SCIENCE AND CONSERVATION DIVISION

Site audit and decommissioning of surface water and climate monitoring data loggers – Toolibin Lake Catchment

Prepared for Parks and Wildlife Services Wheatbelt Region

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Hydrology report series WCP-HR-2017-02
September 2017

GOVERNMENT OF WESTERN AUSTRALIA

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The recommended reference for this publication is:
Bourke, L (2017), Site audit and decommissioning of surface water and climate monitoring data loggers - Toolibin Lake Catchment, Department of Biodiversity, Conservation and Attractions, Kensington, Western Australia.

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Acknowledgements
Jasmine Rutherford, Department of Biodiversity, Conservation and Attractions is acknowledged for assistance developing the project scope and tasks and Darren Farmer is acknowledged for providing assistance downloading data loggers and the equipment/infrastructure decommissioning. Maria Lee, Conservation Officer (Toolibin Lake) and Gary Mills, Recovery Catchment Technical Officer (Toolibin Lake), Parks and Wildlife Service, Narrogin, are acknowledged for field data collection, on-ground support and review comments.

Cover image reference
Outlet of Toolibin Lake in March 2017 (photograph by Lindsay Bourke).

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1 Introduction

The Toolibin Lake Catchment surface water and rainfall monitoring data logger network was expanded between 2007 and 2010 as part of work undertaken for the Future Farm Industries Cooperative Research Centre (FFI CRC). The FFI CRC project was a joint research partnership between the Department of Biodiversity, Conservation and Attractions (formerly the Department of Environment and Conservation), the Centre for Ecohydrology at the University of Western Australia, and Department of Primary Industries and Regional Development (DPIRD) (formerly Department of Agriculture and Food Western Australia). During this period staff from the Centre for Ecohydrology commissioned and maintained monitoring equipment and managed, quality assured and interpreted data (Ovens et al. 2010, Callow et al. 2011). A summary of this infrastructure and the outcomes from this project is provided in Rutherford et al. (2015).

In 2012, the surface water and climate infrastructure ceased to be managed by the Centre for Ecohydrology, although all equipment remained deployed across the Toolibin Lake Catchment. As a short-term measure the Department of Biodiversity, Conservation and Attractions entered a memorandum of understanding from 2013 to 2014 with DPIRD to download infrastructure in the Toolibin Lake Catchment and upload data to their Hydstra database (Appendix A). A site audit conducted by the Department of Biodiversity, Conservation and Attractions in late 2014 found that all deployed equipment and associated infrastructure was near their end-of-life or required substantial maintenance, replacement or decommissioning to ensure the capture of fit for purpose data (Bourke 2014).

A review of historical data retrieved from the logger network was undertaken by Muirden et al. (2014). In summary, they generally found that the use of lower specification equipment and the lack of field observations to calibrate and verify data led to the collection of predominantly poor quality data and that data was generally not suitable for analysis. Muirden et al. (2014) presented a series of recommendations that included locations of essential and secondary monitoring sites, episodic monitoring sites, and described minimum site specifications, data collection and data quality assurance standards (see Appendix B).

At a meeting between staff from the Wheatbelt Region and the Wetlands Conservation Program on 25 June 2015 the status of the deployed data logging infrastructure and associated data was discussed. It was broadly agreed that there was little value in the continued investment in this existing infrastructure given the high cost for replacement and ongoing maintenance and the labour intensive methods required to calibrate and validate data. No further maintenance was proposed or conducted since that meeting and this equipment was later scheduled for decommissioning. In March 2017 remaining data was retrieved and data loggers removed or disabled at surface water and climate monitoring sites across the Toolibin Lake Catchment. These tasks are summarised in this report.

1.1 Scope of works

The scope of this study was to:

1. Retrieve, compile and archive data from the surface water and climate monitoring infrastructure located in the Toolibin Lake Catchment;
2. Remove or disable automated data loggers;
3. Undertake an audit of this data logging infrastructure and summarise retrieved data;

4. Undertake a preliminary assessment of data; and
5. Produce this report

2 Results

A field trip occurred on 15 and 16 March, 2017 by Lindsay Bourke and Darren Farmer and the majority of surface water and climate data logging sites were accessed, data retrieved and data loggers removed or disabled. A second field trip was undertaken by Lindsay Bourke on 9 May 2017 to retrieve a water level data logger in the Dulbining waterway (13DUL008). Field observations of site conditions including qualitative indicators of peak water levels and photographs were taken at each site and various other locations throughout the catchment (see examples in Figure 2, Figure 3 and Figure 4). All retrieved data, site photographs, field notes and supporting calibration files were compiled for each site and transferred to the Wetlands Conservation Program server (Kens-site-001/530-Wetlands Conservation Program). Details for each site are provided in Table 1 and Table 2 (Appendix C), Appendix D and are summarised below:

- Twenty six surface water monitoring sites and two rainfall sites were accessed, data retrieved, and data loggers removed or disabled (see Figure 1, Table 1 and Table 2).
- Nineteen data loggers were found to be still capturing data up until the date of retrieval. In the majority of cases these comprised water level data collected with Scott Parsons Electronics (SPE) capacitance probe type data loggers.
- In three cases, the SPE data loggers were found to be flood damaged or have water ingress observed in the logger housing, although data was still able to be retrieved (Table 2).
- Water level, temperature and salinity data was retrieved from two of the four AquaTroll data loggers deployed across the catchment.
- In all cases data was unable to be retrieved from Unidata data loggers due to flat batteries resulting in the loss of all data and in one case the data logger was found to be vandalized (gunshot holes in cabinet) (Figure 5).
- The batteries on the tipping bucket rain gauges located on the Martin and Tilbrook properties were flat and data ceased to be collected in late 2014 and mid 2015 respectively.

Manual water level measurements were made over recent months by staff from the Parks and Wildlife Services Narrogin Office at four data logging sites. These field observations were used to calibrate and verify retrieved data. A portion of the time-series data was quality assured and assessed for Site B (01DEC001) located in Booloo Creek, Site M (13DUL006) located in the Dulbining waterway, and Site S (14TOT001) located at the outlet of Toolibin Lake. Data retrieved from site A (14TIN001), located at the Toolibin Lake diversion gate was not able to be assessed due to logger failure in July 2015 and a lack of field observations during the data date range.

At Site B, a manual measurement observed at the gauge board taken at 09:00 hrs on 11 February 2017 was 1.20 m (Figure 6), whilst logged water levels captured with an AquaTroll logger at 09:14 was 1.24 m. A review of logged data over the previous 72-hours shows that a peak water level of 1.37 m occurred on 10 February at 15:59 hrs. A strong linear correlation (Y=0.9737*X+0.0195, R^2 0.9978) between all manual measurements and logged data provides a high level of confidence in the logged data. Inspection of trash lines on the adjoining fence indicated that a peak level of ~1.45 m occurred and therefore concurring with the peak level recorded by the automated logger on 10 February 2017.

At Site M, a manual measurement observed at the gauge board taken at 15:15 hrs on 13 February 2017 was 0.38 m (Figure 7). The water levels captured with a Scott Parsons

Electronics data logger at the same time was also 0.38 m. A review of logger data over the previous 72-hours shows that the peak water level of 0.96 m occurred at 16:30 hrs on 11 February. A strong linear correlation (Y=0.9829*X-0.015, R^2 0.9562) between all manual measurements and logged data provides a high level of confidence in the logged data, although there is no other supporting evidence, in the form of site photographs or trash lines on the gauge board or banks of the Dulbining waterway to validate the logged peak level and therefore reducing the level of confidence in the quality of the retrieved data.

At Site S, a manual measurement observed at the gauge board taken at 13:51 hrs on 13 February 2017 was 0.67 m (Figure 8). The calibrated logged water levels captured with a Scott Parsons Electronics data logger at 13:55 was 0.66 m. A review of the logged data over the previous 72-hours shows that a peak water level of 0.73 m occurred at 21:55 hrs on 12 February. A strong linear correlation (Y=1.0959*X-0.1349, R^2 0.9978) between manual measurements and logged data provides a high level of confidence in the logged data.

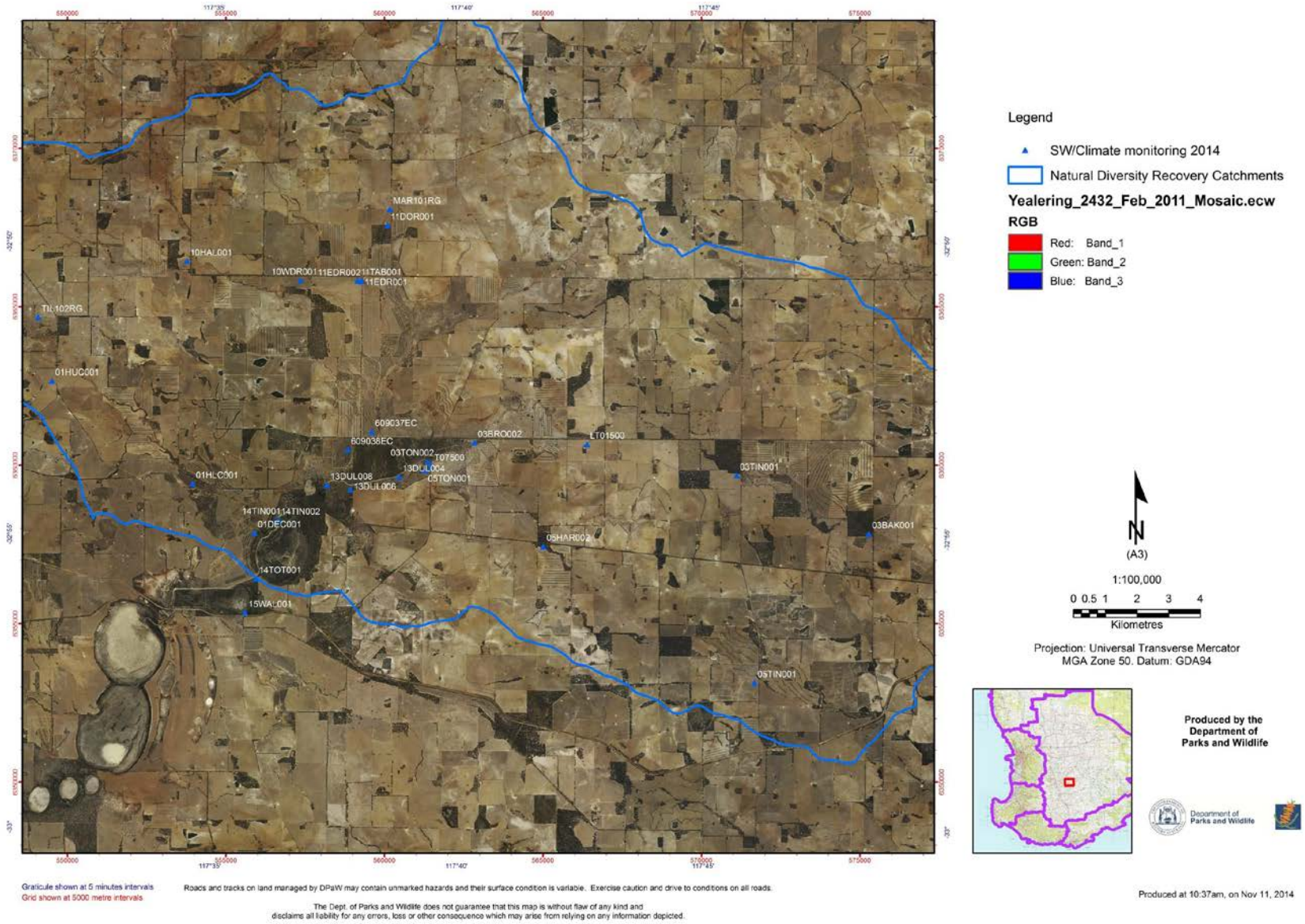

Figure 1. Location map of surface water and climate monitoring infrastructure located throughout the Toolibin Lake Catchment

Table 1. Summary of the surface water (SW) and climate monitoring sites that were visited on 15 to 16 March, 2017 and 9 May, 2017. The field *"Site ID"* is that denoted in the DBCA Wheatbelt region standard operating procedure.

SITE ID	SHORT ID	Site ID	Sensor	TYPE	Easting	Northing
ASWTLB01DEC001	01DEC001	B	Water level, temp, EC	AquaTroll	556041.00	6358016.00
ASWTLB01HLC001	01HLC001		Water level	SPE - USB	554090.00	6359568.00
ASWTLB01HUC001	01HUC001		Water level	SPE - USB	549656.00	6363147.00
ASWTLB03BAK001	03BAK001		Water level	SPE - USB	575424.00	6357984.00
ASWTLB03BRO002	03BRO002		Water level	SPE - USB	562979.10	6360863.80
ASWTLB03TIN001	03TIN001		Water level	SPE - USB	571256.00	6359823.30
ASWTLB03TON002	03TON002		Water level, temp, EC	AquaTroll	561509.43	6360275.38
ASWTLB05HAR002	05HAR002		Water level, temp, EC	AquaTroll	565152.69	6357589.20
ASWTLB05TIN001	05TIN001		Water level	SPE - USB	571810.00	6353284.60
ASWTLB05TON001	05TON001		Water level	SPE - USB	561409.94	6359998.48
ASWTLB10HAL001	10HAL001		Water level, temp, EC	AquaTroll	553895.00	6366581.00
ASWTLB10HAR001	10HAR001		Water level	SPE - USB	548427.60	6366753.80
ASWTLB10WDR001	10WDR001		Water level	SPE - USB	557493.20	6365984.39
ASWTLB11DOR001	11DOR001		Water level	SPE - USB	560233.70	6367722.28
ASWTLB11EDR001	11EDR001		Water level	SPE - USB	559412.60	6365989.00
ASWTLB11EDR002	11EDR002		EC and temp	Unidata	559411.00	6365962.00
ASWTLB11TAB001	11TAB001		Water level	SPE - USB	559291.50	6365976.80
ASWTLB13DUL004	13DUL004		Water level	SPE - Radio	560610.00	6359778.00
ASWTLB13DUL006	13DUL006	M	Water level	SPE - USB	559061.17	6359391.95
ASWTLB13DUL006	13DUL006	M	EC and temp	Unidata	559061.17	6359391.95
ASWTLB13DUL008	13DUL008		Water level	SPE - Radio	557783.00	6359493.00
ASWTLB14TIN001	14TIN001	A	Water level	SPE - USB	556779.34	6358430.34
ASWTLB14TIN002	14TIN002		Water level	SPE - USB	556777.88	6358420.81
ASWTLB14TOT001	14TOT001	S	Water level	SPE - USB	556072.00	6356570.00
ASWTLB15WAL001	15WAL001		Water level	SPE - USB	555745.00	6355497.00
ASWTLB609037EC	609037EC		Water level	SPE - USB	559750.00	6361200.00
ASWTLB609037EC	609037EC		EC and temp	Unidata	559750.00	6361200.00
ASWTLB609038EC	609038EC	L	Water level	SPE - USB	558980.00	6360670.00
ASWTLB609038EC	609038EC	L	Water level	Starlogger - Shaft encoder	558980.00	6360670.00
ASWTLB609038EC	609038EC	L	EC and temp	Unidata	558980.00	6360670.00
ASWTLBMAR101RG	MAR101RG		Rainfall	Hydrological Services	560422.00	6368919.00
ASWTLBTIL102RG	TIL102RG		Rainfall	Hydrological Services	547778.00	6366835.00

Figure 2. Severe erosion occurring on Brown Road, located immediately up-gradient from the West Drain (DWER site ID 609038), as a consequence of surface water flows occurring in February 2017.

Figure 3. Westwards photograph of site 01DEC01, located at outlet of the western tributary of Management Area MA1. Note the trash evident on the fence line, estimated to be at 1.45 m on the staff gauge (photograph Darren Farmer).

Figure 4. Evidence of sedimentation and erosion occurring at site 11TAB001 resulting in changed channel dimensions.

Figure 5. Data logger cabinet at site 03DUL06 located in the waterway east of Oval road. Note the small-calibre gunshot entry points on the door and evidence of forced entry.

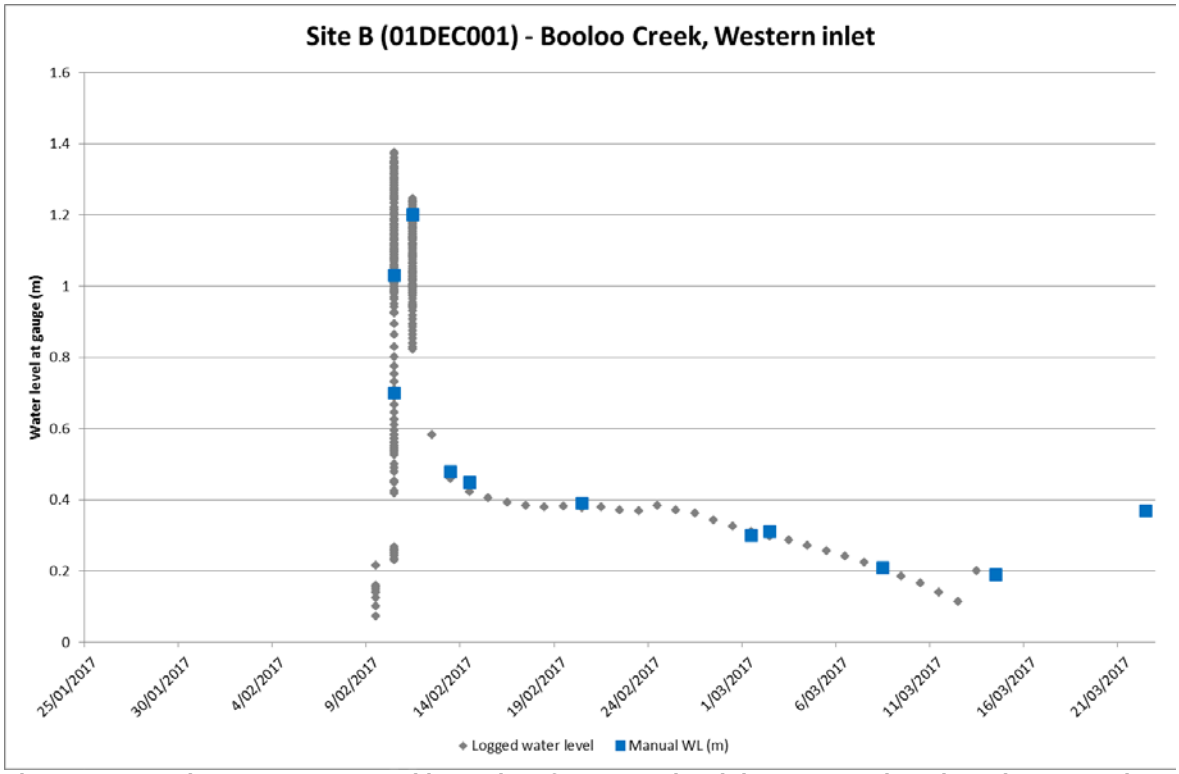

Figure 6. Manual measurements and logged surface water level data captured at Site B (01DEC001), located at Booloo Creek, the western inlet to the waterway at Toolibin Lake

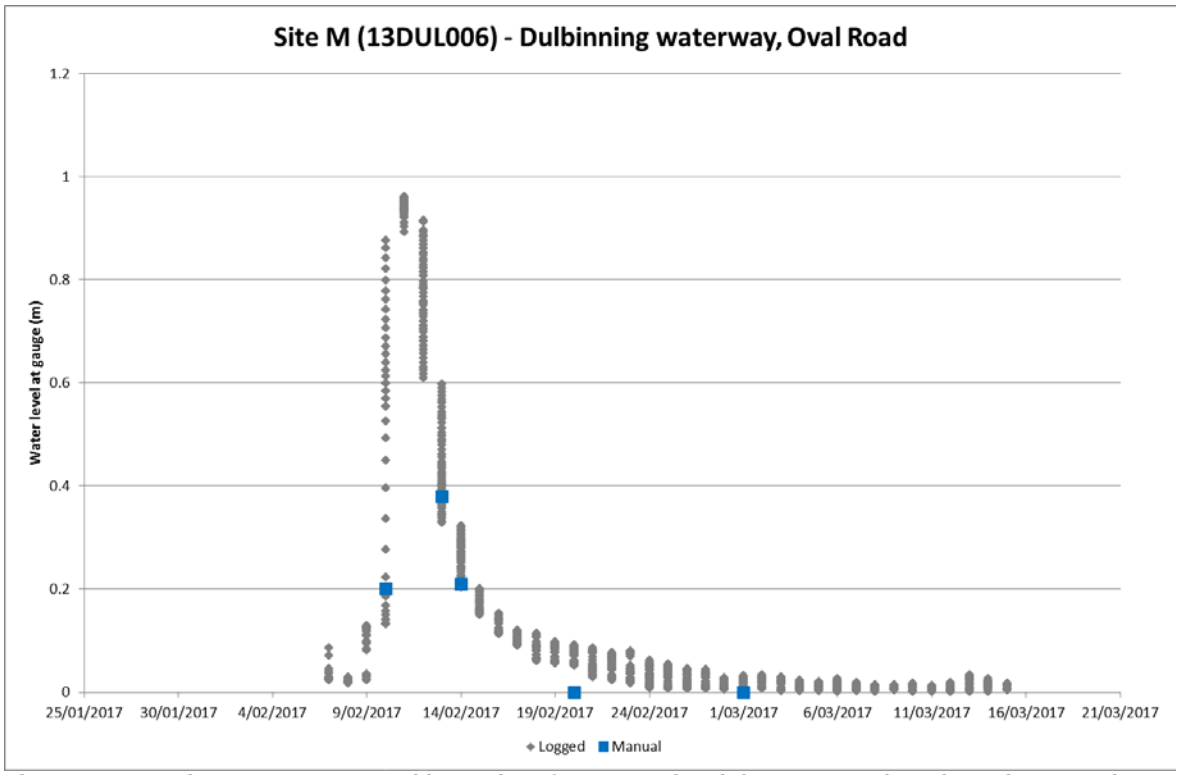

Figure 7. Manual measurements and logged surface water level data captured at Site M (13DUL06), located in the Dulbining waterway adjacent to Oval Road

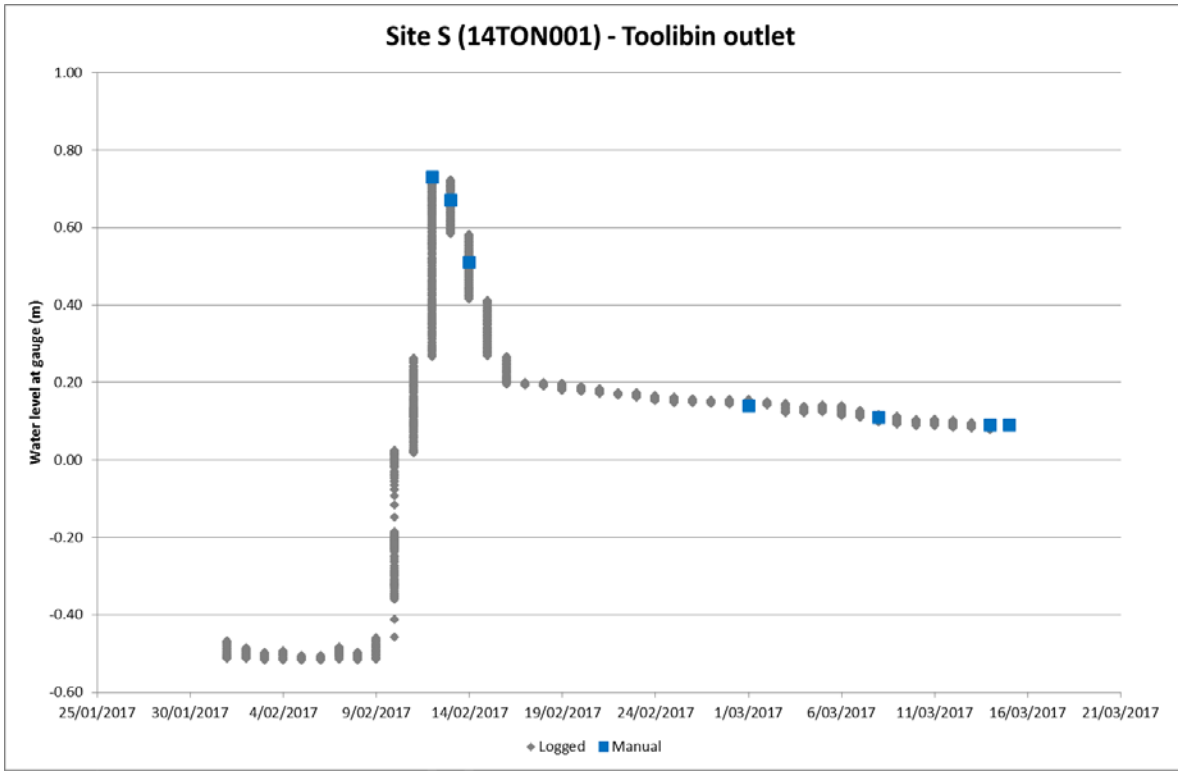

Figure 8. Manual measurements and logged surface water level data captured at Site S (14TON001, DWER site 6091026), located at the outlet of Toolibin Lake.

3 Discussion

In this study, 26 surface water monitoring sites and two rainfall sites were accessed, data retrieved, and data loggers removed or disabled. Of these, 19 data loggers were found to be still capturing data until the date of retrieval. Retrieved data included water levels from sites located in the east drain and west drain (sites 609037 and 609038 respectively), the Dulbining waterway (13DUL006 and 13DUL008), the inlet to Toolibin Lake (14TIN001 and 14TIN002), and its outlet (14TOT001).

Muirden et al. (2014) identified the requirement to develop and adopt standard operating procedures (SOPs) to ensure consistency of data collection and provide an auditable trail of data. Procedures were developed and endorsed by the Parks and Wildlife Service staff in the Narrogin office in the event that an episodic rainfall event occurred. Field data comprising of observations of water levels and salinity (EC) and temperature was collected in accordance with this SOP and this data was used to successfully calibrate and validate retrieved logged data from three sites. Strong correlations between manual measurements and logged data generally provide a high level of confidence in these datasets. In combination with other supporting information these datasets may provide important insights into catchment rainfall/runoff behaviour.

With the exception of data retrieved from three sites, the data retrieved from the logger network does not have sufficient field observations to enable data to be calibrated and validated and therefore not suitable for quantitative analysis or numerical modelling. Therefore the expenditure of further resources to analyse and quality assure all of the retrieved data is not warranted.

Since the last site audit in November 2014 (Bourke 2014), the surface water and rainfall monitoring data loggers and supporting infrastructure in the Toolibin Lake Catchment have further deteriorated. This was exacerbated by the occurrence of significant rainfall and

catchment-scale surface water flows in February 2017 that led to severe erosion and sedimentation of the road network and alteration to site conditions.

Based on the findings of this report, the suitability of data retrieved from the logger network for interpretation is generally constrained by:

- The lack of maintenance and calibration of equipment;
- Poor performance of data logger sensors, particularly salinity sensors that are prone to fouling due the infrastructure location and design;
- The absence of, or lack of recently acquired, detailed site information (e.g. surface elevation, channel specifications);
- Insufficient number of field observations at logging sites over time to verify and calibrate the acquired data; and
- Occurrence of erosion and sedimentation that in many cases led to significantly altered site conditions.

3.1 Logger network status

The removal or disabling of the automated surface water and rainfall data loggers, as undertaken in this study, has rendered the network no longer operational. The supporting infrastructure, comprising of gauge boards at surface water monitoring sites, steel cabinets at rainfall monitoring sites, and the sheds, still-wells and weirs located at the east and west drain sites are still in place. These sites should be decommissioned, or if they are required for future monitoring then these sites will require refurbishment.

The only automated continuous monitoring site that is operational is the Wickepin-Harrismith Road gauging station (site 609010), that is managed by the Department of Water and Environmental Regulation (formerly Department of Water). This site represents the only long-term, appropriately instrumented and managed hydrographic station in the catchment and the ongoing operation of this site is essential to understand surface water contributions to Toolibin Lake.

Local-scale surface water flows in the Toolibin Lake Catchment are most often short-lived, shallow and occur in poorly defined waterways and channels, whilst the larger catchment-scale flows and lake-fill events occur much less frequently. Irrespective of the scale of the event the quantification of surface water flows and storages in these landscapes is inherently difficult. Data loggers, however, remain an effective tool to capture data, but should only be used on the basis that the following principles are applied:

- Data loggers are to be placed in locations within well-defined channels, or areas with control structures and supporting survey data to enable the capture of quantitative data;
- Priority to be allocated to sites where conditions are less vulnerable to change (sedimentation, erosion, or anthropogenic modification). Many wetlands throughout the Toolibin Lake Catchment meet these criteria and are therefore highly suited to data logging applications;
- The use of high quality data logging equipment that have long-battery life, high quality sensors, can be calibrated in-situ and have non-volatile memory;
- Logged data is validated with field data collected in accordance with standard operating procedures;
- Monitoring sites and equipment is inspected, maintained and calibrated on a regular basis to ensure collected data is within desired specifications;
- All data is to be quality assured, appropriately archived and interpreted on a regular basis.

4 References

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Appendix A
Memorandum of Understanding – DEC and DAFWA

MEMORANDUM OF UNDERSTANDING (MOU)

DATA LOGGER DOWNLOAD, MAINTENANCE, DATA QUALITY CONTROL AND ARCHIVING AND DATA SUPPLY FOR THE LAKE BRYDE AND TOOLIBIN LAKE NDRCS: 2013-14 FINANCIAL YEAR

SCHEDULE 1 SPECIFICATION/STATEMENT OF REQUIREMENTS

STATEMENT OF REQUIREMENTS

The Department of Parks and Wildlife (DPaW) Natural Resources Branch (NRB) request the services of the Department of Agriculture and Food (DAFWA) to undertake the management of hydrological data logging devices and associated data management for the Lake Bryde and Toolibin Lake Natural Diversity Recovery Catchments (NDRCs').

The following specification/statement of requirements is based on DPaW's current technical requirements, available budget and staffing resources and the availability of DAFWA staff and resources to undertake the tasks.

CONTACT PERSONS

TECHNICAL/CUSTOMER ENQUIRIES

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SPECIFICATION

Contract detail

The objectives of this project are to:

1. Download hydrological data from logging devices in the Lake Bryde and Toolibin Lake NDCRs;
2. Calibrate and maintain equipment within the catchments[1];
3. Import and quality control newly acquired data (**Toolibin only**) into the DAFWA HYDSTRA database; and
4. Provide raw and archived HYDSTRA datasets and field datasheets to the DPaW.

Lake Bryde NDRC - Site/task summary

Equipment/site summary:

- 4 x rainfall monitoring sites (Hydrological Services TBRG with ML1 loggers paired with SPE loggers)
- 35 x water level (SPE data loggers)
- 2 x salinity (EC), temperature and water level (AquaTROLL loggers)

Two site visits are to occur before 30 June 2014 (suggest March and June). Details are provided in Appendix A, although in summary the field trips involve download of data, filling of logger still-wells, checking of zero (or cease-to-flow) values, changing batteries and calibration of loggers if required and restarting of loggers.

The DPaW estimates that each field trip will consist of seven (7) days for field work; plus two (2) days for preparation, processing field trip forms, archive of raw data and complete any repairs or other related tasks. **Note no Qa of data to be undertaken**, rather DAFWA is to provide DPaW with the raw ascii/txt data and data collection sheets detailing maintenance and audit information. Field trips are assumed to be 10-hour

[1] Maintenance covers cleaning, calibration and sensor replacement only. It does not include repairs or replacement of logger housings or site infrastructure.

days and office duties are assumed to be 7.5 hours. Total of 18 days (14 x 10hr days, 4 x 7.5hr days, or 170 hours).

Toolibin Lake NDRC - Site/task summary
Equipment/site summary:

- 1 x groundwater monitoring site (SPE data logger)
- 2 x rainfall monitoring sites (Hydrological Services TBRG with ML1 loggers)
- 4 x salinity (EC) and temperature sites (Unidata loggers)
- 3 x salinity (EC), temperature and water level sites (Aqua TROLL loggers)
- 1 x water level (Level TROLL logger)
- 18 x surface water level sites (2 x radio and 16 x USB loggers)

Three site visits are to occur before June 2014 (suggest November 2013, March and May 2014). Details are provided in Appendix B, although in summary, the field trips will involve download of data, filling of logger still-wells, checking of zero (or cease-to-flow) values, changing batteries and calibration of loggers if required and restarting of loggers.

The DPaW estimates that each field trip will consist of four (4) days for field work; plus one (1) day to prepare for field trips, process field trip forms, complete any repairs or other related tasks; and three (3) days to archive raw data, import data into HYDSTRA and Qa data. Field trips are assumed to be 10-hour days and office duties are assumed to be 7.5 hours. Total of 24 days (12 x 10hr days, 12 x 7.5hr days, or ~210 hours).

Safety/Scheduled calls
DAFWA to be responsible for making appropriate search and rescue (SAR) arrangements for field trips and to advise the DPaW regional staff (Narrogin or Katanning) prior to departure. DAFWA to advise Lindsay Bourke (DPaW) of their **SAR protocol prior to undertaking field work**. If required, the DPaW can provide support for scheduled calls and after-hours contact.

Timing
Timing of field trips is at the discretion of DAFWA, however DPaW suggests field trips be conducted in the Lake Bryde NDRC in March and June, 2014 and Toolibin Lake NDRC field trips to be conducted in November 2013, March and May, 2014. The work outlined in the project will be completed by June 30, 2014. The delivery of raw data files and other related data (site photographs, field notes etc) will be supplied within four weeks of each field trip.

Charges
All Costs for completing the work will be met by the Department of Parks and Wildlife for work on the project within Western Australia.

Additional Services and Products
Variations to this Schedule require the written endorsement of the Acting Assistant Director, Nature Conservation, Department of Parks and Wildlife.

Payment
Invoices to be issued by DAFWA at the completion of each of the following time-bound milestones:

1. Provision of invoice by 28 February 2014 for the completion of the November 2013 field trip for the Lake Toolibin Lake NDRC and supply of preliminary data (i.e. raw data files and field sheets) (25% of estimated total cost);
2. Provision of invoice by 25 April 2014 at the completion of the March field trips and supply of preliminary data (i.e. raw data files and field sheets) for the Lake Bryde and Toolibin Lake NDRC's (25% of estimated total cost);
3. Provision of invoice by 16 June 2014 at the completion of the May/June field trips and supply of preliminary data (i.e. raw data files and field sheets) for the Lake Bryde and Toolibin Lake NDRC's (25% of estimated total cost);

4. Provision of invoice by 16 June 2014 for the supply of all newly acquired raw and processed datasets for the Lake Toolibin NDRC which have been quality controlled and archived to the DAFWA HYDSTRA database (25% of estimated total cost).

Note: if there is a significant increase in actual costs above the estimate (20% or more), DAFWA will advise DPaW at the earliest opportunity and DPaW will make a decision on increased payment and continuation of the work.

CONTRACT MANAGEMENT REQUIREMENTS

Responsibilities of the Contract Authority

The DPaW will:

- If required, DAFWA to negotiate the provision of one DPaW staff member to assist field activities in Lake Bryde and Lake Toolibin NDRC's;
- Provide relevant support to DAFWA staff, such as provision of GPS coordinates and detailed maps showing logger locations and access routes;
- Provide software schemas, access to a laptop computer and other relevant equipment required to undertake routine maintenance;
- Provide any logger replacements, batteries and other hardware to carry out this work
- Fully test any replacement sensors or loggers for at least one week prior to being deployed
- If required, provide support for scheduled calls and after-hours contact.

Signed in behalf of the Department of Parks and Wildlife, Western Australia

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Signed on behalf of the Department of Agriculture and Food WA

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SCHEDULE 2 PRICING
FIXED SCHEDULE OF RATES

Part A – Operations

A fixed schedule of rates provided by DAFWA are listed below, all prices are **exclusive of GST**.
Note: the below quantities are estimates and are to be used as a guide only

Task	Subtask	Units	Price per unit	Estimated quantity	Total
Lake Bryde field visits and raw data supply March/June 2014	Preparation, process forms, archive and supply raw data etc	Per hour	$51.26	30	$1,537.80
	Field work	Per hour	$51.26	140	$7,176.40
	Travel vehicle 4WD	Per km	$0.30	3,000	$900.00
	Travel vehicle 4WD	Per day	$120	14	$1,680.00
	Overnight stay rate	Per day	$208.55	10	$2,085.50
	Meals on days with no overnight stay	Per day	$79.10	4	$316.40
Toolibin Lake field visits and data mgt November 2013 /March/May 2014	Preparation, process forms, archive data etc	Per hour	$51.26	22.5	$1,153.35
	Field work	Per hour	$51.26	120	$6,151.20
	Travel vehicle 4WD	Per km	$0.30	3,000	$900.00
	Travel vehicle 4WD	Per day	$120	12	$1,440.00
	Overnight stay rate	Per day	$208.55	9	$1,876.95
	Meals on days with no overnight stay	Per day	$79.10	3	$237.30
	Upload, QC and supply new Toolibin datasets.	Per hour	$51.26	67.5	$3,460.05
Other	Up to 20% variation	Per hour	$51.26	76	$3,895.76
Total		-	-	-	**$32,810.71**

Appendix A: Lake Bryde site visit task summary March/June

Catchment	Indicative date	Site type	Equipment	Task Description
Lake Bryde NDRC	March 2014	Rainfall	4 x TBRG (TB4 with ML1 and SPE logger)	Download 2 x loggers per site (Hydrological Services and SPE), sanity check data, adjust time if required and restart loggers.
		SW level	35 x SPE data loggers	Photograph site, download logger, sanity check data, change battery (if req'd), fill still-well with water, check zero value, refill talc tube and restart logger. Calibrate/replace as req'd. **Note: new site at Western Boundary**
		SW level, EC, temp	2 x AquaTROLL	Photograph site, download logger, sanity check data, change battery, fill still-well with water, check zero value and restart logger. Calibrate/replace as req'd.
	June 2014	Rainfall	4 x TBRG (TB4 with ML1 and SPE logger)	Download 2 x loggers per site (Hydrological Services and SPE), sanity check data, adjust time if required and restart loggers.
		SW level	35 x SPE data loggers	Photograph site, download logger, sanity check data, change battery (if req'd), fill still-well with water, check zero value, refill talc tube and restart logger. Calibrate/replace as req'd. **Note: new site at Western Boundary**
		SW level, EC, temp	2 x AquaTROLL	Photograph site, download logger, sanity check data, change battery, fill still-well with water, check zero value and restart logger. Calibrate/replace as req'd.

Appendix B: Toolibin Lake site visit task summary March/May

Catchment	Indicative date	Site type	Equipment	Task Description
Toolibin Lake NDRC	November 2013	Groundwater	1 x SPE data logger	Download, sanity check data, reset and adjust time if required and restart logger.
		Rainfall	2 x TBRG (with ML1 logger)	Download, sanity check data, adjust time if required and restart logger.
		SW level	2 x SPE radio loggers	Photograph site, download logger, sanity check data, change battery (if req'd), fill still-well with water, check zero value and restart logger.
		SW level/EC/Temp	16 x SPE USB loggers, 1 x LevelTROLL,3 x AquaTROLL, 4 x Unidata	Photograph site, download logger, sanity check data, change battery (if req'd), fill still-well with water, check zero value and restart logger. Calibrate/replace as req'd.
	March 2014	Groundwater	1 x SPE data logger	Download, sanity check data, reset and adjust time if required and restart logger.
		Rainfall	2 x TBRG (with ML1 logger)	Download, sanity check data, adjust time if required and restart logger.
		SW level	2 x SPE radio loggers	Photograph site, download logger, sanity check data, change battery (if req'd), fill still-well with water, check zero value and restart logger.
		SW level/EC/Temp	16 x SPE USB loggers, 1 x LevelTROLL,3 x AquaTROLL, 4 x Unidata	Photograph site, download logger, sanity check data, change battery (if req'd), fill still-well with water, check zero value and restart logger. Calibrate/replace as req'd.
	May 2014	Groundwater	1 x SPE data logger	Download, sanity check data, reset and adjust time if required and restart logger.
		Rainfall	2 x TBRG (with ML1 logger)	Download, sanity check data, adjust time if required and restart logger.
		SW level	2 x SPE radio loggers	Photograph site, download logger, sanity check data, change battery (if req'd), fill still-well with water, check zero value and restart logger. Calibrate/replace as req'd.
		SW level/EC/Temp	16 x SPE USB loggers, 1 x LevelTROLL,3 x AquaTROLL, 4 x Unidata	Photograph site, download logger, sanity check data, change battery (if req'd), fill still-well with water, check zero value and restart logger. Calibrate/replace as req'd.

Appendix B

Extract from Muirden and Coleman 2014 – Section 5.2.2

Essential surfacewater sites
For surface water monitoring into the future, it is recommended that it is essential to operate 4 sites as shown in *Table 5.*1. These sites record the flow from 3 key catchments and allow any shorter term sites to be correlated to extend their value. Any reduction in the number of essential sites will impact on understanding the behaviour of the flows (which vary across the catchment). However, when resources are stretched, it is better to reduce the number of continuous sites rather than downgrade the quality of what is being collected. What is absolutely essential is the one long term site currently run be DoW [609010], which has been in operation since August 1978, a period of 35 years. This site is not ideal (as Dulbining Lake is located immediately upstream of it), however, it does have long term, good quality data and is immediately upstream of Lake Toolibin.

*Table 5.*1 –Proposed Essential Sites:

- 609010 #1 – existing DoW site; DoW are apparently upgrading
- 609038 (W) #2 – Operational DPaW site; maintain weir; relocate EC probe
- 609037 (E) #3 – purchase shaft encoder & logger; maintain weir; relocate EC probe
- 13DUL003 #4 – proposed new site; install NEW Aquatroll; create simple control; once its suitability is confirmed, this site should eventually have a floatwell & simple weir constructed;

Episodic monitoring program
5.2.5 Episodic monitoring
Post flood event monitoring
Obtaining data from events like that on 12 December 2012 is essential to understanding the behaviour of surface water flow in the Toolibin catchment. This is partially to better understand the way water moves in the whole catchment plus to more accurately define the behaviour of water at individual monitoring sites (i.e. developing better rating curves and determining local backwater effects). This post flood event monitoring usually occurs after the event has gone and there is only standing water left in wetlands and other pools. With climate change, large winter flows are now rare. A superficial review of types of rainfall events that cause flows are that they are not seasonal, but event based [see Section 4.4.2]. While it would be idea to have a network of monitoring gauges covering the catchment, a significant lack of resources indicates that this is not going to happen. Particularly the poor quality of “cheap and nasty” data and the reality of the actual cost to make it even partially useable.

*Table 5.*3 shows a proposed set of episodic sites and their current infrastructure.

*Table 5.*3 –Proposed Episodic monitoring Sites:
10HAL Existing GB
10WDR Existing GB
10NWT New site (located 700m Sth of 10WDR)
609038 Existing GS
11DOR Existing GB
11EDR001 Existing GB
11EDR003 New site (located 160 m d/s for Wogolin Sth Rd)
609037 Existing GS
12NET New site (potential site located 2 km d/s Toolibin Nth Rd)
12BRO reinstated site (same located; modified control)

03TIN Existing GB
03BRO001 reinstated site (located further d/s)
03BRO002 relocate site (located 5m u/s); existing GB
03TON001 reinstated site (same located)
05TIN Existing GB
05HAR Existing GB
05TON002 New Site (located at Toolibin North Road)
13DUL003 New Site (located u/s of East Drain confluence)
13DUL006 Existing GB
13DUL007 Existing GB
13DUL1 Existing GB (Dulbining 1 Lake)
13DUL2 Existing GB (Dulbining 2 Lake)
13DUL3 Existing GB (Dulbining 3 Lake)
609010 Existing GB
14TIN (1&2) Existing GB
609009 (sump) Existing GB (Lake Toolibin)
01HLC Existing GB
01DEC Existing GB
15WON New site (located south of Toolibin original outlet)
WALB Existing GB (Walbyring Lake)

In this list are surface water 22 sites, plus 5 lakes. All these sites will require a gauge board and Talc tube (at a minimum). Nine new GB's are required, plus all 30 sites will require Talc tubes. During major events, it is also preferable that water level slope be pegged and surveyed. This allows the use of the existing HECRAS models (at most sites) to more accurately determine the peak flow rates.

Talc tubes:
Talc tubes are Clear Extruded Acrylic Tubes that are 1" diameter with ¼" thick walls and are about 1 m long; with a layer of talcum powder on their insides. They are fitted vertically adjacent to the gauge board at each episodic site using a bracket that ensures that they are relocated at the same level each time they are reloaded with talc. They have a cap on their top that allows air to enter, but not rain. As the water level at the site rises, it rises up the tube and removes the talc, leaving the talc above the peak water level. The peak water level since the last time they were reloaded is measured against the gauge board.

Snapshot monitoring
Snapshots are episodic monitoring that occurs at many sites during actual flow events. In the Toolibin catchment, this will most likely be during a winter flow event. Snapshot monitoring occurs at selected sites, where flow, water level, pH, temperature and EC are recorded. This is to determine spatial variability of data. It is preferable that all the episodic sites listed in *Table 5.*3 are visited and data collected.

Appendix C

Table 2

Table 2. Field observations and data logger details for each of the surface water and rainfall monitoring sites visited on 15 to 16 March, 2017 located throughout the Toolibin Lake Catchment.

SITE ID	SHORT ID	Logger SN	Sensor SN	Sensor	TYPE	Water depth (m)	Downloaded successfully	Data Recording Mode	Data start	Data end	Field Notes
ASWTLB01DEC001	01DEC001	A114678		Water level, temp, EC	AquaTroll	0.16	YES	1 min, compressed	10/10/2014	14/03/2017	Able to download logger successfully. Removed logger.
ASWTLB01HLC001	01HLC001	UB0152	0050	Water level	SPE - USB	0	YES	5 mins, compressed	10/10/2014	15/03/2017	Removed logger
ASWTLB01HUC001	01HUC001	UB0003	0058	Water level	SPE - USB	0	NO				Site destroyed, unable to locate logger
ASWTLB03BAK001	03BAK001	UB0073	0017	Water level	SPE - USB	0	YES	5 mins, compressed	10/10/2014	15/03/2017	Removed logger
ASWTLB03BRO002	03BRO002	UB0002		Water level	SPE - USB	0	YES	5 mins, compressed	10/10/2014	15/03/2017	Removed logger
ASWTLB03TIN001	03TIN001	UB0104	0061	Water level	SPE - USB	0	YES	5 mins, compressed	10/10/2014	15/03/2017	Removed logger
ASWTLB03TON002	03TON002	A121701		Water level, temp, EC	AquaTroll	0	YES	1 min, compressed	09/10/2014	14/03/2017	Evidence of water overtopping road. External battery flat, although able to download logger. Removed logger
ASWTLB05HAR002	05HAR002	A114689		Water level, temp, EC	AquaTroll	0	NO	1 min, compressed	10/10/2014	10/10/2014	Unable to connect to logger. Battery likely flat. Removed logger
ASWTLB05TIN001	05TIN001	UB0203	0014	Water level	SPE - USB	0	YES	5 mins, compressed	12/06/2014	15/03/2017	High water mark estimated from likely road level. Evidence of overtopping road. Obvious debris to 1.1-1.2m on fence. Removed logger
ASWTLB05TON001	05TON001	UB0103	009	Water level	SPE - USB	0	YES	5 mins, compressed	09/10/2014	15/03/2017	Removed logger. Peter Muirden has pegged high water mark.
ASWTLB10HAL001	10HAL001	A146226		Water level, temp, EC	AquaTroll	0	NO	1 min, compressed	10/10/2014	26/06/2016	Removed logger
ASWTLB10HAR001	10HAR001	UA0013		Water level	SPE - USB	0	NO				Logger site destroyed December 2012.
ASWTLB10WDR001	10WDR001	UB0112	0043	Water level	SPE - USB	0	YES	5 mins, compressed	10/10/2014	15/03/2017	Removed logger
ASWTLB11DOR001	11DOR001	UB0091	0060	Water level	SPE - USB	0	YES	10 mins, compressed	10/10/2014	13/02/2017	Data logger retrieved by Region staff. Water ingress to internal housing and therefore data likely to be compromised.
ASWTLB11EDR001	11EDR001	UB0111	0016	Water level	SPE - USB	0	YES	5 mins, compressed	10/10/2014	15/03/2017	Removed logger
ASWTLB11EDR002	11EDR002	10087		EC and temp	Unidata	0	NO	10 minute	11/06/2014	10/10/2014	Flat battery, unable to retrieve data. Removed logger
ASWTLB11TAB001	11TAB001	UB0032	0010	Water level	SPE - USB	0	YES	5 mins, compressed	10/10/2014	15/03/2017	Flat battery, unable to retrieve data. Removed logger.
ASWTLB13DUL004	13DUL004	RB0036	0207	Water level	SPE - Radio	0	YES	5mins compressed	10/10/2014	15/03/2017	Removed logger. Downloaded logger 20/07/2017
ASWTLB13DUL006	13DUL006	UB0165	0042	Water level	SPE - USB	0	YES	30 min, compressed	09/10/2014	15/03/2017	Removed logger
ASWTLB13DUL006	13DUL006	10086		EC and temp	Unidata	0	NO	5 minute	11/06/2014	09/10/2014	Logger removed by Maria Lee. Note that cabinet and logger damaged by gun shots (small calibre)
ASWTLB13DUL008	13DUL008	RB0038	0193	Water level	SPE - Radio	0	NO	5 mins, compressed	09/10/2014	11/02/2017	Removed logger 9/05/2017. Probe error (65535) from 11/02/2017 onwards. Moisture found inside logger housing and probe housing, unknown cause.

SITE ID	SHORT ID	Logger SN	Sensor SN	Sensor	TYPE	Water depth (m)	Downloaded successfully	Data Recording Mode	Data start	Data end	Field Notes
ASWTLB14TIN001	14TIN001	UB0167	0223	Water level	SPE - USB	0	NO	5 mins, compressed	10/10/2014	13/07/2015	Removed logger. Diversion weir upstream side
ASWTLB14TIN002	14TIN002	UB0110		Water level	SPE - USB	0	YES	5 mins, compressed	10/10/2014	27/02/2017	Removed logger. Diversion weir downstream side. Logger found on ground and water ingress in housing. Data likely to have been compromised.
ASWTLB14TOT001	14TOT001	UB0115	0052	Water level	SPE - USB	0.09	YES	5 mins, compressed	10/10/2014	15/03/2017	Water level 0.09 on gauge board when downloaded. Clear high watermark on @ 0.19m. Depth appears to be ~0.20 m due to significant erosion at gauge board. Removed logger.
ASWTLB15WAL001	15WAL001	UB0092		Water level	SPE - USB	0	NO				Logger site destroyed December 2012.
ASWTLB609037EC	609037EC	UB0143		Water level	SPE - USB	0	YES	10 mins, compressed	09/10/2014	15/03/2017	Removed logger. East Drain Weir (in stilling well). Peter Muirden has pegged high water mark.
ASWTLB609037EC	609037EC	10085		EC and temp	Unidata	0	NO	10 minute	12/06/2014	09/10/2014	Flat battery, unable to retrieve data. Removed logger.
ASWTLB609038EC	609038EC	UB0150		Water level	SPE - USB	0	YES	5 mins, compressed	09/10/2014	15/03/2017	Removed logger. West Drain Weir (in stilling well). Peter Muirden has pegged high water mark
ASWTLB609038EC	609038EC	60419	6541	Water level	Starlogger - Shaft encoder	0	NO	6 minutes	09/10/2014	26/09/2015	Flat battery on encoder shaft. Logger still has battery and therefore able to download. Left logger on-site.
ASWTLB609038EC	609038EC	10083		EC and temp	Unidata	0	NO	10 minute	11/06/2014	09/10/2014	Flat battery, unable to retrieve data. Removed logger.
ASWTLBMAR101RG	MAR101RG	ML8104	08-629	Rainfall	Hydrological Services		NO	Event	12/06/2014	14/11/2014	Battery flat. Unable to contact logger. Removed logger, left cabinet and TBRG in-situ. Downloaded logger 20/03/2017
ASWTLBTIL102RG	TIL102RG	ML8109	08-626	Rainfall	Hydrological Services		NO	Event	16/06/2014	22/08/2015	Battery flat. Unable to contact logger. Removed logger, left cabinet and TBRG in-situ. Downloaded logger 20/03/2017

Appendix D

2017 surface water monitoring infrastructure site audit

SITE ID	ASWTLB01DEC001
SHORT ID	01DEC001
Site details	MA1, Western Tributary, DEC Access Road upstream
Sensor	Water level, temp, EC
TYPE	AquaTroll
Easting	556041
Northing	6358016
Comment:	

SITE ID	ASWTLB01HLC001
SHORT ID	01HLC001
Site details	MA1 Lower Harrismith Rd Upstream
Sensor	Water level
TYPE	SPE - USB
Easting	554090
Northing	6359568
Comment:	

SITE ID	ASWTLB01HUC001
SHORT ID	01HUC001
Site details	MA1 Upper Harrismith Rd Upstream
Sensor	Water level
TYPE	SPE - USB
Easting	549656
Northing	6363147
Comment:	

SITE ID	ASWTLB03BAK001
SHORT ID	03BAK001
Site details	MA3 Baker Road
Sensor	Water level
TYPE	SPE - USB
Easting	575424
Northing	6357984
Comment:	

SITE ID	ASWTLB03BRO002
SHORT ID	03BRO002
Site details	MA3 Brown Rd Culvert
Sensor	Water level
TYPE	SPE – USB
Easting	562979
Northing	6360864
Comment:	

SITE ID	ASWTLB03TIN001
SHORT ID	03TIN001
Site details	MA3 Tincurrin Nth Rd Upstream
Sensor	Water level
TYPE	SPE – USB
Easting	571256
Northing	6359823
Comment:	

SITE ID	ASWTLB03TON002
SHORT ID	03TON002
Site details	MA3/5 Toolibin Nth Rd Downstream
Sensor	Water level, temp, EC
TYPE	AquaTroll
Easting	561509.434
Northing	6360275.4
Comment:	

SITE ID	ASWTLB05HAR002
SHORT ID	05HAR002
Site details	MA5 Harrismith Rd Downstream
Sensor	Water level, temp, EC
TYPE	AquaTroll
Easting	565152.68
Northing	6357589.2
Comment:	

SITE ID	ASWTLB05TIN001
SHORT ID	05TIN001
Site details	MA5 Tincurrin Nth Rd
Sensor	Water level
TYPE	SPE – USB
Easting	571810
Northing	6353284.6
Comment:	

SITE ID	ASWTLB05TON001
SHORT ID	05TON001
Site details	MA5 Toolibin Nth Rd
Sensor	Water level
TYPE	SPE – USB
Easting	561409.94
Northing	6359998.48
Comment:	

SITE ID	ASWTLB10HAL001
SHORT ID	10HAL001
Site details	MA10 Box Culvert Upstream
Sensor	Water level, temp, EC
TYPE	AquaTroll
Easting	553895
Northing	6366581
Comment:	

SITE ID	ASWTLB10HAR001
SHORT ID	10HAR001
Site details	MA10 Harrismith Rd Upstream
Sensor	Water level
TYPE	SPE – USB
Easting	548427.6
Northing	6366753.8
Comment:	Site destroyed following significant surface water flow event in December 2012 (image in 2012 below).

SITE ID	ASWTLB10WDR001
SHORT ID	10WDR001
Site details	MA10 West Drain Upstream
Sensor	Water level
TYPE	SPE – USB
Easting	557493.204
Northing	6365984.39
Comment:	

SITE ID	ASWTLB11DOR001
SHORT ID	11DOR001
Site details	MA11b Dorakin Road
Sensor	Water level
TYPE	SPE – USB
Easting	560233.7
Northing	6367722.28
Comment:	

SITE ID	ASWTLB11EDR001
SHORT ID	11EDR001
Site details	MA11b East Drain Upstream
Sensor	Water level
TYPE	SPE – USB
Easting	559412.6
Northing	6365989
Comment:	

SITE ID	ASWTLB11EDR002
SHORT ID	11EDR002
Site details	MA11b East Drain Salinity
Sensor	EC and temp
TYPE	Unidata
Easting	559411
Northing	6365962
Comment:	

SITE ID	ASWTLB11TAB001
SHORT ID	11TAB001
Site details	MA11a Table Drain
Sensor	Water level
TYPE	SPE – USB
Easting	559291.5
Northing	6365976.8
Comment:	

SITE ID	ASWTLB13DUL004
SHORT ID	13DUL004
Site details	Dulb&East Drains (Dul4)
Sensor	Water level
TYPE	SPE – Radio
Easting	560610
Northing	6359778
Comment:	

SITE ID	ASWTLB13DUL006
SHORT ID	13DUL006
Site details	Oval Road
Sensor	Water level/EC and temperature
TYPE	SPE – USB/Unidata
Easting	559061.165
Northing	6359391.95
Comment:	

SITE ID	ASWTLB13DUL008
SHORT ID	13DUL008
Site details	Dulbining lake inlet
Sensor	Water level
TYPE	SPE – Radio
Easting	557783
Northing	6359493
Comment:	

SITE ID	ASWTLB14TIN001
SHORT ID	14TIN001
Site details	Toolibin inflow Upstream
Sensor	Water level
TYPE	SPE – USB
Easting	556779.34
Northing	6358430.34
Comment:	

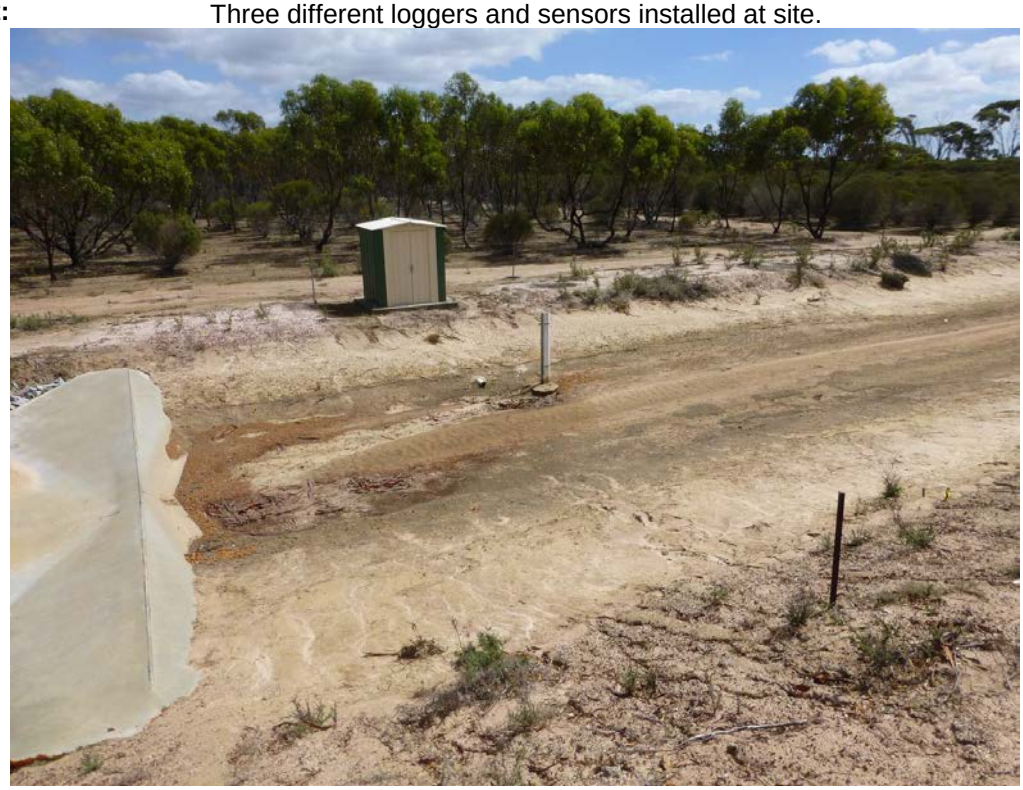
SITE ID	ASWTLB14TIN002
SHORT ID	14TIN002
Site details	Toolibin inflow Downstream
Sensor	Water level
TYPE	SPE – USB
Easting	556777.88
Northing	6358420.81
Comment:	

SITE ID	ASWTLB14TOT001
SHORT ID	14TOT001
Site details	Toolibin outlet
Sensor	Water level
TYPE	SPE – USB
Easting	556072
Northing	6356570
Comment:	

SITE ID	ASWTLB15WAL001
SHORT ID	15WAL001
Site details	Walbyring Inlet
Sensor	Water level
TYPE	SPE – USB
Easting	555745
Northing	6355497
Comment:	Site no longer active, destroyed in December 2012

SITE ID	ASWTLB609037EC
SHORT ID	609037EC
Site details	DWER East Drain
Sensor	Water level/EC and temp
TYPE	SPE – USB/Unidata
Easting	559750
Northing	6361200
Comment:	

SITE ID	ASWTLB609038EC
SHORT ID	609038EC
Site details	DWER West Drain
Sensor	Water level/EC and temp/Water level
TYPE	SPE – USB/Unidata/Unidata
Easting	558980
Northing	6360670
Comment:	Three different loggers and sensors installed at site.



SITE ID	ASWTLBMAR101RG
SHORT ID	MAR101RG
Site details	Toolibin Rain Gauge East (Martins)
Sensor	Rainfall
TYPE	Hydrological Services
Easting	560422
Northing	6368919
Comment:	

SITE ID	ASWTLBTIL102RG
SHORT ID	TIL102RG
Site details	Toolibin Rain Gauge West (Tilbrooks)
Sensor	Rainfall
TYPE	Hydrological Services
Easting	547778
Northing	6366835
Comment: