GOVERNMENT OF
WESTERN AUSTRALIA

Browse LNG Precinct




Browse Liquefied Natural Gas Precinct
Strategic Assessment Report

(Draft for Public Review)
December 2010

Appendix C-23

Browse LNG Development: Browse Hydrology 2009 Study – Local Catchment Flood Study

woodside

BROWSE LNG DEVELOPMENT
Browse Hydrology 2009 Study
Local Catchment Flood Study

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BROWSE LNG DEVELOPMENT
Browse Hydrology 2009 Study

Prepared for:
Woodside Energy Ltd

11 March 2010

BG&E Ref: P09395/Report 04
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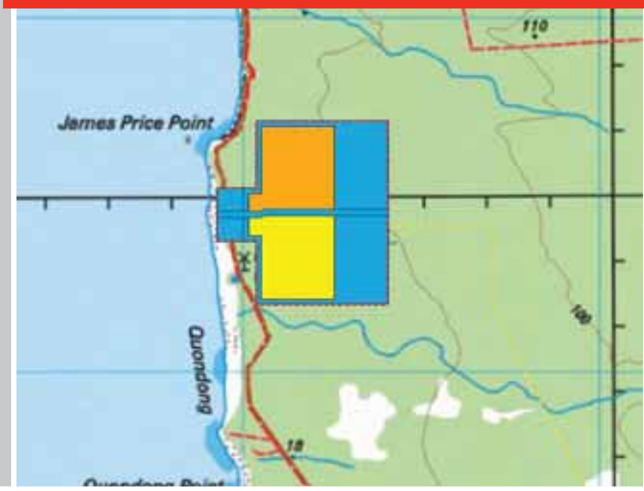
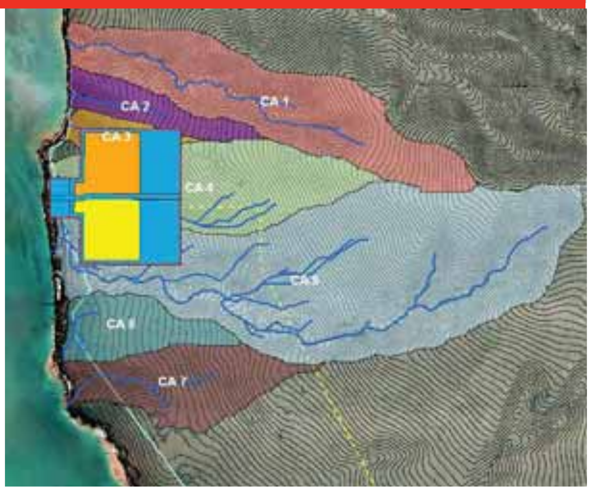
Local Catchment Flood Study





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EXECUTIVE SUMMARY

The desktop local catchment flood study in the vicinity of the proposed Kimberley LNG Precinct and surrounding infrastructure has concluded the following:

Catchment Delineation Review:

- The catchments and streamlines have been delineated electronically using the 10m point survey data provided by the client. These closely match the topographic based delineations provided by the client. A comparison of the two is provided in Appendix A.
- The catchments of greatest concern in regards to future design, both in terms of magnitude of flow and their location relative to the LNG Precinct, are catchments CA4 and CA5.

Flow Estimation Methods:

- Australian Rainfall and Runoff (AR&R) generally forms the current industry standard for hydrological design throughout Australia. The AR&R Kimberley region method is derived from data in the rocky East Kimberley region, and it is generally accepted that it overestimates flows in the sandy location of the proposed LNG Precinct in the West Kimberley.
- It is suggested by Main Roads WA Senior Waterways Engineer that reduction of AR&R design flows by a factor of approximately 3 will provide a reasonable basis for flood studies in the vicinity of the Kimberley LNG Precinct. It is anticipated that this method is to be published in the next revision of AR&R. It is currently used by Main Roads for hydrological assessments within the West Kimberley Region.
- In this study both factored and unfactored AR&R flows have been calculated to determine design flows. Flows have also been calculated using run-off routing models for comparison.

Preliminary Flood Study Outcomes

- Preliminary hydraulic models suggest that the proposed LNG Precinct layout is generally well positioned in terms of catchment hydraulics and drainage can be designed around it.
- Design of pad levels, flow diversion and rock protection systems may be required to the north east corner and southern face of the southern processing plant and to the south west corner of the northern processing plant.
- Lateral drainage along the eastern face of the Precinct may be required to divert sheet flow into the defined channels.

Future drainage design work and areas of analysis:

- Confirm drainage requirements for Precinct infrastructure with detailed hydraulic modelling. It is recommended that the Main Roads WA Modified AR&R method be adopted for the hydrologic assessment of all Regional and Local catchments.
- There does not appear to be defined catchment outlets, with flows accumulating to the east of the sand dunes rather than discharging into the ocean. It is possible that during high intensity storms the flow could accumulate faster than it infiltrates through the dunes, potentially flooding the western side of the Precinct. Further analysis is recommended once more information about the permeability characteristics of the dunes is known.
- This Report excludes consideration of the interaction between runoff and groundwater features. This should be further investigated subsequent to detailed geotechnical investigations.

CONTENTS

DOCUMENT CONTROL

DOCUMENT1

Revision	Date	Description	Prepared by	Reviewed by	Approved by
A	10/12/2009	For Internal Review	LJK	NPD	PJC
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1 INTRODUCTION

1.1 Scope of Local Catchment Flood Study

Woodside Energy Ltd has engaged BG&E Pty Limited (BG&E) to undertake a desktop local catchment flood study of the Regional and Local hydrological characteristics associated with the proposed Kimberley LNG Precinct in the vicinity of James Price Point (JPP) in the Kimberley Region of Western Australia.

This report presents a summary of the desktop study undertaken to determine the local and regional hydrology in the area of the LNG Precinct and in the vicinity of the supporting infrastructure. It includes:

- Electronic delineation of the local catchments within the LNG Precinct and supporting infrastructure and comparison to client provided delineation based on a topographic model.
- Discussion of the various hydrological methods within the Region and their limitations, both statistical and run-off routing.
- Estimation of design flows for various return intervals in increments up to the 2000 year ARI event.
- Indicative hydraulic analyses of local catchments and their relation to the proposed LNG Precinct location.
- Identification of probable drainage requirements and recommended areas of further hydraulic study.

This Report excludes the following:

- Site visit.
- Flood interaction with groundwater features (hydrogeology).

1.2 Reference Documents

Separate reports have been prepared by BG&E, relating to the general hydrology of the Pilbara and Kimberley region and the serviceability of the regional and local roads between Karratha, Broome, James Price Point and Curtin Airbase near Derby. The full list of Reports is presented in Table 1.1 below:

WEL Reference	Title	Author	BG&E Reference
JA6500RC0007	Browse LNG Development Browse Hydrology 2009 Study Regional Roads Access Serviceability	BG&E	P09395/Report 01
JA6500RC0008	Browse LNG Development Browse Hydrology 2009 Study Broome to James Price Point Access Serviceability	BG&E	P09395/Report 02
JA6500RC0009	Browse LNG Development Browse Hydrology 2009 Study Regional & Local Hydrology – LNG Precinct	BG&E	P09395/Report 03
JA6500RC0010	Browse LNG Development Browse Hydrology 2009 Study Local Catchment Flood Study	BG&E	P09395/Report 04

Table 1.1 Reference Documents

2 LNG PRECINCT LOCATION

2.1 Regional location

The proposed Kimberley LNG Precinct plant is located on the Indian Ocean coast of the Dampier Peninsula in the West Kimberley region of Western Australia.

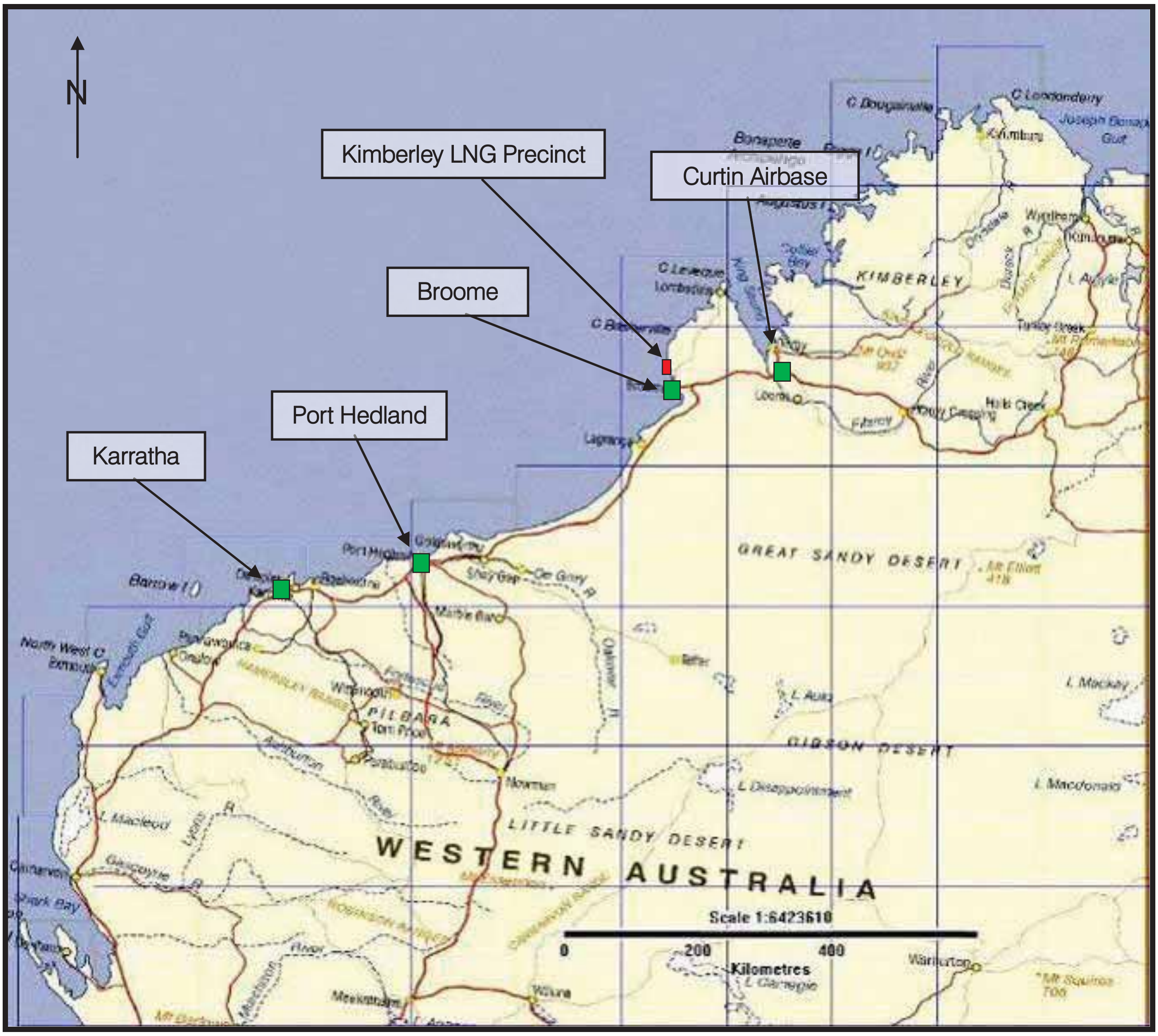


Figure 2.1 - Location of Kimberley LNG Precinct

3 HYDROLOGICAL ANALYSIS

3.1 General

Desktop hydrological analyses of the catchments were carried out to determine design flow estimates for a range of ARI's, based on consideration of the following methods:

- Australian Rainfall & Runoff (AR&R) 1987
  - Kimberley Region Rational Method
  - Kimberley Region Index Flood Method
- Runoff Routing Analysis using RORB software
  - Based on AR&R Kimberley Region parameters
  - Design storms for extreme event estimations developed from the CRC-FORGE extract.
- Discussions with Main Roads WA Waterways Section & Regional Offices
  - Modified AR&R methods for Kimberley Regions
  - Effects of soil types on runoff

Design flows have been conservatively calculated at the coast, assuming that the full area of each catchment contributes to the run-off. A summary of the flows for each method is provided in Appendix A.

3.2 Catchment Delineation

The catchments were delineated using the Digital Elevation Model (DEM) with 10m average contour spacing provided by the client using GIS based software. These catchments generally match the topographic based catchment delineation provided by the client, a comparison of the two is provided in Appendix A. The delineated catchments and their location relative to the current LNG Precinct layout are provided in Figure 3.1.

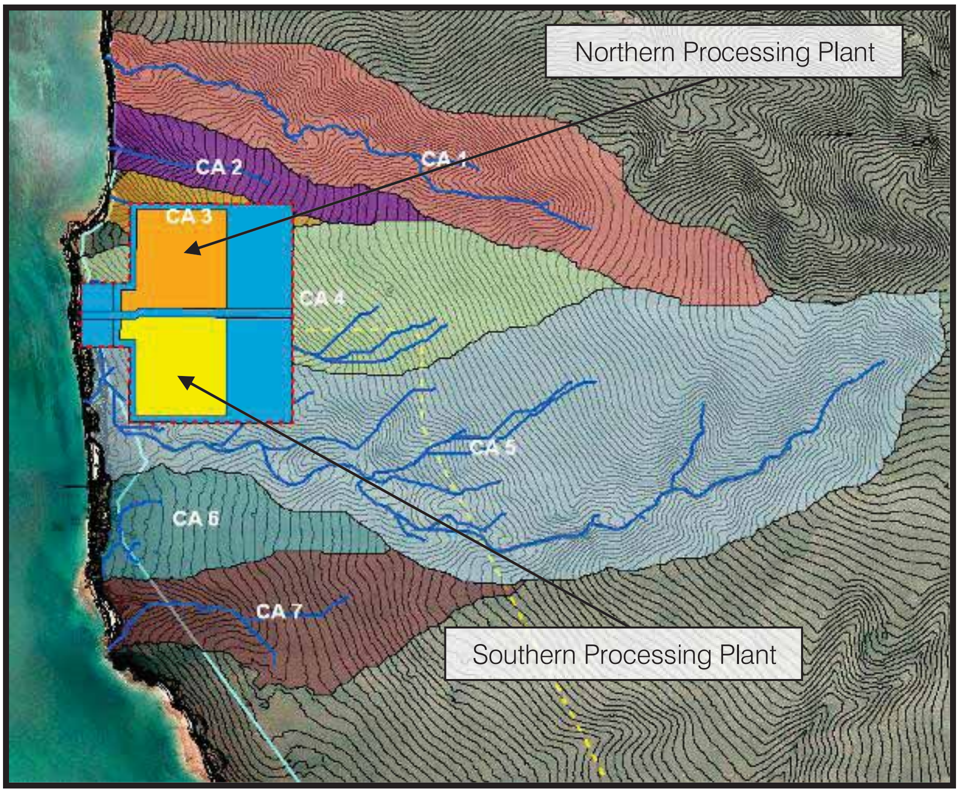


Figure 3.1 - Local Catchments and current LNG Precinct layout

The catchments of greatest concern, both in terms of their size and their location relative to the LNG Precinct are catchments CA4 and CA5.

3.3 Catchment Parameters

The hydrological parameters for each catchment are found within Table 3.1:

Parameter	Catchment						
	CA1	CA2	CA3	CA4	CA5	CA6	CA7
Area (km^2)	36	8	5	29	88	11	18
Main Stream Length (km)	15.9	5.9	3.6	10.2	22.3	5.7	7.1
Equal Area Slope (m/km)	8.4	13.3	12.4	9.2	5.8	7.1	8.6
Perimeter (km)	45	21	14	35	63	20	30
Annual Precipitation (mm/yr)	929	929	929	929	929	929	929

Table 3.1 – Browse LNG Precinct Catchment Parameters

An average annual rainfall of 929mm/year was adopted for the catchments based on consideration of various Bureau of Meteorology gauging stations close to the Precinct location. The gauging stations have between 7 and 69 years of record continuing to 2009. This is considered more accurate than the standard method of using the isohyets within AR&R as they are derived based upon data up to 1986 only. The gauging station locations and calculated annual rainfalls are provided within Appendix A.

Detailed discussion of the rainfall characteristics of LNG Precinct vicinity can be found within the BG&E Report Regional Hydrology (WEL ref: JA6500RC0009; BG&E ref: P09395 Report 03)

3.4 Australian Rainfall and Runoff (AR&R)

Design flows for the catchments have been estimated using procedures presented in Australian Rainfall and Runoff (AR&R) for the Kimberley region. These procedures are based upon statistical analysis of gauged catchments within the Kimberley Region and generally form the current industry standard for hydrological design throughout Australia.

AR&R presents two statistical flood frequency methods (Rational method and Index method) for the determination of design discharges for the 2, 5, 10, 20 and 50 Year ARI in the Kimberley Region. The methods are based on 17 catchments varying in area from 29.6 – 44900km^2, which compares to the local catchments near James Price Point which range from 5 – 88km^2. The AR&R formulae are derived from gauging station data up to 1986.

The AR&R Kimberley region method is based upon gauging stations solely within the East Kimberley region as there are no gauged rivers within the West Kimberley region. The soil properties, and therefore run-off characteristics, of the two regions varies significantly. The location of the catchments used to derive the AR&R Kimberley method and the soil properties of the region are shown in Figure 3.2:

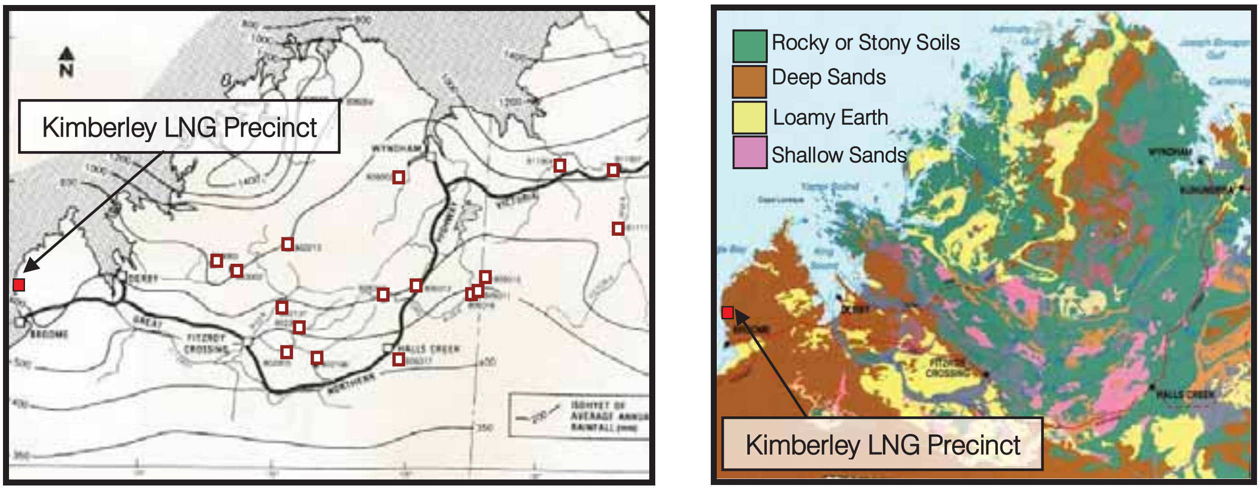


Figure 3.2 – Location of gauging stations used to derive AR&R (left) & Soil characteristics (right)

The West Kimberley region is comprised of deep sand soils, known locally as Pindan, compared with the eastern and northern Kimberley which has predominantly rocky and stony soil. These Pindan soils allow for a

greater infiltration rate than the rocky soils to the east and north. This will lead to a reduction in runoff and attenuation in peak discharge.

It is considered that the direct application of the AR&R Kimberley methods actually overestimate peak design flows by a magnitude of up to 2-3 for catchments within the West Kimberley Region.

It is suggested by Main Roads WA (MRWA) Senior Waterways Engineer that reduction of AR&R design flows by a factor of approximately 3 will provide a reasonable basis for flood studies in the vicinity of the Kimberley LNG Precinct, based upon their Pindan soil characteristics. The MRWA Waterways Section is currently updating their Regional methods, which includes dividing the East and West Kimberley Regions, for the next edition of AR&R. This is discussed in more detail in BG&E Report on Regional Hydrology.

For the purpose of this report both unfactored and factored (reduced using the MRWA modified AR&R methods) flows have been calculated for use in the preliminary hydraulic models and are given in Table 3.2.

3.5 Run-off Routing Analysis

Run-Off Routing analysis models were developed for each catchment using RORB Version 6.0 software. An initial / continuing loss model was adopted with storage and loss parameters for each model determined using the Kimberley Regional method for “sand over rock” outlined in AR&R.

The flows generated by the RORB models provide an alternative method with which to compare to the statistical AR&R flows. The models were also used to calculate the extreme flood events from the rainfall data extracted from the CRC-FORGE extract.

Storm patterns were generated for 4.5 to 72 hour storm events, using the RORB software with intensity, skew, geographic factors and temporal zones taken directly from AR&R. The flows generated by this method are shown in Appendix A and are generally slightly lower than the values generated using the unfactored AR&R Kimberley Region Method.

However, it is considered that use of Regional catchment parameters (eg modified loss coefficients to reflect West Kimberley soil types) would produce lower flows similar to the MRWA modified AR&R methods.

3.6 Extreme Flood Event Estimates

200, 500, 1000 and 2000 year ARI design flows were estimated using RORB run-off routing models with 24 hour duration storms generated using burst rainfalls extracted from the CRC-FORGE database, as per the recommendations in AR&R.

The RORB models were calibrated with two different parameter sets to match the factored and unfactored AR&R Kimberley method design flows, for 24 hour storm duration, in order to estimate the higher ARI flows. The flows generated by this method are shown in Table 3.2.

3.7 Design Flows

Table 3.2 shows the factored and unfactored AR&R Rational Method design flows (m^3/s) used in the hydraulic analysis:

Catchment	Method	Average Recurrence Interval (years)									
		2	5	10	20	50	100	200	500	1000	2000
CA1	AR&R	74	130	185	261	378	486	625	833	951	1119
	Mod AR&R	25	43	62	87	126	162	208	278	317	373
CA2	AR&R	34	55	74	100	138	178	224	299	356	415
	Mod AR&R	11	18	25	33	46	59	75	100	119	138
CA3	AR&R	29	46	61	82	112	146	183	248	280	328
	Mod AR&R	10	15	20	27	37	49	61	83	93	109
CA4	AR&R	72	124	175	245	351	445	558	745	1115	1287
	Mod AR&R	24	41	58	82	117	148	186	248	372	429
CA5	AR&R	123	226	332	484	717	894	1106	1440	2260	2688
	Mod AR&R	41	75	111	161	239	298	369	480	753	896
CA6	AR&R	43	70	96	129	180	231	291	376	429	503
	Mod AR&R	14	23	32	43	60	77	97	125	143	168
CA7	AR&R	57	96	133	183	258	328	411	546	653	760
	Mod AR&R	19	32	44	61	86	109	137	182	218	253

Table 3.2 AR&R and Modified AR&R derived flows for Local LNG Precinct Catchments

3.8 Design Life and Risk

The flood risk for a given project should be considered in the context of the probability of an event occurring over the design life of the project. For a long design life, the probability of an event occurring can be very high.

Table 3.3 shows the probability that a given ARI design flood will be exceeded within a given design life.

Time Period (years)	Average Recurrence Interval (years)									
	2	5	10	20	50	100	200	500	1000	2000
10	99.3	86.5	63.2	39.3	**18.1**	9.5	4.9	2.0	1.0	0.5
25	100.0	99.3	91.8	71.3	39.3	22.1	11.8	4.9	2.5	1.2
50	100.0	100.0	99.3	91.8	63.2	39.3	22.1	9.5	4.9	2.5
100	100.0	100.0	100.0	99.3	86.5	63.2	39.3	18.1	9.5	4.9

Table 3.3 Design Flood Exceedence Probabilities (%)

For example, this table shows that in a 10 year period there is an 18.1% chance of the 50 year ARI event occurring. For a longer period of 50 years, the probability of the 50-year ARI event occurring has risen to 63.2%.

4 HYDRAULIC ANALYSIS

4.1 General

The catchments of greatest concern, both in terms of magnitude of flow and their location relative to the LNG Precinct are catchments CA4 and CA5. Sections 4.2 and 4.3 below include preliminary hydraulic analysis of these catchments, outlining their run-off characteristics, identification of anticipated drainage requirements and areas of further hydraulic study.

The preliminary hydraulic models have been created without a site visit to record the site and associated hydrological characteristics. These initial models are considered suitable in determining locations requiring more detailed analysis in the future.

4.2 Catchment CA4

Catchment CA4 passes directly through the proposed LNG Precinct. It appears to have a relatively well defined channel along the southern edge of the catchment.

During a storm event precipitation to the northern and eastern parts of the catchment will move as sheet flow in a south westerly direction until it enters the defined channel. The flow will then move westwards within the channel accumulating at the sand dunes along the coast.

A drainage system will be required to provide lateral drainage around the eastern end of the Precinct in order to divert the sheet flow directly into the main channel.

A larger scale drainage system will then be required to allow the flow in the southern channel to pass through the Precinct. This is likely to consist of an excavated prismatic drainage channel. The east-west access road pavement in-between the northern and southern processing plants will need to be designed to accommodate this drainage requirement.

The estimated flow patterns and drainage paths are shown in Figure 3.1 below.

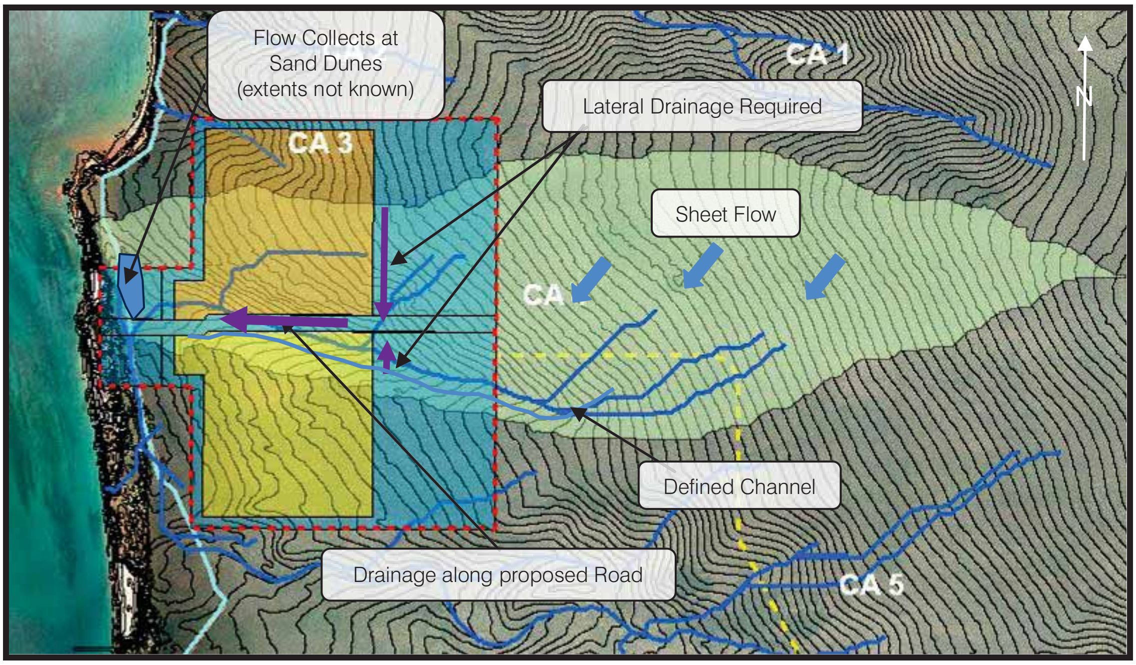


Figure 3.1 – Flow paths and drainage locations for Catchment 4

There does not appear to be a defined catchment outlet with flow accumulating to the east of the sand dunes rather than discharging into the ocean. It is possible that during high intensity storms the flow could accumulate faster than it infiltrates through the dunes, potentially flooding the western side of the Precinct. Further analysis of the drainage outlet is recommended subsequent to a more detailed geotechnical investigation.

It is also envisaged that the proposed drainage system through the LNG Precinct may alter the natural rate of discharge into this area. This may increase the risk of flooding due to accumulation at the sand dunes and should be accounted for during future analysis.

A preliminary one-dimensional steady state hydraulic model was developed for the defined channel within the Precinct location using HEC-RAS Hydraulic Modelling Software Version 4.0. This model is intended to provide an indicative estimate of flood extents of the natural section relative to the proposed LNG processing plants in order to determine potential areas of concern.

A Manning's roughness coefficient estimate of 0.06 was adopted for the whole model, based upon the aerial photography provided by the client and in accordance with the Austroads Waterways Design Guide.

The model was run for both the 100 and 2000 year ARI flood events for the design flows given in Section 3.6. Figure 3.2 below shows the extent of the conservative unfactored 2000 year AR&R flows relative to the proposed Precinct location. The extent of the other design flows are provided in Appendix B.

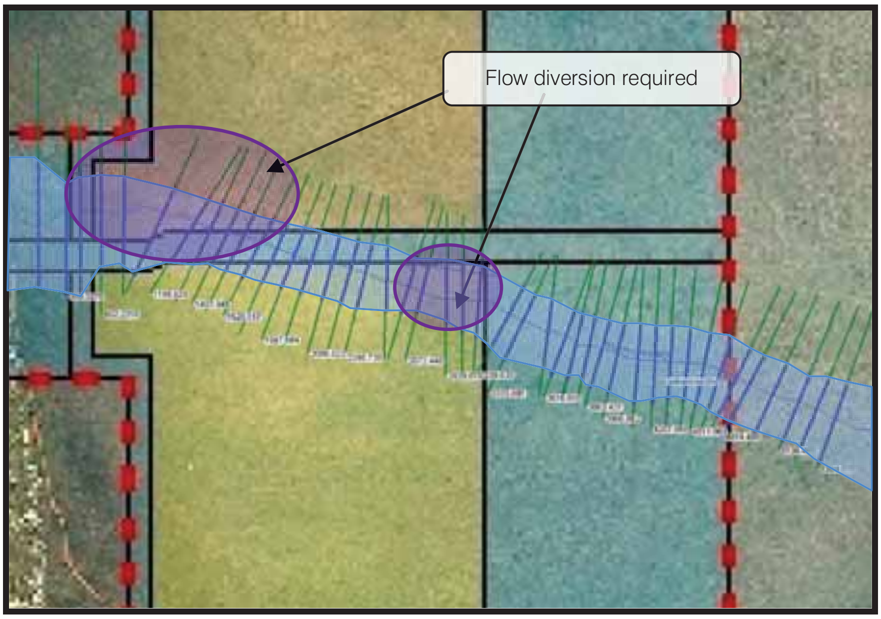


Figure 3.2 – Extent of the unfactored 2000 year ARI flow through the proposed LNG Precinct

The preliminary model indicates that the proposed LNG Precinct layout will require the design of pad levels and flow diversion systems to the north east corner of the southern processing plant and the south west corner of the northern processing plant in order to prevent flooding and erosion at these locations.

4.3 Catchment CA5

Catchment CA5 passes through the south of the proposed Precinct location and has a relatively well defined channel located to the south of the catchment, passing inbetween the southern processing plant and the 2000m industrial buffer zone. Figure 3.3 shows the layout of the streamlines relative to the proposed Precinct layout.

A drainage system will be required to provide lateral drainage around the eastern end of the Precinct in order to divert the sheet flow directly into the main channel. Diversion of the natural creek line around the south west corner of the northern processing plant is also required; this is confirmed in the preliminary hydraulic model, discussed below.

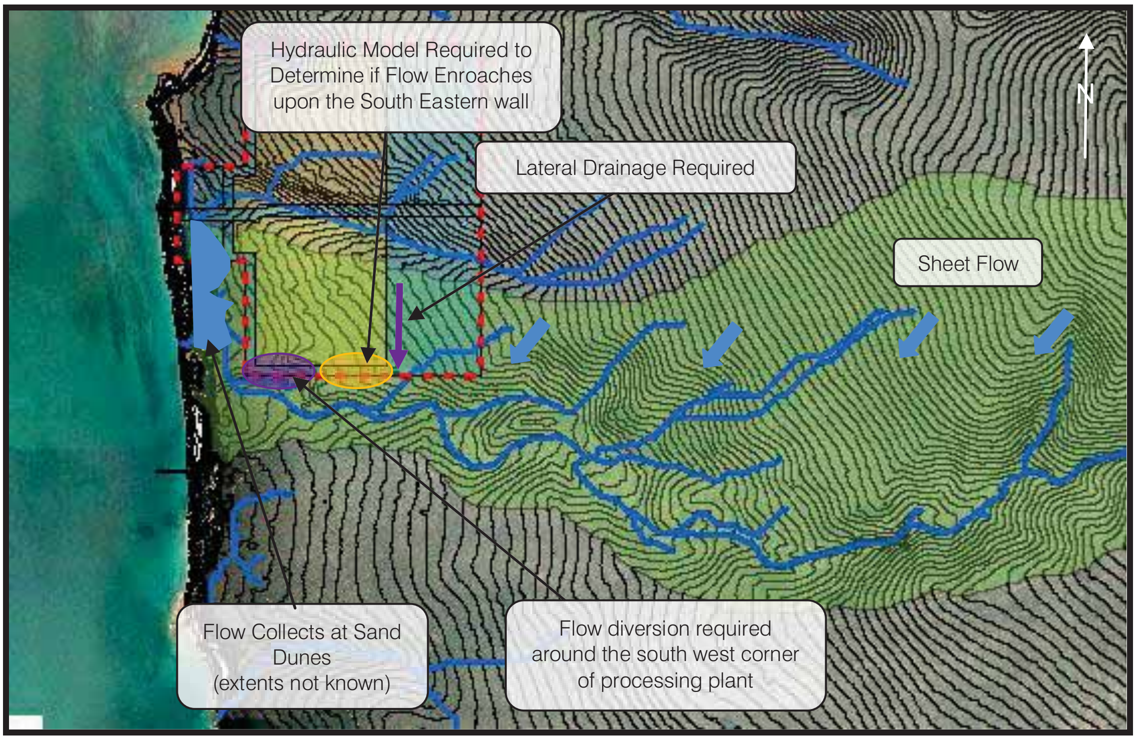


Figure 3.3 Catchment 5 streamlines relative to Proposed LNG Precinct Layout

Similar to Catchment CA4, precipitation to the northern and eastern parts of the catchment will move as sheet flow in a south westerly direction until it enters the defined channel to the south. The flow will then move westwards within the channel accumulating at the sand dunes along the coast, to the west and southwest of the southern processing plant.

A drainage system will be required to provide lateral drainage around the eastern end of the Precinct and in order to divert the sheet flow directly into the main channel.

Diversion of the natural creek line around the south west corner of the processing plant is also required. A preliminary hydraulic model has been prepared to determine flood extents relative to the south eastern corner.

Again it is possible that during high intensity storms the flow could accumulate faster than it infiltrates through the dunes, potentially flooding the south western side of the southern processing plant. Further analysis is recommended subsequent to a more detailed geotechnical investigation.

A preliminary one-dimensional steady state flow hydraulic model was developed for the defined channel within the Precinct location using HEC-RAS Hydraulic Modelling Software Version 4.0. This model is intended to provide an indicative estimate of flood extents relative to the southern LNG processing plant and determine the flood extents relative to the south eastern corner of the southern processing plant.

A Manning's roughness coefficient estimate of 0.06 was adopted for the whole model, based upon the aerial photography provided by the client and in accordance with the Austroads Waterways Design Guide.

The model was run for both the 100 and 2000 year ARI flood events. Figure 3.4 shows the extent of the conservative unfactored 2000 year AR&R flows relative to the proposed Precinct location. The extent of the other design flows are provided in Appendix B.

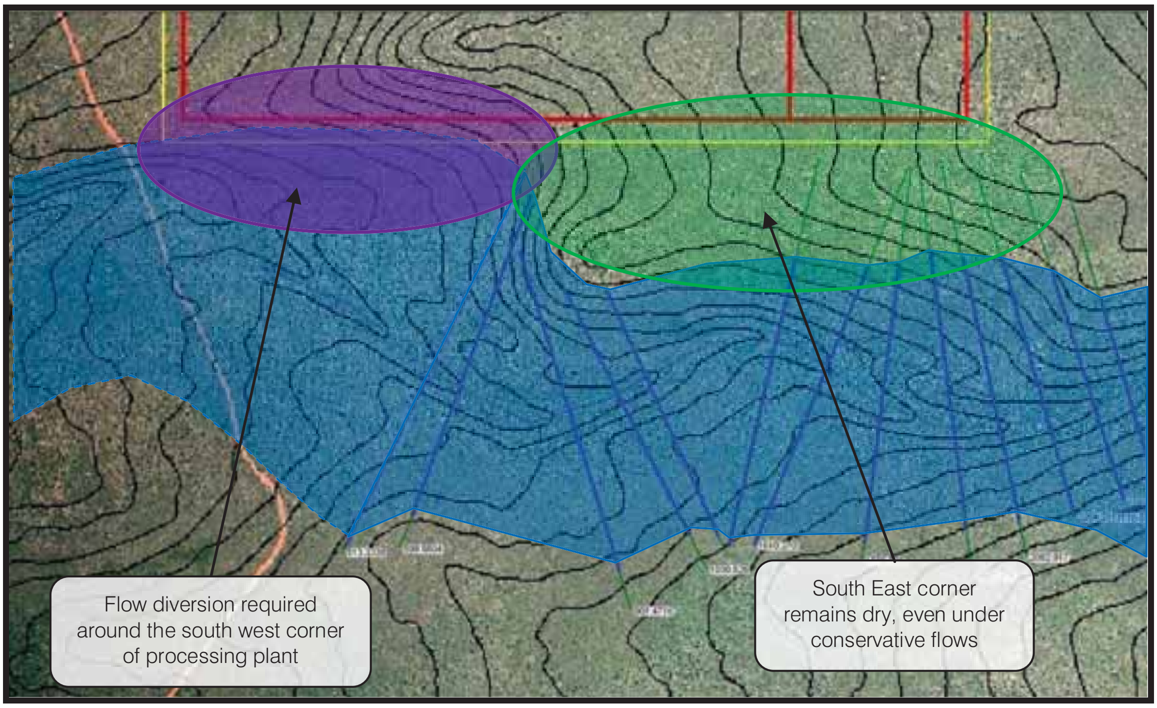


Figure 3.4 Extent of unfactored 2000 year ARI to south of LNG Processing Plant

Figure 3.4 above shows the estimated extent of the extreme 2000 year ARI event, using what are considered to be conservative unfactored AR&R flows for the permeable sandy catchment.

The model confirms that diversion of the natural creek line and design of pad levels is required around the south west corner of the LNG processing plant. It also shows that the flood extents are unlikely to encroach upon the south east corner, even when conservative flows are considered. Further modelling is required to determine exactly where the natural streamline will extend within the plant boundary.

5 CONCLUSION

The desktop local catchment flood study in the vicinity of the proposed Kimberley LNG Precinct and surrounding infrastructure has concluded the following:

Catchment Delineation Review:

- The catchments and streamlines have been delineated electronically using the 10m point survey data provided by the client. These closely match the topographic based delineations provided by the client. A comparison of the two is provided in Appendix A.
- The catchments of greatest concern in regards to future design, both in terms of magnitude of flow and their location relative to the LNG Precinct, are catchments CA4 and CA5.

Flow Estimation Methods:

- Australian Rainfall and Runoff (AR&R) generally forms the current industry standard for hydrological design throughout Australia. The AR&R Kimberley region method is derived from data in the rocky East Kimberley region, and it is generally accepted that it overestimates flows in the sandy location of the proposed LNG Precinct in the West Kimberley.
- It is suggested by Main Roads WA Senior Waterways Engineer that reduction of AR&R design flows by a factor of approximately 3 will provide a reasonable basis for flood studies in the vicinity of the Kimberley LNG Precinct. This method has not been published, but is used by Main Roads for hydrological assessments within the West Kimberley Region.
- In this study both factored and unfactored AR&R flows have been calculated to determine design flows. Flows have also been calculated using run-off routing models for comparison.

Preliminary Flood Study Outcomes

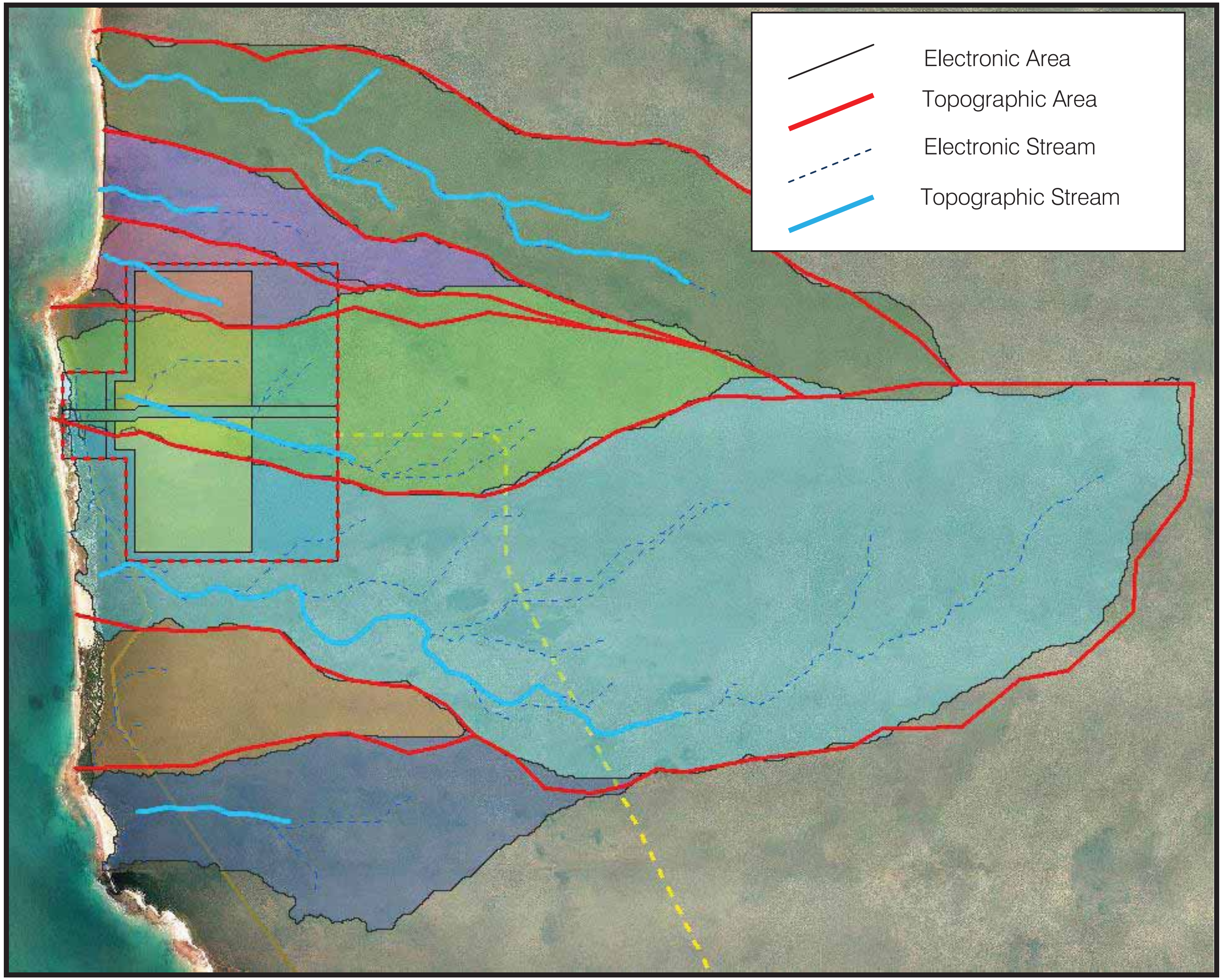
- Preliminary hydraulic models suggest that the proposed LNG Precinct layout is generally well positioned in terms of catchment hydraulics and drainage can be designed around it.
- Design of pad levels, flow diversion and rock protection systems may be required to the north east corner and southern face of the southern processing plant and to the south west corner of the northern processing plant.
- Lateral drainage along the eastern face of the Precinct may be required to divert sheet flow into the defined channels.

Future drainage design work and areas of analysis:

- Confirm drainage requirements for Precinct infrastructure with detailed hydraulic modelling. It is recommended that the Main Roads WA Modified AR&R method be adopted for the hydrologic assessment of all Regional and Local catchments.
- There does not appear to be defined catchment outlets, with flows accumulating to the east of the sand dunes rather than discharging into the ocean. It is possible that during high intensity storms the flow could accumulate faster than it infiltrates through the dunes, potentially flooding the western side of the Precinct. Further analysis is recommended once more information about the permeability characteristics of the dunes is known.
- This Report excludes consideration of the interaction between runoff and groundwater features. This should be further investigated subsequent to detailed geotechnical investigations.

Appendix A

Hydrological Analysis Outputs



Comparison of electronic (BG&E) and topographic (client) delineated catchments and streamlines

Catchment Flows for Various Methods (unfactored):

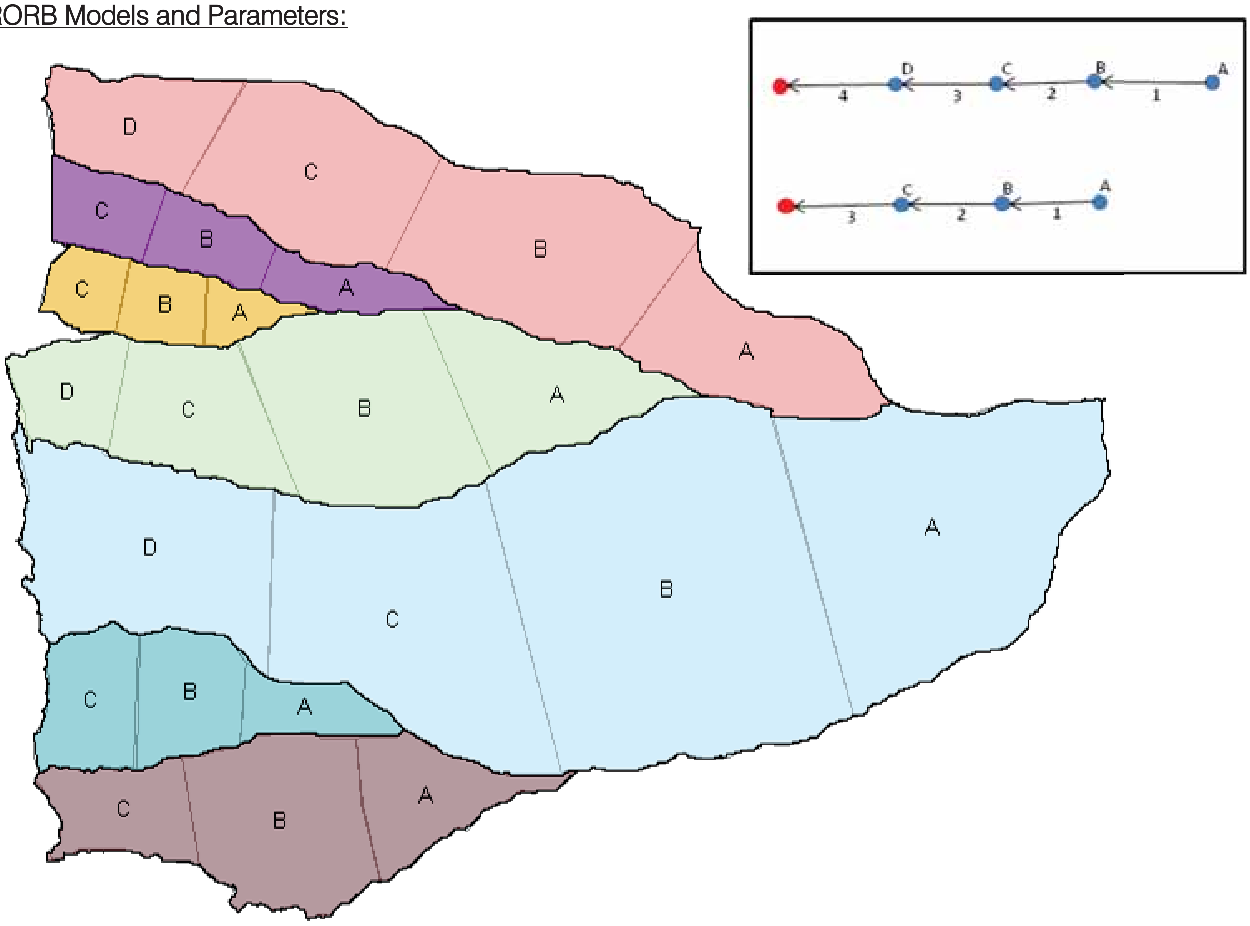
Catchment	Method	Average Recurrence Interval (years)									
		2	5	10	20	50	100	200	500	1000	2000
CA1	AR&R Rational	74	130	185	261	378	486	625	833	951	1119
	AR&R Index Flood	70	107	141	181	240	-	-	-	-	-
	RORB Base AR&R Parameters	95	107	138	267	350	442	-	-	-	-
CA2	AR&R Rational	34	55	74	100	138	178	224	299	356	415
	AR&R Index Flood	30	43	55	67	86	-	-	-	-	-
	RORB Base AR&R Parameters	40	44	55	103	122	156	-	-	-	-
CA3	AR&R Rational	29	46	61	82	112	146	183	248	280	328
	AR&R Index Flood	24	34	43	52	65	-	-	-	-	-
	RORB Base AR&R Parameters	34	36	46	90	104	134	-	-	-	-
CA4	AR&R Rational	72	124	175	245	351	445	558	745	1115	1287
	AR&R Index Flood	62	94	124	158	208	-	-	-	-	-
	RORB Base AR&R Parameters	111	121	155	300	375	474	-	-	-	-
CA5	AR&R Rational	123	226	332	484	717	894	1106	1440	2260	2688
	AR&R Index Flood	115	181	245	323	439	-	-	-	-	-
	RORB Base AR&R Parameters	170	208	294	509	683	874	-	-	-	-
CA6	AR&R Rational	43	70	96	129	180	231	291	376	429	503
	AR&R Index Flood	36	53	67	83	107	-	-	-	-	-
	RORB Base AR&R Parameters	48	52	66	132	153	204	-	-	-	-
CA7	AR&R Rational	57	96	133	183	258	328	411	546	653	760
	AR&R Index Flood	47	71	92	115	150	-	-	-	-	-
	RORB Base AR&R Parameters	81	87	108	218	251	336	-	-	-	-

Bureau of Meteorology Rainfall Gauge Information:

BOM Gauging Station	Name	Start Date	End Date	No. Years	Average Annual Precipitation (mm/yr)
003087	Tanjungpandan	1993	2000	7	929
003001	Country Downs	1969	2008	39	942
003003	Broome Airport	1939	2008	69	600
003096	West Roebuck	1999	2008	9	843

Location Map of Bureau of Meteorology Gauging Stations near LNG Precinct

RORB Models and Parameters:



Parameters:

Catchment	kc	m	IL (mm)	CL (mm)
CA1	4.42	0.8	47	5
CA2	1.51	0.8	47	5
CA3	1.01	0.8	47	5
CA4	2.89	0.8	47	5
CA5	7.01	0.8	47	5
CA6	1.96	0.8	47	5
CA7	2.17	0.8	47	5

Areas:

Catchment	A	B	C	D
CA1	7.6	12.8	10.4	5.55
CA2	2.4	2.7	2.7	-
CA3	1.4	2.1	1.9	-
CA4	7.4	12.0	6.4	3.4
CA5	22.6	33.0	18.7	14.0
CA6	2.6	4.3	4.2	-
CA7	4.7	9.2	4.1	-

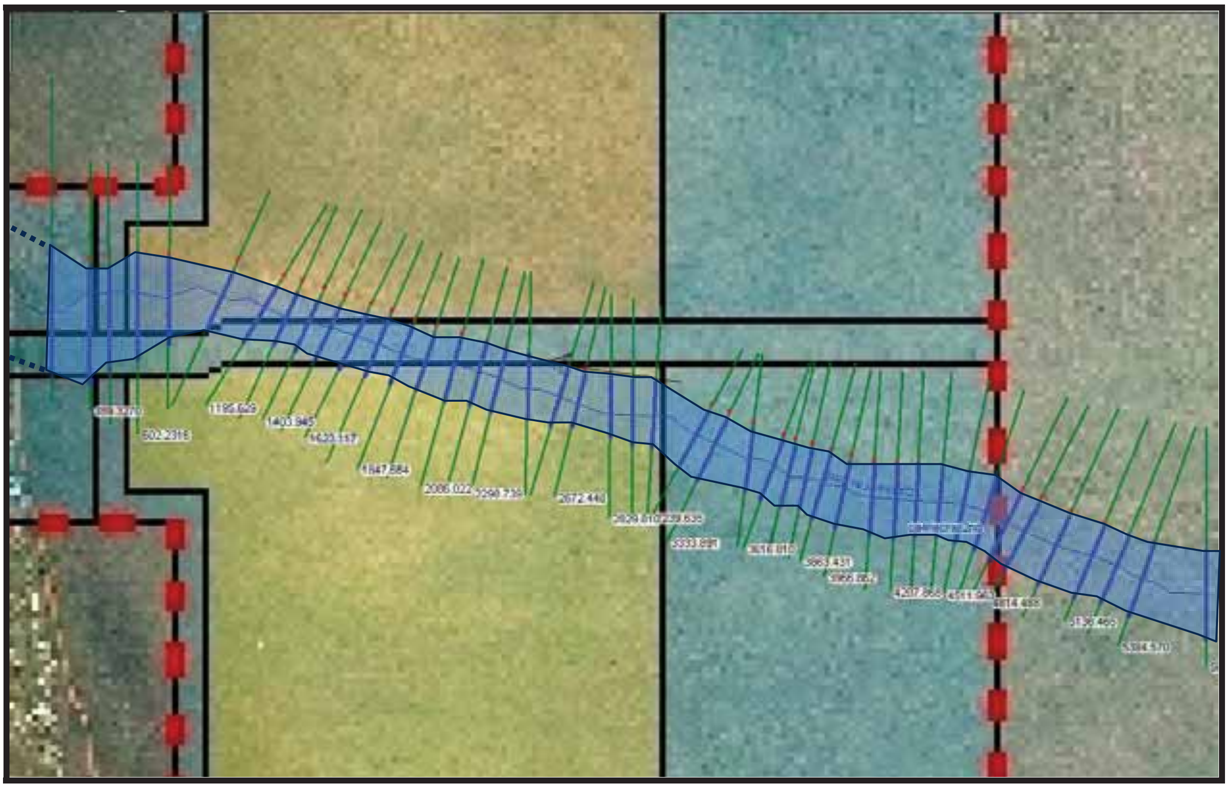
Lengths:

Catchment	1	2	3	4
CA1	4.44	4.89	4.10	1.81
CA2	2.44	1.77	1.01	-
CA3	1.34	1.39	0.94	-
CA4	3.19	3.15	2.16	1.14
CA5	5.49	5.98	4.46	3.45
CA6	2.10	2.20	2.10	-
CA7	292	2.76	1.93	-

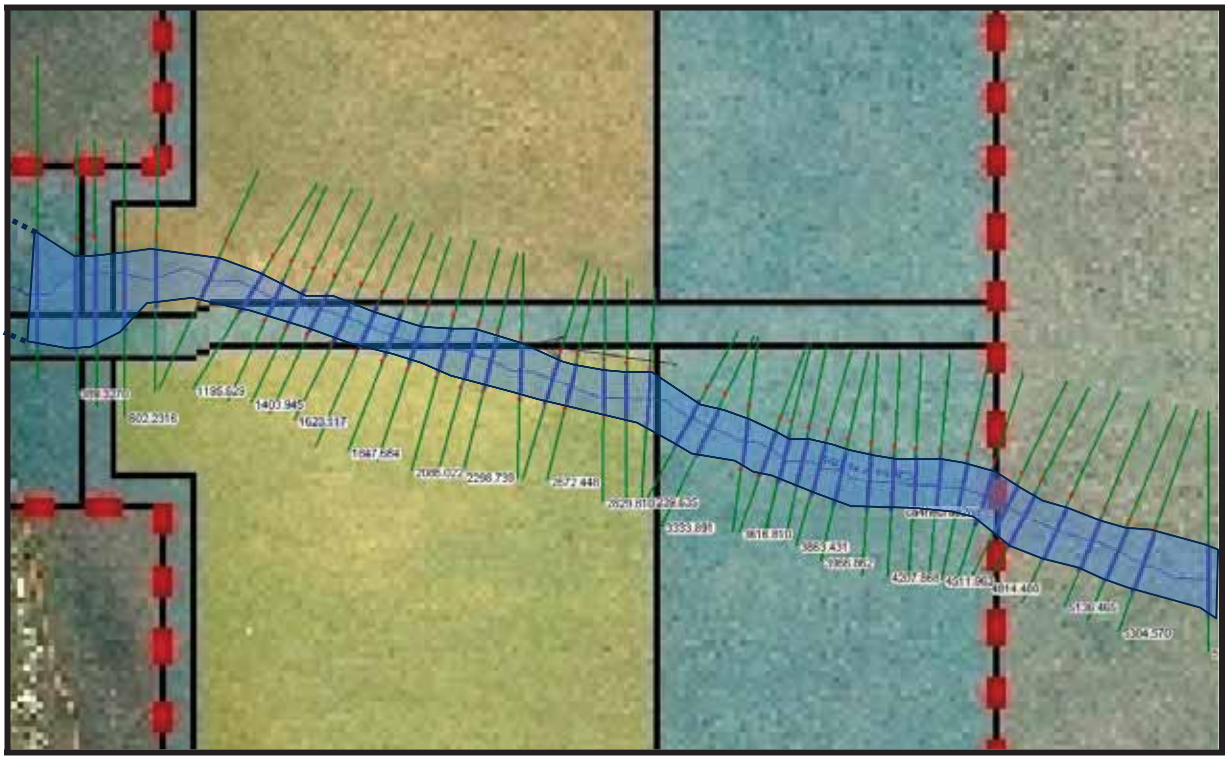
Appendix B

Hydraulic Analysis Outputs

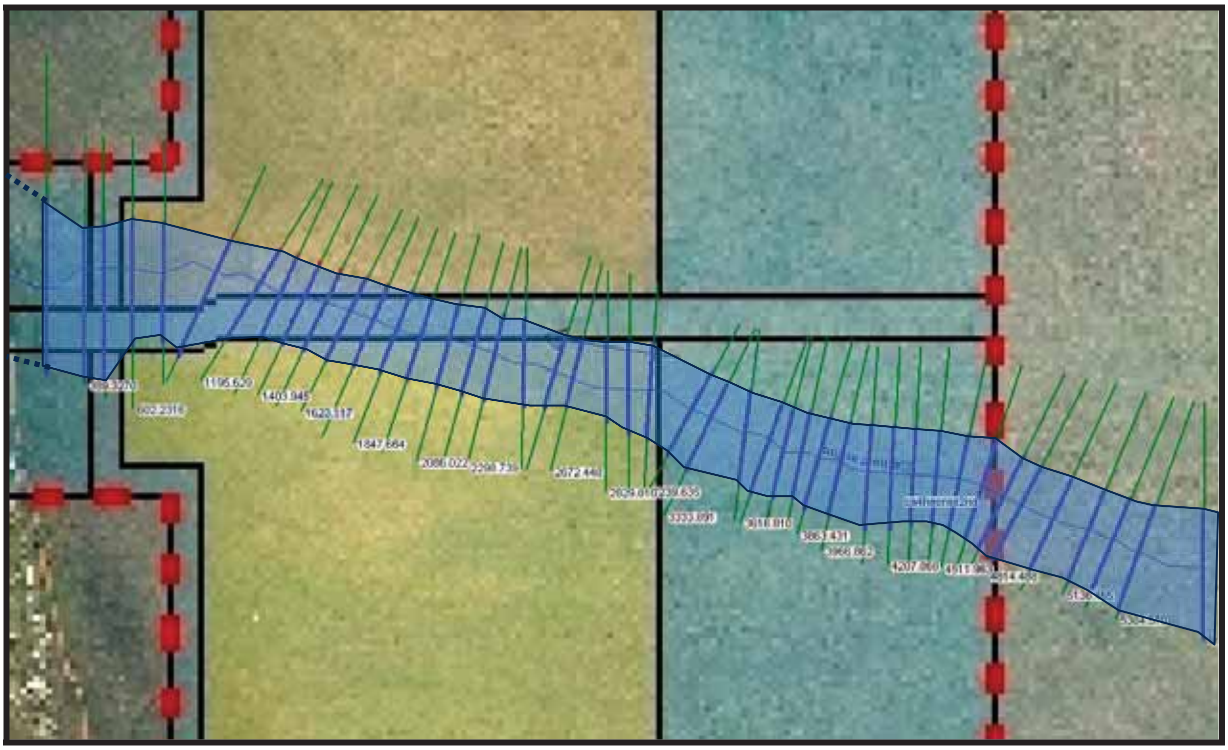
Catchment CA4 Flood Extents for Various Design Flows



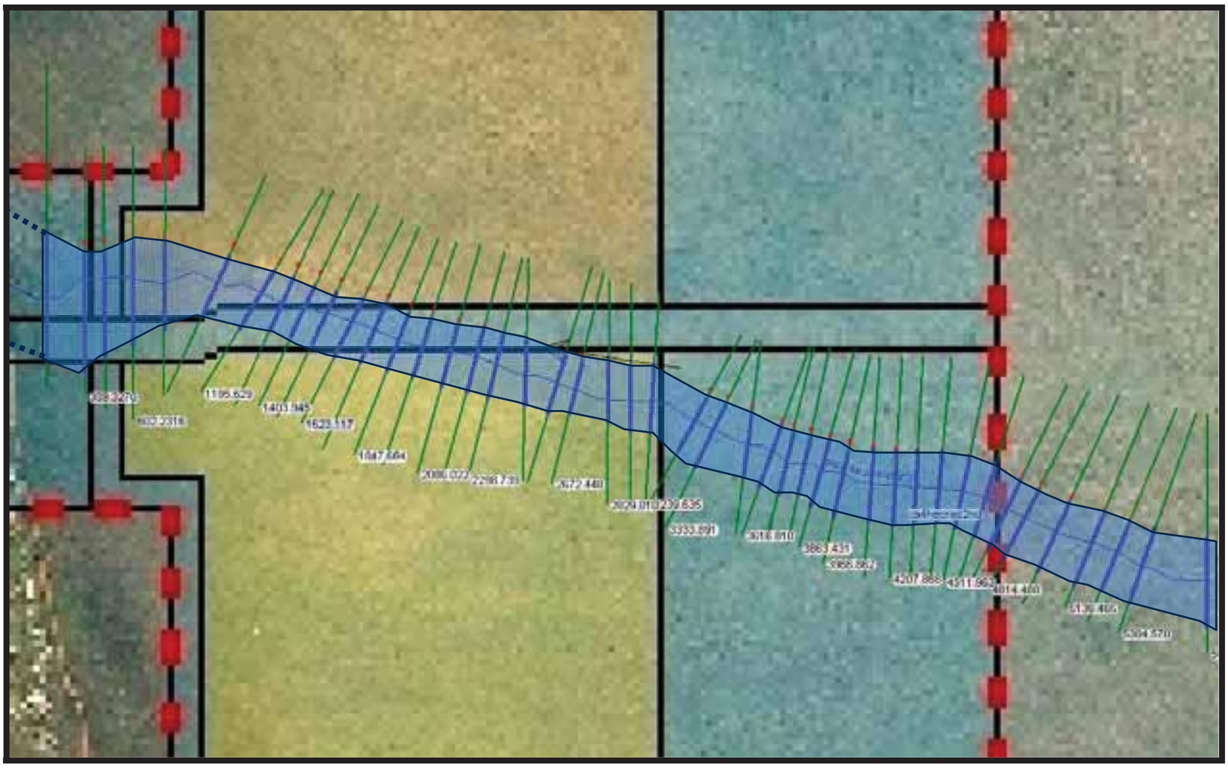
Unfactored AR&R 100 year Design Storm Flood Extents



Factored (reduced) AR&R 100 year Design Storm Flood Extents

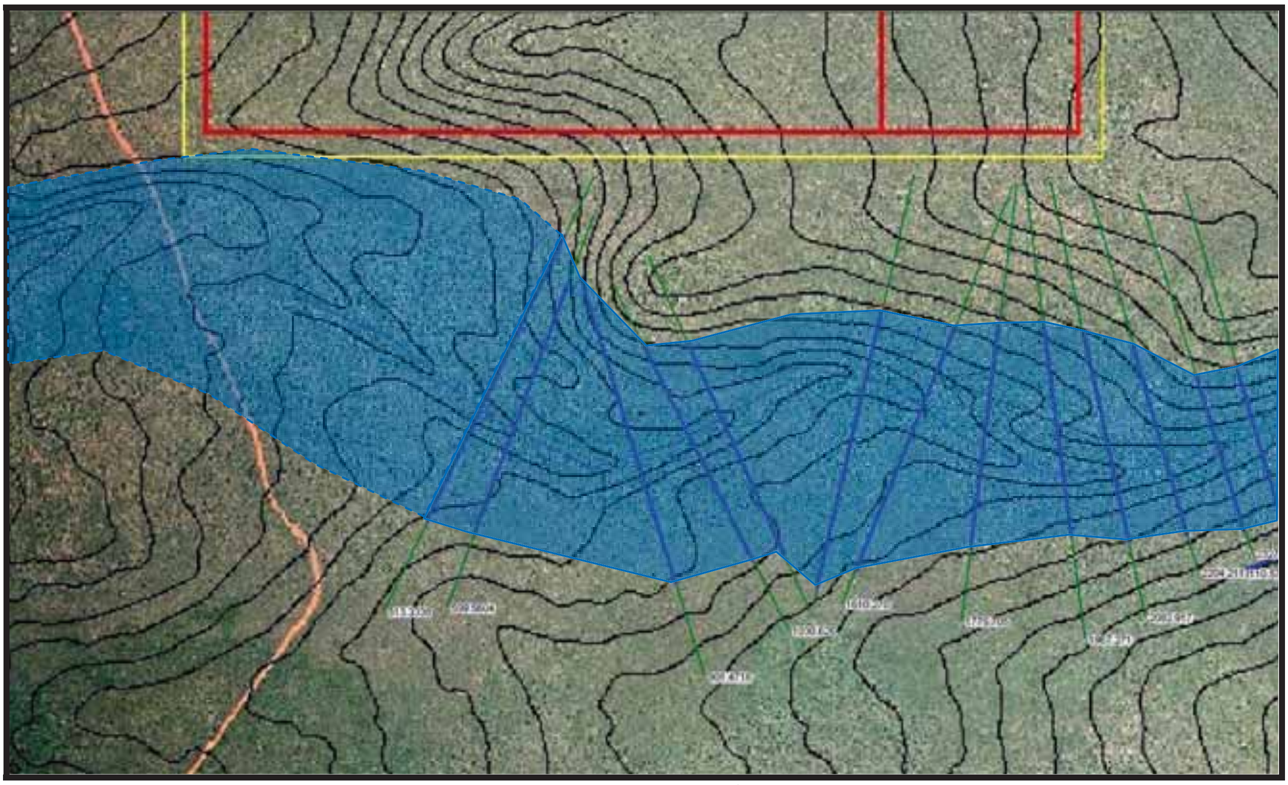


Unfactored AR&R 2000 year Design Storm Flood Extents

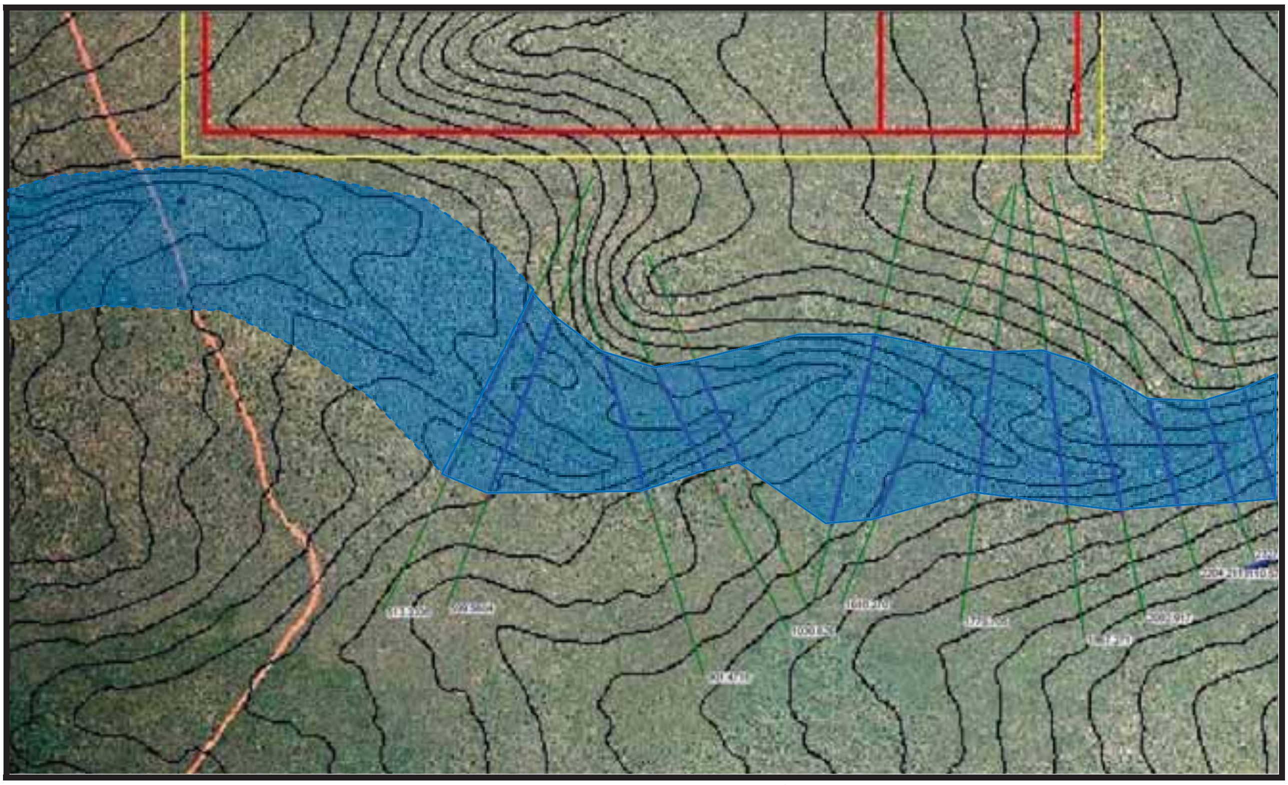


Factored (reduced) AR&R 2000 year Design Storm Flood Extents

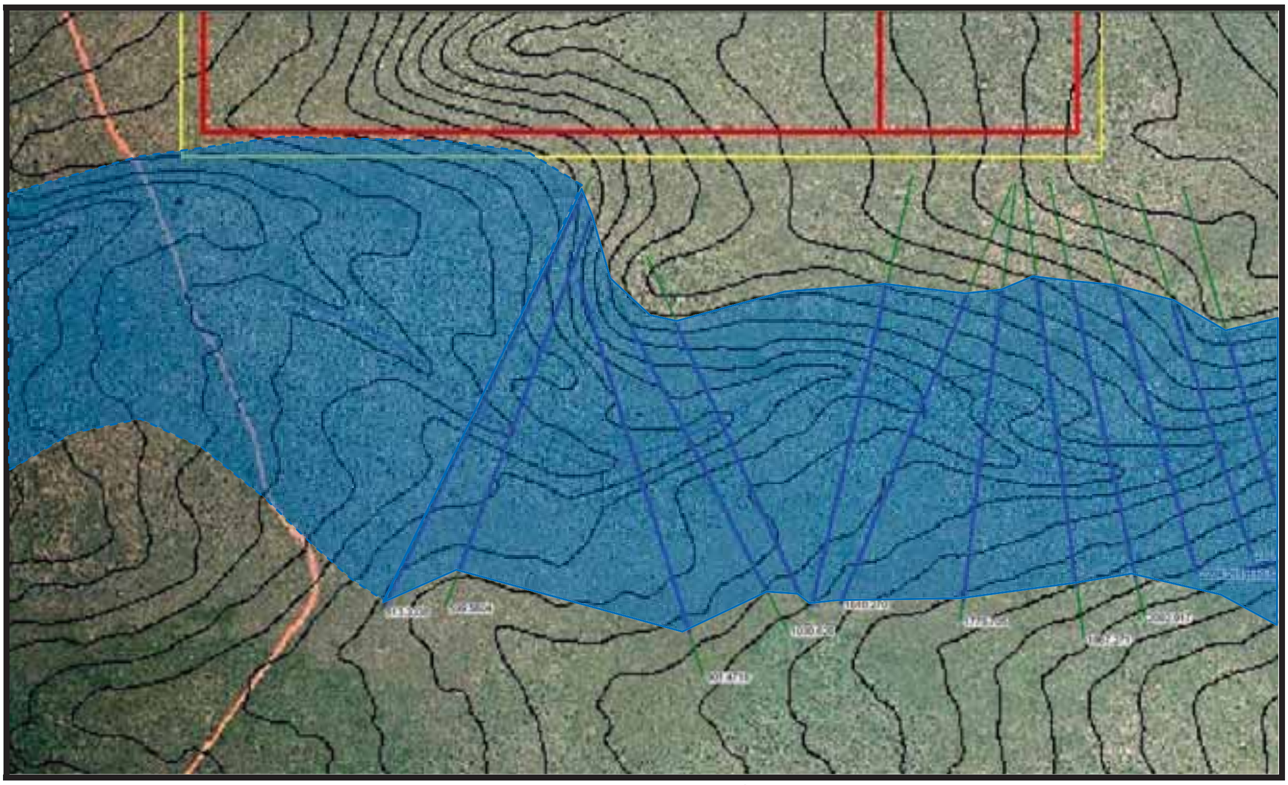
Catchment CA4 Flood Extents for Various Design Flows



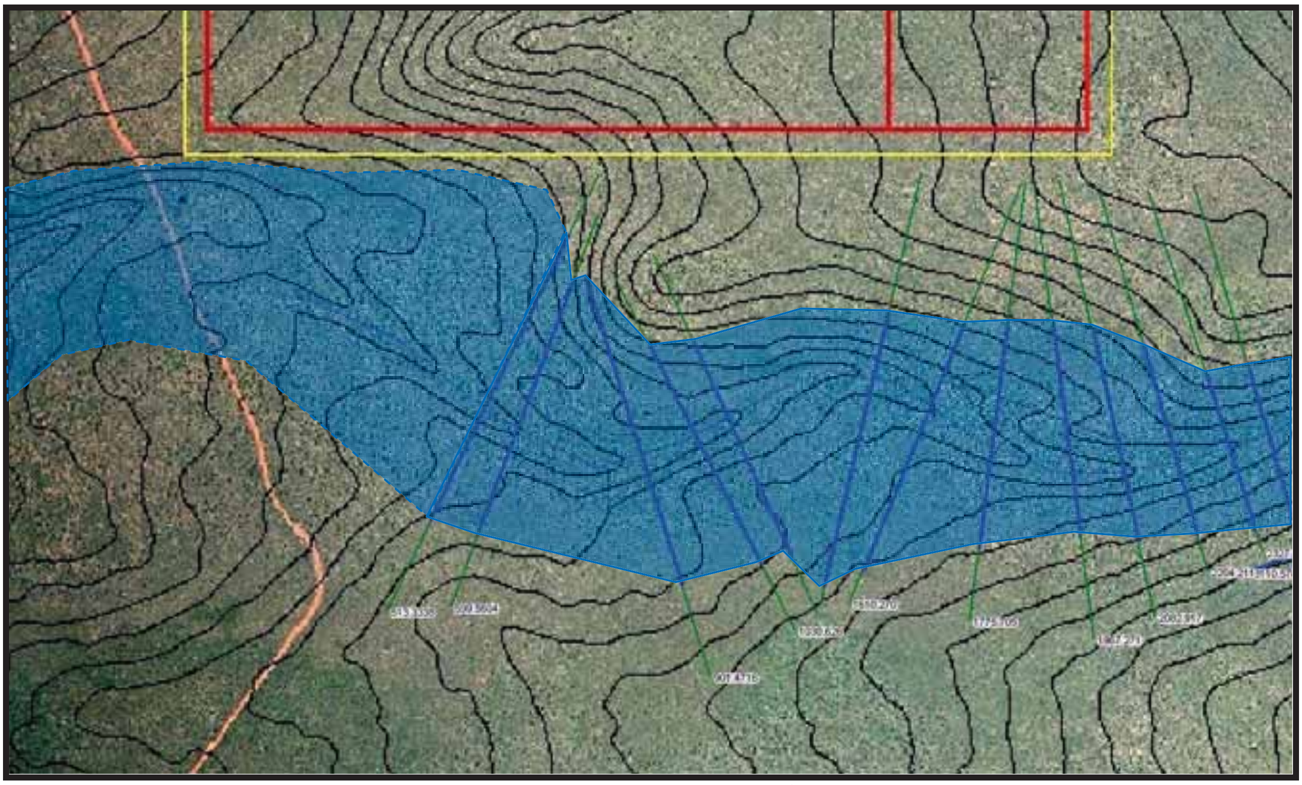
Unfactored AR&R 100 year Design Storm Flood Extents



Factored (reduced) AR&R 100 year Design Storm Flood Extents



Unfactored AR&R 2000 year Design Storm Flood Extents



Factored (reduced) AR&R 2000 year Design Storm Flood Extents