Conceptualizing groundwater recharge mechanisms in riparian zones of the Lower Balonne Floodplain

M.O. Harp

University of Queensland Undergraduate Geologist

CRDC Summer Scholarship Report

In partnership with the Department of Natural Resources and Mines

Queensland Government
Natural Resources and Mines

Australian Government
Cotton Research and Development Corporation

This report was produced as a part of the CRDC 2016-17 Summer Scholarship Program.

Acknowledgement

The author thanks CRDC for the funding to produce this report. Special thanks is given to Andrew Biggs (DNRM) for support and guidance throughout the summer, Jenny Foley (DRNM) for technical help with ERT, Mark Crawford (DNRM) for assistance with ERT data analysis and conceptualization, Wes Davidson (DNRM) for support with ArcMap and Sunny Jacobs (DNRM) and Maria Harris (DNRM) for their contributions.

Abbreviations

CRDC – Cotton Research and Development

DNRM – Department of Natural Resources and Mines

QMDB – Queensland Murray Darling Basin

MDBA – Murray Darling Basin Authority

BOM – Bureau of Meteorology

Executive summary

This report provides a conceptualization of shallow groundwater stores and recharge mechanisms in riparian zones along the Balonne-minor and Ballandool Rivers. Data used for analysis include Electrical Resistivity Tomography (ERT), geologic core data, digital elevation data and water monitoring data. ArcGIS was used to produce a number of transect maps used to interpret such data. Results show that groundwater recharge is highly limited by clay soils which are predominant throughout the Lower-Balonne floodplain. It is hypothesized that floods play a large role in shaping these riparian ecosystems and may also be vital for the recharge of groundwater stores. Further investigation should be undertaken to ascertain precise mechanisms of groundwater recharge in these riparian zones.

Background:

Australia's cotton growing industry is limited to areas with adequate climate, infrastructure and water availability primarily, the MDB. The cotton industry's interaction with river systems and floodplains in this region increases demand for access to natural resources such as water. Within the QMDB, water allocation is regulated by both State and Commonwealth legislation.

The St-George-Dirranbandi region is one of the largest cotton growing regions within the QMDB. Of this area, 80% is irrigated by gravity surface-irrigation systems (Roth et al. 2013). The region is part of the Lower Balonne River Floodplain system, connecting with the Moonie River Floodplain to the east. It experiences a sub-humid to semi-arid climate with highly variable rainfall (Biggs & Pain 2006).

Understanding the water needs of native vegetation in the Lower Balonne Floodplain will allow for greater balance in water usage by all stakeholders in this region. Native vegetation cover in the Lower Balonne is concentrated along major river systems in riparian zones (Pearce et al 2006). The way in which water moves through a landscape determines the health, survival and the position of vegetation in these areas (Casanova 2015). By analysing vegetation patterns and distribution and correlating such data with the hydrological regime of the floodplain, a greater understanding of water usage by riparian vegetation can be obtained. This vegetation is a vital component of all river systems as it helps to maintain key eco-system services.

The Australian Cotton Industry and the CRDC have highlighted the importance of responsible landscape management. Through understanding the connection between cotton farms and natural systems, floodplain vegetation and riparian zones may be managed under best practice.

Aims and Objectives:

This project aims to evaluate the reliance of riparian vegetation on groundwater in the Lower Balonne region. It will do so through analysis and modelling of the stratigraphy and hydrogeology underlying riparian vegetation communities. It will look at the recharge of groundwater through flooding events and help to define the hydrological regimes of shallow aquifers and unsaturated zones within the floodplain.

This information will determine the importance of river flooding in providing water requirements to vegetation in the region. The outcomes of the project will support CRDC's interests in responsible landscape management through better understanding of riparian zones and how they are impacted by flows. It will further build on other CRDC and non-CRDC funded projects by Griffith University (Samantha Capron), UNE (Rhiannon Smith) and DRNM/DSITI/MDB EWKR (Andrea Prior, Andrew Biggs, Don Butler).

Methods

Site information:

The Lower Balonne River catchment is a network of anastomosing channels part of the larger Condamine-Balonne River (Thoms et al 2008).

The first transect is located approximately two kilometres downstream from Dirranbandi along the Balonne-minor River (Appendix A). It is situated where the river meanders significantly and includes a forested riparian area; A 575 m transect was taken perpendicular to the point-bar side of the river headed west. Quaternary alluvium is the dominant lithology in this area, unconsolidated sand; clay; and soil was found at the site.

The second investigation site is located further downstream along the Ballandool River, approximately 5.5 kilometres NW of the town of Hebel (Appendix A). The transect taken at this site covered 310 m.

Other sites within the Lower Balonne were also investigated but are not reported here.

Flows at Balonne-minor and Ballandool

Gauging station 422205A, approximately 19.5 km upstream of the Balonne-minor transect site, shows that in the last 7 years there have been three large discharge events and four instances of very high river levels exceeding 6-6.5 m (Appendix B) (DNRM 2017). The gauging station on the Ballandool River at Hebel-Bollon road shows the same trend in water level associated with three major discharge events (Appendix C). These events correspond with major floods recorded in March 2010, January 2011 and February 2012 (BOM 2017).

Bore and Core Data

Along the Balonne-minor transect, three cores were taken for stratigraphic analysis. Sites SWRES-715, SWRES-716 and SWRES-529 were drilled using a 2" core; site 4222085 is an existing bore originally drilled in 1998. A bore hole was created at site SWRES-716 for groundwater chemistry analysis. The Ballandool transect consisted of two drilled cores; SWRES-723 and SWRES-724; also drilled using 2" core. Cores from each transect were logged and examined to determine the thickness and extent of the sand and clay layers.

Electrical Resistivity Tomography (ERT) Data

A two dimensional resistivity image was taken at each site using an ABEM Terrameter LS (Gradient Plus protocol, multiple gradient array, with a 2.5 m electrode spacing) along each transect. The resistivity image was inverted using RES2DINVx64 version 4.05.12 software, modelled at ½ electrode spacing.

Digital Elevation Data

Digital elevation data was derived from an individual LiDAR survey across this area of the Lower Balonne floodplain.

Vegetation Surveys

Vegetation surveys were taken along each river transect recording species, height, canopy intercepts and crown dimensions using a SLATS approach.

ArcMap

ArcMap 10.4.1 was used to produce the maps associated with this report; data were provided by DNRM in order to construct locality and topographic maps.

Water Monitoring Information

Comprehensive stream water monitoring information was provided by DNRM from gauging stations on the Ballandool River Hebel Bollon Road (Site 422207A) and Balonne-minor River at Hastings (Site 422205A).

Conceptual map

A conceptual diagram of each transect was made using the core and ERT data.

Results & Discussion

Ballandool River Transect

Stratigraphic analysis

Analysis of the ERT data combined with the stratigraphic logs collected from core sites (Appendix D) at this transect allows for interpretation of the underlying stratigraphy.

Along this transect, the resistivity image enabled the identification of clay and sand deposits; the resistive lens furthest from the river corresponds with an outcropping sand ridge which reaches approximately 20 m in depth (Figure 1). A second resistive lens includes and extends either side of the river channel; core SWRES-723 found the river bed and that below to be a clay to sandy clay deposit, consistent with the resistivity data. Using measured resistivity values for sand and clay soils a conceptual model was produced using this resistivity data (Figure 3)

Land systems and Recharge Mechanisms

A soil and vegetation survey was undertaken at the Ballandool transect site to identify the extent of the riparian zone and backplain areas (Appendix E&F). This data enabled Land Units and Land Systems to be assigned to the floodplain (Figure 5).

Land Systems are recurring patterns of geology, landform, vegetation and soils that are uniform and predictable (Holloway et al. 2013). Land System 31 and Land Unit 71 are consistent with the backplain areas at the Ballandool site; brown to grey Vertosols were dominant with coolabah scattered throughout.

Land System 31 and Land Unit 75 correspond to the channel areas along this section of the Ballandool River (Galloway et al. 1974); prominent vegetation types include coolabah and river red gum growing on grey and dark grey-ish brown Vertosols.

The presence of clay dominated soils in Land System 31 limits the drainage and infiltration capacity for these areas. Previous studies conducted on grey Vertosols in the Dirranbandi area found drainage to be between 0-1 mm yr^{-1} (Yee Yet & Silburn 2003) (Tolmie & Silburn 2003). Similar drainage values may thus be assumed for these backplain. Recharge of groundwater is, therefore, unlikely to occur in these areas but may be possible during large flooding events where these areas are inundated for large periods of time (Holloway et al. 2013). Deep drainage is more likely to occur within the river channel due to frequent wetting and little vegetation.

The sand ridge west of the Ballandool transect is comparable with Land System 28. This system describes sand ridges greater than 20 m in depth that are fluvial in origin, essentially, levees which have been partially re-worked. The sand ridge found is approximately 20 m deep and overlies a presumably impermeable clay deposit.

Shallow, fresh groundwater has been found in similar sand ridges within the Balonne floodplain; the species Moreton Bay ash, which is present at this site, is found to be indicative of areas with access to groundwater stores. However, ERT was unable to detect the presence of water at either transect site. Thus, without core data from this ridge the existence of groundwater may only be assumed given the current data.

The potential for drainage to occur along this ridge is higher than that of other backplain areas; Tenosols such as these have been recorded to have drainage of 5 mm yr^{-1} in Dirranbandi (Yee Yet & Silburn 2003). It is therefore reasonable to assume that groundwater recharge may occur during rainfall and flood events along this sand ridge. Should any water drain into the sand lens it would presumably pond on top of the relatively impermeable clay layer beneath, unable to infiltrate any deeper than 20 m, and be confined within the sand lens (Figure 3).

Infiltration of surface waters at the Ballandool site are extremely limited by clay soils. The ERT and core data indicates that the clay soils are present through most of the transect; for this reason the presence of a shallow groundwater source between the sand ridge and the river channel is unlikely, however, more cores are needed along the transect to be certain. Vegetation in this area must therefore be reliant on rainfall, flooding and overbank events. The coolabah species predominantly found at this site requires a flood event every 10-20 years for vigorous growth (Casanova 2015). Deep drainage within the channel area is most likely to occur at this site, core data indicated moist soils at 7 m deep.

Balonne-Minor River Transect

Stratigraphic analysis

Examination of the drill logs from the Balonne-minor transect reveals lateral alternation of sand and clay layers, particularly at the bore site RN4222085 (Appendix D); however, these alternations in sand and clay were too small for detection by ERT. ERT was also unable to detect the shallow groundwater store found at this site; cores SWRES-715 and SWRES-716 both hit water at approximately 6-7 m which is not seen on the ERT image. Further analysis of ERT may resolve this.

ERT data identified a resistive lens (45-2700 ohm-m) which extends west from the river for approximately 350 m (Figure 2) (Figure 4). Core data shows that this is mostly a sand to clayey sand lens, consistent with the resistivity values. Overlying this lens is between 2-3 m of surficial clay which presumably restricts significant recharge of the shallow groundwater from surface waters.

Topography

LiDAR data were used to analyse topographical features at the Balonne-minor transect site and mapped using ArcMAP (Figure 6). This identified a number of drainage depressions running through the vegetated area roughly parallel to the meander of the river. The nature of this section of river may indicate that these drainage depressions are a result of lateral channel migration over time or channel avulsions during overbank events. In order to narrow down to what has caused such depressions, further data must be collected.

The drainage depressions found at the Balonne-minor transect correlate to a degree to vegetation densities. Levees either side of the depressions are sandier than other backplain areas, seen in the ERT data (Figure 2). Vegetation seemingly concentrates along these levees; the break in clay soils may allow for greater root penetration and resultantly, greater access to the groundwater store below. Numerous depressions and levees and the presence of a significant shallow groundwater source at this site may account for the greater density of vegetation in comparison to the Ballandool River site. The presence of river red gum at the site suggests more frequent inundation of flood waters than the Ballandool riparian zone; river Red Gum requires flooding every two to four years for woodlands to survive (Casanova 2015) (Appendix G).

Flooding is integral in building and re-shaping riparian ecosystems along meandering rivers and critical in driving erosion and deposition of sediments (Richter & Richter 2000).

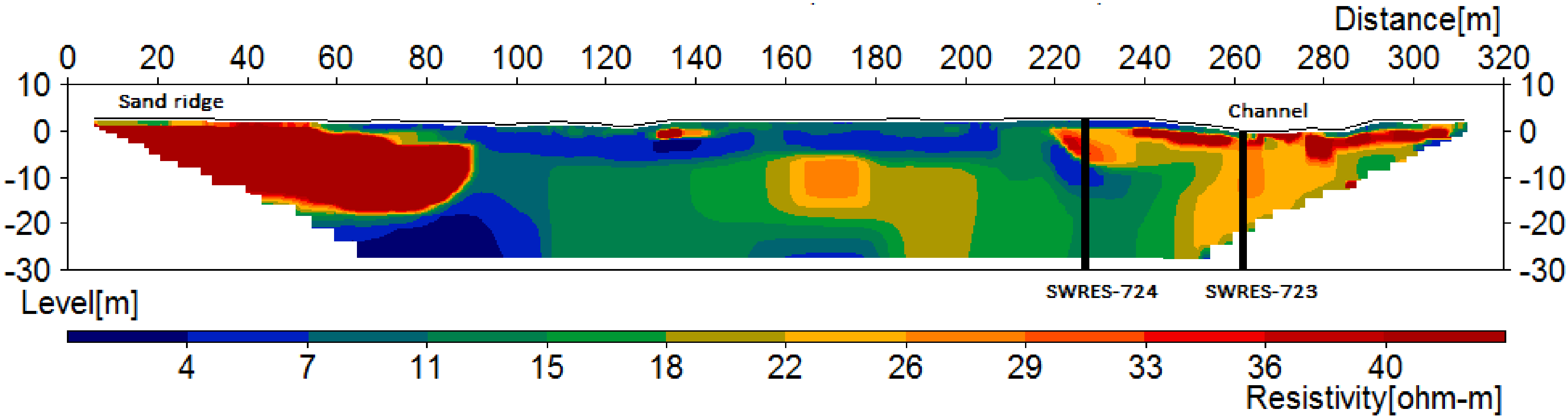

Figure 1 ERT Ballandool River transect

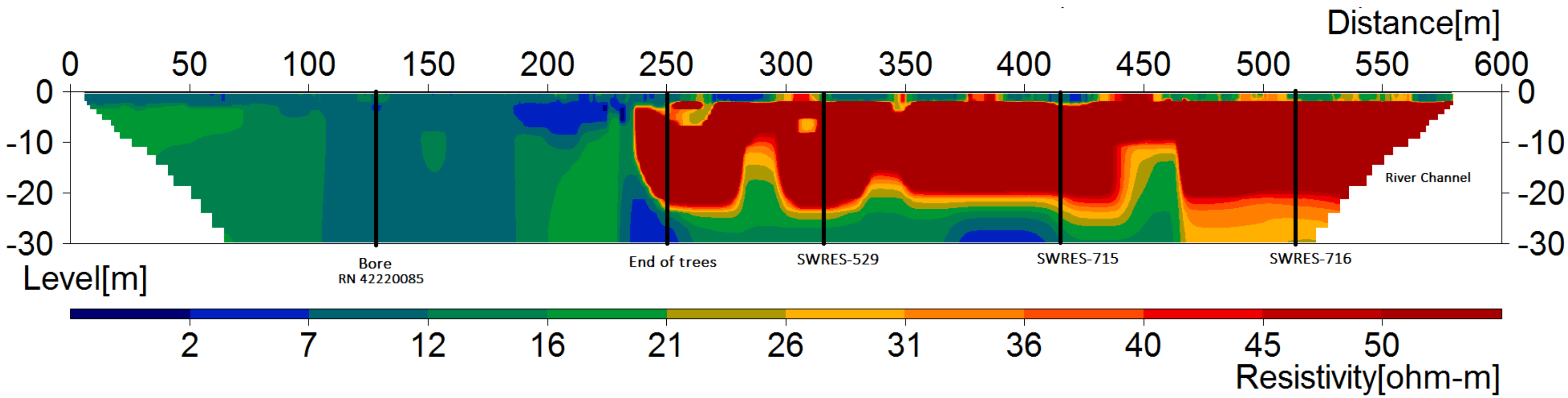

Figure 2 ERT resistivity Balonne-minor River transect

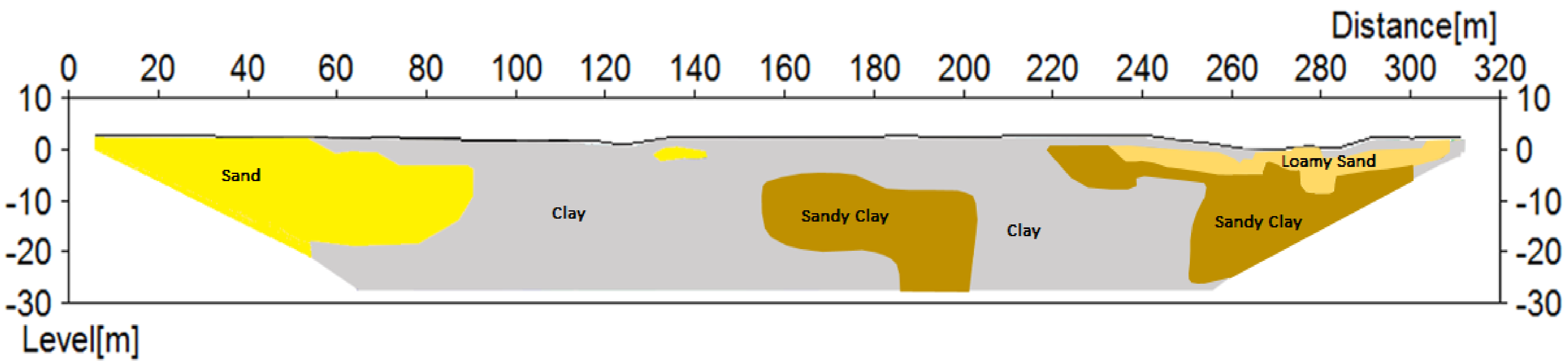

Figure 3 Ballandool Concept Diagram

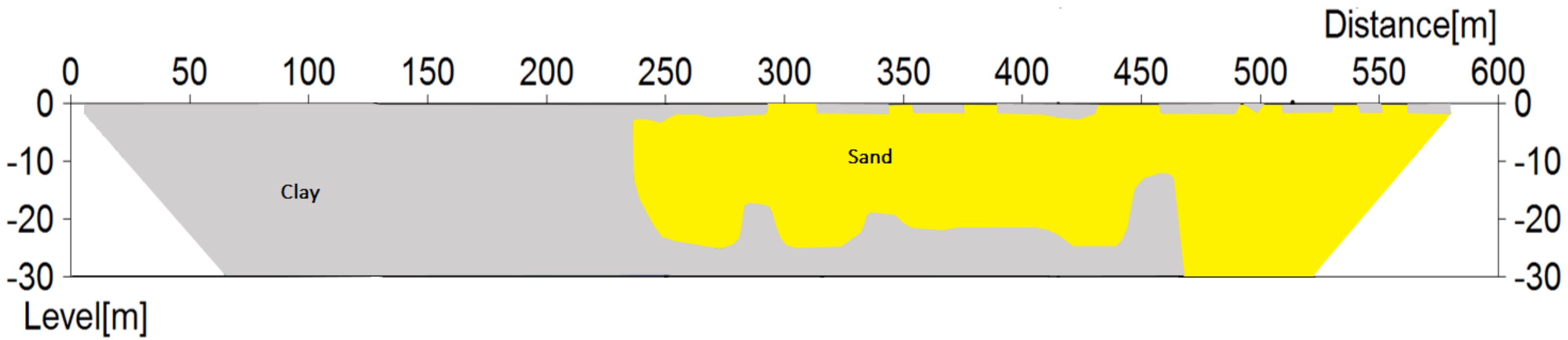

Figure 4 Balonne-Minor Concept Diagram

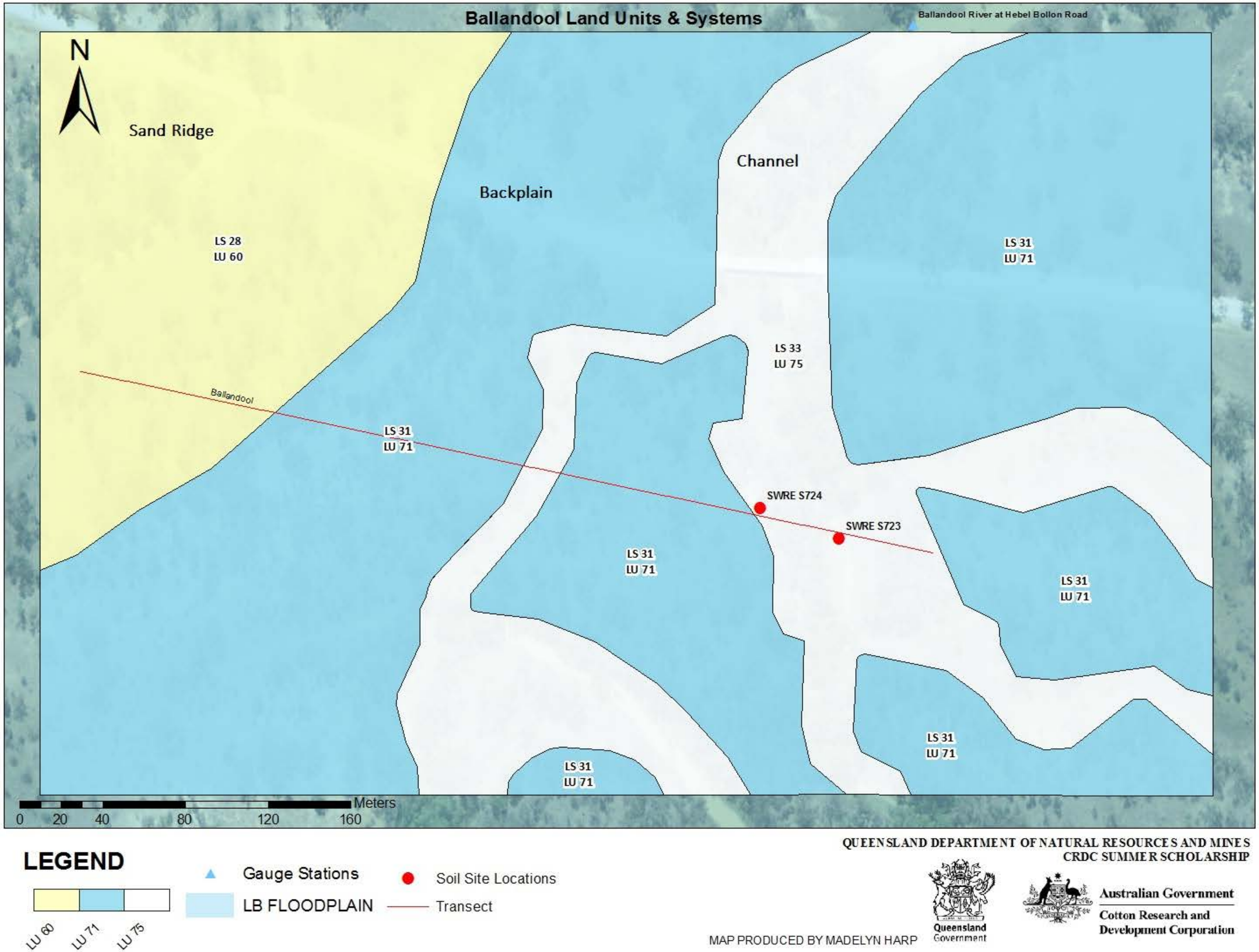

Figure 5 Ballandool Land Map

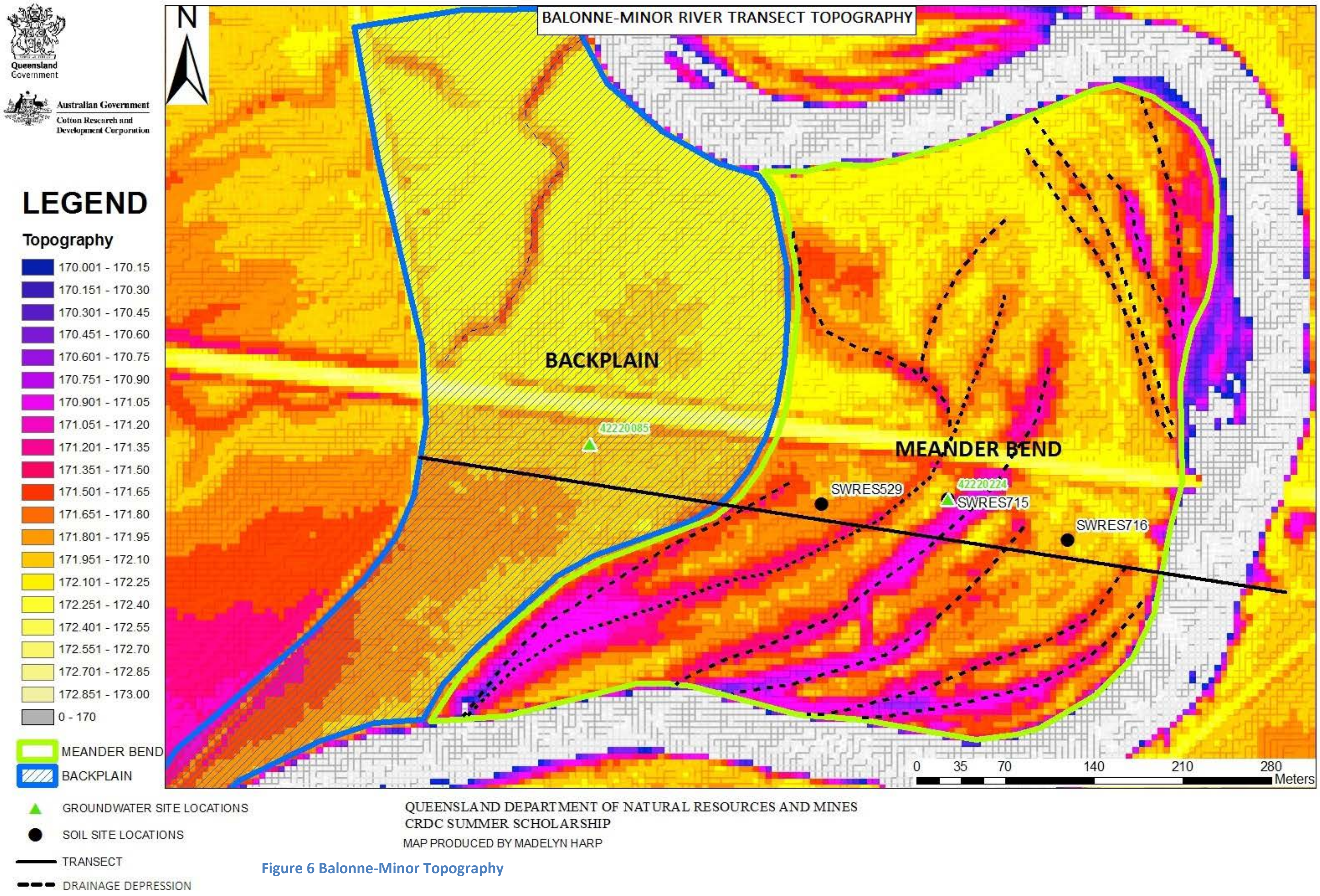

Figure 6 Balonne-Minor Topography

Recharge mechanisms

The dominant clay layer overlying the large sand lens at the Balonne-minor transect site limits recharge potential for the shallow groundwater store, drainage rates of such clays would not allow for significant recharge during rainfall events. However, the sandy levees found at this site may play a key role in the landscape during a flood event or during heavy rainfall. These areas have high infiltration potential and may result in the recharge of groundwater from surface waters

These drainage depressions found at the Balonne-minor site suggest that water may flow across the surface during high flow events in a N-S direction.

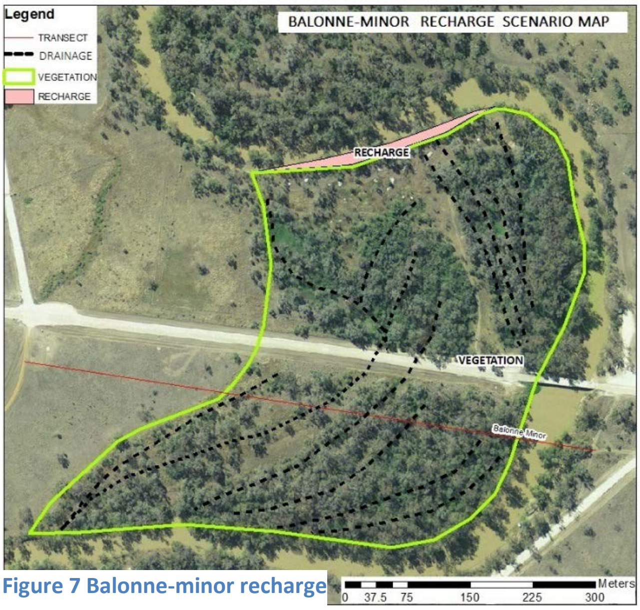

Figure 7 Balonne-minor recharge

Assuming that the sand lens identified in the ERT extends north and south of the transect line, it is reasonable to assume that groundwater may also flow in a similar pattern. Thus, recharge of this groundwater source may occur to the north of the transect in a N-S direction (Figure 7).

The ability for water to flow in such direction will be dynamic and dependent of various stages of flood. Violent flows would have the ability to erode beds and expose sand allowing for flood waters to recharge this groundwater store. To confirm such the direction of groundwater flow further transects would need to be taken across this meander bend.

Conclusion

The two transects outlined in this report offer two ends of the spectrum in regards to the type of channels and riparian zones that are found in the Lower-Balonne Floodplain. The Balonne minor site with higher flows and significant vegetation cover contrasts with the lower flow and sparse vegetation found at the Ballandool transect. These two areas show that the occurrence and abundance of clay soils in riparian zones impacts the availability of groundwater and, thus, the type of riparian eco-system that is present. More data is required to determine the extent to which these eco-systems rely on flooding events; however, data does indicate that vegetation in these zones may be dependent on such overbank events as a source of water.

Overall, the hydrological connectivity between rivers and groundwater within riparian zones is intrinsically linked to vegetation health and therefore, critical to the survival of these ecosystems.

Further research & Highlights

There are many factors which influence the presence of health of riparian vegetation. This report looked at the way in which water may infiltrate through a landscape as a function of soil type; it was found that clay soils largely prohibit deep drainage and groundwater recharge. Further research should be conducted to identify and strengthen the relationships drawn between soil type, land systems and riparian communities.

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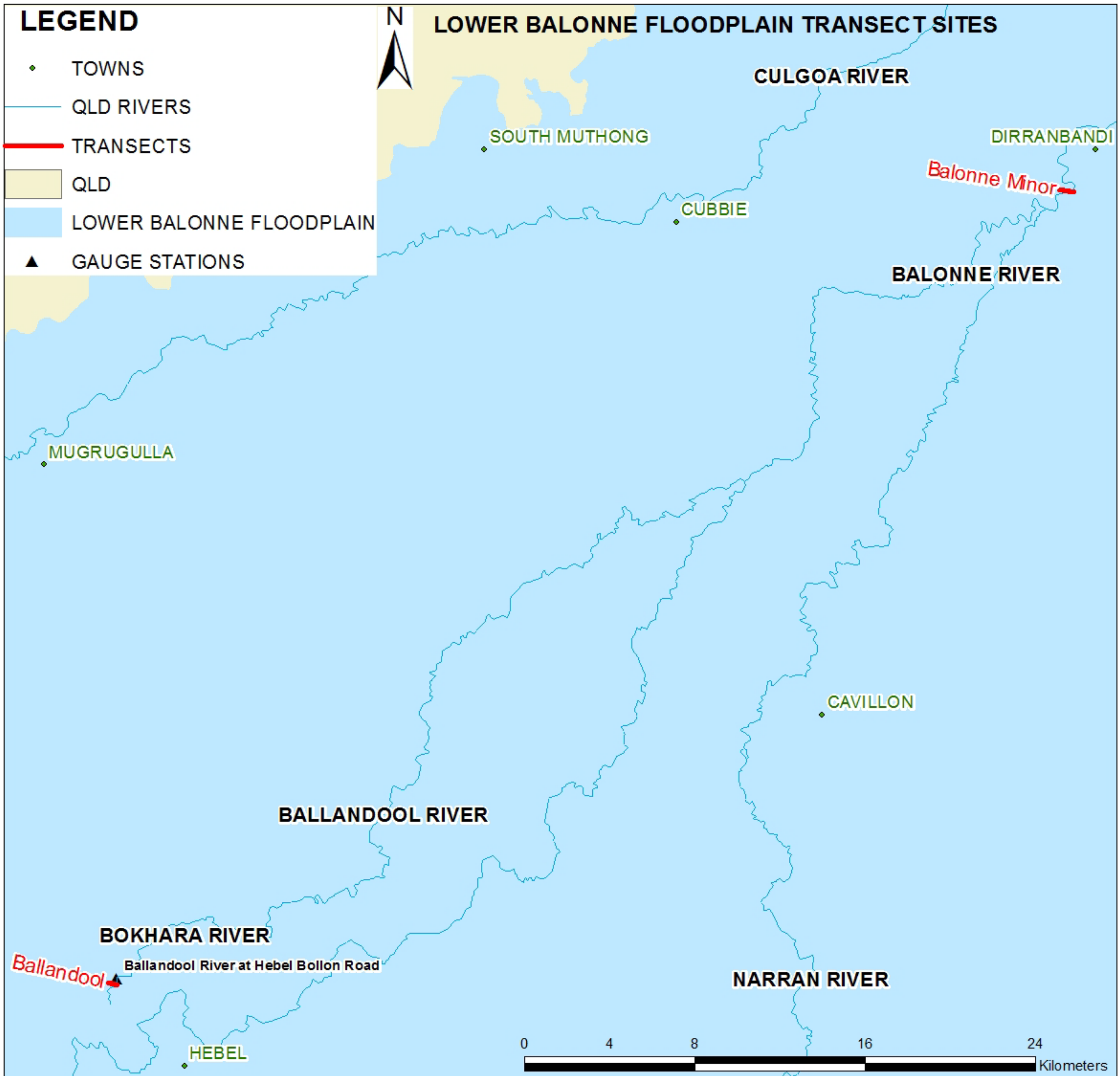
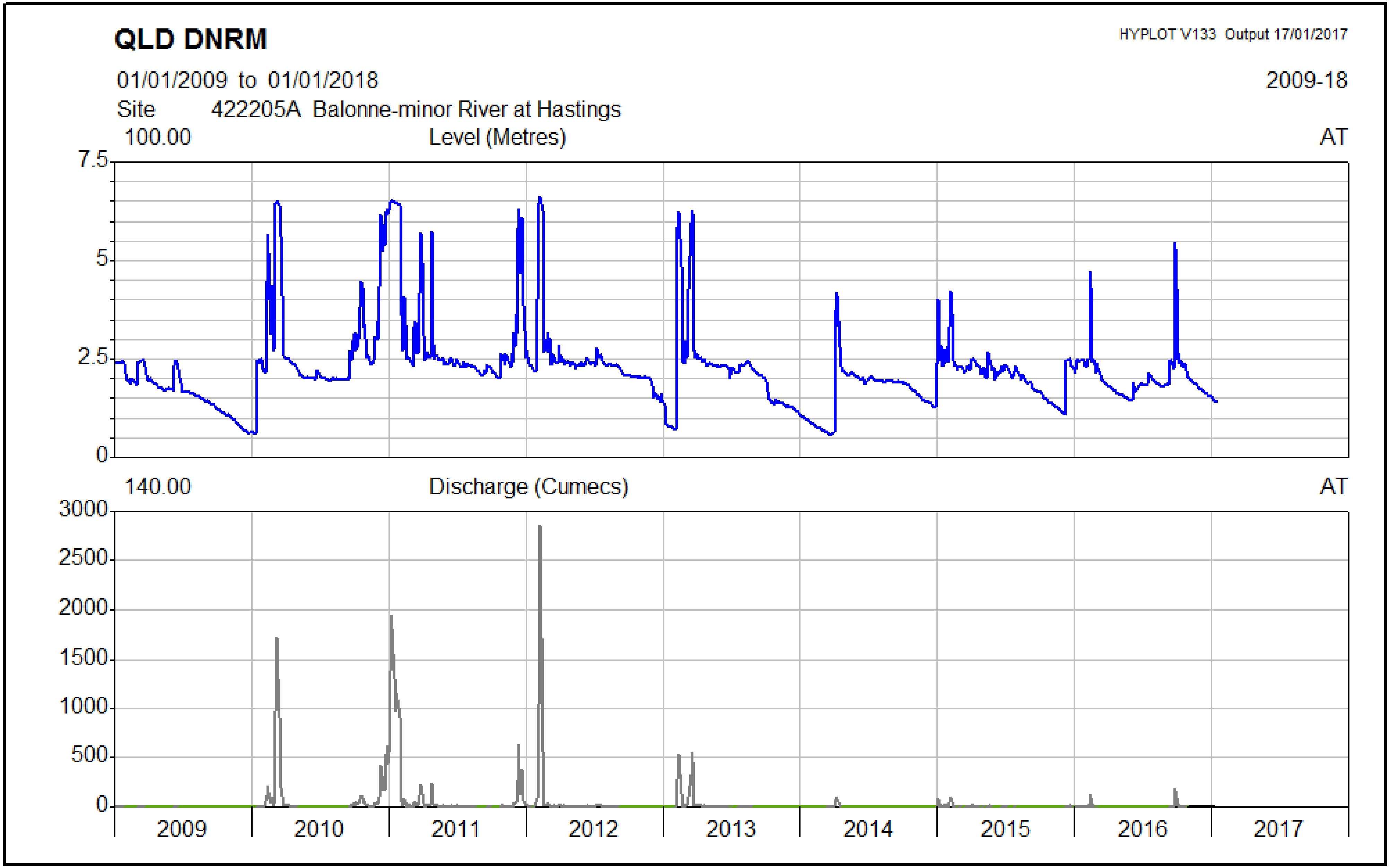
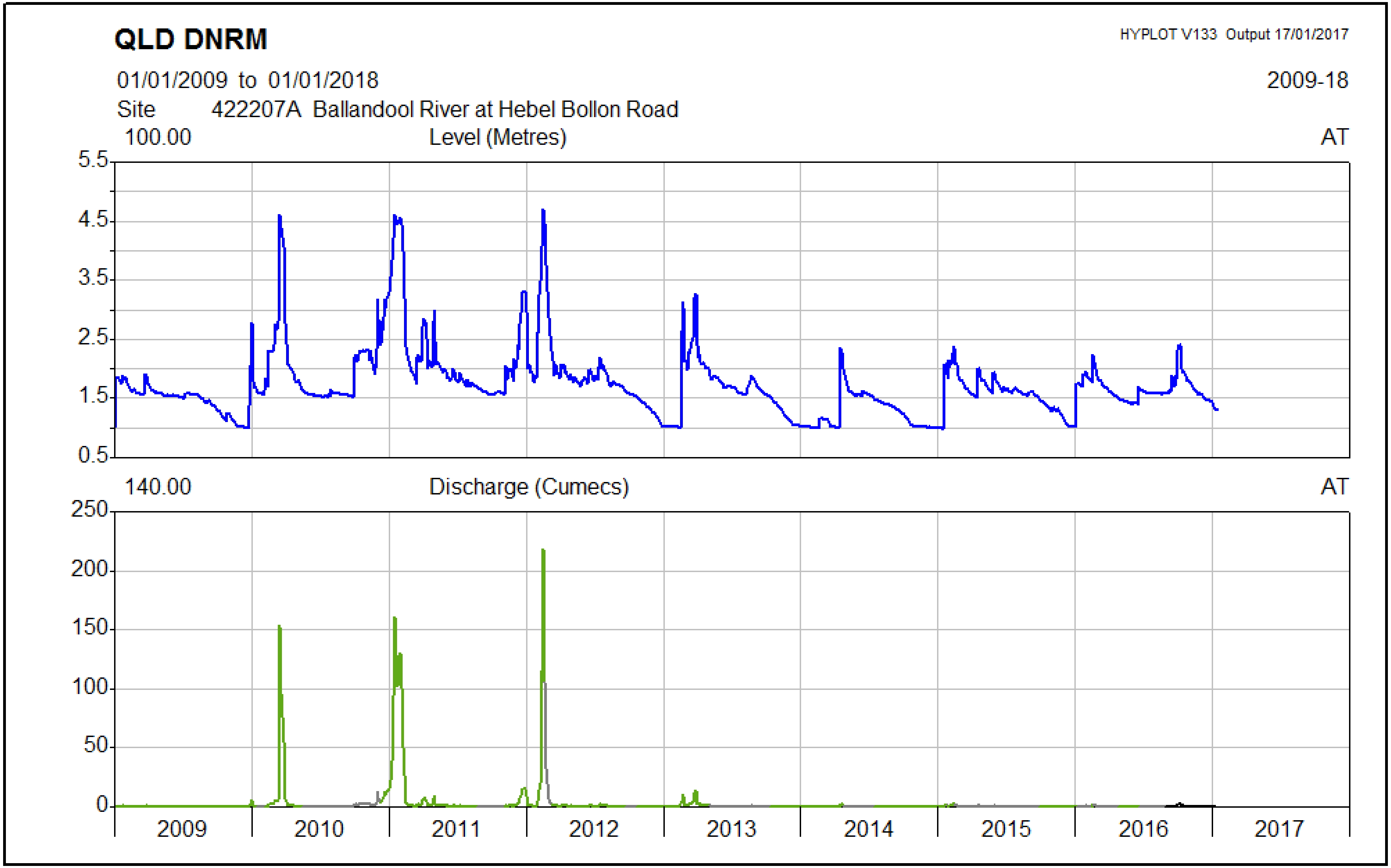
Appendix A


LEGEND
TOWNS
QLD RIVERS
TRANSECTS
QLD
LOWER BALONNE FLOODPLAIN
GAUGE STATIONS
N
LOWER BALONNE FLOODPLAIN TRANSECT SITES
CULGOA RIVER
SOUTH MUTHONG
DIRRANBANDI
Balonne Minor
CUBBIE
BALONNE RIVER
MUGRUGULLA
CAVILLON
BALLANDOOL RIVER
BOKHARA RIVER
Ballandool
Ballandool River at Hebel Bollon Road
NARRAN RIVER
HEBEL
0
4
8
16
24
Kilometers

Appendix B


QLD DNRM
HYPLOT V133 Output 17/01/2017
01/01/2009 to 01/01/2018
2009-18
Site 422205A Balonne-minor River at Hastings
100.00
Level (Metres)
AT
7.5
5
2.5
0
140.00
Discharge (Cumecs)
AT
3000
2500
2000
1500
1000
500
0
2009
2010
2011
2012
2013
2014
2015
2016
2017

Appendix C



QLD DNRM
HYPLOT V133 Output 17/01/2017
01/01/2009 to 01/01/2018
2009-18
Site 422207A Ballandool River at Hebel Bollon Road
100.00
Level (Metres)
AT
5.5
4.5
3.5
2.5
1.5
0.5
140.00
Discharge (Cumecs)
AT
250
200
150
100
50
0
2009
2010
2011
2012
2013
2014
2015
2016
2017

Appendix D

Bore 42220085		
Depth (m)	Strata	
0.0-9.4		Clay
9.4-11.4		Fine to coarse sand
11.4-12.0		Sandy clay
12.0-13.5		Fine to coarse sand
13.5-17.5		Clay
17.5-18.8		Fine sand
18.8-21.4		Silty and sandy clay
21.4-22.0		Fine to medium sand
22.0-23.2		Clay
23.2-23.4		Fine to medium sand
23.4-25.4		Silty clay
25.4-29.5		Fine sand
29.5-32.8		Silty clay
32.8-34.6		Fine sand and water
34.6-37.3		Clay
37.3-37.6		Sand and water
37.6-38.6		Clay
38.6-42.0		Silty sand & water
42.0-43.0		Clay
43.0-45.0		Fine sand and water
45.0-47.4		Clay and silty clay

Bore SWRES-529	Date:8/10/15	
Depth (m)	Strata	
0.0-1.1		Medium heavy clay
1.1-2.0		Moist clayey sand
2.0—2.45		Clayey sand
2.45-2.7		Fine sand
2.7-2.85		Fine sandy clay loam
2.85-5.5		Coarse sand
5.5-10.2		Moist clayey sand

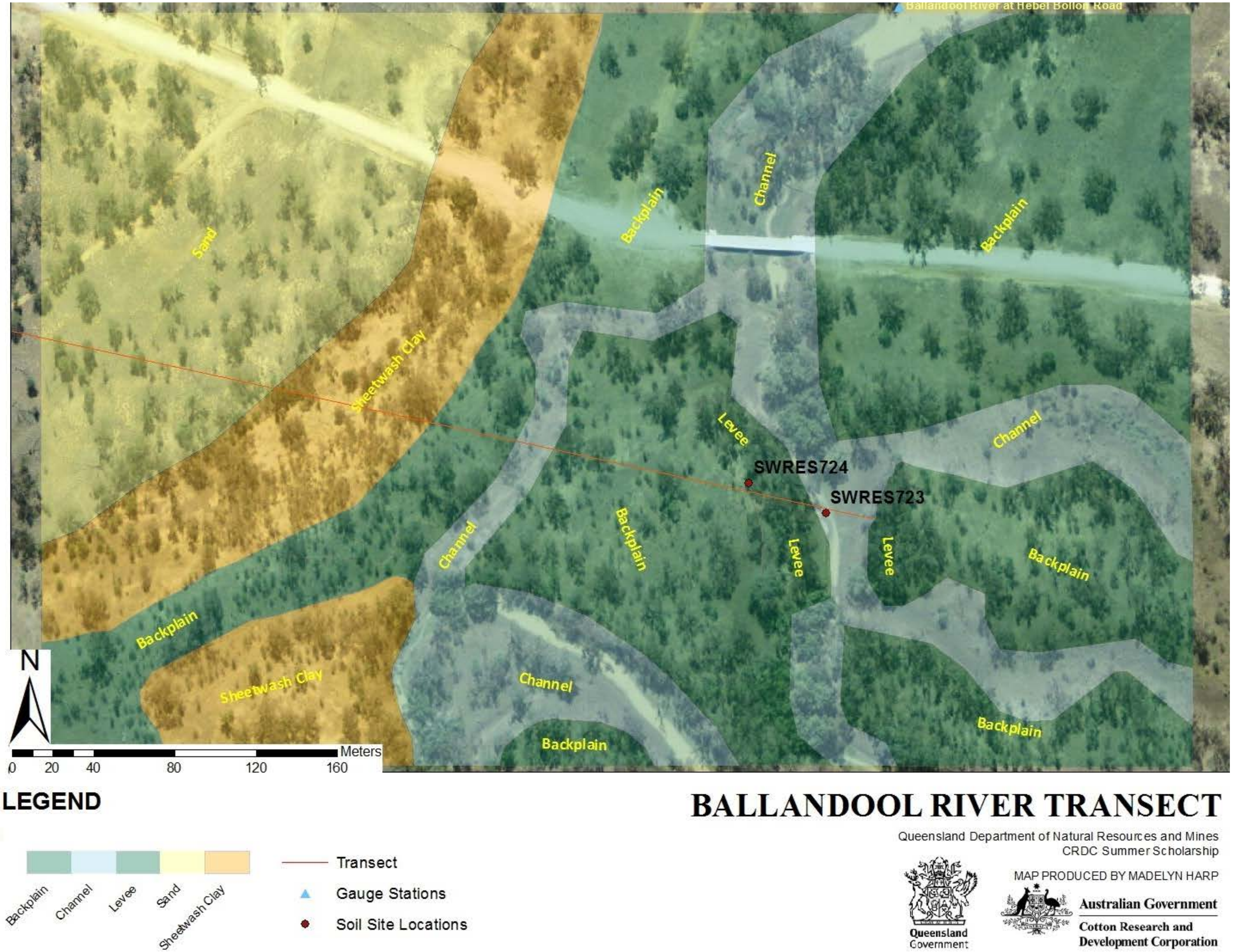
Bore SWRES-715	Date:22/11/15	
Depth (m)	Strata	
0-3.6		Medium heavy clay
3.6-4.1		Fine sand
4.1-4.55		Sandy light medium clay
4.55-4.75		Sand
4.75-4.97		Clayey sand
4.97-5.1		Sand
5.1-5.45		Clayey coarse sand
5.45-5.55		Sandy medium clay
5.55-6		Sand
6-7		Coarse sand

Bore SWRES-716	Date:22/11/16
Depth (m)	Strata
0.0-2.0	Medium heavy clay
2.0-2.6	Moist fine sand
2.6-3	Moist loamy fine sand
3-3.9	Fine Sand
3.9-4.2	Sand
4.2-5.15	Fine sand
5.15-5.5	Sand
5.5-5.75	Coarse sand
5.75-6.1	Sand
6.1-6.5	Loamy sand
6.5-6.75	Clayey sand
6.75-7	Medium clay
7-7.1	Clayey sand
7.1-7.5	Medium heavy clay
7.5-8.75	Loamy sand
8.75-8.95	Fine loamy sand
8.95-9.1	Clayey coarse sand

Bore SWRES-723	Date:24/11/16
Depth (m)	Strata
0.0-0.4	Medium clay
0.4-0.9	Medium heavy clay
0.9-1.2	Medium clay
1.2-2.1	Medium heavy clay
2.1-2.17	Sandy medium clay
2.17-2.75	Sandy loam
2.75-3.5	Medium clay
3.5-5.4	Sandy medium clay
5.4-6.45	Sandy light medium clay
6.45-6.9	Sandy clay

Bore SWRES-724	Date:24/11/16
Depth (m)	Strata
0.0-3.9	Medium heavy clay
3.9-4.1	Fine sand
4.1-4.3	Medium heavy clay
4.3-4.43	Fine sand
4.43-4.48	Sand
4.48-4.6	Sandy Clay
4.6-4.9	Sand
4.9-7.2	Medium heavy clay

Appendix E



BALLANDOOL RIVER TRANSECT

Queensland Department of Natural Resources and Mines
CRDC Summer Scholarship

MAP PRODUCED BY MADELYN HARP

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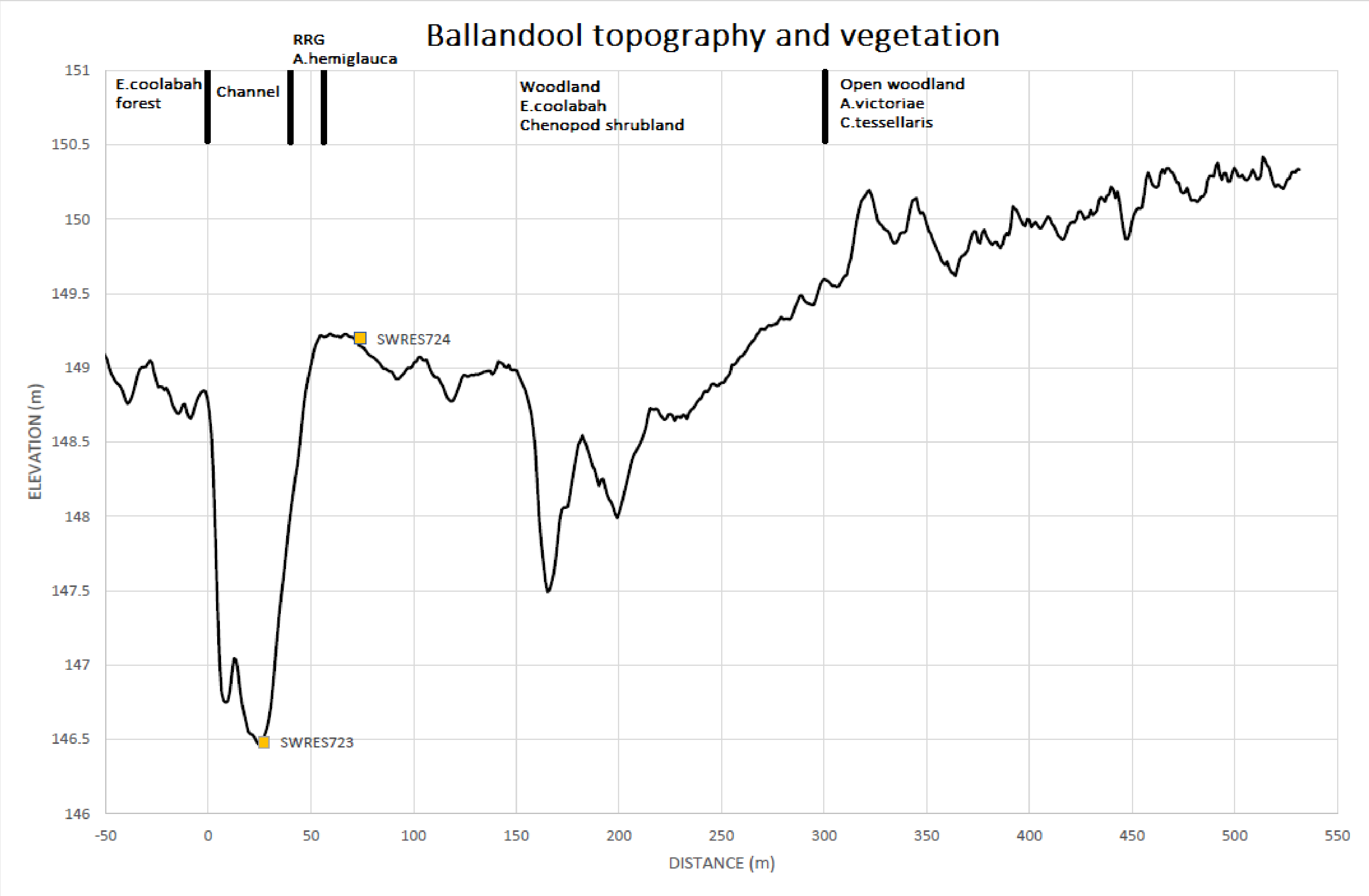
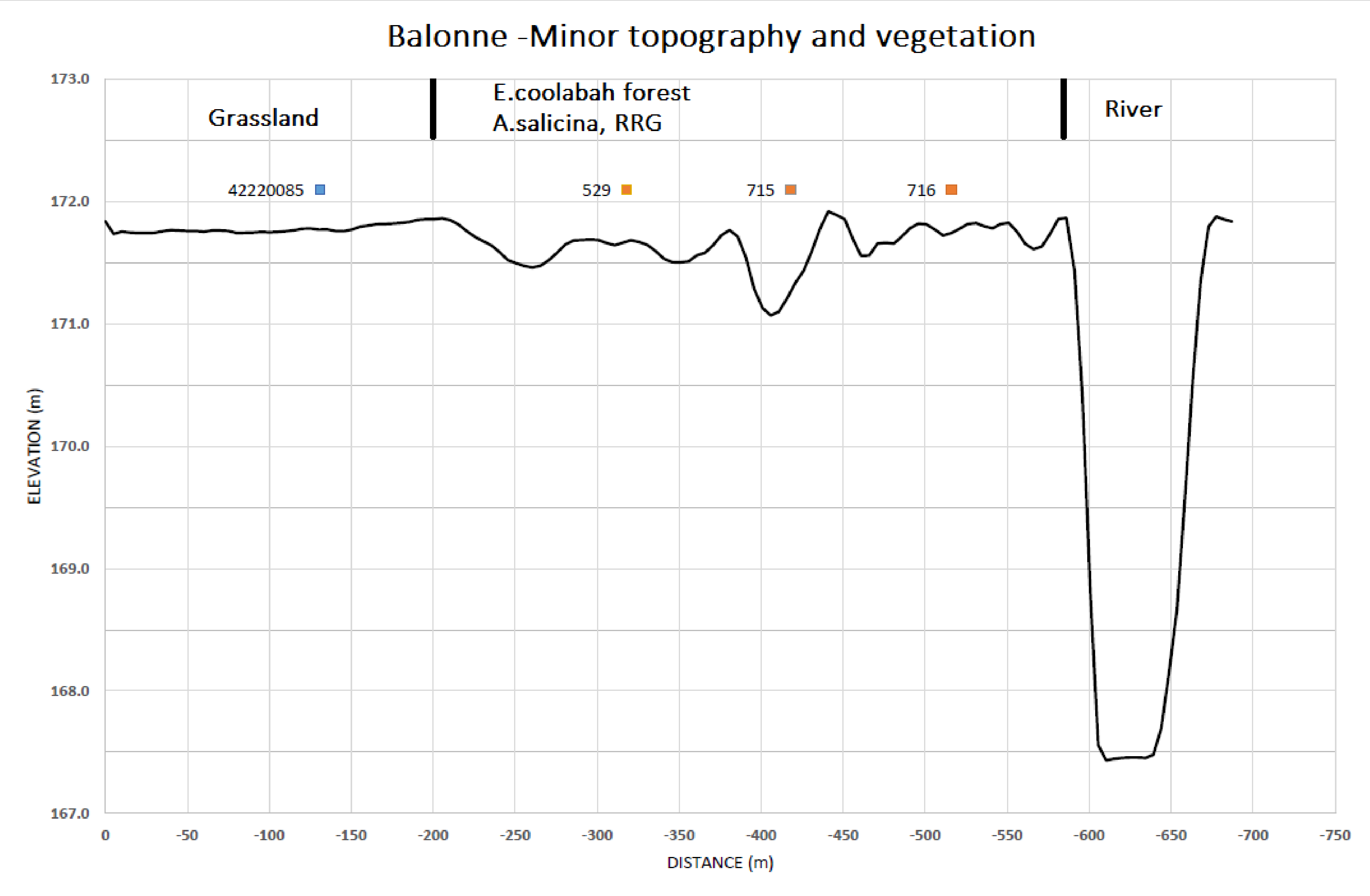
Appendix F



Ballandool topography and vegetation
E.coolabah forest
Channel
RRG
A.hemiglauca
Woodland
E.coolabah
Chenopod shrubland
Open woodland
A.victoriae
C.tessellaris
SWRES724
SWRES723
ELEVATION (m)
DISTANCE (m)
151
150.5
150
149.5
149
148.5
148
147.5
147
146.5
146
-50
0
50
100
150
200
250
300
350
400
450
500
550

Appendix G



Balonne -Minor topography and vegetation
Grassland
E.coolabah forest
A.salicina, RRG
River
42220085
529
715
716
173.0
172.0
171.0
170.0
169.0
168.0
167.0
ELEVATION (m)
0
-50
-100
-150
-200
-250
-300
-350
-400
-450
-500
-550
-600
-650
-700
-750
DISTANCE (m)