REPORT:

Surat Gas Project – Supplementary Report to the Environmental Impact Statement

Supplementary Surface Water Assessment Part C – Preliminary Environmental Flows Assessment

June 2013

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Abbreviations

ACARP	Australian Coal Association Research Program
AEP	Annual Exceedance Probability
Alluvium	Alluvium Consulting Australia
ARI	Average Recurrence Interval
Arrow	Arrow Energy Pty Ltd
CL	Continuing Loss
Coffey Environments	Coffey Environments Pty Ltd
CGPF	Central Gas Processing Facility
DA	Discharge Area
DEM	Digital Elevation Model
EIS	Environmental Impact Statement
FFA	Flood Frequency Analysis
ML/d	Megalitres per day
m value	For RORB, dimensionless exponent used in reach storage-discharge calculations
RORB	Hydrological modelling software package
SEWPaC	Sustainability, Environment, Water, Population and Communities
SREIS	Supplementary Report to the Environmental Impact Statement
TWAF	Temporary Workers Accommodation Facility

Glossary

alluvium	Material deposited by rivers.
fluvial geomorphology	The science that describes explains and predicts the shape and form of waterways.
hydraulic	The branch of science concerned with the conveyance of liquids through pipes and channels.
hydrograph	A graph showing changes in the discharge of a river over a period of time.
hydrology	The scientific study of the properties, distribution, and effects of water on the earth's surface.
sediment	Solid fragmented material, such as silt, sand and gravel, that is transported and deposited by water.

1 Introduction

Arrow Energy Pty Ltd (Arrow) is required to prepare a Supplementary Report to the Environmental Impact Statement (SREIS) to present information on updates to the project description, address issues identified in the Environmental Impact Statement (EIS) as requiring further consideration and/or information, and to respond to comments raised in submissions on the EIS.

This report by Alluvium Consulting Australia (Alluvium) for Coffey Environments Pty Ltd (Coffey Environments) provides a preliminary assessment of the coal seam gas water discharge regime required to minimise the impacts on the receiving environment. It identifies the acceptable frequency, timing and volume of flow at the two proposed discharge sites of the CGPF2 and CGPF9 properties and provides a basis for further development and assessment of proposed discharge regimes.

This report is one of four reports covering aspects of surface water:

- Alluvium (2013) *Surat Gas Project – Supplementary Report to the Environmental Impact Statement: Supplementary Surface Water Assessment Part A – Geomorphology and Hydrology.* Alluvium Consulting Australia for Coffey Environments.
- NRA (2013) *Surat Gas Project – Supplementary Report to the Environmental Impact Statement: Supplementary Surface Water Assessment Part B – Water Quality*. NRA & Alluvium Consulting Australia for Coffey Environments.
- Alluvium (2013) *Surat Gas Project – Supplementary Report to the Environmental Impact Statement: Supplementary Surface Water Assessment Part C – Preliminary Environmental Flows Assessment.* Alluvium Consulting Australia for Coffey Environments. – this report
- AMEC (2013) *Surat Gas Project – Supplementary Report to the Environmental Impact Statement: Supplementary Aquatic Ecology Assessment*. AMEC for Coffey Environments.

1.1 Context

Arrow has revised the project description for its Surat Gas Project to include two water treatment facilities (from six presented in the EIS) to be co-located with two of the eight proposed central gas processing facilities (CGPFs). It is proposed to discharge treated and untreated coal seam gas water from the water treatment facilities to nearby watercourses under emergency situations as assessed in the EIS, as well as part of normal operations where other water management options cannot account for all of the produced water.

The water treatment facilities are co-located with the CGPFs in drainage area 2 (CGPF2 property) and in drainage area 9 (CGPF9 property). The exact locations of infrastructure within these sites have not been determined and the final siting of infrastructure will be determined in consideration of environmental and technical constraints. Site-specific surface water assessments, which were not able to be conducted for the EIS, have now been undertaken at the receiving environments of the properties where the water treatment facilities are to be located. The findings of the assessments are provided in the other reports outlined above.

Figure 1 shows the location of the properties on which the water treatment facilities co-located with CGPFs are planned to be developed. This figure also shows the location of the other three properties acquired by Arrow as freehold or under a long-term lease arrangement for location of a further two CGPFs and a temporary workers accommodation facility (TWAF). The northern water treatment facility, co-located with CGPF2, is expected to be sized to treat a maximum of approximately 35 ML/d of coal seam gas water. The southern water treatment facility, co-located with CGPF9, is expected to be rated at approximately 90 ML/d.

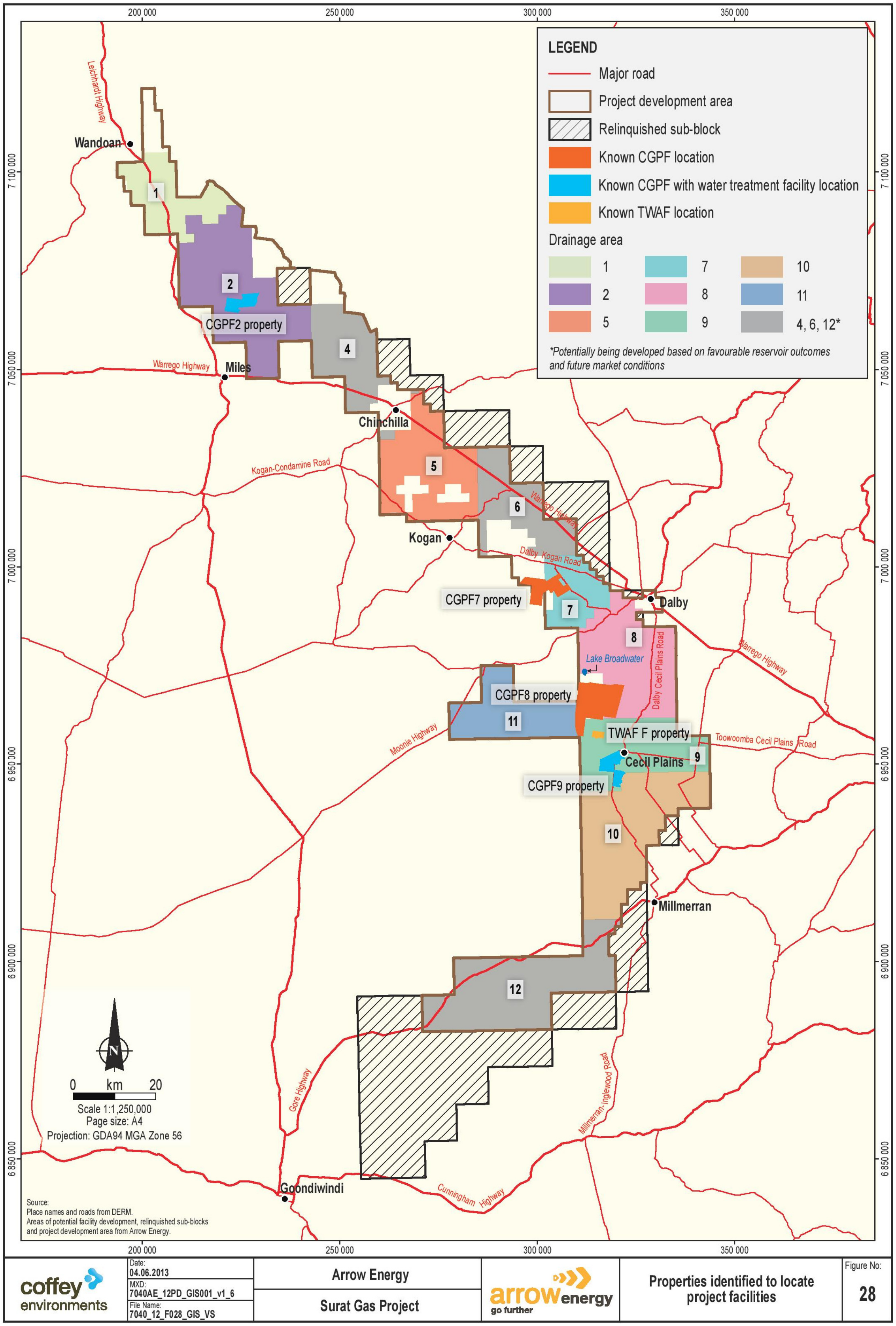

Figure 1. *Properties identified to locate project facilities* (figure by Coffey Environments)

Both of the proposed water treatment facilities will discharge coal seam gas water to nearby watercourses under both normal operations and emergency situations to manage variations in seasonal conditions and in the demand for other coal seam gas water management options (i.e. distribution to existing and new water users for beneficial use and injection to a suitable aquifer). These discharges will occur as required and will be within the prescribed limits, to be determined by subsequent investigations that will support the applications for an environmental authority.

Surface water attributes such as watercourse type, morphology, water quality and aquatic ecosystems at the two identified water treatment facility sites (CGPF2 and CGPF9 properties) will dictate the management options that should be adopted at each facility site. These attributes have been assessed in the three other surface water reports listed at the beginning of this section. This report provides an understanding of the timing, frequency and volume of water that can be sustainably discharged without compromising ecosystem functioning and in particular stream geomorphology, riparian vegetation and aquatic ecology.

1.2 Approach

The review of the proposed release of coal seam gas water at the two sites in the Surat Gas Project area (CGPF2 property and CGPF9 property) has been undertaken in four stages:

1. Documentation of approaches adopted for the description and determination of environmental flows.
2. Undertaking a 'spells analysis' to describe the current flow regime at both sites.
3. A workshop to discuss the results of the spells analysis and agree upon a range of flows that can be sustainably discharged without compromising ecosystem function.
4. Presenting the results of the first three stages in a format suitable to inform the development of a discharge strategy (This report).

These stages are described in detail in the following sections.

2 Background to environmental flow descriptions and determinations

2.1 Describing the flow regime

There is a multitude of interconnected and dynamic ecological functions that shape aquatic ecosystems. Understanding the full spectrum of ecological functions and their linkages is a difficult and complex task and defining the risks to these functions of altering the natural flow regime is a growing area of research.

A brief review of the literature reveals a number of approaches have been developed for south-eastern Australia rivers, which provide a simple, “high level” approach to the determination of environmental flows requirements to achieve key ecological functions (DNRE 2002, VanLaarhoven and van der Wielen 2009, Alluvium 2010, and Bunn and Arthington 2002). The stream systems being the subject of this assessment are located with the south east Queensland region of the Murray Darling Basin. The literature and investigations cited for south-eastern Australia and the Murray Darling Basin are assumed to be appropriate for the subject stream systems.

At an Australia-wide level Kennard et al (2010) developed a classification of natural flow regimes which provides an initial basis for predicting the ecological impacts of flow alteration. Flow regime classes were identified based on streams across the continent which had experienced minimal anthropogenic disturbance, and included a number located in south-east Queensland. Twelve distinct flow regime classes were identified. These were differentiated by seasonal discharge pattern, flow permanence and variations in the magnitude and frequency of extreme events. The premise of the study was that all streams in a flow regime class have similar assemblage composition and species traits and therefore the ecological response to flow regime change should be similar.

Defining flow components

Typically, flow regimes are described in relation to one or more of the standard flow components used in the Victorian FLOWS method (DNRE 2002):

- **Cease to flows** – when no flows are recorded in the channel. During these periods, the stream may contract to a series of isolated pools or ponds, may dry out completely, or simply be still deep water over a long distance (with some internal deep-shallow structures). Cease to flow periods are typical of ephemeral and semi-permanent watercourses.
- **Base flows** – the low level of persistent flow that maintains water flowing through the channel, keeping in-stream habitats wet and pools full. Typically a higher base flow is observed during the high flow season. Base flows are typical of permanent watercourses.
- **Low Freshes** – relatively small and short duration flow events resulting from localised rainfall. Low freshes can be observed in permanent, semi-permanent and ephemeral watercourses.
- **High Freshes** – relatively short duration higher flow events resulting from more intense localised rainfall. High freshes can be observed in permanent, semi-permanent and ephemeral watercourses.
- **Bankfull Flows** – flows that fill the channel, but do not spill onto the floodplain. Bankfull flows can be observed in permanent, semi-permanent and ephemeral watercourses.
- **Overbank Flows** – higher flows than the bankfull flows that spill out of the channel onto the floodplain. Overbank flows can be observed in permanent, semi-permanent and ephemeral watercourses.

Based on a first principles assessment, Alluvium (2010) found that each of these flow components are essential for the ecological functioning of all stream types found within the Murray Darling Basin. While each flow component is understood to have a role in the ecological process of rivers, it was previously noted by Bunn and Arthington (2002) that despite this growing recognition of the importance of the various flow components we are currently limited in our ability to predict and quantify the biotic response of each component.

Lake et al (2006) assessed the ecological response of high flow events in upland and lowland river systems and found that despite different ecological processes occurring in the different system types, flooding always has a key role in the dynamics and long-term persistence of their ecosystems.

An investigation into the impact of an altered flow regime on ecological condition in the Mount Lofty Ranges catchments was undertaken by VanLaarhoven and van der Wielen (2009) for the South Australian Government. Expert panel workshops were undertaken to identify the environmental flow requirements to support self-sustaining populations of biota under different geomorphic conditions. These were subsequently translated into measurable hydrologic 'metrics' that correspond to each of the flow components:

- Base flow: 80th percentile exceedance flow for the season (calculated on non-zero flows)
- Fresh: 2 times the median of all non-zero flows for the season
- Bankfull/overbank: 1.5 annual return interval flow (based on annual maximum flows)

Alluvium undertook a separate study for the Murray Darling Basin Authority in 2010 to identify environmental water requirements to meet key ecosystem functions in the Murray-Darling Basin and to describe the characteristics of the flow regime required to drive those functions. The study reviewed different methods for determining environmental flow requirements, including the Mount Lofty Ranges study, and proposed adoption of seasonal exceedance probability (seasonal flow duration curves) to define standard flow components.

Comparisons were made between the seasonal exceedance values (for 'undisturbed' catchment conditions) and the recommended flows determined using the Victorian FLOWS method. Key findings from the comparison are:

- The median low flow season and high flow season base flow recommendation from FLOWS studies was equivalent to the 85th percentile exceedance probability (approximately) for the season of interest. This is similar to the 80th percentile exceedance probability base flow criteria proposed for the Mt Lofty Ranges.
- The median low flow season and high flow season fresh recommendation from FLOWS studies was equivalent to the 23rd percentile exceedance probability (approximately) for the season of interest.

Cease to flow days were removed from the seasonal flow duration curves on the basis that base flow occurs in ephemeral streams when there is flow. This was consistent with the approach used in the Mount Lofty Ranges study.

Acceptable deviations from natural

VanLaarhoven and van der Wielen in 2009 investigated and established limits for each metric in terms of how far these could deviate from values under natural conditions while still maintaining the ecological process supported by that flow component at low risk (Table 1). Comparison of ecological monitoring data with the percentage of metrics passed at a site showed a good correlation between increasing ecological condition and increasing percentage of metrics passed.

Table 1. Priority groups for metrics and percentage deviation from the natural value for low ecological risk

Priority	Functions	Low risk deviation from natural	
		Decrease	Increase
1	Maintenance of core refuge habitat, or critical life-cycle processes	20%	25%
2	Promote resilience in the long term (e.g. large breeding events)	30%	50%
3	General information or metrics that represent resilient water requirements	50%	100%

Based on the deviation limits identified by VanLaarhoven and van der Wielen (Table 1), and the principle that all ecosystems processes nominated for this project are essential, Alluvium (2010) proposed the adoption of a 20% (decrease) target deviation from natural (Table 2) as being likely to provide for ongoing ecological functioning of stream systems. Target increase deviations were only identified for the cease to flow metric. This metric was reduced from the 25% increase proposed by VanLaarhoven and van der Wielen (2009) on the assumption that the limit on any deviation in the occurrence and duration of cease to flow events be the same as the deviation in the base flow rate and the occurrence and duration of freshes i.e. adoption of a deviation target for the cease to flow metrics of 20%.

Table 2. Target percentage deviation from the natural value for low ecological risk proposed by Alluvium (2010)

Flow component related metrics	**Target deviation from natural**	
	Decrease	**Increase**
Base flow	20%	NA
Freshes: number of years with a fresh, number of freshes per season and average duration of freshes	20%	NA
Bankfull and overbank events	20%	NA
Cease to flow: number of years with a cease to flow, number of cease to flow per season and average duration of cease to flow	NA	20%

Alluvium (2010) also noted that following discussions with Mike Wilson (MDBA manager Sustainable Rivers Audit) revealed that the systems that achieved 50% scores for agreed metrics were assessed as being in poor condition. Good condition was considered for the purpose of the Sustainable Rivers Audit to be reserved to those systems with metrics in the 80 to 100% range, i.e. allowing for up to 20% deviation from intact systems for the identified metrics.

2.2 Guidelines for managing flow regimes

Guidelines for managing coal seam gas water releases have been prepared as part of the Healthy HeadWaters Coal Seam Gas Water Feasibility Study (DNRM 2012). The high level steps outlined to determine the impact of discharging coal seam gas water into a river are:

1. Identify the hazards related to the disposal of coal seam gas water. This requires an understanding of the hydrological characteristics of the receiving environment.
2. Select ecological assets, which represent the ecological values of the system, to be used as indicators of hydrological alteration of the flow regime. Knowledge of biota relying on aspects of the flow regime needs to be considered when discharging large volumes of water.
3. Develop coal seam gas water disposal scenarios using existing knowledge on discharge volume and timing.
4. Analyse the potential risks associated with disposal of coal seam gas water.
5. Characterise the risks and incorporate this into the management framework. The seasonality and timing of flows must be explicitly considered.

The method adopted in this report provides a high level assessment for each of these steps using the information that was available for the sites. The guidelines recommend that decisions are based on system-specific knowledge of the ecological flow dependencies of the receiving environment. Flow regime changes should be explicitly expressed in terms of facets of the flow regime (i.e. magnitude, timing and rate of change). Any non-flow related impacts should also be identified. Given the current gaps in flow-ecological response relationships, and the need to consider the site-specific conditions, an adaptive management approach to managing coal seam gas water discharge is proposed.

3 Spells analysis

A spells analysis has been undertaken on the hydrologic regimes for the gauged flow data at sites near the proposed coal seam gas water discharge points. The spells analysis has been used to describe and characterise the flow regime in the stream systems near the proposed coal seam gas water discharge points. For the purpose of this investigation, and based on the absence of specific flow criteria, the following flow components have been adopted:

Cease to flow:	Zero flow
Low season base flow:	Flow that is exceeded on 80% of days in the low flow season
High season base flow:	Flow that is exceeded on 80% of days in the high flow season
Low season low fresh:	Flow that is exceeded on 20% of days in the low flow season
High season low fresh:	Flow that is exceeded on 20% of days in the high flow season
Low season high fresh:	Flow that is exceeded on 5% of days in the low flow season
High season high fresh:	Flow that is exceeded on 5% of days in the high flow season
Bankfull event:	2 year ARI flow

3.1 Bottle Tree Creek at the CGPF2 property

The receiving environment of discharge from the CGPF2 property is Bottle Tree Creek. The CGPF2 property is located approximately 7 kilometres upstream of Bottle Tree Creek's confluence with Dogwood Creek. The catchment upstream of the survey site is approximately 400 km^2 of predominantly agricultural land (Figure 2).

Only one significant hydraulic structure exists within the model extent. This structure is a dam on the west side of Bottletree Creek, within the area of interest.

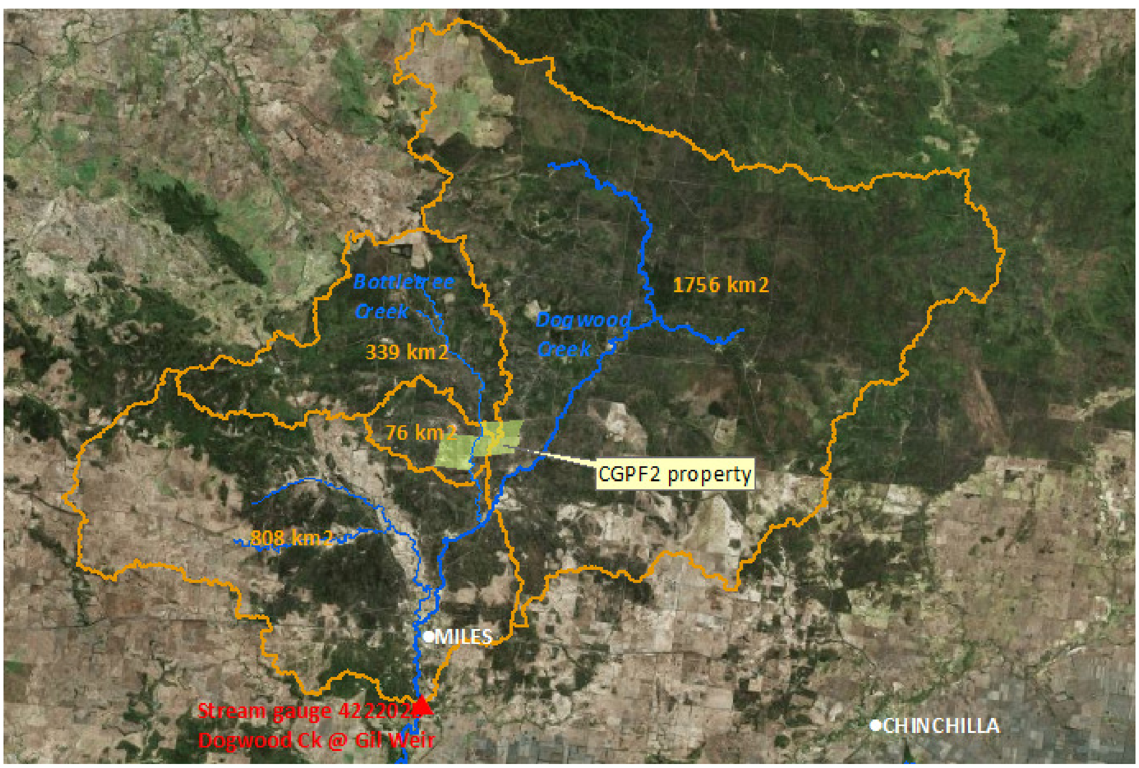

Figure 2. *CGPF2 property and catchment*

Geomorphology

Bottle Tree Creek is stable and is generally characterised by a single thread sand bed channel. Condition issues are generally associated with the upper bank and consist of some localised erosion of the sand banks either through slumping or removal of trees during floods, and some minor gullying on sections of Bottle Tree Creek through the CGPF2 property (Alluvium 2013).

Potential geomorphic and hydrologic issues that have been identified from discharging coal seam gas water at the CGPF2 property include:

- Increased bed and bank erosion in Bottle Tree Creek and downstream into Dogwood Creek .
- Slumping at the toe of banks in sandy soils if discharges were immediately ceased.
- Changed hydrology in Bottle Tree Creek and downstream into Dogwood Creek.
- Reduced crossing access on private properties along Bottle Tree Creek and Dogwood Creek.

Hydrology

There are no streamflow gauges located on Bottle Tree Creek. The closest gauge (422202B) is approximately 14 kilometres downstream of the Dogwood Creek and Bottle Tree Creek confluence at Gilweir (Figure 2).

The gauge at Gilweir (422202B) has a number of limitations for use in this study that need to be considered:

- <u>Flows will be significantly higher</u> at this site than at the site of CGPF2 due to the inclusion of flows from Dogwood Creek and its other tributaries. The total catchment area to the gauge is approximately 3,000km^2 compared with only 400 km^2 to the study site.

  Despite the difference in magnitude, this is currently the best available streamflow data for assessing the flow variability. A more thorough approach would be to develop a continuous rainfall-runoff model for the catchment, however this is considered beyond the scope of this project.

- <u>Issues with the rating curve</u> at this site were identified by Water Technology (2011) and can be summarised as:
  - Stream gauging finishes 1.71 metres below the top of bank
  - Peak water levels have been recorded about 1.0 metre above the top of bank
  - DERM has advised that the highest stream gauging may be incorrect due to an error on the hydrographers' part and the discharge for this gauge should be doubled
  - The weir crest was raised in 1995 (by 2.7 metres).

  The issues associated with the rating curve relate mostly to high flows where fewer data records are available. For this study, low and cease to flow periods are more important since the increase in stream flow due to coal seam gas water discharges will be most significant when natural flow is low. Consequently the impact on the environment of coal seam gas water discharges will be most significant during low flows. During high flows, the volume of coal seam gas water being discharged will form a relatively small proportion of the total flow volume and therefore is expected to have a relatively small impact on the ecological processes. Flooding impacts will be important during high flows, however an assessment of flooding has been undertaken separately for this EIS. For this report, it is therefore considered adequate to use the gauge at Gilweir despite the known issues with the high flow record.

  The highest flow used in the analysis is the 2 year ARI flow. If there are any errors in this 'higher flow' data we can assume (from Water Technology's assessment) that the reported flow is an underestimate of the actual flow. This will provide a conservative assessment of the impact of discharging coal seam gas water on the 2 year ARI flow (since if the 2 year ARI flow is underestimated the discharge volume will be a greater proportion of the stream flow).

- There are a number of gaps in the historic streamflow record, some of which are significant and could not be infilled. Streamflow records at the site commenced on 15 October 1949, although 10% of days have missing, or un-rated data. Small gaps were infilled by interpolation. Due to large gaps, nine years were omitted from the time series analysed (1965, 1972, 1973, 1980, 1992, 1993, 1994, 1995 and 2012).

In undertaking this assessment we have assumed that the historic flow data at Gilweir is representative of the flow magnitude and variability experienced naturally at this site.

Climatic condition

The flow regime in Dogwood Creek has been considered in this study for four prevailing climatic conditions. The climatic conditions represent the four quartiles of the flow record on an annual basis. That is:

- Drought year – years where the total annual flow is in the bottom 25% of years
- Dry years – years where the total annual flow is exceeded in 50-75% of years
- Average Years – years where the total annual flow is exceeded in 25-50% of years
- Wet Years – years where the total annual flow is exceeded in 25% of years.

The annual flow totals used for determining the 'climatic condition' were based on a water year starting on the first of January. Commonly in hydrological analyses the water year is defined as starting on the first of July, however this is not considered appropriate for this study given that July is midway through the low flow season for Dogwood Creek (refer seasonality section below) when ecological risks are likely to be more significant. By adopting a water year starting on first of January, low flow "events" (such as cease to flow events) are less likely to be split between two water years.

The median annual flow in Dogwood Creek at Gilweir is 31.2 GL, the 25th percentile annual flow is 7.9 GL and the 75th percentile annual flow is 85.3 GL. The available data were categorised into the climatic conditions as displayed in Figure 3.

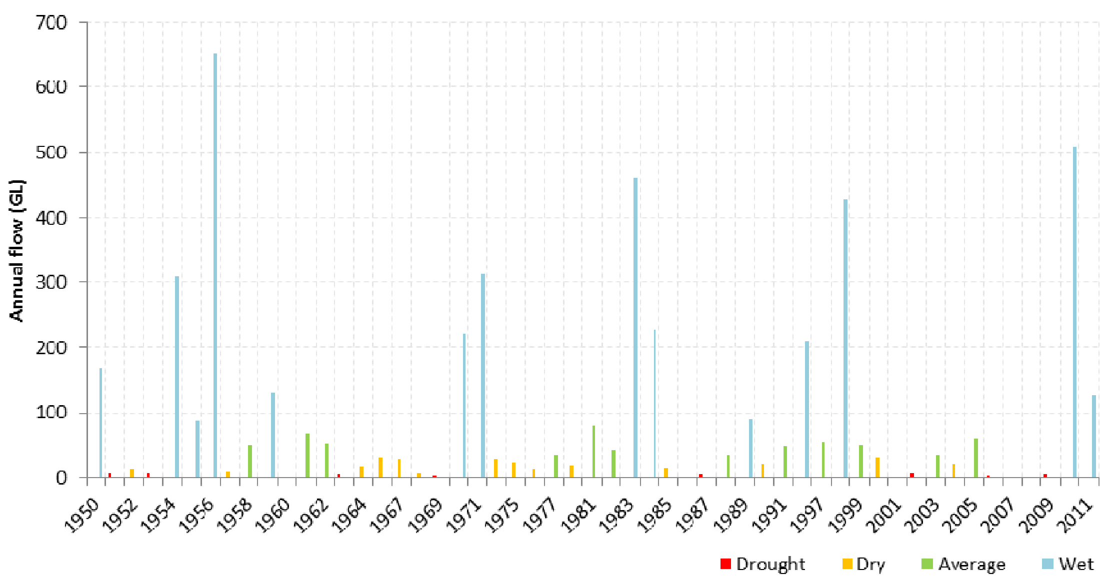

Figure 3. ***Annual flows – Dogwood Creek at Gilweir***

Seasonality

The annual flow regime can be divided into two seasons, not entirely related to the calendar seasons, but determined by changes in the characteristics of the natural flow regime:

- a ***low flow season***: generally extended periods of low flows driven mostly by base flow– or periods of no flow, called cease-to-flow periods – with infrequent shorter periods of high flow – freshes – caused by small localised rainfall events.
- a ***high flow season***: higher base flow with frequent, sometimes extended, periods of higher flows from larger and more widespread storms.

Identifying when the low and high flow seasons occur is somewhat arbitrary, but a method that has been used is to perform a frequency analysis on monthly flow data in each month. In this method, the percentage of individual daily flows in each month that lie within a number of particular flow bands is calculated. The most frequent flow bands and the distribution of frequent flows can be used to identify the characteristics of the various flow seasons.

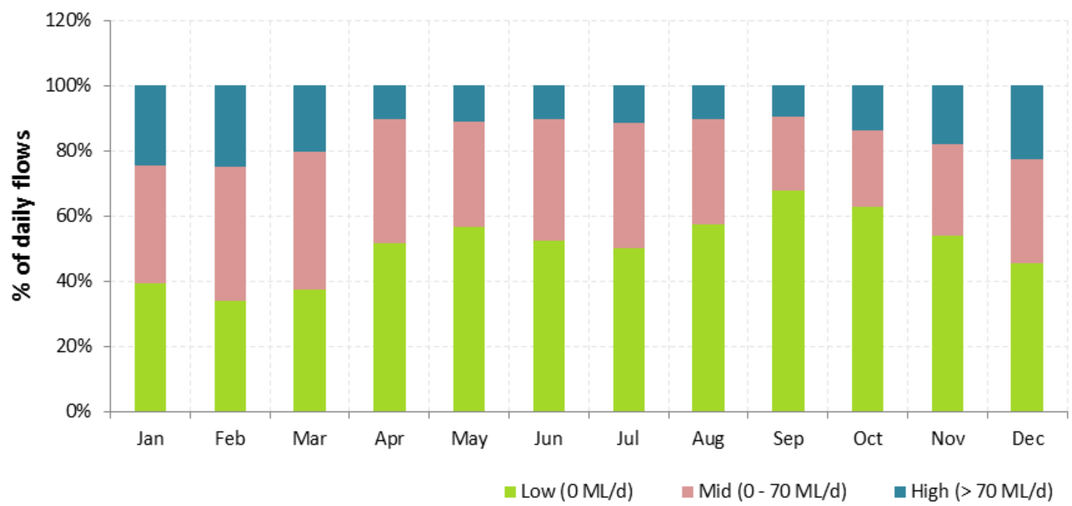

Figure 4. *Proportion of daily flows in Dogwood Creek in low, mid and high bands*

From this analysis, a long low flow season and shorter high flow season in Dogwood Creek has been identified (Table 3). The flow pattern is characterised by:

- From March to November there is a constant high proportion in the lower flow band (and constant proportions in the upper flow bands as well). These are the *low flow season* months.
- From December to February there is a constant high proportion in the upper flow band (and constant proportions in the lower flow bands as well). These are the *high flow season* months.

Table 3. Flow seasons for the Dogwood Creek at Gilweir

Flow season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Low flow season			■	■	■	■	■	■	■	■	■	
High flow season	■	■										■

During different climatic conditions (i.e. wet, average, dry and drought years), the start of flow seasons may differ. For the purpose of this study it was considered adequate to use a single high and low flow season.

Spells analysis

The spells analysis for the Dogwood Creek at Gilweir was undertaken initially for all years with available flow data. Subsequently the data was separated into the different climatic conditions so that the spells analysis could be performed for each condition.

The results of the spells analysis for all years of flow data found the existing flow regime in Dogwood Creek at Gilweir is comprised of the following components:

- Cease to flow lasting on average for about half the low flow season (73 days), and a month of the high flow season
- Low freshes (flow exceeded 20% of the time) of 20 ML/d occurring on average 3-4 times and lasting for 15 days during the low flow season and of 83 ML/d occurring on average 1-2 times per high flow season and lasting for 10 days.
- High freshes (flow exceeded 5% of the time) of 1,292 ML/d occurring on average 1-2 times per high flow season and lasting for 4 days
- Bankfull flow (2 year ARI) of 12,275 ML/d occurring once every 2 years and lasting for on average 3 days

Note that there is no baseflow in either the high or low flow season due to the flow exceedance on 80% of days equalling zero (i.e. there is no flow on more than 20% of days in both seasons).

Results of the spells analysis for Dogwood Creek at Gilweir under each of the climatic conditions (drought, dry, average and wet years) are presented in Table 4. The components remain the same with the exception of baseflows which are introduced in wet years (1 ML/d during the low flow season and 1.9 ML/d during the high flow season

Table 4. Dogwood Creek Gilweir (CGPF2 property receiving environment) spells analysis

		LOW FLOW SEASON *Mar – Nov*					**HIGH FLOW SEASON** *Dec - Feb*				
		Flow (ML)	# per season	average duration (days)	Total duration (days)	Median duration (days)	Flow (ML)	# per season	average duration (days)	Total duration (days	Median duration (days)
DROUGHT	Cease to flow	0	1.8	145	256	152	0	2.5	25	62	20
	Flow exceeded 80% of the time	0					0				
	Flow exceeded 20% of the time	0					5.2	2.4	8	18	6
	Flow exceeded 5% of the time	0.7	1.4	10	14	8	91	1.5	3	5	2
DRY	Cease to flow	0	3.4	49	167	17	0	2.1	20	42	19
	Flow exceeded 80% of the time	0					0				
	Flow exceeded 20% of the time	8.6	4.8	11	54	8	43	2.1	9	18	8
	Flow exceeded 5% of the time	80	2.6	5	14	4	607	1.3	4	5	3
AVERAGE	Cease to flow	0	2.7	61	162	32	0	2.5	16	40	11
	Flow exceeded 80% of the time	0					0				
	Flow exceeded 20% of the time	13	4.3	13	55	10	90	3.3	5	18	3
	Flow exceeded 5% of the time	158	2.6	5	14	4	1,359	1.8	3	5	2
	2 year ARI	12,275	0.1	1	0	1	12,275	0.3	1	0.3	1
WET	Cease to flow	0	1.3	35	44	15	0	0.8	11	10	9
	Flow exceeded 80% of the time	1	3.6	72	257	24	1.9	3.2	27	84	18
	Flow exceeded 20% of the time	104	6.0	11	64	7	925	3.2	7	21	5
	Flow exceeded 5% of the time	1,153	3.5	5	16	4	10,858	1.5	4	5	4
	2 year ARI	12,275	0.9	3	3	3	12,275	1.5	3	5	3
ALL YEARS	Cease to flow	0	2.1	73	156	21	0	1.3	27	35	12
	Flow exceeded 80% of the time	0					0				
	Flow exceeded 20% of the time	20	3.6	15	55	7	83	1.8	10	18	7
	Flow exceeded 5% of the time	256	2.5	6	14	3	1,292	1.1	4	5	3
	2 year ARI	12,275	0.3	3	1	3	12,275	0.3	3	1	3

Note: Greyed sections identify the absence of flow for flow component e.g. base flows (flow exceeded 80% of the time) in average year low flow season.

3.2 Condamine River at the CGPF9 property

The CGPF9 property is located on the Condamine River upstream of the Cecil Weir. The site is a short distance upstream of where the Condamine River North Branch reconnects with the main river. The upstream catchment area is approximately 7,753 km^2 (Figure 5). There are a number of weirs and dams located in the catchment, including Leslie Dam (106 GL) which supplies irrigation and town water supply (to Warwick and Cecil Plains) and Talgai Weir (0.64 GL).

Crawlers Creek is a tributary which passes through the western part of the CGPF9 property, and discharges into the Condamine River upstream of Cecil Weir. Flow conditions through the site have been altered by the weir.

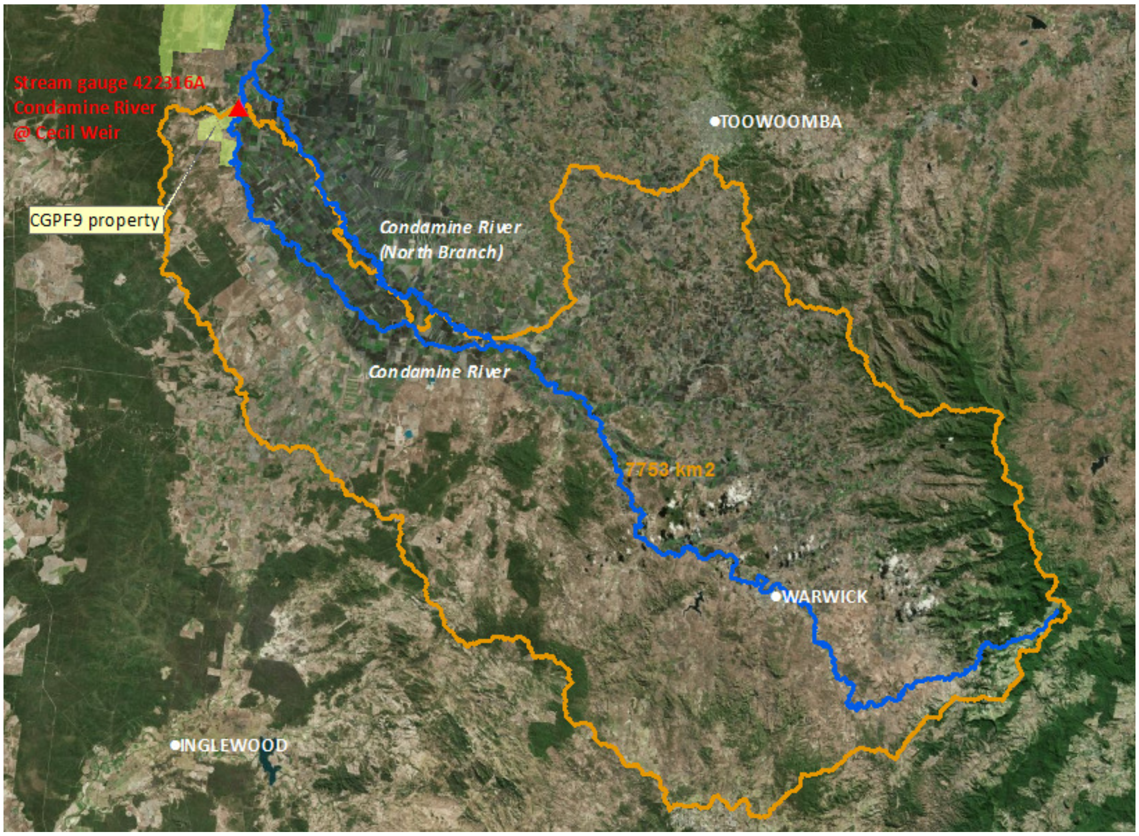

Figure 5. *CGPF9 property and Upper Condamine Catchment*

Geomorphology

The Condamine River is the major watercourse running south to north through the CGPF9 property. Overall the Condamine River is laterally active as it meanders across the broad floodplain. The Cecil Weir is at the downstream end of the CGPF9 property boundary, which provides some stability to the reach. However, overall there is low stability, with extensive gullying through Reach 1 and active meander migration with several meander cut-offs (Alluvium 2013).

There are a number of palustrine wetlands within the discharge receiving environment of the CGPF9 property, however, these are within the 1% AEP flood extent and are not expected to be disturbed by project activities. There is a palustrine wetland downstream from the CGPF9 property on the right floodplain of the Condamine River, approximately 600 m downstream from the Toowoomba-Cecil Plains Road bridge. This is located in an area of the Condamine River undergoing active lateral adjustment, with significant bank erosion occurring near the downstream end of the wetland. At this point, the current distance between the wetland and the Condamine River is approximately 25 m (Alluvium 2013).

The discharge of coal seam gas water at the CGPF9 property is not expected to have any adverse geomorphic impacts on the Condamine River upstream of Cecil Plans as the back-pooling from the weir controls flow and maintains a stable channel and floodplain condition. Geomorphic issues that have been identified from discharging coal seam gas water at the receiving environment of the CGPF9 property include:

- Any infrastructure proposed which may impact upon Crawlers Creek needs to consider the risk of increased run-off, which could exacerbate existing instabilities. As this creek is currently undergoing geomorphic adjustment in response to current land condition and flood flows, it is inherently unstable. Concentration of overland flows from project infrastructure or the discharge of treated or untreated coal seam gas water could exacerbate existing erosion unless significant erosion control management works were implemented.
- Increased and prolonged increases in current flows from the discharge of coal seam gas water could increase already occurring erosion at a number of locations downstream from the CGPF9 property.
- The flood channel linking the Condamine River and the Condamine River (North Branch) could experience increased bank erosion if flows in this channel are increased.
- The palustrine wetland downstream from the CGPF9 property is located in an area of the Condamine River undergoing active lateral adjustment, with significant bank erosion occurring near the downstream end of the wetland. Erosion could continue to proceed towards the wetland, compromising the wetland. This process could be exacerbated by prolonged increases in current flows from the discharge of coal seam gas water.

Hydrology

While a number of streamflow gauges exist along the Condamine River, gauge 422316A (Cecil Weir gauging station) is immediately downstream of the CGPF9 property, located at the Cecil Weir (Figure 5), and therefore is the most appropriate record for assessing the historic flow behaviour at the site.

There are some gaps in the historic streamflow record at Cecil Weir. Records commenced on 31 October 1972, although 9% of days have missing, or un-rated data. Small gaps were infilled by interpolation. Due to large gaps, five years were omitted from the time series analysed (1994, 1995, 2002, 2003 and 2012).

It should be noted that the Condamine River system has been altered from its pre-European settlement condition including extraction for irrigation, land clearance, dams and drains. 53% of surface water in the catchment is diverted for use (mostly in private dams) (MDBA 2013). The opportunity for the release of treated and untreated coal seam gas water to more closely mimic its pre-European flows could be explored as a potential beneficial use.

An Integrated Quantity Quality (IQQM) model of the Condamine River under current and 'pre-European settlement' conditions would be useful for understanding the current and natural hydrology of the Condamine River.

Climatic condition

The existing flow regime of the Condamine River at Cecil Weir has been considered in this study for the same four prevailing climatic conditions used for Dogwood Creek (refer Section 0). Similarly to Dogwood Creek, the annual flow totals used for determining the 'climatic condition' in the Condamine River were based on a water year starting on the first of January.

The median annual flow in the Condamine River at Cecil Weir is 140.9 GL, the 25th percentile annual flow is 49.6 GL and the 75th percentile annual flow is 492.3 GL. The available data were categorised into the climatic conditions as displayed in Figure 6.

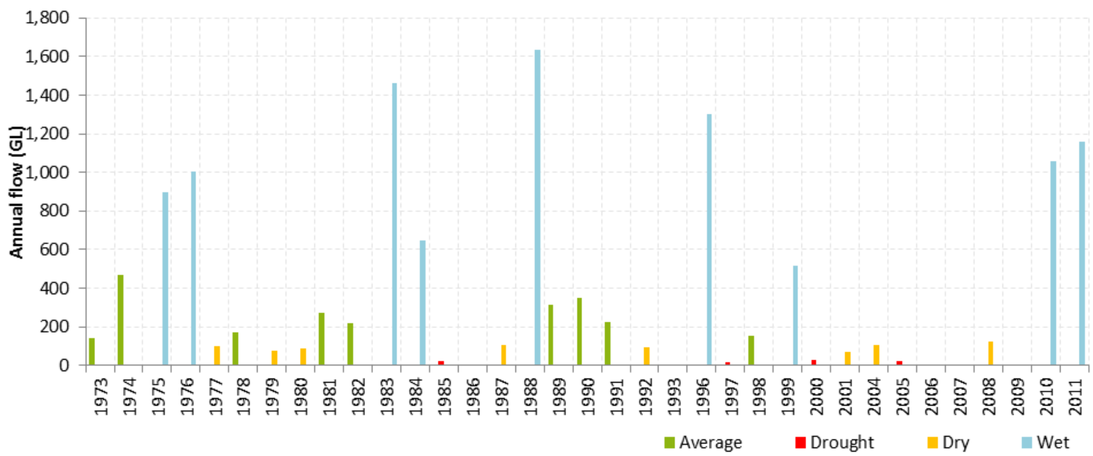

Figure 6. ***Annual flows – Condamine River at Cecil Weir***

Seasonality

The high and low flow seasons for the Condamine River at Cecil Weir were identified by analysing the flow record to determine the proportion of daily flows in each month which were zero, between zero and 510 ML/d and greater than 510 ML/d (Figure 7).

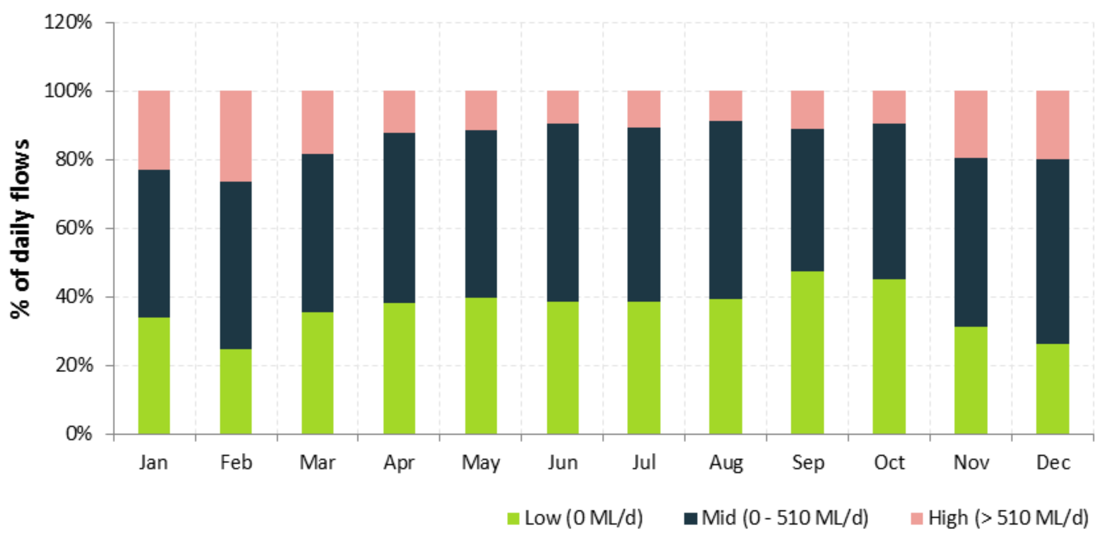

Figure 7. *Proportion of daily flows in Condamine River at Cecil Weir in low, mid and high bands*

From this analysis, a long low flow season and shorter high flow season in the Condamine River has been identified (Table 5). The flow pattern is characterised by:

- From March to October there is a constant high proportion in the lower flow band (and constant proportions in the upper flow bands as well). These are the *low flow season* months.
- From November to February there is a constant high proportion in the upper flow band (and constant proportions in the lower flow bands as well). These are the *high flow season* months.

Table 5. Flow seasons for the Condamine River at Cecil Weir

Flow season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Low flow season												
High flow season												

Table 5 represents the seasonality for all years of data. It is worth noting that when the flow record is separated into the four climatic conditions some different seasonality is observed. Figure 8 shows the mean monthly flows for each month under each climatic condition.

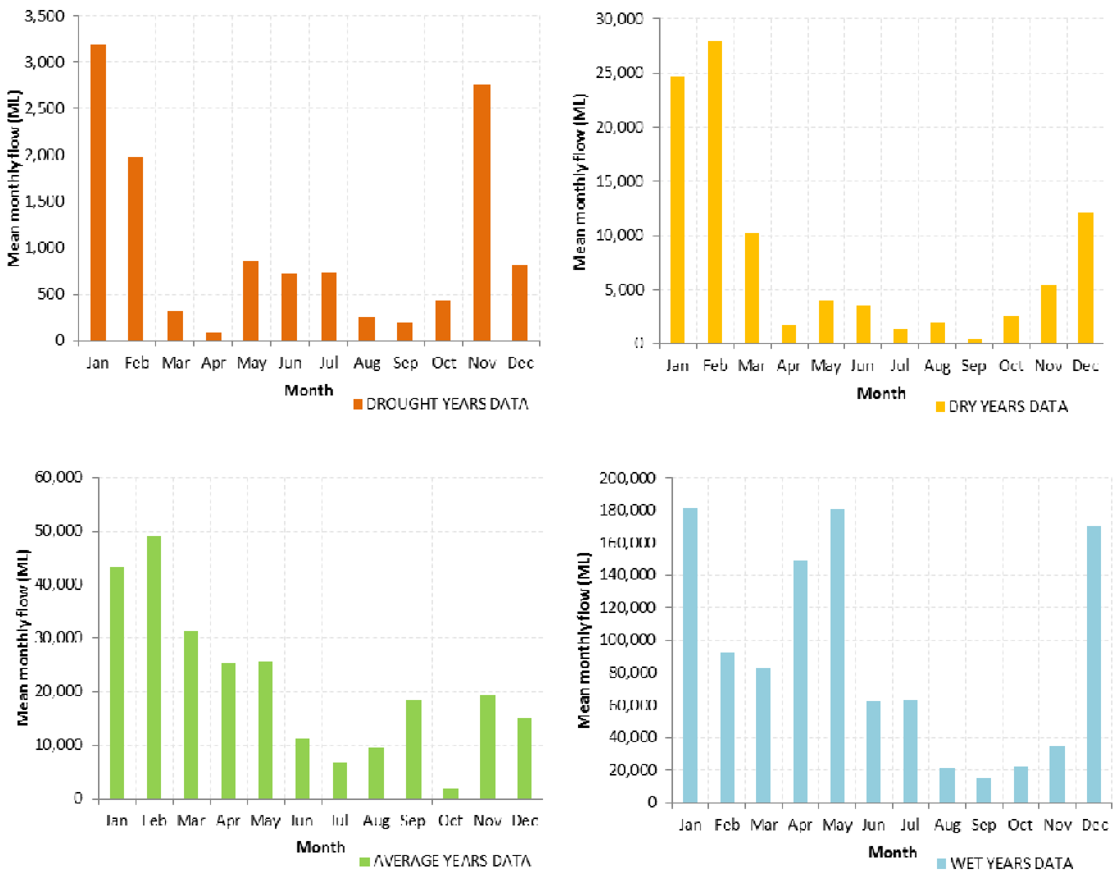

Figure 8. *Mean monthly flows in the Condamine River at Cecil Weir – by climatic condition*

In wet years April and May are clearly "high flow" months, despite being classified within the low flow season. The result of this anomaly is that the wet years baseflow (flow exceeded 80% of the time) was found to be higher in the defined low flow season (53 ML/d) compared with high flow season (21 ML/d). Separate seasonality for the different climatic conditions could be used to more accurately define the flow component magnitudes and ensure the wet years low flow season is adequately represented. For the purpose of this preliminary assessment it was decided to use a common seasonality for all climatic conditions in order to assist management decisions, while noting this anomaly around the wet season baseflow data.

Spells analysis

The spells analysis for the Condamine River at Cecil Weir was undertaken initially for all years with available flow data. Subsequently the data was separated into the different climatic conditions so that the spells analysis could be performed for each condition.

The results of the spells analysis for all years of flow data found the existing flow regime in Condamine River at Cecil Weir is comprised of the following components:

- Cease to flow lasting on average for one month during the low flow season, and 16 days during the high flow season
- Low freshes (flow exceeded 20% of the time) during low flow season of 244 ML/d occurring on average 3-4 times per low flow season and lasting for 15 days and during high flow season of 425 ML/d occurring on average 3 times per high flow season and lasting for 8 days
- High freshes (flow exceeded 5% of the time) of 4,859 ML/d occurring on average 1-2 times per high flow season and lasting for 5 days
- Bankfull flow (2 year ARI) of 23,466 ML/d occurring once every 2 years and lasting for on average 4 days

Note that there is no baseflow in either the high or low flow season due to the flow exceedance on 80% of days equalling zero (i.e. there is no flow on more than 20% of days in both seasons).

Results of the spells analysis for Condamine River at Cecil Weir under each of the climatic conditions (drought, dry, average and wet years) are presented in Table 6.

Table 6. Condamine River at Cecil Weir (CGPF9 property receiving environment) spells analysis

		LOW FLOW SEASON *March - October*					HIGH FLOW SEASON *November - February*				
		Flow (ML)	# per season	average duration (days)	median duration (days)	Total duration (days	Flow (ML)	# per season	average duration (days)	median duration (days)	Total duration (days
DROUGHT	Cease to flow	0	3.0	61	12	183	0	3.1	24	14	73
	Flow exceeded 80% of the time	0					0				
	Flow exceeded 20% of the time	3.5	3.6	14	3	49	38	4.2	6	4	24
	Flow exceeded 5% of the time	83	2.4	5	7	12	222	1.8	3	3	6
DRY	Cease to flow	0	3.6	25	6	90	0	3.0	10	6	31
	Flow exceeded 80% of the time	0					0				
	Flow exceeded 20% of the time	83	4.0	10	5	42	312	4.4	5	4	21
	Flow exceeded 5% of the time	336	1.9	6	5	11	2,726	1.3	4	4	5
AVERAGE	Cease to flow	0	3.8	14	6	55	0	2.4	10	5	25
	Flow exceeded 80% of the time	0					0				
	Flow exceeded 20% of the time	302	4.7	11	4	49	583	3.6	7	6	24
	Flow exceeded 5% of the time	2,056	2.1	6	5	12	3,914	2.1	3	3	6
	2 year ARI	23,466					23,466	0.3	3	3	1
WET	Cease to flow	0	1.0	26	18	26	0	1.3	9	7	12
	Flow exceeded 80% of the time	53	3.7	53	18	196	21	4.0	24	12	96
	Flow exceeded 20% of the time	843	5.8	8	5	49	1,808	3.6	7	3	24
	Flow exceeded 5% of the time	6,008	2.4	5	4	12	16,772	1.2	5	5	6
	2 year ARI	23,466	1.0	6	5	6	23,466	1.2	4	3	5
ALL YEARS	Cease to flow	0	3.0	30	7	91	0	2.3	16	6	36
	Flow exceeded 80% of the time	0					0				
	Flow exceeded 20% of the time	244	3.4	15	6	49	425	3.1	8	4	24
	Flow exceeded 5% of the time	1,632	2.0	6	5	12	4,859	1.3	5	3	6
	2 year ARI	23,466	0.3	5	5	2	23,466	0.5	4	3	1

Note: Greyed sections identify the absence of flow for flow component.

4 Workshop assessment

The third component of the environmental flows assessment was the convening of a workshop of environmental professionals in the fields of geomorphology, water quality, aquatic ecology and riparian vegetation together with Coffey Environments Surat Gas Project EIS specialists. The workshop was convened on Wednesday 15th May at Coffey Environments' office in Brisbane. The attendees were:

Attendee	Organisation	Areas of expertise
Jason Carter, Ross Hardie	Alluvium	Geomorphology, hydrology, environmental flows assessment
Greg Vinall, Tim Howell	AMEC	Aquatic ecology
Martine Adriaansen, Paul Godfrey	NRA	Water quality
David Stanton	3D Environmental	Riparian, terrestrial vegetation and land use
Barton Napier, Stephan Gabas, Cheryl Crumblin, Thomas Wiltshire, Tania Kenyon	Coffey Environments	Surat Gas Project EIS specialists

The purpose of the workshop was to identify potential environmental impacts of discharging coal seam gas water from the CGPF2 and CGPF9 properties and rank their risks to formulate an acceptable deviation from the natural flow regime.

4.1 Baseline assumptions

A number of assumptions were applied as input to the assessment as follows:

1. There are two proposed locations for discharges – CGPF2 property (Bottle Tree Creek/Dogwood Creek) and CGPF9 property (Condamine River).
2. The water treatment plants will have the following nominal capacities – 35 ML/d at the CGPF2 property and 90 ML/d at the CGPF9 property.
3. Alternative uses are being investigated by Arrow, which might result in not all of the above volumes being required to be discharged to watercourses.
4. The actual volumes of water to be discharged are expected to vary throughout the year depending upon other uses and gas production.
5. For the purposes of this assessment, the nominal water treatment plant capacities will be assumed to be the upper discharge limits, although, it is acknowledged that the spells analysis may indicate higher flows are possible where they mimic existing conditions and events.
6. The potential to transfer water between the CGPF2 and CGPF9 properties, if required, introduces a degree of flexibility in the timing, volume and duration of discharges.
7. The total lifespan of the project is not yet confirmed and may vary depending upon demand and the ability to extract gas, which due to developing technology may enable the project lifespan to extend beyond the currently projected 30 years.

4.2 Identification of risks and opportunities associated with discharges

Risks

A number of risks to watercourse geomorphology, hydrology, water quality, aquatic ecology and land use were identified in relation to the discharge of coal seam gas water. The risks vary in magnitude in relation to the volume and duration of releases and include:

- Mobilisation of bed and bank material thereby inducing erosion.
- Sudden drawdown of water levels inducing slumping in saturated banks.
- Changes in a range of physical and chemical water quality parameters.
- Increased growth and/or death of riparian and/or aquatic vegetation, favouring some native and/or exotic species. Increased growth could lead to some geomorphic changes including trapping of sediment, reduced channel capacity and channel migration.
- Changes in the composition of all aquatic communities from primary producers (such as phytoplankton) through to high order vertebrate consumers/predators (such as fish, turtles and mammals).
- Changes in the ecosystem processes that support aquatic communities.
- Potential to facilitate the colonisation and/ or the expansion of opportunistic species, particularly European carp, *Cyprinus carpio*.
- Potential reduction of crossing opportunities for landholders, particularly bed level crossings.

Opportunities

While there are a number of identified risks there are also some potential opportunities, which include:

- Ability to vary discharges to more closely mimic natural flow variations. It is recognised that the systems have been altered through various human uses and the ability to increase flows and create a flow regime that more closely replicates the pre-European settlement flow regime may provide an environmental benefit.
- The discharge of water could offset current extractions from watercourses for consumptive uses.

4.3 Discussion and guidelines for acceptable discharges

Taking into account the baseline assumptions and the identified risks and opportunities the workshop participants reviewed the results of the spells analysis and developed an agreed set of guidelines as input to the development of an operating strategy for the discharge of coal seam gas water. Those guidelines and the workshop outcomes are as follows:

1. The protection of geomorphic values (natural rates of sedimentation and erosion within the acknowledged currently altered systems) will, partially assist with the protection of aquatic ecology and riparian vegetation values in the subject streams
2. The replication or approximation of the pre-European settlement flow regime may provide an environmental benefit. Using the spells analysis developed for this assessment a baseline range of releases can be developed (see Section 3 for specific details).
3. A 20% deviation from the current condition flow metrics identified in the spells analysis was considered by the workshop participants to represent an acceptable level of deviation that would limit the extent of adverse impacts on ecosystem function in the subject watercourses. This is based, in part, on experience gained in environmental flow studies undertaken for the Murray-Darling Basin. However, given the lack of site specific information available, this 20% deviation from the existing conditions should be considered as a basis for further development of the proposed arrangements and should be the subject of adaptive management a suitably designed aquatic ecology monitoring program.

4. Pending more detailed analysis a maximum 20% deviation from the current condition flow metric could be adopted as a basis for further development of the proposed Coal Seam Gas water discharge strategy.

The results of the spells analysis and workshop discussion for Dogwood Creek at Gilweir and the Condamine River at Cecil Weir can be used to understand the existing flow regime at the CGPF2 and CGPF9 properties receiving environments. This understanding can be used to provide a basis for discussions to determine acceptable volumes timing and duration of coal seam gas water which may be discharged at these sites, on the basis that a 20% deviation from current flow conditions taking into account replication of natural flow components is not expected to result in significant adverse impacts on watercourse geomorphology, water quality and aquatic ecology.

It should be noted that this assessment has been based only on hydrologic data. The assessment;

- does not identify whether any of the proposed modifications or existing arrangements are near an existing physical threshold. The identification of such thresholds should be the subject of a more detailed assessment that should be undertaken prior to the release of discharges.
- has not used long term natural flow series data for the subject sites. As a consequence the assessment identifies current flow conditions. It is recommended that a more detailed assessment consider deviations from both current and natural flow regimes for the subject sites.

4.4 Management options

The management options available to Arrow to achieve compliance with the guidelines for acceptable discharge were discussed at a high level in the workshop. It is understood that Arrow will comply with legislative requirements when considering management options. Key constraints and opportunities that were identified and should be considered are outlined below.

Storage capacity
The ability to vary flow rates and durations will require onsite storage capacity due to the ephemeral and semi-permanent nature of the receiving watercourses that have drying and no flow periods. Estimates of storage volumes will be required to be developed as a component of plant design and the development of operating procedures.

Storage outlets
Discharges from storages will require the ability to vary flow rates to a range greater than daily production of 35 ML/d at the CGPF2 property and 90 ML/d at the CGPF9 property in order to benefit from the opportunity to discharge at high flow events and to increase storage capacity. The identification of upper limits and timing for discharges will require detailed assessment. Geomorphic and water quality assessments as part of the SREIS to date have assumed discharges at the nominated capacity of the water treatment facilities (plus some additional discharge rates as safety buffers), which are lower levels than those that may be required to provide greatest flexibility for operations.

Flexibility
The discharge strategy will need to be flexible and able to respond to real time changes in natural flows to take advantage of opportunities to discharge coal seam gas water at the same time as natural high flow events. This will enable increased dilution of discharge water and provide greater flexibility to maintain or increase dry spells.

Water quality
The discharged coal seam gas water will need to be of a quality that meets the water quality objectives and guideline values for protection of the environmental values (i.e., aquatic ecosystem and human use values) that have been nominated for the Surat Gas Project. An approach to deriving site-specific water quality guideline values and objectives is outlined in NRA 2013. The process of characterising the water quality of Bottle Tree/Dogwood Creek and Condamine River under baseline conditions will also inform the target water quality for the water treatment and disposal processes. It would be reasonable to have the ability to match the

natural variations in water quality of the receiving waters when discharging coal seam gas water. Site-specific guideline values should be calculated for different flow conditions recognising that water quality conditions may differ between high and low flows. The development of discharge arrangements should be based on dilution modelling if and as necessary to account for any slight differences between water quality within the receiving body and the discharges.

Storage design

There may be an opportunity to reduce the volume of water needing to be pumped into the streams by designing the storage with a pervious base to maximise seepage into shallow aquifers. This would also reduce the volume of water needing to be stored and potentially restore aquifer volumes. A detailed hydrogeological assessment would be required to determine whether this "leaky-dam" concept is feasible and will not result in any damage to the surrounding environment.

5 Next steps

The discharge guidelines described in Section 4.3 provide a basis for Arrow to develop operating arrangements, which will have an acceptable impact on the functioning of the receiving waters. Using the spells analysis, Arrow can now assess different operating arrangements to determine a preferred approach to the management of coal seam gas surface water discharges.

Further assessments will be required to confirm that the proposed arrangements are within an acceptable deviation from the natural flow and will not exacerbate existing flow stress prior to commencing releases. It is recommended that such assessments include:

- Development and extraction of current and 'natural' modelled flow data for the subject sites from an IQQM model and additional rainfall runoff modelling as required.
- Identification of specific flow criteria and related flow components, undertake hydraulic modelling to determine the magnitudes for each flow component with a more widely recognised level of accuracy, and link each of these to specific ecological objectives.
- Update of the spells analysis for the defined flows using the IQQM modelled flows.
- Definition of performance criteria for defined flows (spells).
- Development of operating rules using statistical analysis and ecological modelling to produce operating protocols.

The establishment of a monitoring and evaluation program is recommended to assess the impact of the discharge regime and to complement an adaptive approach to management. A suitable program could draw on elements of the MERI (Monitoring Evaluation Reporting and Improvement) framework.

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