LAND COURT OF QUEENSLAND

REGISTRY: BRISBANE
NUMBER: MRA428-14, EPA429-14
MRA430-14, EPA431-14
MRA432-14, EPA433-14

Applicant:	ADANI MINING PTY LTD
	AND
First Respondent:	LAND SERVICES OF COAST AND COUNTRY INC.
	AND
Second Respondent:	CONSERVATION ACTION TRUST
	AND
Statutory Party:	CHIEF EXECUTIVE, DEPARTMENT OF ENVIRONMENT AND HERITAGE PROTECTION

SECOND AFFIDAVIT OF JOHN WILLIAM BRADLEY

I, John William Bradley, Principal Hydrogeologist, JBT Consulting Pty Ltd, in the State of Queensland, affirm as follows:

1 I am the Principal Hydrogeologist at JBT Consulting Pty Ltd and have been since 2009. I am a geologist and hydrogeologist with over 23 years' experience in groundwater assessment and management.

2 I have been engaged by McCullough Robertson, on behalf of the Applicant, to appear as an expert witness in these proceedings in relation to issues raised in the objections to the Applicant's mining lease applications and environmental authority applications for the Carmichael Coal Mine project.

Deponent

Taken by:
Solicitor / ~~Justice of the Peace~~ / ~~Commissioner for Declarations~~

Second Affidavit of John William Bradley
Filed on behalf of the Applicant
Form 46 R.431

McCullough Robertson Lawyers
Level 11 Central Plaza Two 66 Eagle Street
BRISBANE QLD 4000
Phone: (07) 3233 8888 Fax: (07) 3229 9949
GPO Box 1855, BRISBANE QLD 4001
Ref: CEM:GMR:PWS:159359-00022

3 I previously affirmed an affidavit in these proceedings on 6 February 2015 (**First Affidavit**). My First Affidavit attaches my curriculum vitae and lists previous instances where I have provided expert evidence in relation to groundwater matters.

4 I have been provided by McCullough Robertson Lawyers with a copy of a document titled 'Expert report on groundwater impacts to the Land Court by Dr John Webb' dated 6 February 2015 (**Webb Report**).

5 I have prepared a report responding to certain matters raised in the Webb Report. Exhibited to my Affidavit and marked '**JWB-2**' is a true copy of my report to McCullough Robertson Lawyers dated 17 March 2015 (**Second Individual Report**).

6 Pursuant to rule 428(3) *Uniform Civil Procedure Rules 1999* (Qld), I confirm that:

(a) the factual matters stated by me in the Second Individual Report are, as far as I know, true;

(b) I have made all enquiries considered appropriate;

(c) I genuinely hold the opinions stated by me in the Second Individual Report;

(d) the Second Individual Report contains reference to all matters that I considered significant; and

(e) I understand my duty to the court and I have complied with this duty.

Deponent

Taken by:
Solicitor / ~~Justice of the Peace~~ / ~~Commissioner for Declarations~~

7 All the facts and circumstances deposed to in this affidavit are within my own knowledge except those stated to be on information and belief. I have, as required, set out the basis and source of my knowledge or information and belief.

Affirmed by John William Bradley

at Brisbane

this 18th day of March 2015

Before me:

A Justice of the Peace / Solicitor /
Commissioner for Declarations

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CERTIFICATE OF EXHIBIT

Exhibit '**JWB-2**' to the second affidavit of John William Bradley affirmed 18 March 2015.

Signed:
Deponent

Taken by:
Solicitor / Justice of the Peace /
Commissioner for Declarations

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MEMORANDUM

From: John Bradley, JBT Consulting

To: Peter Stokes, McCullough Robertson Lawyers

Subject: Adani Mining Pty Ltd v Land Services of Coast and Country Inc & Ors
Response to Expert Report of Dr John Webb

Date: 17 March 2014

Our reference: JBT01-049-004-Response to J Webb Expert Report.docx

1. Introduction

This document presents a response to a number of assertions in the Expert Report of Dr Webb[1] that relate to:

- Interpretation of hydrochemistry data;
- Groundwater flow direction;
- The potential for the Rewan Formation to transmit water, both as recharge in topographically elevated areas to the west of the Carmichael Project and in the area of the Doongmabulla Springs where Dr Webb asserts that the springs are fed via groundwater flow from the Colinlea Sandstone that underlies the Rewan formation; and,
- A number of observations relating to Dr Webb's geological reinterpretation.

In the text presented below, direct quotes from Dr Webb's Expert Report are presented in italics. Comments or observations that I have made within Dr Webb's quoted text are presented within square brackets thus [.....].

2. Hydrochemistry

2.1. Introductory Summary of Dr Webb's Report

1. Dr Webb contends in his Expert Report (paragraph 11) that:
   (i) *"Hydrogeological and hydrochemical evidence indicates that the Doongmabulla Springs are probably fed from the underlying Permian aquifers rather than the Dunda beds at the surface..."*
2. The hydrochemical evidence discussed by Dr Webb is related to:
   (i) Groundwater and spring salinity data (expressed as total dissolved solids (TDS) in units of milligrams per litre (mg/L);
   (ii) The chloride (Cl) concentration of groundwater and spring water; and,
   (iii) The use of strontium (Sr) isotope data
3. Supporting opinion provided by Dr Webb includes the following:
   (i) Paragraph 54, including:
      a. Paragraph 54 (e) - *Groundwater with a similar salinity to the springs occurs in the D seam in 2 bores to the east of the springs (50-60 mg/L Cl).*
      b. Paragraph 54 (f) - *The Sr isotope composition of most springs matches that of Mellaluka bore, consistent with the origin of the spring water from the same aquifer, i.e. the Colinlea Sandstone or immediately underlying Joe Joe Formation.*

[1] Expert Report on groundwater impacts to the Land Court by Dr John Webb, dated 6 February 2015.

(ii) *Paragraph 44 - Mellaluka Spring and the adjacent bore were sampled on 21 November 2014. The water samples were analysed for their Strontium (Sr) isotope ratio* [shown below as Table 2-1]. *The bore water (0.723883) is more radiogenic than the spring water (0.713531), which has a signature likely to be close to that of rainfall in this area. It seems probable that the spring water is recording input from recent rainfall in the area (within the last few weeks), and that the bore water Sr signature represents the typical composition derived from interaction with the Permian aquifers.*

Table 2-1: Strontium (Sr) Isotopic composition of sampled springs and bores

Spring/bore	87Sr/86Sr
Mellaluka Spring	0.713531
Mellaluka Bore	0.723883
Joshua	0.719035
Main Moses	0.722041
Moses East - inflow	0.724029
Moses East - centre	0.713291
Snake	0.724125
Little Moses	0.715527
Surprise	0.726992

(iii) Paragraph 52 - *The Sr isotope composition of the water from most springs is very similar to the Mellaluka bore* [Table 2-1]. *Two samples have less radiogenic signatures (similar to Mellaluka Spring) that probably indicate the influence of recent rainfall.*

(iv) Paragraph 51 – "*A fault or fracture system is believed to be present at Joshua Spring, forming a relatively rapid pathway for both recharge and groundwater flow to the spring (Water quality EIS). This is shown by the rapid flow rate of Joshua Spring (~5 L/sec) and the low salinity of the spring water. The other springs have lower flow rates, but most are probably also derived from fracture flow; the inlet for Moses East issues from a low sandstone outcrop* [Figure 15 of Dr Webb's report]."

2.2. Response to Dr Webb's Report

2.2.1. Introduction

4. The opinions outlined above in Section 2.1 are used by Dr Webb to support his assertion that the source aquifer for the Doongmabulla Springs is Permian sediments (i.e. the Colinlea Sandstone) rather than shallow sediments that occur above the Rewan Formation. The discussion of hydrochemistry in Dr Webb's report also relates to the Mellaluka Springs. However the source aquifer for the Mellaluka Springs is the subject of only minor contention, therefore this memorandum principally considers the hydrochemical evidence as it relates to the source aquifer for the Doongmabulla Spring Complex.
5. It is my opinion that the hydrochemical evidence presented by Dr Webb does not support any firm conclusion as to the source aquifer for the Doongmabulla Spring Complex. My reasoning is outlined below.

2.2.2. Chloride Data

6. Dr Webb asserts (paragraph 54 (e)) that "*groundwater with a similar salinity to the springs occurs in the D seam in 2 bores to the east of the springs (50-60 mg/L Cl).*
7. I have undertaken an assessment of Project water quality data available for the 2014 year for chloride (Cl) concentration data; the results are shown below in Table 2-2. In summary:
   (i) The Cl concentration for Joshua Spring samples ranges from 53-90 mg/L, with a mean (average) and median concentration of 72 mg/L (based on 2 samples);

(ii) Colinlea Sandstone samples show a data range from 38 to 1240 mg/L (79 samples), with a mean of 347 mg/L and median of 200 mg/L;

(iii) Clematis Sandstone samples show a data range from 68 to 150 mg/L (11 samples), with a mean of 109 mg/L and median of 110 mg/L;

(iv) The chloride concentration of groundwater units in-between the Colinlea Sandstone and Clematis Sandstone (Bandanna Formation, Rewan Formation, Dunda beds) is highly variable, though both the Bandanna Formation and Rewan Formation have significantly higher mean Cl concentration (817 and 1221 mg/L respectively) than the Colinlea Sandstone and the Joshua Springs. Given that water from the Colinlea Sandstone would need to travel through these formations to reach the Joshua Springs, it could reasonably be expected that the water would mix to some degree so that the water quality of samples taken from the Colinlea Sandstone at depth would not be the same as the water quality of Colinlea Sandstone water that had travelled to surface through several hundred metres of rock containing higher salinity water

(v) It is not certain which two bores Dr Webb is referring to when he states (paragraph 54 (e)) that *"Groundwater with a similar salinity to the springs occurs in the D seam in 2 bores to the east of the springs (50-60 mg/L Cl)"*, however the location of bores for which water quality samples were available for the 2014 year are shown on Figure 2-1 of this report. Based on the summary Cl data presented below in Table 2-2 it is concluded that there is no clear correlation between Cl from the Doongmabulla Spring Complex (Joshua Spring) and any particular groundwater unit. Therefore Dr Webb's assertion that Cl data can be used to support an interpretation that the Colinlea Sandstone is the source aquifer for the Doongmabulla Spring Complex is rejected.

Table 2-2: Summary data for Chloride (Cl) Concentration (mg/L) – 2014 Data

	Water Source	Count	Min	Max	Mean	Median	StDev
Springs	Mellaluka Spring	2	370	770	570	570	283
	Joshua Spring	2	53	90	72	72	26
Groundwater	Alluvium/Tertiary	39	91	20000	5074	3900	5331
	Clematis Sandstone	11	68	150	109	110	29
	Dunda beds	31	50	225	100	67	55
	Rewan Formation	26	43	7600	1221	170	2043
	Bandanna Formation	66	80	6520	817	395	1548
	Colinlea Sandstone/ coal	79	38	1240	347	200	291

8. Further, it is my opinion that further gathering of hydrochemical data would be unlikely to shine further light on the source aquifer to the Doongmabulla Spring Complex – i.e. I am of the opinion that sufficient data is available to date to be able to conclude that the water quality of individual groundwater units in the vicinity of the Carmichael Project site is similar to the likely range of water quality within the Doongmabulla Spring Complex. This is not to say that ongoing sampling is not warranted for environmental compliance reasons; rather that additional water quality data is unlikely to provide definitive proof of the source aquifer for the Doongmabulla Spring Complex.

2.2.3. Strontium Isotope Data

9. The following observations are made with respect to the strontium isotope data presented in Dr Webb's Expert Report (refer Table 2-1 of this memorandum):

(i) One sample is available from a groundwater bore (Mellaluka bore, interpreted to be screened within the Jochmus Formation), with the rest of the samples being taken from spring sources;

(ii) Dr Webb attempts to draw a conclusion that, because the Sr isotope ratio of some springs is similar to the Sr isotope ratio of Mellaluka bore, this supports a conclusion that the Doongmabulla Spring is fed by water from a Permian aquifer source. In fact, all that can be said from the Sr isotope chemistry is that the Sr isotope chemistry observed for some of the Doongmabulla springs is indicative of a groundwater source. However there is no evidence to support which groundwater unit the water is derived from as Dr Webb has not undertaken sampling from any other groundwater units;

(iii) Dr Webb dismisses results for the Moses Spring that do not fit his hypothesis by stating that the results are impacted by recent rainfall in the area. This may be true, or it may also be the case that the results are indicative of input from another water source (e.g. a shallow groundwater unit);

(iv) It is my opinion that the Sr isotope results are inconclusive and that this data cannot be used to make firm conclusions with respect to the source aquifer for the Doongmabulla Spring Complex.

2.2.4. Summary

10. Based on review of chloride (Cl) concentration data and strontium isotope data it is my opinion that the available hydrochemical data does not support any firm conclusion as to the source aquifer for the Doongmabulla Spring Complex;
11. Further, it is my opinion that gathering of additional hydrochemical data would be unlikely to shine further light on the source aquifer to the Doongmabulla Spring Complex. This is because, in my opinion, sufficient hydrochemical data has been gathered to date (including salinity data, major ion data, strontium isotope data) to indicate that:
    (i) The salinity (as chloride concentration) of all aquifers at site is within the range observed for the Doongmabulla Spring Complex;
    (ii) The strontium isotope data does not present sufficient contrast between water sources to enable conclusive statements as to the source aquifer for the Doongmabulla Spring Complex; and, and,
    (iii) It is possible that water samples from the Doongmabulla Spring Complex can be affected by the input of water from rainfall and surface water flow; this limits the ability to make conclusive statements with respect to the groundwater source to the springs.

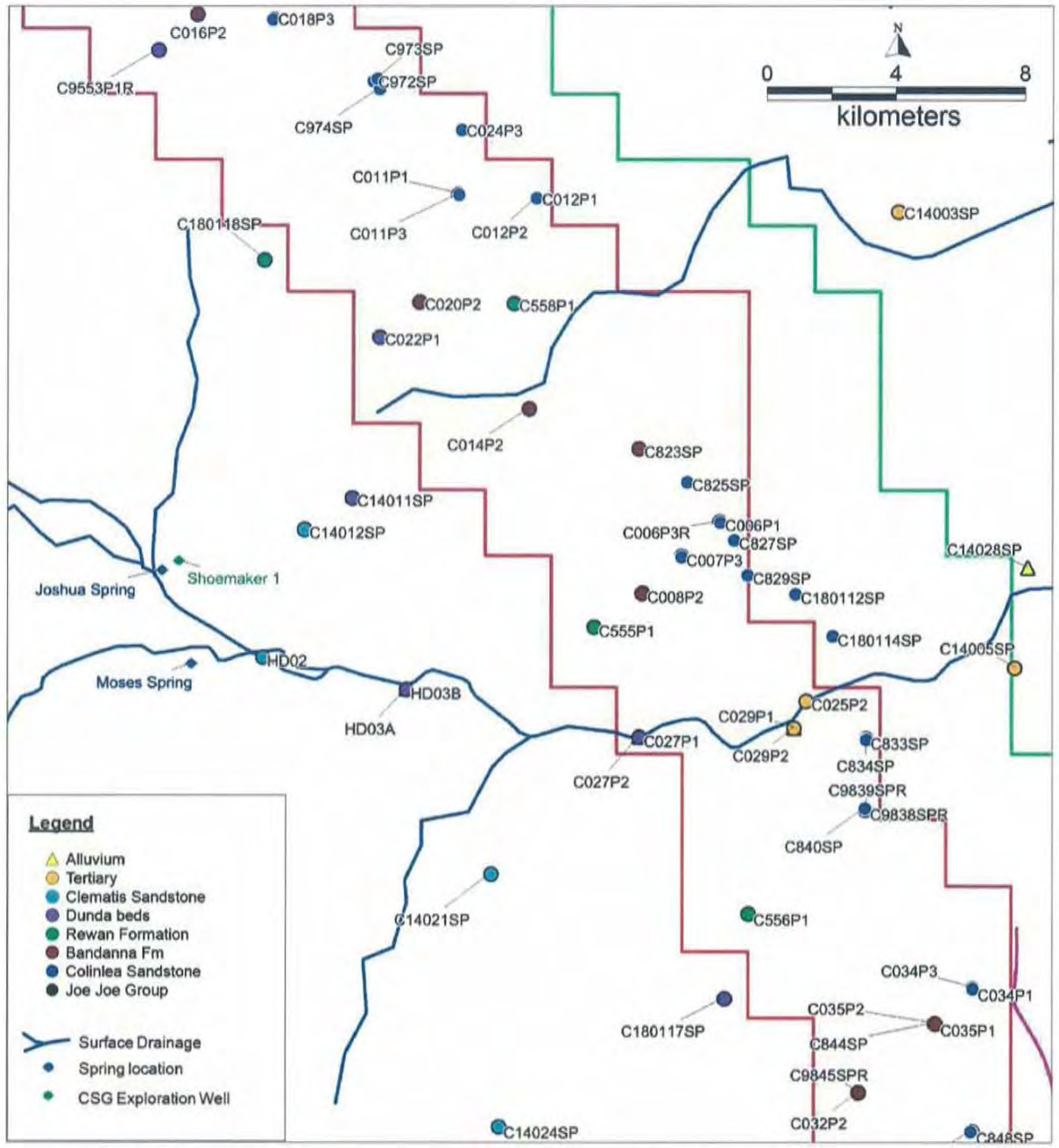

Figure 2-1: Water Sample Sites – 2014 Data

3. Groundwater Flow Direction and Rewan Formation Properties

3.1. Introductory Summary of Dr Webb's Report

12. Dr Webb contends in his Expert Report (paragraph 11) that "Hydrogeological *and hydrochemical evidence indicates that the Doongmabulla Springs are probably fed from the underlying Permian aquifers rather than the Dunda beds at the surface…"*
13. Further, Dr Webb states (paragraph 12) that *"The current hydrogeological modelling is, therefore, based on an incorrect geological model and, most likely, a misunderstanding of the aquifer feeding the Doongmabulla Springs. In addition, the* springs *are fed by fracture flow which is not explicitly modelled in the present hydrogeological modelling. As a result, the conclusions of the current modelling, that there will be little impact of the proposed Carmichael mine on Doongmabulla Springs, are unlikely to be correct, and there is the real possibility that the dewatering for the mine could cause the springs to dry up (as acknowledged for the Mellaluka Springs)."*
14. In support of the above statements Dr Webb offers the following supporting opinions:
    (i) Paragraph 39 – "*The compilation of piezometric data for the Colinlea Sandstone shows clearly that there* is *a groundwater divide to the west of the Carmichael lease, in the vicinity of Lake Galilee (Fig. 8 of Dr Webb's report). This coincides reasonably closely with the topographic divide in this area and with an anticlinal axis located on the basis of the geological mapping discussed above."*
    (ii) Paragraph 40 – *"Recharge to the Colinlea Sandstone must be occurring along this groundwater divide, and the hydraulic gradients to the east and west cause groundwater flow in these respective directions within this formation* [Fig. 7b of Dr Webb's report]. *However, the Rewan Formation overlies the Colinlea/Bandanna aquifer along the groundwater divide; this is true whether the west dipping model in the Hydrogeology EIS* [Fig. 7a of Dr Webb's report] *or the revised folding model of the geology presented here* [Figs 12, 13 of Dr Webb's report] *is followed. Therefore, recharge to the Colinlea Sandstone is occurring through the Rewan Formation, which must be a leaky aquitard. The Rewan Formation is dominantly clay-rich and the majority of hydraulic conductivity measurements from this formation are low; Bradley points out in the joint experts' report that any fractures or faults through the Rewan Formation might be expected to be self-healing. Nevertheless, the presence of the groundwater divide to the west of the Carmichael lease indicates unequivocally that recharge is occurring through the Rewan Formation in this area, and it is notable that parts of the Rewan Formation are quite transmissive, as shown by scattered high vertical hydraulic conductivity values of 0.3-1.2 m/day (Kevin's Corner EIS, 12 Groundwater, Table 12-30)."*
    (iii) Paragraph 41 – *"The knowledge that the Rewan Formation is sufficiently permeable that it allows* recharge *to the underlying Colinlea Sandstone is directly relevant to the potential source aquifer for the Doongmabulla Springs (discussed below)."*
    (iv) In paragraph 13 of Dr Webb's report it is also stated that "*This conceptual geological model* [the conceptual model of the Project proponent] *shows the aquifer (CD-DE sandstones) dipping to the west, whereas the potentiometric surface of this aquifer, as shown by the water level data from bores in the area (Fig. 8), dips to the east. The potentiometric surface (the height of the water level in bores) measures the groundwater pressure; groundwater always flows from areas of high hydraulic pressure to areas of low hydraulic pressure. Therefore, groundwater flow in the aquifer must be towards the east, following the dip of the potentiometric surface, but in the opposite direction to the dip of the aquifer, which is towards the west, i.e. the groundwater is flowing up-dip. Typically, groundwater flows down the dip of an aquifer (this is true in the Great Artesian Basin to the west of the study area and probably to the south of the proposed mine in the South Galilee proposed mine area; Heritage Computing 2013, Fig. 3.9). The groundwater flow in the area of the proposed Carmichael coal mine (and also the proposed Alpha and Kevin's Corner coal mines to the south) flows in the opposite direction to that expected.*

15. In summary, Dr Webb is asserting that:
    (iv) the elevated groundwater levels in the Colinlea Sandstone indicate *"unequivocally that recharge is occurring through the Rewan Formation in this area"* and that on this basis the Rewan Formation *"must be a leaky aquitard"*; and,
    (v) In the conceptual groundwater model used for the Project (as well as in the GHD groundwater model) groundwater flow from west to east is occurring against the dip of the geological strata (which is from east to west), which Dr Webb asserts does not typically occur
16. These opinions are used to support Dr Webb's assertion that the artesian groundwater flow to the Doongmabulla Springs Complex is derived from the Colinlea Sandstone via upward flow through the Rewan Formation, where at Paragraph 54 (d) Dr Webb states *"Although faults and fractures in the Rewan Formation might be expected to be self-sealing due to the clay-rich nature of this formation, there is clear evidence that the Colinlea Formation to the west of the Carmichael lease is recharged through the Rewan Formation, which therefore must allow groundwater flow through it in places."*

3.2. Response to Dr Webb's Report

17. It is my opinion that recharge through the Rewan Formation to the west of the Carmichael Project is not required in order to explain the observed groundwater pressures in the underlying Colinlea Sandstone and the subsequent groundwater flow direction in that aquifer from west to east (i.e. in a direction that is up-dip of the geological strata).
18. In order to demonstrate my point I have constructed a simple 2-dimensional groundwater model using the program Seep/W. It should be noted that the model is not intended to be an accurate representation of the geology/hydrogeology of the Project area, but rather has been constructed to demonstrate a concept relating to groundwater pressure and groundwater flow.
19. The model is loosely based on the actual hydrogeology observed along an east-west section through the area of the proposed Carmichael Project and has the following features:
    (ii) The model shows the geology dipping from east to west at a similar dip to that observed for the strata observed at the location of the Carmichael Project, as shown in Figure 3-1 below. The vertical exaggeration of the model section is 40 x.
    (iii) The geological units shown in the cross section model are the same as those observed at the Carmichael Project site and include (from top to bottom, refer Figure 3-1):
        a. Moolayember Formation
        b. Clematis Sandstone
        c. Dunda beds
        d. Rewan Formation
        e. Bandanna Formation/ Colinlea Sandstone
        f. Joe Joe Group
    (iv) The geological units have been given the similar (in most cases the same) horizontal hydraulic conductivity (Kh) values as those applied as the final calibration parameters of the Carmichael Project groundwater model (GHD 2014[2]) as shown below in Table 3-1. The vertical anisotropy applied to the model is 0.1 (i.e. vertical hydraulic conductivity (Kz) is 0.1 times the Kh value). Note that the model also included the same storage properties as those applied to the model, though these properties are not important as the model was run to steady state.

[2] GHD (2014) Carmichael Coal Project. Response to Federal Approval Conditions – Groundwater Flow Model. Report by GHD to Adani Mining Pty Ltd, November 2014.

Table 3-1: Horizontal Hydraulic Conductivity (Kh) Values used in model

Groundwater Unit	Hydraulic Conductivity (Kh) (m/d)
Moolayember Formation	5.18×10^{-2}
Clematis Sandstone	1.55×10^{-0}
Dunda beds	7.90×10^{-2}
Rewan Formation	7.38×10^{-5}
Bandanna Formation/ Colinlea Sandstone	1.00×10^{-4}
Joe Joe Group	1.00×10^{-4} (in GHD model Kh was variable)

(v) Two steady-state models were utilised for the purpose of demonstrating the concepts discussed in this report. These include:
   a. Steady-state model 1, where constant-head boundary conditions were applied to the western and eastern edges of the model to create an initial flat phreatic surface; and,
   b. Steady-state model 2. This model utilised the same boundary conditions at the eastern and western edges of the model as were used for model 1, but included the application of recharge in the topographically elevated area, which is an exaggerated representation of the Great Dividing Range to the west of the Carmichael Project (i.e. the approximate location of the groundwater divide in the GHD model).

(vi) Recharge was applied to Steady-state model 2 at a rate of 2.2% of annual average recharge of 550 mm (i.e. 12 mm/year). Note that this recharge rate was applied for the sole purpose of generating the groundwater mound seen in Figure 3-2, and bears no relation to the recharge rates utilised in the GHD model (where recharge was applied over the entire model surface, whereas in the Seep/W model recharge was only applied to the topographically high area)

20. Output from the model is presented below in Figures 3-1 to 3-6. In summary:

(i) Figure 3-1 shows the layout of Steady-State Model 1, which uses constant head nodes at the eastern and western edges of the model to create an initial flat phreatic surface;

(ii) Figure 3-2 shows the layout of Steady-State Model 2. This model utilised the same boundary conditions at the eastern and western edges of the model as were used for model 1, but included the application of recharge in the topographically elevated area, which is an exaggerated representation of the Great Dividing Range to the west of the Carmichael Project (i.e. the approximate location of the groundwater divide in the GHD model).

(iii) Recharge applied to the topographically elevated region of the model has created a groundwater mound under the recharge area, which can be seen to be intersecting the ground surface to the east of the recharge area in the area where the Clematis Sandstone is outcropping in the model.

(iv) Figure 3-3 shows detail from Steady State Model 2, with groundwater flow velocity vectors turned on in the model. Information from this figure is summarised as follows:
   a. The groundwater flow vectors show both the direction of groundwater flow as well as the relative magnitude of overall groundwater flow in a particular direction (larger vector arrows indicated a greater overall portion of groundwater flow). Note that Seep/W only draws one line of vector arrows in the middle of each grid element; real groundwater flow would occur pervasively through the groundwater unit.
   b. Included on Figure 3-3 is the location of the groundwater divide, i.e. the region of the model where the overall direction of groundwater flow changes from west (down-dip) to east (up-dip)
   c. The groundwater flow vectors are largest in the direction of westward (i.e. down-dip) groundwater flow; however a component of easterly (up-dip) groundwater flow occurs as flow in this direction is controlled by groundwater pressure rather than the dip of the geology;
   d. Groundwater flow occurs principally within the Clematis Sandstone, which is the unit with the highest hydraulic conductivity in the model. Groundwater flow vectors are also visible within the Moolayember Formation and Dunda beds, however no flow vectors are shown in units below

the Dunda beds (Rewan Formation and lower). This is not to say that groundwater flow is not occurring in these units, but that the magnitude of groundwater flow is so small that the flow vectors are not visible for these units.

(v) Figure 3-4 shows a blown-up area of Figure 3-3 in the area of the Clematis Sandstone outcrop. The greatest magnitude of groundwater flow (based on flow vectors) can be seen to be occurring from the boundary between the Clematis Sandstone and the underlying Dunda beds. This figure demonstrates the simplest and most likely explanation as to why the Doongmabulla Springs are occurring at the location that they are, with the reasoning summarised as follows:
   a. The groundwater mound beneath the recharge area does not develop symmetrically. In part this is due to the asymmetry of the recharge area with respect to the boundaries of the model (where the constant heads are located). However the major reason for the asymmetry is interpreted to be related to the presence of the low-permeability Rewan Formation close to surface, which "holds up" the groundwater mound to the east of the recharge area
   b. Groundwater discharge occurs from the model from the highest permeability unit (in this case the Clematis Sandstone) in the area where the aquifer pinches out against underlying lower permeability units
   c. This serves to demonstrate that groundwater flow to the springs can be derived from shallow groundwater units and that the springs in this case are occurring as rejected recharge springs - i.e. downward flow of recharge is prevented by the presence of the low-permeability Rewan Formation, with lateral groundwater flow then discharging to surface as springs in topographically low areas

(vi) Figure 3-5 shows contours of groundwater pressure head from Steady State Model 1. The zero pressure line is the phreatic surface (blue dotted line) with groundwater pressure increasing linearly with depth below the phreatic surface. The variable hydraulic conductivity of the different groundwater units is not perturbing (i.e. deflecting) the pressure contours as the groundwater model has been run to steady-state

(vii) Figure 3-6 shows contours of groundwater pressure head from Steady State Model 2 (incorporating groundwater recharge in the topographically elevated area of the model). This figure demonstrates the following:
   a. Groundwater pressure is elevated beneath the recharge area. This equates to the groundwater divide that occurs in the Colinlea Sandstone to the west of the proposed Carmichael mining area;
   b. Elevated groundwater pressures occur in all units underlying the recharge area, including the Rewan Formation and the underlying Bandanna Formation/ Colinlea Sandstone. This is because:
      i. In a continuous porous medium model (e.g. Seep/W, MODFLOW) all groundwater units below the phreatic surface are saturated with water
      ii. Generally speaking, clay has a higher porosity than a gravel (e.g. in the range of 40% for a clay vs 20-25% for a gravel. However, porosity includes two components; specific yield (the component that drains under gravity flow) and specific retention (the component that remains in the aquifer after gravity drainage has occurred). Gravel has a very high specific yield (i.e. almost all the porosity can be drained) whereas clay has a very high specific retention (i.e. almost none of the porosity can be drained via gravity drainage)
      iii. The high phreatic surface under the recharge area applies pressure to all underlying groundwater units, resulting in a higher pressure head being applied to all units. This would manifest (e.g. for the Colinlea Sandstone) as a higher groundwater level under the recharge area, with lower pressure beneath the groundwater discharge area (i.e. the springs) in the east. This is consistent with the groundwater contours shown as Figure 1 of

the Joint Expert Report, which show groundwater flow occurring from the topographically elevated areas to the west of the mine, towards the east (and centring on the Doongmabulla Spring Complex)

21. It is noted that, based on output from the model discussed in this report, the Colinlea Sandstone is not recharged in areas where the Rewan Formation overlies the Colinlea Sandstone. Actual recharge to the Colinlea Sandstone (where water enters the aquifer) will occur in areas where the unit outcrops or subcrops at shallow depth beneath permeable surface strata.

3.3. Summary

22. In summary, the model output demonstrates that high-permeability flow paths within the Rewan Formation are not required for high groundwater pressures in the underlying Colinlea Sandstone to be generated. The Rewan Formation has been modelled as a uniform low-permeability unit, with high groundwater pressures in the underlying Bandanna Formation/ Colinlea Sandstone unit being generated solely by the weight of water (from the recharge area) acting on an underlying, continuously saturated porous medium. This pressure has been generated in the underlying Bandanna Formation/ Colinlea Sandstone unit without groundwater flow occurring through the Rewan Formation – the elevated water level in the Bandanna Formation/ Colinlea Sandstone is generated simply via pressure transfer alone (i.e. the transfer of pressure through the Rewan Formation can occur without the transfer of water through that unit).
23. The model also demonstrates that the groundwater flow patterns derived from groundwater monitoring data and the GHD groundwater model can be generated based on existing geology – i.e. there is no need to re-map the regional geology to suit the existing patterns of groundwater flow, and up-dip flow of groundwater can occur in cases where groundwater is moving from a region of high groundwater pressure to a region of low groundwater pressure.
24. Based on output from the model discussed in this report, the Colinlea Sandstone is not recharged in areas where the Rewan Formation overlies the Colinlea Sandstone. Actual recharge to the Colinlea Sandstone (where water enters the aquifer) will occur in areas where the unit outcrops or subcrops at shallow depth beneath permeable surface strata.

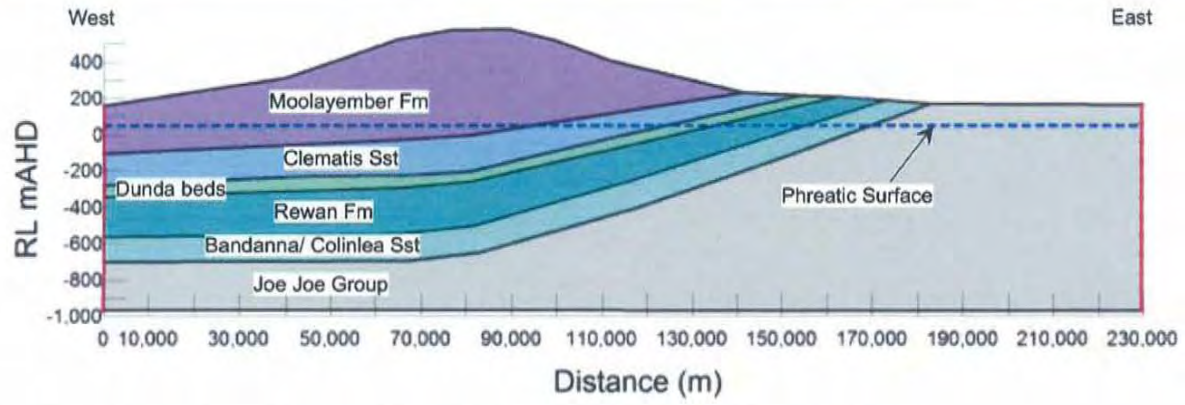

Figure 3-1: Model layout showing phreatic surface for Steady-State Model 1

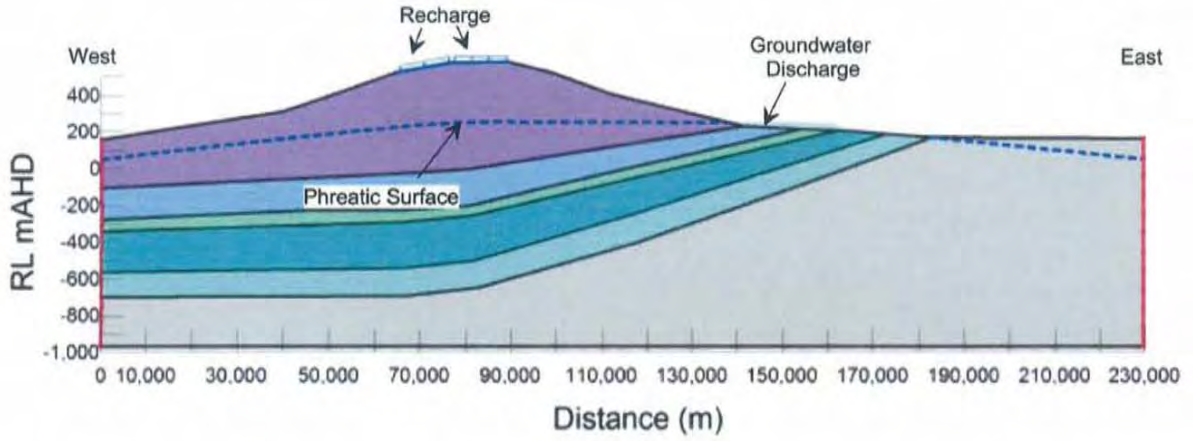

Figure 3-2: Area of groundwater recharge and resulting phreatic surface for Steady-State Model 2

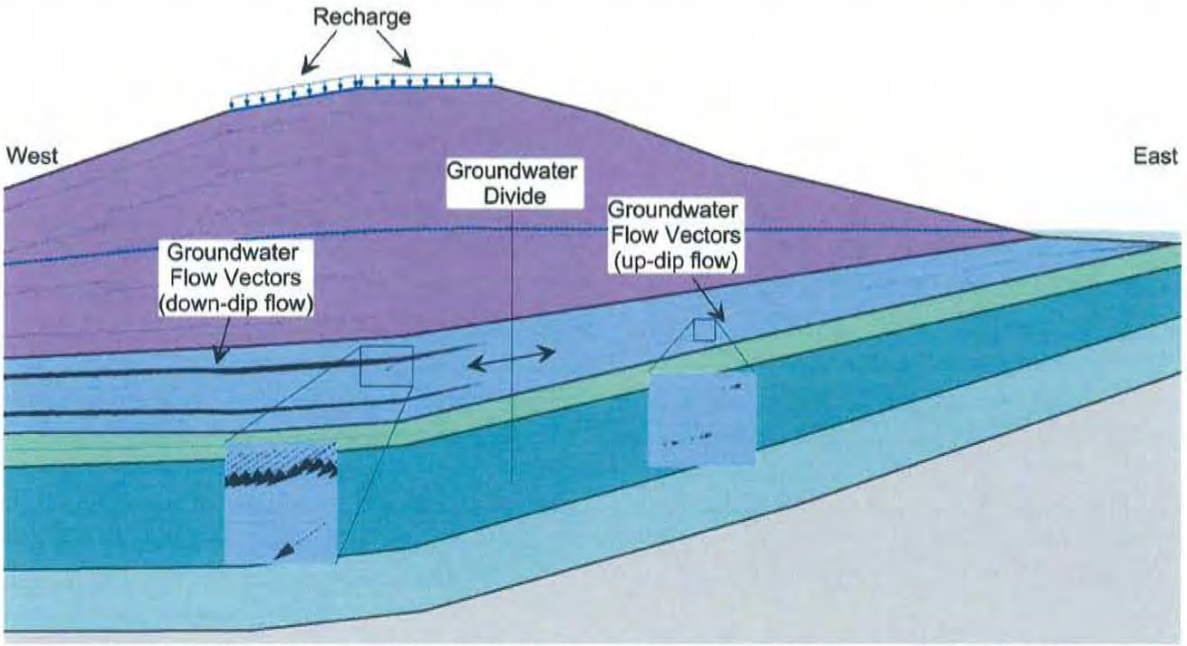

Figure 3-3: Detail from Steady-State Model 2 showing groundwater divide and flow vectors

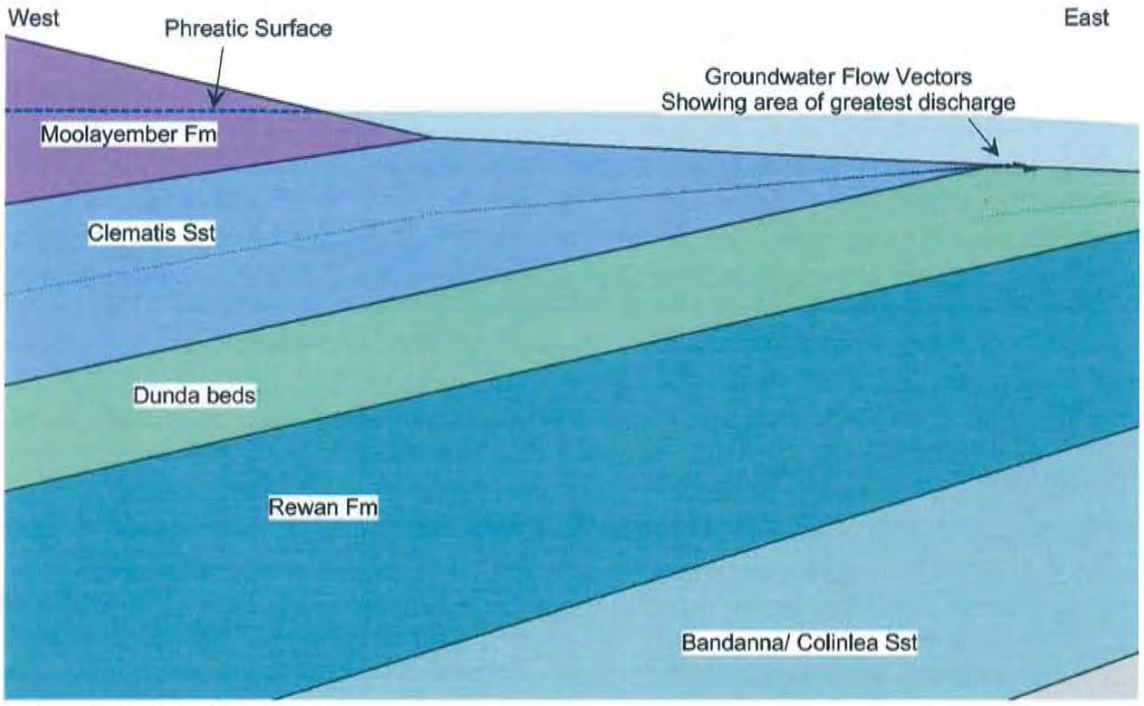

Figure 3-4: Detail from Steady-State Model 2 showing groundwater discharge area

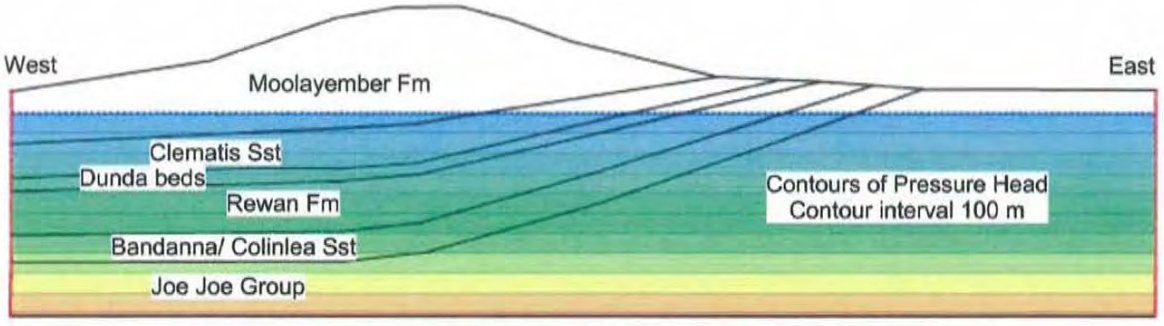

Figure 3-5: Output from Steady-State Model 1 showing contours of Pressure Head

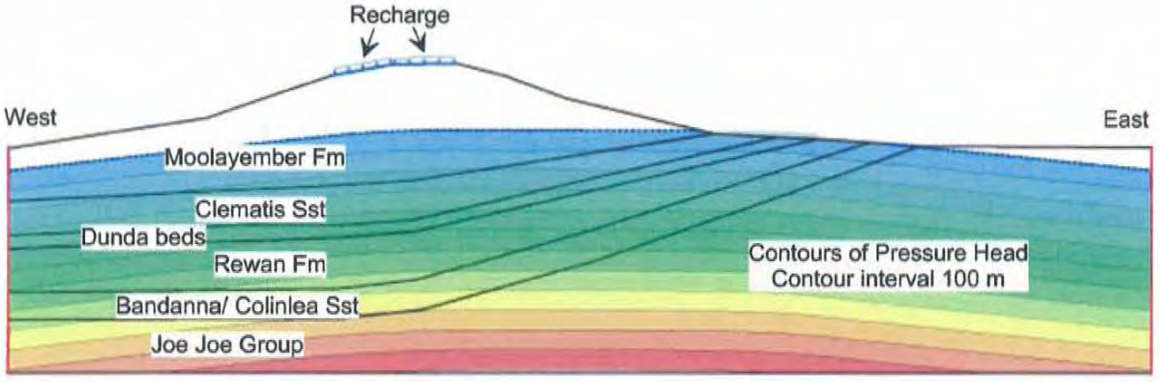

Figure 3-6: Output from Steady-State Model 2 showing contours of Pressure Head

4. Observations Relating to Geological Interpretation

25. Dr Webb relies on well completion reports for Carmichael 1 and Lake Galilee 1 in production of his geological cross sections (refer paragraphs 14, 22 and 26 of Dr Webb's Expert Report). These well completion reports are appended to this report as Appendix A (well completion report for Carmichael 1) and Appendix B (well completion report for Lake Galilee 1).
26. Dr Webb asserts in his discussion of Figures 10 (a to d) that a number of geological features are clearly evident from these figures. For example in the text accompanying Figure 10 (page 21 of Dr Webb's report) it is stated that 10a shows *"Radiometric image, showing pink area (Rewan Formation)"* and Figure 10b shows *"457 image, clearly showing Dunda Beds outcrop"*. However the figures as presented are quite small and all figures are unlabelled. Therefore it is difficult to distinguish the features to which Dr Webb refers.
27. To aid in my interpretation of Dr Webb's report I have registered a number of Dr Webb's figures into the GIS program MapInfo and have included the location of features such as the Joshua and Moses springs, the location of wells including Shoemaker 1, Lake Galilee 1 and Carmichael 1, and the location of photos from Dr Webb's report (based on the latitude/ longitude provided in the caption for Figures 4, 5 and 6 of Dr Webb's report). The figures attached to this report include:
    (i) Figure 4-1, showing the location of features described above with a background of the published 1:250,000 geological maps of Galilee and Buchanan; and,
    (ii) Figure 4-2, showing the location of features described above with a background of the radiometrics image shown as Figure 10a of Dr Webb's report (based on a hard-copy of the radiometrics image which was provided to me by Dr Webb during our joint groundwater experts conclave of 22 December 2014.

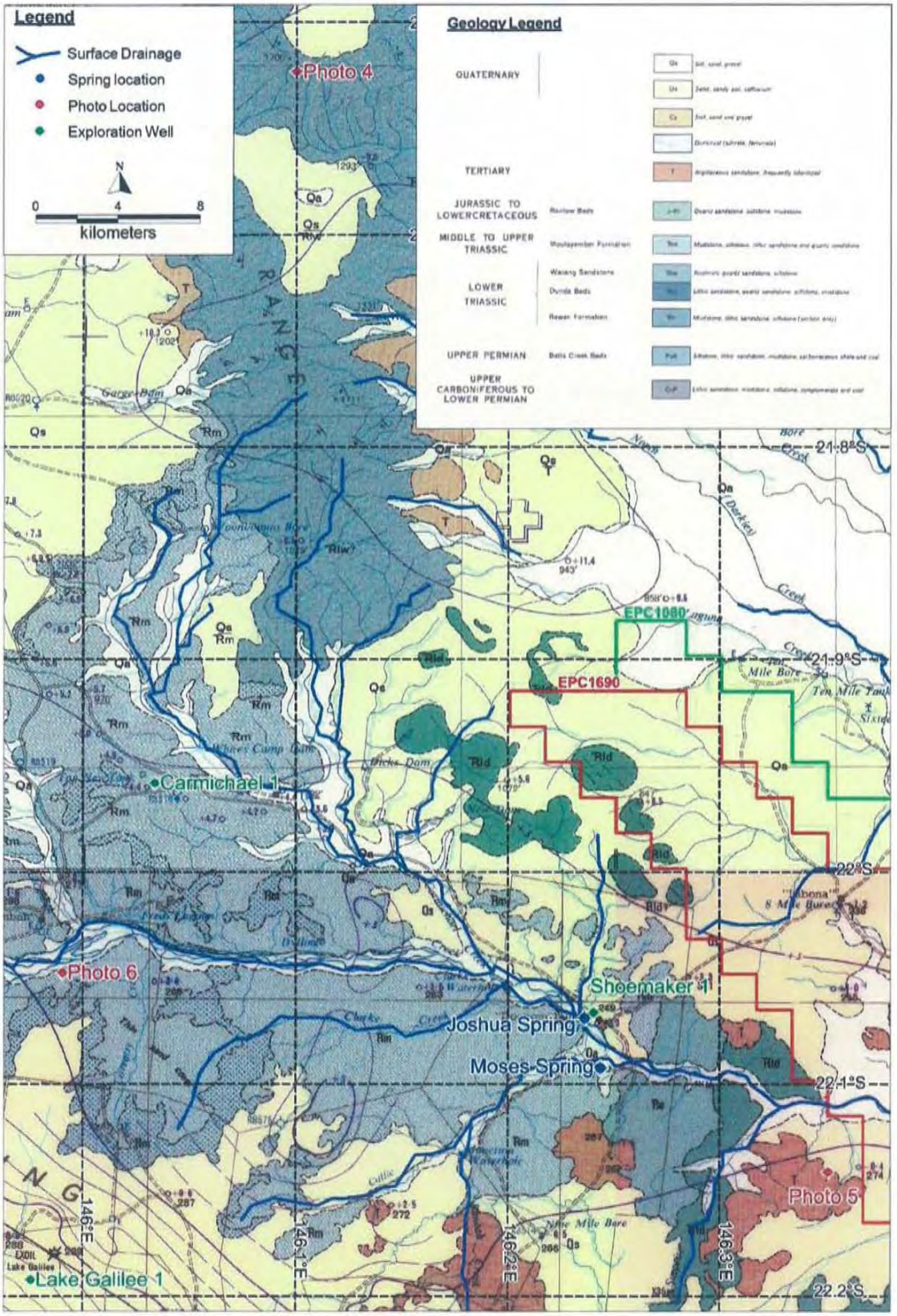

Figure 4-1: Location of Springs, Wells and Photo Locations from Dr Webb's Report with background of 1:250,000 scale geology

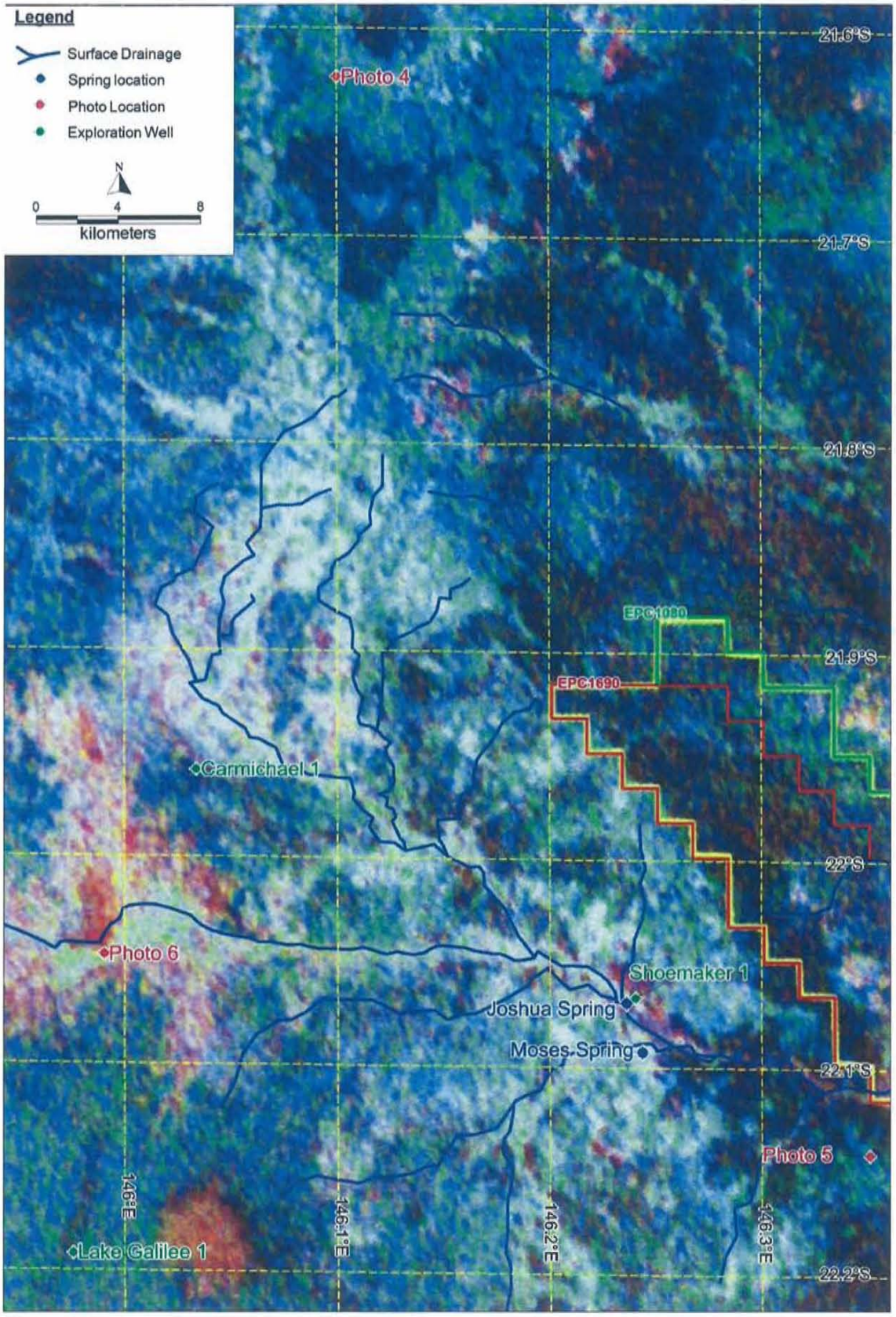

Figure 4-2: Location of Springs, Wells and Photo Locations from Dr Webb's Report with background Radiometrics Image