Government of **Western Australia**
Department of **Water**

Monitoring program to support the Pilbara groundwater allocation plan

October 2013

Looking after all our water needs

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Department of Water

Water resource allocation and planning report series

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Contents

Figures

Tables

Summary

The Department of Water has developed the *Pilbara groundwater allocation plan* (2013). The monitoring program sets out how the Department of Water will monitor the groundwater resources (using both departmental and licensee monitoring) to support plan evaluation and understand groundwater resources over time.

We will assess monitoring information against performance indicators to see if the resource objectives stated in the plan are being met, and report the results in regular evaluation statements.

Specifically, the collection of monitoring data allows the department to:

- evaluate against the resource objectives set out in the plan
- trigger management responses to ensure risks to the resource are being managed
- collect ecological monitoring data to validate predicted groundwater-dependent ecosystem response to changes in groundwater availability
- conduct monitoring for future planning needs
- regulate through licences.

This document outlines the key elements of the monitoring programs tailored specifically for each of the nine target resources and links with the evaluation of the allocation plan.

The department and current and future water users will implement the monitoring program through operating strategies associated with licences.

1 Introduction

1.1 Purpose of the monitoring program

The monitoring program supports the *Pilbara groundwater allocation plan* (Department of Water 2013) and sets out how the Department of Water will monitor water resources in the plan area. The information that is collected will allow us to:

- evaluate against the resource objectives set out in the plan
- trigger management responses to ensure risks to the resource are being managed
- collect ecological monitoring data to validate predicted groundwater-dependent ecosystem response to changes in groundwater availability
- conduct monitoring for future planning needs
- regulate through licences.

Monitoring data will be collected from the following nine target resources:

- coastal alluvial aquifers of the lower Fortescue, lower Robe, lower Yule, lower De Grey, lower Cane and lower Turner rivers
- Millstream aquifer
- Wallal and Broome sandstone aquifers of the West Canning Basin.

Monitoring in non-target resources, primarily the fractured rock resources located in the central Pilbara, will continue to be required. These requirements will be captured in licence operating strategies and will be the responsibility of individual licensees to carry out and report to the department. These monitoring programs are developed to manage local water issues. We will review the results of this monitoring and manage resources on a case-by-case basis.

1.2 Determining monitoring effort

Monitoring effort for each of the target resources closely aligns with the allocation status of the water resource, the identified risks of abstraction to groundwater-dependent values (ecological risks) and the resource itself (hydrogeological risks) (Table 1). As water use and risk increases, the level of management response and monitoring effort also increases.

The non-target resources (primarily fractured rock resources) are monitored on a case-by-case basis depending on the assessment of risks.

Table 1: Level of monitoring effort for each resource

Aquifer	Ecological risk	Hydrogeological risk		Resource status		Level of Effort
	Risk to dependent values	Prevent seawater intrusion	Maintain water quality	Current allocation	Future demand	
Target aquifer						
Millstream	high	low	medium	high (100%)	high	high
Fortescue	medium	medium	medium	high (100%)	high	medium
Robe	high	low	medium	low (<30%)	medium	medium
De Grey	medium	low	low	high (100%)	high	medium
Yule	medium-high	medium	medium	high (100%)	high	high
West Canning (Wallal and Broome)	Low	medium	medium	low (<30%)	high	medium
Cane	medium	medium	high	medium (30-70%)	medium	medium
Turner	low	low	medium	low (<30%)	low	low
Non-target aquifer						
Fractured rock	case-by-case	case-by-case	case-by-case	not applicable	not applicable	case-by-case
Others resources	case-by-case	case-by-case	case-by-case	case-by-case	not applicable	case-by-case

1.3 Existing monitoring in the plan area

The majority of groundwater monitoring is collected by licensees as a requirement of their licence. Appendix C provides further detail on monitoring across the target resources prior to implementation of the *Pilbara groundwater monitoring program*.

Monitoring of the Yule, De Grey, and Cane alluvial aquifers is conducted by Water Corporation as the sole licensee for these resources. Water Corporation also conducts the majority of monitoring at Millstream.

In the West Canning Basin the department will commence monitoring in recently completed bores and plans to expand the program into the eastern portion of the basin once current investigations are complete. This will complement monitoring currently being undertaken by licensees.

The Turner alluvial aquifer is currently unlicensed and has no monitoring program. Monitoring of this resource will be the responsibility of future licensees.

The department currently monitors a network of 18 groundwater bores which provide data for the Robe and Fortescue alluvial aquifers. Data have been collected from these sites since 1984 at frequencies ranging from monthly to annually.

In addition to groundwater monitoring, the department maintains and manages 24 gauging stations and 30 rainfall sites across the Pilbara. Seven of the nine target resources have a river gauging station. These stations were installed in the 1970s and 1980s and have reliable continuous river flow data.

Table 2: Monitoring program responsibilities

Resource	Department monitoring	Licensee monitoring
Lower Yule alluvial	River gauging (plus 2 bores)	√
Lower De Grey alluvial	River gauging only	√
Millstream aquifer	River gauging (plus 4 bores)	√
Lower Fortescue alluvial	√	when water use > 70% of allocation
Lower Robe alluvial	√	future water user
West Canning Basin (WCB) Broome	To be implemented through this program	
WCB Wallal	To be implemented through this program	√
Lower Cane alluvial	River gauging only	√
Lower Turner alluvial	River gauging only	future water user
Fractured rock	Not applicable	√ (case-by-case)
Other resources	Not applicable	√ (case-by-case)

2 Monitoring program for the Pilbara

The department and licensees have a responsibility to ensure that the resources in the plan area are managed so that groundwater productivity, water quality and dependent values are maintained into the future.

To support the plan we have developed monitoring programs for each of the resources as outlined in chapters 3–10 (coordinates are provided in Appendix D). Due to the region's size and the cost of implementing a regional monitoring program, the department will continue to use a combination of departmental and licensee monitoring.

2.1 Monitoring to evaluate against the resource objectives

The monitoring program has been developed to ensure we have adequate information to evaluate if the resource objectives in the allocation plan are being met and whether we need to change how we regulate and manage abstraction.

We have set water resource objectives for the nine target aquifers. They reflect how we want the resources to perform so that the outcomes identified in the plan are delivered.

Resource objectives are underpinned by performance indicators which are specific and measurable water level, volume and/or quality targets that need to be maintained to meet the hydrogeological or ecological objective (see Appendix A for further information). For some of the objectives, baseline data need to be collected before we can set performance indicators.

Resource objectives and performance indicators for the individual target resources are outlined in chapters 3–10.

Resource objectives and performance indicators for non-target resources are not included in this document as they will be determined on a case-by-case basis during the licence assessment process and documented in proponent's operating strategies or monitoring programs.

Performance indicators

We have selected performance indicators that help us identify where abstraction is posing a risk to groundwater-dependent values or the resource itself. Monitoring programs for each target resource may include some or all of the indicators outlined below.

Groundwater level

Performance indicators using groundwater levels have been set to manage the risks from abstraction to groundwater-dependent ecosystems (GDEs). For these performance indicators we have adopted 'criteria' and 'target' water levels, based on

defined environmental water provisions (EWPs). The criteria set a minimum water level (m AHD) and should not be breached, while targets set a high water level (m AHD) that should be reached.

These performance indicators may vary annually depending on annual streamflow and rainfall. We have designed the performance indicators like this to mimic the natural variability of the Pilbara climate and to allow proponents to have appropriate abstraction in dry years.

Explanation on how we set these criteria water levels can be found in Appendix A of the *Pilbara groundwater allocation plan*.

Surface water level indicator

Where sufficient data are available, surface water level indicators have been set to manage the impacts of abstraction on river pools. For these performance indicators we have adopted criteria water levels, based on defined ecological water requirements (EWRs). They relate to a minimum pool level to support aquatic fauna, and should not be breached.

Explanation on how we set these criteria water levels can be found in Appendix A of the *Pilbara groundwater allocation plan*.

Groundwater quality indicator

Performance indicators have been set for salinity in production bores (TDS mg/L) to manage the risks to water quality from bore field abstraction. They are based on maintaining salinity at or below historic levels.

Performance indicators have also been set for salinity in selected monitoring bores to ensure brackish water from the aquifer's flanks are not drawn into the productive part of the aquifer. In some instances, baseline data will need to be collected for several years prior to establishing these performance indicators.

In the Yule, De Grey, Robe and Fortescue resources, modelling has identified that current and further abstraction activities have the potential to impact on the position of the seawater interface. Performance indicators will be established for these resources once adequate baseline data have been collected through surface water interface monitoring (SWIM).

Streamflow indicator

Streamflow is the primary source of recharge to the Millstream and alluvial aquifers. Ongoing review of recharge and aquifer level relationships as abstraction increases (in some target aquifers) is an important part of the monitoring and evaluation cycle.

Total wet season flow needs to be calculated in May every year to determine the applicable groundwater level performance indicator in the following year.

2.2 Monitoring to trigger management response

- For the performance indicators using groundwater levels (as described in the previous section) we have set triggers – in addition to criteria – to assist in the management of abstraction activities.
- When the trigger level is reached it will require a management response so that any adverse effects can be minimised. This will also ensure that water levels do not reach criteria levels and significant impacts can be averted.
- Trigger levels are not included in the monitoring program. Where applicable, they will be detailed in proponents' licence conditions and associated operating strategies.
- The triggers and responses and how we developed them are described in Appendix A of the *Pilbara groundwater allocation plan* (Department of Water, 2013).

2.3 Ecological monitoring

Ecological monitoring is carried out to ensure that the performance indicators have been set at an appropriate level to achieve the intended ecological objectives. This allows us to validate our predictions of groundwater-dependent ecosystem response to changes in groundwater availability.

Ecological monitoring will be carried out at representative ecological sites in the Yule, De Grey and Millstream resources on a yearly basis, at least while baseline data are being collected. Ecological monitoring will also be carried out at representative ecological sites in the Robe and Fortescue resources once abstraction has increased. Monitoring will target vegetation parameters sensitive to changes in water availability through vegetation surveys and canopy photography.

2.4 Monitoring for future planning needs

We carry out some monitoring in the region to help us with future planning activities. This is the main purpose of our monitoring program in the Robe aquifer and planned monitoring in the eastern portion of the West Canning Basin (not included in this program).

The Robe aquifer is currently an unlicensed resource. As demand for this resource is expected to increase in the future, we monitor the resource to provide baseline information on water availability as well as to provide an understanding of constraints to water abstraction.

In the West Canning Basin we have recently begun investigative work in the eastern portion of the resource. Once this work is completed we plan to start a monitoring program to improve our understanding of the resource and refine the allocation limits for the West Canning Basin. These details are currently not available and have not been included in the monitoring program.

In addition to the Robe aquifer and West Canning Basin, some monitoring is required across the resources to assess water resource trends and improve our understanding of groundwater resources or refine groundwater models, thereby supporting future planning.

2.5 Licensee compliance monitoring

We have identified monitoring which is collected and reported by licensees as a requirement of their licences and as detailed in their operating strategies. This will enable us to confirm licensees are complying with the conditions of their licences and ensure that we make the best use of their monitoring efforts.

Because the monitoring program is designed to support the *Pilbara groundwater allocation plan*, it may not include all licensee monitoring requirements. Licensees are directed to their operating strategy which will be revised to include their requirements with regard to this monitoring program and monitoring required to meet local objectives.

3 Lower Yule River

3.1 Site description

The Yule bore field has operated as part of the Port Hedland water supply scheme since 1967. The Water Corporation is the sole water licence holder. Abstraction is managed through a licence and operating strategy. Mundabullangana station also sources water for stock from the aquifer.

The aquifer supports groundwater-dependent river pools, riparian vegetation and aquifer ecosystems (Braimbridge 2010). The river pools and riparian vegetation are of local conservation significance and were identified as having cultural significance to the Karriyarra traditional owners.

The monitoring program for the Yule aquifer covers the bore field and surrounds, extending downstream along the Yule River towards the saltwater interface.

3.2 Resource objectives

The resource objectives and performance indicators for the Yule River are detailed below:

1 Prevent saltwater intrusion into the aquifer caused by abstraction.

2 Maintain water quality for the most beneficial use (potable water supply).

3 Maintain groundwater and pool levels within a target range, to maintain aquatic habitat and riparian vegetation that are dependent on groundwater.

3.3 Recommended monitoring program

The monitoring program detailed in Table 3 will ensure adequate information is collected to allow us to evaluate the aquifer's performance against the resource objectives and ensure that risks are being managed. This program is subject to change if bore field configuration or abstraction rates change.

Table 3: Yule River recommended monitoring program

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [i]
							Groundwater level (mAHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
1				WC	28/10	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
1				WC	29/10	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
1				WC	01/11	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
1				WC	02/11	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
1				WC	03/11	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
1				WC	04/11	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
1				WC	05/11	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
1				WC	06/11	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
1				WC	22/73	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	3, 8
1				WC	1/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<800	1
2				WC	3/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<800	1
2				WC	2/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<500	1
2				WC	5/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<500	1
2				WC	7/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<500	1
2				WC	11/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<500	1
2				WC	12/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<500	1

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [i]
							Groundwater level (mAHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
2				WC	13/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<500	1
2				WC	15/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<500	1
2				WC	16/96	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<500	1
2				WC	21/73	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<1000	1
2				WC	20/73	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<1000	1
2				WC	No 3	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<1000	1
2				WC	No 8A	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<1000	1
2				WC	14/70	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<1000	1
2				WC	No 21	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<1000	1
2				WC	No 20	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<1000	1
2				WC	No 18B	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	<1000	1
3	✓		✓	WC	37/04	Mon bore	Monthly (plus Department of Water logger)	Table 5				1, 6
		✓		WC	MM1	Veg transect			Ecological health	October	Baseline	2, 8
3	✓			WC	10/04	Mon bore	Monthly	Table 5				1
		✓		WC	MK04	Veg transect			Ecological health	October	Baseline	2, 8
3	✓			WC	13/04	Mon bore	Monthly	Table 5				1

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [i]
							Groundwater level (mAHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
3	✓		✓	WC DoW	21/04	Mon bore	Monthly (plus Department of Water logger)	Table 5				1, 6
3	✓			WC	17/04	Mon bore	Monthly	Table 5				1
		✓		WC	MC	Veg transect			Ecological health	October	Baseline	2, 8
3	✓			WC	08/04	Mon bore	Monthly	Table 5				1
3	✓			WC	12/04	Mon bore	Monthly	Table 5				1
		✓		WC	MI/04	Veg transect			Ecological health	October	Baseline	2, 8
3	✓			WC	14/04	Mon bore	Monthly	Table 5				1
		✓		WC	MI/04	Veg transect			Ecological health	October	Baseline	2, 8
3	✓			WC	15/04	Mon bore	Monthly	Table 5				1
3	✓			WC	34/04	Mon bore	Monthly	Table 5				1
		✓		WC	MN/04	Veg transect			Ecological health	October	Baseline	2, 8
3	✓				Jelliabidina Well	Gauging station			Total flow (ML)	May	Recharge class	1
				WC		Production bores			Total production (ML)	May	Allocation limit	1
			✓	WC	15/73	Mon bore	Monthly					1
			✓	WC	4/96	Mon bore	Monthly					1

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [i]
							Groundwater level (mAHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
			✓	WC	6/96	Mon bore	Monthly					1
			✓	WC	8/96	Mon bore	Monthly					1
			✓	WC	19/73	Mon bore	Monthly					1

[I] **Site status legend**

1 This site is currently monitored.

2 A new monitoring site is required in order to collect adequate data to evaluate a resource objective.

3 Condition of this bore is unknown – condition assessment is required. Based on results, maintenance may be required or a different bore selected.

4 Access to this site is unknown – track assessment (and possibly regrading and clearing) is required.

5 Groundwater level is currently used as a surrogate for surface water level at this pool. Department of Water to undertake bathymetry and survey work to allow a performance indicator for surface water level to be developed.

6 Department of Water has a logger at this key aquifer response site to ensure more frequent and representative data are collected.

7 This site will only be required if a new bore field configuration or an increase in water licence occurs.

8 Baseline data will be collected at this site for two years and then reviewed to develop a performance indicator.

Water level performance indicators to maintain dependent ecosystems are variable and are linked to river flow. To determine which indicators are applicable in the coming water year, these steps are followed:

1 Total river flow for the previous water year (May–April) is calculated and used to set a recharge class based on the total flows in Table 4.

2 Recharge class determines the performance indicator for each site for the following water year (May–April) using the table below. Target levels are not enforceable but should be reached in recharge class 4 years.

Table 4: Yule River recharge classes

Total flow from May to April	Recharge class
0–3000 ML	1
3001–50 000 ML	2
50 001–500 000 ML	3
>500 000 ML	4

Table 5: Yule River alluvial aquifer variable performance indicators

Site	Recharge class			
	1	2	3	4
	Performance indicator (m AHD)	Performance indicator (m AHD)	Performance indicator (m AHD)	Target (m AHD)
Bore 8_04	7.28	8.25	9.23	10.78
Bore 10_04	7.45	8.87	9.86	12.18
Bore 12_04	11.09	13.32	14.30	15.39
Bore 13_04	14.61	16.55	17.53	18.34
Bore 14_04	16.46	17.79	18.77	19.82
Bore 15_04	21.37	22.14	23.12	24.22
Bore 34_04	8.43	9.07	10.06	10.68
Bore 37_04	7.19	7.88	8.87	10.32

Site	Recharge class			
	1	2	3	4
	Performance indicator (m AHD)	Performance indicator (m AHD)	Performance indicator (m AHD)	Target (m AHD)
Bore 17_04	27.98	28.66	28.96	29.48
Bore 21_04	31.16	31.73	32.03	32.48

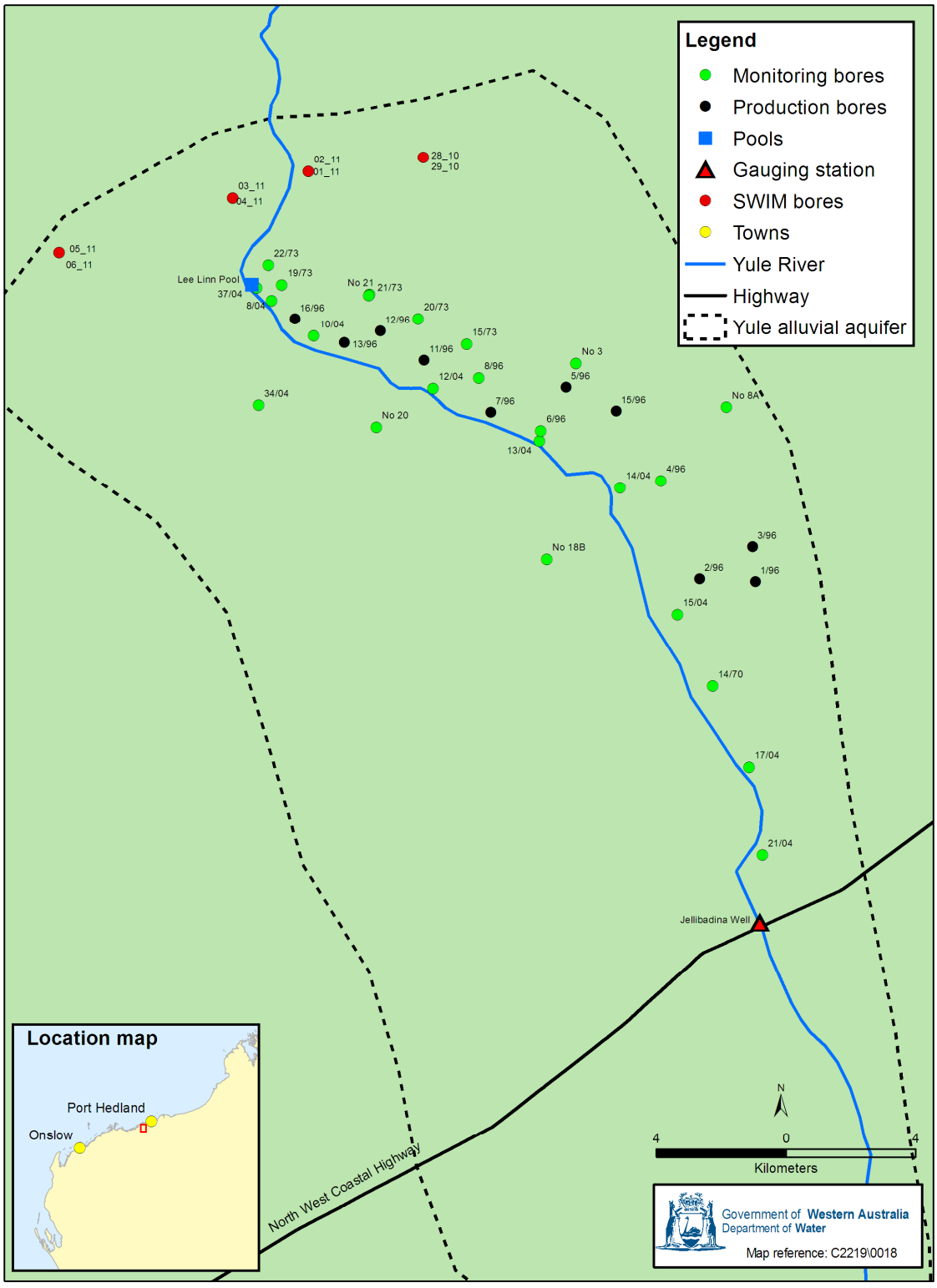

Figure 1: Yule River alluvial aquifer monitoring program

4 Lower De Grey River

4.1 Site description

The De Grey River is located approximately 70 km north-east of Port Hedland. The monitoring program focuses on a 35 km length of the lower De Grey River downstream of the confluence of the Shaw River. These lower reaches of the De Grey River overlie an alluvial aquifer which holds considerable volumes of potable water.

The Namagoorie bore field on the lower De Grey River has operated as part of the Port Hedland water supply scheme since 1979, in conjunction with the Yule River bore field. The Water Corporation is the sole water licence holder. Small volumes of water are also abstracted for stock and domestic use by the De Grey Station.

The aquifer supports groundwater-dependent river pools, riparian vegetation and aquifer ecosystems (Loomes 2012). The De Grey River, from the confluence of the Nullagine and Oakover rivers to the Indian Ocean at Poissonnier Point, is listed in the *Directory of important wetlands in Australia* (Environment Australia 2001) and is also recognised as a wetland of subregional significance (Kendrick & Stanley 2002).

The De Grey River's pools are also important to the Ngarla people, traditional owners of the land incorporating the bore field.

4.2 Resource objectives

The following resource objectives have been developed for this resource and are the focus of the monitoring program:

1 Prevent saltwater intrusion into the aquifer caused by abstraction.

   Water quality monitoring in current monitoring bores is required to collect baseline data and access their suitability for monitoring saltwater intrusion. Performance indicators (TDS mg/L) will be developed once an adequate baseline is available. Three new bores are required to extend coverage across the saltwater interface if the current bore field is extended northward.

2 *Maintain water quality for the most beneficial use (potable water supply).*

3 *Maintain groundwater and pool levels within a target range, to maintain aquatic habitat and riparian vegetation dependent on groundwater and protect values as listed in the* Directory of Important Wetlands in Australia.

4.3 Recommended monitoring program

The monitoring program detailed in Table 6 will ensure that adequate information is collected to allow us to evaluate the aquifer's performance against the resource objectives and ensure that risks are being managed.

This program is subject to change if bore field configuration or abstraction rates are altered.

Table 6: De Grey River recommended monitoring program

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [i]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
1				WC	New 1	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7, 8
1				WC	New 2	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7, 8
1				WC	New 3	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7, 8
1				WC	X1	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
1				WC	1/04	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
2				WC	T1	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
2				WC	T2	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
2				WC	T3	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
2				WC	T4	Mon bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	1, 8
2				WC	7/03	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly	average across bores <800 mg/L	1
2				WC	2/76	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	3/76	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	5/76	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	7/76	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	14/03	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	12/76	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [i]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
2				WC	15/03	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	9/03	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	8/03	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	13/03	Prod bore	Monthly		Groundwater quality (TDS mg/L)	Quarterly		1
3	✓			WC	U1,	Mon bore	Monthly	Table 8				1
	✓			WC	Pool J96	Pool			Surface water level (mAHD)	Monthly	Table 8	1
		✓		WC	MV	Veg transect			Ecological health	October	Baseline	2, 8
1, 3	✓			WC	9/04 Homestead	Mon bore	Monthly	Table 8	Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 8
	✓			WC	MT	Pool			Surface water level (m AHD)	monthly	Table 8	1
		✓		WC		Veg transect			Ecological health	October	Baseline	2, 8
3	✓			WC	6/04	Mon bore	Monthly	Table 8				1
	✓			WC	Makanykarra	Pool			Surface water level (m AHD)	monthly	Table 8	1
		✓		WC	MZ	Veg transect			Ecological health	October	Baseline	2, 8
3	✓		✓	WC	7/04	Mon bore (plus Department of Water logger)	Monthly	Table 8				1, 6
	✓			WC	Coolenar	Pool (7/04)	Monthly	Table 8	Surface water level (m AHD)	Monthly	Baseline	1, 5
		✓		WC	MY3	Veg transect			Ecological health	October	Baseline	2, 8

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [i]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
3	✓			WC	H2	Mon. bore	Monthly	Table 8				1
	✓			WC	Nardeegeecarblin	Pool			Surface water level (m AHD)	Monthly	Baseline	5
		✓		WC	New	Veg transect			Ecological health	October	Baseline	2
3	✓			WC	I2	Mon. bore	Monthly	Table 8				1
3	✓			WC	F1	Mon. bore	Monthly	Table 8				1
3					Coolenar	Gauging station			Total flow (ML)	May	Recharge class	1
				WC		Production bores			Total production (ML)	May	Allocation limit	1
			✓	WC	11/76	Mon bore	Quarterly					1
			✓	WC	4/76	Mon bore	Quarterly					1
			✓	WC	E1	Mon bore	Quarterly					1
			✓	WC	E3	Mon bore	Quarterly					1
			✓	WC	E4b	Mon bore	Quarterly					1
			✓	WC	H1	Mon bore	Quarterly					1
			✓	WC	I1	Mon bore	Quarterly					1
			✓	WC	R1	Mon bore	Quarterly					1
			✓	WC	U2	Mon bore	Quarterly					3, 4

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [i]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
			✓	WC	U3	Mon bore	Quarterly					1
			✓	WC	U4	Mon bore	Quarterly					1
			✓	WC	8/04	Mon bore	Quarterly (plus Department of Water logger)					1, 6

[i] **Site status legend**

1 This site is currently monitored.

2 A new monitoring site is required in order to collect adequate data to evaluate a resource objective.

3 Condition of this bore is unknown – condition assessment is required. Based on results, maintenance may be required or a different bore selected.

4 Access to this site is unknown – track assessment (and possibly regrading and clearing) is required.

5 Groundwater level is currently used as a surrogate for surface water level at this pool. Department of Water to undertake bathymetry and survey work to allow a performance indicator for surface water level to be developed.

6 Department of Water has a logger at this key aquifer response site to ensure more frequent and representative data are collected.

7 This site will only be required if a new bore field configuration or an increase in water licence occurs.

8 Baseline data will be collected at this site for two years and then reviewed to develop a performance indicator.

Water level performance indicators to maintain dependent ecosystems are variable and are linked to river flow:

To determine which indicators are applicable in the coming year, these steps are followed:

1 Total river flow for the previous wet season (November–April) is calculated and used to set a recharge class based on the total flows using Table 7.

2 Recharge class determines the performance indicator for each site for the following water year (May–April) using the table below. Target levels are not enforceable but should be reached in recharge class 4 years.

Table 7: De Grey River recharge classes

Total flow from November to April	Recharge class
<100 000 ML	1
100 000–450 000 ML	2
450 000–2 000 00 0ML	3
>2 000 000 ML	4

Table 8: De Grey River alluvial aquifer variable performance indicators

Site	Recharge class			
	1	2	3	4
	Performance indicator (m AHD)	Performance indicator (m AHD)	Performance indicator (m AHD)	Target (m AHD)
Bore U1	9.15	9.61	9.65	10.06
J96 Pool	9.56	9.79	10.09	10.58
Bore 9/04	6.90	7.25	7.38	7.72
Homestead Pool	6.31	6.64	6.98	7.10
Bore 6/04	7.81	8.38	8.48	9.14
Makanykarra Pool	8.38	8.81	9.51	9.52
Bore 7/04 (Coolenar Pool)	13.96	14.45	14.47	14.96
Bore H2	18.05	18.30	18.39	18.94

Site	Recharge class			
	1	2	3	4
	Performance indicator (m AHD)	Performance indicator (m AHD)	Performance indicator (m AHD)	Target (m AHD)
(Nardeegeecarblin Pool)				
Bore I2	20.17	20.36	20.48	20.82
Bore F1	21.30	21.88	22.16	23.38

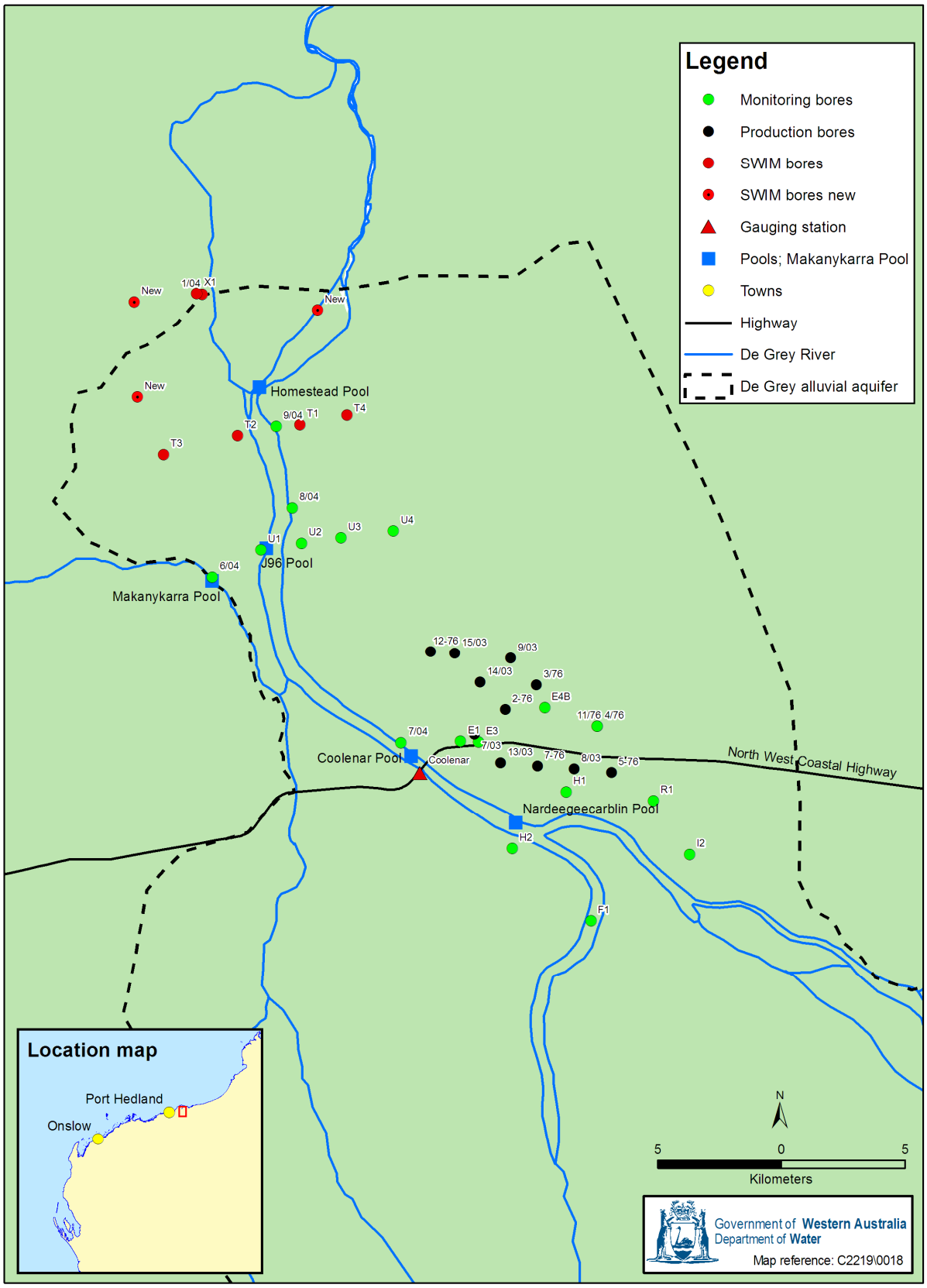

Figure 2: Lower De Grey River alluvial aquifer monitoring program

5 Millstream aquifer

5.1 Site description

The Millstream aquifer is situated on the Fortescue River approximately 100 km south of Karratha. The focus of the monitoring program is the broad extent of the Millstream aquifer and the downstream wetlands which occur for approximately 20 km along the Fortescue River and its tributaries.

The Millstream aquifer holds a significant quantity of fresh water and is a vital component of the West Pilbara water supply scheme which provides water for industrial and domestic purposes to Karratha, Dampier, Roebourne, Wickham and Point Samson. The resource has been used since 1969 and is fully allocated with Water Corporation as the sole licensee.

The aquifer also supports a complex system of wetlands sustained by groundwater discharge and intermittent seasonal flow from the Fortescue River. The wetlands and adjacent area are part of the Millstream National Park established to protect and maintain areas of significant ecological, cultural and/or social value. These wetlands are considered to be unique and regionally rare and are listed as a wetland of national significance in the *Directory of important wetlands in Australia* (May and McKenzie 2002). Millstream also holds important cultural and mythological significance for the Yindjibarndi and Ngarluma traditional owners (Department of Environment and Conservation 2007).

5.2 Resource objective

The resource objectives for the Millstream aquifer are as follows:

1 *Maintain water quality for the most beneficial use (potable water supply).*

The performance indicator for the production bores is to maintain salinity below 900 mg/L (TDS). This is based on the *Australian drinking water guidelines* (NHMRC & NRMMC 2011) which states that 600–900 mg/L TDS gives a fair palatability for drinking water. As salinity levels across the bore field vary spatially and temporally (individual bore averages are 600–1000 mg/L) this indicator has been set as an average to be achieved across the production bores as listed in Table 9.

Performance indicators for unused production bores are set at the 90th percentile (TDS mg/L) based on historical data. These bores are just upstream of the bore field where any decline in groundwater quality is likely to be captured.

2 *Maintain water quality for the environment.*

3 *Maintain target aquifer levels to support groundwater-dependent vegetation and protect groundwater-dependent values in the national park and as listed in the* Directory of Important Wetlands in Australia.

4 *Maintain target aquifer discharge to support springs, pools, wetlands and vegetation in the delta and river channel and to protect groundwater-dependent values in the national park and as listed in the* Directory of Important Wetlands in Australia.

5 *Maintain target groundwater and discharge levels to support groundwater-dependent cultural and social values.*

Further information on development of the above performance indicators can be found in Antao et al. (2012).

5.3 Recommended monitoring program

Table 9 details the recommend monitoring program for Millstream. This program will ensure that adequate information is collected to evaluate our performance against the resource objectives and ensure risks are being managed.

Table 9: Millstream recommended monitoring program (draft)

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status[l]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
1				WC	PB1	Prod. bore	Monthly		Groundwater quality (TDS mg/L)	November or monthly if operating	average across bore field <900	1
1				WC	PB2	Prod. bore	Monthly		Groundwater quality (TDS mg/L)	November or monthly if operating		1
1				WC	PB3	Prod. bore	Monthly		Groundwater quality (TDS mg/L)	November or monthly if operating		1
1				WC	PB4	Prod. bore	Monthly		Groundwater quality (TDS mg/L)	November or monthly if operating		1
1				WC	PB5	Prod. bore	Monthly		Groundwater quality (TDS mg/L)	November or monthly if operating		1
1				WC	PB6	Prod. bore	Monthly		Groundwater quality (TDS mg/L)	November or monthly if operating		1
1				WC	PB7	Prod. bore	Monthly		Groundwater quality (TDS mg/L)	November or monthly if operating		1
1				WC	PB8	Prod. bore	Monthly		Groundwater quality (TDS mg/L)	November or monthly if operating		1
1				WC	PB9	Un-used prod. bore	Monthly		Groundwater quality (TDS mg/L)	November	< 1033	1

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status[l]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
1				WC	PB10	Un-used prod. bore	Monthly		Groundwater quality (TDS mg/L)	November	< 1178	1
1				WC	PB11	Un-used prod. bore	November		Groundwater quality (TDS mg/L)	November	< 1126	1
1				WC	PB12	Un-used prod. bore	November		Groundwater quality (TDS mg/L)	November	<1215	1
2 5	✓			WC	Chinderwarriner (Miliyanha)	Pool			Pool water quality (TDS mg/L) Pool outflow (kL/s)	2-monthly or fortnightly if being supplemented	< 1060 Table 11	1
2 5	✓			WC	Deep Reach (Nhankangunha)	Pool			Pool water quality (TDS mg/L) Pool outflow (kL/s)	2-monthly or fortnightly if being supplemented	<1400 Table 11	1 this site may be replaced by Cross Pool
2				WC	DR1 (1/84)	Supplement-ation bore	November or month if operating		Groundwater quality (TDS mg/L)	November or month if operating	When in use, TDS within 10% of Deep Reach pool	1
2				WC	DR2 (2/84)	Supp. bore	Nov or month if operating		Groundwater quality (TDS mg/L)	November or month if operating		1
2				WC	DR3 (3/84)	Supp. Bore	Nov or month if operating		Groundwater quality (TDS mg/L)	November or month if operating		1

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status[l]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
2				WC	CP1 (1A)	Supp. Bore	Nov or month if operating		Groundwater quality (TDS mg/L)	November or month if operating	When in use, TDS within 10% of Chinder-warriner Pool	1
2				WC	CP2 (8/81)	Supp. Bore	Nov or month if operating		Groundwater quality (TDS mg/L)	November or month if operating		1
2				WC	CP3 (11/81)	Supp. Bore	Nov or month if operating		Groundwater quality (TDS mg/L)	November or month if operating		1
3	✓			WC	1C	Monitoring bores; the average of these bores = MAL8	2-monthly	Table 11				1
3				WC	1E		2-monthly					1
3				WC	2B		2-monthly					1
3				WC	2C		2-monthly					1
3				WC	4A		2-monthly					1
3				WC	5B		2-monthly					1
3				WC	7C		2-monthly					1
3				WC	8C		2-monthly					1
3	✓	✓		DEC	National Park	Landsat			Aerial percentage foliage cover (PFC)–funded by Water Corporation	November	Calc PFC	
3	✓			WC	P7/77 Transect E	Mon. bore	2-monthly (plus DoW logger)	290.46				1, 6
		✓		WC		Veg transect			Ecological health	November	Baseline	2

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status[l]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
3	✓			WC	P8/77 Transect F (1/2)	Mon. bore	2-monthly	Table 11				1
		✓		WC		Veg transect			Ecological health	If triggered		1
3	✓			WC	P7/78 Transect F (2/2)	Mon. bore	2-monthly	Table 11				1
		✓		WC		Veg transect			Ecological health	If triggered		1
3	✓			WC	8/04 New transect	Mon. bore	2-monthly (plus DoW logger)	Table 11				1, 6
		✓		WC		Veg transect			Ecological health	November		2
3	✓			WC	P2	Mon. bore	2-monthly	278.74				1
		✓		WC	New transect	Veg transect			Ecological health	If triggered		2
3	✓			WC	P8 New transect	Mon. bore	2-monthly	Table 11				1
		✓		WC		Veg transect			Ecological health	If triggered		2
4 5				WC	Woodley Creek (Mitharnu)	Parshall flume			Discharge (kL/s)	2-monthly		1
4				WC	Peters Creek	Parshall flume			Discharge (kL/s)	2-monthly		1
4				WC	Palm Creek	Parshall flume			Discharge(kL/s)	2-monthly		1

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status[l]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
4 5				WC	Livistona (Mardiyambarlanha)	Pool			Stage height (m)	2-monthly	no or low flow	1
4				WC	P2/77 Transect C	Mon. bore	2-monthly (plus DoW logger)	278.70				1, 6
				WC		Vegetation plot			Ecological health	November	Baseline	2
4				WC	P3/77 Transect G (1/2)	Mon. bore	2-monthly (plus DoW logger)	278.01				1, 6
				WC		Vegetation plot			Ecological health	If triggered	Baseline	2
4				WC	P4/78	Mon. bore	2-monthly	283.22				1
				WC	Transect G (2/2)	Vegetation plot			Ecological health	If triggered	Baseline	2
4				WC	3/04	Mon. bore	2-monthly	285.76				1
				WC	New transect	Vegetation plot			Ecological health	If triggered	Baseline	2
4				WC	4/04	Mon. bore	2-monthly	287.32				1
				WC	New transect	Vegetation plot			Ecological health	If triggered	Baseline	2
4				WC	12/04	Mon. bore	2-monthly (plus DoW logger)	283.96				1, 6
				WC	New transect	Vegetation plot			Ecological health	November	Baseline	2
4				WC	P10	Mon. bore	2-monthly	270.07				1
				WC	Transect A	Vegetation plot			Ecological health	If triggered	Baseline	2

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status[I]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
4 5	✓			DoW	Gregory Gorge (Wuyumarri)	Gauging station			Total flow (ML)	Continuous	Table 11	1
				WC		Production. bores			Total production (ML)	May	Allocation limit	1
			✓	WC	7A	Mon bore	2-monthly					1
			✓	DoW	13C	Mon bore	Continuous					3, 4, 6
			✓	DoW	23B	Mon bore	Continuous					3, 4, 6
			✓	DoW	26A	Mon bore	Continuous					3, 4, 6
			✓	DoW	7A upstream	Mon bore	Continuous					3 ,4, 6

I Site status legend

1 This site is currently monitored.

2 A new monitoring site is required in order to collect adequate data to evaluate a resource objective.

3 Condition of this bore is unknown – condition assessment is required. Based on results, maintenance may be required or a different bore selected.

4 Access to this site is unknown – track assessment (and possibly regrading and clearing) is required.

5 Groundwater level is currently used as a surrogate for surface water level at this pool. Department of Water to undertake bathymetry and survey work to allow a performance indicator for surface water level to be developed.

6 Department of Water has a logger at this key aquifer response site to ensure more frequent and representative data are

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status[l]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				

collected.

7 This site will only be required if a new bore field configuration or an increase in water licence occurs.

8 Baseline data will be collected at this site for two years and then reviewed to develop a performance indicator.

Variable indicators have been developed for this resource. As river flow is the best predictor of aquifer status, the indicators have been linked to river flow using recharge classes.

To determine which indicators are applicable in the coming year, these steps are followed:

1 Total river flow for the previous water year (May–April) is calculated and a recharge class is set based on Table 10.

2 Recharge class determines the applicable indicator for each site for the following water year (May–April) using the table below. This is the performance indicator for the year.

Table 10: Millstream aquifer recharge classes

Flow	Recharge class
Total flow for each of the previous three years <43 000 ML	1
Total flow for the each of the previous one to two years <43 000 ML	2
Total flow for the previous wet season >43 000 ML	3

Table 11: Millstream aquifer variable performance indicators and targets

Site	Recharge class		
	1	2	3
	Performance indicator	Performance indicator	Performance indicator
Deep Reach Pool (may be replaced with Crossing Pool)	0.20 kL/s		0.26 kL/s
Chinderwarriner Pool	0.11 kL/s	0.16 kL/s	0.21 kL/s
MAL (surrogate for P8/77, P7/78, 8/04, P8, 1E)	293.50 mAHD	293.60 mAHD	293.80 mAHD
Targets			
Allowable period of no flow at Gregory Gorge	1 month	3 months	5 months

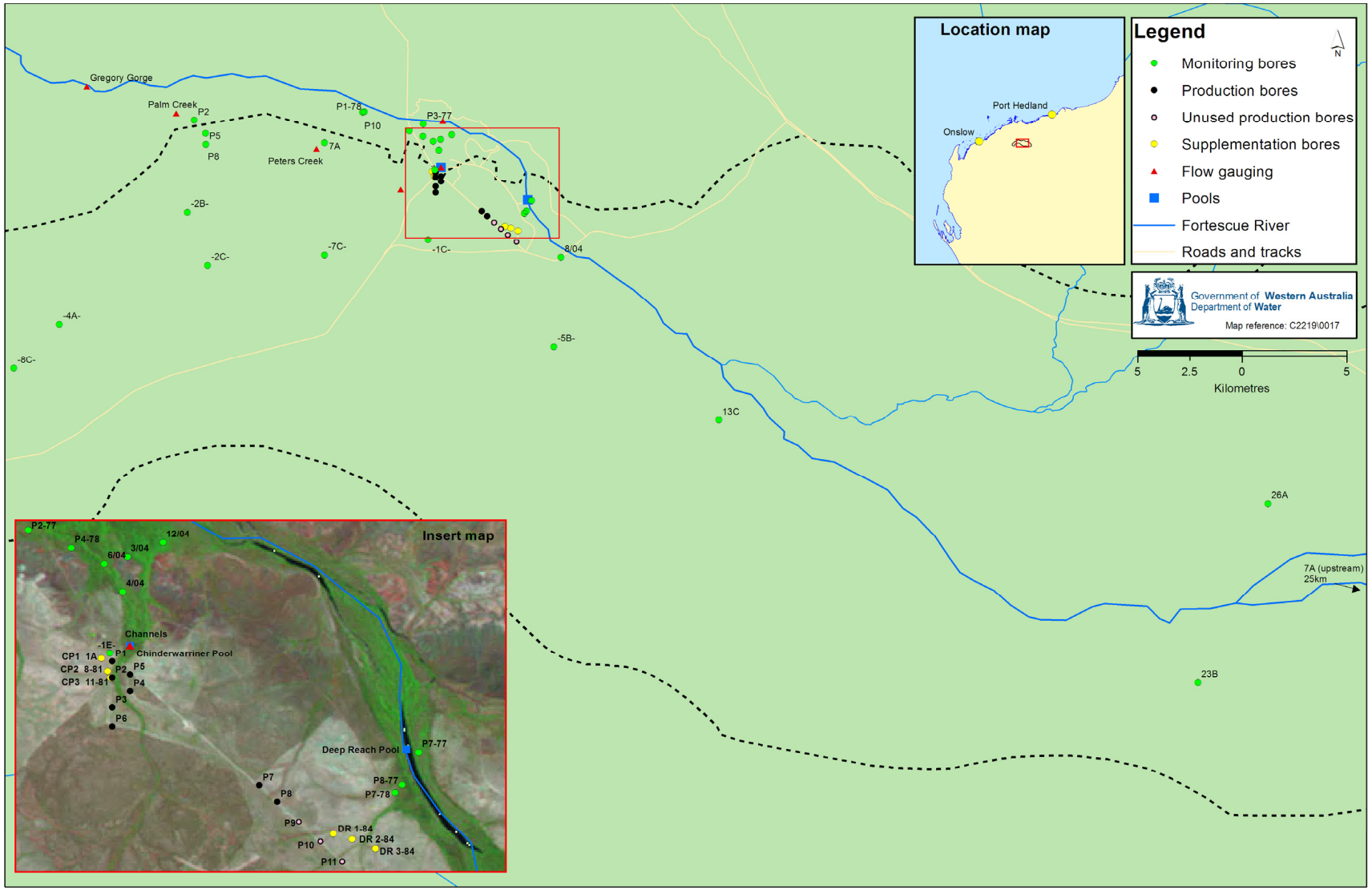

Figure 3: Millstream aquifer monitoring program

6 Lower Fortescue River

6.1 Site description

The lower Fortescue River alluvial aquifer is approximately 100 km south-west of Karratha. The monitoring program focuses on the Fortescue River downstream of the North West Coastal Highway to the coast.

The potentially groundwater-dependent riparian vegetation along the lower Fortescue and delta is highly degraded mainly as a consequence of mesquite (a weed of national significance) invasion. However, fish fauna of the Fortescue River is the most diverse of all rivers in the Pilbara region with several groundwater-dependent pools likely to have high habitat value (Loomes R 2010).

While current groundwater use is largely restricted to pastoral wells and a small amount of mine water, an application for the remaining groundwater allocation has been submitted to the department.

6.2 Resource objectives

The following resource objectives have been developed for this resource and are the focus of the monitoring program:

1 Prevent saltwater intrusion into the aquifers caused by abstraction.

2 Maintain water quality for the most beneficial use (potable water supply).

3 Maintain groundwater and pool levels within a target range, to maintain aquatic habitat and riparian vegetation that are dependent on groundwater.

6.3 Recommended monitoring program

The recommended monitoring program (Table 12) will capture the baseline data necessary to develop performance indicators for saltwater interface, aquifer water quality and dependent ecosystems.

As abstraction increases and new production bores are commissioned, this program may be revised. It is expected that responsibility will shift to the licensee when water use is equivalent to 70 per cent of the allocation limit

Table 12: Lower Fortescue River recommended monitoring program

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [l]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
1					26	Monitoring bore	6 monthly	Baseline	Groundwater quality (TDS mg/L)	6 monthly		3, 4, 6
1					29	Mon. bore	6 monthly	Baseline	Groundwater quality (TDS mg/L)	6 monthly		3, 4*
2					11A	Mon. bore	6 monthly	Baseline	Groundwater quality (TDS mg/L)	6 monthly		1
2					16B	Mon. bore	6 monthly	Baseline	Groundwater quality (TDS mg/L)	6 monthly		3, 4
2					31A	Mon. bore	6 monthly	Baseline	Groundwater quality (TDS mg/L)	6 monthly		3, 4
2					12A or 20A	Mon. bore	6 monthly	Baseline	Groundwater quality (TDS mg/L)	6 monthly		3, 4
3	✓				22A	Mon bore	Continuous	Table 14				3, 4, 6
	✓			Licensee	Mungajee	Pool			Stage height (m AHD)	2-monthly	Baseline	2 ,5, 7
		✓		Licensee	New veg	Veg trans			Ecological health	November	Baseline	2, 7
3	✓				8A	Mon bore	Continuous	Table 14				1, 6
	✓			Licensee	Jilan Jilan	Pool			Stage height (m AHD)	2-monthly	Baseline	2, 5, 7
		✓		Licensee	New veg	Veg trans			Ecological health	November	Baseline	2, 7
3				Citic Pacific	23A	Mon. bore	Continuous	10.656 mbtoc				1
3	✓				2B	Mon bore	Continuous	Table 14				1, 6
	✓			Licensee	Stewart	Pool			Stage height (m AHD)	2-monthly	Baseline	2, 5, 7

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [I]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
		✓		Licensee	New veg	Veg trans			Ecological health	November	Baseline	2, 7
3	✓				Bilanoo	Pool			Stage height (m AHD)	Continuous (stage)	Table 14	5, 1
3			✓		Bilanoo	Gauging station			Total flow (ML)	May	Recharge class	1
				Citic Pacific		Production bores			Total production (ML)	May	Allocation limit	
			✓		1A	Mon. bore	6 monthly					1
			✓		4A	Mon. bore	6 monthly					1
			✓		6A	Mon. bore	6 monthly					1
			✓	Citic Pacific	10A	Mon. bore	Continuous					1
			✓		32A	Mon. bore	Continuous					1, 6
			✓		32B	Mon. bore	Continuous					1

I Site status legend

1 This site is currently monitored.

2 A new monitoring site is required in order to collect adequate data to evaluate a resource objective.

3 Condition of this bore is unknown – condition assessment is required. Based on results, maintenance may be required or a different bore selected.

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [1]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				

4 Access to this site is unknown – track assessment (and possibly regrading and clearing) is required.

5 Groundwater level is currently used as a surrogate for surface water level at this pool. Department of Water to undertake bathymetry and survey work to allow a performance indicator for surface water level to be developed.

6 Department of Water has a logger at this key aquifer response site to ensure more frequent and representative data are collected.

7 This site will only be required if a new bore field configuration or an increase in water licence occurs.

8 Baseline data will be collected at this site for two years and then reviewed to develop a performance indicator.

A variable threshold system has been developed for this resource. As river flow is the best indicator of aquifer recharge the thresholds have been linked to river flow using recharge classes.

To determine which indicators are applicable in the coming year, these steps are followed:

1 Total river flow for the previous wet season (January–April) is calculated and a recharge class is set based on the following ranges (Table 13).

2 Recharge class determines the performance indicator for each site for the following water year (May–April) using the table below. Target levels are not enforceable but should be reached in recharge class 4 years.

Table 13: Lower Fortescue River recharge classes

Total flow from January to April	Recharge class
< 1000 ML	1
1000 to 50 000 ML	2
50 000 to 600 000 ML	3
>600 000 ML	4

Table 14: Lower Fortescue River alluvial aquifer variable performance indicators

Site	Recharge class			
	1	2	3	4
	Performance indicator (m AHD)	Performance indicator (m AHD)	Performance indicator (m AHD)	Target (m AHD)
Bilanoo Pool[1]	9.00	9.01	9.23	9.63
2B (Stewart Pool[1])	16.28	17.48	17.75	19.41
8A (Jilan Jilan Pool[1])	13.01	13.80	14.07	15.59
22A (Mungajee Pool[1])	5.32	5.70	5.97	7.66

[1] Interim pending bathymetry

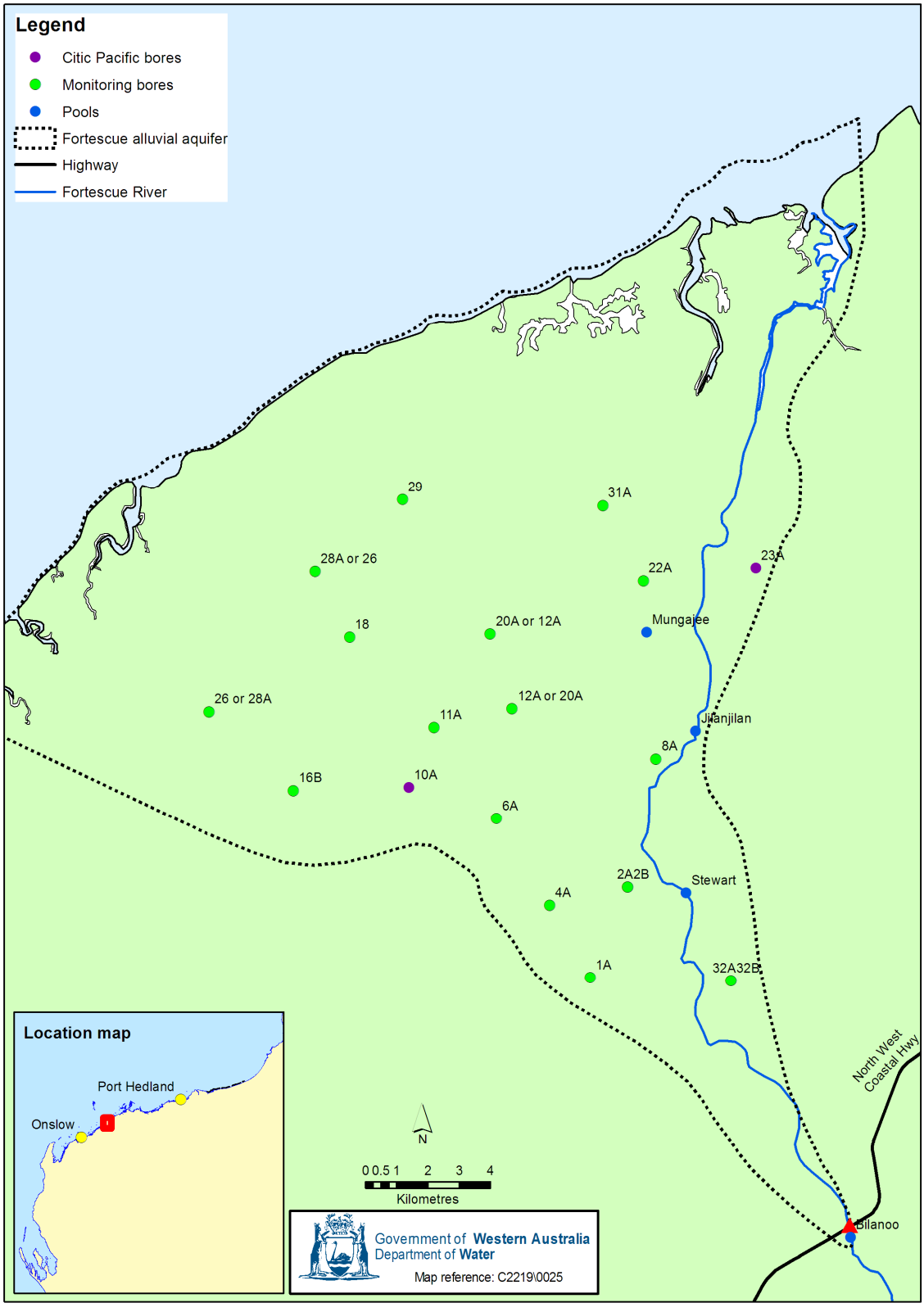

Figure 4: Lower Fortescue River monitoring program

7 Lower Robe River

7.1 Background

The lower Robe River is located 80 km east of Onslow and 50 km west of Pannawonica. The focus of the monitoring program is the alluvial aquifer which follows the course of the river for about 40 km downstream of the North West Coastal Highway.

The aquifer supports groundwater-dependent river pools and riparian vegetation which are of conservation significance at the local scale (Antao & Braimbridge 2010). It also supports aquifer ecosystems with distinct stygofauna species expected to be of high conservation value (Biota Environmental Sciences 2006). The pools and surrounds hold high value for the Kuruma Marthudunera people, traditional owners of the area (Pilbara Native Title Service 2009).

Current groundwater use is restricted to stock watering bores. Due to its proximity to Onslow the aquifer has been identified as a potential water source for the Onslow water supply scheme.

7.2 Resource objective

The following resource objectives have been developed for this resource and are the focus of the monitoring program.

1 *Prevent saltwater intrusion into the aquifers caused by abstraction.*

2 *Maintain water quality for the most beneficial use (potable water supply).*

3 *Maintain groundwater and pool levels within a target range, to maintain aquatic habitat and riparian vegetation that are dependent on groundwater.*

7.3 Recommended monitoring program

Table 15 details the recommended monitoring program for the Robe River. This program will capture the baseline data necessary to develop indicators for saltwater interface and aquifer water quality and confirm performance indicators for pools and riparian vegetation.

Management to achieve performance indicators will be implemented once the resource has been licensed and becomes the responsibility of the licensee.

Licensees will be required to install new monitoring bores to monitor impacts of abstraction on groundwater-dependent ecosystems and the saltwater interface as negotiated with the department and detailed in the monitoring program.

Table 15: Lower Robe River recommended monitoring program

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator:					Site status [1]
							Groundwater level (mAHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
1				Licensee	New	SWIM	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7
1				Licensee	New	SWIM	Quarterly		Groundwater quality TDS mg/L	Quarterly	Baseline	2, 7
2					2A	Mon. bore	6 monthly		Groundwater quality (TDS mg/L)	6 monthly	Baseline	1
2					4A	Mon. bore	6 monthly		Groundwater quality (TDS mg/L)	6 monthly	Baseline	1
2					6A	Mon. bore	6 monthly		Groundwater quality (TDS mg/L)	6 monthly	Baseline	1
2					20A	Mon. bore	6 monthly		Groundwater quality (TDS mg/L)	6 monthly	Baseline	3, 4
2					11A	Mon. bore	6 monthly		Groundwater quality (TDS mg/L)	6 monthly	Baseline	1
2					15A	Mon. bore	6 monthly		Groundwater quality (TDS mg/L)	6 monthly	Baseline	3*
2					22A	Mon. bore	6 monthly		Groundwater quality (TDS mg/L)	6 monthly	Baseline	3*
3	✓				1A	Mon. bore	Continuous	Table 17				1, 6
	✓			Licensee	Little Jimuttda	Pool			Stage height (m AHD)	2-monthly	Baseline	2, 5, 7
		✓		Licensee	Robe04	Veg trans			Ecological health	November	Baseline	2, 7
3	✓				9A	Mon. bore	Continuous	Table 17				1, 6
	✓			Licensee	Unnamed	Pool			Stage height (mAHD)	2-monthly	Baseline	2, 5, 7
			✓	Licensee	New veg	Veg trans			Ecological health	November	Baseline	2, 7
3	✓			Licensee	New bore	Mon. bore	Continuous	Table 17				2, 7

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator:					Site status [1]
							Groundwater level (mAHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
	✓			Licensee	Maraminji	Pool			Stage height (mAHD)	2-monthly	Baseline	5, 7
		✓		Licensee	Robe02	Veg trans			Ecological health	November	Baseline	2, 7
3	✓			Licensee	New bore	Mon. bore	Continuous	Table 17				2, 7
	✓			Licensee	Waralie	Pool			Stage height (m AHD)	2-monthly	Baseline	5, 7
		✓		Licensee	Robe03	Veg trans			Ecological health	November	Baseline	2, 7
3			✓		Yarraloola	Gauging station			Total flow (ML)	May	Recharge class	1

I Site status legend

1 This site is currently monitored.

2 A new monitoring site is required in order to collect adequate data to evaluate a resource objective.

3 Condition of this bore is unknown – condition assessment is required. Based on results, maintenance may be required or a different bore selected.

4 Access to this site is unknown – track assessment (and possibly regrading and clearing) is required.

5 Groundwater level is currently used as a surrogate for surface water level at this pool. Department of Water to undertake bathymetry and survey work to allow a performance indicator for surface water level to be developed.

6 Department of Water has a logger at this key aquifer response site to ensure more frequent and representative data are collected.

7 This site will only be required if a new bore field configuration or an increase in water licence occurs.

8 Baseline data will be collected at this site for two years and then reviewed to develop a performance indicator.

Variable performance indicators have been developed for this resource. As river flow is the best predictor of aquifer recharge the indicators have been linked to river flow using recharge classes.

To determine which indicators are applicable in the coming year, these steps are followed:

1 Total river flow for the previous wet season (November–April) is calculated, and based on the following ranges a recharge class is set (Table 16).

2 Recharge class determines the performance indicator for each site for the following water year (May–April) using the table below (Table 17). Target levels are not enforceable but should be reached in recharge class 4 years.

Table 16: Robe River recharge classes

Total wet season flow (November–April)	Recharge class
Previous 2 years wet season flow ML < 4 000	1
< 20 000 ML (except where recharge class 1 applies)	2
20 001–100 000 ML	3
> 100 001 ML	4

Table 17: Lower Robe River alluvial aquifer variable performance indicators

Site	Recharge class			
	1	2	3	4
	Performance indicator (m AHD)	Performance indicator (m AHD)	Performance indicator (m AHD)	Target (m AHD)
Bore 1A and Little Jimutda Pool[1]	40.47	41.25	42.28	42.94
Bore 9A and unnamed pool[1]	29.57	30.27	30.82	31.71
Bore new[1] and Maraminji Pool[1]	22.56	23.19	23.74	24.18
Bore new[1] and Warali Pool[1]	10.53	11.00	11.77	12.14

[1] Interim pending bathymetry and/or baseline data

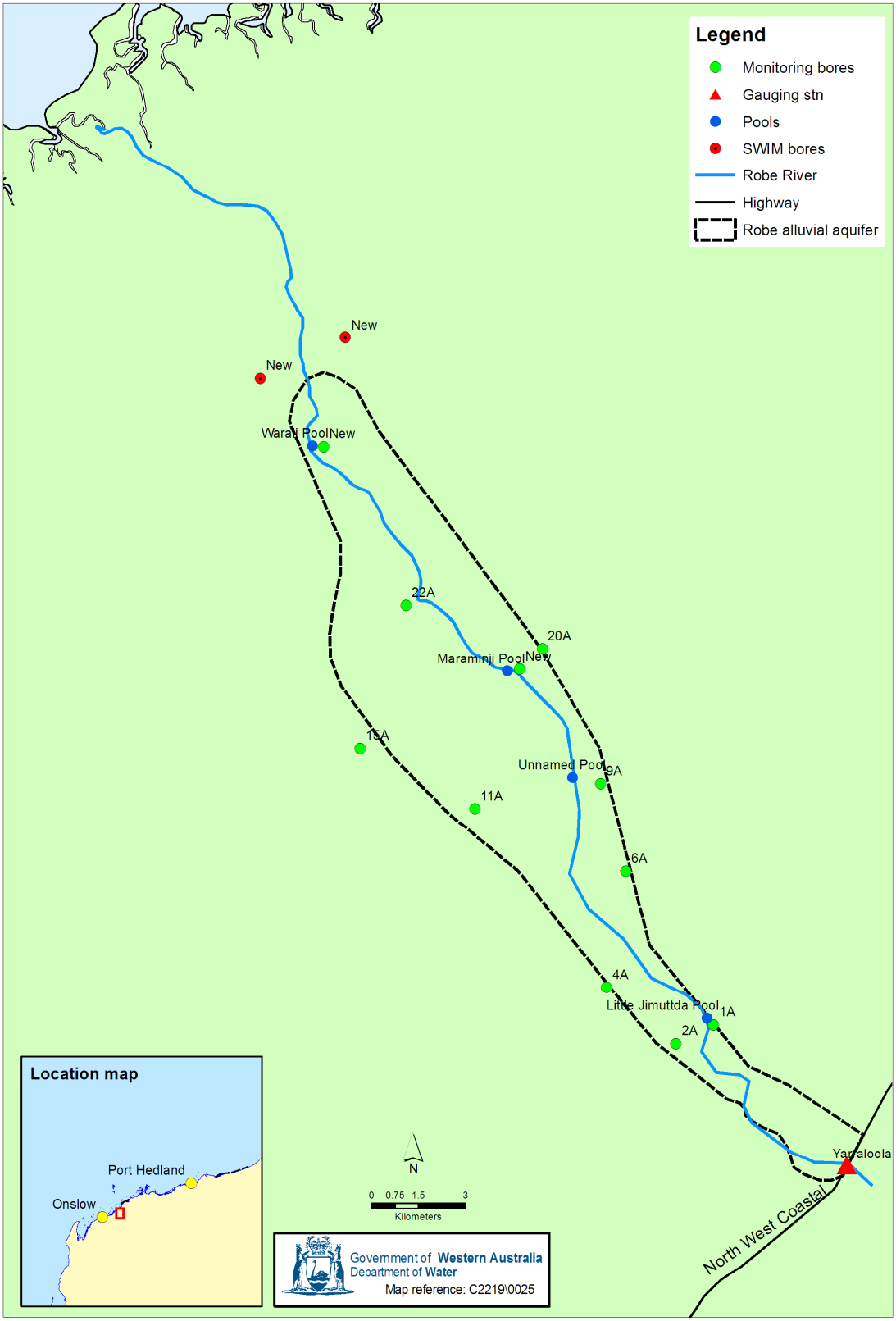

Figure 5: Robe River alluvial aquifer monitoring program

8 West Canning Basin

8.1 Background

The West Canning Basin is located about 100 km east of Port Hedland and about 30 km east of the De Grey River bore field. It covers an area of approximately 3500 km^2 and represents the western edge of the Canning Basin, the largest sedimentary basin in Western Australia.

The West Canning Basin holds large quantities of fresh water and is potentially a regionally significant resource. The main aquifers of the basin are the Wallal and Broome sandstones. The Wallal (sandstone) aquifer is mostly fresh, extensively confined and is artesian in places. The top of the aquifer is at a considerable depth (60 m to at least 100 m below ground). The Wallal is overlain by the Broome (sandstone) aquifer which is mostly brackish and unconfined.

Use of groundwater in the West Canning Basin is currently quite low. Groundwater is abstracted from the Wallal aquifer for mine site and camp use, and by pastoral stations. Abstraction by pastoral stations is expected to increase as they undertake pastoral diversification projects. Current use is approximately 1.8 GL/year from the Wallal aquifer.

There is currently no licensed abstraction from the Broome sandstone, however some stock watering bores access this aquifer.

Due to the large depths to groundwater of the Wallal aquifer across the basin, groundwater-dependent ecosystems are relatively limited. Several springs occur on the coastal plain which may be sourced from minor upward leakage from the Wallal or by the Broome sandstone, however they have been heavily impacted by grazing and weed invasion and are likely to be of low ecological value.

A series of Ramsar-listed wetlands occur along the coast as part of the Eighty Mile Beach system. Their dependence on groundwater is unknown but discharge from the Broome sandstone aquifer may also provide some hydrological support to these systems.

8.2 Resource objective

The resource objectives for water management in the West Canning Basin are:

1 *Limit seawater intrusion into the Broome sandstone aquifer caused by abstraction.*

2 *Prevent seawater intrusion into the onshore area of the Wallal aquifer.*

3 *Maintain groundwater levels in the Broome sandstone aquifer to avoid impacts to coastal wetlands.*

4 *Maintain pressure heads in the Wallal aquifer above the top of the aquifer so that it remains confined.*

8.3 Recommended monitoring program

The recommended monitoring program for the West Canning Basin is detailed in Table 18.

Table 18: West Canning Basin recommended monitoring program (draft)

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator				Site status
							Groundwater level	Indicator	Groundwater quality	Indicator	
2, 4	✓			Wallal	WCB25Y	Monitoring bore	Monthly	>5 m AHD	6 monthly	Baseline	Current - equipped with logger
1, 3				Wallal	WCB25Z	Mon bore	monthly	Baseline	6 monthly	baseline	Current
2, 4	✓			Pardoo	WCB4B	Mon bore	monthly	>5 m AHD	6 monthly	baseline	Current
2, 4	✓			Pardoo	WCB9E	Mon bore	monthly	>5 m AHD	6 monthly	baseline	Current
2, 4	✓			TBD	WCB17C	Mon bore	monthly	>5 m AHD	6 monthly	baseline	New
2, 4	✓			Wallal	WCB22C	Mon bore	monthly	>5 m AHD	6 monthly	baseline	Current
			✓	Pardoo	WCB10B	Mon bore	6 monthly				Current
			✓	Pardoo	WCB8C	Mon bore	6 monthly				Current
			✓	DoW	WCB21Z	Mon bore	6 monthly				New
			✓	DoW	WCB21Y	Mon bore	6 monthly				New
			✓	DoW	WCB5Y	Mon bore	6 monthly				New
			✓	DoW	WCB15Y	Mon bore	6 monthly				New
			✓	DoW	WCB18Y	Mon bore	6 monthly				New
			✓	DoW	WCB24Y	Mon bore	6 monthly				New
			✓	DoW	WCB24Z	Mon bore	6 monthly				New
				Licensee	All prod. bores			Total abstraction			

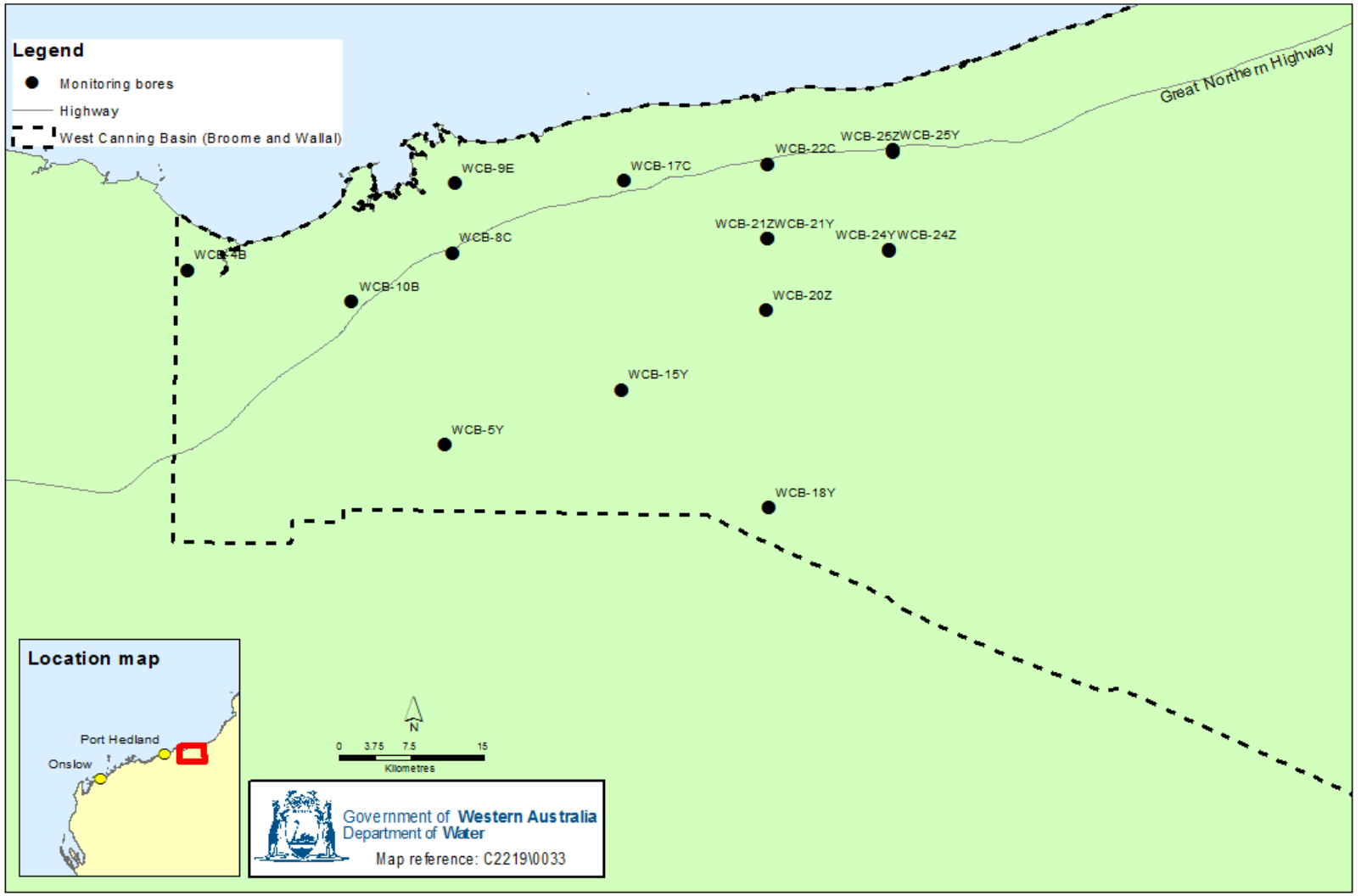

Figure 6: West Canning Basin, Broome and Wallal aquifer monitoring program

9 Lower Cane River

9.1 Background

The lower Cane River alluvial aquifer is located 30 km east of Onslow. It underlies the Cane River and runs from the North West Coastal Highway almost to the coast, a distance of about 40 km.

Water Corporation is the only licensed water user, and has been abstracting water from the Cane River bore field since 1955 to supply water to Onslow. There is also a small amount of water abstracted from shallow bores for stock in the area.

Demand for water at Onslow is forecast to rise due to the expansion of the offshore oil and gas industries and associated increase in the town's population. Additional water supply to meet part of this demand may be sought by water service providers from the lower Cane River alluvial aquifer. The Water Corporation is currently investigating whether there is capacity to expand their current bore field and increase the level of abstraction to meet increasing demand.

The aquifer supports several permanent pools and riparian vegetation communities which have been assessed as being in good condition and of moderate conservation value.

9.2 Resource objectives

The resource objectives for water management of the Cane River alluvial aquifer are:

1 *Prevent saltwater intrusion into the potential productive area of the aquifers.*

   Performance indicators for the saltwater interface will be developed once adequate baseline data is collected. Two monitoring bores situated near the saltwater interface have been identified to be used as surface water interface monitoring (SWIM) bores.

2 *Maintain water quality for the most beneficial use (potable water supply).*

   Performance indicators for production bores have been developed based on maintaining water quality within historical levels.

3 *Maintain groundwater levels within a target range to avoid impacts to groundwater-dependent ecosystems.*

   Performance indicators based on the fifth percentile historical groundwater level have been developed.

9.3 Proposed monitoring program

The recommended monitoring program for the Cane River is detailed in Table 19.

Table 19: Cane River recommended monitoring program

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator:					Site status[1]
							Groundwater level (mAHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
1				WC	6/88	Mon. bore (SWIM)	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	baseline	1
1				WC	10/88	Mon. bore (SWIM)	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	baseline	1
2	✓			WC	1/69	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Average of bores to remain <500mg/L TDS	1
2				WC	2/69	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	3/09	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	8/79	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	4/82	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	5/82	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	12/86	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	31/88	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	32/88	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	13/94	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	15/94	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	3/97	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	4/97	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator:					Site status[1]
							Groundwater level (mAHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
2				WC	5/97	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	1/09	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	11/09	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	2/09	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	No 1	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	16/97	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
2				WC	No 2	Prod bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly		1
3	✓			WC	13/88	Mon. bore	Quarterly	> 12.86				1
3	✓			WC	1/79	Mon. bore	Quarterly	> 3.21				1
3	✓			WC	11/88	Mon. bore	Quarterly	>11.29				1
				WC		All prod. bores			Total production (ML)	March–April	Allocation limit	1
			✓	WC	1/65	Mon. bore	May & Nov					1
			✓	WC	No 4	Mon. bore	May & Nov					1
			✓	WC	No 6	Mon. bore	May & Nov					1
			✓	WC	2/70	Mon. bore	May & Nov					1
			✓	WC	1/71	Mon. bore	May & Nov					1
			✓	WC	2/79	Mon. bore	May & Nov					1

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator:					Site status[I]
							Groundwater level (mAHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
			✓	WC	12/88	Mon. bore	May & Nov					1
			✓	WC	16/88	Mon. bore	May & Nov					1
			✓	WC	30/88	Mon. bore	May & Nov					1
			✓	WC	29/88	Mon. bore	May & Nov					1
			✓	DoW	Toolunga	Gauging station			Streamflow (ML)			1

I Site status legend

1 This site is currently monitored.

2 A new monitoring site is required in order to collect adequate data to evaluate a resource objective.

3 Condition of this bore is unknown – condition assessment is required. Based on results, maintenance may be required or a different bore selected.

4 Access to this site is unknown – track assessment (and possibly regrading and clearing) is required.

5 Groundwater level is currently used as a surrogate for surface water level at this pool. Department of Water to undertake bathymetry and survey work to allow a performance indicator for surface water level to be developed.

6 Department of Water has a logger at this key aquifer response site to ensure more frequent and representative data are collected.

7 This site will only be required if a new bore field configuration or an increase in water licence occurs.

8 Baseline data will be collected at this site for two years and then reviewed to develop a performance indicator.

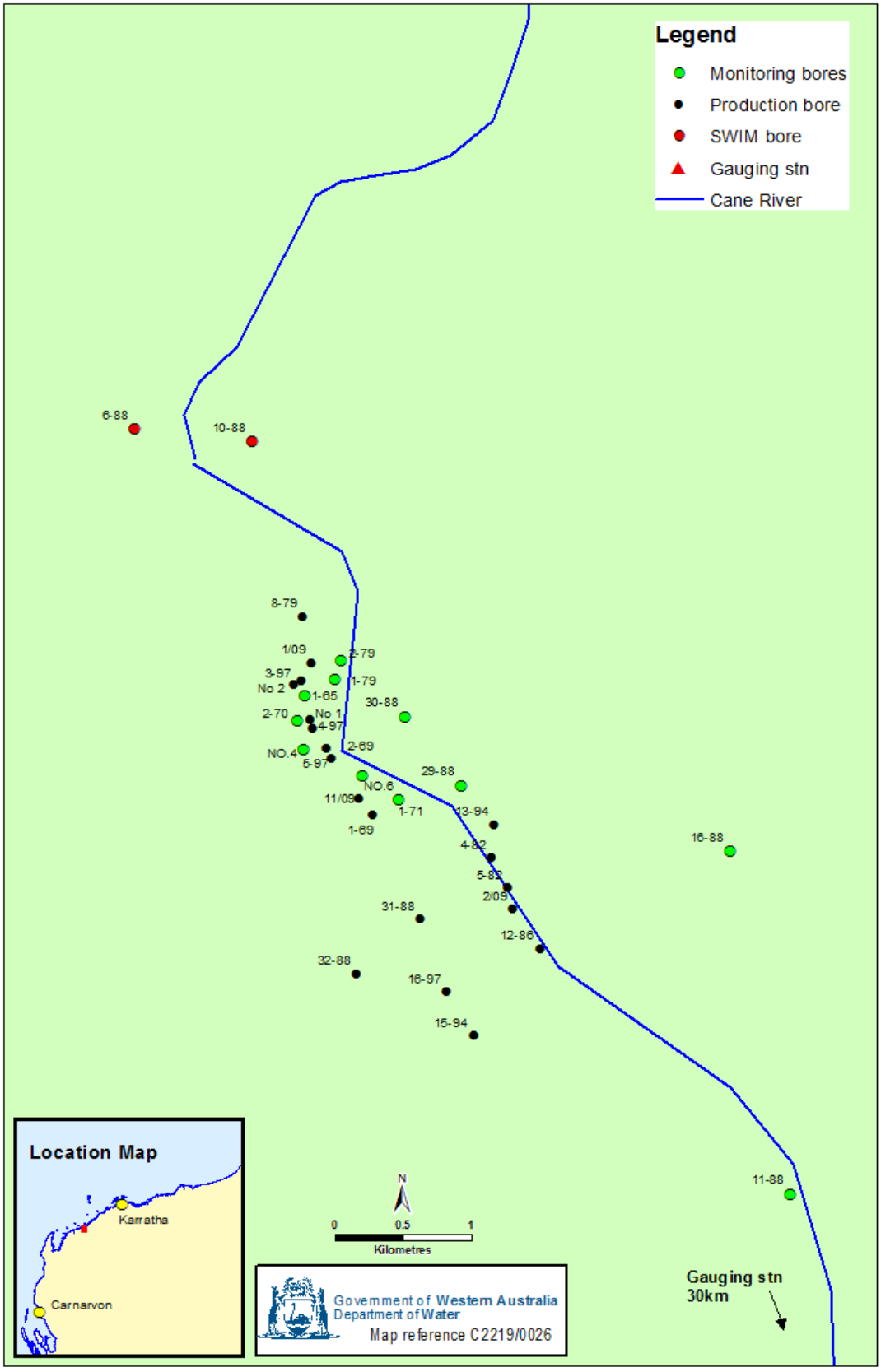

Figure 7: Cane River monitoring program

10 Lower Turner River

10.1 Background

The lower Turner River alluvial aquifer is about 27 km west of Port Hedland. It is an alluvial aquifer which extends 28 km along the river upstream from the delta.

Currently, there is limited water taken from the aquifer. Water use is mainly for the Turner River estate – a rural lifestyle development to the south of the North West Coastal Highway – and for stock and domestic use. Demand for water from the resource is likely to increase due to extra water requirements needed for Port Hedland and the East Pilbara Supply Scheme.

There are several subregionally significant pools and areas of riparian vegetation along this section of the Turner River. These are likely to be supported at least in part by shallow groundwater from the alluvial aquifer.

10.2 Resource objectives

The resource objectives for the Turner River are:

1 *Prevent saltwater intrusion into the aquifer caused by abstraction.*

2 *Maintain water quality for ongoing use (potable or industrial water supply depending on demand for water).*

3 *Maintain groundwater levels within a target range, to avoid impacts to groundwater-dependent ecosystems.*

Due to limited available data no performance indicators have been developed. The monitoring program recommends installation of six new monitoring bores and collection of baseline data so that performance indicators can be developed. These recommendations would be carried out by future water users subject to negotiations with the department.

10.3 Recommended monitoring program

The recommended monitoring program for the Cane River is detailed in Table 20.

Licensees will be required to install new monitoring bores to monitor impacts of abstraction on groundwater-dependent ecosystems, saltwater interface and aquifer quality as negotiated with the department and guided by the monitoring program. Bore locations shown in Figure 8 are approximate only and will be decided in consultation with proponents.

Table 20: Turner River hydrogeological monitoring program

Objective	Trigger	Ecological	Future	Compliance	Site name	Site type	Indicator					Site status [I]
							Groundwater level (m AHD)		Other	Frequency	Indicator	
							Frequency	Indicator				
1				Licensee	New	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7
1				Licensee	New	SWIM bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7
2				Licensee	New	Monitoring bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7
2				Licensee	New	Mon. bore	Quarterly		Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7
2 3				Licensee	New	Mon. bore	Quarterly	Baseline	Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7
2 3				Licensee	New	Mon. bore	Quarterly	Baseline	Groundwater quality (TDS mg/L)	Quarterly	Baseline	2, 7
3			√		Pincunah	Gauging station			Streamflow (ML)	Continuous		1

I Site status legend

1 This site is currently monitored.

2 A new monitoring site is required in order to collect adequate data to evaluate a resource objective.

3 Condition of this bore is unknown – condition assessment is required. Based on results, maintenance may be required or a different bore selected.

4 Access to this site is unknown – track assessment (and possibly regrading and clearing) is required.

5 Groundwater level is currently used as a surrogate for surface water level at this pool. Department of Water to undertake bathymetry and survey work to allow a performance indicator for surface water level to be developed.

6 Department of Water has a logger at this key aquifer response site to ensure more frequent and representative data are collected.

7 This site will only be required if a new bore field configuration or an increase in water licence occurs.

8 Baseline data will be collected at this site for two years and then reviewed to develop a performance indicator.

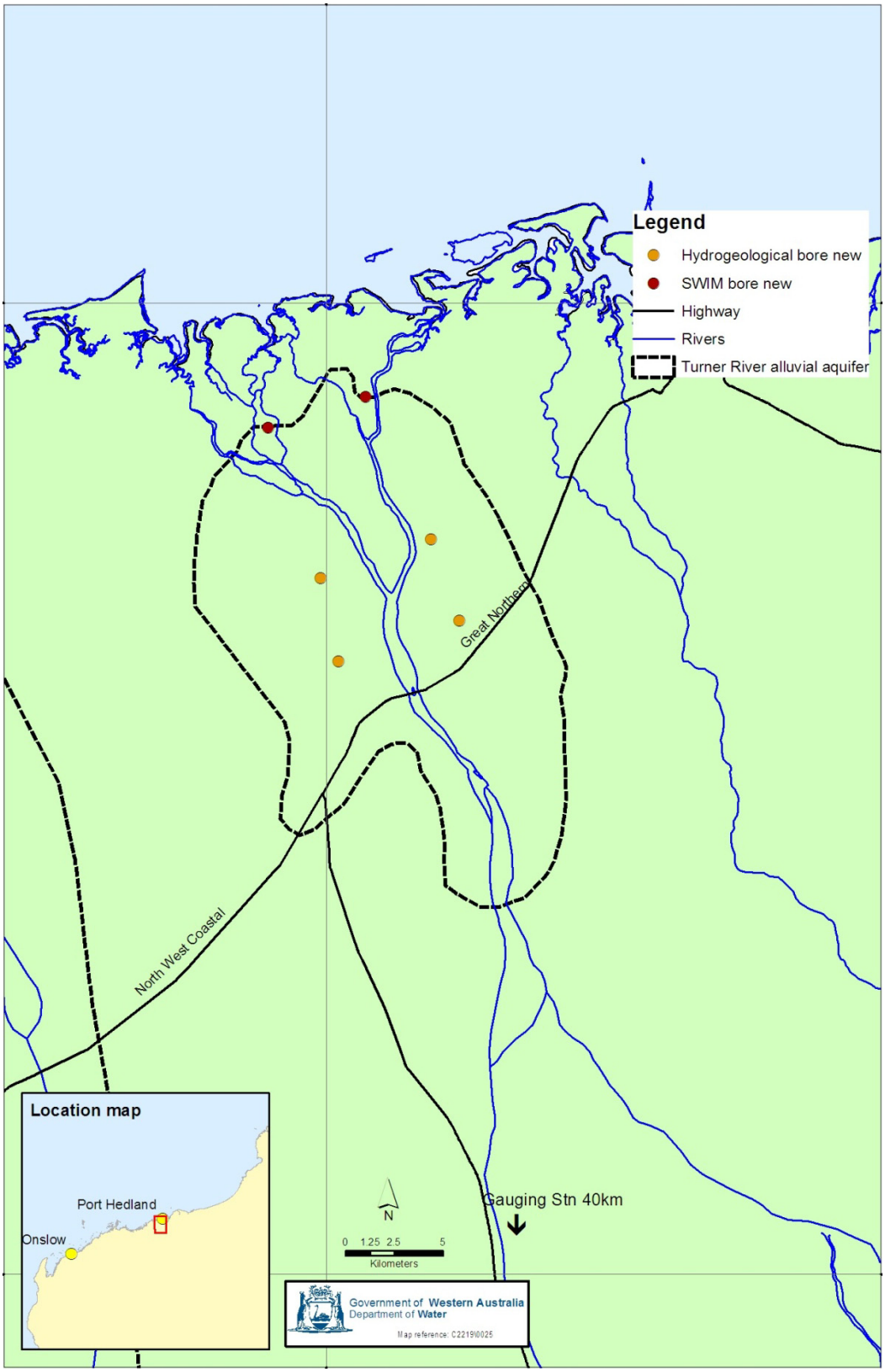

Figure 8: Turner River monitoring program

11 Implementation

11.1 Monitoring program implementation

The actions, responsibilities and timelines required by the department to implement the monitoring program are shown in Table 20. Implementation responsibilities of licensees will be captured through the operating strategies.

Table 21: Actions to implement monitoring program

Action	Responsible (Department of Water unless otherwise stated)	Timeline
Develop vegetation monitoring methodology.	Water allocation planning in consultation with licensee	August 2013
Install loggers into selected bores (details Appendix B).	As detailed in Appendix B	Sept 2013 or as updated in operating strategy
Establish new vegetation monitoring sites and conduct preliminary surveys (details Appendix B).	Water allocation planning, water users	Yule, De Grey: October 2013 Millstream: November 2013 Fortescue, Robe: October 2014
Incorporate new/revised monitoring requirements into regional measurement program.	Regional measurement	October 2013
Update data management system with new monitoring program.	Water allocation planning	October 2013
Conduct bore condition assessments and evaluate access (details Appendix B).	Measurement and assessment	December 2013
Equip Robe River with telemetry.	Regional measurement	March 2014
Carry out pool bathymetry and survey (details Appendix B).	Regional measurement	May 2014

Action	Responsible (Department of Water unless otherwise stated)	Timeline
Develop performance indicators and trigger and response mechanisms for saltwater intrusion, water quality and ecological objectives.	Water resource assessment and Water allocation planning	2015, or once 2 years of baseline data have been collected
Implement SWIM sampling guideline when finalised.	Water resource assessment	When available
Update operating strategies with new monitoring requirements and trigger and response tables.	Licensing	As required

12 Data collection and review

12.1 Data collection and storage

The storage of monitoring data is an essential part of the monitoring program. The department stores all site information and point source data in the Water information network (WIN) database. This database will be updated to ensure all monitoring sites have been registered.

Monitoring sites which generate continuous data will also be registered in the department's Hydstra database, which stores all continuous data.

Data collected by the department will be entered into the applicable databases yearly or more frequently if required.

Data collected by licensees will be provided to the department once a year with their annual report or as required by the conditions of their water licence. Where appropriate these data will be entered into WIN and/or Hydstra.

The department will work with licensees to confirm an agreed format for the provision of monitoring program data to facilitate entering the data into the systems.

12.2 Data reporting and review

Review and reporting of monitoring results is critical to the improvement of management. The reporting and review responsibilities in Table 22 have been identified for data generated through the monitoring program. Where applicable, the specific responsibilities will be incorporated into licensee operating strategies.

Table 22: Reporting and review

	Report details	Report by	Review and action by
1	Annual report (August), including: a) report on compliance against monitoring program b) report monitoring data against triggers and criteria c) report on compliance to trigger and response framework d) report on ecological monitoring data.	Licensee	a) Department of Water, Regional licensing b) Department of Water, Regional licensing and Water allocation planning c) Department of Water, Water allocation planning d) Department of Water, Water allocation planning

	Report details	Report by	Review and action by
2	Source review to include (September every three years): a) review recharge relationship for the alluvial aquifers and Millstream b) report aquifer performance against predictions of numerical model c) assess long term groundwater trends against abstraction, climate and GDE condition.	b) Licensee c) Licensee	a) Department of Water – Regional licensing and Water allocation planning b) Department of Water, Regional licensing and Water Resource Assessment c) Department of Water, Regional licensing, Water allocation planning and Water resource assessement
3	Plan evaluation (annual review): a) monitoring data against the performance indicators and objectives.	No report – internal review of data only Department of Water – Regional licensing, Water Resource Assessment and Water Allocation Planning	Internal review only
4	Plan evaluation (triennial review): a) monitoring data against the performance indicators and objectives b) adequacy of the monitoring program c) adequacy of the performance indicators (may be reviewed on a longer time scale depending on ecological requirements – see section 12.3) Publish the results of the plan evaluation at least every three years.	Department of Water – Regional licensing, Water resource assessment and Water allocation planning	Publicly available

12.3 Performance indicator review

As detailed in this monitoring program, measurable performance indicators have been identified to meet the resource objectives. A performance indicator is the point at which changes in water quality or water level are predicted to represent a risk to the in-situ values of the resources. They represent targets which have been based on the information available at the time.

As data on the response of the aquifer and its in-situ values to abstraction become available, we can begin to assess our performance indicators and our management response. This is done through the plan evaluation process.

The performance indicator review framework (Figure 9) shows the process followed by the department to determine the type of review that should be undertaken.

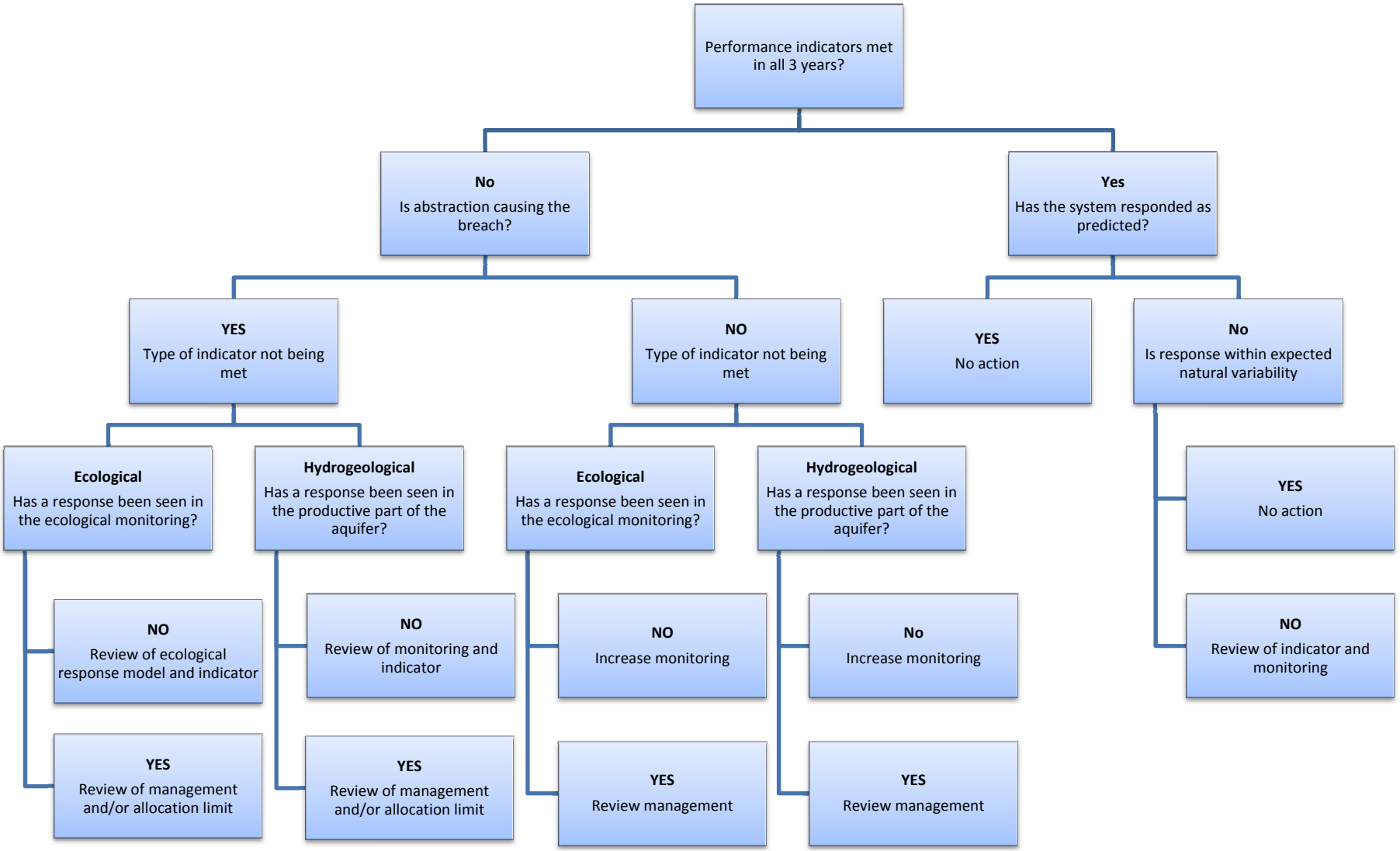

Figure 9: Performance indicator evaluation framework

Appendices

Appendix A — Performance indicators and monitoring site selection

Performance indicators

Groundwater levels

Groundwater level is a key indicator of aquifer status. Monitoring allows us to determine if the aquifer is responding to abstraction and other hydrological factors as predicted.

Groundwater level monitoring is also carried out where it is considered to be representative of the water availability conditions at riparian vegetation sites. Groundwater level monitoring near river pools is important to confirm connectivity between the groundwater and the pools and ensure that pool levels are maintained.

Additional bores will be required in some target resources to make sure representative groundwater-dependent ecosystems (GDEs) are adequately monitored.

Timing and frequency

Monitoring frequency has been tailored to meet the target resource objectives. Where possible, water level monitoring should start before the resource is developed or its use expanded. The aim is to ensure that pre-development water levels are characterised, and the range of natural variability is understood prior to any abstraction impacts.

Data loggers

Due to the vastness of the Pilbara monitoring network, manual monitoring of water levels is time-consuming and expensive. Only relatively small amounts of data can be collected and often recharge events and seasonal changes in groundwater levels are not adequately captured.

Installation of automated data loggers is a priority for the region and key groundwater monitoring bores will be equipped with loggers to provide more frequent measurement data. This will also address the loss of site access during and after flooding events which can result in important recharge/response data not being collected.

Groundwater quality

Abstraction-induced movement of higher salinity water from the saltwater interface and aquifer flanks is a possible risk to the water quality in the coastal alluvial aquifers. Maintaining aquifer through-flow to the ocean and managing drawdown on the sides of the aquifers (away from recharge zones along the rivers) to prevent this, are key management issues for the department.

To manage water quality, monitoring of salinity (TDS mg/L) in bores at points along the saltwater interface and aquifer flanks is required. To do this we will extend the current water quality monitoring programs towards the saltwater/freshwater interface and along aquifer flanks where salinity increases.

Performance indicators will be developed following collection of baseline data (see below).

Where possible, existing bores will be used, however in some resources new monitoring bores are required.

In this document water quality refers to salinity as TDS mg/L unless otherwise stated.

Timing and frequency

Initial data collection will focus on establishing baseline conditions. Six monthly monitoring is recommended during baseline data collection to characterise seasonal and interannual variability in salinity levels.

It is anticipated that 2–3 years' data will be required to adequately capture the water quality variability in these zones and allow performance indicators to be established and implemented. Once performance indicators have been developed, monitoring frequency can be reduced.

Pool surface water levels

Performance indicators for groundwater-dependent river pools have been set at stage height (m) if the infrastructure is available or as a groundwater level (mAHD) at a nearby bore. These indicators were designed to maintain minimum pool levels for water quality and habitat for aquatic fauna.

In the case where groundwater level is used, work will be required to establish a stage height performance indicator. This will include pool bathymetry and pool survey, collection of baseline data over two years and establishment of a stage height performance indicator.

Frequency

Where possible, monitoring of pool stage should be done in conjunction with local groundwater level monitoring. This will improve, and at some sites help develop, quantitative relationships between pool water levels and groundwater.

Ecosystem health

Ecological monitoring of groundwater-dependent riparian vegetation will be carried out at selected resources. Monitoring will focus on groundwater dependent vegetation and target ecosystem parameters sensitive to changes in water availability (such as vegetation canopy density).

The department will develop suitable performance indicators for ecosystem health during implementation of the monitoring program.

Frequency

Where possible, ecosystem indicators will be monitored before a new resource is developed or an existing bore field is expanded.

It is anticipated that 2–3 years' data will be required to adequately capture the variability in ecological health and allow performance indicators to be established and implemented.

Annual monitoring late in the dry season (at the time of maximum potential stress) or as triggered by a decline in water availability is recommended.

Streamflow

The collection of good quality, continuous streamflow data is an essential part of the monitoring program. Streamflow is the primary source of recharge to the alluvial and Millstream aquifers. Ongoing review of recharge and aquifer level relationships as abstraction increases (in some target aquifers) is an important part of the monitoring and evaluation cycle for the allocation plan and the monitoring program.

Groundwater level performance indicators for GDEs are variable and are linked to annual streamflow. Total wet season flow needs to be calculated in May every year to determine the applicable groundwater level performance indicator.

Calculation of the wet season flow is the performance indicator for streamflow.

Timing and frequency

Streamflow gauging stations collect continuous stage data which is converted to volume using a stage-discharge relationship. Conversion needs to be done at least yearly (in May) to determine the total wet season flow.

Appendix B – Existing monitoring program

Existing monitoring at Yule River

Water Corporation conduct monitoring at Yule River for compliance with the groundwater licences for the Port Hedland regional water supply scheme. This compliance monitoring has been running in its current form since March 2004 although some of the individual bores have data dating back to the 1970s.

The objective of the current program is to monitor the potential impacts of groundwater abstraction on groundwater-dependent vegetation, aquifer water status and water quality. The program consists of:

- five environmental water provision (EWP) criteria bores, monitored monthly and assessed against EWP triggers (fortnightly monitoring triggered if EWP water level is reached)
- 11 aquifer performance bores, monitored monthly to detect changes in aquifer water level variation over time to determine the influence of water abstraction and recharge events
- 16 vegetation monitoring bores located in the vicinity of the vegetation transects and monitored monthly (established and monitored since 2005 to replace existing EWP monitoring bores)
- 10 production bores, monitored monthly for water level and conductivity
- 17 vegetation transects surveyed twice a year to quantify trends in ecological health (two-monthly monitoring triggered by water level in EWP bores) – monitoring ceased during pumping trial
- one pool stage height at Lin Lee Pool, monitored monthly to observe pool fluctuations in relation to local groundwater levels
- four stock bores, monitored monthly for water level and conductivity to monitor impacts on other users
- one stream gauge monitored continuously (operated by the Department of Water).

Existing monitoring at De Grey River

Water Corporation has conducted monitoring at De Grey River as part of their licence to abstract water since 1974. The objective of the program is 'to accurately measure water level and quality variation with time so as to determine the influence of water abstraction and recharge events' (Water Corporation 2008). The program currently consists of:

- 18 observation bores, monitored three-monthly as required for compliance with the licence to abstract water and to collect data for future assessment
- 12 monitoring bores, located in the vicinity of established vegetation transects and monitored monthly to detect changes in water level
- 11 production bores, monitored monthly for water level and conductivity

- five staff gauges in river pools, monitored monthly to measure pool fluctuations in relation to local water levels
- two stock bores, monitored three-monthly for water level and annually for conductivity as required by local pastoralists
- one stream gauge station at Coolenar Pool monitored continuously since 1974 (operated by Department of Water).

Vegetation transects have also been established although monitoring has been discontinuous:

- ten vegetation transects surveyed in1998, 2003 and 2004 to quantify ecological health.

Existing monitoring at Millstream

Water Corporation conducts monitoring at Millstream as part of its water licence conditions. Compliance monitoring commenced in 1984 and consists of groundwater, surface water and biological monitoring components.

The objective of the current program is to 'provide information which will be used in the day-to-day management of groundwater abstraction and the management of water-dependent environmental values of key areas of significance' (Welker Environmental Consultancy 1998).

The current groundwater monitoring program consists of:

- eight production bores, water level monitored monthly, water quality monitored monthly when in use and major components monitored annually
- four unused production bores, water level monitored two-monthly
- nine aquifer status bores monitored two-monthly (increasing to monthly when trigger is reached)
- six supplementation bores, water level and conductivity monitored monthly when in use
- ten environmental bores, monitored two-monthly
- nine intensive monitoring bores, monitored two-monthly.
- The current surface water monitoring program consists of:
- six streamflow monitoring points: four tributaries entering the Fortescue River (Chinderwarriner Pool (flow and conductivity) and Woodley, Peters and Palm Creeks) are currently monitored on a two-monthly basis. Streamflow is also measured at Crossing Pool (midstream) and Gregory Gorge (downstream)
- two pool level gauging stations (Deep Reach Pool and Chinderwarriner Pool)
- one stream gauging station at Gregory Gorge operated by the department.

The current biological monitoring program consists of:

- aerial photography taken annually.

Existing monitoring at Fortescue River

The department conducts monitoring of groundwater levels and quality of the lower Fortescue Alluvial aquifer. Groundwater levels in 36 bores were monitored six-monthly until 1991 when the program was significantly reduced. Currently, water levels and quality are monitored twice a year at 11 bores and streamflow is recorded at Bilanoo gauging station on a continuous basis. There is no ecological monitoring on the lower Fortescue. The current monitoring program consists of:

- 11 aquifer investigation bores, monitored six-monthly to detect changes in aquifer water level and quality (TDS) in relation to recharge events
- one stream gauging station.

Existing monitoring at Robe River

Monitoring of the lower Robe alluvial aquifer is currently undertaken by the department and includes:

- seven aquifer investigation bores, monitored two-monthly to detect changes in aquifer water level and quality in relation to recharge events
- one stream gauging station.

Existing monitoring at West Canning Basin

Monitoring is currently undertaken by various licensees as part of the conditions on their licence.

Existing monitoring at Cane River

Water Corporation currently conducts groundwater monitoring for compliance with the groundwater licence for the Cane River bore field. This monitoring includes:

- 18 production bores, with water level, conductivity and temperature monitored three monthly and major components monitored annually
- 15 monitoring bores, with water level monitored six-monthly in May and November
- one stream gauge operated by the department.

Existing monitoring at Turner River

There is no current groundwater monitoring program for the Turner River. River flow is recorded at Pincunah gauging station located 90 km upstream. This station has been monitored since 1986.

Appendix C – Coordinates for monitoring sites

Coordinates for monitoring sites excluding vegetation transects

Resource	Site name	Latitude	Longitude
West Canning Basin	WCB-8C	-20.0800684860	119.784730223
West Canning Basin	WCB-17C	-20.0075009000	119.953323840
West Canning Basin	WCB-5Y	-20.2663311200	119.780683950
West Canning Basin	WCB-21Z	-20.0611858300	120.096154460
West Canning Basin	WCB-21Y	-20.0610955800	120.096156120
West Canning Basin	WCB-25Z	-19.9743549230	120.219264805
West Canning Basin	WCB-9E	-20.0123739910	119.785838086
West Canning Basin	WCB-20Z	-20.1308204600	120.095863520
West Canning Basin	WCB-4B	-20.1008560410	119.522846496
West Canning Basin	WCB-18Y	-20.3224028300	120.102349900
West Canning Basin	WCB-22C	-19.9886821860	120.095481235
West Canning Basin	WCB-15Y	-20.2104553400	119.954037970
West Canning Basin	WCB-10B	-20.1292090100	119.685954979
West Canning Basin	WCB-24Y	-20.0700767100	120.217156740
West Canning Basin	WCB-24Z	-20.0701850200	120.217154830
West Canning Basin	WCB-25Y	-19.9743549230	120.219265000
Turner alluvial aquifer	Pincunah	-21.2305287000	118.833847300
Turner alluvial aquifer	Proposed surface water interface monitoring (SWIM) bore	-20.3991678329	118.422189673
Turner alluvial aquifer	Proposed SWIM	-20.3867761243	118.460494337
Turner alluvial aquifer	Proposed	-20.4617739291	118.444546394
Turner alluvial aquifer	Proposed	-20.4547988444	118.484197291

Resource	Site name	Latitude	Longitude
Turner alluvial aquifer	Proposed	-20.4979477926	118.450652019
Turner alluvial aquifer	Proposed	-20.4945598699	118.494190876
Cane alluvial aquifer	31-88	-21.6915803000	115.371000600
Cane alluvial aquifer	32-88	-21.6951298000	115.366398700
Cane alluvial aquifer	No. 1	-21.6782722000	115.363361400
Cane alluvial aquifer	No. 2	-21.6760117000	115.362208000
Cane alluvial aquifer	No. 8	-21.6835713000	115.366712900
Cane alluvial aquifer	1-69	-21.6846605232	115.367665307
Cane alluvial aquifer	2-69	-21.6809066903	115.364780703
Cane alluvial aquifer	8-79	-21.6714884507	115.362882634
Cane alluvial aquifer	4-82	-21.6875837000	115.376090500
Cane alluvial aquifer	5-82	-21.6895638000	115.377218300
Cane alluvial aquifer	12-86	-21.6935960000	115.379434700
Cane alluvial aquifer	13-86 (G-86)	-21.6909851000	115.377540700
Cane alluvial aquifer	15-94	-21.6993211000	115.374673200
Cane alluvial aquifer	13-94	-21.6853543000	115.376260500
Cane alluvial aquifer	3-69	-21.6745532621	115.363443315
Cane alluvial aquifer	3-97	-21.6756940031	115.362705188
Cane alluvial aquifer	4-97	-21.6789149191	115.363510417
Cane alluvial aquifer	5-97	-21.6801898649	115.364483402
Cane alluvial aquifer	16-97	-21.6963950981	115.372804102
Cane alluvial aquifer	NO.4	-21.6802620681	115.362914189
Cane alluvial aquifer	NO.6	-21.6820365527	115.366999386
Cane alluvial aquifer	1-79	-21.6756519000	115.365101500
Cane alluvial aquifer	2-79	-21.6744467000	115.365617600
Cane alluvial aquifer	11-88	-21.7099980000	115.396988100

Resource	Site name	Latitude	Longitude
Cane alluvial aquifer	12-88	-21.7241044000	115.399577000
Cane alluvial aquifer	13-88	-21.7252393000	115.395523600
Cane alluvial aquifer	16-88	-21.6873334000	115.393015800
Cane alluvial aquifer	29-88	-21.6827843314	115.374017689
Cane alluvial aquifer	30-88	-21.6781745474	115.370071798
Cane alluvial aquifer	1-65	-21.6767455891	115.362966398
Cane alluvial aquifer	2-70	-21.6783412203	115.362423204
Cane alluvial aquifer	1-71	-21.6836373578	115.369586570
Cane alluvial aquifer	6-88	-21.6589559991	115.351151937
Cane alluvial aquifer	10-88	-21.6599065879	115.359469589
Cane alluvial aquifer	Toolunga	-22.0226001000	115.594518700
Yule alluvial aquifer	3/96	-20.5955880000	118.296645000
Yule alluvial aquifer	2/96	-20.6043800000	118.281932000
Yule alluvial aquifer	1/96	-20.6052130000	118.297446000
Yule alluvial aquifer	11/96	-20.5436627821	118.205512552
Yule alluvial aquifer	12/96	-20.5354390000	118.193352000
Yule alluvial aquifer	13/96	-20.5387600000	118.183375000
Yule alluvial aquifer	15/96	-20.5577970000	118.258783000
Yule alluvial aquifer	5/96	-20.5512030000	118.244878000
Yule alluvial aquifer	16/96	-20.5321400000	118.169619000
Yule alluvial aquifer	13/04	-20.5661658000	118.237474400
Yule alluvial aquifer	12/04	-20.5515085000	118.207987700
Yule alluvial aquifer	17/04	-20.6566684000	118.295700100
Yule alluvial aquifer	8/04	-20.5270334000	118.163101800
Yule alluvial aquifer	37/04	-20.5234906415	118.158955943
Yule alluvial aquifer	34/04	-20.5561654015	118.159532163

Resource	Site name	Latitude	Longitude
Yule alluvial aquifer	10/04	-20.5368236618	118.174860710
Yule alluvial aquifer	14/04	-20.5791302624	118.259894585
Yule alluvial aquifer	15/04	-20.6142570868	118.275766739
Yule alluvial aquifer	Jellibadina Well	-20.6997506492	118.298610997
Yule alluvial aquifer	21/04	-20.6811714535	118.299372539
Yule alluvial aquifer	Lee Linn Pool	-20.5225650514	118.157747741
Yule alluvial aquifer	14/70	-20.6342272475	118.285574369
Yule alluvial aquifer	15/73	-20.5391200267	118.217305355
Yule alluvial aquifer	No. 18B	-20.5990267596	118.239528674
Yule alluvial aquifer	19/73	-20.5226317843	118.165982010
Yule alluvial aquifer	No. 20	-20.5622812627	118.192247330
Yule alluvial aquifer	20/73	-20.5320645152	118.203850658
Yule alluvial aquifer	No. 21	-20.5252779692	118.190279889
Yule alluvial aquifer	21/73	-20.5255418138	118.190148386
Yule alluvial aquifer	No. 3	-20.5445061513	118.247658071
Yule alluvial aquifer	4/96	-20.5772208600	118.271144650
Yule alluvial aquifer	6/96	-20.5633139600	118.237887130
Yule alluvial aquifer	8/96	-20.5485475600	118.220627850
Yule alluvial aquifer	No. 8A	-20.5567132100	118.289382120
Yule alluvial aquifer	22/73	-20.5171737000	118.162254500
Yule alluvial aquifer	7/96	-20.5580999025	118.223996785
Fortescue alluvial aquifer	29	-21.0820090000	116.007834000
Fortescue alluvial aquifer	31A	-21.0841650000	116.069429000
Fortescue alluvial aquifer	12A or 20A	-21.1427330000	116.041135000
Fortescue alluvial aquifer	16B	-21.1658270000	115.973565000
Fortescue alluvial aquifer	18	-21.1216630000	115.991201000

Resource	Site name	Latitude	Longitude
Fortescue alluvial aquifer	20A or 12A	-21.1210120000	116.034535000
Fortescue alluvial aquifer	22A	-21.1059160000	116.081809000
Fortescue alluvial aquifer	23A	-21.1024860000	116.116490000
Fortescue alluvial aquifer	26 or 28A	-21.1430820000	115.947721000
Fortescue alluvial aquifer	28A or 26	-21.1026290000	115.980740000
Fortescue alluvial aquifer	32A	-21.2217000000	116.108074000
Fortescue alluvial aquifer	32B	-21.2217000000	116.108074000
Fortescue alluvial aquifer	1A	-21.2205620000	116.064722000
Fortescue alluvial aquifer	2A	-21.1944260000	116.076447000
Fortescue alluvial aquifer	2B	-21.1944260000	116.076447000
Fortescue alluvial aquifer	6A	-21.1743250000	116.036116000
Fortescue alluvial aquifer	8A	-21.1574330000	116.085344000
Fortescue alluvial aquifer	10A	-21.1651360000	116.009207000
Fortescue alluvial aquifer	11A	-21.1480160000	116.017025000
Fortescue alluvial aquifer	4A	-21.1995817341	116.052334747
Fortescue alluvial aquifer	Jilanjilan	-21.1495119914	116.097638318
Fortescue alluvial aquifer	Stewart	-21.1962396432	116.094351542
Fortescue alluvial aquifer	Bilanoo	-21.2959054392	116.144565698
Fortescue alluvial aquifer	Mungajee	-21.1207548968	116.082737156
De Grey alluvial aquifer	6/04	-20.2406854000	119.173755500
De Grey alluvial aquifer	T2	-20.1891525000	119.182977900
De Grey alluvial aquifer	12-76	-20.2680000000	119.253200000
De Grey alluvial aquifer	13/03	-20.3082459000	119.278552100
De Grey alluvial aquifer	7-76	-20.3095000000	119.292000000
De Grey alluvial aquifer	E4B	-20.2883370000	119.294632600
De Grey alluvial aquifer	E3	-20.3007071000	119.270596900

Resource	Site name	Latitude	Longitude
De Grey alluvial aquifer	8/03	-20.3105670000	119.305418700
De Grey alluvial aquifer	T1	-20.1851703000	119.205689800
De Grey alluvial aquifer	1/04	-20.1378635000	119.170165200
De Grey alluvial aquifer	U2	-20.2284230000	119.206204200
De Grey alluvial aquifer	15/03	-20.2685889000	119.261999300
De Grey alluvial aquifer	E1	-20.3004760000	119.264036500
De Grey alluvial aquifer	3/76	-20.2801000000	119.291600000
De Grey alluvial aquifer	H1	-20.3187868000	119.302386000
De Grey alluvial aquifer	11/76	-20.2950486000	119.313712400
De Grey alluvial aquifer	8/04	-20.2155526000	119.202806900
De Grey alluvial aquifer	U4	-20.2239358000	119.239628400
De Grey alluvial aquifer	9/03	-20.2702310000	119.282312500
De Grey alluvial aquifer	5-76	-20.3118000000	119.318900000
De Grey alluvial aquifer	7/04	-20.3009489000	119.242349700
De Grey alluvial aquifer	R1	-20.3220497000	119.334160700
De Grey alluvial aquifer	U1	-20.2308634000	119.191406800
De Grey alluvial aquifer	2-76	-20.2890000000	119.280300000
De Grey alluvial aquifer	9/04	-20.1857746000	119.196944200
De Grey alluvial aquifer	U3	-20.2264364000	119.220528100
De Grey alluvial aquifer	4/76	-20.2950486000	119.313712400
De Grey alluvial aquifer	X1	-20.1374478474	119.168120850
De Grey alluvial aquifer	I2	-20.3416479731	119.347296515
De Grey alluvial aquifer	H2	-20.3394621776	119.282790192
De Grey alluvial aquifer	F1	-20.3656749480	119.311468534
De Grey alluvial aquifer	Coolenar	-20.3120369119	119.249276377
De Grey alluvial aquifer	T3	-20.1959505515	119.156085883

Resource	Site name	Latitude	Longitude
De Grey alluvial aquifer	T4	-20.1816606867	119.222771919
De Grey alluvial aquifer	New	-20.1435543805	119.212054520
De Grey alluvial aquifer	New	-20.1751111653	119.146559306
De Grey alluvial aquifer	New	-20.1405773253	119.145368484
De Grey alluvial aquifer	7/03	-20.2979952271	119.269107690
De Grey alluvial aquifer	14/03	-20.2790328246	119.271163855
Robe alluvial aquifer	1A	-21.5753900000	115.881853000
Robe alluvial aquifer	2A	-21.5807320000	115.870222000
Robe alluvial aquifer	4A	-21.5643260000	115.849103000
Robe alluvial aquifer	6A	-21.5309430000	115.855160000
Robe alluvial aquifer	9A	-21.5055960000	115.847637000
Robe alluvial aquifer	11A	-21.5125510000	115.808967000
Robe alluvial aquifer	22A	-21.4537316356	115.788306627
Robe alluvial aquifer	15A	-21.4949079542	115.773859477
Robe alluvial aquifer	Warali Pool	-21.4075777051	115.759925554
Robe alluvial aquifer	Maraminji Pool	-21.4729655350	115.819292326
Robe alluvial aquifer	Little Jimuttda Pool	-21.5735145382	115.879796310
Robe alluvial aquifer	Unnamed Pool	-21.5038404244	115.839020843
Robe alluvial aquifer	Yarraloola	-21.6167041750	115.922470632
Robe alluvial aquifer	New	-21.4078120726	115.763330095
Robe alluvial aquifer	New	-21.3879578215	115.744085454
Robe alluvial aquifer	New	-21.3763662343	115.770335477
Robe alluvial aquifer	New	-21.4723616684	115.823102159
Millstream aquifer	20A	-21.4664762977	115.830082510
Millstream aquifer	3/04	-21.5794530000	117.068604000
Millstream aquifer	6/04	-21.5803930000	117.065484000

Resource	Site name	Latitude	Longitude
Millstream aquifer	P2-77	-21.5756940000	117.055232000
Millstream aquifer	P4-78	-21.5782220000	117.061029000
Millstream aquifer	4/04	-21.5842320000	117.067968000
Millstream aquifer	12/04	-21.5774630000	117.073413000
Millstream aquifer	P3-77	-21.5727100000	117.061220000
Millstream aquifer	8/04	-21.6316360000	117.120375000
Millstream aquifer	7/04	-21.6173230000	117.110208000
Millstream aquifer	P7-78	-21.6121680000	117.104619000
Millstream aquifer	P8-77	-21.6110830000	117.105585000
Millstream aquifer	P2	-21.5710060000	116.962696000
Millstream aquifer	P5	-21.5767890000	116.967621000
Millstream aquifer	P8	-21.5816680000	116.967717000
Millstream aquifer	P1-78	-21.5672060000	117.035911000
Millstream aquifer	P10	-21.5673870000	117.035139000
Millstream aquifer	P7-77	-21.6065680000	117.107802000
Millstream aquifer	1E	-21.5928770000	117.066216000
Millstream aquifer	1C	-21.6238620000	117.063300000
Millstream aquifer	2B	-21.6116630000	116.959787000
Millstream aquifer	2C	-21.6351550000	116.968478000
Millstream aquifer	4A	-21.6613320000	116.904682000
Millstream aquifer	5B	-21.6712570000	117.117324000
Millstream aquifer	7C	-21.6306400000	117.018727000
Millstream aquifer	8C	-21.6809890000	116.885104000
Millstream aquifer	DR 1-84	-21.6178380000	117.096304000
Millstream aquifer	DR 2-84	-21.6185770000	117.098836000
Millstream aquifer	DR 3-84	-21.6198220000	117.101987000

Resource	Site name	Latitude	Longitude
Millstream aquifer	CP1 1A	-21.5935760000	117.065094000
Millstream aquifer	CP2 8-81	-21.5962860000	117.066302000
Millstream aquifer	CP3 11-81	-21.5953820000	117.065916000
Millstream aquifer	P1	-21.5940270000	117.066543000
Millstream aquifer	P10	-21.6188600000	117.094575000
Millstream aquifer	P11	-21.6215680000	117.097476000
Millstream aquifer	P12	-21.6247280000	117.101343000
Millstream aquifer	P2	-21.5962860000	117.066544000
Millstream aquifer	P3	-21.6003510000	117.066546000
Millstream aquifer	P4	-21.5980920000	117.068960000
Millstream aquifer	P5	-21.5958330000	117.068959000
Millstream aquifer	P6	-21.6030620000	117.066547000
Millstream aquifer	P7	-21.6111840000	117.086358000
Millstream aquifer	P8	-21.6134420000	117.088774000
Millstream aquifer	P9	-21.6161510000	117.091675000
Millstream aquifer	Peters Creek	-21.5836490000	117.015340000
Millstream aquifer	Palm Creek	-21.5678420000	116.954970000
Millstream aquifer	Woodley Creek	-21.6017120000	117.051572000
Millstream aquifer	Gregory Gorge	-21.5561090000	116.916599000
Millstream aquifer	Crossing Pool D-S	-21.5713700000	117.069584000
Millstream aquifer	Irrigation channel	-21.5917710000	117.068956000
Millstream aquifer	Eastern channel	-21.5917710000	117.068956000
Millstream aquifer	Central channel	-21.5917710000	117.068956000
Millstream aquifer	Western channel	-21.5917710000	117.068956000
Millstream aquifer	Chinderwarriner Pool	-21.5917710000	117.068956000

Resource	Site name	Latitude	Longitude
Millstream aquifer	Deep Reach Pool	-21.6062080000	117.106159000
Millstream aquifer	13C	-21.7037670000	117.188353000
Millstream aquifer	23B	-21.8201000000	117.394337000
Millstream aquifer	7A	-21.5809420000	117.018720000
Millstream aquifer	26A	-21.7407090000	117.424418000
Millstream aquifer	7A	-21.8884480000	117.630744000

Appendix D – Map disclaimer

Datum and projection information

Vertical datum: Australian Height Datum (AHD)

Horizontal datum: Geocentric Datum of Australia 94

Projection: MGA 94 Zone 50

Spheroid: Australian National Spheroid

Project information

Client: Department of Water

Map author: Michelle Antao

Disclaimer

These maps are a product of the Department of Water, Water resource use division and were printed as shown.

These maps were produced with the intent that they be used for information purposes at the scale as shown when printing.

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Sources

The Department of Water acknowledges the following datasets and their custodians in the production of this map:

Towns –Department of Land Information – Current

Road Centrelines – Department of Land Information – Current

Hydrography, Linear (Hierarchy) – Department of Water – 05/11/2007

Divertible water allocation information database (DWAID) Aquifers – Department of Water – Current

Water information network (WIN) Surface Water Sites-Stream Gauging (Department of Water) – Department of Water – Continual

WIN Sites – Department of Water - Continual

WA Coastline, Water and Rivers Commission (Poly) – Department of Water – 20/07/2006

Australian Coastline Derived - Department of Water – 30 December, 2009

Shortened forms

AHD	Australian height datum
CTF	Cease to flow
DEC	Department of Environment and Conservation
DoW	Department of Water
DWAID	Divertible water allocation information database
EWP	Environmental water provision
EWR	Ecological water requirements
kL	Kilolitre
kL/s	Kilolitres per second
ML	Megalitre
Mg/L	Milligrams per litre
PI	Performance indicator
PFC	Percentage foliage cover
SWIM	Surface water interface monitoring
TDS	Total dissolved solids
WC	Water Corporation
WCB	West Canning Basin

Glossary

Abstraction	Withdrawal of water from any surface water or groundwater source of supply.
Allocation limit	Annual volume of water set aside for use from a water resource.
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecological water requirement	The water regime needed to maintain the current ecological values (including assets, functions and processes) of water-dependent ecosystems at a low level of risk.
Environmental water provision	The water regime provided to, or left in, the environment resulting from the water allocation decision-making process taking into account ecological, social, cultural and economic impacts. It may meet in part, or in full, the ecological water requirements.
Groundwater-dependent ecosystem	An ecosystem that is at least partially dependent on groundwater for its existence and health.
Groundwater-dependent social value	An *in situ* quality, attribute or use associated with a groundwater resource (or dependent on a groundwater resource) that is important for public benefit, welfare, state or health.
Licence (or licensed entitlement)	A formal instrument which entitles the licence holder to take water from a watercourse, wetland or underground source under the *Rights in Water and Irrigation Act 1914.*
Performance indicator	A groundwater, pool level or water quality level that should not be breached, usually relating to maintaining water quality, aquifer productivity and/or water for ecology. This is the performance indicator used to assess whether water resource objectives are being met.
Seawater or saltwater intrusion	The inland or up-gradient intrusion of salt water into a layer of fresh groundwater, from the sea or from the edges of the aquifer.
Target resource (or aquifer)	A water resource in the *Pilbara groundwater allocation plan* that is being targeted or focused on for water supply and management, due to its importance and proximity to coastal centres where water demand is high.

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