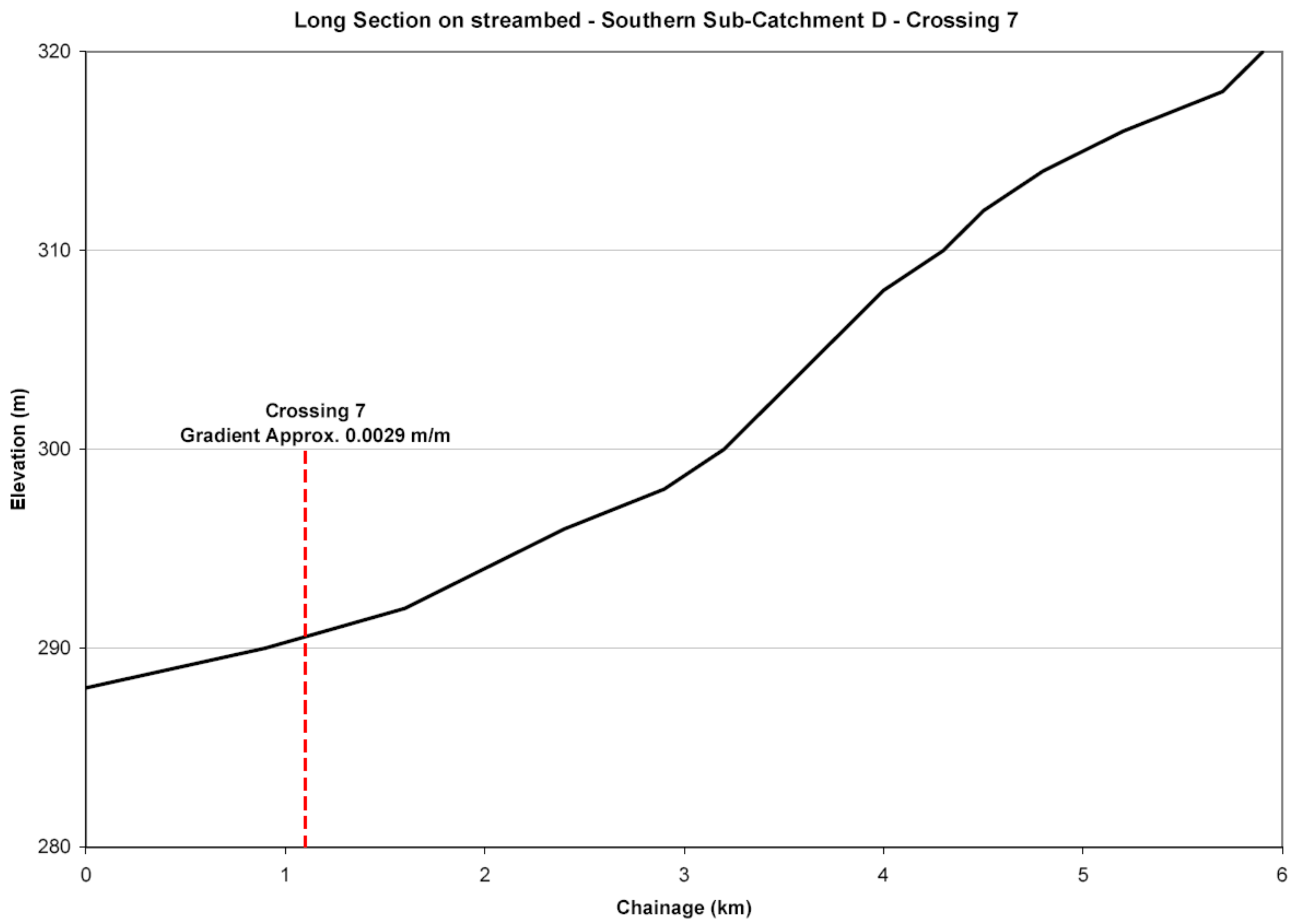

Long Section on streambed - Northern Sub-Catchment - Crossing 1
Elevation (m)
330
320
310
300
290
280
270
0
1
2
3
4
5
6
7
8
9
10
Chainage (km)
Crossing 1
Gradient Approx. 0.0050 m/m


Long Section on streambed - Southern Sub-Catchment A - Crossings 2 & 3
Elevation (m)
370
350
330
310
290
270
Chainage (km)
0
2
4
6
8
10
12
14
Crossing 2
Gradient Approx. 0.0036 m/m
Crossing 3
Gradient Approx. 0.0033 m/m



Long Section on streambed - Southern Sub-Catchment B - Crossing 4
Crossing 4
Gradient Approx. 0.0036 m/m
Elevation (m)
390
370
350
330
310
290
270
0
2
4
6
8
10
12
14
Chainage (km)


Long Section on streambed - Southern Sub-Catchment C - Crossings 5 & 6
Elevation (m)
390
370
350
330
310
290
270
Chainage (km)
0
2
4
6
8
10
12
14
Crossing 6
Gradient Approx. 0.0027 m/m
Crossing 5
Gradient Approx. 0.0040 m/m


Long Section on streambed - Southern Sub-Catchment D - Crossing 7
Crossing 7
Gradient Approx. 0.0029 m/m
Elevation (m)
320
310
300
290
280
Chainage (km)
0
1
2
3
4
5
6

Appendix V

Ecologist's Report on Biodiversity Assets

Ecological Assessment of the Yarra Yarra Catchment

Final Report

Prepared for

Yarra Yarra Catchment Management Group

February 2002

Prepared by

Regeneration Technology Pty Ltd

Yarra Yarra Catchment Management Group

Ecological Assessment of the Yarra Yarra Catchment

Final Report

Prepared by

Regeneration Technology Pty Ltd

February 2002

CONTENTS

SUMMARY

Land salinisation, salinisation of inland waters and maintaining biodiversity are considered the highest priority environmental issues in Western Australia. Salinity poses a threat to the States land, water and biological resources in addition to rural infrastructure assets. The major management issue within the Yarra Yarra catchment relates to increased volumes of surface water entering the lakes system. The effect of this on the lakes is unknown which potentially has far reaching consequences from both an agricultural and conservation perspective.

The Yarra Yarra catchment and lakes system is situated in the Northern Agricultural Region of Western Australia and covers an area of 4,258,102 ha. The key objective of this study was to determine the current status of the biological resources in the catchment. The study involved three main components; a desktop study, ground truthing of remnant vegetation and a fauna assessment. A total of 112,842 ha of remnant vegetation (in over 7,500 individual remnants) was identified in the desktop study for the Yarra Yarra catchment. Of this, 2,852 remnants were visited during the field survey, located within fifteen sub catchments. Overall, this represents 27,165ha or approximately 25% of the remnant vegetation identified in the Yarra Yarra catchment being field assessed. The remnants were broadly assessed for vegetation communities, condition, fencing status, grazing presence and salt status. This data was compiled into the GIS database which is the catchment group houses in its Regional Information Centre (RIC) at Perenjori.

Five dominant vegetation types were recognised and from this the communities most vulnerable to salinity were identified. Over 64% of remnant vegetation assessed in the Yarra Yarra catchment was considered to be in pristine or excellent condition (condition rating 1-2 and 2-3).

Succession of vegetation communities (ie change from one community type to another) is clearly evident in the Yarra Yarra Catchment. The progression of the succession vegetation (ie samphire) is most obvious in areas where water logged woodlands have been replaced by the lower growing succulents. The successional vegetation was most obvious in the valley floors of the sub catchments indicating these are the areas that are the most severely affected by hydrological changes as a result of land clearing. By contrast the woodland and shrubland vegetation associated with the lakes system was mostly unaffected by encroachment of samphire vegetation. Areas surrounding the lakes that showed evidence of successional vegetation are narrow bunds of woodland vegetation often found between seasonally flooded basins at the bottom end of the subcatchments (valley floors) and the adjoining lake. This indicates an altered hydroperiod in the seasonally flooded basin and is affecting woodland vegetation close to the lakes. Woodland and shrubland vegetation surrounding the lakes away from these outlet zones of the subcatchments was generally in good condition with no evidence of samphire encroachment. This indicates that altered hydrology resulting from land clearing has had virtually no impact to date on the woody vegetation associated with the lakes.

Vegetation distribution, representativeness and condition are important considerations in vegetation conservation and management, particularly in relation to setting priorities. With the large size of the catchment, it was necessary to start with a broad brush approach, collating existing data to give an overview for the region and to determine an approach to collect additional meaningful data. This report describes collected and collated base line data and is intended as a starting point for the management of the biological resources of the Yarra Yarra catchment and for future studies on the whole catchment and its sub catchments.

PART ONE - INTRODUCTION

1.1 BACKGROUND

Land salinisation, salinisation of inland waters and maintaining biodiversity have been identified as the three highest priority environmental issues in Western Australia (Western Australian State of Environment Report, 1998). Salinity threatens not only the conservation of the States land, water and biological resources but also rural infrastructure assets (ie: roads, railways, town buildings and services). It is one of the State's most serious environmental problems, with far reaching economic and biological consequences. More than 1.8 million hectares (10%) of cleared farmland in WA is salt affected, with a larger area considered under threat (George et al., 1997; Agriculture WA *et al*., 1996)

Salinity has developed from the widespread clearing of deep-rooted native vegetation and its replacement with annual crops and pastures. Clearing of native woodland and forest vegetation decreases transpiration and interception, and increases runoff and recharge. George *et al*. (1997) estimated that in low rainfall areas (350 mm/yr) the average annual recharge rate increased from <0.01-0.1 mm/yr to at least 6-10 mm/yr after clearing. This report also estimated that groundwater levels have risen by more than 30m and aquifers now exist where none had before clearing. Salts brought to the surface are washed down streams, river and lake systems, affecting their value as both a potential potable water supply and as environmental and recreational assets. More than 80% (by length) of stream riparian zones are seriously degraded by salinity (Agriculture WA *et al*., 1996). Salinity in streams is increasing at a rate of 10-90mg/L each year (George *et al*., 1997). The salinisation of land and water resources also kills native vegetation, causes degradation and loss of flora and fauna habitats, thereby reducing biological diversity both on land and in water ways. Salinity poses a major threat to the remaining remnant vegetation, wetlands, unique species and ecosystems.

Remnant vegetation on both private and public land throughout WA is being rapidly degraded by dryland salinity, inundation, soil structure decline and weed invasion. Previous studies, such as the Western Australian Salinity Action Plan (1996) and George *et al*., (1997) have found that remnant vegetation in low lying parts of catchments and sub catchments are considered to be most at risk of salinity. Consequently, there is a need to identify those remnants that have high conservation values for which cost effective recovery plans or protection plans can be developed and implemented (Briggs, 2001). It is estimated that without corrective action over 80% of remnant vegetation on private land and as much as 50% within public reserves could be lost over the next 30-50 years (Agriculture WA *et al*., 1996).

Successful salinity control requires the management of saline groundwater. A variety of methods for addressing salinity and increasing watertables have been proposed. These solutions have been well detailed in the Western Australian Salinity Action Plan (1996). Broadly, they have ranged from revegetation and conservation of remnant vegetation, alternative crops (deep rooted crops) to engineering solutions such as saline drainage systems. Saline drainage systems may be either surface and subsurface (deep) drainage or drainage arising from groundwater pumping (Regeneration Technology, 2000). The beneficial and detrimental effects of agricultural drainage on the long term viability of remnants in representative areas needs to be established. Studies should address both the short term and long term effects of drainage on the remnants. An integrated approach to tackling land degradation problems uses farm planning to:

- reorientate paddock boundaries;
- revegetate and fence drainage lines;
- protect and connect existing vegetation;

- establish windbreaks
- replant on both recharge and degraded areas (Grein, 1994).

One fact is certain, solutions to land degradation, in particular salinity, require an integrated approach, linking planning and actions at effective scales (catchment, sub catchment as well as landholder levels) for landscape and habitat preservation and rehabilitation. Managing landscape processes and conserving species requires cooperation and action across a broad geographic area, encompassing different management groups. Management groups need to have access to cost effective methods of treatments and packages of biophysical information that can be used to design and predict the impact of physical and economic management systems (George *et al*., 1997).

For effective management, information on the biological and physical resources of an area is essential. An inventory of the biological and physical resources should include but not be limited to remnant vegetation extent, composition and condition, hydrology, tenure and cadastral information. This provides baseline data, which enables short and long term monitoring and assessment of the success of management techniques employed. The information gathered from previous studies, mapping and field surveys leads to the establishment of priority areas that can be targeted for management agreements, fencing subsidies and other incentive schemes.

The major management issues evident within the Yarra Yarra catchment relate to increased volumes of surface water entering the lakes system. The effect of the increased water volumes in the lakes is unknown. This potentially has far reaching consequences from both an agricultural and conservation perspective.

Western Australia's flora and fauna has been greatly diminished by land clearing and is further compromised by salinity.

1.2 STUDY AREA

The Yarra Yarra catchment and lakes system is situated in the Northern Agricultural Region of Western Australia. The Yarra Yarra catchment covers an area of 4,258,102 ha, encompassing several Shire boundaries. It stretches from Three Springs and Yarra Yarra Lake in the east, Lake Moore (not included in Yarra Yarra Catchment) in the west, Pastoral land in the north and to Burakin in the south (Map 1). Land uses are predominately wheat and sheep farming, with some alternative crops including lupins and plantation trees, such as oil mallees. The Yarra Yarra catchment contains 112,842 ha of remnant vegetation (in over 7,500 individual remnants). Approximately 74% (83, 534 ha) of remnants are located on privately owned land.

Study Area Map - include overview of WA, Yarra Yarra Catchments and individual named sub catchments.

The climate is described as warm Mediterranean, with winter dominated average annual rainfall of 388mm. Mean maximum daily temperatures ranged from 36^{o}C in January to 18^{o}C in July (Bureau of Meterology, 2001).

Approximately 60% of the north-eastern area of the catchment remains un-cleared as pastoral lease, and has not been considered in this study. The remainder of the Yarra Yarra catchment was divided up into 56 sub catchments based on ridge divides. Each individual sub catchment is managed by a Land Conservation District (LCD's). The Yarra Yarra Catchment Management Group is a community group that has formed to provide a united approach to the collection and dissemination of data and information to the entire catchment. The catchment group houses the data and referred to in this report in it's Regional Information Centre (RIC) at Perenjori.

According to the Interim Biogeographic Regionalisation of Australia, the Yarra Yarra catchment lies within the Eremaean subregion of Yalgoo (Thackway & Cresswell 1995). The Yarra Yarra Basin is very wide and flat with some of the most arable productive agricultural land lying across the broad valley floors. This is an area of low relief with a 65m decline in elevation from Lake Hillman to the bottom of Yarra Yarra Lake .

The Yarra Yarra lake system is a series of lakes, acting as a vast drainage system, terminating at the Yarra Yarra lakes themselves. The numerous lakes perform a similar function to the Yarra Yarra lakes in that they act as evaporation basins and discharge via groundwater, draining the whole catchment. Water flows through the lake system to the Yarra Yarra lakes.

The Yarra Yarra lakes at the bottom of the catchment extend for 28km in length and are 8.8km at their widest (Yestertener *et al*., 2000). At full capacity, they have a surface area of 127km^2 and are 2.1m deep. The lake system receives inflow of saline water from Mongers Lake to the east and from local ephemeral waterways such as Darlings Creek (Yesertener *et al*., 2000). Yesertener *et al.*, (2000) estimated the groundwater throughflow or discharge from the lake system to be approximately 0.3 M m3/yr. Soil types of the lakes include clay and sandy clay.

The presence of a palaeochannel underlying the Yarra Yarra lakes and the groundwater hydrochemistry demonstrate that the Yarra Yarra catchment and the Moore catchment are hydrogeologically linked (Yesertener *et al*., 2000). The palaelochannel provides a direct pathway for salts concentrated by evaporation in the lakes to flow beneath the surface divide and into the Moore River catchment. The groundwater salinity of the palaeochannel aquifer progressively decreases southwards from 280,000mg/L to 14,000mg/L, due to lateral recharge from Mesozoic sandstone aquifers (Yesertener *et al*., 2000). Survey of the lake shows that it has a total capacity of 200 M m^3, after which overflow to the Moore catchment will occur (Yesertener *et al*., 2000). The lakes are not known to have overflowed in recent times, however, in 1999 the lake rose to within 300 mm of overflowing. Generally the catchment is internally drained and discharges via ground water recharge and evaporation of the lakes.

1.3 OBJECTIVES

The key objective of this study was to determine the current status of the biological resources in the catchment. The key questions for the ecological component of this study were:

- What is there?
- How much is there?
- How reliable is existing data (especially Beards vegetation mapping of the region)
- Is it at risk? and
- What management strategies should be considered.

The overall aim of the Yarra Yarra Catchment Project is to prepare Catchment Management Plans for each of the sub catchments as a means of conserving the biological resources of the region while implementing management strategies to deal with salinity.

1.4 SCOPE

With the total area of the catchment being in excess of 1,000,000 ha it was necessary to start with a broad brush approach, collating existing data to give an overview for the region and to determine an approach to collect additional meaningful data. This report describes collected and collated base line data and is intended as a starting point for management of the biological resources of the Yarra Yarra catchment and future studies on the whole catchment and its sub catchments.

It was beyond the scope of this study to specifically assess what is in the lakes themselves, ie: fauna. Information was collated on water quality and soil type from previous studies and peripheral vegetation from ground truthing.

PART TWO - METHODOLOGY

A project methodology was defined which combined all the necessary steps outlined in the project description. The steps in this process can be separated into 3 main sections and are summarised as follows:

2.1 DESKTOP STUDY

The desktop study consisted of two parts; use of Arcview to identify remnant vegetation in the Yarra Yarra and the production of an inventory of available information. Each procedure is outlined separately.

2.1.1 IDENTIFICATION OF REMNANT VEGETATION BLOCKS.

Remnant vegetation within the Yarra Yarra Catchment was identified from Landsat TM Satellite Imagery obtained from the Spatial Resource Information Group at Agriculture WA. Perennial vegetation cover for the polygonized 1:100,000 scale mapsheets acquired was derived from Landsat Satellite Imagery 1995/96 and updated by AgWA from digital orthophotos acquired post 1995. This data includes principally native vegetation, with some pine and tagasaste plantations.

The remnant vegetation blocks were identified using Arcview software following the procedure outlined in the training session and the procedure brief (Appendix 1). The main steps in the process are outlined as follows:

- The polygonized Landsat imagery was limited to an individual sub catchment and assigned areas, with remnant vegetation blocks less than 1 ha being deleted.
- Each remnant vegetation block was assigned a unique identification number consisting of an abbreviated sub catchment name or number followed by a record number.
- Beard vegetation types and data were assigned to the remnant vegetation polygons.
- The percentage area was calculated for each vegetation association.

This procedure was repeated for each sub catchment, producing an individual shapefile for each sub catchment containing specific information relating to each sub catchment. Sub catchment no 31 and part of sub catchment no's 7 and 12 could not have the remnant vegetation blocks identified, using the above procedure, due to a lack in data coverage for these areas (both the AgWA data and original Landsat Imagery did not cover this part of the Yarra Yarra Catchment).

2.1.2 REVIEW AND COLLATION OF EXISTING DATA.

A thorough literature review was conducted using Biological Abstracts and web searches of agency databases to identify and locate existing reports, relating specifically to the Yarra Yarra Catchment and sub catchments and to salinity in the wheatbelt. Relevant reports and literature were acquired through meeting with key stakeholders from CALM, WRC, AgWA, and local LCDC representatives. Literature was sourced from the appropriate agency (eg CALM, WRC, AgWA, DEP) and University libraries for collation in the Yarra Yarra Catchment GIS system.

Sourced reports and literature were reviewed, summarised and collated within an Excel spreadsheet to compile an inventory of available data that relates to issues within the Yarra Yarra Catchment. The following details were recorded for each document:

- Title of report;
- Author;
- Publication date;
- A short topic summary;
- Number of pages;
- Where the report can be obtained;
- Contact name;
- Contact telephone number;
- Reference sub catchment.

Reports discussing numerous sub catchments were duplicated for each sub catchment. Documents containing tabular data and vegetation information, relating to specific remnant vegetation blocks (identified using the above procedure), had this information reproduced in an spreadsheet, with the new remnant vegetation number being recorded, for inclusion in the GIS system.

2.1.3 Lake System

A literature search was conducted for previous studies conducted on the salt lake ecology as there was no available literature on the Yarra Yarra lakes. The information obtained was summaried into a table outlining the types of flora and fauna typically found in lakes of different salinities.

2.2 Ground Truthing

2.2.1 Remnant vegetation assessment

Remnant vegetation in fifteen sub catchments was field assessed, upon completion of the desktop study. Sub catchments selected for ground truthing were Jibberding, Geranium Rock, Goodlands, Burakin, Lower Darling Creek, Mid Darling Creek, Upper Darling Creek, Campbells, Yarra Yarra Lake, East Butine, sub catchment no 15, 16, 38, 47 and 48 (Map 2). Site information was recorded using data sheets developed during the desktop review of the catchment and the project brief (See Appendix 2 for an example of the data sheets). Each accessible remnant vegetation block within a sub catchment was assessed by a single walk through transect. Information recorded in the field assessment of the sub catchments included:

- Dominant species present
- Vegetation association of the remnant vegetation (determined from vegetation structure and community). How closely this matches with Beards vegetation association was also noted.
- Vegetation condition (Trudgen code) ranging from condition rating 1: Pristine or nearly so, (no obvious signs of disturbance) to condition rating 6: Completely degraded vegetation.
- Fencing of remnant vegetation.
- Stock access or evidence of previous stock access.
- Whether the vegetation is salt affected or borders salt affected land.
- Possible connection/linkage of remnant vegetation blocks.
- Any additional comments relating to the status of the remnant vegetation (eg: description of understorey vegetation, presence of drainage and grade banks, weed cover/presence, topography, position in the landscape and other disturbances).

Map 2 - Ground truthed Subcatchments

The data collected in the field survey was entered into the GIS system for each sub catchment with an individual field for each theme. In addition, information on the date the remnant was assessed and whether the remnant was on private or reserve land was included.

The ecological data collated in the GIS system was statistically summarised, producing values for the total area of remnant vegetation within each sub catchment (both on private and reserve land), area of remnant vegetation ground truthed, percentage of remnant vegetation fenced and the amount of remnant vegetation in good/poor condition.

2.2.2 *Beard's mapping*

The accuracy of Beards mapping was assessed during the ground truthing process. The vegetation community observed in each assessed remnant was compared to the vegetation community assigned by Beard.

The current Beard map, was identified to have three 'edge joins' in the Yarra Yarra where discrepancies were observed in the vegetation descriptions. The 'edge joins' are located in the:

- northern end of the Yarra Yarra catchment running east/west, near Gutha East Rd (crossing sub catchments 42, 45, 47 and 48).
- southern end of the catchment running east/west, near Leeson Rd (crossing sub catchments 32, 35 and 37).
- southern end of the catchment running north/south, Struggle Rd (crossing sub catchments 22 and 34).

These discrepancies were investigated in the field assessment using remnant vegetation covering the 'edge joins'. The remnant vegetation obtained from the satellite imagery was overlaid on the Beard map. Remnants spanning the 'edge joins' were field checked to determine the vegetation association and hence reclassify Beard's vegetation types.

2.2.3 *Field Work*

Ground truthing was the most time consuming aspect of this study, but utimately the most important to provide vital field information on individual remnants. Past studies have utilised the knowledge of farmers to complete the majority of field work, which minimises the time spent in the field and subsequent costs. In theory this is a good method, but often not practical due to the low return in survey sheets and reliability of the information (ie: correct species identification). The survey of thirty large vegetation remnants on private land in the Dalwallinu Shire by J-P Orsini (1991) is a typical example of this, where only 20% of farmer questionnaires were completed and returned. The low percentage was attributed to the busy work load of the farmers. The vegetation assessment by a qualified individual also provides consistent and reliable base information over property and subcatchment boundaries. The field work established vegetation community type, condition, fencing status and other noteworthy information.

One of the first steps in the ground truthing process was to contact private landholders in the survey subcatchment. This informed them of the project and provided them with an opportunity to discuss their opinions in addition to obtaining their permission to enter their property. In several instances arrangements were made to visit farmers on their property during the field visit.

2.2.3.1 Farmers Attitudes

Discussing the project with farmers enabled a small community consultation process to be undertaken. By no means is this process complete or adequately started, it merely provided a basis for obtaining a general feeling of farmers attitudes towards the project.

In general, farmers willingness to discuss the project was overwhelming. They also readily provided information on the hydrology of their farm and strategies they had employed to cope with salinity (ie: gradebanks, contour banks, remnant fencing and tree plantings). They seemed aware of various projects being undertaken in their catchment and what methods were being experimented with by their neighbours and land care groups.

One concern that arose was the level of detail of the vegetation survey and whether threatened and rare species were being targeted. This is attributed to the high conservation aspects of the species that may force them to alter their farming techniques.

2.3 FAUNA ASSESSMENT

A fauna assessment was undertaken on the North Western edge of Lake Goorley, on the Stanley Property, over a three year period (30˚04'604"S 117˚03'385"E). This site is situated in the upper end of the Yarra Yarra catchment, within the Goodlands sub catchment. The site was chosen as the remnant vegetation community type was considered to be most representative of vegetation in the Yarra Yarra. Beard described the vegetation community type as Succulent steppe with woodland and thicket; York gum over Melaleuca thyoides and samphire. It is also an indicator site for the effects of a management proposal to divert water to a paleo-drainage line in the upper end of the catchment. The expected result of this practice is increased water depths in the Yarra Yarra lake system. Other sites downstream are currently being monitored as part of the Salinity Action Plan. The Salinity Action Plan will compliment our study and will be used as the baseline data for future studies.

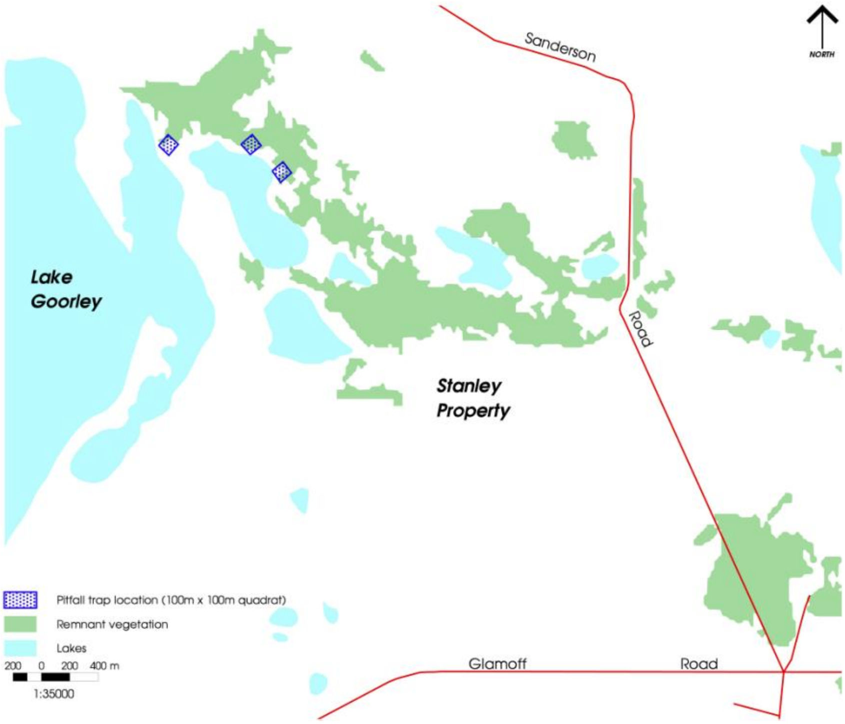
Photo 1 : Fauna assessment site (Lake Goorley in the background).

The fauna assessment consisted of pitfall trapping, elliot trapping and an avian assessment. Over the three year period the pitfall and elliot trapping was undertaken three times, in November 1999, May 2000 and November 2000. The avian survey was undertaken only once, on an opportunistic occasion. The methodology for each survey technique is outlined below.

2.3.1 PITFALL TRAPS

Three quadrats of 25 (5x5 quadrats) pitfall traps were installed at the study site, running at a 90^{o}angle from the lake (generally in an easterly direction starting at the lake). Refer to Map 1 below. 20 L buckets with lids were used as pitfall traps, which were dug into the ground until the lids were equal to ground level. The pitfall traps were spaced 25m apart, forming a 100x100m quadrat in total.

The pitfall traps were opened and monitored for 2 nights in November 1999 and May 2000, and for 3 nights in November 2000. The pitfall traps were checked daily. Species observed in the pitfall traps were identified, photographed and measurements (snout-vent length, tail length) were recorded. Fauna was then removed from the traps and released. Once the monitoring period was completed the traps were securely covered using the lids.



Map 3 : Location of pitfall traps in the Yarra Yarra catchment.

2.3.2 *ELLIOT TRAPS*

Seventy-five Elliot traps were assembled and arranged in the woodland and lake areas for a 2 night period, for each of the sampling periods. The first survey (Nov 1999), in addition to the 75 traps included 10 large cages, with all the traps being located in the vegetation at the edge of the lake. The traps in the second survey (May 2000) were arranged running into the salt lake. The third survey (Nov 2000) was organised into three lines of twenty-five traps, which ran from the fenceline of the paddock on the Stanley property towards the lake. The location of the Elliot traps was varied due to no fauna being caught. The traps were baited with a mixture of rolled oats and peanut butter, with a small amount of the mixture placed in each trap. The traps were checked each morning and the fauna caught was recorded and measured.

2.3.3 *AVIAN SURVEY*

An avian survey was undertaken by Rob Davies in May 2000. The bird species observed in a visual assessment, during a walk through the woodland area and salt lake, were noted.

2.3.4 *VEGETATION*

Vegetation in the vicinity of the fauna assessment was identified and ground truthed, as per the method previously described. The vegetation along the three lines of pitfall traps was recorded.

PART THREE – RESULTS AND DISCUSSION

3.1 REMNANT VEGETATION ASSESSMENT

A total of 112,842 ha of remnant vegetation (in over 7,500 individual remnants) was identified in the desktop study for the Yarra Yarra catchment. The desktop study only took into account remnants greater than 1ha in size.

3.1.1 LAND TENURE OF THE REMNANT VEGETATION

Remnant vegetation within the Yarra Yarra catchment was classified as privately or publicly (reserves) owned land. This classification was based on ground truthing and cadastral information from the GIS database. Public land, or reserves included vacant crown land, road reserves and shire owned property. Appendix 2 contains a list of the areas of remnant vegetation on private and public land for each sub catchment.

Approximately 74% or 83,534ha of remnant vegetation is located on private land within the Yarra Yarra catchment. Sub catchments 6, 10, East Three Springs, 12, Goodlands, Bywaters,40 and Collier-Dingo have no remnants, classified in the desktop study, as reserves or publicly owned land. The Morawa sub catchment has a high percentage of its remnant vegetation vested as reserves (99%), including a large reserve of 1,856 ha (Reserve 40563).

3.1.2 CATCHMENTS

2,852 remnants were visited during this survey of the Yarra Yarra catchment, within the fifteen sub catchments. Overall, this represents 27,165ha or approximately 25% of the remnant vegetation identified in the Yarra Yarra catchment being field assessed. The remnants were broadly assessed for vegetation communities, condition, fencing status, grazing presence and salt status. This data was compiled into the GIS database. The area of remnant vegetation identified, for each field assessed sub catchment is listed in Table 1

The percentage of remnants ground truthed in each sub catchment was greater than 65%, and in the majority of cases (8 sub catchments) more than 85% of remnants were ground truthed. Of the remnants assessed 72% were located on private land.

The main factor limiting ground truthing was access to the remnants. A large percentage of remnants are located on private land and often surrounded by pastures. This makes access to the remnant blocks difficult, especially late in the wheat season when crops are ready to harvest.

198 remnants were noted as being fenced or partly fenced in the assessed sub catchments. Of these 168 are located on private land. The area and percentage of assessed remnant vegetation that was fenced is listed below. Sub catchments 16, 38 and East Buntine had the highest percentage of remnant vegetation fenced (25.9%, 32.2% and 27.6%, respectively). Yarra Yarra Lakes had a very small proportion of its remnants fenced, even though most of the sub catchment (94%) was ground truthed.

Appendix 3 contains spreadsheet summarising information on the sub catchments (ie: areas of remnant veg).

Table 1: Area of remnants, percentage ground truthed and percentage of assessed remnants fenced in each of the 15 ground truthed sub catchments.

Ground truthed Sub catchment	Area of Remnant Vegetation (ha)	Remnant Vegetation Ground truthed		Fenced Remnants	
		Area (ha)	%	Area (ha)	%
Campbells	1021.0	995.5	97.5%	10.5	1.0%
Upper Darling Creek	854.0	835.0	97.8%	106.3	12.4%
Mid Darling Creek	842.1	744.6	88.4%	194.6	17.5%
15	530.0	410.7	77.5%	49.0	5.8%
16	1453.4	1229.0	84.6%	137.5	25.9%
Goodlands	2477.8	2006.2	81.0%	477.1	19.2%
Jibberding	2324.9	1884.2	81.0%	115.5	5.0%
Burakin	2428.9	1711.3	70.4%	480.1	19.8%
Geranium Rock	511.6	337.6	66.0%	74.8	14.6%
38	762.5	696.5	91.3%	245.7	32.2%
47	2674.7	2588.1	96.8%	52.7	2.0%
48	4945.5	3916.2	79.2%	885.9	17.9%
Lower Darling Creek	5673.4	5224.5	92.1%	302.2	5.3%
Yarra Yarra Lake	5037.9	4733.6	94.0%	9.4	0.2%
East Buntine	1784.7	1563.7	87.6%	492.4	27.6%
Total	33322.4	28876.7		3633.7	

3.2 BEARDS VEGETATION MAPPING

3.2.1 ACCURACY OF BEARDS VEGETATION MAPPING

Remnant vegetation identified in the desktop study was assigned a vegetation type according to Beards mapping. This vegetation classification was compared to the vegetation type observed during the ground truthing survey. If the vegetation type did not correspond to the vegetation observed, than this was noted on the field survey sheets. The number of 'non-matches' was only 249 out of the 2,852 remnants assessed (<9%). Therefore, overall Beards mapping was found to be quite accurate in all of the sub catchments assessed. The dominant species (ie: Acacia, Melaleuca species, York gum, Salmon gum, etc.) and vegetation structure (ie: shrubland, woodland etc.) closely matched. The discrepancies were mostly associated with vegetation of a low condition rating (ie: 4-5 & 5) and had been degraded by grazing or salinity and the species or structure subsequently changed, ie: to salt vegetation or less species diversity.

3.2.2 BEARD'S MAP EDGE JOINS

Beard's vegetation mapping of the Yarra Yarra catchment was identified to have 3 'edge joins' in the map sheets.

Remnants spanning the northern 'edge join' were field checked to assess the vegetation type. Remnant numbers 42_177, 42_176 and 48_286 were visited. The southern end of remnant 42_177 was classified by Beard as Medium woodland: York gum and Salmon gum, with the northern end classified as medium woodland: York gum. During the field assessment, no salmon gums were observed in this remnant and therefore the vegetation type of the whole remnant was noted as Medium woodland: York gum. Remnant 42_176 was classified by Beard as Medium woodland: York gum, although this remnant did not span the edge join, but was field checked as it was adjacent to remnant 47_177. Beard classified the southern section of remnant 48_286 as Shrublands: mixed acacia thicket on sandplain and the northern section as Shrublands: acacia, casuarina and melaleuca thicket. The vegetation in the southern section was observed to have species of casuarina and melaleuca as well as acacia species and also the appearance of the soil did not correspond to sandplain. Therefore this remnant was reclassified as Shrublands: acacia, casuarina and melaleuca thicket. Whilst these individual remnants could be reclassified, there is insufficient remnant vegetation covering the length of the 'edge join' within the Yarra Yarra catchment to confidently amend the original vegetation mapping by Beard. Also the vegetation types described are very similar, often with the same structure but with different species composition, therefore it was felt that reclassification was unnecessary. This was further supported by the high degree of accuracy observed overall in Beards mapping. Subsequently, the other 'edge joins' were not field assessed due to the lack of remnant vegetation traversing the 'edge joins'.

It should be noted that this situation specifically relates to the 'edge joins' within the Yarra Yarra catchment. It is recommended that in other locations where there is a sufficient area of remnant vegetation covering the 'edge joins' of Beards map, the vegetation should be ground truthed and the 'edge join' vegetation type be amended accordingly.

3.3 Vegetation Communities

Within the Yarra Yarra, 42 vegetation communities have been recorded in the remnant vegetation, according to Beards mapping (Table 2). Five dominant (ie: greater than 10,000 ha) vegetation types were recognised and are listed below:

- Succulent steppe with woodland and thicket; york gum over Melaleuca thyroids and samphire (22,644 ha);
- Medium woodland; York gum (15,493 ha);
- Medium woodland; York gum and Salmon gum (10,990 ha);
- Shrublands: Mallee and Casuarina thicket and (10,361 ha);
- Shrublands: Acacia neurophylla, A. beauverdiana and A. resinimarginea thicket (10,122 ha).

6 vegetation communities types are not well represented in the Yarra Yarra catchment, representing less than 0.1% (≥100 ha). With more than half of the vegetation communities (24 out of 42 communities) recording less than 1%.

The distribution and representiveness of plant communities are important considerations in vegetation conservation and mangement, particularly in relation to setting priorities. Representiveness was assessed for two context areas; Yarra Yarra catchment and Conservation Reserves in Western Australia. Table 2 below lists the percentage of remnant vegetation in the Yarra Yarra catchment, each condition rating, each elevation interval and in Western Australia's Conservation Reserves (percentages obtained from Hopkins *et al*., 1996).

Table 2 Vegetation Community Representativeness

Vegetation Community	% in the Yarra Yarra	% in each Condition Rating					% in each Elevation Interval			% in Conservation Reserves (WA)
		1-2	2-3	3-4	4-5	5	200-300	300-400	400-500	
Bare areas; rock outcrops	0.60%	0.015	0.0	0.019	0.0	0.0	0.042	0.542		17.9
Bare areas; salt lakes	0.90%	0.003	0.059	0.09	0.084	0.0	0.764	0.171		10.1
Medium woodland; York gum	13.70%	0.234	1.218	1.120	0.562	0.173	9.433	4.297		0.9
Medium woodland; York gum & red mallee	0.09%	0.014	0.023	0.008	0.0	0.0		0.095		8.8
Medium woodland; York gum & salmon gum	9.74%	0.118	0.317	0.300	0.490	0.087	6.321	3.419		5.4
Medium woodland; York gum, salmon gum & gimlet	1.11%	0.0	0.018	0.0	0.0	0.0	0.351	0.757		3.8
Mosaic: Medium woodland; York gum/Shrublands; Allocasuarina campestris thicket	11.87%	N/A	N/A	N/A	N/A	N/A	0.438	0.869	0.561	
Mosaic: Low woodland: Allocasuarina heugeliana over mallee and acacia scrub/Allocasuarina campestris thicket	1.73%	N/A	N/A	N/A	N/A	N/A	0.853	0.166	0.707	
Mosaic: Shrublands; scrub-heath Dryandra-Calothamnus assoc. with B. prionotes on limestone in the northern Swan Region/Sparse low woodland; wandoo & powderbark wandoo	0.77%	0.265	0.020	0.010	0.0	0.0		0.768		
Mosaic: Shrublands; Shrublands; jam scrub with scattered York gum in the valleys / Allocasuarina campestris thicket	3.48%	0.010	0.060	0.098	0.014	0.0	1.318	2.168		0.5
Mosaic: Succulent steppe with thicket; Melaleuca thyroids over samphire / Shrublands; bowgada open scrub	0.10%	N/A	N/A	N/A	N/A	N/A	0.102			
Shrubalnds; Mixed acacia thicket on sandplain	4.06%	0.361	0.270	0.076	0.0	0.0	0.539	2.212	1.305	
Shrublands; Acacia neurophylla, A. beauverdiana & A. resinimarginea thicket	8.97%	1.241	1.090	0.511	0.084	0.0	2.920	6.050		14.1
Shrublands; acacia scrub, various species	0.55%	0.0	0.0	<0.001	0.0	0.0	0.449	0.104		11.3
Shrublands; Acacia thicket with patches of heath	0.31%	0.035	0.058	0.079	0.002	0.0		0.313		
Shrublands; acacia, casuarina & melaleuca thicket	2.85%	0.298	0.109	1.425	0.067		0.272	2.573		17.2
Shrublands; Allocasuarina campestris scrub	0.04%		0.018	0.015	0.001		0.037			0.0
Shrublands; Allocasuarina campestris thicket	5.02%	0.260	0.668	0.762	0.109		3.101	1.913		5.4

Table 2 continued

Vegetation Community	% in the Yarra Yarra	% in each Condition Rating					% in each Elevation Interval			% in Conservation Reserves (WA)
		1-2	2-3	3-4	4-5	5	200-300	300-400	400-500	
Shrublands; Allocasuarina campestris thickets with scattered jam & casuarina	0.15%	0.081	0.016				0.133	0.020		
Shrublands; bowgada & jam scrub	0.67%		0.416	0.063	0.035			0.668		0.2
Shrublands; bowgada & jam scrub with scattered York gum	0.01%		0.007					0.007		0.1
Shrublands; bowgada & jam scrub with scattered York gum & red mallee	0.32%	0.050	0.101	0.026	0.016		0.234	0.086		0.0
Shrublands; bowgada and associated spp. scrub	0.41%	N/A	N/A	N/A	N/A	N/A	0.409			17.0
Shrublands; bowgada scrub with scattered York gum	0.13%	N/A	N/A	N/A	N/A	N/A	0.103	0.027		130.3
Shrublands; bowgada, jam and Melaleuca uncinata thicket	1.65%	0.353	0.979	0.123	0.008		0.090	1.557		0.0
Shrublands; casuarina & dryandra thicket with wandoo and powderbark wandoo	0.33%	N/A	N/A	N/A	N/A	N/A		0.327		18.9
Shrublands; casuarina & melaleuca thicket	1.47%	N/A	N/A	N/A	N/A	N/A	1.021	0.381	0.067	1.9
Shrublands; dodonaea scrub	0.14%	N/A	N/A	N/A	N/A	N/A	0.136			
Shrublands; Dryandra quercifolia & Eucalyptus spp. thicket	0.23%	N/A	N/A	N/A	N/A	N/A		0.229		18.2
Shrublands; mallee & casuarina thicket	9.18%	1.081	0.955	0.827	0.075		0.258	8.67	0.257	1.4
Shrublands; Melaeuca thyioides thicket	0.14%	0.072					0.066	0.076		15.6
Shrublands; scrub-heath on lateritic sandplain in the central Geraldton Sandplain Region	1.01%	0.100	0.016					1.014		10.0
Shrublands; scrub-heath on lateritic sandplain in the southern Geraldton Sandplain Region	1.66%	0.996	0.348	0.085	0.026	0.001	0.567	1.088		10.0
Shrublands; scrub-heath on sandplain	0.21%	N/A	N/A	N/A	N/A	N/A	0.003	0.207		30.7
Shrublands; scrub-heath on yellow sandplain banksia-xylomelum alliance in the Geraldton Sandplain & Avon-Wheatbelt Regions	0.06%	N/A	N/A	N/A	N/A	N/A	0.055			46.5
Succulent steppe with open woodland & thicket; york gum over Melaleuca thyiodes & samphire	0.65%	N/A	N/A	N/A	N/A	N/A		0.647		17.8

Table 2 continued

Vegetation Community	% in the Yarra Yarra	% in each Condition Rating					% in each Elevation Interval			% in Conservation Reserves (WA)
		1-2	2-3	3-4	4-5	5	200-300	300-400	400-500	
Succulent steppe with scrub; teatree (Melaleuca thyioides?) over samphire	0.01%	N/A	N/A	N/A	N/A	N/A		0.011		10.5
Succulent steppe with thicket; Melaleuca thyoides over samphire	5.17%	0.009	1.719	0.064	0.052		5.171	0.003		2.5
Succulent steppe with woodland and thicket; york gum over Melaleuca thyoides & samphire	20.07%	0.583	0.078	0.029	0.134		20.05	0.018		4.3
Succulent steppe; saltbush	0.05%	N/A	N/A	N/A	N/A	N/A		0.049		1.6
Succulent steppe; saltbush & samphire	0.36%	N/A	N/A	N/A	N/A	N/A		0.360		0.0
Succulent steppe; samphire	0.002%	N/A	N/A	N/A	N/A	N/A	0.002			11.0

3.3.1 SPECIES

An overall species list was not compiled for the Yarra Yarra catchment as it was not considered a useful tool for the management or revegetation of remnants in individual sub catchments and would have contained an extremely large number of species. A wide variety of previous studies have been conducted on the sub catchment scale or a more focused area which contain specific species lists representative of the remnant vegetation. A list of the reports available relating to each sub catchment can be found in the GIS database. Information provided in the database includes a short summary on the report contents in addition to general information on title, author and where the report can be obtained. Tabular data from the reports on individual remnants in the Glamoff, Goodlands, Jibberding, Geranium Rock, Lake Goorley, Bywaters, 36, Collier-Dingo, Lower Darling Creek and 56 is also available in the GIS system.

3.3.2 WEEDS

In many remnants, the understorey vegetation contained a large percentage of grassy weed species. These weeds appeared to have entered the remnants mainly from the surrounding pastures and have colonised in the understorey, especially where it has been disturbed by stock grazing. However, weed invasion was not considered a major overall problem within remnants, with highly invasive weeds not widely recorded.

3.3.3 THREATENED ECOLOGICAL COMMUNITIES

The vegetation survey completed was a large scale broad brush assessment to ascertain base information on remnant vegetation in the Yarra Yarra catchment. Rare and threatened flora was not specifically assessed. The Department of Conservation and Land Management (CALM) has data on threatened ecological communities for the Yarra Yarra region. The issue of rare and threatened flora should be dealt with in the management of specific remnants and the Department of Conservation and Land Management should be contacted to obtain this information.

3.3.4 SUCCESSIONAL VEGETATION

Succession of vegetation communities (ie change from one community type to another) is clearly evident in the Yarra Yarra Catchment. The progression of the succession vegetation (ie samphire) is most obvious in areas where water logged woodlands have been replaced by the lower growing succulents. It is less obvious in areas where the samphire vegetation has replaced a lower growing vegetation type such as Melaleuca shrublands or encroached on farmland that is no longer being cropped.

During the ground truthing it was difficult in some areas to discern where the boundary of the succulent samphire vegetation as mapped by Beard had encroached on another vegetation type unless there was clear evidence of tree deaths. The Yarra Yarra Catchment has always had extensive areas of samphire/succulent vegetation associated with seasonally flooded margins and basins adjoining the Lake system. With very little evidence of disturbance factors such as weeds and trampling these areas are given a condition rating of 1 as they are considered to be in pristine condition. The dilemma about how to rate what appears to be pristine samphire vegetation in an area that may have once been shrubland or woodland resulted in many of these samphire areas not being given a condition rating. Areas where there were clearly tree deaths were given a condition rating of 5.

The successional vegetation from woodland to samphire was most obvious in the valley floors of the sub-catchments indicating these are the areas that are the most severely affected by hydrological changes as a result of land clearing. By contrast the woodland and shrubland vegetation associated with the lakes system (ie from Lake DeCourcey all the way through to the Yarra Yarra Lakes) was mostly unaffected by encroachment of samphire vegetation. Areas surrounding the lakes that showed evidence of successional vegetation are narrow bunds of woodland vegetation often found between seasonally flooded basins at the bottom end of the subcatchments (valley floors) and the adjoining lake. This indicates an altered hydroperiod in the seasonally flooded basin is affecting woodland vegetation close to the lakes.

Photo 2 :Vegetation intact

Photo 3: Trees affected by salinity, vegetation starting to degrade.

Photo 4: Samphire enroaching into woodland vegetation.

Woodland and shrubland vegetation surrounding the lakes away from these outlet zones of the subcatchments was generally in good condition with no evidence of samphire encroachment. This indicates that altered hydrology resulting from land clearing has had virtually no impact to date on the woody vegetation associated with the lakes.

Photo 5 : Vegetation around salt lakes looking from Goodlands Road

Photo 6 : Vegetation around salt lakes in the Yarra Yarra Lake Sub catchment

3.4 QUALITY OF REMNANT VEGETATION

3.4.1 REMNANT VEGETATION CONDITION

Remnant vegetation was assessed for condition and each assessed remnant was assigned an overall condition rating, based on the condition ratings developed by Trudgen, 1991 and modified by Keighery, 1993 (Brown, 1999). The ratings and associated descriptions are listed in Table 3 The data set (woody perennial 1996 vegetation, updated by Agriculture WA) used to identify the remnant vegetation often does not detect severely degraded or salt affected vegetation. For example if the tree cover decreases or is lost from a vegetation community the satellite imagery may not detect the remnant vegetation, similarly samphire vegetation is not readily pick up. The data set obtained from Agriculture WA was an improvement on the original data set with more samphire vegetation being recognised from the orthophotos although it was still found to be incomplete in some areas.

Table 3: Remnant vegetation condition ratings.

Condition Rating		Description	Photo Example
1-2	'Pristine'	Pristine or nearly so, no obvious signs of disturbance.	
2-3	Excellent	Vegetation structure intact, disturbance affecting individual species and weeds are non aggressive species.	
3-4	Very good	Vegetation structure altered, obvious signs of disturbance.	
4-5	Good	Vegetation structure significantly altered by very obvious signs of multiple disturbance. Retains basic vegetation structure or the ability to regenerate.	
5	Degraded	Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management.	
6	Completely degraded	The structure of the vegetation is no longer intact and the area is completely or almost completely without native species.	*No vegetation was recorded as condition 6*

Over 64% of remnant vegetation assessed in the Yarra Yarra catchment was considered to be in pristine or excellent condition (condition rating 1-2 and 2-3). Only a very small proportion (just over 1%) was degraded (condition rating 5). No remnant vegetation assessed was given a condition rating of 6. This is attributed to the previously discussed reasons of the data set not detecting severely degraded vegetation or not accurately determining the total area of the vegetation and only a small proportion of the remnant being identified and being selected out as less than 1 ha. Despite the Medium woodland community type being one of the most dominant within the Yarra Yarra catchment, it is potentially the most degraded community. The canopy cover of this vegetation decreases and disappears through disturbances and the satellite imagery does not adequately sample it. This emphasizes the importance of establishing base data to enable future comparisions and to document further community transitions.

Sub catchments Campbells, Burakin and Yarra Yarra Lakes had the majority of their vegetation classified as 1-2 (in pristine condition). The overall condition of remnant vegetation in the Geranium Rock sub catchment was excellent, with all of the assessed vegetation being classified as 1-2 and 2-3. Only 3 sub catchments recorded the poorest condition rating of 5 (Sub catchment 38, Yarra Yarra Lakes and East Buntine).

A total of 2,282 ha of assessed remnant vegetation was not assigned a condition rating. A large proportion of not rated vegetation was located in the Lower Darling Creek and Yarra Yarra Lake sub catchments (1099.8 and 493.8 ha). This vegetation was mainly samphire vegetation located around the lakes edge or associated with salt affected land. A condition rating was not assigned as there were two ways of assessing the condition, based on the perception of the vegetation community. If the vegetation type was viewed as samphire vegetation then its condition was excellent, however, if the vegetation type was viewed to be York gum changed to samphire vegetation through some disturbance then it was in a degraded condition. In some instances the samphire vegetation was growing into a pasture area which made it difficult to assign a rating to. Therefore, vegetation in these situations were not given a condition rating (refer to Section 3.3.4 - Succession).

Table 4: Area and percentage of assessed remnant vegetation for each condition rating, in each of the 15 ground truthed sub catchments.

Ground truthed Sub catchment	Area of Remnants with each Condition Rating (ha)					
	1-2	2-3	3-4	4-5	5	Not rated
Campbells	771.6	100.7	80.7	28.4	0	0
Upper Darling Creek	93.9	113.4	256.8	299.6	0	0
Mid Darling Creek	113.2	254.5	238.9	39.6	0	94.8
15	43.2	100.4	161.9	91.5	0	13.7
16	39.9	376.6	630.1	182.4	0	0
Goodlands	575.9	897.1	378.0	115.7	0	0
Jibberding	905.7	860.9	102.0	11.3	0	0
Burakin	797.8	235.9	606.4	33.5	0	0
Geranium Rock	66.9	255.8	0	0	0	0
38	75.1	147.0	353.4	14.2	106.8	0
47	826.5	1506.0	161.6	31.9	0	72.2
48	389.6	749.0	2076.2	193.2	0	508.2
Lower Darling Creek	100.8	3143.6	547.7	432.6	0	1099.8
Yarra Yarra Lake	2639.0	521.6	669.5	310.4	100.3	493.8
East Buntine	449.6	578.5	308.0	202.8	24.8	0
Total	7887.7	9840.0	6570.2	1986.1	236.9	2282.5

Several environmental factors potentially pose a threat to remnant vegetation. These include salinity, water and wind erosion, loss of soil fertility and structure, stock grazing and weed invasion, plus many others. The major threats to vegetation in the Yarra Yarra catchment are discussed below.

1. Salinity and Water logging

   Water logging is one of the most critical environmental problems facing agricultural areas. It is caused by replacing deep-rooted native plants with shallow-rooted crops and pastures (Agriculture WA *et al*., 1996). More rainfall passes below the root zone and accumulates as groundwater so that the watertables rise. The groundwater mobilises natural salts in the soil as it rises and carries them towards the surface, eventually degrading land and streams (Agriculture WA *et al*., 1996).

2. Stock grazing

   Stock access to remnant vegetation causes extensive damage, primarily through grazing and trampling of the understorey and regenerating seedlings. Larger shrubs and trees are less prone to direct damage in comparison to seedling, although ringbarking and root trampling can cause severe damage in heavy grazing. Stock grazing was also found to cause the introduction of weeds and erosion associated with trampling (Orsini, 1996).

Photo 7 : Effect of stock grazing remnant vegetation..

3. Weed invasion

   Grassy weeds compete with native understorey species and outcompete natives as they rapidly establish in the understorey due to degradation by stock of natural vegetation. Grassy weeds generally enter remnants from pastures.

Photo 8 : Grassy weeds present in a remnant adjacent to pasture.

4. Size of remnants

   Small scattered remnants have less species diversity and are potentially not as efficient at hydrological functions (such as evapotranspiration and groundwater recharge). They may also be more susceptible to degradation through stock grazing and other threats. The edge effect is also more prominent in smaller remnants.

5. Position in the landscape

   The low lying areas of remnant vegetation (valley floors and wetlands) are considered to be most at risk of salinity and water logging as groundwaters approach and/or discharge at the surface. In the Yarra Yarra catchment, the vegetation in the valley floors of the sub catchments are most affected or under threat from salinity. However, the peripheral vegetation of the actual lakes (ie: Yarra Yarra Lakes) did not appear to be suffering from the effects of salinity or other hydrological changes such as increased drainage (ie: it was in quite good condition).

3.4.2 Remnant Vegetation Condition and Position in the Landscape

The condition of the remnant vegetation in relation to their position in the landscape are summarised into three elevation intervals (200-300, 300-400 and 400-500m above sea level) in Table 4 below. Contour data was missing for parts of sub catchment 48 and Yarra Yarra Lake and the remnant vegetation could not be accurately divided into the elevation intervals and were excluded.

Overall, remnant vegetation assessed in the low elevation interval (200-300) had less vegetation classified as condition 1-2 and 2-3 (922.1 and 3601.6 ha, respectively) compared to the medium elevation interval (2378.4 and 4046.5 ha, respectively). There was no vegetation classified as condition 5 in the medium elevation interval, where as 2% (202.9 ha) of remnant vegetation recorded the lowest condition in the low elevation interval. This trend also applied for vegetation with a rating of 4-5. No remnant vegetation was given a condition rating in the highest elevation interval (400-500 m).

In the low elevation interval, 6 out of the 13 sub catchments assessed, had the majority of their remnant vegetation classified as good (condition rating 2-3) or excellent (condition rating 1-2). Sub catchment 38 had approximately 15% of its low lying vegetation rated as 5 (severely degraded). All of the low lying vegetation in the Burakin sub catchment was given a condition rating of 4-5. The Upper Darling Creek and sub catchment 15 had most of their low lying vegetation rated as 4-5. In the medium elevation interval, 9 out of the 13 sub catchments had the majority of their vegetation rated as good or excellent. Upper darling creek, sub catchment 15 and 38 had the majority of their medium positioned vegetation rated as 3-4. Sub catchments 38, Jibberding and Geranium Rock had no medium positioned vegetation in a degraded condition (4-5 or 5 ratings).

Burakin and Goodlands sub catchments were the only sub catchments to have vegetation in the highest elevation interval, although these remnants were not assigned a condition rating.

Remnant vegetation in low lying valley floors was found to be more susceptible to salinity and are at greater risk to this form of degradation. Although this pattern was observed overall in comparing the low lying vegetation to the medium lying vegetation, it was not as obvious on the sub catchment basis. This may be attributed to the position of the sub catchments within the Yarra Yarra catchment, with sub catchments at the bottom of the catchment and the ridge divides not exceeding 400m in elevation and therefore no vegetation was classified in the highest elevation interval. The entire catchment is very flat with only a 65m drop in elevation from one end to the other, which may also affect this relationship. Ideally, approximately the same amount of vegetation should be assessed within each elevation class to give a more accurate picture, however, due to the previously discussed factors this was not possible in this survey.

Table 5 : Area of remnant vegetation with condition ratings in three elevation classes.

Sub catchment	Elevation 200-300						Elevation 300-400						Elevation 400-500					
	1-2	2-3	3-4	4-5	5	Un-rated	1-2	2-3	3-4	4-5	5	Un-rated	1-2	2-3	3-4	4-5	5	Un-rated
Campbells	661.8	48.9	62.5	23.9	0.0	0.0	109.8	51.8	18.2	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Darling Creek	0.0	4.2	125.8	274.6	71.3	0.0	93.9	109.2	131.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mid Darling Creek	51.7	96.3	21.0	1.2	0.0	94.8	61.5	158.2	130.7	38.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	38.0	13.3	70.4	0.0	13.7	43.2	62.4	148.6	21.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	62.2	263.6	135.3	0.0	128.1	39.9	314.4	240.2	47.1	0.0	114.3	0.0	0.0	0.0	0.0	0.0	0.0
Goodlands	155.6	0.0	0.0	0.0	0.0	155.0	420.3	897.1	378.0	115.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.6
Jibberding	51.3	247.7	78.1	11.3	0.0	194.6	854.4	613.2	23.9	0.0	0.0	250.4	0.0	0.0	0.0	0.0	0.0	0.0
Burakin	0.0	0.0	0.0	13.7	0.0	142.0	797.8	235.9	606.4	19.8	0.0	523.1	0.0	0.0	0.0	0.0	0.0	90.2
Geranium Rock	0.0	0.0	0.0	0.0	0.0	0.0	66.9	255.8	0.0	0.0	0.0	188.9	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	5.1	14.2	106.8	11.8	75.1	147.0	348.3	0.0	0.0	54.2	0.0	0.0	0.0	0.0	0.0	0.0
47	0.0	242.8	60.7	27.4	0.0	74.4	826.5	1263.2	100.9	4.5	0.0	74.3	0.0	0.0	0.0	0.0	0.0	0.0
48	Limited contour data available.																	
Lower Darling Creek	1.7	2653.7	204.6	404	0.0	1417.4	99.1	389.9	343.1	28.6	0.0	131.3	0.0	0.0	0.0	0.0	0.0	0.0
Yarra Yarra Lake	Limited contour data available.																	
East Buntine	0.0	207.8	255.9	148.1	24.8	146.6	449.6	370.7	52.1	54.7	0.0	74.4	0.0	0.0	0.0	0.0	0.0	0.0
Overall	922.1	3601.6	1090.6	1124.1	202.9	2378.4	4046.5	4868.8	2521.4	359.4	0.0	1410.9	0.0	0.0	0.0	0.0	0.0	105.8

3.5 Vegetation Risk

One of the key outcomes of this study was to determine not only what 's out there but to also assign a vegetation risk factor to aide in decision making regarding the management of remnants within the Yarra Yarra Catchment.

Possible threats and the stability of the vegetation need to be considered in setting management priorities. The key threat (but not the only one) to remnant vegetation in the Yarra Yarra catchment is that of water logging. Both threats and stability may change with or without active intervention

Table 6: Vegetation Risk

		Stability Status (relates to condition)		
		Improving	Stable	Degrading
Threat Status	Currently Threatened		Moderate risk	High risk
	Not Threatened	Very low risk	Low risk	

Using this matrix we can see that vegetation of a good condition, not at risk of water logging (ie high in the landscape) would be considered very low to low risk and would not be considered a high priority for management. On the other hand vegetation of a poorer quality lower in the landscape is at greater risk of irreversible damage. Vegetation that is potentially at risk of water logging (ie: low in the landscape) and that is not typically present in water logged areas (ie: succulent steppe vegetation around the lakes has been eliminated) has been mapped within the Yarra Yarra Catchment (Map 4).

3.6 Setting priorities for management

The distribution and representativeness of vegetation communities are important considerations in vegetation conservation and management particularly in relation to setting priorities.

- Representativeness was assessed as a percentage of the total vegetation type within each of the following classes

- percentage of vegetation type protected (ie within a reserve) for the entire state (Hopkins *et al* 1996.
- percentage of the vegetation type within the Yarra Yarra Catchment
- percentage of the vegetation type within three elevation classes the lower in the landscape the more vulnerable it is to the most dominant threat, waterlogging.
- percentage vegetation type in each condition range

Table 7: Vegetation community representativeness – composite ratings

		Reserves within WA	
		Poorly represented	Well Represented
Remnants within the Yarra Yarra Catchement	Poorly represented	A	C
	Well represented	B	D

In conservation terms, communities with rating 'A" are of greatest concern while rating 'D' communities are of least concern.

It is possible to combine both the risk and the representativeness matrixes to determine priorities for conservation. Once these priorities have been determined it is possible to prepare a management response for each remnant.

Once the moderate to high risk remnants have been identified it may be necessary to prioritise remnants to preserve. The criteria we have used for the basis of this assessment is the representativeness of the community both within the Yarra Yarra Catchment and within conservation reserves in WA.

Using the above analysis the following vegetation types were determined to be most vulnerable and should be considered as priorities for management.

- Mosaic: Medium woodland; York Gum/shrublands; Allocasuarina campestris
- Mosaic: Low woodland: Allocasuarina heugeliana over mallee and acacia scrub/Allocasuarina campestris thicket
- Mosaic: Shrublands; Shrublands; jam scrub with scattered York gum in the valleys /Allocasuarina campestris thicket
- Shrublands; Allocasuarina campestris thickets with scattered jam & casuarina
- Shrublands; bowgada & jam scrub with scattered York gum & red mallee

Each one of the above communities is represented in the lower elevation interval and is not represented in conservation reserves in WA. All of the above had remnants in the medium elevation but no remnants in the higher elevations. These vegetation communities were located in the north-west section of the Yarra Yarra Catchment and are shown in Map 5.

Map 4 - Veg at risk

Map 5 - Vulnerable Veg Map

3.7 Management considerations

3.7.1 Integrated Approach to Management

Priority levels for management recommendations are based on several objectives:

- minimising land degradation;
- conserving a range of native species representative of the flora of the area;
- conserving a representative range of plant communities in the catchment;
- protecting healthy remnants with low disturbance levels in priority to degraded remnants;
- protecting a minimum amount of native vegetation on each property for nature conservation (Read, 1992).

3.7.2 Connecting Remnant Vegetation

Criteria for linking remnant vegetation with revegetated corridors:

- proximity to other remnants (single remnant or multiple remnants, road reserves/corridors).
- potential size of remnants (ie: possibly no point in putting a lot of effort and funding into connecting two remnants that still create only a small sized remnant).
- condition of the remnants
- vegetation community types (similar or dissimilar).

3.7.3 Fencing of Remnant Vegetation

Fencing is considered to be one of the most important management activities, which would have immediate results in terms of regenerating of native flora. Fencing every remnant, on each farm would prove to be a huge, costly and potentially unrealistic task, which leads to the formation of fencing priorities. Fencing of a remnant may not be necessary if it is unlikely to be grazed.

One of the major causes of remnant degradation is stock grazing. Degradation is visible from the high incidence of grassy weeds and a reduction in native understorey species. The effect of stock grazing includes:

- limited or no regeneration, as seedlings are eliminated as soon as they are produced;
- depletion of the soil seed bank over time;
- increased disturbance through ground compaction, trampling and nutrient enrichment of the soil (Read, 1992).

The fencing of remnants prevents stock access, which limits degradation and allows natural regeneration of the vegetation.

3.7.4 Drainage

Drainage is used throughout the wheat belt to protect arable land but it can be employed to equally to protect remnant vegetation. Consideration for the type and design of the drain will be site dependent. One example of the use of drainage to protect remnant vegetation is at Lake Toolibin not only from rising groundwater but also to prevent saline water entering what is a fresh water lake system. At Lake Toolibin the drains have been designed to carry excess and saline water around the perimeter of the lake conveying it to a saline lake system further down stream.

Drainge into the the Yarra Yarra lake system has been proposed as a method for tackling the rising water and associated salinity in this area. However, there is concern that the increase in surface water from drainage into the lakes will decrease the amount of groundwater evaporation, as the salt crust on the surface of the lakes acts as a wick drawing up more groundwater. The increased volume of surface and ground water may cause the Yarra Yarra Lake to overflow into the Moore River catchment, affecting the hydrology of this region aswell.

The tidal period of the lakes should not vary significantly with the increased amount of water, as the surface water is predicted to evaporate. Therefore there should be no enroachment into the fringing vegetation. The succulent steppe with woodland vegetation located between the small lakes at the catchment outflow areas act as bunds. The concept of utilising drainage to remove saline water from arable land in the Yarra Yarra catchment requires further investigation to assess the potential impact of increased volumes of saline water entering this system.

Photo 9: An example of drainage in the Goodlands Sub catchment

3.8 LAKE SYSTEM

The salinity level of Mongers Lake and Lake DeCourcey was analysed from water samples collected from free standing water. This assessment was undertaken on 19th August 2001. The salinity level was 130,000 μS/cm for Mongers Lake and 77,000 μS/cm for Lake DeCourcey. Mongers Lake and Lake DeCourcey are classified as hypersaline and polysaline, receptively. The salinity level of the lakes may vary with the season and when the lakes dry out the salinity level increases. Sampling was undertaken at the end of winter when the salinity level is at its lowest. In general, the lakes of the catchment would be classified as hypersaline.

A literature search was conducted on the lake system to determine what types flora and fauna are typically found in lakes of different salinities levels (Appendix 3). Table * summaries the results of this search and outlines the characteristics of the lakes. The vertebrates, invertebrates and macrophytes of the hypersaline category would be characteristics of the lakes in the Yarra Yarra (Table 6). Limited species typical of the polysaline category may also be found. The lakes in this system are termed salt pans (or evaporative basins) and are dry for part of the year, particularly in summer. Consequently the biological components stated in the table below are ephemeral and would only be found in the lakes at certain times of the year.

Table 8: Ecology of changing salinity for non tidal saline wetlands.

Terms Salinity Range ppm	Meiomesosaline 1,000 – 3,000	Hyposaline 3,000 – 20,000	Mesosaline 20,000 – 50,000	Polysaline 50,000 – 100,000	Hypersaline > 100,000
Diversity Vertebrates	High Frogs numerous, numerous fish species (eg. minnows, *Galaxiella* spp, western pygmy perch, *Edelia vittata)*	High Frogs uncommon	Moderate Estuarine fish species (black bream, *Acanthopagrus butcherii*), numerous bird species (eg. black ducks)	Reduced One or two fish species present of *Chrinodon* and *Atherinosoma* genera. *Galaxias maculatus* Waders very common (eg. stilts, avocets)	Low Waders very common
Invertebrates	Numerous crustaceae (eg. cladocerans, isopods, amphipods, shrimps yabbies, (*Cherax* spp)), damselfly, dragonflys	Few crustaceae, Shield shrimp (*Triops* spp) dominate *Daphnia carinata* *Alona sp.*	Rotifera (*Brachionus, Hexaarthra*) Anostraca (*Parartemia*) *Daphniopsis pusilla* *Daphniopsis australis* *Gladioferens spinosus* *Mytilocypris splendida*	*Artemia/Parartemia* start. Some species of *Diptera,* isopod crustacean *(Haloniscus searlei, Austrochiltonia subtenuis*) at lower range. Species of gastropod *Coxiella*at lower range	Artemia common, Trichoptera (*Symphytoneuria wheeleri*)
Macrophytes	Nardoo *(Marsilea spp)* Duckweed (*Lemna* spp.), Water fern (*Azolla* spp.), Pondweed (*Potamogeton* spp), Water Ribbons (*Triglochin* spp) Sedges & rushes (*Baumea* spp., *Gahnia trifida Juncus* spp, *Typha domingensis*)	Nardoo *(Marsilea spp),* Water Ribbons (*Triglochin* spp), Pondweed (*Potamogeton* spp), *Ruppia* spp Sedges & rushes (*Baumea* spp., *Gahnia trifida, Juncus* spp, *Typha domingensis*)	Estuarine species, *Ruppia* spp.	Rare clumps of *Ruppia, Lepilaena* species	Upper range of *Ruppia, Lepilaena* [1](rarely seen)
			Mainly green algae, *Ulva*, *Chaetomorpha*. Estuarine species, green algae diatoms, dinoflagellates	Filamentous green algae in small numbers. Diatoms and dinoflagellates dominate biota	*Dunaliella salina*, *Carteria* sp

3.9 Fauna Assessment

3.9.1 Vegetation

The vegetation of the remnant in which the fauna assessment was undertaken consists of two distinct vegetation communities. The York and Salmon gum woodland is located to the east of the pitfall trap transects, adjacent to the paddock area. The succulent steppe (samphires and saltbushes) with an overstorey of *Melaleuca* species was observed at the lakes edge and surrounding area. A notable stand of *Callitris preissii* was present towards the centre of the remnant. There were few understorey species, although the remnant appeared not to have been grazed recently. The open areas were dominated by *Austrostipa flavescens* (native grass) species.

3.9.2 Pitfall Traps

A total of 48 faunal species were captured in the pitfall traps in the three survey periods (Table 7). The two spring sampling times (Nov 1999 & 2000) recorded the highest species diversity (31 and 26 species, respectively), compared to the May 2000 sampling time (8 species). 12 reptile species (geckos and skinks) were identified in sampling. 3 species of dunnarts were recorded, with the highest abundance being captured and released in November 2000 (3 individuals). The highest number of mice were sampled in the May 2000 survey (almost double the number recorded in the November 1999 survey), with no mice being observed in the Nov 2000 survey. Of interest, is the 2 species (6 individuals) of frogs observed in the May 2000.

Photo 10 : Pogona minor

Photo 11 : Sminthopsis dolichura

Photo 12 : Ctenotus mimetes

Photo 13 : Diplodactylus pulcher

Photo 14 : Diplodactylus granariensis rex

Table 9 Species abundance in pitfall traps in the three sampling periods.

Species	Common Name	Nov 1999	May 2000	Nov 2000
Pogona minor	Bearded Dragon	1	1	2
Heteronotia binoei	Binoe's Gecko		1	
Strophurus spinigerus	Spiny-tailed Gecko		1	
Strophurus granariensis	Wheatbelt stone gecko	1		
Strophurus strophurus	Spiny tailed gecko	1		
Lerista gerrardii		2		1
Lerista distingvenda				1
Ctenophorus caudicincus	Skink			1
Ctenotus mimetes		4		4
Diplodactylus pulcher				1
Diplodactylus granariensis rex				1
Morethia butleri		2	1	
Mus musculus	House Mouse	7	16	
Sminthopsis crassicaudata	Fat-tailed Dunnart		1	
Sminthopsis dolichura	Little Long-tailed Dunnart		1	2
Sminthopsis granulipes	Dunnart	1		1
Neobatrachus sutor	Shoemaker Frog (?)		3	
Neobatrachus sp	Burrowing Frog		3	
	Wolf spider	12		11
	Plate shield bug #1	10		11
	Carob beetle	2		
	Ant	3		> 100
	Tick	1		
	Shield bug #2	2		
	Trapdoor spider	5		
	Red hornet	2		
	Slater beetle	2		
	Black Wolf spider ?	1		
	Cricket	5		1
	Grasshopper	2		
	Small wolf spider	1		
	Centipede	1		
	#3 sandy cow	1		
	Spider	3		
	Orb weaver spider	2		
	Brown beetle	1		
	Scorpion	1		2
	Soldier ant	1		

	Christmas beetle	10
	Wasp	6
	Moth	1
	Stick insect	1
	Centipede	1
	Fang spider	1
	Wood Cockroach	1
	Red spider	1
	Praying mantis	1
	Black beetle	1

3.9.3 Elliot Traps

The results of the elliot trapping was not tabulated as only one species (*Mus musculus* or house mouse) was caught in the first two sampling periods, with no species being caught in the last sampling. It is worth noting that quite a large number of mice were caught in both the elliot and pitfall traps in the first and second survey (Nov 1999 and May 2000), with this number decreasing over the 6 month period, with no mice caught in either the elliot or pitfall traps in Nov, 2000.

3.9.4 Avian Survey

26 bird species were identified belonging to 18 different families in the remnant vegetation surrounding Lake Goorley. The bird species together with their common name and family are listed in Appendix 4.

CONCLUSION

This report describes collected and collated base line data on the remnant vegetation and fauna of the Yarra Yarra Catchment. It is intended to be used by Landcare and Management Groups as a starting point for the successful management of the biological resources of this region.

Through this study the vegetation communities, areas and condition were assessed. Information was also collected on land tenure, remnant fencing, successional vegetation and areas of vegetation that is potentially at risk of salinity. Beards vegetation mapping was acknowledged to be an accurate data set for use in this region. Over 64% of remnant vegetation assessed in the Yarra Yarra catchment was considered to be in pristine or excellent condition, with only a very small proportion (just over 1%) being degraded. Succession of vegetation communities (ie change from one community type to another) is clearly evident in the Yarra Yarra Catchment. The successional vegetation from woodland to samphire was most obvious in the valley floors of the sub-catchments indicating these are the areas that are the most severely affected by hydrological changes as a result of land clearing. By contrast the woodland and shrubland vegetation associated with the lakes system was mostly unaffected by encroachment of samphire vegetation.

Vegetation distribution, representativeness and condition are the most important considerations in vegetation conservation and management, specifically in regard to setting priorities. This report provides the background statistics and the process by which to assess remnant vegetation status to establish conservation priorities for individual remnants and vegetation over a sub catchment basis. The main management considerations were also outlined to provide initial information of issues facing the Yarra Yarra Catchment.

The subsequent stages in the Yarra Yarra Catchment Project can now be undertaken. These include further field work to prepare Sub catchment Management Plans which outline specific strategies to conserve their biological resources and will analyze methods to deal with salinity

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APPENDIX 1 : PROCEDURE FOR DETERMINING REMNANT VEGETATION FROM THE LANDSAT SATELLITE IMAGE

PART A - PROCESS TO POLYGONIZE LANDSAT WOODY VEGETATION IMAGE.

1. Load *Veggrid*, limit analysis properties to display.
2. Use the map calculator to divide by one and save as grid this will reduce the size of the dataset to a manageable level.
3. Convert the grid created in point 2 to a shapefile. Call the shapefile "*step. Shp*".
4. Use geo- processing wizard to dissolve "*step1. Shp*" by grid code.
5. Delete unwanted polygons. This will leave a shapefile with the polygonized remnant vegetation blocks.
6. Use geo- processing wizard to clip the polygons to the sub catchment boundaries. Call the shapefile "*clipstep. Shp*".
7. Use vector transformations to explode the polygons. Use join field “gridcode" the shapefile “*step1. Shp*”.
8. Use WG public to assign area is to these polygons.
9. Delete polygons of less than hectares in area.
10. Fill in any obvious holes in polygons.
11. Re-calculate area is using WG tools.
12. Use Mila tools to create a unique identification for each polygons, name the ID field "Poly _Id". Syntax: "Bell" +recno. As string. Where "Bell" is a unique code for each sub catchment.

PART B - ASSIGN THE BEARD VEGETATION TYPES TO WOODY VEGETATION POLYGONS.

1. Use the geo- processing wizard and clip the Beard map using “*step1. Shp”*. Call this file “*step2.Shp”*
2. Use the tool polygon to centriod to generate centriods for all the polygons *in “step2. Shp”*. The file is auto-named “*step2_PT.Shp”*.
3. Use the geo- processing wizard spatial join to assign the data from “*step1. Shp* “ to “*step2_PT.Shp”*. This process will attach the overall area of the remnant vegetation stand to centriod shapefile (*step2_PT.Shp*). Re-name the area field to stand _ area.
4. Load *“vegstrip. Shp”* using geo- processing wizard merge “*step2_PT.Shp”* using the fields in *vegstrip* with *vegstrip* and call the resultant file “*cent. Shp”*.
5. Use the pseudo-spatial join tool button to join the centriod shapefile (“*cent. Shp”*) to “*step 2.Shp*”. This process will attach the overall remnant vegetation stand area to each vegetation type within the stand. Syntax Poly _ ID +"_" +veg _ assoc.as string. Note to make this process work both themes must be active in the view, use the Mila tool to add record numbers to both tables highlight the record number field in both tables, make “*step 2.Shp*”active and use the tool.
6. Create new field within the “*step 2.Shp*” (call this field disol) and combine the fields veg _ assoc and Poly _ ID into it, separate the two fields by "_". Dissolve the polygons in “*step 2.Shp*” using this new field, call this file “*step3. Shp*”.

7. Load *vegtemp. Shp.* Use in the geo- processing wizard merge "*step3. Shp"* with *vegtemp.shp* using the *vegtemp* fields. Call this shapefile *"step3a.Shp"*

8. Use the overlay attribute tool to update the fields in *"step3a. Shp"* with the values from "*step 2.Shp*". Update the following fields:

   - map ID, cell no,
   - Beard num
   - Beard area
   - grid code
   - veg code
   - ms250k
   - veg assoc
   - H. code
   - super group
   - lbl_load
   - area
   - perimeter
   - Study area
   - Warms_numb
   - Beard code
   - Description
   - Stand_area
   - Poly_id

9. Use WG tools to re-calculate the area for each vegetation type, then calculate the percentage area for each vegetation type. Use the following field names:

   - St_area_ha
   - Area_ha
   - %ofstand.

Appendix 2 - An example of the field data sheet

Sub-catchment		Vegetation structure unit	Vegetation community	Dominant species	Vegetation condition	Management issues	Fenced	Stock Present	Connection to other remnants	Comments/Photo Number
Remnant Number	Transect Number									

Appendix 3 - Area of Remnant Vegetation within each sub catchment on private land and reserves

Sub catchment	Area of remnant vegetation in reserves (ha)	% of remnant vegetation in reserves	Area of remnant vegetation in private land (ha)	% of remnant vegetation in private land	Total area of remnant vegetation (ha)
Morawa	2334	2.069	18.5	0.016	2352.5
2	4.7	0.004	1457.9	1.292	1462.6
3	1844	1.634	1469.5	1.302	3313.5
Campbells	**792.8**	**0.703**	**228.2**	**0.202**	**1021**
5	2565.8	2.274	668.1	0.592	3233.9
6	0	0.000	3470.7	3.076	3470.7
7	1.7	0.002	275.7	0.244	277.4
Upper Darling Creek	**144.7**	**0.128**	**709.3**	**0.629**	**854**
Perenjori	344.5	0.305	1035.5	0.918	1380
10	0	0.000	376.5	0.334	376.5
East Three Springs	0	0.000	1685.8	1.494	1685.8
12	0	0.000	225.7	0.200	225.7
19	527.5	0.468	586.1	0.519	1113.6
Mid Darling Creek	**221.8**	**0.197**	**620.3**	**0.550**	**842.1**
15	**16.1**	**0.014**	**513.9**	**0.455**	**530**
16	**168.8**	**0.150**	**1284.6**	**1.139**	**1453.4**
17	4.3	0.004	873.8	0.774	878.1
Glamoff	34.4	0.030	1428.7	1.266	1463.1
19	172.2	0.153	1055.9	0.936	1228.1
Goodlands	**0**	**0.000**	**2477.8**	**2.196**	**2477.8**
Jibberding	**299.2**	**0.265**	**2025.7**	**1.795**	**2324.9**
22	22.7	0.020	826.8	0.733	849.5
Lake De Courcy North	47.7	0.042	466.1	0.413	513.8
Lake Hillman	179.4	0.159	379.7	0.337	559.1
Lake De Courcy South	55.8	0.049	746.6	0.662	802.4
Kulja	149.1	0.132	884.6	0.784	1033.7
Burakin	**913**	**0.809**	**1515.9**	**1.344**	**2428.9**
28	69.3	0.061	1948.2	1.727	2017.5
29	95.1	0.084	651.1	0.577	746.2
30	57.7	0.051	385.4	0.342	443.1
31		0.000		0.000	N/A
Geranium Rock	**80.9**	**0.072**	**430.7**	**0.382**	**511.6**
Lake Goorley	29.3	0.026	3706	3.285	3735.3
Xantipe	38.4	0.034	2439.9	2.163	2478.3
Bywaters	0	0.000	1037.1	0.919	1037.1
36	42.9	0.038	3789.7	3.359	3832.6
37	26.5	0.023	2469.2	2.189	2495.7
38	**261.9**	**0.232**	**500.6**	**0.444**	**762.5**
Bellaranga	1202.3	1.066	2599.8	2.304	3802.1
40	0	0.000	3000.4	2.659	3000.4
41	18.3	0.016	1144.2	1.014	1162.5
42	577.9	0.512	4614.2	4.090	5192.1
43	1055.2	0.935	5690.1	5.043	6745.3
Pastural		0.000		0.000	N/A
45	1938.6	1.718	1178.9	1.045	3117.5
46	1.6	0.001	1301.5	1.154	1303.1
47	**598.8**	**0.531**	**2075.9**	**1.840**	**2674.7**
48	**1480.1**	**1.312**	**3465.4**	**3.071**	**4945.5**
Collier - Dingo	0	0.000	1236.9	1.096	1236.9
Lower Darling Creek	**5501.6**	**4.876**	**171.8**	**0.152**	**5673.4**
Yarra Yarra Lake	**3002.4**	**2.661**	**2035.5**	**1.804**	**5037.9**
Three Springs	16.6	0.015	2174.3	1.927	2190.9
53	112.3	0.100	1454.1	1.289	1566.4
54	106.4	0.094	3550.1	3.147	3656.5
East Buntine	**445.5**	**0.395**	**1339.2**	**1.187**	**1784.7**
56	1687.6	1.496	1835.9	1.627	3523.5
Yarra Yarra Catchment	29291.4	-	83534.0	-	112825.4

APPENDIX 4 - BIRD LIST FOR 28/5/00 – 29/5/00

Anatidae (swans, geese and ducks)	
Australian Wood Duck	*Chenonetta jubata*
Accipitridae (kites, hawks and eagles)	
Wedge-Tailed Eagle	*Aquila audax*
Charadriidae (lapwings and plovers)	
Banded Lapwing	*Vanellus tricolor*
Columbidae (pigeons and doves)	
Crested Pigeon	*Ocyphaps lophotes*
Common Bronzewing	*Phaps chalcoptera*
Cacatuidae (cockatoos)	
Galah	*Cacatua roseicapilla*
Corella sp.	*Cacatua sp.*
Psittacidae (lorikeets and parrots)	
Australian Ringneck (Twenty-eight Parrot)	*Barnadius zonarius*
Cuculidae (cuckoos)	
Horsfield's Bronze-cuckoo	*Chrysococcyx basalis*
Tytonidae (barn owls)	
Barn Owl	*Tyto alba*
Aegothelidae (owlet-nightjars)	
Australian Owlet-nightjar	*Aegotheles cristatus*
Maluridae (fairy-wrens)	
White-winged Fairy-wren	*Malurus leucopterus*
Pardalotidae (pardalotes)	
Striated Pardalote	*Pardalotus striatus*
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*
Meliphagidae (honeyeaters)	
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*
Singing Honeyeater	*Lichenostomus virescens*
Yellow-throated Miner	*Manoria flavigula*
Red Wattlebird	*Anthochaera chrysoptera*
Petroicidae (Australian robins)	
Red-capped Robin	*Petroica multicolor*
Pachycephalidae (whistlers)	
Grey Shrike Thrush	*Colluricincla harmonica*

Dicruridae (flycatchers)	
Magpie-lark	*Grallina cyanoleuca*
Willie Wagtail	*Rhipidura leucophrys*
Grey Fantail	*Rhipidura fuliginosa*
Artamidae (woodswallows)	
Grey Butcherbird	*Cracticus torquatus*
Corvidae (ravens and crows)	
Australian Raven	*Corvus coronoides*
Hirundinidae (swallows)	
Welcome Swallow	*Hirundo neoxena*

Appendix VI

Ecologist's Report on Outfall Area of Five Drains

Deep Drainage Assessment

Monitoring Report

Prepared for
The Yarra Yarra Catchment Group

November 2004

Prepared by

Regeneration Technology Pty Ltd

Deep Drainage Assessment

Monitoring Report

November 2004

Regeneration Technology Pty Ltd

Cover photo by Georgina Nielssen

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INTRODUCTION

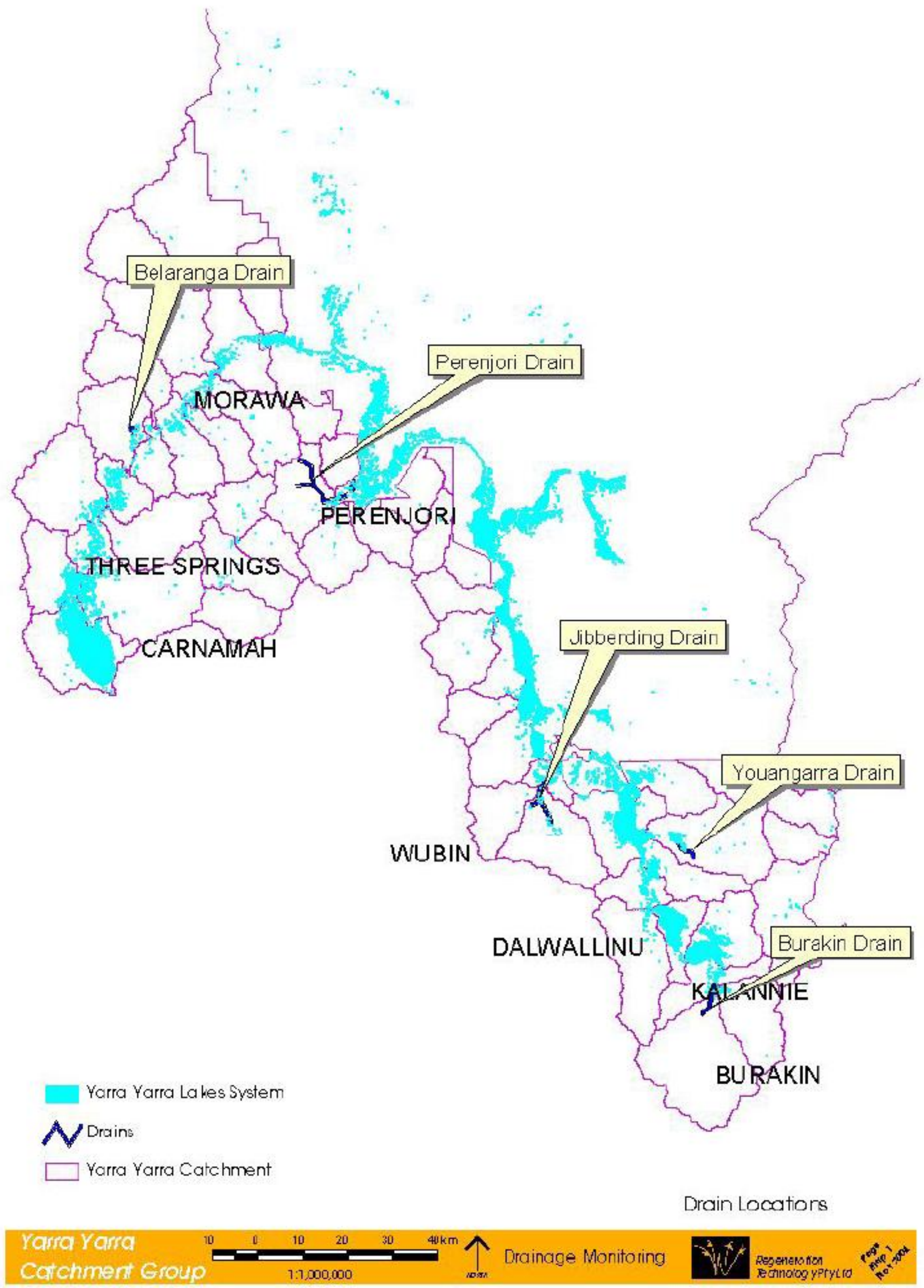
The Yarra Yarra catchment covers an area of 4,258,102ha with approximately 1,000,000 ha being agricultural land. The catchment is internally drained into the Yarra Yarra lakes system, which cover 220,800 ha and stretch over 300 km. It is an ephemeral saline playa system. The main lakes only occasionally (ie once every several years) contain free surface water. The lake system was saline pre-clearing. The smaller tributary wetlands and low points in the catchment contain chains of salt lakes linked by samphire-dominated depressions while the larger expanses of the main system have a thick salt layer.

Deep drainage is being used across the wheatbelt of Western Australia as a means to lower the groundwater aquifer and reclaim arable land. Saline ground water in the Yarra Yarra catchment is a result of clearing deep-rooted native perennial vegetation for agriculture. Ground water levels have risen over time resulting in salt scalds on the landscape and localized deaths of low lying vegetation. Annual recharge of the ground water in the Yarra Yarra is extremely low due to low rainfalls and high evaporation rates. The ancient geology of the area also means that the ground water aquifer is restricted in some areas. The Yarra Yarra Catchment Group is undertaking an extensive program of drilling and monitoring bores across the catchment that will provide some insight into the movement (and containment) of groundwater in the catchment.

This evaluation has utilised the guidelines for assessment of saline drainage developed by Regeneration Technology and Actis Environmental for the Department of Conservation Land Management. The guidelines were developed specifically for the Nyabing catchment with the view that they could be used to evaluate drainage proposals elsewhere in the wheat belt of Western Australia. The assessment guidelines used for the Nyabing catchment were developed to examine the downstream impacts of saline drainage on nature conservation. The Nyabing impact assessment requires the identification of both the primary and final receiving wetland, which for most areas in the south west of Western Australia will be a river system.

In the Yarra Yarra catchment the primary receiving wetland for drainage discharge are low lying valley floors which are a series of ephemeral lakes and samphire depressions. The final receiving wetland are the 300km of salt lakes of the Yarra Yarra lakes system. Large volumes of water have been recorded as being discharged from the drains, however with the exception of small areas of localized flooding there is no evidence that the water is transported any distance beyond the discharge point of the drain. Low rain fall (334mm) and high evaporation rates recorded to be in excess of 2.5m per annum (Bureau of

Meteorology) in the Yarra Yarra Catchment results in the discharge water not being transported beyond the valley floors.



Five deep drains in the Yarra Yarra Catchment were targeted for this study. Locations of the drains are shown in Map 1 they are a representative sample of drains being constructed within the Yarra Yarra catchment. The five drains are:

1) Youangarra (Stanley) in the Goodlands area. this drain was the subject of previous monitoring that was undertaken in 2003.
2) Belaranga (Sasse and Moffitt).
3) Burakin (Nixon);
4) Perenjori (Solomon) At the time of monitoring this drain had not yet been dug and soil and water samples were taken from the end point (ie the lake) and from monitoring bores further up in the catchment.
5) Jibberding. This drain was constructed to remove ground water that had risen to the surface the flooded Jibberding Hall Rd that was impassable for a number of years.

MONITORING METHODS

VEGETATION

Vegetation type along the length of the drain was recorded using dominant species as the indicator. A 500m buffer along the entire length of the drain was mapped for vegetation using field notes and aerial photography in Arcview.

All mapped areas were calculated from shape files held by the Yarra Yarra Catchment Group in Arcview. Climatic data was down loaded from the Bureau of Meteorology web site. All sampling points were located using a hand held GPS.

SOIL AND WATER SAMPLES

Each of the drains was visited on at least two occasions during the winter of 2004. Water samples were collected from three locations along the drain, 1) the starting point of the drain, 2) a midway point along the drain, and 3) from the end point of the drain and if possible a sample was also taken from the receiving wetland. Soil samples were taken from the shoreline of the primary receiving wetland near the end point of the drain from the surface and a depth of 30cm, which represented a change in the soil structure/type (the b horizon). All soil and water samples were stored in a refrigerated container and delivered to SGS Environmental (NATA accredited laboratory) within 2 day of collection for analysis.

All samples were analysed for the following:

pH,

Conductivity,

Sodium (Na),

Calcium (Ca),

Magnesium (Mg),

Chloride (Cl),

Sulphate (SO_4),

Total nitrogen (N), and

Total Phosphorus (P).

Estimates of the discharge volumes from the drains were calculated by recording the flow rates. Flow rates were estimated by timing and measuring the distance traveled by a cork down the drain and calculating a cross sectional area of the drain.

Photo: Collecting water samples from deep drain in Burakin.

BORE MONITORING DATA

Bore monitoring is s separate project being undertaken by the Yarra Yarra Catchment Group and to date the data has not been compiled and analysed. For the purpose of comparison the results form 18 bores in the Perenjori subcatchment and 24 bores from the Belaranga subcatchment have been include in this report. Information recorded form each bore was depth to ground water pH and salinity. The bores were monitored in August 2004.

RESULTS AND DISCUSSION

The results show a considerable variation between the volumes of water and the water quality being discharged via the deep drains in the Yarra Yarra (Table 1). Belaranga the most northern drain has very high volumes of discharge from a short length of drain and although the water quality appears to be better than that from the other drains the discharge water is still hypersaline. The salinity of the all the primary receiving wetlands is within similar range to that of the drain water being discharged.

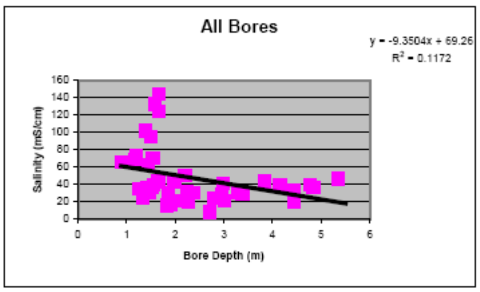
The most serious issue with regards to water quality from the drains is the decrease in the pH (increase in acidity) of the ground water being drained compared to the water in the receiving wetland. A decrease in the pH of the water will result in the mobilization of heavy metals that would otherwise remain bound in the soils this can have a negative impact on flora and fauna, however given the salinity of the water there is very little that lives in the water or the salt lakes. Analysis of the soils in the receiving wetland gives an indication of the buffering capacity (ie the ability to neutralize pH) of the wetland soils. Nutrients (nitrogen and phosphorus) in the discharge water were at very low levels and are not considered an issue for any of the drains monitored.

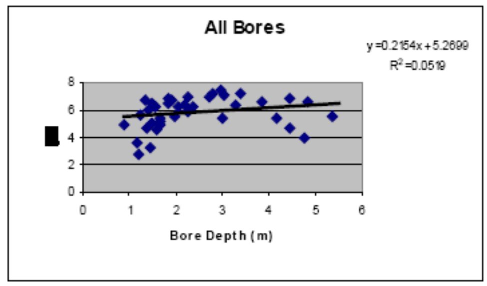
Table 1 Summary of information used for this assessment

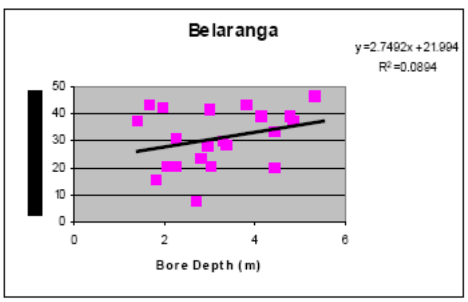
	Drain Name					
	Youangarra (2003)	Youangarra (2004)	Belaranga	Burakin	Jibberding	Perenjori (not constructed)
Sub catchment name	Goodlands (20)	Goodlands (20)	Belaranga (39)	Burakin (27)	Jibberding (2)	Perenjori (9)
Sub catchment size (ha)	32794	32794	21708	44911	27623	19738
Type of drain	deep open drain	deep open drain	deep open drain	deep open drain	open drain	deep open drain
Length of drain (km)	2.72	2.72	2.76	7.13	12.70	24
Area to be drained (ha)	27.2	27.2	27.6	71.3	127	240
Estimated time of construction	November 2000	November 2000		2000	2002	
Estimate drain discharge (m^3 per year)	107222	10512	136875	47304	685382	
Primary receiving wetland name and type	samphire depression	samphire depression	Valley floor salt lake chain	Valley floor salt lake chain	Valley floor salt lake chain	Valley floor salt lake chain
Width depth and slope or fall of primary receiving wetland at discharge point	nil	nil	nil	nil	nil	nil
Area of primary receiving wetland (ha)	290	290	Joins wetland system	Joins wetland system	Joins wetland system	Joins wetland system
Final receiving wetland name and type	Yarra Yarra Lakes	Yarra Yarra Lakes	Yarra Yarra Lakes	Yarra Yarra Lakes	Yarra Yarra Lakes	Yarra Yarra Lakes
Area of final receiving wetland (ha)	12293	12293	12293	12293	12293	12293
Total area of wetland in the system (ha)	795625	795625	795625	795625	795625	795625
turnover factor (years)	50+	50+	50+	50+	50+	50+
average yearly rainfall (mm)	360	360	334	360	334	360
average yearly evaporation (m)	2.5	2.5	2.5	2.5	2.5	2.5
ionic concentration of drain water (uS/cm)	65,000 -100,000	76,000 – 86,000	34,000 - 42000	53,000 – 120,000	49,000 – 90,000	33,000 (from monitoring bore)
pre-drainage ionic concentration of receiving wetland (uS/cm)	14,000 (only have figure for soil)		42,000	110,000	90,000	29,000
pH of groundwater to be drained	3.2 - 4	3.4 – 3.5	7.7	3.2 – 3.4	3.3 – 4.2	7.1 (from monitoring bore)
pH of receiving wetland for open drain systems	7.2 (only have figure for soil)		7.7	7.6	4.8	7.3
average concentrations of nitrogen and phosphorus in drain water (mg/l)	N 26mg/l P <0.05	14 – 16 0.05	18 – 23 <0.05 – 0.07	<0.2 – 4.2 <0.05	3.9 <0.05	2.8 <0.05
average concentrations of nitrogen and phosphorus receiving wetland (mg/l)	N 210mg/kg P 56 mg/kg (figure for soil no free water in the wetland)		4.5 <0.05	<0.02 0.1	3.1 <0.05	7.7 0.12

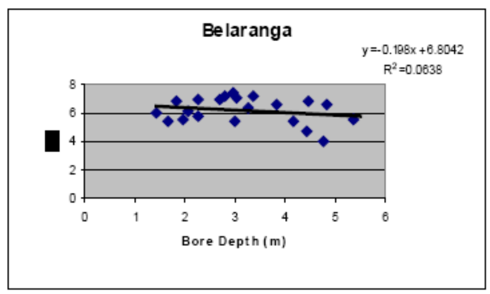
BORE MONITORING RESULTS

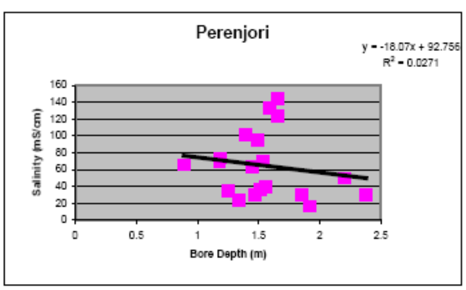
The bore monitoring data shows that the salinity of the ground water increases the closer the water is to the surface. This is not a surprising result as the salt in the soil closer to the surface is being dissolved back into solution resulting in higher salinity in the water closer to the surface. However when we look at the data from Belaranga the correlation is not evident and the salinity of the ground water is lower in this catchment than the Perenjori catchment. There appears to be no correlation between bore depth and pH however in the Perenjori catchment the correlation is stronger between increasing bore depth and increasing pH.

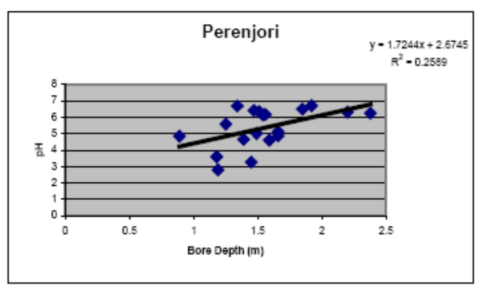


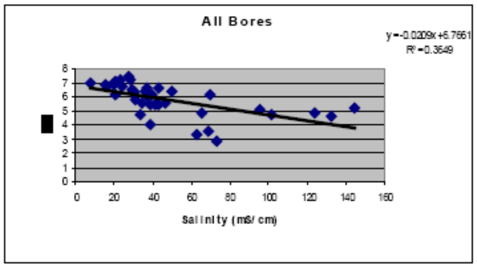


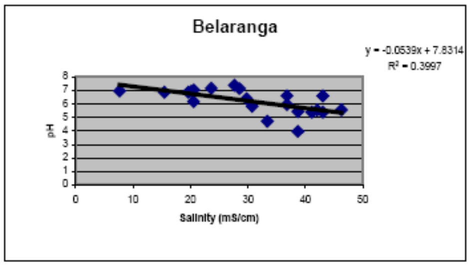


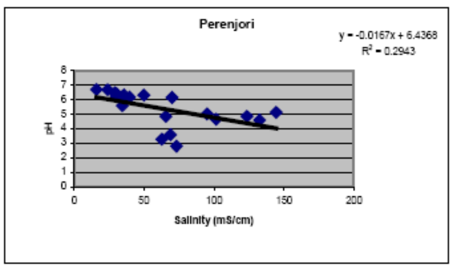












The correlation between salinity and pH is apparent for all bores as well as the individual catchments with the trend being increasing salinity resulting in lowered pH. This may have downstream implications and will be discussed in more detail later in this report.

YOUANGARRA DRAIN

Monitoring data from the Youangarra drain has been collected on three occasions since 2001.

Vegetation

Vegetation mapped along the length of the drain shows that a great deal of the area through which the drain passes is agricultural land. The drain passes through a small section of remnant vegetation that contains York gum and melaleucas before passing directly through lowlying samphire (Map 2).

Vegetation health along the length of the drain was recorded over the 3 year study period and appears to not have altered. On the northern side of the road the drain runs along the outer edge of a stand of native vegetation. The vegetation to the east of the drain at this point consists of occasional trees with a sparse understorey of Melaleuca. The vegetation at this site was in poor condition at the commencement of the study and 3 years on there is no evidence of further decline in the vegetation (ie no evidence of recent tree deaths). The presence of the drain appears to have no effect on the woody vegetation.

The vegetation on the western side of the drain is typically samphire and joins with the receiving wetland.

Receiving wetland area and Zone of influence

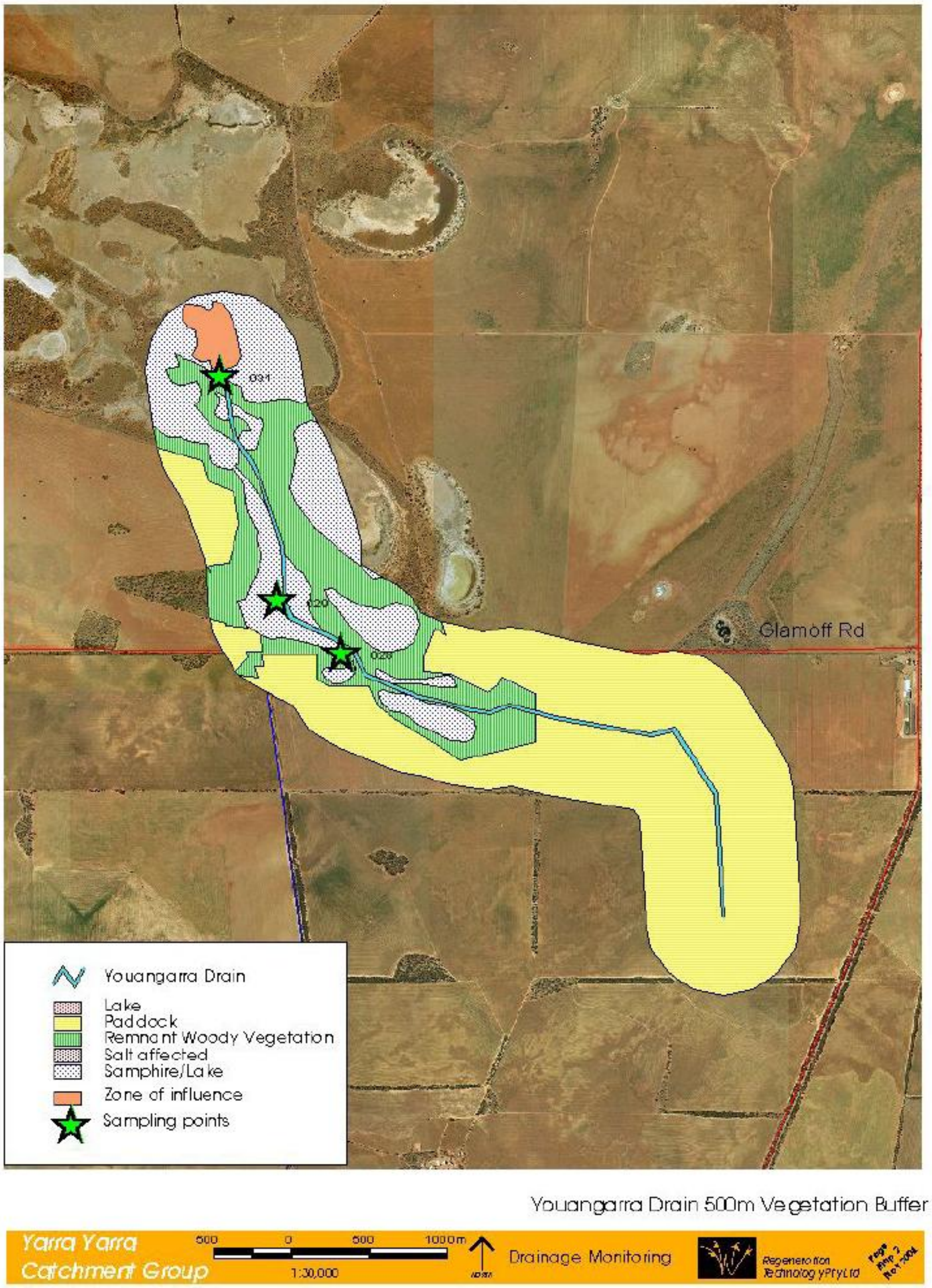
The receiving wetland is an ephemeral depression covered in samphire. No open or standing water has been noted in this wetland since the commencement of this study. The primary receiving wetland is part of the Yarra Yarra Lakes system and is 290ha in size.

The zone of influence was determined by mapping the edge of the wet area using a hand held GPS (Map 2). There is no free water in this wetland even in the middle of winter so the edge of the wet area was determined using a probe. The zone of influence in the receiving wetland was measured in August 2001, 9 months after the drain was constructed and again in October 2003 and July 2004. The zone of influence including the ponding area at the end of the drain was determined to be 11ha in 2003.

This 11ha represents less than 4% of the primary receiving wetland and after 3 years of the wetland receiving discharge from the drain there has been no increase in the area of the zone of influence from the drain. This indicates that the water flowing into the wetland is being discharged; most likely via evaporation at the same rate (if not faster than) it is moving into the wetland. This being the case it is reasonable to conclude that if water continues to enter the wetland system at the same rate the impact of the additional water on the wetland will be minimal.

Photo: End of Youangarra Drain (Primary receiving wetland

The samphire vegetation within the zone of influence appears to be greener than elsewhere in the wetland however without any tissue analysis of the vegetation it is not possible to determine if this is due to a luxurious uptake of water or nutrients. There appears to be a decreasing gradient of total nitrogen in the soils (See Table 2) from the drain end to outside the zone of influence. A more detailed study of the uptake of nitrogen by samphire is necessary to draw any conclusions as to the effect this gradient may be having on the vegetation.



Youangarra Drain 500m Vegetation Buffer

Quantity of water discharging into the wetland

The quantity of water discharging into the wetland from this drain was estimated by Glen Biggins to be 107,222m^3 per annum in 2003. Discharge was estimated to be 10,512m^3 per annum in 2004. It was noted at the time of sampling in 2004 that the flow rates appeared to be considerably lower than on previous occasions. Bore monitoring data may show that the depth to the water table has decreased over the study period. Previous bore monitoring across the catchment showed a decrease from in the water table from an average depth of 1.42m below the surface in 1997 to 1.9m below the surface in 2003. This is a significant drop however it is not possible to determine why this has occurred. It is most likely to be due to a number of factors including the planting of deep-rooted perennials, drainage and climatic factors.

Depth of the drains and base flows

The drains were constructed in November 2000. There appears to be virtually no slumping along the length of the drain and no build up of sediment in the drain. Minor slumping is occurring towards the end of the drain. The depth of the drain (prior to Glamoff Rd) is approximately 2m after Glamoff Road the drain picks up surface runoff from the road and adjacent wet depressions. The base flow in the drain has been constant as indicated by a depth gauge at the Glamoff Road crossing since the drain was constructed in November 2000.

Region of Influence of the Drain

The region of influence the drain is having on the groundwater aquifer difficult to determine and is a contentious issue. The influence of the drain on groundwater levels declines with distance away from the drain but is related to the permeability of the soils. No detailed analysis of the soils along the length of the drain have been undertaken for this purpose though it has been observed that at depths greater than 1m especially in the upper reaches of the drain there is shale lying in horizontal sheets. It is possible the hydraulic conductivity of these sheets is greater than that of either sand or clay resulting in the zone of influence of the drain being greater than has been recorded elsewhere in WA where the soils are sandy loams or clays.

The yearly discharge from the drain has been estimated to be 107,222m^3 per annum or 321,666m^3 since the drain was constructed. Average annual rainfall in the region is 360mm, which would account for some recharge of the groundwater aquifer however with average annual evaporation being 2.5 m, recharge from rainfall is considered to be minimal.

The depth of the water in the drain is 10cm, the average width of the drain base is 150cm and the length is 2.72km. The water in the actual drain therefore accounts for 408m^3. In 2003 the estimated annual discharge from the drain was 107,222m^3, which is 263 times the volume in the drain. In 2004 the estimated annual discharge was 10,512m^3. This drop is significant with an estimated 7% of the volume of the water in the drain being added daily in 2004 compared to 71% in 2003.

These results show dramatic decline in the interception and removing ground water. This is most likely to be due to the aquifer within the region of the drain being drained to base level of the drain. Additional monitoring of the bores in the area and flows in the drain should confirm this.

Chemical analysis of water and soils

Table 2 shows the results of soil and water analysis undertaken in August 2001, October 2003 and 2004. Water samples collected in October 2003 were collected from 2 sites in the drain the one to the south of Glamoff Rd before the drain connects with surface runoff from Galmoff Rd and one at the drain end where it meets the wetland.

Soil samples were collected in October 2003 from 3 locations (the drain end, the zone of influence and outside of the zone of influence) 30-50cm below the surface in the receiving wetland.

Table 2 Ion concentrations of Water and Soils from the Youangarra drain.

Sample Code	Date Collected	Type	pH	*u*S/cm	Na mg/L	Ca mg/l	Mg mg/l	Cl mg/l	SO4 mg/l	Total N mg/l	Total P mg/l
A	12/10/2003	soil	7.1	14000	16000	5700	1600	32000	20000	350	98
B	14/10/2003	soil	7.2	12000	11000	4200	930	19000	13000	210	56
C	12/10/2003	soil	6.5	9800	8800	4800	820	19000	16000	420	96
3030	1/07/2004	soil	4.4	5400	3300	3500	410	7900	13000	170	59
30s	1/07/2004	soil	5.1	5500	4600	4300	410	7100	13000	190	100
3130	1/07/2004	soil	5.4	6900	6500	4300	650	13000	15000	220	50
31s	1/07/2004	soil	5.8	12000	15000	5000	1500	26000	17000	470	59
IS2 52	17/08/2001	water	3.4	70000	12000	120	1200	25000	3000		<0.05
IS2 53	17/08/2001	water	4.1	77000	17000	180	1300	24000	3500		<0.05
IS2 54	17/08/2001	water	3.3	92000	15000	150	1600	29000	4500		<0.05
IS2 55	17/08/2001	water	3.4	65000	20000	260	1900	20000	3300		<0.05
IS2 56	17/08/2001	water	4	58000	98000	220	1100	18000	3100		<0.05
28	1/07/2004	water	3.4	76000	15000	670	1200	25000	3000	16	0.05
30	1/07/2004	water	3.5	86000	14000	780	1500	30000	3600	14	0.05

A = Within the zone of influence

B = Outside the zone of influence

C = Drain end

These results show:

pH and Ionic Concentrations

The discharge in the drain is acidic with readings of between pH 3.2 and 4. There appears to be no change in the acidity of the discharge over the 3 sample periods. The pH of the wetland soil is slightly lower at the end of the drain however the acidic discharge appears to have no influence on the pH of the soils within the "zone of influence", which was recorded to have the same pH as the soil sampled from outside of the zone of influence.

The buffering capacity of the soil at the end of the drain appears to have been saturated with the pH of the soil samples from the end of the drain decreasing from pH 6.5 to pH 5.8 over that last year. It is reasonable to assume the initial pH of the soil at the end of the drain would have been similar to that elsewhere in the wetland (ie between 7.1 and 7.2). At the drain end where the soil has been saturated by discharge for a period of 4 years the soil has been capable of neutralizing most of the acidy from the discharge with the soil pH dropping by a pH of 1.4. This is a very interesting result given the estimated quantities of water (332,178m^3) discharged at this point since the drain was built. The drop in pH in soil at the point of discharge while it is significant the pH is still within the medium acidic range (Hunt and Gilkes, 1992) and is not considered toxic. With the quantity of water being discharged from the drain dropping from 100,000m^3 per annum to 10,000m^3 per annum the moderate acidification of the soil will not spread beyond the drains end. The zone of influence in the wetland will decrease over time as the wetland dries.

BELARANGA DRAIN

The Belaranga drain is the most northern drain monitored for this report. It consists of 2 parallel drains that link into the salt lakes of the valley floor.

Vegetation

The vegetation within a 500m buffer of the drain consists of paddocks and the samphire lake system of the valley floor (Map 3). The drain links into a lake that is part of a chain of lakes in the valley floor. The health of the vegetation surrounding the lake appears to not have changed in recent times, as there is no evidence of recent flooding of dryland vegetation or tree deaths.

Primary receiving wetland

The primary receiving wetland is a chain of lakes that currently have standing water that attracts bird life. There is no obvious change in the shoreline of the lake indicating the volumes of water discharging into the wetland from the drain are not impacting on the water levels in the lake.

Belaranga Drain 500m Vegetation Buffer

Quantity of water discharging into the wetland

An estimate of the annual volume of water entering the primary wetland was calculated to be 136,875m^3 per annum which represents a considerable draw down of the water table, however there is no evidence to indicate this volume of water is having even a minor impact on water levels in the lakes further downstream. This drain was constructed 2002,over time it is expected that the volumes of water being discharged will decrease as has been recorded for the Youangarra drain.

Chemical analysis of water and soils

Table 3 Shows the results of soil and water analysis undertaken in August 2004.

These results show:

The soils and water samples collected all show a slightly alkaline pH. With pH values being close to neutral there is very little concern for the mobilization of metals from the soil into solution. The water quality entering the lake from the drain is not too different from the water that already exists in the lake and it is therefore unlikely to have an impact on the ecological functioning of the primary wetland or those further down stream.

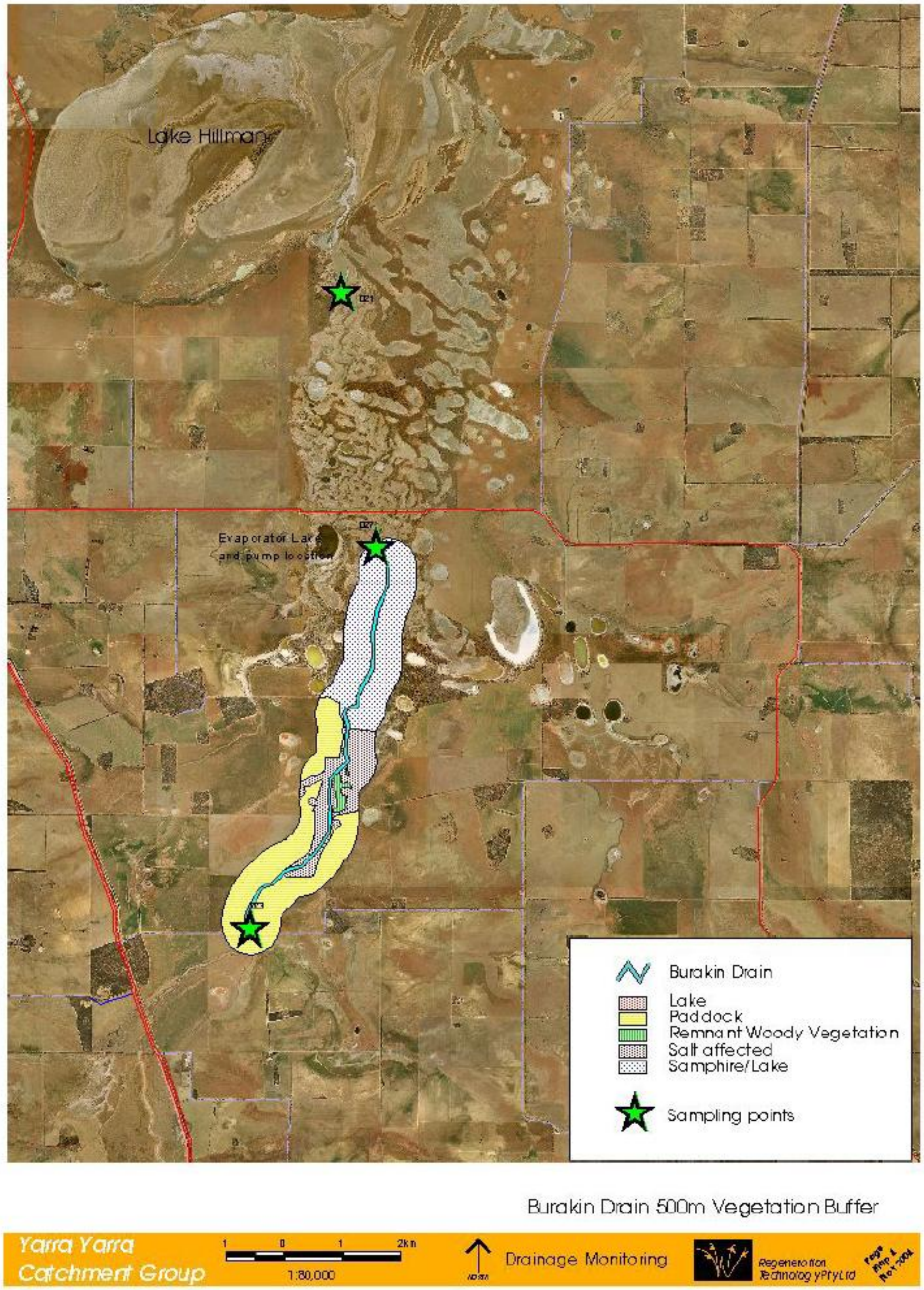
The results of the water quality testing of the discharge water and the water in lake are consistent with the results from the bore monitoring in the area (See previous section) that also indicated a neutral pH and comparably low salinity in the ground water in the catchment.

Table 3 Ion concentrations of Water and Soils from the Belaranga drain.

Sample Code	Date Collected	Type	pH	uS/cm	Na mg/L	Ca mg/l	Mg mg/l	Cl mg/l	SO4 mg/l	Total N mg/l	Total P mg/l
4230	81/08/2004	soil	7.8	12000	13000	280	2200	25000	2600	4500	8
42s	18/08/2004	soil	8.8	6200	7200	100	700	8300	1800	1300	46
39	18/08/2004	water	7.6	42000	10000	270	1100	6300	2300	23	0.07
38	18/08/2004	water	7.7	34000	7400	160	760	12000	1900	18	<0.05
42	18/08/2004	water	7.7	42000	9400	180	1100	6200	2200	4.5	<0.05

BURAKIN DRAIN

The Burakin drain was constructed along a natural watercourse during 2000, which is the same year the drain at Youangarra was constructed. This is the first year this drain has been monitored and it is likely if we are to base assumptions on the monitoring results from the Youangarra drain that the volume of the discharge from this drain is also decreasing from when it was constructed. Other methods within the vicinity of the drain have also been used to lower the ground water in the area including the use of a bore pump and evaporation lake to dispose of the water.



Vegetation

A 500m buffer of vegetation was mapped either side of the drain (Map 4). Vegetation along the natural watercourse is samphire with Melaleucas in the higher areas. There is a small patch of remnant woody vegetation within the buffer zone.

Receiving wetland area

The primary receiving wetland for the Burakin Drain is a chain of lakes along the valley floor that drain into Lake Hillman. Lake Hillman covers an area of approximately 3717ha and is only ever partially inundated. The photo below is taken from the middle of the lake.

Photo: Lake Hillman primary receiving wetland for the Burakin Drain

Quantity of water discharging into the wetland

The quantity of water currently being discharged from the Burakin drain is estimated to be 47,304m^3 per annum. If the area of the receiving wetland, Lake Hillman (3,717ha) and annual evaporation rates (2.5m) are taken into account it is clear to see why the water from this drain never makes it beyond the primary receiving wetland.

Chemical analysis of water and soils

Table 4 Shows the results of soil and water analysis undertaken in August 2004.

Table 4 Ion concentrations of Water and Soils from the Burakin drain.

Sample Code	Date Collected	Type	pH	uS/cm	Na mg/L	Ca mg/l	Mg mg/l	Cl mg/l	SO4 mg/l	Total N mg/l	Total P mg/l
2130	01/07/2004	soil	5.6	13000	14000	220	2900	24000	3200	50	79
2730	01/07/2004	soil	5.7	5900	6200	140	720	13000	1500	54	33
21s	01/07/2004	soil	6.4	9900	9800	3300	1700	22000	13000	420	110
27s	01/07/2004	soil	4.3	600	6200	140	720	10000	1500	71	4321
12	01/07/2004/	water	3.1	77000	1800	180	2100	30000	4400	3.2	<0.05
23	01/07/2004	water	3.2	53000	11000	220	1200	17000	2300	.02	10
27	01/07/2004	water	3.4	120000	23000	450	2100	43000	5100	4.2	0.05
21	01/07/2004	water	7.6	110000	21000	1600	2300	41000	5800	<0.02	0.1

These results show:

The pH of the discharge water is very low and the salinity is correspondently high. The pH of the water in the receiving wetland is neutral with a value of 7.6 however the salinity of the water is extremely high. The soil samples taken from the receiving wetland are also acidic however it is likely they would have a reasonably high capacity to buffer the low pH from the discharge as large expanses of Lake Hillman contain gypsum deposits, which is used as a soil amendment to help neutralize acidic soils. There are surprisingly high levels of nitrogen and phosphorus found in the surface soil of the receiving wetland this is most likely to be due to a localized natural effect as there is no direct runoff from the adjacent farming land into this area.

JIBBERDING DRAIN

The Jibberding drain was constructed primarily to relieve the permanent flooding of roads due to raised ground water levels. With the ground water being so close to the surface the prime function of this drain is the conveyance of water to a discharge into the low lying chain of lakes in the valley floor. The benefits of this drainage project have become immediately obvious with the water being cleared from the Jibberding Hall Rd. If this drain continues to function by draining ground water the problem of flooding is unlikely to occur again. Once the surface water has been drained the flows should slow down to a base level and eventually as seen elsewhere in the Yarra Yarra, drop off to virtually nothing.

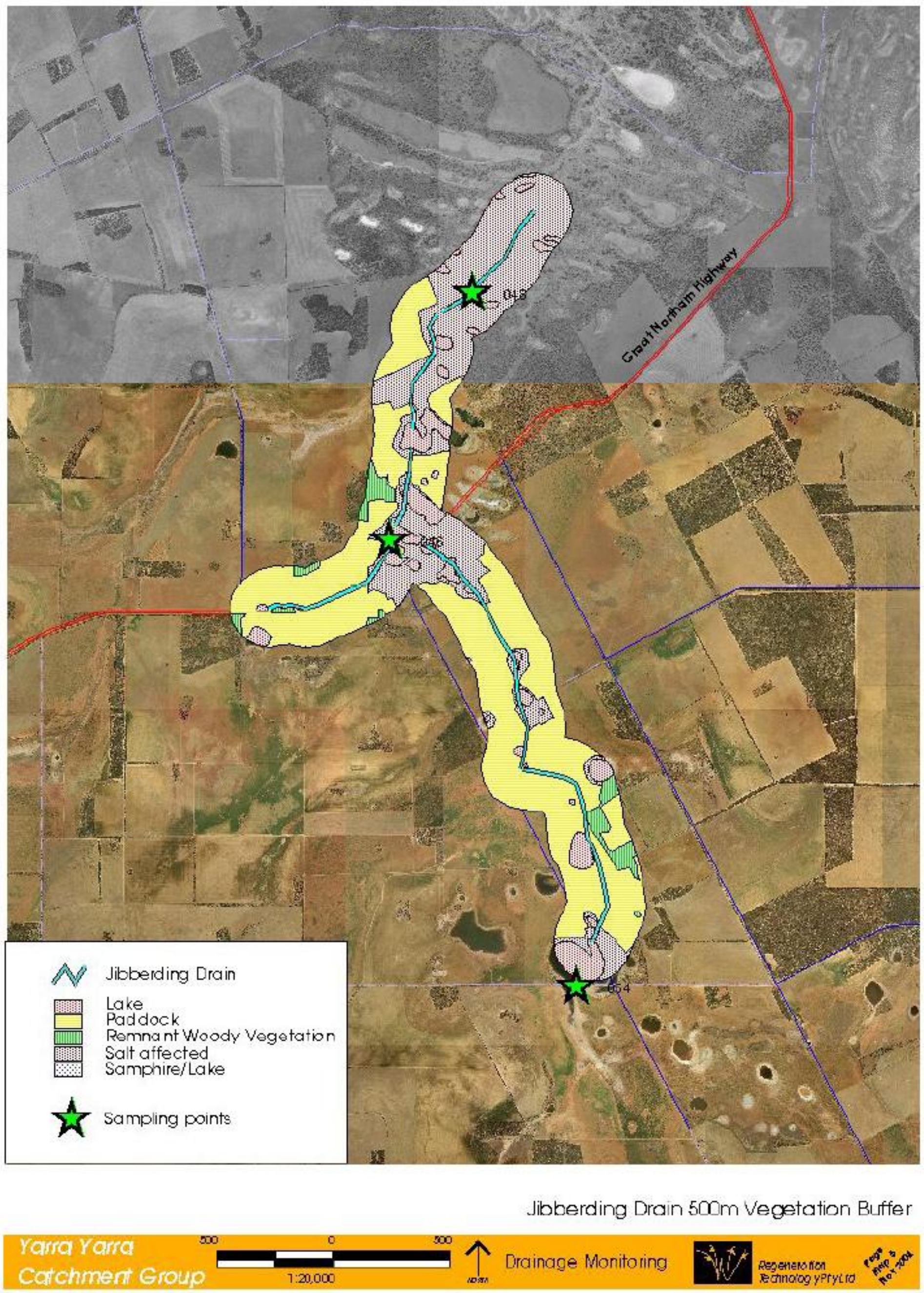
Photo: One of the series of lakes the Jibberding drain flows through

Vegetation

The vegetation mapped with a 500m buffer (Map 5) of this drain comprises of farmland, samphire in the low lying areas and some small remnants of woody vegetation.

Quantity of water discharging into the wetland

The quantity of water discharging being discharged from this drain is estimated to be 685,382m^3 per annum. This is a huge volume of water and currently represents the drainage of water that has been land locked for a number of years. Despite the volume of water discharging down this drain there appears to be no change in the water levels of the chain of lakes to the north of Great Northern Highway since the drain was constructed. Wetlands and lakes on the southern side of Great Northern Highway have decreased in volume and the shoreline of these lakes is gradually decreasing.



Receiving wetland area and Zone of influence

The receiving wetland for the Jibberding drain is an ephemeral depression covered in samphire similar in appearance to the Youangarra receiving wetland.

Chemical analysis of water and soils

Table 4 shows the results of soil and water analysis undertaken in August 2004.

These results show, that the pH of the discharge water is acidic and the soil of the receiving wetland slightly acidic to neutral indicating the wetland spoils may have the capacity to buffer the acidic groundwater. The salinity of the discharge water is moderate (for the Yarra Yarra Catchment) and it is interesting to note that the sample from the starting point of the drain was approximately half the salinity than the lower reaches of the drain. This indicate that once the groundwater that caused the flooding of lakes and roads to the south of Great Northern Highway have been turned over the new water entering the drainage and wetland system will have a slightly lower salinity level.

Table 5 Ion concentrations of Water and Soils from the Jibberding drain.

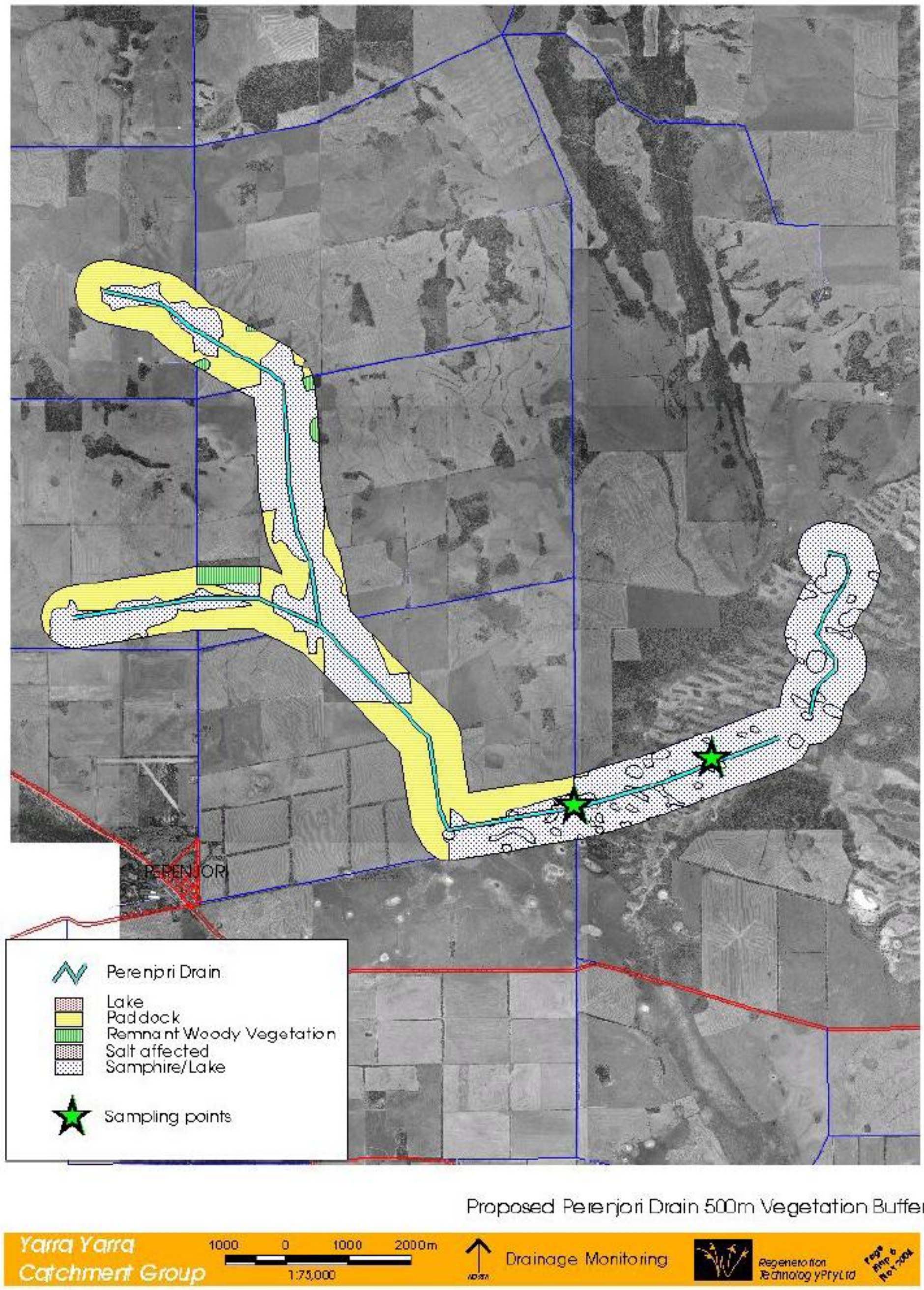
Sample Code	Date Collected	Type	pH	*u*S/cm	Na mg/L	Ca mg/l	Mg mg/l	Cl mg/l	SO4 mg/l	Total N mg/l	Total P mg/l
4630	18/08/2004	soil	4.8	2900	2900	21	110	4800	680	400	14
46s	18/08/2004	soil	5	6000	6300	86	630	11000	1600	310	11
48s	18/08/2004	soil	7	1300	1200	18	38	1800	230	210	19
4830	18/08/2004	soil	7.1	5000	5400	140	460	8300	1300	1300	30
46	18/08/2004	water	3.3	90000	21000	680	2200	37000	5500	4.2	<0.05
52	18/08/2004	water	3.5	80000	18000	360	1700	25000	4000	3.3	<0.05
54	18/08/2004	water	4.2	49000	12000	270	1200	10000	2400	3.9	<0.05
48	18/08/2004	water	4.8	98000	21000	1100	2300	39000	6700	3.1	<0.05

PERENJORI DRAIN

The Perenjori drain has not been constructed yet. It is being designed to combat rising ground water levels within proximity to the townsite. It will be approximately 24 km in length draining into the Yarra Yarra chain of wetlands in the valley floor.

Vegetation

The vegetation within a 500m buffer of the proposed Perenjori Drain is for the most part farm land and salt affected pastures in the lower reaches of the proposed drainage area there is samphire vegetation and chains of lakes with melaleucas on the higher ground. The Perenjori drain passes over the clearing line of the whaetbelt and ends in the pastoral country to the east.


PERENJORI
Perenjori Drain
Lake
Paddock
Remnant Woody Vegetation
Salt affected
Samphire/Lake
Sampling points
Proposed Perenjori Drain 500m Vegetation Buffer
Yarra Yarra
Catchment Group
1000 0 1000 2000m
1:75,000
Drainage Monitoring
Regeneration Technology Pty Ltd

Quantity of water discharging into the wetland

An estimate of the amount of discharge from this drain has been made based on discharge rates from the Youangarra Drain. When it was flowing at it's maximum capacity one year after it was constructed the 71% of the volume of water in the drain was being replaced daily. If we use this figure and make some assumptions on the drain width and water depth we can make an estimate of the volume of water this drain with discharge for the first 3 years after construction. If the drain is to be 24 km long 1.5 m wide and the water depth in the drain 10cm then the total volume of water in the drain will be 360m^3 of water, 71% of this is 255.6m^3 which is the daily input into the drain. Multiply by 365 gives and estimate of 93,294m^3 per annum being discharged from this drain.

Receiving wetland area

The receiving wetland is typical of others in the Yarra Yarra Catchment being a samphire depression that links ephemeral lakes.

Photo: Typical samphire vegetation associated with the salt lake chains on the valley floor.

Chemical analysis of water and soils

Table 4 Shows the results of soil and water analysis undertaken in August 2004.

These results show, that the water and soils collected from this area have a neutral to slightly alkaline pH. These results do not confer with those from the bore monitoring data that recorded pH of between pH 4.6 and pH 6.8. The soil pH indicates that the soils of the receiving wetland will have the capacity to buffer some of the acidity from the ground water discharging from the drain. The salinity levels are similar to those from the bore monitoring and are relatively low by comparison with salinity levels elsewhere in the Yarra Yarra.

Table 6 Ion concentrations of Water and Soils from the Perenjori drain.

Sample Code	Date Collected	Type	pH	uS/cm	Na mg/L	Ca mg/l	Mg mg/l	Cl mg/l	SO4 mg/l	Total N mg/l	Total P mg/l
3630	18/08/2004	soil	7.7	3100	3600	8	40	5000	1100	680	42
36s	18/08/2004	soil	7.8	2900	3300	18	47	4900	950	2400	380
34	18/08/2004	water	7.1	33000	5700	1300	1400	10000	1500	2.8	<0.05
36	18/08/2004	water	7.3	29000	6900	70	640	11000	1900	7.7	0.12

GENERAL DISCUSSION

Some of the key findings of this study are:

1) the volume of water being discharged over time decreases with the aquifer being drained;
2) Recharge of the aquifer in the region is minimal due to climatic conditions (ie low rainfall high evaporation)
3) The zone of influence the discharge waters have on the receiving wetlands are insignificant when the entire Yarra Yarra Lake system is taken into account.
4) Down stream discharge past the primary receiving wetland is highly unlikely given the high evaporation rates for the area. There is no free water connecting the lakes even in the lowest points of the catchment.
5) The wetland soils have the capacity to buffer the pH of the discharge water.
6) The salinity of the discharge water is generally higher than that of the lakes but all water measured was in the hyper-saline range.
7) The salt lakes do not support an abundance of flora and fauna.

There appears to be a general trend for pH to move to wards neutral and salinity levels in the water to decrease with the further north (and the further downstream in the Yarra Yarra lakes system).

Appendix VII

Report on heavy metal content of drain deposits

Report on heavy metal investigation of deep-drain deposits in the Kalannie area, Yarra Yarra catchment.

Dr Ian Fordyce
Yarra Yarra Catchment Management Group

11/05/05

Summary

Sediments from the outfall wetlands of three deep drains in the Yarra Yarra catchment were sampled to test for possible heavy-metal contamination. Of the 15 metals investigated, none was present at levels known to cause environmental detriment. Furthermore, there was no consistent trend in metal concentrations between the immediate discharge area at the drain mouth and distant parts of the same wetland. There is no empirical support for the belief that deep drainage in the Kalannie area results in metal contamination.

Introduction

As in other parts of the WA wheatbelt, deep drains are being used at a number of localities in the Kalannie area, Dalwallinu Shire, to relieve waterlogging and associated salinity problems. There is a perception in the non-farming community, however, that drains become toxic sewers in the rural landscape and discharge large quantities of heavy metals, such as arsenic, cadmium and lead, into 'downstream' wetlands. In order to test this heavy-metal hypothesis, we sampled soil/sediment from three privately funded drains that had been operating for at least five years. If the drains are indeed responsible for contamination in receiving wetlands, then metal concentrations in sediments at the discharge point should be noticeably higher than those in relatively undisturbed wetlands.

Methods

At each of the drains (Fig. 1), soil/sediment samples were collected from (a) the mouth, i.e. immediately outside the drain itself, and (b) the receiving wetland, approximately 1 km ‘downstream’ of the discharge point (and presumably beyond the drain’s geochemical influence). The De Courcy drain flowed directly into a broad, ephemeral saltlake (Lake De Courcy; dry at the time of sampling). The Burakin and Youangarra drains discharged into samphire-covered, saline claypans. Each sample was a composite of five cores taken from the surface 15 cm, using a 50 mm Dormer auger. At the drain mouth, individual cores were collected from the circumference of a 3 m-diameter circle. Wetland cores were collected at 3 m intervals along lines placed at right angles to the nearest shore. The composited samples were air-dried, tied in plastic bags, and submitted to SGS Environmental, Perth (a NATA-accredited laboratory), for heavy-metal analyses by the Package #15 HM method, according to Department of Environment (DoE) guidelines. At submission, each sample weighed 1-1.5 kg. Both the Burakin and De Courcy drains were sampled on 25/4/05. The Youangarra drain was sampled two and a half weeks earlier on 7/4/05.

Drain water was collected at the same time for metal analyses at the Adelaide laboratories of CSIRO, Land & Water. The water samples were filtered on site to 0.1 μm, acidified with high-purity conc. HNO_3, and stored in a cool situation in 250 mL plastic bottles. At the time of writing, however, none of the CSIRO analytical results are available.

Results

Table 1 shows that metal concentrations are universally below DoE specifications for ‘contaminated soil’. There is no evidence that metals are being concentrated in sediments at the drain discharge point, relative to the distal wetland. On the contrary, the only consistent trend observed in the analytical results is a slight increase in the levels of manganese, copper and zinc away from the drain mouth at Burakin.

The Assessment Levels listed in Table 2 are published Ecological Investigation Levels (EILs) and Health Investigation Levels (HILs) used by the DoE to implement the Contaminated Sites Act

2003 and the Contaminated Sites Regulations 2004. The HILs shown here are for commercial/industrial sites. The EILs are based primarily on threshold levels for phytotoxicity or impairment of plant growth/reproduction. They are not intended as pass-fail criteria for WA soils, and in fact there are soils with naturally high background levels that are higher than these EILs. Rather, contaminant values exceeding the EILs should trigger further investigation to determine whether there is a local environmental impact.

The metal concentrations are also universally below National Water Quality Management Strategy guidelines for freshwater sediments (Table 3), which, in the absence of guidelines specifically designed for assessing sediments in hypersaline water, are recommended by commonwealth authorities as the most appropriate standard for drain sediments (Steve Rogers, CSIRO, pers. comm.).

Discussion

The small sample size and the imbalance of the sampling regime (four samples from both the Youangarra and Burakin drains; only two samples from the De Courcy drain) precludes rigorous statistical analysis. However, an eyeball examination of the analytical results indicates that, if there is any metal contamination, then it is either trivial or below the level considered detrimental in DoE guidelines. A recent ecological study commissioned by the Yarra Yarra Catchment Management Group (Regeneration Technology Pty Ltd, 2003) found no environmental deterioration in the outfall of the Youangarra drain. The only environmental impact observed was a slight increase over an area of 11 ha in the succulence of samphire.

References

Department of Environment (2003) Assessment Levels for Soil, Sediment and Water. Version 3 (November 2003). Contaminated Sites Management Series. DoE, Perth.

Regeneration Technology Pty Ltd (2003) Ecological Report on the Effects of Deep Drainage in the Youangarra Subcatchment. Report to Yarra Yarra Catchment Management Group, November 2003.

Table 1. Preliminary results for heavy metal analysis of 10 soil/sediment samples from three farm drains by SGS Environmental, Perth

DRAIN:			**YOUANGARRA**					**BURAKIN**					**DE COURCY**	
drainwater pH			3.25					3.07					7.59	
Location			drain mouth	drain mouth	Wetland	wetland		drain mouth	drain mouth	wetland	wetland		drain mouth	wetland
SGS Reference:			88685-1	88685-2	88685-3	88685-5		88685-6	88685-7	88685-8	88685-9		88685-10	88685-11
YYCMG Reference			YOU1S	YOU2S	YOU4S	YOU6S		NIX1S	NIX2S	NIX3S	NIX4S		BAT1S	BAT2S
Antimony, Sb #	mg/kg		<3	<3	<3	<3		<3	<3	<3	<3		<3	<3
Arsenic, As	mg/kg		0.8	2.1	0.9	<0.5		0.8	2.7	3.1	3.2		3.7	8.3
Barium, Ba	mg/kg		41	<20	33	27		<20	<20	43	25		37	33
Beryllium, Be	mg/kg		0.6	0.6	<0.5	<0.5		1	<0.5	<0.5	<0.5		<0.5	<0.5
Cadmium,Cd	mg/kg		<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5		<0.5	<0.5
Chromium, Cr	mg/kg		17	16	9.7	11		21	36	34	39		34	31
Cobalt, Co	mg/kg		<5	<5	<5	<5		<5	<5	<5	<5		8	<5
Copper, Cu	mg/kg		9	7	<5	<5		<5	<5	11	12		12	12
Lead, Pb	mg/kg		<5	<5	<5	<5		<5	<5	<5	<5		9.2	<5
Manganese, Mn	mg/kg		81	130	100	62		19	49	330	400		420	230
Mercury, Hg	mg/kg		<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05		<0.05	<0.05
Molybdenum, Mo	mg/kg		<5	<5	<5	<5		<5	<5	<5	<5		<5	<5
Nickel, Ni	mg/kg		<5	6	<5	<5		6	6	13	12		10	7
Tin, Sn #	mg/kg		<50	<50	<50	<50		<50	<50	<50	<50		<50	<50
Zinc, Zn	mg/kg		9.9	6	<5	<5		6	6	23	23		18	16

not NATA-accredited for these elements (Sb, Sn)

Table 2. Assessment Levels for soil (from Department of Environment, 2003).

Metal	Ecological Investigation Levels	Health Investigation Levels
	(mg/kg)	(mg/kg)
Antimony, Sb	20	820
Arsenic, As	20	500
Barium, Ba	400	100 000
Beryllium, Be	nla	100
Cadmium, Cd	3	100
Chromium (total), Cr	50	nla
Cobalt, Co	50	500
Copper, Cu	60	5 000
Lead, Pb	300	1 500
Manganese, Mn	500	7 500
Mercury, Hg	1	75
Molybdenum, Mo	40	10 220
Nickel, Ni	60	3 000
Tin, Sn	50	100 000
Zinc, Zn	200	35 000

nla no level available

Table 3 ARMCANZ/ANZECC National Water Quality Management Stategy guideline for metals in freshwater sediments.

Metal	**ISQG-Low**	**ISQG-High (Trigger Value)**
	(mg/kg)	(mg/kg)
Antimony	2	25
Arsenic	20	70
Cadmium	1.5	10
Chromium	80	370
Copper	65	270
Lead	50	220
Mercury	0.15	1.0
Nickel	21	52
Silver	1.0	3.7
Zinc	200	410

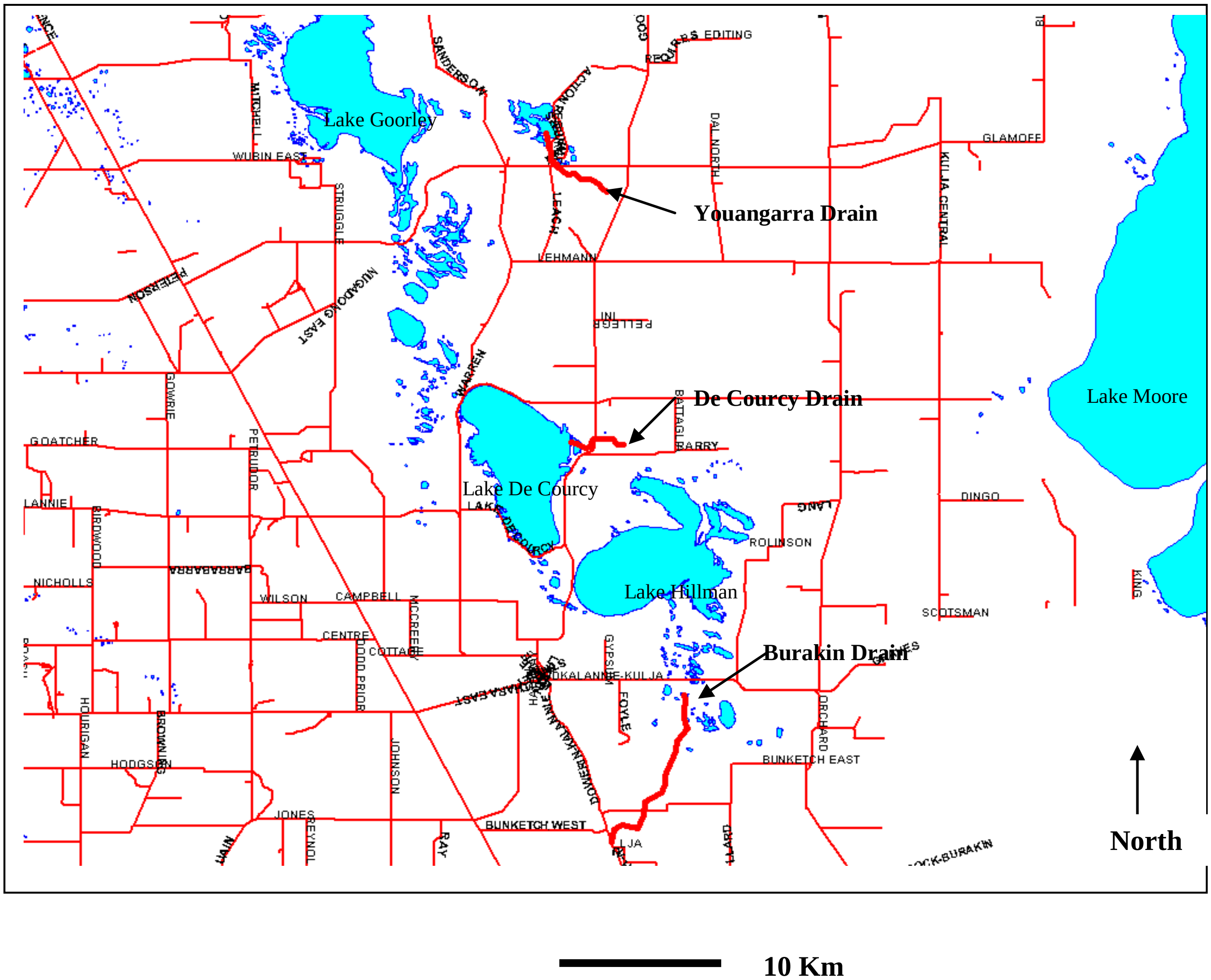


Fig. 1 **Location of Youangarra, Burakin and De Courcy drains for heavy metal investigation**

Appendix VIII

Landowner's memorandum of understanding (MOU)

MEMORANDUM OF UNDERSTANDING BETWEEN ZONE LAND HOLDERS, THE YARRA CATCMENT MANAGEMENT GROUP AND NACC

- I agree in principal that if required I will take both ground and surface water through my property to be delivered safely to the Yarra Yarra Lake system by means of an appropriately excavated channel

- I agree in principal, that if the National Action Plan will fund the construction of an arterial drainage channel that will accept ground water delivered out of my property, I will then undertake to contribute on a pro rata basis for the maintenance of that channel as deemed necessary by the Zone committee in consultation with the appropriate Catchment authority.

- Also I agree in principal that I will undertake to protect this Public facility and the surrounding ecology by adhering to an appropriate farm plan over a ten year implementation period. The plan to be agreed on by the members of my Zone Committee consultation with the Yarra Yarra Catchment Management Group or other appropriate authority,

- Also I agree in principal to the basic water way design as described below

  The waterway will follow closely the natural drainage line of the valley floor. It will consist of an excavated ground water channel that will have a mean depth of at least 2 metres and the spoil excavated will have a mass of approximately 5 cubic metres per metre.

  The spoil will be deposited in a continuous windrow on either side of the channel. Further more a broadbased channel will be constructed on either side of the excavated channel. The spoil from these constructions will be deposited in a continuous windrow against the spoil from the aforementioned ground water channel to form a consolidated bank with a settled height of approximately 2 metres.

  The broad based channel will be at least 5 metes wide with a mean depth not more that 750 mm and not less that 500 mm. Where a satisfactory broad base channel exists then this may be used on one side of the ground water channel.

.

- I Also understand that ground water from the adjacent farm lands may be delivered at farmers own cost into this public facility discharging close to the bottom of the ground water channel through a pipe not less than 300 mm in diameter

Name and signature of land owner or authorized person or persons:

Appendix IX

Revegetation Species List

Plant species for revegetation of drainage lines

The following plant list draws heavily from Clarke (undated). It also takes into account the native flora of the region, as well as successful revegetation on the Goodlands corridor and on a number of farms. In addition, we have considered the ease with which seeds can be collected and nursery stock raised. Our aim is to recreate a York gum woodland, with an understorey initially of bluebush and/or saltbush, and then, as the soil becomes progressively less saline and sodic, of meleucas and wattles. There is no plan for deliberate plantings of ground-storey perennials or annuals. Local experience is that these plants voluntarily recolonise the new woodland as soon as conditions become suitable.

An observation of many botanical workers in the area (e.g. Beard 1976; Wilcox *et al.* 1996; Mike Hislop, botanist with WA Herbarium, pers. comm.) is that the distribution of native vegetation is, to a large extent, determined by soil. For this reason, we present a different list (with many overlapping species) for each of the three main soil types encountered on valley floors (Schoknecht 2002).

1. Colluvial flat (red-brown earth)

Eucalyptus loxophleba ssp. *supralaevis* (York gum)
E. loxophleba ssp. *lissophloia*
E. myriadena
E. brachycorys
E. spathulata
Casuarina obesa (swamp sheoak)
Melaleuca eleuterostachya
M. lateriflora
M. uncinata (broombush)
M. adnata
Acacia obtecta
A. microbotrya (manna wattle)
A. jennerae
A. brumalis
A. eremaea
A. hemiteles (tan wattle)

Hakea preissii (needlebush)

Maireana brevifolia (small-leaf bluebush)

<u>2. Colluvial flat (clay)</u>

Eucalyptus loxophleba ssp. *supralaevis* (York gum)

E. loxophleba ssp. *lissophloia*

Casuarina obesa (swamp sheoak)

Melaleuca adnata

M. eleuterostachya

M. lateriflora

M. acuminata

M. uncinata (broombush)

Callistemon phoeniceus

Acacia hemiteles (tan wattle)

Hakea preissii (needlebush)

Maireana brevifolia (small-leaf bluebush)

<u>3. Alluvial flat (sand over clay)</u>

Eucalyptus loxophleba ssp. *supralaevis* (York gum)

E. salicola

E. sargentii

Melaleuca halmaturorum

M. uncinata (broombush)

M. eleuterostachya

M. lateriflora

M. acuminata

M. thyoides

Acacia eremaea

A. hemiteles (tan wattle)

Pittosporum angustifolium (weeping pittosporum)

Maireana brevifolia (small-leaf bluebush)

References

Beard, J.S. 1976. 'The vegetation of the Perenjori area, Western Australia.' Vegmap Publications, Perth.

Clarke, M. (undated). Goodlands catchment revegetation report. Report prepared for the Goodlands Catchment Group, WA Department of Agriculture, Geraldton.

Schoknecht, N. 2002. Soil groups of Western Australia: a simple guide to the main soils of WA. Resource Management Technical Report No. 246 (3rd ed), WA Department of Agriculture, Perth.

Wilcox, D.G., Lefroy, E.C., Stoneman, T.C., Schoknecht, NR & Griffin, E.A. 1996. Trees and shrubs for the Midlands and Northern Wheatbelt. Bulletin 4324, WA Department of Agriculture, Perth

Appendix X

Local fauna expected to benefit from the construction of green corridors

Benefits to Fauna

Comprehensive species lists of vertebrates and invertebrates collected from Yarra Yarra sites are given in the CD issued with Kieghery *et al.* (2004), published by the WA Museum describing a survey with the Science Division of the WA Department of Conservation and Land Management of the South-West Wheatbelt. The lists are too large to reproduce here. Instead, we concentrate on one group – birds – a group that was neglected in the Museum-CALM study. The table below lists birds in the agricultural sector of the Yarra Yarra catchment that are confined largely to patches of remnant woodland and are likely to benefit from our addition to the landscape of vegetated corridors. Note that birds such as the white-fronted chat or the white-winged fairy wren are not included as, in the Yarra Yarra region, they are found almost only in wetland habitats. Birds that are commonly found in farmland or in the narrow treebelts between paddocks (e.g. willy wagtail and crested pigeon) are not expected to benefit substantially from our proposed revegetation, and are also excluded from the list.

Note that we are not implying that all the listed birds can be found together at a single site. It seems likely that there are geographical, as well as habitat, constraints on species distribution within the region. For example, I have never come across black honeyeaters south of Perenjori.

Species identification , nomenclature and order follow Pizzey & Knight (1997). Useful references in selecting candidates for the list were Saunders & Curry (1990) and Saunders & Hobbs (1991).

Table 1. Birds expected to benefit from revegetation corridors.

Common name	***Scientific name***
mallee fowl	*Leipoa ocellata*
Australian bustard	*Ardeotis australis*
bush stone-curlew	*Burhinus grallarius*
common bronzewing	*Phaps chalcoptera*
Australian owlet-nightjar	*Aegotheles cristatus*
southern scrub robin	*Drymodes brunneopygia*
red-capped robin	*Petroica goodenovii*
western yellow robin	*Eopsaltria griseogularis*
jacky winter	*Microeca leucophaea*
golden whistler	*Pachycephala pectoralis*
rufous whistler	*Pachycephala rufiventris*
grey shrike thrush	*Colluricincla harmonica*
crested bellbird	*Oreoica gutturalis*
grey fantail	*Rhipidura fuliginosa*
white-browed babbler	*Pomatostomus superciliosus*
redthroat	*Sericornis brunneus*
weebill	*Smicornis brevirostris*
western gerygone	*Gerygone fusca*
inland thornbill	*Acanthiza pusilla*
chestnut-rumped thornbill	*Acanthiza uropygialis*
yellow-rumped thornbill	*Acanthiza chrysorrhoa*
varied sitella	*Daphoenositta chrysoptera*
red wattlebird	*Anthocaera carunculata*
spiny-cheeked honeyeater	*Acanthagenys rufogularis*
singing honeyeater	*Lichenostomus virescens*
white-eared honeyeater	*Lichenostomus leucotis*
brown-headed honeyeater	*Melithreptus brevirostris*
brown honeyeater	*Lichmera indistincta*
black honeyeater	*Certhionyx niger*
white-fronted honeyeater	*Phylidonyris albifrons*
striated pardalote	*Pardalotus stratus*
grey butcherbird	*Craticus torquatus*

References

Keighery, G.J., Halse, S.A., Harvey, M.S. & McKenzie, N.L. (eds) 2004. A biodiversity survey of the Western Australian agricultural zone. *Records of the WA Museum* Supplement No. 67. Western Australian Museum, Perth.

Pizzey, G. & Knight, F. 1997. 'Field Guide to the Birds of Australia.' Angus & Robertson, Sydney.

Saunders, D.A. & Curry, P.J. 1990. The impact of agricultural and pastoral industries on birds in the southern half of Western Australia: past, present and future. *Proceedings of the Ecological Society of Australia* **16**, 303-321.

Saunders, D.A. & Hobbs, R.J. (eds) 1991. 'Nature Conservation 2: The Role of Corridors.' Surrey Beatty & Sons, Chipping Norton, NSW.

Appendix XI

Geophysical Surveys

APRIL 2005 PROGRESS REPORT ON CRC LEME WORK FOR YARRA YARRA CATCHMENT MANAGEMENT GROUP

1. **Soil mapping project**

Digital data for the Burakin airborne geophysical survey have been purchased from Geoscience Australia. These data have been processed and imaged to produce images of each of the three radioelements Potassium, Uranium and Thorium, and a combined ternary image which shows the three elements as a red green blue colour composite. Images have also been created of total magnetic intensity and digital elevation data. These images have been shown to members of the Catchment Management Group at a meeting in late August 2004 at Kalannie.

Soil sampling has been done in September / October 2004 by staff from the WA Department of Agriculture. 864 sites have been sampled and described.

Classification of the radiometric data is in progress to relate the soil sample data to the airborne radiometric data. Work is also in progress to relate soil types to elevation data and also to vegetation.

Comparison has been made between the geophysically derived digital elevation (DEM) data and that derived from the Land Monitor project.. The geophysical DEM is derived from the altimeters and GPS onboard the geophysical aircraft so is only measured along the flight tracks. The Land Monitor data is sampled on a 10 x 10 metre basis and is accurate to 1-2 metres. The comparison was made for each of the 864 soil sample points and showed that at 72 % of the sites the elevation data agreed to with + / - 5 metres. And 96 % agreed to within + / - 10 metres. This is a good result especially as interpolation is involved to calculate the values at sites which are not in general directly underneath the geophysical flight paths.

We plan to complete the analysis and the new soil maps by end June 2005 and note that Max Hudson has applied for an extension to the funding period to cover this..

2. **Paleochannel investigations**.

It is planned to do the gravity and electromagnetic (EM) fieldwork in May / June 2005. It is hoped that we can get dry conditions to do this work and that we will not be restricted by newly planted crops. If necessary the transects can be moved to minimise any access difficulty with crops. We need vehicle access along the transects when we do the electromagnetic work and probably quad bike access for the gravity and gps work.

We plan to do the gravity first and follow this with the time domain EM. The gravity will either be done by Haines Surveys or by Paul Wilkes (gravity) and
Dene Solomon (kinematic GPS).

We expect to complete the analysis of the paleochannel investigations within three months of doing the fieldwork.

Max – please provide the coordinates for the end points of the six planned transects.

3. **Contract agreement**

We need to get a signed agreement for both the soil mapping and paleochannel surveys. I plan to cover both aspects in the one document and will email this to you in the next week.

Paul Wilkes
Deputy CEO
CRC LEME
Perth

8 April 2005

Ph 08 6436 8699