

snowy 2.0

EMM

VOLUME 2: APPENDICES

RESPONSE TO SUBMISSIONS

EXPLORATORY WORKS FOR SNOWY 2.0

October 2018

RESPONSE TO SUBMISSIONS REPORT

APPENDICES

A Register of submitters

B Biodiversity offset strategy

C Historic heritage reassessment of management and mitigation measures

D Geodiversity assessments of significance

E Updated surface water assessment



CHAPTER A

REGISTER OF SUBMITTERS

Community submissions

Name	Number	Position	Location	State	Type	Category	Issues	Reference
Anne Reeves	276880	Objects	Broadway	NSW	Community	**Theme**	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
						Theme	**KNP**	6.13
						Sub-theme	Adequacy of assessment/survey	6.13
						Theme	**Process**	6.4
						Sub-theme	National Parks	6.4.3
						Sub-theme	Staged approvals process	6.4.2
Matthew Moloney	276035	Objects	Brucedale	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
Fabrizio Fiorese	275353	Objects	Charnwood	ACT	Community	**Theme**	**Biodiversity**	6.7
						Sub-theme	Impacts to aquatic ecology	6.7.2
						Theme	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Process**	6.4
						Sub-theme	Adequacy of EIS	6.4.1
						Sub-theme	Public exhbition	6.4.4
						Theme	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Water**	6.11
						Sub-theme	Impacts to water quality	6.11.1
Ross Shield	276679	Supports	Talbingo	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Theme	**Transport**	6.6
						Sub-theme	Adequacy of assessment/survey	6.6.2
						Theme	**Water**	6.11
						Sub-theme	Subaqueous placement	6.11.1
Carol Talbot	275499	Comments	Cooma	NSW	Community	**Theme**	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
						Theme	**Mitigation**	6.12
						Sub-theme	Committed funding	6.12
						Theme	**Social**	6.2
						Sub-theme	Local workforce	6.2.5
						Theme	**Transport**	6.6
						Sub-theme	Adequacy of assessment/survey	6.6.2
						Theme	**Water**	6.11
						Sub-theme	Subaqueous placement	6.11.1
Regina Roach	276752	Objects	Cooma	NSW	Community	**Theme**	**Other**	6.14
						Sub-theme	Noise	6.14.2
						Theme	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Adequacy of assessment/survey	6.6.2
Peter Anderson	276766	Objects	Cooma	NSW	Community	**Theme**	**Biodiversity**	6.7
						Sub-theme	Threatened fauna impacts	6.7.1
						Theme	**Description**	6.9
						Sub-theme	Subaqueous placement	6.9.1
						Sub-theme	Tunnelling	6.9.2
						Theme	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
						Theme	**KNP**	6.4.3
						Sub-theme	Adequacy of assessment/survey	6.4.1
						Theme	**Land**	6.10
						Sub-theme	Adequacy of assessment/survey	6.10.2
						Theme	**Process**	6.4
						Sub-theme	National Parks	6.4.3
						Sub-theme	Staged approvals process	6.4.2
						Theme	**Social**	6.2
						Sub-theme	Local workforce	6.2.5
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Adequacy of assessment/survey	6.6.2
wouter vochteloo	275149	Supports	Cooma	NSW	Community	**Theme**	**Process**	6.4
						Sub-theme	Staged approvals process	6.4.2
(Name withheld)	275130	Objects	Cootamundra	NSW	Community	**Theme**	**Other**	6.14
						Sub-theme	Public safety	6.14.1
						Theme	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Safety on Miles Franklin Drive	6.6.1
						Theme	**Water**	6.11
						Sub-theme	Impacts to water quality	6.11.1
John Brush	276758	Objects	Wanniassa	ACT	Community	**Theme**	**Biodiversity**	6.7
						Sub-theme	Threatened fauna impacts	6.7.1
						Theme	**Description**	6.9
						Sub-theme	Rock emplacement areas	6.9.1
						Theme	**Heritage**	6.8
						Sub-theme	Adequacy of assessment/survey	6.8.1
						Theme	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
						Theme	**Land**	6.10
						Sub-theme	Geodiversity	6.10.1
						Theme	**Process**	6.4
						Sub-theme	Adequacy of EIS	6.4.1
						Sub-theme	Staged approvals process	6.4.2
						Sub-theme	Public exhbition	6.4.4
						Theme	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Adequacy of assessment/survey	6.6.2

Community submissions

Name	Number	Position	Location	State	Type	Category	Issues	Reference
Russell Davies	276563	Comments	Henty	NSW	Community	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
						Sub-theme	Economic impacts to Talbingo	6.2.2
John Taber	275911	Comments	Menangle Park	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Water**	6.11
						Sub-theme	Impacts to water quality	6.11.1
David Hooper	276714	Comments	Merricks North	VIC	Community	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
						Theme	**Social**	6.2
						Sub-theme	Adequacy of assessment	6.2.3
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Impacts to services	6.2.4
						Sub-theme	Public access to recreation areas	6.2.1
(Name withheld)	277277	Comments	n/a	NSW	Community	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
						Theme	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
Andrew Thaler	276824	Objects	Nimmitabel	NSW	Community	**Theme**	**Heritage**	6.8
						Sub-theme	Adequacy of assessment/survey	6.8.1
						Sub-theme	Adequacy of engagement with Aboriginal people	6.8.2
						Theme	**Process**	6.4
						Sub-theme	Public exhibition	6.4.4
Bob Erskine	276041	Comments	Talbingo	NSW	Community	**Theme**	**Transport**	6.6
	276223					Sub-theme	Adequacy of assessment/survey	6.6.2
	276302					Sub-theme	Safety on Miles Franklin Drive	6.6.1
	276723					**Theme**	**Social**	6.2
	276734					Sub-theme	Economic impacts to Talbingo	6.2.2
	276777					Sub-theme	Adequacy of assessment	6.2.3
						Sub-theme	Public access to recreation areas	6.2.1
						Sub-theme	Impacts of services	6.2.4
						Sub-theme	Access to accomodation	6.2.4
Brian McIntosh	275991	Comments	Bonegilla	VIC	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
John Weckert	276748	Comments	Talbingo	NSW	Community	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Justification**	6.5
						Theme	**Social**	6.2
						Sub-theme	Adequacy of assessment	6.2.3
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Safety on Miles Franklin Drive	6.6.1
Ian Parsons	276882	Comments	Talbingo	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
Reg Payne	276842	Comments	Talbingo	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
Talbingo Lodge	276781	Comments	Talbingo	NSW	Business	**Theme**	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
(Name withheld)	276760	Comments	Talbingo	NSW	Community	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Mitigation**	6.12
						Sub-theme	Committed funding	6.12
						Theme	**Process**	6.4
						Sub-theme	Public exhibition	6.4.4
						Theme	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
Gary Bilton	276738	Objects	Talbingo	NSW	Community	**Theme**	**Biodiversity**	6.7
						Sub-theme	Impacts to aquatic ecology	6.7.2
						Sub-theme	Offsets and management measures	6.7.3
						Theme	**Description**	6.9
						Sub-theme	Rock emplacement areas	6.9.1
						Sub-theme	Subaqueous placement	6.9.1
						Sub-theme	Tunnelling	6.9.2
						Theme	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Heritage**	6.8
						Sub-theme	Adequacy of assessment/survey	6.8.1
						Theme	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
						Sub-theme	Planning policies	6.5.2
						Theme	**KNP**	6.13
						Sub-theme	Adequacy of assessment/survey	6.13
						Sub-theme	Agreed compensation package	6.12
						Theme	**Land**	6.10
						Sub-theme	Adequacy of assessment/survey	6.10.2
						Sub-theme	Geodiversity	6.10.1
						Theme	**Other**	6.14
						Sub-theme	Cumulative impacts	6.14.3
						Theme	**Process**	6.4
						Sub-theme	National Parks	6.4.3
						Sub-theme	Staged approvals process	6.4.2
						Theme	**Social**	6.2

Community submissions

Name	Number	Position	Location	State	Type	Category	Issues	Reference
						Sub-theme	Adequacy of assessment	6.2.3
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Water**	6.11
						Sub-theme	Flooding	6.11.2
Allen Moffatt	275897	Supports	Talbingo	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
Bernard Cass	276335	Supports	Talbingo	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
Bruce Duff	275895	Supports	Talbingo	NSW	Community	**Theme**	**Other**	6.14
						Sub-theme	Public safety	6.14.1
						Theme	**Process**	6.4
						Sub-theme	Adequacy of EIS	6.4.1
						Theme	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
Talbingo Supermarket	276241	Supports	Talbingo	NSW	Business	**Theme**	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
Doug Gibson Electrical Contractor	276085	Supports	Talbingo	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
Michael Measday	275890	Supports	Talbingo	NSW	Community	**Theme**	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
						Theme	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
Owen Bennetts	275985	Supports	Talbingo	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
(Name withheld)	275648	Supports	Talbingo	NSW	Community	**Theme**	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
Dawn and Bill Byatt	276744	Supports	Talbingo	NSW	Community	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Process**	6.4
						Sub-theme	Adequacy of EIS	6.4.1
						Theme	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Impacts to services	6.2.4
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Safety on Miles Franklin Drive	6.6.1
Deb Blackwell	276756	Supports	Talbingo	NSW	Community	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Mitigation**	6.12
						Sub-theme	Committed funding	6.12
						Theme	**Other**	6.14
						Sub-theme	Noise	6.14.2
						Theme	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Impacts to services	6.2.4
						Sub-theme	Public access to recreation areas	6.2.1
Dianne Smith	276565	Supports	Talbingo	NSW	Community	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Safety on Miles Franklin Drive	6.6.1
						Theme	**Water**	6.11
						Sub-theme	Impacts to water quality	6.11.1
Heather Byatt	276551	Supports	Talbingo	NSW	Community	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Process**	6.4
						Sub-theme	Adequacy of EIS	6.4.1
						Theme	**Social**	6.2
						Sub-theme	Adequacy of assessment	6.2.3
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Safety on Miles Franklin Drive	6.6.1
Talbingo Tourist Park	276746	Supports	Talbingo	NSW	Business	**Theme**	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Mitigation**	6.12
						Sub-theme	Construction environmental management	6.12
						Theme	**Process**	6.4
						Sub-theme	Adequacy of EIS	6.4.1
						Theme	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Safety on Miles Franklin Drive	6.6.1
Joel Moller	276719	Supports	Wagga Wagga	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Safety on Miles Franklin Drive	6.6.1
						Theme	**Water**	6.11
						Sub-theme	Impacts to water quality	6.11.1
Louise Moffatt	276632	Supports	Talbingo	NSW	Community	**Theme**	**Justification**	6.5
						Sub-theme	Alternatives and options considered	6.5.1
						Theme	**Other**	6.14
						Sub-theme	Public safety	6.14.1
						Theme	**Social**	6.2
						Social	Public access to recreation areas	6.2.1

Community submissions

Name	Number	Position	Location	State	Type	Category	Issues	Reference
(Name withheld)	276762	Supports	Talbingo	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
Richard Poll	276064	Comments	Tumut	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
Paul Lucas	276750	Comments	Wa	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Adequacy of assessment	6.2.3
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Safety on Miles Franklin Drive	6.6.1
Jim Dennis	276844	Comments	Wagga Wagga	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
Ryan Dennis	276839	Comments	Wagga Wagga	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
(Name withheld)	276100	Objects	Wagga Wagga	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
George Thomas	276717	Objects	Wagga Wagga	NSW	Community	**Theme**	**Description**	6.9
	276742					Sub-theme	Rock emplacement areas	6.9.1
						Theme	**Heritage**	6.8
						Sub-theme	Further information required on identified items	6.8.1
						Sub-theme	Adequacy of assessment/survey	6.8.1
						Theme	**Mitigation**	6.12
						Sub-theme	Construction environmental management	6.12
						Theme	**Process**	6.4
						Sub-theme	Adequacy of EIS	6.4.1
						Sub-theme	Public exhibition	6.4.4
						Theme	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Water**	6.11
						Sub-theme	Site water management	6.11.3
Mark Drum	276685	Objects	Wagga Wagga	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Public access to recreation areas	6.2.1
David Comerford	276754	Supports	Wagga Wagga	NSW	Community	**Theme**	**Social**	6.2
						Sub-theme	Economic impacts to Talbingo	6.2.2
Talbingo Progress and Ratepayers Association		Comments	Talbingo	NSW	Community	**Theme**	**Biodiversity**	6.7
						Sub-theme	Impacts to aquatic ecology	6.7.2
						Theme	**Engagement**	6.3
						Sub-theme	Insufficient level of engagement	6.3
						Theme	**Other**	6.14
						Sub-theme	Noise	6.14.2
						Theme	**Process**	6.4
						Sub-theme	Staged approvals process	6.4.2
						Theme	**Social**	6.2
						Sub-theme	Access to accomodation	6.2.4
						Sub-theme	Economic impacts to Talbingo	6.2.2
						Sub-theme	Public access to recreation areas	6.2.1
						Theme	**Transport**	6.6
						Sub-theme	Public access	6.6.4
						Sub-theme	Safety on Miles Franklin Drive	6.6.1
						Theme	**Water**	6.11
						Sub-theme	Flooding	6.11.2

Government submissions

Name	Number	Position	Location	State	Type	Category	Issues	Reference
OEH NPWS	277147	Comments	State govt		Government	**Theme**	**Biodiversity**	4.1.6
						Sub-theme	Adequacy of assessment/survey	4.1.6
						Sub-theme	GDEs	4.1.9
						Sub-theme	Offsets and management measures	4.1.6
						Theme	**Description**	4.1
						Sub-theme	Bridges	4.1.3
						Sub-theme	Road upgrades	4.1.3
						Sub-theme	Rock emplacement areas	4.1.2
						Sub-theme	Barge infrastructure	4.1.3
						Theme	**Heritage**	4.1.5
						Sub-theme	Adequacy of assessment/survey	4.1.5
						Sub-theme	Further information required on identified items	4.1.5
						Sub-theme	Monitoring	4.1.5
						Theme	**KNP**	4.1.1
						Sub-theme	Agreed compensation package	4.1.1
						Sub-theme	Continued park operations	4.1.1
						Theme	**Land**	4.1.10
						Sub-theme	Further info required	4.1.10
						Sub-theme	Geodiversity	4.1.4
						Theme	**Mitigation**	4.1.5
						Sub-theme	Construction environmental management	4.1.5
						Theme	**Other**	4.1
						Sub-theme	Noise	4.1.11
						Sub-theme	Public safety	4.1.12
						Theme	**Transport**	4.1.3
						Sub-theme	Public access	4.1.3
						Theme	**Water**	4.1
						Sub-theme	Adequacy of assessment/survey	4.1.7
						Sub-theme	Flooding	4.1.7
						Sub-theme	Subaqueous placement	4.1.8
Fire & Rescue NSW	275997	Comments	State govt		Government	**Theme**	**Other**	4.9
						Sub-theme	Public safety	4.9
EPA	276461	Comments	State govt		Government	**Theme**	**Water**	4.2
						Sub-theme	Groundwater	4.2.9
						Sub-theme	Impacts to water quality	4.2.1, 4.2.2, 4.2.8
						Sub-theme	Site water management	4.2.5, 4.2.6, 4.2.7, 4.2.10
						Sub-theme	Subaqueous placement	4.2.4
Snowy Monaro Regional Council	276865	Comments	Local govt		Government	**Theme**	**Biodiversity**	4.11.4
						Sub-theme	Offsets and management measures	4.11.4
						Theme	**Description**	4.11.1, 4.11.2
						Sub-theme	Rock emplacement areas	4.11.1
						Theme	**Mitigation**	4.11.6
						Sub-theme	Licenses/permits	4.11.6
						Theme	**Other**	4.11.2
						Sub-theme	Waste	4.11.2
						Theme	**Social**	4.11.5
						Sub-theme	Local workforce	4.11.5
						Theme	**Transport**	4.11.3
						Sub-theme	Adequacy of assessment/survey	4.11.3
						Sub-theme	Road repairs/dilapidation surveys	4.11.3
						Sub-theme	Truck/vehicle movements	4.11.3
RMS Maritime	277149	Comments	State govt		Government	**Theme**	**Mitigation**	4.7
						Sub-theme	Construction environmental management	4.7.1
RMS Roads	277149	Comments	State govt		Government	**Theme**	**Description**	4.8
						Sub-theme	Construction hours	4.8
						Theme	**Mitigation**	4.8
						Sub-theme	Construction environmental management	4.8
						Sub-theme	Licenses/permits	4.8
						Theme	**Process**	4.8
						Sub-theme	Staged approvals process	4.8
						Theme	**Transport**	4.8
						Sub-theme	Adequacy of assessment/survey	4.8
						Sub-theme	Public access	4.8
						Sub-theme	Road repairs/dilapidation surveys	4.8
						Sub-theme	Road safety	4.8
						Sub-theme	Truck/vehicle movements	4.8

Government submissions

Name	Number	Position	Location	State	Type	Category	Issues	Reference
Department of Industry - Water		Comments	State govt		Government	**Theme**	**Biodiversity**	4.4.3
						Sub-theme	Adequacy of assessment/survey	4.4.3
						Sub-theme	Groundwater dependent ecosystems	4.4.3
						Sub-theme	Impacts to aquatic ecology	4.4.3
						Theme	**Description**	4.4.5
						Sub-theme	Layout	4.4.5
						Sub-theme	Water management	4.4.1
						Theme	**Justification**	4.4.5
						Sub-theme	Planning policies	4.4.5
						Theme	**Land**	4.4.3
						Sub-theme	Further information required	4.4.3
						Theme	**Mitigation**	4.4
						Sub-theme	Construction environmental management	4.4
						Sub-theme	Licenses/permits	4.4
						Theme	**Process**	4.4
						Sub-theme	Adequacy of EIS	4.4
						Theme	**Water**	4.4.1, 4.4.2
						Sub-theme	Adequacy of assessment/survey	4.4.1, 4.4.2
						Sub-theme	Groundwater	4.4.2
						Sub-theme	Impacts to water quality	4.4.1
						Sub-theme	Site water management	4.4.1
Department of Primary Industries - Fisheries		Comments	State govt		Government	**Theme**	**Biodiversity**	4.3
						Sub-theme	Adequacy of assessment/survey	4.3.1
						Sub-theme	Impacts to aquatic ecology	4.3.2
						Theme	**Description**	4.3
						Sub-theme	Bridges	4.3.5
						Theme	**Mitigation**	4.3
						Sub-theme	Construction environmental management	4.3.4
						Theme	**Process**	4.3
						Sub-theme	Adequacy of EIS	4.3
						Theme	**Water**	4.3
						Sub-theme	Subaqueous placement	4.3.3
Department of Industry - Lands		Comments	State govt		Government	**Theme**	**Justification**	4.5
						Sub-theme	Tenure	4.5
OEH Heritage Council	278402	Comments	State govt		Government	**Theme**	**Heritage**	4.6
						Sub-theme	Adequacy of assessment / survey	4.6
						Sub-theme	Further information required on identified items	4.6
						Theme	**Mitigation**	4.6
						Sub-theme	Construction environmental management	4.6
Snowy Valleys Council	277420	Comments	Local govt		Government	**Theme**	**Mitigation**	4.12
						Sub-theme	Construction environmental management	4.12
						Sub-theme	Licenses/permits	4.12
						Theme	**Other**	4.12
						Sub-theme	Waste	4.12.4
						Theme	**Social**	4.12.3
						Sub-theme	Access to accomodation	4.12.3
						Sub-theme	Impacts to services	4.12.3
						Sub-theme	Public access to recreation areas	4.12.3
						Theme	**Transport**	4.12.2
						Sub-theme	Adequacy of assessment/survey	4.12.2
						Sub-theme	Truck/vehicle movements	4.12.2

Special interest group submissions

Name	Number	Position	Location	State	Type	Category	Issues	Reference
National Parks Association of NSW	276855	Objects			SIG	**Theme**	**Biodiversity**	5.5
						Sub-theme	Impacts to aquatic ecology	5.5.2
						Sub-theme	Offsets and management measures	5.5.4
						Theme	**Description**	5.4
						Sub-theme	Excavated rock management	5.4.3
						Sub-theme	Interactions with Snowy 2.0	5.4.1
						Sub-theme	Layout	5.4.2
						Sub-theme	Rehabilitation	5.4.4
						Theme	**Justification**	5.2
						Sub-theme	Alternatives and options considered	5.2.1
						Theme	**KNP**	5.6
						Sub-theme	Agreed compensation package	5.6.2
						Sub-theme	Continued park operations	5.6.1
						Theme	**Process**	5.3
						Sub-theme	Adequacy of EIS	5.3.1
						Sub-theme	Commonwealth	5.3.2
						Sub-theme	National Parks	5.3.4
						Sub-theme	Staged approvals process	5.3.3
						Theme	**Social**	5.10
						Sub-theme	Adequacy of assessment/survey	5.10
						Theme	**Water**	5.8
						Sub-theme	Subaqueous placement	5.8.3
Australian Cave and Karst Management Association	276999	Comments			SIG	**Theme**	**Biodiversity**	5.5
						Sub-theme	Adequacy of assessment/survey	5.5.3
						Sub-theme	Offsets and management measures	5.5.4
						Sub-theme	Threatened fauna impacts	5.5.1
						Theme	**Justification**	5.2
						Sub-theme	Alternatives and options considered	5.2.1
						Theme	**KNP**	5.6
						Sub-theme	Adequacy of assessment/survey	5.6
						Sub-theme	Continued park operations	5.6.1
						Theme	**Land**	5.7
						Sub-theme	Geodiversity	5.7.1
						Theme	**Process**	5.3
						Sub-theme	Public exhbition	5.3.5
						Theme	**Transport**	5.9
						Sub-theme	Truck movements	5.9
						Theme	**Water**	5.8
						Sub-theme	Groundwater	5.8.2
						Sub-theme	Subaqueous placement	5.8.3
Nature Conservation Council	276869	Objects			SIG	**Theme**	**Biodiversity**	5.5
						Sub-theme	Impacts to aquatic ecology	5.5.2
						Sub-theme	Offsets and management measures	5.5.4
						Sub-theme	Threatened fauna impacts	5.5.1
						Theme	**Justification**	5.2
						Sub-theme	Alternatives and options considered	5.2.1
						Theme	**Process**	5.3
						Sub-theme	Commonwealth	5.3.2
						Sub-theme	Staged approvals process	5.3.3
						Sub-theme	Public exhbition	5.3.5
						Theme	**Water**	5.8
						Sub-theme	Impacts to water quality	5.8.1
The Colong Foundation for Wilderness	276622	Objects			SIG	**Theme**	**Biodiversity**	5.5
						Sub-theme	Offsets and management measures	5.5.4
						Sub-theme	Threatened fauna impacts	5.5.1
						Theme	**Description**	5.4
						Sub-theme	Rehabilitation	5.4.4
						Theme	**KNP**	5.6
						Sub-theme	Continued park operations	5.6.1
						Sub-theme	Impacts to recreational values	5.6.2
						Theme	**Land**	5.7
						Sub-theme	Naturally occuring asbestos	5.7.2

Special interest group submissions

Name	Number	Position	Location	State	Type	Category	Issues	Reference
						Theme	**Process**	5.3
						Sub-theme	Adequacy of EIS	5.3.1
						Sub-theme	Commonwealth	5.3.2
						Sub-theme	National Parks	5.3.4
						Sub-theme	Staged approvals process	5.3.3
						Theme	**Water**	5.8
						Sub-theme	Subaqueous placement	5.8.3



CHAPTER B

BIODIVERSITY OFFSET STRATEGY

Snowy 2.0 Exploratory Works

Biodiversity Offset Strategy

Prepared for Snowy Hydro Limited | 28 September 2018

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Snowy 2.0 Exploratory Works

Final

Report J17188RP46 | Prepared for Snowy Hydro Limited | 28 September 2018

Prepared by	**Nathan Garvey**	Approved by	**Brett McLennan**
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Signature		Signature	
Date	28 September 2018	Date	28 September 2018

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1 Introduction

This report sets out the proposed biodiversity offset strategy (BOS) for the Exploratory Works for Snowy 2.0. This 27/09/2018report builds on the biodiversity offset framework outlined in the biodiversity development assessment report prepared for the environmental impact statement (EIS) for Exploratory Works for Snowy 2.0(EMM 2018), following consultation with the NSW Office of Environment and Heritage (OEH), , NSW Department of Planning and the Environment (DPE) and Snowy Hydro Limited. This BOS also considers submissions made by government agencies, community groups and private individuals.

1.1 Offset requirements

A total of 1,865 ecosystem credits and 2,060 species credits are required to offset residual impacts arising from Exploratory Works. Table 1.1 and Table 1.2 provide a summary of these offset requirements for each plant community type (PCT) and threatened species credit species, as calculated using the Biodiversity Offsets Payment Calculator (BOPC).

Table 1.1 Summary of ecosystem credits required for the Exploratory Works

Plant Community Type (PCT)	Credits required	Payment
285-Broad-leaved Sally grass - sedge woodland on valley flats and swamps in the NSW South Western Slopes Bioregion and adjoining South Eastern Highlands Bioregion	182	$435,790.16
296-Brittle Gum - peppermint open forest of the Woomargama to Tumut region, NSW South Western Slopes Bioregion	925	$2,214,867.56
300-Ribbon Gum - Narrow-leaved (Robertsons) Peppermint montane fern - grass tall open forest on deep clay loam soils in the upper NSW South Western Slopes Bioregion and western Kosciuszko escarpment	164	$392,690.03
302-Riparian Blakely's Red Gum - Broad-leaved Sally woodland - tea-tree - bottlebrush - wattle shrubland wetland of the NSW South Western Slopes Bioregion and South Eastern Highlands Bioregion	112	$268,178.56
311-Red Stringybark - Broad-leaved Peppermint - Nortons Box heath open forest of the upper slopes subregion in the NSW South Western Slopes Bioregion and adjoining South Eastern Highlands Bioregion	62	$148,455.99
729-Broad-leaved Peppermint - Candlebark shrubby open forest of montane areas, southern South Eastern Highlands Bioregion and South East Corner Bioregion	364	$871,580.32
999-Norton's Box - Broad-leaved Peppermint open forest on footslopes, central and southern South Eastern Highlands Bioregion	13	$31,127.87
1196-Snow Gum - Mountain Gum shrubby open forest of montane areas, South Eastern Highlands Bioregion and Australian Alps Bioregion	43	$102,961.41
Grand Total	**1865**	**$4,465,651.90**

Table 1.2 Summary of threatened species credits required for the Exploratory Works

Species	Credits required	Payment
Booroolong Frog	45	$17,052.10
Eastern Pygmy-possum	1961	$1,006,665.61

Table 1.2 Summary of threatened species credits required for the Exploratory Works

Species	Credits required	Payment
Gang-gang Cockatoo	24	$14,566.09
Masked Owl	24	$14,566.09
Smoky Mouse	6	$29,720.87
Grand Total	**2060**	**$1,082,570.76**

1.2 Legislative framework

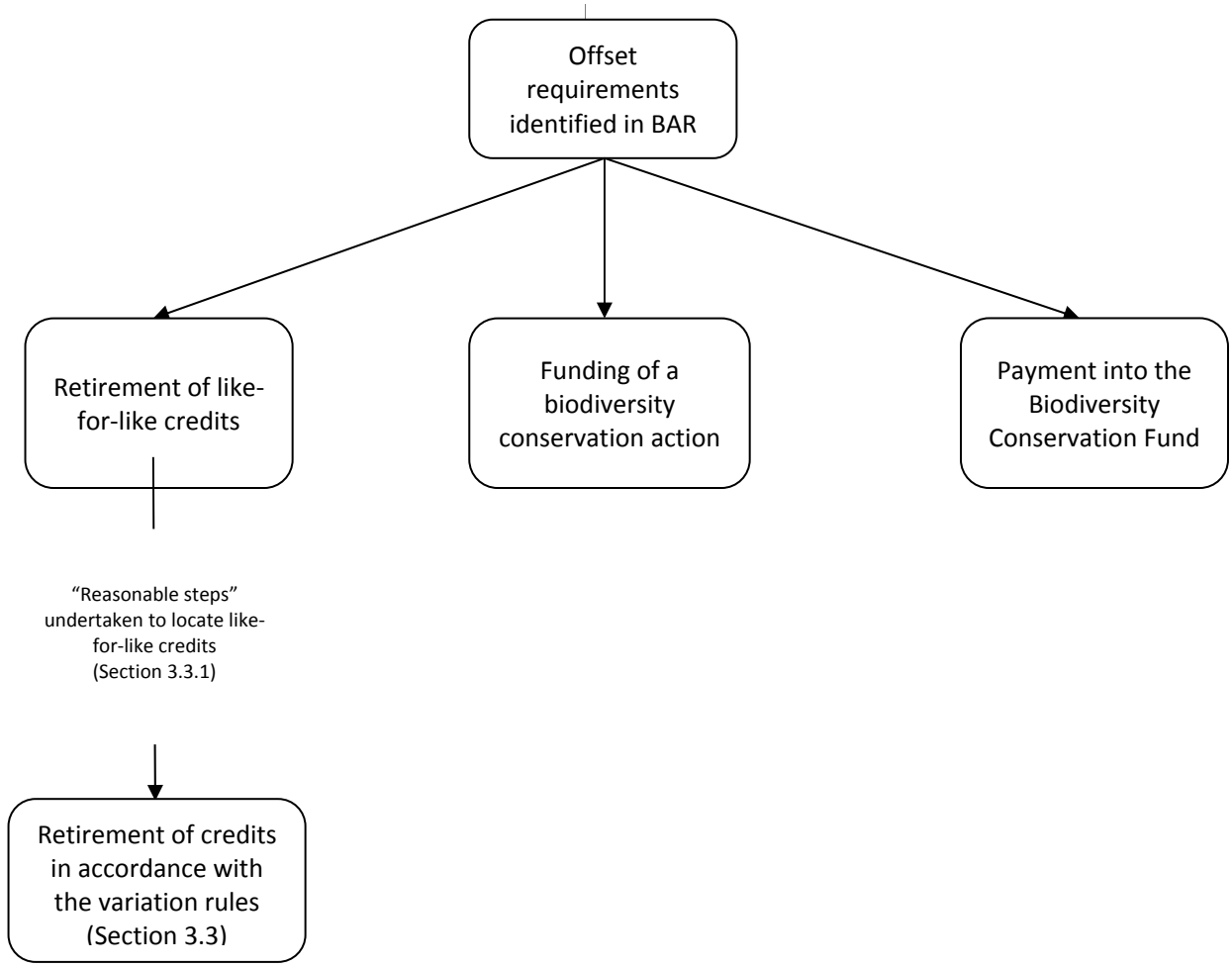
The Secretary's Environment Assessment Requirements (SEARs) for the EIS, issued by DPE on 17 May 2018, require "preparation of an offset strategy for any residual impacts of the project focusing on improving the biodiversity and conservation values of KNP in medium to long term." OEH supported this approach in submission on the EIS letter dated 20 August 2018.

In development of this BOS, consideration has been given to the SEARs as well as the legislative framework. The NSW *Biodiversity Conservation Regulation 2017* (BC Regulation) sets out a framework for how offset are to be provided under the biodiversity offsets scheme.

Under section 6.2 of the BC Regulation three options to offset impacts are provided (see Plate 1.1). The measures to offset impacts may include "any one or a combination" of these options. Any funding of a biodiversity conservation action or payment into the BCF must be equivalent to the value of the credits as determined by the BOPC referred to in section 6.32 of the NSW *Biodiversity Conservation Act 2016* (BC Act).

Following extensive consultation with OEH and DPE, and a review of submissions from a variety of interest groups and individuals, the best possible conservation outcome from the offset for Snowy 2.0 will be funding of conservation actions within the Kosciuszko National Park (KNP), as stipulated in the SEARs. The legislation doesn't allow for like-for-like offsetting through establishment of a stewardship site within KNP, or BCF programs to be applied within national parks. If the offsets are to be realised within KNP the funding of a biodiversity conservation action that benefits the relevant threatened species or ecological community, as per section 6.2(c) of the BC Regulation, would be appear to provide the best option to enable this outcome. In addition, section 7.14 of the BC Act provides the NSW Minister for Planning with discretion on how offsets are provided.

Plate 1.1 Offset options under the biodiversity offsets scheme



It is Snowy Hydro's intention that offset credits required for Exploratory Works be realised within KNP and its preferred option is through conservation actions. To enable this outcome, Snowy Hydro will make payment to NPWS equivalent to the amount calculated for payment into the BCF, totalling $5,548,222.66.

2 Biodiversity offset framework

2.1 Biodiversity offset principles

Significant and extensive consultation has been undertaken with OEH and DPE regarding the biodiversity offsets for the Snowy 2.0 project, including for Exploratory Works. Throughout this consultation process, the objective of any offset has been to ensure any offsets achieve best value for the management of biodiversity values in KNP from offset payments for Snowy 2.0.

Through these discussions a number of guiding principles have been developed to guide the development of an offset strategy. These include:

- management measures/actions that achieve a direct conservation outcome within KNP are preferred over out of park conservation or payment into the BCF;
- management measures/actions will seek to provide a net improvement in the biodiversity values of KNP over time;
- management measures/actions adopted should, where feasible, target threatened species, ecological communities or protected matters being impacted by the project;
- management measures/actions adopted should, where feasible, provide a measurable conservation gain for the threatened species, ecological communities or protected matters being impacted by the project;
- in some cases, a better conservation outcome may be achieved through broader management of the KNP that management measures/actions which target specific species;
- management measures/actions adopted will seek to provide a whole of catchment benefit, providing measurable conservation gains for biodiversity in KNP;
- management measures/actions will be informed by scientific advice and evidence, and will be transparent, effective and efficient; and,
- payment of any offsets by the project is to be made once and will be proportional to the residual impacts after all measures to avoid, minimise and mitigate impacts have been considered.

These rules have been used to guide this BOS.

2.2 Biodiversity offset rules

A number of mechanisms have been considered for the delivery of biodiversity offsets for Snowy 2.0, in consultation with OEH and DPE. Following ongoing consultation it has been determined that a set of offset rules will be developed for Snowy 2.0 for review and endorsement by the Chief Executive of OEH, and provided to DPE. Offset would be delivered in accordance with these endorsed rules, as permitted by section 7.14 of the BC Act. Offsets for all phases of Snowy 2.0, including Exploratory Works will be provided in accordance with these rules.

For Snowy 2.0, offsets will be delivered via conservation actions to be delivered in KNP. Conservation actions will:

- be delivered preferentially in the catchment(s) in which the impact is occurring. Actions that improve catchment health across KNP will also be considered;
- They will be delivered in the same interim biogeographic regionalisation of Australia (IBRA) subregion(s) or adjacent subregion(s);
- benefit the threatened species or ecological communities impacted by Snowy 2.0; and
- be of an equivalent value to the amount calculated by the offsets payment calculator (as in force from time to time) for the retirement of the number of like-for-like biodiversity credits for which the action is intended to be a measure to offset or compensate.

In consultation with OEH, it has been determined that the best way to ensure conservation actions benefit the threatened species or ecological communities impacted by Snowy 2.0 is to develop a proposal which:

- identifies the threatened species associated with the PCTs impacted by Snowy 2.0;
- identifies Savings Our Species (SOS) actions that would benefit these threatened species;
- where SOS projects or activities have not been identified for threatened species, identify management actions for each threatened species; and
- considers projects that provide a cumulative benefit to key conservation actions across the catchments of KNP.

This list of projects would be taken forward for review and endorsement by the Chief Executive of OEH and inform the development of a list of conservation actions to be implemented by OEH.

3 Proposed conservation actions

This sections set out proposed conservation actions that will be implemented to offset impacts of Exploratory Works, in line with the principles and rules outlined above. In development of the conservation actions proposed in this BOS, key documents have been reviewed to ensure alignment with conservation works and priorities being undertaken by the NSW Government, including OEH, in KNP. A summary of this review is provided below.

To ensure conservation outcomes undertaken as a part of this BOS provide a benefit for the threatened species or ecological communities impacted a list of threatened species aligned with the PCTs being impacted by Exploratory Works was developed. Where available, SOS actions and/or management actions outlined for each species in BioNet were documented. The SOS program is an established program managed by OEH to address impacts to threatened species and communities, providing targeted conservation projects and actions required to save specific plants and animals. The management actions for each species have been developed to address threats and causes of ongoing decline for threatened species. These actions have been developed by species experts and accountable officers in OEH.

The *Kosciuszko National Park Plan of Management 2006* (KNP PoM, DEC 2006) provide(s) "a framework of objectives, principles and policies to guide the long-term management of the broad range of values contained in the park ... (and) contains a suite of actions to be undertaken by the National Parks and Wildlife Service and other organisations to protect and conserve the values of the park." Given the importance of this document to the ongoing management and conservation of KNP, the management objectives in the PoM were reviewed and all conservation actions proposed have been aligned with the relevant management objective(s).

Caring for our Australian Alps Catchments (Worboys and Good 2011) was commissioned by the Australian Alps Liaison Committee as a technical report to the Commonwealth Government to "evaluate the natural condition of Australia's high mountain catchments ...; to identify significant current and future threats to those catchments associated with climate change and to assess priority adaptation responses." This document provided a number of policy recommendations to protect the natural values of the Alps, including recommendations for catchment based management at the whole-of-Alps scale to protect water yield. The recommendations from Worboys and Good (2011) have been used to inform the submission on Exploratory Works made by Pittock et al (2018). These documents were reviewed to ensure conservation actions proposed in this BOS were aligned with the recommendations from Worboys and Good (2011) and Pittock et al. (2018).

The list of actions, developed using the process outlined above, was reviewed in consultation with OEH to define a set of conservation actions that would be carried forward to inform the BOS. Conservation actions have been assigned to management stream, KNP PoM management objectives and aligned with elements of Pittock et al. (2018) to demonstrate how they will achieve key outcomes across the catchments of KNP, providing an overall conservation benefit.

Key conservation actions are outlined further below.

Table 3.1 Establish a program to restore and regenerate dry open eucalypt forest and woodland within KNP, improving connectivity and water yield

Conservation action	Establish a program to restore and regenerate dry open eucalypt forest and woodland within KNP, improving connectivity and water yield.

Table 3.1 Establish a program to restore and regenerate dry open eucalypt forest and woodland within KNP, improving connectivity and water yield

Management theme	2 – Restoration activities - existing habitat and landscapes.
KNP PoM management objectives	4.2 – Maintain or improve the condition of the natural and cultural values that together make the park a special place. 6.3.2 - Rehabilitation and construction works are undertaken in ways that protect significant rocks, landforms and geological processes. 6.7.1 – Native plant species and communities are maintained and/or rehabilitated and include a representative range of successional stages and age classes. 6.8.1 – Viable populations of all native animal species that currently occur in the park are maintained or restored. 6.8.4 – Research informs the management of the native animals of the park 11.1.1 – Soil conservation, revegetation and introduced plant and animal control programs are delivered in an integrated way across the park. 11.2.1 – Disturbed sites are stabilised and the creation of new sites of disturbance is minimised. 11.2.2 – All site rehabilitation works are undertaken in ways that protect the values of the park.
Alignment with Pittock et al. (2018) elements	1.1 Rehabilitation of damaged sites/revegetation. 1.4 Restore subalpine snow gum communities for water yield. 3. Minimize the environmental impacts of Snowy 2.0.
Details	Revegetation works to establish and reconnect patches of eucalypt forests and woodlands is identified as a key management action for a number of threatened species that will be impacted by the Exploratory Works project. To provide a benefit for these species a program to restore and regenerate dry open eucalypt forest and woodland across the KNP will be established. Sites proposed for restoration will be identified by OEH, with a view to rehabilitating degraded sites, connecting smaller patches of woodland and improving connectivity and the biodiversity values of the KNP. These works may include elements: • Targeted works to increase the size of existing remnants, improve connectivity and establish buffer zones around key habitat for threatened species. • Revegetation works will be preceded by weed control, where required, to improve the success of the revegetation works. • Revegetation works will be undertaken using a diverse mix of locally appropriate native species, focussing on expanding areas of existing habitat, connecting isolated habitat patches (either through corridor or stepping stone plantings) or establishing additional habitat patches in landscapes with already existing, although insufficient, patches of suitable habitat. • Areas with access to water, especially riparian areas, are particularly important and will be prioritised. • Revegetation works will include use of key feed species for the Eastern Pygmy-possum (in areas of suitable habitat and where relevant). • In suitable habitat for Robins (*Petroica* spp.), revegetation works will include augmentation planting of missing structural layers (e.g., mid-layer wattles (Acacia spp.), shrub layer species, or coarse tussocky ground layer species), using locally indigenous species appropriate to the vegetation type predicted for replanting sites.

Table 3.2 Undertake an expanded weed control program across KNP to improve vegetation condition and habitat for threatened species

Conservation action	Undertake an expanded weed control program across KNP to improve vegetation condition and habitat for threatened species.
Management stream	1 – Targeted weed control (catchment wide)
KNP PoM management objectives	11.3.1 – The distribution and abundance of all existing weed species found in the park are reduced and populations are eradicated wherever feasible. 11.3.4 – All weed control programs are undertaken in ways that protect the values of the park. 11.3.5 – Weed control is strategically coordinated across the greater landscape and involves neighbours, public and private authorities, and local communities.
Alignment with Pittock et al. (2018) elements	1.1 Rehabilitation of damaged sites/revegetation. 1.7 Weed control. 3. Minimize the environmental impacts of Snowy 2.0.
Details	Weeds are a significant issue in areas to be impacted by Exploratory Works, particularly Lobs Hole, due to past land use. To address this key management issue, a weed control program will be implemented across KNP, targeting removal of weeds significantly compromising habitat values. This program will be undertaken on conjunction with the conservation action outlined above, assisting in the restoration of native vegetation. Key elements of the weed control plan will include: • Control weeds in areas of known habitat for threatened species. • Care will be taken to avoid widespread removal of beneficial exotic woody vegetation without replacement and avoid non-target impacts of herbicides. • Implement control of exotic berry-bearing trees or shrubs (e.g. sweet briar rose, hawthorn, blackberry) in woodland remnants and ensure to replace removed thickets with locally indigenous species, particularly bipinnate wattles (Acacia spp.), prickly native shrubs (e.g. Bursaria spinosa) or she-oaks (Allocasuarina spp.), as appropriate. • Increase and enhance native ground cover by replacing areas of exotic perennial pasture grasses (e.g. Phalaris, cocksfoot, Paspalum) or aggressive environmental weeds (e.g. African love-grass, serrated tussock) with native grass species appropriate to the vegetation type. Weeds will be removed using best-practice methods.

Table 3.3 Development and implement a program to improve watercourses within KNP, restoring Alpine watercourses, recovering habitat for threatened species and improving water yield

Conservation action	Development and implement a program to improve watercourses within KNP, restoring Alpine watercourses, recovering habitat for threatened species and improving water yield.
Management stream	4 – Erosion Control and rehab- watercourses
KNP PoM management objectives	6.6.1 – The environmental condition of all watercourses and waterbodies is maintained or improved. 11.6.1 – Environmental quality is maintained or improved.
Alignment with Pittock et al. (2018) elements	2. Restore Alpine rivers

Table 3.3 Development and implement a program to improve watercourses within KNP, restoring Alpine watercourses, recovering habitat for threatened species and improving water yield

Details	The Exploratory Works project is located adjacent to a number of key watercourses in KNP, including Wallaces Creek and the Yarrangobilly River. Impacts to watercourses have been avoided and minimised wherever possible, some residual impacts to riparian vegetation communities and watercourses remain. Watercourses in the Exploratory Works project area, and across KNP, have been significantly affected by past land use and anthropogenic activities, resulting in degradation of some areas. To compensate for impacts of the Exploratory Works project and result in improvements in water yield across the catchments in KNP, a program will be developed to rehabilitate watercourses across KNP. Key elements will include: • Maintenance of natural stream channel morphology. • Minimising levels of erosion and/or sedimentation in waterways. • Undertaking bank stabilisation works in degraded waterways. • Control weeds, particularly willows, and rehabilitate streamside habitats.

Table 3.4 Establish a program to reduce the distribution and abundance of feral predators across KNP

Conservation action	Establish a program to reduce the distribution and abundance of feral predators across KNP.
Management stream	3 – Feral Animal control (rabbits, deer, pigs, foxes and cats)
KNP PoM management objectives	11.4.1 – The distribution and abundance of introduced animal species found in the park are reduced and populations are eradicated wherever feasible. 11.4.4 – Introduced animal control is strategically coordinated across the greater landscape and multiple land tenures, and involves neighbours, public and private authorities, and local communities.
Alignment with Pittock et al. (2018) elements	1.6 Other feral animal control
Details	Introduced feral predators are a key threat to a number of threatened species recorded in or adjacent to the Exploratory Works project area, including the Smoky Mouse, Eastern Pygmy-possum and Booroolong Frog. The Exploratory Works project has the potential to increase number of feral predators in and around key areas of human activity in Lobs Hole. To compensate for this a program to reduce the distribution and abundance of feral predators across KNP will be established. Key elements of the feral predator control plan will include: • Targeting Fox and feral Cat control, particularly in key habitat areas for threatened species. • Wherever possible, utilise introduced animal control measures that include multiple control methods, target multiple species and form part of an integrated ecological restoration program. • Utilisation of poison-baiting techniques least likely to affect Spotted-tailed Quolls. • Cross-tenure, landscape scale predator control programs in areas where significant populations of Spotted-tailed Quoll are known to occur and monitor populations of the target introduced predator. • Monitoring of significant Spotted-tailed Quoll populations to investigate the impact of fox and wild dog baiting.

Table 3.5 Establish a program to reduce the distribution and abundance of feral herbivores across KNP

Conservation action	Establish a program to reduce the distribution and abundance of feral herbivores across KNP.
Management stream	3 – Feral Animal control (rabbits, deer, pigs, foxes and cats)
KNP PoM management objectives	11.4.1 – The distribution and abundance of introduced animal species found in the park are reduced and populations are eradicated wherever feasible. 11.4.4 – Introduced animal control is strategically coordinated across the greater landscape and multiple land tenures, and involves neighbours, public and private authorities, and local communities.
Alignment with Pittock et al. (2018) elements	1.6 Other feral animal control
Details	Introduced feral herbivores present a key threat to vegetation and associated threatened species within KNP, with feral herbivores responsible for degradation of vegetation and riparian environments and impacts to water quality and yield across the Alps. Impacts from feral herbivores were recorded at a number of vegetation survey locations undertaken as a part of the Exploratory Works project, with impacts such as vegetation damage and destruction, creation and proliferation of tracks, introduction of exotic (weed) species, soil erosion and deterioration in water quality and the health of aquatic ecosystems noted. The Exploratory Works project provides an opportunity to fund management of feral herbivore control. Key elements of a feral herbivore control plan will include: • Targeting of a variety of feral herbivores, including Rabbits, Deer and Pigs, particularly in sensitive environments and/or habitat for threatened species and communities. • Wherever possible, utilise introduced animal control measures that include multiple control methods, target multiple species and form part of an integrated ecological restoration program. • Cross-tenure, landscape scale approach to control.

Table 3.6 Undertake targeted conservation actions to benefit threatened species within KNP

Conservation action	Undertake targeted conservation actions to benefit threatened species within KNP.
Management stream	6 – Threatened Species Ecosystem Credit Species Recommendations
KNP PoM management objectives	6.7.1 – Native plant species and communities are maintained and/or rehabilitated and include a representative range of successional stages and age classes. 6.8.1 – Viable populations of all native animal species that currently occur in the park are maintained or restored.
Alignment with Pittock et al. (2018) elements	1.1 Rehabilitation of damaged sites/revegetation 3. Minimize the environmental impacts of Snowy 2.0
Details	The Exploratory Works project will impact on habitat for a number of threatened species credit species. Specific conservation actions have been identified for these species, in consultation with OEH . Specific conservation actions are outlined below for each species. **Booroolong Frog** • Develop a SOS site in Yarrangobilly River and implement following actions:

Table 3.6 Undertake targeted conservation actions to benefit threatened species within KNP

- Reduce and maintain weed densities at low levels through broad-scale weed control, and restore riparian vegetation.
- Undertake a pest species control program to reduce impacts of pest species, and maintain at low levels.
- Minimising levels of erosion and/or sedimentation with the catchment through targeted restoration works.
- Undertake regular monitoring of species abundance, extent and condition to determine population trends through time. The extent and severity of threats will also be monitored to assess the effectiveness of management actions. Management actions will be adapted, added or removed over time in response to monitoring results, based on maximising effectiveness of the management actions.

Eastern Pygmy-possum

- In known habitat and movement areas investigate options for safer road crossing options such as underpasses or overpasses.
- Control feral predators and rabbits.
- Regenerate and replant local feed sources.

Smoky Mouse

- Undertake surveys to locate new populations and determine the extent of high-quality habitat in KNP.
- Trial the effectiveness of a trained Smoky Mouse detector dog to locate Smoky Mouse sites.
- Undertake Fox and Cat control program in areas of identified habitat.

Gang-gang Cockatoo

- Restore gang-gang cockatoo habitat in strategic locations close to known habitat and movement corridors, using appropriate local tree, shrub and ground cover species. Care must be taken to ensure that the removal of exotic berry-bearing shrubs and trees such as cotoneaster, hawthorn and pyracantha, that provide foraging habitat, is compensated for by planting of appropriate native foraging plant species such as acacias and eucalypts.
- Conduct surveys and research on the locations of key breeding sites, and measure the breeding ecology and success of the Gang-gang Cockatoo.

Masked Owl

- Survey and map known nest/roost sites across the area to inform habitat mapping, which should include vegetation, floristic, structural and condition attributes.
- Undertake strategic survey for the presence of masked owls within the species' core range to develop an accurate habitat model for NSW.
- Trial camera traps at nest trees as a long term monitoring tool for assessing nest-site use and reproductive success. Apply this information to the development of nest/roost site suitability attributes that inform habitat management prescriptions.
- Retain and protect stands of native vegetation, especially those with hollow-bearing trees.

OEH will use these conservation actions to develop priorities for the detailed management actions, including details on sites, management, costing and outcomes to be achieved.

3.1 Funding mechanism

Snowy Hydro will make payment of $5,548,222.66 to OEH for in-Park conservation measures to be implemented. This money will be held in a trust, to be managed by OEH under a separate NSW Government authorised Trust. Conservation actions will be funded by this Trust.

The required biodiversity credits will be refined before any development is carried out that will impact on biodiversity values, in accordance with section 7.14 (4) of the BC Act.

3.2 Government arrangements

The offset strategy will be binding as a condition of the project approval. The agreed conservation actions will be measured, monitored and audited by OEH as a part of it's park management obligations.

4 Conclusion

Following extensive consultation with NSW government agencies, the offsets required for residual impacts arising from Exploratory Works for Snowy 2.0 will be used to fund conservation actions within KNP, providing an overall benefits for the threatened species and catchments of KNP. This outcome is in line with the key objectives identified in a number of plans, particularly the KNP PoM (DEC 2006), Worboys and Good (2011) and Pittock et al. (2018).

To offset impacts arising from the Exploratory Works, Snowy Hydro will make a payment to OEH to fund conservation actions within KNP. This money will be held in a Trust, with conservation actions funded by the Trust.

A set of principles and rules have been developed to guide the development of this BOS. In line with these principles and rules a list of conservation actions has been developed; these conservation actions will be implemented by OEH to offset the impacts of the Exploratory Works.

5 References

DEC 2006. *Kosciusko National Park Plan of Management*. Department of Environment and Conservation, Hurstville.

EMM 2018. *Biodiversity Development Assessment Report: Exploratory Works for Snowy 2.0.* Prepared for Snowy Hydro Limited by EMM Consulting Pty Ltd, St Leonards.

Pittock J, Banks S, Driscoll D, Hope G, Lake PS, Nicotra A, Sato C & Worboys GL, 2018. *The Environmental Dividend from Snowy 2.0.* A submission to the Department of Planning and Environment.

Worboys GL & Good RB, 2011. *Caring for our Australian Alps Catchments: Summary Report for Policy Makers*. Department of Climate Change and Energy Efficiency, Canberra.



CHAPTER C

HISTORIC HERITAGE REASSESSMENT OF MANAGEMENT AND MITIGATION MEASURES

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R1	Site of 1885 West Pinbeyan Station Homestead; subsequently used as the mine manager's (Lobs Hole Copper Mine) residence and finally as the Yan house (the last family to leave Lobs Hole).	Bricks appear to delineate the footings of a structure. The wider area is highly disturbed as an industrial site and from NPWS grading activity to clear weed shrubs	Lobs Hole historic landscape **West Pinbeyan Station Homestead**	Local	West Pinbeyan Homestead is important for its association with the pattern of pastoral settlement in the Snowy Mountains The building remains at R1 meet the threshold against the criteria for its historical values	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	This site is part of a group that is likely to include R2, R3, R4, R6, R17; R19; R33, R97 This site, and its components, is part of an 1885 station. The features have the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the excavation program will determine the final management measures.
	Preliminary interpretation This site is probably associated with R2 – metal water pipe; R3 – possible building structure; R4 – rectilinear depression; R17 levelled area -; RH19 – levelled pad; R33 – excavation and bricks; and R97 – exotic trees. It is likely that the items described above and in 'rationale' are associated with the 1885 Pinbeyan Homestead although it is possible some may relate to the later mining and Yan family occupation phases. As such, research is required to ascertain to which phase items belong to. This research will be in the form of the research design and excavation methods for items that will be impacted by the project.						
R2	Metal water pipe	Part of Lobs Hole Copper Mine water race; subsequently used as water tank in Yan's house. Note another piece of this pipe is *associated* with the Police Station building at Ravine (R60)	Lobs Hole historic landscape **West Pinbeyan Station Homestead**	Contributory - part of R1 (West Pinbeyan Station Homestead)	Contributory - part of R1 (West Pinbeyan Station Homestead)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method Implement measures to protect moveable heritage	To be investigated as part of the archaeological excavation program.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R3	Possible building structure	Collection of stone and brick. Possibly a structure associated with the 1885 West Pinbeyan Station/mine managers residence, Yan house complex	Lobs Hole historic landscape **West Pinbeyan Station Homestead**	Contributory - part of R1 (West Pinbeyan Station Homestead)	Contributory - part of R1 (West Pinbeyan Station Homestead)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R4	Rectilinear depression	Possibly a structure associated with the 1885 West Pinbeyan Station/mine manager's residence/Yan house complex	Lobs Hole historic landscape **West Pinbeyan Station Homestead**	Contributory - part of R1 (West Pinbeyan Station Homestead)	Contributory - part of R1 (West Pinbeyan Station Homestead)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R5	Slag	Probably slag relocated from the reverberatory furnace	Lobs Hole historic landscape **Lobbs Hole Copper Mine**	N/A	The slag at R5 does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R6	Stone flagging	Probably a structure associated with mining or domestic occupation	Lobs Hole historic landscape **Pinbeyan Station Homestead** **Lobbs Hole Copper Mine**	Contributory - part of R1 (West Pinbeyan Station Homestead)	Contributory - part of R1 (West Pinbeyan Station Homestead)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R7	Depression	Subtle depression may not be historic. May be a dam associated with the homestead.	Lobs Hole historic landscape	N/A	The depression at R7 does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R8	Depression	Amorphous depression; may not be historic	Lobs Hole historic landscape	N/A	The depression at R8 does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R9	Lobbs Hole Copper Mine Shafts	Lobbs Hole Copper Mine: capped mine shafts	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Local	The Lobbs Hole Copper Mine is an important component of the mining history at Lobs Hole. It has a strong association with Reeckmann and Julius Forsstrom, who were important in developing mining at Lobs Hole and as central figures in the Lobbs Hole Copper Mining Company. The Lobbs Hole Copper Mine remains are assessed to be of local significance against criteria a, b, d, and f.	Include in a no-go buffer to avoid inadvertent impacts Archival recording Include in the archaeological research design and excavation method report	The shafts are in proximity to the disturbance zone. The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
	Preliminary interpretation This site is a component of the Lobs Hole Copper Mine features and is associated with R10 – Lobbs Hole Copper Mine No 1 shaft, mullock and cage; R11 Lobbs Hole Copper Mine: mullock and metal ore bucket; R12 Foundations for Pelton Wheel; R13 Tramway cutting; R14 Site of reverberatory furnace; R45 Lobbs Hole Copper Mine water race; R51 Coronation mine adit in cliff; R67 Lobbs Hole Central Mine; R68 Shaft and mullock; R69 circular beehive brick kiln; R74 Metal Water Pipe; R75 Mine shaft on ML 31; R81 Yarrangobilly River water race/road; R90 Lick Hole Gully Adit; R96 Open cut in Lick Hole Gully; R98 Excavated pit; R112 shaft; R117 shaft. Archival recording. Research is required to ascertain which phase of the site these structures belonged to. This research will be in the form of the research design and excavation methods for features that will be impacted by the project.					
R10	Lobbs Hole Copper Mine	Lobbs Hole Copper Mine: No 1 Shaft, mullock and cage	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R11	Mullock and metal ore bucket	Lobbs Hole Copper Mine: mullock and metal ore bucket	Lobs Hole historic landscape **Lobbs Hole Copper Mine**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R12	Foundations for Pelton Wheel	Lobbs Hole Copper Mine: concrete foundations for Pelton Wheel in river bed	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R13	Tramway cutting	Lobbs Hole Copper Mine: 12 m long cutting likely to have been used for overhead tram for transporting ore from the mine to the reverberatory furnace	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R14	Site of reverberatory furnace	Lobbs Hole Copper Mine: reverberatory furnace ruin (it was blown up in the 1950s); a sparse scatter of bricks, slag and metal beams	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Implement measures to protect moveable heritage if the object is at risk of impacts from the project. Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R15	Stone channel	Linear stone feature on valley floor, on southwestern side of Yarrangobilly River. The feature extends for ~10m, and runs east to west, with a post hole at the western end. A section of plain and chicken wire fence is also present across the surface and continues to the southwest across the adjoining flat.	Lobs Hole historic landscape **Possibly Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm infrastructure)	Contributory – part of R113 (Yan Farm infrastructure)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R16	Pile of rocks and drums	The site comprises two piles/cairns of rock situated approximately 20 m apart. Each rock pile is approximately 1-2 m across and 50-80 cm high and may be a product of field clearance. There are three metal drums/tanks present in association with the rock piles. Probably associated with the homestead (R1)	Lobs Hole historic landscape	Contributory - part of R1 (West Pinbeyan Station Homestead)	Contributory - part of R1 (West Pinbeyan Station Homestead)	Archival recording Implement measures to protect moveable heritage. Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	This site, and its components, is part of the Lobs Hole historic landscape and includes mine relics. The features have the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R17	Levelled area	A poorly defined/indistinct earth platform measuring c. 7 m by 4 m and oriented NW/SE. Possibly associated with the homestead (R1) but has undergone a high level of disturbance thus requires further investigation. This feature may also be the result of recent activity in the area.	Lobs Hole historic landscape **West Pinbeyan Station Homestead** **(possible)**	Contributory – Part of R1 (West Pinbeyan Station Homestead)	Contributory – Part of R1 (West Pinbeyan Station Homestead)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation may be of this item may be included in the research design and excavation method	May be a component of Pinbeyan Station Homestead and therefore assessed as part of the homestead complex. The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R18	Fallen fence	Rabbit proof fence: chicken wire and thick plain wire anchored with stones. Probably part of the Yan's infrastructure as they were the last people to live at Lobs Hole but may also be related to the Rabbit Nuisance Act of 1883.	Lobs Hole historic landscape **Yan Farm Infrastructure** **West Pinbeyan Station Homestead**	Contributory – part of R113 (Yan Farm infrastructure)	Contributory – part of R113 (Yan Farm infrastructure)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	May be a component of Yan Farm Infrastructure and therefore assessed as part of the Yan Farm complex. The features have been assessed to potentially contribute to the significance of the site and therefore should be considered prior to impacts. The results of the test excavation will determine the final management measures.
	Preliminary interpretation This site is probably associated with the following features as a component of the Yan farm infrastructure: R35 rabbit proof fence; R43 rabbit proof fence; R48 excavation possible shed; R49 circular stone wall; R50 shed with bullock wagon frame; R73 rabbit proof fence; R93 fence; R99 well; R100 Single furrow plough; R103 levelled platform; R104 Lick Hole Gully water race; R105 ditch; R113 shed platforms It is likely that the items described above are a part of the Yan farm. Research is required to ascertain the nature of these structures and how they relate to each other. This research will be in the form of the research design and excavation methods for features that will be impacted by the project.						
R19	Levelled pad	A levelled pad measures c. 4 m by 2.5 m and is orientated 170°/350°. It is highly eroded. A sparse scatter of glass, pottery and metal appears to be associated with the feature	Lobs Hole historic landscape **West Pinbeyan Station Homestead** **Yan family residence**	Contributroy – part of R1 (West Pinbeyan Station Homestead)	Contributory – Part of R1 (West Pinbeyan Station Homestead)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R20	Washington Hotel	Washington Hotel ruin	Lobs Hole historic landscape **Ravine township**	Local	The Washington Hotel marks an important final phase in mining at Lobs Hole. The building's ruinous state is a testimony to the temporary nature of the settlement. It has a strong association with Julius Forsstrom, who was important during the final years of Ravine as a central figure in the village and as part of the Lobbs Hole Copper Mining Company. The site is also notable as an important element of the aesthetics of Lobs Hole. The Washington Hotel displays excellent research potential that may contribute to a better understanding of various aspects of the history of Lobs Hole and the broader Snowy Mountains region. It is also a relatively rare site type and is a good example of a pisé ruin and a turn of the century hotel/pub site. The Washington Hotel is assessed to be of local significance against criteria a, b, c, e, and g.	Implement measures to protect fabric and moveable heritage Ensure no inadvertent impacts Determine curtilage around the item and prepare an archaeological research design to ascertain what, if any parts of the hotel complex are in the disturbance zone. Reassess the significance of component parts Archival recording Include in the archaeological research design and excavation method report	While the main building of the Washington Hotel is in the avoidance zone, the curtilage of the item can only be ascertained through archaeological test excavation where it crosses into the disturbance zone. The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
	Preliminary interpretation This site is probably associated with the following features as a component of the Ravine township: R21 depression and debris; R22 Potential earthen feature; R23 excavation; R24 depression; R25 building platform; R26 mound; R27 depression with rock; R28 Pisé ruin; R30 rectilinear earth feature; R31 water race; R33 mound of stone; R34 mound of stone; R39 excavation; R40 cutting for building platform; R42 Rosie Cook's place; R47 Ravine Public School site; R60 Police Station site; R61 well; R63 pile of shale; R 64 water race; R65 John Thomas homestead; R71 butcher shop; R92 Building platforms; R116 house site; R118 Ravine cemetery; R121 depression; R122 fireplace platform. It is likely that the items described above are a part of the Ravine township. Research is required to ascertain the nature of these structures and how they relate to each other. This research will be in the form of the research design and excavation methods for features that will be impacted by the project.					
R21	Depression and debris	Depression and a sparse scatter of bricks and metal	Lobs Hole historic landscape. **Ravine township**	Contributory – part of R28 (Ravine Township)	Contributory – part of R28 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R22	Potential earthen feature	Potential earthen feature: The remains at the site comprise two north-south aligned platforms that are distinguishable primarily as changes in vegetation, but also evidenced as subtle earth features. This feature may be a building platform.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R28 (Ravine Township)	Contributory – part of R28 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R23	Excavation	Perhaps borrow pit for earth for walls of hotel	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.
R24	Depression	Two rectilinear depressions c. 2m apart, each approximately 1m square and 30cm deep.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.
R25	Building platform	Building platform: the site is a 6-7m long building platform, aligned north-south. The platform is approximately 3m across. Brick and sheet metal are present on the surface at the southern end. Metal pipe and straps are also present.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The features have the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R26	Mound	Mound of stone and earth measuring c. 4 x 1.5m. Post holes and an ephemeral earth mound are present on the southern side of the stone mound. A few metres to the southwest there is a shallow rectilinear depression. These features are interpreted as a probable fireplace and associated privy and cover an area measuring c. 15 x 15m.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The features have the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results will determine the final management measures.
R27	Depression with rock	Depression and a sparse scatter of bricks and metal	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The features have the potential to reach the threshold of relics and therefore should be considered as part of the research design prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R28	Pisé ruin	Possible stable associated with hotel comprised of three eroded pisé walls. The structure measures 8 m long by c. 3 m wide and is orientated E/W. The remains of the earth walls measure c. 2 m wide by 0.5 m high.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research and excavation design method report	The feature has been assessed as relics. While R28 is not in the impact zone, associated archaeological resources may be impacted by the project and therefore this feature and the surrounding landscape should be considered in the research design prior to impacts. Archaeological test excavation in the adjacent area of impact may be required. The research design will determine if archaeological test excavation should be conducted adjacent to this item in the impact zone and the results will determine the final management measures.
R29	Mound of stone and brick	Mound of stone and brick, an east-west aligned mound of stone and brick, approximately 1 m wide and 4 m long.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R30	Rectilinear earth feature	Rectilinear earth feature	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The features have been assessed to be potentially relics and therefore must be further investigated prior to impacts. The results will determine the final management measures.
R31	Water race	Water race with relatively steep gradient	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R32	Excavation and bricks	Excavation and bricks	Lobs Hole historic landscape **West Pinbeyan**	Contributory – Part of R1 (West Pinbeyan Station Homestead)	Contributory – Part of R1 (West Pinbeyan Station Homestead)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The features have been assessed to be potentially relics and therefore must be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R33	Mound of stone	Possible hearth; It comprises a low rectilinear mound of stone approximately 2 m square. There is a possible earth platform extending out on the northern side of the mound that is possibly a building platform.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method.	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R34	Rabbit proof fence	Rabbit proof fence: chicken wire and thick plain wire anchored with stones; extends for at least 30m along a southeast-northwest alignment	Lobs Hole historic landscape **Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm infrastructure)	Contributory – part of R113 (Yan Farm infrastructure)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R35	Rabbit proof fence	Rabbit proof fence: chicken wire and thick plain wire anchored with stones; extends for at least 30m along a southeast-northwest alignment	Lobs Hole historic landscape **Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm infrastructure)	Contributory – part of R113 (Yan Farm infrastructure)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R36	Hole	Excavation possibly associated with SMA flying fox	Lobs Hole historic landscape **SMA**	N/A	The hole at R36 does not meet the threshold against any of the criteria at either local or state levels.	Archival recording. Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R37	Flying fox	Flying fox over the Yarrangobilly River. The southern component comprises a Colorbond, flat-roofed shed erected on a levelled cutting, with a cable support on the southern side and cables running across the river to a single tower on the northern side of the river.	Lobs Hole historic landscape **SMA**	N/A	The flying fox at R37 does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R38	Yarrangobilly Stream Gauging Station 2	A Besser block cubicle shed, with colorbond gable roof, built on random rubble foundations on the north aspect slope leading down the river. The building is accessed by a wooden door on the southern side, and a series of flood level markers are situated down slope towards the river.	Lobs Hole historic landscape **SMA**	N/A	The Gauging Station at R38 does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R39	Excavation	A square excavation measuring 1.8 m by 1.8 m. The excavation has been infilled but contains some old turn of the century glass. It is on the same contour as R27, and a similar feature. It is possibly a well or privy or rubbish pit.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation may be of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R40	Cutting for building platform	Two rectilinear features. The first is a cutting into the hill slope that is approximately 10m long. The second is a more ephemeral cutting further downslope. The features are orientated NE/SW. Possible building platforms.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R41	Parallel stone alignment	2 m long parallel alignment of stone, 1 m apart	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation e of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R42	Rosie Cook's place	Rosie Cook's (widow) lot. Her husband was a miner. Comprises exotic plants (Apple, periwinkle, iris and quince tree?) that appear to be the remains of a former garden likely to be associated with a house site. The area is quite overgrown and the location of any former structures, or form of the garden is not easily discernible. There are numerous depressions and mounds over an area of c. 50 x 50m.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R43	Rabbit proof fence	Grid ref at strainer post hole. Rabbit proof fence from post to 135° and to 280°.	Lobs Hole historic landscape **Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm infrastructure)	Contributory – part of R113 (Yan Farm infrastructure)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R44	Stable Creek Stream Gauging Station	Named by KHA as Stable Creek SGS, but it is on Wallaces Creek. It is locked; not operational. Wallaces Creek stream flows were measured intermittently at a Snowy Hydro operated stream gauge (410507) between 1969 and 1998; could be the same. Braided steel cable in north creek bank.	Lobs Hole historic landscape **SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording. Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R45	Lobbs Hole Copper Mine water race	Extends from an unspecified source on Wallaces Creek (believed to be near junction with Stable Creek) to Lobs Hole Copper Mine. It is on south side of Mine Trail Road and mostly intact until it becomes truncated by the existing road at grid ref: 627406.6038061. It appears that Mine Trail Road has been built on the race from that point, and west to where the race would have joined the steel pipe (R74) to take the water down eastwards to the mine.	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory – part of R9 (Lobs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R46	Large excavation	Large pit; The cutting is up to 4 m deep, at least 20 m across and approximately 40 m long (along north-south axis). Function unknown.	Lobs Hole historic landscape	N/A	Unknown	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	This feature has not been identified and should be included in the research design and excavation method for the purpose of more detailed assessment.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R47	Ravine Public School site	The new school (Ravine Public School) was built in 1910 and teaching commenced on 21 September 1910; school site with artefacts.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.
R48	Excavation possible shed	This feature is an excavation measuring c. 10 x 4 x c. 1 m deep which contains stacked piles of sheet tin, corrugated iron and other metal, including roof capping. Some of the stacks of tin are weighed down with cobbles and appear to be untouched since they were put in place.	Lobs Hole historic landscape **Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm infrastructure)	Contributory – part of R113 (Yan Farm infrastructure)	Include in a no-go buffer to avoid inadvertent impacts Archival recording Include in an archaeological research design and excavation method report Implement measures to protect moveable heritage	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R49	Circular stone wall	Semicircular stone wall measuring 9 m wide by c. 6 m deep; part of a circular feature. Stone wall made with massive natural boulders of 4-5 courses. Some rocks up to 90 cm long. The stone forms a flat platform for a horse or other to walk around driving a shaft attached to whatever mechanical device being uses ie chaff cutter, wheat grinding. The heavy metal whim nearby; adjustable, wedge locked. The feature is adjacent to shed remains which are believed to have been used by the Yans.	Lobs Hole historic landscape **Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm infrastructure)	Contributory – part of R113 (Yan Farm infrastructure) Stone features for processing plant material are locally rare. The feature does meet the threshold against criteria f at a local level.	Include in a no-go buffer to avoid inadvertent impacts Archival recording Include in an archaeological research design and excavation method report Implement measures to protect moveable heritage	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R50	Shed with bullock wagon frame	Stone shed platform c. 12m x 9m, frame complete with thick wire rope for 'lowering' bullocks; rear axle missing (could have been wooden and hence burnt)	Lobs Hole historic landscape **Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm infrastructure)	Contributory – part of R113 (Yan Farm infrastructure)	Include in a no-go buffer zone to avoid inadvertent impacts Implement measures to protect moveable heritage Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R51	Coronation mine	Adit in cliff	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R52	Survey Mark	Fallen metal survey mark	Lobs Hole historic landscape **SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R53	Old road	Old cut and benched road	Lobs Hole historic **landscape**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R54	Site of bridge	At end of Mine Trail probably SMA	Lobs Hole historic landscape **SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R55	Brick hearth	Possibly SMA or shire picnic site at end of Mine Trail; machine pressed bricks: early 20th century and other	Lobs Hole historic landscape	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.
R56	Excavated ditch	7 m x 1.5 m x 1.4 m deep; function unknown. Earth and rock mounded on downhill side.	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Include in a no-go buffer zone to avoid inadvertent impacts Implement measures to protect moveable heritage Archival recording Include in the archaeological research design and excavation method report.	A component of the features in the Struggle Street area and therefore assessed as part of Struggle Street. The feature has been assessed to be potentially a relic. While the item should be included in the archaeological research design to better understand the site, test excavation should not be undertaken unless it is in the impact zone.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
	Preliminary interpretation This site is probably associated with the following features as a component of the features in Struggle Street: R57 old road alignment; R76 Scatter of tin, glass and brick; R80 Elizabeth Frazer's orchard; R106 old road; R107 building platform; R108 old road; R109 house platform with wooden cross; R110 building platform; R111 path to creek; R115 stone lined channel; R120 building platform. The items are located in the area of Lobs Hole known as Struggle street. The area was occupied by mine employees. Research is required to ascertain the nature of these features and how they relate to each other. This research will be in the form of the research design and excavation methods for features that will be impacted by the project.						
R57	Oold road alignment	Old cut and benched road alignment in the Struggle Street locale. It is aligned 30/°210° and measures c. 2 m wide.	Lobs Hole historic landscape **Struggle Street**	Local	Part of the cultural landscape of Struggle Street, an area associated with mine workers dwellings	Include in a no-go buffer to avoid inadvertent impacts Implement measures to protect moveable heritage Archival recording Include in the archaeological research design and excavation method report.	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R58	Large metal pipes	2 long metal pipes, one purposefully situated with one end propped up on rock base	Lobs Hole historic landscape	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report. Include in a no-go buffer to avoid inadvertent impacts Implement measures to protect moveable heritage	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R59	Domestic metal glass etc	Scatter in area 10 x 10m	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report.	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R60	Police Station site	Police station platform and debris in copse of slippery elm; bricks, chicken wire, tin sheet metal, piece from mine water pipe, possibly used as water tank	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R61	Well	Possibly associated with police station brick and stone lined hole 2 x 2 x 1.5 deep	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report. Archaeological test excavation of this item may be included in the research design and excavation	The features have the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R62	Possible shaft	Can be seen in aerial on east side of river, possible shaft. Hasn't been ground truthed.	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Unverified	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R63	Pile of shale	Pile of shale at Rose Cook's place. It is unlike the local rock found in the immediate locale and has been brought to the site. It measures c. 1.2 x 1.2 m and c. 20 cm high.	Lobs Hole historic landscape **Ravine township**	Unverified	Possibly contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method Implement measures to protect moveable heritage	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R64	Water race	At Rosie Cooks place. A water race cut into the north margin of an alluvial terrace on the southern side of the Yarrangobilly River, with the spoil placed downslope to form a channel running parallel to the river (southeast to northwest). The channel is approximately 1m wide and 0.6 m deep. It extends for c. 170 m	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R65	Thomas house	The John Thomas homestead on Sheep Station Creek	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R66	House platform	Excavated platform 5.6m x 3.1m with stone hearth	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R67	Lobbs Hole Central Mine	Lobs Hole Central Mine - on NE side of river	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory - part of R9 (Lobs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R68	Shaft and mullock	Lobbs Hole Central Mine - mine working on NE side of the river; not inspected for this project	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R69	Brick kiln	Circular beehive brick kiln for production of bricks for the reverberatory furnace. A zone of excavated soil at base of slope (hummocky and open rectilinear pit) with access road (R94), platform, cut), and remains of brick kiln. c. 50 x 40 m area.	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory - part of R9 (Lobs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method Implement measures to protect moveable heritage	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R70	Concrete fire place	A two-bay fire place constructed in two phases with concrete. It measures 2 m long x 0.95 deep x 0.6 m high. It is decorated with beer can pressings on the top.	Lobs Hole historic landscape	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R71	Butcher shop	Two building platforms cut into slope with rubble of a building in pile on slope above platforms. They each measure c. 10 m long by c. 5 m wide. The platforms are cut into a moderate gradient hillslope. Bridle family connections.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method Implement measures to protect moveable heritage	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R72	Stone furnace	The function of this feature is not known however, it is believed to be a stone furnace and possibly a lime kiln. It is a semicircular walled structure built against bedrock stone; the blocky conglomerate bedrock is used as the basis of the construction. The stone is laid with a mud packing mortar. It is partially faced but largely made with flat faced stone cobbles. On the downslope side is 1.6m high. Its diameter is 2m. The front face on the inside of the rear wall is 1.85m high. On both sides there is a pile of earth and rubble.	Lobs Hole historic landscape	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report Implement measures to protect moveable heritage	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R73	Rabbit proof fence	Chicken and plain wire fence	Lobs Hole historic landscape **Yan farm infrastructure**	Contributory – part of R113 (Yan farm infrastructure)	Contributory – part of R113 (Yan farm infrastructure)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R74	Metal Water Pipe	located on steep slope/bank 10 e of Mine trail - it extends from west end of water race down steep bank to NE to Lobbs Hole Mine; parts of the pipe are in river further downstream	Lobs Hole historic landscape **Lobbs Hole Copper Mine**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in an archaeological research design and excavation method report Ensure no inadvertent impacts	Will not be impacted. The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R75	Mine shaft on ML 31	Lobbs Hole Copper Mine shaft on M.L. 31 at east end of main lode. The site could not be found and grid reference is suggestive only. See LRGM 2002:135. On M.L. 31 at east end of main lode	Lobs Hole historic landscape **Lobbs Hole Copper Mine**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R76	Scatter of tin, glass and brick	Scatter of domestic debris in area 15 x 15.	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R77	Site of meteorological station	Does not exist, exact location uncertain; it was a Stephenson Screen (George Thomas pers. Comm March 2018)	Lobs Hole historic landscape **SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R78	Pine tree	Large live tree	Lobs Hole historic landscape	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R79	Bridge remains	Concrete pylons of old Powerline era bridge	Lobs Hole historic landscape **SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R80	Elizabeth Frazer's orchard	Elizabeth Frazer's (nee Thomas) orchard; she lived on site (see diagram showing location of school children) too overgrown to inspect. Daughter of James and Mary. Widowed c. 1877; d. 1928 Buried Tumut. Brothers: James, John, Abraham, Samuel & George.	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R81	Yarrangobilly River water race/road	~1,100 m long earthen channel (assumed to be hand excavated) extending along the east side of the Yarrangobilly. It is located at the break of slope between the west facing simple slope of the High Ground and the Yarrangobilly flat. The depression is deeply incised (up to a meter in places) and a width of up to 4 m. Near its southern termination on the north side of Wallaces Creek, various disturbances are present where it seems to have been excavated out or eroded. The race was a part of Julius Forsstrom's work (see Plan in R45). It is assumed that it was originally built for transporting water (to the race R45 on Wallaces Creek) for the transport of water to the Lobbs Hole Copper Mine (see Plan in R45). Grid reference is nominal 628045.6038840 midway.	Lobs Hole historic landscape **Lobbs Hole Copper Mine**	Contributory - part of R9 (Lobs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R82	Front seat of car; ~1960s	On water race: spring loaded cushioned front seat of car. 1.3m wide. Old seat frame arched hub at front of seat for the drive shaft to run underneath; spring loaded adjustable to move front or back	Lobs Hole historic landscape	N/A	The car remains do not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R83	Pile of sheet metal	Pile of ~3 metal sheets: 1.35 x .65m, <2mm thick; drilled around edges: 7mm diam drill holes; irregular spaced, one drill hole with screw in it	Lobs Hole historic landscape	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R84	Possible old road	Old road cutting, N/S alignment; continues north under powerline	Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape.	Contributory – part of the Lobs Hole historic landscape.	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R85	Possible old road	20°/230° alignment; cut and benched up to 1m deep, 3-3.5 m wide; seems to follow spurline down to dam	Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape.	Contributory – part of the Lobs Hole historic landscape.	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R86	Possible old road	15 m NW of R85, cut and benched up to 0.8 m deep, 2 m wide	Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape.	Contributory – part of the Lobs Hole historic landscape.	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R87	Tree with scar and axe marks	Large old Eucalyptus (mannifera) immediate adjacent to track on NW side; 2 parallel axe cuts in burnt scar face. Given the relatively young age of axe marks could be incidental	Lobs Hole historic landscape	N/A	The item does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R88	Artificial mound of stone	River cobbles of various sizes; area: 4 x 4m; on west side of crest facing river. Appears to be cultural made rather than natural. Function uncertain. Given its proximity to the Ravine Cemetery, the question is raised as to whether it is a European burial.	Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape.	Contributory – part of the Lobs Hole historic landscape.	Archival recording Include in the archaeological research design and excavation method report Ensure no inadvertent impacts	Some possibility that it is a burial. Will not be impacted. The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R89	Artificial mound of stone	Small pile of stone: semi-circular form measuring 0.60m with a loose scatter over 1 x 2m area. Function uncertain but probably modern camp fire	Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape.	Contributory – part of the Lobs Hole historic landscape	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R90	Lick Hole Gully Adit	Lobbs Hole Copper Mine Located on west side of Lick Hole Creek; rotted wooden probs visible; passage 1.2m wide x 9m leading into mine opening; mound of rock and earth in passage at opening. Adit c 3m high. At c. 15m in front of adit 2 metal rail tracks.	Lobs Hole historic landscape **Lobbs Hole Copper Mine**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R91	Mine Shaft (? No. 4)	c. 13m wide; filled in; mullock on all side by mostly S, E & W.	Lobs Hole historic landscape **Lobbs Hole Copper Mine**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R92	Building platforms	Two parallel benches of levelled ground, one above the other. ~ 20m long x 4 m wide. Chicken and plain wire with rocks (rabbit proof fences); sparse scatter of metal 2 bricks	Lobs Hole historic landscape Possibly Yan farm infrastructure	Contributory – part of the Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R93	Fence	Chicken wire and plain wire with rocks (reinforcing) extends from platforms (R92) in SE direction to 626536.6038187 in Lick Hole Gully immediately below road. Grid ref at what appears to be gate post hole 2 m apart. Each measures c. 45cm wide x 70cm deep oval shaped.	Lobs Hole historic landscape **Possibly Yan farm infrastructure**	Contributory – part of R113 (Yan Farm Infrastructure).	Contributory – part of R113 (Yan Farm Infrastructure).	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R94	Road alignment	The feature is what appear to be a road alignment and creek crossing (Lick Hole Gully). It appears to extend from the west side as deep wheel track. On the east side of the gully, the road alignment becomes a cutting and may be associated with the mining activity in Lick Hole Gully.	Lobs Hole historic landscape	Contributory	R94 has significance as a contributory item that relates to the old access routes in and out of the region.	Archival recording Include this feature in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R95	Road alignment	Grid ref at intersection with Flying Fox Road. Vestigial linear feature. C. 4-4.5m wide and cut c. 30cm deep. Overgrown. Extends downslope SE towards mine in Lick Hole Creek. Becomes indistinct at 626505.6038317	Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R96	Open cut in Lick Hole Gully	The open cut mine was a part of the Lobbs Hole Copper Mine. It is in Lick Hole Gully. There is a cut and level zone at base of slope adjacent to creek on west side. It measures c. 30 m long x 10m wide. There is a cutting at base of the slope measuring 2m deep. Material evidence on the floor of the cut includes bricks, brick fragments and slag. Site of original open cut but has also been a brick manufacturing area. The site possesses no obvious features of the open cut mining venture.	Lobs Hole historic landscape **Lobbs Hole Copper Mine**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R97	Exotic trees	Willow, poplar, apple along valley. Grid reference is a nominal location	Lobs Hole historic landscape **West Pinbeyan**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	Exotic species including fruit trees are often an indication of an archaeological site nearby. The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R98	Excavated pit	This it is located on the south side of Lick Hole Gully. It measures approximately 5m x 4m x 1.5m deep. It has old metal plate and debris in it. Its function is unknown.	Lobs Hole historic landscape **Possibly Lobbs Hole Copper Mine**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be considered in the research design prior to impacts. The results of the test excavation will determine the final management measures.
R99	Well	This feature is interpreted to be a well, although that function is not confirmed. The feature is in the drainage depression of Lick Hole Gully. It is an excavation with wooden collar made from round (undressed) wood posts that line the hole in a rectilinear shape, measuring c. 1.8 x 0.8m. The depth is unknown. The 'well' is in a larger depression: 6m long x 4m wide.	Lobs Hole historic landscape **Possibly Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm Infrastructure).	Contributory – part of R113 (Yan Farm Infrastructure).	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R100	Single furrow plough	Horse drawn single furrow mould board plough.	Lobs Hole historic landscape **Possibly Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm Infrastructure).	Contributory – part of R113 (Yan Farm Infrastructure).	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	May be a component of Yan Farm Infrastructure and therefore assessed as part of the Yan Farm complex. The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.
R101	Possible building site	Site described as an old house site by a camper. Apple trees and Euphorbia, cluster of old billies, oil cans, beer and wine bottles and drink cans. No obvious evidence of building.	Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape	Archival recording Include in the archaeological research design and excavation method report. Archaeological test excavation of this item may be included in the research design and excavation method.	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.
R102	Stone culverts	Stone culverts on either side of road	Lobs Hole historic landscape **SMA**	Contributory – part of the Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R103	Levelled platform	Cut and benched platform-oriented NW/SE. c. 20m long x 2m wide by up to 1m deep. Could be associated with chicken wire fence to SW.	Lobs Hole historic landscape **Possibly Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm Infrastructure)	Contributory – part of R113 (Yan Farm Infrastructure)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R104	Lick Hole Gully water race	10m long trench 1m wide x 0.5m deep aligned 30°/210°. Earth banked on downhill side; tuff pieces strewn around. Becomes curved to extend around a low narrow rise to the edge of a rock ledge in creek proper at 626404.6037779.	Lobs Hole historic landscape **Possibly Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm Infrastructure)	Contributory – part of R113 (Yan Farm Infrastructure)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R105	Ditch	East end of a ditch that extends westward along contour for c. 20m.	Lobs Hole historic landscape **Possibly Yan Farm Infrastructure**	Contributory – part of R113 (Yan Farm infrastructure)	Contributory – part of R113 (Yan Farm Infrastructure)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R106	Old road	Easterly extension of old road	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R107	Building platform	Level platform; 10m long x 4m wide aligned N/S on contour. With a scatter of tin. In same location as 'old mine buildings' as per Ravine map 1911	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R108	Old road	Deeply incised track that descends into creek channel (Lick Hole Gully)	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R109	House platform with wooden cross	Probably Paterick house site, platform 18m long x 9m wide x 1.4 m deep cutting; The wooden cross for Emily fallen on ground on house platform; extensive Euro vegetation including stump of big fig tree.	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation may be required in adjacent areas	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R110	Building platform	This feature is a building platform in the Struggle Street area and near the creek. It is a level platform excavated into the hillslope at a depth of c. 0.8m. The size is unknown as it is covered with blackberry thicket. The platform is aligned E/W on a contour. A scatter of rusty tin sheet occurs on the site.	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include in the archaeological research design and excavation method report Avoid impacts if possible	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R111	Path to creek	Struggle Street: path descends into creek channel (Lick Hole Gully) to R115 stone channel	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R112	Possible shaft	On east side of river and out of project area; not inspected.	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory - part of R9 (Lobbs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in the archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R113	Shed platforms	The Yan's sheds (see 1937 photo of horse riders) in an area measuring c. 30 x 30 m with numerous cut and benched excavations. On southwest side of road.	Lobs Hole historic landscape **Yan Farm Infrastructure**	Local	Yan farm infrastructure represent another phase in the history of the area, and ingenuity, in particular around rabbit management.	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.
R114	Excavation	A deep pit with recycled steel on steel rail tracks (function uncertain)	Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape	Contributory – part of the Lobs Hole historic landscape	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R115	Stone lined channel	stone lined channel in Lick Hole Gully. R111 path descends to feature	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R116	House site	Noted by (Pearson 1979). Mound of earth measuring c. 12 x 12m with cast iron bed frame, metal, brick covered in thick high grass.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R117	Possible shaft	Location of Lobbs Hole Central Mine test shaft. grid ref provisional; there is no evidence on the ground (see Pearson 1979)	Lobs Hole historic landscape **Lobbs Hole Copper Mines**	Contributory - part of R9 (Lobs Hole Copper Mines)	Contributory - part of R9 (Lobbs Hole Copper Mines)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R118	Ravine cemetery	Overgrown Ravine town cemetery. grid ref denotes entrance off the Ravine Powerline Road. The cemetery measures c. 150 x 200m and has at least six graves (see	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in	The feature has the potential to reach the threshold for relics and therefore should be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
		Table 9 of the HHAR), the precise location of which is unknown. The cemetery is overground and there are no surface indicators of graves. The Ravine Cemetery was revoked on 28 February 1986 (Government Gazette of the State of New South Wales 8 November 1985; 28 February 1986). Prior to the formalisation and gazettal of the Ravine General Cemetery site, deceased persons were designated as being buried simply at Lobs Hole (Wilkinson et al 1999). Referring to the gazetted Ravine Cemetery, Wilkinson et al. (1999) state: 'From the number of burials prior to 1910 it would seem there was an established unofficial cemetery on the site for many years'. However, this is a non sequitur and it is not necessarily correct. Most people at Lobs Hole lived and worked well away from				the research design and excavation method	

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
		the Ravine Cemetery area, at the south end of the valley in and around Struggle Street and near to the mines. There could be earlier graves in the gazetted Ravine cemetery, but there is no good reason for there to be. It is much more likely that people were buried closer to where they lived and worked. The exact locations of the Lobs Hole grave sites are now not known, and it has to be recognised that they could be anywhere in the Lobs Hole valley. See Figures 20 and 21 of the HHAR.					
R119	SH weather station	Active	Lobs Hole historic landscape **Snowy Hydro**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording Explore options for moving item	Weather station (in use but can be relocated)

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R120	Building platform	Building platform with short (2m long) alignment of stone on one edge. The feature is on a prominent knoll at the top of Struggle Street. All features are vestigial. The feature is slightly level but there is no obvious cut and fill. The alignment of a single course of cobbles is on the north side.	Lobs Hole historic landscape **Struggle Street**	Contributory – part of R57 (Struggle Street)	Contributory – part of R57 (Struggle Street)	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.
R121	Depression	Amorphous depression measuring 1.2m x 0.8m. Function unknown.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R208 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The features have been assessed to be potentially relics and therefore must be further investigated prior to impacts. The results will determine the final management measures.
R122	Fireplace platform	Slightly raised stone and earth platform, possibly a hearth. It measures 1.2 by 3.5 m. Two bricks are visible.	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township)	Archival recording Include in the archaeological research design and excavation method report Archaeological test excavation of this item may be included in the research design and excavation method	The features have been assessed to be potentially relics and therefore must be further investigated prior to impacts. The results will determine the final management measures.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R123	Survey marker	Talbingo: Survey marker is in a laydown area on a hairpin bend. It is a cylindrical column on a square concrete base. It measures 1.2 m high by c. 0.3 m diameter.	**SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording	
R124	SMA laydown area	Talbingo: Extensive area of rehabilitated laydown. The site is strewn with fencing wire, metal, dumped gravel including a heavy metal door of an explosives safe. The site has been graded level.	**SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording	Item does not meet relevant significance criteria.
R125	SMA quarry	Talbingo: Extensive area of quarry for construction of Talbingo Dam.	**SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording	Item does not meet relevant significance criteria.
R126	SMA survey marker	Talbingo: Concrete survey marker. Remnant yellow paint with small round metal centre piece.	**SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording	Item does not meet relevant significance criteria.
R127	SMA survey marker	Talbingo: concrete obelisk shaped survey marker. Remnant yellow paint with small round metal centre piece.	**SMA**	N/A	The feature does not meet the threshold against any of the criteria at either local or state levels.	Archival recording	Item does not meet relevant significance criteria.

Table C.1 Reassessment of management and mitigation measures

Code	Name	Description	Complex	Significance Level	Statement of Significance	Management Measures	Rationale
R128	First school at Lobs Hole	Site not found; grid ref. nominal	Lobs Hole historic landscape **Ravine township**	Contributory – part of R20 (Ravine Township)	Contributory – part of R20 (Ravine Township) As the first school at Lobs Hole, the site of the school has the potential to possess significance at a local level for its historic, social and research values.	Archival recording Include in an archaeological research design and excavation method report	The inclusion of this item in the archaeological research design and excavation method is to prepare a comprehensive document to guide archaeological test excavation; if impacts are not proposed, the item will not be subject to archaeological test excavation.



CHAPTER D

GEODIVERSITY ASSESSMENTS OF SIGNIFICANCE

REPORT INTO ASPECTS OF THE GEODIVERSITY OF THE LOBS HOLE–RAVINE AREA, KOSCIUSZKO NATIONAL PARK

Prepared by Dr. Ian Percival (Ph.D Palaeontology)

PURPOSE & AIMS

This letter was commissioned by Snowy Hydro to supplement the Environmental Impact Statement dated July 2018 regarding Exploratory Works for Snowy 2.0. This report also responds to matters raised by National Parks and Wildlife Service (NPWS) in regards to concerns to impacts on geodiversity due to the proposed improvements on the existing Lobs Hole Ravine Road within Kosciuszko National Park (KNP).

Specifically this Report considers the effect of widening the Lobs Hole Ravine Road to safely allow the movement of trucks associated with excavating an exploratory tunnel to the proposed underground power station complex for Snowy 2.0. The options considered in this Report have been designed since the publication of the EIS as further design and safety information is now available. Each of these options result in changes to previously assessed disturbance of fossiliferous rocks. This road passes through an area with several known sites of scientific significance in terms of geodiversity of the KNP. One of these sites is the only known occurrence of fossiliferous limestone of Early Devonian age in KNP, within the Lick Hole Formation.

PREVIOUS KNOWLEDGE OF THE SITE

First geological investigations of the Lobs Hole–Ravine area were undertaken at the beginning of the twentieth century by officers of the Geological Survey of NSW and continued intermittently for two decades. Andrews (1901) reported on the auriferous Kiandra Lead and briefly mentioned the occurrence of fossiliferous limestone in the area. The fossils he collected from limestone at Lobs Hole were identified by Geological Survey palaeontologist W.S. Dun and listed in the Annual Report of the Department of Mines for that year. Dun (1902) assigned an Upper Silurian age to these brachiopods and molluscs. The fossils seem to represent Lower Devonian as well as Upper Silurian species and genera, and it is possible that samples from the older limestones at Yarrangobilly were intermixed with those from the Lobs Hole area. Subsequent investigations in this area resulted in further fossils being collected which were identified as being of undoubted Devonian age (Harper 1913). These fossils included the coral *Cyathophyllum* and brachiopods identical to those known from limestones of the Murrumbidgee Group exposed around Burrinjuck Reservoir to the north. All subsequent reports on the fossils from the limestone in the Lobs Hole–Ravine area confirmed the Devonian age and focussed on expanding taxonomic knowledge of the fauna and its diversity, thereby increasing the precision of the biostratigraphy for age-dating. Carne & Jones (1919, p.326), in their review of all limestones known in NSW, barely mention the presence of fossils in the limestone at Lobs Hole but describe in some detail the presence of tufa (secondary carbonate of recent origin, formed by weathering of the Devonian limestone) enveloping the tea-tree scrub, as well as calcrete occasionally forming stalactites. Benson (1922) listed, but neither described nor illustrated, several different types of macrofossils from limestone at Ravine (his site no. 33), all of which were ascribed a Devonian age.

The second phase of geological investigations in the Lobs Hole–Ravine area came about as a direct result of the development of the Snowy Mountains Hydroelectric Scheme in the 1950s with a need for more detailed knowledge of the rocks exposed and underlying the infrastructure of the project. Reconnaissance mapping by Adamson (1957, 1958) outlined component units of the regional geology and defined the main stratigraphic units (summarised in Moye et al. 1969). The Ravine beds (an informal grouping) includes the upper Silurian Yarrangobilly Limestone, now known to be of Ludlow age, and overlying largely clastic strata lacking fossils, but thought to be certainly latest Silurian to possibly earliest Devonian age. A volcanic-dominated succession termed the Boraig Group, including rhyolite, tuffaceous and pyroclastic sediments may be laterally equivalent to and in part overlie the upper Ravine beds, and hence is interpreted as being of Early Devonian age on regional stratigraphic grounds, no fossils having been found in it. The volcanics are overlain (in places with a pronounced angular unconformity) by the Byron Range Group, which is exposed to the southwest of Yarrangobilly and occupies all the Lobs Hole–Ravine valley and surrounding elevated ridges. It consists of three conformable units; lowermost is the Milk Shanty Formation 170 m thick, a thick to massive-bedded fining upwards succession of clastic rocks devoid of fossils, which passes gradationally upwards into the Lick Hole Limestone consisting of blue-grey fossiliferous limestone, often nodular and interbedded with siltstones and shales, with a total thickness of approximately 420 m according to Moye et al. (1969). Flood (1969) measured a comparable thickness of 488 m along the Lobs Hole Ravine Road. The limestone disappears up sequence and is replaced entirely by fossiliferous quartzite at the base of the Round Top Formation. Early reports suggested the fossils in this unit were pelecypods, but subsequent research had identified them as lingulate brachiopods, quite well preserved according to Pedder (1971). These have not been formally described.

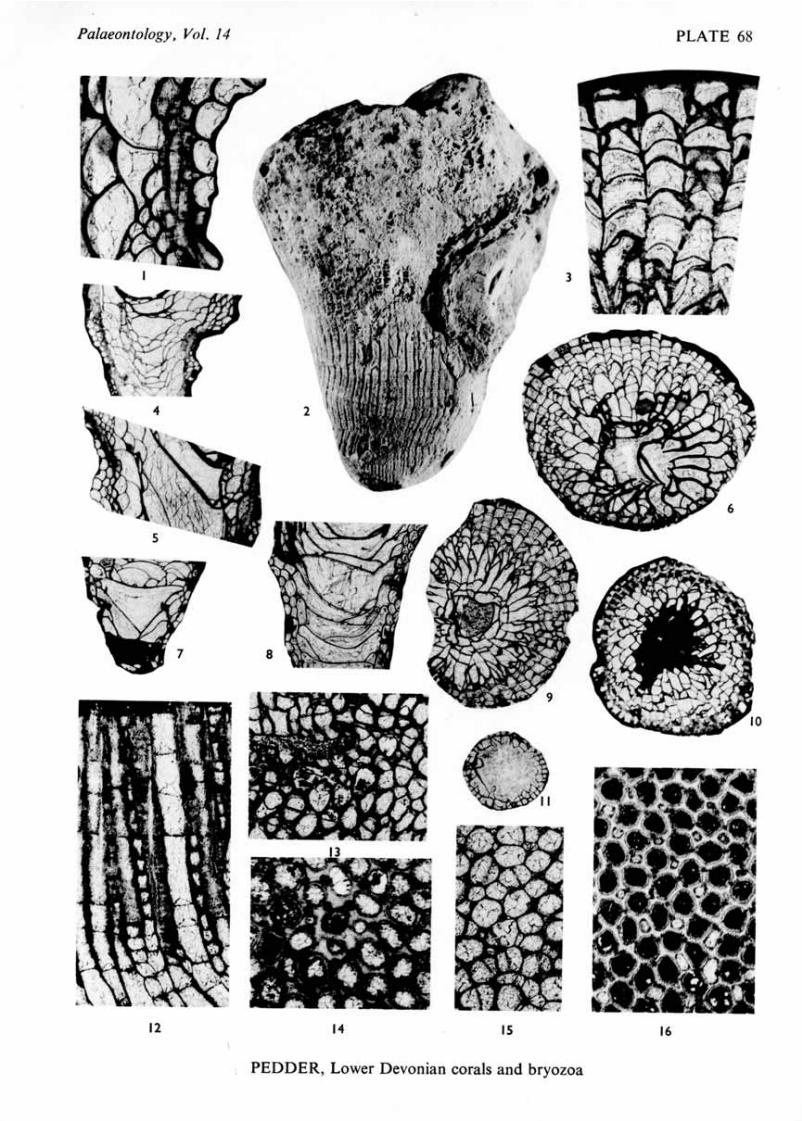
Lishmund et al. (1986) briefly described the Lick Hole Limestone in the Lobs Hole–Ravine area, accompanying the description with a geological map of the region, based on those published by Adamson (1958) and Flood (1969).

The extent of the Byron Range Group is shown on the regional geological map of the KNP (Wyborn et al. 1990) which does not separately identify its component formations due to their small scale. This map is the most recent published of the region and clearly demonstrates that the Lower Devonian Byron Range Group is quite separate from the more extensive outcrop of the upper Silurian Yarrangobilly Limestone to the northeast.

The first fossils to be described from the limestone were tentaculitids (small conical shells of unknown affinity), published by Sherrard (1967). Two genera and species were recognised: *Tentaculites chapmani* Sherrard and *Nowakia* aff. *acuaria* (Richter). This was the forerunner of a series of palaeontological publications spanning the next six years.

Detailed geological mapping (still the best currently available) and palaeontological sampling of the Lobs Hole–Ravine area was undertaken by P.G. Flood and his colleagues of the University of New England in 1967. Results of this study, published two years later (Flood 1969), include a measured section through the Lick Hole Limestone – now known as the Lick Hole Formation – from which Flood obtained approximately 1,300 identifiable well-preserved conodont elements from the acid digestion of about 200 kg of limestone. Among 14 form species of conodonts identified by Flood from the locality, the most important is the index microfossil *Polygnathus*

dehiscens Philip & Jackson. This conodont has been widely recognised in other Devonian limestones in southeastern Australia, including the Cavan Limestone and lower part of the Taemas Limestone at Burrinjuck Reservoir, and the Buchan Caves Limestone in the Gippsland region of Victoria, and is indicative of the early Emsian Stage in the later part of the Early Devonian Period. Mawson & Talent (2000) reviewed the evidence for the precise age of the conodonts obtained from this unit (citing an unpublished study by one of their students) and came to the conclusion that it could span the *dehiscens* and overlying *perbonus* zones of the lower Emsian.

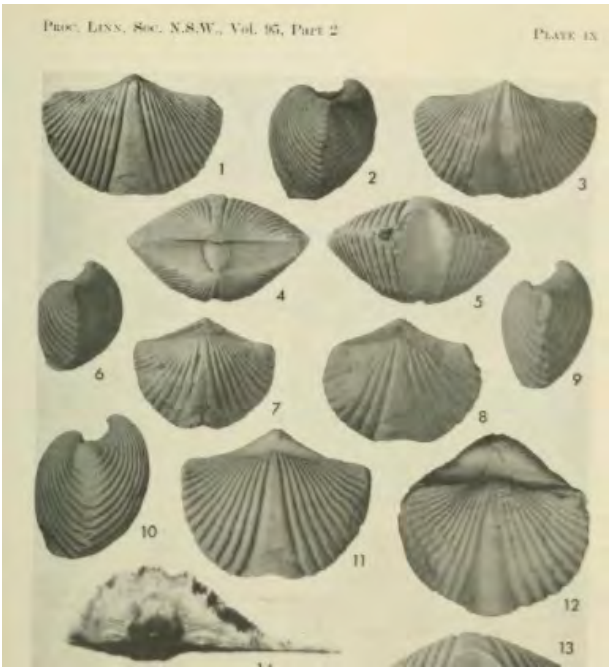


(left): corals and bryozoa from the Lick Hole Formation (Pedder 1971)

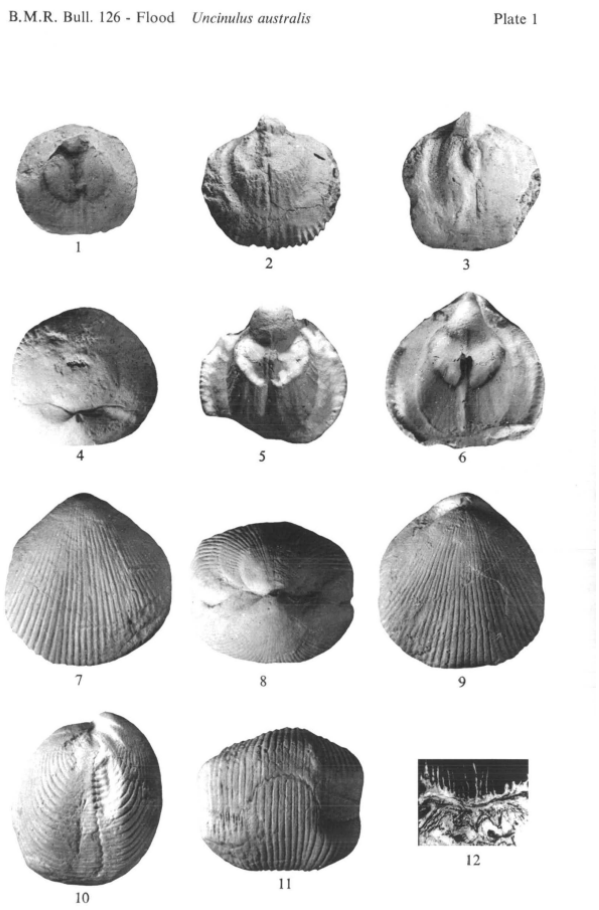
1-11: *Chalcidophyllum discorde giandarrense*

12-16: *Heterotrypa rapinae*

The most abundant macrofossils found in the measured section are shells of brachiopods, less common corals, pelecypod molluscs and bryozoan. Only some of these fossils have been formally described. The brachiopods *Spinella yassensis ravina* Flood and *Uncinulus australis* Flood, described in Strusz et al. (1970) and Flood (1973) respectively, are closely allied to species recognised in the Taemas Limestone in the Burrinjuck Reservoir area. Flood (1973) also identified (but did not describe) the brachiopods *Parachonetes* sp. nov., *Athyris waratahensis* (Talent), *Howittia multiplicatus* (de Koninck), *Howellella* sp., and *Globithyris* sp. nov. Pedder (1971) described three new species including the corals *Tropidophyllum hillae* and *Chalcidophyllum discorde giandarrense*, and the bryozoan *Heterotrypa rapinae*.



Brachiopods from the Lick Hole Formation
(above): *Spinella yassensis ravina* Flood, from Strusz et al. (1970)
(below): *Uncinulus australis* Flood, from Flood (1973)



SCIENTIFIC SIGNIFICANCE OF FOSSILS IN THE LICK HOLE FORMATION

The site is **locally significant** for the following reasons:

1. It is the only limestone of Devonian age in KNP, and so represents an important part of the geological history of the Snowy Mountains region in NSW.
2. It contains microfossils (conodonts) and macrofossils (mainly brachiopods and corals) that enable precise correlation with strata of identical age (early Emsian Stage of the Early Devonian) and depositional environment (shallow marine conditions in a subtropical to warm temperate setting) elsewhere in southeastern Australia.
3. The fossiliferous rocks exposed in the road cutting are the type locality for several fossil species, including at least two brachiopods, two corals and a bryozoan.

Regionally, and at a statewide level, the palaeontological significance of the Lick Hole Formation is judged to be at a considerably lower level. There are far more extensive outcrops of Early Devonian limestones in the Burrinjuck area to the north and the Buchan Caves Limestone to the south in Victoria that were deposited over a much greater time interval; these exposures are far more spectacular and are much richer in fossil diversity and abundance. As a result the Murrumbidgee Group limestones around Burrinjuck Reservoir have been the focus of far more palaeontological research (summarised in Percival & Zhen 2017) and are very much better known. Provided the entire outcrop of the Lick Hole Limestone was not impacted by proposed road works or other infrastructure, excavation of a relatively small amount of the formation exposed on the Lobs Hole Ravine Road, if carefully managed, would not substantially affect the integrity or significance of the site.

Note that these comments on the geoscientific significance of the Lick Hole Formation do not apply to the area of karstification and secondary carbonate deposition, particularly tufa and calcrete, that occurs elsewhere in the outcrop as described by Carne & Jones (1919). These features are of very high importance at a state level or greater, and are very delicate and easily susceptible to disturbance. They are relatively unknown elsewhere in the state, and have not been adequately studied here. However, because the tufa and calcrete deposits are not found in the cuttings on the Lobs Hole Ravine Road, they will not be further considered in this report.

The first assessment of the geodiversity of the Lobs Hole–Ravine area, specifically focussing on the fossils in the Lick Hole Limestone, was undertaken in 1978 by the current author and documented in an unpublished report prepared for the Australian Heritage Commission and the Planning & Environment Commission of NSW the following year as part of an initial statewide study of geological heritage in NSW (Percival 1979). In that report (p.98) the major risk to the site was identified as “unauthorised removal of the fossils”, and three recommendations were made to alleviate this problem.

1. Firstly, that the significance of the locality be brought to the attention of NPWS so that this area be included in an appropriate category in the KNP Zoning Scheme.
2. Secondly, that NPWS staff be made aware of the location of the site so that periodic checks could be made on its integrity and whether fossils were being removed illegally.
3. Thirdly, that no publicity about the site be made available to the general public.

The first point has been addressed by inclusion of the fossil site in the KNP Plan of Management, as a direct result of which the impact of proposed works in the Snowy 2.0 project is being investigated as part of the approval process.

The second recommendation has been adopted so that NPWS rangers are aware of the site, though its remoteness combined with accessibility to 4WD vehicles means that it is impractical to ensure surveillance of the fossils.

Apart from passing mention in several scientific papers and maps published since 1979, the site has not been publicised. It was specifically excluded from a book (Percival 1985) subsequently published by NPWS, which documented many of the other places covered in the earlier unpublished report. However, the problem remains that a detailed map of the site is readily available in a local scientific journal (Flood 1969), and that illustrations of the macrofossils have been widely disseminated in three other papers (Strusz et al. 1970, Pedder 1971, Flood 1973), all of which are freely obtainable via a Google search.

KEY OBSERVATIONS

1. The fossils found in the Lick Hole Formation occur in an artificial exposure (a road cutting, about 500 m in length) in which they are not evenly distributed.
2. Based on the low dip of the beds and geological mapping in the vicinity, the fossiliferous beds extend into the ridge above the road. They also extend beneath the road surface (potentially up to a depth of over 500 m), based on the shallow dip of the bedding.
3. The fossils are relatively unprotected at present – they continue to be subject to erosion and potential illegal collecting. Fossils such as complete brachiopod shells which occur at this site have a (small) value to collectors and dealers.

IMPACT ASSESSMENT OF ROAD CONSTRUCTION SCENARIOS

Snowy Hydro has provided construction options for road works to Lobs Hole Ravine Road through the existing exposed fossiliferous limestone area.

These options all involve disturbance to the existing roadway as well as some disturbance to the existing exposed fossiliferous limestone areas. Each of these options results in changes to the previously assessed disturbance to the exposed fossiliferous areas.

Table 1 below provides a summary of the disturbance required (and the change to the previously assessed disturbance) for each of these options. These options are also shown in drawings provided in Appendix A.

Table 1: Exploratory Works construction options for Lobs Hole Ravine Road within the existing exposed fossiliferous limestone areas

Option	Volume excavation (m^3)	Area outside EIS boundary (m^2)	Area inside EIS boundary but not required (m2)	Construction notes[1]
1 - Gabion Wall with Straps + Fill earthworks with preparation (1 m steps)	13,445	1,555	NA	- Fill excavation very difficult, likely to result in further impacts to existing slope
2 - Cut 2 m into existing face	4,630	4,874	6,195	- Access is good, minimal safety risks to workers; - Faster construction compared with other options - Impact on one side of existing road only;
3 - Post and panel + Fill earthworks with preparation (1 m steps) as in option 1	8,020	1,555	NA	- Significantly time consuming to construct - Will impact existing fill side when constructing wall - Safety of workers to be taken into consideration

Notes – 1. Construction notes provided by SMEC.

The sections below describe the construction method for each of the options.

1. **Option 1 – A site-specific mix of Fill and Gabion wall.**
    a. The Fill sites involve significantly extending the existing road on the valley side via a series of terraced fills; this design would have least impact on the ridge side with only a relatively narrow cut to provide for gutter drainage impacting the present road cutting;
    b. The Gabion wall sites involve a less extensive intrusion of fill on the valley side of the road, being bolstered by gabions, but would necessitate very substantial lowering of the current road and backfilling to attain the final extended width as the gabions would require anchoring by reinforcing straps or mesh; impact on the ridge side outcrops is about the same as for the Fill sites described above;

2. **Option 2** involves no valley side fill, all the widening of the road being accommodated by excavating the ridge side of the present road cuttings; the width of excavation is unspecified but may be of the order of 2 – 2.5 m;
3. **Option 3 – post & panel** involves excavating a narrow channel approximately 5 m deep on the valley side of the road to support the down-side extension of the roadway as well as a barrier; while on the ridge-side the amount of excavation for drainage would be of the order of that envisaged for Option 1.

Snowy Hydro's maps (refer to Appendix A) of the present and projected plans for the road widening as shown in the information document. All these maps depict the fossil area (coloured purple) extending only on the up (ridge) side of the road. However, the low dips of the strata (4-7 degrees to the southeast) evident in the outcrop in the road cuttings imply that the fossil-bearing beds in fact extend under the present road and out into the valley side where they have been eroded away to present day ground level. It should be realised that any significant excavation on the valley side adjacent to the road will also intersect these limestones.

Option 1 – Fill combined with Gabion Wall (each method to be used as appropriate in various sections of the road construction) is likely to involve the greatest visual impact of all the construction scenarios. It also entails a very substantial excavation into the fossil beds extending beneath the present roadway, also of which would be used as replacement fill and hence lost to science. The Lobs Hole–Ravine area is not pristine wilderness but is relatively undeveloped forested and bush vegetation on rugged topography. The aesthetics of a significant scar on the landscape introduced by the extended down-side fill would likely be entirely unsympathetic with the present appearance of the valley.

In summary, the removal of 13,445 m^2 of fossil bed material to provide for road safety improvements to this section of Lobs Hole Ravine Road is considered acceptable provided the recommended mitigation measures (outlined below) are implemented. However, this would not be the preferred option due to the fact that any fossiliferous rock excavated from the existing road would either be used as fill on the down side of the widened road or used as fill under the road.

Option 2 encroaches laterally into the fossil bed. However, it involves the least volume of total excavated material, and so actually impacts less on the fossil-bearing material. Also, as the fossil-bearing beds extend back up into the ridge, excavation of the present cuttings may well have unintended positive consequences. Compared to the other options under consideration, additional excavation of the road cuts would expose less rubbly rock in which fossils will be clearly visible but less easily extractible. This could form the basis for an educational interpretative site. The available geological mapping suggests that ample fossiliferous rock would remain intact on the hillside above the road if no more than 2.5 m was excavated laterally into the existing cuttings.

Similar excavation and disturbance has occurred in other fossil sites that were documented in my report on the geological heritage of NSW (Percival 1979). The Allandale Railway cutting in the Hunter Valley needed widening in 2010-2011 to accommodate a third rail line for coal trains. The entire cutting was excavated and all fossiliferous material was set aside for the Geological Survey to examine and sample. This resulted in a substantial contribution on fossils retrieved

from the Allandale site being incorporated into a publication on the palaeontology of the lower Hunter Valley (Percival et al. 2012).

In summary, the removal of 4,630 m^2 of fossil bed material to provide for road safety improvements to this section of Lobs Hole Ravine Road is considered acceptable provided the recommended mitigation measures (outlined below) are implemented. Of the three options, this seems to present the best opportunity to save potentially scientifically valuable fossiliferous limestone, rather than have it simply buried or used as fill, and the excavation can be more carefully controlled from the existing road surface to ensure that fossils are relatively undamaged in the process.

Option 3 – post & panel involves little or no fill on the valley side and minimal disturbance of the outcrop on the ridge side. The deep channel excavation would still impact the fossil bearing beds extending under the present road surface, but not to the extent of excavating the road surface to secure the gabion wall (see Option 1). However, this option does little (relative to Option 2) to enhance the opportunities for educational interpretation of the fossil site. There are also importance geotechnical considerations to be taken into account – the reason that the fossiliferous unit is termed the Lick Hole Formation rather than Lick Hole Limestone (now superseded) is because a significant proportion of the outcrop is composed of shale and siltstone, and the limestone itself is quite rubbly rather than continuous and highly competent. Thus any deep excavation involving support for a wall on the down-side of the extended road would need to be very substantial to ensure that the footings were anchored into solid rock.

In summary, the removal of 8,020 m^2 of fossil bed material to provide for road safety improvements to this section of Lobs Hole Ravine Road is considered acceptable provided the recommended mitigation measures (outlined below) are implemented. Advantages of this option are that it does not result in as detrimental a visual impact on the down side of the road as Option 1, and there is no significant removal of material from the existing cuttings on the up side as in Option 2. However, excavation of a narrow, very deep channel section on the valley side of the roadway will present considerable safety challenges, and almost certainly all fossiliferous rock excavated in the process will be pulverised.

RECOMMENDATIONS

The following mitigation measures are recommended to be implemented:

- Representative excavated spoil is to be preserved off site so that palaeontologists (from Geoscience Australia in Canberra, ANU also in Canberra, the Geological Survey of NSW based in Sydney and Maitland, and the Australian Museum in Sydney) could look through the fresh material and collect fossil specimens for scientific research and curation in their respective collections.
- It would be advantageous to implement road safety improvements to the road which would benefit the general public in the longer term, as well as for the construction of Snowy 2.0 infrastructure.
- Depending on the option of road upgrades to be implemented, interpretive signs could be installed in an appropriate location near the cuttings to highlight features in the exposures, provided the fossils were protected from being easily collected.

CONCLUSIONS

1. Limestones within the Lick Hole Formation, exposed in cuttings along the Lobs Hole Ravine Road, contain a small fauna of macrofossils (of which only a few brachiopods, corals and bryozoan have been formally described) and conodont microfossils, the latter confirming an early Emsian (Early Devonian) age.
2. These fossils are locally significant as outcrops of the formation in the Ravine area represent the sole occurrence of Devonian sedimentary rocks in KNP. The limestones here differ significantly in age from upper Silurian limestone that is extensively exposed around Yarrangobilly, and are part of the youngest package of sedimentary rocks in KNP that were exposed and eroded over approximately 380-390 million years prior to deposition of early Miocene lacustrine sediments (containing fossil leaves) at Kiandra.
3. The regional significance of the Lick Hole Limestone is relatively restricted to providing a correlation point for Lower Devonian rocks between the more extensive, better exposed and more abundantly fossiliferous limestones of the Murrumbidgee Group around the Burrinjuck Reservoir and the Buchan Caves Limestone in Victoria.
4. The road cuttings are artificial exposures, without which knowledge of their fossil content would be markedly less. There are indications that more species, particularly of brachiopods, may be present in the limestone (Flood 1973) but without additional specimens these fossils will remain undescribed and unknown.
5. Whilst all three options are considered acceptable, Option 2 is the preferred option given it presents the best opportunity to save potentially scientifically valuable fossiliferous limestone, rather than have it simply buried or used as fill.
6. Widening of the Lobs Hole Ravine Road has the potential to yield fresher limestone that is very likely to contain more fossils. If the excavation of this rock is carefully managed so as to provide palaeontologists with additional fossils for research, this will mitigate the effects of excavation of the outcrop.
7. Widening of the road has additional benefits in providing more safety for the public travelling this route, as well as for trucks using the road to carry spoil excavated from the Snowy 2.0 exploratory works. Enhanced opportunities for public education and interpretative signage of the outcrop, with measures to protect the fossils from pilfering, are additional possibilities arising from the roadworks.

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Appendix A

Indicative construction drawings for Exploratory Works options for Lobs Hole Ravine Road

- EXISTING ROAD
- FOSSIL AREA

NOT FOR CONSTRUCTION

SCALE 1:1000 10 0 10 20 30 40 50

AT A1 SIZE SHEET

DRAWING FILE LOCATION / NAME

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SNOWY 2.0

IMPACTS TO GEODIVERSITY - FOSSIL AREA

RAVINE ROAD - EXISTING

INFORMATION DOCUMENT

S2-180918-INF-KG-RVD-FA001

snowy hydro renewable energy

snowy 2.0



NOT FOR CONSTRUCTION

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AT A1 SIZE SHEET

DRAWING FILE LOCATION / NAME

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SNOWY 2.0

IMPACTS TO GEODIVERSITY - FOSSIL AREA

RAVINE ROAD - FEASIBILITY

INFORMATION DOCUMENT

S2-180918-INF-KG-RVD-FA002

snowyhydro renewable energy

snowy2.0

OPTION 1

FILL SECTION

WALL SECTION

FILL SECTION

WALL SECTION

FILL SECTION

WALL SECTION

FILL SECTION

FILL SECTION

WALL SECTION

11200

11300

11400

11500

11600

11700

11800

11900

12000

12100

12200

12300

12400

12500

- EXISTING ROAD

- TENDER DESIGN

- FOSSIL AREA

NOT FOR CONSTRUCTION

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AT A1 SIZE SHEET

DRAWING FILE LOCATION / NAME

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SNOWY 2.0

IMPACTS TO GEODIVERSITY - FOSSIL AREA

RAVINE ROAD - IFT

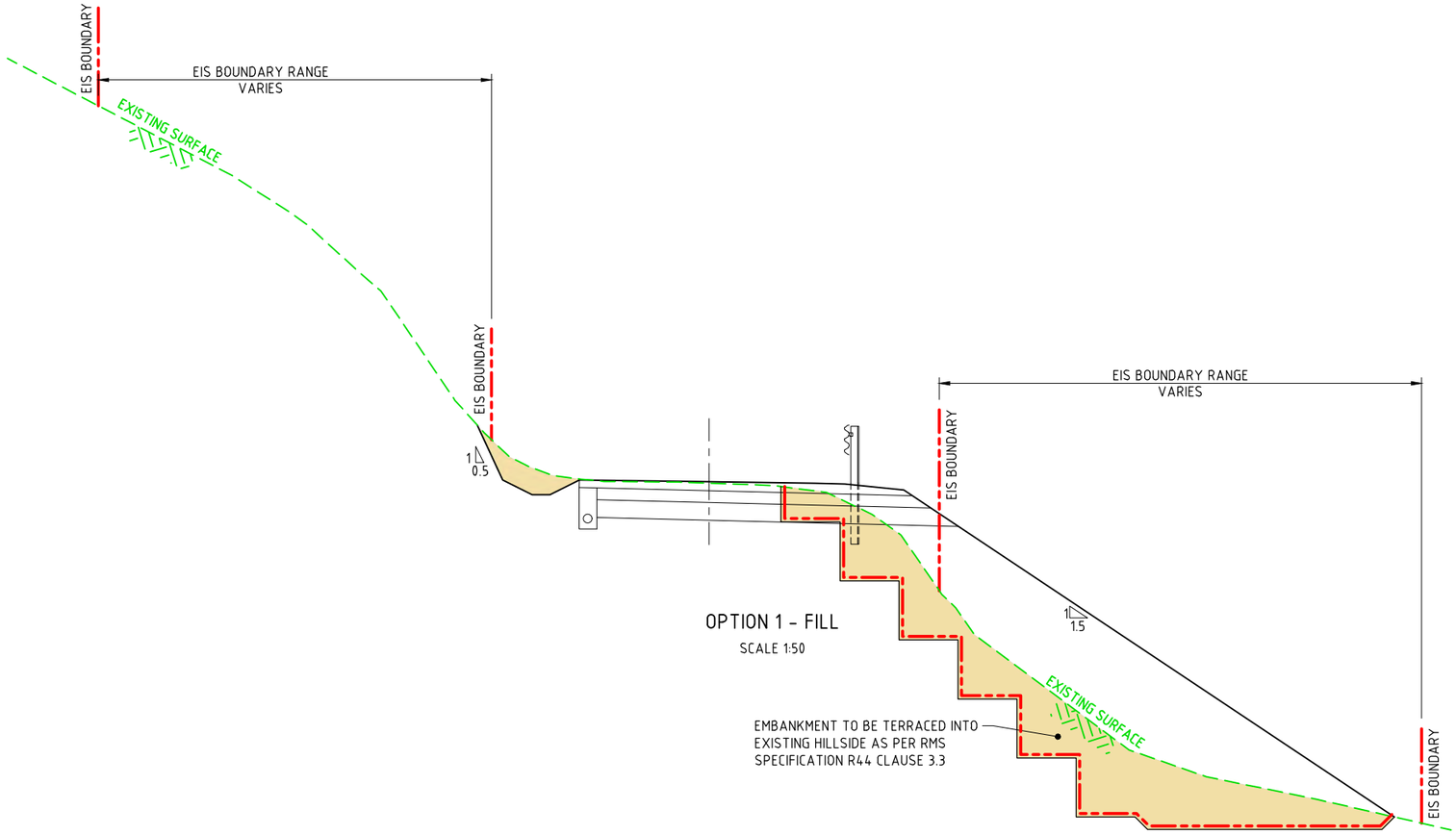
INFORMATION DOCUMENT

S2-180918-INF-KG-RVD-FA003

snowy hydro renewable energy

snowy 2.0

OPTION 1 - FILL



OPTION 1 - FILL

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NOT FOR CONSTRUCTION

SCALE 1:50 0.5 0 1 2

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SNOWY 2.0

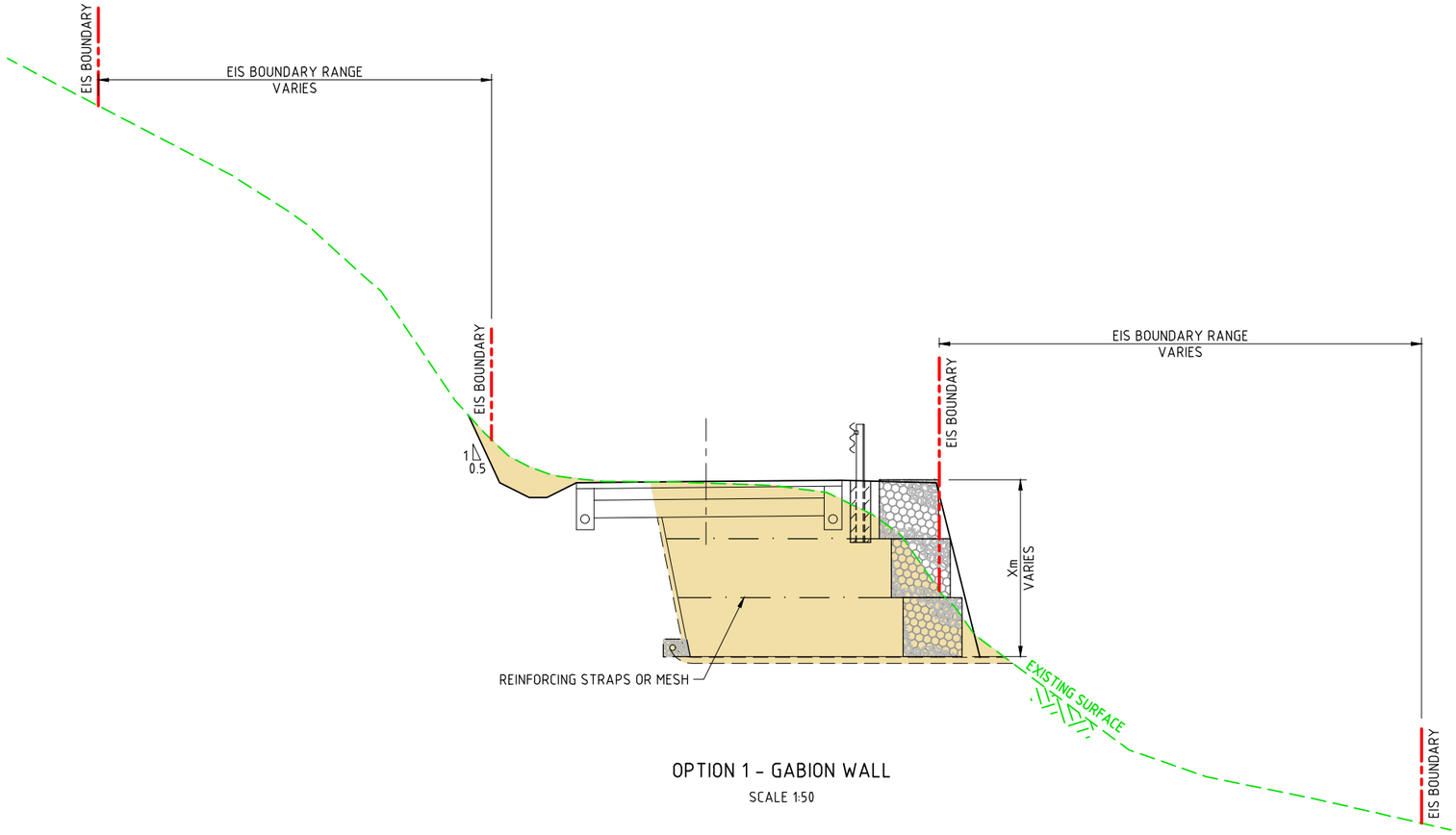
IMPACTS TO GEODIVERSITY - FOSSIL AREA

TYPICAL CROSS SECTIONS - SHEET 01

INFORMATION DOCUMENT

S2-180918-INF-KG-RVD-FA201

OPTION 1 - GABION WALL



OPTION 1 - GABION WALL

SCALE 1:50

NOT FOR CONSTRUCTION

SCALE 1:50 0,5 0 1 2

DRAWING FILE LOCATION / NAME

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SNOWY 2.0

IMPACTS TO GEODIVERSITY - FOSSIL AREA

TYPICAL CROSS SECTIONS - SHEET 02

INFORMATION DOCUMENT

S2-180918-INF-KG-RVD-FA202

snowy2.0

AREA OUTSIDE EIS BOUNDARY = 4874m^2
AREA PULLING IN BOUNDARY = 6195m^2

- EXISTING ROAD
- POST TENDER DESIGN OPTION
- FOSSIL AREA

NOT FOR CONSTRUCTION

SCALE 1:1000 10 0 10 20 30 40 50

AT A1 SIZE SHEET

DRAWING FILE LOCATION / NAME

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SNOWY 2.0

IMPACTS TO EIS BOUNDARY ALLOWING FOR SEMI FOSSIL AREA

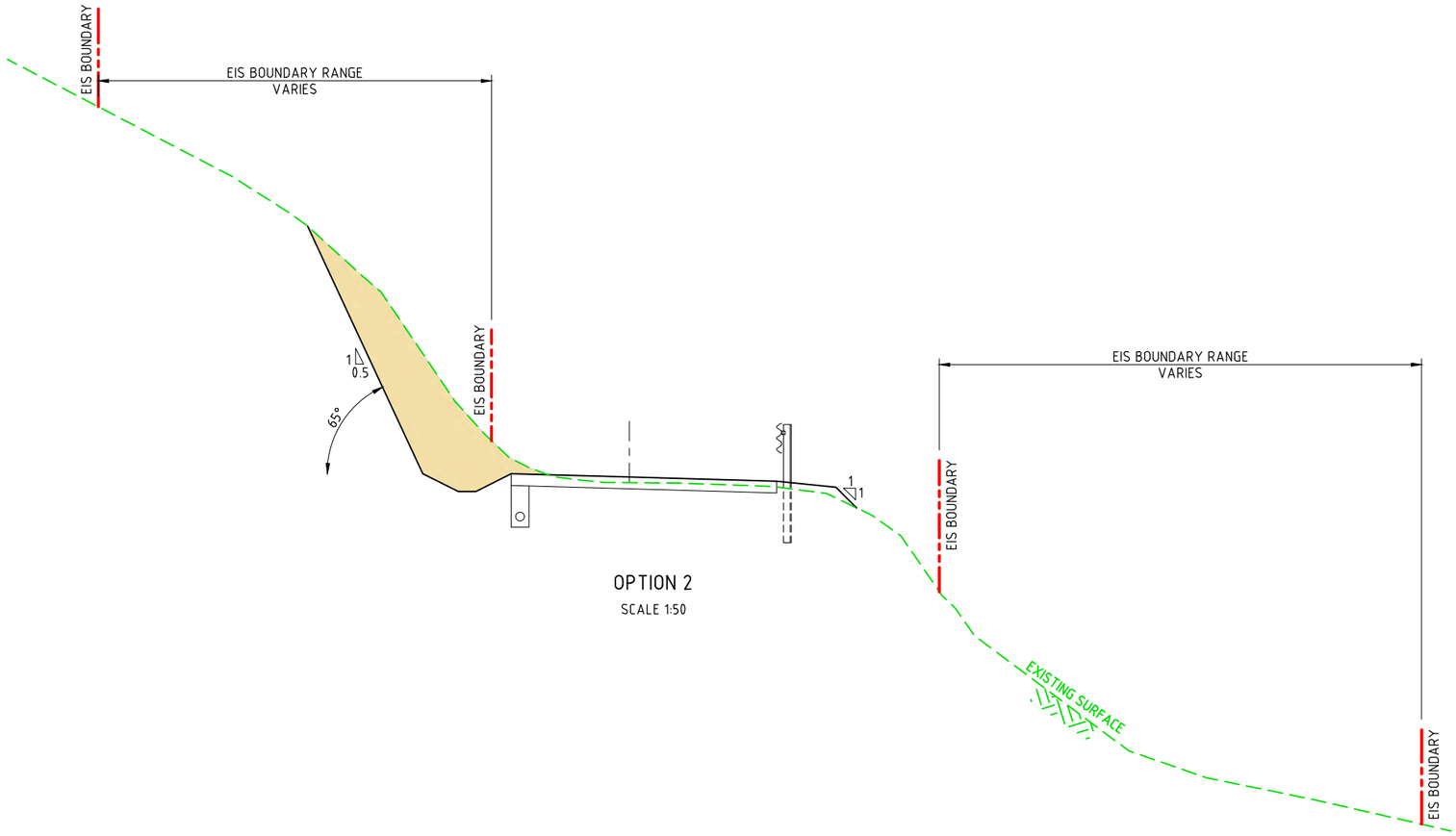
INFORMATION DOCUMENT

S2-180924-INF-EIS-IMPACT-KG-FA001

snowyhydro renewable energy

snowy2.0

OPTION 2



OPTION 2
SCALE 1:50

NOT FOR CONSTRUCTION

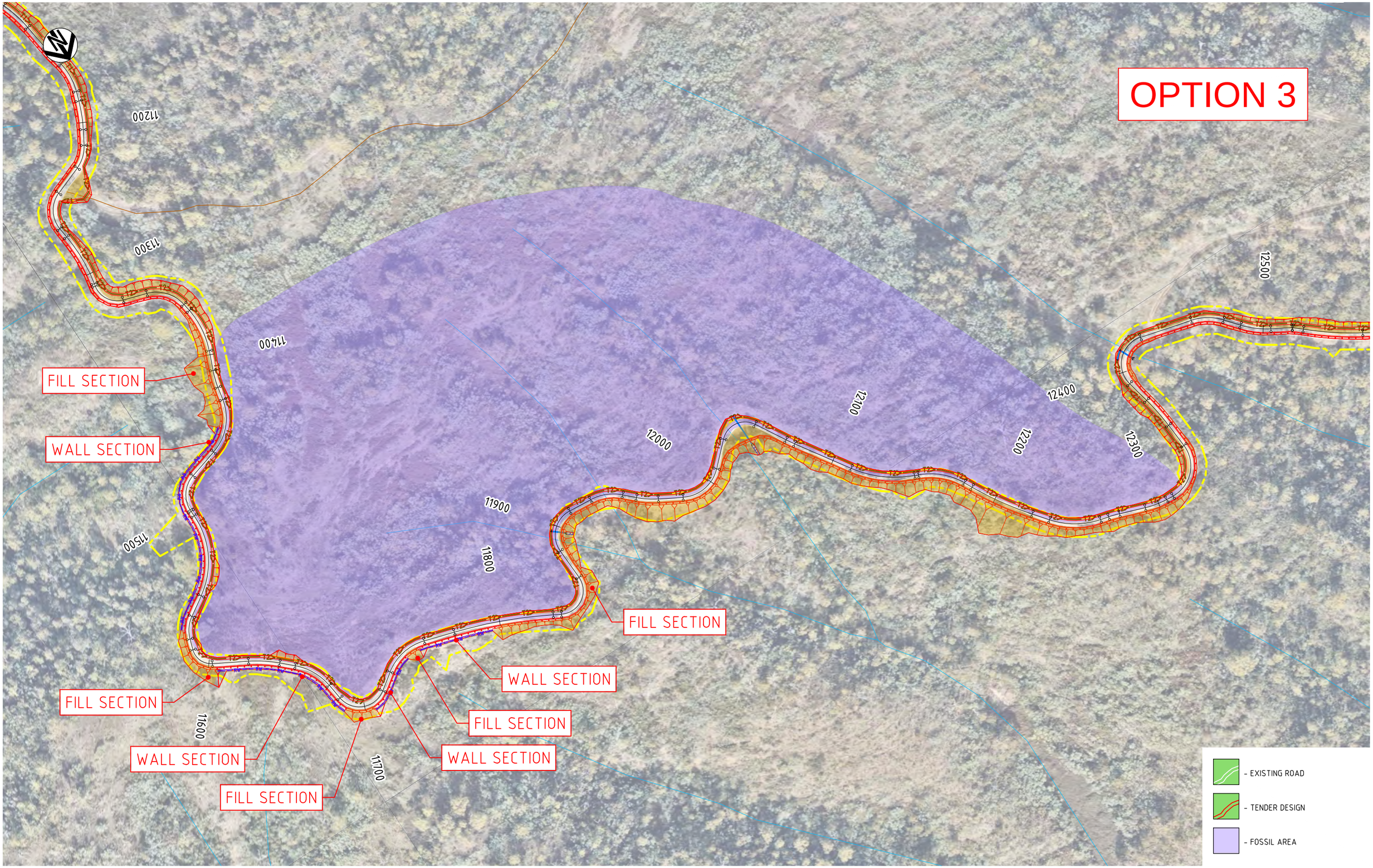
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SNOWY 2.0
IMPACTS TO GEODIVERSITY - FOSSIL AREA
TYPICAL CROSS SECTIONS - SHEET 03

INFORMATION DOCUMENT

S2-180918-INF-KG-RVD-FA203



NOT FOR CONSTRUCTION

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AT A1 SIZE SHEET

DRAWING FILE LOCATION / NAME

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SNOWY 2.0

IMPACTS TO GEODIVERSITY - FOSSIL AREA

RAVINE ROAD - POST IFT - OPTION 3

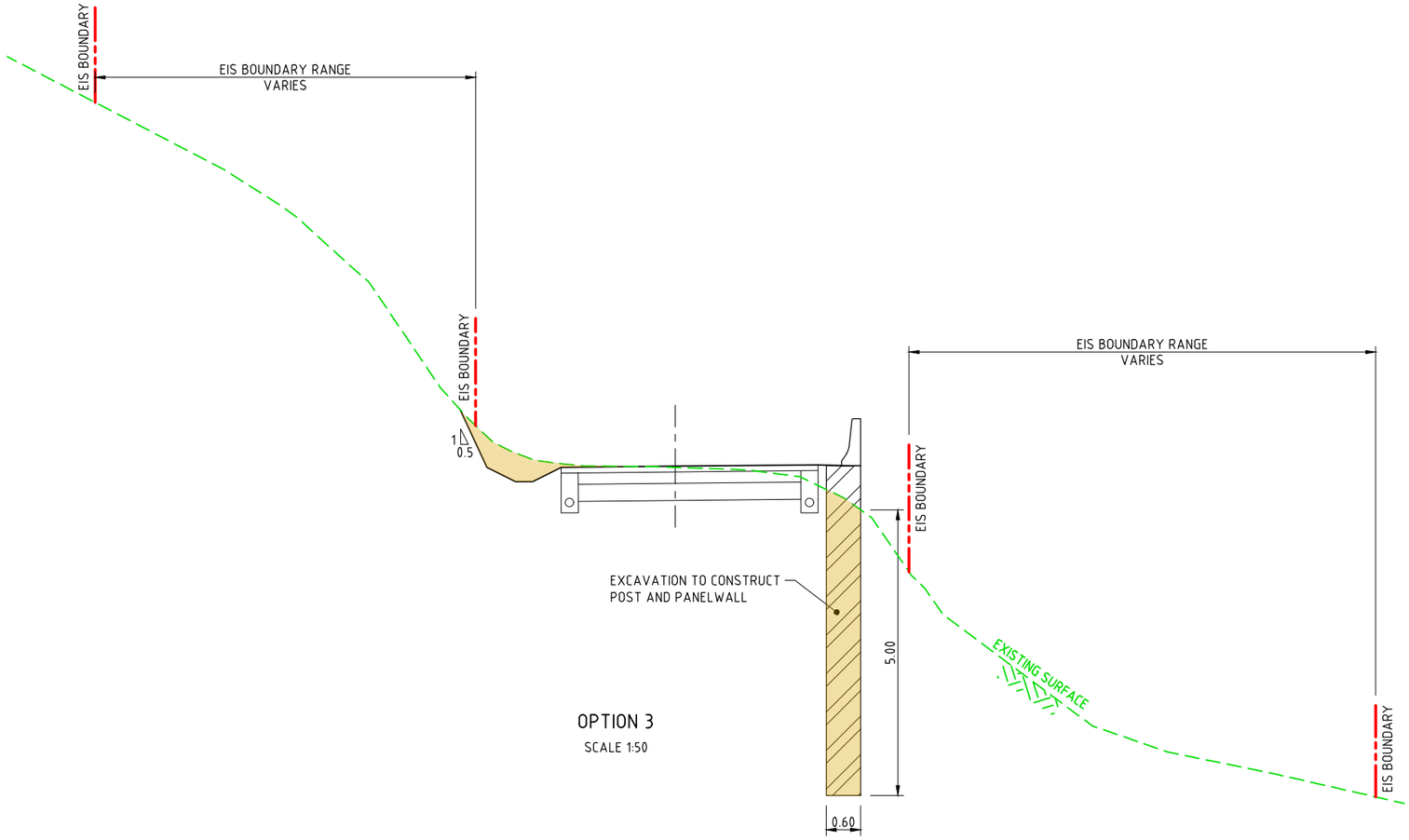
INFORMATION DOCUMENT

S2-180918-INF-KG-RVD-FA005

snowyhydro renewable energy

snowy2.0

OPTION 3



NOT FOR CONSTRUCTION

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DRAWING FILE LOCATION / NAME
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SNOWY 2.0
IMPACTS TO GEODIVERSITY - FOSSIL AREA
TYPICAL CROSS SECTIONS - SHEET 04

INFORMATION DOCUMENT

S2-180918-INF-KG-RVD-FA204

Appendix B

About the author

Dr Ian Percival recently retired as Senior Principal Research Scientist (Palaeontologist) with the Geological Survey of New South Wales where he worked for the past 23 years. Immediately prior to that he worked in various teaching and research positions at the University of Sydney and Macquarie University. He also was employed by Esso Australia between 1982 and 1991 in various roles in petroleum exploration, basin studies and strategic planning.

Dr Percival gained his B.Sc. (Hons 1) at the University of Sydney and continued on to study for his Ph.D. in palaeontology there, conferred in 1981. He was awarded a Rotary International Graduate Fellowship to study palaeontology for a year at the University of Kansas.

Dr Percival has published extensively, with 120 peer-reviewed papers published or in press, mostly concerning palaeontological or stratigraphical topics. He is a co-author of one major book (published by Columbia University Press in 2004) and sole author of a book *The Geological Heritage of New South Wales, Volume 1* published by the NSW National Parks & Wildlife Service in 1985. The latter was based on an unpublished report, commissioned by the Australian Heritage Commission and the NSW Planning & Environment Commission, that was submitted in 1979. This report presented the initial documentation of 47 geological sites throughout the State, including the fossiliferous beds of the Lick Hole Formation on the Lobs Hole Ravine Road.

Dr Percival has been a member of the Geological Society of Australia (GSA) since 1973, and has served for many years on the Geological Heritage Subcommittee of the NSW Division of that Society (including recently as its Chair). He is also on the Standing Committee for Geotourism of GSA. He holds roles in several other Australian scientific societies, and has an established international research profile in geoheritage, palaeontology and biostratigraphy, currently serving as Secretary of the International Subcommission on Ordovician Stratigraphy (part of the International Union of Geological Sciences).

Characteristics of Periglacial Rock Streams along the Lobs Hole Ravine Road

By

Dr. Bradley N. Opdyke

The Australian National University

Research School of Earth Science

1.0 Introduction

This letter was commissioned by Snowy Hydro to supplement the Environmental Impact Statement dated July 2018 regarding Exploratory Works for Snowy 2.0. This report also responds to matters raised by National Parks and Wildlife Service (NPWS) in regards to concerns to impacts on geodiversity due to the proposed improvements on the existing Lobs Hole Ravine Road within Kosciuszko National Park (KNP).

The objective of this report is to consider the effects of minor widening of the existing Lobs Hole Ravine Road to safely allow the movement of trucks associated with excavating the exploratory tunnel to the proposed underground power station complex for Snowy 2.0.

The road passes through three areas of periglacial deposits (known as rock streams), that will be intersected by minor widening (approximately 2 meters) of the Lobs Hole Ravine Road. The road is to be widened and upgraded, and the design has considered the presence of the periglacial deposits to minimise impacts on significant geo-heritage features such as the periglacial rock streams, whilst ensuring safe and continued access to Lobs Hole. The Lobs Hole Ravine Road will be an important access road for Exploratory Works for Snowy 2.0 development (Geodiversity Report, EMM Consulting. Figure 1).

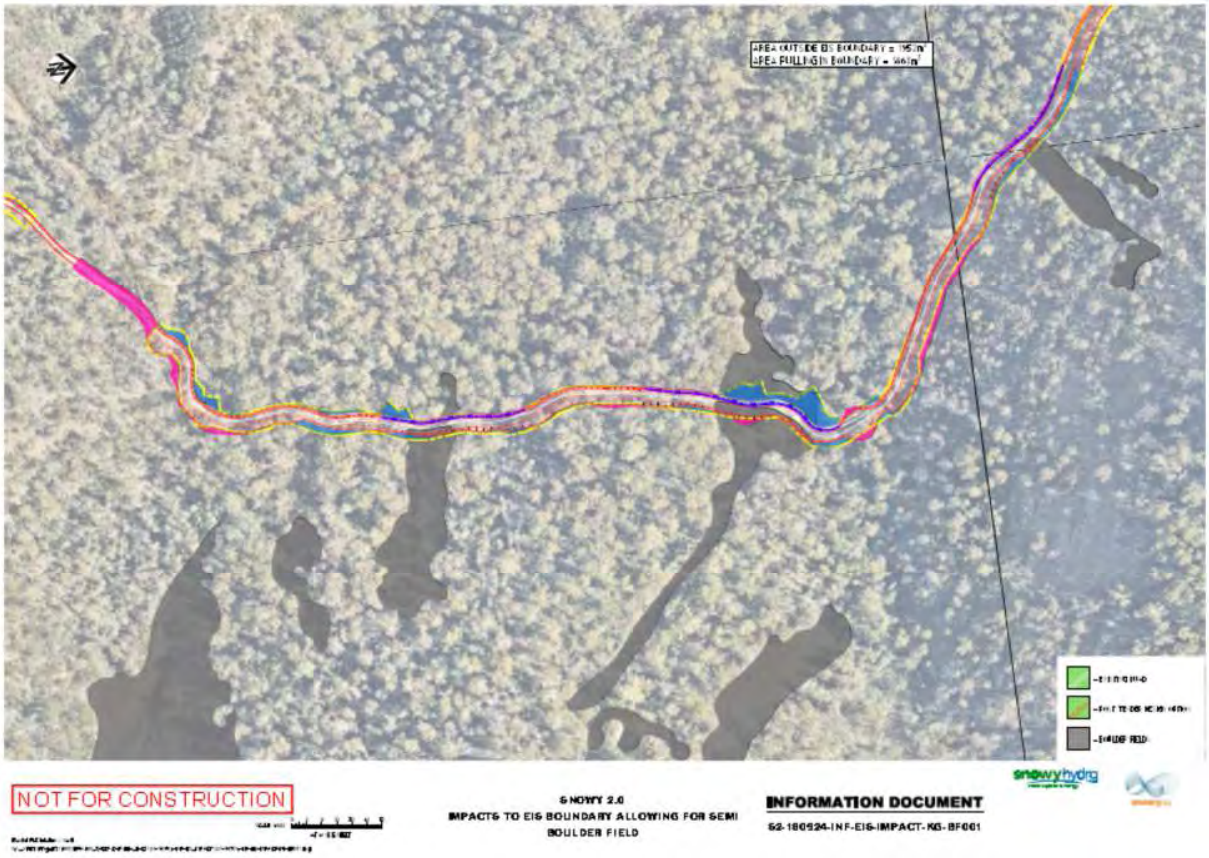


Figure 1 – Proposed road design along Lobs Hole Ravine Road crossing three rock streams

2.0 Rock Stream Characteristics

Rock streams typically have the following characteristics:

- They occur in alpine areas.
- They are often deposited on steep slopes.
- They often occur in shallow depressions in the landscape.
- They are relict features of a previous (colder) climate state.
- They are comprised of angular cobbles (between 6 and 25 cm in diameter) and boulders (>25 cm in diameter).

Rock streams are remnants of rock glaciers that date to an extraordinarily cold and dry period in Australia that date to between 22 and 16 thousand years ago and are found at various places throughout the southern highlands of Australia (Burrows et al. 2004). These boulder streams are sometimes referred to as 'fossil rock glaciers'. When active, they would have been 'cored' with ice, with the ice acting as a lubricant for the flow of the cobbles and boulders. When the climate began to warm significantly 16 thousand years ago the ice between the cobbles and boulders melted away and these boulders streams became static, with the angular shapes of the interlocking boulders impeding continued movement.

3.0 Significance of Rock Streams on Lobs Hole Ravine Road

Periglacial (or near glacial conditions) deposits do occur in the high country up Australia's eastern highlands as far north as 30 degrees South, and are worth preserving, particularly in our national parks (Slee and Shulmeister, 2015). Rock streams are often periglacial in nature and can be found far from true glacial deposits. The rock streams along Lobs Hole Ravine Road were bisected by the existing Lobs Hole Ravine Road in the late 19th century (Figure 1).

While there are approximately 4,000 rock streams, boulder streams and similar features throughout the highlands of southeastern Australia, each one has a story to tell about the glacial history of this part of the world (Slee and Shulmeister, 2015). Because of the altitude of most of these features the general public has little knowledge of their existence and significance. The initial damage to the large rock stream in the center of Figure 1 was done in the late 19th century during the construction of the existing Lobs Hole Ravine Road. While similar damage would be avoided today, road upgrade works in this area will provide an opportunity to enhance this area as a geo-heritage education site. This could be achieved by providing a turnout and educational

signage with information regarding the age and climate conditions that existed when the rock stream was formed.

4.0 Assessment of potential impacts of road works on the rock stream

Rock streams are typically comprised of shattered rock. These rocks are extremely angular with sharp corners and angles, which enables them to interlock and resist movement, even on the steep slopes on which they form. If care is taken, and the roadworks do not cut too deeply into the rock stream it can be done without seriously compromising the stability of the feature.

As previously mentioned road works will occur adjacent to rock streams in three sections on Lobs Hole Ravine Road. Road works in these sections will involve building a retaining wall/structure to avoid earthworks/disturbance downslope into the rock streams. To do this, the road needs to be built up vertically in this area. The retaining wall will be anchored into the existing road surface to provide for stability and safety. The road will be slightly widened in this area resulting in some encroachment, principally through fill, on the rock stream on the upslope. This is shown in Figure 2.

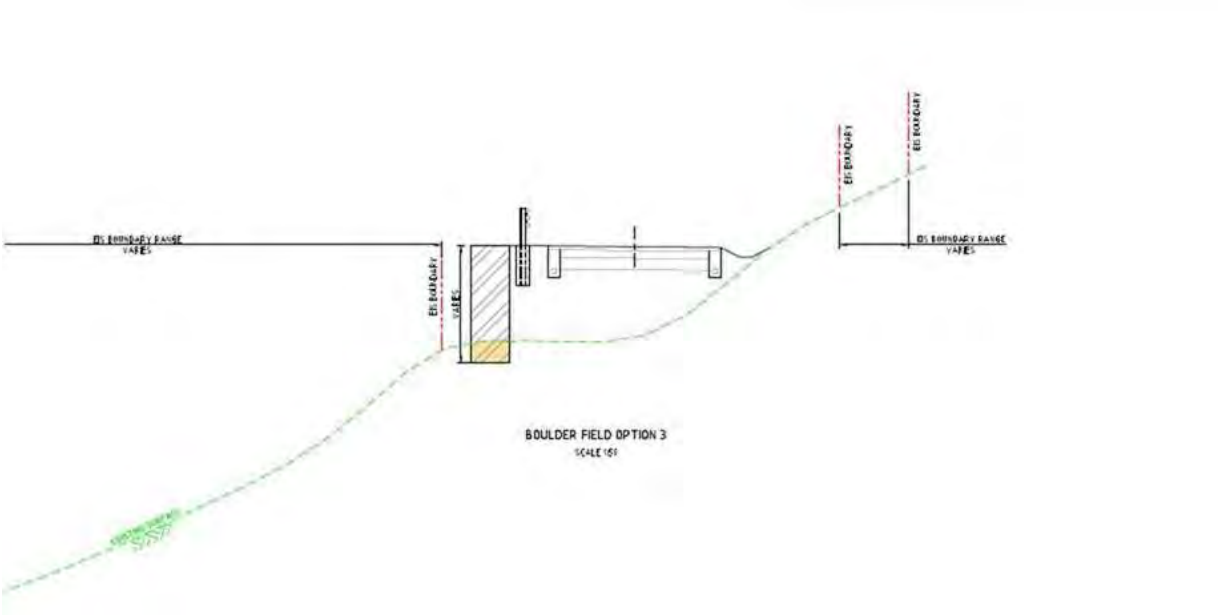


Figure 2 -Indicative cross-section of construction in rock stream area on Lobs Hole Ravine Road

If any works are required to stabilise upslope sections of rock stream it is recommended that open mesh wire fencing is used so the general public and scientists can see and appreciate the architecture of the deposit. Figure 3 shows the upslope side of a rock stream on Lobs Hole Ravine Road. Building a solid wall or spraying concrete on the upstream side should be avoided. On the downslope side of the road the deposit is already covered with road material for 5 or 6 metres downslope due to the previous road establishment works undertaken as early as the 19th century and this will continue to be the case.

Figure 4 shows the downslope of a rock stream on Lobs Hole Ravine Road. While this is not ideal it is an existing impact from the original construction of Lobs Hole Ravine Road. Where practical additional covering of the deposit (in terms of area) should be avoided. Figure 5 shows the existing road bisecting the rock stream.



Figure 3 – Rock stream along Lobs Hole Ravine Road – looking at upslope



Figure 4 - Rock stream along Lobs Hole Ravine Road – looking at downslope



Figure 5 - Existing road bisecting the rock stream

5.0 Recommendations for management measures to minimise/avoid impacts to the rock stream

The following mitigation measures for the road construction are recommended to avoid and minimise impacts to periglacial rock streams:

- Digging the road deeper into the rock stream should be avoided where practical, and excavations that take place to widen the road should be undertaken on the upslope side of the road.
- Because rock streams are stacked cobbles and boulders, they are extremely porous and permeable, they almost always sit in a valley or depression with potential water flow moving along their base. This should be considered when any development is done

across them, like the road in question, so water flow along their base is not impeded. Appropriate drainage should be constructed under the road to ensure no buildup of water occurs above the road, within the rock stream, during heavy rain.

- Educational signage should be provided in a nearby suitably widened area to provide information on the periglacial rock stream geoheritage features.

If any works are required to stabilise upslope sections of rock stream it is recommended that open mesh wire fencing is used so the general public and scientists can see and appreciate the architecture of the deposit. Building a solid wall or spraying concrete on the upslope side should be avoided. It is expected that the widening and strengthening of the road will not contribute significant additional damage to this heritage landscape and may provide an opportunity to educate the general population about the history behind this particular, geomorphic feature.

6.0 Conclusions

The rock streams along Lobs Hole Ravine Road are significant geomorphic features that educate us about a time when Australia and the globe was much colder than today. For this reason the proposed Lobs Hole Ravine Road upgrade will be carried out in such a manner as to minimise further damage to rock stream geoheritage features and perhaps increase their value to the KNP as a designated geo-heritage site with appropriate signage.

Provided appropriate management measures are taken in the road construction methods, a safe and stable road can be constructed with minimal additional impacts to the periglacial deposits. Impact to the sites can be mitigated by ensuring widening the road is only done to the width

needed to accommodate safe single lane access for construction vehicles, which, in the area of the rock streams, would be minimal.

References

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Adrian Slee and James Shulmeister, 2015, The distribution and climatic implications of periglacial landforms in eastern Australia, Journal of Quaternary Science, 30(8):848 – 858.

Geodiversity review. EMM Consulting 13 July 2018

About the Author

Dr. Bradley Opdyke is on the Faculty at The Research School of Earth Sciences at the Australian National University. Dr Opdyke has a back ground in Sedimentology and Geochemistry and has worked extensively on creating Paleo-climate records for the Quaternary Period (the last 2.6 million years). While much of his research has been marine based and extends from the Antarctic to the Australian Tropics, a recent project looking at Paleo-climate records and the geomorphology around Lake George in NSW has bought him back on shore again to investigate evidence of climate changes in south eastern Australia. This study has particular relevance to the wider geomorphic features, such as the alpine rock streams being investigated in this report. Dr. Opdyke is also researching the geochemistry of precipitation over the high country of NSW in an effort to better quantify both overland and groundwater flows in this region.



CHAPTER E

UPDATED SURFACE WATER ASSESSMENT

Surface Water Assessment

Final Draft

Report Surface Water Assessment | Prepared for SnowyHydro | 3 October 2018

Prepared by	**Chris Kuczera**	Approved by	**Duncan Peake**
Position	Associate water resource engineer	Position	Director
Signature		Signature	
Date	3 October 2018	Date	3 October 2018

This report has been prepared in accordance with the brief provided by the client and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of the client and no responsibility will be taken for its use by other parties. The client may, at its discretion, use the report to inform regulators and the public.

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Document Control

Version	Date	Prepared by	Reviewed by
V1	13/7/2018	Chris Kuczera	Alex Frolich John Ross
V2-0	03/10/2018	Chris Kuczera	Dr Phil Towler

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Executive Summary

ES1 Overview

ES1.1 Exploratory Works

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and a hydro-electric power station.

Snowy 2.0 has been declared to be Critical State Significant Infrastructure by the NSW Minister for Planning under the provisions of the NSW *Environmental Planning and Assessment Act 1979* (EA&A Act) and is defined in Clause 9 of Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011.* Separate applications and environmental impact statements (EIS) for different phases of Snowy 2.0 are being submitted under Part 5, Division 5.2 of the EP&A Act. The application for Exploratory Works is the first application for Snowy 2.0.

The purpose of Exploratory Works is primarily to gain a greater understanding of the conditions at the proposed location of the power station, approximately 850 metres (m) below ground level. Understanding factors such as rock conditions, ground temperature and stress conditions is essential to confirm the suitability of the site for the underground power station.

Exploratory Works comprise:

- the establishment of an exploratory tunnel to the site of the underground power station for Snowy 2.0, including a portal and construction pad;
- the establishment of a portal construction compound;
- excavated rock management;
- the establishment of an accommodation camp;
- road establishment and upgrades providing access to the proposed construction areas;
- establishment of barge access infrastructure on Talbingo reservoir; and
- supporting power and communication.

ES1.2 Assessment overview

This surface water assessment supports the EIS for the Exploratory Works. The assessment has been informed by the reference design prepared for the Exploratory Works. The following aspects of the project are considered relevant to this assessment:

- Flood risk management associated with works proposed on flood prone land.

- Water management during construction of access roads, the accommodation camp, construction pad and other infrastructure.
- Water management during operations (ie tunnel excavation) including for:
  - stormwater runoff from the access roads, accommodation camp and construction pads;
  - water produced by and used by the proposed construction activities;
  - waste water (ie sewage); and
  - rock and soil emplacement areas.

This assessment has been undertaken with reference to the NSW Water Quality Objectives (WQOs) and environmental values for the receiving waters, including indicators and trigger values provided in the *Australian Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000).

This assessment has identified potential impacts and considers all practical controls to avoid or mitigate identified impacts. The controls presented in this assessment are principles or design objectives, that will be further developed in the detailed design of the Exploratory Works. The management measures assessed are presented to determine the feasibility of achieving the proposed discharge water quality. The management measures implemented may vary from those presented but will still need to meet the proposed water quality or other stated objectives.

Residual impacts are assessed relative to the WQOs.

ES2 Existing environment

ES2.1 Overview

The Exploratory Works will predominantly be in the Ravine region of the Kosciuszko National Park (KNP). This region is located between Talbingo Reservoir to the north-west and the Snowy Mountains Highway to the east. Major infrastructure – including the construction pad, accommodation camp and access roads – will be located in Lobs Hole.

ES2.2 Yarrangobilly River

The Yarrangobilly River is a major regional watercourse that flows into the Talbingo Reservoir, downstream of Lobs Hole. The Yarrangobilly River has a catchment area of 271 km^2. The catchment is wholly within the KNP. The catchment is characterised by a range of subalpine grasslands and woodlands and montane dry sclerophyll forests. Elevations range from 545 m Australian Height Datum (AHD) at Lobs Hole to more than 1,500 m AHD in the head water catchments. Median rainfall within the Yarrangobilly River catchment ranges from 950 mm/year at Lobs Hole to 1,400 mm/year in the head water catchments. The spatial variation in median rainfall generally reflects the variation in topography within the catchment.

Over the year, the highest flows occur in late winter and early spring. Stream flows progressively decrease over summer and are at their lowest in late summer and generally remain low until the winter months. This is a typical regime for rivers in the Australian Alps.

Water quality monitoring results for the Yarrangobilly River are available for three occasions (between February and April 2018). All samples were collected during base flow conditions, which are dominant in the summer months. The water quality during these base flow conditions can be characterised as neutral to slightly alkaline, high carbonate levels, low salinity, low suspended solids and low levels of nutrients and metals. This monitoring program is continuing.

Water quality during non-base flow conditions is expected to have lower carbonate levels and potentially higher suspended solids and nutrient levels. Monitoring during elevated stream flow conditions will be undertaken in late winter and early spring 2018.

ES2.3 Wallaces Creek

Wallaces Creek is a major tributary to the Yarrangobilly River. The creek has a catchment area of 43.4 km^2, which extends to the south and forms the southernmost potion of the Yarrangobilly River catchment.

Wallaces Creek has a similar stream flow regime and water quality characteristics to the Yarrangobilly River.

ES2.4 Local watercourses

There are numerous smaller watercourses in vicinity of the Exploratory Works area. These watercourses are tributaries to the Yarrangobilly River, have catchment areas of up to 4 km^2 and typically have intermittent flow regimes.

ES2.5 Talbingo Reservoir

Talbingo Reservoir is an existing reservoir that forms part of the Snowy Scheme. Water is released from the reservoir through the Tumut 3 power station into Jounama Pondage, which releases water into Blowering Reservoir. Blowering Reservoir is operated by Water NSW and releases water into the Tumut River to supply the Murrumbidgee Irrigation Scheme. The Tumut 3 power station also can pump water from Jounama Pondage back into Talbingo Reservoir.

Average annual inflows (excluding pumping) into Talbingo Reservoir are 1,221 GL/year. The majority (86%) of inflows occur due to discharge from the Tumut 2 power station. Inflows from the Yarrangobilly River and ungauged catchments are 8% and 6% of the total inflows respectively.

Comprehensive water quality sampling in the reservoir was undertaken in March 2018. Water quality (at the time of sampling) can be characterised as having a neutral pH, low carbonate, low salinity, low levels of suspended solids and low nutrient levels. Elevated concentrations of copper and zinc were identified in most samples from the southern (upstream) portion of the reservoir.

ES3 Flood risk assessment

The flood assessment was informed by flood modelling of the Yarrangobilly River, Wallaces Creek and minor tributaries. The modelling was undertaken in accordance with the methods recommended in Australian Rainfall and Runoff (Commonwealth of Australia 2016). The flood model results have been used to establish flood characteristics within Lobs Hole for the 20%, 5%, 1%, 0.2%, 0.05% annual exceedance probability and probable maximum flood events.

Exploratory Works will avoid flood prone land where possible. However, the following infrastructure will unavoidably need to be constructed on flood prone land:

- bridge crossings over the Yarrangobilly River and Wallaces Creek;
- the western emplacement area; and
- the water management basin for the construction pad.

The flood model was applied to assess changes to the existing flooding regime associated with the infrastructure. This process concluded that the predicted changes to flood regimes will not impact infrastructure or items of heritage significance.

ES4 Water management

A water management system is presented that will to manage both runoff from Exploratory Works and water produced by and used by Exploratory Works. The water management system has been categorised into eight focus areas. Table E.1 provides an overview of the management approach applied to each focus area.

Table E.1 Water management summary

Focus area	Management approach summary
Clean water management	• Where possible, clean water will be diverted around or through water management areas.
Water management during construction (initial phase only)	• Erosion and sediment controls will be established to manage sediment laden runoff from construction disturbance areas. • Water treatment chemicals will be used to reduce sediment, turbidity and phosphorous levels for construction areas that are >2,500 m^2.
Runoff from unsealed access roads	• Erosion and sediment controls will be established to manage sediment laden runoff from unsealed access roads.
Stormwater management: accommodation camp	• A stormwater management system will manage runoff from impervious areas. • All pervious areas including batters will be vegetated with endemic native vegetation.
Stormwater management: portal construction pad	• A stormwater management system will manage runoff from the portal construction pad. • Activities that have significant potential to contaminate stormwater runoff will be isolated from the stormwater system by covering (ie by a building or roof) and/or bunding. • The stormwater management system will be designed to contain any leak, spill or fire water runoff from the portal construction pad. • Water treatment chemicals will be used to reduce sediment, turbidity and phosphorous levels
Process water management	• A process water management system will be established to manage water produced by and used by construction activities. • Any surplus process water will meet the prescribed criteria (refer to Table 6.18) for discharge into the Yarrangobilly River arm of Talbingo Reservoir. • Any additional water required will be sourced from Talbingo Reservoir.
Waste water management	• All waste water will meet the prescribed criteria (refer to Table 6.24) for discharge into the Yarrangobilly River arm of Talbingo Reservoir.
Rock and soil emplacement water management	• Rock and soil emplacements will be designed to be physically stable landforms.

Table E.1 Water management summary

Focus area	Management approach summary
	• All emplacement seepage will be captured and managed (treated or irrigated back to emplacement) to avoid discharge to the Yarrangobilly River.

Chapter 6 of this report describes the water management risks, water management approach, expected impacts and monitoring and contingency measures for each of the water management focus areas. The controls presented in this assessment are principles or design objectives, that will be further developed in the detailed design of the Exploratory Works. A summary of all controls is provided in Appendix F.

ES5 Residual impacts

Residual impacts of Exploratory Works on the surface water environment have been assessed relative to the WQOs and relevant trigger values.

ES5.1 Impacts to the Yarrangobilly River

The potential for impacts to the Yarrangobilly River and other watercourses due to stormwater discharges from Exploratory Works has been assessed. All practical controls to avoid or mitigate impacts are presented. The assessment of residual impacts concluded that:

- stormwater discharges from disturbed areas >2,500 m^2 will occur up to ten times per year on average – during and immediately following rainfall;
- stormwater discharges from disturbed areas <2,500 m^2 will occur up to 50 times per year on average but discharge volumes will be small;
- turbidity, and suspended solids and nutrients concentrations in discharged stormwater are expected to exceed default trigger levels for physical and chemical stressors on occasions and it is possible that metal concentrations may also exceed the relevant default trigger levels;
- stormwater discharges will rapidly mix with river flows, so no concentration impacts are predicted;
- load increases due to stormwater discharges are conservatively estimated to be less than 2.6% of existing loads for all pollutants;
- no change to stream flow regimes is predicted; and
- no ecological impacts are predicted.

ES5.2 Impacts to Talbingo Reservoir

The potential for impacts to the water quality of Talbingo Reservoir from the following have been assessed:

- discharge of treated waste water and treated process water into the Yarrangobilly River arm of Talbingo Reservoir; and
- the discharge of stormwater runoff into the Yarrangobilly River, upstream of Talbingo Reservoir.

All practical controls to avoid or mitigate impacts are presented. An assessment of residual impacts has concluded that:

- discharges of treated waste water and process water may exceed default trigger levels for Talbingo Reservoir at the point of discharge;
- a mixing zone, conservatively assessed to extend 10 m from the point of discharge, will be required;
- pollutant load increases are conservatively estimated to be less than 5% of existing loads; and
- no ecological impacts are predicted.

The potential for impacts to the water quality of Talbingo Reservoir from subaqueous dredged material placement and subaqueous excavated rock placement are assessed in the *Middle Bay Dredging and Dredge Impact Assessment* (RHDHV 2018a) and the *Subaqueous Excavated Rock Placement Program* (RHDHV 2018b) respectively.

Due to the separation of these activities from the mouth of the Yarrangobilly River and the discharge point in the Yarrangobilly arm, no cumulative impacts between these activities are predicted.

ES5.3 Works within riparian zones

Some local watercourses will unavoidably be disturbed by the establishment of rock emplacement areas, bridge crossings and the accommodation camp.

ES6 Proposed monitoring

The current surface water monitoring program will continue. A surface water monitoring program will be implemented over the duration of the Exploratory Works. The primary objectives of the monitoring program are to collect sufficient data to:

- continue to monitor baseline conditions (upstream of Exploratory Works);
- identify and quantify water quality impacts (downstream of Exploratory Works);
- enable the effectiveness of water quality controls to be assessed; and
- enable compliance with relevant consent and licence conditions to be assessed.

The monitoring program includes commitments to monitor weather, stream flows, process water quantity and quality, stormwater quality and receiving water quality.

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1 Introduction

1.1 The project

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). This would be achieved by establishing a new underground hydro-electric power station that would increase the generation capacity of the Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) generating capacity, and providing approximately 350,000 megawatt hours (MWh) of storage available to the National Electricity Market (NEM) at any one time, which is critical to ensuring system security as Australia transitions to a decarbonised NEM. Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and hydro-electric power station.

Snowy 2.0 has been declared to be State significant infrastructure and critical State significant infrastructure (CSSI) by the NSW Minister for Planning under the provisions of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and is defined in Clause 9 of Schedule 5 of the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP). Separate applications and environmental impact statements (EIS) for different phases of Snowy 2.0 are being submitted under Part 5, Division 5.2 of the EP&A Act. This technical assessment has been prepared to support an EIS for Exploratory Works to undertake investigative works to gather important technical and environmental information for the main Snowy 2.0 project. The main project will be subject of a separate application and EIS next year.

The purpose of Exploratory Works for Snowy 2.0 is primarily to gain a greater understanding of the conditions at the proposed location of the power station, approximately 850 metres (m) below ground level. Understanding factors such as rock conditions (such as stress conditions) and ground temperature is essential to inform decisions about the precise location of the power station cavern and confirm the cavern construction methods.

Exploratory Works comprises:

- an exploratory tunnel to the site of the underground power station for Snowy 2.0;
- horizontal and other test drilling, investigations and analysis in situ at the proposed cavern location and associated areas, and around the portal construction pad, access roads and excavated rock management areas all within the disturbance footprint;
- a portal construction pad for the exploratory tunnel;
- an accommodation camp for the Exploratory Works construction workforce;
- road works and upgrades providing access and haulage routes during Exploratory Works;
- barge access infrastructure, to enable access and transport by barge on Talbingo reservoir;
- excavated rock management, including subaqueous placement within Talbingo Reservoir;
- services infrastructure such as diesel-generated power, water and communications; and
- post-construction revegetation and rehabilitation, management and monitoring.

1.2 Purpose of this report

This surface water assessment supports the EIS for the Exploratory Works. It describes proposed flood risk and water management methods, monitoring and contingency measures and residual impacts.

1.3 Location of Exploratory Works

Snowy 2.0 and Exploratory Works are within the Australian Alps, in southern NSW. The regional location of Exploratory Works is shown on Figure 1.1. Snowy 2.0 is within both the Snowy Valleys and Snowy Monaro Regional local government areas (LGAs), however Exploratory Works is entirely within the Snowy Valleys LGA. The majority of Snowy 2.0 and Exploratory Works are within Kosciuszko National Park (KNP). The area in which Exploratory Works will be undertaken is referred to herein as the project area and includes all of the surface and subsurface elements further discussed in Section 2.1.

Exploratory Works is predominantly in the Ravine region of the KNP. This region is between Talbingo Reservoir to the north-west and the Snowy Mountains Highway to the east, which connects Adaminaby and Cooma in the south-east to Talbingo and Tumut to the north-west of the KNP. Talbingo Reservoir is an existing reservoir that forms part of the Snowy Scheme. The reservoir, approximately 50 kilometres (km) north-west of Adaminaby and approximately 30 km east-north-east of Tumbarumba, is popular for recreational activities such as boating, fishing, water skiing and canoeing.

The nearest large towns to Exploratory Works are Cooma and Tumut. Cooma is approximately one hour and forty five minutes drive (95 km) south-east of Lobs Hole. Tumut is approximately half an hour (45 km) north of Talbingo. There are several communities and townships near the project area including Talbingo, Tumbarumba, Batlow, Cabramurra and Adaminaby. Talbingo and Cabramurra were built for the original Snowy Scheme workers and their families. Adaminaby was relocated to alongside the Snowy Mountains Highway from its original location (now known as Old Adaminaby) in 1957 due to the construction of Lake Eucumbene. Talbingo and Adaminaby provide a base for users of the Selwyn Snow Resort in winter. Cabramurra was modernised and rebuilt in the early 1970s and is owned and operated by Snowy Hydro. It is still used to accommodate Snowy Scheme employees and contractors. Properties within Talbingo are now predominantly privately owned. Snowy Hydro now only owns 21 properties within the town.

Other attractions and places of interest in the vicinity of the project area include Selwyn Snow Resort, the Yarrangobilly Caves complex and Kiandra. Kiandra has special significance as the first place in Australia where recreational skiing was undertaken and is also an old gold rush town.

The project area is shown on Figure 1.1 and comprises:

- **Lobs Hole:** Lobs Hole will accommodate the excavated rock emplacement areas, an accommodation camp as well as associated infrastructure, roads and laydown areas close to the portal of the exploratory tunnel and portal construction pad at a site east of the Yarrangobilly River;
- **Talbingo Reservoir:** installation of barge access infrastructure near the existing Talbingo Spillway, at the northern end of the Talbingo Reservoir, and also at Middle Bay, at the southern end of the reservoir, near the Lobs Hole facilities, and installation of a submarine cable from the Tumut 3 power station to Middle Bay, providing communications to the portal construction pad and accommodation camp. A program of subaqueous rock placement is also proposed;

- **Mine Trail Road** will be upgraded and extended to allow the transport of excavated rock from the exploratory tunnel to sites at Lobs Hole that will be used to manage excavated material, as well as for the transport of machinery and construction equipment and for the use of general construction traffic; and

- several sections of **Lobs Hole Ravine Road** will be upgraded in a manner that protects the identified environmental constraints present near the current alignment.

The project is described in more detail in Chapter 2.

1.4 Proponent

Snowy Hydro is the proponent for Exploratory Works. Snowy Hydro is an integrated energy business – generating energy, providing price risk management products for wholesale customers and delivering energy to homes and businesses. Snowy Hydro is the fourth largest energy retailer in the NEM and is Australia's leading provider of peak, renewable energy.

1.5 Assessment guidelines and requirements

This surface water assessment has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) for Exploratory Works, issued on 17 May 2018, as well as relevant governmental assessment requirements, guidelines and policies, and in consultation with the relevant government agencies.

The SEARs must be addressed in the EIS. Table 1.1 lists the matters relevant to this assessment and where they are addressed in this report.

Table 1.1 Relevant matters raised in SEARs - Water

Requirement	Section addressed
An assessment of the impacts of the project on the quantity and quality of the region's surface water resources, including Yarrangobilly River, Wallaces Creek and Talbingo Reservoir.	Section 6 and 7
An assessment of the impacts of the project on groundwater aquifers and groundwater dependent ecosystems having regard to the NSW Aquifer Interference Policy and relevant Water Sharing Plans.	Refer to Groundwater Assessment (EMM, 2018b)
An assessment of the potential flooding impacts and risks of the project.	Sections 5 and 7
A detailed site water balance for the project, including water supply and wastewater disposal arrangements.	Section 6.7

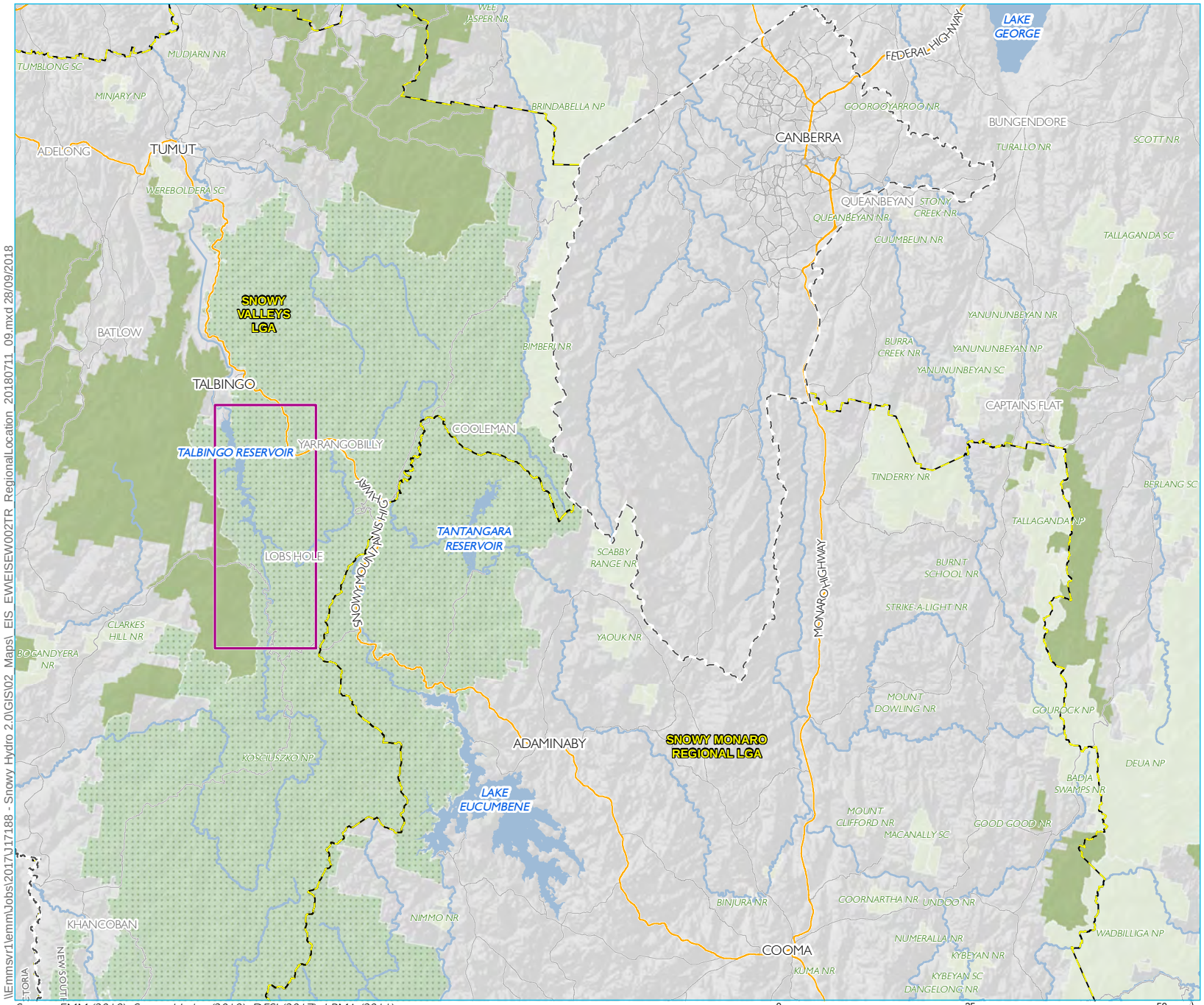
To inform preparation of the SEARs, the Department of Planning and Environment (DPE) invited relevant government agencies to advise on matters to be addressed in the EIS. These matters were taken into account by the Secretary for DPE when preparing the SEARs.

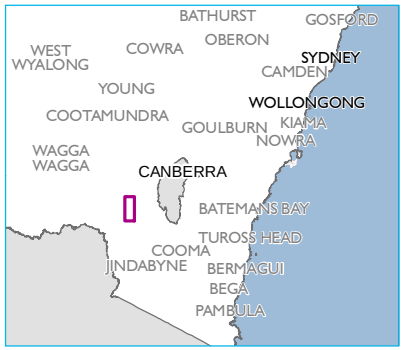
1.5.1 Other relevant reports

This Surface Water Assessment has been prepared with reference to other technical reports that were prepared as part of the Exploratory Works EIS. The other relevant reports referenced in this Surface Water Assessment are listed below:

- Excavated rock emplacement areas assessment (SGME 2018) – Appendix K of the EIS

- Groundwater assessment (EMM 2018) – Appendix N of the EIS
- Soils and land assessment (EMM 2018) – Appendix H of the EIS





KEY

- Exploratory Works project area
- Main road
- Local road
- Watercourse
- Waterbodies
- Kosciuszko National Park
- NPWS reserve
- State forest
- Local government area boundary
- State boundary

Regional location of Snowy 2.0 and Exploratory Works

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 1.1

Source: EMM (2018); Snowy Hydro (2018); DFSI (2017); LPMA (2011)

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2 Project description

2.1 Overview

Exploratory Works comprises construction associated with geotechnical exploration for the underground power station for Snowy 2.0. The Exploratory Works elements are shown on Figure 2.1 and involve:

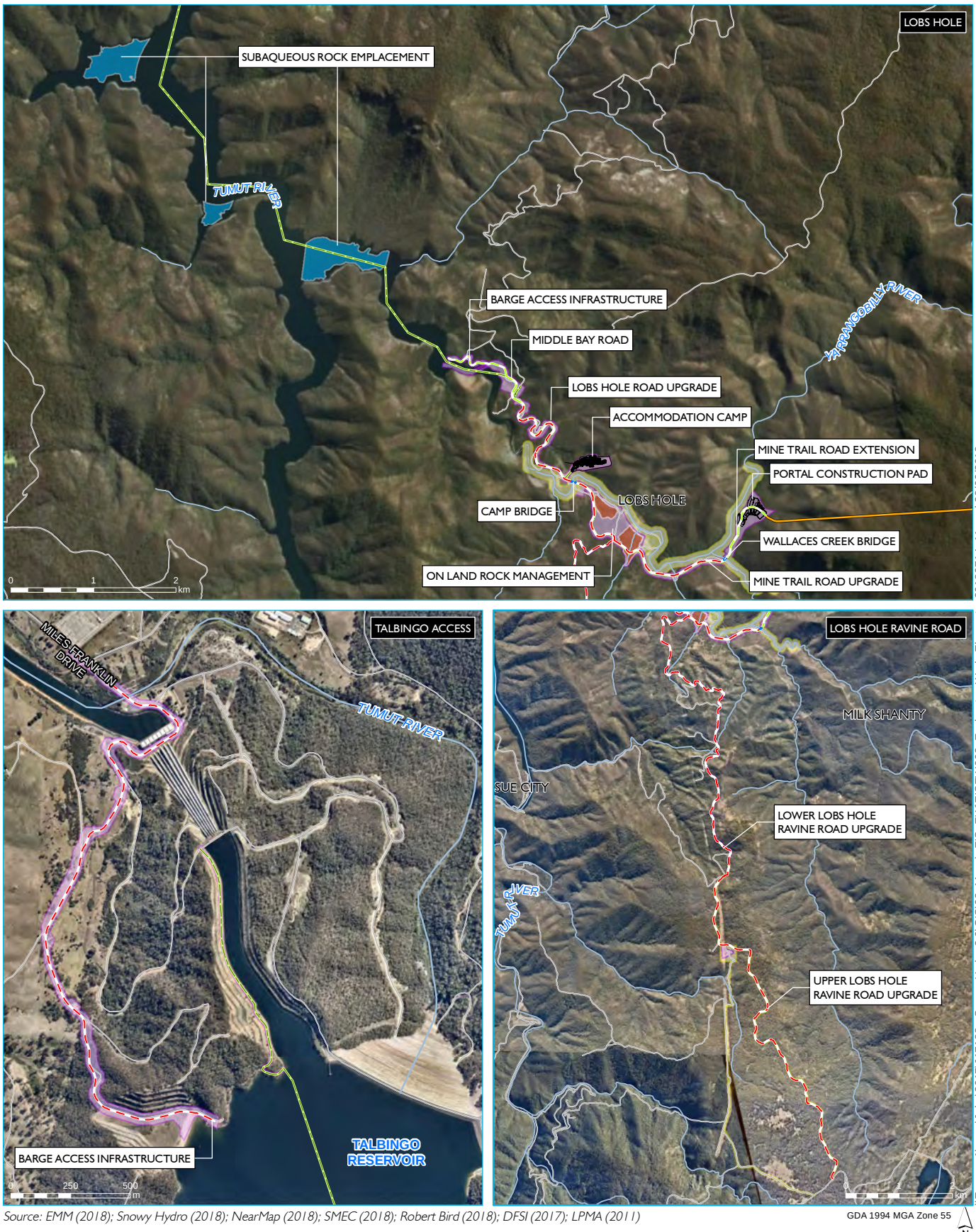
- establishment of an exploratory tunnel to the site of the underground power station for Snowy 2.0;
- horizontal and other test drilling, investigations and analysis in situ at the proposed cavern location and associated areas, and around the portal construction pad, access roads and excavated rock management areas all within the disturbance footprint;
- establishment of a portal construction pad for the exploratory tunnel;
- establishment of an accommodation camp for the Exploratory Works construction workforce;
- road works and upgrades providing access and haulage routes during Exploratory Works;
- establishment of barge access infrastructure, to enable access and transport by barge on Talbingo reservoir;
- excavated rock management, including subaqueous placement within Talbingo Reservoir;
- establishment of services infrastructure such as diesel-generated power, water and communications; and
- post-construction revegetation and rehabilitation, management and monitoring.

2.2 Exploratory tunnel

An exploratory tunnel of approximately 3.1 km is proposed to provide early access to the location of the largest cavern for the underground power station. This will enable exploratory drilling and help optimise the location of the cavern which, in turn, will optimise the design of Snowy 2.0.

The exploratory tunnel is proposed in the north-east section of Lobs Hole and will extend in an east-west direction with the portal construction pad to be outside the western end of the tunnel at a site east of the Yarrangobilly River, as shown on Figure 2.2.

The location of the proposed exploratory tunnel and portal construction pad is shown in Figure 2.2. The exploratory tunnel will be excavated by drill and blast methods and have an 8 x 8 m D-Shaped cross section, as shown on Figure 2.3.



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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Exploratory tunnel
- Access road upgrade
- Access road extension
- Permanent bridge
- Portal construction pad and accommodation camp conceptual layout
- Communications cable
- Local road or track
- Watercourse
- On land rock management
- Subaqueous excavated rock placement
- Disturbance footprint
- Avoidance footprint

Exploratory Works elements

Snowy 2.0
Suirface water assessment
Exploratory Works
Figure 2.1

snowy 2.0

EMM
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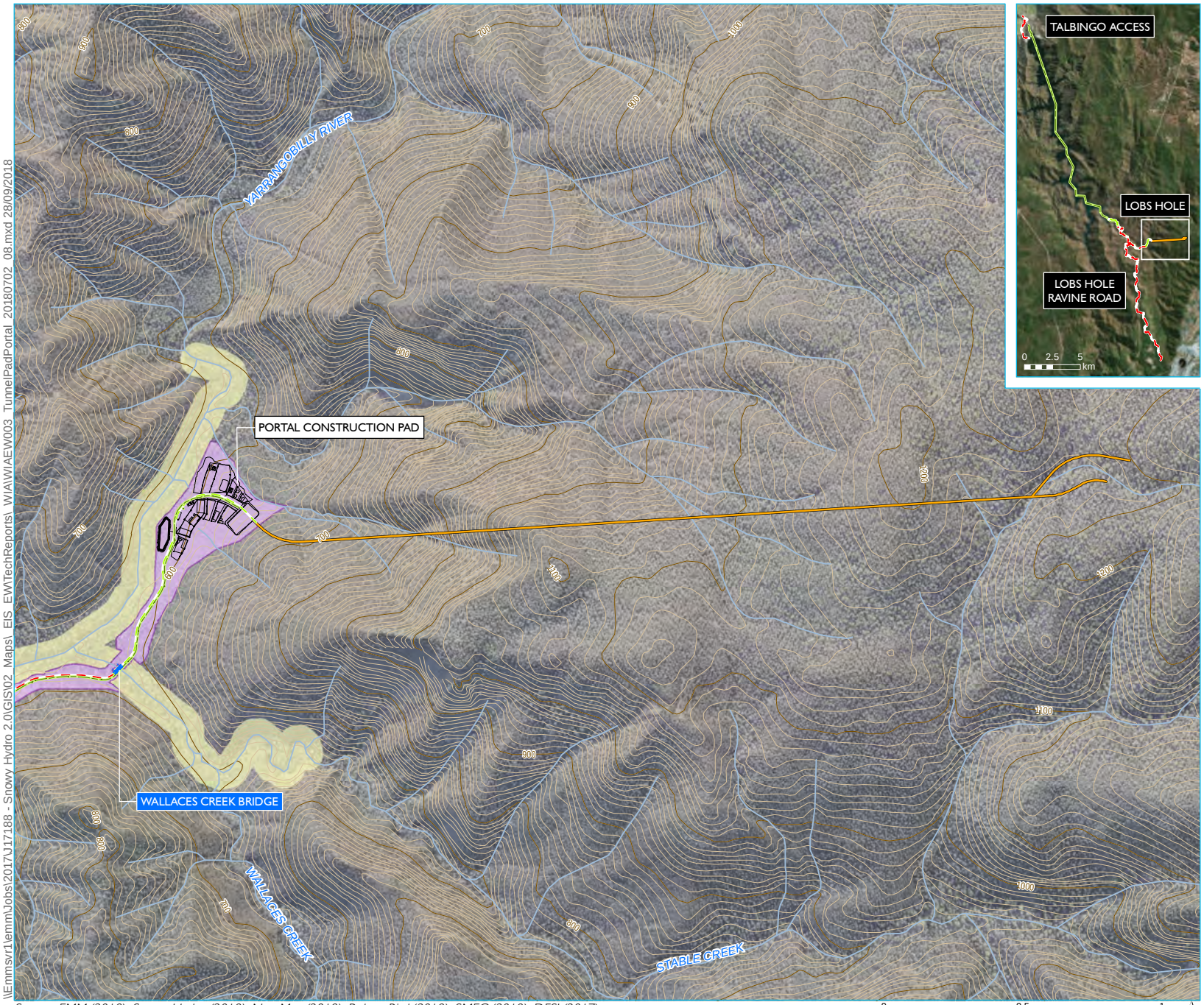
The drill and blast excavation process will be repeated cyclically throughout the tunnelling works, involving:

- marking up and drilling blast holes in a predetermined pattern in the working face of the tunnel;
- loading the blast holes with explosives, attaching detonators and connecting the holes into a blast sequence, and detonating the blast;
- ventilating the tunnel to remove blast fumes and dust;
- removing blasted rock;
- scaling and wash down of the tunnel roof and walls to remove loosened pieces of rock;
- geological mapping of the exposed rock faces and classification of the conditions to determine suitable ground support systems for installation;
- installing ground support; and
- advancing construction ventilation ducting and other utilities including power, water, compressed air and communications.

The exploratory tunnel will be shotcrete-lined with permanent anchor support, and incorporate a groundwater management system. The exploratory tunnel shape and dimensions are designed to allow two-lane traffic for the removal of excavated material, along with additional space for ventilation and drainage of groundwater inflows. Groundwater intersected during tunnelling will be contained and transferred to the portal for treatment and management. Areas identified during forward probing with the potential for high groundwater flows may require management through a detailed grouting program or similar.

The tunnel portal will be established at the western end of the exploratory tunnel and provide access and utilities to the exploratory tunnel during construction. The portal will house power, communications, ventilation and water infrastructure. The portal will also provide a safe and stable entrance to the exploratory tunnel.

It is anticipated that the exploratory tunnel will be adapted for multiple functions during construction of the subsequent stages of the Snowy 2.0 project. The exploratory tunnel will also eventually be utilized to form the main access tunnel (MAT) to the underground power station during the operational phase of Snowy 2.0, should it proceed.



\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02 Maps\ EIS EWTechReports\ WIA\WIAEW003 TunnelPadPortal 20180702 08.mxd 28/09/2018

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); Robert Bird (2018); SMEC (2018); DFSI (2017)

Exploratory tunnel location

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.2

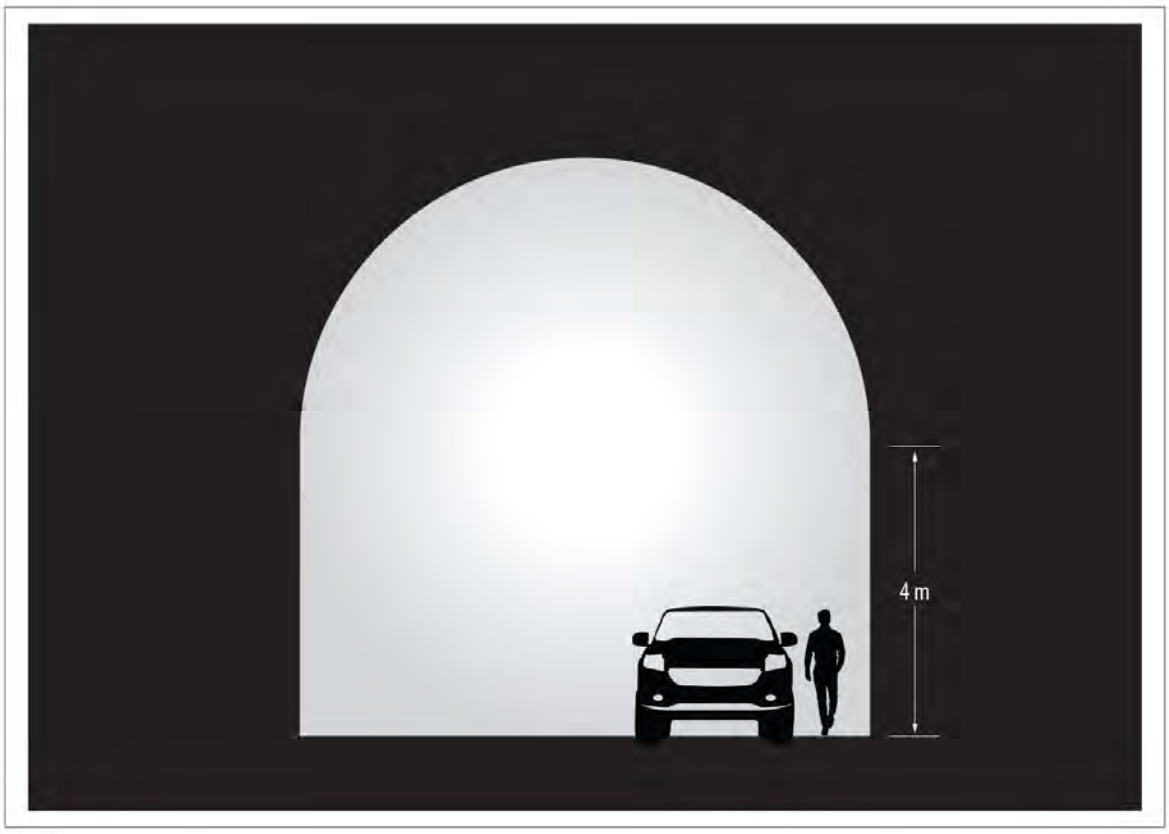
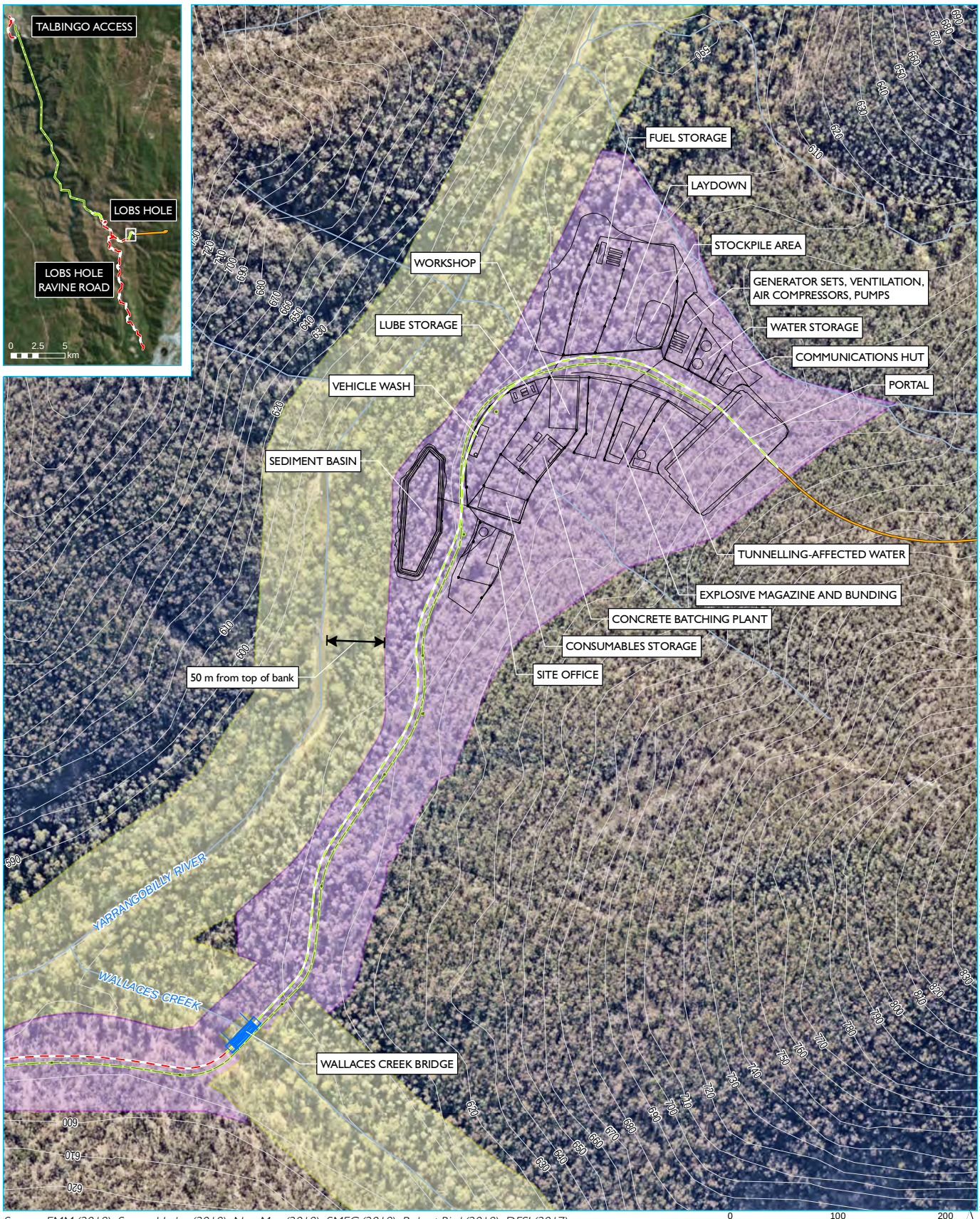


Figure 2.3 Exploratory tunnel indicative cross section

2.3 Portal construction pad

A portal construction pad for the exploratory tunnel will provide a secure area for construction activities. Infrastructure at the portal construction pad, shown in Figure 2.4, will primarily support tunnelling activities and include a concrete batching plant and associated stockpiles, site offices, maintenance workshops, construction support infrastructure, car parking, equipment laydown areas. Stockpile areas will allow for around two to three months supply of concrete aggregate and sand for the concrete batching plant to ensure that the construction schedule for the proposed access road works do not interfere with the exploratory tunnel excavation schedule. A temporary excavated rock stockpile area is also required to stockpile material excavated during tunnel construction prior to its transfer to the larger excavated material emplacement areas.

The portal construction pad will be at the western end of the exploratory tunnel. The portal construction pad will be excavated to provide a level construction area with a near vertical face for the construction of the portal and tunnelling. The area required for the portal construction pad is approximately 100,000 m^2.



\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWE\SEW010_ConstructionCompound_20180626_06.mxd 28/09/2018

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017)

KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable
- Watercourse
- Contour (10m)
- Disturbance footprint
- Avoidance footprint

Conceptual layout – portal construction pad

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.4

snowy 2.0

EMM creating opportunities

2.4 Excavated rock management

It is estimated that approximately 750,000 m^3 of bulked materials will be excavated, mostly from the exploratory tunnel and portal construction pad with additional quantities from road upgrade works. Subject to geochemical testing of the rock material, excavated rock will be placed either on land or subaqueously within Talbingo Reservoir.

2.4.1 On land placement

Excavated materials will be placed in one of two rock emplacement areas at Lobs Hole as shown on Figure 2.5.

The strategy for excavated rock management is for excavated material to be emplaced at two areas with the final placement of excavated material to be determined at a later date.

Excavated materials for on land placement will be placed in one of two temporary rock emplacement areas at Lobs Hole as described in Figure 7.5 and shown on Figure 7.6, the eastern and western emplacement areas. On land placement of excavated rock will be placed within one of the two on land emplacement areas for temporary storage through the duration of Exploratory Works. Following Exploratory Works the excavated material placed in the on land emplacement areas will be disposed of via one of the following options:

- Disposal with the Main Works excavated material – should Snowy 2.0 proceed, any excavated material from the on land emplacement areas will be disposed of with the excavated material from the Snowy 2.0 Main Works. This will involve either subaqueous placement within an existing reservoir or disposal to a suitable location outside the KNP. The placement of excavated material for Snowy 2.0 Main Works will be subject to further assessment and approvals.

- Disposal outside the KNP – if the main Snowy 2.0 project does not proceed, any excavated material not able to be re-used will be disposed of to a suitable location outside the KNP within five years of the completion of Exploratory Works subject to consultation with NPWS and further assessment and approvals.

The eastern emplacement area has a capacity of up to 600,000 m^3 for temporary storage of excavated material. The northern edge of the emplacement will be setback 50 m from the Yarrangobilly River.

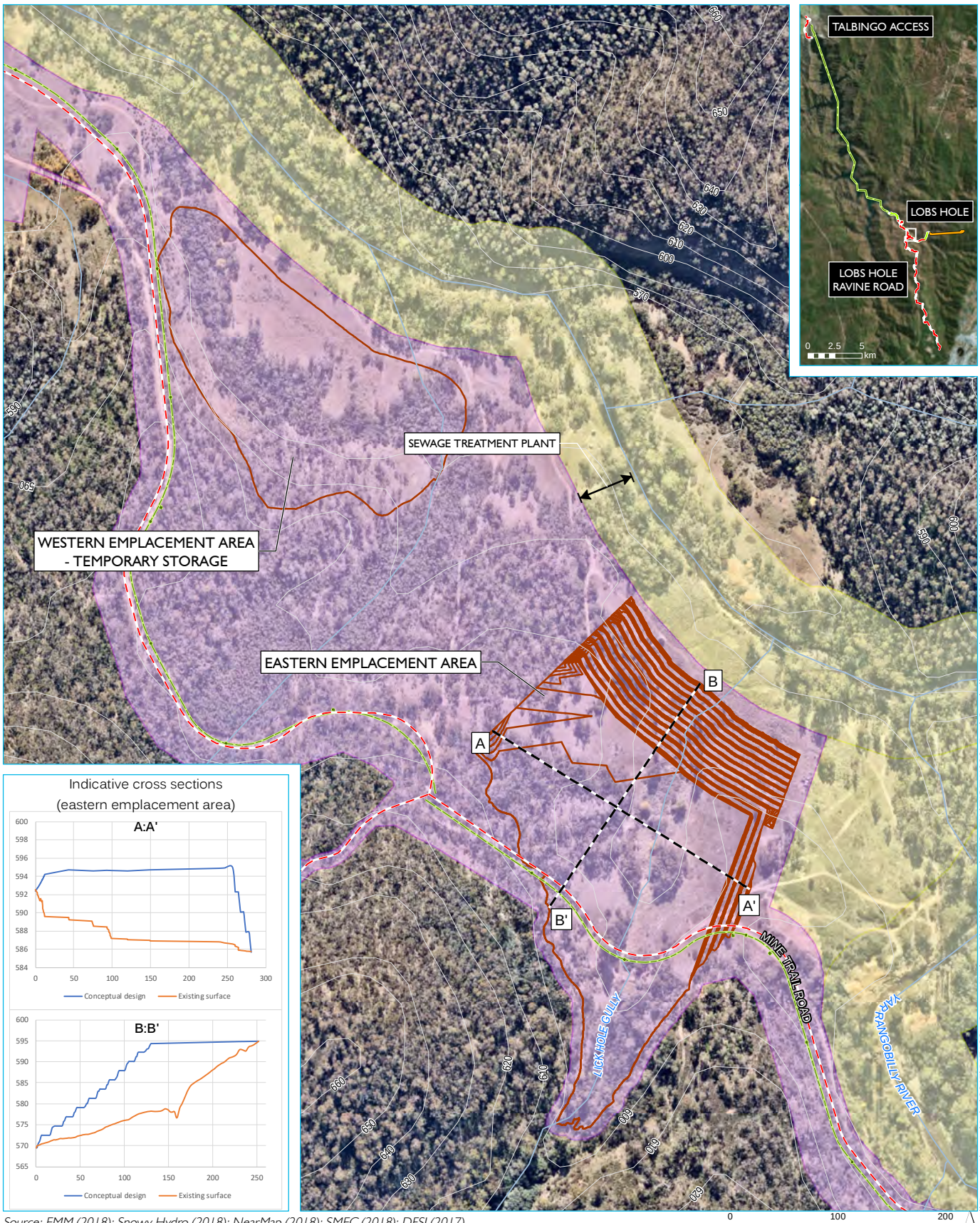
The western emplacement area will be used to store excavated material should it not be able to be placed within the eastern emplacement area. It is envisaged this emplacement area will be used to store excavated materials suitable for re-use within the construction of Exploratory Works or for use by NPWS in KNP maintenance activities. All remaining material placed in this emplacement area will be removed within five years of the completion of Exploratory Works.

The guiding principles for the design, construction method and management of emplacement areas undertaken for Exploratory Works have been as follows:

- reducing potential for acid rock drainage from the excavated rock emplacement area entering the Yarrangobilly River or forming groundwater recharge;

- avoid known environmental constraints; and

- manage existing surface water flows from Lick Hole Gully.



\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWEISEW008_RockStockpileLocations_20180714_09.mxd 28/09/2018

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); DFSI (2017)

KEY

- Cross-section
- Exploratory tunnel
- Access road upgrade
- Access road extension
- Communications cable
- On land rock management
- Watercourse
- Contour (10m)
- Disturbance footprint
- Avoidance footprint

Conceptual layout – excavated material emplacement areas

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.5

The design and management of the emplacement areas have not yet been finalised due to the need for further investigations to determine the likely geochemical characteristics of the excavated material. Following further investigation and prior to construction of Exploratory Works a management plan will be prepared and implemented.

2.4.2 Subaqueous placement

An initial program for the placement of excavated rock within Talbingo Reservoir also forms part of Exploratory Works. The program will be implemented in an appropriate section of Talbingo Reservoir in accordance with a detailed management plan based on an engineering method informed through the materials' geochemistry and reservoir's characteristics. The purpose of the program is to confirm the suitability of the emplacement method for future excavated rock material from the construction of Snowy 2.0, should it proceed.

The rock for subaqueous placement will be taken from the excavated rock emplacement areas as described above. Testing of the rock would be conducted during excavation to assess geochemical properties. Any rock assessed as unsuitable for subaqueous placement based on the prior geochemical and leachability testing would be separately stockpiled and not used in the program. Suitable (ie non-reactive material) would be transported and loaded to barge, for placement at the deposition area. Suitable placement locations have been identified for Exploratory Works and are shown indicatively on Figure 2.6.

All placement within the reservoir would occur within silt curtains and would be subject to a detailed monitoring regime including survey monitoring of pre-placement and post-placement bathymetry, local and remote background water quality monitoring during placement with a structured management response to monitoring results in the event of an exceedance of established triggers. The management, mitigation and monitoring measures would be refined following the ongoing investigations.

2.5 Accommodation camp

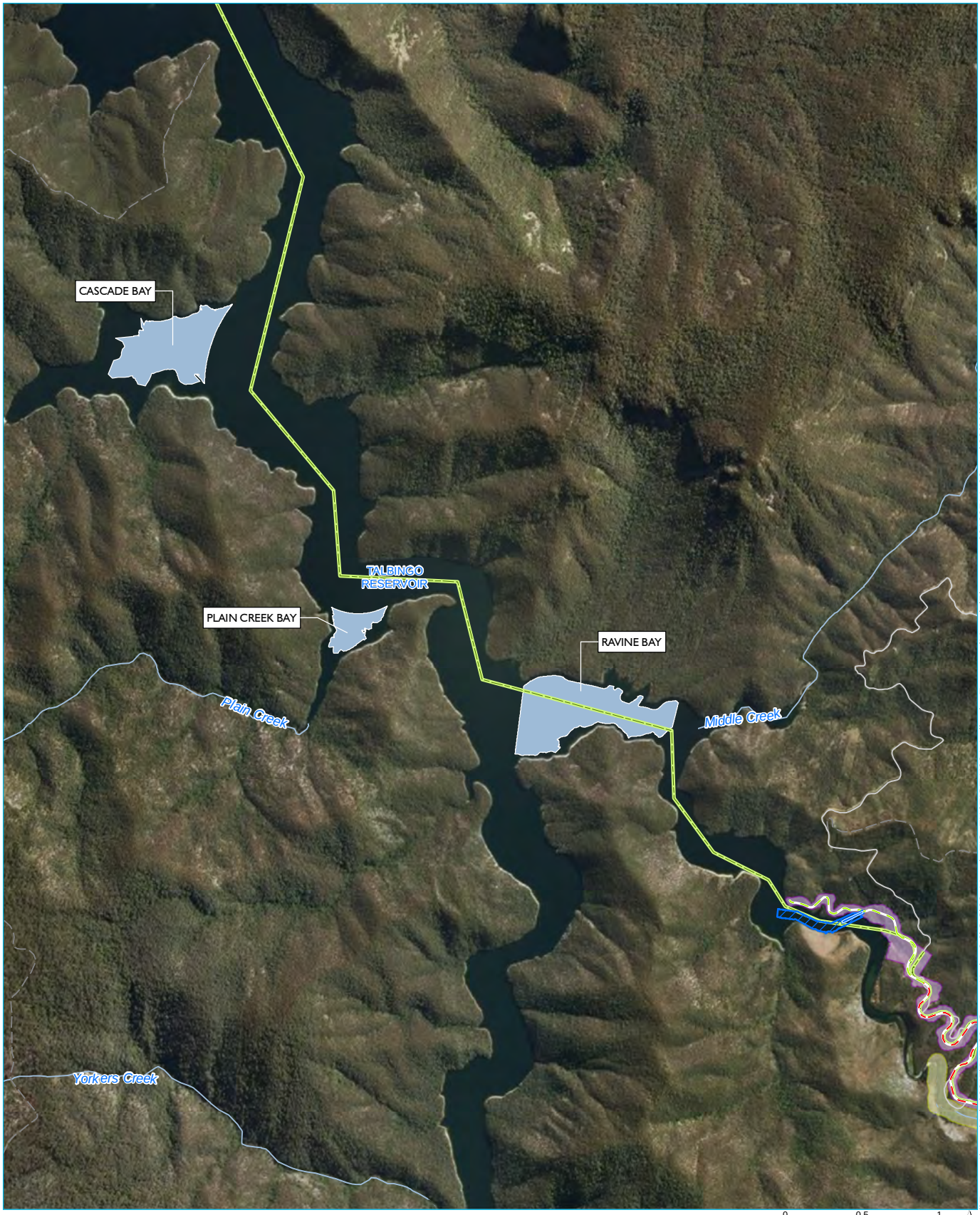
An accommodation camp is proposed to provide accommodation and supporting services for workers in close proximity to the exploratory tunnel. The accommodation camp layout is shown on Figure 2.7 and includes ensuite rooms surrounding central facilities including a kitchen, tavern, gym, admin office, laundry, maintenance building, sewage and water treatment plants and parking that will service the Exploratory Works workforce. The accommodation camp access road will connect to the north side of Lobs Hole Road at Lobs Hole. The conceptual layout of the accommodation camp is shown on Figure 2.7.

2.6 Road and access provisions

Existing road and access will need to be upgraded to a suitable standard to:

- provide for the transport of excavated rock material between the exploratory tunnel and the excavated rock emplacement areas;
- accommodate the transport of oversized loads as required; and
- facilitate the safe movement of plant, equipment, materials and construction staff to the portal construction pad.

Given the topographic constraints of the area, the standard of the existing roads and the environmental values associated with KNP, the option of barging larger and oversized loads to the site is available. This is discussed further at Section 2.7.



Source: EMM (2018); Snowy Hydro (2018); ESRI (2018); SMEC (2018); DFSI (2018); GA (2017); LPMA (2011)

0 0.5 1 km
GDA 1994 MGA Zone 55
N

KEY

- Access road upgrade
- Access road extension
- Communications cable
- Subaqueous rock placement area
- Major watercourse
- Local road
- Track
- Middle Bay barge access
- Disturbance area - barge infrastructure
- Disturbance footprint
- Avoidance footprint

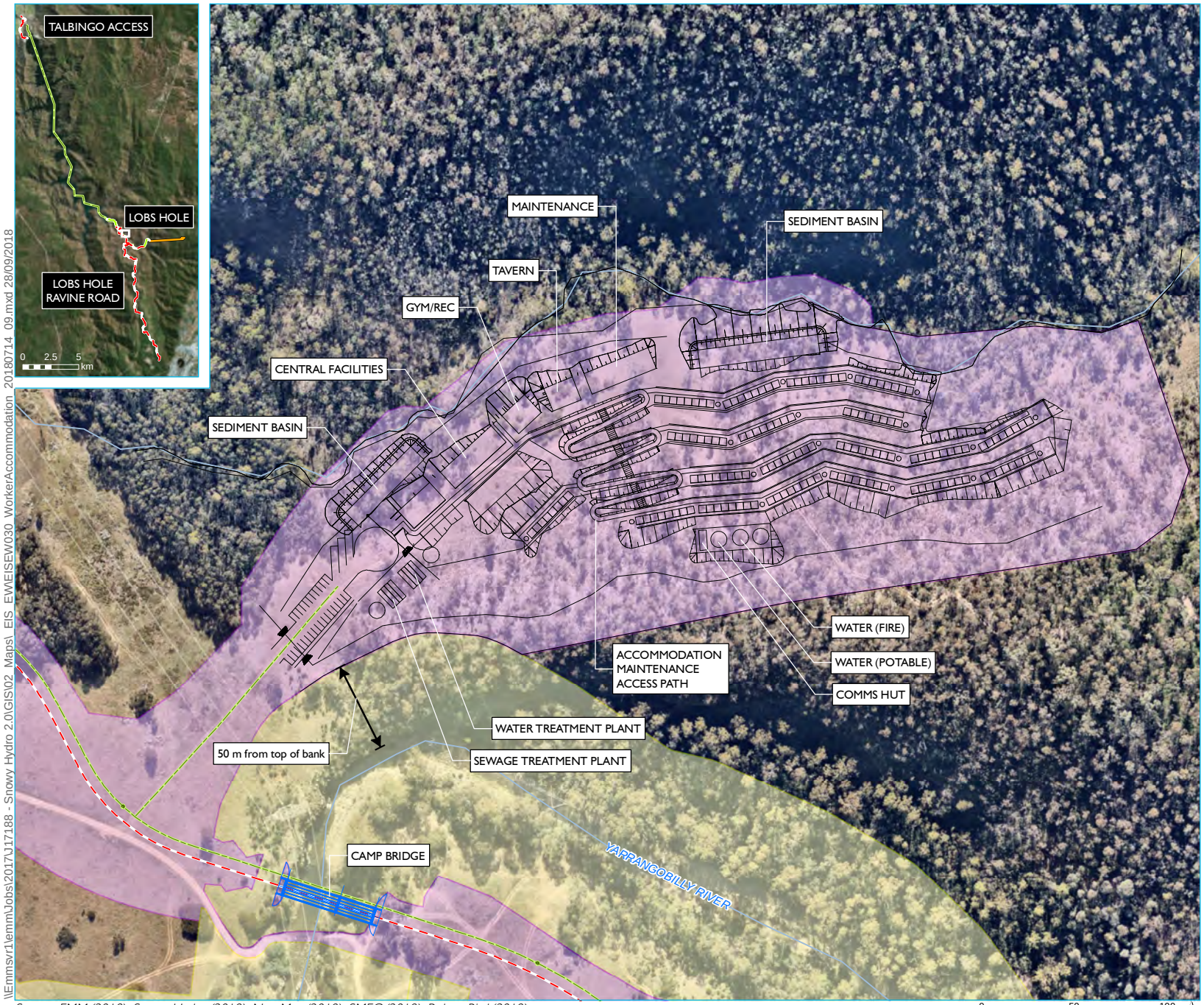
Subaqueous excavated rock placement

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.6

snowy 2.0

EMM creating opportunities

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KEY

- Exploratory tunnel
- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Communications cable
- Watercourse
- Disturbance footprint
- Avoidance footprint

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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018)

0 50 100 m

GDA 1994 MGA Zone 55

N

Conceptual layout – accommodation camp

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.7

snowy2.0

EMM
creating opportunities

2.6.1 Access road works

The access road upgrades will be designed based on access for a truck and dog trailer. The proposed road works are shown in Figure 2.8 and described in Table 2.1. It is expected that materials and equipment will travel along the Snowy Mountains Highway, Link Road and Lobs Hole Ravine Road, with some travelling on Miles Franklin Drive via Talbingo to Talbingo Reservoir and be transferred via a barge to site. The primary haul routes for construction material on site are provided in Figure 2.9. Where existing roads are replaced by new access roads or road upgrades, the existing roads will be removed and rehabilitated in line with the rehabilitation strategy for Exploratory Works.

Table 2.1 Access road works summary

Roadwork area	Overview
Upper Lobs Hole Ravine Road upgrade	Minor upgrades to 7.5 km section of existing road. Only single lane access will be provided. No cut and fill earthworks or vegetation clearing will be undertaken.
Lower Lobs Hole Ravine Road upgrade	Upgrades to 6 km section of existing road involving cut and fill earthworks in some sections. Only single lane access will be provided.
Lobs Hole Road upgrade	Upgrade to 5.7 km section of existing road and establishment of 1.6 km of new road providing two-way access.
Mine Trail Road upgrade	Upgrade to 2.2 km section of existing track to two-way access.
Mine Trail Road extension	Establishment of a new two-way road providing access to the exploratory tunnel portal.
Middle Bay Road	Establishment of a two-way road to the proposed Middle Bay barge ramp including 0.4 km of road upgrades and 0.9 km of new road.
Spillway Road	Upgrade of a 3 km section of existing road to provide two-way access to the proposed Spillway barge ramp.

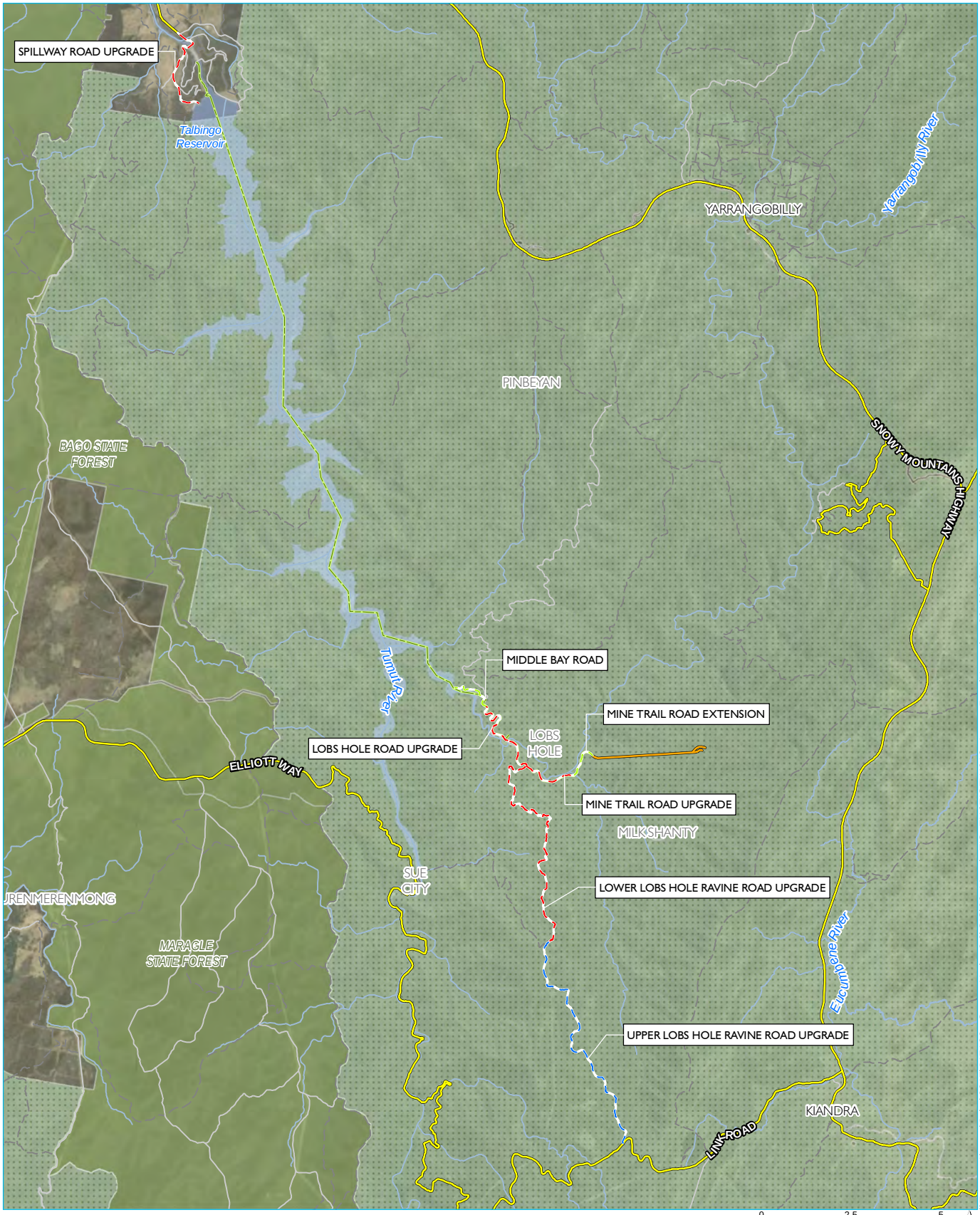
While no cut and fill earthworks or vegetation clearing is proposed along Upper Lobs Hole Ravine Road, a laydown area is proposed within and adjacent to the existing transmission line easement. This area will be used to store materials required for the road works to the lower section of Lobs Hole Ravine Road.

2.6.2 Watercourse crossings

Bridge construction will be required at two locations as described in Table 2.2. The locations of proposed bridge works are shown in Figure 2.9.

Table 2.2 Watercourse crossing summary

Bridge works area	Overview
Camp bridge	An existing crossing on Yarrangobilly River will be used as a temporary crossing while a new permanent bridge is built as part of Lobs Hole Road upgrade. The temporary crossing to be used will be selected during detailed design and may require construction of a pre-fabricated 'Bailey bridge', a pipe culvert or raising the crossing level with rocks to facilitate vehicle passage. The temporary crossing will be removed and the crossing no longer used once the permanent bridge has been constructed. The new bridge (Camp Bridge) will be a permanent crossing and used for both Exploratory Works and Snowy 2.0 main works (if it proceeds).
Wallaces Creek bridge	Establishment of a new permanent bridge at Wallaces Creek as part of the Mine Trail Road extension. Establishment of this bridge will require an initial temporary pre-fabricated 'Bailey bridge' to be constructed, which will be removed before the end of Exploratory Works.



\\Emmsvr1\emmJobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWE\SEW012_AccessRoadUpgrades_20180613_07.mxd 28/09/2018

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); DFSI (2017); GA (2015); LPMA (2011)

0 2.5 5 km

GDA 1994 MGA Zone 55

N

KEY

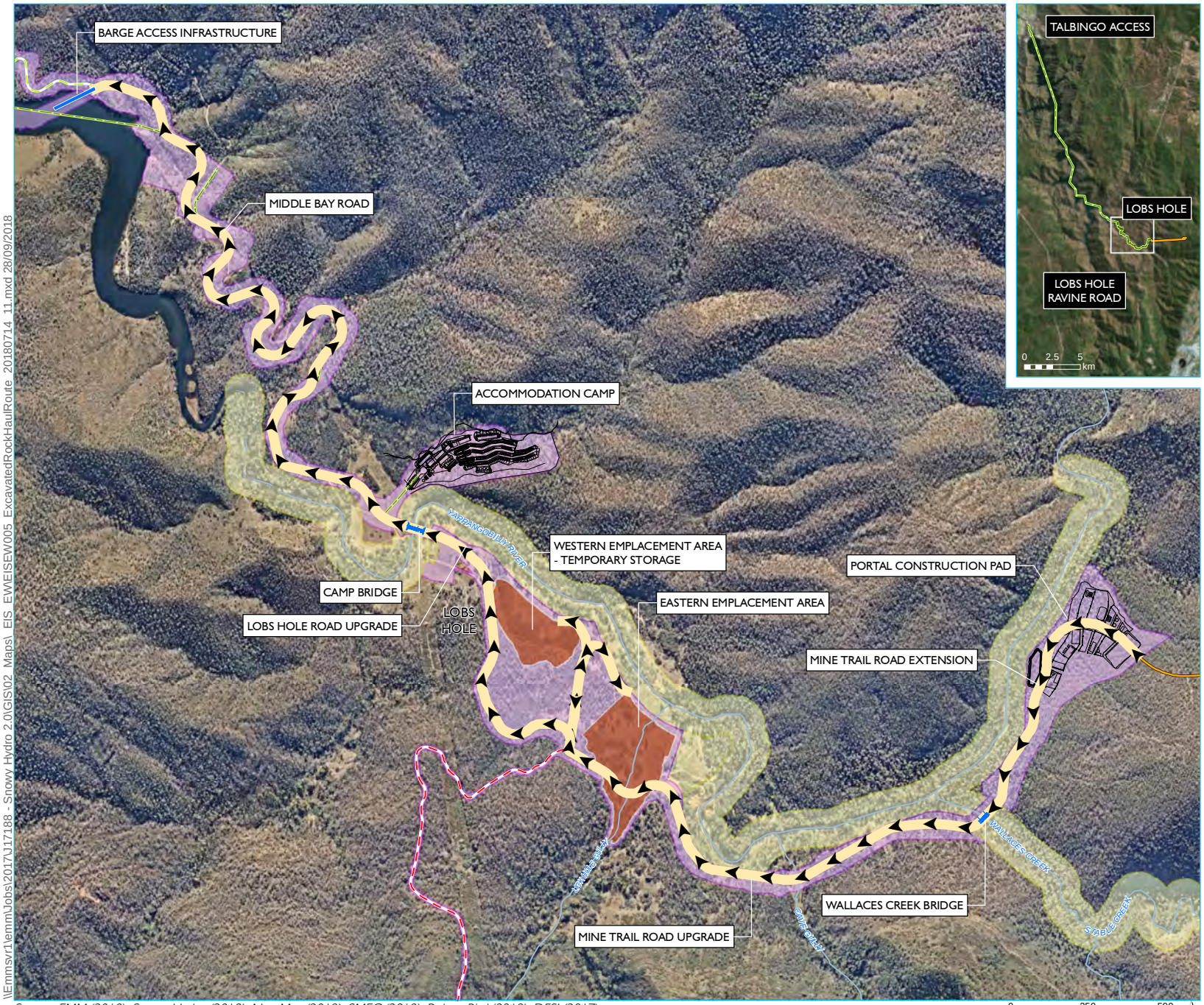
- Access road upgrade - without widening
- Access road upgrade - with widening
- Access road extension
- Exploratory tunnel
- Communications cable
- Main road
- Local road
- Vehicular track
- Perennial watercourse
- Scheme storage
- Kosciuszko National Park
- State forest

Access road upgrades and establishment

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.8

snowy2.0

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KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Exploratory tunnel
- Portal construction pad and accommodation camp conceptual layout
- Communications cable
- Excavated rock haul route
- Watercourse
- On land rock management
- Middle Bay barge access
- Disturbance footprint
- Avoidance footprint

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02 Maps\ EIS EWEISEW005 ExcavatedRockHaulRoute 20180714 11.mxd 28/09/2018

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017)

Excavated material haul route

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.9

The design for permanent bridges at both crossings will consist of steel girders with a composite deck. This is the most common type of permanent bridge constructed in and around the existing Snowy Scheme. Lightweight steel girders are easy to transport and will therefore allow for efficiencies in the construction schedule and permit the use of smaller-scale lifting equipment at the construction site.

2.7 Barge access infrastructure

To provide an alternative to road access, a barge option is proposed, not only for bulky and heavy equipment but for materials and also in case of emergency. During Exploratory Works, barges will be loaded at the northern barge ramp (Talbingo barge ramp), travel about 18 km along Talbingo Reservoir and be unloaded at the southern barge ramp (Middle Bay barge ramp) before returning to the north. Some loads may also be transported in the reverse direction.

Barge access infrastructure will comprise two dedicated barge ramps at Middle Bay and Talbingo Spillway, with a slope of approximately 1 vertical to 10 horizontal (1V: 10H) at each location. A navigation channel is also required adjacent to the Middle Bay barge ramp. Construction will involve:

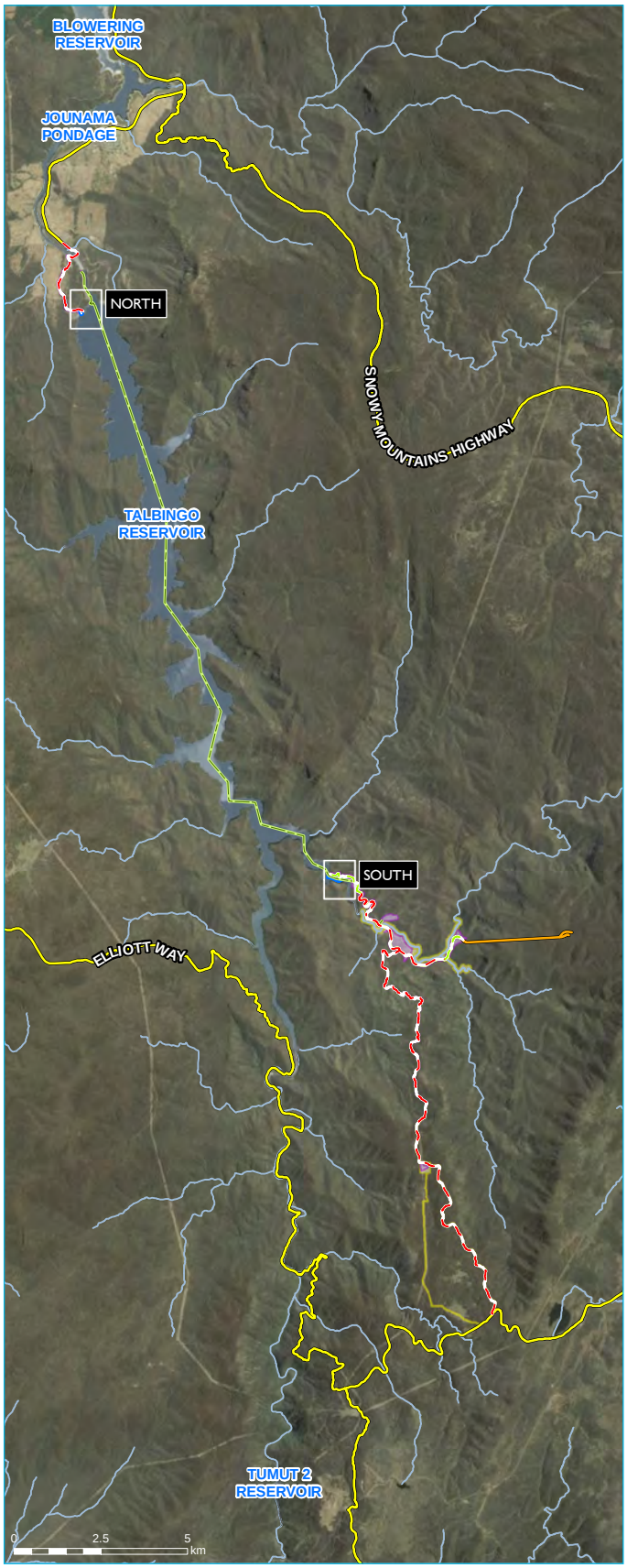
- geophysical and geotechnical investigation of the barge access area to inform detailed design;
- site establishment and excavation of barge access area;
- installation of precast concrete panels at the ramp location;
- installation of bollards for mooring lines;
- removal of trees and debris to establish a navigation channel allowing barge access; and
- minor dredging to allow barge access at the reservoir minimum operating level.

To facilitate construction, laydown areas are proposed adjacent to the Middle Bay barge ramp and adjacent to the water inlet pipeline. Laydown will also be used within the footprint of the Talbingo barge ramp.

Dredged material will be placed as part of the subaqueous placement program or within one of the designated on land rock emplacement areas. The infrastructure proposed for the Talbingo Spillway barge ramp and Middle Bay barge ramp is provided in Figure 2.10.

2.8 Services and infrastructure

The Exploratory Works will require additional power and communication infrastructure. Water services are also needed and include a water services pipeline and water and waste water (sewage) treatment facilities. A summary of services required is provided at Table 2.3.







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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Exploratory tunnel
- Access road upgrade
- Access road extension
- Communications cable
- Main road
- Local road or track
- Perennial watercourse
- Middle Bay barge access
- Disturbance area - barge infrastructure
- Disturbance footprint
- Avoidance footprint

Barge access locations

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 2.10

snowy 2.0

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creating opportunities

Table 2.3 Summary of services and infrastructure

Services infrastructure	Description
Power	Power will be provided at the portal construction pad and accommodation camp by diesel generators, with fuel storage provided at the portal construction pad.
Communication	Communication will be provided via fibre optic link. The fibre optic service has been designed to incorporate a submarine cable from Tumut 3 power station across Talbingo Reservoir to Middle Bay, and then via a buried conduit within the access roads to the accommodation camp and the portal construction pad.
Water and waste water (sewage)	A water services pipeline is proposed for the supply and discharge of water for Exploratory Works which will pump water between Talbingo Reservoir and the exploratory tunnel portal, portal construction pad and accommodation camp.
	A package water treatment plant is proposed at the accommodation camp to provide potable water to the accommodation camp and portal construction pad facilities and will be treated to a standard that complies with the Australian Drinking Water Guidelines. The accommodation camp water supply will be pumped via the water pipeline from Talbingo Reservoir at Middle Bay.
	A package waste water (sewage) treatment plant (STP) is proposed at the accommodation camp for Exploratory Works waste water. The STP will produce effluent quality comparable to standard for inland treatment facilities in the region (eg Cabramurra). Following treatment waste water will be discharged to Talbingo reservoir via the water services pipeline connecting the accommodation camp to Talbingo Reservoir.
	Waste water from the exploratory tunnel and concrete batching plant will be either re-used on site or sent to the waste water treatment plant for treatment prior to discharge.

2.9 Construction and schedule

2.9.1 Geotechnical investigation

To assist the design development for the portal construction pad, accommodation camp, Middle Bay Road, Spillway Road, and Lobs Hole Ravine Road, further survey of ground conditions is required. A program of geotechnical investigations including geophysical survey, construction of test pits, and borehole drilling within the disturbance footprint, will be undertaken as part of construction activities. Excavation of test pits in areas where information on relatively shallow subsurface profiles is required, or where bulk sampling is required for laboratory testing. Borehole drilling is required to facilitate the detailed design of cuttings, bridge foundations, retaining wall foundations, and drainage structures.

2.9.2 Construction activities

A disturbance footprint has been identified for Exploratory Works. The extent of the disturbance footprint is shown on Figure 2.1 and shows the area required for construction, including the buildings and structures, portal construction pad, road widening and bridges, laydown areas, and rock emplacement areas. Typical construction activities that will occur within the footprint are summarised in Table 2.4.

Table 2.4 Construction activities

Activity	Typical method
Geophysical and geotechnical investigation	Geophysical surveys will generally involve: • laying a geophone cable at the required location and establishing seismic holes; • blasting of explosives within seismic holes; and • in-reservoir geophysics surveys will use an air gun as the seismic source. Geotechnical surveys will generally involve: • establishing a drill pad including clearing and setup of environmental controls where required; • drilling a borehole to required depth using a tracked or truck mounted drill rig; and • installing piezometers where required for future monitoring program. Geophysical and geotechnical investigation within Talbingo Reservoir will be carried out using barges and subject to environmental controls.
Site establishment for portal construction pad, accommodation camp, rock placement areas and laydown areas	Site establishment will generally involve: • identifying and flagging areas that are to be avoided during the Exploratory Works period; • clearing of vegetation within the disturbance footprint, typically using chainsaws, bulldozers and excavators; • civil earthworks to create a stable and level area suitable for establishment. This will involve a cut and fill approach where required to minimise the requirement for imported material; • installing site drainage, soil erosion and other permanent environmental controls where required; • surface finishing, compacting only existing material where possible, or importing additional material. Where suitable, this material will be sourced locally (eg from upgrade works to Lobs Hole Ravine Road); and • set up and commissioning of supporting infrastructure, including survey marks.
Road works	Upgrades of existing tracks (no widening) will generally involve: • identifying and flagging areas that are to be avoided during the Exploratory Works period; and • removing high points, infilling scours, levelling of rutting, and compacting surfaces. Extension or widening of existing tracks will generally involve: • identifying and flagging areas that are to be avoided during the Exploratory Works period; • installing site drainage, soil erosion and other permanent environmental controls where required; • clearing and earthworks (earthworks may involve blasting in some sections where practical) within the disturbance footprint; and • placing road pavement material on the roadway.
Bridge works	Establishment of permanent bridges will generally involve: • installing erosion and sedimentation controls around watercourses and installing scour protection as required; • establishing temporary diversions within the watercourse where required, including work to maintain fish passage; • establishing temporary bridges to facilitate permanent bridge construction; • constructing permanent bridges including piling, establishment of abutments and piers; and • removal and rehabilitation of temporary bridges and diversions.

Table 2.4 Construction activities

Activity	Typical method
Barge access works	Establishment of barge access infrastructure will generally involve: • installing sediment controls; • excavating and dredging of barge ramp area and navigation channel; • installing precast concrete planks and bollards; and • set up and commissioning of supporting infrastructure.
Exploratory tunnel construction	The drill and blast excavation process will be repeated cyclically throughout the tunnelling works, involving: • marking up and drilling blast holes in a predetermined pattern in the working face of the tunnel; • loading the blast holes with explosives, attaching detonators and connecting the holes into a blast sequence, and detonating the blast; • ventilating the tunnel to remove blast fumes and dust; • removing blasted rock; • scaling and wash down of the tunnel roof and walls to remove loosened pieces of rock; • geological mapping of the exposed rock faces and classification of the conditions to determine suitable ground support systems for installation; • installing ground support; and • advancing construction ventilation ducting and other utilities including power, water, compressed air and communications.

2.9.3 Ancillary construction areas

Ancillary facilities and laydown areas have been identified within the conceptual layout for the portal construction pad and accommodation camp. A number of other indicative construction and laydown areas have also been identified to support Exploratory Works. A summary of these sites are:

- Upper Lobs Hole Ravine Road laydown area;
- rock emplacement area laydown, storage and ancillary uses;
- barge access infrastructure laydown areas at Talbingo and Middle Bay; and
- other minor laydown areas as needed during site establishment of watercourse crossings.

All laydown areas are within the disturbance footprint identified for Exploratory Works.

In addition, an area near Camp Bridge has been identified to be used for a plant nursery and organic stockpile area.

2.9.4 Construction workforce requirements

i Staffing levels

It is currently expected that workforce for Exploratory Works will be approximately 200 people in total at peak construction. Workers are anticipated to work a 'swing' shift, for example two weeks on and one week off. These workers will be accommodated within the accommodation camp at Lobs Hole when rostered on.

The majority of the workforce will work on a fly-in fly-out and drive-in drive-out basis. It is expected that the majority of workers will fly in and out of either Cooma Airport or Canberra Airport and then travel to site via bus.

During construction of the accommodation camp, workers will be accommodated at Cabramurra. Some workers may also be accommodated at Snowy Hydro existing accommodation units at Talbingo during construction of the Talbingo barge ramp. No accommodation will be required outside of Cabramurra, the construction accommodation camp or Talbingo for the Exploratory Works workforce.

ii Hours of operation

It is expected that construction of the exploratory tunnel and haulage of rock material between the tunnel and excavated rock stockpile locations at Lobs Hole will be 24 hours a day, seven days a week for the duration of the tunnel drilling and blasting operation. Other construction activities, including the establishment works, road and infrastructure works, will normally work a 12 hour day, seven days a week.

The transport of materials along the haul route from Snowy Mountains Highway, Link Road and Upper Lobs Hole Ravine Road will only occur during day time hours (except during emergency), to avoid impacts to threatened species (Smoky Mouse). Transport by barge will be 24 hours a day, seven days a week.

2.9.5 Timing and staging

Exploratory Works are expected to take about 34 months, with the exploratory tunnel expected to be completed by late 2021.

It is expected that the construction works will be completed largely in parallel. However, road and access works are expected to be completed within the first six months from commencement. The proposed staging of construction activities are highlighted in Figure 2.11.

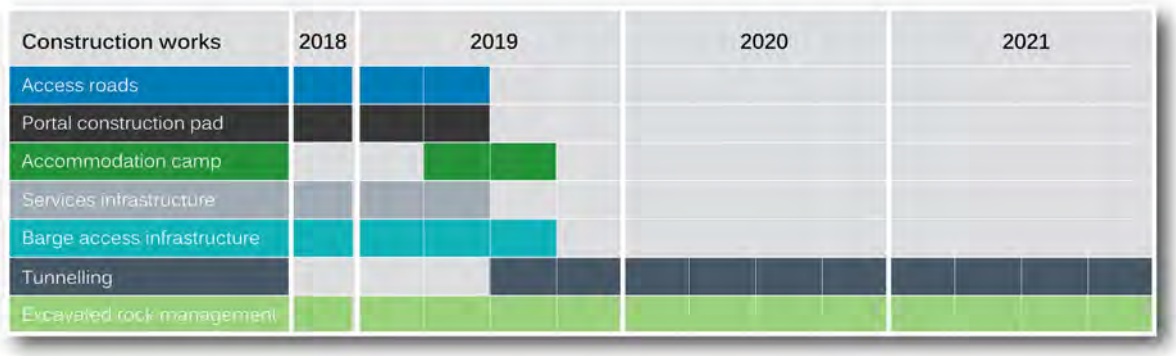


Figure 2.11 Indicative timing of Exploratory Works elements

2.10 Site rehabilitation

All Exploratory Works align with components of the main works for Snowy 2.0. However, should Snowy 2.0 not be approved or not progress, the project area will need to be rehabilitated, and project elements decommissioned in consultation with NPWS. Anticipated rehabilitation activities are summarised in Table 2.5.

Table 2.5 Planned Exploratory Works rehabilitation activities

Exploratory Works element	Indicative rehabilitation activities
Exploratory tunnel	Tunnel to remain open, and allowed to flood in lower portion provided groundwater impacts are negated.
Exploratory tunnel portal area	Permanent portal facade to be constructed, portal to be sealed from entry.
Portal construction pad and associated infrastructure	To be demobilised and all infrastructure removed. Site to be revegetated and returned to “original state”.
Excavated rock emplacement areas	Emplaced excavated rock in the western emplacement area to be removed offsite and area to be revegetated and returned to “original state”. The eastern emplacement area could remain in-situ and the landform rehabilitated as agreed with NPWS.
Accommodation camp	To be demobilised and all infrastructure removed. Site to be revegetated and returned to “original state”.
Road access works	No remediation required as works are to be designed to be permanent.
Barge access infrastructure	No remediation works required as wharf and loading ramps are designed as permanent. Wharf can be removed if desired.
Services and infrastructure	To be demobilised and all infrastructure removed. Site to be revegetated and returned to “original state”.

2.11 Decommissioning

Should Snowy 2.0 not proceed following the commencement or completion of Exploratory Works, elements constructed are able to be decommissioned and areas rehabilitated. Given works are within KNP, Snow Hydro will liaise closely with NPWS to determine the extent of decommissioning and types of rehabilitation to be undertaken. This approach will be taken to ensure that decommissioning allows for integration with future planned recreational use of these areas and to maintain the values of KNP.

2.12 Key aspects relevant to surface water assessment

The assessment has been informed by the reference design prepared for the Exploratory Works. The following aspects of project are considered relevant to this assessment:

- Flood risk management associated with the following works that are proposed on flood prone land:
  - Camp and Wallaces Bridges;
  - the western rock and soil emplacement area; and
  - the water management basin for the construction pad.
- Water management during construction of access roads, the accommodation camp, construction pad and other infrastructure.

- Water management during operation including:
    - stormwater runoff from the access roads, accommodation camp and construction pad;
    - water produced by and used by the proposed construction activities; and
    - waste water (ie sewage).
- Water management approach for rock and soil emplacement areas.

This assessment recommends controls to mitigate potential impacts. These controls will be considered in the detailed design of the Exploratory Works.

3 Regulation and Guidelines

This section describes assessment requirements and government regulation, plans and guidelines that have been considered in this assessment.

3.1 NSW regulatory framework

Water (both supply and discharge) will be used throughout the construction of Exploratory Works. The primary water related statutes that apply to Exploratory Works are the *NSW Water Management Act 2000* (WMA 2000), *Water Act 1912 (*WA 1912*), Protection of the Environment Operations Act 1997* (POEO Act), and their attendant regulations (including water sharing plans under the WMA 2000).

3.1.1 Water Act 1912

The WA 1912 is gradually being repealed and replaced by the WMA 2000 as water sharing plans (WSPs) are developed for water sources across NSW, and as new regulations are made. However, some aspects of the WA 1912 are still operational across all of NSW. Licences for monitoring bores greater than 40 m in depth are the only expected commitment under the WM 1912 for the Exploratory Works.

3.1.2 NSW Water Management Act 2000

The WMA 2000 is the relevant statute for the regulation water take from surface and alluvial water sources. The act provides for water sharing between different water users, including environmental, basic rights or existing water access licence (WAL) holders and provides security for licence holders. The licensing provisions of the WMA 2000 apply to those areas where a Water Sharing Plan (WSP) has commenced.

i Water Sharing Plans

WSPs are statutory documents that apply to one or more water source areas. They contain the rules for sharing and managing the water resources within water source areas. WSPs describe the basis for water sharing, and document the water available and how it is shared between environmental, extractive, and other uses. The WSPs then outline the water available for extractive uses within different categories, such as local water utilities, domestic and stock, basic rights and access licences.

The *Water Sharing Plan for the Murrumbidgee unregulated and alluvial water sources (2012)* applies to surface and alluvial water sources within the Exploratory Works project area. The Exploratory Works are located within the Upper Tumut water source which covers all contributing catchment areas to Blowering Reservoir. Existing surface water allocations within the Upper Tumut water source are shown in Table 3.1.

The dominant use of water in the Upper Tumut water source is for town water supply, with the past three water years (ie 2015/16 to 2017/18) reporting usage of between 12.2 and 67.5 ML/yr, significantly below the total annual share component of 153 ML/yr.

Table 3.1 Water rights and allocations in the unregulated WSP for the Murrumbidgee unregulated and alluvial water sources 2012 – Upper Tumut

Surface water source	Unit	Upper Tumut
Basic landholder rights		
Domestic and stock	ML/day	nd
Native title	ML/yr	0
Harvestable rights		nd
Water access licences		
Domestic and stock licences	ML/yr	7
Local water utility licences	ML/yr	153
Unregulated river access licences (tradeable)	Unit shares	45

Notes: nd - volume not defined based on an entire water source.

3.1.3 Protection of the Environment Operation Act 1997

The POEO Act establishes the NSW environmental regulatory framework and includes licensing requirements for certain activities. EPLs for water discharge and waste water treatment systems are administered by the NSW Environment Protection Authority (EPA) under the POEO Act.

3.2 Snowy Hydro Corporatisation Act 1997

The NSW *Snowy Hydro Corporatisation Act 1997* (SHC Act) came into effect on 28 June 2002. The Act enabled the corporatisation of the former Commonwealth Snowy Mountains Hydro-Electric Authority to Snowy Hydro Limited, and entitled Snowy Hydro to a number of key operating instruments to enable the continued operation of the Snowy Scheme.

Part 4 and 5 of the SHC Act relates to water. Part 4 sets out the terms and timing for the Snowy Water Inquiry which was to examine environmental issues arising in rivers and streams from the operations of the Snowy Scheme. Part 5 established the entitlement of Snowy Hydro to the Snowy Water Licence and prescribes the basic rights and obligations that are to be contained in the licence.

The Snowy Water Licence embodies the operating and accounting principles of the Snowy Scheme. The Snowy Water Licence confers the following rights on Snowy Hydro:

- to collect all water from the rivers, streams and lakes within the Snowy Water Catchment;
- to divert that water;
- to store that water;
- to use that water to generate electricity and for purposes that are incidental or related to the generation of electricity; and
- to release that water from storage.

Snowy Hydro's rights are subject to the rights of certain other occupiers to take and use water (eg local councils). In addition to these rights, the Snowy Water Licence also sets out Snowy Hydro's water related obligations, in particular, release obligations.

3.2.1 Applicability to Exploratory Works

The right to divert, store, take and use surface water for the construction, and operation of all works associated with the Snowy 2.0, is provided for within the *Snowy Hydro Corporatisation Act 1997 No 99*. In summary, the Act, under Section 23, allows the take of water by Snowy Hydro Corporation for the generation of electricity, and for purposes that are *'incidental or related to the generation of electricity, or for the management of that water in the Company's works'.*

The water management works for diversion, storage, and or release of water that is for construction activities in respect of Snowy 2.0 is deemed 'incidental or related to the generation of electricity' and therefore the diversion, storage, use and release of surface water with respect to construction activities is licenced within the Snowy water licence.

3.3 Relevant Guidelines

The following guidelines are referenced in this assessment.

3.3.1 Guidelines for controlled activities on waterfront land

The WMA 2000 defines waterfront land as the bed of any river, lake or estuary and any land within 40m of the river banks, lake shore or estuary mean high water mark. Controlled activity approvals are generally required for works on waterfront land. Guidelines for controlled activities have been prepared by the NSW Department of Industry – Water (DoI –Water). These guidelines provide information on the design and construction of a controlled activity, and other ways to protect waterfront land.

The Exploratory Works are categorised as CSSI under section 89J (1) (g) of the EP&A Act 1979. Should approval be granted, a controlled activity approval to undertake work on waterfront land will not be required.

3.3.2 Australian Rainfall and Runoff

Australian Rainfall and Runoff (Commonwealth of Australia, 2016) is a national guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia. This guideline is referred to as ARR2016 in the remainder of this document.

3.3.3 Floodplain Development Manual

The NSW Floodplain Development Manual is a document published in 2005 by the NSW Government. The document details flood prone land policy which has the primary objective of reducing the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time, the policy recognises the benefits from occupation and development of flood prone land.

3.3.4 Erosion and Sediment Control Guidelines

The following NSW government guidelines have been referred to when developing erosion and sediment control strategies for the project:

- Managing Urban Stormwater: Soils and Construction – Volume 1 (Landcom, 2004);

- Managing Urban Stormwater: Soils and Construction – Volume 2C – Unsealed roads (DECC, 2008); and
- Managing Urban Stormwater: Soils and Construction – Volume 2D – Main road construction (DECC, 2008).

3.3.5 Bunding and Spill Management Guidelines

The following NSW Government guidelines detail best practice storage, handling and spill management procedures for liquid chemicals:

- Liquid Chemical Storage, Handling and Spill Management: Review of Best Practice Regulation (DECC, 2005); and
- Storing and Handling Liquids: Environmental Protection: Participant's Manual (DECC, 2007).

3.3.6 Australian Guidelines for Water Quality Monitoring and Reporting – ANZECC, 2000

The Australian and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australian and New Zealand (ARMCANZ) published the revised Australian and New Zealand guidelines for fresh and marine water quality in 2000. These guidelines provide a framework for:

- assessing and managing water quality for environmental values;
- establishing water quality objectives; and
- establishing protection levels, water quality indicators and trigger values.

These guidelines have been applied to establish water quality objectives and environmental values for the project. Water quality objectives and environmental values are discussed in Section 3.4.

3.4 Water quality objectives and environmental values

The *NSW Water Quality and River Flow Objectives* (DECCW 2006) provides Water Quality Objectives that are consistent with ANZECC/ARMCANZ (2000) water quality guidelines for the protection of the aquatic environment. The Water Quality Objectives are "primarily aimed at maintaining and improving water quality, for the purposes of supporting aquatic ecosystems, recreation and where applicable water supply and the production of aquatic foods suitable for consumption and aquaculture activities" (DECCW 2006).

Water Quality Objectives are provided for catchments throughout NSW (DECCW 2006). Talbingo Reservoir and the Yarrangobilly River, the waterbodies potentially impacted by the Exploratory Works, are within the "Murrumbidgee River and Lake George catchment". Specifically, they are classified as "Streams affected by Snowy Scheme".

Table 3.2 summarises the Water Quality Objectives for "Streams affected by Snowy Scheme" and applicability to Exploratory Works. It is noted that the term "Yarrangobilly River" should be taken to include the lower reach of Wallaces Creek and minor tributaries potentially impacted by Exploratory Works.

Table 3.2 Application of Water Quality Objectives

Environmental value	Water Quality Objective	Application to Exploratory Works
Aquatic ecosystems	Maintaining or improving the ecological condition of water bodies and their riparian zones over the long term.	There are aquatic ecosystems immediately downstream of the Exploratory Works. The protection of aquatic ecosystems is the primary water quality objective to be met.
Visual amenity	Aesthetic qualities of waters.	There will be no public views or access to the Yarrangobilly River downstream of Exploratory Works. Views to the majority of the Yarrangobilly Arm of the Talbingo Reservoir will be restricted as this area will be closed to public access. There will be views to most of Talbingo Reservoir from boats and from public access areas at the north and south ends of the reservoir.
Secondary contact recreation	Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed.	There will be no public access to the Yarrangobilly River downstream of Exploratory Works for secondary contact recreation such as boating. Other than in the Yarrangobilly Arm, public boating on Talbingo Reservoir will continue.
Primary contact recreation	Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed.	There will be no public access to the Yarrangobilly River downstream of exploratory works for primary contact recreation such as swimming. Public access to the O'Hares Rest Area at the south end of Talbingo Reservoir will be maintained. This is about 7.5 km from the western end of the Yarrangobilly arm where Exploratory Works activities will occur. Public access to the spillway at the north end of Talbingo Reservoir will be closed. The provision of recreational facilities such as a swimming area at the Talbingo Boat Ramp are being considered. These areas are approximately 18 km from the start of the Yarrangobilly arm where Exploratory Works activities will occur and 16 km north of the Plain Creek Bay emplacement area.
Irrigation water supply	Protecting the quality of waters applied to crops and pasture.	No water is extracted from Yarrangobilly River or Talbingo Reservoir for irrigation. Water from discharged Talbingo Reservoir enters Blowering Reservoir about 25 km from the Plain Creek Bay emplacement area. Water discharged from Blowering Reservoir (20 km long) is used for irrigation. Given these distances and the associated dilution of any water discharged from Exploratory Works activities, the trigger values for irrigation water supply are not a primary consideration.

Table 3.2 Application of Water Quality Objectives

Environmental value	Water Quality Objective	Application to Exploratory Works
Homestead water supply	Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing.	No water is extracted from Yarrangobilly River or Talbingo Reservoir for homestead water supply. Water discharged from Talbingo Reservoir is used for homestead water supply, downstream of Talbingo Reservoir Given these distances and the associated dilution of any water discharged from Exploratory Works activities, the trigger values for homestead water supply are not a primary consideration.
Drinking water at point of supply - Disinfection only Drinking water at point of supply - Clarification and disinfection Drinking water at point of supply - Groundwater	These objectives apply to all current and future licensed offtake points for town water supply and to specific sections of rivers that contribute to drinking water storages or immediately upstream of town water supply offtake points. The objective also applies to subcatchments or groundwaters used for town water supplies.	No water is extracted from Yarrangobilly River or used for drinking water supply. Water discharged from Talbingo Reservoir is used for homestead water supply, downstream of Talbingo Reservoir Given these distances and the associated dilution of any water discharged from Exploratory Works activities, the trigger values for these uses are not a primary consideration.
Aquatic foods (cooked)	Refers to protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.	Recreational fishers use Talbingo Reservoir. However, the trigger values for aquatic foods apply to aquaculture not recreational fishing. The required level of protection will be provided by meeting the trigger values for aquatic ecosystems.

3.4.1 Trigger values

The trigger values applicable to each water quality objective are provided in DECCW (2006). The trigger values vary depending on the environmental value, with the trigger values for the protection of aquatic ecosystems generally being the lowest. Default trigger values for the Yarrangobilly River and Talbingo Reservoir are provided in Table 3.3. These include an expanded list of analytes that are applicable to the visual amenity, secondary recreational contact and primary recreational contact.

The default trigger values have been applied to this surface water assessment. The default trigger values do not make allowance for site specific factors that may influence water quality. Site specific trigger values may be established for some analytes during the operation of Exploratory Works.

Table 3.3 Default trigger values

Indicator	Location	Trigger value	Basis (most sensitive use)
Physico-chemical			
pH	Yarrangobilly River	6.5–8.0 (changes of more than 0.5 pH units from the natural seasonal maximum or minimum should be investigated).	Aquatic ecosystems
	Talbingo Reservoir (outside of mixing zones)	6.5–8.0 (changes of more than 0.5 pH units from the natural seasonal maximum or minimum should be investigated).	Aquatic ecosystems

Table 3.3 Default trigger values

Indicator	Location	Trigger value	Basis (most sensitive use)
Temperature	Yarrangobilly River	>80%-ile	Aquatic ecosystems
		<20%-ile	
	Talbingo Reservoir (outside of mixing zones)	>80%-ile	Aquatic ecosystems
		<20%-ile	
Turbidity	Yarrangobilly River	2–25 NTU	Aquatic ecosystems
	Talbingo Reservoir (outside of mixing zones)	1–20 NTU	Aquatic ecosystems
	Talbingo Reservoir (swimming areas: O'Hares and Talbingo Boat Ramp)	A 200 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m (approximately 6 NTU).	Primary contact recreation
Salinity (electrical conductivity)	Yarrangobilly River	30–350 µS/cm	Aquatic ecosystems
	Talbingo Reservoir (outside of mixing zones)	20–30 µS/cm	Aquatic ecosystems
Dissolved oxygen	Yarrangobilly River	90–110%	Aquatic ecosystems
	Talbingo Reservoir (outside of mixing zones)	90–110%	Aquatic ecosystems
Visual clarity and colour	Talbingo Reservoir (outside of mixing zones)	Natural visual clarity should not be reduced by more than 20%. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.	Visual amenity
Surface films and debris	Talbingo Reservoir (outside of mixing zones)	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.	Visual amenity
Chemicals			
Filterable reactive phosphate (FRP)	Yarrangobilly River	15 µg P/L	Aquatic ecosystems
	Talbingo Reservoir (outside of mixing zones)	5 µg P/L	Aquatic ecosystems
Total phosphorus	Yarrangobilly River	20 µg P/L	Aquatic ecosystems
	Talbingo Reservoir (outside of mixing zones)	10 µg P/L	Aquatic ecosystems
Total ammonia-N	Yarrangobilly River	13 µg N/L	Aquatic ecosystems
	Talbingo Reservoir (outside of mixing zones)	10 µg N/L	Aquatic ecosystems
Oxides of nitrogen (NO_x)	Yarrangobilly River	15 µg N/L	Aquatic ecosystems
	Talbingo Reservoir (outside of mixing zones)	10 µg N/L	Aquatic ecosystems
Total nitrogen	Yarrangobilly River	250 µg N/L	Aquatic ecosystems
	Talbingo Reservoir (outside of mixing zones)	350 µg N/L	Aquatic ecosystems
Chlorophyll-a	Yarrangobilly River	Not applicable	Aquatic ecosystems

Table 3.3 Default trigger values

Indicator	Location	Trigger value	Basis (most sensitive use)
	Talbingo Reservoir (outside of mixing zones)	5 µg/L	Aquatic ecosystems
Chemical contaminants/ toxicants	Yarrangobilly River	ANZECC/ARMCANZ (2000), Chapter 3.4 and Table 3.4.1 - see Section 3.4.2 below.	Aquatic ecosystems Secondary and primary contact
	Talbingo Reservoir (outside of mixing zones)	ANZECC/ARMCANZ (2000), Chapter 3.4 and Table 3.4.1 - see Section 3.4.2 below.	
	Talbingo Reservoir (outside of mixing zones)	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed values in tables 5.2.3 and 5.2.4 of ANZECC/ARMCANZ (2000) - see Section 3.4.2 below.	Secondary recreational contact
	Talbingo Reservoir (swimming areas: O'Hares and Talbingo Boat Ramp)	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed the concentrations provided in tables 5.2.3 and 5.2.4 of ANZECC/ARMCANZ (2000) - see Section 3.4.2 below.	Primary recreational contact
Organisms			
Nuisance organisms	Yarrangobilly River	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.	Visual amenity
	Talbingo Reservoir	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.	Visual amenity
Faecal coliforms	Talbingo Reservoir	Median bacterial content in fresh and marine waters of <1,000 faecal coliforms per 100 mL, with four out of five samples <4,000/100 mL (minimum of five samples taken at regular intervals not exceeding one month).	Secondary contact recreation
	Talbingo Reservoir (swimming areas: O'Hares and Talbingo Boat Ramp)	Beachwatch considers waters are unsuitable for swimming if: - the median faecal coliform density exceeds 150 colony forming units per 100 millilitres (cfu/100 mL) for five samples taken at regular intervals not exceeding one month, or - the second highest sample contains equal to or greater than 600 cfu/100 mL (faecal coliforms) for five samples taken at regular intervals not exceeding one month. ANZECC/ARMCANZ (2000) recommend: Median over bathing season of <150 faecal coliforms per 100 mL, with four out of five samples <600/100 mL (minimum of five samples taken at regular intervals not exceeding one month).	Primary contact recreation

Table 3.3 Default trigger values

Indicator	Location	Trigger value	Basis (most sensitive use)
Enterococci	Talbingo Reservoir	Median bacterial content in fresh and marine waters of <230 enterococci per 100 mL (maximum number in any one sample: 450–700 organisms/100 mL).	Secondary contact recreation
	Talbingo Reservoir (swimming areas: O'Hares and Talbingo Boat Ramp)	Beachwatch considers waters are unsuitable for swimming if: - the median enterococci density exceeds 35 cfu/100 mL for five samples taken at regular intervals not exceeding one month, or - the second highest sample contains equal to or greater than 100 cfu/100 mL (enterococci) for five samples taken at regular intervals not exceeding one month. ANZECC 2000 Guidelines recommend: Median over bathing season of < 35 enterococci per 100 mL (maximum number in any one sample: 60–100 organisms/100 mL).	Primary contact recreation
Protozoans	Talbingo Reservoir	-	Secondary contact recreation
	Talbingo Reservoir (swimming areas: O'Hares and Talbingo Boat Ramp)	Pathogenic free-living protozoans should be absent from bodies of fresh water. (Note, it is not necessary to analyse water for these pathogens unless temperature is greater than 24°C).	Primary contact recreation
Algae and blue-green algae	Talbingo Reservoir	<15,000 cells/mL	Secondary and primary contact recreation

3.4.2 Aquatic ecosystem protection

The ANZECC/ARMCANZ (2000) guidelines (Table 3.4.1) present default trigger values for toxicants for the protection of 99%, 95%, 90% and 80% of aquatic species. This table also presents default trigger values for the protection of slightly–moderately disturbed ecosystems that are based on the default trigger values for the protection of 95% of species, but which use the lower default trigger values for the protection of 99% of species for chemicals for which possible bioaccumulation and secondary poisoning effects should be considered.

While Talbingo Reservoir is surrounded by the Kosciuszko National Park (KNP), the reservoir is characterised as being a slightly–moderately disturbed ecosystem because:

- the reservoir is an artificial water body created by flooding the Tumut River valley in the 1970s;
- water levels in the reservoir are not natural, being controlled for electricity generation as part of the Snowy Mountains Hydro-electric Scheme (Snowy Scheme); and
- the reservoir supports low biodiversity, consistent with its recent relatively formation and its largely homogeneous bed habitat (see EIS Appendix G, *Aquatic Ecology Assessment*).

The Yarrangobilly River downstream of the Exploration Works activities (a 5km long stretch) is characterised as follows:

- it within the KNP;
- the river provides relatively undisturbed aquatic and riparian habitat – non-native species of fish (brown trout and rainbow trout) are abundant, but there are climbing galaxias, Murray crayfish and other native species in the river (EIS Appendix G, *Aquatic Ecology Assessment*);
- the river discharges to the reservoir within the project area; and
- parts of the river and floodplain downstream and adjacent to the Exploration Works activities are impacted by contamination from historical mining (discussed in Section 4.4.1).

In the absence of site-specific trigger values, default trigger values for toxicants for the protection of 99% of species are generally applicable within a sensitive receiving environment such as a national park. This level of protection has been adopted in this assessment.

4 Existing surface water environment

This section provides a description of the existing surface water environment in the vicinity of the Exploratory Works and is structured as follows:

- Section 4.1 describes the general setting at Lobs Hole where most of the construction activities will occur;
- Section 4.2 describes rainfall and evaporation characteristics;
- Section 4.3 provides a summary of soil characteristics;
- Section 4.4 describes the catchments, flow regimes and key features of the Yarrangobilly River and its tributaries;
- Section 4.5 describes Talbingo Reservoir and its operating regime; and
- Section 4.6 describes the water quality in the Yarrangobilly River, Wallaces Creek and Talbingo Reservoir.

Existing flood characteristics are discussed separately in Chapter 5.

4.1 Setting

The Exploratory Works will predominantly be in the Ravine region of the KNP. This region is between Talbingo Reservoir to the north-west and the Snowy Mountains Highway to the east. Major infrastructure including the construction pad, accommodation camp and access roads will be in Lobs Hole.

The Yarrangobilly River is the defining feature of Lobs Hole. The river initially flows in a southerly direction before turning to the west, towards Talbingo Reservoir. The river's floodplain levels range from 545 m AHD at the river's interface with Talbingo Reservoir to approximately 585 m AHD adjacent to the construction pad. There are some areas of relatively flat and open terrain within or adjacent to the floodplain, which ranges in width between 100 to 350 m. The floodplain is generally bound by steep topography which rises up to mountain ranges that have peak elevations ranging from 800 to 1,500 m AHD.

Former mine workings including shafts and spoil piles are located on the Yarrangobilly River floodplain and immediate areas. These works are remnant from copper mines that operated intermittently between 1874 and 1919.

4.2 Weather

Lobs Hole is within the western extent of the Australian Alps. The climate of the Australian Alps is influenced by three features of the general circulatory system affecting south-eastern Australia (Brown and Millner, 1988):

- the latitudinal position of the westerly airstream that encircles the southern hemisphere;
- the influence of depressions lying off the east coast of NSW; and
- the occasional intrusion of moist tropical air masses from northern Australia.

In general, in winter and spring there is a predominance of westerly weather that results in regular precipitation on the western slopes. Precipitation depths increase in the alpine areas due to orographic effects. From late autumn to early spring, precipitation at the higher elevations predominantly occurs as snow. Snow cover usually begins to form in the highest areas in late autumn. By the middle of June areas above 1500 m AHD are usually covered. Snow cover usually peaks in August and begins to melt in late winter through to early spring (Brown and Millner 1988).

Summer and autumn are generally drier with the weakening of the westerly circulation. However, there are occasional intrusions of moist air which results in thunderstorm activity that tends to favour the eastern slopes. Summer rainfall is generally of higher intensity and of shorter duration than winter rainfall (Brown and Millner 1988).

The following sections provide further information on rainfall and evaporation characteristics at Lobs Hole.

4.2.1 Rainfall

This section describes rainfall characteristics within the Yarrangobilly River catchment using available information from regional Bureau of Meteorology (BoM) rainfall gauges and rainfall maps that are also produced by BoM. Rainfall characteristics within the catchment are relevant to understanding the Yarrangobilly River flow regime, while rainfall characteristics at Lobs Hole are relevant to water management for Exploratory Works. It is noted that some rainfall will occur as snowfall and should correctly be referred to as precipitation. However, the term rainfall has been used to maintain consistency with other sections of the EIS.

The following rainfall gauges are within the proximity to the Yarrangobilly River catchment and provide the best available information on rainfall within the catchment:

- Talbingo (72131) – this gauge is within the township of Talbingo, approximately 3.5 km to the north of the Tumut 3 Power Station and 26 km to the north-west of Lobs Hole. The gauge elevation is 395 m AHD, which is approximately 150 to 200 m lower than levels at Lobs Hole (550 to 600 m AHD).

- Cabramurra SMHEA AWS (72161) – this gauge is approximately 8 km to the south-west of the head waters of Wallaces Creek, which is a major tributary to the Yarrangobilly River catchment. The gauge elevation is 1,482 m AHD.

- Yarrangobilly Caves (72141) – this gauge is centrally in the Yarrangobilly River catchment. The gauge elevation is 980 m AHD.

Figure 4.1 locates these three gauges relative the Yarrangobilly River Catchment and the Exploratory Works. Median annual rainfall depth contours that were sourced from BoM's online climate maps are also shown. Table 4.1 presents key information and statistical data from the three gauges.

Table 4.1 Rainfall statistics[1]

Rainfall[2] Statistics (annualised)		Talbingo (72131)	Cabramurra SMHEA AWS (72161)	Yarrangobilly Caves (72141)
Rainfall record		1997 - present	1996 - present	1906 – 1919 1978 - present
Distance from Lobs Hole	(km)	25 km to the north west	15 km to the south	15 km to the north-east
Elevation (m AHD)	(m AHD)	395	1482	980
Average rainfall	(mm/year)	952	1178	1169
Lowest rainfall	(mm/year)	361	567	552
5th percentile rainfall	(mm/year)	663	877	818
10th Percentile rainfall	(mm/year)	771	992	905
Median rainfall	(mm/year)	946	1202	1158
90th percentile rainfall	(mm/year)	1220	1386	1511
95th percentile rainfall	(mm/year)	1313	1427	1535
Highest rainfall	(mm/year)	1343	1634	1902

Notes: *1.Data sourced from BoM website (climate data online)*

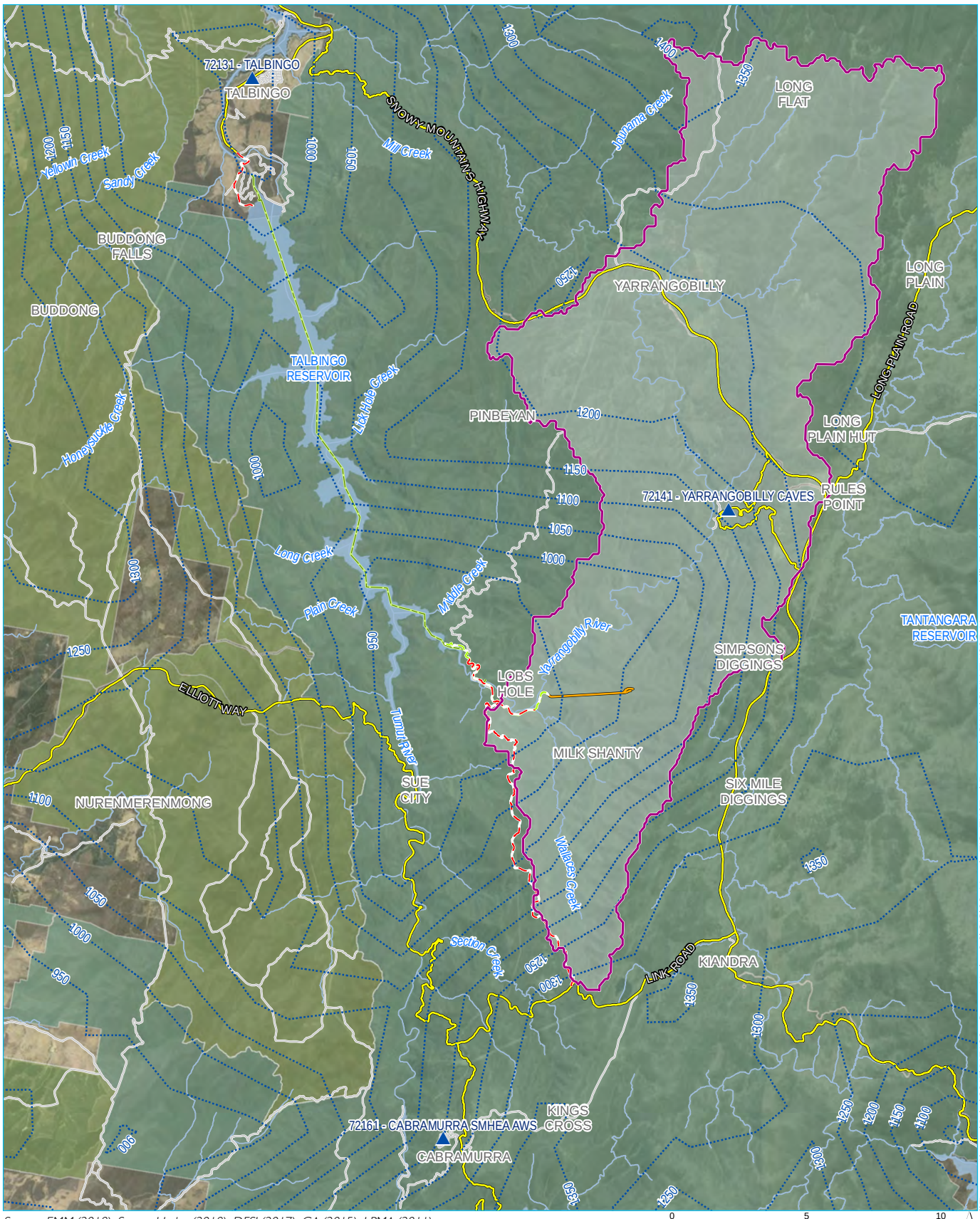
2. Some precipitation will occur as snow fall but has been referred to as rainfall to maintain consistency with other sections in the EIS.

The median annual rainfall depth contours shown in Figure 4.1 indicate that median rainfall within the Yarrangobilly River catchment ranges from 1,400 mm/year in the head water catchments to the 950 mm/year at Lobs Hole. The spatial variation in median rainfall generally reflects the variation in topography within the catchment. The median annual rainfall depth contours are consistent with median values from the three rainfall gauges. This information indicates that:

- Stream flows in the Yarrangobilly River are likely to be primarily influenced by runoff from the headwater catchments that receive higher rainfall, rather than runoff from lower portions of the catchment around Lobs Hole.

- The median annual rainfall depth contours shown in Figure 4.1 indicate that the median annual rainfall at Lobs Hole is similar to median annual rainfall at Talbingo. This indicates that rainfall characteristics at Lobs Hole and Talbingo are likely to be similar. Accordingly, the Talbingo rainfall gauge (72131) record is considered to be the most reliable representation of rainfall characteristics at Lobs Hole. This rainfall record has been applied to stormwater management calculations that are presented in subsequent sections of this report.

Figure 4.2 plots the 10th, 50th and 90th percentile monthly rainfall depths that have been calculated by BoM from the Talbingo (72131) gauge record. This information indicates that the highest and most consistent rainfall occurs in winter to early spring. Rainfall in summer is more variable with significant differences between the 10th and 90th percentile monthly rainfall depths.



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Rainfall in the Yarrangobilly River catchment

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 4.1

snowy 2.0

EMM
creating opportunities

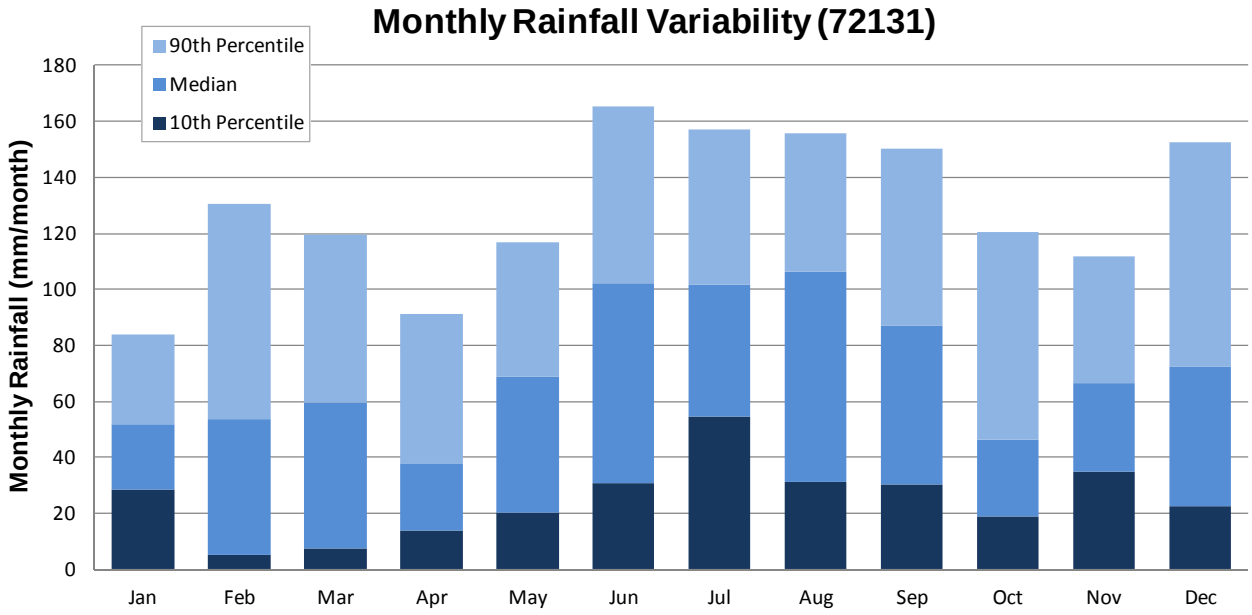


Figure 4.2 Monthly rainfall variability at Talbingo

i Design rainfall information at Lobs Hole

Design rainfall information is used to calculate aspects of the stormwater management system. The following design rainfall information has been established for the Lobs Hole area:

- Table 4.2 provides design rainfall depths for a range of Annual Exceedance Probability (AEP) events of varying duration. This information was sourced from the ARR2016 data portal; and
- Table 4.3 presents rainfall depths for 2, 5, 10 and 20 day rainfall events. This information was calculated from the Talbingo (72131) rainfall record and is used for establishing sedimentation basin volumes.

Table 4.2 Design rainfall depths from Australian Rainfall and Runoff 2016

	Annual Exceedance Probability (AEP) – Rainfall depths (mm)						
	63.2%	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**
15 min	10	11	14	17	20	24	27
30 min	13	14	19	22	26	31	35
1 hour	17	18	24	28	32	38	43
2 hour	21	24	30	35	40	47	52
3 hour	25	27	35	40	46	53	59
6 hour	32	36	46	52	59	69	76
12 hour	42	46	60	69	78	91	101
24 hour	54	59	77	89	101	118	131
48 hour	65	73	95	109	123	144	160
72 hour	72	80	104	120	134	156	173

Notes: Data sourced from Australian Rainfall Runoff Data Portal.

Table 4.3 Design rainfall depths for frequent events

	Rainfall Duration			
	2 day	**5 day**	**10 day**	**20 day**
80th Percentile event	7.5 mm	24.2 mm	47.4 mm	86.9 mm
85th Percentile event	11.4 mm	30.6 mm	56.0 mm	99.0 mm
90th Percentile event	18.4 mm	41.6 mm	68.1 mm	116.0 mm
95th Percentile event	30.0 mm	56.8 mm	85.0 mm	138.0 mm

Notes: Rainfall depths have been calculated from the Talbingo (72131) gauge record

4.2.2 Evaporation

Mean annual pan evaporation in the Australian Alps ranges from approximately 1,400 mm/year at an elevation of 400 m AHD to approximately 1,000 mm/year at an elevation of 1,300 m AHD (Brown and Millner 1988). Table 4.4 presents regional monthly mean evaporation and potential evapotranspiration data sourced from evaporation records at Eucumbene (Brown and Millner 1988) and climate maps that are available from BoM's website. This information is considered to be representative of evaporation characteristics at Lobs Hole in areas that receive full sun. Areas that are partially shaded (such as a road cut into steep topography) would be expected to have lower evaporation rates.

Table 4.4 Evaporation and evapotranspiration data

		Mean Class A pan evaporation		Mean areal potential evapotranspiration
Month	**Units**	**Eucumbene Dam[1]**	**BoM[2]**	**BoM[2]**
January	mm/month	205	206	156
February	mm/month	158	169	118
March	mm/month	133	139	102
April	mm/month	87	76	69
May	mm/month	45	42	47
June	mm/month	30	27	37
July	mm/month	31	29	41
August	mm/month	45	46	54
September	mm/month	77	69	73
October	mm/month	117	110	115
November	mm/month	148	148	140
December	mm/month	192	191	140
Annual	mm/year	**1,268**	**1,255**	**1,091**

Notes: 1. Data Source (Brown and Millner, 1988)

2. Data Source BoM website (climate data online)

4.2.3 Recent weather

Figure 4.3 plots the monthly rainfall totals that were recorded at Talbingo from 1997 to present. The deviation of rainfall totals over the previous 12 month period have been calculated and compared to annualised monthly average rainfall to identify and characterise periods of extended dry and wet conditions. The magnitude and extent of wet and dry periods can be inferred by the shape and value of the deviation curve. This analysis indicates that:

- below average rainfall occurred during the 2001 to 2003, 2006 to mid 2007, and mid 2012 to 2014 periods; and
- above average rainfall occurred during the 2000 to 2001, 2010 to 2012, and 2016 periods. Significant flood events occurred in the Yarrangobilly River in October 2010 and March 2012. Further information on these events is provided in Chapter 5.

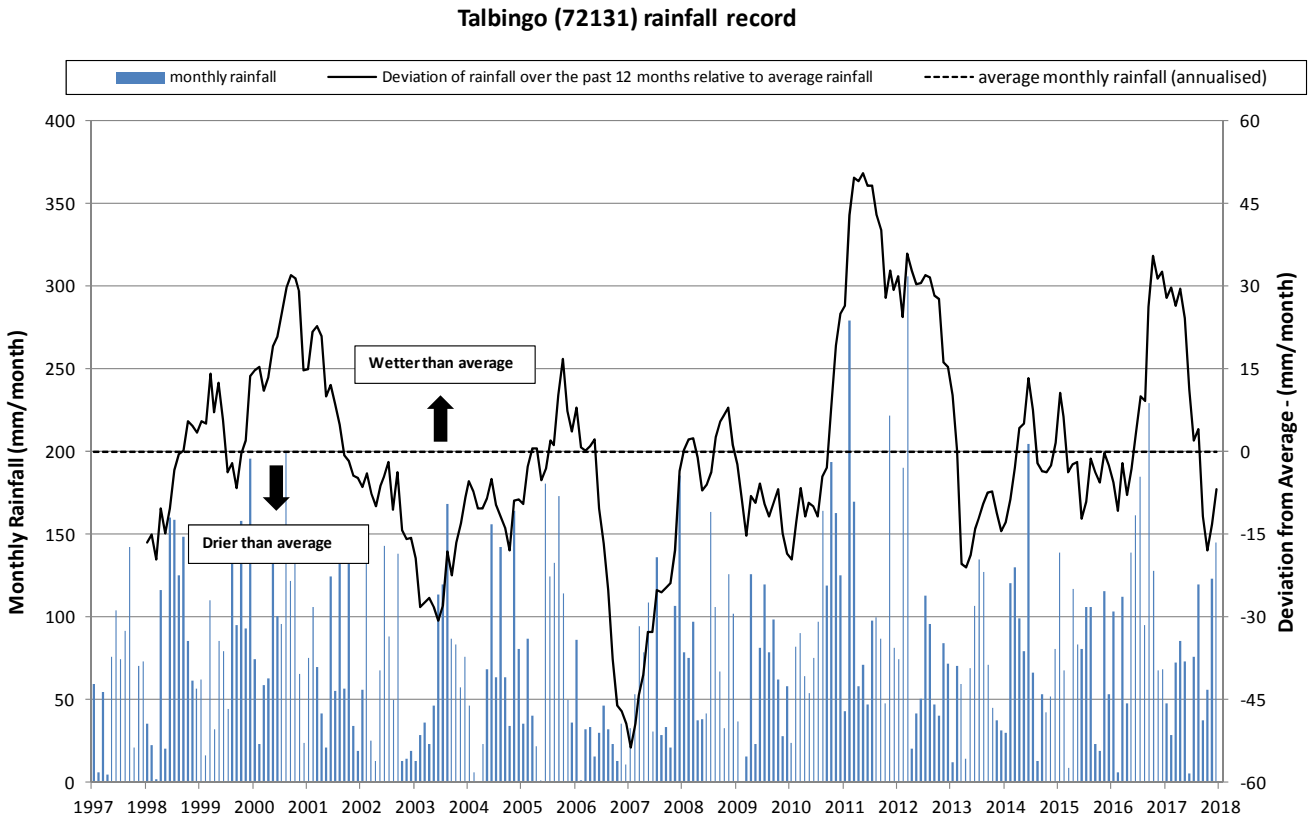


Figure 4.3 Talbingo rainfall over the 1997 to 2017 period

4.3 Soil characteristics

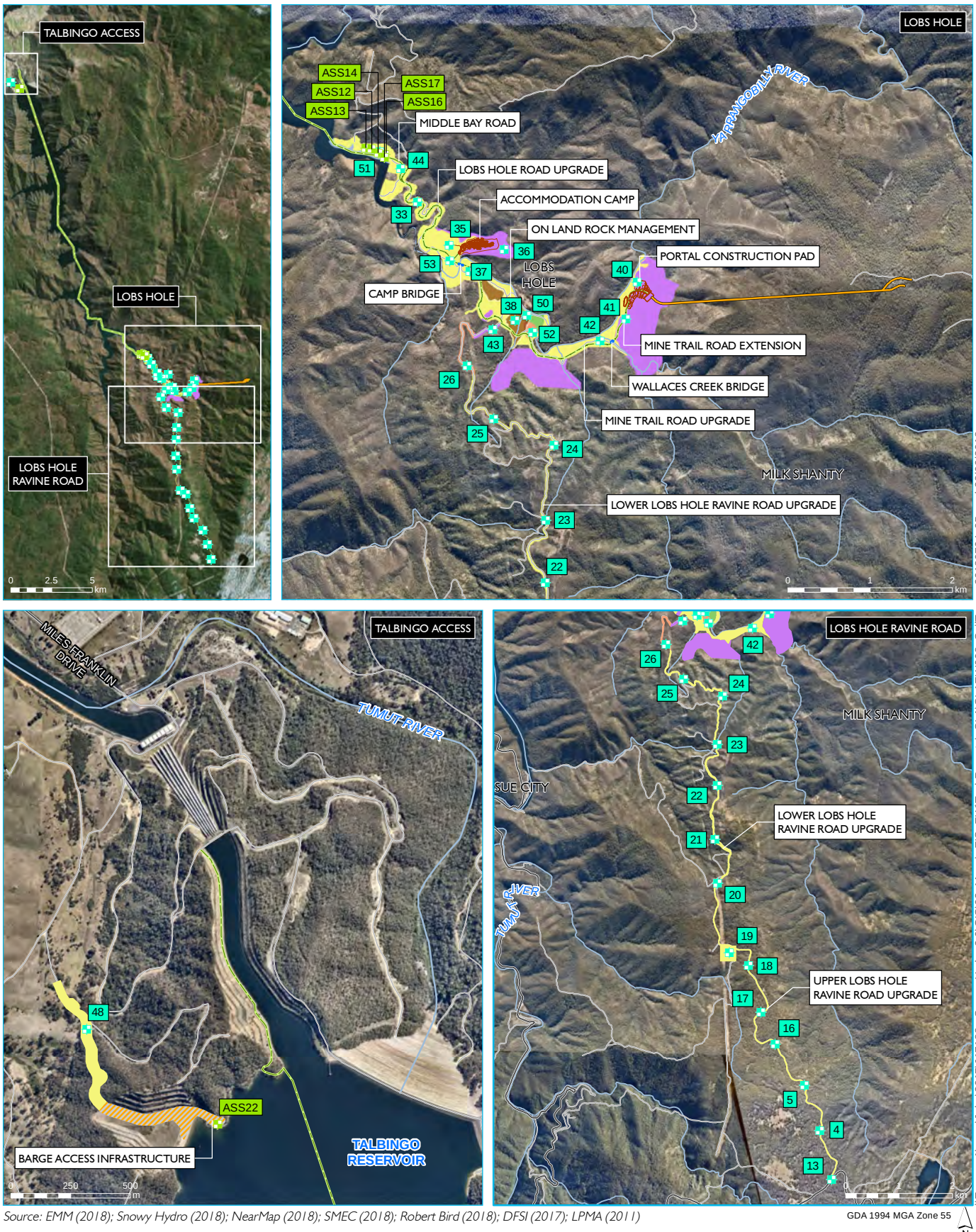
A soil assessment has been undertaken as part of the EIS (EMM 2018a). This assessment identified four predominant soil types in vicinity to the Exploratory Works. The estimated distribution of each soil type is shown in Figure 4.4. Table 4.5 provides a summary of each soil type and includes information on expected hydrologic characteristics and erosion potential. This information is used to inform erosion and sediment control methods that are discussed in Section 6.3.

Table 4.5 Soil characteristics

Soil Type	Description	Hydrologic Characteristics	Erosion potential
Tenosols	The Tenosols generally occur on mid to upper slopes and crests of undulating hills. They can also occur as a result of alluvial processes. Lithic Orthic Tenosols are characterised by a weakly developed B horizon, usually in terms of colour, texture or structure or a combination of these. The B horizon directly overlies hard rock. These soils vary in texture across the project area but typically contain loamy sand to sandy clay loam in the A horizon and silty loam to clay loam in the B horizon. Coarse fragments are common on the soil surface and are of soft, organic condition. The profile has some gravel below the A1 horizon with weak pedality below the A2 horizon (or below the A1 horizon where no A2 is present).	• Low water holding capacity due to their shallowness. • Moderately low inherent soil fertility. • Categorised as Soil Hydrologic Group B due to their medium textures.	• Low to moderate erosion potential. • Moderately dispersive throughout the profile in the eastern portion of the project area.
Kandosols	The Kandosols occur along the gentler mid to upper slopes on Lobs Hole Road (Brown) as well as the lower slopes and flats of Lobs Hole Ravine (Red and Grey) on varying geology. There are two distinct variants of Brown Kandosol, those formed on Basalt surface geology (higher elevations; above Sites 19 and 20) and those formed on Limestone and Shale surface geology (lower elevations; below Sites 19 and 20). Haplic Eutrophic Red Kandosols lack a strong texture contrast and have a well developed, weakly structured B horizon. Sandy clay loams to clay loams occur in the A horizon with clay loams to light clays in the B horizon. The soil surface is without coarse fragments with the exception of those on steeper slopes. The profile has some gravel once below the A1 horizon with weak pedality below the A2 horizon (or below the A1 where no A2 is present).	• Moderate to moderately low water holding capacity due to the high clay content and deep profiles. • Moderately low inherent soil fertility. • Categorised as Soil Hydrologic Group C due to their moderately fine to fine textures and weak structure.	• Low to moderate erosion potential. • Moderately dispersive in the B horizon.
Haplic Epipedal Black Vertosols	Haplic Epipedal Black Vertosols occur in a small area on a floodplain in the south-eastern corner of Lobs Hole. Clay alluvium has been deposited over time by the Yarrangobilly River on the inside of a meander. These soils exhibit strong cracking when dry and at depth have slicken slides and/or lenticular structural aggregates. Gilgai microrelief is not present. A clay texture of 35% or more is present throughout the profile with no thin, crusty surface horizon. The surface horizon is strongly structured and is not self-mulching. The soil surface is without coarse fragments and is of a soft, organic condition. No coarse fragments are evident in the profile. Pedality is strong throughout the profile.	• High water holding capacity due to the very high clay content and deep profiles. • High fertility and are considered some of the most fertile soils in Australia. • Categorised as Soil Hydrologic Group D due to their shrink/swell properties.	• Low erosion potential.

Table 4.5 Soil characteristics

Soil Type	Description	Hydrologic Characteristics	Erosion potential
Dermosols	The Dermosols occurs as a small pocket on mid slopes on Lobs Hole Road and is associated with a reddish pink landscape. They are moderately well developed and do not have a strong texture contrast. These soils have a clay loam A horizon and a light clay B horizon. Some coarse fragments are present on the soil surface. The soil surface is of soft, organic condition. The profile has minimal gravel with moderate pedality in the B horizon.	• Moderately high water holding capacity due to the medium-strong pedality, high clay content and deep profiles. • Moderately high inherent soil fertility. • Categorised as Soil Hydrologic Group C due to their moderately fine textures and moderate structure.	• Low to moderate erosion potential. • Bottom 0.3m of the profile is moderately dispersive.



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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

GDA 1994 MGA Zone 55

N

KEY

- Soil sample site
- ASS sample site
- On land rock management
- Portal construction pad and accommodation camp conceptual layout
- Exploratory tunnel
- Communications cable
- Main road
- Local road or track
- Watercourse

Soils assessment area - Soil type

- Not assessed
- Dermosols
- Kandosols
- Tenosols
- Vertosols
- Water

Soil type distribution of the assessment area

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 4.4

snowy2.0

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4.4 Yarrangobilly River and tributaries

This section describes the Yarrangobilly River and major tributaries within Lobs Hole. For each watercourse a description of the catchment area, watercourse characteristics and stream flow regimes is provided. Water quality characteristics are discussed separately in Section 4.6.

This section makes frequent reference to Figure 4.5 which shows the key characteristics of the Yarrangobilly River and other local watercourses at Lobs Hole.

4.4.1 Yarrangobilly River

i Catchment overview

The Yarrangobilly River is a major regional watercourse that flows into Talbingo Reservoir, downstream of Lobs Hole. The river's catchment has an area of 271 km^2 that is wholly within the KNP. The catchment is characterised by a range of subalpine grasslands and woodlands and montane dry sclerophyll forests. Elevations range from 550 m AHD at Lobs Hole to more than 1,400 m AHD in the head water catchments. Figure 4.1 (in Section 4.2) shows the Yarrangobilly River catchment and major tributaries.

As discussed in Section 4.2.1, median rainfall within the Yarrangobilly River catchment ranges from 950 mm/year at Lobs Hole to 1350 mm/year in the head water catchments. The spatial variation in median rainfall generally reflects the variation in topography within the catchment.

There are no dams or flow diversions in the Yarrangobilly River catchment upstream of the Talbingo Reservoir.

ii River and floodplain characteristics

The Yarrangobilly River initially flows through Lobs Hole in a southerly direction before turning to the west, towards Talbingo Reservoir. The river's channel ranges in width between 20 and 50 m and has an average longitudinal grade of 2.8%. Channel banks are typically densely vegetated with native and exotic species, including blackberries.

The river's floodplain is typically 2 to 3 m higher than the adjoining channel bed and varies in width between 100 to 350 m and is generally bound by steep topography. There is evidence of remnant river channels at a number of locations within the floodplain. Some areas of floodplain are densely vegetated with native and exotic species, while other areas are characterised by open grasslands.

Former mine workings including shafts and spoil piles are on the Yarrangobilly River floodplain and surrounding areas. These workings are remnant from copper mines that operated intermittently between 1874 and 1919.

Photograph 4.1 to Photograph 4.4 show typical sections of the Yarrangobilly River and its floodplain.

Figure 4.5 shows the following information:

- the alignment of the top of the river bank that has been digitised from LiDAR levels;
- indicative floodplain extents (defined by the 0.2% AEP flood extent); and
- the location of mine workings and spoil piles.



Photograph 4.1 Shows the Yarrangobilly River floodplain at Lobs Hole, looking north from higher ground



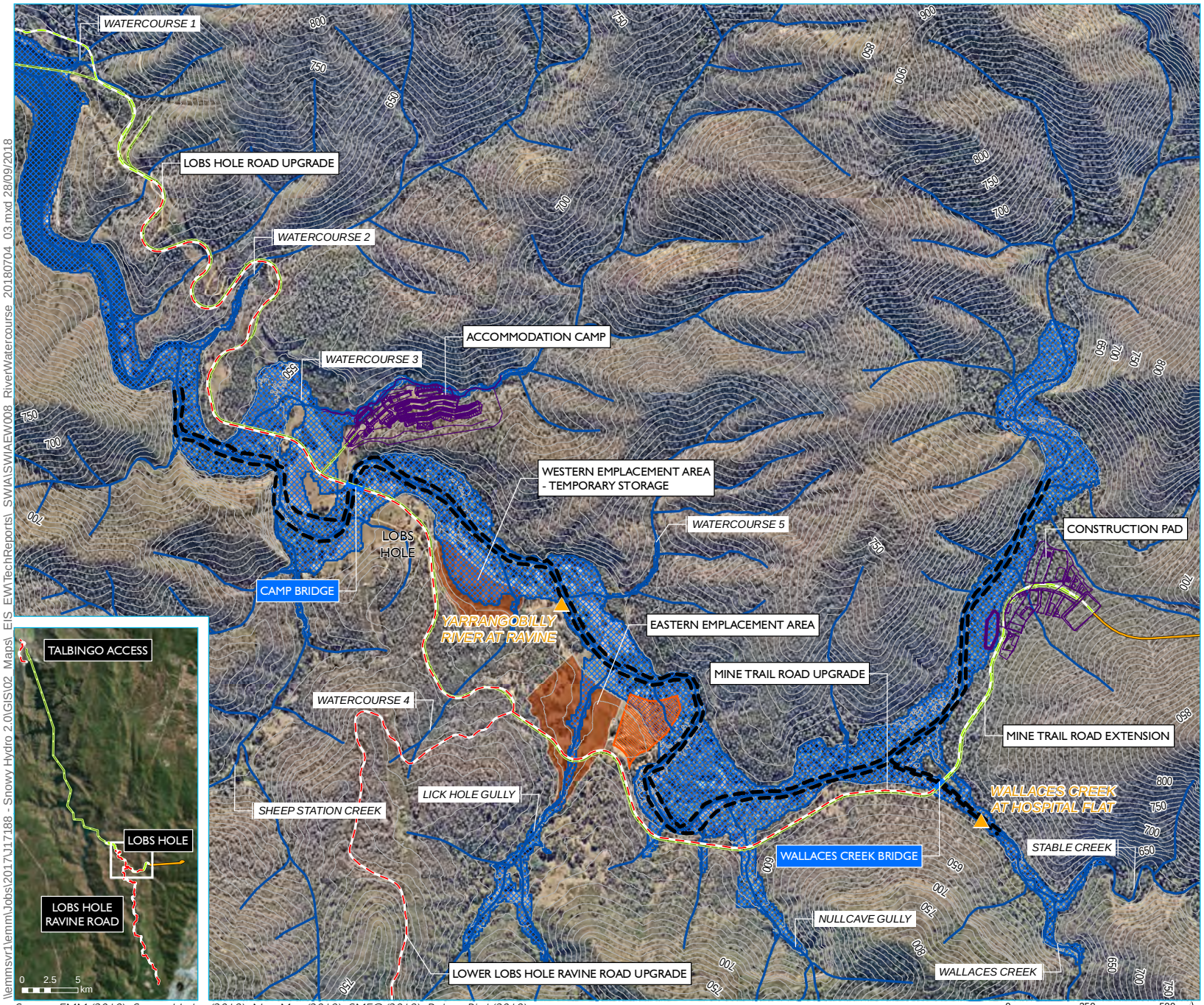
Photograph 4.2 Shows the Yarrangobilly River at Lobs Hole (looking upstream to the east). Mine workings are evident on the southern overbank area



Photograph 4.3 **Shows a typical reach of the Yarrangobilly River at Lobs Hole (looking downstream to the west)**



Photograph 4.4 **Shows a remnant river channel on Yarrangobilly River floodplain in Lobs Hole**



KEY

- Stream gauge location
- Exploratory tunnel
- Portal construction pad and accommodation camp conceptual layout
- Access road upgrade
- Access road extension
- Permanent bridge
- Communications cable
- Yarrangobilly River top of bank
- Watercourse
- Contour (10 m)
- On land rock management
- Mine workings area
- 500 year flood extent (indicative floodplain extent)

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018)

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River and watercourse characteristics

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 4.5

iii Stream flow regime

Yarrangobilly River stream flows are measured at a Snowy Hydro-operated stream gauge at Lobs Hole (gauge ID: Yarrangobilly River at Ravine: 410574). The gauge location is shown in Figure 4.5. A continuous stream flow record from 1972 to present time (a 46 year period) was provided by Snowy Hydro. Stream gauge data is summarised in the following tables and figures:

- Table 4.6 presents the range in annualised runoff volumes and runoff coefficients that have been calculated by EMM from the gauge record.
- Figure 4.6 plots the minimum 10th, 50th, and 90th percentile monthly stream flows that have been calculated by EMM from the gauge record.
- Figure 4.7 plots the monthly stream flows recorded over the 2000 to 2017 period. The monthly stream flows are compared to median monthly flows.

Table 4.6 Annual stream flow statistics (Yarrangobilly River at Ravine – 410574)

	Annual runoff	Runoff coefficient[1]
Minimum	15 GL/year	10% of rainfall
10th percentile	58 GL/year	22% of rainfall
50th percentile	99 GL/year	32% of rainfall
Average	115 GL/year	34% of rainfall
90th percentile	184 GL/year	47% of rainfall
Maximum	235 GL/year	54% of rainfall

Notes: 1. The runoff coefficient has been calculated using rainfall from the Yarrangobilly Caves (72141) rainfall record

GL - gigalitres

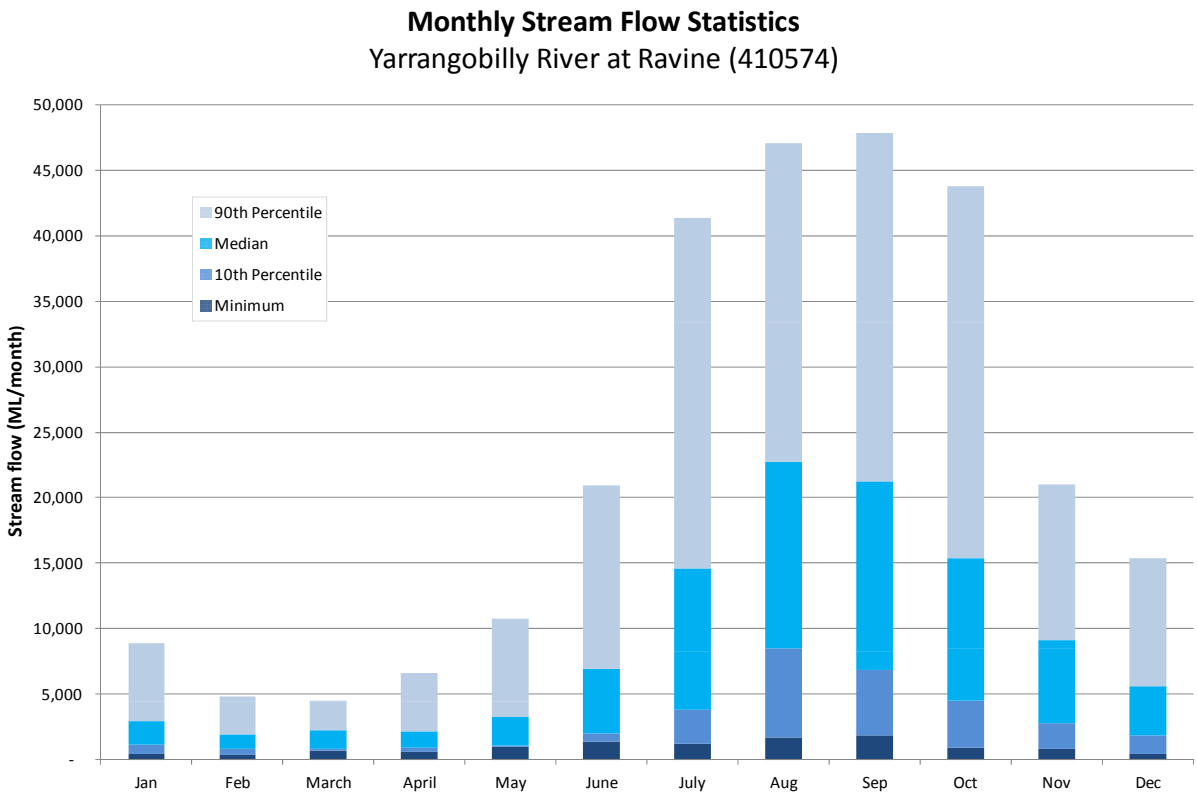


Figure 4.6 **Monthly stream flow statistics (Yarrangobilly River at Ravine – 410574)**

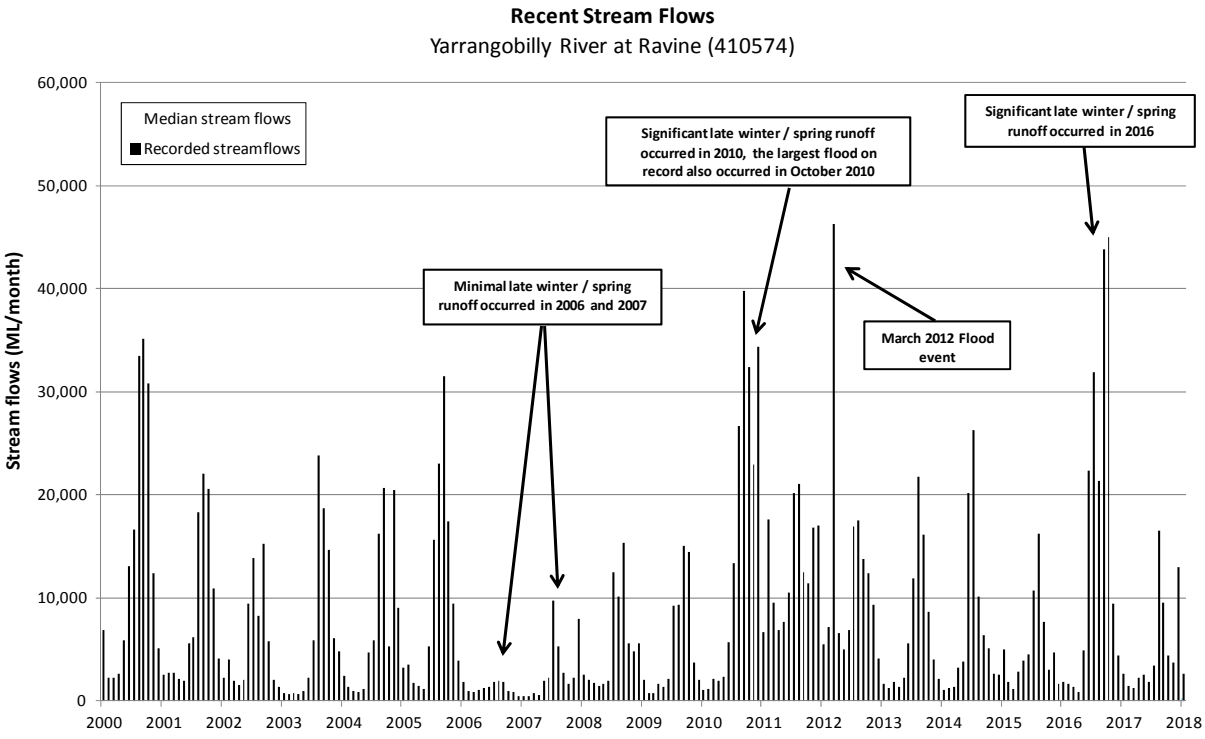


Figure 4.7 **Recent stream flows (Yarrangobilly River at Ravine – 410574)**

With reference to the data presented in Table 4.6, Figure 4.6, and Figure 4.7, the Yarrangobilly River's stream flow regime is described as follows:

- The average runoff coefficient for the catchment is estimated to be 34% of rainfall, but ranges between 10% of rainfall in dry years to 54% of rainfall in wet years.
- The majority of annual stream flows occur in late winter and early spring. Stream flows progressively reduce over summer and are at their lowest in late summer and generally remain low until the winter months. This is a typical regime for rivers in the Australian Alps.
- Winter and spring runoff volumes were abnormally low in 1982 and 2006, following abnormally dry winter months. The lowest monthly flow on record was 390 ML/month, which occurred in February 1983 following an abnormally dry winter and spring/summer in 1982. This data indicates that permanent base flows are maintained in the river by groundwater discharges during drought conditions.
- The 90th percentile stream flows in summer and early autumn months are not substantially higher than the 10th and 50th percentile flows. This indicates that significant stream flows in summer or early autumn will only occur as a result of flood producing rainfall.

Stream gauge information associated with flooding is discussed separately in Chapter 5.

4.4.2 Wallaces and Stable creeks

Wallaces Creek is a major tributary to the Yarrangobilly River. The creek has a catchment area of 43.4 km^2, which extends to the south and forms the southernmost potion of the Yarrangobilly River Catchment. Stream flows in Wallaces Creek are perennial. Photograph 4.5 shows a typical reach of Wallaces Creek. Stable Creek is a watercourse with a 19.6 km^2 catchment that joins Wallaces Creek approximately 600 m upstream of the confluence of Wallaces Creek and the Yarrangobilly River.



Photograph 4.5 Wallaces Creek (looking upstream)

i Stream flow regime

Wallaces Creek stream flows were measured intermittently at a Snowy Hydro-operated stream gauge (410507) between 1969 and 1998. The gauge is currently not operational. The gauge was 350 m upstream of the Yarrangobilly River and downstream of the confluence with Stable Creek. The gauge location is shown in Figure 4.5.

A continuous stream flow record from 1983 to 1998 (a 16 year period) was provided by Snowy Hydro. This gauged data indicates that Wallaces Creek has a similar flow regime to the Yarrangobilly River. The total gauged flows over the 1983 to 1998 period was equivalent to 15% of the total gauged flows in the Yarrangobilly River (at 410574), which is similar to the relative catchment area ratios.

4.4.3 Other watercourses

There are a number of smaller watercourses in Lobs Hole, which are shown in Figure 4.5. Table 4.7 describes the stream order, catchment area and flow regime of the 2nd order or greater watercourses in proximity to the Exploratory Works. Flow regimes have been established based on site observations and have been categorised as follows:

- Perennial – refers to watercourses where stream flows are continuous all year round during normal rainfall conditions.
- Intermittent – refers to watercourses where stream flows will cease for weeks or months each year. This will typically occur in late summer and early autumn.
- Ephemeral – refers to watercourses where stream flows only occur during and shortly after rainfall.

Table 4.7 Description of smaller watercourses

Name	Stream order[1]	Catchment area	Flow regime[2]
Cave Gully	3rd order watercourse	128 ha	Intermittent
Lick Hole Gully	3rd order watercourse	149 ha	Intermittent
Sheep Station Creek	3rd order watercourse	396 ha	Intermittent
Watercourse 1	3rd order watercourse	44 ha	Intermittent
Watercourse 2	3rd order watercourse	130 ha	Intermittent
Watercourse 3	3rd order watercourse	224 ha	Intermittent
Watercourse 4	2nd order watercourse	33 ha	Ephemeral
Watercourse 5	2nd order watercourse	56 ha	Intermittent

Notes: 1.Stream order has been established using the Strahler system of ordering watercourses using information provided on a 1:25 000 topographic map.

2. Flow regimes have been estimated based on site observations.

3. ha - hectares

4.5 Talbingo Reservoir

Talbingo Reservoir is an existing reservoir that forms part of the Snowy Scheme. The reservoir is approximately 25 km long and has a surface area of approximately 19.4 km^2 (at full supply level). Water is released from the reservoir through the Tumut 3 power station into Jounama Pondage, which releases water into Blowering Reservoir. Blowering Reservoir is operated by Water NSW and releases water into the Tumut River to supply a variety of consumptive users but primarily large irrigation schemes such as that run by Murrumbidgee Irrigation. The Tumut 3 power station also has the ability to pump water from Jounama Pondage back into Talbingo Reservoir.

Table 4.8 provides a summary of key operating levels, storage volumes and Tumut 3 power station discharge and pump capacities.

Table 4.8 Talbingo Reservoir information

Characteristic	Value
Full supply level (FSL)	543.2 m AHD
Minimum operating level (MOL)	534.4 m AHD
Operating range (FSL-MOL)	8.8 m
Spillway crest	544.7 m AHD
Active storage (within operating range)	239 GL
Gross storage	921 GL
Tumut 3 peak discharge	1,100 m^3/s
Tumut 3 pump back rate	300 m^3/s

4.5.1 Operating regime

Talbingo Reservoir is operated as head water pondage for generation of hydro-power from the Tumut 3 power station and head storage for the operation of the Tumut 3 pumped storage project. As noted in Table 4.8, the water level is maintained within an 8.8 m operating range, between the FSL and MOL.

The reservoir receives inflows from:

- the Tumut River (primary from discharges from Tumut 2 power station);
- Yarrangobilly River;
- pumping from Jounama Pondage; and
- minor tributaries.

Water levels can change rapidly due to discharge of water through Tumut 3 power station or from inflows due to rainfall or discharge from Tumut 2 power station. Figure 4.8 shows the reservoir water level between 2010 and 2017.

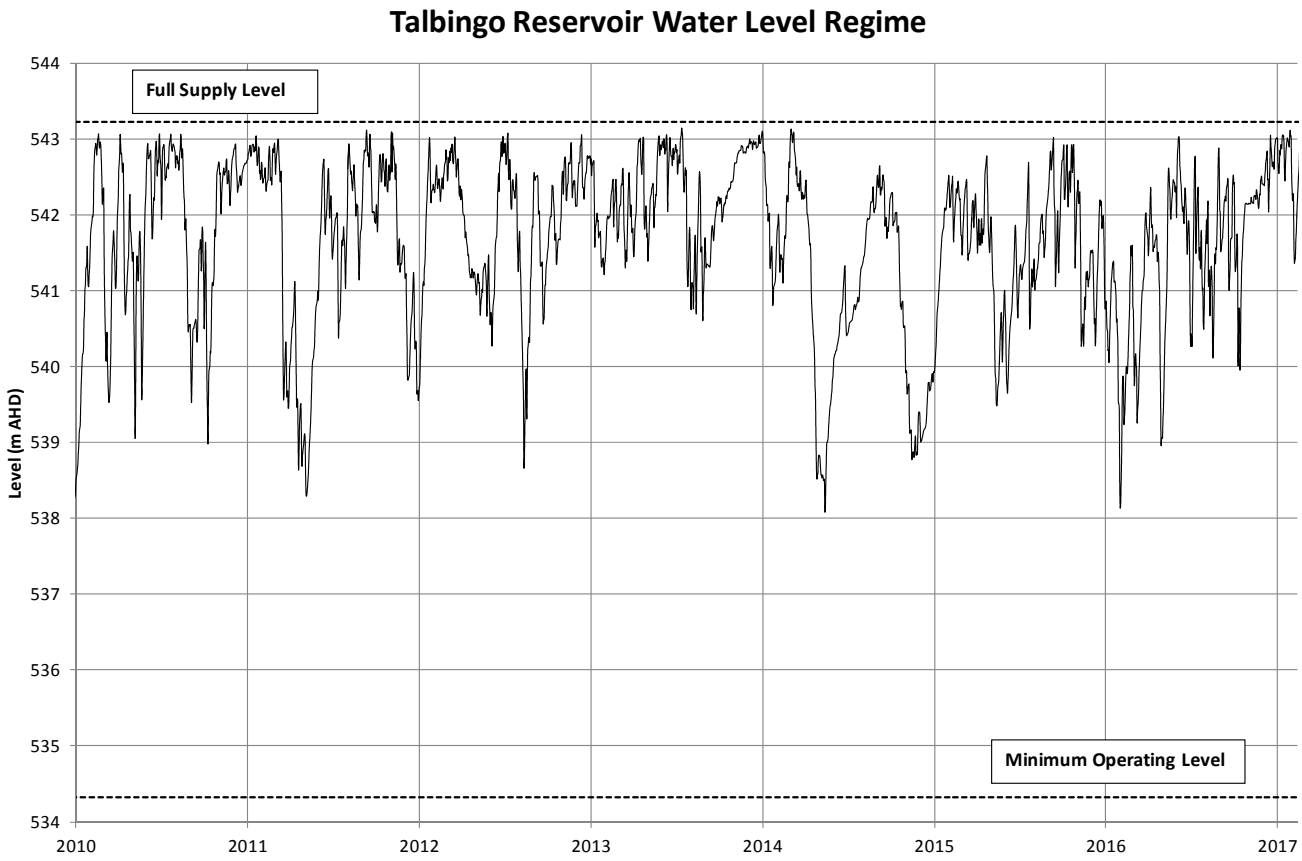


Figure 4.8 Talbingo Reservoir water level regime

Snowy Hydro provided estimates of daily discharge from Tumut 2 and Tumut 3 power stations and Tumut 3 pump-back volumes. Annual average values have been calculated over the 1994 to 2017 period. These values are presented in Table 4.9 along with the gauged Yarrangobilly River stream flows over the period. Table 4.9 also provides estimates of the inflows expressed as a percentage of the net discharge from the reservoir.

Table 4.9 Talbingo Reservoir inflow and discharge statistics

	Average annual flow volume[1] (GL/year)	Percentage of net discharge through Tumut 3 (%)[1 & 2]
Inflows		
- Yarrangobilly River	100[4]	8%
- Tumut 2 discharge	1,043	86%
- Tumut 3 pumping	394	-
- Other (ungagged catchments less evaporation losses)[3]	78	6%
Total inflows	1,615	-
Outflows		
- Tumut 3 discharge	1,615	-
Net discharge[2]	1,221	

Notes: *1.Calculated over the 1994 to 2017 period*

2. net discharge refers to Tumut 3 discharge less Tumut 3 pumping

3. value calculated as the difference between inflows and outflows.

4. The average annual flow from the Yarrangobilly River is different to the value provided in Table 4.6. This is due to the values being calculated from different periods.

The average residence time or turnover time of water in the reservoir can be calculated as a function of the gross storage volume (921 GL) divided by the average net discharge volume of 1,221 GL/year. This calculation indicates that water on average will remain in the reservoir for 9 months before discharge.

4.6 Water quality characteristics

This section describes a surface water characterisation program that has commenced for the broader Snowy 2.0 project and available results that are relevant to the Exploratory Works.

4.6.1 Surface water characterisation program

A surface water quality characterisation program commenced for the broader Snowy 2.0 project in February 2018. This program includes water quality sampling from Tantangara and Talbingo reservoirs, all major watercourses that contribute runoff to the reservoirs and watercourses within proximity to potential surface infrastructure. Water quality data from the Yarrangobilly River and its tributaries, Talbingo Reservoir and Tumut River sampling locations are relevant to Exploratory Works and are presented and discussed in this report.

i Sampling locations

Sampling locations referenced in this report are shown in Figure 4.9 and described in Table 4.10.

Table 4.10 Surface water sampling locations

ID	location	Notes
Yarrangobilly River sampling locations		
PN_SW_001	Yarrangobilly Caves, 20km upstream of Lobs Hole	
LH_SW_004	Upstream of Wallaces Creek confluence	
LH_SW_007	Adjacent to remnant mine workings	
LH_SW_006	Upstream of Talbingo Reservoir	
Wallaces and Stable Creeks sampling locations		
LH_SW_001	Stable Creek, upstream of Wallaces Creek confluence	
LH_SW_002	Wallaces Creek, upstream of Stable Creek confluence	
LH_SW_003	Wallaces Creek, downstream of Stable Creek confluence	
Minor Watercourse sampling locations		
LH_SW_005	Lick Hole Gully	No samples collected[1]
Tumut River sampling locations		
TalS_SW_001	Tumut River, upstream of Talbingo Reservoir	
Talbingo Reservoir sampling locations		
TAL_01	Northern end of the reservoir, adjacent to the dam wall	Samples collected from the surface, mid-depth and bottom of the reservoir
TAL_09	Middle portion of the reservoir	
TAL_15	Long Creek inlet	
TAL_19	Southern end of the reservoir, Tumut River inlet	
TAL_20	Southern end of the reservoir, Yarrangobilly River inlet	

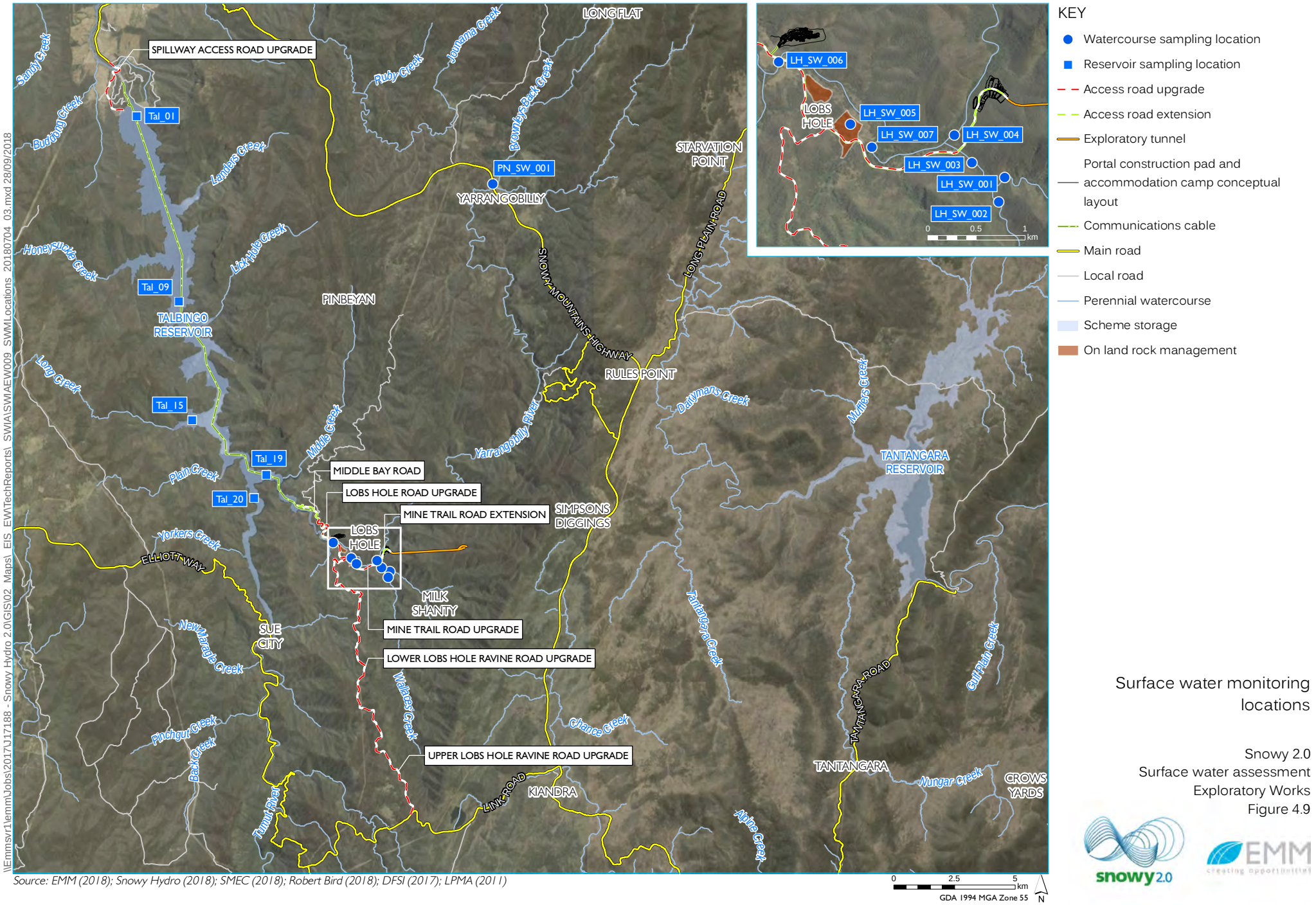
Notes: 1.No samples were collected as the sampling locations were dry during the monitoring period (February to April 2018)

ii Analysis methods

The applied sampling and analysis methods and monitoring analytes are detailed in Table 4.11. It is noted that there was some variation in analysis parameters between the sampling events.

Table 4.11 Analysis methods and parameters

Category	Sampling analytes	Analysis method
Physiochemical properties	pH, electrical conductivity (EC), turbidity, dissolved oxygen, temperature, redox potential	Measured using a portable water quality meter in the field
	total suspended solids, total dissolved solids, total hardness	Analysis undertaken by a NATA certified laboratory
Nutrients	total nitrogen, ammonia, nitrate, nitrite and total kjeldahl nitrogen	Analysis undertaken by a NATA certified laboratory
	total phosphorus and reactive phosphorus	
	total organic carbon, dissolved organic carbon	
Metals (dissolved)	Al, As, Ag, B, Ba, Cr (total), Co, Cu, Fe, Hg, Mg, Mn, Ni, Pb, Se, V and Zn	Analysis undertaken by a NATA certified laboratory



KEY

- Watercourse sampling location
- Reservoir sampling location
- Access road upgrade
- Access road extension
- Exploratory tunnel
- Portal construction pad and accommodation camp conceptual layout
- Communications cable
- Main road
- Local road
- Perennial watercourse
- Scheme storage
- On land rock management

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); DFSI (2017); LPMA (2011)

\\Emmsvr1\emmJobs\2017\J17188 - Snowy Hydro 2.0\GIS\02 Maps\ EIS EWTechReports\ SWIA\SWIAEW009 SWMLocations 20180704 03.mxd 28/09/2018

Surface water monitoring locations

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 4.9

iii Sampling frequency

At the time of writing this report, results from the following sampling events were available:

- Samples collected from river locations in February, March and April 2018. All sampling was undertaken during base flow conditions.
- A single round of samples collected from Talbingo Reservoir in March 2018.

iv Water quality data

Water quality data is presented in the following tables:

- Table 4.12 provides a summary of water quality results in the Yarrangobilly River and Wallaces Creek. All results are provided in Table A1 (Yarrangobilly River) and Table A2 (Wallaces Creek) in Appendix A.
- Table 4.13 provides a summary of water quality results from Talbingo Reservoir. A summary of results from the Yarrangobilly and Tumut rivers is provided for context. All Talbingo Reservoir results are provided in Table A3 in Appendix A.

The results are compared to relevant trigger values that were established in Section 3.4.

The results are discussed in Section 4.6.2.

Table 4.12 Water quality results summary: Yarrangobilly River (base flow conditions)

			Yarrangobilly River					Wallaces Creek		
	Unit	**Trigger value[1]**	**# Samples**	**10th percentile[6]**	**Median**	**90th percentile[6]**	**# Samples**	**Min**	**Median**	**Max**
Field Parameters										
Temperature	°C	-	11	14	19	22	5	13	15	16
Dissolved Oxygen (DO)	%	90 – 110[1]	8	**75**	**85**	93	5	**75**	**78**	92
Electrical Conductivity (EC)	µS/cm	30 – 350[1]	11	32	171	185	5	65	178	185
pH		6.5 – 8.0[1]	11	7.5	7.9	8.1	5	7.5	7.6	8.4
Oxidising and Reducing Potential (ORP)		-	11	112	130	143	5	62	133	146
Turbidity	NTU	2 - 25	7	<2	<2	5	3	<2	<2	<2
Analytical Results - General										
Suspended Solids (SS)	mg/l	-	11	<5	<5	<5	5	<5	<5	<5
Total Alkalinity (as $CACO_3$)	mg/l	-	7	15	86	109	3	38	99	104
Total Hardness (as $CACO_3$)	mg/l	-	4	9	89	97	2	87	96	94
Analytical Results - Nutrients										
Total ammonia-N	mg/l	0.013	7	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Oxidised Nitrogen (NOx)	mg/l	0.015	7	0.01	**0.03**	**1.9**	2	**0.03**	**0.035**	**0.04**
Total Kjeldahl Nitrogen (TKN)	mg/l	-	7	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1
Total Nitrogen (TN)	mg/l	0.25	7	<0.1	<0.1	**1.9**	2	<0.1	<0.1	<0.1
Reactive Phosphorus (FRP)	mg/l	0.015	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Total Phosphorus (TP)	mg/l	0.020	7	0.01	0.01	0.02	2	<0.01	<0.01	<0.01
Total Organic Carbon	mg/l	-	4	1	11	23	2	8	16.5	25
Dissolved Organic Carbon	mg/l	-	4	<1	<1	<1	2	<1	<1	<1
Analytical Results - Inorganics (Dissolved)										
Fluoride	mg/l	2.4[3]	7	0.1	0.1	0.6	3	0.1	0.1	0.1
Analytical Results - Metals (Dissolved)[2]										
Aluminium (Al)	mg/l	0.027	4	0.01	0.01	**0.06**	2	<0.01	<0.01	<0.01
Arsenic (As)	mg/l	0.0008[4]	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001

Table 4.12 Water quality results summary: Yarrangobilly River (base flow conditions)

			Yarrangobilly River				Wallaces Creek		
	Unit	Trigger value[1]	# Samples	10th percentile[6]	Median	90th percentile[6]	# Samples	Min	Median	Max
Barium (Ba)	mg/l	0.008[3]	4	**0.011**	**0.0285**	**0.042**	2	**0.088**	**0.097**	**0.106**
Boron (B)	mg/l	0.09	4	<0.05	<0.05	<0.05	2	<0.05	<0.05	<0.05
Cobalt (Co)	mg/l	0.0014[3]	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001
Total Chromium (Cr)	mg/l	0.0001[5]	7	<0.001	<0.001	<0.001	3	<0.001	<0.001	<0.001
Copper (Cu)	mg/l	0.001	4	<0.001	<0.001	<0.001	2	0.001	**0.002[4]**	**0.003[4]**
Manganese (Mn)	mg/l	1.2	4	0.001	0.001	0.002	2	0.001	0.0015	0.002
Nickel (Ni)	mg/l	0.008	7	0.001	0.001	0.002	3	0.001	0.002	0.002
Lead (Pb)	mg/l	0.001	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001
Selenium (Se)	mg/l	0.005	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Silver (Ag)	mg/l	0.0002	4	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001
Vanadium (V)	mg/l	0.006[3]	4	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01
Zinc (Zn)	mg/l	0.0024	4	<0.005	<0.005	<0.005	3	<0.005	<0.005	<0.005
Mercury (Hg)	mg/l	0.00006	4	<0.0001	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001
Iron (Fe)	mg/l	0.3[3]	4	0.05	0.05	0.06	2	<0.05	<0.05	<0.05

Notes: *1. The trigger values for field parameters and nutrients refer to the trigger values for physical and chemical stressors in south-east Australia (upland rivers) that are reported in Tables 3.3.2 and 3.3.3 of ANZECC/ARMCANZ (2000).*

2. Trigger values for the protection of 99% of species (freshwater) that are reported in Table 3.4.1 of ANZECC/ARMCANZ (2000). It is noted that no hardness adjustments have been made.

3. Trigger value refers to a low reliability trigger value that has been established using the methods recommended in Section 8.3.4.5 of ANZECC (2000).

4. For As (V).

5. For Cr (VI).

6. If less than 10 samples are available, the minim value is reported instead of the 10th percentile value and the maximum value is reported instead of the 90th percentile value.

***Bold** denotes trigger value is exceeded.*

Table 4.13 Water quality results summary: Talbingo Reservoir (March 2018)

			Talbingo Reservoir (March 2018)				Yarrangobilly River (Feb – April 2018)				Tumut River (Tals_SW_001)	
	Unit	**Trigger value[1]**	**# Samples**	**10th percentile[6]**	**Median**	**90th percentile[6]**	**# Samples**	**Min**	**Median**	**Max**	**March 18**	**April 18**
Field Parameters												
Temperature	°C	-	-	-	-	-	11	13	19	22	22	13
Dissolved Oxygen (DO)	%	90 – 110[1]	-	-	-	-	8	**75**	**85**	93	**82**	**74**
Electrical Conductivity (EC)	µS/cm	20 – 30	15	27	29	**32**	11	32	171	185	86	115
pH		6.5 – 8.0	15	6.8	7.0	7.2	11	7.5	7.9	8.1	7.8	9.5
Oxidising and Reducing Potential (ORP)		-	-	-	-	-	11	112	130	143	137	183
Turbidity	NTU	1- 20	-	-	-	-	7	<2	<2	5	<2	-
Analytical Results - General												
Suspended Solids (SS)	mg/l	-	15	<1	2	6	11	<5	<5	<5	<5	<5
Total Alkalinity (as $CACO_3$)	mg/l	-	15	<20	<20	<20	7	15	86	109	46	-
Total Hardness (as $CACO_3$)	mg/l	-	15	6	7	10	4	9	89	97	-	30
Analytical Results - Nutrients												
Total ammonia-N	mg/l	0.010	15	<0.01	<0.01	<0.01	7	<0.01	<0.01	<0.01	-	<0.01
Oxidised Nitrogen (NOx)	mg/l	0.01	15	<0.05	<0.05	**0.07**	7	<0.01	**0.03**	**1.9**	-	**0.03**
Total Kjeldahl Nitrogen (TKN)	mg/l	-	15	<0.2	<0.2	<0.2	7	<0.1	<0.1	<0.1	-	<0.1
Total Nitrogen (TN)	mg/l	0.35	15	<0.2	<0.2	<0.2	7	<0.1	<0.1	**1.9**	-	<0.1
Reactive Phosphorus (FRP)	mg/l	0.005	15	<0.05	<0.05	<0.05	4	<0.01	<0.01	<0.01	-	<0.01
Total Phosphorus (TP)	mg/l	0.01	15	<0.05	<0.05	<0.05	7	0.01	0.01	**0.02**	-	<0.01
Total Organic Carbon	mg/l	-	15	<5	<5	<5	4	1	11	23	-	<1
Dissolved Organic Carbon	mg/l	-	15	<5	<5	<5	4	<1	<1	<1	-	<1
Analytical Results - Inorganics (Dissolved)												
Fluoride	mg/l	2.4[3]	15	<0.5	<0.5	<0.5	7	0.1	0.1	0.6	0.13	-
Analytical Results - Metals (Dissolved)[2]												
Aluminium (Al)	mg/l	0.055	15	<0.05	<0.05	<0.05	4	0.01	0.01	**0.06**	-	<0.01

Table 4.13 Water quality results summary: Talbingo Reservoir (March 2018)

			Talbingo Reservoir (March 2018)					Yarrangobilly River (Feb – April 2018)			Tumut River (Tals_SW_001)	
	Unit	**Trigger value[1]**	**# Samples**	**10th percentile[6]**	**Median**	**90th percentile[6]**	**# Samples**	**Min**	**Median**	**Max**	**March 18**	**April 18**
Arsenic (As)	mg/l	0.013[4]	15	<0.001	0.001	0.001	4	<0.001	<0.001	<0.001	-	<0.001
Barium (Ba)	mg/l	0.008[3]	15	<0.02	<0.02	<0.02	4	**0.011**	**0.0285**	**0.042**	-	**0.01**
Boron (B)	mg/l	0.370	15	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05	-	<0.05
Cobalt (Co)	mg/l	0.0014[3]	15	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001	-	<0.001
Total Chromium (Cr)	mg/l	0.001[5]	15	<0.001	<0.001	<0.001	7	<0.001	<0.001	<0.001	<0.002	-
Copper (Cu)	mg/l	0.0014	15	<0.001	**0.032**	**0.069**	4	<0.001	<0.001	<0.001	-	0.001
Manganese (Mn)	mg/l	1.9	15	<0.005	<0.005	0.007	4	0.001	0.001	0.002	-	0.008
Nickel (Ni)	mg/l	0.011	15	0.001	0.003	0.005	7	0.001	0.001	0.002	-	0.001
Lead (Pb)	mg/l	0.0034	15	<0.001	0.002	0.003	4	<0.001	<0.001	<0.001	-	<0.001
Selenium (Se)	mg/l	0.005	15	<0.001	<0.001	<0.001	4	<0.01	<0.01	<0.01	-	<0.01
Silver (Ag)	mg/l	0.0005	15	<0.005	<0.005	<0.005	4	<0.001	<0.001	<0.001	-	<0.001
Vanadium (V)	mg/l	0.006[3]	15	<0.005	<0.005	<0.005	4	<0.01	<0.01	<0.01	-	<0.01
Zinc (Zn)	mg/l	0.008	15	<0.005	**0.024**	**0.065**	4	<0.005	<0.005	<0.005	-	<0.005
Mercury (Hg)	mg/l	0.00006	15	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001	-	<0.0001
Iron (Fe)	mg/l	0.3[3]	15	<0.05	<0.05	<0.05	4	0.05	0.05	0.06	-	0.09

Notes: *1. The trigger values for field parameters and nutrients refer to the trigger values for physical and chemical stressors in south-east Australia (fresh water lakes and reservoirs) that are reported in Tables 3.3.2 and 3.3.3 of ANZECC/ARMCANZ (2000).*

2. Trigger values for the protection of 95% of species (freshwater) that are reported in Table 3.4.1 of ANZECC/ARMCANZ (2000). It is noted that no hardness adjustments have been made. These trigger values only apply to the Talbingo Reservoir results, refer to Table 4.12 for trigger values for the Yarrangobilly and Tumut Rivers.

3. Trigger value refers to a low reliability trigger value that has been established using the methods recommended in Section 8.3.4.5 of ANZECC (2000).

4. For As (V).

5. For Cr (VI).

6. If less than 10 samples are available, the minim value is reported instead of the 10th percentile value and the maximum value is reported instead of the 90th percentile value.

***Bold** denotes trigger value is exceeded.*

4.6.2 Surface water quality

This section describes the water quality characteristics of the Yarrangobilly River, Wallaces Creek and Talbingo Reservoir.

i Yarrangobilly and tributaries water quality

Water quality monitoring was undertaken in the Yarrangobilly River and Wallaces Creek on three occasions between February and April 2018. All samples were collected during base flow conditions, which are dominant in the summer months. During base flow conditions, constant stream flows are maintained by groundwater discharges into the river and its tributaries. Accordingly, water quality during base flow conditions reflects the water quality of regional groundwater systems that contribute to base flows and may not be representative of water quality during periods of higher stream flow when surface water runoff is dominant.

With reference to Table 4.12 the water quality of the Yarrangobilly River and Wallaces Creek during base flow conditions can be characterised as:

- Neutral to slightly alkaline, with pH measurements ranging between 7.5 and 8.4, within the trigger value range of 6.5 to 8.5.
- High carbonate levels and associated hardness and alkalinity. This is associated with the groundwater origin of base flows. Lower carbonate levels are expected during non-base flow conditions.
- Low salinity, with electrical conductivity (an indicator of salinity) ranging between 32 to 185 µS/cm, within the trigger value range of 30 to 350 µS/cm. Low salinity levels are expected during non-base flow conditions.
- Low levels of suspended solids and turbidity. Suspended solids and turbidity were consistently either below detection limits or within the lower end of the trigger value range. This is in line with expectations given the base flow conditions and clear appearance of the water. There is potential for higher levels of suspended solids during non-base flow conditions.
- Low levels of nutrients (phosphorus, nitrogen and carbon). Phosphorus and nitrogen concentrations were below trigger values in all samples except for a single sample from the Yarrangobilly River that recorded a Nitrate concentration of 1.9 mg/l. There is potential for higher levels of nutrients during non-base flow conditions.
- Low levels of metals. All dissolved metal concentrations were below trigger value except for:
    - a single sample of copper was elevated relative to the trigger value;
    - a single sample of Aluminium was marginally elevated relative to the trigger value; and
    - all samples of Barium were elevated relative to the low reliability trigger value.

ii Talbingo Reservoir water quality

The Talbingo Reservoir is operated as part of the Snowy Hydro scheme. As discussed in Section 4.5, the gross volume of the reservoir is equivalent to 75% of the average annual flow through the reservoir and significant inflows are maintained during the summer months due to diversions from the greater Snowy Scheme. As a result, the water quality is expected to be less sensitive to seasonal changes in stream flow regimes than river systems such as the Yarrangobilly River.

With reference to Table 4.13 the water quality of Talbingo Reservoir can be characterised as having a neutral pH, low carbonate (hardness and alkalinity), low salinity, low levels of suspended solids and low nutrient levels.

Metal concentrates were below trigger levels except for copper and zinc. Dissolved copper concentrations ranged from below detection to 0.088 mg/l (the 90th percentile value was 0.069 mg/l) relative to a trigger value of 0.0014 mg/l. 7 of the 15 samples exceeded the trigger value. Dissolved zinc concentrations ranged from below detection to 0.068 mg/l (the 90th percentile value was 0.065 mg/l) relative to a trigger value of 0.008 mg/l. 9 of the 15 samples exceeded the trigger value. With reference to Table A3 (in Appendix A), the elevated copper and zinc occurred at TAL 09 (mid reservoir), TAL 15 (long creek inlet) and TAL 19 (Tumut River inflow arm).

Elevated copper and zinc concentrations were not identified in either the Yarrangobilly or Tumut River inflow locations. Hence, the source of the elevated metal concentrations is unknown. This is not considered relevant to Exploratory Works but will be further investigated as part of the broader Snowy 2.0 project.

5 Flooding

This section documents the flood assessment for Exploratory Works and is structured as follows:

- Section 5.1 describes the assessment methodology;
- Section 5.2 describes existing flood characteristics;
- Section 5.3 describes proposed infrastructure that will be located on flood prone land, associated flood risks and changes to existing flooding regimes;
- Section 5.4 discusses flood emergency response; and
- Section 5.5 provides a summary of this section.

This section refers to:

- Appendix B, which provides a detailed assessment method statement; and
- Appendix C, which provides all flood figures.

5.1 Assessment methodology

EMM engaged GRC Hydro to undertake hydrology analysis and flood modelling for Exploratory Works. The analysis and modelling was undertaken in accordance with the methods recommended in ARR2016. This section provides an overview of the assessment methodology and key outcomes. A detailed method statement prepared by GRC Hydro is provided in Appendix B.

5.1.1 Hydrology analysis

The hydrological assessment approach included both Flood Frequency Analysis (FFA) and hydrologic modelling. The FFA was undertaken using the peak annual flows recorded at the Yarrangobilly River at Ravine stream gauge (410574) between 1972 to 2017, a 46 year period. The largest flood on record occurred in 2010 and had a peak flow of 210 m^3/s. This event is estimated to be a 1 in 70 year event.

Hydrologic modelling of the Yarrangobilly River catchment was undertaken using XP-RAFTS software. The model was developed using the methods recommended in ARR2016 and was parameterised to the peak flows derived from the FFA. The calibrated hydrologic model was applied to simulate the 20%, 5%, 1%, 0.2%, 0.05% and Probable Maximum Flood (PMF) events.

Table 5.1 compares the peak flows that were derived from the FFA and hydrologic model. The peak flows estimated from the hydrologic model have been adopted as design flows. Refer to Appendix B for a detailed description of analysis and modelling methodologies, assumptions and results.

Table 5.1 Yarrangobilly River Design flow summary

Event	Peak flows (m^3/s)	
	FFA	Hydrologic model
20% AEP	83	92
5% AEP	142	154
1% AEP	233	244
0.2% AEP	-	408
0.05% AEP	-	714
PMF	-	6,000

5.1.2 Hydraulic Modelling

Hydraulic modelling was undertaken using the TUFLOW two-dimensional numerical modelling package. The model includes the Yarrangobilly River reach between the portal construction pad and Talbingo Reservoir and all tributaries in proximity to the Exploratory Works. Refer to Appendix B for a description of the model set-up.

The model was applied to simulate the 20%, 5%, 1%, 0.2%, 0.05% AEP and PMF events for both existing and Exploratory Works conditions. The model results were used to establish existing flood characteristics, identify potential flood impacts and inform flood risk management measures for the Exploratory Works. The results have and will be used to inform engineering design of the project.

5.2 Existing flooding characteristics

Flood model results for each event are presented in figures that show flood depth and level (as contours) and the peak velocity depth product (VD). The VD results provide an indication of flood hazard and flood conveyance. Results for all events assessed are provided in figures in Appendix C. Table 5.2 provides a figure reference.

Table 5.2 Flood characteristics figure reference

	Flood depth and level	Peak VD
20% AEP	Figure C1	Figure C7
5% AEP	Figure C2	Figure C8
1% AEP	Figure C3	Figure C9
0.2% AEP	Figure C4	Figure C10
0.05% AEP	Figure C5	Figure C11
PMF	Figure C6	Figure C12

The flood model results indicate that:

- for the lower magnitude flood events such as the 20% and 5% AEP events, flooding is predominantly confined to the channel and immediate floodplain areas. Full inundation of the floodplain occurs in the 1% AEP and greater magnitude events; and

- for all events except the PMF, most of the flow conveyance occurs within the channel and immediate floodplain areas.

5.3 Potential flood impacts

5.3.1 Proposed infrastructure on flood prone land

The Exploratory Works avoid flood prone land where possible. However, some infrastructure will unavoidably need to be constructed on flood prone land. Table 5.3 lists and describes this infrastructure.

It is noted that:

- The flood extents of minor tributaries are not considered to be flood prone land for the purposes of this assessment. Management of runoff from minor tributaries is addressed in Section 6.2.

- With reference to Figure C6, minor portions of the eastern emplacement area, accommodation camp and portal construction pad are located within the periphery of the PMF flood extent, but below the 0.05% AEP event. As the magnitude of inundation is minor further assessment of flood risks and impacts is not considered to be necessary.

Table 5.3 Proposed infrastructure on flood prone land

Infrastructure	Permanent / temporary	Description of infrastructure
Camp Bridge (Lobs Hole Road crossing over the Yarrangobilly River)	Permanent	Lobs Hole Road will cross the Yarrangobilly River to the south of the accommodation camp. The floodplain width at the bridge location is approximately 120 m. The bridge will be a double span structure with the deck soffit elevated above the 1% AEP flood level. The road embankment leading to the bridge is approximately 1.5 m above floodplain levels and will form a complete blockage of floodplain conveyance on the left (southern) floodplain area.
Wallaces Bridge (Mine Trail Road crossing over Wallaces Creek)	Permanent	Mine Trail Road will cross Wallaces Creek approximately 110 m upstream of the Yarrangobilly River. The floodplain width at the bridge location is approximately 90 m. The bridge will be a single span structure with the deck soffit elevated above the 1% AEP flood level. The bridge abutments will be constructed to levels that are 4 to 5 m above floodplain levels and will form a complete blockage of floodplain conveyance.
Western emplacement area	Temporary, the western emplacement will be removed at the end of the project.	The western emplacement area will be established on the southern portion of the Yarrangobilly River floodplain. The footprint of the emplacement area is indicated in all flood results figures. The floodplain width at the emplacement location ranges between 120 to 190 m. The emplacement is located on a higher portion of the floodplain and avoids areas of elevated flow conveyance that are indicated in the VD results. It is expected that the emplacement will result in a constriction of the floodplain during higher magnitude (1% AEP and greater) flood events.
Portal construction pad water management basin	Temporary, the dam will be removed as part of the portal construction pad rehabilitation.	The water management basin for the portal construction pad will be established on the eastern side of the Yarrangobilly River floodplain. The basin will be constructed on top of the floodplain, rather than via excavation. The footprint of the basin is indicated in all flood results figures. The floodplain width at the basin location is approximately 110 m. The basin is on a higher portion of the floodplain and avoids areas of elevated flow conveyance that are indicated in the VD results. It is expected that the basin embankments will result in a constriction of the floodplain during higher magnitude (5% AEP and greater) flood events.

5.3.2 Changes to flooding regimes

The hydraulic model was applied to assess changes to the existing flooding regime associated with the infrastructure described in Table 5.3. This was done by applying the following modifications to the existing conditions hydraulic model:

- The assumed surface levels (also referred to as the digital elevation model) were updated to include the design levels and footprints of the road and dam embankments and the western emplacement area.
- Bridge structures were included in the model using flow constriction cells. This method accounts for blockage and form losses at bridge structures associated with the bridge piers and deck structures.

Refer to Appendix B for further details on methodologies applied to assess proposed conditions.

The Exploratory Works hydraulic model was simulated for the 20%, 5%, 1%, 0.2%, 0.05% AEP and PMF events. For each event, changes to the existing flooding regime have been quantified by calculating the difference in peak flood levels and velocities between existing and Exploratory Works model results. The resulting changes are shown spatially in:

- flood level difference maps that show the areas and magnitude of flood level change; and
- velocity difference maps that show changes to velocity expressed as a percentage.

Results for all events assessed are provided in figures in Appendix C. Table 5.4 provides a figure reference.

Table 5.4 Flood difference maps figure reference

	Change in flood level	Change in velocity
20% AEP	Figure C13	Figure C19
5% AEP	Figure C14	Figure C20
1% AEP	Figure C15	Figure C21
0.2% AEP	Figure C16	Figure C22
0.05% AEP	Figure C17	Figure C23
PMF	Figure C18	Figure C24

The following sections discuss the changes to flood regimes due to the proposed infrastructure on flood prone land.

i Camp Bridge

Camp Bridge will be a double span bridge structure that crosses the Yarrangobilly River channel. The road embankment leading to the bridge will be constructed to levels that are approximately 1.5m above floodplain levels and will form a complete blockage of floodplain conveyance through the left (southern) floodplain area. The road is elevated to provide flood free access during a 1% AEP event. Model results indicate that:

- For the 20 and 5% AEP events, there will be minimal change to existing flooding regimes. This is because the majority of the flow conveyance occurs in the river channel and flood levels are below the bridge soffit.

- For the 1% AEP event, flood levels upstream of the bridge structure are predicted to increase by up to 200 mm. Velocities are predicted to increase by 10 to 20% in floodplain areas that are adjacent to the bridge abutments.

- For the 0.2% AEP events flood levels upstream of the bridge structure are predicted to increase by up to 900 mm. This is due to the road embankment forming a complete blockage of floodplain conveyance on the left (southern) floodplain area. Velocities are predicted to increase by up to 30% in vicinity of the bridge structure. Similar results are predicted for the 0.05% AEP event.

- For the PMF event, flood waters overtop the road embankment. Hence, the flood level and velocity impacts are lower relative to the 0.2% and 0.05% AEP events.

The predicted changes to flooding regimes is consistent with expectations for a bridge that is designed to AustRoads standards and are unavoidable if the bridge is to be designed to maintain access during a 1% AEP event. It is noted that:

- there is no infrastructure or items of heritage significance in the flood level and velocity impact areas; and

- the former Washington Hotel is downstream of the road embankment. Model results indicate that the road embankment will shield this area, reducing the risk of flood damage to the ruins.

During detailed design, the potential to lower the levels of the road embankment leading into the bridge will be reviewed. This will reduce the magnitude of flood level increases in 0.2% AEP and greater magnitude events. If this is practical, the design will be amended to incorporate lower road embankment levels.

ii Wallaces Bridge

Wallaces Bridge will comprise a single span structure with the deck soffit elevated above the 1% AEP flood level. The bridge abutments will be constructed to levels that are 4 to 5 m above floodplain levels and will form a complete blockage of floodplain conveyance. The road is elevated to provide flood free access during a 1% AEP event. Model results indicate that the bridge structure will result in similar impacts to those described above for the Lobs Hole Road crossing (Camp Bridge) over the Yarrangobilly River. There is no infrastructure or items of heritage significance in the flood level and velocity impact areas.

iii Western emplacement area

The western emplacement area will be used as temporary rock and soil stockpiles and will be established on the southern portion of the Yarrangobilly River floodplain. The stockpile area will be rehabilitated at the end of Exploratory Works. The stockpiles will be on a higher portion of the floodplain and avoid areas of elevated flow conveyance that are indicated in the VD results. Model results indicate that the stockpiles will result in minimal change to existing flood regimes for the 1% AEP and lower magnitude events. For the 0.2% AEP and higher magnitude events, the emplacement will displace flow conveyance area resulting in moderate flood level and velocity increases in the adjoining floodplain areas. There is no infrastructure or items of heritage significance in the flood level and velocity impact areas.

iv Portal construction pad water management basin

The water management basin for the portal construction pad will be established on the eastern side of the Yarrangobilly River floodplain. The basin will be removed at the end of Exploratory Works as part of the construction pad rehabilitation. Model results indicate that the basin will result in minimal change to existing flood regimes for the 1% AEP and lower magnitude events. For the 0.2% AEP and higher magnitude events, the basin will displace flow conveyance area resulting moderate flood level and velocity increases in the adjoining floodplain areas. There is no infrastructure or items of heritage significance in the flood level and velocity impact areas.

5.4 Emergency response

With reference to Figures C6 and C12, the accommodation camp and portal construction pad will be predominantly established above the PMF flood extent and will therefore provide flood refuge for site personal. Snowy Hydro routinely monitor weather conditions and have sufficient expertise, systems and monitoring equipment in place to identify weather systems that have potential to produce flood producing rainfall. Accordingly, it is expected that adequate warning will be provided to enable to safe and orderly evacuation of all site personnel to designated flood refuge locations above the PMF extent.

A flood emergency response plan will be prepared as part of the Exploratory Work's emergency response plans.

5.5 Summary and mitigation

A flood assessment has been undertaken as part of the EIS. The assessment is informed by modelling of flooding in the Yarrangobilly River, Wallaces Creek and minor tributaries in proximity to the Exploratory Works. The modelling has been undertaken in accordance with the methods recommended in ARR2016. The flood model results have been used to establish flood characteristics within Lobs Hole for the 20%, 5%, 1%, 0.2%, 0.05% AEP and PMF events.

The Exploratory Works avoid flood prone land where possible. However, the following infrastructure will unavoidably need to be constructed on flood prone land:

- bridge crossings over the Yarrangobilly River and Wallaces Creek;
- the western emplacement area; and
- the water management basin for the portal construction pad.

The flood model was applied to assess changes to the existing flooding regime associated with the infrastructure. This process concluded that the predicted changes to flood regimes will not impact infrastructure or items of heritage significance.

Table 5.5 provides a summary of the proposed flood risk management controls and commitments to additional design development that are recommended.

Table 5.5 Proposed flood risk management controls and design development recommendations

Control	Description
Proposed controls	
FM 1.1 – Bridge Design	Camp and Wallaces Bridges will be designed in accordance with AustRoads bridge design standards which require the: • bridge deck soffit to be located above the 1% Annual Exceedance Probability (AEP) flood level; • bridge structure to be designed to withstand a 0.05% AEP event; and • abutments to be protected by appropriately designed scour protection.
FM 1.2 – Emplacement area design	The western emplacement will be designed to minimise the risk of emplacement material being entrained in flood waters during a 0.2% AEP event. This may require a flood protection berm or rock armouring along the northern toe of the emplacement.
FM 1.3 – Flood Emergency Response	A flood emergency response plan will be prepared as part of the project's emergency response plans
Proposed design development	
Lobs Hole Road Embankment Design	During detailed design, the potential to lower the levels of the road embankment leading into the bridge will be reviewed. This will reduce the magnitude of flood level increases in 0.2% AEP and greater magnitude events. If this is practical the design will be amended to incorporate lower road embankment levels.

6 Water Management

6.1 Overview

A water management system will manage both runoff from Exploratory Works and water produced by and used by Exploratory Works. The water management system for Exploratory Works has been categorised into the following focus areas:

- management of runoff from clean water catchments that traverse the project area;
- water management during construction disturbance;
- management of runoff from unsealed access roads;
- management of stormwater runoff from the accommodation camp;
- management of stormwater runoff from the portal construction pad;
- management of water produced by or used by Exploratory Works;
- management of waste water (ie sewage); and
- rock and soil emplacement water management.

This chapter describes the water management risks, water management approach, discharge characteristics, monitoring and contingency measures presented for each of these focus areas. The eight water management focus areas are documented in Sections 6.2 to 6.9 respectively. Residual impacts are assessed relative to WQOs in Chapter 7.

Each section describes water management controls, which are labelled sequentially as WM 1, WM 2, etc. The controls presented in this assessment are principles or design objectives, that will be further developed in the detailed design of the Exploratory Works. The management measures assessed are presented to determine the feasibility of achieving the proposed water quality on discharge. The management measures implemented may vary from those presented but will still need to meet the proposed water quality or other stated objectives.

A summary of all controls presented is provided in Appendix F.

6.1.1 Terminology

The following terminology is used in this section:

- Receiving water – refers to any watercourse that receives runoff or water discharge from Exploratory Works.
- Clean water – refers to surface water runoff from catchments that are undisturbed or rehabilitated following disturbance.
- Sediment laden water – refers to surface water runoff from construction disturbance and unsealed access roads. Sediment laden water is likely to contain elevated suspended sediment concentrations.

- Stormwater – refers to runoff from Exploratory Works. Stormwater may contain elevated concentrations of suspended sediment and nutrients.
- Process water – refers to water that will be produced by or used by the proposed construction activities.
- Tunnel affected water – refers to intercepted groundwater and all other water that is dewatered from the exploratory tunnel. It is part of the process water stream.
- Emplacement seepage – refers to water that seeps from the rock and soil emplacements.
- Waste water – refers to waste water generated from the accommodation camp and other onsite amenities.
- Potable water – refers to water that has been treated to a potable water standard.
- Fire water – refers to water that is produced by fire fighting activities.

6.2 Clean water management

6.2.1 Overview

Exploratory Works will predominately be constructed in steep terrain and will traverse existing drainage lines and watercourses of varying sizes. Management of clean water from upslope areas and transverse drainage lines or watercourses will be an integral aspect of the water management system and civil design for the project.

6.2.2 Potential water management impacts

Identified water management risks include:

- potential for clean water runoff during major flood events to result in damage or failure of road embankments and other infrastructure;
- potential for clean water runoff to enter the water management system - this can increase the volume of water that requires management, reducing the effectiveness of the presented controls;
- diversion of clean water into adjoining watercourse - this can increase flow rates and erosion risks; and
- potential for erosion upstream and downstream of culvert and bridge structures.

6.2.3 Mitigation and management

The management of clean water interfaces with Exploratory Works can be achieved through appropriate design and construction of clean water diversion systems. The most appropriate design for each diversion system needs to be established on a case-by-case basis. Table 6.1 describes presented controls (or design principles) that will be applied to the design of all clean water diversions.

Table 6.1 Water management controls clean water management

Control	Description
WM_1.1	Where practical, all clean water will be diverted around or through water management areas. Runoff from clean water areas that cannot be diverted must be accounted for in the design of water management systems.;
WM_1.2	All permanent clean water drainage will be designed and constructed to convey the 1% AEP peak flow and will have adequate scour protection. Temporary clean water drainage will be designed to convey the 50% AEP peak flow.;
WM_1.3	Where practical, diversions will seek to avoid materially increasing flow rates in adjoining watercourses.; and
WM_1.4	Where practical, the permanent diversion of drainage lines or watercourses using contour drains will be avoided.

Notes: 1. Contour drains refer to diversion drains that are constructed along the contour. Contour drains for larger watercourses can require substantial earthworks and are prone to failure on the fill batter side if uncontrolled overflows occur due to the drain capacity being exceeded or a blockage (such as a tree falling into the drain).

6.2.4 Residual impacts

It is expected that clean water interfaces with the Exploratory Works can be adequately managed through the appropriate design and construction of clean water diversion systems.

6.2.5 Monitoring and contingency measures

All clean water diversions will be inspected and maintained as required. No water quality monitoring of clean water diversions is proposed.

6.3 Water management during construction

6.3.1 Overview

As described in Section 2.9, the construction of surface infrastructure including the access roads, construction pad, accommodation camp, services infrastructure and barge access infrastructure will be undertaken within the initial nine months of Exploratory Works. Table 6.2 provides an overview of the construction activities, disturbance areas, disturbance durations and receiving waters for the various construction works. The predominant soil type in each construction zone is also noted. The construction disturbance area is also shown in Figure 7.1 (in Chapter 7).

Disturbance associated with the rock and soil emplacement areas is discussed separately in Section 6.9.

Table 6.2 Summary of construction disturbance areas

Infrastructure	Construction activities	Disturbance area[1] (ha)	Disturbance duration	Predominant soil type(s)[2]	Receiving waters
Access roads					
Upper Lobs Hole Ravine Road upgrade	Minor upgrades to 7.5 km section of existing road. Only single lane access will be provided. No cut and fill earthworks or vegetation clearing will be undertaken.	3.0	6 months	Kandosols	Yarrangobilly River tributaries • Wallaces Creek Tumut River tributaries • Prospectors Creek
Lower Lobs Hole Ravine Road upgrade	Upgrades to 6 km section of existing road involving cut and fill earthworks in some sections. Only single lane access will be provided.	10.5	6 months	Kandosols Tenosols Dermosols	Yarrangobilly River tributaries • Wallaces Creek • Cave Gully • Lick Hole Gully Tumut River tributaries • O'Hares Creek
Lobs Hole Road upgrade	Upgrade to 7.3 km section of existing road providing two-way access.	16.8	6 months	Kandosols	Yarrangobilly River
Mine Trail Road upgrade	Upgrade to 2.2 km section of existing track to two-way access.	8.3	6 months	Kandosols	Yarrangobilly River
Mine Trail Road extension	Establishment of a new two-way road providing access to the exploratory tunnel portal.	3.8	6 months	Kandosols	Yarrangobilly River
Middle Bay Road	Establishment of a new two-way road to the proposed Middle Bay barge ramp.	12.0	6 months	Kandosols	Talbingo Reservoir
Spillway Road	Upgrade of a 3 km section of existing road to provide two-way access to the proposed spillway barge ramp.	13.7	6 months	Kandosols	Jounama Pondage and Talbingo Reservoir
Access roads (total)		**68.1**			
Portal construction pad	Vegetation clearing, substantial earthworks and establishment of all proposed infrastructure.	9.9	6 months	Tenosols	Yarrangobilly River
Accommodation camp	Vegetation clearing, earthworks and construction of roads and buildings.	7.6	6 months	Tenosols	Watercourse 2 and Yarrangobilly River
Services infrastructure	Services will be installed within service corridors that will form part of the access roads	minimal	6 months	Kandosols	Yarrangobilly River
Total (all works)		**85.6**			

Notes: 1. Disturbance area refers to the area subject to clearing and ground disturbance.

2. Figure 4.4 shows the distribution of soil types relative to Exploratory Works.

6.3.2 Potential water management impacts

The construction of surface infrastructure will unavoidably require the removal of vegetation and disturbance of soils. Hence, key water management risks include:

- sedimentation in receiving waters due to runoff from construction areas laden with coarse sediment; and
- discharge of runoff laden with fine and/or dispersive sediments that will not readily settle under gravity in receiving waters.

6.3.3 Mitigation and management

The risk of sediment-laden water discharge from construction areas can be managed through minimising disturbance areas and durations and establishing appropriately designed erosion and sediment controls for areas that are disturbed. Water quality treatment can also improve the water quality prior to discharge.

The proposed management approach is described in the following sections.

i Soil characteristics

The effectiveness of erosion and sediment control strategies is a function of the characteristics of the soils that will be disturbed. With reference to Table 6.2, most construction activities will occur in Kandosols and Tenosols soils (refer to Section 4.3 for a description of soil characteristics).

It is expected that runoff from disturbed areas in both the Kandosols and Tenosols soil types will be laden with coarse and fine sediments, with some potential for the entrainment of dispersive material.

ii Terrain constraints

Sediment and erosion control options are limited for construction areas that will occur in steep terrain. In particular, the construction of sedimentation basins is not considered possible in steep terrain. Hence, separate sediment and erosion control strategies are proposed for construction areas that are constrained by terrain (or the project boundary) and are not constrained by terrain.

Table 6.3 provides a break-down of the portion of each construction area this is and is not constrained by terrain.

Table 6.3 Construction area disturbance: terrain constraints

	Construction disturbance area (ha)		
	Constrained by terrain	**Not constrained by terrain**	**Total**
Access roads			
Upper Lobs Hole Ravine Road upgrade	Nil	3.0	3.0
Lower Lobs Hole Ravine Road upgrade	10.5	Nil	10.5
Lobs Hole Road upgrade	Nil	16.8	16.8
Mine Trail Road upgrade	5.0	3.3	8.3

Table 6.3 Construction area disturbance: terrain constraints

	Construction disturbance area (ha)		
	Constrained by terrain	**Not constrained by terrain**	**Total**
Mine Trail Road extension	Nil	3.8	3.8
Middle Bay Road	6.0	6.0	12.0
Spillway Road	Nil	13.7	13.7
Access roads (combined)	**21.5**	**46.6**	**68.1**
Portal construction pad	Nil	9.9	9.9
Accommodation camp	Nil	7.6	7.6
Total (all works)	**21.5**	**64.1**	**85.6**

iii Erosion and sediment control approach

An Erosion and Sediment Control Plan (ESCP) will be prepared for each construction area. Each ESCP will:

- consider local soil characteristics, clean water management and the proposed construction methods;
- apply all practical source control and rehabilitation methods; and
- be progressively amended as required during construction.

A suitably qualified erosion and sediment control expert will be commissioned to develop and execute each ESCP. The expert will be responsible for overseeing the development of the ESCP and inspecting and auditing controls during implementation. Regular expert input will ensure that erosion and sediment control practices are established and operated to a high standard and progressively improved.

iv Water treatment approach

Erosion and sediment controls will minimise the entrainment of suspended sediment and other pollutants in runoff from construction areas and rapid rehabilitation will limit the period of disturbance. Sedimentation dams and water treatment systems are proposed for construction areas that are 2,500 m^2 or larger. These controls are discussed further below.

a. Sedimentation dams

Sedimentation dams will be established for construction areas that are 2,500 m^2 or larger and are not constrained by terrain or the proposed disturbance footprint. Sedimentation basins will be constructed in accordance with the methods recommended in *Managing Urban Stormwater: Soils and Construction: Volume 1* (Landcom 2004) and Volume 2D (DECC 2008). Sedimentation basin sizing methodologies are provided in Appendix E.

When practical, water captured in sedimentation basins will be used for dust suppression.

It is noted that a larger basin will be established for the portal construction pad compound. Details are provided in Section 6.6.

b. Water treatment systems

Chemical water treatment is proposed to improve the water quality of discharge from construction areas that are 2,500 m^2 or larger. The following treatment approach is proposed:

- Sedimentation basins will be partitioned into inlet and settling zones.
- Water will be pumped from the inlet zone into a chemical dosing and mixing unit. An iron salt coagulant (or similar) and calcium carbonate (or similar) will be dosed at a controlled rate and will be allowed to mix in a series of gravity mixing tanks. Outflow from the tanks will be discharged through 'floc blocks' to add an anionic polymer flocculant (or similar).
- The settling zone will be sized to facilitate settling at the design treatment rate.

For non-terrain constrained construction areas (larger than 2,500 m^2), the water treatment system will be incorporated into sedimentation basins. The chemical water treatment system will be designed to treat the 1 year average recurrence interval (ARI) peak flow. Figure 6.1 shows the proposed system functionality.

A similar system will be implemented for terrain constrained areas (larger than 2,500 m^2). As sedimentation basins are not practical in terrain constrained areas, a pump-out system and a mobile water treatment plant will be used. The design treatment rate will be the 1 in 3 month ARI peak flow. The lower capacity is due to the need for settling to occur in tanks, rather than a basin. Figure 6.2 shows the proposed system functionality.

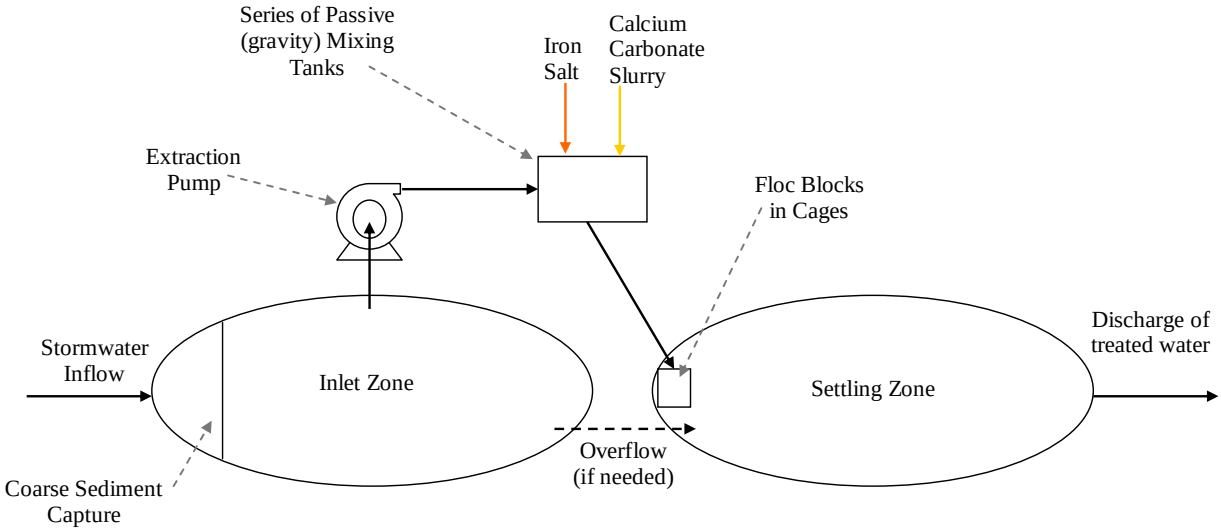


Figure 6.1 Water treatment design concept (non-terrain constrained system)

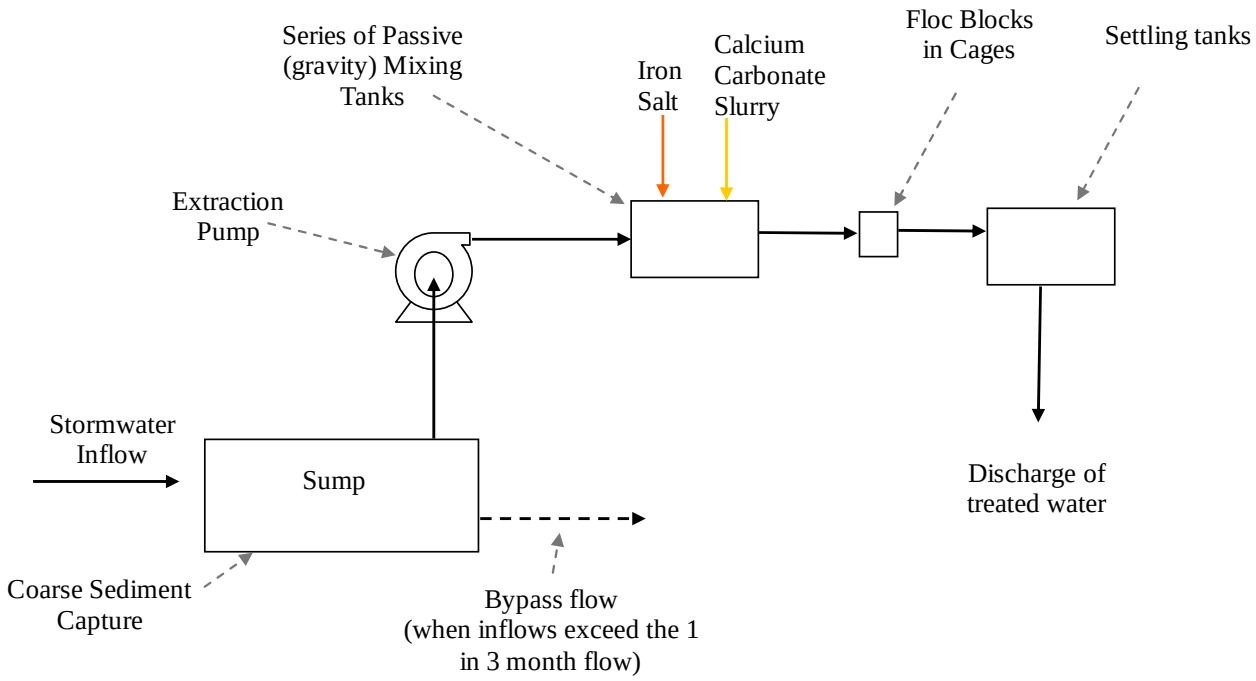


Figure 6.2 Water treatment design concept (terrain constrained system)

The treatment approach is expected to provide the following water treatment:

- suspended solid concentrations and turbidity levels will be significantly reduced;
- phosphorus concentrations will be significantly reduced; and
- anionic polymer flocculants tend to bind dissolved metals. Hence, some dissolved metal concentrations will be reduced (if they are elevated in stormwater).

The use of calcium carbonate will provide a buffer against changes to pH and potential iron salt coagulant overdoses. The use of the proposed treatment chemicals will result in a minor (10 to 30 µS/cm) increase in salinity. This will be an unavoidable effect of using water treatment chemicals. The change to salinity levels will be minimised by optimising dosing rates.

The proposed approach is not expected to increase the toxicity of discharge due to:

- the selection of low risk chemicals. Higher risk chemicals such as aluminium based chemicals and cationic flocculants will be avoided; and
- an automated chemical dosing system will optimise dosing rates. Regular local input and monitoring is proposed to ensure the system is operating effectively.

It is noted that the proposed water treatment chemicals will be verified by laboratory and field trials. Alternative chemicals will also be considered to ensure the optimal configuration is applied.

v Controls

Table 6.4 provides a summary of presented controls.

Table 6.4 Water management controls: construction areas

Control	Description
Controls for all construction areas	
WM_2.1	An Erosion and Sediment Control Plan (ESCP) will be prepared for each construction area. Each ESCP will: • consider local soil characteristics, clean water management and the proposed construction methods; • apply all practical source control and rehabilitation methods; and • be progressively amended as required during construction. A suitably qualified erosion and sediment control expert will be commissioned to develop and execute each ESCP. The expert will be responsible for overseeing the development of the ESCP and inspecting and auditing controls during implementation. Regular expert input will ensure that erosion and sediment control practices will be established and operated to a high standard and progressively improved.
WM_2.2	The clean water management controls WM_1.1 to 1.4 apply to all ESCPs.
WM_2.3	Stockpiles will be located where they are not exposed to concentrated or flood flow. Flood flow is defined as the 20% AEP flood extent. Monitoring for dispersion and erosion of soil stockpiles will be undertaken, particularly on moderately dispersive soils. Addition of ameliorants, such as gypsum and organic matter for dispersive soils will be undertaken as needed.
WM_2.4	Soils will be lightly scarified on the contour to encourage rainfall infiltration and minimise run-off. As soon as practicable after respreading, a cover crop will be established to limit erosion and soil loss. This will also provide good mulch for native plant establishment.
WM_2.5	Sediment traps or filters will be maintained at all discharge locations to target the removal of coarse sediments.
Additional controls for construction areas that are constrained by terrain or the proposed disturbance boundary	
WM_2.6	Runoff from construction areas that are constrained by terrain or the proposed disturbance boundary and are larger than 2,500 m^2 will be captured in a sump and pumped to a water treatment plant. The water treatment plant will use water treatment chemicals to enhance sedimentation and phosphorus and dissolved metal removal rates using an automated chemical dosing system. Only water treatment chemicals that have a low risk of increasing the toxicity of treated stormwater will be used. The design dewatering and treatment rate will be the 1 in 3 month average return interval (ARI) peak flow.
Additional controls for construction areas that are not constrained by terrain	
WM_2.7	Where appropriate, sedimentation basins will be constructed in accordance with the methods recommended in *Managing Urban Stormwater: Soils and Construction: Volume 1* (Landcom 2004) and Volume 2D (DECC 2008). Water treatment chemicals will be applied to sedimentation basins with catchment areas greater than 2,500 m^2 to enhance sedimentation and phosphorus and dissolved metal removal rates. Only water treatment chemicals that have a low risk of increasing the toxicity of treated stormwater will be used. Water treatment chemicals will be applied using an automated chemical dosing and mixing system. The design treatment rate will be the 1 year ARI peak flow.
WM_2.8	When practical, water captured in sedimentation basins will be used for dust suppression.

6.3.4 Discharge characteristics

The following sections provide a summary of discharge regimes and quality. Residual impacts are discussed in Chapter 7.

i Discharge regimes

Table 6.5 describes the discharge mechanisms and regimes for terrain constrained and non-terrain constrained construction areas.

Table 6.5 Discharge regimes from construction areas

Terrain constrained construction areas (no sedimentation basins)	
Basin type	Basins will not be practical for construction areas that are constrained by terrain or the disturbance boundary.
Discharge mechanism	Discharge will occur following any material rainfall[1].
Discharge frequency	Discharge will occur approximately 50 days per year.
Water treatment (construction areas >2,500 m^2 only)	A chemical water treatment system will treat all discharge during a 1 in 3 month ARI and lower magnitude rainfall events.
Dewatering	Nil
Discharge volumes	Discharge volumes will be similar to runoff volumes (approximately 40% of rainfall).
Non-terrain constrained construction areas (sedimentation basins are proposed)	
Basin type	Sedimentation basins will be constructed in accordance with the methods recommended in *Managing Urban Stormwater: Soils and Construction: Volume 1* (Landcom 2004) and Volume 2D (DECC 2008). Sedimentation basin sizing methodologies are provided in SWA Appendix E.
Discharge mechanism	Discharges will occur when the sedimentation basins are full. When full, discharge will occur via spillway overflows during and shortly after rainfall.
Discharge frequency	Discharge will occur approximately 8 to 10 times per year[2].
Water treatment (construction areas >2,500 m^2 only)	A chemical water treatment system will treat all discharge during a 1 year ARI and lower magnitude rainfall events.
Basin dewatering	Basins will be dewatered (via pumping) as soon as possible following rainfall cessation. Water will be used for dust suppression within construction areas and will not be discharged to receiving waters.
Discharge volumes	Discharge volumes are estimated to be on average, 40% of the runoff volume (or approximately 16% of rainfall[3]), with 60% of runoff volume removed from the basins via dewatering.

Notes: *1. Material rainfall refers to 5 mm or more in a day.*

2. A discharge event refers to a rainfall period where overflows occur intermittently within a wet weather period. Discharge periods will typically be 1 to 3 days (similar to most wet weather events).

3. This assumes a runoff coefficient of 40% of rainfall and a discharge coefficient of 40% of runoff.

ii Discharge quality

Table 6.6 provides the predicted water quality characteristics of discharges from construction areas. The water quality characteristics have been established based on data from other representative sites, with consideration given to the benefits of presented controls. No allowance has been made for site-specific factors that may influence water quality. Site specific trigger values may be developed during Exploratory Works.

Table 6.6 Discharge quality for construction areas

Analyte	Units	Trigger value	Discharge concentration		Comments
			Typical	Maximum	
Discharge quality for construction areas that are less than 2,500 m² (erosion and sediment controls only, no chemical water treatment)					
Turbidity	NTU	2-25	2-50	150	Erosion and sediment controls will remove coarse sediment. Some fine and dispersive material is expected to be suspended in runoff.
Suspended sediment	mg/L	-	25	40	
Oxidised nitrogen	mg/L	0.015	0.2	0.5	The key sources of nutrients are expected to be from: • the weathering and breakdown of natural and anthropogenic materials, including rock and soils; • entrainment with fine and dispersive materials (this typically only applies to phosphorus and organic forms of nitrogen); and • atmospheric deposition onto unvegetated areas. Erosion and sediment controls are expected to provide limited treatment of nutrients.
Total nitrogen	mg/L	0.25	0.6	1.5	
Reactive phosphorus	mg/L	0.015	0.04	0.12	
Total phosphorus	mg/L	0.02	0.08	0.20	
Dissolved metals	mg/L	Note 1	Concentrations of some metals may exceed relevant trigger values for the Yarrangobilly River.		It is expected that concentrations of some metals in runoff will at times be above the relevant trigger values for the Yarrangobilly River. The key sources of metals are expected to be from: • atmospheric deposition onto unvegetated areas; and • the weathering and breakdown of natural and anthropogenic materials, including rock and soils.
Discharge quality for construction areas that are more than 2,500 m² (erosion and sediment controls plus chemical water treatment)					
Turbidity	NTU	2-25	2-25	25	Water treatment will enhance removal of fine and dispersive suspended sediments. This will result in low turbidity levels and suspended solids concentrations.
Suspended sediment	mg/L	-	<5	20	
Oxidised nitrogen	mg/L	0.015	0.2	0.5	Water treatment chemicals may reduce organic nitrogen concentrations. No material reduction in oxidised nitrogen concentrations is expected.
Total nitrogen	mg/L	0.25	0.4	1.5	
Reactive phosphorus	mg/L	0.015	0.02	0.05	Water treatment chemicals will reduce phosphorus concentrations.
Total phosphorus	mg/L	0.02	0.02	0.05	
Dissolved metals	mg/L	Note 1	Concentrations of some metals may exceed relevant trigger values for the Yarrangobilly River.		Water treatment may reduce the concentrations of some dissolved metals (if they are elevated in runoff).

Notes: 1. Trigger values for 99% level of species protection apply.

6.3.5 Monitoring and contingency measures

i Proposed monitoring

The following inspections and water quality monitoring will be undertaken during construction disturbance:

- erosion and sediment controls will be inspected daily to ensure they are maintained in good working order;
- monitoring of turbidity and visual inspections will be undertaken on a daily basis when runoff from construction areas to the receiving waters occurs; and
- comprehensive monitoring of runoff from construction areas to the receiving waters will be undertaken during wet weather conditions.

A comprehensive receiving water monitoring program will also be undertaken for the duration of Exploratory Works. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Contingency measures

The following additional measures could be implemented if monitoring identifies unacceptable impacts:

- adjustments to chemical treatment methods (chemicals, dosing rates); and
- progressive improvement of to erosion and sediment control practices.

6.4 Access road water management

6.4.1 Overview

The project will require the use of access roads that have a collective trafficable area of 12.6 ha. It is noted that trafficable area is less than the construction disturbance area that includes all areas subject to land clearing and ground disturbance during construction.

The access roads will be constructed in the initial six months of the project schedule and will generally comprise upgrades to existing unsealed public roads. Access roads will be designed and constructed as permanent roads, will be unsealed and will be used by both light and heavy vehicle traffic. Sections of existing public dirt roads at Lobs Hole that will no longer be required following construction of the new access roads will be removed and rehabilitated.

This section discusses the management of runoff from access roads during Exploratory Works (ie following site establishment and completion of roads). Water management during construction is addressed in Section 6.3.

6.4.2 Potential water management impacts

As the access roads will be unsealed and heavily used by both light and heavy vehicle traffic. The key water management risks include:

- sedimentation in receiving waters due to runoff from access roads laden with coarse sediment;

- discharge of runoff laden with fine or dispersive sediments that will not readily settle under gravity in receiving waters; and
- erosion due to failure of the road drainage.

6.4.3 Mitigation and management

The effective management of runoff from unsealed access roads requires appropriate design and ongoing maintenance of the road and drainage systems. Table 6.7 describes controls (or design principles) that will be applied to the design and management of access roads. As with construction areas, construction of basins to treat runoff from some road sections in steep terrain will not be practical. It is estimated that this will apply to approximately 20 to 30% of the access road area.

Table 6.7 Water management controls: access roads

Control	Description
Controls for all access roads	
WM_3.1	Sections of Lobs Hole Road that will no longer be required following the construction of the new access roads will be removed and rehabilitated. This will reduce associated sediment loads.
WM_3.2	All cut and fill batters will be stabilised as soon as practicable.
WM_3.3	The clean water management controls WM_1.1 to 1.4 will apply to the design of all access roads.
WM_3.4	Access road surfaces will be maintained with appropriate aggregate material to reduce the risk of erosion.
WM_3.5	Where practicable and safe to do so access roads will be single cross fall and will grade to table drains located against the toe of the cut batters. The drains will be stabilised by rock armouring as required.
WM_3.6	Where appropriate, the sedimentation basins established to manage runoff during construction of the access roads will be maintained during the Exploratory Works to provide ongoing treatment of runoff from access roads.
Additional controls for access roads that are not constrained by terrain or the proposed disturbance footprint	
WM_3.7	The sedimentation basins established to manage runoff during construction of the access roads will be modified to be constructed wetland style basins where practicable. Constructed wetland style basins will maintain permanent water. An extended detention zone will be established above the permanent water. The extended detention zone will drain slowly through a low flow outlet control. Where practical, runoff from road embankments that have been stabilised by vegetation will be diverted into the clean water drainage system to minimise the contributing catchment area to the constructed wetlands. This will increase the effective size of the basin (in terms of depth of rainfall captured) and will result in a treatment volume that is greater than the 5 day 85th percentile volume that is proposed for sedimentation basins for construction areas.

6.4.4 Discharge characteristics

The following sections provide a summary of discharge regimes and quality. Residual impacts are discussed in Chapter 7.

i Discharge regimes

Table 6.8 describes the discharge mechanisms and regimes for access roads that are terrain constrained and not terrain constrained.

Table 6.8 Discharge regimes from access roads during operation

Constrained access road sections (no basins): approximately 20 to 30% of total road area	
Basin type	Basins will not be practical for sections of access road that are constrained by terrain or the disturbance boundary.
Discharge mechanism	Discharge will occur following any material rainfall[1].
Discharge frequency	Discharge will occur approximately 50 days per year.
Dewatering	Nil
Discharge volumes	Discharge volumes will be similar to runoff volumes (approximately 60%[2] of rainfall)
Non-constrained access road sections (with basins): approximately 70 to 80% of total road area	
Basin type	Sedimentation basins established for the construction phase will be modified to be constructed wetland style basins. The basins will maintain permanent water. An extended detention zone will be provided above the permanent water zone. The extended detention zone will drain slowly through a low-flow outlet. Overflows will occur via a high-flow outlet when the basins are full.
Discharge mechanism	Discharges from the extended detention zone will occur via a low-flow outlet during and for 2 to 3 days after most material rainfall events. Overflows via a high-flow outlet will occur when basins are full.
Discharge frequency	Discharge of low flows is expected to occur 50 to 100 days per year. Overflows via the high-flow outlet will occur occasionally during intense rainfall.
Basin dewatering	No dewatering is proposed.
Discharge volumes	Discharge volumes will be similar to runoff volumes (approximately 60%[2] of rainfall)

Notes: 1. Material rainfall refers to 5 mm or more in a day.

2. A runoff coefficient of 60% of rainfall is a conservative value for an unsealed road.

ii Discharge quality

Table 6.7 provides the predicted water quality characteristics of discharges from access roads. The water quality characteristics have been established based on data from other representative sites, with consideration given to the benefits of the presented controls. No allowance has been made for site-specific factors that may influence water quality. Site specific trigger values may be developed during Exploratory Works.

Table 6.9 Discharge quality for access roads (during operation)

Analyte	Units	Trigger value	Discharge concentration		Comments
			Typical	Maximum	
Constrained access road sections (source controls, no basins): approximately 20 to 30% of total road area					
Turbidity	NTU	2-25	2-50	150	Source controls will remove coarse sediment. Some fine and dispersive material is expected to be suspended in runoff.
Suspended sediment	mg/L	-	25	40	
Oxidised nitrogen	mg/L	0.015	0.2	0.5	The key sources of nutrients are expected to be from: • the weathering and breakdown of natural and anthropogenic materials, including rock and soils; • entrainment with fine and dispersive materials (this typically only applies to phosphorus and organic forms of nitrogen); and • atmospheric deposition onto unvegetated areas. Source controls are expected to provide limited treatment of nutrients.
Total nitrogen	mg/L	0.25	0.6	1.5	
Reactive phosphorus	mg/L	0.015	0.04	0.12	
Total phosphorus	mg/L	0.02	0.08	0.20	
Dissolved metals	mg/L	Note 1	Concentrations of some metals may exceed relevant trigger values for the Yarrangobilly River.		It is expected that concentrations of some metals in stormwater will at times be above the relevant trigger values for the Yarrangobilly River. The key sources of metals are expected to be from: • atmospheric deposition onto unvegetated areas; and • the weathering and breakdown of natural and anthropogenic materials, including rock and soils.
Non-constrained access road sections (source controls, with basins): approximately 70 to 80% of total road area					
Turbidity	NTU	2-25	2-25	50	Constructed wetland style basins will remove some fine and dispersive suspended sediments. This will result in lower turbidity levels and suspended solids concentrations.
Suspended sediment	mg/L	-	<10	25	
Oxidised nitrogen	mg/L	0.015	0.1	0.4	Constructed wetland style basins will reduce nitrogen concentrations.
Total nitrogen	mg/L	0.25	0.4	1.0	
Reactive phosphorus	mg/L	0.015	0.02	0.05	Constructed wetland style basins will reduce phosphorus concentrations.
Total phosphorus	mg/L	0.02	0.05	0.1	
Dissolved metals	mg/L	Note 1	Concentrations of some metals may exceed relevant trigger values for the Yarrangobilly River.		Constructed wetland style basins will reduce the concentrations of some dissolved metals (if they are elevated in runoff).

Notes: 1. Trigger values for 99% level of species protection apply.

6.4.5 Monitoring and contingency measures

i Proposed monitoring

Monitoring of runoff from access roads at four random locations will be undertaken four times per year during wet weather conditions. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Contingency measures

The following additional measures could be implemented if monitoring identifies unacceptable impacts:

- the water treatment chemical approach proposed for construction areas can be applied to any poorly performing section of road;
- restrictions could be applied to the use of access roads during intense rainfall; and
- poorly performing sections of road could be sealed.

6.5 Stormwater management: accommodation camp

6.5.1 Overview

i Proposed facility

The accommodation camp will provide accommodation and supporting services for workers near the exploratory tunnel. The camp layout is shown on Figure 2.7 and includes ensuite rooms surrounding central facilities including a kitchen, tavern, gym, administration office, laundry, maintenance building, waste water (ie sewage) and water treatment plants and parking. An access road will connect to the north side of Lobs Hole Road.

ii Setting

The accommodation camp will be located to the south of Watercourse 3 (refer to Figure 4.5) on steep topography that falls to the north at approximately 1V to 4H. All runoff from the camp area drains into Watercourse 3, which is described in Table 4.7 as being a 3rd order watercourse that has an intermittent flow regime. Watercourse 3 has a catchment area of 224 ha and flows into the Yarrangobilly River approximately 500 m downstream of the camp and 400 m upstream of Talbingo Reservoir.

The camp will be established in Tenosols soils that are described in Table 4.5 as being shallow soils that typically overlie hard rock. The soils have a low water holding capacity (due to their shallowness) and are categorised as Soil Hydrologic Group B, implying a low to medium runoff potential. Due to the shallow nature of the soils and steep terrain, infiltration-based stormwater systems are not considered to be suitable.

A conceptual design has been prepared to inform the camp layout (Figure 2.7). Given the steep terrain, the design seeks to establish accommodation units on terraced landforms. Stormwater runoff from each terrace will drain to a swale drain that will be located along the back (ie along the toe of the next lift) of the terrace. These drains are likely to be founded within hard rock and may need to be concrete lined. Larger buildings and services such as water tanks will be constructed on flat pads that will be established by earthworks.

6.5.2 Potential water management impacts

The accommodation camp will provide accommodation and supporting services for workers. No construction activities that could introduce chemical contaminants to stormwater runoff will occur within the accommodation camp. Hence, identified water management risks include:

- stormwater flooding issues and/or erosion of the landform due to inadequate drainage system design;
- changes to runoff regimes due to the introduction of impervious areas; and
- increased concentrations and loads of suspended solids and nutrients in runoff from roof areas and road pavements.

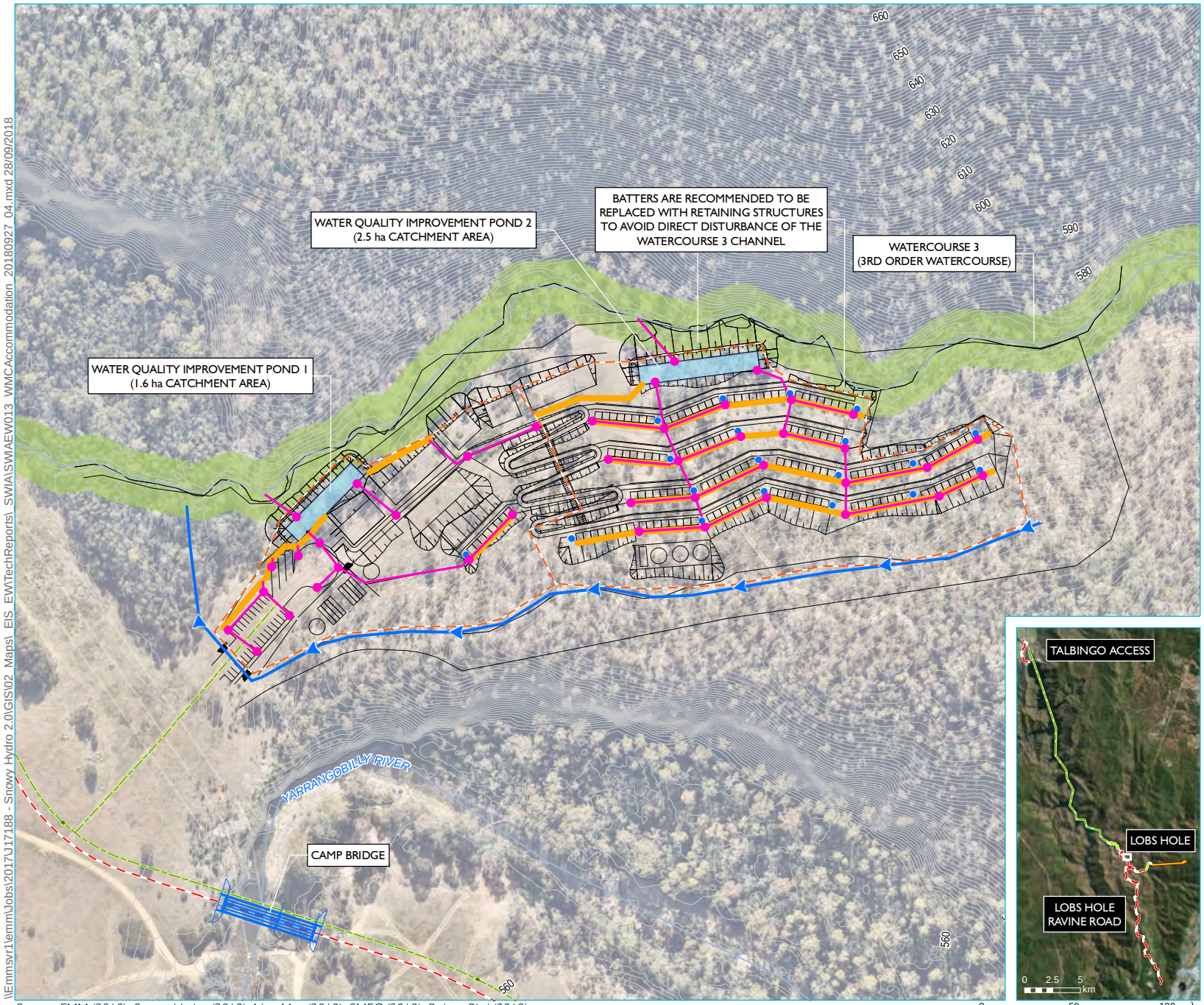
Waste water (ie sewage) management is discussed separately in Section 6.8.

6.5.3 Mitigation and management

The effective management of stormwater from the accommodation camp requires a stormwater system design that can be integrated with the proposed civil design and is suitable for the steep topography and shallow soils. The stormwater management area is 4.1 ha. The proposed approach will seek to:

- maximise the use of source controls, such native endemic landscaping, permeable paving and rain gardens;
- avoid infiltration-based systems (due to the shallow soils);
- provide a piped drainage system to convey stormwater through the camp area to downstream controls; and
- provide water quality improvement ponds to treat runoff from the accommodation camp and attenuate peak runoff flows.

Table 6.10 provides a summary of the presented controls (or design principles). These controls are shown in a conceptual stormwater management plan (Figure 6.3).



KEY

- Accommodation camp conceptual layout
- Exploratory tunnel
- Permanent bridge
- Access road upgrade
- Communications cable
- Watercourse
- Contour (1m LiDAR)
- Rainwater tank
- Clean water diversion
- Piped drainage
- Surface drain
- Water quality improvement pond
- 15m vegetated riparian zone (inner zone)
- Catchment area boundary

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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018)

Accommodation camp: stormwater management concept

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 6.3

Table 6.10 Water management controls: accommodation camp

Control	Description
WM_4.1	A stormwater management plan will be prepared as part of the detailed design of the project. The plan will consider geotechnical constraints including shallow soils.
WM_4.2	Clean water from upslope areas will be diverted around the accommodation camp.
WM_4.3	A piped drainage system will be established to capture stormwater and convey it to the proposed water quality improvement ponds. The drainage system will have a 20% AEP capacity. Overland flow paths will be provided as required.
WM_4.4	All pervious areas including batters will be vegetated with endemic native vegetation where practicable.
WM_4.5	Runoff from roof areas will be collected in rainwater tanks where practicable. Captured water will be used for non-potable uses, reducing runoff volumes.
WM_4.6	Source controls including permeable pavers and rain gardens will be used where practicable.
WM_4.7	All runoff from the accommodation camp will be treated in water quality improvement basin(s). The basin(s) will be designed as constructed wetlands where practicable and will provide a water quality improvement function and attenuate peak runoff rates from the accommodation camp.
WM_4.8	Collectively, the stormwater controls will be sized and configured to achieve the water quality specifications provided in Table 6.12.
WM_4.9	The water quality improvement pond batters will be established using retaining structures or other suitable measures to avoid disturbance of the Watercourse 3 channel.

6.5.4 Discharge characteristics

The following sections provide a summary of discharge regimes and quality of accommodation camp stormwater runoff. Residual impacts are discussed in Chapter 7.

i Discharge regimes

Table 6.11 describes the discharge mechanisms and regimes from the accommodation camp water management basins.

Table 6.11 Discharge regimes from accommodation camp

Accommodation camp	
Basin type	Constructed wetland style basins that will maintain permanent water. An extended detention zone will be provided above the permanent water zone. The extended detention zone will drain slowly through a low-flow outlet. Overflows will occur via a high-flow outlet when the basins are full.
Discharge mechanism	Discharges from the extended detention zone will occur via a low-flow outlet during and for 2 to 3 days after most material rainfall[1] events. Overflows via a high-flow outlet will occur when basins are full.
Discharge frequency	Discharge of low flows is expected to occur 50 to 100 days per year. Overflows via the high-flow outlet will occur occasionally during intense rainfall.
Basin dewatering	No dewatering is proposed.
Discharge volumes	Discharge volumes will be similar to runoff volumes (approximately 50%[2] of rainfall)

Notes: *1. Material rainfall refers to 5 mm or more in a day.*

2. A runoff coefficient of 50% of rainfall is a conservative value for the accommodation camp water management area, which is inclusive of hardstand and landscaped areas and accounts for some volume reduction from the capture and use of roof water in rainwater tanks.

ii Discharge quality

Table 6.12 provides the predicted water quality characteristics of discharges from the accommodation camp. The water quality characteristics have been established based on data from other representative sites, with consideration given to the benefits of the presented controls. No allowance has been made for site specific factors that may influence water quality. Site-specific trigger values may be developed during Exploratory Works.

Table 6.12 Discharge quality for the accommodation camp (during operation)

Analyte	Units	Trigger value	Discharge concentration		Comments
			Typical	Maximum	
Turbidity	NTU	2-25	2-25	50	Constructed wetland style basins will remove some fine and dispersive suspended sediments. This will result in lower turbidity levels and suspended solids concentrations.
Suspended sediment	mg/L	-	<10	25	
Oxidised nitrogen	mg/L	0.015	0.1	0.4	Constructed wetland style basins will reduce nitrogen concentrations.
Total nitrogen	mg/L	0.25	0.4	1.0	
Reactive phosphorus	mg/L	0.015	0.02	0.05	Constructed wetland style basins will reduce phosphorus concentrations.
Total phosphorus	mg/L	0.02	0.05	0.1	
Dissolved metals	mg/L	Note 1	Concentrations of some metals may exceed relevant trigger values for the Yarrangobilly River.		Constructed wetland style basins will reduce the concentrations of some dissolved metals (if they are elevated in runoff).

Notes: 1. Trigger values for 99% level of species protection apply.

6.5.5 Monitoring and contingency measures

i Proposed monitoring

Monitoring of runoff from the two water quality improvement ponds will be undertaken four times per year during wet weather conditions as part of the comprehensive wet weather monitoring program. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Contingency measures

The following additional measure could be implemented if monitoring identifies unacceptable impacts:

- the water treatment chemical approach proposed for construction areas can be applied if required.

6.6 Stormwater management: portal construction pad

6.6.1 Overview

i Proposed facility

A portal construction pad for the exploratory tunnel will provide a secure area for construction activities. Proposed infrastructure at the pad will primarily support tunnelling activities and include a concrete batching plant and associated stockpiles, site offices, maintenance workshops, refuelling facilities, construction support infrastructure, car parking and equipment laydown areas.

Stockpile areas will allow for around two to three months supply of concrete aggregate and sand for the concrete batching plant to ensure that the construction schedule for the proposed access road works do not interfere with the exploratory tunnel excavation schedule. A temporary excavated rock stockpile area is also required to stockpile material excavated during tunnel construction prior to its transfer to the larger excavated material emplacement areas.

The proposed layout of the portal construction pad is shown in Figure 2.4.

ii Setting

The portal construction pad will be established in steep topography that falls to the west towards the Yarrangobilly River floodplain at approximately 1V to 5H. There are several steep ephemeral drainage lines that traverse the pad area. These drainage lines receive runoff from the steep terrain located to the east of the proposed construction pad and have catchment areas of up to 6 ha.

Soils within the construction pad and upslope area are identified as Tenosols soils that are described in Table 4.5 as being shallow soils that typically overlie hard rock.

The construction pad will comprise a terraced landform that will provide near-level lay down areas that are suitable for the proposed activities. The landform will be primarily established by cutting into the underlying hard rock. However, the lower lay down area will be partially established by filling. Stabilised rock batters or retaining walls will be established between terraces and the existing landform.

The lay down areas will comprise either concrete hardstand or compacted road base and will be integrated with an access road that will be aligned centrally through the facility. Stormwater runoff will be collected in a piped drainage system that will discharge to a water management basin located on the Yarrangobilly River floodplain.

iii Water management overview

Water within the construction pad will be managed by the following water management systems:

- The risk of contamination of stormwater from construction activities will be minimised by covering and bunding high risk areas.
- A stormwater system will manage runoff from the pad and upslope clean water areas. The stormwater management system is described in this section.
- A process water system will manage water produced in the tunnel and water that is used by the construction activities. The process water management system is described in Section 6.7.

- Waste water (ie sewage) will be transported (via tanker) to a waste water treatment plant near the accommodation camp. The waste water management system is described in Section 6.8.

6.6.2 Potential water management impacts

The portal construction pad will provide a secure area for construction activities. Some construction activities and material stored within in the pad area have potential to contaminate stormwater. Key water management risks include:

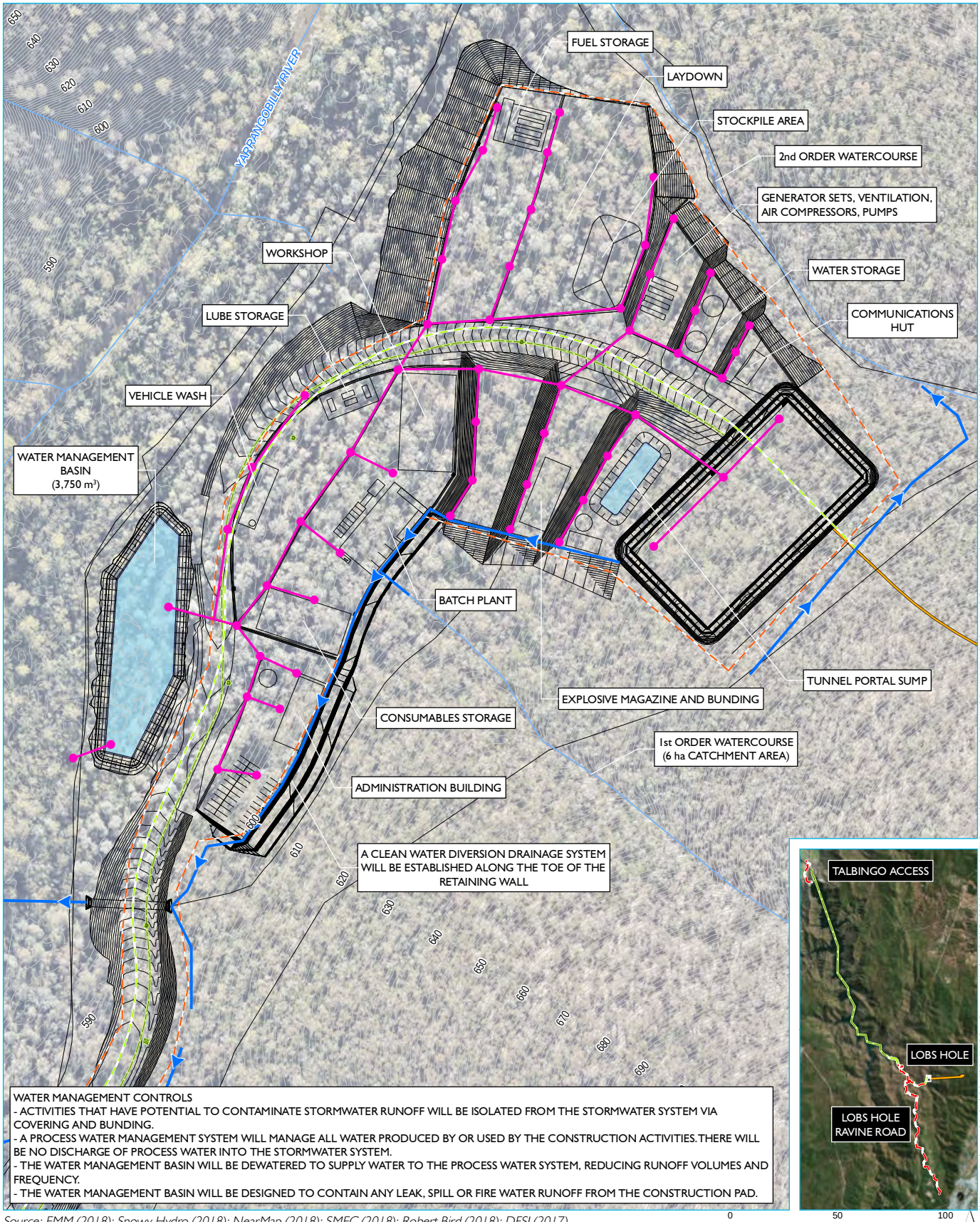
- contamination of stormwater runoff due to construction activities;
- stormwater flooding issues and/or erosion of the landform due to inadequate drainage system design;
- increased concentrations and loads of suspended solids and nutrients concentrations in runoff from the construction pad; and
- potential for contamination of receiving waters due to accidental leaks or spills or runoff of water used for fire fighting purposes (referred to as fire fighting water).

6.6.3 Water management and mitigation

The effective management of stormwater from the portal construction pad requires controls to:

- minimise the risk of contamination of stormwater from construction activities;
- manage stormwater runoff from the construction pad and upslope clean water areas; and
- contain accidental leaks or spills and fire water runoff.

A stormwater management concept for the portal construction pad is shown in Figure 6.4. Additional information on the controls is provided following the figure.



Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017)

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GDA 1994 MGA Zone 55

KEY

- Exploratory tunnel
- Access road extension
- Communications cable
- Portal construction pad conceptual layout
- Watercourse
- Contour (1m LiDAR)
- Clean water drainage
- Piped drainage
- Water management area

Portal construction pad: water management concept

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 6.4

snowy 2.0

EMM creating opportunities

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i. Management of areas with elevated water quality risks

Some activities that will occur on the portal construction pad have the potential to contaminate stormwater runoff. These areas will be isolated from the stormwater system by covering (ie by a building or roof) and/or bunding. Water produced within the covered and bunded areas will be either:

- managed by the process water system that is described in Section 6.7; or
- disposed as liquid waste to an appropriate facility.

Table 6.13 describes activities that will be undertaken in covered and/or bunded areas.

Table 6.13 Activities that will be undertaken in covered and/or bunded areas

Activity	Water quality risks	Controls
Concrete batching	Runoff from cementitious areas can contain elevated pH, suspended sediments and metals.	All cementitious areas will be covered and bunded, with all water managed in the process water system.
Equipment wash down bays	Construction equipment will be washed using process water in designated wash bays. Wash down water is likely to contain elevated suspended solids and potential for oils and greases. The use of washing agents may also impact water quality and will be avoided where possible.	Equipment wash down bays will be bunded to prevent stormwater ingress. Runoff from the wash bays will be collected and transferred to the process water system.
Hazardous consumables storage	Some hazardous consumables are likely to be hazardous materials.	Hazardous consumables will be stored in a building. Any hazardous materials will be stored in bunded areas.
Workshop	Water produced from work shop area may contain oils and greases and numerous other pollutants.	All workshop activities will be undertaken within a building. Any waste will be disposed offsite to an appropriate waste management facility.
Fuel storage and refuelling area	Hydrocarbons in stormwater runoff and the risk of major leaks or spills of hydrocarbons.	Fuel storage and refuelling areas will be covered and bunded to prevent stormwater ingress and capture any leaks or spills.
Generator and air compressor pumps	Risk of major leaks and spills of hydrocarbons or compressor fluids.	Generator and air compressor pumps will be bunded to contain any leak or spill.

ii. Management of stormwater runoff

A stormwater management system will be prepared that describes the management of runoff from:

- the portal construction pad and adjoining access road area, which has a collective area of 5.6 ha; and
- clean water catchments.

The following management approach is proposed:

- Clean water runoff from upslope catchments (that have areas of up to 6 ha) will be diverted through the portal construction pad in a designated clean water drainage system. This will avoid the use of contour drains to divert clean water around the pad.

- Runoff from the pad area will be collected in a piped stormwater drainage system that will convey runoff to a water management basin that will be located on the Yarrangobilly River floodplain, immediately to the west of the pad. The piped drainage system will have a 1% AEP capacity.

- All aggregate storage and stockpile areas will be bunded to prevent stormwater ingress. Runoff from these areas will be treated in sediment wedge pits to remove all aggregate material and coarse sediments. Sediment wedge pits will overflow into the piped drainage system.

- All runoff from the portal construction pad and adjoining access road will be conveyed to a water management basin. A basin volume of 3,750 m^3 is considered to be practical (to be confirmed at detailed design). A basin volume of 3,750 m^3 will capture the runoff volume from 85 mm of rainfall over 5 days, exceeding the 5 day 95th percentile rainfall event (56.8 mm over five days). The basin will provide a water quality improvement function during overflow conditions. Water captured in the basin will be extracted to supply the process water system.

- The chemical water treatment system that is proposed for construction areas (see Section 6.3.3) will be incorporated into the basin. Water captured in the basin will be extracted to supply the process water system. The water balance modelling described in Section 6.7 estimates that extraction will reduce overflow volumes from the basin into the Yarrangobilly River by 69% (reference Table 6.20) over the 26 month tunnel construction period.

i Containment leaks or spills and fire water runoff

A major leak, spill or firewater runoff could occur from any portion of the portal construction pad area. Where possible and safe, leaks and spills will be contained near the source and remediated. However, as these incidents are generally associated with some sort of accident or emergency containment at source may not be possible. The water management basin will be designed to provide a freeboard between its overflow pipe and spillway. The freeboard volume will be calculated to contain all conceivable leak, spill and firewater runoff volumes. The overflow pipe will have a manual shutoff valve that will enable site management to shut off the overflow pipe to enable the basin to contain any leak, spill or fire water runoff.

ii Summary of controls

Table 6.14 provides a summary of controls (or design principles).

Table 6.14 Water management controls: portal construction pad

Control	Description
WM_5.1	A stormwater management plan will be prepared as part of the detailed design of the project. The plan will be integrated with the process water system.
WM_5.2	Where practical, all activities that will occur on the portal construction pad with potential to contaminate stormwater runoff will be isolated from the stormwater system by covering (ie by a building or roof) and bunding. Water produced within the covered and bunded areas will be either: • managed by the process water system; or • disposed as liquid waste to an appropriate facility.
WM_5.3	Clean water from upslope areas will be diverted through or around the portal construction pad in a designated clean water drainage system.
WM_5.4	A piped drainage system will be established to capture stormwater and convey it to the water management basin. The drainage system will have a 1% AEP capacity. Overland flow paths will be provided as required.

Table 6.14 Water management controls: portal construction pad

Control	Description
WM_5.5	All aggregate storage and stockpile areas will be bunded to minimise stormwater ingress. Runoff from these areas will be treated in sediment wedge pits or other sediment controls to remove all coarse material. Sediment wedge pits will overflow into the piped drainage system.
WM_5.6	All runoff from the portal construction pad and adjoining access road will be conveyed to a water management basin with adequate capacity for at least a 5 day 95th percentile rainfall event and include additional volume to accommodate required water quality treatments (ie a total volume of at least 3,750 m^3). The basin will provide a water quality improvement function. Water captured in the basin will be extracted to supply the process water system. Water treatment chemicals will be applied to the water management basin to enhance sedimentation and phosphorous and dissolved metal removal rates. Only water treatment chemicals that have a low risk of increasing the toxicity of treated stormwater will be used. Water treatment chemicals will be applied using an automated chemical dosing and mixing system. The system will be designed to meet the water quality specifications provided in Table 6.16. The design treatment rate will be the 1 year ARI peak flow.
WM_5.7	The water management basin will be designed to provide a freeboard between its overflow pipe and spillway. The freeboard volume will be calculated to contain probable leaks, spills and firewater runoff volumes. The overflow pipe will have a manual shutoff valve that will enable site management to shut off the overflow pipe to enable the basin to contain any leak, spill or fire water runoff.

6.6.4 Discharge characteristics

The following sections provide a summary of discharge regimes and water quality. Residual impacts are discussed in Chapter 7.

i Discharge regimes

Table 6.15 describes the discharge mechanisms and regimes from the portal construction pad water management basins.

Table 6.15 Discharge regimes from portal construction pad

Portal construction pad	
Basin type	Sedimentation basin. A basin volume of 3,750 m^3 is considered to be practical (to be confirmed at detailed design). A basin volume of 3,750 m^3 will capture the runoff volume from 85 mm of rainfall over 5 days, exceeding the 5 day 95th percentile rainfall event (56.8 mm over five days).
Water treatment	A chemical water treatment system will treat all discharge during a 1 year ARI and lower magnitude rainfall events.
Discharge mechanism	Discharges will occur when the basin is full. When full, discharge will occur via spillway overflows during and shortly after rainfall.
Discharge frequency	Discharge will occur approximately 2 to 3 times per year.
Basin dewatering	The basin will be dewatered to top-up the process water system.
Discharge volumes	Water balance model results (Table 6.20) estimate that discharge volumes are 31% of the runoff volume, with 69% of runoff removed from the basins via dewatering.

Notes: 1. Material rainfall refers to 5 mm or more in a day.

ii Discharge quality

Table 6.16 provides the predicted water quality characteristics of discharges from the portal construction pad basin. The water quality characteristics have been established based on data from other representative sites, with consideration given to the benefits of the presented controls. No allowance has been made for site specific factors that may influence water quality. Site specific trigger values may be developed during Exploratory Works.

Table 6.16 Discharge quality for the portal construction pad (during construction and operation)

Analyte	Units	Trigger value	Discharge concentration		Comments
			Typical	Maximum	
Turbidity	NTU	2-25	2-25	25	Water treatment will enhance removal of fine and dispersive suspended sediments. This will result in low turbidity levels and suspended solids concentrations.
Suspended sediment	mg/L	-	<5	20	
Oxidised nitrogen	mg/L	0.015	0.2	0.5	Water treatment chemicals may reduce organic nitrogen concentrations. No material reduction in oxidised nitrogen concentrations is expected.
Total nitrogen	mg/L	0.25	0.6	2.0	
Reactive phosphorus	mg/L	0.015	0.02	0.05	Water treatment chemicals will reduce phosphorus concentrations.
Total phosphorus	mg/L	0.02	0.02	0.05	
Dissolved metals	mg/L	Note 1	Concentrations of some metals may exceed relevant trigger values for the Yarrangobilly River.		Water treatment may reduce the concentrations of some dissolved metals (if they are elevated in runoff).

Notes: 1. Trigger values for 99% level of species protection apply.

6.6.5 Monitoring and contingency measures

i Monitoring

Monitoring of water in the water management basin will be undertaken four times per year during wet weather conditions as part of the comprehensive wet weather monitoring program. Refer to Chapter 8 for further details on the proposed surface water monitoring plan.

ii Contingency measures

The following additional measure could be implemented if monitoring identifies unacceptable impacts:

- stormwater from the water management basin could be dewatered to Talbingo Reservoir using the pipeline that will convey the controlled discharge of process water (discussed in Section 6.7).

6.7 Process water management

6.7.1 Overview

As discussed in Section 6.6, construction activities that may produce contaminated water streams will be isolated from the stormwater system to avoid the contamination of stormwater runoff. A process water system is required to manage this water. The system will manage tunnel affected water that will be dewatered from the exploratory tunnel.

Groundwater modelling undertaken for the Exploratory Works predicts that groundwater inflows into the tunnel will increase from zero at tunnel commencement to 0.45 ML/day (161 ML/year) near completion (EMM 2018b). Hence, the volume of water that requires management will progressively increase over the tunnel construction period. Figure 6.5 shows the predicted and maximum plausible inflow rates over the 26-month tunnel construction period (EMM 2018b).

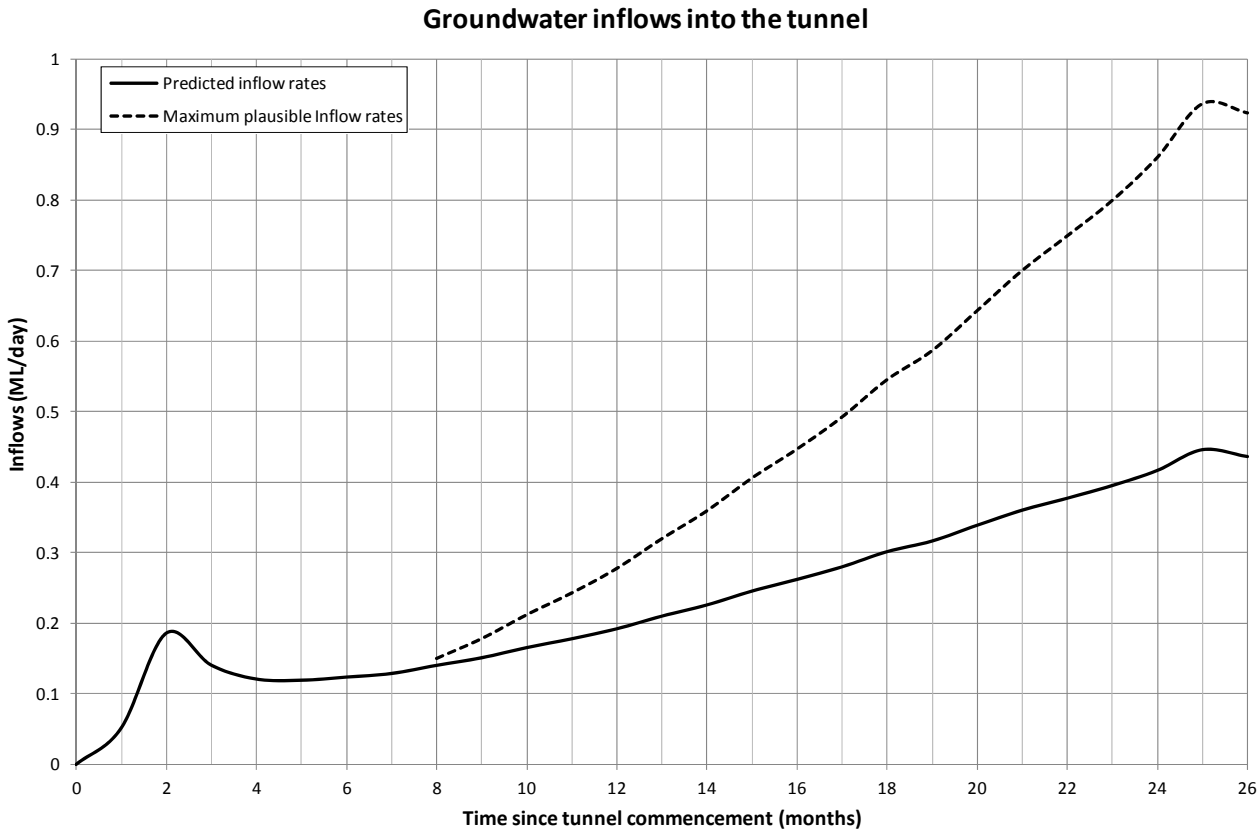


Figure 6.5 Predicted groundwater inflow rates

Water balance modelling has been undertaken to assess the functionality of the process water system over the tunnel construction period, under a range of weather conditions. Modelling methods, assumption and results are explained in a method statement provided in Appendix D.

This section describes the process water management system and presents key water balance results.

6.7.2 Potential water management impacts

Untreated process water has the potential to be contaminated due to its use in and interaction with construction activities. Potential management risks include:

- the uncontrolled discharge of process water into the stormwater system due to inadequate system design or stormwater ingress into the process water system;
- operational health and safety risks from the re-use of process water; and
- receiving water impacts due to the:
  - inadequate treatment of process water that is discharged; or
  - extraction of water.

6.7.3 Process water management system

The process water management system will be designed to:

- manage potentially contaminated water produced from construction activities; and
- supply water for use in construction activities.

The system will be designed to prevent (where possible) the ingress of stormwater into the process water system. This will be achieved by covering and bunding process water areas. Captured process water will be treated in a water treatment plant to a level that can be used for:

- tunnel construction;
- concrete production;
- equipment wash-down; and
- access road dust suppression.

At times, the process water management system will source additional water from the portal construction pad's water management basin and Talbingo Reservoir as required to meet demand. Any surplus process water will be further treated prior to discharge to Talbingo Reservoir. This arrangement will avoid either discharge to or extraction from the Yarrangobilly River.

Figure 6.6 shows the process water management system. Additional information on the sources and uses of process water and water treatment plant specifications is provided in Table 6.17.

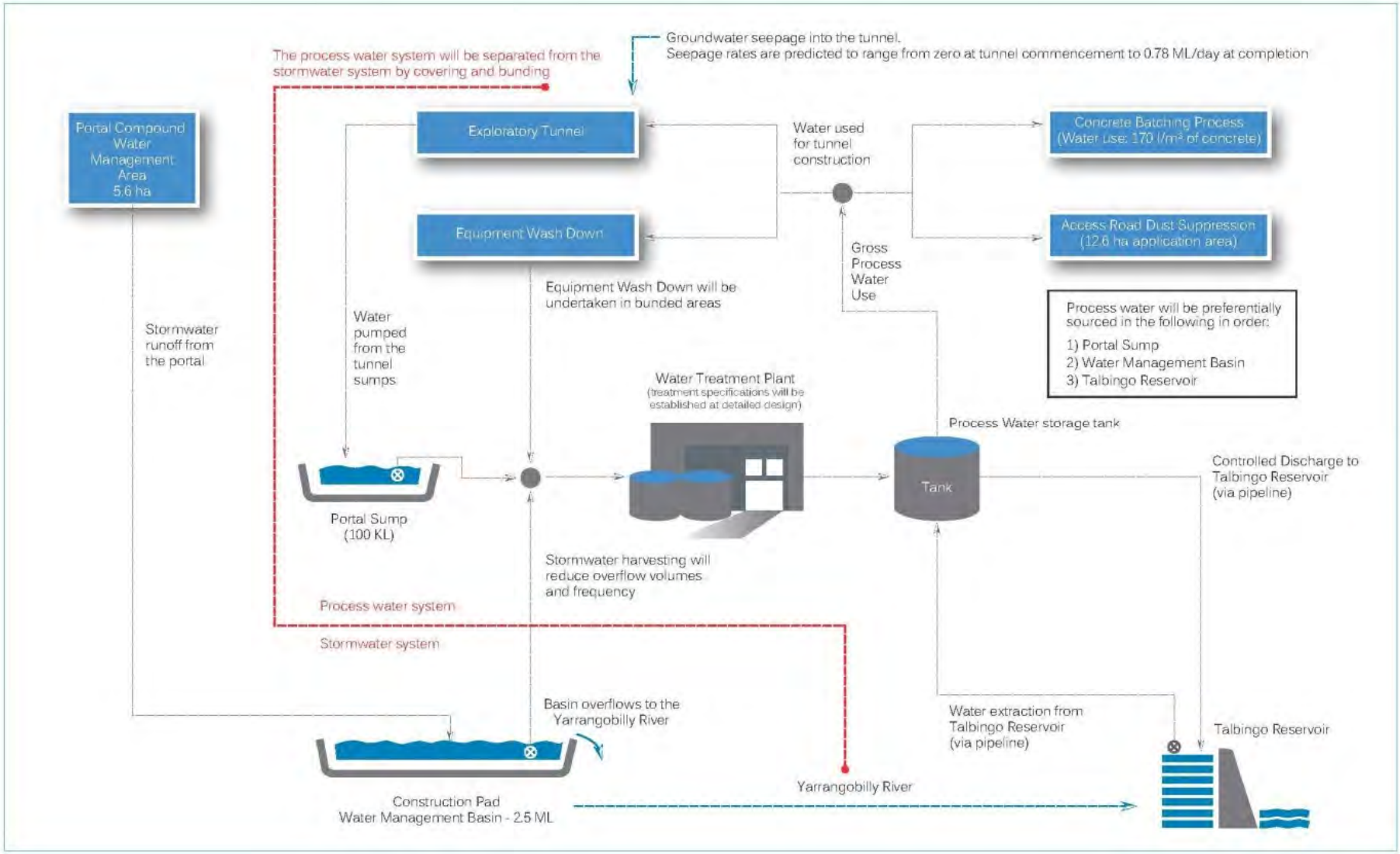


Figure 6.6 Process water management system

i Process water sources and uses

Table 6.17 provides information on expected process water sources and uses.

Table 6.17 Process water sources and uses

	Description
Sources	
Tunnel affected water	Tunnel affected water refers to all water that will be dewatered from sumps within the exploratory tunnel. The majority of the water will originate from groundwater inflows which are expected to progressively increase from zero to 0.45 ML/day over the estimated 26-month exploratory tunnel construction period. Some additional water will originate from water used in the construction activities. Groundwater inflows into the tunnel are not expected to have poor water quality based on groundwater sampling results (EMM 2018b). Hence, the potential for contamination of the tunnel affected water is due to the use and interaction with construction activities that include drilling, blasting, shotcreting and washing down of equipment. The water quality characteristics of tunnel affected water are likely to be variable and cannot be reliably established. However, the water may contain elevated suspended solids, nitrate (due to use of explosives) and metal concentrations.
Uses	
Equipment wash facilities	Construction equipment will be washed using process water in designated wash bays. Runoff from the wash bays will be collected and transferred to the process water system. As the washing will be undertaken with process water, the net use of water will be minimal. Wash down water is likely to contain elevated suspended solids and potential for oils and greases. The use of washing agents may also impact water quality and will be avoided where possible.
Shotcrete production	The production of shotcrete will require 170 L of water per m^3 of concrete. Average water use for shotcrete is estimated to be 12 kL/day.
Tunnel construction water use	Process water will be used in the tunnel construction process. The average water use is estimated to be 10 kL/day.
Access road dust suppression	Water application to access roads is a proposed air quality management control (Jacobs 2018). It is estimated that water application to 12.6 ha of access roads will be required for the duration of Exploratory Works. Daily water use for dust suppression will range from zero during wet weather to over 1 ML/day on a dry summers day.

ii Water treatment

The process water system will incorporate a water treatment plant that will treat water to a suitable quality for its proposed use in construction activities. Additional treatment will be provided for any water that is to be discharged to the Yarrangobilly River arm of Talbingo Reservoir via the controlled discharge pipeline to meet the proposed discharge estimates shown in Table 6.18. For each analyte, the number of dilutions required to meet relevant trigger values is also expressed as a dilution factor.

Table 6.18 Process water – predicted treated quality and required dilutions

	Units	Trigger value[1]	Groundwater inflows		Untreated process water[2]		Treated process water[3]			
			Median	Max	Median	Max	Median	DF	Max	DF
Physio-chemical										
Electrical conductivity (EC)	µS/cm	20–30	780	1,122	780	1,122	780	26	1,122	37
pH	-	6.5–8.0	8.4	9.3	6.5–8.0	6.5–8.0	6.5–8.0	1	6.5–8.0	1
Turbidity	NTU	1–20	1–20	1–20	50–100	150	1–20	1	1–20	1
Oil & grease	mg/L	5	Nil	Nil	<5	10	<5	1	<5	1
Nutrients										
Total ammonia - N	mg N/L	0.01	0.16	0.30	0.16	0.30	0.05	5	0.1	10
Oxidised nitrogen (NO_x)	mg N/L	0.01	0.03	0.20	0.6	0.8	0.18	18	0.25	25
Total nitrogen (TN)	mg N/L	0.35	0.55	0.70	0.6	1.0	0.23	<1	0.35	1
Reactive phosphorus (FRP)	mg P/L	0.005	0.01	0.01	0.15	0.3	0.02	4	0.05	10
Total phosphorus (TP)	mg P/L	0.01	0.06	0.66	0.3	0.66	0.02	2	0.05	5
Metals (dissolved)										
Aluminium (Al)	mg/L	0.055	-	-	<0.055	0.01	<TV	<1	<1	<1
Cadmium (Cd)	mg/L	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<TV	<1	<1	<1
Total chromium (Cr)	mg/L	0.001[4]	0.001	0.013	0.003	0.013	<TV	<1	<1	<1
Copper (Cu)	mg/L	0.0014	0.0015	0.004	0.003	0.007	<TV	<1	<1	<1
Mercury (Hg)	mg/L	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<TV	<1	<1	<1
Nickel (Ni)	mg/L	0.011	0.002	0.008	0.002	0.008	<TV	<1	<1	<1
Lead (Pb)	mg/L	0.0034	<0.001	<0.001	<0.001	<0.001	<TV	<1	<1	<1
Zinc (Zn)	mg/L	0.008	0.0095	0.128	0.020	0.128	<TV	<1	<1	<1

Notes: *1. Trigger values (chronic) for Talbingo Reservoir.*

2. Untreated process water accounts for some contamination due to tunnel construction activities.

3. Treated process water quality information is based on water treatment analysis and other available data.

4. For Cr(VI).

DF - refers to dilution factor, which is calculated as the maximum concentration/trigger value. TV - refers to trigger value

6.7.4 Water balance

A water balance of the process water system has been prepared using GoldSim water balance software. The objectives of the model are to:

- demonstrate the functionality of the process water system over the estimated 26-month exploratory construction period;
- estimate the probable range in water transfer volumes over the above period, having regard to variable weather conditions; and
- assist in the determination of water licensing requirements.

Modelling methods, assumptions and results are explained in a method statement provided in Appendix D.

i Model results

Model results are presented in flow chart and table formats.

a. Flow chart results

The flow charts have been prepared to describe the typical functionality of the process water management system during dry, median and wet rainfall conditions. The flow charts present monthly values that have been calculated from annualised results (ie monthly value = annual value divided by 12). This was done to avoid any seasonal variation in the results. Flow charts have been prepared for months 1, 12 and 26 of the tunnel construction period. Results from median conditions are provided in this section while other flow charts are provided in Appendix D. Table 6.19 provides a reference to all figures.

Table 6.19 Water Balance figure reference

	Dry conditions	Median conditions	Wet conditions
Month 1	Figure D3	Figure 6.7	Figure D5
Month 12	Figure D6	Figure 6.8	Figure D8
Month 26	Figure D9	Figure 6.9	Figure D11

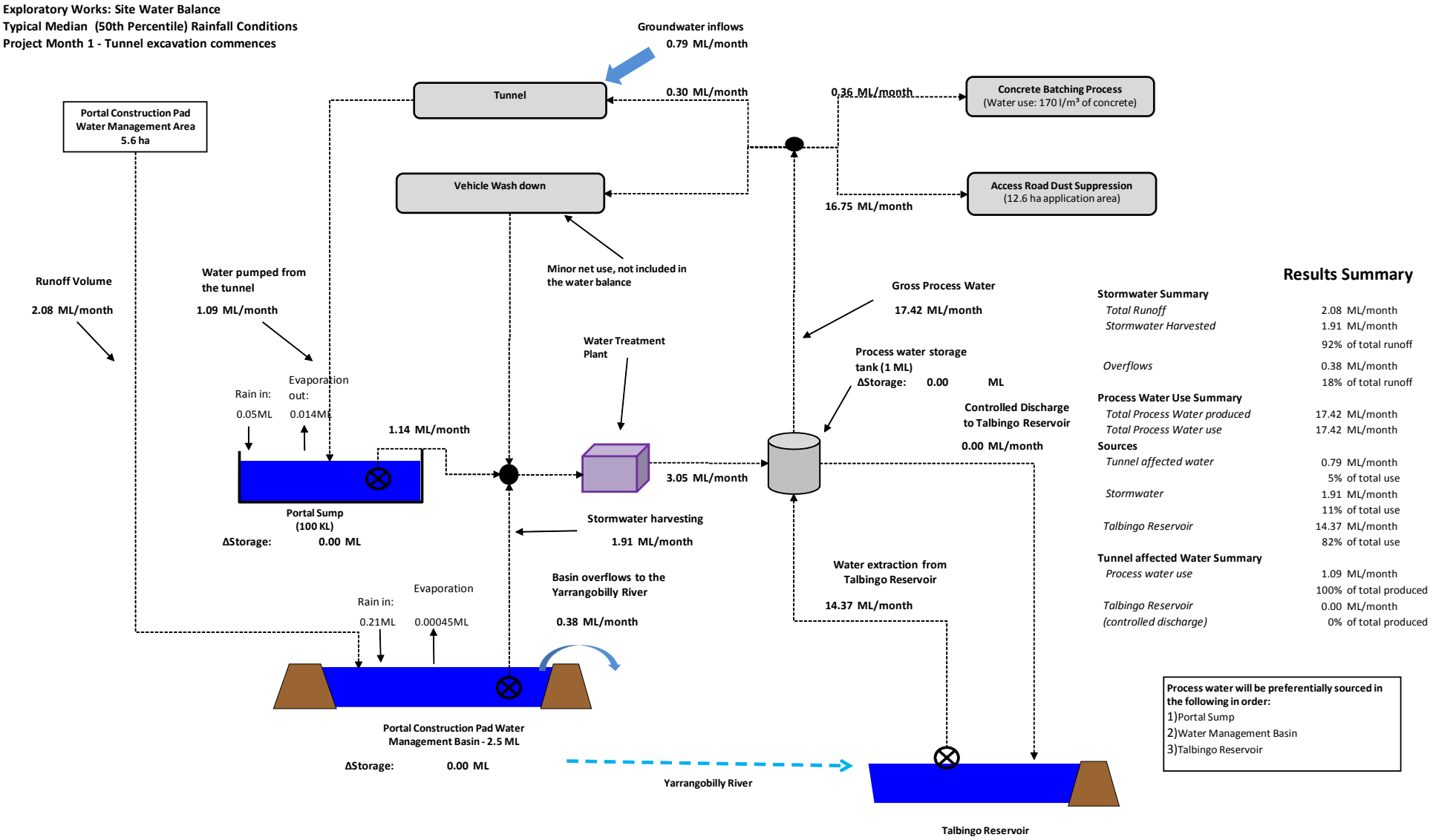


Figure 6.7 Water balance results: Tunnel Month 1 – median rainfall year

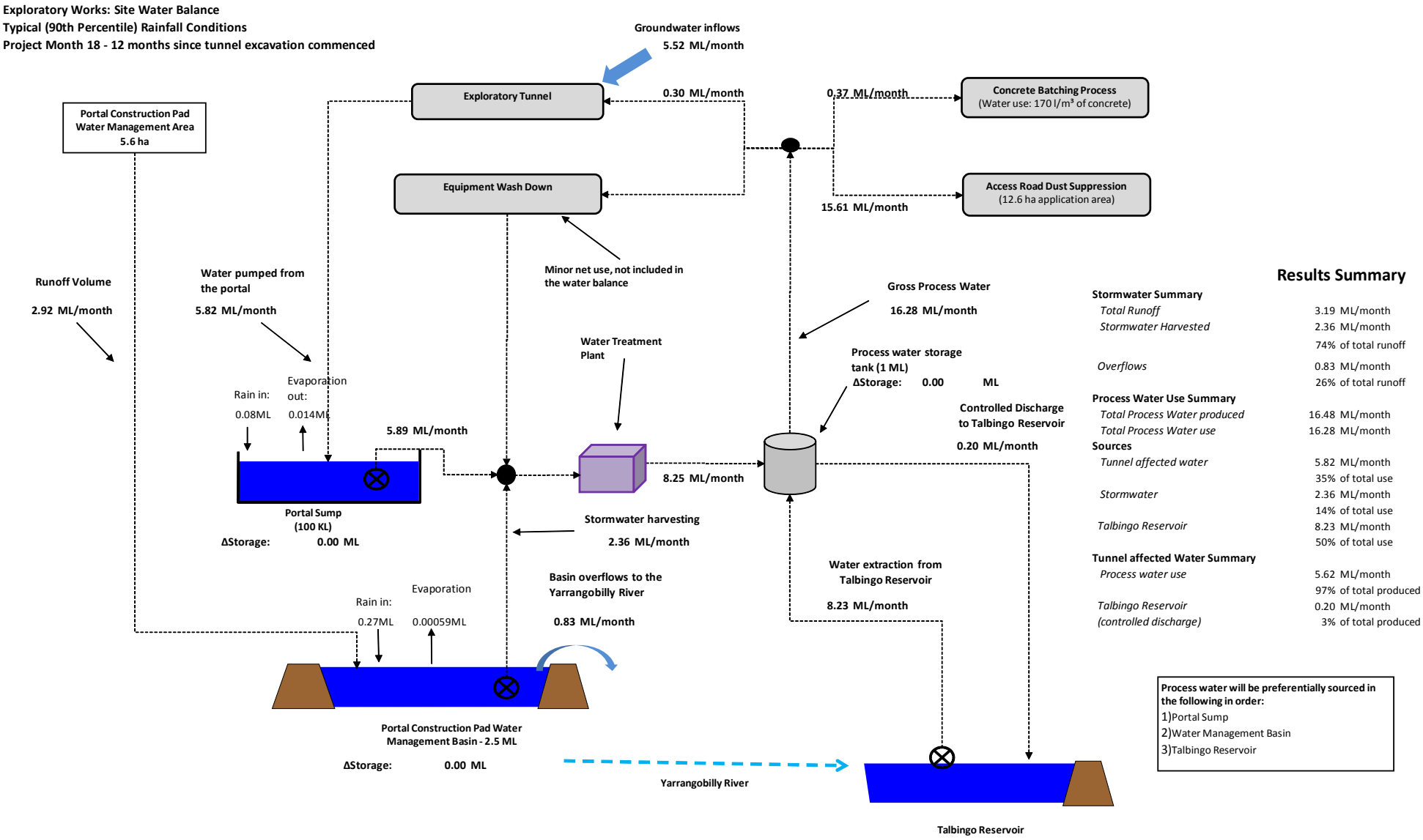


Figure 6.8 Water balance results: Tunnel Month 12 – median rainfall year

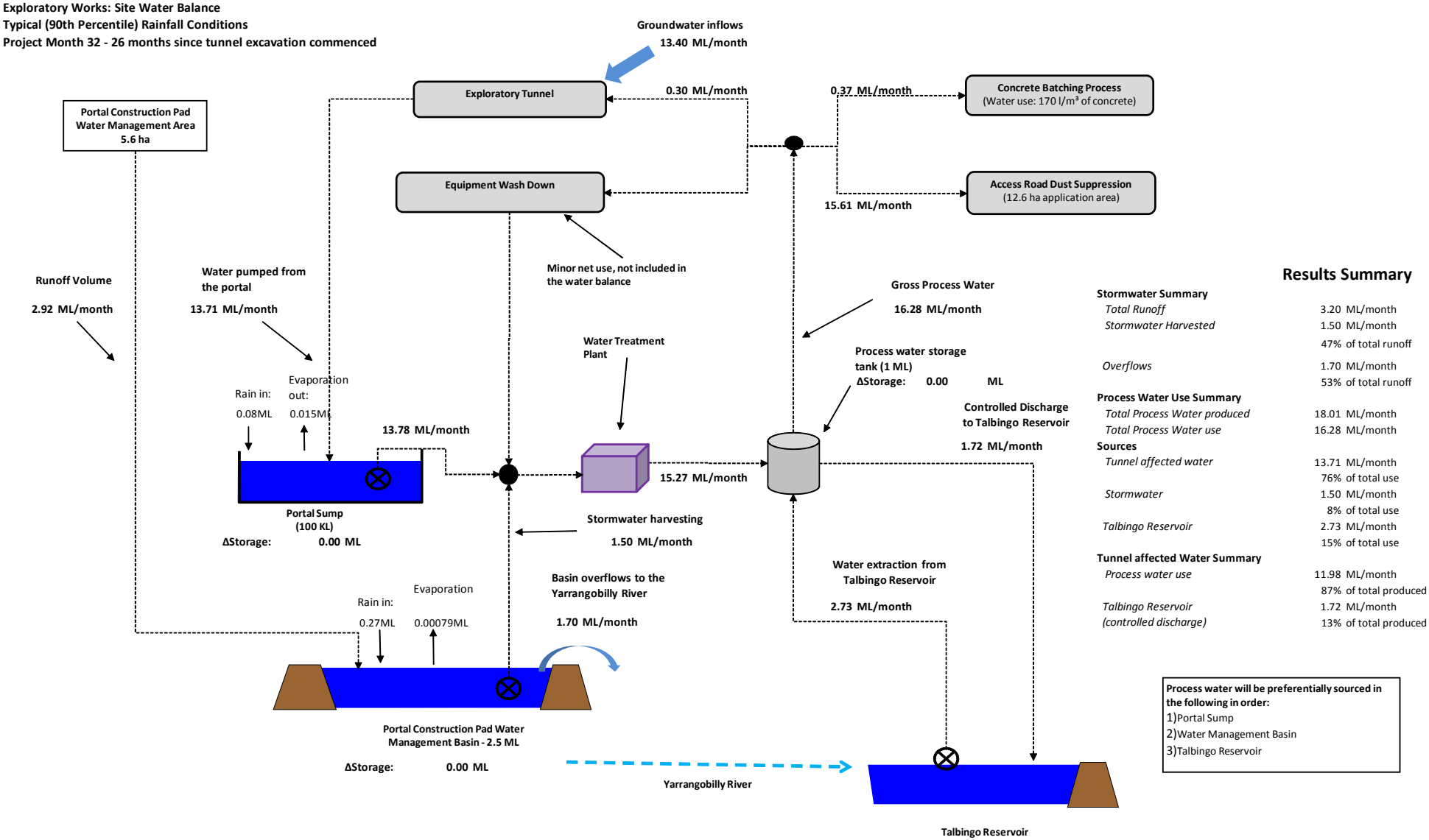


Figure 6.9 Water balance results: Tunnel Month 26 – median rainfall year

b. Tabulated results

The following results are provided in table format:

- Table 6.20 provides a summary of key results that have been calculated for the estimated 26-month exploratory tunnel construction period; and
- Table 6.21 provides monthly and annual statistics for transfers between the process water system and Talbingo Reservoir. The statistics are provided for months 1, 12 and 26 of the tunnel construction period.

Table 6.20 Water balance model results summary

Results	Average values[1]
Stormwater summary	
Stormwater harvested	69% of total runoff
Stormwater overflows	31% of total runoff
Process water use summary	
Sourced from tunnel affected water	41% of total use
Sourced from stormwater	10% of total use
Sourced from Talbingo Reservoir	49% of total use
Tunnel affected water management	
Used process water sources	95% of the total tunnel affected water
Discharge to Talbingo Reservoir (controlled discharge)	5% of the total tunnel affected water

Notes: 1. Average values have been over the 26 month tunnel construction period using the probalistic modelling methods that are discussed in Appendix D.

Table 6.21 Talbingo Reservoir water transfers

	Water transfer volumes		
Conditions	**Month 1**	**Month 12**	**Month 26**
Monthly statistics (ML/month)			
Controlled discharge to Talbingo Reservoir			
Minimum value	0	0	0
10th percentile value	0	0	0.1
50th percentile value	0	0	1.0
90th percentile value	0	0.4	3.1
Maximum value	0	1.1	4.9
Extraction from Talbingo Reservoir			
Minimum value	2.8	0	0
10th percentile value	7.9	3.3	0
50th percentile value	16.9	10.7	2.8
90th percentile value	23.1	18.2	9.4
Maximum value	26.2	21.8	12.5
Annualised statistics (ML/year)			
Controlled discharge to Talbingo Reservoir			
Minimum value	0	0	6

Table 6.21 Talbingo Reservoir water transfers

	Water transfer volumes		
Conditions	**Month 1**	**Month 12**	**Month 26**
10th percentile value	0	0	12
50th percentile value	0	1	16
90th percentile value	0	2	20
Maximum value	0	4	22
Extraction from Talbingo Reservoir			
Minimum value	146	94	26
10th percentile value	149	100	38
50th percentile value	172	118	44
90th percentile value	186	133	55
Maximum value	209	152	64

c. Results discussion

The water balance model results indicated that:

- The majority of tunnel affected water produced over the estimated 26-month exploratory tunnel construction period will be used as process water. However, discharge of treated process water to Talbingo Reservoir will be required at times. This is most likely to occur during winter months or extended periods of wet weather when access road dust suppression water use requirements are low. The frequency and magnitude of discharge will increase over the exploratory tunnel construction period, in line with the expected increase in groundwater inflows.

- Extraction of water from Talbingo Reservoir will be required in most months to meet process water demand. Extraction will be required more frequently in the summer when access road dust suppression demands are higher and during the initial construction period when groundwater inflows are lower.

- Extraction from the portal construction pad's water management basin will reduce overflow volumes from the basin into the Yarrangobilly River by 69% (reference Table 6.20) over the estimated 26-month exploratory tunnel construction period.

ii Model sensitivity

The water balance model has been applied to assess the functionality of the process water management system based on predicted groundwater inflows and estimates of process water use rates. As indicated in Figure 6.5 and described in the groundwater assessment (EMM 2018b), the maximum plausible groundwater inflow rate is approximately double the predicted rate near the end of the tunnel construction period.

Table 6.22 describes the sensitivity of model results due to variation in the following key water balance assumptions:

- assumed groundwater inflow rate; and

- assumed water use for access road dust suppression.

Table 6.22 Model sensitivity

Changes to assumptions	Resulting changes to model results
• Groundwater inflows lower than predicted; and/or • Access road dust suppression water use higher than predicted.	• Decrease in the frequency and magnitude of controlled discharge to Talbingo Reservoir. • Increase in the frequency and magnitude of extraction from to Talbingo Reservoir. • Greater opportunities for stormwater harvesting.
• Groundwater inflows higher than predicted; and/or • Access road dust suppression water use lower than predicted.	• Increase in the frequency and magnitude of controlled discharge to Talbingo Reservoir. • Decrease in the frequency and magnitude of extraction from to Talbingo Reservoir. • Reduced opportunities for stormwater harvesting.

6.7.5 Mitigation and management

Table 6.23 provides a summary of the process water management system controls.

Table 6.23 Water management controls: process water management system

Control	Description
WM_6.1	A process water management system will be established to manage any potentially contaminated water that may be produced by the construction activities.
WM_6.2	The process water management system will be separated from the stormwater system to avoid uncontrolled overflows associated with stormwater ingress.
WM_6.3	The process water system will incorporate a water treatment plant that will treat water to a suitable quality for its proposed use in construction activities. If required to meet water quality criteria, additional treatment will be provided for any water that is discharged to Talbingo Reservoir via the controlled discharge pipeline. This treatment system will meet the water quality specifications provided in Table 6.18.
WM_6.4	The process water management system will have the ability to extract water from the portal construction pad's water management basin. This will be done to top-up supply.
WM_6.5	A reticulation system will be established to enable the process water system to: • extract water from Talbingo Reservoir (as required); and • discharge treated process water into Talbingo Reservoir (as required).

6.7.6 Residual impacts

Residual impacts are discussed in Chapter 7.

6.7.7 Monitoring and contingency measures

i Monitoring

The process water management system will be progressively monitored to ensure adjustments to the system configuration and operation can be made if required. The following monitoring will be undertaken:

- Continuous measurement of all key water transfers including water pumped from the tunnel, all process water use, stormwater harvesting and transfers to and from Talbingo Reservoir.

- Monthly comprehensive monitoring of the quality of tunnel affected water and treated process water.

A comprehensive receiving water monitoring program will also be undertaken for the duration of the Exploratory Works. This program will include monitoring of water quality in Talbingo Reservoir, upstream and downstream of the process water discharge location (refer to Chapter 8)

ii Contingency measures

If the controlled discharge of water to Talbingo Reservoir is of an unacceptable quality, tunnel affected water can be temporarily stored in the tunnel (or an alternative storage) until appropriate adjustments to the water treatment plant are made.

6.8 Waste water management

6.8.1 Overview

As described in Section 2.9.4, it is expected that the workforce for Exploratory Works will be approximately 200 people at peak construction. These workers will be accommodated within the accommodation camp. Waste water will be produced from amenities (showers, toilets, laundry, kitchens etc) within the accommodation camp and construction pad.

Waste water loads have been estimated using a hydraulic load of 240 L/person/day, which includes a 20% contingency above typical values. Applying this load to the peak workforce of around 200 people, a total project waste water load of 48 kL/day has been estimated.

This section describes the waste water management approach and expected impacts.

6.8.2 Potential water management impacts

Potential management risks from the discharge of waste water include:

- changes to the ambient water quality in Talbingo Reservoir due to the disposal of treated waste water; and

- potential for the discharge of untreated waste water into the Yarrangobilly River due to equipment failure.

6.8.3 Mitigation and management

Effective management of waste water requires controls to:

- manage the volumes and quality of waste water produced;

- provide emergency storage to minimise the risk of overflows of untreated waste water to the receiving environment; and

- provide treatment of waste water prior to discharge to the receiving environment.

These controls are described in the following sections.

i Source controls

The following source controls will be implemented to manage the volumes and quality of waste water produced:

- Waste water from the accommodation camp will be reticulated to the waste water treatment plant via a sewer system. The sewer system will be designed to restrict stormwater ingress into the waste water system.
- Water-efficient appliances will be used throughout the accommodation camp to minimise waste water volumes.
- Low phosphorus products will be used for washing activities controlled by site management (ie laundry services and mess hall) and encouraged (via education) for general use.

ii Emergency storage

The waste water treatment plant will provide emergency storage to minimise the risk of overflows of untreated waste water due to power outages or equipment failure. The storage volume will be calculated during detailed design based on analysis of response times from regional waste management contractors to provide emergency trucking and offsite disposal options.

iii Waste water treatment

The waste water system will incorporate a water treatment plant that will treat water to a suitable quality for discharge to the Yarrangobilly River arm of Talbingo Reservoir via the controlled discharge pipeline to meet the proposed discharge estimates shown in Table 6.24. For each analyte, the number of dilutions required to meet relevant trigger values is also expressed as a dilution factor.

Table 6.24 Waste water – predicted discharge quality and required dilutions

	Units	Trigger value[1]	Treated waste water	
			Max	DF
Physio-chemical				
Electrical conductivity (EC)	µS/cm	20–30	20-30	1
pH	-	6.5–8.5	6.5–8.5	-
Turbidity	NTU	2–25	<25	<1
Oil & grease	mg/L	5	<5	<1
BOD	mg/L	-	<5	-
Nutrients				
Total ammonia - N	mg/L	0.01	0.1	10
Oxidised nitrogen (NOx)	mg/L	0.01	0.1	10
Total nitrogen (TN)	mg/L	0.35	0.2	<1
Filterable reactive phosphorus (FRP)	mg/L	0.005	0.06	12
Total phosphorus (TP)	mg/L	0.01	0.06	6
Pathogenic organisms				
E-coli	cfu/100 mL	150	<1	<1

Table 6.24 Waste water – predicted discharge quality and required dilutions

	Units	Trigger value[1]	Treated waste water	
			Max	DF
Enterococci	cfu/100 mL	35	<1	<1
Protozoans	orgs/100 mL	nil	0	<1
Metals (dissolved)				
Aluminium (Al)	mg/L	0.055	<0.055	<1
Cadmium (Cd)	mg/L	0.0002	<0.0002	<1
Chromium (Cr)	mg/L	0.001[2]	<0.001	<1
Copper (Cu)	mg/L	0.0014	<0.001	<1
Nickel (Ni)	mg/L	0.011	<0.004	<1
Lead (Pb)	mg/L	0.0034	<0.001	<1
Zinc (Zn)	mg/L	0.008	<0.008	<1

Notes: 1. Trigger values for Talbingo Reservoir.

2. For Cr(VI).

Max - refers to the maximum concentration. Typical or median concentrations are expected to be substantially lower.

DF - refers to dilution factor, which is calculated as the maximum concentration/trigger value.

iv Summary of controls

Table 6.25 provides a summary of the waste water management controls.

Table 6.25 Water management controls: waste water management system

Control	Description
WM_7.1	Waste water from the accommodation camp will be reticulated to a waste water treatment plant via a sewer system. The sewer system will be designed to restrict stormwater ingress into the waste water system.
WM_7.2	Water efficient fittings will be used to minimise waste water loads.
WM_7.3	Low phosphorus products are to be used for washing activities controlled by site management (ie laundry services and mess hall) and encouraged (via education) for general use.
WM_7.4	The waste water storage system will include emergency storage of untreated waste water. The storage volume will be calculated at detailed design based on analysis of response times from regional waste management contractors to provide emergency trucking and offsite disposal options.
WM_7.5	A waste water treatment plant will meet the water quality specifications provided in Table 6.24.
WM_7.6	Treated waste water will be disposed to Talbingo Reservoir via the controlled discharge pipeline.

6.8.4 Residual impacts

Residual impacts are discussed in Chapter 7.

6.8.5 Monitoring and contingency measures

The waste water system will be progressively monitored to ensure adjustments to the system configuration and operation can be made if required. The following monitoring will be undertaken:

- continuous measurement of the volumes of treated waste water discharge; and

- monthly water quality monitoring of treated waste water.

A comprehensive receiving water monitoring program will also be undertaken for the duration of the Exploratory Works. This program will include monitoring of water quality in Talbingo Reservoir, upstream and downstream of the treated waste water discharge location (refer to Chapter 8).

i Contingency measures

The following additional measures could be implemented if monitoring identifies unacceptable impacts:

- waste water can be temporarily transported for disposal outside of KNP by a waste management contractor; or
- the waste water treatment plant can be modified to improve treatment performance.

6.9 Rock and soil emplacement water management

6.9.1 Overview

i Management concept

It is estimated that up to 750,000 m^3 of bulked rock and soil will be excavated during Exploratory Works. These materials will be placed in one of two emplacement areas at Lobs Hole, which are referred to as the eastern and western emplacement areas. As discussed in Section 2.4, some material will also be subaqueously placed in Talbingo Reservoir.

The eastern emplacement area has a proposed capacity of 500,000 m^3 and will be established in a gully known as Lick Hole Gully. The western emplacement area will be used to store cuttings and other material that has a low geochemical risk. Material stored in the western emplacement area will be suitable for use within the construction of Exploratory Works or for re-use by Snowy Hydro or NPWS in KNP maintenance activities. Both the eastern and western emplacements will be temporary landforms. Should any material remain at these locations following the conclusion of Exploratory Works, it will be transported to a nominated location outside of the KNP, or disposed subaqueously, within a timeframe agreed with NPWS.

The emplacement areas are shown in Figure 2.5.

ii Setting

a Eastern emplacement

The eastern emplacement will be established within Lick Hole Gully. Lick Hole Gully is a third order watercourse that has a 149 ha catchment area (refer to Table 4.7) that extends to the south of the emplacement location to Round Top Mountain.

Site observations indicate that the watercourse has an intermittent flow regime, which means that:

- constant base flows are likely to occur during winter and spring; and
- base flows are expected to cease for weeks or months in late summer and early autumn.

Surface water runoff is expected to occur during and shortly after any material rainfall event.

With reference to the flood maps provided in Appendix C, the eastern emplacement will be above the Yarrangobilly River's 0.05% AEP flood extent, but within the periphery of the PMF extent.

b Western emplacement

The western emplacement will be established on the southern periphery of the Yarrangobilly River floodplain. The flood risk management aspects of the emplacement design are discussed in Chapter 5. There are no watercourses within the emplacement footprint.

6.9.2 Design concept

The primary design objectives are to:

- establish physically stable temporary landforms with low risk of uncontrolled movement either from erosion or flooding; and
- actively manage water quality risks by diverting clean water around the emplacements and capturing and treating seepage from the emplacements.

This section provides an overview of the design concepts for both the eastern and western emplacements.

i Eastern rock emplacement

The eastern emplacement will be designed as a temporary landform. This section describes the landform design and water management approaches.

a. Landform design

The eastern emplacement will be constructed within Lick Hole Gully. The landform will have a large 'flat top' at a level of 595 m AHD. The stockpile will interface with existing topography at the 595 m AHD contour along the western, southern and some portions of the eastern boundary. Benching is proposed along the northern and some portions of the eastern boundary. The benching will comprise 2 m lifts separated by 4 m benches. The benches will be top soiled and revegetated and will grade back towards the emplacement so any runoff from direct rainfall onto the benches and upslope lift will temporarily pond against the toe of the above lift prior to infiltration.

Figure 6.10 shows a design concept for the eastern emplacement.

b. Geochemistry risks and management approach

Some geochemistry analysis of rock samples from a drill hole near the exploratory tunnel and sediment samples from Middle Bay have been undertaken. The results from this analysis are summarised as follows:

- Some rock samples identified that some material may be potentially acid forming (PAF), while other rock samples had excess acid neutralising capacity (ANC) and therefore have acid consuming (AC) potential (SGM environmental 2018).
- The Middle Bay sediment geochemistry indicated high concentrations of total aluminium and iron, that could be released if exposed to acidity (SGM environmental 2018).

Completed geochemistry analysis cannot determine conclusively that the eastern rock emplacement without treatment will attenuate the potential for acid rock drainage (ARD) from PAF rock.

To avoid the uncontrolled placement of PAF rock, excavated material will be geochemically characterised prior to placement. If any potentially acid forming material is encountered, it will be placed in a select area of the emplacement. The potential for acid rock drainage will be treated by placing and compacting layers of limestone (or other suitable AC material) between each rock and sediment layer as required. The volume of limestone (or other suitable AC material) in each layer will be determined stoichiometrically so that the maximum potential acidity from the overlying layer of rock and sediment is treated. This approach will neutralise AMD within the stockpile.

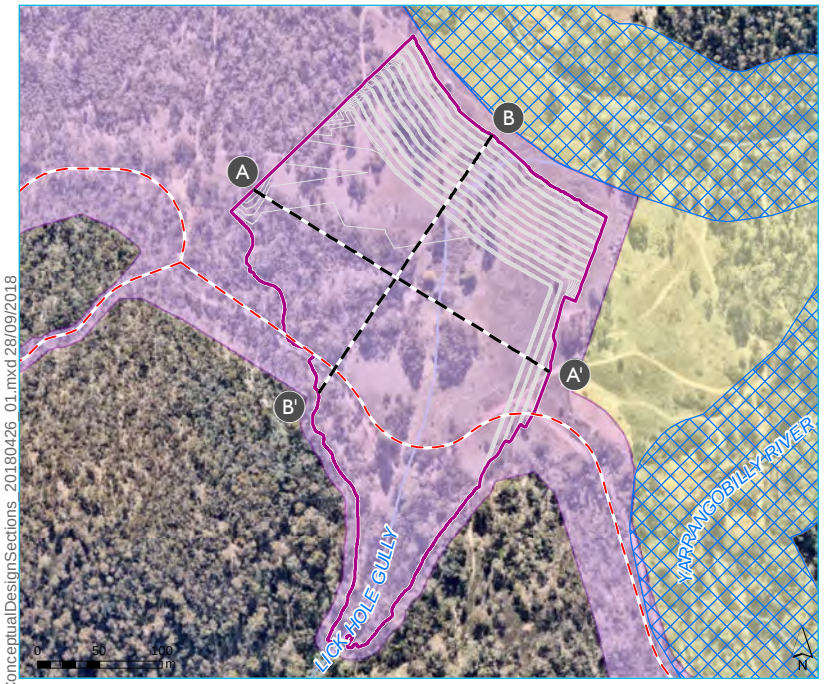
c. Water management approach

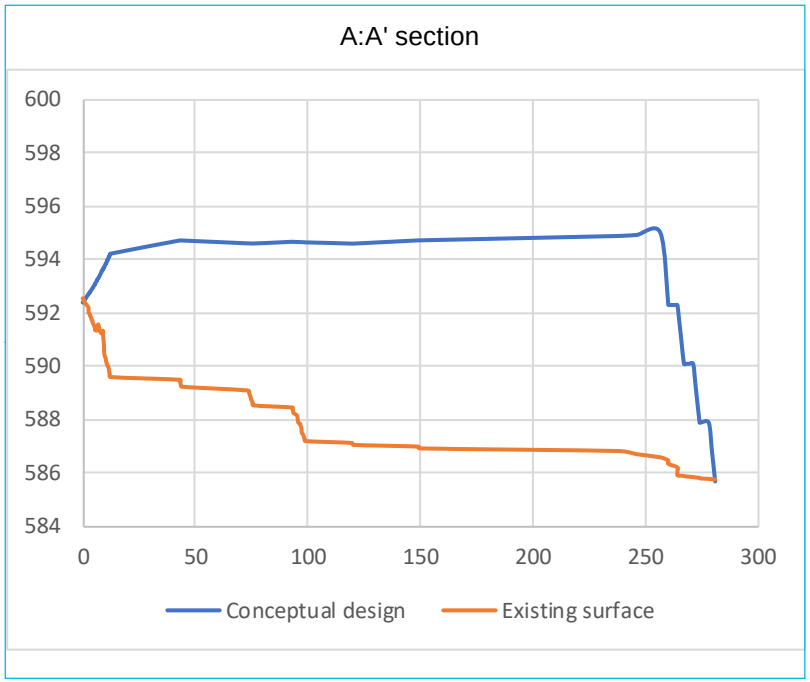
Water quality risks associated with emplacement seepage will be actively managed by capturing all seepage. Captured seepage (water) will be either irrigated to the emplacement (to promote evaporation losses) or treated in the process water treatment plant (as described in Section 6.7). Lick Hole Gully will be diverted around the emplacement to minimise the volume of emplacement seepage.

ii Western emplacement

The western emplacement will be used to store cuttings and other material that has a low geochemical risk and is able to be reused. The landform will be built in a manner that limits compaction and will be top soiled and vegetated to stabilise the landform.

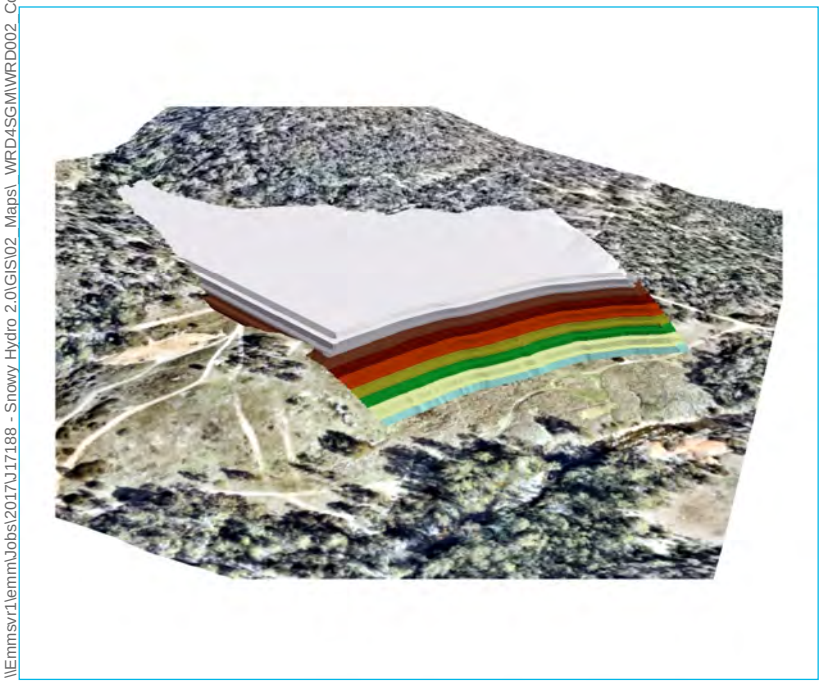
As discussed in Chapter 5, the western emplacement will be designed to prevent the risk of emplacement material being entrained in flood waters during a 0.2% AEP event. This may require a flood protection berm or rock armouring along the northern toe of the emplacement.

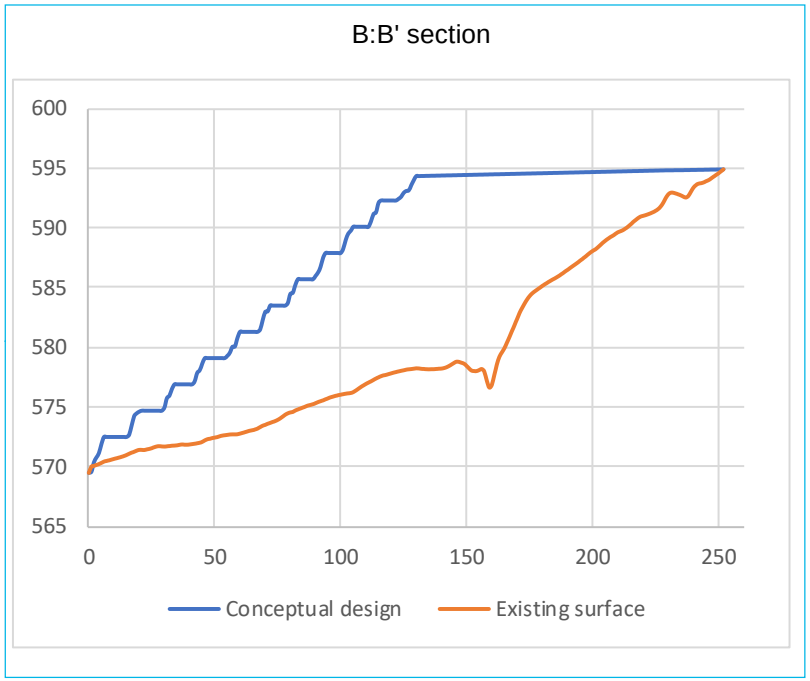




KEY

- Cross-section
- Access road upgrade
- Watercourse
- Conceptual WRD design contour
- Conceptual WRD design footprint
- Yarrangobilly exclusion area
- Disturbance footprint
- Avoidance footprint





Eastern excavated rock emplacement

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 6.10

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); NearMap (2018)

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6.9.3 Potential water management impacts

i Eastern emplacement

Runoff from Lick Hole Gully will be captured and diverted around the eastern emplacement. Some infiltration from direct rainfall onto the emplacement will occur. Identified water management risks include:

- the potential for ARD to occur from some portions of the emplacement material; and
- the potential for the landform to be eroded.

ii Western emplacement

The western emplacement will only be used to store cuttings and other material that has a low geochemical risk. Hence, identified water management risks are limited to the potential erosion of the landform.

6.9.4 Mitigation and management

i Eastern emplacement

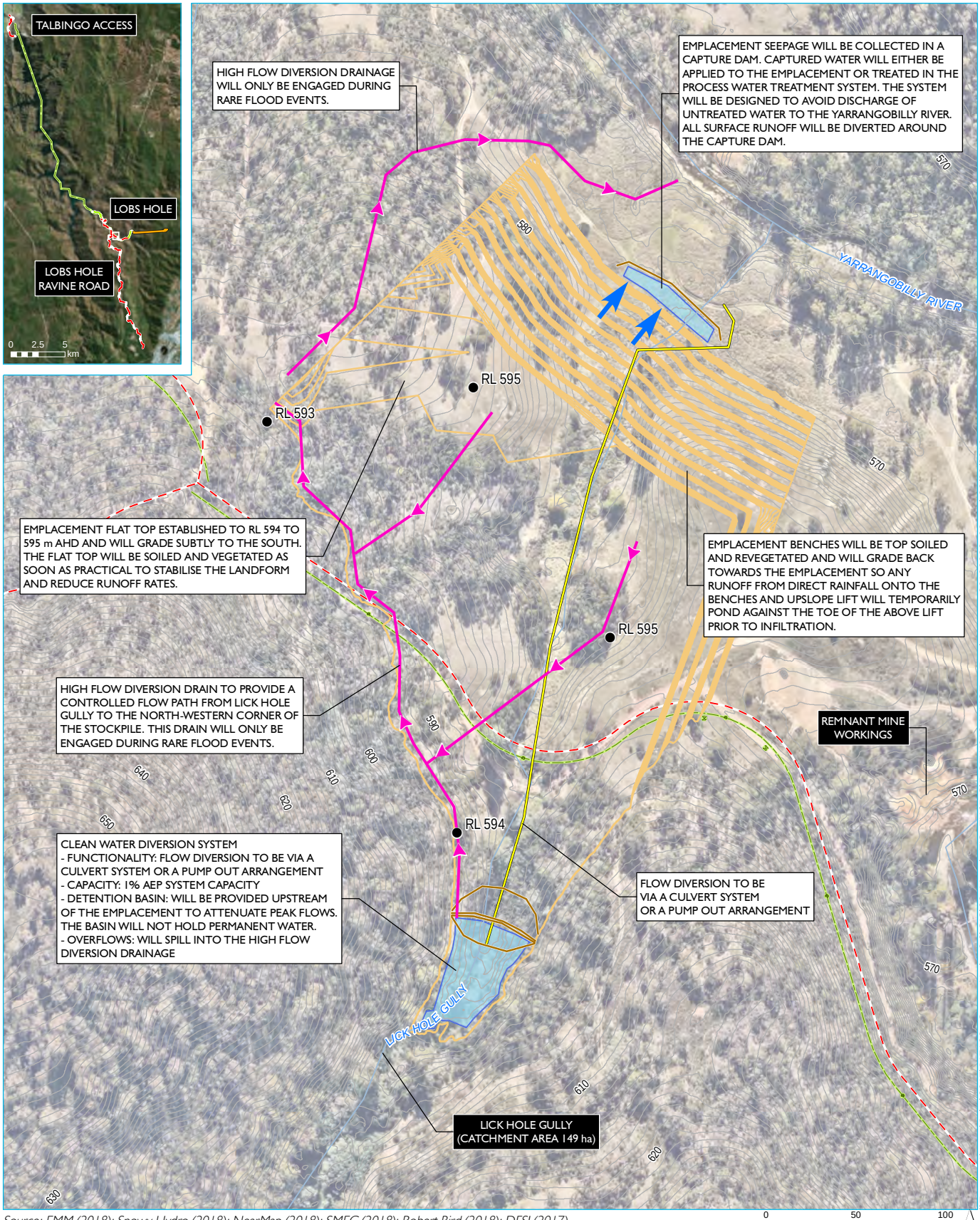
The water management approach for the eastern emplacement seeks to:

- manage sediment laden runoff during establishment;
- manage ARD risks, through the selective placement of PAF material with AC material;
- capture and divert runoff from Lick Hole Gully around the emplacement;
- promote infiltration of direct rainfall onto the emplacement; and
- actively manage water quality risks by capturing all seepage from the emplacement. Captured water will be either irrigated to the emplacement (to promote evaporation losses) or treated in the process water treatment plant (as described in Section 6.7).

Table 6.26 provides a summary of controls for the establishment and post establishment phases of the eastern emplacement. A water management concept for the post establishment phase is shown in Figure 6.11.

ii Western emplacement

The western emplacement will be used to store cuttings and other material that has a low geochemical risk and is able to be reused. The landform will be built in a manner that limits compaction and will be top soiled and vegetated to stabilise the landform. Sedimentation basins will be established to manage runoff from the emplacement area during establishment. Table 6.26 provides a summary of controls.



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Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SMEC (2018); Robert Bird (2018); DFSI (2017)

KEY

- Exploratory tunnel and portal
- Access road upgrade
- Communications cable
- Watercourse
- Contour (1m LiDAR)
- Design level (indicative)
- Eastern emplacement design contours
- Culvert
- Dam embankment
- Emplacement drainage
- High flow diversion drainage
- Water management basin

Eastern emplacement: revised water management concept

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 6.11

snowy2.0

EMM creating opportunities

Table 6.26 Water management controls: rock and soil emplacements

Control	Description
WM_8.1	The eastern and western rock and soil emplacement areas will be constructed as temporary landforms. The rock will be subject to the subaqueous emplacement program associated with Exploratory Works. Soil will be used for rehabilitation. Should any rock remain at these locations following the conclusion of Exploratory Works, it will be transported to a nominated location outside of Kosciuszko National Park within a timeframe agreed with NPWS.
WM_8.2	During establishment, the water management controls for construction areas (WM_2.1 to 2.8) will be applied.
WM_8.3	The western emplacement area will be used to store cuttings and other material that has a low geochemical risk. This landform will be built in a manner that limits compaction and will be top-soiled and vegetated to stabilise the landform.
WM_8.4	Any remnant mine workings located within the eastern and western rock and soil emplacement areas will be rehabilitated (if necessary).
WM_8.5	The eastern emplacement area will be used to store any material that that has higher geochemical risk. Excavated material will be geochemically characterised prior to placement. The potential for acid rock drainage will be treated by placing and compacting layers of limestone (or other suitable AC material) between each rock and sediment layer as required. The volume of limestone (or other suitable AC material) in each layer will be determined stoichiometrically so that the maximum potential acidity from the overlying layer of rock and sediment is treated. This approach will neutralise AMD within the stockpile. Once design levels are reached, the landform will be top-soiled and vegetated.
WM_8.6	Runoff from Lick Hole Gully will be diverted around or through the eastern emplacement area. The diversion works will comprise a dam upstream of the diversion inlet and either a gravity or pump assisted diversion system. The diversion works will have a 1% AEP capacity. The dam upstream of the diversion inlet will be designed as a detention basin and will not permanently hold water. A high-flow diversion drain will be established to convey runoff from Lick Hole Gully around the emplacement area in a controlled manner, avoiding uncontrolled overflows through the emplacement area. This diversion drain will only be engaged if a flood greater than a 1% AEP event occurs.
WM_8.7	Seepage from the eastern emplacement area will be collected in a water management dam. Collected water will either be irrigated to the emplacement (to promote evaporation) or treated in the process water treatment plant. Discharge of seepage water to the Yarrangobilly River will be avoided.
WM_8.8	The eastern and western emplacement areas will be rehabilitated following removal of all material. Lick Hole Gully will be resinated as part of the rehabilitation works. Geomorphic and ecological characterisation of Lick Hole Gully will be undertaken prior to disturbance to record the existing conditions and values of Lick Hole Gully. The rehabilitation approach will seek to create a physically stable landform that reinstates or improves the existing values

6.9.5 Residual impacts

i Eastern emplacement

No residual impacts are expected from the eastern emplacement area as:

- the diversion of Lick Hole Gully flows is not expected to alter water quality;
- ARD risks will be managed within the stockpile through the selective placement of PAF material with AC material; and
- there will be no discharge of emplacement seepage to the Yarrangobilly River.

ii Western emplacement

No residual impacts are expected from the western emplacement area as:

- the emplacement will only be used to store cuttings and other material that has a low geochemical risk and is able to be reused; and
- the emplacement will be soiled and vegetated to stabilise the landform.

6.9.6 Monitoring and contingency measures

i Monitoring measures

Water upstream of the eastern emplacement and seepage from the emplacement will be monitored to identify any change in water quality due to the emplacement. The following monitoring will be undertaken:

- stream flows in Lick Hole Gully upstream of the emplacement will be continuously monitored when in flow;
- emplacement seepage rates will be continuously monitored;
- the pH and electrical conductivity of emplacement seepage and stream flows in Lick Hole Gully upstream and downstream of the emplacement will be continuously monitored when in flow; and
- comprehensive water quality monitoring of emplacement seepage and stream flows in Lick Hole Gully upstream and downstream of the emplacement will be undertaken monthly, when in flow.

A comprehensive receiving water monitoring program will also be undertaken for the duration of the Exploratory Works. This program will include comprehensive monitoring of water quality in the Yarrangobilly River (refer to Chapter 8).

ii Contingency measures

If water quality monitoring identifies that the eastern emplacement is posing an unacceptable risk to the receiving environment:

- the active management controls (ie the capture and management of emplacement seepage) can be modified; or
- the emplacement areas can be removed and rehabilitated earlier than scheduled.

7 Residual impacts

7.1 Overview

This section describes residual impacts of Exploratory Works on the surface water environment and is structured as follows:

- Section 7.2 describes residual surface water impacts to the Yarrangobilly River and other watercourses that are tributaries of the Yarrangobilly River;
- Section 7.3 describes residual surface water impacts to Talbingo Reservoir; and
- Section 7.4 provides a summary of flood impacts.

7.1.1 Approach

Each section provides the following information (where relevant):

- a description of WQOs and environmental values that are relevant to the receiving water;
- a summary of presented controls and discharge regimes;
- characterisation of discharges relative to trigger values;
- a description of mixing zones;
- an assessment of increases in pollutant loads;
- an assessment of cumulative impacts (where relevant); and
- a description of impacts to ecology.

All discharge locations and disturbance areas are shown in Figure 7.1.

7.1.2 Terminology

The following terminology is used in this section:

- Controlled discharge – refers to the controlled discharge of treated waste water and treated process water into the Yarrangobilly arm of Talbingo Reservoir.
- Concentration impact – refers to an impact from an increase in a concentration due to water discharges.
- Dilution factor –refers to the discharge concentration divided by the relevant trigger value. A dilution factor of one (or less) indicates that the discharge concentration will not exceed the trigger value while a dilution factor of more than one indicates the level of dilution (or mixing) that will be required to achieve the trigger value.
- Load impact – refers to an impact from an increase in the load of a potential contaminant in the receiving environment due to a water discharge.

- Mixing zone – refers to an area where the water quality of a discharge does not immediately meet water quality objectives and where discharged water mixes with water in the receiving environment, progressively becoming more diluted. Dilution of the discharged water within the mixing zone needs to ensure that quality objectives to are met at the edge of the mixing zone.

7.2 Impacts to the Yarrangobilly River and other watercourses

This section describes the potential residual impacts to the Yarrangobilly River (including the lower reach of Wallaces Creek and minor tributaries of the lower Yarrangobilly River) due to stormwater discharges.

7.2.1 Summary of Water Quality Objectives

Section 3.4 describes WQOs and environmental values for the Yarrangobilly River. The WQOs were established using the methods and numerical values provided in the ANZECC/ARMCANZ (2000) guidelines. The following default trigger values were adopted:

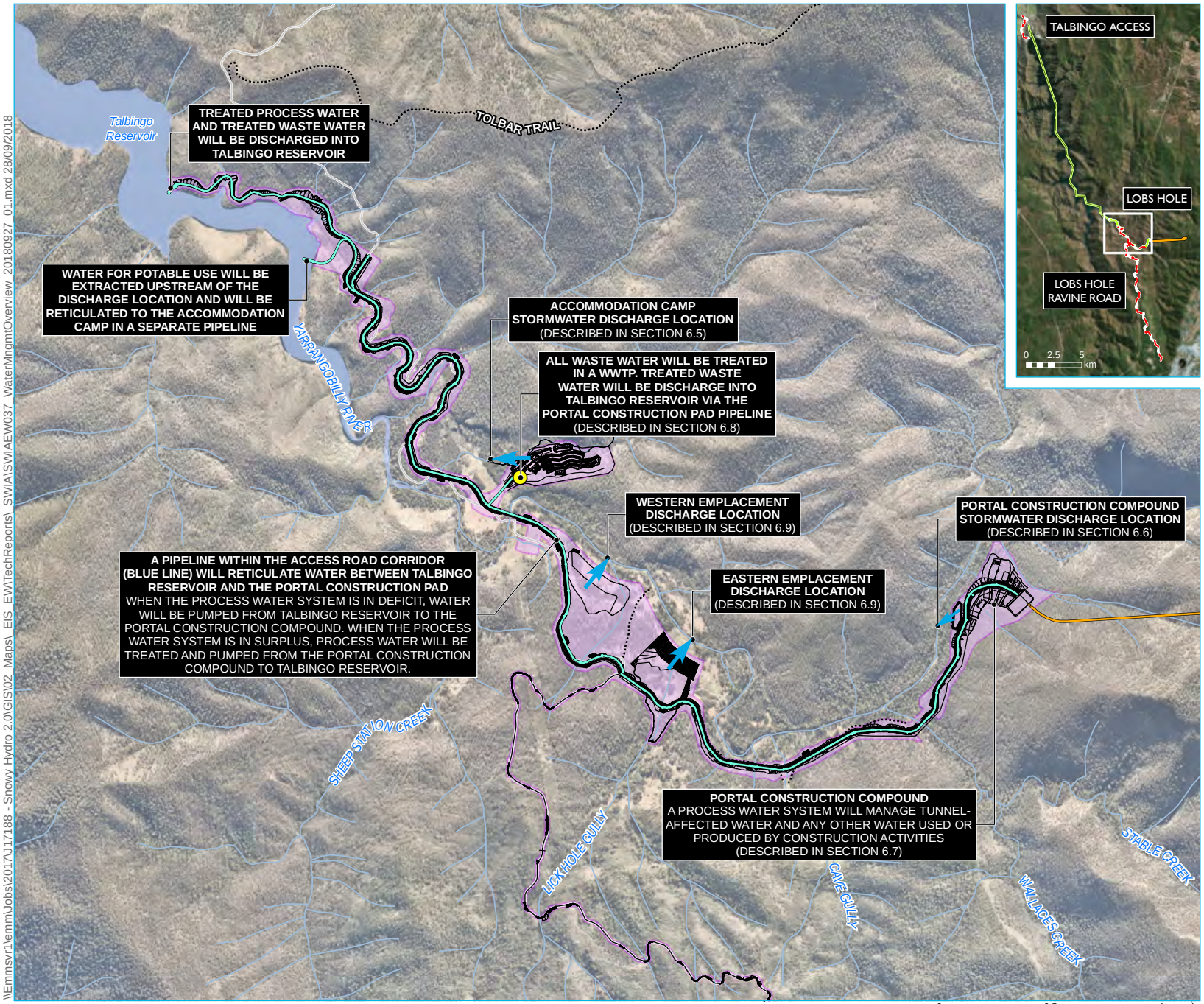
- physical and chemical stressor trigger values for upland rivers in south-eastern Australia; and
- toxicant trigger values for the protection of 99% of aquatic species.

Table 7.1 provides key trigger values that have been applied in the assessment of residual impacts.

Table 7.1 Trigger values applied to the assessment of residual impacts

	Trigger value
Physico-chemical	
pH	6.5–8.0
Turbidity	2–25 NTU
Salinity (electrical conductivity)	30–350 µS/cm
Dissolved oxygen	90–110%
Suspended sediment	Provided for reference only[1]
Nutrients	
Total ammonia-N	13 µg N/L
Oxides of nitrogen (NO_x)	15 µg N/L
Total nitrogen	250 µg N/L
Filterable reactive phosphate (FRP)	15 µg P/L
Total phosphorus	20 µg P/L

Notes: 1. ANZECC/ARMCANZ (2000) guidelines do not provide a trigger value for suspended sediment.



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Source: EMM (2018); Snowy Hydro (2018); SGM (2018); Robert Bird (2018); SMEC (2018); NearMap (2018); DFSI (2017); GA (2015); LPMA (2011)

Overview of disturbance areas and discharge locations

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 7.1

The potential residual impacts to Yarrangobilly River are assessed relative to the default trigger values that are provided in Table 7.1. Residual impacts for metals and other toxicants are assessed qualitatively. Site specific trigger values may be established for some analytes during the operation of Exploratory Works.

7.2.2 Stormwater discharges

The management of the following stormwater category discharges are described in Section 6:

- areas disturbed by construction (Section 6.3);
- access roads for the duration of Exploratory Works (Section 6.4);
- the accommodation camp for the duration of Exploratory Works (Section 6.5); and
- the portal construction pad for the duration of Exploratory Works (Section 6.6).

Section 6 provides detailed information on constraints, controls and monitoring and contingency measures for each of the above categories. There will be no discharges of seepage from the eastern emplacement (see Section 6.9). Hence, no residual impacts require assessment.

Table 7.2 provides the following information for each stormwater category:

- duration of disturbance;
- basin functionality and size (ie treatment volume);
- chemical treatment; and
- discharge and dewatering regimes.

As discussed in Section 6.3.4iv, the management measures are presented to determine the feasibility of achieving the proposed water quality on discharge. The management measures implemented from those presented but will still need to meet the proposed water quality.

Table 7.2 Summary of stormwater discharge regimes

Category	Duration of disturbance	Basin details	Discharge regime and frequency
Construction areas (excluding the portal construction pad)	Construction of all surface infrastructure will be completed within the initial nine months of Exploratory Works. Disturbance durations for individual construction areas will range from less than a week to a number of months.	**Basin type**: Sedimentation basin, no controlled discharge, overflows will occur when the basin is full. **Treatment:** Water treatment chemicals will be applied to sedimentation basins with catchment areas greater than 2,500 m^2 to enhance sedimentation and phosphorus and dissolved metal removal rates. Water treatment chemicals will be applied using an automated chemical dosing and mixing system. A similar system will be implemented for terrain constrained areas using a pump-out system and a water treatment plant (See section 6.3.3). **Dewatering:** Basins will be dewatered (via pumping) as soon as possible following rainfall cessation. Water will be used for dust suppression within construction areas and will not be discharged to receiving waters. **Basin size**: Basins will be sized to capture all runoff during a 5 day 85th percentile rainfall event (30.6 mm over five days). The basin sizes will be a function of catchment area and runoff coefficients. See Appendix E for further information.	Terrain constrained areas (source controls only, no sedimentation basins): • Discharge will occur following any material rainfall: 50 days per year[1]. • For construction areas with catchments that are greater than 2,500 m^2, a pump dewatering and treatment system will be designed to treat the 1 in 3 month peak flow. This system will treat flows continuously. Discharge of treated water will occur following any material rainfall: 50 days per year[1]. Areas not constrained by terrain (source controls and basins): • Discharge will occur approximately 8 to 10 times per year[2]. • Discharges will only occur during and shortly after rainfall. • The chemical water treatment system will be designed to treat all discharge during a 1 year ARI and lower magnitude rainfall events. • Discharge volumes are estimated to be on average, 40% of the runoff volume, with 60% of runoff volume removed from the basins via dewatering.
Access roads	Duration of Exploratory Works Some roads will be sealed and maintained as permanent infrastructure.	**Basin type**: Sedimentation basins established for the construction phase will be modified to be constructed wetland style basins. The basins will maintain permanent water. An extended detention zone will be provided above the permanent water zone. The extended detention zone will drain slowly through a low-flow outlet. Overflows will occur via a high-flow outlet when the basin is full. Basins will not be practical in areas constrained by terrain or the project boundary (approximately 20 to 30% of the road area). **Dewatering:** No dewatering is proposed. **Basin size**: The basins established for the road construction phase will be modified. It is expected that the catchment area can be reduced as runoff from rehabilitated batters can be diverted to clean water drainage. This will increase the effective size of the basin (in terms of mm of rainfall capture).	Constrained road sections (source controls only - no basins) • Discharge will occur following any material rainfall: 50 days per year[1]. Road sections not constrained by terrain (source controls and basins) • It is not proposed to extract water from the basins. • Discharges from the extended detention zone will occur via the low-flow outlet during and for 2 to 3 days after most material rainfall events. Discharge of low flows is expected to occur 50 to 100 days per year. • Overflows via the high-flow outlet will occur occasionally during intense rainfall. • Discharge volumes will be similar to runoff volumes (approximately 60%[3] of rainfall).

Table 7.2 Summary of stormwater discharge regimes

Category	Duration of disturbance	Basin details	Discharge regime and frequency
Accommodation camp (storm water)	Duration of Exploratory Works The accommodation camp will be rehabilitated following the completion of construction works.	**Basin type**: Constructed wetland style basin. The basin will maintain permanent water. An extended detention zone will be provided above the permanent water zone. The extended detention zone will drain slowly through a low-flow outlet. Overflows will occur via a high-flow outlet when the basin is full. **Dewatering:** No dewatering is proposed. **Basin size**: To be sized to achieve target pollutant load reductions (see Section 6.5).	• It is not proposed to extract water from the basins. • Discharges from the extended detention zone will occur via the low-flow outlet during and for 2 to 3 days after most material rainfall events. Discharge of low flows is expected to occur 50 to 100 days per year. • Overflows via the high-flow outlet will occur occasionally during intense rainfall. • Discharge volumes will be similar to runoff volumes (approximately 50%[4] of rainfall).
Portal construction pad (construction and operation)	Duration of Exploratory Works The pad area will be rehabilitated following the completion of construction works. However, it will remain a modified landform.	**Basin type**: Sedimentation basin, overflows will occur when the basin is full. There will be no controlled discharges to watercourses. **Treatment:** Water treatment chemicals will be applied to the basin to enhance sedimentation and phosphorus and dissolved metal removal rates. Water treatment chemicals will be applied using an automated chemical dosing and mixing system. **Dewatering:** Basins will be dewatered (via pumping) to top-up the process water system. **Basin size**: A basin volume of 3,750 m^3 is considered to be practical (to be confirmed at detailed design). A basin volume of 3,750 m^3 will capture the runoff volume from 85 mm of rainfall over 5 days, exceeding the 5 day 95th percentile rainfall event (56.8 mm over five days).	• Discharge will occur approximately 2 to 3 times per year[2]. • Discharges will only occur during and shortly after rainfall. • The chemical water treatment system will be designed to treat all runoff during a 1 year ARI and lower magnitude rainfall events. • Water balance model results (Table 6.20) estimate that discharge volumes are 31% of the runoff volume, with 69% of runoff removed from the basins via dewatering.

Notes: *1. Material rainfall refers to 5 mm or more in a day.*

2. A discharge event refers to a rainfall period where overflows occur intermittently within a wet weather period. Discharge periods will typically be 1 to 3 days (similar to most wet weather events).

3. A runoff coefficient of 60% of rainfall is a conservative value for an unsealed road.

4. A runoff coefficient of 50% of rainfall is a conservative value for the accommodation camp water management area, which is inclusive of hardstand and landscaped areas.

7.2.3 Residual impacts to water quality

This section describes residual water quality impacts to the Yarrangobilly River (and other receiving watercourses) due to the discharge of stormwater from Exploratory Works. The following are described:

- concentration impacts at the point of discharge; and
- potential pollutant load impacts.

i Concentration impacts at the point of discharge

This section provides the predicted water quality characteristics of stormwater discharges from Exploratory Works. The water quality characteristics have been established based on data from other representative sites. No allowance has been made for site-specific factors that may influence water quality. These factors will be reviewed as part of the preparation of the water management plan, which may include site-specific trigger values.

Residual concentration impacts at the point of discharge are assessed in this section by comparing the predicted concentrations to relevant default trigger values.

a. General analytes

It is expected that the pH of stormwater will not be appreciably altered by Exploratory Works and will be within the default trigger value range (pH 6.5–8.0). Similarly, it is expected that the dissolved oxygen concentration will not be appreciably altered by Exploratory Works and will be within the default trigger value range (90–110%).

The electrical conductivity of rainwater is close to 0 µS/cm and will not greatly increase in stormwater runoff. The use of water treatment chemicals (see Section 6.3.3) will increase the electrical conductivity. However, the electrical conductivity will remain within the default trigger value range (30–350 µS/cm).

b. Suspended sediment and turbidity

The proposed source controls for all stormwater categories will remove coarse sediment. This will prevent sedimentation impacts (ie where sediment is deposited from sediment-laden water) in receiving waters. Chemical water treatment is proposed to improve the water quality of discharge from construction areas (that have areas greater than 2,500 m^2) and the portal construction pad basin. This will remove fine and dispersive sediments and reduce suspended solid concentrations and turbidity levels.

Table 7.3 provides estimates of typical (ie median) and maximum suspended solids concentrations and turbidity from each stormwater category.

Table 7.3 Expected sediment and turbidity values

Category	Turbidity (NTU)		Suspended solids (mg/L)		Comments
	Typical	Maximum	Typical	Maximum	
Trigger value (Yarrangobilly River)	2–25		-		
Construction areas (<2,500 m^2) and constrained access roads	2–50	150	25	40	Typical values from construction sites with best practice erosion and sediment controls.
Construction areas (>2,500 m^2 with chemical treatment)	2–25	25	<5	20	Water treatment chemicals will reduce turbidity and suspended solids levels.
Access roads (with basins)	2–25	50	<10	25	Constructed wetland style basin will provide improved treatment during low-flow discharge conditions.
Accommodation camp	2–25	50	<10	25	Lower concentrations expected due to the use of native landscaping and limited trafficable hardstand areas. Constructed wetland style basins will provide improved treatment during low-flow discharge conditions.
Portal construction pad (with chemical treatment)	2–25	25	<5	20	Water treatment chemicals will reduce turbidity and suspended solids levels.

Notes: 1. Estimates are based on water quality data from representative sites.

c. Nutrients

Exploratory Works are not expected to introduce nutrients (ie phosphorus and nitrogen) to stormwater runoff through the use of uncontrolled fertiliser application or other anthropogenic materials. The key sources of nutrients are expected to be from:

- the weathering and breakdown of natural and anthropogenic materials, including rock and soils;
- entrainment with fine and dispersive materials (this typically only applies to phosphorus and organic forms of nitrogen); and
- atmospheric deposition onto impervious surfaces and unvegetated areas.

As a result, it is expected that nutrient concentrations in overflows of stormwater (which will only occur during or immediately following rainfall) may be above the default trigger values for the Yarrangobilly River (see Table 7.1).

Source controls such as use of native landscaping and rapid revegetation of disturbed areas are proposed to limit the occurrence of nutrients from the above sources. Chemical water treatment is proposed to improve the water quality of discharge from construction areas (that have areas greater than 2,500 m^2) and the portal construction pad basin (see Section 6.6). This is expected to reduce concentrations of phosphorus and potentially some organic forms of nitrogen.

Estimates of typical (ie median) and maximum concentrations of nitrogen (oxidised and total) and phosphorus (reactive and total) from each stormwater category are provided in Table 7.4 and Table 7.5 respectively.

Table 7.4 Expected nitrogen concentrations in stormwater runoff

Category	Oxidised nitrogen (mg N/L)		Total nitrogen[2, 3] (mg N/L)		Comments
	Typical	Maximum	Typical	Maximum	
Trigger value (Yarrangobilly River)	0.015		0.25		
Construction areas (<2,500 m^2) and constrained access roads	0.2	0.5	0.6	1.5	Elevated nitrogen concentrations are generally not associated with elevated suspended sediment concentrations .
Construction areas (> 2,500 m^2 with chemical treatment)	0.2	0.5	0.4	1.5	Water treatment chemicals may reduce organic nitrogen levels. No material reduction in oxidised nitrogen is expected.
Access roads (with basins)	0.1	0.4	0.4	1.0	Constructed wetland style basin will provide treatment during low-flow discharge conditions.
Accommodation camp	0.1	0.4	0.4	1.0	Source controls such as native landscaping will reduce concentrations. Constructed wetland style basin will provide treatment during low-flow discharge conditions.
Portal construction pad (with chemical treatment)	0.2	0.5	0.6	2.0	Higher concentrations expected due to the extensive impervious area. Water treatment chemicals may reduce organic nitrogen levels. No material reduction in oxidised nitrogen concentrations is expected.

Notes: *1. Estimates are based on water quality data from representative sites. No allowance has been made for site specific factors that may influence water quality.*

2. Ammonium concentrations are expected to be similar to trigger values and are therefore not reported.

3. The majority of total nitrogen is expected to be in organic form, which has low bioavailability.

Table 7.5 Expected phosphorus concentrations in stormwater runoff

Category	Reactive phosphorus (mg P/L)		Total phosphorus (mg P/L)		Comments
	Typical	Maximum	Typical	Maximum	
Trigger value (Yarrangobilly River)	0.015		0.02		
Construction areas (<2,500 m^2) and constrained access roads	0.04	0.12	0.08	0.2	Elevated phosphorus concentrations can be associated with elevated suspended sediment concentrations .
Construction areas (> 2,500 m^2 with chemical treatment)	0.02	0.05	0.02	0.05	Water treatment chemicals will reduce phosphorus concentrations.

Table 7.5 Expected phosphorus concentrations in stormwater runoff

Category	Reactive phosphorus (mg P/L)		Total phosphorus (mg P/L)		Comments
	Typical	Maximum	Typical	Maximum	
Access roads (with basins)	0.02	0.05	0.05	0.1	Constructed wetland style basins will provide improved treatment during low-flow discharge conditions.
Accommodation camp	0.02	0.05	0.05	0.1	Source controls such as native landscaping will reduce concentrations. Constructed wetland style basins will provide treatment during low-flow discharge conditions.
Portal construction pad (with chemical treatment)	0.02	0.05	0.02	0.05	Water treatment chemicals will reduce phosphorus concentrations.

Notes: 1. Estimates are based on water quality data from representative sites. No allowance has been made for site specific factors that may influence water quality.

d. Metals

The key sources of metals are expected to be from:

- atmospheric deposition onto impervious surfaces and unvegetated areas; and
- the weathering and breakdown of natural and anthropogenic materials, including rock and soils.

The following source controls are proposed to minimise metal contamination of stormwater runoff:

- potentially contaminating areas such as concrete batching plants and workshops will be isolated from the stormwater system through covering and bunding;
- the process water system will manage all water produced by construction activities; and
- only water treatment chemicals that have a low risk of increasing the toxicity of treated stormwater will be used. These chemicals include iron salt coagulants, calcium carbonate and anionic polymer flocculants. Water treatment chemicals will be applied using an automated chemical dosing and mixing system to minimise the risk of overdosing.

The proposed controls, including the use of water treatment chemicals will reduce concentrations of some metals. But it is expected that concentrations of some metals in stormwater may exceed the default trigger values for the protection of 99% of aquatic species on occasions. The occurrence, magnitude and frequency of exceedance for each metal cannot be reliably predicted given the variables discussed above. Based on experience of stormwater runoff monitoring, maximum dissolved concentrations are generally below acute trigger values levels for all metals.

Sampling from local watercourses within proximity to the proposed works will continue and will provide site specific baseline data. Monitoring will also continue during Exploratory Works (see Section 8).

e. Other pollutants

The following pollutants are considered to have a low risk of occurring above non-trivial levels in stormwater runoff:

- pesticides and herbicides will generally not be used within water management areas. If required for weed control, application will be undertaken using controlled doses;
- surfactants (ie detergents) will not be used outside of covered and bunded areas; and
- hydrocarbon related pollutants will be stored and handled in designated areas.

ii Concentration impacts

With the exception of construction areas <2,500 m^2, the typical turbidity in discharges (Table 7.3) will be within the default trigger value range (2–25 NTU).

For the construction areas <2,500 m^2, the runoff catchment area will be very small (<2,500 m^2, 0.25 ha) compared to the total watercourse catchment and discharge will cease almost immediately after rainfall ceases. If the turbidity is in the turbidity range (26-50 NTU) above the trigger value range, it will be very rapidly diluted at the point of discharge given that the flow in the watercourse will be large compared to the flow of runoff from the construction area.

Therefore, no 'concentration impacts' are predicted.

The maximum dilution factors required to meet default trigger values for nutrients in stormwater discharge (Table 7.4) are:

- between 1.3 (reactive phosphorus) and 13 (oxidised nitrogen) for median (ie typical) concentrations; and
- between 2.6 (reactive phosphorus) and 33 (oxidised nitrogen) for maximum concentrations.

These are all classified by ANZECC/ARMCANZ (2000) as chemical stressors as ongoing (chronic) elevated concentrations may result in impacts such as eutrophication. Elevated concentrations of these stressors over short periods (days) will not result in acute toxicity or other impacts. The potential concentration impacts due to the discharge of nutrients in stormwater discharges are assessed in Table 7.6.

Table 7.6 Stormwater discharges (nutrients) - concentration impacts

Category	Receiving waters	Discharge regime[1]	Concentration impacts
Construction areas <2,500 m^2 (no sedimentation basins) and constrained access roads	Yarrangobilly River/tributaries of the Yarrangobilly River	Discharge of treated water will occur following any material rainfall: 50 days per year.	The runoff catchment area will be very small (<2,500 m^2, 0.25 ha) compared to the total watercourse catchment. Discharge will cease almost immediately after rainfall ceases. Very rapid dilution will occur at the point of discharge given that the flow in the watercourse will be large compared to the flow of runoff from the construction area. Therefore, no concentration impacts are predicted.

Table 7.6 Stormwater discharges (nutrients) - concentration impacts

Category	Receiving waters	Discharge regime[1]	Concentration impacts
Construction areas >2,500 m^2 (with sedimentation basin)	Yarrangobilly River	Discharges will occur approximately 8 to 10 times per year, during and shortly after rainfall.	No concentration impacts are predicted from nutrients as discharges will only occur 8 to 10 times per year.
Access road	Yarrangobilly River/tributaries of the Yarrangobilly River	Discharge of treated water will occur following any material rainfall: 50 days per year.	Very rapid dilution will occur at the point of discharge given that the flow in the watercourse will be large compared to the flow of runoff from each access road discharge location. Therefore, no concentration impacts are predicted.
Accommodation camp	Watercourse 3 then Yarrangobilly River	Discharges will occur for 2 to 3 days after material rainfall events.	Very rapid dilution will occur at the point of discharge given that the flow in the watercourse will be large compared to the flow of runoff. Therefore, no concentration impacts are predicted.
Portal construction pad	Yarrangobilly River	Discharges (will occur approximately 2 to 3 times per year during and shortly after rainfall.	No concentration impacts are predicted from nutrients as discharges will only occur 2 to 3 times per year.

1. *See Table 7.2.*

In summary, no concentration impacts in the Yarrangobilly River or its tributaries are predicted due to stormwater discharges.

iii Load impacts

a. Overview

The potential for stormwater discharge to materially change pollutant loads in the Yarrangobilly River can be calculated as a function of discharge concentrations and volumes, ambient concentrations in the river and stream flows. The potential for load impacts will be dynamic as the disturbance area will change with the construction, operation and rehabilitation schedule. Conservative estimates of load impacts during the construction and operation phases of Exploratory Works are described below.

b. Construction phase

The construction phase of Exploratory Works will occur within the initial nine months of schedule. A conservative assessment of potential load increases during the construction phase has been undertaken. The following assumptions were applied:

- Disturbance area: 59.9 ha. This is the maximum disturbance area within the Yarrangobilly River catchment that is provided in Table 6.2. This is conservative as it assumes that all construction will occur at the same time.

- Runoff volume: runoff from the 59.9 ha disturbance area has been calculated as mean rainfall (952 mm/year from Table 4.1) multiplied by a runoff coefficient of 40% of rainfall. This runoff coefficient compares to 34% of rainfall coefficient for the Yarrangobilly River (Table 4.6). The calculated mean annual runoff volume is 228 ML/year.

- Discharge volume: it is predicted that 60% of runoff into sedimentation basins will be dewatered and used for dust suppression (Table 7.2). Hence, discharge from the basins will be approximately 40% of runoff (91 ML/year). This is equivalent to 0.08% of the mean annual stream flow in the Yarrangobilly River (Table 4.6). Similar ratios are expected for wetter-than-average and drier-than-average years.

- Discharge concentrations: calculations of potential load increases of suspended sediment, oxidised nitrogen, total nitrogen, reactive phosphorus and total phosphorus concentrations have been undertaken based on the medium and maximum concentrations of runoff from construction areas (with no chemical treatment). This is conservative as chemical treatment will be provided for all construction areas that have catchments of more than 2,500 m^2.

Table 7.7 provides the calculated potential pollutant load increases for the construction phase based on median and maximum concentrations.

Table 7.7 Conservative load impact analysis – construction phase

		Conservative load impact analysis	
	Units	**Median values[1]**	**Maximum values[2]**
Runoff volume and stream flows			
Mean annual discharge volume (from 59.9 ha construction disturbance area)	ML/year	91	91
Mean annual Yarrangobilly River stream flows	ML/year	115,000	115,000
Dilution factor		1,264	1,264
Increase in total suspended sediment (TSS)			
TSS in discharge[4]	mg/L	25	40
	kg/year	2,275	3,640
TSS in river flows[5]	mg/L	2[3]	2[3]
	kg/year	230,000	230,000
Increase in TSS	%	1.0%	1.6%
Increase in oxidised nitrogen (NO_x)			
NO_x in discharge[4]	mg/L	0.2	0.5
	kg/year	18.2	45.5
NO_x in river flows[5]	mg/L	0.015	0.015
	kg/year	1,725	1,725
Increase	%	1.1%	2.6%
Increase in total nitrogen (TN)			
TN in discharge[4]	mg/L	0.6	1.5
	kg/year	54.6	136.5
TN in river flows[5]	mg/L	0.25	0.25
	kg/year	28,750	28,750
Increase	%	0.2%	0.5%
Increase in filterable reactive phosphorus (FRP)			
FRP in discharge[4]	mg/L	0.04	0.12
	kg/year	3.64	10.92
FRP in river flows[5]	mg/L	0.015	0.015
	kg/year	1,725	1,725

Table 7.7 Conservative load impact analysis – construction phase

		Conservative load impact analysis	
	Units	**Median values[1]**	**Maximum values[2]**
Increase	%	0.2%	0.6%
Increase in total phosphorus (TP)			
TP in discharge[4]	mg/L	0.08	0.2
	kg/year	7.28	18.2
TP in river flows[5]	mg/L	0.02	0.02
	kg/year	2,300	2,300
Increase	%	0.3%	0.8%

Notes: *1. refers to the median concentration in runoff from construction areas (with no chemical treatment).*

2. refers to the maximum concentration in runoff from construction areas (with no chemical treatment).

3. ANZECC/ ARMCANZ (2000) does not provide a trigger value for suspended solids. An average concentration of 2 mg/L has been adopted for the purposes of load impact analysis.

4. Loads in discharge have been calculated as mean annual discharge volume x the predicted concentration.

5. Loads in river flows have been calculated as mean annual stream flow x default trigger value.

6. The mean annual discharge volume assumes a catchment area of 59.9 ha, mean rainfall of 952 mm/year, a runoff coefficient of 40% of rainfall and a discharge coefficient of 40% of runoff.

c. Operational phase

A conservative assessment of potential load increases during the operational phase has been undertaken. This assessment considers runoff from access roads, the accommodation camp and the portal construction pad. Table 7.8 provides the assumptions applied to calculate mean annual discharge volume for each of these areas.

Table 7.8 Annual discharge volumes from operational areas

	Disturbance Area	**Runoff coefficient**	**Discharge coefficient**	**Mean annual discharge volume[1]**
	ha			**ML/year**
Access roads (constrained)[2]	3.15	60%	100%	54
Access roads (with basins)[2]	9.45	60%	100%	18
Accommodation camp	4.1	50%	100%	20
Portal construction pad	5.6	85%	31%	14
Total	**22.3**	**-**		**106**

Notes: *1. The mean annual discharge volume is calculated as the mean rainfall of 952 mm/year x disturbance area x runoff coefficient (% of rainfall) x discharge coefficient (% of runoff that is discharged).*

2. It is assumed that 25% of the access road area is constrained and 75% is not constrained (ie basins are practical).

Table 7.9 provides the calculated potential pollutant load increases for the operational phase based on median and maximum concentrations.

Table 7.9 Conservative load impact analysis – operational phase

		Conservative load impact analysis	
	Units	**Median values[1]**	**Maximum values[2]**
Runoff volume and stream flows			
Mean annual discharge volume (from 22.3 ha operational disturbance area)	ML/year	106	106
Mean annual Yarrangobilly River stream flows	ML/year	115,000	115,000
Dilution factor		1,090	1,090
Increase in total suspended sediment (TSS)			
TSS in discharge[4]	mg/L	11.9	26.9
	kg/year	1,255	2,838
TSS in river flows[5]	mg/L	2	2
	kg/year	230,000	230,000
Increase in TSS	%	0.5%	1.2%
Increase in oxidised nitrogen (NO_x)			
NO_x in discharge[4]	mg/L	0.13	0.43
	kg/year	13.8	45.4
NO_x in river flows[5]	mg/L	0.015	0.015
	kg/year	1,725	1,725
Increase	%	0.8%	2.6%
Increase in total nitrogen (TN)			
TN in discharge[4]	mg/L	0.46	1.22
	kg/year	48.6	128.6
TN in river flows[5]	mg/L	0.25	0.25
	kg/year	28,750	28,750
Increase	%	0.2%	0.4%
Increase in filterable reactive phosphorus (FRP)			
FRP in discharge[4]	mg/L	0.02	0.06
	kg/year	2.5	6.5
FRP in river flows[5]	mg/L	0.015	0.015
	kg/year	1,725	1,725
Increase	%	0.1%	0.4%
Increase in total phosphorus (TP)			
TP in discharge[4]	mg/L	0.05	0.11
	kg/year	5.4	11.7
TP in river flows[5]	mg/L	0.02	0.02
	kg/year	2,300	2,300
Increase	%	0.2%	0.5%

Notes: *1. refers to the median concentration in runoff from construction areas (with no chemical treatment).*

2. refers to the maximum concentration in runoff from construction areas (with no chemical treatment).

3. ANZECC/ARMCANZ (2000) does not provide a trigger value for suspended solids. An average concentration of 2 mg/L has been adopted for the purposes of load impact analysis.

4. Loads in discharge have been calculated as mean annual discharge volume x the predicted concentration.

5. Loads in river flows have been calculated as mean annual stream flow x default trigger value.

6. The mean annual discharge volume based on total discharge volumes from operational phase access roads, accommodation camp and portal construction pad (refer to Table 7.8).

d. Conclusion

The discharge of treated stormwater from Exploratory Works into the Yarrangobilly River will:

- increase the suspended sediment loads by up to 1.6% during construction and 1.2% during operation;
- increase oxidised nitrogen loads by up to 2.6% during construction and during operation;
- increase in total nitrogen loads by up to 0.5% during construction and 0.4% during operation;
- increase reactive phosphorus loads by up to 0.6% during construction and 0.4% during operation; and
- increase total phosphorus loads by up to 0.8% during construction and 0.5% during operation.

The above load increase estimates are conservative as they are based on maximum concentrations.

There will be negligible load impacts to the Yarrangobilly River from stormwater discharge from Exploratory Works.

7.2.4 Impacts to flow regimes

i Surface water impacts

It is not proposed to extract water from the Yarrangobilly River or Wallaces Creek.

There is negligible potential for impacts to stream flow regimes in the Yarrangobilly River and Wallaces Creek from capturing water in water management dams as the volumes captured will be insignificant compared to river flows. Hence, no surface water impacts to the stream flow regimes are expected in Yarrangobilly River or Wallaces Creek.

The lower portion of Lick Hole Gully will be disturbed by the eastern emplacement area. This will change the flow regime in the lowest 450 m reach of Lick Hole Gully.

ii Groundwater impacts

The Snowy 2.0 *Exploratory Works Groundwater Assessment* (EMM 2018) assesses the reduction in base flows in the Yarrangobilly River associated with groundwater seepage into the exploratory tunnel. This assessment concluded that the reduction in baseflows will be minor relative to the simulated baseflows in the Yarrangobilly River. Accordingly, the predicted reductions in baseflows are not expected to change the stream flow regimes in either the Yarrangobilly River or Wallaces Creek during normal or drought conditions. Impacts to ecology

iii Potential impacts due to discharges

The Yarrangobilly River provides key habitat for the Booroolong Frog and Murray Crayfish, with interstitial spaces between cobbles providing key breeding habitat for these species. Potential impacts to the Booroolong Frog and Murray crayfish and other aquatic ecology include:

- sedimentation that can smother habitat, fill deeper holes, smother snags and other cover, and bury clay banks required for burrowing;
- low dissolved oxygen concentrations such as those experienced in blackwater events after flooding;

- increases in salinity levels can lead to changes to the physical environment that can be detrimental; and

- exposure to elevated levels of nutrients and toxicants have potential to be detrimental.

The Booroolong Frog and Murray Crayfish is known to inhabit relatively disturbed environments, including watercourses in pastural areas, which are impacted by increased turbidity and nutrient concentrations and so must be tolerant to a range of water quality conditions.

iv Impacts of water treatment chemicals

As discussed in Section 6.3.3, it is proposed to use iron salt coagulants, calcium carbonate and anionic polymer flocculants (or similar chemicals) to treat stormwater discharge from construction areas and the portal construction compound. The use of these chemicals will reduce turbidity, and fine and dispersive sediments, phosphorus and some metals concentrations in stormwater discharges.

The proposed approach is not expected to increase the toxicity of discharge due to:

- the selection of low risk chemicals. Higher risk chemicals such as aluminium based chemicals and cationic flocculants will be avoided; and

- an automated chemical dosing system will optimise dosing rates and prevent overdosing.

The use of an iron salt coagulant will increase salinity by 10 to 30 µS/cm. However, the electrical conductivity will remain within the default trigger value range (30–350 µS/cm).

v Risk assessment

Table 7.10 assesses the risks associated with discharges and the use of water treatment chemicals.

Table 7.10 Impacts of stormwater discharges to ecology

Potential Impact	Description of risk	Risk to ecology
Sedimentation impacts due to the discharge of water laden with coarse sediments.	Controls for all stormwater categories will capture coarse sediments (that may quickly settle) and the majority of finer sediments that may take hours or days to settle. Hence, there is negligible risk of sedimentation that may alter the bed or bank habitat occurring in the moving receiving waters due to Exploratory Works.	Negligible
Low dissolved oxygen	Stormwater discharge is expected to have dissolved oxygen levels that are within the trigger vale range. In addition, discharge is not expected to contain loads of nutrients or organic material at levels that could cause a black water event. Hence, there is negligible risk low dissolved oxygen conditions occurring in receiving waters due to Exploratory Works.	Negligible
Elevated nutrient and toxicants	Stormwater discharge has potential to contain concentrations of nutrients and toxicants above default (chronic) trigger values on occasions. The concentrations at the point of discharge are predicted to be below acutely toxic levels.	Negligible

Table 7.10 Impacts of stormwater discharges to ecology

Potential Impact	Description of risk	Risk to ecology
Increases in salinity	The use of an iron salt coagulant will increase salinity by 10 to 30 µS/cm. Discharges of chemically treated water are expected to occur less than 10 times per year and the electrical conductivity will remain within the default trigger value range (30–350 µS/cm).	Negligible
Use of water treatment chemicals	The proposed approach to use controlled doses of low-risk water treatment chemicals in expected to have a low risk of increasing the toxicity of stormwater discharge.	Negligible

7.3 Impacts to Talbingo Reservoir

Residual impacts to Talbingo Reservoir may occur due to:

- the discharge of treated waste water into the Yarrangobilly River arm of Talbingo Reservoir;
- the discharge of treated process water into the Yarrangobilly River arm of Talbingo Reservoir;
- the discharge of stormwater runoff into the Yarrangobilly River, upstream of Talbingo Reservoir; and
- subaqueous dredged material placement.

7.3.1 Summary of Water Quality Objectives

The WQOs and trigger values for Talbingo Reservoir are described in Section 3.4. The WQOs were established using the methods and numerical values provided in the ANZECC/ARMCANZ (2000) guidelines. The following principles were applied:

- default trigger values for physical and chemical stressors in freshwater lakes and reservoirs in south-eastern Australia; and
- default trigger values for toxicants for the protection of slightly–moderately disturbed ecosystems.

Table 7.11 provides key trigger values that have been applied in the assessment of residual impacts.

Table 7.11 Trigger values applied to the assessment of residual impacts

	Trigger value
Physico-chemical	
pH	6.5–8.0
Turbidity	1-20 NTU
Salinity (electrical conductivity)	20–30 µS/cm
Dissolved oxygen	90–110%
Nutrients	
Total ammonia-N	13 µg N/L
Oxides of nitrogen (NO_x)	10 µg N/L
Total nitrogen	350 µg N/L

Table 7.11 Trigger values applied to the assessment of residual impacts

	Trigger value
Filterable reactive phosphate (FRP)	5 µg P/L
Total phosphorus	10 µg P/L
Toxicants	
Dissolved metals	Trigger values for the protection of slightly–moderately disturbed ecosystems

The potential residual impacts to Talbingo Reservoir are assessed relative to the default trigger values provided in Table 7.11. Site specific trigger values may be established for some analytes during the operation of Exploratory Works.

7.3.2 Summary of discharges

i Treated waste water

The accommodation camp will generate up to 48 kL/day of waste water. All waste water will be treated to meet prescribed discharge criteria. It is important to note that different nutrient removal technologies and techniques may be used to achieve these criteria.

Waste water will be discharged to the Yarrangobilly River arm of Talbingo Reservoir via a diffuser arrangement on the bed of the reservoir. Discharge quality specifications are provided in Table 6.24 and are reproduced Table 7.12.

Refer to Section 6.8 for further details on accommodation camp waste water management.

ii Treated process water

The process water system will receive groundwater that is pumped from the tunnel sumps (tunnel affected water). Process water will be primarily tunnel affected water but will include a minor contribution of water that is used underground during construction and wash-down. Process water will be treated and used for dust suppression and concrete production. The process water system will be separated from the stormwater systems.

Discharge of treated excess process water will be required when inflows into the system exceed process water demand. This will primarily occur:

- during the second half of the construction schedule when groundwater inflows into the tunnel will be highest; and
- during winter or extended periods of wet weather when dust suppression requirements are lowest.

Water balance model results (Table 6.20) predict that:

- the majority of tunnel affected water (about 95%) will be used for dust suppression and concrete production, with the excess (5%) discharged to Talbingo Reservoir after treatment;
- the median monthly discharge at the end of the construction schedule will be 1.0 ML/month; and

- the maximum potential monthly discharge is 4.9 ML/month which would only occur if there is a significant wet weather period near the end of the construction schedule.

The predicted groundwater inflow rates into the tunnel over the 26 month construction schedule are shown in Figure 6.5. These groundwater inflows rates have been established using a predictive model and could be higher or lower than predicted. Higher groundwater inflows would increase the frequency and magnitude of discharges to Talbingo Reservoir, while lower inflows could negate the need for discharge. The maximum discharge rate is estimated to be 400 kL/day.

Process water will be treated in a water treatment plant. Discharge quality specifications are provided in Table 6.18 and are reproduced Table 7.12.

Refer to Section 6.7 for further details on the process water management and treatment.

7.3.3 Impacts to water quality

This section describes the following potential residual water quality impacts to Talbingo Reservoir:

- concentration impacts at the point of discharge (and the need for a mixing zone); and
- potential pollutant load impacts.

i Concentration impacts at the point of discharge

This section describes the predicted water quality characteristics of treated waste water and treated process water discharges from Exploratory Works to Talbingo Reservoir. Residual concentration impacts at the point of discharge are assessed by comparing the predicted concentrations to the default trigger values. No allowance has been made for site-specific factors that may influence ambient water quality. These factors will be reviewed as part of the preparation of the water management plan, which may include site-specific trigger values.

Table 7.12 provides the characteristics of:

- treated waste water discharge quality (maximum concentrations only);
- treated process water discharge quality (median and maximum concentrations); and
- combined discharge quality (median and maximum concentrations).

Dilution factors for each analyte have also been calculated.

Table 7.12 Talbingo Reservoir discharge concentrations

	Units	Trigger value[1]	Treated waste water		Treated process water				Combined discharge[3] (waste water plus process water)			
			Maximum	DF	Median	DF	Maximum	DF	Median[3]	DF	Maximum	DF
Discharge	kL/day		38.4[4]	-	up to 400	-	up to 400	-	up to 438	-	up to 438	-
Physio-chemical												
Electrical conductivity (EC)	µS/cm	20–30	20-30	1	780	26	1,122	37	714	24	1,026	34
pH	-	6.5–8.0	6.5–8.0	-	6.5–8.0	-	6.5–8.0	-	6.5–8.0	-	6.5–8.0	-
Turbidity	NTU	1–20	<25	<1	1–20	1	<20	1	<25	<1	<25	<1
Oil and grease	mg/L	5	<5	<1	<5	1	<5	1	<5	<1	<5	<1
Biochemical oxygen demand	mg/L	-	<5	<1	<5	<1	<5	<1	<5	<1	<5	<1
Nutrients												
Total ammonia - N	mg/L	0.01	0.1	10	0.05	5	0.1	10	0.05	5	0.1	10
Oxidised nitrogen (NO_x)	mg/L	0.01	0.1	10	0.18	18	0.25	25	0.17	17	0.24	24
Total nitrogen (TN)	mg/L	0.35	0.2	<1	0.23	<1	0.35	1	0.23	<1	0.34	<1
Reactive phosphorus (FRP)	mg/L	0.005	0.06	12	0.02	4	0.05	10	0.02	5	0.05	10
Total phosphorus (TP)	mg/L	0.01	0.06	6	0.02	2	0.05	5	0.02	2	0.05	5
Pathogenic organisms												
E-coli	cfu/100 mL	150	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Enterococci	cfu/100 mL	35	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Protozoans	orgs/100 mL	nil	0	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toxicants												
Dissolved metals	-	varies	<TV	<1	<TV	<1	<TV	<1	<TV	<1	<TV	<1

Notes: *1. Trigger values (TVs) for Talbingo Reservoir.*

2. The combined median values have been calculated from the maximum waste water and median process water values.

3. The combined concentration values have been calculated based on 38.4 kL/day of treated waste water blended with 400 kL/day of blended process water. The concentrations will change for different blending ratios. The values for treated waste water and treated process water are the upper and lower bound of the blended range.

4. Assumes that 80% of the waste water volume is discharged and 20% is contained in a treatment by-product that will not be discharged and will be disposed to an appropriate facility.

DF - refers to dilution factor, which is calculated as the concentration/trigger value.

ii Mixing zone

As described above, a range of design and management measures are proposed to ensure that the levels of pollutants are minimised to the greatest practical extent in the waste water and process water discharges. Even with the implementation of these measures, some trigger values applicable to Talbingo Reservoir are predicted to be exceeded at the point of discharge. This discharge will generally be continuous, once the accommodation camp is occupied, but the discharge volume will vary.

In summary, the following dilutions will be required to meet the default trigger values (Table 7.12):

- For the discharge of treated waste water alone, a maximum of 12 dilutions will be required to meet all trigger values (based on the discharged FRP concentration).
- For the discharge of treated process water (which will not occur without treated waste water discharge) a maximum of 37 dilutions will be required to meet all trigger values (based on the discharged electrical conductivity).
- For the combined discharge of treated waste water and process water a maximum of 34 dilutions will be required to meet all trigger values (based on the discharged electrical conductivity).

The dilution of the treated waste water and treated process water following discharge to Talbingo Reservoir has been modelled by Royal HaskoningDHV (Appendix G). The modelling examined the initial dilution primarily caused by the momentum of the discharged water and its buoyancy within a near-field model and the dispersion of the resulting plume by water movement within the reservoir in a far-field model.

Two scenarios were assessed:

- the discharge of waste water without the discharge of excess process water; and
- the discharge of waste water with the maximum discharge of excess process water.

The dilution modelling found that a near-field dilution of 100 will be achieved less than 10 m from the discharge point, this exceeds the maximum dilution required (37 dilutions). It is therefore conservatively proposed that there is a mixing zone extending 10 m from the discharge point. The mixing zone will be 20 m across.

iii Pollutant load impacts

a. Load impacts due to controlled discharge

As described in Table 7.12, salinity and concentrations of nitrogen and phosphorus will exceed trigger values for the Talbingo Reservoir within the mixing zone. Associated load increases have been calculated in the Yarrangobilly River arm of the Talbingo Reservoir for drought, typical summer and typical winter conditions. The calculations have been undertaken for the following analytes which require the highest dilution factors (Table 7.12):

- salinity (based on electrical conductivity);
- oxidised nitrogen (NO_x); and
- reactive phosphorus.

The calculated load increases are provided in Table 7.13 for:

- A drought summer conditions scenario. This scenario applied waste water discharge volume of 38.4 kL/day (or 1.2 ML/month). No process water discharge was applied as all surplus process water can be used for dust suppression during summer drought conditions.

- Typical summer and typical winter conditions scenarios. This scenario applied:

    - the median (1 ML/month) process water discharge volume that was established by water balance modelling (see Table 6.20); and

    - the waste water discharge volume of 38.4 kL/day (or 1.2 ML/month).

A maximum process water discharge scenario was also assessed for winter conditions only. This scenario applied:

- the maximum (4.9 ML/month) process water discharge volume that was established by water balance modelling (see Table 6.20); and

- the waste water discharge volume of 38.4 kL/day (or 1.2 ML/month).

Maximum monthly process water discharges will only occur during winter or extended periods of wet weather. As stream flows would be elevated under these conditions, an assessment of maximum discharge volumes during summer drought and typical summer condition scenarios is not considered to be a plausible scenario.

The following assumptions were applied to the load impact calculations:

- Calculations have been undertaken based on average monthly process water discharge volumes and median or typical concentrations that are provided in Table 7.12. Load impact calculations based on maximum concentrations are conservative as maximum concentrations would only occur for short periods of time; and the load impact will be offset by periods of discharge where discharge quality is below median values.

- The increase in loads is a function of the load in discharge divided by the load in inflows to the Yarrangobilly River arm of Talbingo Reservoir, which were assumed to occur from the Yarrangobilly River only. This is conservative as some additional flushing would occur due to the rapid change in water levels associated with the T2 and T3 hydro-power operation and other mixing processes. Relevant trigger values were applied to reservoir inflow volumes to calculate loads.

The waste water and process water treatment plants will remove suspended solids and the turbidity in the discharge will be low (<25 NTU). Therefore, the load of solids discharged will be low and load calculations for suspended solids are not provided.

Table 7.13 Talbingo Reservoir load impact analysis – controlled discharge

		Talbingo Reservoir (Yarrangobilly River arm)		
	Units	**Drought flow[1]**	**Median summer flow[2]**	**Median winter flow[2]**
Load impacts based on median monthly process water discharge (1.0 ML/month)				
Discharge[4]	kL/day	38.4	71	71
Reservoir inflows[3]	kL/day	12,581	51,613	709,677
Dilution factor	-	328	730	10,044
Increase in electrical conductivity (EC)				
EC in discharge[4]	µS/cm	30	372	372
EC in reservoir inflows[3]	µS/cm	30	30	30
Increase in salinity (as indicated by EC)	%	0.31%	1.70%	0.12%
Increase in oxidised nitrogen (NO_x)				
NO_x in discharge[4]	kg/day	0.004	0.010	0.010
NO_x in reservoir inflows[3]	kg/day	0.13	0.52	7.10
Increase	%	3.05%	1.87%	0.14%
Increase in filterable reactive phosphorus (FRP)				
FRP in discharge[4]	kg/day	0.002	0.003	0.003
FRP in reservoir inflows[3]	kg/day	0.06	0.26	3.55
Increase	%	3.66%	1.14%	0.08%
Load impacts based on maximum monthly process water discharge (4.9 ML/month) – winter only				
EC in Discharge[4]	kL/day	-[5]	-[5]	197
EC in reservoir inflows[3]	kL/day	-[5]	-[5]	709,677
Dilution factor	-			3,612
Increase in electrical conductivity (EC)				
EC in discharge[4]	µS/cm	-[5]	-[5]	633
EC in reservoir[3]	µS/cm	-[5]	-[5]	30
Increase in salinity (as indicated by EC)	(%)	-[5]	-[5]	0.58%
Increase in oxidised nitrogen (NO_x)				
NO_x in discharge[4]	kg/day	-[5]	-[5]	0.032
NO_x in reservoir inflows[3]	kg/day	-[5]	-[5]	7.10
Increase	(%)	-[5]	-[5]	0.46%
Increase in filterable reactive phosphorus (FRP)				
FRP in discharge[4]	kg/day	-[5]	-[5]	0.005
FRP in reservoir inflows[3]	kg/day	-[5]	-[5]	3.55
Increase	(%)	-[5]	-[5]	0.15%

Notes: *1. Calculation based on the lowest monthly stream flow on record of 390 ML/month. No process water discharge is applied to the summer drought conditions scenario as all surplus process water can be used for haul road dust suppression.*

2. Calculation based on a typical median monthly stream flow in summer months of 1,600 ML/month and 22,000 ML/month in winter

3. Reservoir inflows refer to inflows from the Yarrangobilly River only. The relevant trigger value has been applied to reservoir inflow calculations.

4. Calculations have been undertaken based on average monthly process water discharge volumes and median or typical concentrations that are provided in Table 7.12.

5. Maximum monthly process water discharges will only occur during winter or extended periods of wet weather. As stream flows would be elevated under these conditions, an assessment of maximum values has not been undertaken for the summer drought and typical summer condition scenarios.

The discharge of treated waste water and process water into the Yarrangobilly River arm of Talbingo Reservoir will (Table 7.13):

- increase the salt load (as indicated by EC) loads by up 0.31% during summer drought conditions;
- increase nutrient (NOx and FRP) loads by up 3.66% during summer drought conditions;
- increase the salt load (as indicated by EC) loads by up 1.70% during typical summer conditions; and
- increase nutrient (NOx and FRP) loads by up 1.87% during typical summer conditions.

Smaller proportional load increases are predicted during winter for median and maximum process water discharges. This is due to higher inflows from the Yarrangobilly River in winter months.

The potential load increases in the greater reservoir are expected to be orders of magnitude less due to the high year-round inflows into the Tumut River arm of Talbingo Reservoir due to discharges from Tumut 2 Power Station.

b. Cumulative load impacts

Conservative analysis of potential pollutant load impacts due to stormwater discharges into the Yarrangobilly River calculated a maximum load increase (considering TSS, TN, FRP and TP) of 2.6% (see Section 7.2.3). This maximum increase will occur during the construction phase of the project when the disturbance area is greatest (the initial nine months). The maximum load increase during operations is 2.5%. (see Section 7.2.3).

Controlled discharges of treated waste water and process water to Talbingo Reservoir will not commence until the accommodation camp is commissioned (approximately nine months from the start of Exploratory Works). Controlled discharges will progressively increase over the remainder of the Exploratory Works schedule as the need for process water discharges increases due to higher groundwater inflows into the tunnel. The peak load increase during non-drought conditions is estimated to be 1 to 2% (see Table 7.13).

The cumulative potential for Exploratory Works to increase of suspended sediment, nutrients and salt loads in the Yarrangobilly River arm of Talbingo Reservoir is conservatively estimated to be less than 5% of existing loads that occur naturally via inflows from the Yarrangobilly River. Algal blooms are not known to occur within Talbingo Reservoir historically. A 5% or less increase in nutrient loads in the Yarrangobilly arm of the reservoir is predicted not to result in blooms during Exploratory Works.

The small increase in the salt load to the Yarrangobilly arm of the reservoir (less than 1.7% for all scenarios) is not predicted to have any impacts to water quality or aquatic ecology.

c. Subaqueous dredged material placement

The potential for impacts to the water quality of Talbingo Reservoir from subaqueous dredged material placement and subaqueous excavated rock placement are assessed in the *Middle Bay Dredging and Dredge Impact Assessment* (RHDHV 2018a) and the *Subaqueous Excavated Rock Placement Program* (RHDHV 2018b) respectively.

Due to the separation of these activities from the mouth of the Yarrangobilly River and the discharge point in the Yarrangobilly River arm in Talbingo Reservoir, no cumulative impacts between these activities and water discharges are predicted.

7.3.4 Impacts to ecology

Some water quality trigger values for salinity and nutrients chemical stressors are predicted to be exceeded in the mixing zone (20 m across, about 315 m^2) surrounding the discharge outlet. Mobile organisms that are intolerant of salinity or nutrient concentration increases in the mixing zone will not remain within the mixing zone for long periods so no significant impacts to mobile organisms are predicted. The species and/or abundance of benthic infauna within the mixing zone may be impacted by the increased salinity or nutrient concentrations. However, the habitat in the small mixing zone is widely represented in the reservoir so this impact will be negligible.

7.4 Flood impacts

The Exploratory Works avoid flood prone land where possible. However, the following infrastructure will unavoidably need to be constructed on flood prone land:

- bridge crossings over the Yarrangobilly River and Wallaces Creek;
- the western emplacement area; and
- the water management basin for the portal construction pad.

The flood model was applied to assess changes to the existing flooding regime associated with the infrastructure. This process concluded that the predicted changes to flood regimes will not impact infrastructure or items of heritage significance.

8 Monitoring and trigger action response plan

8.1 Overview

This section describes a surface water monitoring program that will be implemented over the duration of the Exploratory Works. This will be an extension of the current baseline monitoring program. The primary objectives of the monitoring program are to collect sufficient data to:

- continue to monitor baseline conditions (upstream of impact areas);
- identify and quantify water quality impacts (downstream of impact areas);
- enable the effectiveness of water quality controls to be assessed; and
- assess compliance with relevant consent and licence conditions.

The monitoring program includes requirements to monitor weather, stream flows, process and waste water quantity and quality, stormwater quality and receiving water quality. Table 8.1 provides a break-down of the program and describes the monitoring objectives, locations and methods.

Further information on monitoring locations is provided in Section 1.1. Section 8.3 describes the monitoring regime, sampling analytes and analysis methods.

Table 8.1 Surface water monitoring program framework

Aspect	Objectives	Monitoring locations	Monitoring methods
Weather monitoring	• Record rainfall and other meteorological conditions at Lobs Hole.	• Lobs Hole.	• Install and operate a weather station within the Lobs Hole area.
Stream gauge monitoring (Monitoring ID[1] = SG)	• Measure stream flows in the Yarrangobilly River and Lick Hole Gully and overflows from the portal construction pad's water management basin.	• Yarrangobilly River. • Lick Hole Gully (upstream and downstream of the eastern emplacement). • Portal construction pad water management basin spillway.	• Continue to operate stream gauge 410574 on the Yarrangobilly River, downstream of the eastern emplacement. • Install stream gauges on Lick Hole Gully, upstream and downstream of the eastern emplacement. • Install a water level meter in the portal construction pad's water management basin.
Process water quantity monitoring	• Measure all process water uses, sources and controlled discharge volumes.	• All process water use points including dust suppression and the concrete batching plant. • Tunnel dewatering location. • Stormwater harvesting from the construction. pad's water management dam. • Water extraction from Talbingo Reservoir. • Controlled discharge to Talbingo Reservoir.	• Cumulative flow meters will be installed at all monitoring locations. • Meter readings will be recorded weekly.
Receiving water quality monitoring (Monitoring ID[1] = RW)	Monitor receiving water quality to: • establish baseline conditions; and • identify impacts to water quality.	• Yarrangobilly River (4 locations). • Wallaces Creek (1 location). • Talbingo Reservoir (2 locations).	• A minimum of 12 samples per year will be collected from each monitoring location. Sampling will be undertaken during base flow, wet weather and after wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].
Process water quality monitoring (Monitoring ID[1] = PW)	• Monitor the quality of water within the process water management system.	• Exploratory tunnel portal sump. • Process water tank (post treatment).	• Sampling will be undertaken on a monthly basis. All samples will be analysed for a comprehensive suite of parameters[2].

Table 8.1 Surface water monitoring program framework

Aspect	Objectives	Monitoring locations	Monitoring methods
Stormwater quality monitoring (Monitoring ID[1] = SW)	• Monitor the quality of water within stormwater management basins.	• Portal construction pad water management basin. • Accommodation camp ponds (2 locations).	• A minimum of 12 samples per year will be collected from each monitoring location. Sampling will be undertaken during base flow, wet weather and after wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].
Treated effluent monitoring (Monitoring ID[1] = TE)	• Monitor the quality of treated effluent that will be discharged to Talbingo Reservoir.	• Waste water treatment plant.	• Sampling will be undertaken on a monthly basis. All samples will be analysed for a comprehensive suite of parameters[2].
Emplacement water quality monitoring (Monitoring ID[1] = EM)	• Monitor the quality of seepage and runoff from the eastern and western emplacements.	• Lick Hole Gully (upstream of the eastern emplacement). • Downstream of the eastern emplacement. • Downstream of the western emplacement.	• Continuous measurement of pH and electrical conductivity. Measurement devices will be incorporated into the stream gauges. • A minimum of 12 samples per year will be collected from each monitoring location. Sampling will be undertaken during base flow, wet weather and after wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].
Access road runoff monitoring (Monitoring ID[1] = AR)	• Monitor the quality of runoff from access roads	• Monitoring will be undertaken at four random discharge locations each monitoring round.	• Event based sampling[2] and inspection of sediment and erosion controls will be undertaken following material wet weather events[3]. • A minimum of 4 samples per year will be collected from each monitoring location during wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].
Construction disturbance area monitoring (Monitoring ID[1] = CD)	• Monitor the quality of runoff from areas disturbed by construction.	• Monitoring locations will be established as part of the detailed sediment and erosion control plans that will be prepared for each construction zone.	• Event sampling[2] and inspection of sediment and erosion controls will be undertaken following material wet weather events[3]. • A minimum of 4 samples per year will be collected from each monitoring location during wet weather conditions. All samples will be analysed for a comprehensive suite of parameters[2].

Notes: *1. Monitoring ID is used to describe monitoring locations. This is explained further in Section 1.1.*

2. Refer to Section 8.3 for detailed information on the monitoring regime, sampling analytes and analysis methods.

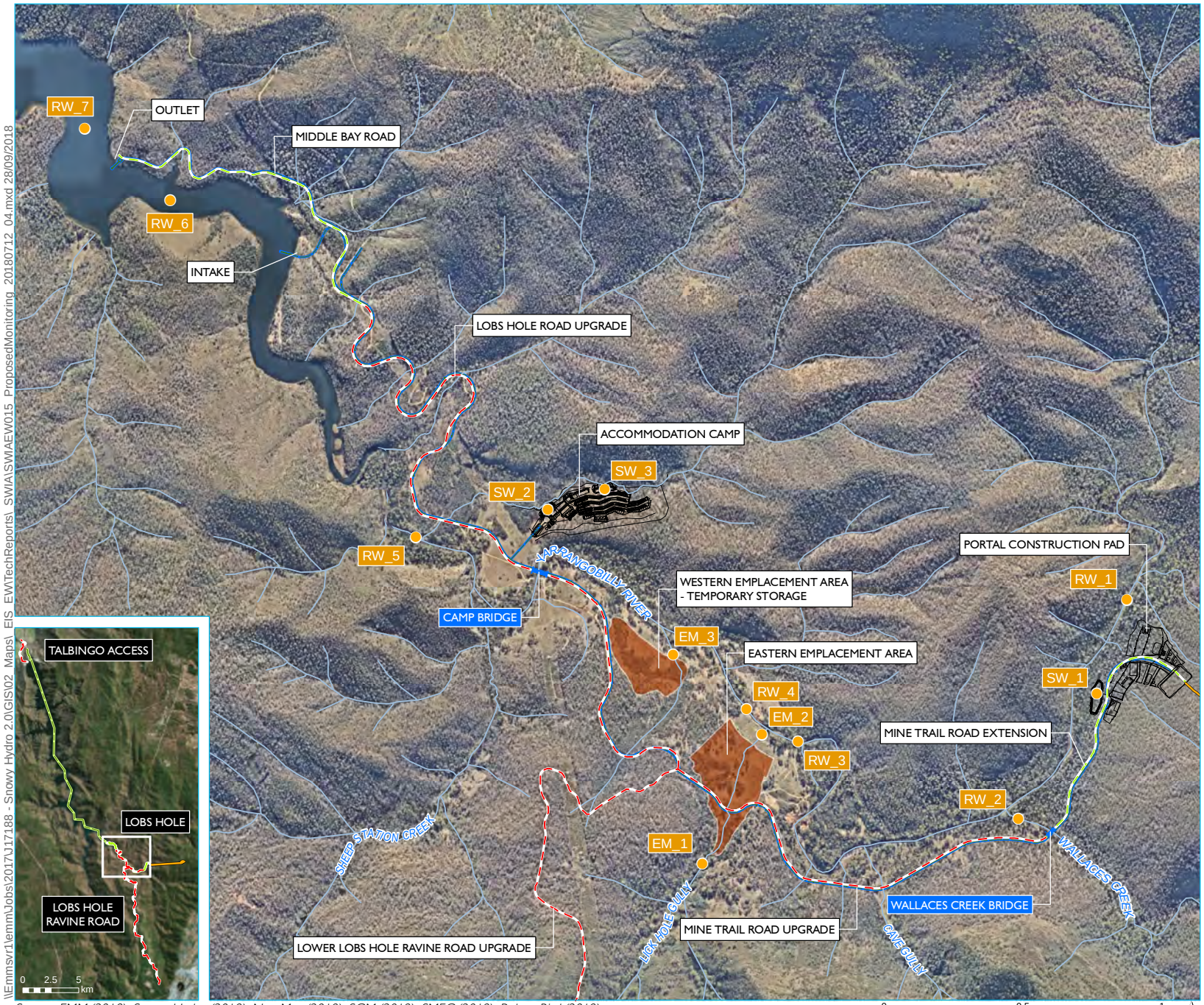
3. a material wet weather event refers to any rainfall event that results in the discharge of surface water from the project's water management dams. This will typically require 30 to 50mm of rainfall over a 2 to 3 day period.

8.2 Monitoring locations

Table 8.2 provides additional information on the monitoring locations described in Table 8.1. The stream gauge, receiving water, stormwater and emplacement monitoring locations are indicated in Figure 8.1.

Table 8.2 Water monitoring locations

ID	Location	Comment
Stream gauge monitoring locations		
SG_1	Yarrangobilly River	Refers to the existing stream gauge (410574) located on the Yarrangobilly River, downstream of the eastern emplacement
SG_2	Lick Hole Gully	A stream gauge will be installed in Lick Hole Gully, upstream of the eastern emplacement
SG_3	Lick Hole Gully	A stream gauge will be installed on Lick Hole Gully, downstream of the eastern emplacement
SG_4	Portal Water Management Basin	A water level meter will be installed in the portal compound's water management basin to record dam overflow volumes and rates
Receiving water monitoring locations		
RW_ 1	Yarrangobilly River	Upstream of the exploratory tunnel and construction pad
RW_ 2	Wallaces Creek	Upstream of the confluence with the Yarrangobilly River
RW_ 3	Yarrangobilly River	Downstream of remnant mine workings, upstream of the eastern emplacement
RW_ 4	Yarrangobilly River	Downstream of the eastern emplacement
RW_ 5	Yarrangobilly River	Downstream of the accommodation camp, upstream of Talbingo Reservoir
RW_ 6	Talbingo Reservoir	Upstream of the controlled discharge location
RW_ 7	Talbingo Reservoir	Downstream of the controlled discharge location
Process water monitoring locations		
PW_1	Tunnel portal sump	The tunnel portal sump will receive water dewatered from the tunnel
PW_2	Treated process water (from the process water tank)	This water will be used for dust suppression, concrete batching and may be discharge to Talbingo Reservoir via controlled discharge
Treated effluent monitoring locations		
TE_1	Treated effluent	Treated effluent from the waste water treatment plant will be discharged to Talbingo Reservoir
Stormwater monitoring locations		
SW_1	Construction pad basin	Receives runoff from the portal construction pad water management area
SW_2	Accommodation camp pond 1	Receives runoff from the southern portion of the accommodation camp
SW_3	Accommodation camp pond 2	Receives runoff from the northern portion of the accommodation camp
Emplacement monitoring locations		
EM_1	Lick Hole Gully	Upstream of the eastern emplacement
EM_2	Lick Hole Gully	Downstream of the eastern emplacement
EM_3	Western Emplacement	Downstream of the western emplacement
Access road monitoring locations		
AR_1 to AR_4	Four random access road discharge locations will be selected each sampling event.	Access road discharge locations refer to any location where runoff from access road drainage enters a clean water drainage system. This may be overflow from a sedimentation basin or from a sediment trap
Construction disturbance area monitoring		
Monitoring locations will be established as part of the detailed sediment and erosion control plans that will be prepared for each construction zone.		



KEY

- Proposed monitoring location
- Exploratory tunnel
- Portal construction pad and accommodation camp conceptual layout
- Permanent bridge
- Access road upgrade
- Access road extension
- Water services pipeline
- Watercourse
- On land rock management

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); SGM (2018); SMEC (2018); Robert Bird (2018)

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Proposed monitoring locations

Snowy 2.0
Surface water assessment
Exploratory Works
Figure 8.1

snowy2.0

EMM creating opportunities

8.3 Monitoring regime and methods

8.3.1 Terminology

The following terminology is used to describe the proposed monitoring regime:

- Continuous – refers to the use of continuous monitoring methods.
- Monthly – refers to routine monitoring that will be undertaken monthly, regardless of weather.
- Baseflow (Quarterly) – refers to monitoring that will be undertaken on a quarterly basis to assess base flow conditions.
- Wet Weather (Quarterly) – refers to monitoring that will be undertaken on a quarterly basis during wet weather conditions. Wet weather events are defined as any rainfall event that results in the discharge of surface water from the project's water management dams. This will typically require 30 to 50 mm of rainfall over a 2 to 3 day period.
- After Wet Weather (Quarterly) - refers to monitoring that will be undertaken on a quarterly basis, approximately 1 week after each of the wet weather samples.
- Wet Weather (Event-based) – refers to monitoring that will be undertaken daily during wet weather conditions. Wet weather events are defined as any rainfall event that results in the discharge of surface water from the Exploratory Work's water management dams.

8.3.2 Monitoring regime and methods

Table 8.3 details the proposed monitoring regime for each monitoring category and Table 8.4 details the proposed sampling analytes and analysis methods.

Table 8.3 Monitoring regime

	Continuous	**Monthly**	**Baseflow**	**Wet weather (comprehensive)**	**After wet weather**	**wet weather (Basic)**
Frequency	Continuous	Monthly	Quarterly	Quarterly	Quarterly	Event Based
Method	Stream gauge	Comprehensive	Comprehensive	Comprehensive	Comprehensive	Basic
Stream gauge (SG)	✓					
Receiving water (RW)			✓	✓	✓	
Process water (PW)		✓				
Treated effluent (TE)		✓				
Stormwater (SW)				✓	✓	✓
Emplacement (EM)	✓		✓	✓	✓	
Access road (AR)				✓		✓
Construction area (CA)				✓		✓

Table 8.4 Monitoring methods

Category	Sampling analytes	Analysis method
	Basic monitoring	
Physiochemical Properties	pH, electrical conductivity (EC), turbidity, dissolved oxygen, temperature, redox potential	To be measured using a portable water quality meter in the field
Inspection		Inspection of erosion and sediment controls and downstream drainage
	Comprehensive monitoring	
Physiochemical Properties	pH, electrical conductivity (EC), turbidity, dissolved oxygen, temperature, redox potential	To be measured using a portable water quality meter in the field
	major cations (Na, K, Mg, Ca) and major anions (Cl, SO_4, HCO_3 and CO_3)	Analysis to be undertaken by a NATA certified laboratory
	total suspended solids, total dissolved solids, total hardness, Total Recoverable Hydrocarbons	Analysis to be undertaken by a NATA certified laboratory
Nutrients	total nitrogen, ammonia, nitrate, nitrite and total kjeldahl nitrogen	Analysis to be undertaken by a NATA certified laboratory
	total phosphorus and reactive phosphorus	
	total organic carbon, dissolved organic carbon	
Metals (dissolved)	Al, As, Ag, B, Ba, Cr (total), Co, Cd, Cu, Fe, Hg, Mn, Ni, Pb, Se, V and Zn	Analysis to be undertaken by a NATA certified laboratory
	Comprehensive monitoring (TE_1, RW_6 and RW_7 only)	
Oxygen Demand	Chemical oxygen demand, Biological oxygen demand	Analysis to be undertaken by a NATA certified laboratory
Biological	Total plate count, E Coli, Faecal Coli form	Analysis to be undertaken by a NATA certified laboratory

9 Water licensing

This section discusses the surface water licensing requirements for the Exploratory Works.

9.1 Expected surface water take

Surface water extraction from Talbingo Reservoir will be required to provide potable water for the project and to top-up the process water system, which will supply water for use in construction activities. Table 9.1 provides a summary of the expected maximum surface water take.

Table 9.1 Expected maximum surface water take

Water take	Volume
Extraction from the Yarrangobilly River	
No extraction of surface water from the Yarrangobilly River is proposed	nil
Extraction from Talbingo Reservoir	
Extraction for potable water	18 ML/year[1]
Extraction for use in construction activities	209 ML/year[2]
Total	227 ML/year

Notes: 1. Calculated using the estimated daily waste water load of 48 KL/day.

2. The maximum annual total from Table 6.21 has been adopted.

As discussed in Section 3.2.1, the water management works for diversion, storage, and or release of water that is for construction activities in respect of Exploratory Works for Snowy 2.0 are considered to be 'incidental or related to the generation of electricity' and therefore the diversion, storage, use and release of surface water with respect to construction activities is licenced within the Snowy water licence.

Snowy Hydro will discuss the above proposed licensing pathway with DoI Water.

9.2 Water management dams

Water management dams are proposed to manage runoff from construction disturbance areas, access roads, the construction pad and the accommodation camp. The capture of surface water runoff in the water management dams is considered to be excluded works under *Water Management (General) Regulation 2011, Schedule 1, item 3 (dams solely for the capture, containment or recirculation of drainag*e). Accordingly, no WALs or WUAs are required from DoI Water for the capture of surface water in management dams.

10 Conclusion

10.1 Assessment approach

This surface water assessment forms part of the EIS for the Exploratory Works. This assessment has been informed by the reference design prepared for the Exploratory Works. The following aspects of the project have been addressed in this assessment:

- Flood risk management associated with the following works on flood prone land:
  - Camp and Wallaces bridges;
  - the western rock and soil emplacement area; and
  - the water management basin for the construction pad.
- Water management during construction of access roads, the accommodation camp, portal construction pad and other infrastructure.
- Water management during operation including:
  - stormwater runoff from the access roads, accommodation camp and portal construction pad;
  - water produced by and used by the construction activities;
  - waste water (ie sewage); and
  - water management for rock and soil emplacement areas.

This assessment has identified potential impacts and considers all practical controls to avoid or mitigate identified impacts. The controls presented in this assessment are principles or design objectives, that will be further developed in the detailed design of the Exploratory Works. The management measures assessed are presented to determine the feasibility of achieving the proposed discharge water quality. The management measures implemented may vary from those presented but will still need to meet the proposed water quality or other stated objectives.

Appendix F provides a summary of controls.

10.2 Residual impacts

Residual impacts of Exploratory Works on the surface water environment have been assessed relative to the WQOs and environmental values for the receiving waters, including indicators and trigger values provided in the ANZECC/ARMCANZ (2000).

10.2.1 Impacts to the Yarrangobilly River

Potential impacts to the Yarrangobilly River and other watercourses will occur due to stormwater discharges from Exploratory Works. All practical controls to avoid or mitigate impacts are presented. An assessment of residual impacts has concluded that:

- stormwater discharges from disturbed areas >2,500 m^2 will occur up to ten times per year on average – during and immediately following rainfall;
- stormwater discharges from disturbed areas <2,500 m^2 will occur up to 50 times per year on average but discharge volumes will be small;
- turbidity, and suspended solids and nutrients concentrations in discharged stormwater are expected to exceed default trigger levels for physical and chemical stressors on occasions and it is possible that metal concentrations may also exceed the relevant default trigger levels;
- stormwater discharges will rapidly mix with river flows, so no concentration impacts are predicted;
- load increases due to stormwater discharges are conservatively estimated to be less than 2.6% of existing loads for all pollutants;
- no change to stream flow regimes is predicted; and
- no ecological impacts are predicted.

10.2.2 Impacts to Talbingo Reservoir

The potential for impacts to the water quality of Talbingo Reservoir from the following have been assessed:

- discharge of treated waste water and treated process water into the Yarrangobilly River arm of Talbingo Reservoir; and
- the discharge of stormwater runoff into the Yarrangobilly River, upstream of Talbingo Reservoir.

All practical controls to avoid or mitigate impacts are presented. An assessment of residual impacts has concluded that:

- discharges of treated waste water and process water may exceed default trigger levels for Talbingo Reservoir at the point of discharge;
- a mixing zone, conservatively assessed to extend 10 m from the point of discharge, will be required;
- pollutant load increases are conservatively estimated to be less than 5% of existing loads; and
- no ecological impacts are predicted.

11 References

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Glossary

Term	Meaning
Access road upgrade	Upgrade works (realignment, widening or no widening) of existing access roads
Access road extension	A new access road that is an extension of an existing access road
Accommodation camp	Area used for temporary housing and facilities for construction personnel
Avoidance footprint	Areas excluded from clearing and ground disturbance due to sensitive environmental constraints
Barge access infrastructure	A ramp and associated facilities to allow the loading and unloading of barge(s) on Talbingo Reservoir
Camp bridge	The permanent bridge structure across Yarrangobilly River
Communications cable	Fibre optic communications cable in Talbingo Reservoir
Concentration impact	Refers to an impact from an increase in a concentration due to water discharges.
Controlled discharge	Refers to the controlled discharge of treated waste water and treated process water into the Yarrangobilly arm of Talbingo Reservoir
Clean water	surface water runoff from catchments that are undisturbed or rehabilitated following disturbance
Disturbance footprint	The area subject to clearing and ground disturbance
Dilution factor	Refers to the discharge concentration divided by the relevant trigger value. A dilution factor of one (or less) indicates that the discharge concentration will not exceed the trigger value while a dilution factor of more than one indicates the level of dilution (or mixing) that will be required to achieve the trigger value.
Emplacement seepage	Water that seeps from the rock and soil emplacements
Exploratory tunnel	A 3.1 km tunnel to the cavern of the proposed Machine Hall for the purposes of understanding geotechnical and underground conditions
Exploratory Works	A program of exploratory works for Snowy 2.0, subject of this EIS and as described in Section 2.
Fire water	Water that is produced by fire fighting activities
Load impact	Refers to an impact from an increase in the load of a potential contaminant in the receiving environment due to a water discharge.
Lobs Hole	A former settlement location within Kosciuszko National Park, and primary location of Exploratory Works
Lobs Hole Mine	The site of a former copper mine circa 1908, located at Lobs Hole
Lobs Hole Ravine Road	The main access road to Lobs Hole
Lower Lobs Hole Ravine Road	The section of Lobs Hole Ravine Road from Link Road to where it crosses the transmission easement
Middle Bay barge ramp	Location of barge access infrastructure at the southern end of Talbingo Reservoir
Middle Bay Road	The access road from the accommodation camp to the Middle Bay barge ramp. An extension to Middle Bay Road is proposed as part of Exploratory Works.
Miles Franklin Drive	Existing road leading to Spillway Road, for access to the Talbingo barge ramp
Mine Trail Road	The access road from the intersection with Lower Lobs Hole Ravine Road and the portal construction pad. An extension to Mine Trail Road is proposed as part of Exploratory Works.

Glossary

Term	Meaning
Mixing Zone	Refers to an area where the water quality of a discharge does not immediately meet water quality objectives and where discharged water mixes with water in the receiving environment, progressively becoming more diluted. Dilution of the discharged water within the mixing zone needs to ensure that quality objectives to are met at the edge of the mixing zone.
On land rock emplacement area	The locations for rock emplacement at Lobs Hole being the western emplacement area and the eastern emplacement area
Permanent bridge	The permanent bridge crossings comprising Wallace Creek bridge and Camp bridge
Portal	Location of surface connection with the exploratory tunnel
Portal construction pad	Area used for construction for the exploratory tunnel and portal, including ancillary facilities, laydown and storage, and environmental controls
Potable water	Water that has been treated to a potable water standard
Project area	The area required to access and build project infrastructure, including surface and tunnel components of the project
Process water	Water that will be produced by or used by the proposed construction activities.
Receiving water	Any watercourse that receives runoff or water discharge from the Exploratory Works
Rock emplacement area	Land area identified for the placement and storage of excavated rock from Exploratory Works
Sediment laden water	Surface water runoff from construction disturbance and unsealed access roads. Sediment laden water is likely to contain elevated suspended sediment levels and requires sedimentation treatment prior to release.
Snowy 2.0	A pumped-hydro expansion of the Snowy Scheme that will link the two existing reservoirs of Tantangara and Talbingo through underground tunnels, and include a new underground power station with pumping capabilities.
Spillway	Structure used to provide the controlled release of flows from Talbingo Dam into the reservoir
Spillway Road	The access road to Talbingo barge ramp
Stormwater	Runoff from the accommodation camp and portal compound. Stormwater may contain elevated concentrations of suspended sediment and nutrients
Study area	Define if appropriate for the technical study (ie. Is different to the Exploratory Works project area)
Subaqueous rock emplacement area	The location for rock emplacement within Talbingo Reservoir
Talbingo barge ramp	Location of barge access infrastructure at the northern end of Talbingo Reservoir
Talbingo Spillway	Structure used to provide the controlled release of flows from Talbingo Dam into the reservoir
Temporary bridge	A temporary structure or causeway across a watercourse to allow construction of permanent bridges
Tunnel affected water	Intercepted groundwater and all other water that is dewatered from the exploratory tunnel (a component of process water)
Tumut 3 power station	Power station at the northern end of Talbingo Reservoir
Upper Lobs Hole Ravine Road	The section of Lobs Hole Ravine Road from where it crosses the transmission easement to Lobs Hole
Wallaces Creek Bridge	The permanent bridge structure across Wallaces Creek

Glossary

Term	Meaning
Water services pipeline	Utility pipeline for Exploratory Works providing water supply and waste water discharge between accommodation camp, portal construction pad and Talbingo Reservoir
Waste water	Waste water generated from the accommodation camp and other onsite amenities

Abbreviations

AC	*Acid consuming*
AEP	*Annual Exceedance Probability*
ANC	*Acid Neutralising Capacity*
ANZECC/ARMCANZ	*Australian and New Zealand Environmental Conservation Council*
ARD	*Acid Rock Drainage*
ARR2016	*Australian Rainfall and Runoff (2016)*
BoM	*Bureau of Meteorology*
DECC	*(former) NSW Department of Environment and Climate Change*
DPE	*Department of Planning and Environment*
DoI – Water	*Department of Industry - Water*
EC	*Electrical Conductivity*
EIS	*Environmental Impact Statement*
EPA	*NSW Environment Protection Authority*
ESCP	*Erosion and Sediment Control Plan*
FFA	*Flood Frequency Analysis*
KNP	*Kosciuszko National Park*
PAF	*Potentially Acid Forming*
POEO	*Protection of the Environment Operations Act 1997*
PMF	*Probable Maximum Flood*
SEARs	*Secretary's Environmental Assessment Requirements*
SHC Act	*The NSW Snowy Hydro Corporatisation Act 1997*
VD	*Velocity Depth product*
WAL	*Water Access License*
WA 1912	*Water Act 1912*
WQO	*Water quality objectives*
WMA 2000	*Water Management Act 2000*
WSP	*Water Sharing Plan*
WUA	*Work and Use Approval*

Appendix A

Water Quality Results

Table A1 Water quality results: Yarrangobilly River

	Unit	Month	February			March				April				Yarrangobilly River summary			
		Site	LH_SW_004	LH_SW_007	PN_SW_002	LH_SW_004	LH_SW_006	LH_SW_007	PN_SW_002	LH_SW_004	LH_SW_006	LH_SW_007	PN_SW_002				
		Date	14/02/2018	14/02/2018	14/02/2018	13/03/2018	13/03/2018	13/03/2018	13/03/2018	12/04/2018	12/04/2018	12/04/2018	9/04/2018				
		Trigger Value												# Samples	10th Percentile	Median	90th Percentile
Field Parameters																	
Temperature	°C	-	21	23	19	19	21	22	21	15	13	14	15	11	14	19	22
Dissolved Oxygen (DO)	%	90 – 110[1]	**-**	**-**	**-**	**75**	**84**	**88**	**85**	**79**	93	90	**75**	8	**75**	**84**	93
Electrical Conductivity (EC)	µS/cm	30 – 350[1]	121	146	**28**	183	185	187	32	174	171	171	39	11	32	171	185
pH		6.5 – 8.0[1]	7.3	7.6	7.5	**8.1**	8.0	8.0	7.7	8.0	7.9	7.9	**8.3**	11	7.5	7.9	**8.1**
Oxidising and Reducing Potential (ORP)		-	119	104	112	132	128	130	137	120	167	144	143	11	112	130	144
Turbidity	NTU	2 - 25	<2	<2	5.14	<2	<2	<2	2.78	-	-	-	-	7	<2	<2	5
Analytical Results - General																	
Suspended Solids (SS)	mg/L	-	<5	<5	<5	<2	<2	2	2	<5	<5	<5	6	11	<5	<5	<5
Total Alkalinity (as $CACO_3$)	mg/L	-	68	86	15	109	106	109	16	-	-	-	-	7	15	86	109
Total Hardness (as $CACO_3$)	mg/L	-	-	-	-	-	-	-	-	86	97	91	9	4	9	89	97
Analytical Results - Nutrients																	
Ammonia	mg/L	0.013	<0.01	<0.01	<0.01	-	-	-	-	<0.01	<0.01	<0.01	<0.01	7	<0.01	<0.01	<0.01
Oxidised Nitrogen (NOx)	mg/L	0.015	**1.92**	**0.04**	**0.02**	-	-	-	-	**0.03**	<0.01	**0.05**	**0.03**	7	0.01	**0.03**	**1.92**
Total Kjeldahl Nitrogen (TKN)	mg/L	-	<0.1	<0.1	0.1	-	-	-	-	<0.1	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.1
Total Nitrogen (TN)	mg/L	0.25	**1.9**	<0.1	0.1	-	-	-	-	<0.1	<0.1	<0.1	<0.1	7	0.1	0.1	**1.9**
Reactive Phosphorus	mg/L	0.015	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01
Total Phosphorus (TP)	mg/L	0.02	<0.01	0.02	<0.01	-	-	-	-	<0.01	<0.01	<0.01	<0.01	7	0.01	0.01	0.02
Total Organic Carbon	mg/L	-	-	-	-	-	-	-	-	6	1	23	16	4	1	11	23
Dissolved Organic Carbon	mg/L	-	-	-	-	-	-	-	-	<1	<1	<1	1	4	<1	<1	<1
Analytical Results - Inorganics (Dissolved)																	
Fluoride	mg/L	2.4	0.6	<0.1	<0.1	0.1	0.11	0.1	0.08	-	-	-	-	7	0.08	0.1	0.6
Analytical Results - Metals (Dissolved)																	
Aluminium (Al)	mg/L	0.027	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	**0.06**	4	0.01	0.01	**0.06**
Arsenic (As)	mg/L	0.0008	-	-	-	-	-	-	-	<0.001	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001
Barium (Ba)	mg/L	0.008	-	-	-	-	-	-	-	**0.026**	**0.042**	**0.031**	**0.011**	4	**0.011**	**0.0285**	**0.042**
Boron (B)	mg/L	0.09	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05
Cobalt (Co)	mg/L	0.0014	-	-	-	-	-	-	-	<0.001	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001
Total Chromium (Cr)	mg/L	0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-	-	7	<0.001	<0.001	<0.001
Copper (Cu)	mg/L	0.001	-	-	-	-	-	-	-	0.001	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001
Manganese (Mn)	mg/L	1.2	-	-	-	-	-	-	-	<0.001	0.001	0.001	0.002	4	0.001	0.001	0.002
Nickel (Ni)	mg/L	0.008	-	-	-	-	-	-	-	0.001	<0.001	<0.001	<0.001	7	0.001	0.001	0.002
Lead (Pb)	mg/L	0.001	-	-	-	-	-	-	-	<0.001	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001
Selenium (Se)	mg/L	0.005	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01
Silver (Ag)	mg/L	0.0002	-	-	-	-	-	-	-	<0.001	<0.001	<0.001	<0.001	4	<0.001	<0.001	<0.001
Vanadium (V)	mg/L	0.006	-	-	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	4	<0.01	<0.01	<0.01
Zinc (Zn)	mg/L	0.0024	-	-	-	-	-	-	-	<0.005	<0.005	<0.005	<0.005	4	<0.005	<0.005	<0.005
Mercury (Hg)	mg/L	0.00006	-	-	-	-	-	-	-	<0.0001	<0.0001	<0.0001	<0.0001	4	<0.0001	<0.0001	<0.0001
Iron (Fe)	mg/L	0.3	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	0.06	4	0.05	0.05	0.06

Notes:

1. Refer to Section 4.6.1 for further information on guideline values.

Bold *denotes Guideline Value or Range is exceeded.*

Table A2 Water quality results: Wallaces Creek

	Unit	Month	March			April			Wallaces Creek Summary			
		Site	LH_SW_001	LH_SW_002	LH_SW_003	LH_SW_001	LH_SW_002	LH_SW_003				
		Date	13/03/2018	13/03/2018	13/03/2018	12/04/2018	12/04/2018	12/04/2018				
		Trigger Value				Dry			# Samples	Min	Median	Max
Field Parameters												
Temperature	°C	-	15	13	16	-	15	14	5	13	15	16
Dissolved Oxygen (DO)	%	90 – 110[1]	**75**	**77**	**78**	-	92	**85**	5	**75**	**78**	92
Electrical Conductivity (EC)	µS/cm	30 – 350[1]	65	185	176	-	183	178	5	65	178	185
pH		6.5 – 8.0[1]	7.5	7.5	7.6	-	**8.4**	7.9	5	7.5	7.6	**8.4**
Oxidising and Reducing Potential (ORP)		-	146	144	133	-	70	62	5	62	133	146
Turbidity	NTU	2 - 25	<2	<2	<2	-	-	-	3	<2	<2	<2
Analytical Results - General												
Suspended Solids (SS)	mg/L	-	2	<2	<2	-	<5	<5	5	2	2	5
Total Alkalinity (as $CACO_3$)	mg/L	-	38	104	99	-	-	-	3	38	99	104
Total Hardness (as $CACO_3$)	mg/L	-	-	-	-	-	87	94	2	87	90.5	94
Analytical Results - Nutrients												
Ammonia	mg/L	0.013	-	-	-	-	<0.01	<0.01	2	<0.01	<0.01	<0.01
Oxidised Nitrogen (NOx)	mg/L	0.015	-	-	-	-	**0.04**	**0.03**	2	**0.03**	**0.035**	**0.04**
Total Kjeldahl Nitrogen (TKN)	mg/L	-	-	-	-	-	<0.1	<0.1	2	<0.1	<0.1	<0.1
Total Nitrogen (TN)	mg/L	0.25	-	-	-	-	<0.1	<0.1	2	<0.1	<0.1	<0.1
Reactive Phosphorus	mg/L	0.015	-	-	-	-	<0.01	<0.01	2	<0.01	<0.01	<0.01
Total Phosphorus (TP)	mg/L	0.02	-	-	-	-	0.01	<0.01	2	<0.01	<0.01	<0.01
Total Organic Carbon	mg/L	-	-	-	-	-	8	25	2	8	16.5	25
Dissolved Organic Carbon	mg/L	-	-	-	-	-	1	1	2	<1	<1	<1
Analytical Results - Inorganics (Dissolved)												
Fluoride	mg/L	2.4	0.09	0.1	0.1	-	-	-	3	0.09	0.1	0.1
Analytical Results - Metals (Dissolved)												
Aluminium (Al)	mg/L	0.027	-	-	-	-	<0.01	<0.01	2	<0.01	<0.01	<0.01
Arsenic (As)	mg/L	0.0008	-	-	-	-	<0.001	<0.001	2	<0.001	<0.001	<0.001
Barium (Ba)	mg/L	0.008	-	-	-	-	**0.088**	**0.106**	2	**0.088**	**0.097**	**0.106**
Boron (B)	mg/L	0.09	-	-	-	-	<0.05	<0.05	2	<0.05	<0.05	<0.05
Cobalt (Co)	mg/L	0.0014	-	-	-	-	<0.001	<0.001	2	<0.001	<0.001	<0.001
Total Chromium (Cr)	mg/L	0.0001	<0.002	<0.002	<0.002	-	-	-	3	<0.002	<0.002	<0.002
Copper (Cu)	mg/L	0.001	-	-	-	-	<0.001	**0.003**	2	0.001	**0.002**	**0.003**
Manganese (Mn)	mg/L	1.2	-	-	-	-	0.001	0.002	2	0.001	0.0015	0.002
Nickel (Ni)	mg/L	0.008	-	-	-	-	0.001	<0.001	3	0.001	0.002	0.002
Lead (Pb)	mg/L	0.001	-	-	-	-	<0.001	<0.001	2	<0.001	<0.001	<0.001
Selenium (Se)	mg/L	0.005	-	-	-	-	<0.01	<0.01	2	<0.01	<0.01	<0.01
Silver (Ag)	mg/L	0.0002	-	-	-	-	<0.001	<0.001	2	<0.001	<0.001	<0.001
Vanadium (V)	mg/L	0.006	-	-	-	-	<0.01	<0.01	2	<0.01	<0.01	<0.01
Zinc (Zn)	mg/L	0.0024	-	-	-	-	<0.005	<0.005	3	<0.005	<0.005	<0.005
Mercury (Hg)	mg/L	0.00006	-	-	-	-	<0.0001	<0.0001	2	<0.0001	<0.0001	<0.0001
Iron (Fe)	mg/L	0.3	-	-	-	-	<0.05	<0.05	2	<0.05	<0.05	<0.05

Notes:

1. Refer to Section 4.6.1 for further information on guideline values.

***Bold** denotes Guideline Value or Range is exceeded.*

Table A3 Water quality results: Talbingo Reservoir

	Unit	Month															Talbingo Reservoir summary			
		Site	TAL01-S	TAL01-M	TAL01-B	TAL09-S	TAL09-M	TAL09-B	TAL15B-S	TAL15B-M	TAL15B-B	TAL19-S	TAL19-M	TAL20-S	TAL20-M	TAL15-S	TAL15-M				
		Date	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018	march 2018				
		Trigger Value																# Samples	10th Percentile	Median	90th Percentile
Field Parameters																					
Temperature	°C		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved Oxygen (DO)	%	90 – 110[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electrical Conductivity (EC)	µS/cm	20 – 30[2]	**66**	**31**	26	29	29	27	29	29	27	**32**	**31**	30	30	**31**	28	15	27	29	**32**
pH		6.5 – 8.0[2]	7	7	6.8	7	6.9	6.9	7	7	6.8	7.2	7.1	7.1	7.2	6.8	7.1	15	6.8	7.0	7.2
Oxidising and Reducing Potential (ORP)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	1 - 20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Analytical Results - General																					
Suspended Solids (SS)	mg/L	-	2.5	1.3	19	1	< 1	< 1	1.7	1.1	1.4	5.8	3.4	2.2	1	4	4.6	15	<1	2	6
Total Alkalinity (as $CACO_3$)	mg/L	-	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	15	<20	<20	<20
Total Hardness (as $CACO_3$)	mg/L	-	11	7.1	5.3	6.9	11	6.6	7.8	7.2	6.3	8.4	9.3	7.3	7.3	6.6	7.1	15	6	7	10
Analytical Results - Nutrients																					
Ammonia	mg/L	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	15	<0.01	<0.01	<0.01
Oxidised Nitrogen (NOx)	mg/L	0.01	< 0.05	< 0.05	**0.07**	< 0.05	< 0.05	**0.25**	< 0.05	< 0.05	**0.06**	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	15	<0.05	<0.05	**0.07**
Total Kjeldahl Nitrogen (TKN)	mg/L	-	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	15	<0.2	<0.2	<0.2
Total Nitrogen (TN)	mg/L	0.35	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	15	<0.2	<0.2	<0.2
Reactive Phosphorus	mg/L	0.005	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	15	<0.05	<0.05	<0.05
Total Phosphorus (TP)	mg/L	0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	15	<0.05	<0.05	<0.05
Total Organic Carbon	mg/L	-	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	15	<5	<5	<5
Dissolved Organic Carbon	mg/L	-	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	15	<5	<5	<5
Analytical Results - Inorganics (Dissolved)																					
Fluoride	mg/L	2.4	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	15	<0.5	<0.5	<0.5
Analytical Results - Metals (Dissolved)																					
Aluminium (Al)	mg/L	0.055	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	15	<0.05	<0.05	<0.05
Arsenic (As)	mg/L	0.013	< 0.001	0.001	0.001	0.001	< 0.001	0.001	0.001	0.001	0.001	0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	15	<0.001	0.001	0.001
Barium (Ba)	mg/L	0.008	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	15	<0.02	<0.02	<0.02
Boron (B)	mg/L	0.37	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	15	<0.05	<0.05	<0.05
Cobalt (Co)	mg/L	0.0014	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	15	<0.001	<0.001	<0.001
Total Chromium (Cr)	mg/L	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	15	<0.001	<0.001	<0.001
Copper (Cu)	mg/L	0.0014	< 0.001	< 0.001	0.001	< 0.001	**0.008**	**0.064**	**0.015**	**0.088**	**0.045**	**0.032**	**0.033**	< 0.001	< 0.001	0.001	< 0.001	15	0.001	**0.032**	**0.069**
Manganese (Mn)	mg/L	1.9	< 0.005	< 0.005	0.082	< 0.005	< 0.005	< 0.005	< 0.005	0.008	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	15	<0.005	<0.005	0.007
Nickel (Ni)	mg/L	0.011	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.004	0.002	0.01	0.003	0.004	0.004	0.003	< 0.001	< 0.001	< 0.001	15	<0.001	<0.001	0.004
Lead (Pb)	mg/L	0.0034	0.002	0.002	0.003	0.002	< 0.001	0.003	0.002	**0.005**	< 0.001	0.002	0.002	< 0.001	< 0.001	< 0.001	< 0.001	15	<0.001	0.002	0.003
Selenium (Se)	mg/L	0.005	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	15	<0.001	<0.001	<0.001
Silver (Ag)	mg/L	0.0005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	15	<0.005	<0.005	<0.005
Vanadium (V)	mg/L	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	15	<0.005	<0.005	<0.005
Zinc (Zn)	mg/L	0.008	< 0.005	< 0.005	< 0.005	0.006	**0.010**	**0.068**	**0.020**	**0.140**	**0.048**	**0.037**	**0.061**	**0.012**	< 0.005	**0.094**	0.006	15	<0.005	**0.024**	**0.065**
Mercury (Hg)	mg/L	0.00006	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	15	<0.0001	<0.0001	<0.0001
Iron (Fe)	mg/L	0.3	< 0.05	< 0.05	**0.67**	< 0.05	< 0.05	0.07	< 0.05	< 0.05	< 0.05	0.05	< 0.05	0.06	< 0.05	< 0.05	< 0.05	15	<0.05	<0.05	0.066

Notes:

1. Refer to Section 4.6.1 for further information on guideline values.

***Bold** denotes Guideline Value or Range is exceeded.*

Appendix B

Flood Assessment Method Statement

Job Number: *180021*
Date: *29 May 2018*

GRC Hydro
Level 9, 233 Castlereagh Street
Sydney NSW 2000

Tel: +61 432 477 036
www.grchydro.com.au

Chris Kuczera
EMM
Suite 01, 20 Chandos Street
ST LEONARDS NSW 2065

Dear Chris,

Re: Yarrangobilly River Flood Study

INTRODUCTION

The project

Snowy Hydro Limited (Snowy Hydro) proposes to develop Snowy 2.0, a large scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). This would be achieved by establishing a new underground hydro-electric power station that would increase the generation capacity of the Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) generating capacity, and providing approximately 350 gigawatt hours (GWh) of storage available to the National Electricity Market (NEM) at any one time, which is critical to ensuring system security as Australia transitions to a decarbonised NEM. Snowy 2.0 will link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and hydro-electric power station.

The purpose of the Exploratory Works for Snowy 2.0 is primarily to gain a greater understanding of the conditions at the proposed location of the power station, approximately 850 metres (m) below ground level. Understanding factors such as rock conditions (such as stress conditions) and ground temperature is essential to confirm the suitability of the site for the underground power station.

The Exploratory Works comprise:

- establishment of an exploratory tunnel to the site of the underground power station for Snowy 2.0;
- establishment of a construction pad;
- excavated rock management;
- establishment of an accommodation camp;
- road establishment and upgrades providing access and haulage routes during Exploratory Works;
- establishment of barge access infrastructure to enable access and transport by barge on Talbingo reservoir;
- establishment of services infrastructure such as diesel-generated power and communication; and

- geotechnical investigation to inform detailed design for Exploratory Works components listed above.

Yarrangobilly Flood Study

EMM Consulting Pty Ltd (EMM) requested a flood study be undertaken for the Yarrangobilly River at the site of Exploratory Works for Snowy 2.0 (the Site). The Yarrangobilly River is a tributary of the Tumut River, located upstream of Talbingo Dam in southern NSW (see Image 1).

The Site is subject to flooding from the Yarrangobilly River which flows through the Site in a westerly direction. Minor tributaries which enter the River from both the north and south within the Site are also subject to flooding.

The flood study objectives are to:

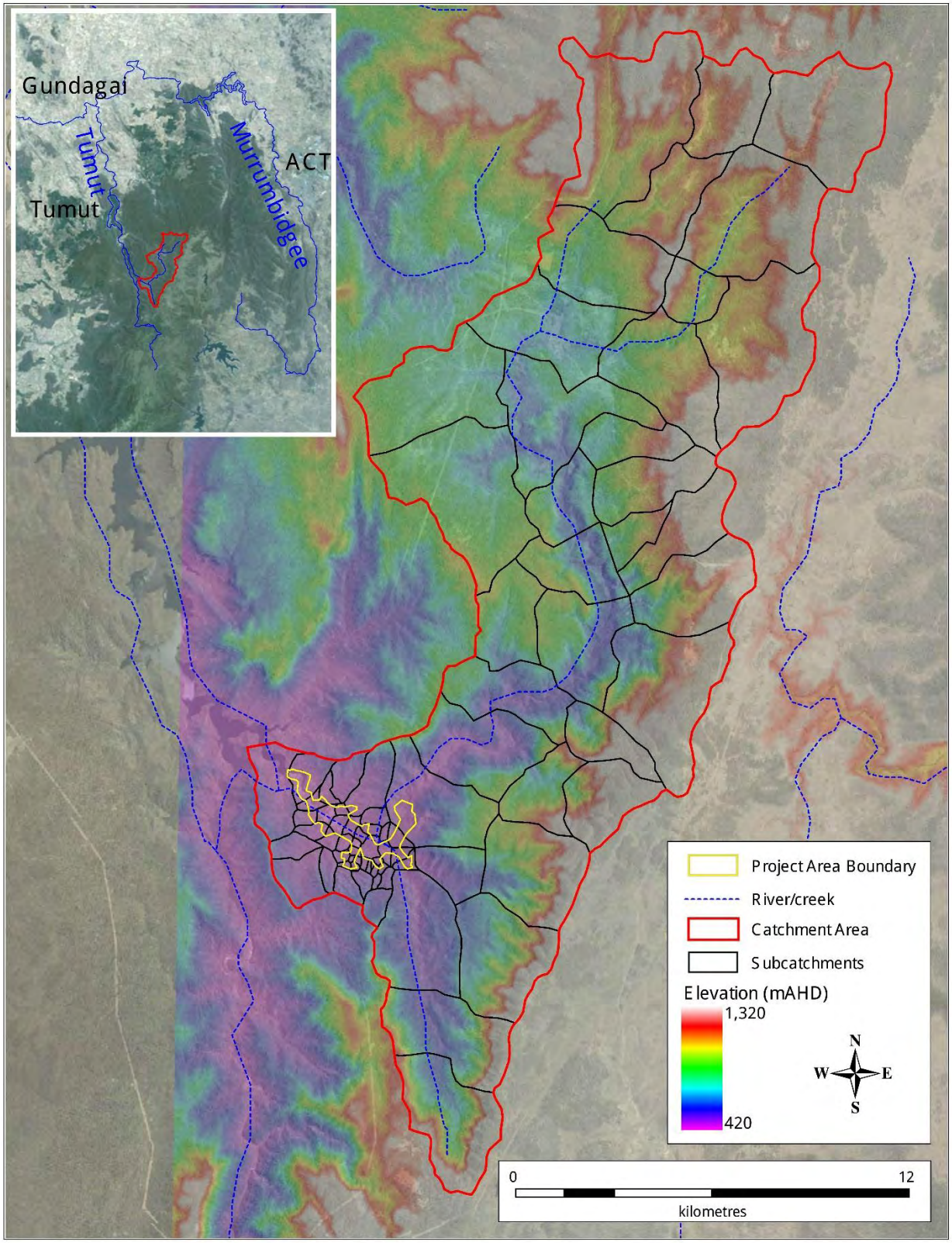
- Develop a XP-RAFTS hydrologic model;
- Undertake Flood Frequency Analysis (FFA) for the Yarrangobilly@Ravine (410574) stream gauge;
- Calibrate the XP-RAFTS model to FFA derived flows using Australian Rainfall and Runoff (ARR2016) methodology;
- Derive design flow hydrographs using ARR2016 methods for the 20%, 5%, 1%, 0.2% AEP, 0.05% and Probable Maximum Flood (PMF) events for the Yarrangobilly River;
- Validate the 1% Annual Exceedance Probability (AEP) flow estimate using regional flood frequency estimates;
- Develop a TUFLOW hydraulic model for the Site; and
- Model design flood behaviour for the above-mentioned events.

The purpose of this report is to describe the data analysis and modelling methodologies that have been applied to the Yarrangobilly Flood Study. Model results, flood impacts and flood risk management measures are presented and discussed in the surface water assessment for Exploratory Works.

HYDROLOGY

Hydrologic analysis consisted of the development of a XP-RAFTS hydrologic model which was then calibrated to FFA. The following sections outline the implemented approach.

Image 1: Yarrangobilly Sub-catchments, Project Area Boundary and Locality Map



Flood Frequency Analysis

FFA was performed on the annual maximum series of flows recorded at the Yarrangobilly@Ravine (410574) stream gauge (the Gauge). The gauge was commissioned in March 1972 and has a largely continuous and homogenous record period suitable for FFA. FFA was undertaken on the maximum annual flow for the 46 years of record from 1972 to 2017.

Table 1: Yarrangobilly@Ravine Annual Series (m^3/s)

Year	Flow	Year	Flow	Year	Flow
1972	30	1988	96	2004	47
1973	61	1989	29	2005	92
1974	62	1990	60	2006	3
1975	126	1991	38	2007	40
1976	75	1992	66	2008	36
1977	44	1993	77	2009	14
1978	57	1994	11	2010	210
1979	42	1995	119	2011	64
1980	45	1996	78	2012	163
1981	94	1997	25	2013	28
1982	6	1998	50	2014	31
1983	58	1999	37	2015	19
1984	102	2000	75	2016	62
1985	41	2001	27	2017	49
1986	50	2002	27		
1987	39	2003	67		

The extreme value analysis software package 'FLIKE' was used for FFA, following the procedures outlined in ARR2016. A Log-Person Type 3 (LPIII) distribution was fitted to the annual series. Other distributions were also examined, however the LPIII distribution was noted to have the best fit to the annual series data. The Grubbs-Beck Test for statistical outliers was applied, with five events with a peak flow less than 25 m^3/s censored from the record during analysis. Application of the Grubbs-Beck test was undertaken in unison with visual assessment of the applied distribution. FFA design flow estimates for the Site are presented in Table 2 and the FFA plot is presented in Chart 4.

Table 2: FFA Design Flow Estimates

AEP	Expected Parameter Quantile (m^3/s)	90% Confidence Limits (m^3/s)	
0.2EY	83	69	101
10%	111	90	144
5%	142	111	201
2%	191	137	312
1%	233	157	428

Hydrologic Modelling

Hydrologic model design flows have been determined using ARR2016 guidelines. Selected model parameters and inputs are described in the ensuing sections.

Model Schematisation and Parameters

An XP-RAFTS model was developed for the Yarrangobilly River catchment downstream to Talbingo Dam. Details of the XP-RAFTS model schematisation are presented in Table 3 with sub-catchment delineation presented in Image 1.

Table 3: XP-RAFTS Model Schematisation

Total model catchment area (km^2)	Area of catchment at the Gauge (km^2)	Number of Catchments	Average catchment size (km^2)
280	271	78	3.6

XP-RAFTS model parameters were determined via inspection of available data including photographs, aerial imagery and SRTM DEM. This information was used to inform sub-catchment Mannings, slope and lag times.

A global Mannings value of 0.07 was implemented which is consistent with the moderate to dense vegetation typical for the region and as identified via inspection of photographs and imagery. Sub-catchment slopes were determined via methods outlined in the XP-RAFTS user manual, where by the 'equal angle slope' was calculated based on a sub-catchment's minimum and maximum elevation and maximum stream length. Lag times for inter-catchment routing were determined using the major flow path length (L) and slope (S) and the formula outlined in the Laurenson's method (lag time = $L / S^{0.5}$).

Design Rainfall

ARR2016 design rainfall depths for various durations were obtained from the Bureau of Meteorology (BoM). Due to a significant rainfall gradient across the Yarrangobilly River catchment, a single uniformly applied rainfall depth was not appropriate for modelling of design rainfall. Instead, spatially varying design rainfalls were applied across the catchment with each sub-catchment receiving a unique rainfall depth. The Yarrangobilly River catchment's minimum, maximum and average rainfall depths are presented in Table 6.

Table 4: Design Rainfall Depths (Average / Minimum / Maximum)

Duration (min)	20% AEP Event	10% AEP Event	5% AEP Event	2% AEP Event	1% AEP Event	0.2% AEP Event	0.02% AEP Event
720	64 / 60 / 76	74 / 69 / 88	83 / 78 / 100	97 / 90 / 116	108 / 100 / 130		
1080	75 / 70 / 91	87 / 80 / 106	99 / 91 / 121	116 / 106 / 142	129 / 118 / 160		
1440	84 / 77 / 104	97 / 89 / 121	111 / 101 / 139	130 / 117 / 164	145 / 131 / 185	188 / 169 / 244	255 / 203 / 300
2160	97 / 88 / 122	112 / 101 / 142	127 / 115 / 163	150 / 134 / 193	167 / 149 / 218	212 / 186 / 283	304 / 220 / 345
2880	105 / 95 / 134	122 / 109 / 157	138 / 123 / 180	163 / 144 / 214	182 / 160 / 242	224 / 194 / 311	287 / 225 / 373

Probable Maximum Precipitation (PMP) rainfall depths were determined using the methods outlined in the GSDM. The catchment is defined as 100% 'Rough' and a Moisture Adjustment Factor of 0.64 was applied. PMP rainfall depths for 'Ellipse A' for various durations are presented in Table 5.

Table 5: PMP Rainfall Depths

Duration	1 hour	2 hour	3 hour	4 hour	5 hour	6 hour
Rain (mm)	320	480	580	660	730	770

Areal Reduction Factor

Areal Reduction Factors (ARF) were applied to design rainfall depths to adjust for the Catchment's areal average rainfall intensity. The ARFs were determined following the methods outlined in ARR2016 for the 'Southern Temporal' region. Calculated ARFs were based on the catchment's area and event's duration and probability. Applied ARFs are presented in Table 6.

Table 6: Areal Reduction Factors

Duration (min)	20% AEP Event	10% AEP Event	5% AEP Event	2% AEP Event	1% AEP Event	0.2% AEP Event	0.05% AEP Event
720	0.91	0.90	0.90	0.89	0.88		
1080	0.92	0.92	0.92	0.91	0.91		
1440	0.94	0.94	0.94	0.94	0.93	0.93	0.93
2160	0.95	0.94	0.94	0.94	0.94	0.94	0.94
2880	0.95	0.95	0.95	0.94	0.94	0.94	0.94

Rainfall Losses

An Initial and Proportional Loss (IL / PL) model was implemented for events up to an including the 1% AEP. ARR2016 notes that studies undertaken by Dyer et al (1994) and Hill et al (1996) found that 'the IL/PL model resulted in generally improved calibrations'.

It must be noted that calibration to FFA was first attempted using an Initial and Continuing Loss (IL / CL) model. The calibration was unsuccessful and required that CL's were increased with event magnitude. This is in contradiction with ARR2016 which notes that the 'majority of Australian studies of losses at catchment scale have concluded that both ILs and CL do not vary systematically with the severity of the event; that is loss is independent of AEP.' ARR2016 recommends 'to keep the ILs and CL values the same for AEPs unless there is specific evidence to suggest that there is a systematic variation of loss with AEP.' However, the opposite is true for the IL / PL model, with ARR2016 noting that the PL component of this model is noted to 'vary with the AEP of the event'.

Initial losses as recommended by ARR2016 have been used for design flood modelling. For events up to and including the 1% AEP, an IL of 26 mm has been adjusted to account for pre-burst as per ARR2016. The burst initial losses used in design flood modelling are presented in Table 6. Pre-burst adjusted initial losses range from 15 to 26 mm depending on the event duration and AEP. 0.2% and 0.05% AEP losses have been determined via interpolating between 1% AEP and PMF losses which follows methods outlined in ARR2016.

Table 7: Applied Initial Losses (incorporating pre-burst)

Duration (min)	20% AEP Event	10% AEP Event	5% AEP Event	2% AEP Event	1% AEP Event	0.2% AEP Event	0.05% AEP Event
720	23.9	23.7	23.5	18.8	15.3		
1080	25.2	24.7	24.1	21.1	18.9		
1440	25.7	25.5	25.4	24.6	24.1	7.8	2.9
2160	26.0	26.0	26.0	25.9	25.9	8.3	3.1
2880	26.0	26.0	26.0	26.0	26.0	8.3	3.1

A variable proportional loss has been applied for each design event. The applied PL for design events up to and including the 2% AEP event were determined via calibration to the FFA. Due to the relative short record

period of available gauge data, reduced confidence is held in FFA design flow estimates for events rarer than the 2% AEP. For events larger than the 5% AEP, the PL was calculated following methods outlined in ARR2016, whereby it was assumed that PL vary linearly on a log-log plot of losses versus AEP, up until the recommended PMF loss. As the IL / CL model is recommended for the PMF, a conservative PL estimate of 0.01 was used in this interpolation. This method of determining loss values is more consistent with the interpolation procedure used for design rainfalls. The applied PL's are presented in Table 8.

Table 8: Applied Proportional Losses

Event AEP	20%	10%	5%	2%	1%	0.2%	0.05%
Proportional Loss	0.69	0.66	0.64	0.61	0.59	0.53	0.48

ARR2016 recommends caution for implementation of IL / PL model for estimating 'Very Rare' or 'Extreme' events. Accordingly, modelling was also undertaken using an IL / CL model for events exceeding the 1% AEP. A CL of 4.2 mm/hr was applied as per recommendations in ARR2016. ARR2016 recommends a method of estimating 'Very Rare' floods via interpolation methods between 'Rare' floods and the PMF. These methods were used to determine which loss model was most appropriate for implementation for the 0.2% and 0.05% AEP events. These works are discussed in the 'Calibration of the XP-RAFTS Model to FFA' section of this report.

PMF rainfall losses have been applied as an IL / CL model (IL = 0 mm, CL = 1 mm/hr) as per the methods outlined in the GSDM.

Rainfall Temporal Patterns

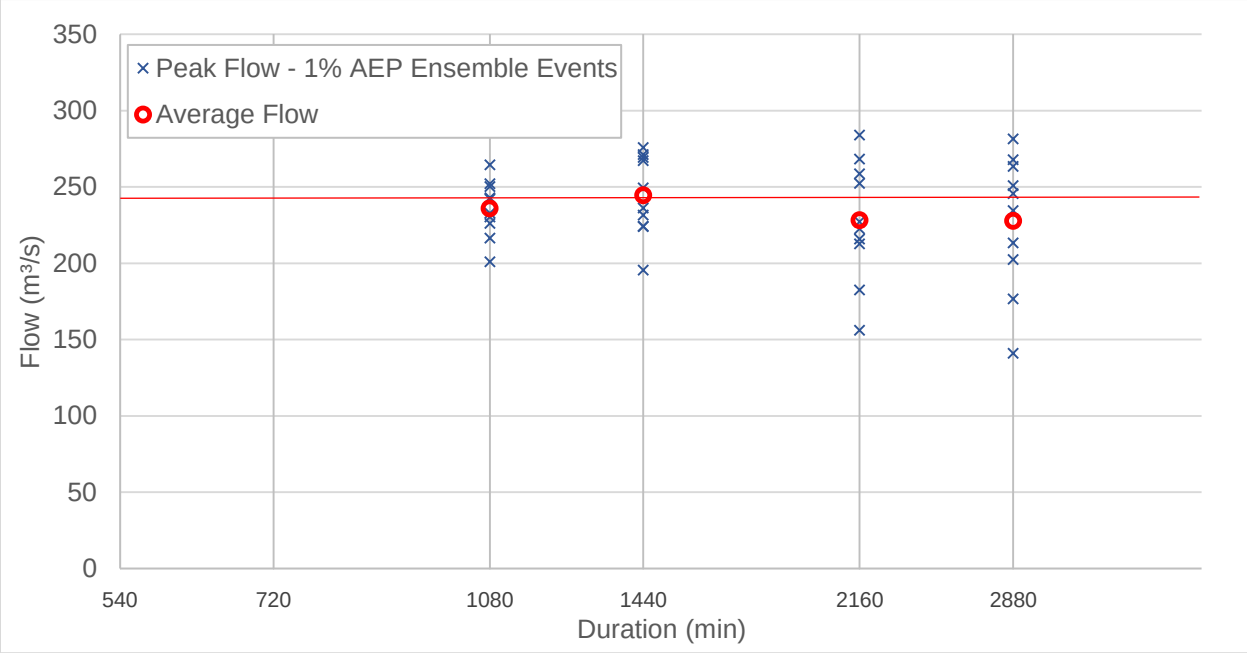
Rainfall temporal patterns are used to describe how rainfall is distributed as a function of time. The recommended ARR2016 ensemble approach to applying temporal patterns has been utilised in the current study. The ensemble approach to flood modelling applies a suite of 10 different temporal patterns for each duration. Areal Temporal Patterns have been implemented due to the catchment size exceeding 75 km². The temporal patterns were obtained from ARR2016 for the 'Murray Basin' region for a theoretical catchment area of 200 km². The implementation of the ensemble approach required the modelling of 300 design flood events (5 durations x 6 AEP x 10 temporal patterns) in the hydrologic model using the varying design rainfall depths, ARF and losses as presented above. Ensemble modelling techniques aim to overcome issues associated with the application of a single temporal pattern as per the methods used in ARR87.

ARR2016 recommends that for 'Very Rare' events, at-site and generalised PMP patterns be applied in an ensemble to ensure a smooth transition over the complete design flood frequency curve. The GSAM ensemble of temporal patterns were not available at the time of this study, and accordingly only at-site temporal patterns have been implemented. The GSDM temporal pattern was used in analysis of the PMF.

Hydrologic model design flows are presented in Chart 1 to Chart 3 for the 1%, 5% and 20% AEP events at the Yarrangobilly@Ravine (410574) stream gauge. Each blue 'x' indicates the peak flow of a modelled event. The red circle is the average flow for each duration. The ensemble method identifies the critical duration as the duration with the highest mean flow and each AEPs design event is selected as the event which is closest to, but above the mean.

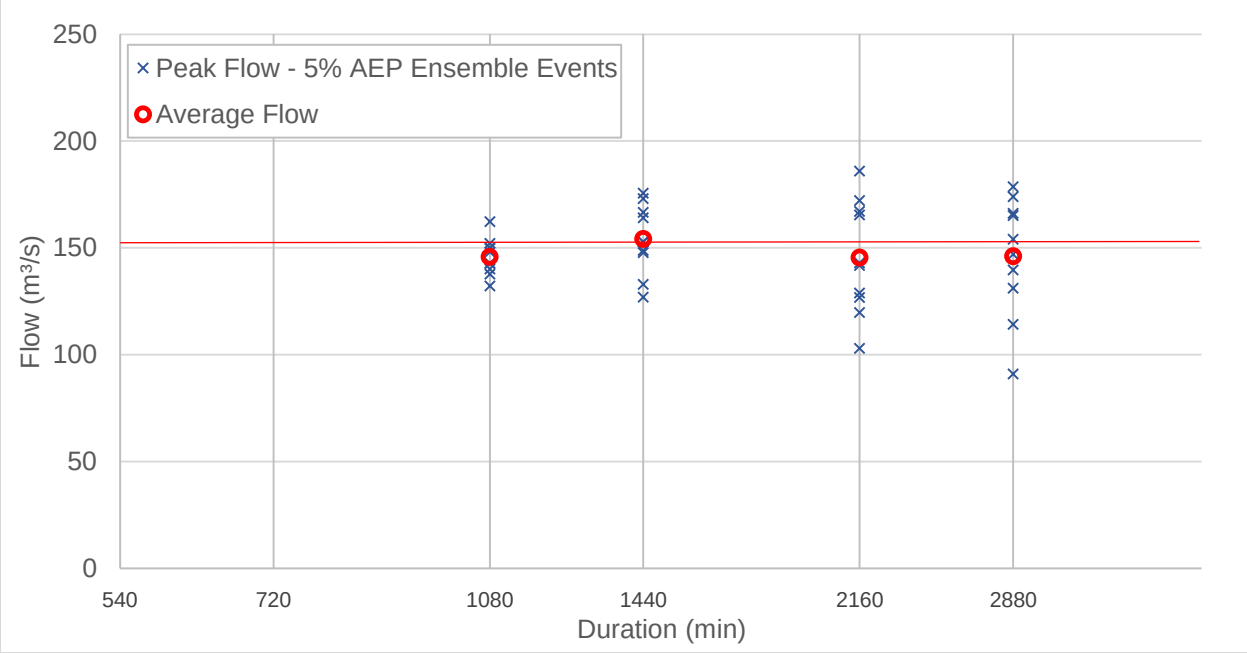
For the 1% AEP event the critical duration at the Site is the 24 hour event with an ensemble average flow of 244 m³/s.

Chart 1: 1% AEP Design Flow Results at Yarrangobilly@Ravine (410574) Stream Gauge Location



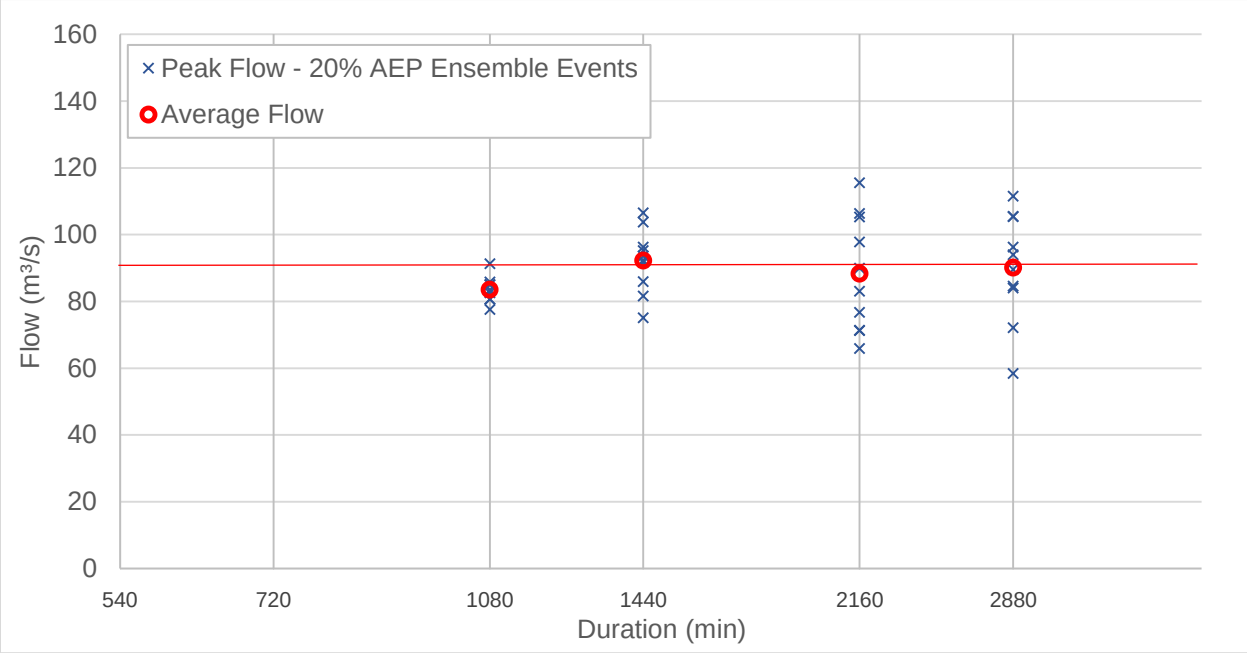
For the 5% AEP event the critical duration at the Site is the 24 hour event with an ensemble average flow of 154 m³/s.

Chart 2: 5% AEP Design Flow Results at Yarrangobilly@Ravine (410574) Stream Gauge Location



For the 20% AEP event the critical duration at the Site is the 24 hour event with an ensemble average flow of 92 m³/s.

Chart 3: 20% AEP Design Flow Results at Yarrangobilly@Ravine (410574) Stream Gauge Location



The critical duration of the 10%, 2%, 0.2% and 0.05% AEP events were determined to be 24 hours. The PMF critical duration was determined to be 6 hours.

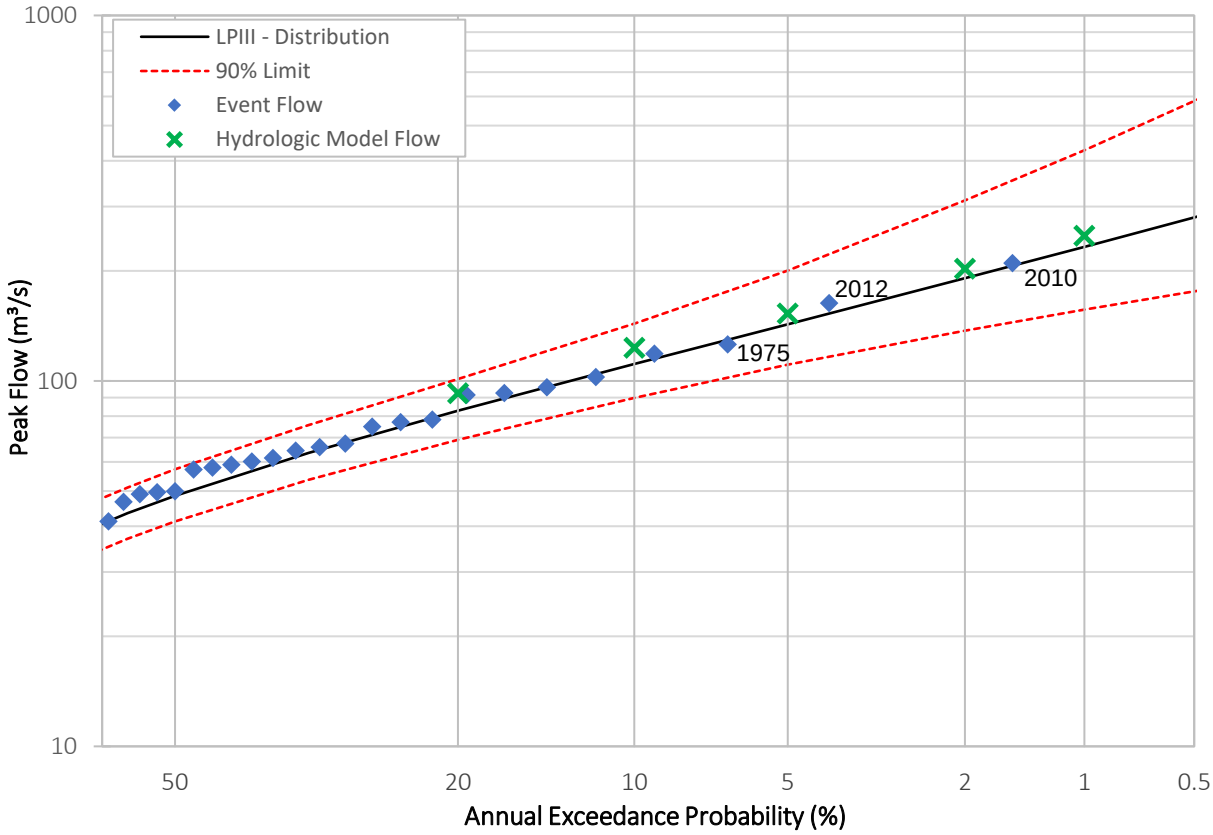
Calibration of the XP-RAFTS Model to FFA

Calibration of the XP-RAFTS model was undertaken by comparing model flows to FFA undertaken at the Yarrangobilly@Ravine (410574) stream gauge. Adjustment of applied proportional losses in the hydrologic model were made to obtain a good fit to the FFA design flows.

Chart 4 presents the Yarrangobilly@Ravine (410574) stream gauge FFA along with flows obtained from the XP-RAFTS hydrologic model (green 'X'). Hydrologic model flows for events from the 20% to the 1% AEP are a close match to the LPIII distribution expected quantile (black line) and within the 90% confidence interval limits (hashed red lines) indicating that the model is accurately reproducing design flood behaviour for these events. The 0.2 and 0.05% AEP events begin to diverge from the LPIII distribution and exceed FFA design flow estimates, however are well within the 90% confidence intervals.

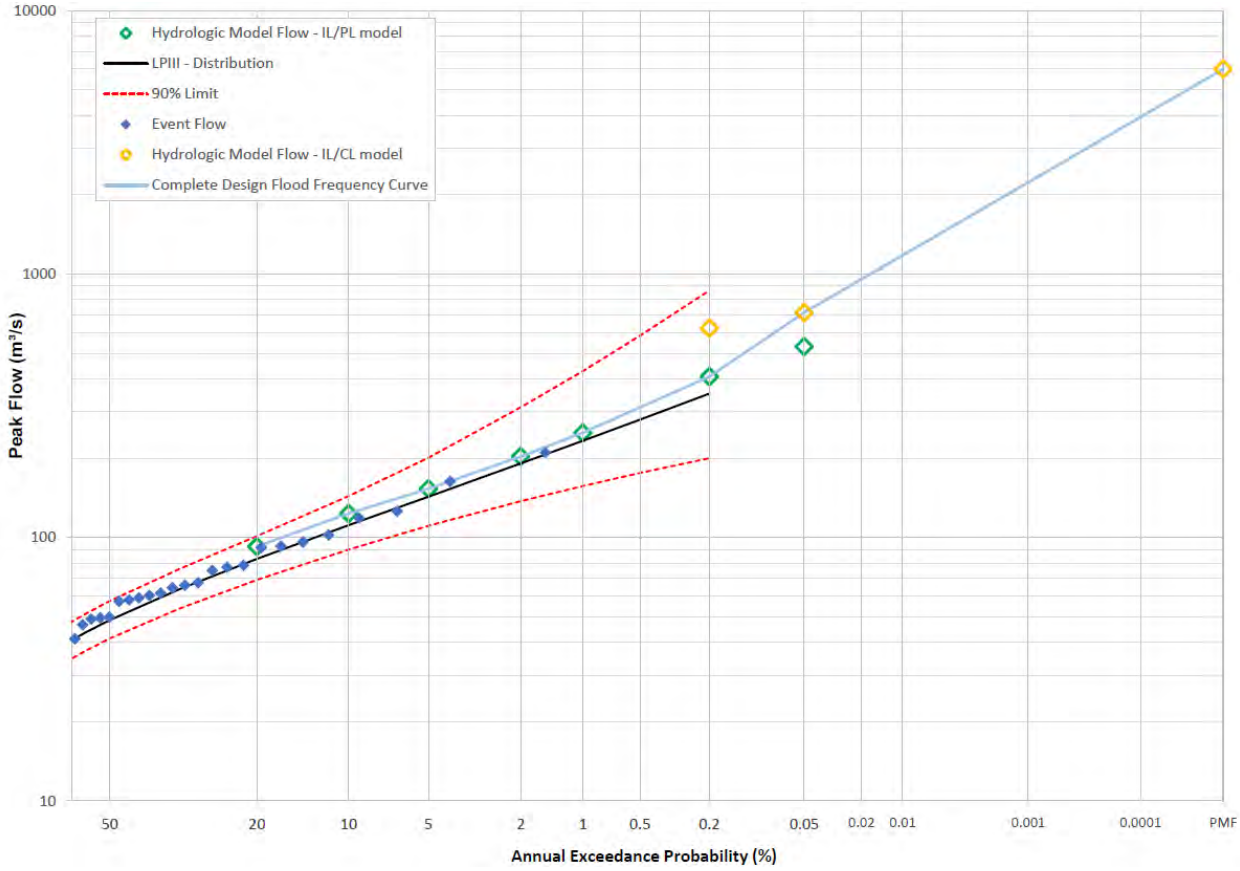
The calibration process indicates that the XP-RAFTS model is accurately producing design flood behaviour thus providing confidence in design flow estimates.

Chart 4: Comparison of Hydrologic Model Flows to FFA



ARR2016 outlines a method of estimating 'Very Rare' floods via interpolation methods between 'Rare' floods and the PMF. This method was used to determine the preferred loss model for calculation of the 0.2% and 0.05% AEP events. An approximation of the complete design flood frequency curve was derived by interpolating between the 'Rare' events and the PMF (see Chart 5). The findings from this analysis indicated that use of the recommended ARR2016 CLs overestimated 0.2% AEP flows and the IL/PL loss method underestimated the 0.05% AEP event. Accordingly, the IL/PL method was applied for events up to and including the 0.2% AEP event and the IL/CL method was applied for the 0.05% AEP event.

Chart 5: Approximation of the Complete Design Flood Frequency Curve



Validation of the 1% AEP Flow to Regional Flood Frequency Estimates

The ARR2016 RFFE model was used to determine the 1% AEP flow at the Yarrangobilly@Ravine (410574) gauge location. The 1% AEP flow at the gauge was determined to be 191 m³/s, which is similar to the 245 m³/s determined by hydrologic modelling. This adds robustness to the design flow estimates from the hydrologic model.

Design Flow Results

Design flows obtained from the XP-RAFTS model have been implemented in the TUFLOW model. Design flows at the Yarrangobilly@Ravine (410574) gauge location are presented in Table 9.

Table 9: Hydrologic Model flows at Yarrangobilly@Ravine stream gauge

AEP	Hydrologic Model Flows (m^3/s)
20%	92
5%	154
1%	244
0.2%	408
0.05%	714
PMF	6,000

Hydrologic model flows have also been extracted at Wallace Creek which is a major tributary of the Yarrangobilly River (see Table 10).

Table 10: Hydrologic Model flows on Wallace Creek

AEP	Hydrologic Model Flows (m^3/s)
20%	20
5%	31
1%	58
0.2%	89
0.05%	236
PMF	1,146

HYDRAULIC MODELLING

Hydraulic Model Setup

A TUFLOW hydraulic model was constructed for the Site. TUFLOW is 2D numerical modelling package which is suitable for modelling complex flood behaviour of channels and floodplains such as those at the Site.

Various data and parameters implemented in the TUFLOW model are discussed below and are presented in Image 2:

- *Model Domain and Grid Size* – The hydraulic model domain covers an area of 3.2 km^2, extending from 500 m upstream of the construction pad on Yarrangobilly River, and 400 m upstream on Wallace Creek. The downstream boundary is situated approximately 2.5 km downstream of the accommodation camp. A model grid size of 5 m x 5 m has been implemented which is considered suitable for adequately modelling key hydraulic features of the Yarrangobilly River.
- *Digital Elevation Model (DEM)* – A 1 m DEM provided by EMM has been used to inform the topography of the 2D hydraulic model
- *Mannings Roughness* – Mannings values were selected based on inspection of aerial imagery and photographs of the Site. Selected Mannings values are consistent with ARR2016 and are presented in Table 11;

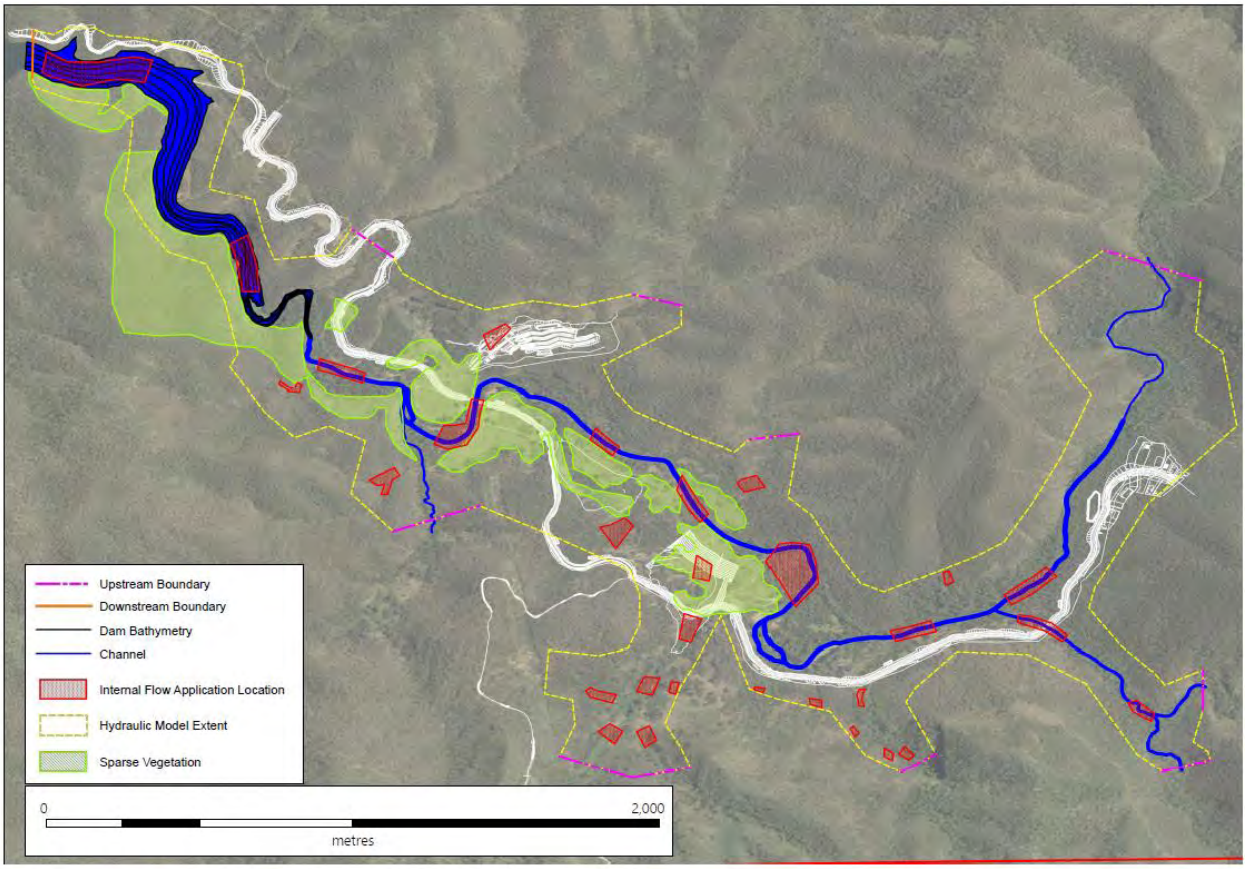
Table 11: Mannings roughness values

Land Use	Mannings
River / creek channel	0.05
Sparse vegetation	0.06
Dense vegetation	0.09

- *Boundary Conditions* – The inflows to the TUFLOW were obtained from the calibrated XP-RAFTS model discussed previously. The downstream boundary was set as a fixed water level boundary in Talbingo Dam. The following levels were implemented:
    - 20% to 0.2% AEP events – Full Supply Level (FSL) of 543.3 mAHD; and
    - PMF event – Spillway invert (544.7 mAHD) plus one meter of overtopping flow.

Implementing the various details discussed above, a Base Case model was constructed to model existing conditions flood behaviour for the Site.

Image 2: Hydraulic Model Setup



*Note: the proposed development works are presented in white. These have not been included in the hydraulic model and is shown purely for representational purposes.

Hydraulic Model Results

Design results for the 20%, 5%, 1%, 0.2% AEP events and the PMF have been developed. The results present flood depths, levels, velocities and flood hazard.

Design flood levels at the Yarrangobilly@Ravine (410574) gauge location are presented in Table 12.

Table 12: Design Flood Levels and Gauge Stage at the Yarrangobilly@Ravine (410574) Stream Gauge

AEP	Hydraulic Model Gauge Level (mAHD)	Estimated Gauge Stage (m)*
0.2EY	563.8	2.3
5%	564.3	2.8
1%	564.8	3.3
0.2%	565.3	3.8
0.05%	566.2	4.7
PMF	572.2	10.7

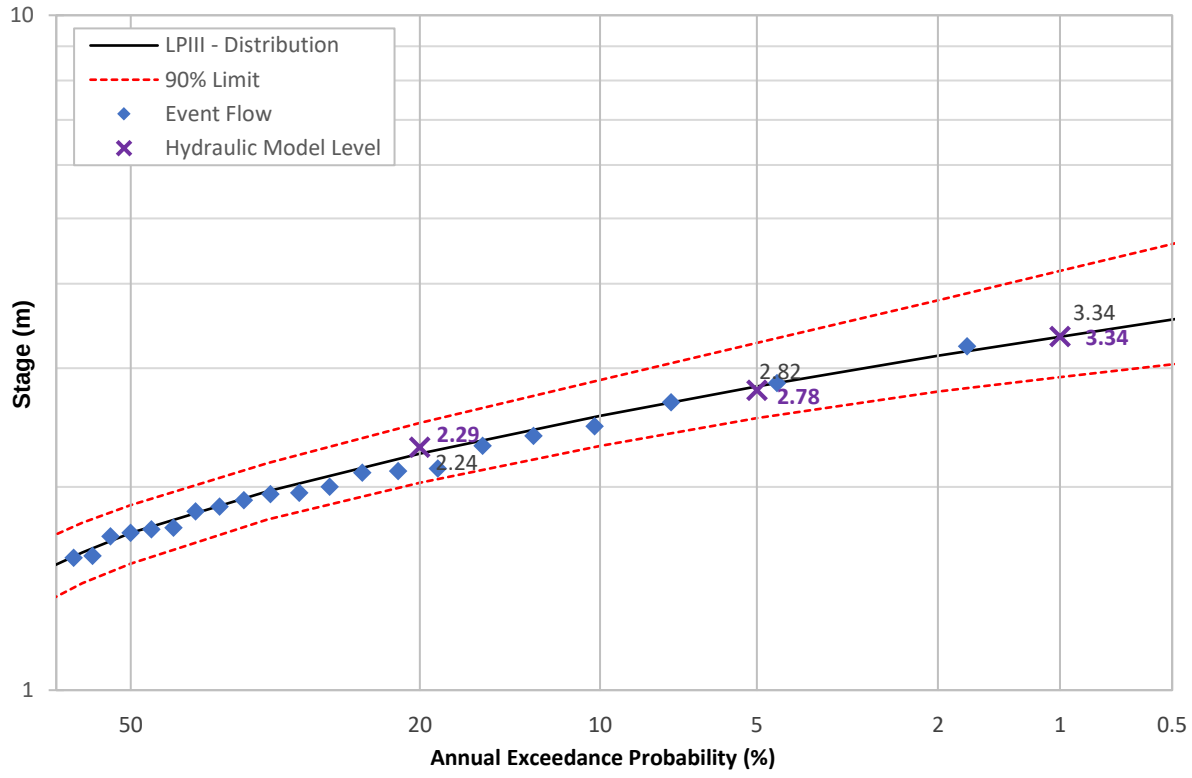
* Note that gauge stage has been estimated by assuming a gauge zero of 561.48 mAHD. The gauge zero has been estimated via interrogation of the LiDAR and is subject to an accuracy of approximately ±0.3 m, however gauge zero levels are likely to not exceed a level of 561.48 mAHD.

Validation of Hydraulic Model Results

Frequency analysis was performed on the annual maximum series of gauge stages' at the Yarrangobilly@Ravine (410574) stream gauge. The frequency analysis was undertaken for the period of 1982 to 2017 as gauge levels were not available for the period prior to 1982. The analysis was undertaken using the same methods outlined for the flow FFA. The results are presented in Chart 6.

A comparison of hydraulic model stage and frequency analysis stage is presented in Chart 6. Results indicate an excellent match to the LPIII distribution expected quantile (black line) indicating that the model is accurately reproducing design flood levels at the gauge location.

Chart 6: Comparison of Stage Frequency Analysis to the Hydraulic Model at Yarrangobilly@Ravine



IMPACT OF PROPOSED INFRASTRUCTURE ON FLOOD REGIMES

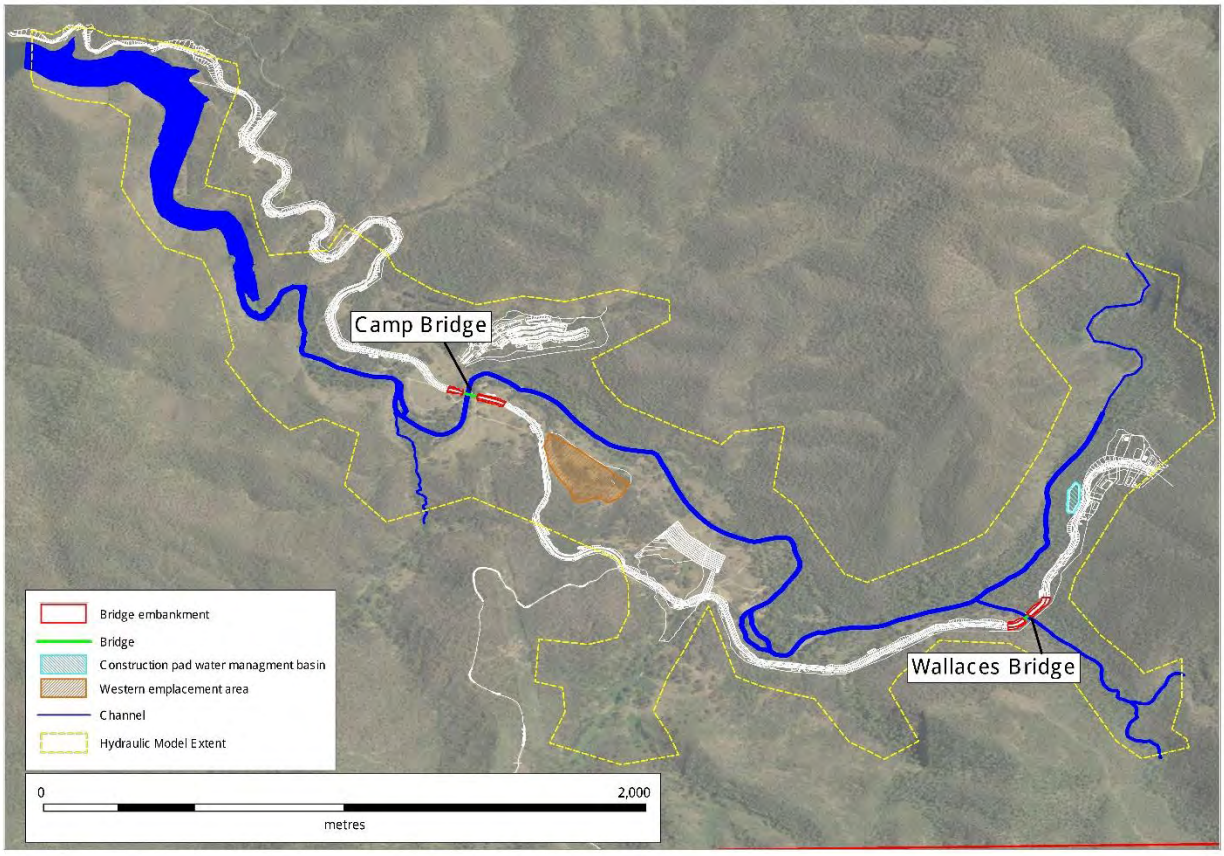
The TUFLOW hydraulic model was used to assess changes to the existing flooding regime associated with the following infrastructure:

- Camp Bridge – Lobbs Hole Road crossing over the Yarrangobilly River;
- Wallaces Bridge – Mine Trail Road crossing over Wallaces Creek;
- Western emplacement area; and the
- Construction pad water management basin.

The TUFLOW model was modified to incorporate the above infrastructure with the locations of these infrastructure presented in Image 3. The following modelling methods were applied:

- The assumed surface levels (also referred to as the digital elevation model) were updated to include the design levels and footprints of the road embankments;
- The dam and western stockpile footprints were 'nulled' from the model domain to simulate areas of zero flow; and
- Bridge structures were included in the model using layered flow constriction cells. This method accounts for blockage and form losses at bridge structures associated with the bridge piers and deck structures.

Image 3: Hydraulic Model Setup for Proposed Infrastructure



The proposed infrastructure works were modelled in the TUFLOW hydraulic model for a full range of events from the 20% AEP to the PMF. For each event, changes to the existing flooding regime have been quantified by calculating the difference in peak flood level and velocities between existing and proposed floodplain conditions. The resulting changes are shown spatially in:

- Flood level difference maps that show the areas and magnitude of flood level changes; and
- Velocity difference maps that show changes to velocity expressed as a percentage.

CONCLUSIONS

EMM requested a flood study be undertaken for the Yarrangobilly River at the site of Exploratory Works for Snowy 2.0. The Site is subject to flooding from the Yarrangobilly River which flows through the Site in a westerly direction.

The flood study methodology is summarised below:

- Development of a XP-RAFTS hydrologic model;
- Flood Frequency Analysis (FFA) for the Yarrangobilly@Ravine (410574) stream gauge;
- Calibration of the XP-RAFTS model to FFA derived flows using ARR2016 methodology;
- Derivation of design flow hydrographs using ARR2016 methods for the 20%, 5%, 1%, 0.2% AEP, 0.05% and PMF events for the Yarrangobilly River;
- Validation of the 1% AEP flow estimate using regional flood frequency estimates;
- Development of a TUFLOW hydraulic model for the Site; and
- Model design flood behaviour for the above-mentioned events.

The calibration/validation procedures indicate that both the hydrologic and hydraulic models are providing robust design flow and level estimates for events up to and including the 1% AEP event. The 0.2 and 0.05% AEP events required examination of the applied loss model through comparison to an approximation of the complete design flood frequency curve, and have used the at-site temporal pattern ensemble rather than a combined GSAM/at-site temporal pattern ensemble. This approach has likely led to a conservative estimate of these events. The PMF was determined using the methods outlined in the GSDM.

Yours Sincerely

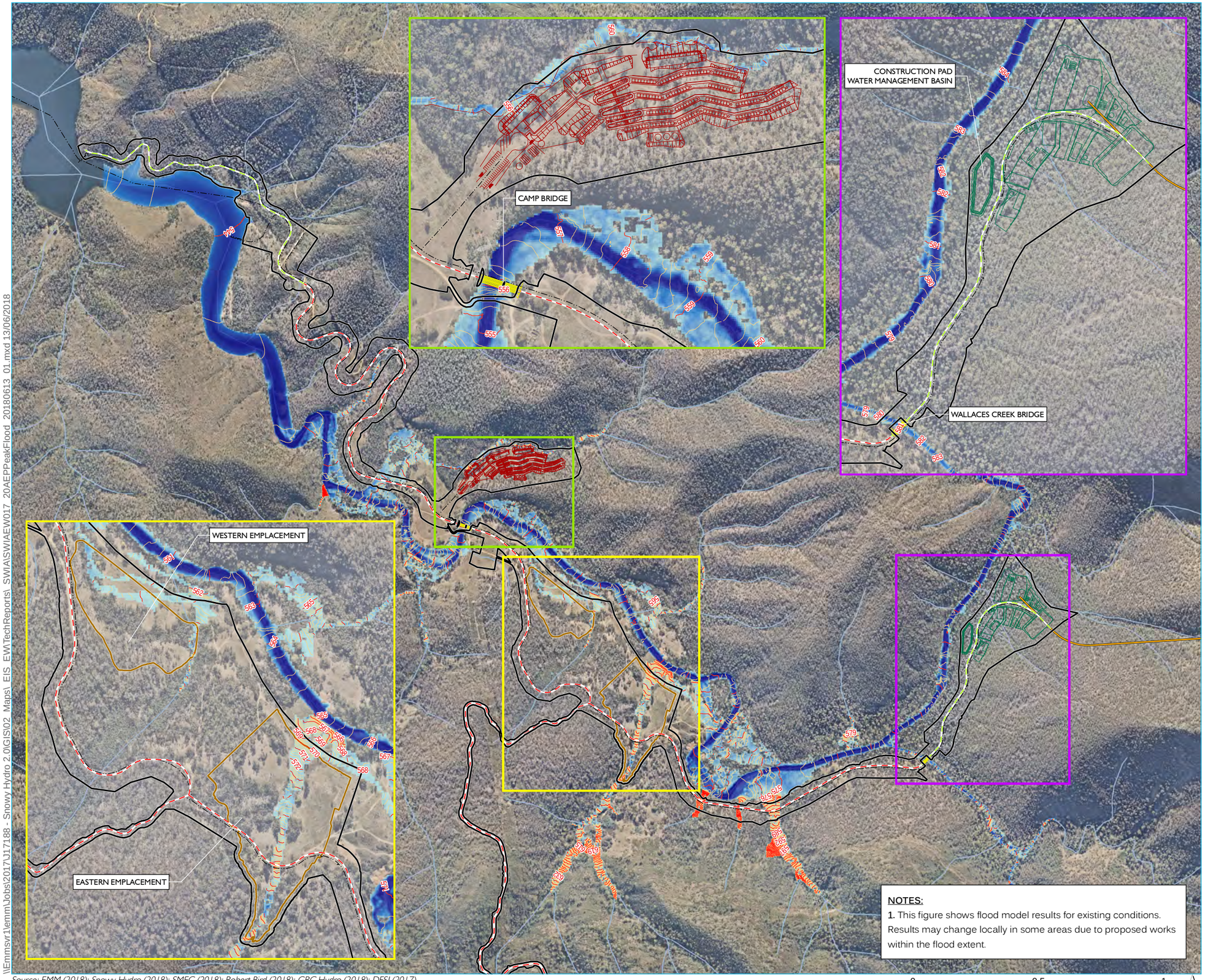


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Director

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Tel: +61 432 477 036

Appendix C

Flood Maps



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line
- Major flood level contour (1 m AHD)
- Minor flood level contour (0.2 m AHD)

Peak flood depth

2 m

0 m

NOTES:

1. This figure shows flood model results for existing conditions. Results may change locally in some areas due to proposed works within the flood extent.

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55 N

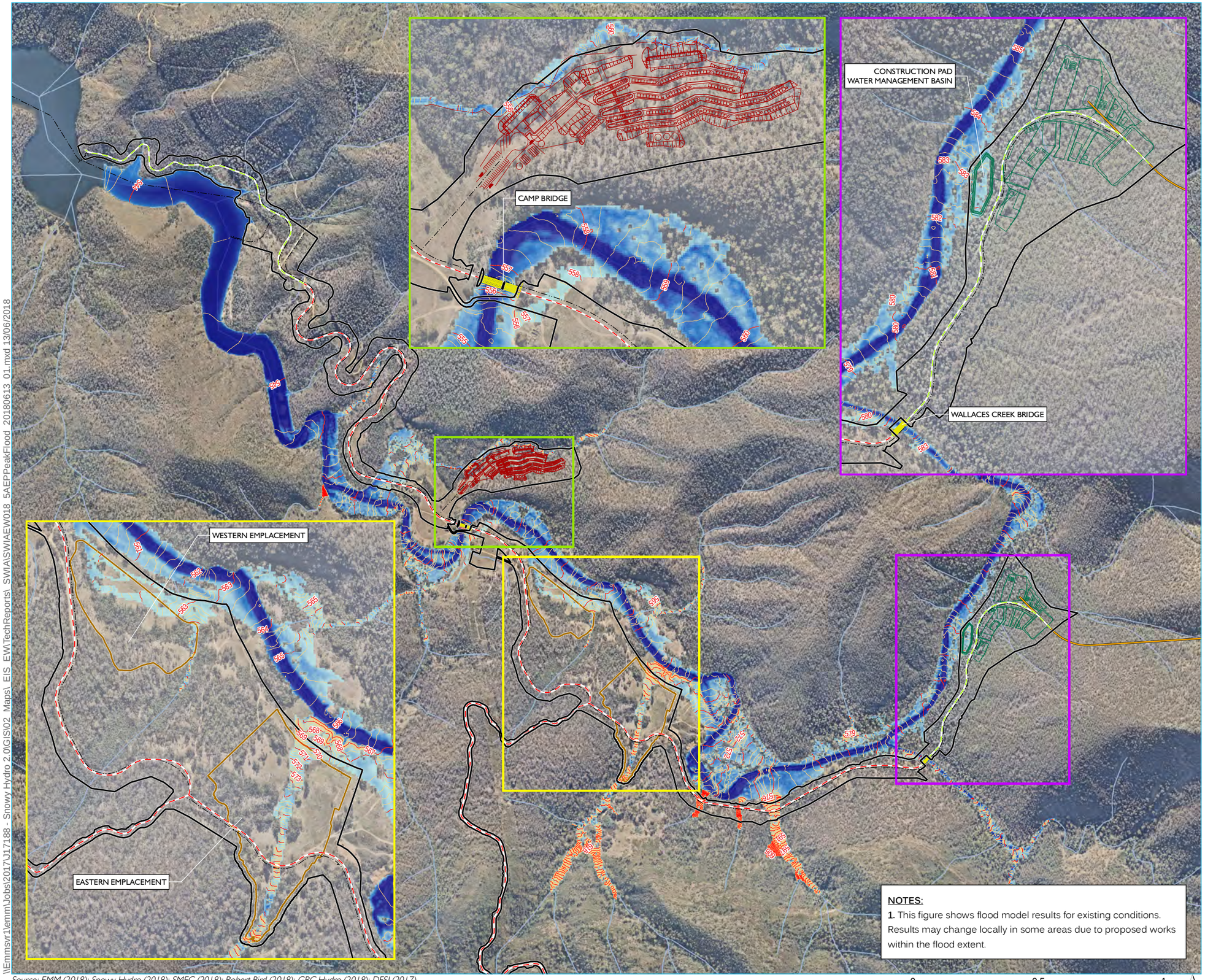
\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW017_20AEPPeakFlood_20180613_01.mxd 13/06/2018

20% AEP event - Peak flood depth and level
Existing conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C1

snowy2.0

EMM



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line
- Major flood level contour (1 m AHD)
- Minor flood level contour (0.2 m AHD)

Peak flood depth

2 m

0 m

NOTES:

1. This figure shows flood model results for existing conditions. Results may change locally in some areas due to proposed works within the flood extent.

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55 N

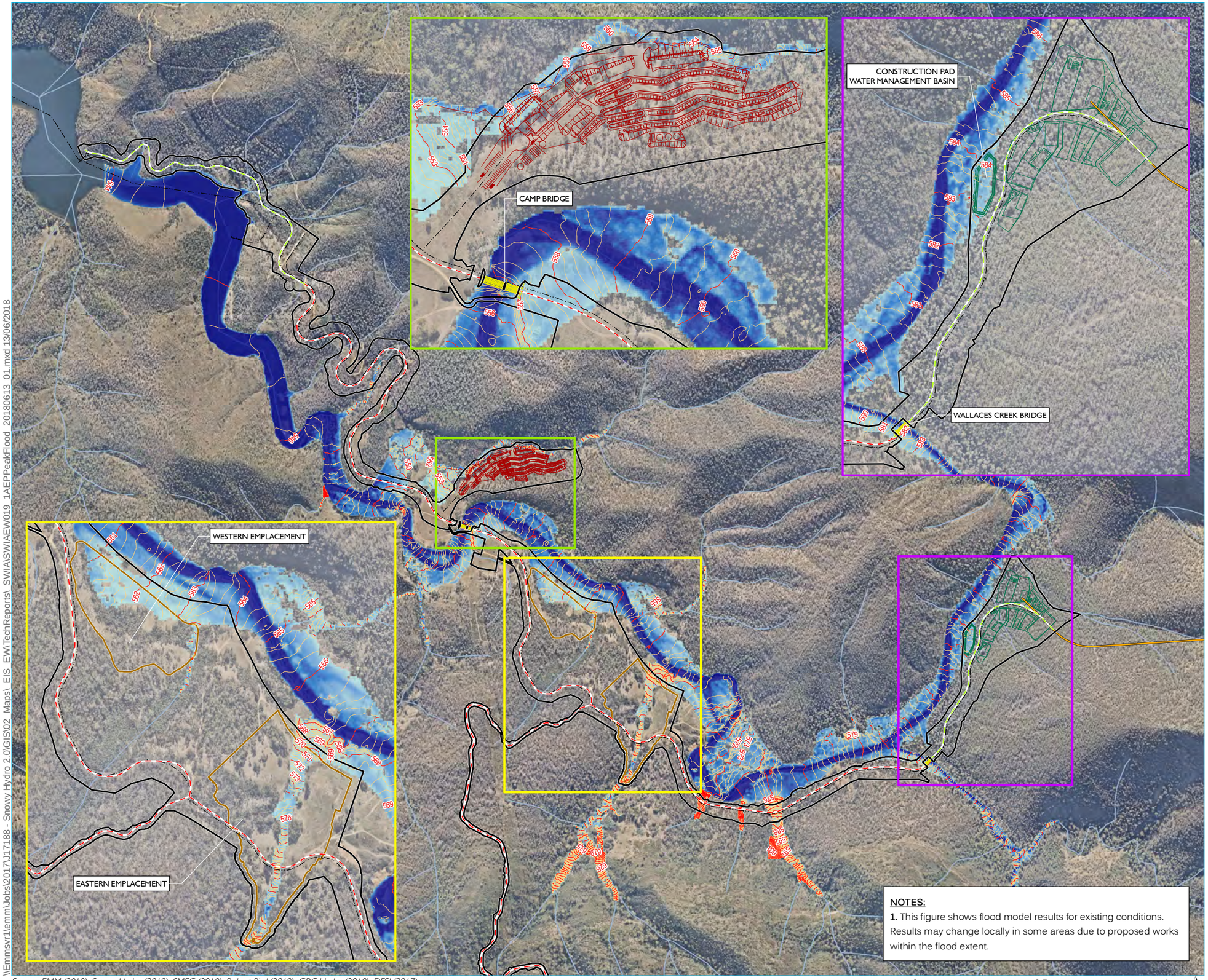
5% AEP event - Peak flood depth and level
Existing conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C2

snowy2.0

EMM

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KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line
- Major flood level contour (1 m AHD)
- Minor flood level contour (0.2 m AHD)

Peak flood depth

2 m

0 m

NOTES:

1. This figure shows flood model results for existing conditions. Results may change locally in some areas due to proposed works within the flood extent.

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55 N

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW019_1AEPPeakFlood_20180613_01.mxd 13/06/2018

1% AEP event - Peak flood depth and level
Existing conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C3

snowy2.0

EMM

CAMP BRIDGE

CONSTRUCTION PAD
WATER MANAGEMENT BASIN

WALLACES CREEK BRIDGE

WESTERN EMPLACEMENT

EASTERN EMPLACEMENT

KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line
- Major flood level contour (1 m AHD)
- Minor flood level contour (0.2 m AHD)

Peak flood depth

2 m

0 m

NOTES:

1. This figure shows flood model results for existing conditions. Results may change locally in some areas due to proposed works within the flood extent.

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55 N

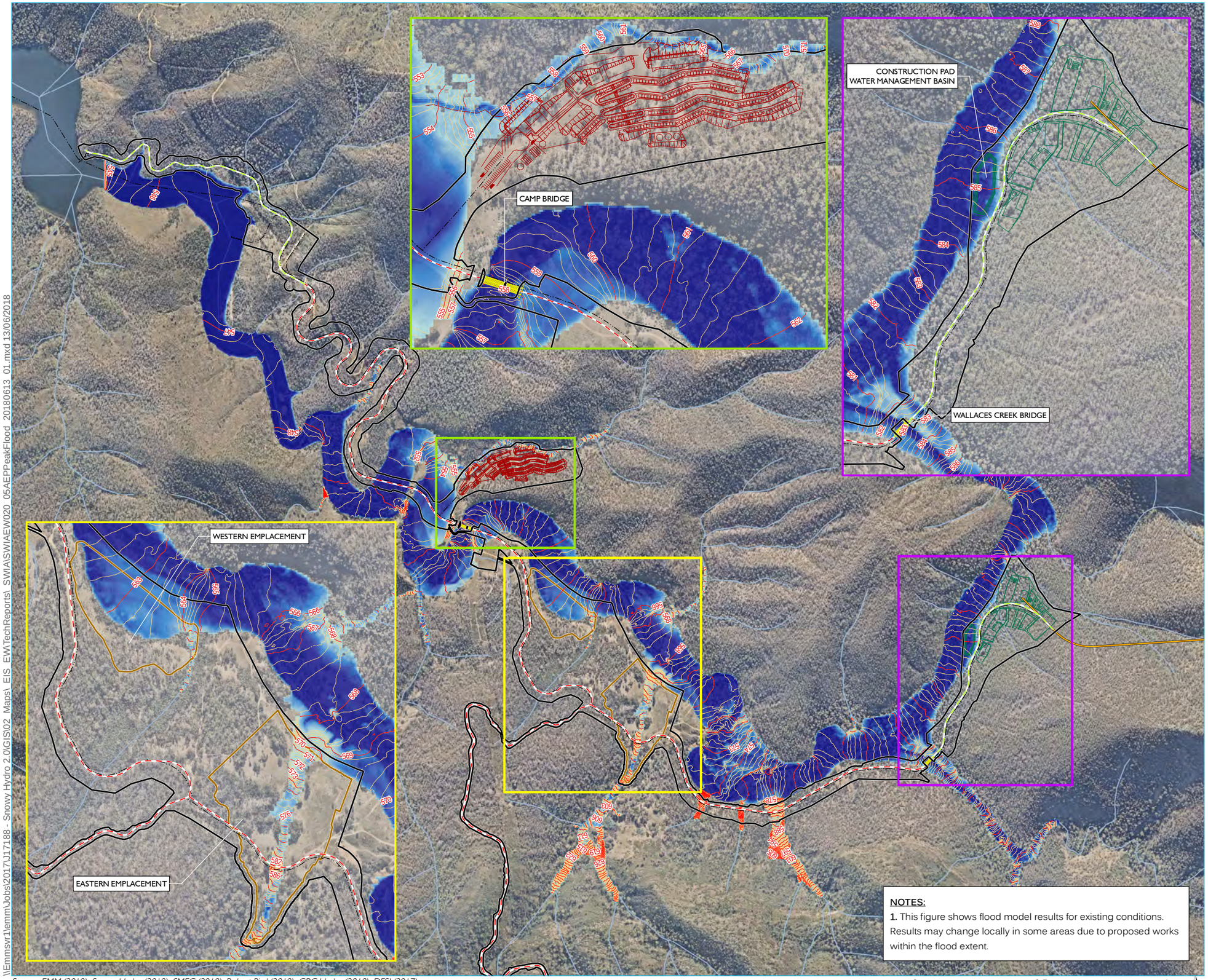
0.2% AEP event - Peak flood depth and level
Existing conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C4

snowy2.0

EMM

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KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line
- Major flood level contour (1 m AHD)
- Minor flood level contour (0.2 m AHD)

Peak flood depth

2 m

0 m

NOTES:

1. This figure shows flood model results for existing conditions. Results may change locally in some areas due to proposed works within the flood extent.

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55

N

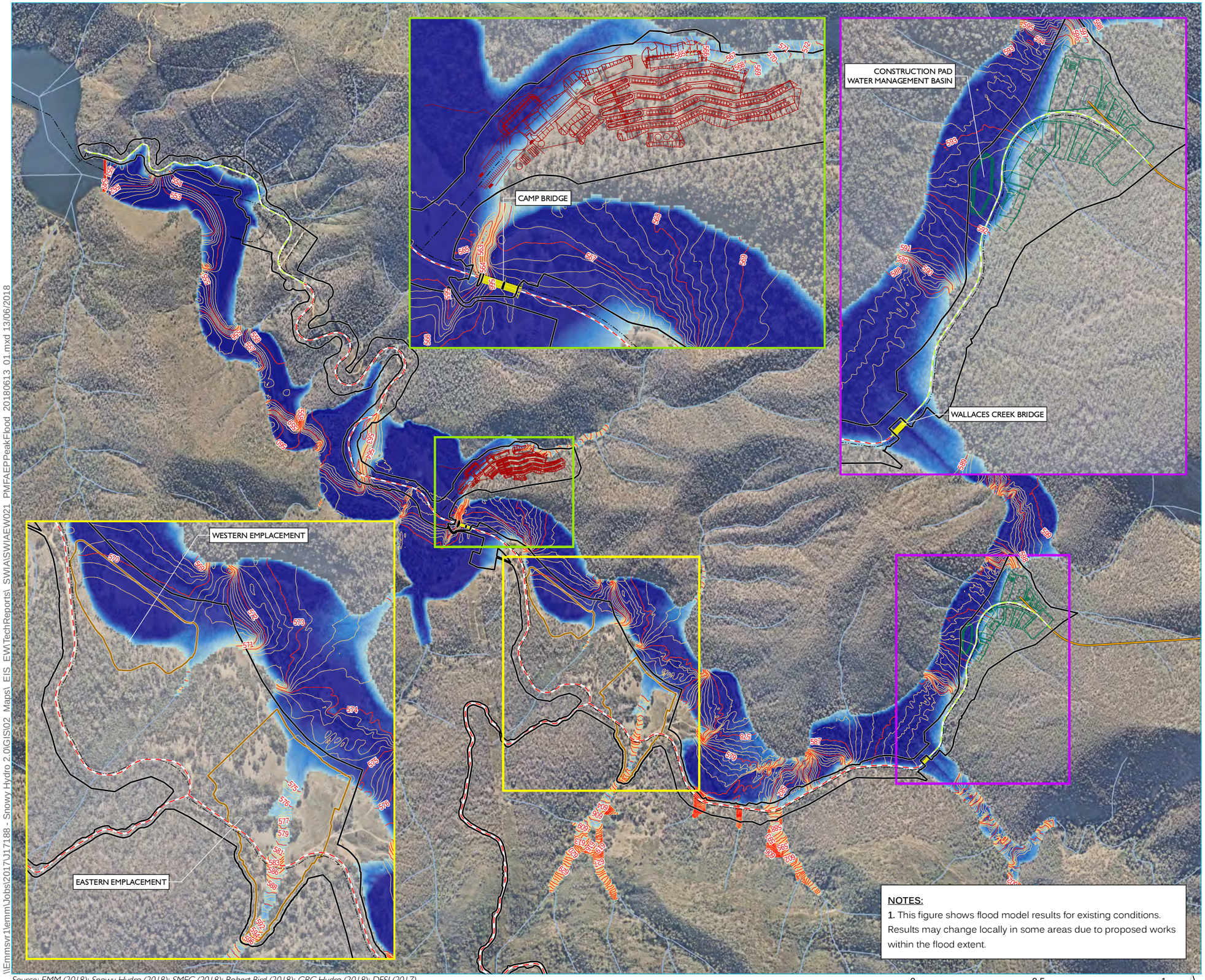
\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW020_05AEPPeakFlood_20180613_01.mxd 13/06/2018

0.05% AEP event - Peak flood depth and level
Existing conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C5

snowy2.0

EMM



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line
- Major flood level contour (1 m AHD)
- Minor flood level contour (0.2 m AHD)

Peak flood depth

8 m

0 m

NOTES:

1. This figure shows flood model results for existing conditions. Results may change locally in some areas due to proposed works within the flood extent.

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55 N

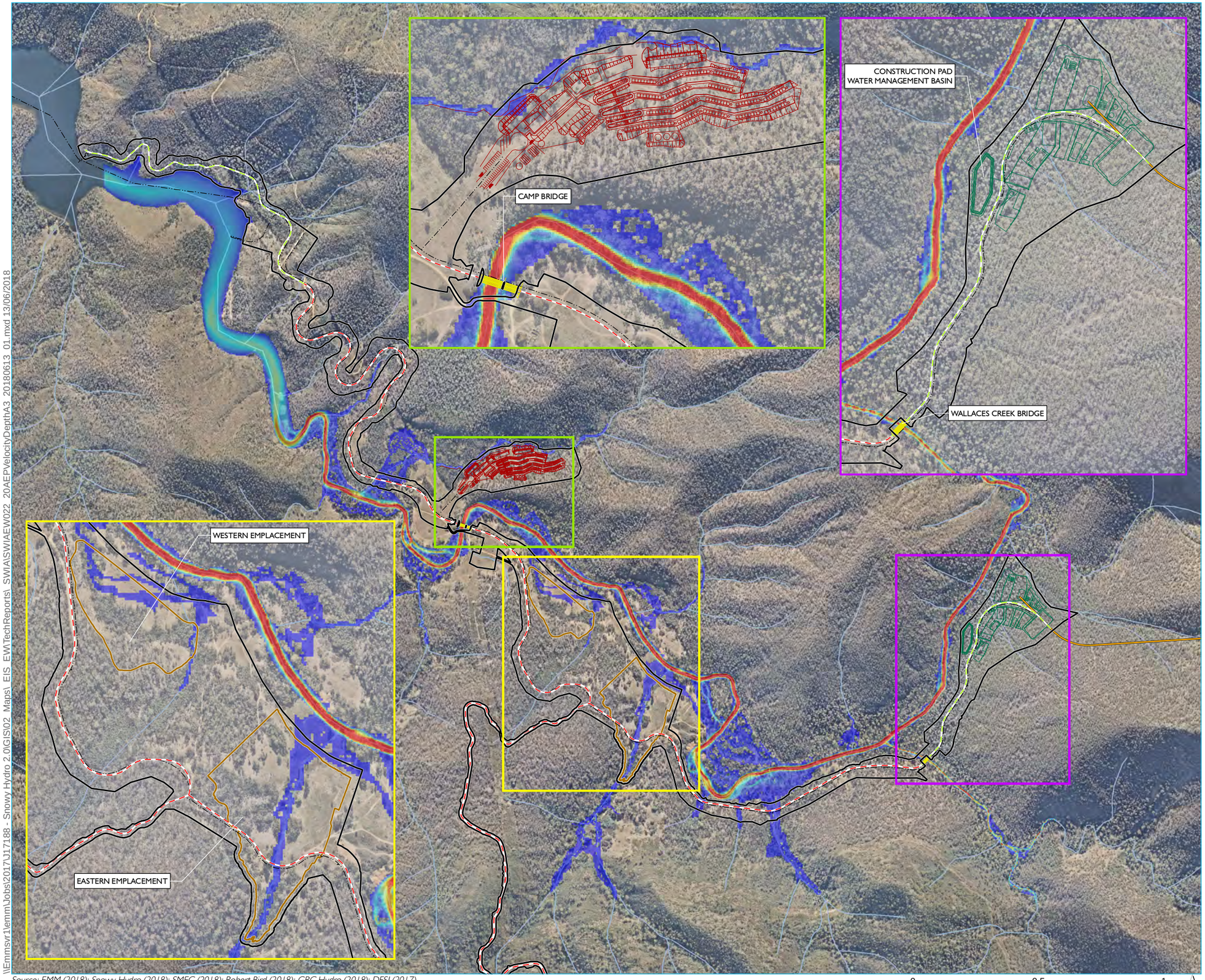
Probable Maximum Flood event - Peak flood depth and level Existing conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C6

snowy2.0

EMM

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KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Peak velocity depth

4 m^2/s

0 m^2/s

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW022_20AEPVelocityDepthA3_20180613_01.mxd 13/06/2018

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3

GDA 1994 MGA Zone 55

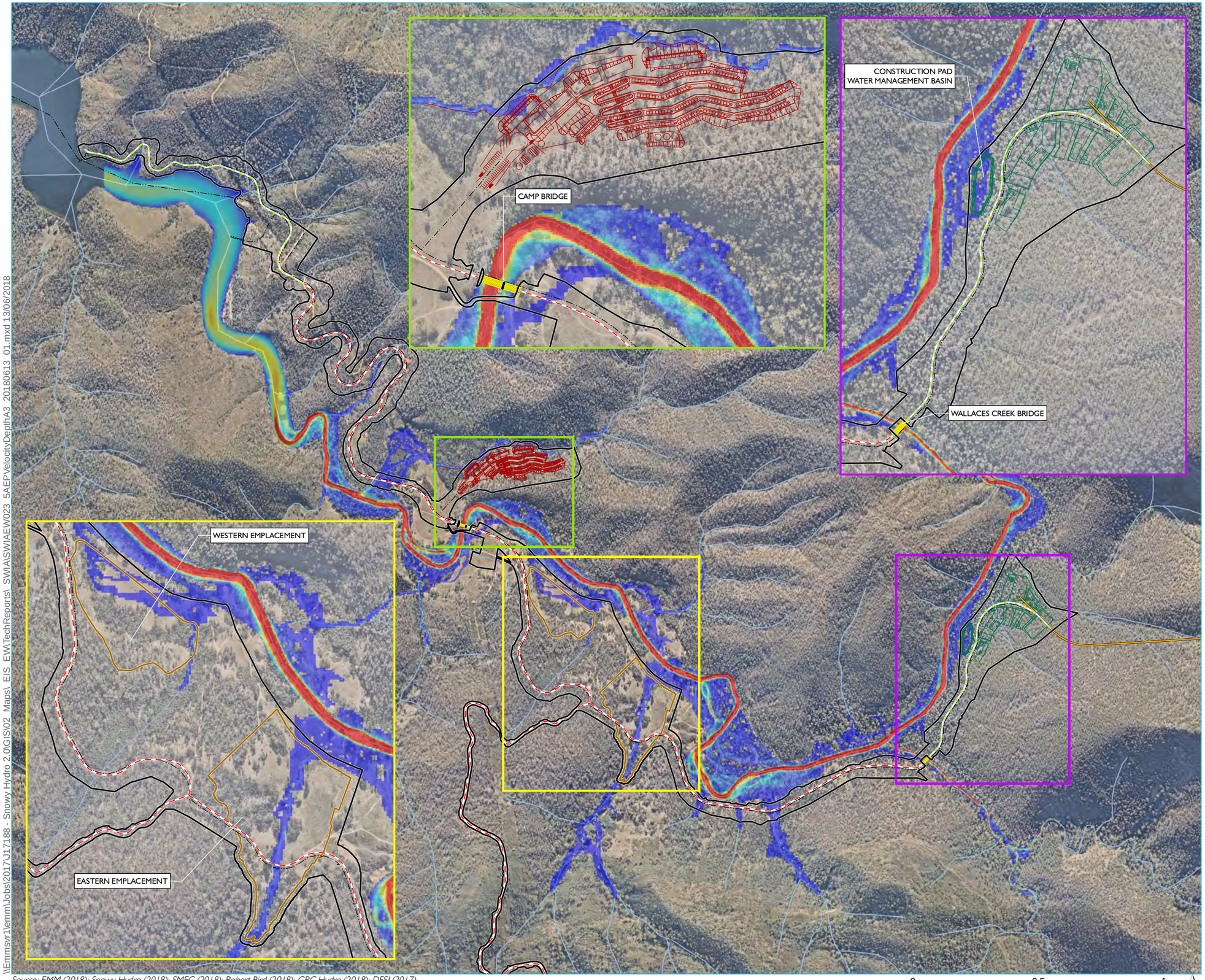
N

20% AEP event - Peak velocity depth
Existing Conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C7

snowy2.0

EMM



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Peak velocity depth

4 m^2/s

0 m^2/s

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55 N

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

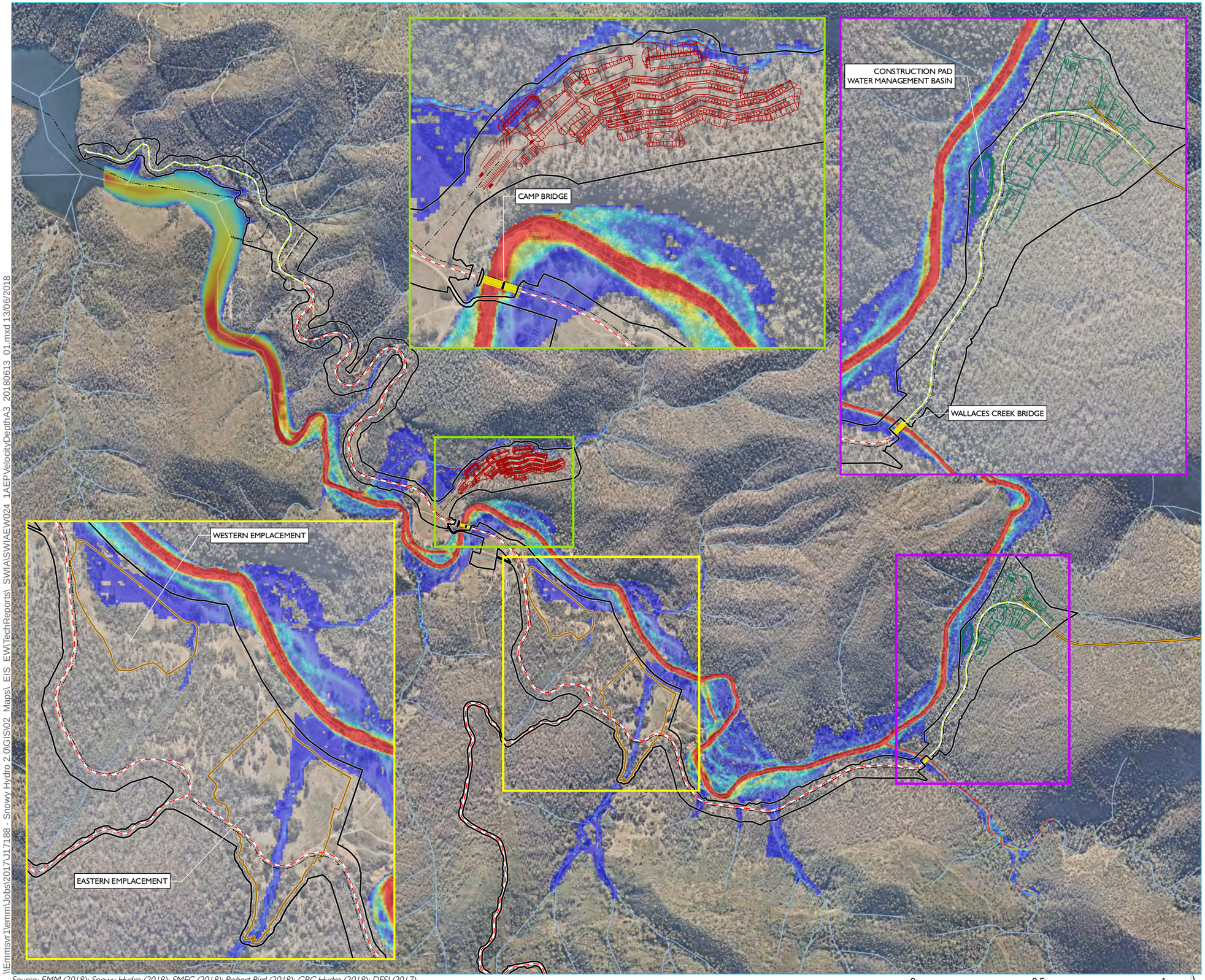
5% AEP event - Peak velocity depth
Existing Conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C8

snowy2.0

EMM

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KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Peak velocity depth

4 m^2/s

0 m^2/s

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW024_1AEPVelocityDepthA3_20180613_01.mxd 13/06/2018

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55

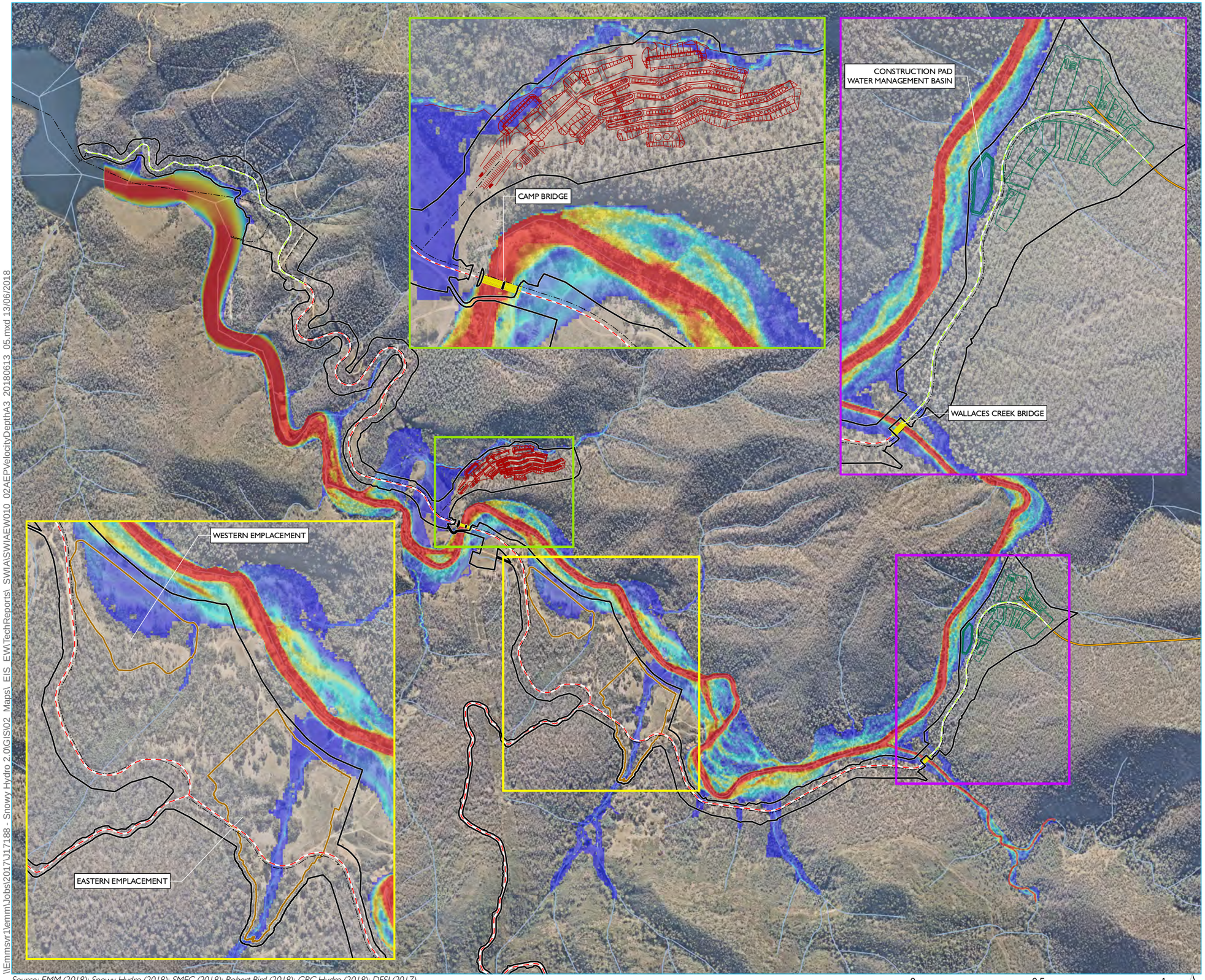
N

1% AEP event - Peak velocity depth
Existing Conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C9

snowy2.0

EMM



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Peak velocity depth

4 m^2/s

0 m^2/s

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55 N

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

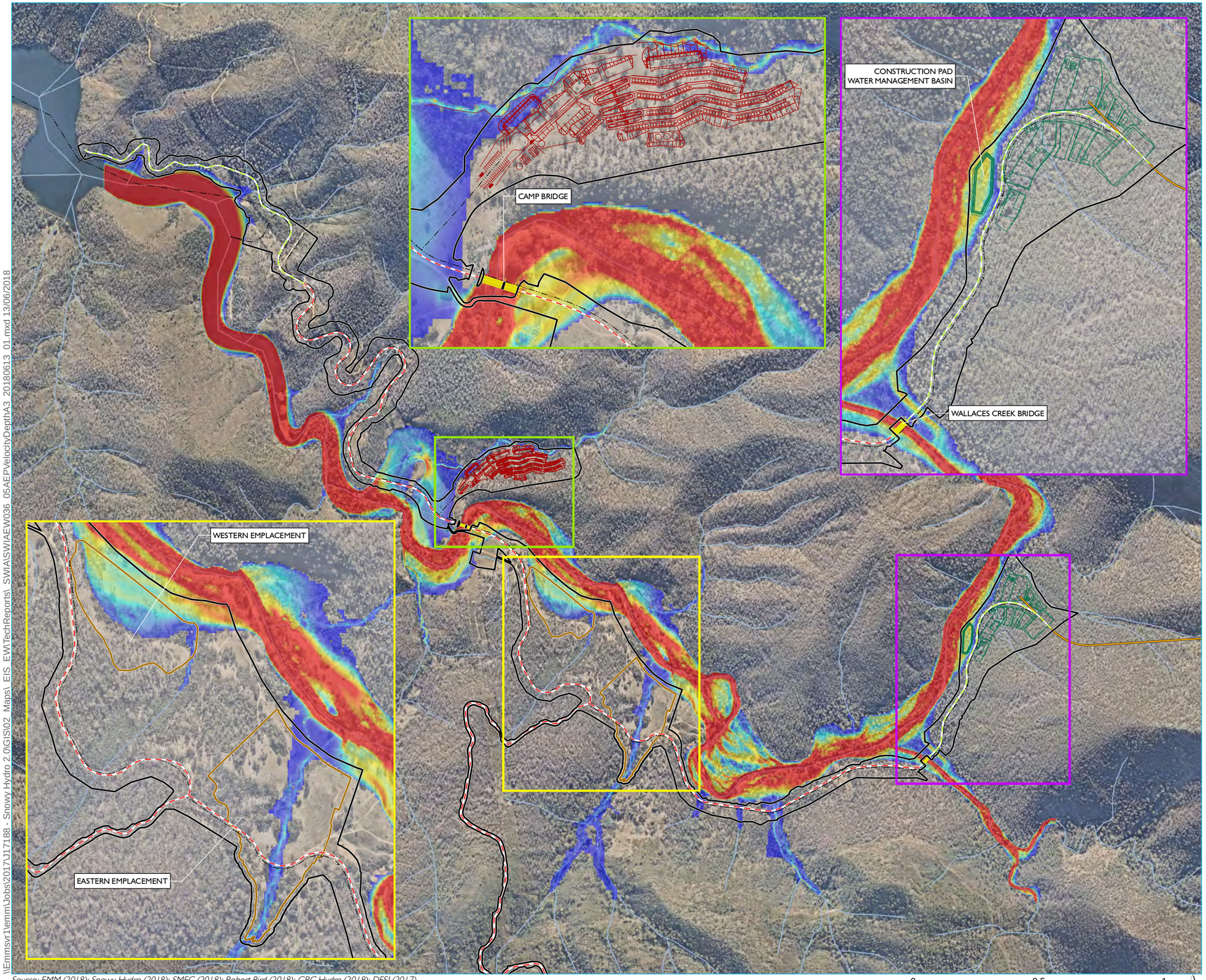
0.2% AEP event - Peak velocity depth
Existing Conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C10

snowy2.0

EMM

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KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Peak velocity depth

4 m^2/s

0 m^2/s

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55

N

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

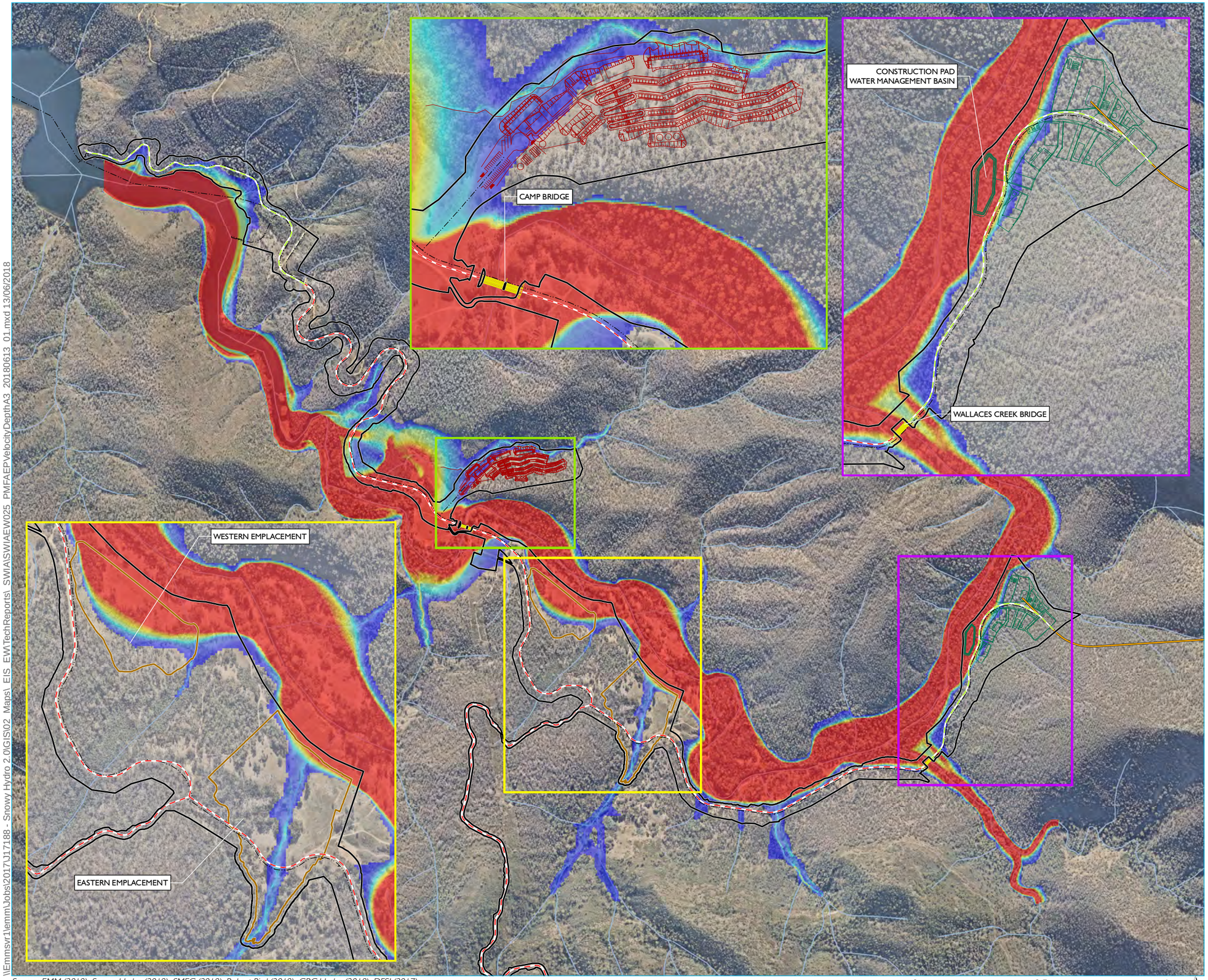
0.05% AEP event - Peak velocity depth
Existing Conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C11

snowy2.0

EMM

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KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Peak velocity depth

12 m^2/s

0 m^2/s

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55 N

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

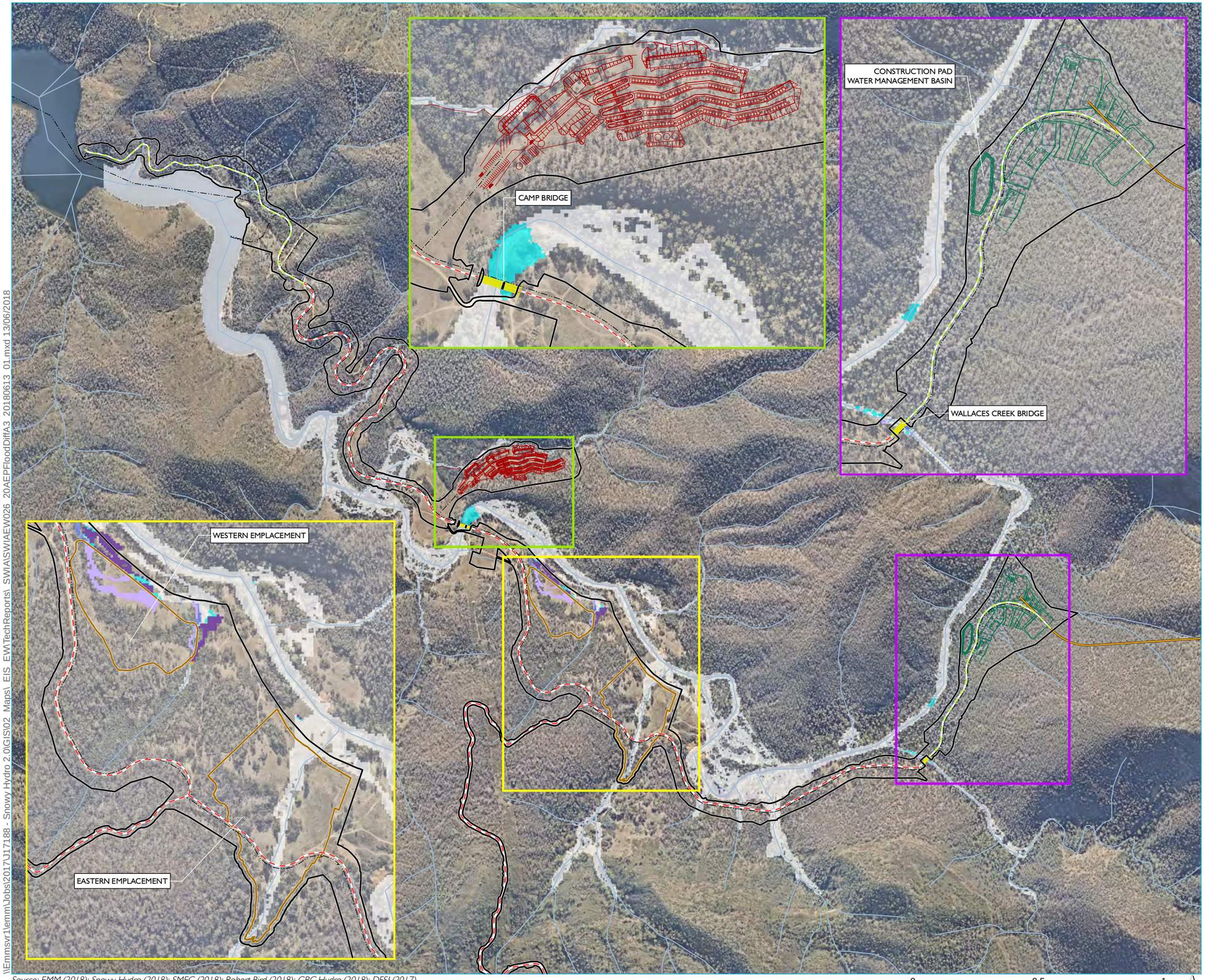
Probable Maximum Flood event - Peak velocity depth
Existing Conditions

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C12

snowy2.0

EMM

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW025_PMFAEPVelocityDepthA3_20180613_01.mxd 13/06/2018



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in flood level (m)

- < -0.1
- -0.1 to -0.01
- No change
- 0.01 to 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- 0.7 - 0.9
- > 0.9
- No longer flooded
- Newly flooded

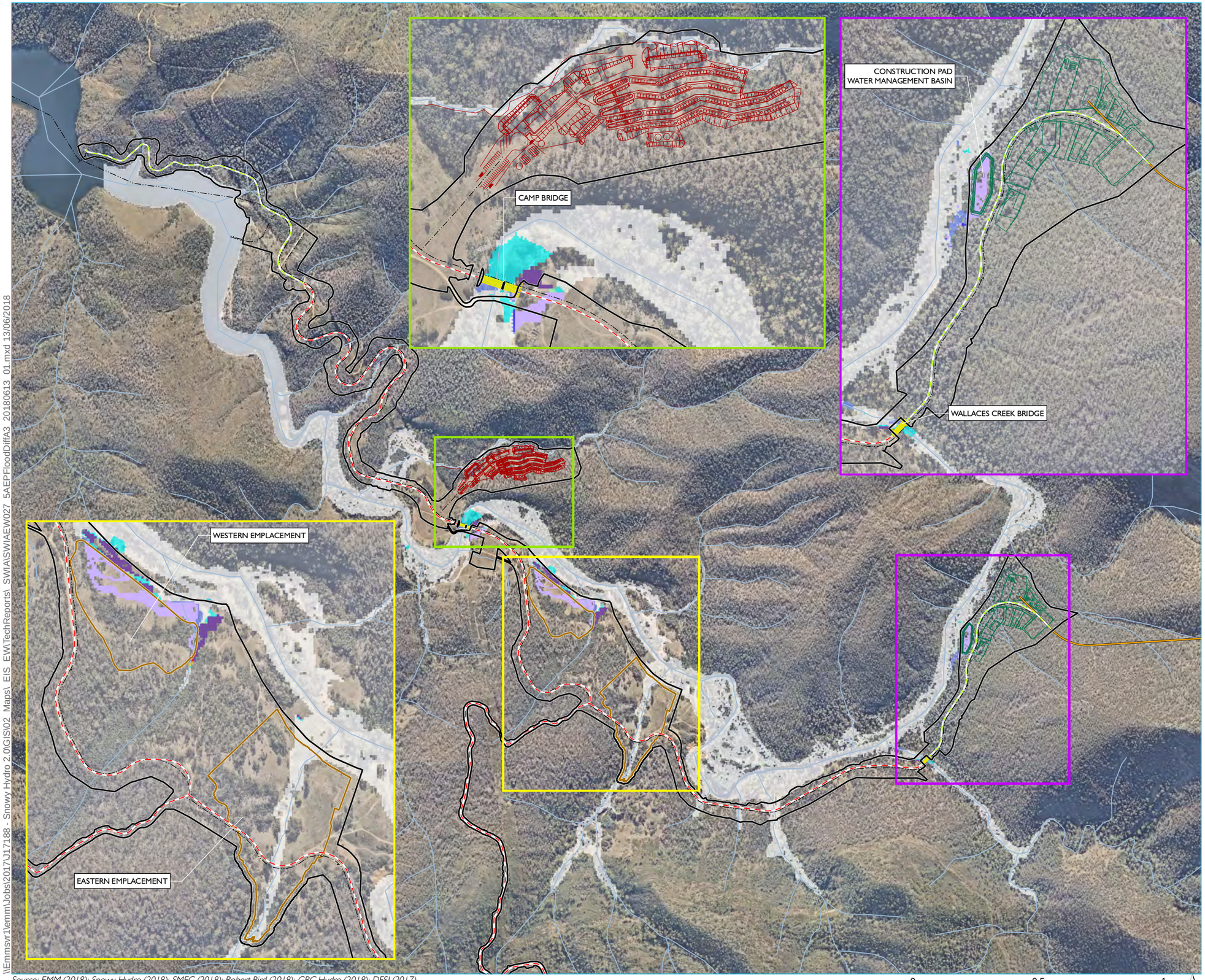
20% AEP event - Changes to peak flood levels

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C13

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km
1:15,000 @ A3
GDA 1994 MGA Zone 55
N

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW026_20AEPFloodDiffA3_20180613_01.mxd 13/06/2018



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in flood level (m)

- < -0.1
- -0.1 to -0.01
- No change
- 0.01 to 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- 0.7 - 0.9
- > 0.9
- No longer flooded
- Newly flooded

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55

N

5% AEP event - Changes to peak flood levels

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C14

snowy2.0

EMM

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW027_5AEPFloodDiffA3_20180613_01.mxd 13/06/2018

CAMP BRIDGE

CONSTRUCTION PAD
WATER MANAGEMENT BASIN

WALLACES CREEK BRIDGE

WESTERN EMPLACEMENT

EASTERN EMPLACEMENT

KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in flood level (m)

- < -0.1
- -0.1 to -0.01
- No change
- 0.01 to 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- 0.7 - 0.9
- > 0.9
- No longer flooded
- Newly flooded

1% AEP event - Changes to peak flood levels

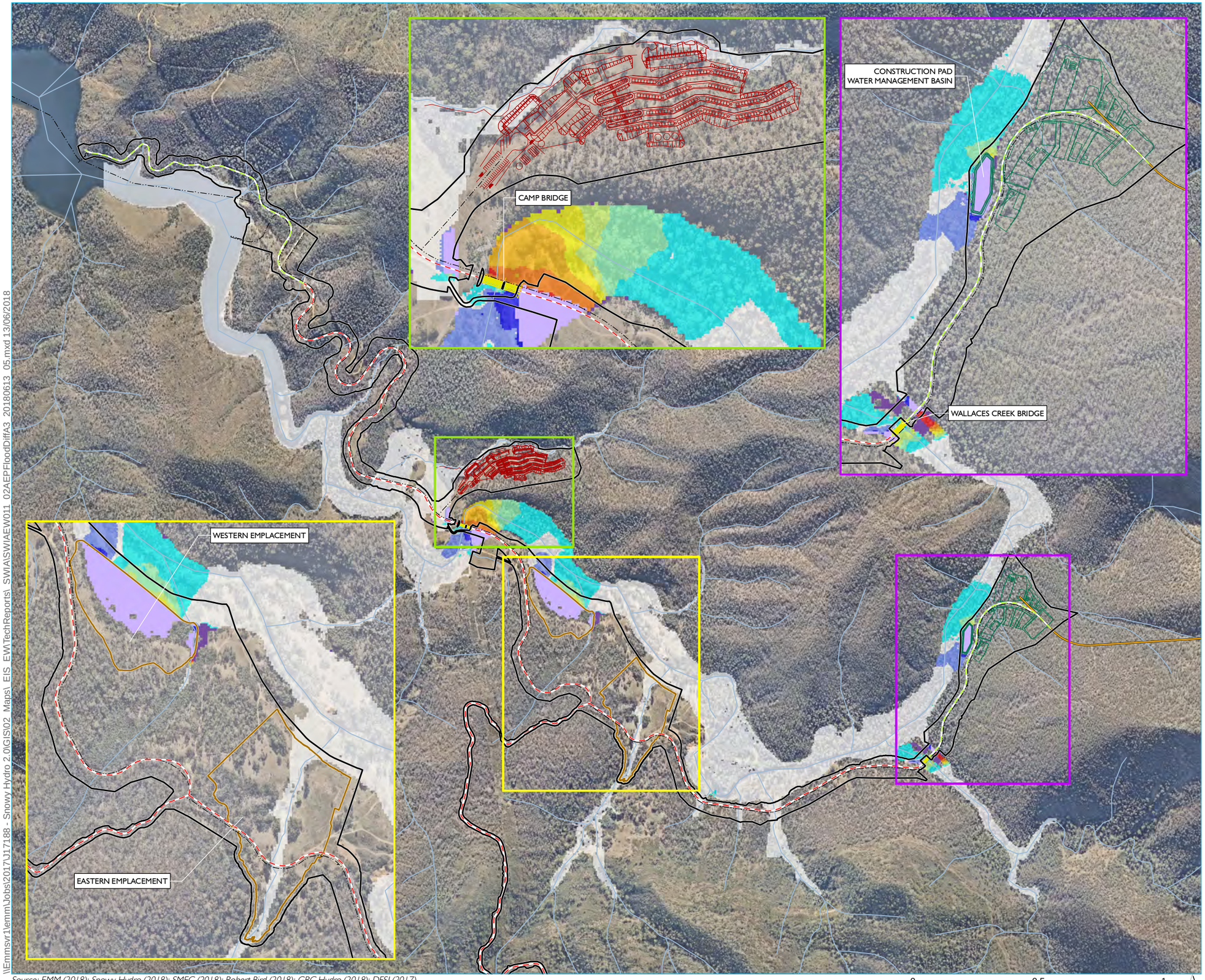
Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C15

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km
1:15,000 @ A3 GDA 1994 MGA Zone 55

N

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW028_1AEPFloodDiffA3_20180613_01.mxd 13/06/2018



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in flood level (m)

- < -0.1
- -0.1 to -0.01
- No change
- 0.01 to 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- 0.7 - 0.9
- > 0.9
- No longer flooded
- Newly flooded

0.2% AEP event - Changes to peak flood levels

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C16

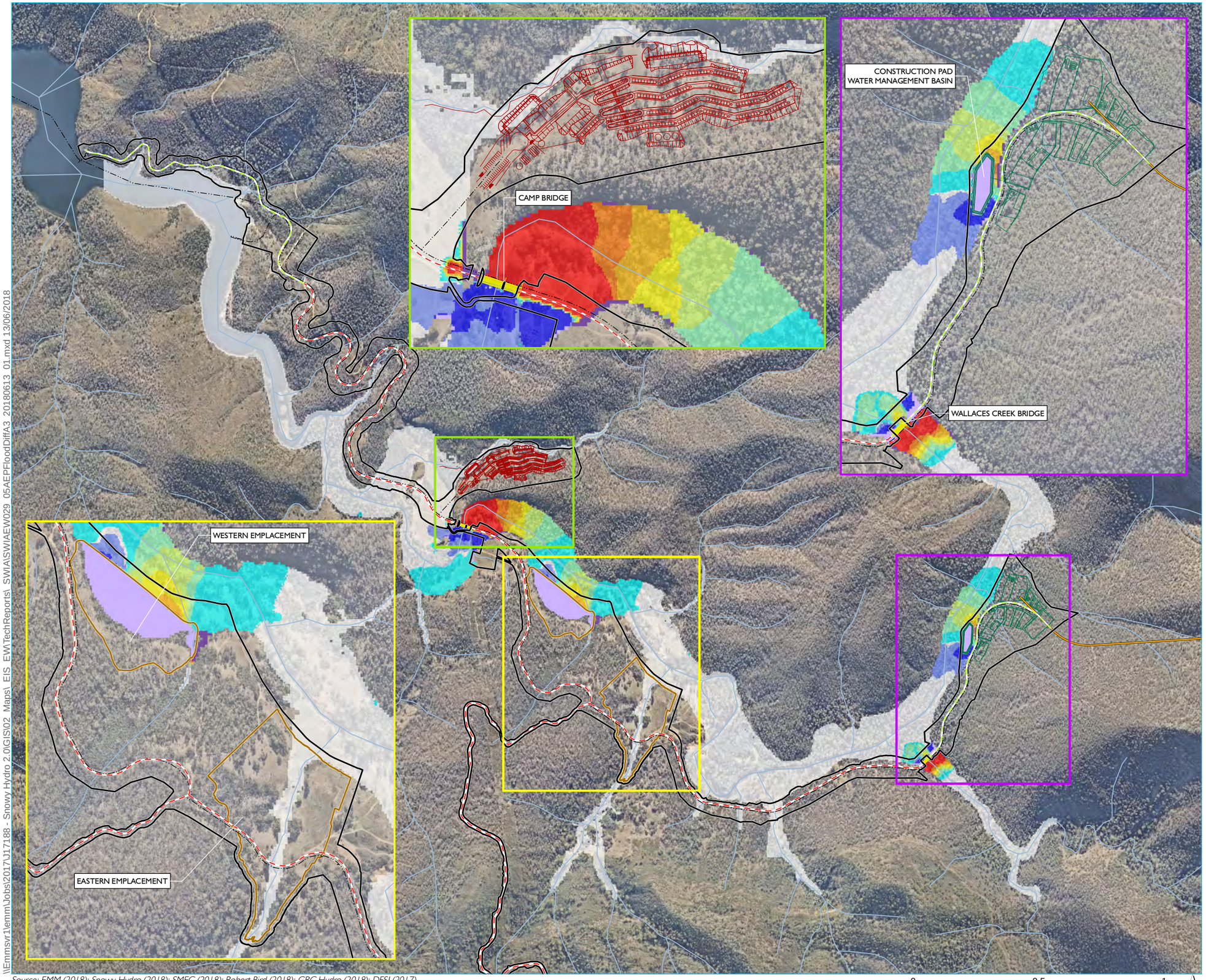
Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km
1:15,000 @ A3
GDA 1994 MGA Zone 55
N

\\Emmsvr1\emm\Jobs\2017\J171188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW011_02AEPFlood

snowy2.0

EMM



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in flood level (m)

- < -0.1
- -0.1 to -0.01
- No change
- 0.01 to 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- 0.7 - 0.9
- > 0.9
- No longer flooded
- Newly flooded

\\Emmsvr1\emm\Jobs\2017\J171188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW029_05AEPFloodDiffA3_20180613_01.mxd 13/06/2018

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55

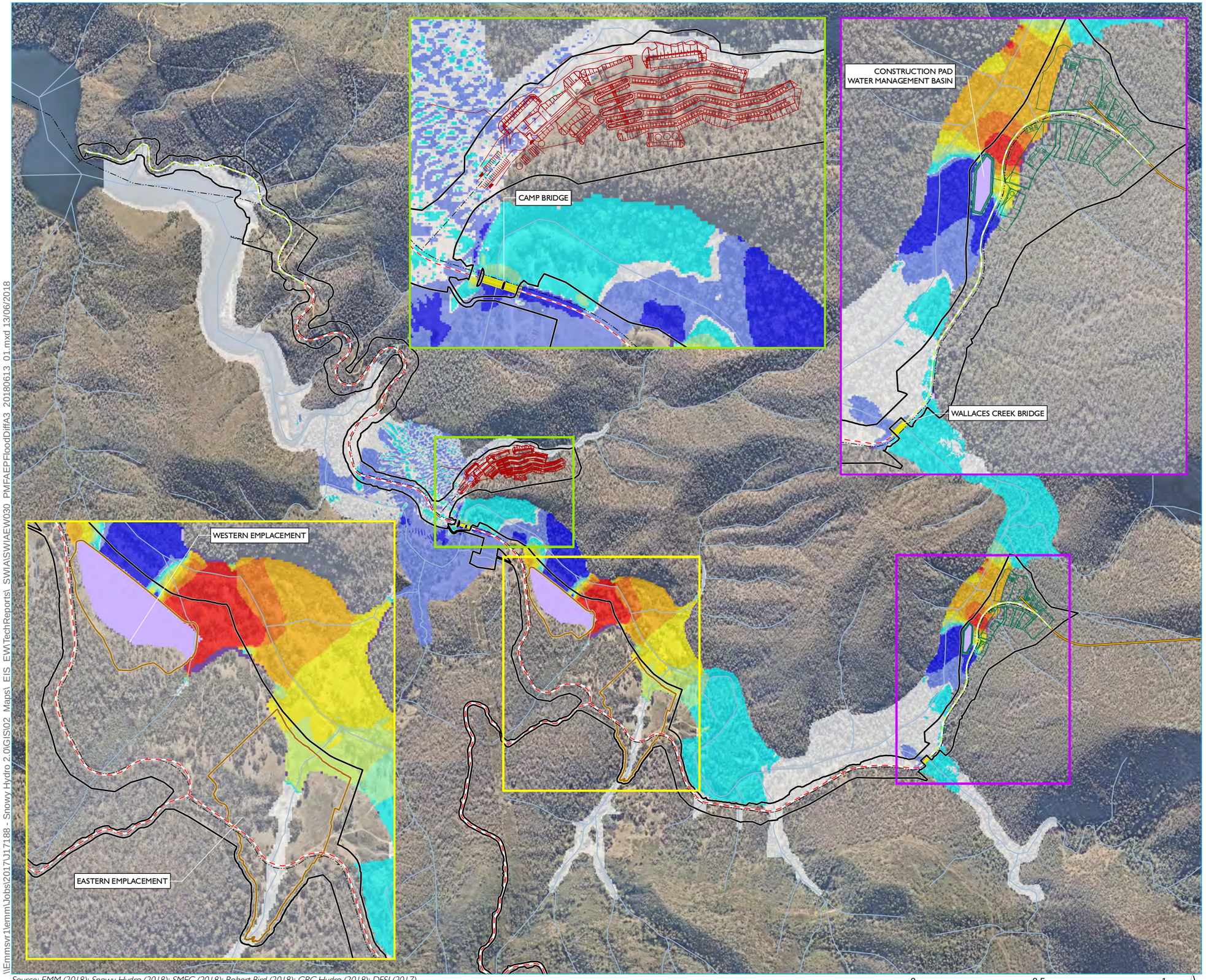
N

0.05% AEP event - Changes to peak flood levels

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C17

snowy2.0

EMM



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in flood level (m)

- < -0.1
- -0.1 to -0.01
- No change
- 0.01 to 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 0.7
- 0.7 - 0.9
- > 0.9
- No longer flooded
- Newly flooded

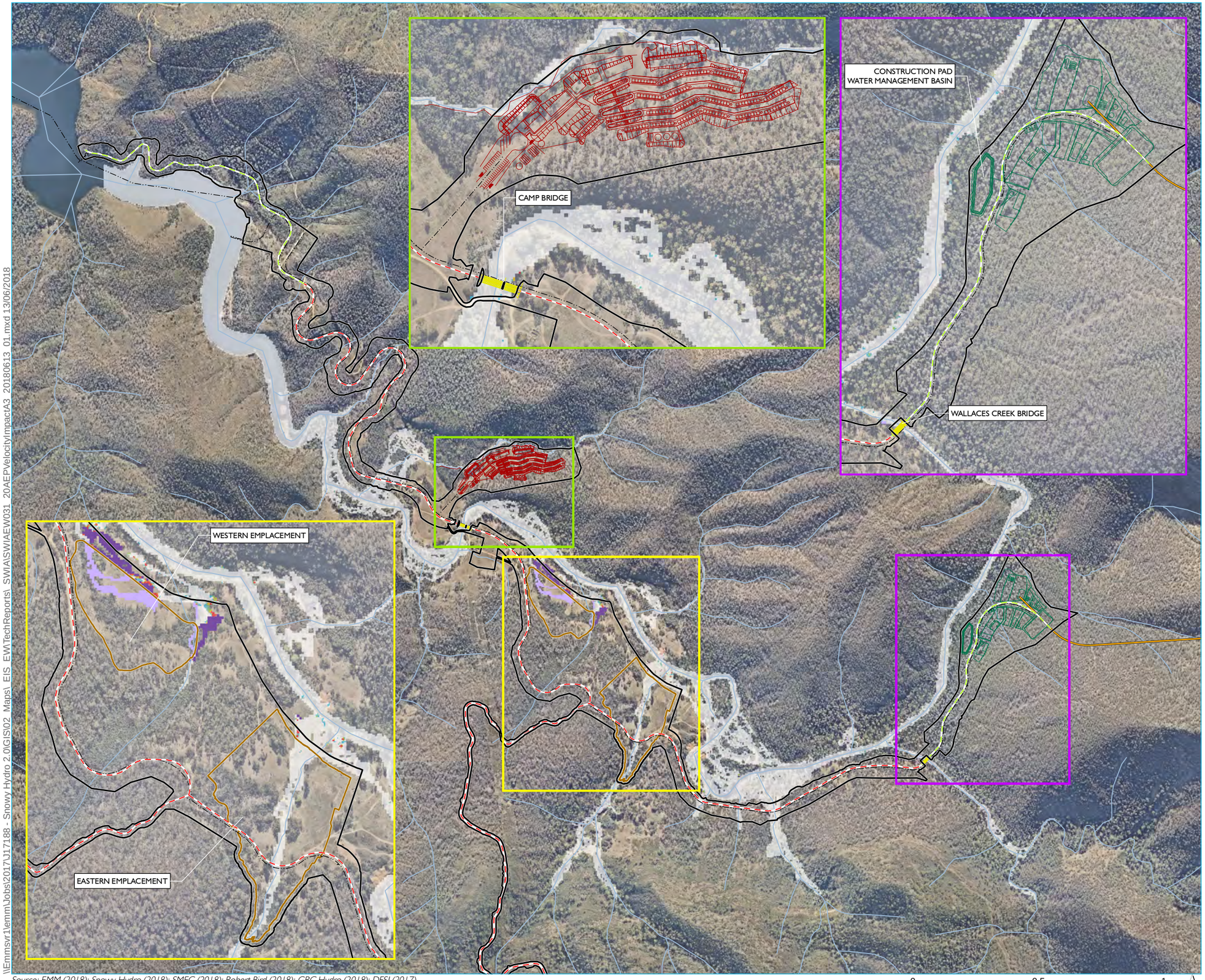
Probable Maximum Flood event - Changes to peak flood levels

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C18

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km
1:15,000 @ A3
GDA 1994 MGA Zone 55
N

\\Emmsvr1\emm\Jobs\2017\J171188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW030_PMFAEPFloodDiffA3_20180613_01.mxd 13/06/2018



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in velocity

- 0 to10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 t0 100
- No longer flooded
- Newly flooded

20% AEP event - Changes to peak velocity

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C19

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km
1:15,000 @ A3
GDA 1994 MGA Zone 55
N

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW031_20AEPVelocityImpactA3_20180613_01.mxd 13/06/2018

CAMP BRIDGE

CONSTRUCTION PAD
WATER MANAGEMENT BASIN

WALLACES CREEK BRIDGE

WESTERN EMPLACEMENT

EASTERN EMPLACEMENT

KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in velocity

- 0 to10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 t0 100
- No longer flooded
- Newly flooded

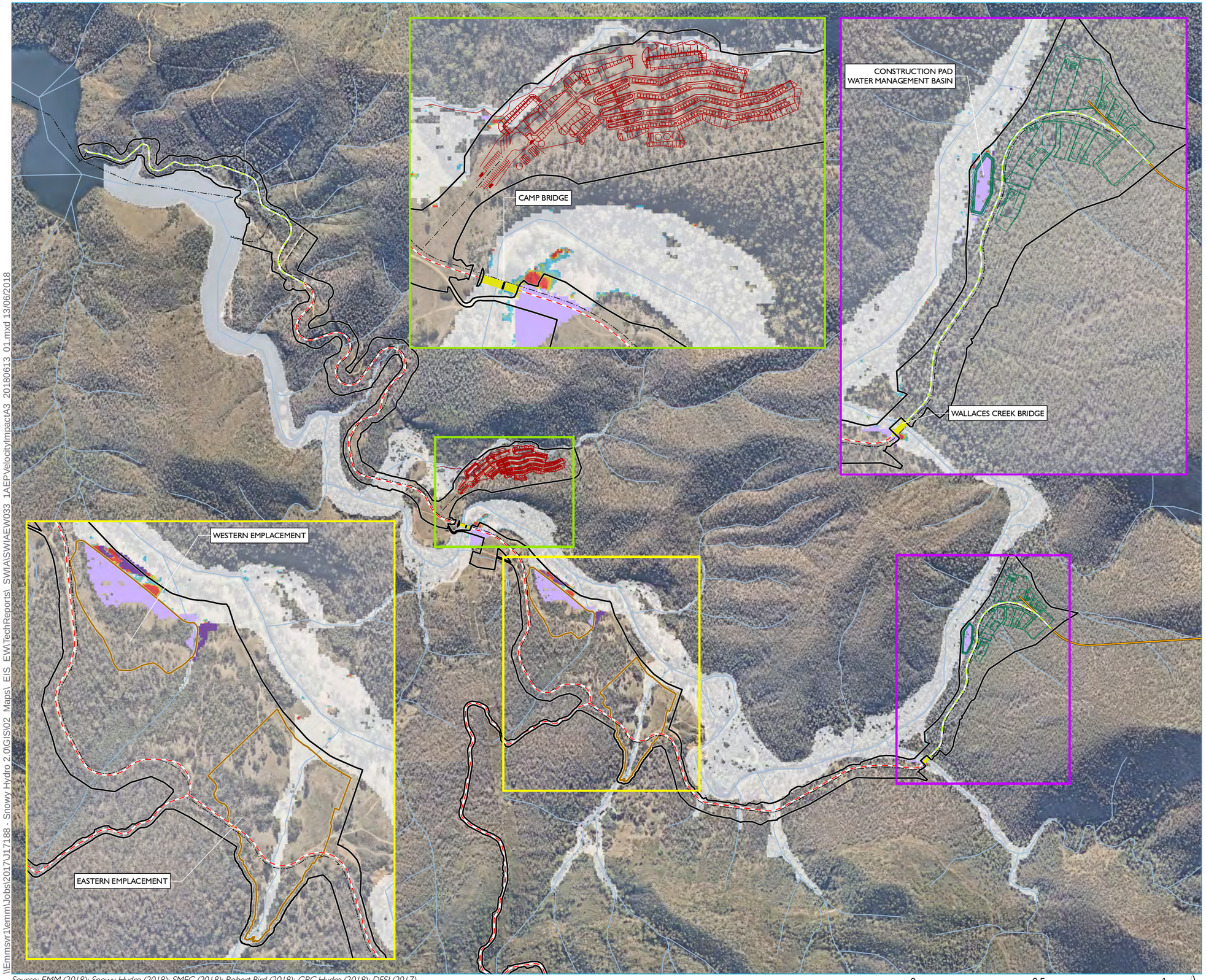
5% AEP event - Changes to peak velocity

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C20

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km
1:15,000 @ A3
GDA 1994 MGA Zone 55
N

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW032_5AEPVelocityImpactA3_20180613_01.mxd 13/06/2018



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in velocity

- 0 to10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 t0 100
- No longer flooded
- Newly flooded

1% AEP event - Changes to peak velocity

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C21

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km
1:15,000 @ A3
GDA 1994 MGA Zone 55
N

\\Emmsvr1\emm\Jobs\2017\J171188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW033_1AEPVelocityImpactA3_20180613_01.mxd 13/06/2018

CAMP BRIDGE

CONSTRUCTION PAD
WATER MANAGEMENT BASIN

WALLACES CREEK BRIDGE

WESTERN EMPLACEMENT

EASTERN EMPLACEMENT

KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in velocity

- 0 to10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 t0 100
- No longer flooded
- Newly flooded

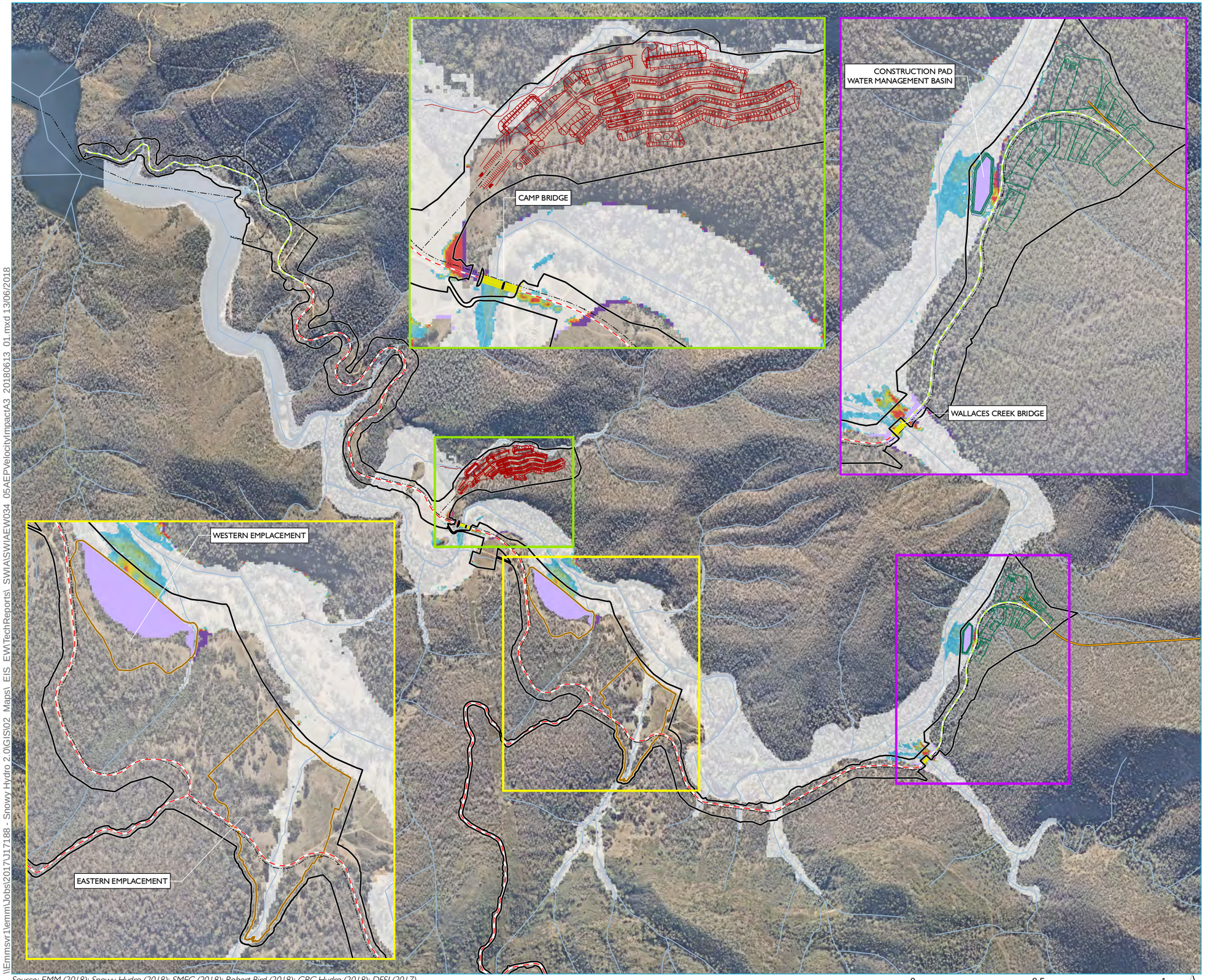
0.2% AEP event - Changes to peak velocity

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C22

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km
1:15,000 @ A3
GDA 1994 MGA Zone 55
N

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW012_02AEPVelocityImpactA3_20180613_05.mxd 13/06/2018



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in velocity

- 0 to10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 t0 100
- No longer flooded
- Newly flooded

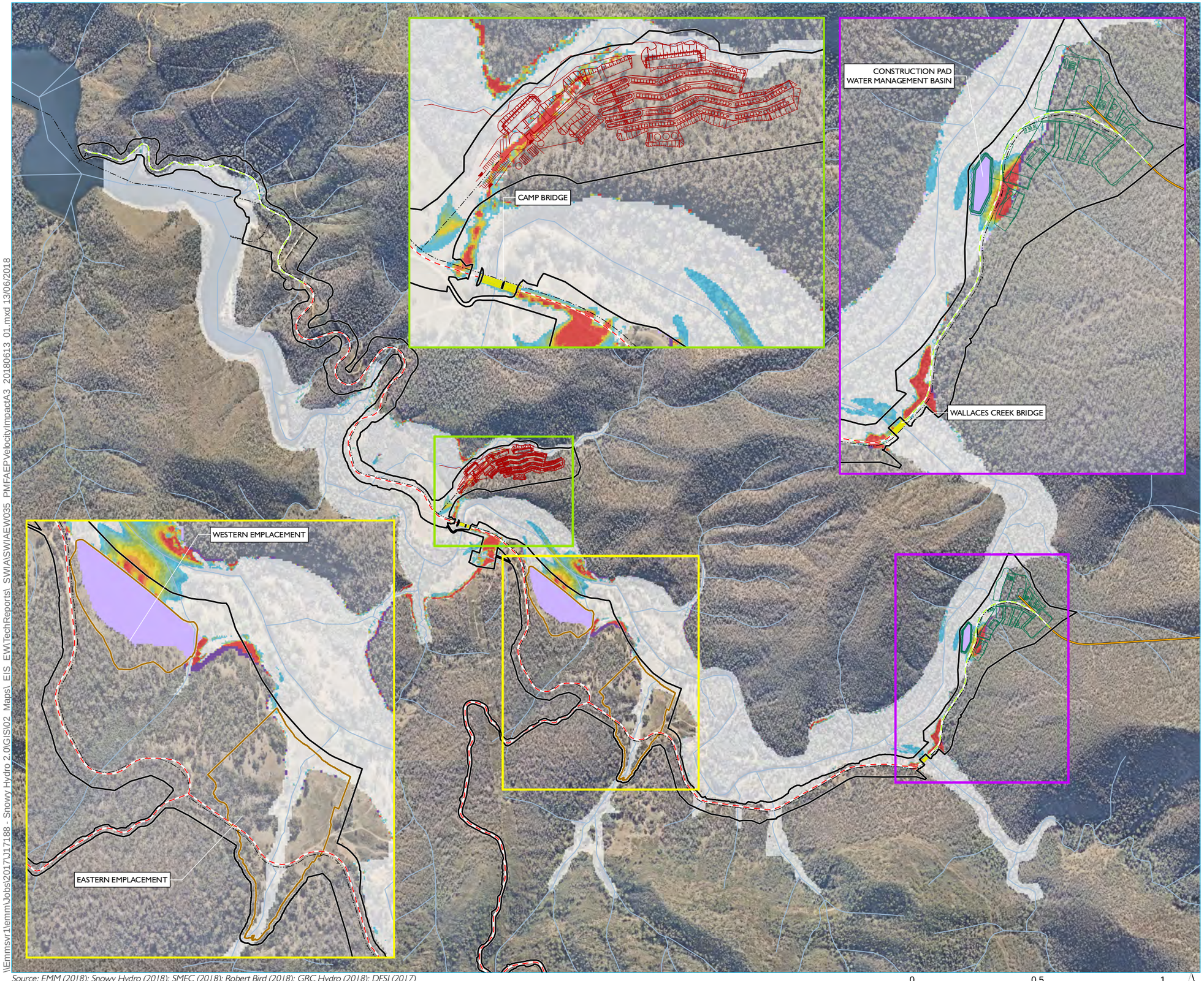
0.05% AEP event - Changes to peak velocity

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C23

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km
1:15,000 @ A3 GDA 1994 MGA Zone 55 N

\\Emmsvr1\emm\Jobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW034_05AEPVelocityImpactA3_20180613_01.mxd 13/06/2018



KEY

- Access road upgrade
- Access road extension
- Permanent bridge
- Accommodation camp conceptual layout
- Portal construction pad conceptual layout
- Exploratory tunnel
- Communications cable and water services pipeline location
- On land rock emplacement area
- Disturbance footprint
- Watercourse / drainage line

Changes in velocity

- 0 to10
- 10 to 20
- 20 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 to 70
- 70 to 80
- 80 to 90
- 90 t0 100
- No longer flooded
- Newly flooded

\\Emmsvr1\emmJobs\2017\J17188 - Snowy Hydro 2.0\GIS\02_Maps_EIS_EWTechReports_SWIA\SWIAEW035_PMFAEPVelocityImpactA3_20180613_01.mxd 13/06/2018

Source: EMM (2018); Snowy Hydro (2018); SMEC (2018); Robert Bird (2018); GRC Hydro (2018); DFSI (2017)

0 0.5 1 km

1:15,000 @ A3 GDA 1994 MGA Zone 55 N

Probable Maximum Flood event - Changes to peak velocity

Snowy 2.0
Surface Water Assessment
Exploratory Works
Figure C24

snowy2.0

EMM

Appendix D

Water Balance Method Statement

D.1 Introduction

A site water balance was developed for the process water management system that is described in Section 6.7. The appendix is a method statement that describes the modelling approach, assumptions and results.

D.2 Model objectives

The objectives of the water balance modelling process are to:

- demonstrate the functionality of the process water system over the 26 month tunnel construction period;
- estimate the probable range in water transfer volumes over the above period, having regard to variable weather conditions; and
- assist in the determination of water licensing requirements.

D.3 Overview of the process water system

The process water system will be designed to:

- manage potentially contaminated water produced from construction activities; and
- supply water to construction activities.

The system will be designed to prevent (where possible) the ingress of stormwater into the process water system. Captured process water will be treated in a water treatment plant. Treated process water will be used for:

- use in the tunnel construction;
- concrete production;
- equipment wash down; and
- access road dust suppression.

The process water system will source additional water from the construction pad's water management basin and Talbingo Reservoir as required to meet demand. Any surplus treated process water will be discharged to Talbingo Reservoir. This arrangement will avoid either discharge to or extraction from the Yarrangobilly River.

Figure D1 describes the proposed process water management system.

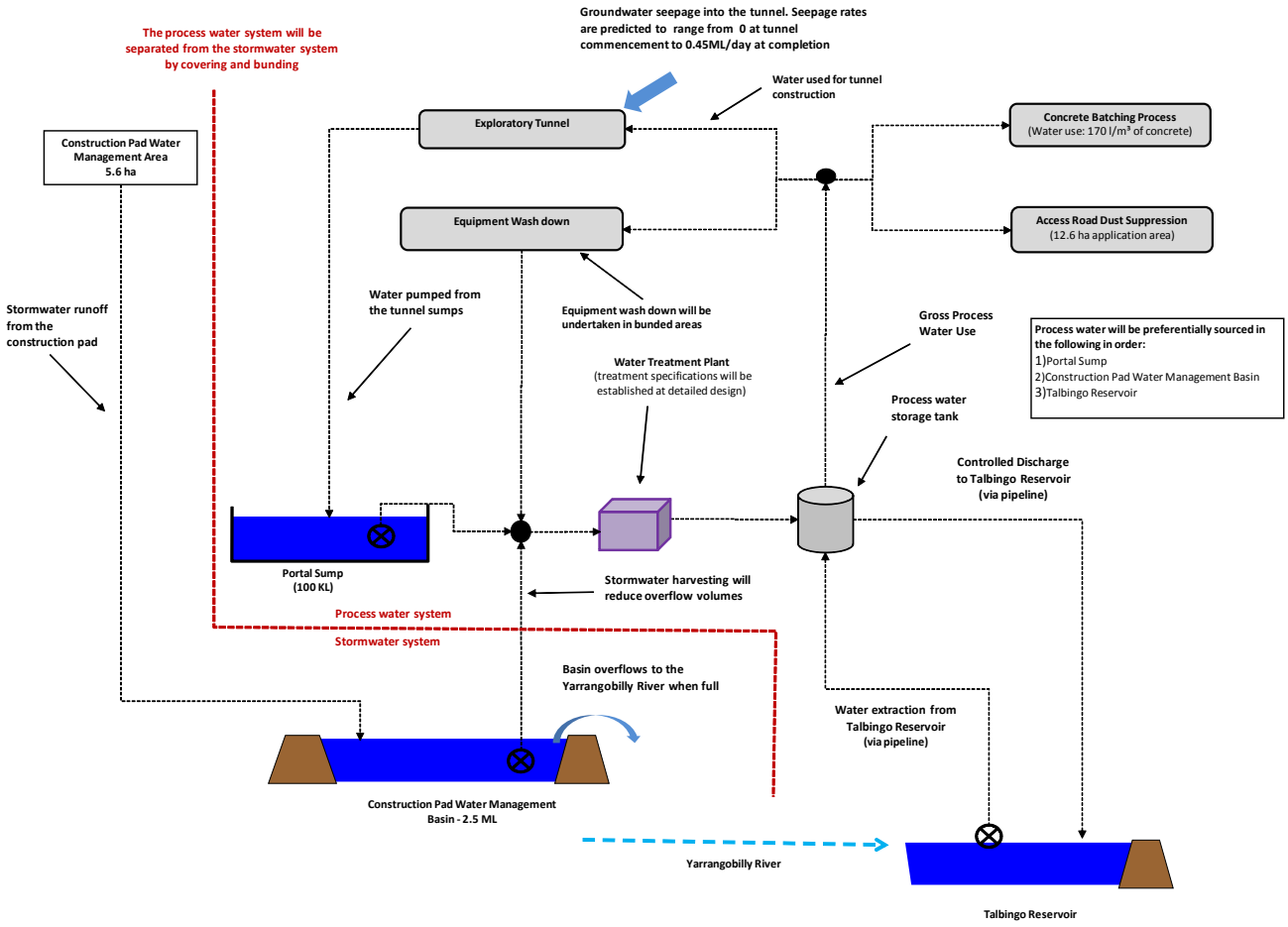


Figure D1 Process water system

D.4 Modelling Assumptions

D.4.1 Rainfall Data

Daily rainfall data from the Talbingo (72131) rainfall gauge over the January 1997 to December 2017 period was applied to the model.

D.4.2 Evaporation

Average monthly evaporation and evapotranspiration rates that are reported in Table 4.4 were applied to the model. Evaporation losses were calculated as a function of the evaporation rate and the surface area of the storage. A pan factor of 0.7 was applied to the calculation of evaporation losses from surface water storages.

Evapotranspiration factors were applied in the hydrologic model to simulate evapotranspiration losses from catchments.

D.4.3 Process water system configuration

a. Process Water Demands

Process water is required for as dust suppression of access roads, concrete production, tunnel construction activities and vehicle wash down.

Dust suppression application rates were calculated by applying the following equation:

Dust Suppression (t) = [(Shading Multiplier x ET (t)) – Rainfall (t) + Loss Factor] x Area

Where:

Shading Multiplier = 0.8

ET (t) = Daily Evapotranspiration Rate (mm/day)

Rainfall (t) = Rainfall Rate (mm/day)

Loss Factor = Dust Suppression Loss Factor 3mm/day

Area = 12.6 (ha)

The other water demands included:

- Concrete production – average daily use rate of 12 KL/day.
- Water use in the tunnel construction - average daily use rate of 10 KL/day.
- Equipment wash down was assumed to have a minimal net demand compared to other process water uses and was therefore not modelled in the water balance.

b. Groundwater Inflows

Estimates of groundwater flows into the exploratory tunnel were established by the Groundwater Assessment (EMM, 2018b) and are presented in Figure D2.

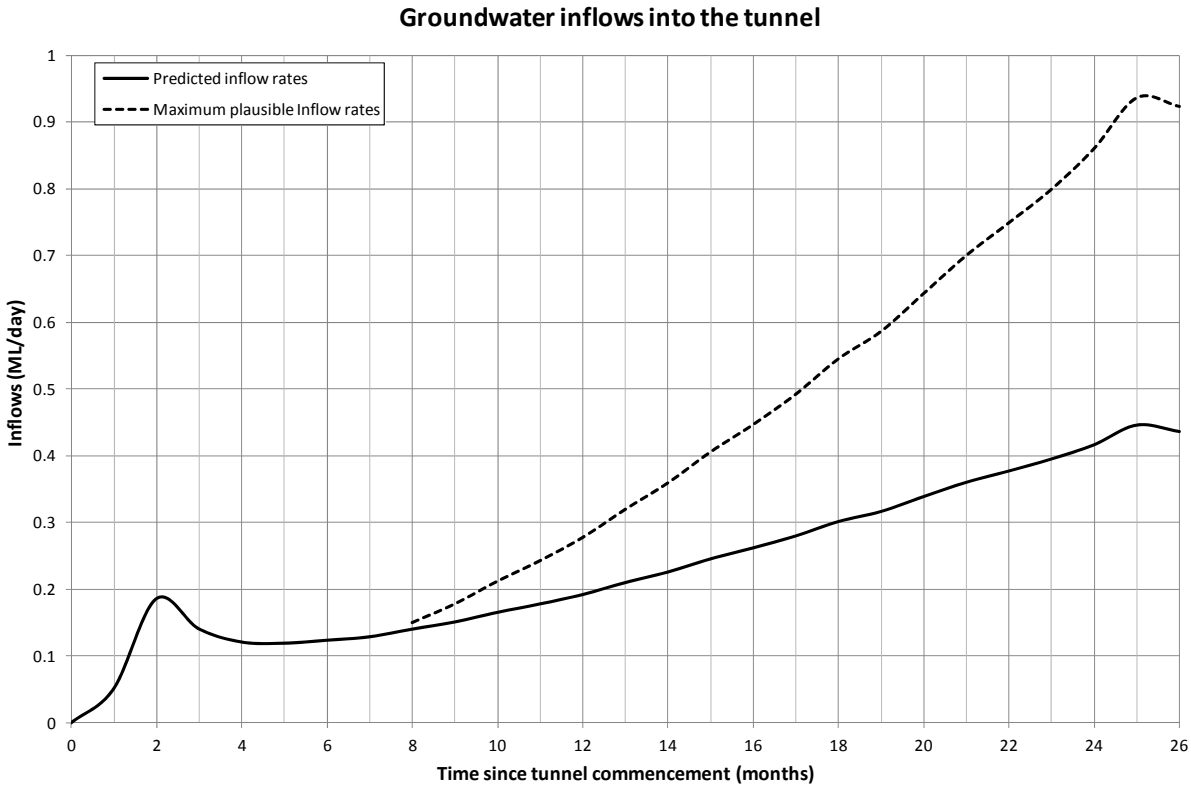


Figure D2 Estimated Groundwater Inflows into Exploratory Tunnel (EMM, 2018)b

c. Portal Sump

A portal sump will receive water dewatered from the tunnel. The sump is assumed to have a 0.1ML capacity and be a turkeys nest style dam. A turkeys nest style dam receives direct rainfall but no runoff from adjoining catchment areas.

d. Water Management Basin

The construction pad water management basin will receive runoff from the 5.6 ha construction pad water management area. The basin is assumed to have a 2.5 ML capacity. Water can be extracted from the basin to supply process water as required. When the basin is full, it will overflow into the Yarrangobilly River.

e. Water Treatment Plant

A water treatment plant will treat water from the portal sump and the water management basin. The treatment process will have no influence on volumetric flows and is not included in the water balance model.

f. Process Water Tank

A process water tank will supply treated process water to all process water use points. The process water tank will be toped up with clean water extracted from the Talbingo Reservoir as required. If process water supply exceeds use, the excess treated process water will be discharge to Talbingo Reservoir via a controlled discharge arrangement.

g. Order of use

Process water is preferentially sourced by the water balance model in the following order:

- Portal sump;
- Construction pad water management basin; and
- Talbingo Reservoir.

Controlled discharge to Talbingo Reservoir will only occur when dewatering requirements from the portal sump exceed the net process water demand.

D.5 Modelling Representation

D.5.1 Modelling Approach

The water balance model was developed in GoldSim version 12.0. The model applied a continuous simulation methodology that simulated the performance of the system under a range of climatic conditions.

D.5.2 Time Steps and Simulation Time

The model simulated the water management system for the 26 month tunnel construction timeline with hourly time steps. The primary change to the water management system over the project timeline is the change in groundwater inflows (as shown in Figure D2).

D.5.3 Runoff

Runoff from the construction pad's water management area was estimated using the Australian Water Balance Model (AWBM). The AWBM model was developed by Boughton (2003) and is widely used across Australia to estimate stream flow and runoff. The hydrological model calculates runoff from rainfall after allowing for relevant losses and storage. Parameters in the AWBM model were adjusted to reflect the expected hydrologic response of the construction pad's water management area.

D.5.4 Probabilistic Modelling

To assess the impact of rainfall variation on the system, 100 different rainfall patterns (referred to as 'realisations') were applied to the 26 month simulation period. Each of the rainfall patterns was obtained randomly from the Talbingo (72131) rainfall record that is described in Section D.4.1. The 100 realisations enabled statistical assessment of the system and were used to determine statistics for monthly and annual water transfer volumes over 26 month tunnel construction timeline.

Probabilistic model results are presented as minimum, 10th Percentile, 50th Percentile, 90th percentile and maximum monthly values.

D.5.5 Scenarios

Scenario model simulations were undertaken to provide a representative 'snap shot' of the functionality of the water management system at months 1, 12 and 26. Scenario simulations were run for 10th, 50th and 90th percentile rainfall years. The results from each scenario are presented in flow chart format as annualised monthly average (ie the annual value divided by 12). This was done to avoid seasonal influences in the results.

D.6 Model Results

D.6.1 Probabilistic modelling results

Table 6.21 presents the minimum, 10th Percentile, 50th Percentile, 90th percentile and maximum monthly values and annual values for extraction from and discharge to Talbingo Reservoir. Results are presented for Months 1, 12 and 26 and are discussed in Section 0.

D.6.2 Scenarios

Scenario model simulations were undertaken to provide a representative 'snap shot' of the functionality of the water management system at months 1, 12 and 26. Results are provided in flow chart format for 10th, 50th and 90th percentile rainfall years in Figure D3 to D12. The 50th percentile rainfall year results are also provided in Section 0.

D.6.3 Results discussion

Results are discussed in Section 0.

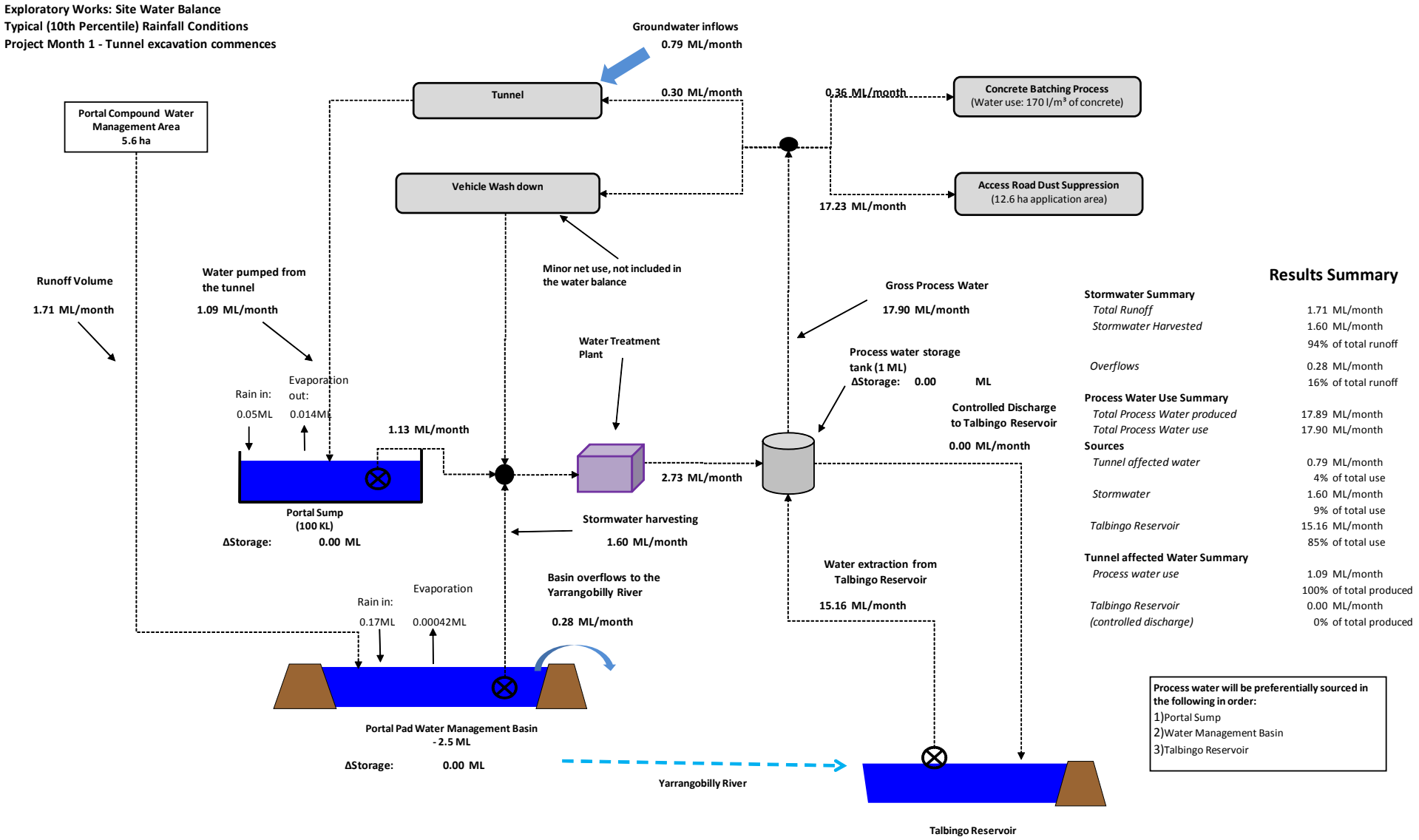


Figure D3 Water balance results: Tunnel Month 1 – dry conditions

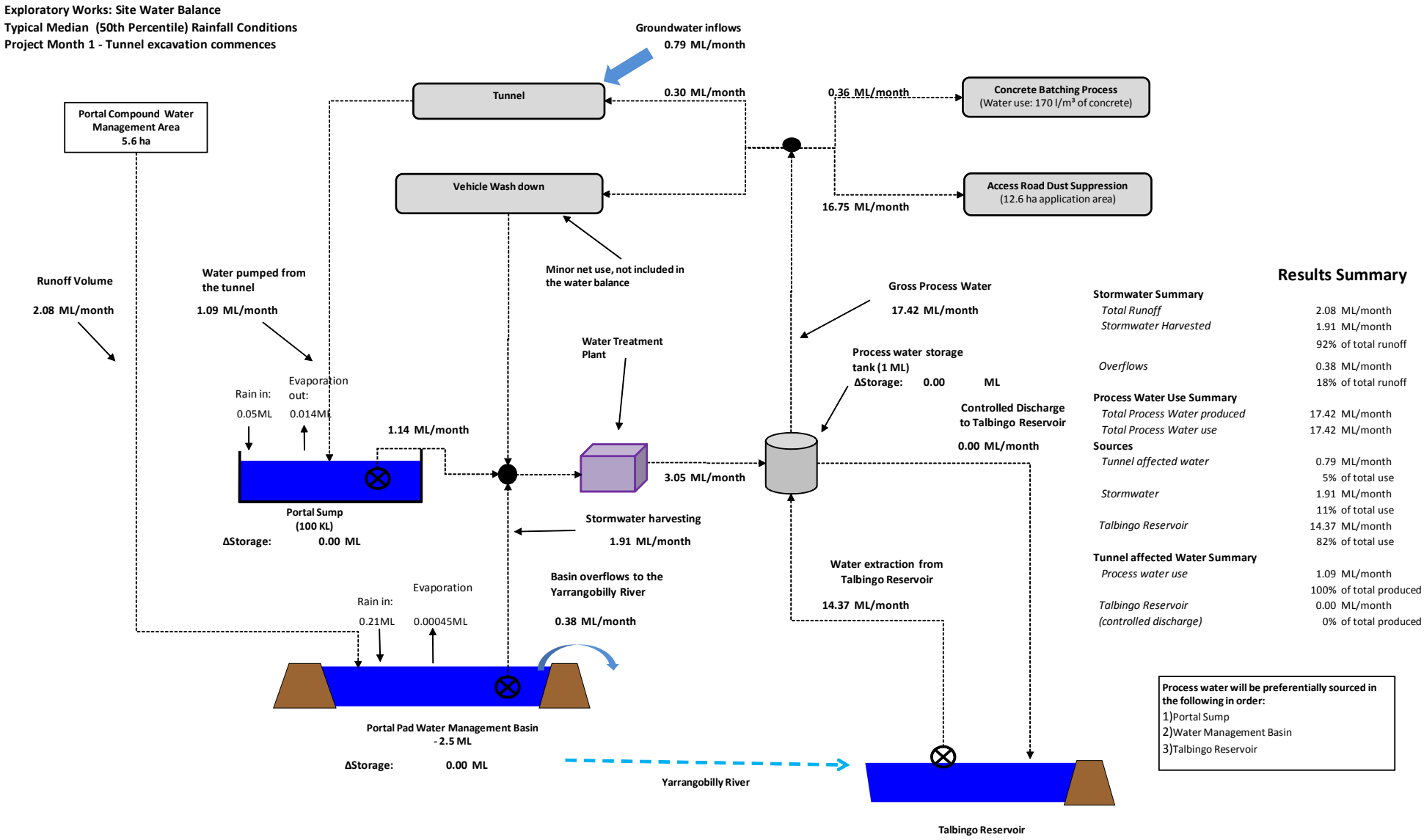


Figure D4 Water balance results: Tunnel Month 1 – median conditions

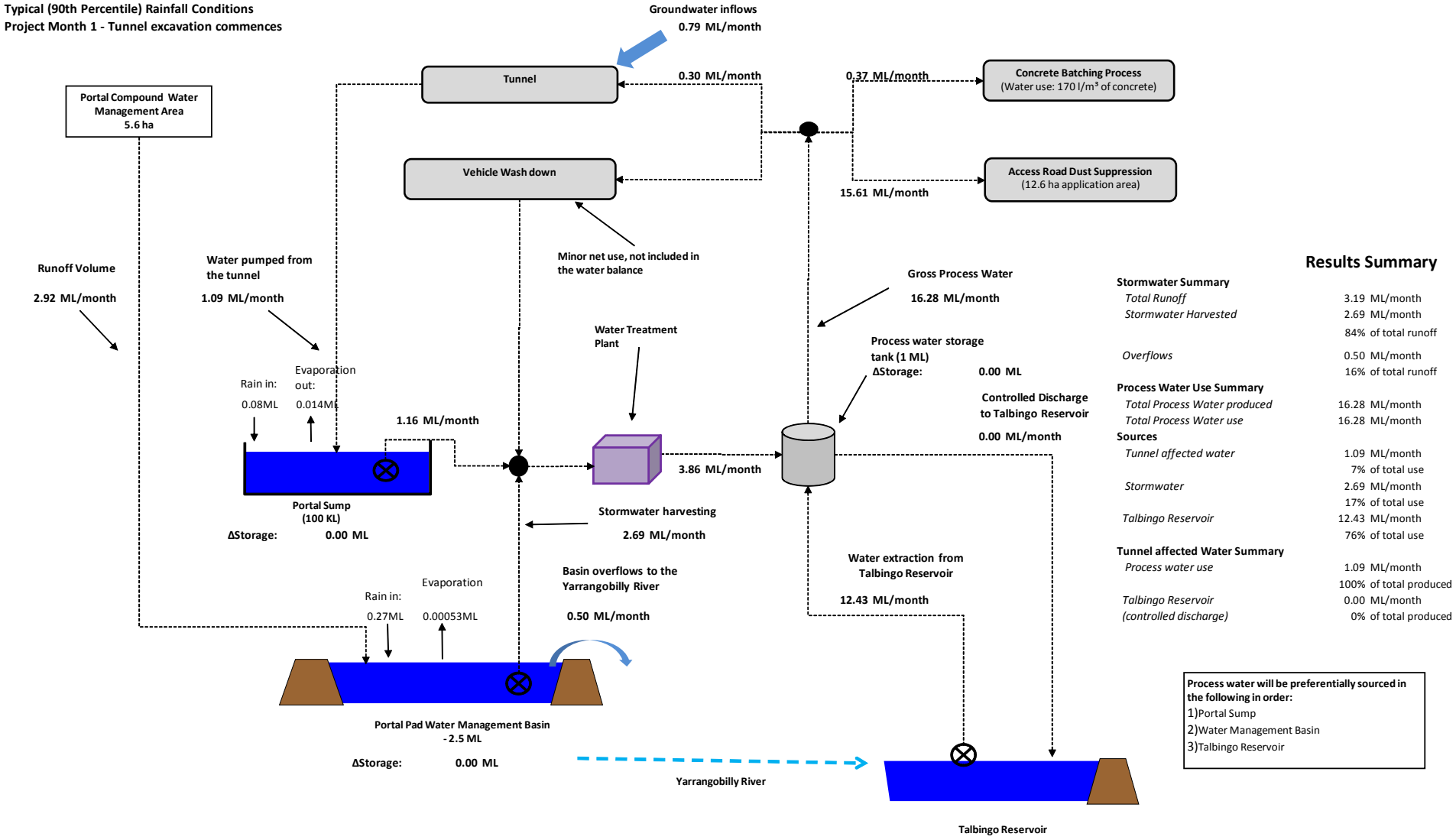


Figure D5 Water balance results: Tunnel Month 1 – wet conditions

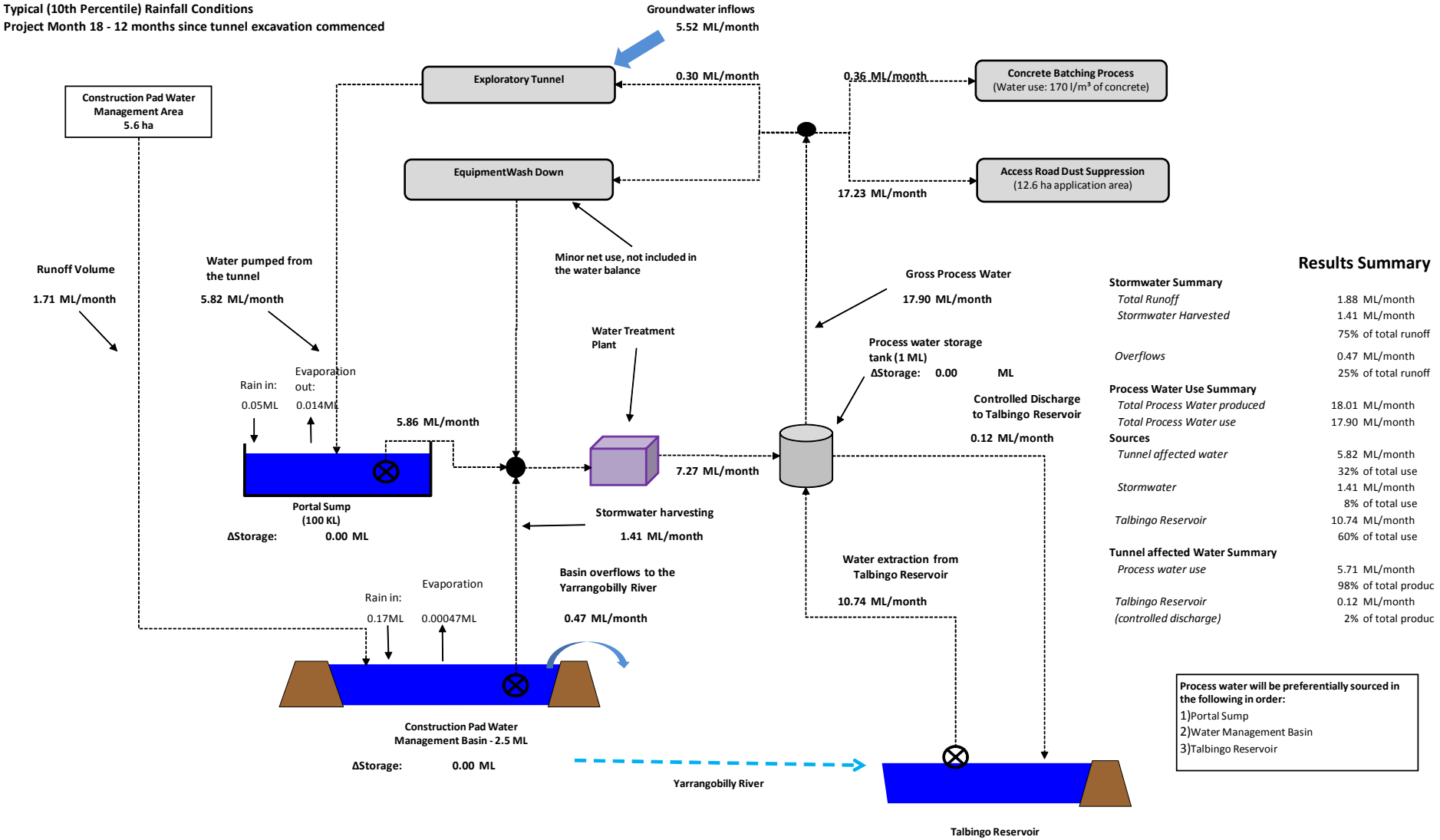


Figure D6 Water balance results: Tunnel Month 12 – dry conditions

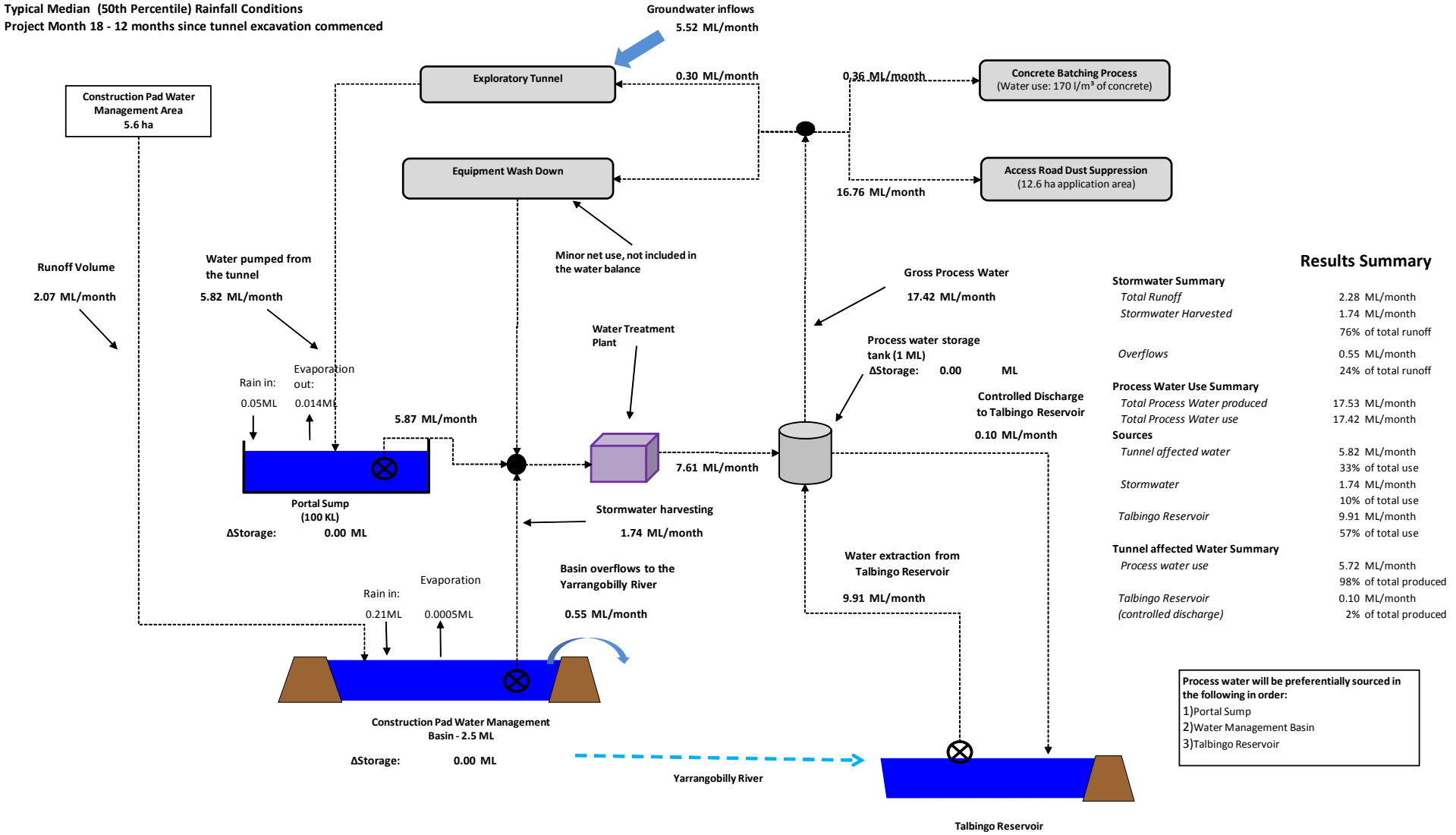


Figure D7 Water balance results: Tunnel Month 12 – median conditions

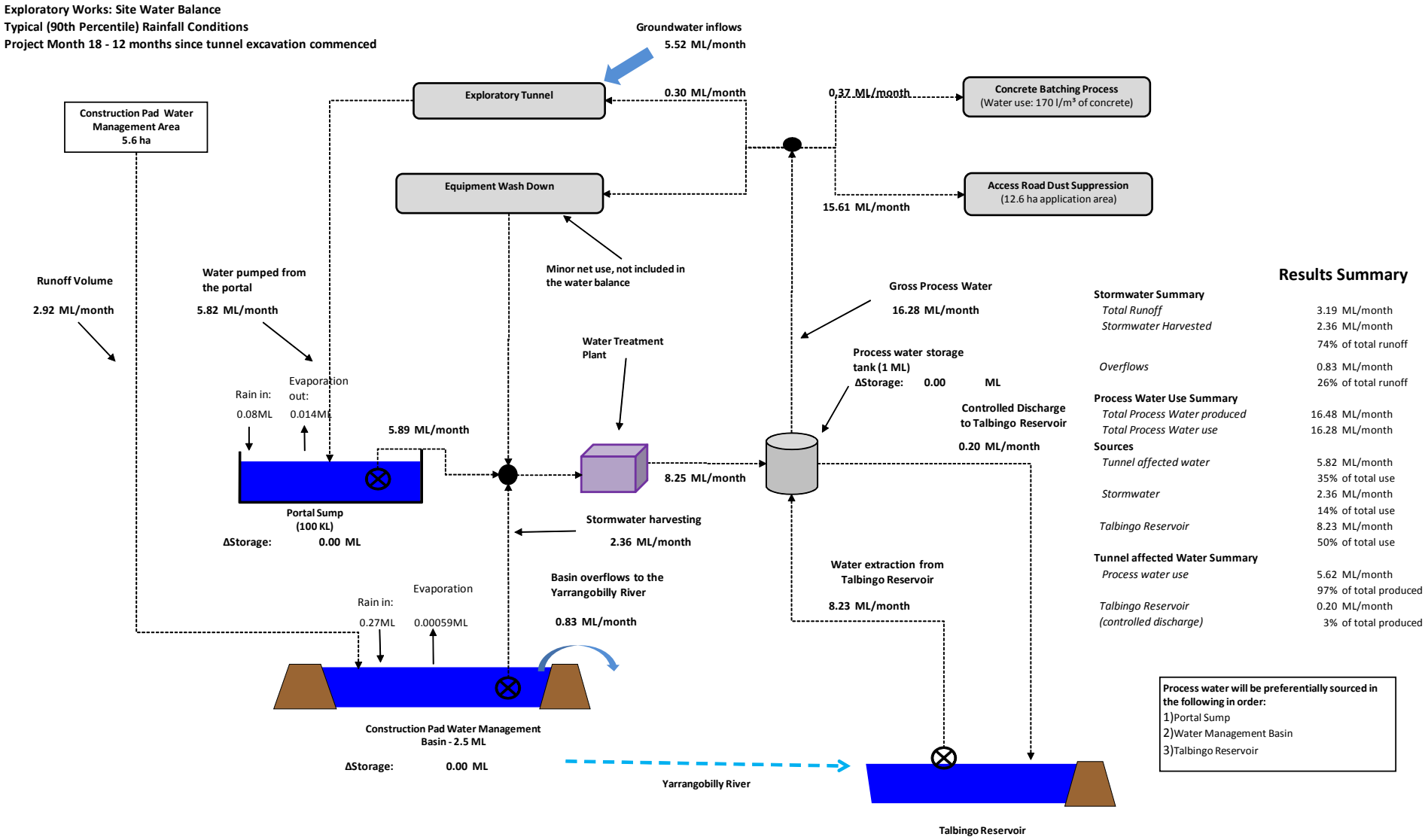


Figure D8 Water balance results: Tunnel Month 12 – wet conditions

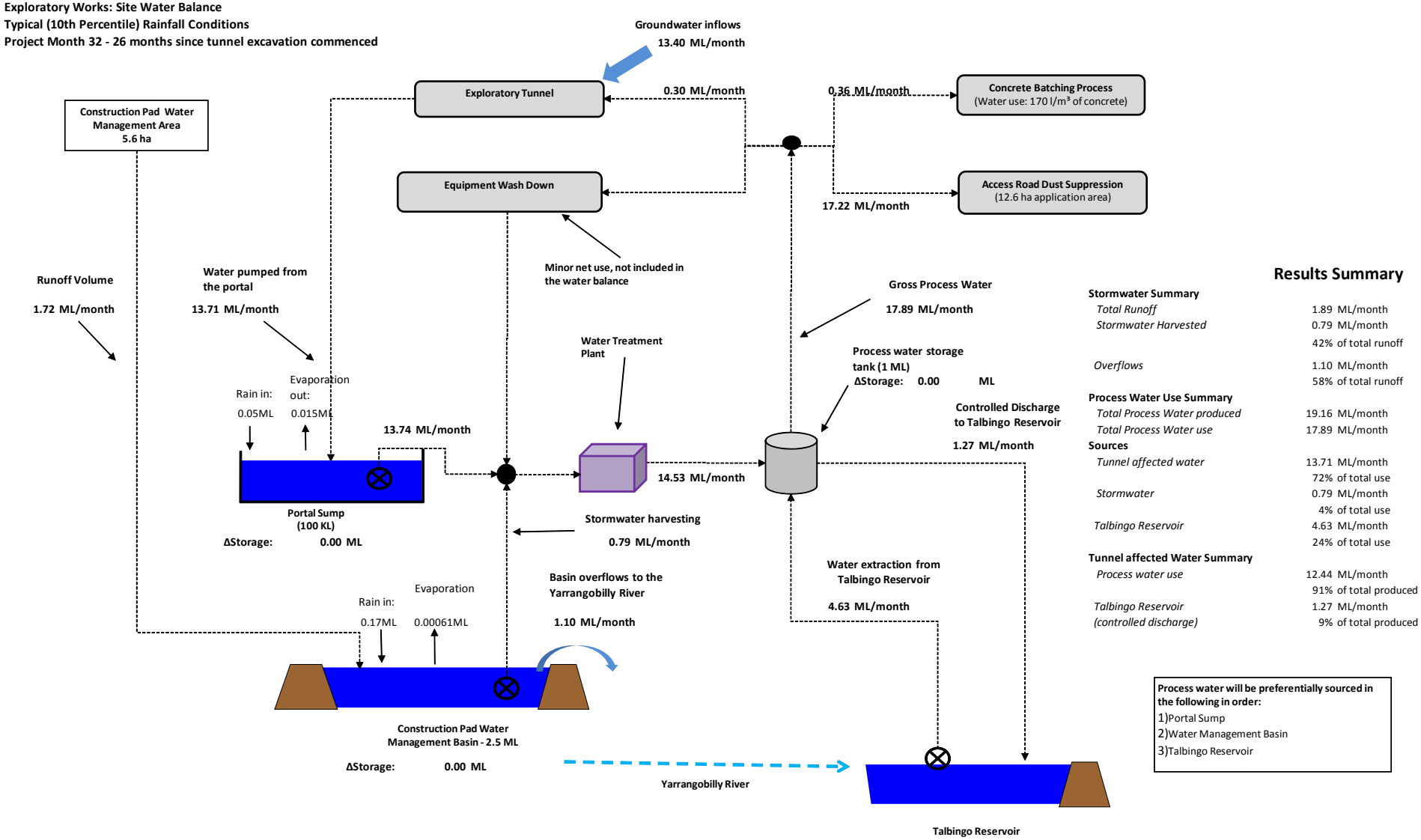


Figure D9 Water balance results: Tunnel Month 26 – dry conditions

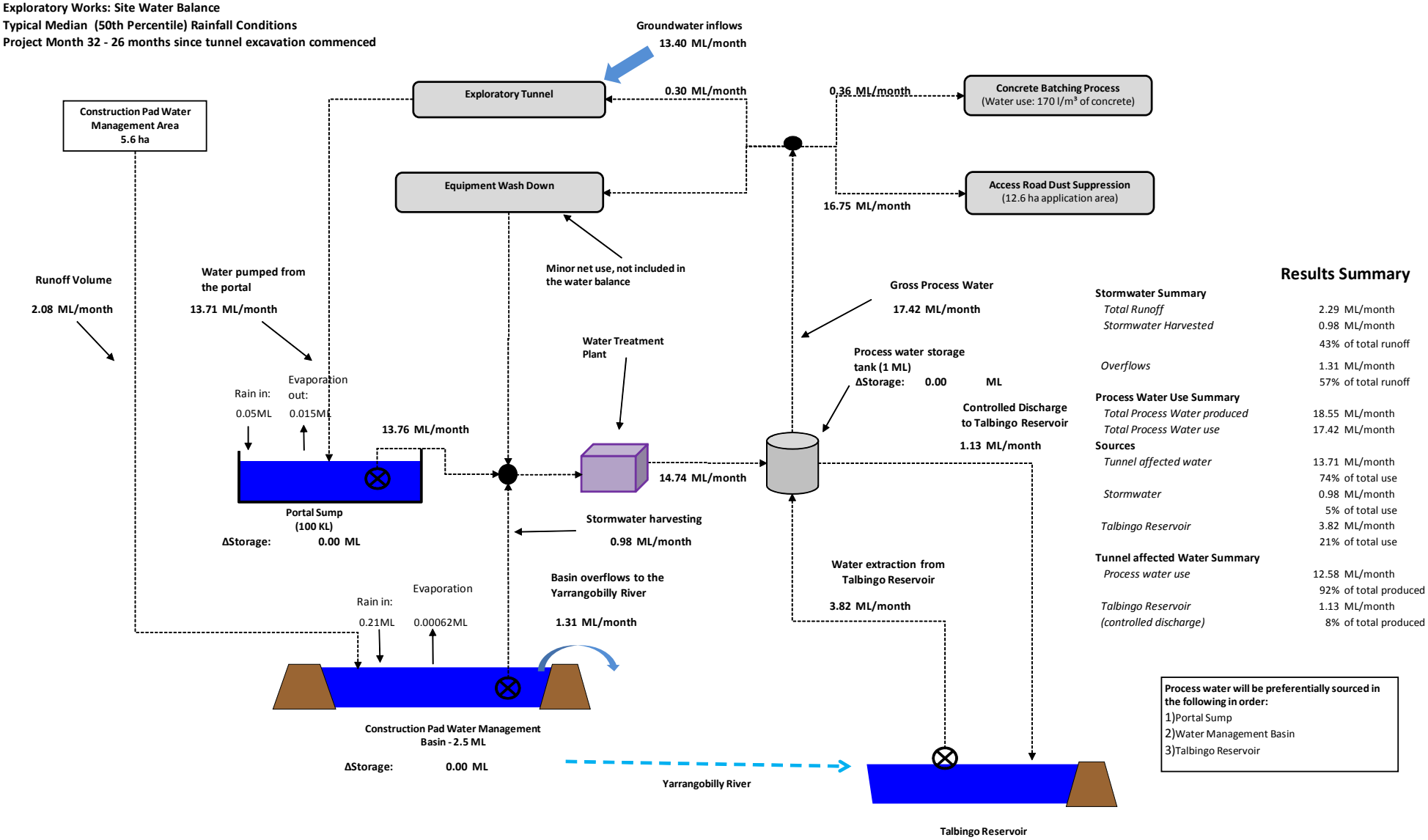


Figure D10 Water balance results: Tunnel Month 26 – median conditions

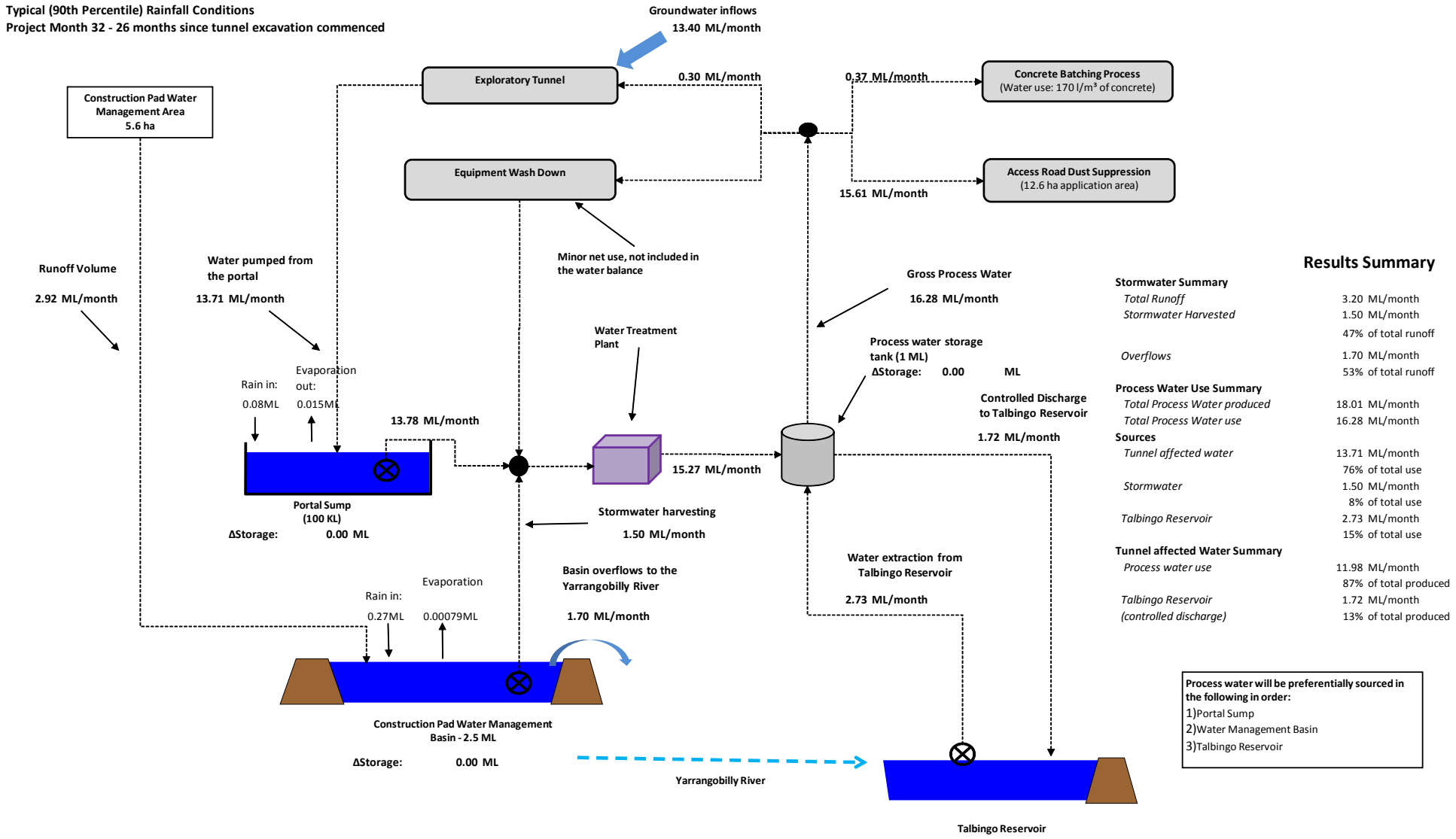


Figure D11 Water balance results: Tunnel Month 26 – wet conditions

Appendix E

Sedimentation Dam Sizing Methodology

E.1 Introduction

This appendix establishes methods for calculating sedimentation dam volumes for the Exploratory Works. The applied methods are recommended in the following NSW government guidelines:

- Managing Urban Stormwater: Soils and Construction – Volume 1 (Landcom, 2004);
- Managing Urban Stormwater: Soils and Construction – Volume 2D – Main road construction (DECC, 2008); and
- Best Practice Erosion & Sediment Control - Appendix B - Sediment basin design and operation (IECA, 2008).

E.2 Design criteria

E.2.1 Sediment dam criteria

All sedimentation basins will be designed as Type F or D sediment retention basins. Table 6.1 from Volume 2D (DECC, 2008) establishes design criteria for sedimentation basins based on the sensitivity of the receiving environment and duration of disturbance. Table E.1 Sedimentation basin design criteria summarises the recommended design criteria.

Table E.1 Sedimentation basin design criteria

	Duration of disturbance			
	< 6 months	**6 – 12 months**	**1 – 3 years**	**>3 years**
Design treatment event[1] (five-day duration event)	80th percentile	85th percentile	85th percentile	95th percentile
Embankment and spillway design capacity[1]	20 year event	50 year event	100 year event	100 year event

Notes: 1. design criteria for a sensitive receiving environment adopted.

E.2.2 Chemical water treatment system criteria

Chemical water treatment is proposed to improve the water quality of discharge from construction areas that are 2,500 m^2 or larger. The treatment systems will be incorporated into:

- sedimentation dams where possible; or
- a series of tanks in terrain constrained areas where sedimentation dams are not practical.

a. Treatment rates

Chemical water treatment systems will be designed to meet the following treatment rates:

- For non-terrain constrained construction areas (larger than 2,500 m^2), water treatment systems will be incorporated into sedimentation basins. The chemical water treatment system will be designed to treat the 1 year average recurrence interval (ARI) peak flow.

- For terrain constrained construction areas (larger than 2,500 m^2), water treatment systems will be incorporated into series of tanks. The design treatment rate will be the 1 in 3 month ARI peak flow. The lower capacity is due to the need for settling to occur in tanks, rather than a basin.

b. Water quality specifications

Table E.2 provides water quality specifications for chemical water treatment systems.

Table E.2 Chemical water treatment systems: water quality specifications

	Unit	Median concentration	Maximum concentration
Turbidity	NTU	2-25	25
Suspended sediment	mg/L	<5	20
Reactive phosphorus	mg/L	0.02	0.05
Total phosphorus	mg/L	0.02	0.05

E.3 Runoff volume calculations

Volume 1 (Landcom, 2004) recommends that sedimentation treatment volumes for Type F and D basins are calculated as a function of the rainfall depth and runoff coefficient for the design treatment event.

E.3.1 Rainfall

Table E2 presents rainfall depths for 2, 5, 10 and 20 day rainfall events. This information was calculated from the Talbingo (72131) rainfall record and is applicable to all construction areas within Lobs Hole (500 to 800 m AHD). Alternative rainfall depths will need to be calculated for construction areas at elevations above 800 m AHD.

Table E.3 Design rainfall depths for frequent events

	Rainfall Duration			
	2 day	**5 day**	**10 day**	**20 day**
80th Percentile event	7.5 mm	24.2 mm	47.4 mm	86.9 mm
85th Percentile event	11.4 mm	30.6 mm	56.0 mm	99.0 mm
90th Percentile event	18.4 mm	41.6 mm	68.1 mm	116.0 mm
95th Percentile event	30.0 mm	56.8 mm	85.0 mm	138.0 mm

Notes: Rainfall depths have been calculated from the Talbingo (72131) gauge record.

E.3.2 Runoff volumes

Appendix F from Volume 1 (Landcom, 2004) provides volumetric runoff coefficients for a range of soil hydrologic groups. Table E.4 describes the soil hydrologic groups that have been identified or may be created following disturbance.

Table E.4 Soil hydrologic groups

	Description	Relevance to Exploratory Works
Soil hydrologic Group B	Low to moderate runoff potential	Tensols soils are soil hydrologic group B. The accommodation camp, construction pad and some access roads will be established in Tensols soils.
Soil hydrologic Group C	Moderate to high runoff potential	Kandosols soils are soil hydrologic group C. The accommodation camp, construction pad and some access roads will be established in proximity to Kandosols soils.
Soil hydrologic Group D	Very high runoff potential	Soil hydrologic Group D conditions may occur at: • construction areas that have shallow soils and/or compacted areas; and • access roads.

Table E.5 provides the runoff coefficients (Cv) from Table F2 (Volume 1 Landcom, 2004) and the calculated runoff volume (on a per ha basis) for:

- soil hydrologic groups B, C and D; and
- the full range of 5 day duration rainfall events.

Table E.5 Design runoff volumes

		Soil Hydrologic Group B		Soil Hydrologic Group C		Soil Hydrologic Group D	
		Cv	Runoff	Cv	Runoff	Cv	Runoff
5 day duration rainfall	(mm)	-	(m^3/ha)	-	(m^3/ha)	-	(m^3/ha)
80th Percentile event	24.2	0.19	46	0.35	85	0.50	121
85th Percentile event	30.6	0.34	104	0.51	156	0.64	196
90th Percentile event	41.6	0.42	175	0.58	241	0.69	287
95th Percentile event	56.8	0.48	273	0.63	358	0.74	420

E.4 Sedimentation basin volumes

Sedimentation basin volumes will be established on a case by case basis having consideration for:

- the contributing catchment area to the basin;
- the duration of disturbance;
- chemical water treatment system requirements; and
- Soil hydrologic groups (pre and post construction disturbance).

Sediment treatment volumes will be established using the volumes provided in Table E.5. An additional sediment storage volume equivalent of 20% of the treatment volume will also be incorporated into the design.

Following rainfall, water captured in sedimentation basins will be dewatered and used for dust suppression.

E.5 Chemical water treatment approach

E.5.1 Approach

Chemical water treatment is proposed to improve the water quality of discharge from construction areas that are 2,500 m^2 or larger. The following treatment approach is proposed:

- Sedimentation basins will be partitioned into inlet and settling zones.
- Water will be pumped from the inlet zone into a chemical dosing and mixing unit. An iron salt coagulant (or similar) and calcium carbonate (or similar) will be dosed at a controlled rate and will be allowed to mix in a series of gravity mixing tanks. Outflow from the tanks will be discharged through 'floc blocks' to add an anionic polymer flocculant (or similar).
- The settling zone will be sized to facilitate settling at the design treatment rate.

The chemical water treatment system will be designed to treat the 1 year ARI peak flow. Figure E.1 shows the proposed system functionality. For non-terrain constrained construction areas (larger than 2,500 m^2), the water treatment system will be incorporated into sedimentation basins.

A similar system will be implemented for terrain constrained areas (larger than 2,500 m^2). As sedimentation basins are not practical in terrain constrained areas, a pump-out system and a mobile water treatment plant will be used. The design treatment rate will be the 1 in 3 month ARI peak flow. The lower capacity is due to the need for settling to occur in tanks, rather than a basin. Figure shows the proposed system functionality.

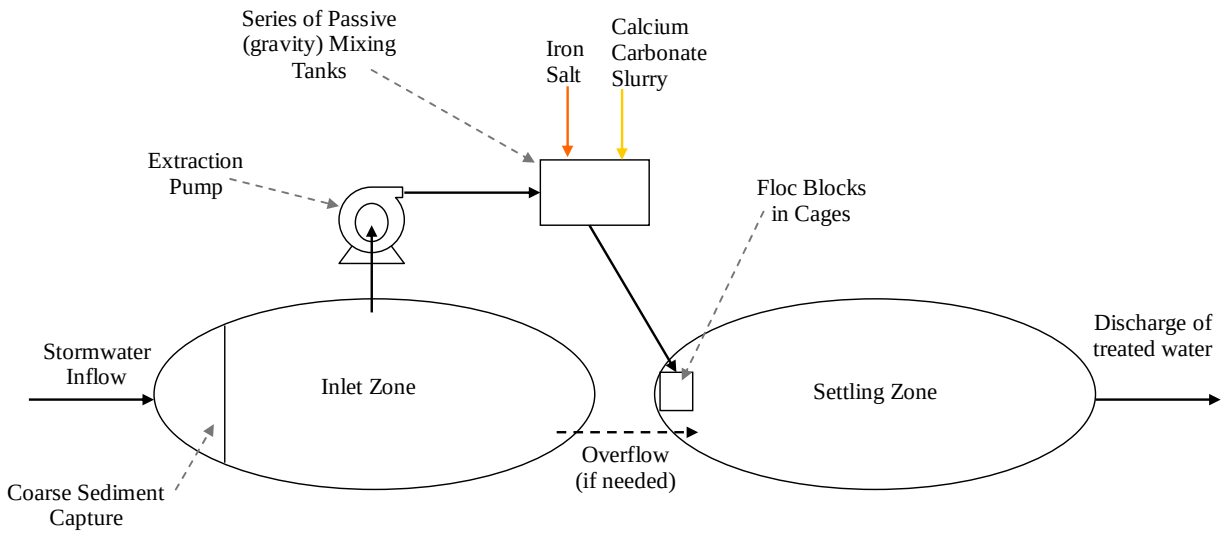
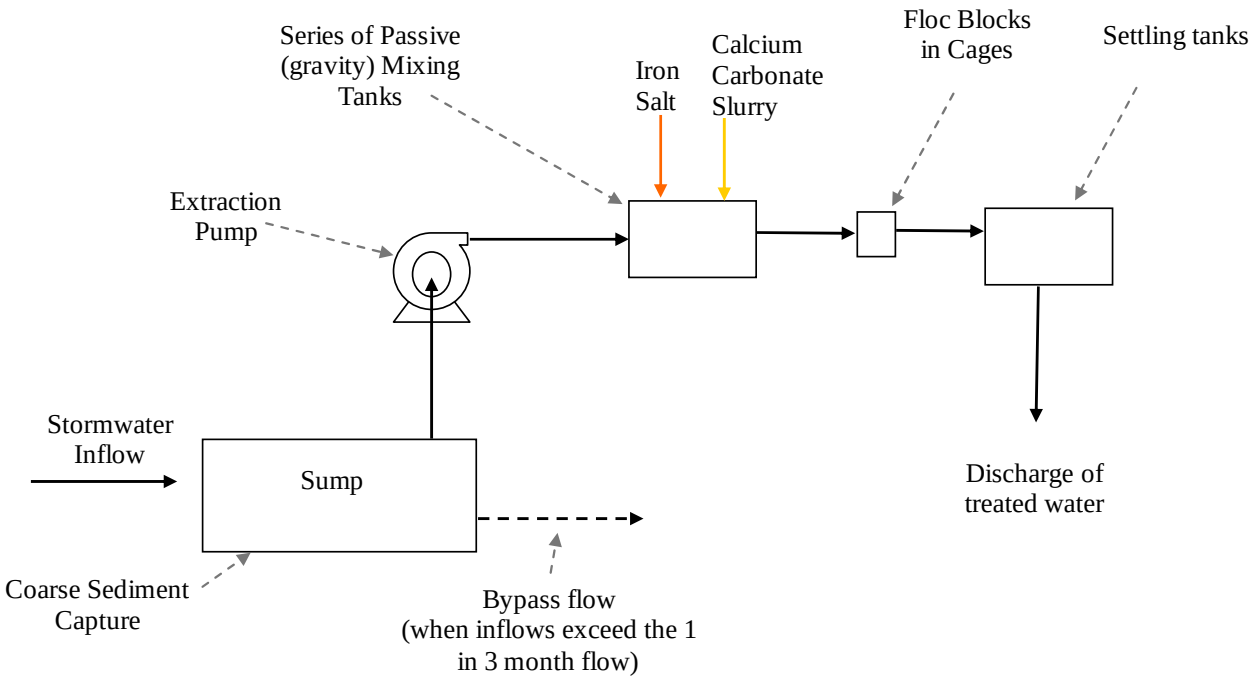


Figure E.1 Water treatment design concept (non-terrain constrained system)



FigureE.2 Water treatment design concept (terrain constrained system)

E.5.2 Specifications

Water treatment chemicals, mixing tank, inlet zone and settling zone specifications will need to be established on a case by case basis to meet the water quality specifications provided in Section E.2.2.

Appendix B of Best Practice Erosion and Sediment Control (IECA, 2008) provides a method for calculating settling pond dimensions. It is expected that the inlet and settling zones can be incorporated into a basin sized based on the 85th percentile 5 day rainfall event.

E.6 Erosion and Sediment Control Plans

Detailed Erosion and Sediment Control Plans (ESCP) will be prepared for each stage of the project at detailed design. The ESCP will include a civil design of proposed sedimentation basins and other erosion and sediment controls.

Appendix F

Summary of Proposed Controls

Table F.1 Summary of proposed controls

Control	Description
General notes	The controls presented in this assessment are principles or design objectives, that will be further developed in the detailed design of the Exploratory Works. The management measures assessed are presented to determine the feasibility of achieving the proposed discharge water quality. The management measures implemented may vary from those presented but will still need to meet the proposed water quality or other stated objectives.
Flood Management Controls	
FM_1.1	Camp and Wallaces bridges will be designed in accordance with AustRoads bridge design standards which require the: • bridge deck soffit to be located above the 1% AEP flood level; • bridge structure to be designed to withstand a 0.05% AEP event; and • abutments to be protected by appropriately designed scour protection.
FM_1.2	The western emplacement will be designed to minimise the risk of emplacement material being entrained in flood waters during a 0.2% AEP event. This may require a flood protection berm or rock armouring along the northern toe of the emplacement.
FM_1.3	A flood emergency response plan will be prepared as part of the project's emergency response plans.
Clean water management controls	
WM_1.1	Where practical, all clean water will be diverted around or through water management areas. Runoff from clean water areas that cannot be diverted must be accounted for in the design of water management systems.
WM_1.2	All permanent clean water drainage will be designed and constructed to convey the 1% AEP peak flow and will have adequate scour protection. Temporary clean water drainage will be designed to convey the 50% AEP peak flow.
WM_1.3	Where practical, diversions will seek to avoid materially increasing flow rates in adjoining watercourses.
WM_1.4	Where practical, the permanent diversion of drainage lines or watercourses using contour drains will be avoided.
Controls for construction disturbance areas	
Controls for all construction areas	
WM_2.1	An Erosion and Sediment Control Plan (ESCP) will be prepared for each construction area. Each ESCP will: • consider local soil characteristics, clean water management and the proposed construction methods; • apply all practical source control and rehabilitation methods; and • be progressively amended as required during construction. A suitably qualified erosion and sediment control expert will be commissioned to develop and execute each ESCP. The expert will be responsible for overseeing the development of the ESCP and inspecting and auditing controls during implementation. Regular expert input will ensure that erosion and sediment control practices will be established and operated to a high standard and progressively improved.
WM_2.2	The clean water management controls WM_1.1 to 1.4 apply to all ESCPs.
WM_2.3	Stockpiles will be located where they are not exposed to concentrated or flood flow. Flood flow is defined as the 20% AEP flood extent. Monitoring for dispersion and erosion of soil stockpiles will be undertaken, particularly on moderately dispersive soils. Addition of ameliorants, such as gypsum and organic matter for dispersive soils will be undertaken as needed.
WM_2.4	Soils will be lightly scarified on the contour to encourage rainfall infiltration and minimise run-off. As soon as practicable after respreading, a cover crop will be established to limit erosion and soil loss. This will also provide good mulch for native plant establishment.

Table F.1 Summary of proposed controls

Control	Description
WM_2.5	Sediment traps or filters will be maintained at all discharge locations to target the removal of coarse sediments.
Additional controls for construction areas that are constrained by terrain or the proposed disturbance boundary	
WM_2.6	Runoff from construction areas that are constrained by terrain or the proposed disturbance boundary and are larger than 2,500 m^2 will be captured in a sump and pumped to a water treatment plant. The water treatment plant will use water treatment chemicals to enhance sedimentation and phosphorus and dissolved metal removal rates using an automated chemical dosing system. Only water treatment chemicals that have a low risk of increasing the toxicity of treated stormwater will be used. The design dewatering and treatment rate will be the 1 in 3 month average return interval (ARI) peak flow.
Additional controls for construction areas that are not constrained by terrain	
WM_2.7	Where appropriate, sedimentation basins will be constructed in accordance with the methods recommended in *Managing Urban Stormwater: Soils and Construction: Volume 1* (Landcom 2004) and Volume 2D (DECC 2008). Water treatment chemicals will be applied to sedimentation basins with catchment areas greater than 2,500 m^2 to enhance sedimentation and phosphorus and dissolved metal removal rates. Only water treatment chemicals that have a low risk of increasing the toxicity of treated stormwater will be used. Water treatment chemicals will be applied using an automated chemical dosing and mixing system. The design treatment rate will be the 1 year ARI peak flow.
WM_2.8	When practical, water captured in sedimentation basins will be used for dust suppression.
Water management controls for access roads	
Controls for all access roads	
WM_3.1	Sections of Lobs Hole Road that will no longer be required following the construction of the new access roads will be removed and rehabilitated. This will reduce associated sediment loads.
WM_3.2	All cut and fill batters will be stabilised as soon as practicable.
WM_3.3	The clean water management controls WM_1.1 to 1.4 will apply to the design of all access roads.
WM_3.4	Access road surfaces will be maintained with appropriate aggregate material to reduce the risk of erosion.
WM_3.5	Where practicable and safe to do so access roads will be single cross fall and will grade to a table drains located against the toe of the cut batters. The drains will be stabilised by rock armouring as required.
WM_3.6	Where appropriate, the sedimentation basins established to manage runoff during construction of the access roads will be maintained during the Exploratory Works to provide ongoing treatment of runoff from access roads.
Additional controls for access roads that are not constrained by terrain or the proposed disturbance footprint	
WM_3.7	The sedimentation basins established to manage runoff during construction of the access roads will be modified to be constructed wetland style basins where practicable. Constructed wetland style basins will maintain permanent water. An extended detention zone will be established above the permanent water. The extended detention zone will drain slowly through a low flow outlet control. Where practical, runoff from road embankments that have been stabilised by vegetation will be diverted into the clean water drainage system to minimise the contributing catchment area to the constructed wetlands. This will increase the effective size of the basin (in terms of depth of rainfall captured) and will result in a treatment volume that is greater than the 5 day 85th percentile volume that is proposed for sedimentation basins for construction areas.
Water management controls for the accommodation camp	
WM_4.1	A stormwater management plan will be prepared as part of the detailed design of the project. The plan will consider geotechnical constraints including shallow soils.
WM_4.2	Clean water from upslope areas will be diverted around the accommodation camp.

Table F.1 Summary of proposed controls

Control	Description
WM_4.3	A piped drainage system will be established to capture stormwater and convey it to the proposed water quality improvement ponds. The drainage system will have a 20% AEP capacity. Overland flow paths will be provided as required.
WM_4.4	All pervious areas including batters will be vegetated with endemic native vegetation where practicable.
WM_4.5	Runoff from roof areas will be collected in rainwater tanks where practicable. Captured water will be used for non-potable uses, reducing runoff volumes.
WM_4.6	Source controls including permeable pavers and rain gardens will be used where practicable.
WM_4.7	All runoff from the accommodation camp will be treated in water quality improvement basin(s). The basin(s) will be designed as constructed wetlands where practicable and will provide a water quality improvement function and attenuate peak runoff rates from the accommodation camp.
WM_4.8	Collectively, the stormwater controls will be sized and configured to achieve the water quality specifications provided in Table 6.12.
WM_4.9	The water quality improvement pond batters will be established using retaining structures or other suitable measures to avoid disturbance of the Watercourse 3 channel.
Water management controls for the portal construction pad	
WM_5.1	A stormwater management plan will be prepared as part of the detailed design of the project. The plan will be integrated with the process water system.
WM_5.2	Where practical, all activities that will occur on the portal construction pad with potential to contaminate stormwater runoff will be isolated from the stormwater system through the use of covering (ie by a building or roof) and bunding. Water produced within the covered and bunded areas will be either: • managed by the process water system; or • disposed as liquid waste to an appropriate facility.
WM_5.3	Clean water from upslope areas will be diverted through or around the portal construction pad in a designated clean water drainage system.
WM_5.4	A piped drainage system will be established to capture stormwater and convey it to the water management basin. The drainage system will have a 1% AEP capacity. Overland flow paths will be provided as required.
WM_5.5	All aggregate storage and stockpile areas will be bunded to minimise stormwater ingress. Runoff from these areas will be treated in sediment wedge pits or other sediment controls to remove all coarse material. Sediment wedge pits will overflow into the piped drainage system.
WM_5.6	All runoff from the portal construction pad and adjoining access road will be conveyed to a water management basin with adequate capacity for at least a 5 day 95th percentile rainfall event and include additional volume to accommodate required water quality treatments (ie a total volume of at least 3,750 m^3). The basin will provide a water quality improvement function. Water captured in the basin will be extracted to supply the process water system. Water treatment chemicals will be applied to the water management basin to enhance sedimentation and phosphorous and dissolved metal removal rates. Only water treatment chemicals that have a low risk of increasing the toxicity of treated stormwater will be used. Water treatment chemicals will be applied using an automated chemical dosing and mixing system. The system will be designed to meet the water quality specifications provided in Table 6.16. The design treatment rate will be the 1 year ARI peak flow.
WM_5.7	The water management basin will be designed to provide a freeboard between its overflow pipe and spillway. The freeboard volume will be calculated to contain probable leaks, spills and firewater runoff volumes. The overflow pipe will have a manual shutoff valve that will enable site management to shut off the overflow pipe to enable the basin to contain any leak, spill or fire water runoff.

Table F.1 Summary of proposed controls

Control	Description
Water management controls for the process water system	
WM_6.1	A process water management system will be established to manage any potentially contaminated water that may be produced by the construction activities.
WM_6.2	The process water management system will be separated from the stormwater system to avoid uncontrolled overflows associated with stormwater ingress.
WM_6.3	The process water system will incorporate a water treatment plant that will treat water to a suitable quality for its proposed use in construction activities. If required to meet water quality criteria, additional treatment will be provided for any water that is discharged to Talbingo Reservoir via the controlled discharge pipeline. This treatment system will meet the water quality specifications provided in Table 6.18.
WM_6.4	The process water management system will have the ability to extract water from the portal construction pad's water management basin. This will be done to top-up supply.
WM_6.5	A reticulation system will be established to enable the process water system to: • extract water from Talbingo Reservoir (as required); and • discharge treated process water into Talbingo Reservoir (as required).
Water management controls for the waste water management system	
WM_7.1	Waste water from the accommodation camp will be reticulated to a waste water treatment plant via a sewer system. The sewer system will be designed to restrict stormwater ingress into the waste water system.
WM_7.2	Water efficient fittings will be used to minimise waste water loads.
WM_7.3	Low phosphorus products are to be used for washing activities controlled by site management (ie laundry services and mess hall) and encouraged (via education) for general use.
WM_7.4	The waste water storage system will include emergency storage of untreated waste water. The storage volume will be calculated at detailed design based on analysis of response times from regional waste management contractors to provide emergency trucking and offsite disposal options.
WM_7.5	A waste water treatment plant will meet the water quality specifications provided in Table 6.24.
WM_7.6	Treated waste water will be disposed to Talbingo Reservoir via the controlled discharge pipeline.
Water management controls for the rock and soil emplacement areas	
WM_8.1	The eastern and western rock and soil emplacement areas will be constructed as temporary landforms. The rock will be subject to the subaqueous emplacement program associated with Exploratory Works. Soil will be used for rehabilitation. Should any rock remain at these locations following the conclusion of Exploratory Works, it will be transported to a nominated location outside of Kosciuszko National Park within a timeframe agreed with NPWS.
WM_8.2	During establishment, the water management controls for construction areas (WM_2.1 to 2.8) will be applied.
WM_8.3	The western emplacement area will be used to store cuttings and other material that has a low geochemical risk. This landform will be built in a manner that limits compaction and will be top-soiled and vegetated to stabilise the landform.
WM_8.4	Any remnant mine workings located within the eastern and western rock and soil emplacement areas will be rehabilitated (if necessary).
WM_8.5	The eastern emplacement area will be used to store any material that that has higher geochemical risk. Excavated material will be geochemically characterised prior to placement. The potential for acid rock drainage will be treated by placing and compacting layers of limestone (or other suitable AC material) between each rock and sediment layer as required. The volume of limestone (or other suitable AC material) in each layer will be determined stoichiometrically so that the maximum potential acidity from the overlying layer of rock and sediment is treated. This approach will neutralise AMD within the stockpile. Once design levels are reached, the landform will be top-soiled and vegetated.

Table F.1 Summary of proposed controls

Control	Description
WM_8.6	Runoff from Lick Hole Gully will be diverted around or through the eastern emplacement area. The diversion works will comprise a dam upstream of the diversion inlet and either a gravity or pump assisted diversion system. The diversion works will have a 1% AEP capacity. The dam upstream of the diversion inlet will be designed as a detention basin and will not permanently hold water. A high-flow diversion drain will be established to convey runoff from Lick Hole Gully around the emplacement area in a controlled manner, avoiding uncontrolled overflows through the emplacement area. This diversion drain will only be engaged if a flood greater than a 1% AEP event occurs.
WM_8.7	Seepage from the eastern emplacement area will be collected in a water management dam. Collected water will either be irrigated to the emplacement (to promote evaporation) or treated in the process water treatment plant. Discharge of seepage water to the Yarrangobilly River will be avoided.
WM_8.8	The eastern and western emplacement areas will be rehabilitated following removal of all material. Lick Hole Gully will be resinated as part of the rehabilitation works. Geomorphic and ecological characterisation of Lick Hole Gully will be undertaken prior to disturbance to record the existing conditions and values of Lick Hole Gully. The rehabilitation approach will seek to create a physically stable landform that reinstates or improves the existing values

Notes: 1.Contour drains refer to diversion drains that are constructed along the contour. Contour drains for larger watercourses can require substantial earthworks and are prone to failure on the fill batter side if uncontrolled overflows occur due to the drain capacity being exceeded or a blockage (such as a tree falling into the drain).

Appendix G

Mixing Zone Analysis

Memo

Haskoning Australia PTY Ltd.
Maritime & Aviation

To:	Philip Towler
From:	Luke Kidd, Rohan Hudson, Arjen Overduin
Date:	24 September 2018
Copy:	Martin Budd, Greg Britton
Our reference:	PA1804 Snowy 2.0
Classification:	Project related

Subject: **Snowy 2.0 Exploratory Works – Waste and Process Water Outfall Plume Assessment**

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1 Introduction and Background

The following provides a summary of an investigation into the potential impact of waste and process water discharges to Talbingo Reservoir planned as part of the Exploratory Works for Snowy 2.0.

The report outlines:

- Near field modelling (using jet/plume model software)
- Far field modelling (using the Mike-3 Flexible Mesh (FM) hydrodynamic software), and
- Total dilution modelling (using the jet source option within the Mike-3 Flexible Mesh (FM) hydrodynamic software).

A mixing zone is the region in which the initial dilution of a discharge occurs (Cormix, 2018). In the mixing zone, the level of pollutants may be higher than the acceptable concentration for the general water body.

Key features of the Exploratory Works relevant to this investigation are presented in **Figure 1**.

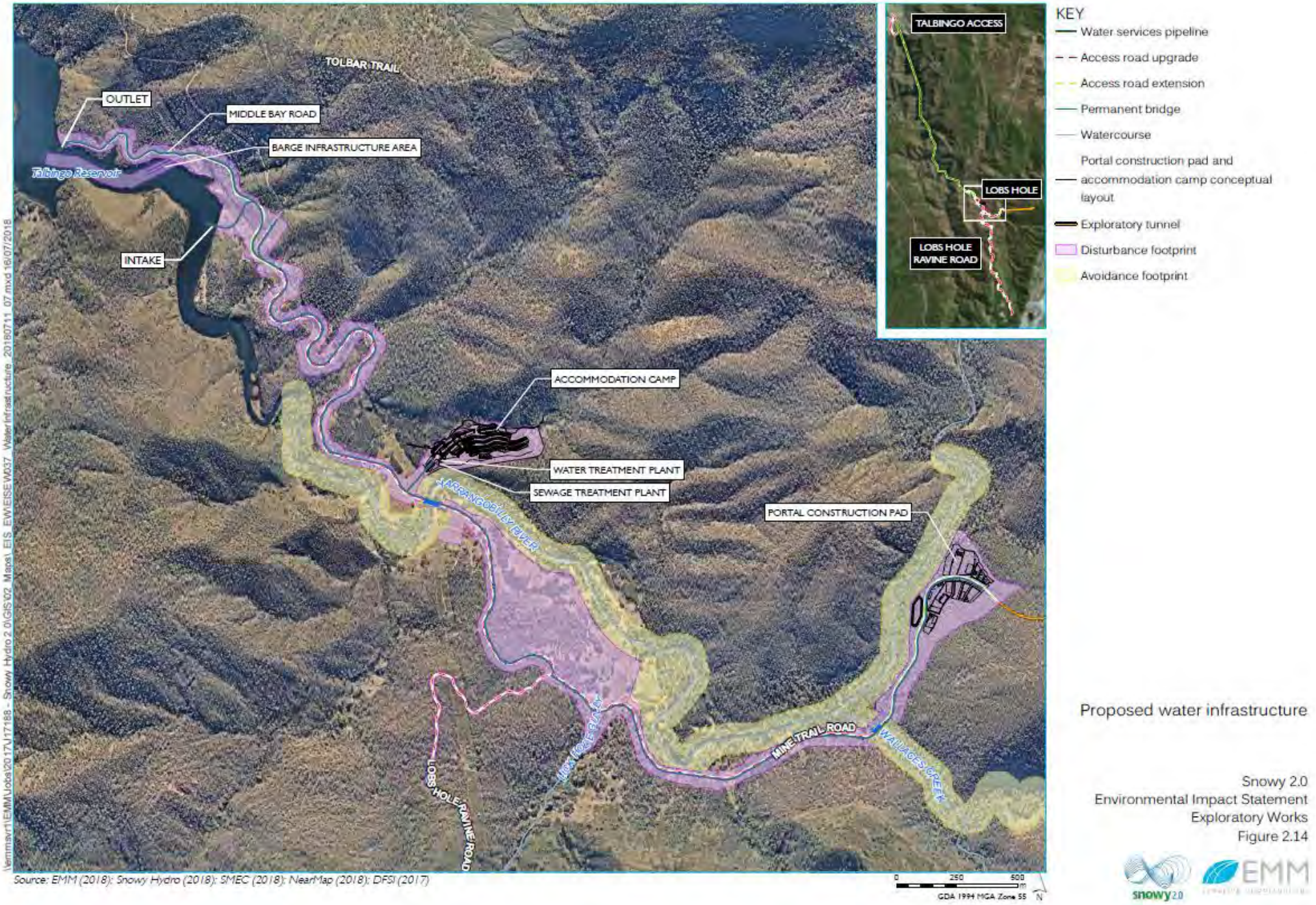


Figure 1: Locality Map showing Outlet/Outfall Location (Fig 2.14, Volume 1 Exploratory Work EIA)

1.1 Wastewater and Process Stream Details

Wastewater Stream

The wastewater stream is derived from approximately 200 people at peak construction. These workers will be accommodated within the accommodation camp. Wastewater will be produced from amenities (showers, toilets, laundry, cooking) within the accommodation camp and construction pad. Wastewater loads are estimated using a hydraulic load of 240 L/person/day, which includes a 20% contingency above typical values. Applying this load to the peak workforce of around 200 people, a total project wastewater load of 48 KL/day was estimated (see Section 6.8.1, EMM, 2018a (SWA Chapter)).

Process Water Stream

Construction activities that may produce contaminated water streams will be isolated from the stormwater system to avoid the contamination of stormwater runoff. A process water system is required to manage this water. In particular, the system will be configured to manage water that will be dewatered from the exploratory tunnel. Groundwater modelling undertaken for the Exploratory Works predicted that groundwater inflows into the tunnel will increase from 0 ML/day at tunnel commencement to 0.45 ML/day (161 ML/yr) near completion (see Sect 6.7.1, EMM 2018a (SWA Chapter)). It is understood that most of the process water will be used for dust suppression and other requirements and it is only in winter (during periods of high rainfall and low evaporation) that excess process water will need to be discharged into Talbingo Reservoir.

Important characteristics of the two effluent discharge streams are provided in **Table 1**. It is assumed that a single pipeline will be used so the wastewater and process water streams will be combined prior to discharge. Three different total outfall discharge characteristics were assessed by this investigation including:

- Q1 – Wastewater only (discharge rate = 0.56 L/s)
- Q2 – Process Water (Monthly Average) and Wastewater (discharge rate = 2.45 L/s)
- Q3 – Process Water (Daily Peak) and Wastewater (discharge rate = 5.19 L/s)

Table 1: Effluent Discharge, Salinity, Temperature and Flow Characteristics

Parameter	Q1 Wastewater Only	Process Water (Monthly Av)	Process Water (Daily Peak)	Q2 Process Water (Monthly Av) + Waste Water	Q3 Process Water (Daily Peak) + Waste Water
Salinity (ppt)	0.5	0.87	0.87	0.79	0.83
Temperature (°C)[a]	15	15	15	15	15
Flow (kL/D)	48	163	400	211	448
Flow (m^3/s)	0.00056	0.00189	0.0046	0.00245	0.00519
Flow (L/s)	0.56	1.89	4.63	2.45	5.19
Waste Water Pre-Dilution Factor	1	n/a	n/a	3.4	8.3

[a] as the waste streams travel through an approximate 2 km long pipeline from the accommodation area to the outfall location the temperature may be closer to ground surface than typical waste water values.

1.2 Outfall Location and Ambient Conditions

Details of the outfall location are presented in **Figure 2**. At this location the reservoir bed is approximately 532 to 533 m AHD. Given that typical reservoir water levels are between 538 to 543 m AHD, the depth of water above the diffuser is likely to vary between 5 and 10 metres. However, it should be noted that while the reservoir is typically operated at higher levels to increase the available head at the T3 offtake, the minimum operating level (MOL) of the reservoir is 534.4 m AHD, which is only 1 to 2 metres above the reservoir bed at the outfall location.

An examination of the 3D Hydrodynamic Model (Mike-3-FM) developed of the reservoir for the SERP study, indicates current speeds near the outfall are typically very low and in the order of 1 mm/s to 1 cm/s. The Mike-3-FM model also predicts surface temperatures of up to 20 ºC (in summer) and down to 10 ºC (in winter), which is in agreement with observed CTD data at Lobbs Hole. The reservoir bed at the outfall location is typically 10 ºC in summer and winter. The reservoir is poorly vertically mixed (i.e. becomes stratified) in summer due to surface heating, while in winter the surface cools and the reservoir becomes vertically fully mixed (i.e. becomes unstratified). The electrical conductivity of reservoir surface water is very low and typically between 20 to 30 µS/cm which is approximately 0.01 ppt (or kg/m^3 or psu).

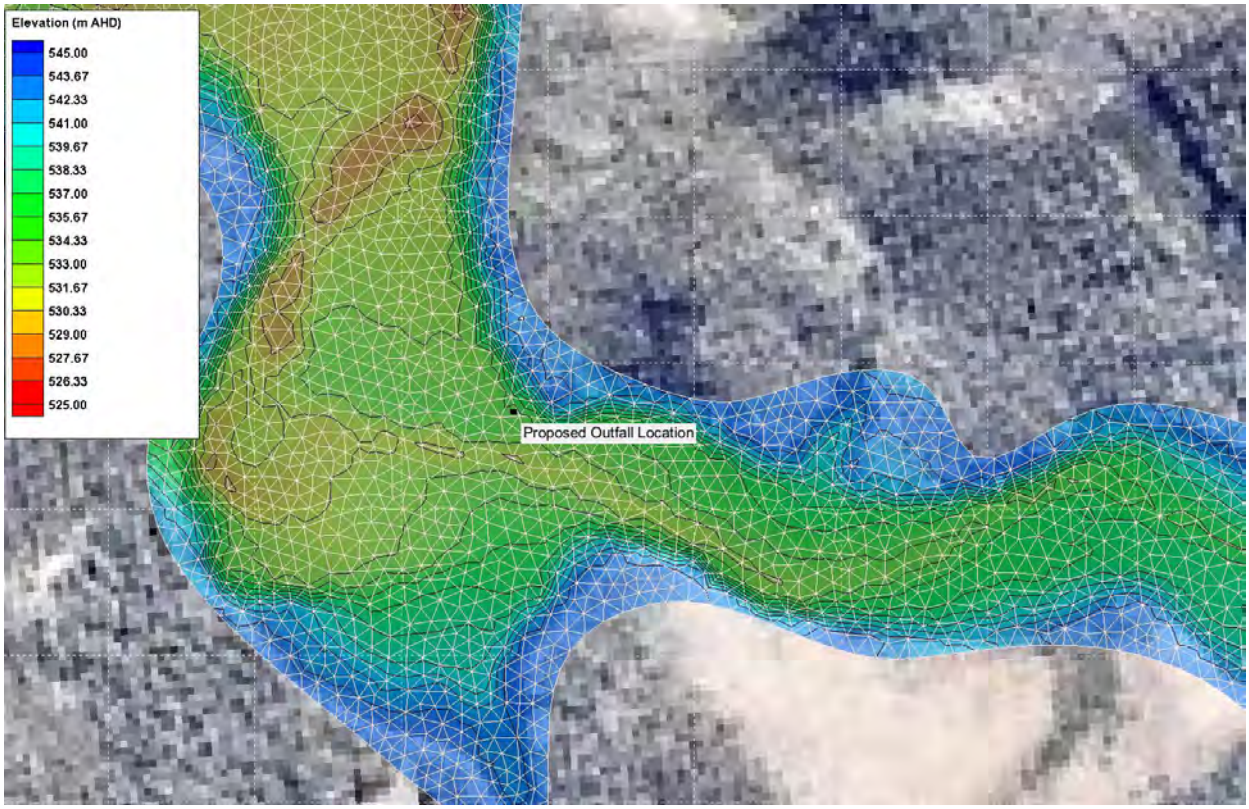


Figure 2: Outfall Location, Local Bathymetry and Model Mesh Resolution

1.3 Factors Influencing Near Field Dilution

The design of an effluent outfall typically depends on the dilution required to meet the relevant guidelines. Occasionally, guidelines may be met after an appropriate level of treatment. However, many constituents will rely on the dilution within receiving waters to meet these guidelines. Dilution depends on:

- Wastewater/discharge flowrate
- Wastewater/discharge density (i.e. temperature and salinity)
- Outlet diameter (and whether a single or multiple outlets will be used)
- Depth of water into which the wastewater is discharged
- Distance of the diffuser from shore
- Configuration of the diffuser (e.g. port configuration and whether duckbill valves are used)
- Ambient conditions (e.g. currents and stratification).

After discharge, if the wastewater is less dense than the receiving water, the effluent rises due to buoyancy (**Figure 3**). If it is more dense it descends. The wastewater then mixes with the ambient currents and is diluted.

Two types of models are used to quantify this process, namely near field and far field models. This separation is made because the time and space scales of the processes in each model are substantially different. In the near field, the motion of the wastewater is dominated by its initial momentum and buoyancy; the velocities and rates of dilution are high. Up to 90% of wastewater dilution takes place within the near field. The outfall is generally designed to maximise dilution in the near field, whereas far-field processes are typically influenced by more 'natural' processes which are more difficult to change.

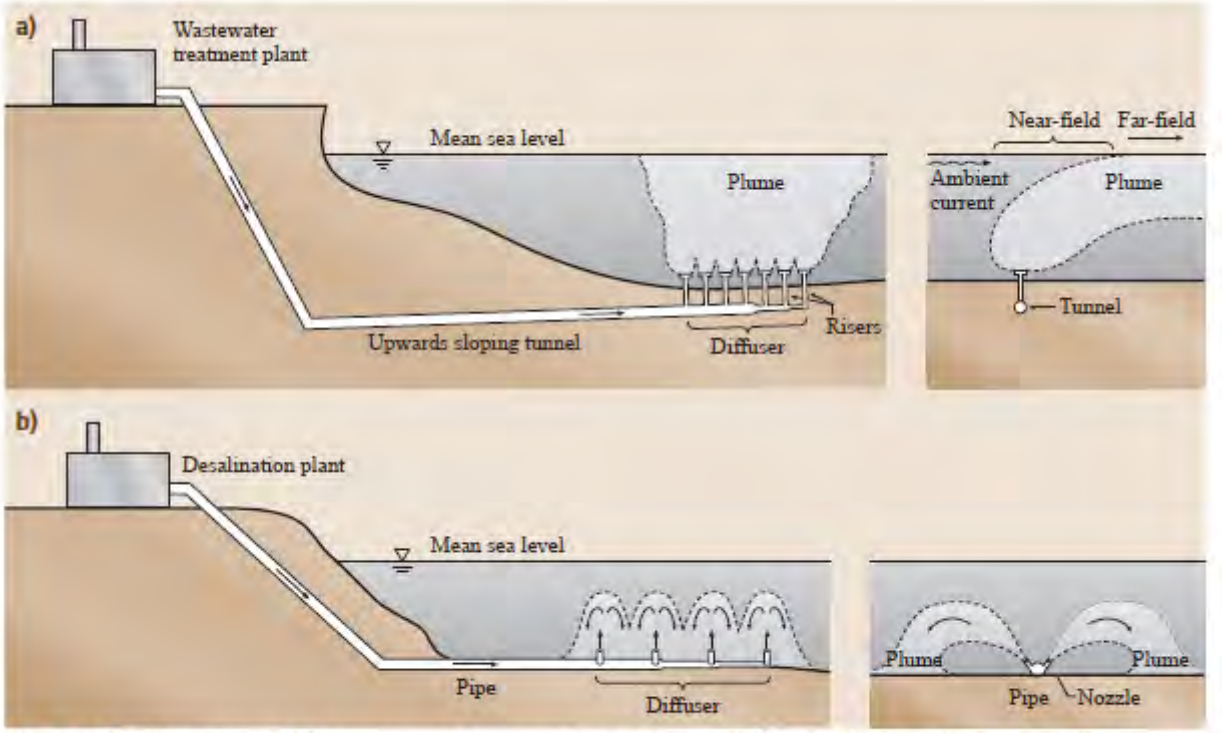


Fig. 32.1a,b Schematics of **(a)** a wastewater treatment plant outfall, and **(b)** a desalination plant outfall, showing side views and end views

Figure 3: Buoyant (a) vs Non-Buoyant Plumes (b) (Source: Peter M. Tate, Salvatore Scaturro, Bruce Cathers (2016))

2 Near Field Plume and Dilution Assessment

2.1 Adopted Diffuser Design

Suggested Port Size

Initial dilution increases with plume initial velocity (V). For a constant discharge, the only way to increase jet velocity is to reduce the port diameter. However, as port head loss (and hence the required pumping head) is proportional to $V^2/2g$ (where g is gravitational acceleration), a compromise between initial dilution and pumping costs is required. Also there tends to be a minimum preferred port size below which fouling / blockage could be an issue. **Table 2** presents port exit velocity and head loss for port diameters between 1 cm and 4 cm for the three effluent discharge scenarios. It is assumed that to reduce pumping requirements, an exit head loss below 10 m is desirable. Based on the requirement to maximise exit velocity to increase dilution and a consideration of associated head loss, a single port diameter may not be able to meet these dual objectives for the range of effluent discharge rates under consideration.

The use of a duckbill valve is a design option which would overcome these issues. However, most plume / dilution models are based on a round port which will tend to produce conservative mixing (i.e. lower than actual dilution) than if a duckbill valve is used (Tang *et al.*, 2005).

Table 2: Relationship Between Outfall Discharge, Port Diameter, Exit Velocity, and Head loss

Discharge ID	Discharge (m^3/s)	Port Diameter			
		1cm	2cm	3cm	4cm
		Port Exit Velocity (m/s)			
Q1	0.00056	7.13	1.78	0.79	0.45
Q2	0.00245	31.19	7.80	3.47	1.95
Q3	0.00516	65.70	16.42	7.30	4.11
		Port Exit Head Loss (m)			
Q1	0.00056	**2.8**	0.2	0.0	0.0
Q2	0.00245	53.0	**3.3**	0.7	0.2
Q3	0.00516	235.1	14.7	**2.9**	0.9

Port Discharge Angle

A 45 degree to the horizontal angle was adopted to maximise dilution for a neutral or slightly negatively buoyant plume.

Adopted Diffuser Conditions

In all cases, it was assumed that the diffuser is located in 10 metre depth of water with the port located 1 metre above the reservoir bed. Raising the diffuser outlet above the bed increases dilution by preventing the reservoir bed from inhibiting mixing.

2.2 Predictions of Near Field Mixing and Dilution

Near field mixing and dilution predictions were carried out using the VISJET_v3_2017 software (Lee and Cheung, 2017), which uses the extensively validated Lagrangian jet mixing model, JETLAG. This software is similar to CORMIX or Visual Plumes but does not include estimates of far-field dilution.

For the stratified ambient conditions, the plume is non-buoyant and dilution is primarily due to turbulent mixing due to the jet velocity. This means that:

- Smaller port sizes (and hence high jet velocity) produce higher dilutions
- For the higher discharge scenarios (i.e. Q2 and Q3) dilutions tend to be higher
- After considering the pre-dilution of the wastewater stream by the process stream, significantly higher rates of dilution are achieved.

2.2.1 Stratified Conditions

Results of initial (near field) dilution are presented in **Table 3** for a range of stratified conditions with ambient current speeds (V) of 1 mm/s, 1 cm/s and 5 cm/s. Example near field mixing plots showing the predicted plume extent for stratified conditions are attached (see **Figure A-1** and **Figure A-2**). It should be noted that for the stratified (i.e. non-buoyant plume) conditions, the initial mixing zone occurred within 10 metres of the diffuser/outfall location based on dilution factors of up to 200.

The results show that for the wastewater discharge only scenario (i.e. Q1, discharge = 0.56 L/s) using a 1 cm diameter port, an initial dilution of 193 is achieved in a stratified near still (V = 1 mm/s) ambient condition, whereas if a 3 cm diameter port was used for the same conditions, the achieved dilution would only be 37. For a higher ambient velocity (i.e. 5 cm/s), the predicted initial dilution for a 3 cm port increases to 165.

For the Q2 (Process Water (Monthly Average) and Wastewater (discharge = 2.45 L/s)) condition, a minimum 2 cm diameter port is required to reduce head loss. Initial dilutions in a stratified near still (V = 1mm/s) ambient condition of 141 are predicted in the near field zone. **Table 1** shows that a pre-dilution of 3.4 times is applicable to Q2 which increases the total dilution of the wastewater stream from 141 to 479 by the end of the near field zone.

Table 3: Predicted Dilution for Different Outfall Discharge, Port Diameter, and Ambient Velocity Field Conditions (Stratified)

Discharge ID	Discharge (m^3/s)	Port Diameter			
		1cm	2cm	3cm	4cm
		Stratified, 1 mm/s Ambient Velocity			
Q1	0.00056	193	69	37	24
Q2	0.00245	n/a[1]	141 (479)[2]	77 (262)[2]	50 (170)[2]
Q3	0.00516	n/a[1]	n/a[1]	111 (921)[3]	72 (598)[3]
		Stratified, 10 mm/s Ambient Velocity			
Q1	0.00056	227	96	61	43
Q2	0.00245	n/a[1]	148 (500)[2]	85 (289)[2]	58 (197)[2]
Q3	0.00516	n/a[1]	n/a[1]	113 (938)[3]	76 (631)[3]
		Stratified, 50 mm/s Ambient Velocity			
Q1	0.00056	672	278	165	114
Q2	0.00245	n/a[1]	389 (1323)[2]	244 (830)[2]	173 (588)[2]
Q3	0.00516	n/a[1]	n/a[1]	264 (2191)[3]	197 (1635)[3]

*1 – head loss considered too high – not simulated
*2 – need to consider additional process water dilution of waste water stream of 3.4 times (see **Table 1**)
*3 – need to consider additional process water dilution of waste water stream of 8.3 times (see **Table 1**)

2.2.2 Unstratified Conditions

Results of initial (near field) dilution for a range of unstratified conditions with ambient current speeds of 1 mm/s, 1 cm/s and 5 cm/s are presented in **Table 4**. Example near field mixing plots showing the predicted plume extent for unstratified conditions are attached (see **Figure A-3** and **Figure A-4**).

For the unstratified case (buoyant plume), dilution due to buoyant rise dominates over the turbulent mixing afforded by the jet velocity. This means that higher outfall discharges and smaller port sizes do not necessarily result in higher dilutions being achieved. The results also show that the buoyant plume that occurs in unstratified ambient conditions tends to produce higher dilutions than those that occur under stratified conditions. It should be noted that for the unstratified (i.e. buoyant plume) conditions, the mixing zone tended to spread further than 10 metres from the diffuser and produced dilutions above 1 000. The near field modelling is focussed on the near field processes and as such limited to within 10 metres of the diffuser based on the discharge and ambient conditions assessed. For this reason, the dilutions calculated for the unstratified 50 mm/s ambient velocity condition does not appear to increase whereas in reality, they will, albeit at a greater distance from the diffuser. The results show that under unstratified conditions, the minimum dilution for the buoyant plume is greater than 100 and in most cases they are above 500.

Table 4: Predicted Dilution for Different Outfall Discharge, Port Diameter, and Ambient Velocity Field Conditions (Unstratified)

Discharge ID	Discharge (m^3/s)	Port Diameter			
		1cm	**2cm**	**3cm**	**4cm**
		Unstratified, 1 mm/s Ambient Velocity			
Q1	0.00056	410[5]	208[5]	148[5]	122[5]
Q2	0.00245	n/a[1]	206[5] (700)[2]	138[5] (469)[2]	105[5] (357)[2]
Q3	0.00516	n/a[1]	n/a[1]	138[5] (>500)[3]	104[5] (>500)[3]
		Unstratified, 10 mm/s Ambient Velocity			
Q1	0.00056	1631[4]	900[4]	495[4]	248[4]
Q2	0.00245	n/a[1]	494[4] (>500)[2]	494[4] (>500)[2]	247[4] (>500)[2]
Q3	0.00516	n/a[1]	n/a[1]	494[4] (>500)[3]	494[4] (>500)[3]
		Unstratified, 50 mm/s Ambient Velocity			
Q1	0.00056	985[4]	494[4]	249[4]	249[4]
Q2	0.00245	n/a[1]	494[4] (>500)[2]	494[4] (>500)[2]	247[4] (>500)[2]
Q3	0.00516	n/a[1]	n/a[1]	494[4] (>500)[3]	494[4] (>500)[3]

*1 – head loss considered too high – not simulated
*2 – need to consider additional process water dilution of waste water stream of 3.4 times (see **Table 1**)
*3 – need to consider additional process water dilution of waste water stream of 8.3 times (see **Table 1**)
*4 – value within 10m of port – higher dilution occurs outside 10m
*5 – at low ambient velocity, near field mixing ends when plume reaches the water surface

2.3 Dilution and Water Quality Objectives

Near field modelling results are presented above in terms of dilution. The total receiving water concentration can be calculated as follows:

receiving water concentration = wastewater concentration x dilution + background concentration

3 Far Field Modelling and Dilution Assessment

3.1 Scope and Objectives

The Mike-3 FM model was used to undertake a far-field modelling assessment of the proposed wastewater and processed water discharges. Using this model, discharges at the potential outfall site were modelled using a conservative tracer under full dynamic conditions to calculate mixing/dilution of discharges in the receiving environment. Given the buoyant properties of the treated effluent (i.e. warm freshwater) capturing the influence of density anomalies on both hydrodynamic and horizontal/vertical mixing processes was important.

The Mike-3 FM model was used to simulate the movement (hydrodynamics) and mixing (advection-dispersion) between Talbingo Reservoir and a proposed wastewater discharge(s). Model scenarios were prepared to simulate a number of different discharge scenarios investigating:

- **Scenario 1** – Low flow conditions (summer) wastewater flow only
- **Scenario 2** – Typical flow conditions (summer) wastewater flow only
- **Scenario 3** – Typical flow condition (winter) combined wastewater and process water (average)
- **Scenario 4** – Typical flow conditions (winter) combined wastewater and process water (peak).

The above scenarios used the three-dimensional model with the 10%ile (low flow) and 50%ile (typical flow) conditions for the Yarrangobilly River and T2 discharge.

3.2 Boundary Forcing

In order to simulate hydrodynamic and mixing processes, the following boundary conditions were applied to the model:

- Initial conditions of salinity, temperature for Talbingo Reservoir
- Flow, salinity and temperature for the Yarrangobilly River
- Flow, salinity and temperature for the T2 discharge
- Flow, salinity and temperature for the proposed wastewater discharge
- Flow, salinity and temperature for the process water discharge.

The influence of wind on pollutant transport was not considered by the far field modelling.

3.2.1 Yarrangobilly River and T2 Discharges

Flows for the Yarrangobilly River and T2 discharges were included in the modelled scenarios as these are the primary flows influencing ambient current speeds near the proposed outfall site. A low (10%ile) river flow and T2 discharge condition was adopted to represent low ambient mixing conditions. A median (50%ile) river flow and T2 discharge was adopted as the 'typical' flow condition.

Flow duration curves for the Yarrangobilly at Ravine stream gauge (see **Figure 4**) were obtained from Water Data Online (http://www.bom.gov.au/waterdata/). Using this dataset, the 10%ile and 50%ile flow for the entire gauge record is approximately 0.4 m^3/s and 2.0 m^3/s respectively. The 10%ile and 50%ile T2 discharge was calculated from existing operations data provided by Snowy Hydro Limited.

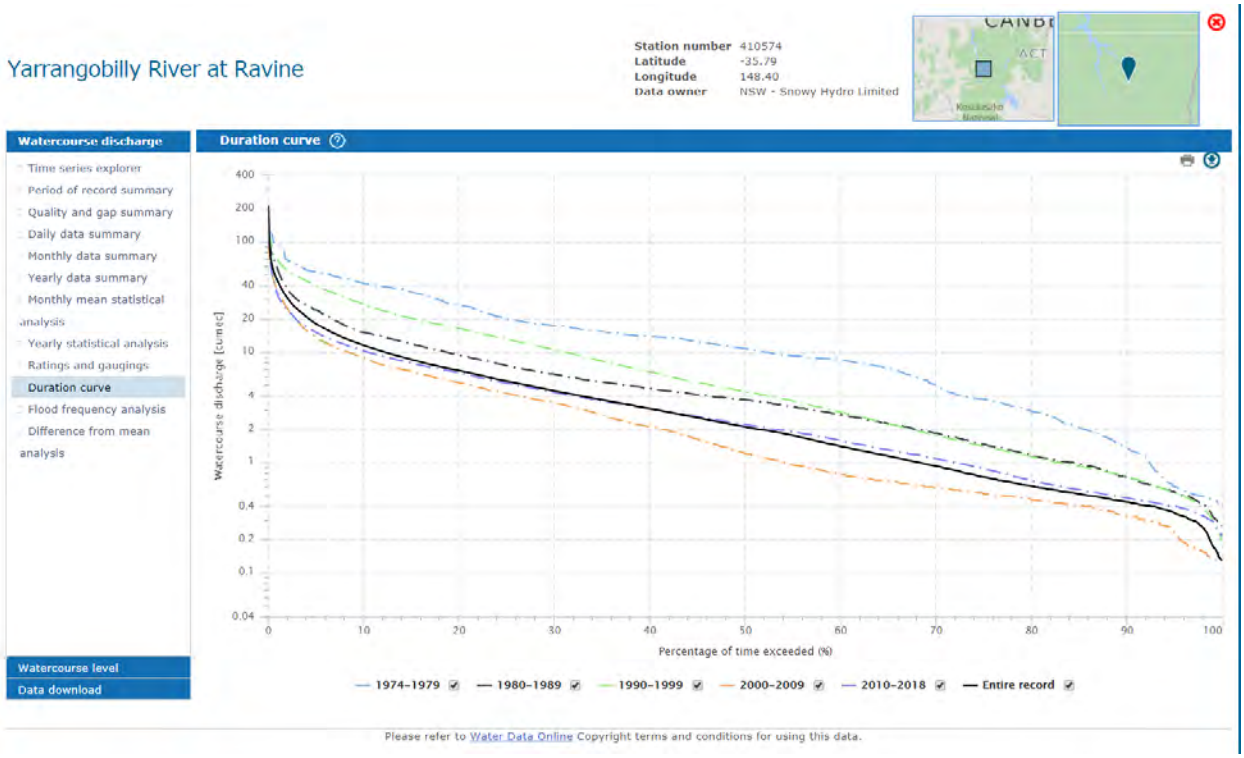


Figure 4: Flow Duration Curves for Yarrangobilly River at Ravine

3.3 Modelled Scenarios

Model scenarios were used to assist with evaluation of the proposed wastewater discharge to Talbingo Reservoir. Three-dimensional modelling (to predict the behaviour of a freshwater (buoyant) plume when discharged near the bed of the reservoir) was undertaken. The four outfall simulations are summarised in **Table 5**.

3.4 Effluent Discharge Characteristics and Outfall Location

Important effluent discharge characteristics used in the model scenarios are presented in **Table 5**. The location of the proposed nearbed diffuser location is shown in **Figure 2**.

The three-dimensional far-field model is unable to fully simulate the near-field dynamics (jet entrainment) of a buoyant plume discharged from an outfall diffuser. As such, estimates of mixing in proximity to the release point will have a lower accuracy compared to predictions of concentration outside of this initial mixing zone. The total dilution (accounting for near field and far field mixing) at a location in the far field domain (i.e. beyond the initial mixing zone) can be estimated as a multiple of the near field and far field dilution factors:

$$dilution_{total} = dilution_{near\ field} \times dilution_{far\ field}$$

Table 5: Far Field Modelling Scenarios and Adopted Boundary Conditions

Scenarios	Initial Conditions					
	Flow			Salinity	Temperature	Tracer
	KL/day	m^3/s	L/s	PSU, PPT or g/kg	deg C	g/m3 or mg/L
Low flow condition (summer)	N/A	N/A	N/A	0.01	summer CTD profile	0
'Median' flow condition (summer)	N/A	N/A	N/A	0.01	summer CTD profile	0
'Median' Case ('winter') - normal Process Water flow	N/A	N/A	N/A	0.01	winter CTD profile	0
'Median' Case ('winter') - peak Process Water flow	N/A	N/A	N/A	0.01	winter CTD profile	0
	Wastewater					
	Flow			Temp.	Salinity	Tracer
	KL/day	m^3/s	L/s	℃	PSU, PPT or g/kg	g/m3 or mg/L
Low flow condition (summer)	48	0.00056	0.56	15	0.5	100
'Median' flow condition (summer)	48	0.00056	0.56	15	0.5	100
'Median' Case ('winter') - normal Process Water flow	48	0.00056	0.56	10	0.5	100
'Median' Case ('winter') - peak Process Water flow	48	0.00056	0.56	10	0.5	100
	Process water (normal)					
	Flow			Temp.	Salinity	Tracer
	ML/month	m^3/s	L/s	℃	PSU, PPT or g/kg	mg/L
Low flow condition (summer)	N/A	N/A	N/A	N/A	N/A	100
'Median' flow condition (summer)	N/A	N/A	N/A	N/A	N/A	100
'Median' Case ('winter') - normal Process Water flow	4.9	0.00186	1.86	15	0.87	100
'Median' Case ('winter') - peak Process Water flow	N/A	N/A	N/A	N/A	N/A	100
	Process water (peak)					
	Flow			Temp.	Salinity	Tracer
	ML/day	m^3/s	L/s	℃	PSU, PPT or g/kg	g/m3 or mg/L
Low flow condition (summer)	N/A	N/A	N/A	N/A	N/A	100
'Median' flow condition (summer)	N/A	N/A	N/A	N/A	N/A	100
'Median' Case ('winter') - normal Process Water flow	N/A	N/A	N/A	N/A	N/A	100
'Median' Case ('winter') - peak Process Water flow	0.4	0.0046	4.63	15	0.87	100
	Yarrangobilly Inflow					
	Flow			Temp	Salinity	Tracer
	%ile	ML/day	m^3/s	℃	PSU, PPT or g/kg	g/m3 or mg/L
	N/A	N/A	N/A	N/A	N/A	0
Low flow condition (summer)	10th	38	0.44	18	0.011	0
'Median' flow condition (summer)	50th	190	0.44	18	0.011	0
'Median' Case ('winter') - normal Process Water flow	50th	190	0.44	6	0.011	0
'Median' Case ('winter') - peak Process Water flow	50th	190	0.44	6	0.011	0
	T2 Discharge					
	Flow			Temp	Salinity	Tracer
	%ile	ML/day	m^3/s	℃	PSU, PPT or g/kg	g/m3 or mg/L
	N/A	N/A	N/A	N/A	N/A	0
Low flow condition (summer)	10th			5	0.011	0
Typical flow condition (summer)	50th			5	0.011	0
Typical Case ('winter') - normal Process Water flow	50th			5	0.011	0
Typical Case ('winter') - peak Process Water flow	50th			5	0.011	0

3.5 Far Field Dilution Results

Scenario modelling was undertaken to assess existing conditions and the fate (i.e. spatial extent, concentration) of proposed point source discharges into the Talbingo Reservoir. The far-field modelling was undertaken to provide information relating to the fate and concentration of a proposed effluent discharge in the broader receiving environment. This modelling provides an estimate of the far field mixing processes only and does not include the initial near field mixing dynamics.

The location of the selected reporting sites used to present time series of dilution is presented in **Figure 5** and includes:

- **Outfall** – this location provides an indication of the instantaneous mixing (dilution) of the effluent at the proposed outfall site.
- **Downstream Yarrangobilly** (100 and 200 metres from outfall site) – these two locations provide an indication of the concentration of the effluent 100 m and 200 m downstream of the proposed outfall.
- **Upstream Yarrangobilly** (100 and 200 metres from outfall site) – these two locations provide an indication of the concentration of the effluent 100 m and 200 m upstream of the proposed outfall.



Figure 5: Reporting Locations

For each of the simulations detailed in **Table 5**, time series of the dilution factor (calculated as the ratio between the effluent discharge concentration and the tracer concentration in the receiving environment) are presented for the surface, centre and bottom of the water column for the selected reporting locations. The time series results are presented in **Figure 6** to **Figure 10** below.

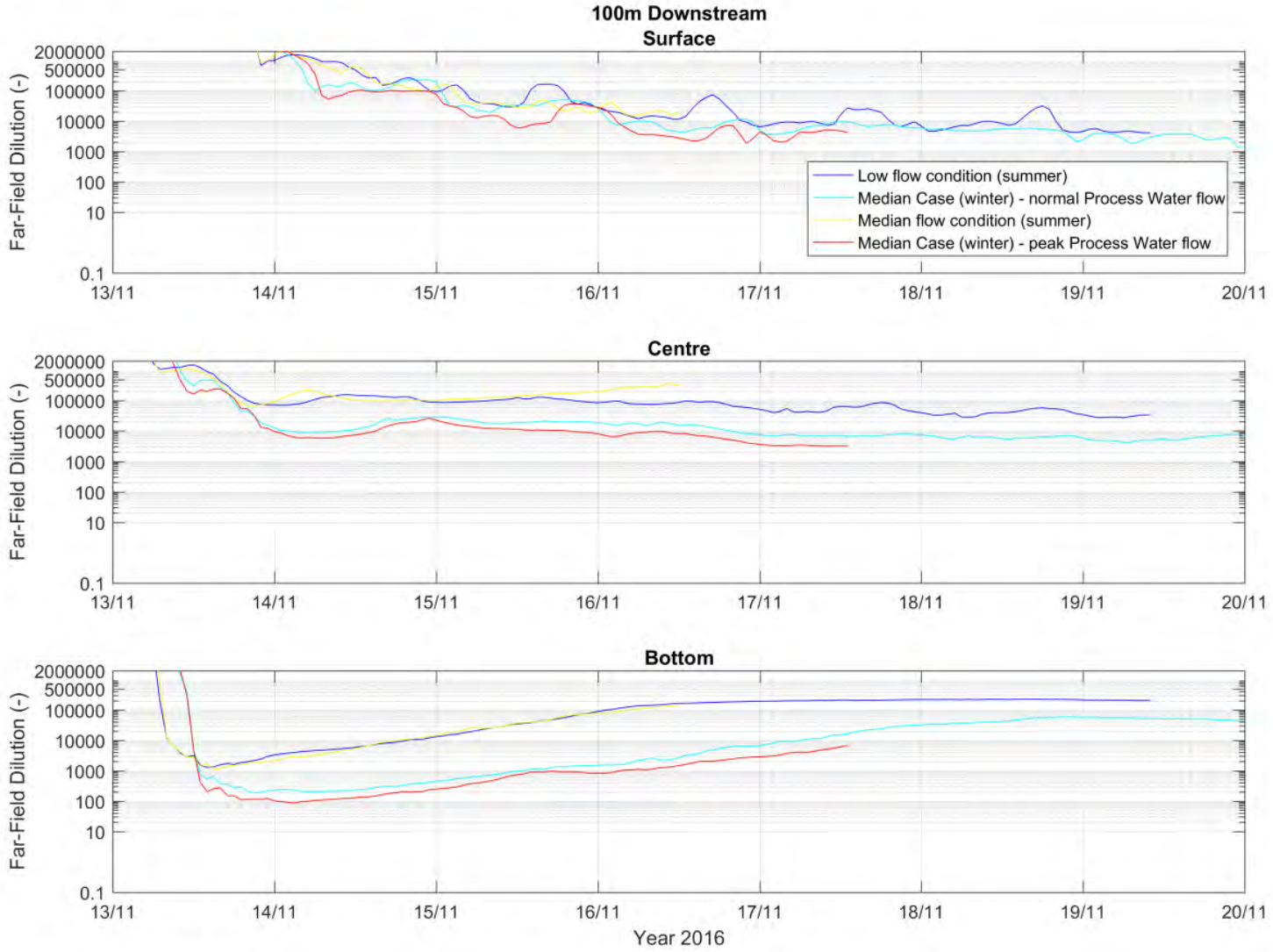


Figure 6: Simulated Far Field Dilution – 200 metres downstream of the outfall site

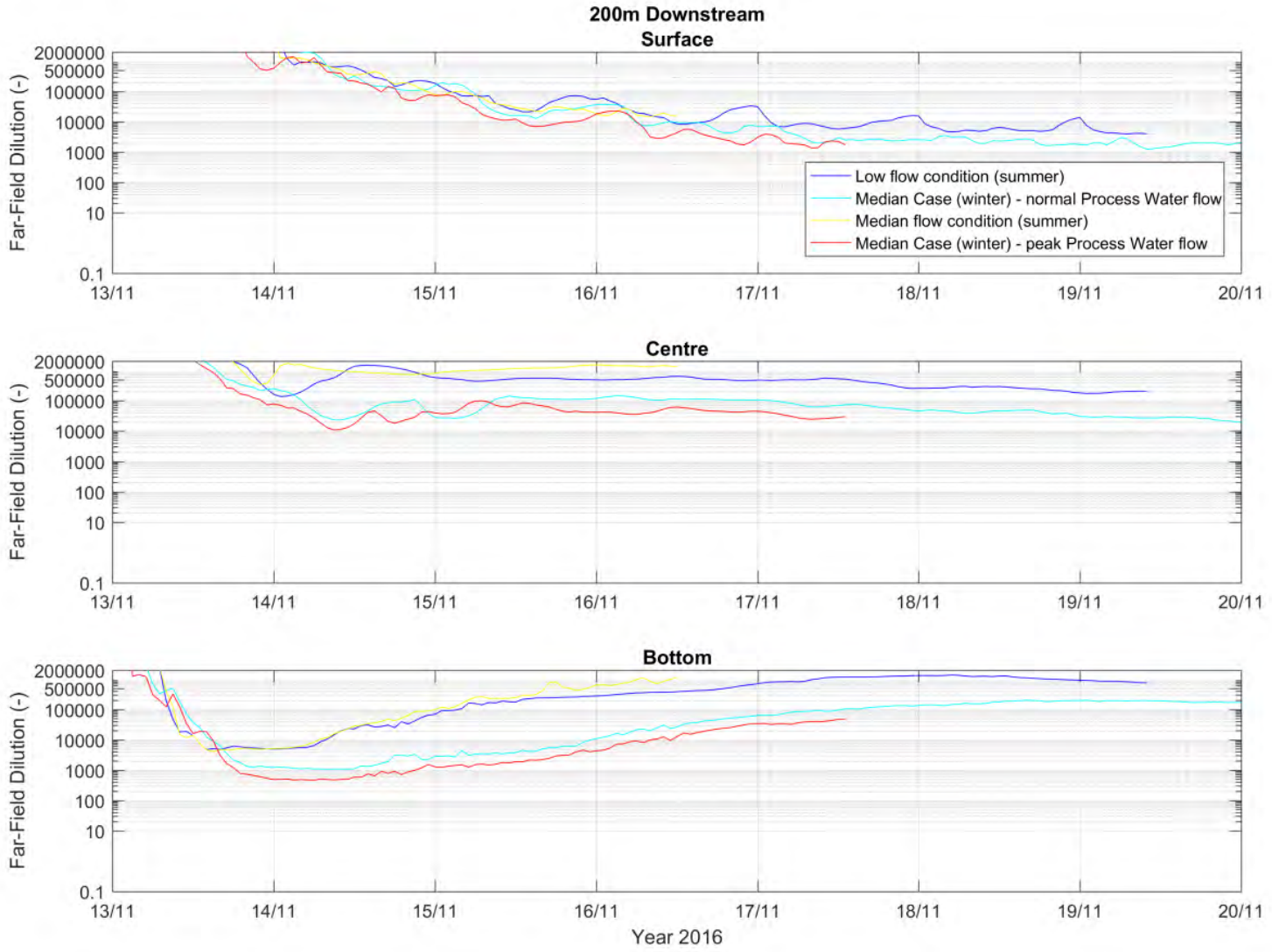


Figure 7: Simulated Far Field Dilution – 100m downstream of the outfall site

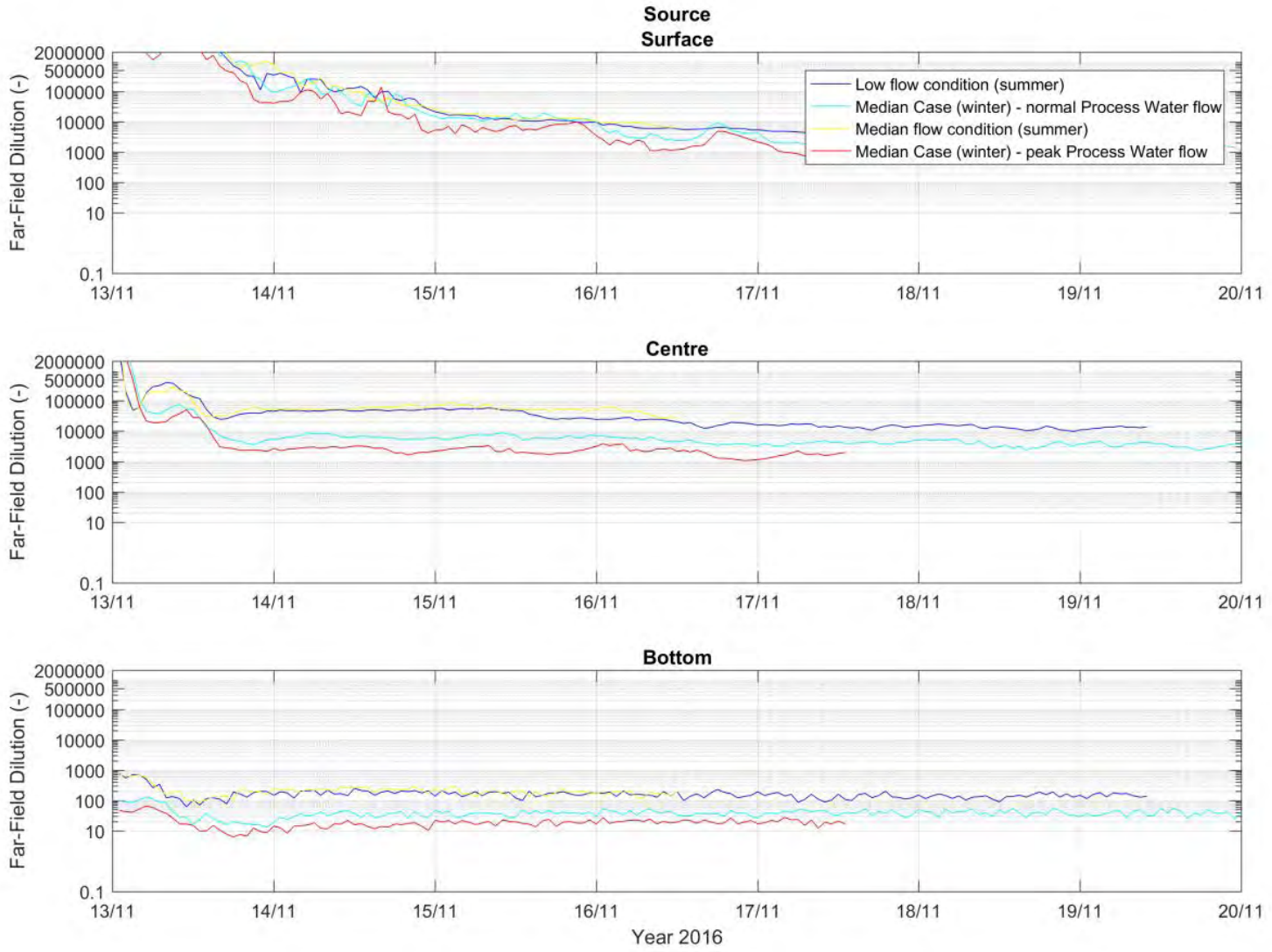


Figure 8: Simulated Far Field Dilution – proposed outfall site (within 10 metres of the discharge location)

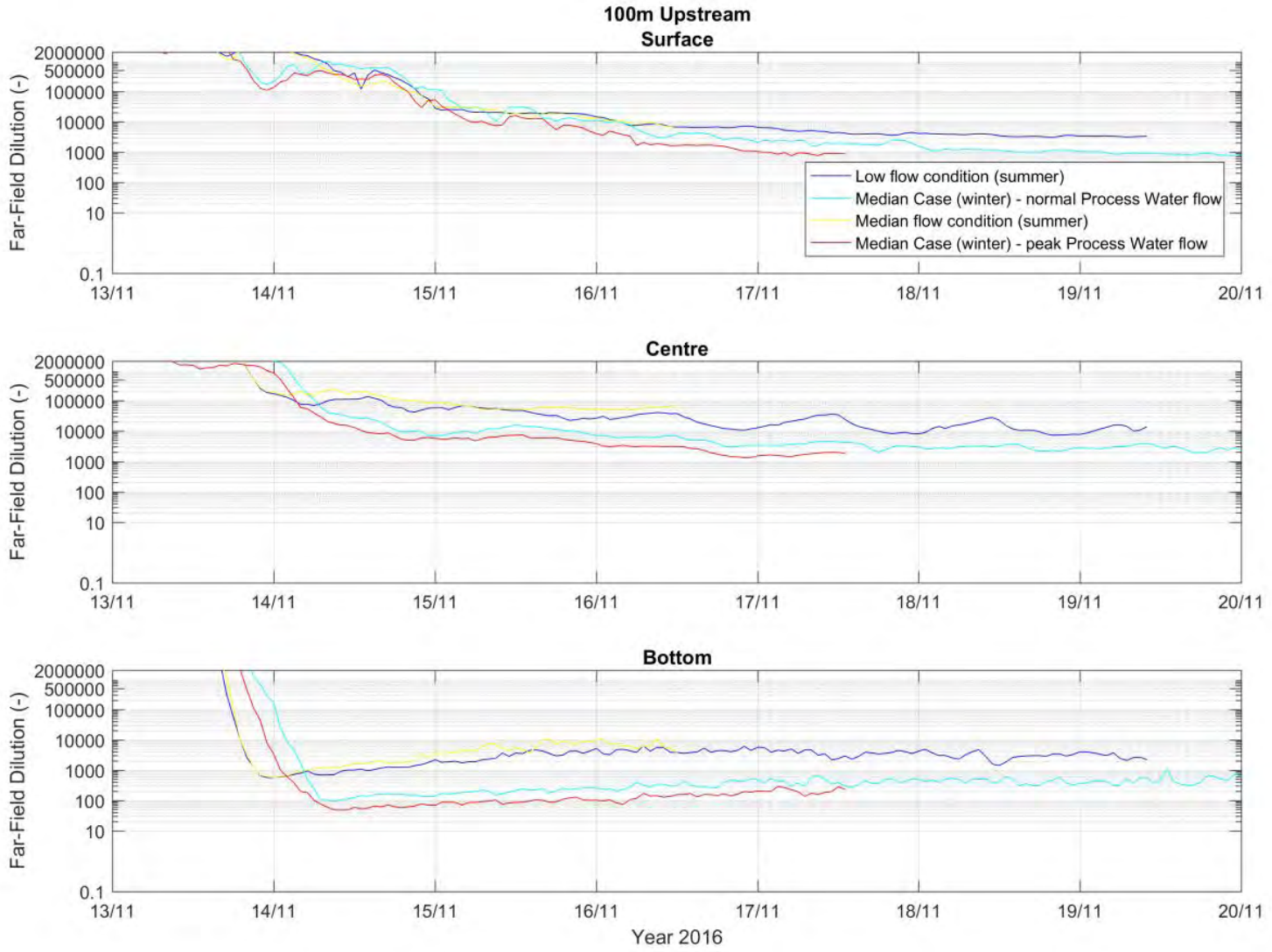


Figure 9: Simulated Far Field Dilution – 100m upstream of the outfall site

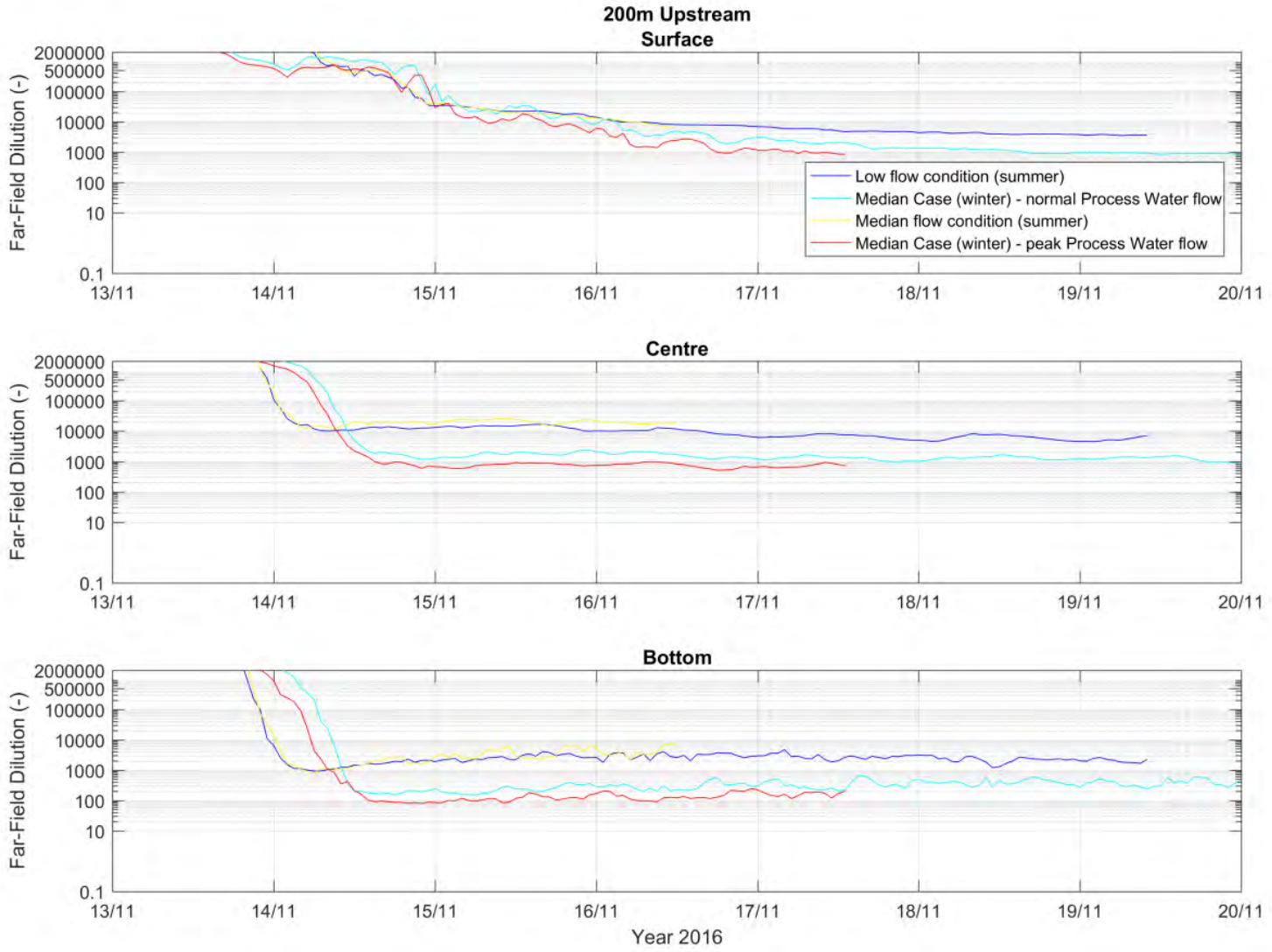


Figure 10: Simulated Far Field Dilution – 200m upstream of the outfall site

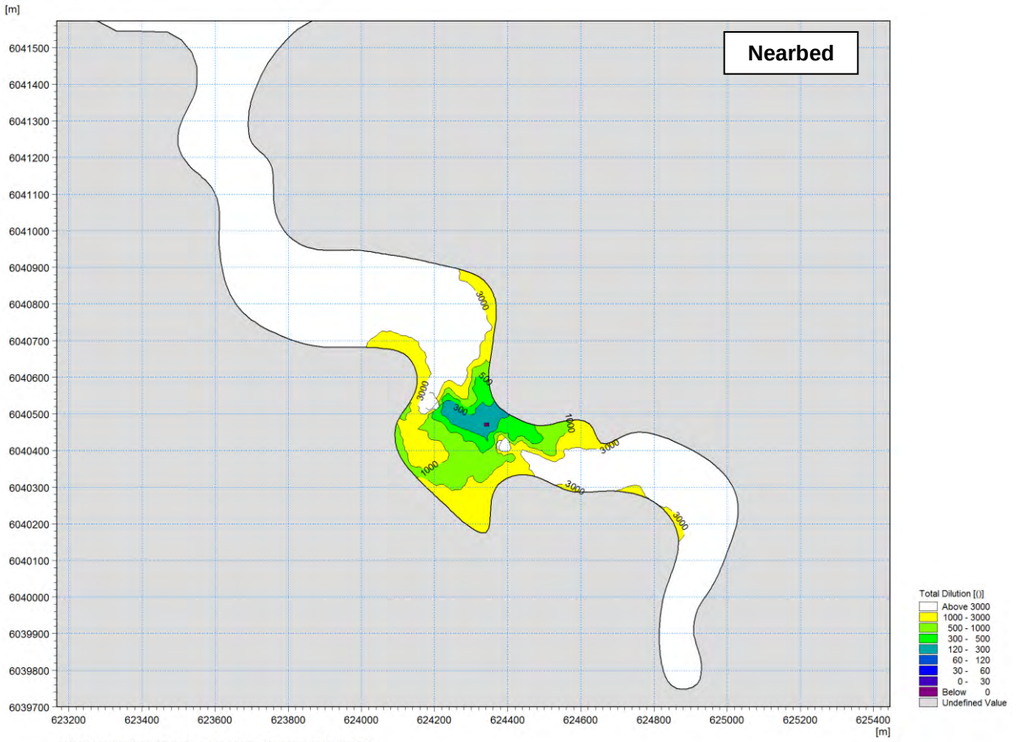
3.6 Total Dilution Results

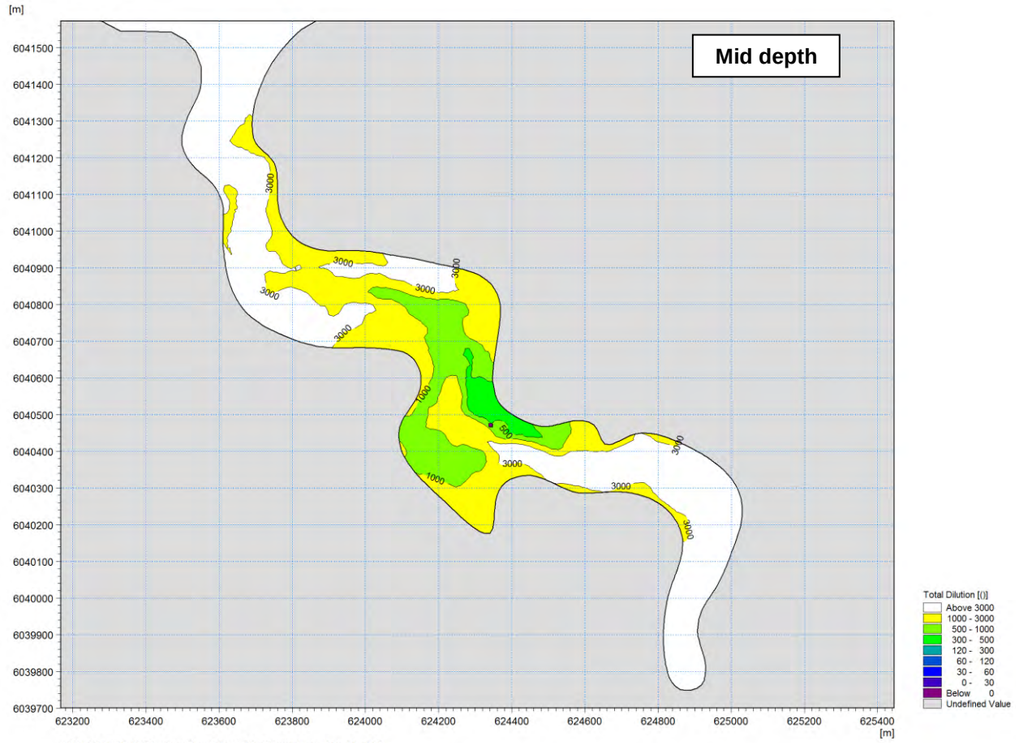
The modelling results above do not provide a direct estimate of the total dilution of wastewater and process water discharges resulting from combined near field and far field mixing processes. The Mike-3 FM model was updated to include a jet source boundary condition to better represent the discharge of wastewater and process water to the receiving environment accounting for both near and far field mixing processes simultaneously, and to provide an estimate of the total dilution in the receiving environment so that the mixing zone extent for selected levels of dilution could be defined.

Mixing zone extents accounting for both near and far field mixing processes were estimated for the expected worst case (i.e. Scenario 3 – Typical flow condition (winter) combined wastewater and process water (average)) and are shown in **Figure 11**. The plots show contours of total dilution around the proposed outfall site at nearbed, mid depth and surface. The distance (nearest and furthest extents) where the 10, 50, 100, 200, 300 and 500 total dilutions are achieved are summarised in **Table 6**.

Table 6: Distance from Outfall to Total Dilution Contours

Total Dilution (-)	Distance from Outfall to Total Dilution Contour			
	Nearbed		Surface	
	Nearest (m)	Furthest (m)	Nearest (m)	Furthest (m)
10	<10	<10	<10	<10
50	<10	<10	<10	<10
100	<10	<10	<10	<10
200	10	13	<10	<10
300	30	135	<10	<10
500	35	160	40	150





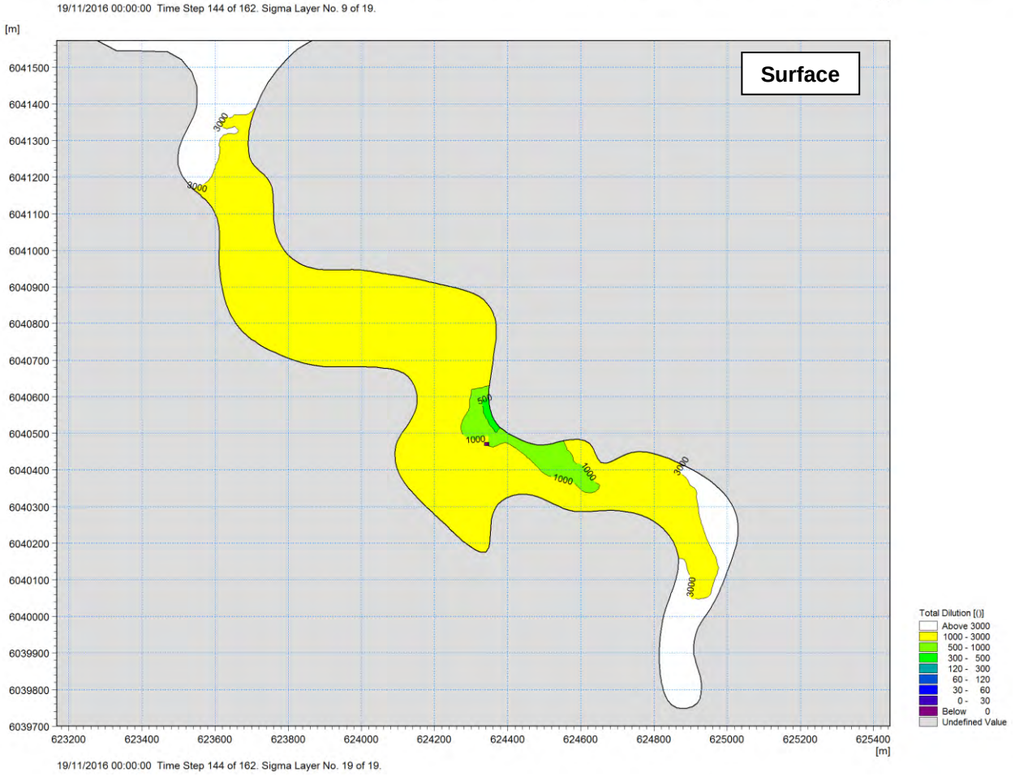


Figure 11: Total Dilution After 1 week – Scenario 3 – Surface, Mid Depth and Nearbed

4 Conclusions

Based on the results of the near field and far field modelling, the following key points are highlighted in the context of the proposed waste and process water discharges to Talbingo Reservoir:

- The initial mixing zone is small, i.e. in the order of 10 m. Summer (stratified) conditions are expected to result in less near field dilution than the winter (unstratified) conditions but in both cases the initial mixing zone is expected to be small.
- The buoyant plume that occurs during unstratified ambient conditions tends to produce higher dilutions (e.g. dilution = 900, 10 mm/s ambient velocity and 2 cm port diameter) than those that occur under stratified conditions for the same conditions (i.e. dilution = 96, for the equivalent velocity and port diameter).
- For the summer stratified (i.e. non-buoyant plume) near still ambient conditions, the initial mixing zone is within 10 m of the diffuser/outfall location. Under these conditions, the near field dilution factor could range between 100 and 200 provided the port diameter is optimised through the use of a duck-bill valve.
- For the winter unstratified case (buoyant plume), dilution due to buoyant rise dominates over the turbulent mixing afforded by the jet velocity.
- The far-field dilution ranges between 10 and 200 (within 10 m of the outfall) and between 100 and 10 000 at locations of more than 100 metres from the outfall. Assuming an initial near field dilution of 100, the total dilution (accounting for near field and far field mixing) is therefore estimated to range between 1 000 and 100 000). The combined dilution within the far field domain would mean that the concentration of a particular constituent above background would be likely less than detection limits at locations beyond the initial mixing zone.
- The fate of effluent discharged from the proposed outfall site is limited to Yarrangobilly River arm with a minimum total dilution of 3 000 occurring within 700 m of the proposed outfall site. Total dilution of 100 is achieved within 10 m of the outfall at the nearbed and surface.

5 References

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Attachment A – Near Field Mixing Zone Plots

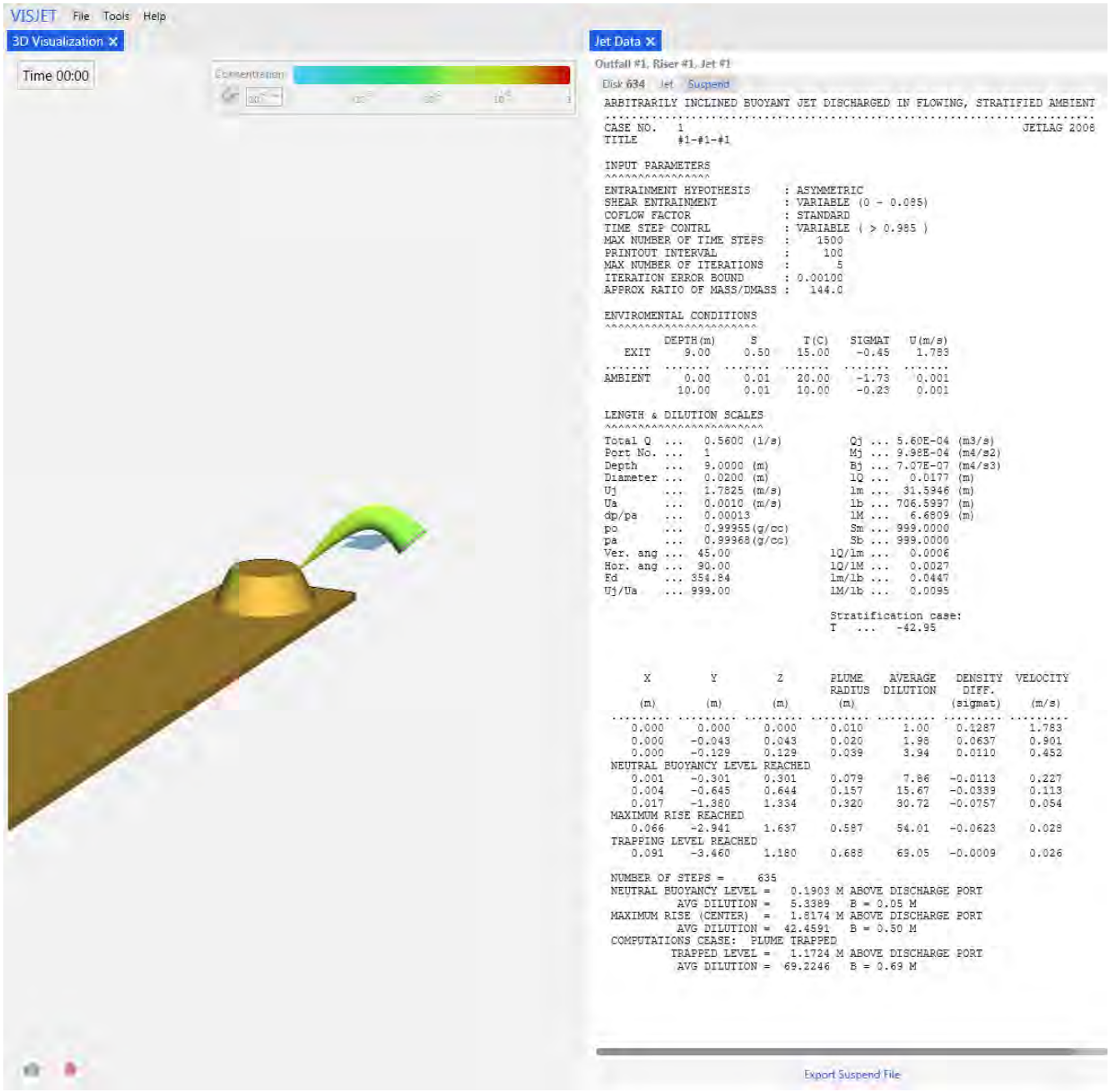


Figure A1: Q1 – 2cm port, stratified, 1mm/s

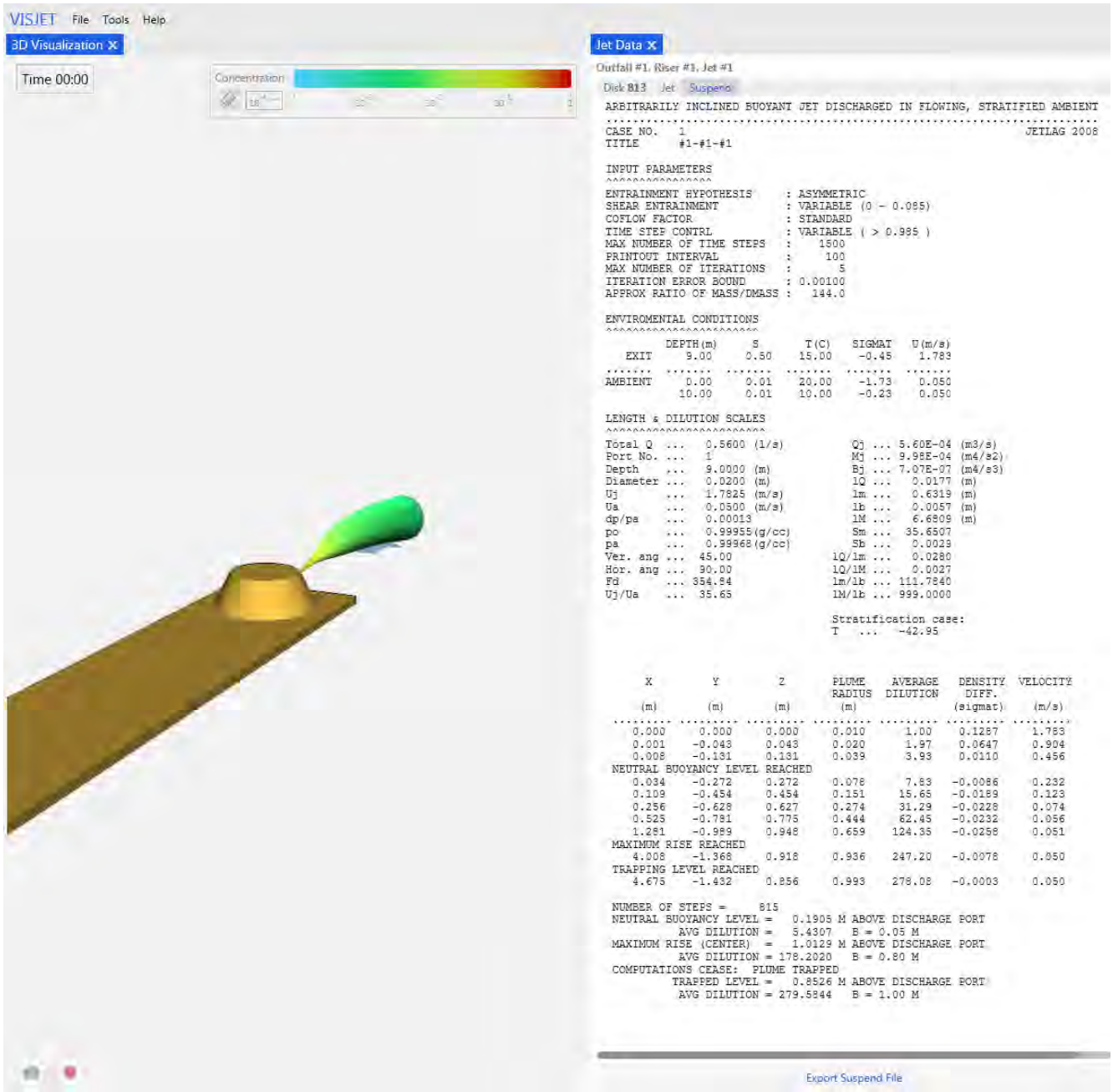


Figure A2: Q1 – 2cm port, stratified, 50mm/s

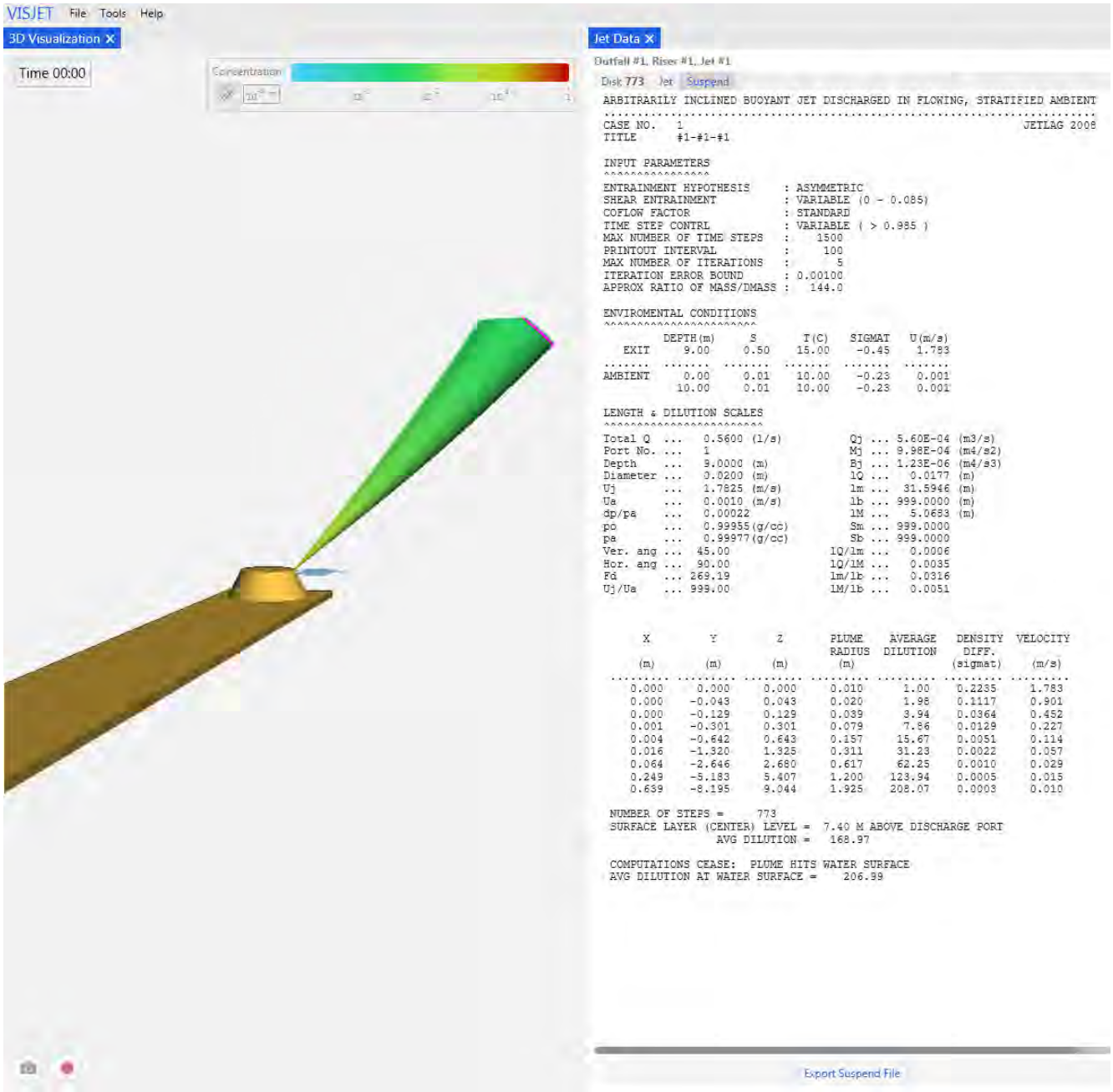


Figure A3: Q1 – 2cm port, unstratified, 1mm/s

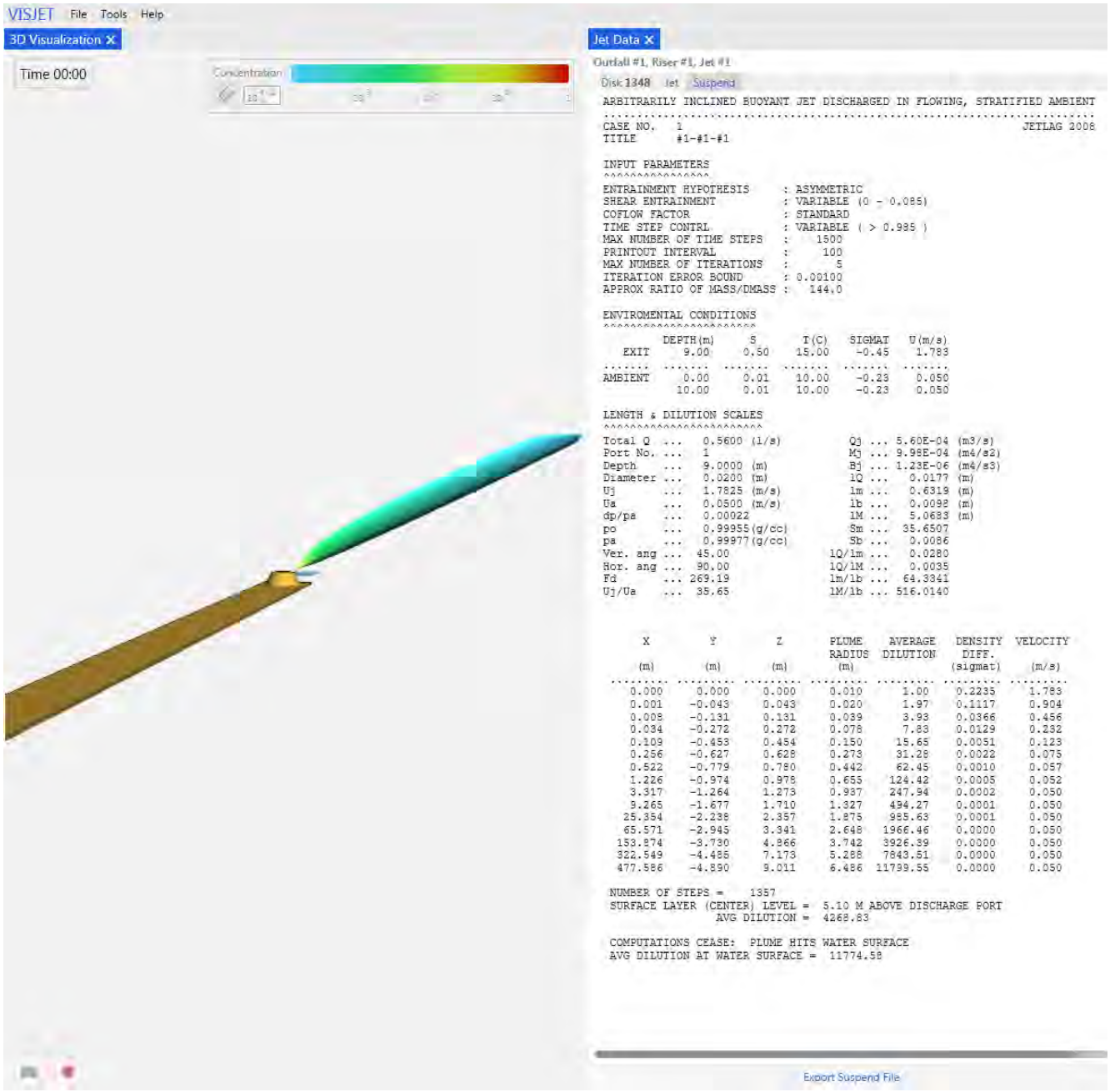


Figure A4: Q1 – 2cm port, unstratified, 50mm/s



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