Level 1, 10 Richardson Street
West Perth WA 6005, Australia

PO Box 943
West Perth WA 6872, Australia

T: +61 8 9288 2000
F: +61 8 9288 2001
E: perth@srk.com.au

www.asia-pacific.srk.com

Lake Disappointment Hydrology Modelling

Client:	Reward Minerals Ltd	**Date:**	25/02/2020
Attention:	Greg Cochran	**From:**	Brian Luinstra
Project No:	REW001	**Revision No:**	3
Subject:	Lake Disappointment Pond Persistence Modelling		

1 Introduction

Reward Minerals Ltd (RML) engaged SRK Consulting (Australasia) Pty Ltd (SRK) to develop a hydrological model to assess the persistence and changing salinity of surface water on Lake Disappointment, a large salt lake system in north-central Western Australia. This included a review of available hydrological and ecological studies completed for the lake and development of a hydrology model to assess surface water pond (see Figure 2-4 – Lake Disappointment Plan) persistence under existing conditions and during extraction of brine from the lake. The objective of the exercise was to develop an understanding of the potential changes of surface water persistence and salinity levels resulting from the proposed development and determine the degree of impacts those changes may have on local fauna habitat.

1.1 Problem definition

RML is seeking to develop the Lake Disappointment Sulphate of Potash Project (the Project), a large brine deposit hosted within the sediments of the Lake Disappointment playa. Extraction of brine hosted in shallow lake sediments is proposed via a network of trenches. Brine extraction via trenches will result in a reduced water table across parts of the lake, and a resultant increase in available water storage in the unsaturated zone. Concerns have been raised that brine extraction will therefore lead to increased infiltration of water that ponds seasonally on the lake sediments, and an associated reduction in either the extent or duration of surface ponding on the playa.

The Banded Stilt (*Cladorhynchus leucocephalus*) is an Australian shorebird that has been known to breed on islands located on Lake Disappointment. The March 2017 survey by Bennelongia (2018) recorded 94,046 adult birds, 49,321 nests on 10 islands, and 7,388 young chicks at Lake Disappointment. This aligns closely with the 93,455 adult Banded Stilt population observed at Lake Disappointment in February 2017. Bennelongia estimates that these numbers represent between 25% (based on estimates from Watkins, 1993) and 46% (based on estimates from Wetlands International, 2018) of the entire species' population.

Banded Stilts require an ephemerally flooded, hypersaline wetland that persists for a minimum of 80–90 days to provide food sources to support successful fledging of young (termed 'recruitment'[1]). Additionally, Banded Stilts typically nest on islands and rely on sufficient water depth in ponds to act as physical barriers to prevent predation of their nests. Based on criteria discussed in Bennelongia (2018), a minimum surface water persistence of more than 80 days with a water depth greater than 10 cm is assumed to be necessary to support a recruitment event. In addition to pond depth, banded stilts rely on brine shrimp as their primary food source. These salt tolerant invertebrates typically reproduce in waters with a salinity less than 30,000 mg/L, but can persist in water having a salinity up to approximately 100,000 mg/L.

[1] Pedler, RD, Ribot, RFH and Bennett, ATD, 2017. Long-distance flights and high-risk breeding by nomadic waterbirds on desert salt lakes, *Conservation Biology,* Article DOI: 10.1111/cobi.13007.

The Lake Disappointment playa is considered an important habitat for Banded Stilts largely attributed to the topography of the playa surface itself. The playa is known to flood completely, and also has a number of depressions in which ponds form as the flood waters recede (evaporate) which allow water to persist for extended periods of time, allowing for nesting, fledging and recruitment of the Banded Stilt. In addition, the presence of several elevated areas on the playa surface which are not subjected to flooding (ephemeral 'islands') provide preferred breeding grounds for the Banded Stilt, as the flooding prevents predation by terrestrial fauna.

The assessment is complicated by the general lack of long-term monitoring data for Lake Disappointment. There are no long-term records of rainfall and/ or pond development, and references to pond formation on the lake and Banded Stilt nesting and recruitment are anecdotal and infrequent.

1.2 Methodology

To address the identified knowledge gaps in historical pond development on Lake Disappointment, SRK developed a deterministic and stochastic hydrology model using GoldSim (v.12) software. A base case model was developed using all available information for the lake, and was used to estimate daily fluxes of water, pond volumes and ultimately to determine the length of pond persistence. Two additional scenarios were incorporated to assess the impact of the proposed development on pond formation frequency and persistence times.

1.3 Previous studies

The following reports were available and used in the development of the model:

- Environmental Review document – Lake Disappointment Potash Project. Letter to Dr Michael Ruane (Reward Minerals Pty Ltd) from Peter Tapsell (DWER), March 2018.
- Lake Disappointment groundwater-dependent vegetation spectral data analysis – NDVI, NDWI and ET calculations. Memorandum to Dan Tenardi & Lisa Chandler (Reward Minerals Pty Ltd) from Phil Whittle (Hydrobiology), August 2017.
- Public Environmental Review for Lake Disappointment Potash Project – Environmental Scoping Document approval. Letter to Dr Michael Ruane from Tom Hatton (Environmental Protection Authority), October 2016.
- Draft Environmental Review Document for Lake Disappointment Potash Project. Prepared by Reward Minerals Pty Ltd, January 2019.
- Environmental Review Document comment table – Lake Disappointment. Summary prepared by Reward Minerals based on information from DWER dated 5 May 2019.
- Lake Disappointment SOP Project: Brine Collection, Evaporation Ponds and Residue Disposal Concept Study. Prepared by Knight Piésold Consulting, December 2016.
- Lake Disappointment – Hydrological Study. Prepared by Knight Piésold Consulting, January 2017.
- Lake Disappointment 2017 Flooding Hydrology Calculations. Memorandum to Daniel Tenardi from Phil Whittle.
- Lake Disappointment Fauna Impact Assessment. Prepared by Terrestrial Ecosystems and Bennelongia, 2018.

2 Modelling

2.1 Conceptual model

A simple conceptual model for Lake Disappointment was developed to guide development of the deterministic numerical model and is provided in Figure 2-1. Runoff from the playa surface is only generated once the storage capacity of the unsaturated zone is filled. (In practice it is possible to generate runoff if the precipitation rate exceeds the infiltration rate; however, given the highly permeable nature of the lake bed sediments, it is assumed for the purposes of modelling that the infiltration rate is greater than the maximum precipitation rate.) Flow into the unsaturated zone is derived from both precipitation onto the lake bed, as well as run-on derived from creeks which discharge into the lake (also known as 'run-on'). The only losses out of the unsaturated zone are from evaporation. Maximum storage in the unsaturated zone is calculated at each time-step as the total volume of the unsaturated zone (a function of the depth of the unsaturated zone multiplied by the area not inundated by the pond) multiplied by the specific yield of the unsaturated zone.

Once the unsaturated zone storage is filled, any additional inputs from playa surface and run-on from tributary creeks is conveyed to the playa surface (herein termed 'runoff') and a pond (or ponds) will form on the playa, after which precipitation and evaporation are the key processes governing the persistence of surface water in the pond. Conceptually, the dominant source of runoff into the ponds is from direct precipitation on the playa. The key inputs into the pond are direct precipitation (while a pond persists) and runoff from the playa surface (and to a small degree run-on from creeks), with the only losses out of the pond from evaporation.

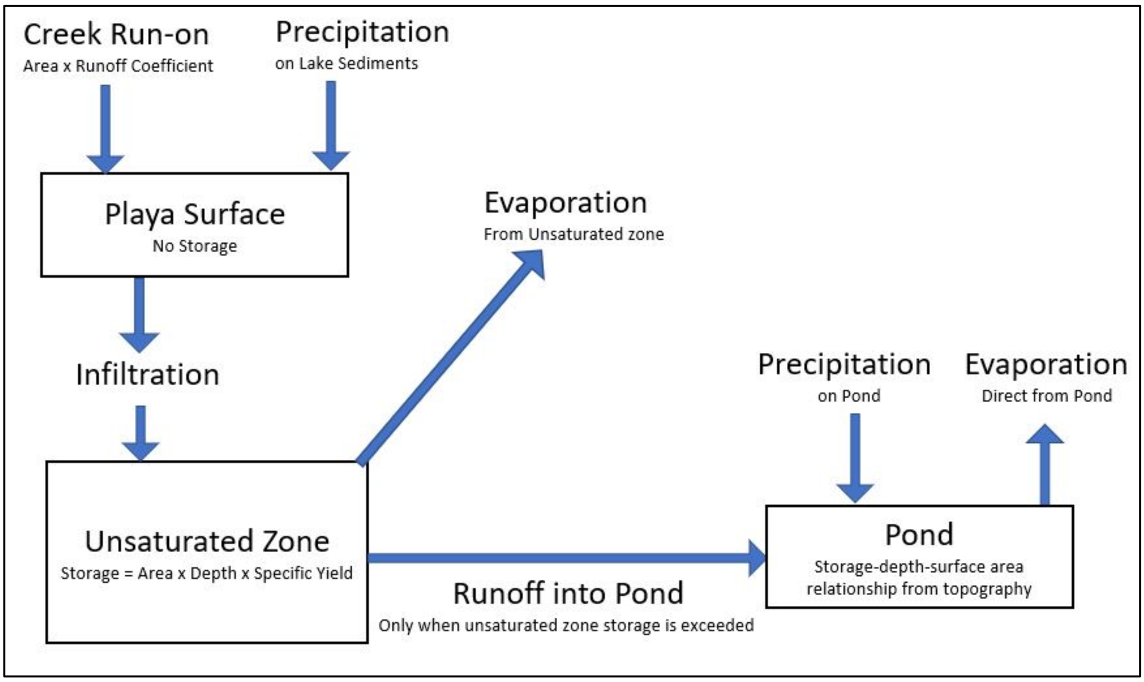


Figure 2-1: Conceptual hydrology model for pond development on Lake Disappointment

2.2 Data Inputs

2.2.1 Precipitation

Precipitation in the project area is characterised by long periods of drought, with occasional rain events (typically 1–2 per year) of varying intensity, with significant rainfall events (i.e. >50 mm) common on an annual to biannual basis. RML has been recording precipitation for the project area since 2017; however, the available data record is not long enough to provide meaningful input into the model. Knight Piésold (2017) determined that the most applicable precipitation record is that of Telfer Airport (Bureau of Meteorology (BOM) Station # 13030). Daily rainfall records for 1974–present are available from the Telfer meteorological station. SILO is a database of Australian climate data from 1889 to the present. It provides daily meteorological datasets for a range of climate variables in ready-to-use formats suitable for biophysical modelling, research and climate applications. SILO uses mathematical interpolation techniques to infill gaps in time series and construct spatial grids. SILO uses spatial and point predictive methods to interpolate rainfall data sets to extend existing periods of record. In this case, the SILO data from the Telfer BOM station was available for the period 1889–2018, extending the available data from 1889 to 1974.

A SILO record for the Telfer Airport BOM station was reviewed and prepared for use in the model. The final period of record for use in the model was established as 1900–2018[2], inclusive.

The rainfall records show a distinct pattern of rainfall events, typically in the first quarter of the year, and on a biennial to annual frequency. Notably, there are extended periods lasting several years with no recorded rainfall, and intervening periods where significant (i.e. >50 mm) rainfall events occur on an almost annual basis.

Using the SILO data, SRK developed a predictive, stochastic rainfall module from the Telfer data using the WGEN weather generator. The WGEN-derived stochastic rainfall was able to successfully produce similar average rainfalls over the period of record (i.e. 1989–2018, inclusive), though it is

[2] Note that data from 1889 to1900 was omitted only as the dates are not compatible with Microsoft Excel or GoldSim software.

noted that in the WGEN-produced data the frequency of significant rainfall events was slightly higher (typically annual), and the intensity of events lower. Comparisons of the monthly average rainfall data simulated in WGEN and the existing SILO record for Telfer are provided in Figure 2-3. Given the close approximation of the monthly and annual average, the WGEN-generated rainfall was considered acceptable for use in assessing pond persistence.

Rainfall records used for the deterministic model runs and for development of the stochastic rainfall are shown graphically in Figure 2-2.

2.2.2 Evaporation

Monthly average evaporation values are available from the Telfer Airport BOM Station and were used in the model. Daily rates are derived from the monthly values for each time-step. Evaporation values used for the deterministic model are shown graphically in Figure 2-2.

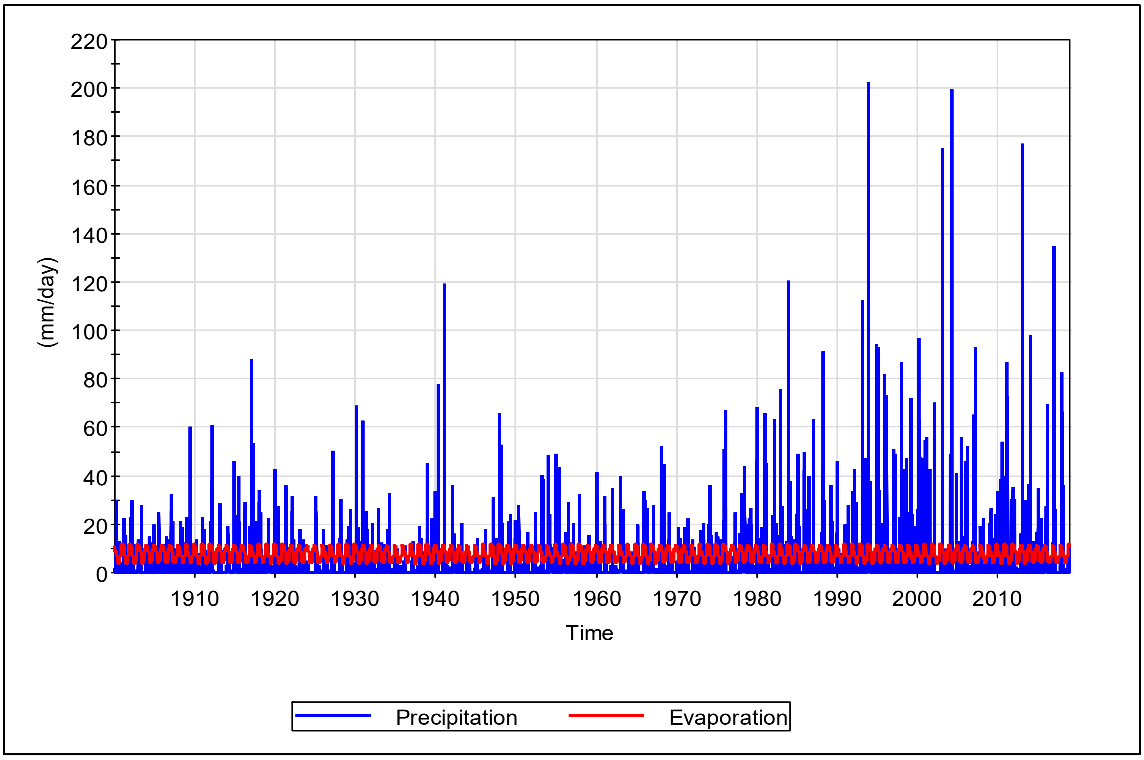


Figure 2-2: Deterministic daily rainfall and evaporation

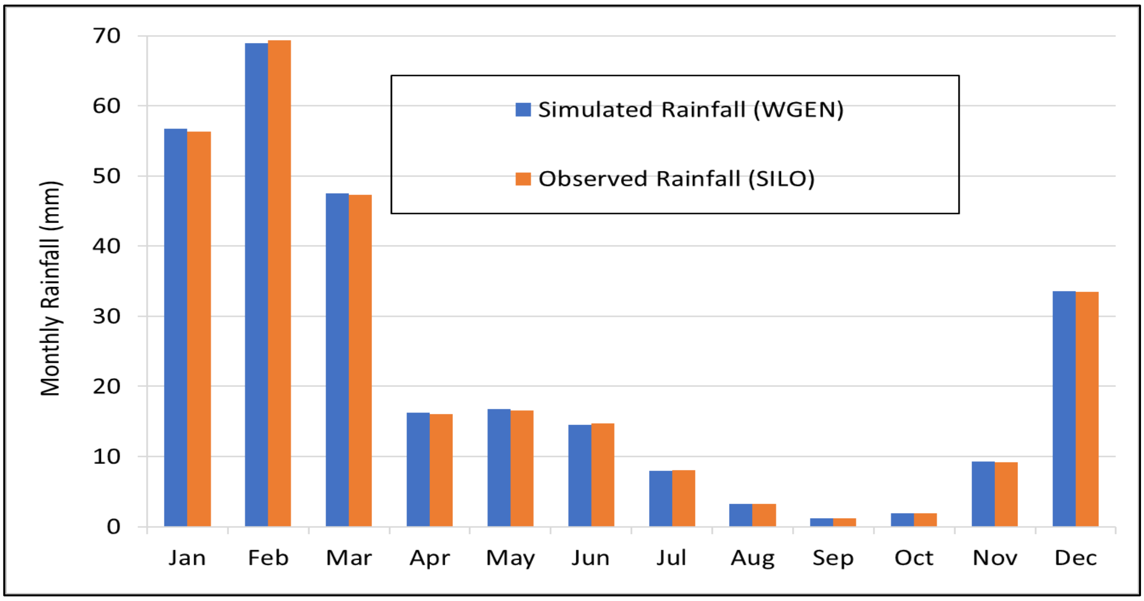


Figure 2-3: Comparison of simulated (WGEN) rainfall and SILO rainfall record (Telfer Airport)

2.2.3 Pond storage

A stage-storage relationship for the Lake Disappointment pond was developed from available topography data and survey elevations collected by RML. The data was processed in AutoCAD, and a 3D model created from which the pond capacity (storage) and pond surface area was calculated for each 1 cm change in potential water depth in the pond (stage).

Due to the generally flat topography of the lake bed, small changes in elevation can result in large changes in surface area and thus water available for evaporation. At a conceptual level, evaporation is the only source of loss from the pond and it would be expected that the modelled pond persistence would be highly sensitive to changes in surface area. Given the ±10 cm estimated level of accuracy for the available elevation data, this is a source of potential uncertainty in the model; however, it is the opinion of SRK that the uncertainties are unlikely to have an impact on the results of the modelling exercise.

2.2.4 Additional hydrologic inputs

Additional hydrologic inputs for the model were derived from existing reports and studies completed by RML and maintained within the model as an initial setting for consistency. Table 2-1 lists the parameters used, as well as a description of the parameter and the source of the information.

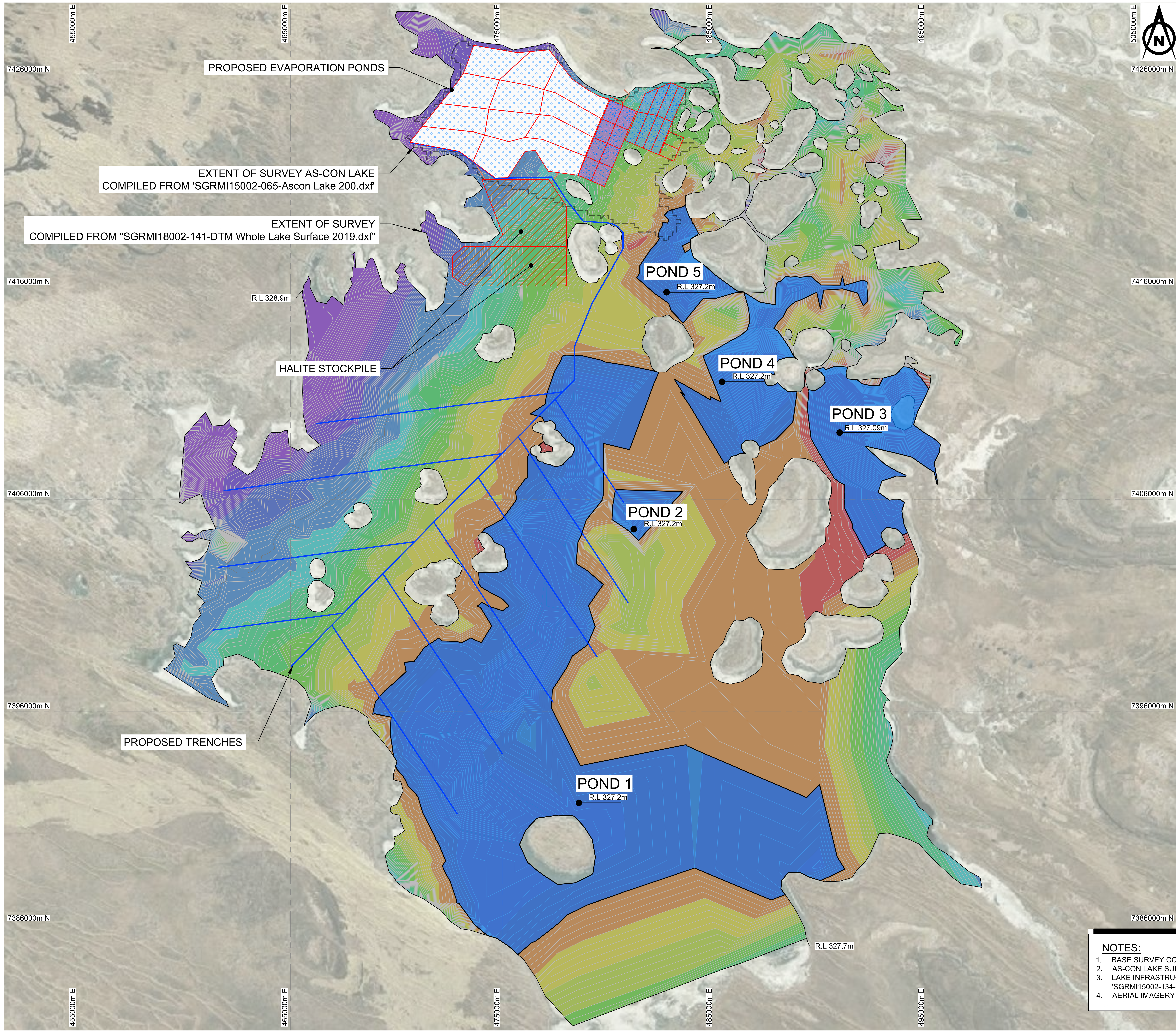
Table 2-1: Additional inputs into the model

Parameter	Value	Description	Source
Pan Factor	0.7	Adjustment from pan evaporation to actual evaporation	Estimated
Specific Yield (Sy)	0.15	Portion of unsaturated zone available for storage	Estimated from resource drilling results
Unsaturated Zone thickness	0.7 m	Thickness of the unsaturated zone	Estimated from available groundwater monitoring data
Unsaturated Evaporation Factor	0.25	Reduces evaporation from unsaturated zone as a portion of daily evaporation	Estimated
Lake Area	1,241 km^2	-	Knight Piésold flood study (2017)
Contributing Creek Effective Catchment area	2,318 km^2	Area within the catchment which contributes runoff to Lake Disappointment	Knight Piésold flood study (2017)
Runoff co-efficient	0.04	Used to estimate runoff for an area	Knight Piésold flood study (2017)

2.3 Calibration targets

Due to the remoteness of Lake Disappointment there is a general lack of monitoring data for the period of record from which to develop calibration targets. Knight Piésold (2017) used satellite imagery to assist with calibration of single events, and more recent pond formation events have been recorded anecdotally. Anecdotal information from Reward Staff indicate that pond formation occurs after large (i.e. >50 mm) rainfall events.

Multiple Landsat images of the Lake were available for 2017, which captured a pond formation event in January. These are provided in Figure 2-5. These images were compared with the simulated pond depths for the same period which are provided in Figure 2-6. The modelled data shows good correlation with observed results and suggests that the model is simulating pond persistence well.



Elevations Table

Colour	Minimum Elevation	Maximum Elevation
	326.2	327.1
	327.1	327.2
	327.2	327.3
	327.3	327.4
	327.4	327.5
	327.5	327.6
	327.6	327.7
	327.7	327.8
	327.8	327.9
	327.9	328.1
	328.1	328.3
	328.3	328.5
	328.5	329.3

LEGEND

- POND
- HALITE STOCKPILE
- CAUSEWAY
- PROPOSED EVAPORATION PONDS
- PROPOSED TRENCHES

NOTES:

1. BASE SURVEY COMPILED FROM'SGRMI18002-141-DTM Whole Lake Surface 2019.dxf'
2. AS-CON LAKE SURVEY COMPILED FROM 'SGRMI15002-065-Ascon Lake 200.dxf'
3. LAKE INFRASTRUCTURE COMPILED FROM CLIENT`S EMAIL DATED FROM 18.07.19 'SGRMI15002-134-Contours & Lake Infrastructure.zip'
4. AERIAL IMAGERY GEOREFERENCED USING GEOLOCATION ONLINE MAPS IN CIVIL 3D

2000 0 2000 4000 6000 8000 10000
SCALE 1:100,000

FIGURE 2.4 - LAKE DISAPPOINTMENT PLAN

SCALE 1:100,000

CONTOUR INTERVALS U.N.O.
EXISTING TOPOGRAPHY: 0.02m & 1m
DESIGN TOPOGRAPHY: N/A

COORDINATE SYSTEM
HORIZONTAL DATUM: GDA94
VERTICAL DATUM: AHD71

FINAL ISSUE
PLOTTED: Tuesday, 11 February 2020 10:06:55 AM

REFERENCE DRAWING TABLE

DRAWING No.	DRAWING TITLE

REVISION HISTORY TABLE

REV.	REVISION DESCRIPTION	DRAWN	DESIGNED	REVIEWED	APPROVED	DATE
1	FINAL ISSUE					
0	FINAL ISSUE	PETR			LUIN	05.02.20

SHEET SIZE A1

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srk consulting

SRK Perth 10 Richardson Street, West Perth, Western Australia 6005
Tel: +61 8 9288 2000 - Fax: +61 8 9288 2001 - http://www.srk.com.au/

LEAD PROJECT DRAFTER	PROJECT MANAGER
A.PETROVSKI	B.LUINSTRA

FILE: P:\REW001 - LAKE DISAPPOINTMENT HYDRO REVIEW\04_WORKING_FILES_\DRAFTING\00 - DRAWINGS\02 - FIGURES\REW001-FIG-01

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LAKE DISAPPOINTMENT HYDRO REVIEW

DRAWING TITLE
FIG-2.4 - LAKE DISAPPOINTMENT PLAN

DRAWING NUMBER
REW001-FIG-01

REVISION
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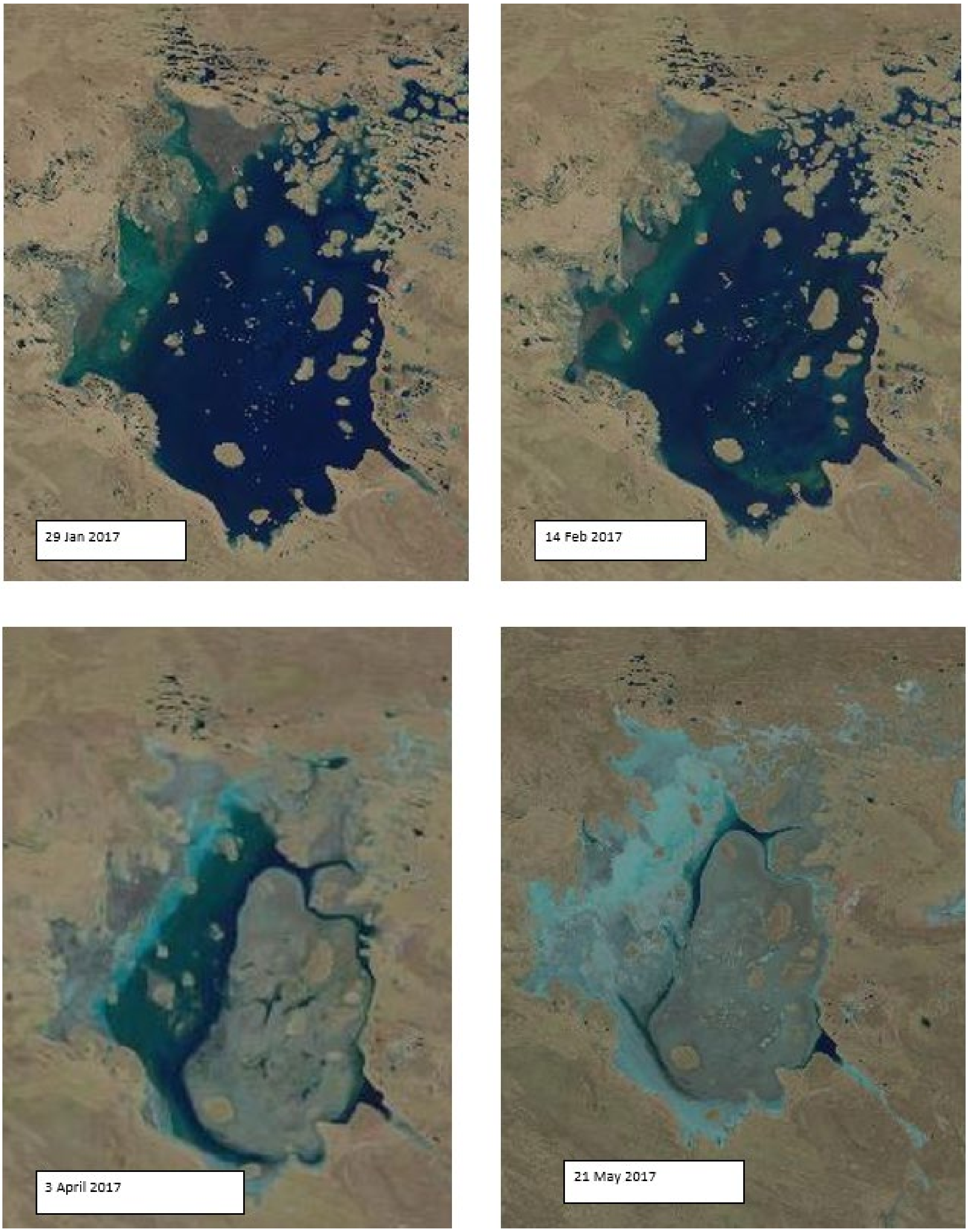


Figure 2-5: Landsat imagery of Lake Disappointment from 2017 ponding event

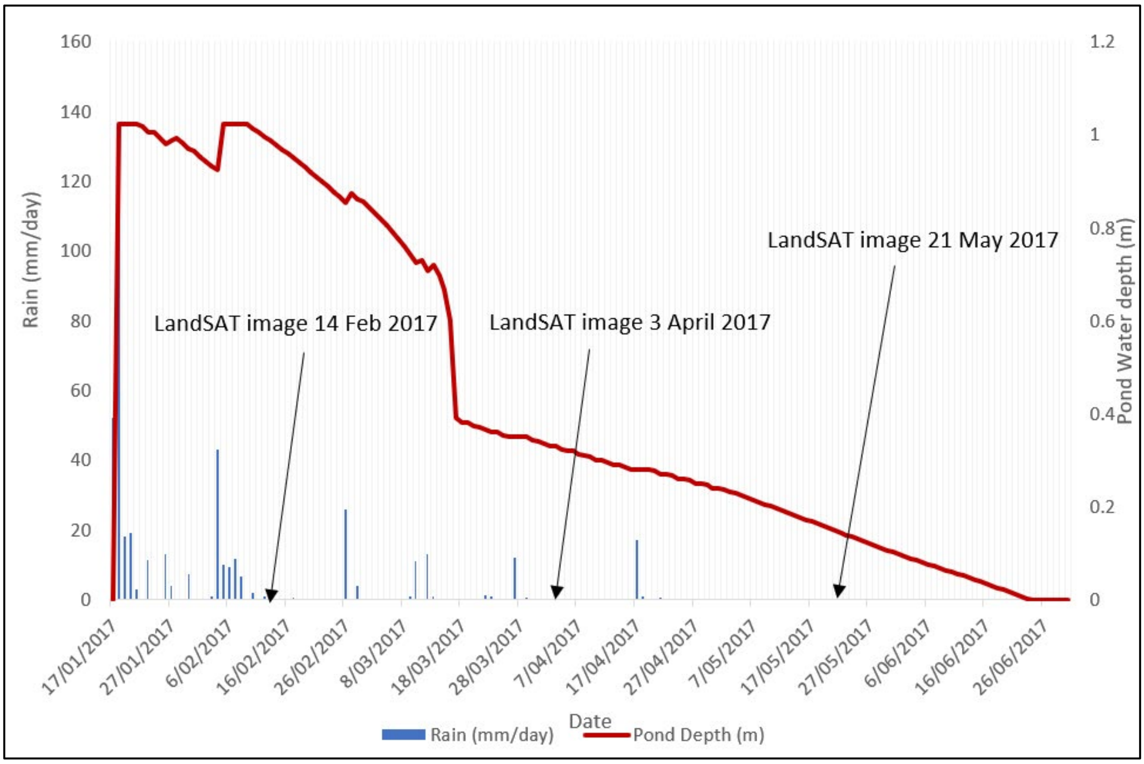


Figure 2-6: Simulated results of the 2017 ponding event

2.4 Modelled scenarios

The model was established and run in deterministic mode for the period of record (1900–2017, inclusive) and calibrated to existing conditions where existing data allowed.

The following four scenarios were developed in order to assess pond persistence:

- Base Case Scenario: Developed to represent current conditions based on the extensive knowledge base for the Project developed by RML using the parameters outlined in Table 2-1. The base case was used to complete a high-level calibration of the model.
- Scenario 1: Involved increasing the depth of the unsaturated zone to represent the drawdown effects of brine extraction; a nominal depth of 1.5 m was used (base case: 0.7 m) and was estimated from trench pumping test data and numerical groundwater modelling from the lake. The specific yield was also altered to reflect the larger unsaturated zone; as specific yields will decrease slightly with depth, a conservative nominal specific yield of 0.10 was adopted (compared to the 0.15 reported in Table 2-1 which was from resource drilling programs).

Additional scenarios were developed using the stochastic rainfall simulator which used a probabilistic approach to run forward-looking assessments in order to simulate future potential impacts, these include:

- Scenario 2A: Used stochastic rainfall to predict likely ponding events for an assumed life of mine of 30 years from 2020 using the base case hydrologic inputs.
- Scenario 2B: Used the stochastic rainfall to predict likely ponding events for an assumed life of mine of 30 years from 2020 using the Scenario 1 modifications to reflect potential conditions during brine extraction.

3 Results

3.1 Scenarios

3.1.1 Base case (Calibration)

The base case scenario was used to calibrate and refine the model against historical data. Given the lack of comprehensive calibration data, model outputs were compared against known information for the Project to evaluate the validity of the results. Results for the base case scenario are provided in Figure 3-1, Figure 3-2 and Figure 3-3. the depth (Figure 3-1) of the unsaturated zone ranges from 0 m to 1.0 m below ground surface and is broadly consistent with observed water levels, including seasonal changes, in the Lake Disappointment sediments (RML, personal communication). Modelled water table levels decline and storage in the unsaturated zone increases during dry periods via evaporation, consistent with estimated rates of decline after precipitation events (RML, personal communication).

Runoff generated from the playa surface (Figure 3-2) and flowing into the pond is generated in the model only when storage in the unsaturated zone is exceeded, and corresponds well with recorded rainfall events (Figure 2-2). Pond development typically occurs after rainfall events of more than 50 mm/day, which is consistent with anecdotal and historical accounts.

After large rainfall, run-on and runoff events, pond persistence is primarily governed by direct rainfall on the pond and evaporation rates from the pond. In Figure 3-3, pond persistence is presented as the duration of water depths (over years), which is again consistent with anecdotal and historical accounts. Within the model, the pond reaches maximum capacity for most events.

This is primarily due to constraints in the stage-storage relationship from the available topographical data which limit pond volume and area to the footprint of the playa. However, the areas outside the playa would be expected to have very shallow water depths (i.e. less than 2 cm) and would not have significant impact on the results of the modelled pond persistence due to the high evaporation rates (typically 10–15 mm/day).

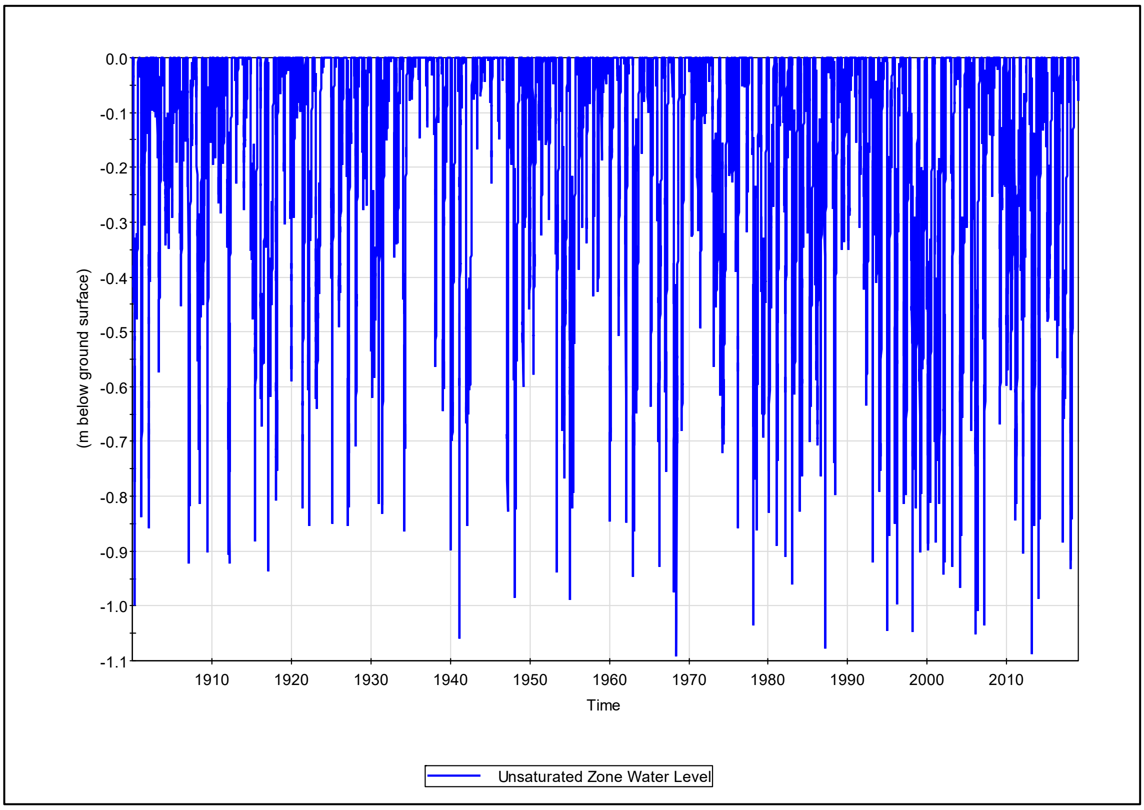


Figure 3-1: Unsaturated zone water levels – 1900–2018

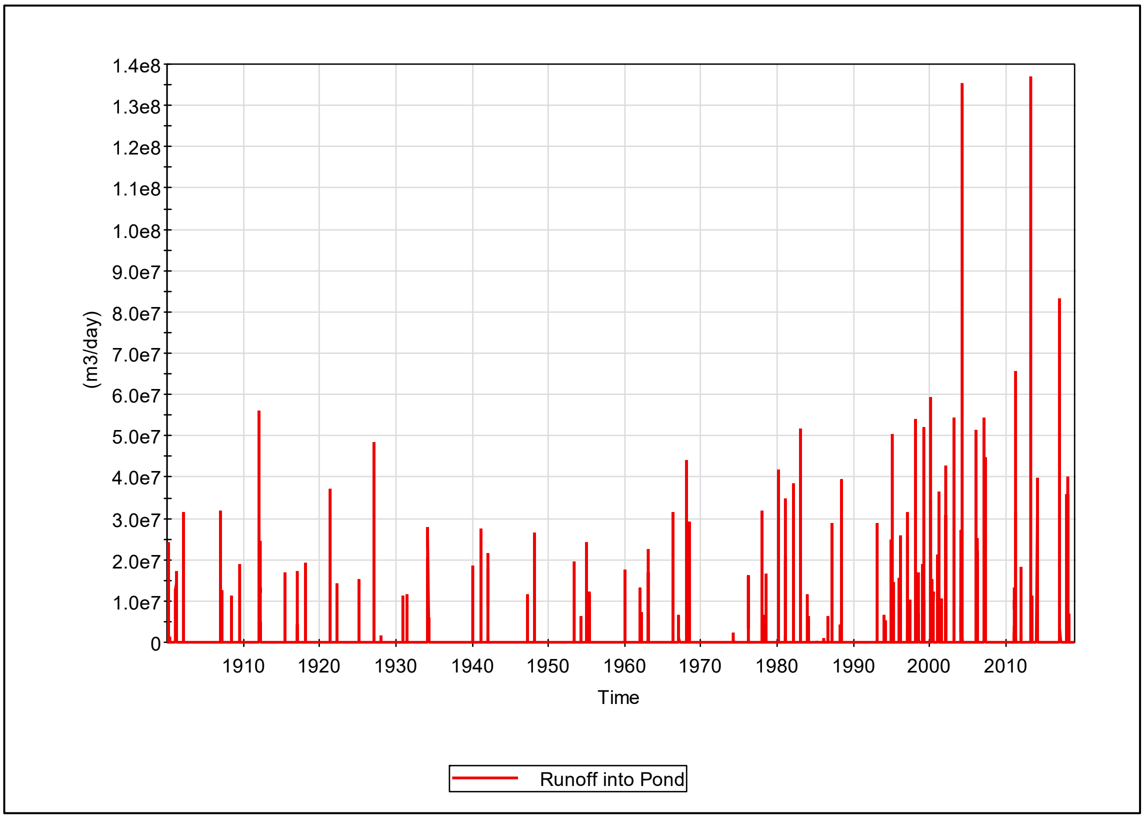


Figure 3-2: Runoff from Lake Disappointment Playa surface to pond – 1900–2018

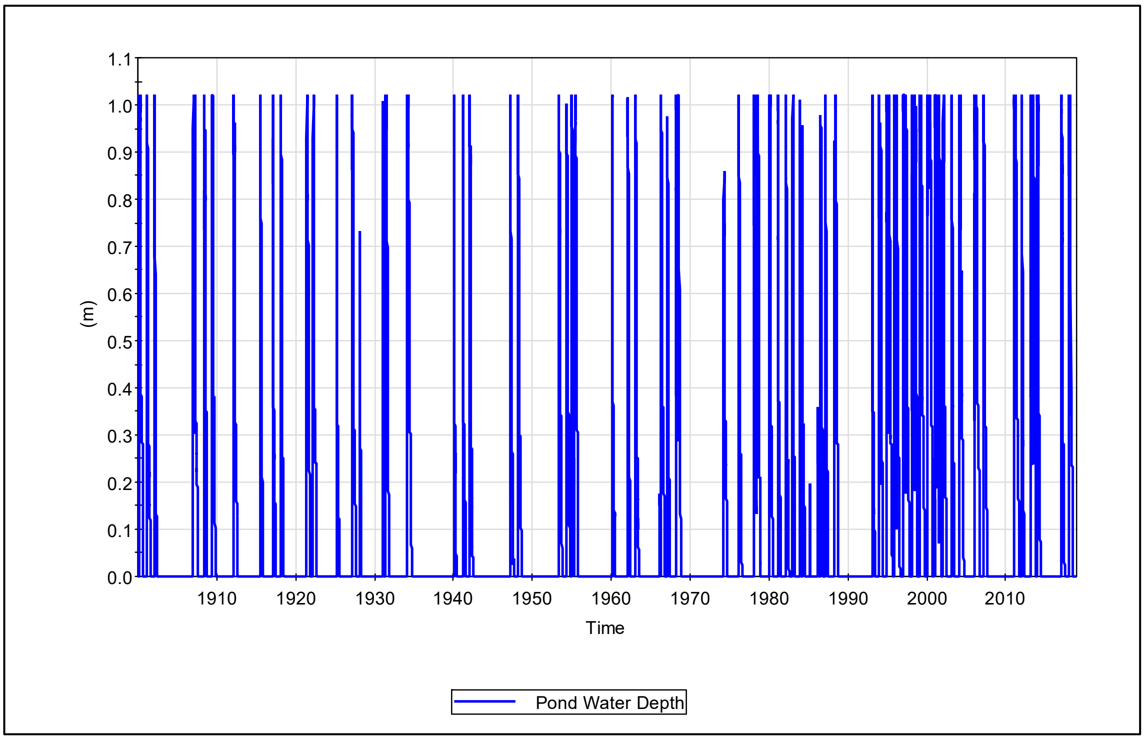


Figure 3-3: Water depths in ponds – 1900–2018

Modelled pond persistence is provided in Table 3-1 for the base case scenario and is discussed in more detail in Section 3.3.

Overall, within the constraints of the available input and calibration data, the model appears to be simulating the lake hydrology system well under base case conditions.

3.1.2 Scenario 1

Scenario 1 was developed to assess the impact of drawdown within the Lake Disappointment sediments on pond persistence. Accordingly, the initial depth of the unsaturated zone (and thus available storage within the zone) was established at 1.5 m, and a conservative specific yield of 0.10 was once again adopted in the model. Results for the Scenario 1 are provided in Figure 3-4, Figure 3-5 and Figure 3-6. Water table depth (Figure 3-4) in the unsaturated zone ranges from 0 m to 2.3 m below ground surface and is consistent with expected water levels during brine extraction from the Lake Disappointment sediments, derived from trench pumping tests and groundwater modelling.

Due to the increased available storage in the unsaturated zone, the frequency and magnitude of runoff events from the lake bed (Figure 3-5) is reduced. The reduction in modelled runoff events is typically noted for small, short-duration precipitation events (i.e. <50 mm over a day) for Scenario 1 conditions. Although this represents an appreciable change from modelled base case results, the small events are unlikely to result in significant pond persistence and therefore are unlikely to have an impact on Banded Stilt recruitment events.

Modelled pond persistence is provided in Table 3-1 for Scenario 1 and is discussed in more detail in Section 3.4.

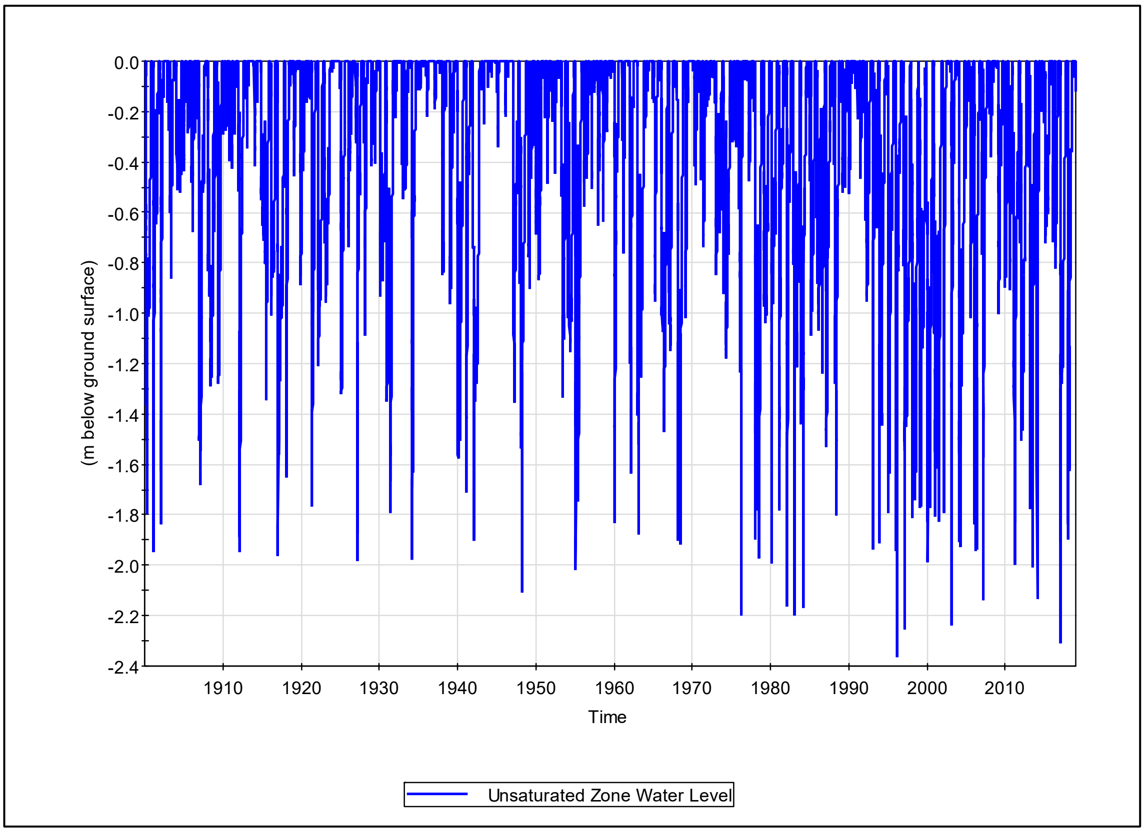


Figure 3-4: Unsaturated zone water levels – operational conditions (Scenario 1) – 1900–2018

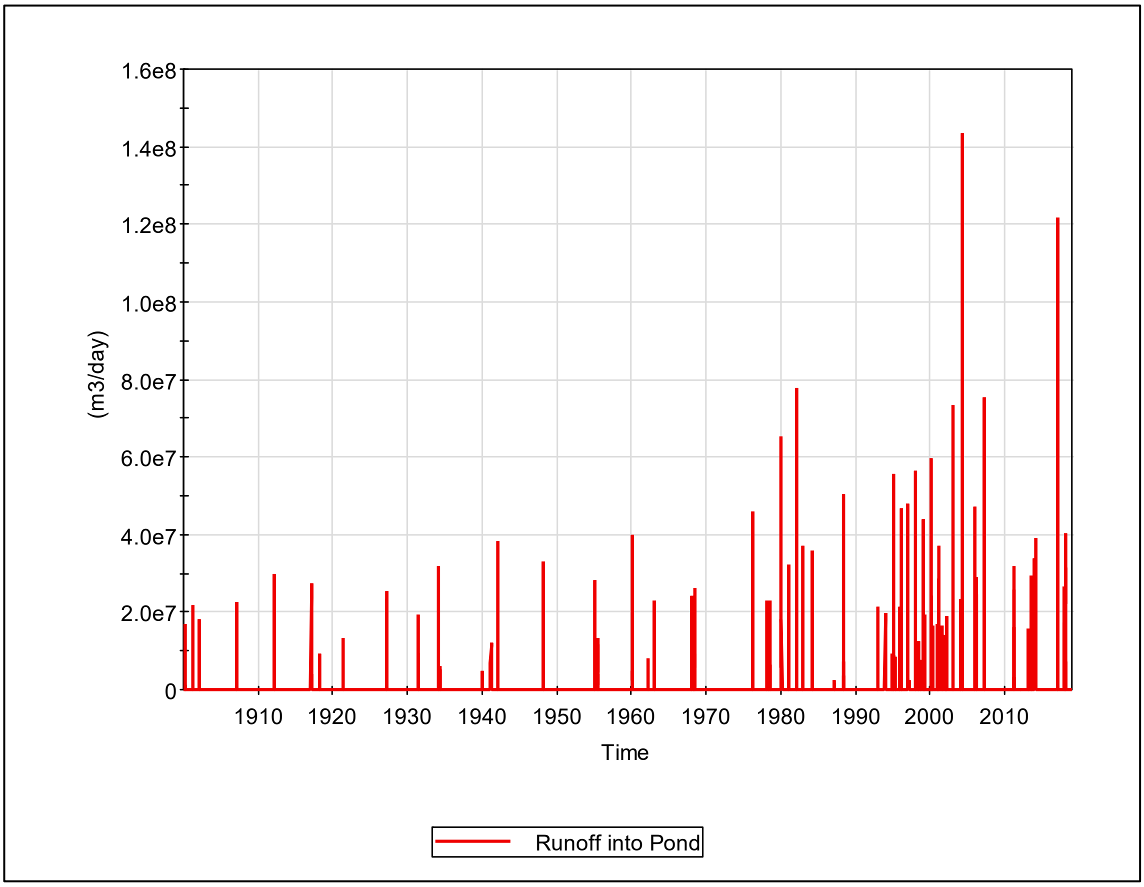


Figure 3-5: Runoff from Lake Disappointment surface to pond – operational conditions (Scenario 1) – 1900–2018

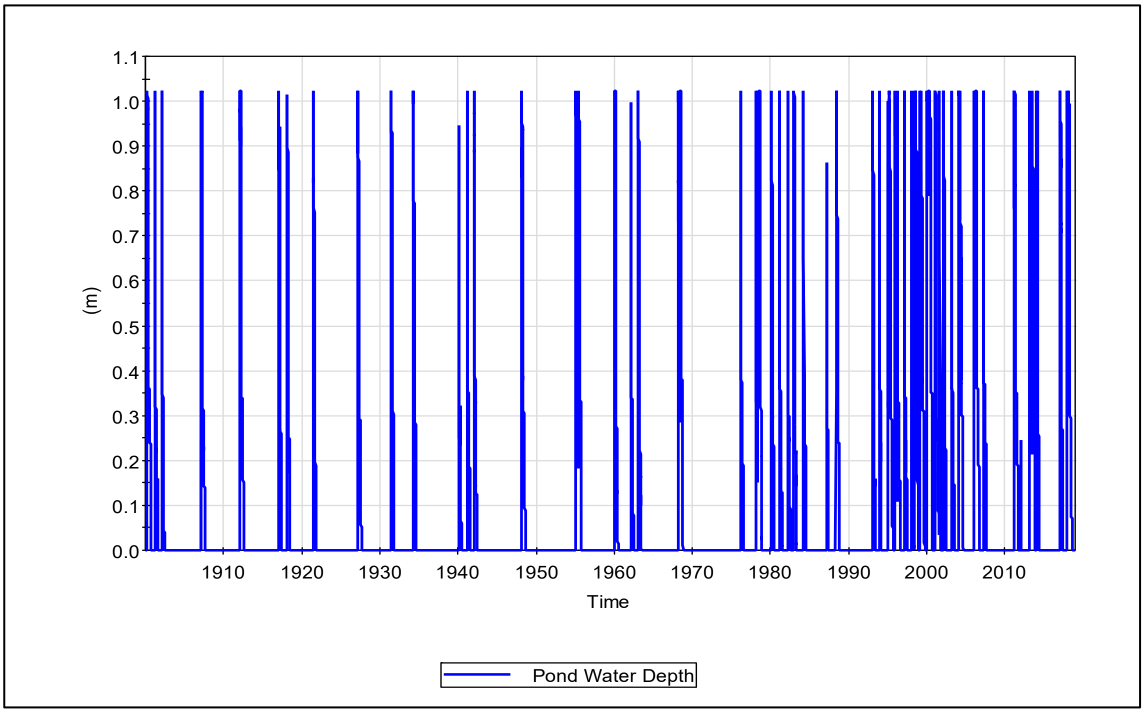


Figure 3-6: Water depths in pond – operational conditions (Scenario 1) – 1900–2018

3.1.3 Deterministic modelling results

The results of the deterministic exercise, developed to compare historical and current conditions with potential operational conditions for the period 1900–2018, are provided in Table 3-1. Discussion of the results is provided in Section 3.4.

Table 3-1: Modelled pond persistence and potential recruitment events – 1900–2018

Event Date	Pond persistence (days)		Notes
	Base case	Scenario 1	
May 1908	147	-	Potential recruitment event – Winter rain
June 1909	122	-	Potential recruitment event – Winter rain
February 1912	168	135	Recruitment unlikely – Summer event
January 1917	123	128	Recruitment unlikely – Summer event
February 1927	166	141	Recruitment unlikely – Summer event
May 1931	151	120	Potential recruitment event – Winter rain
March 1934	179	152	Recruitment unlikely – Summer event
January 1942	121	133	Recruitment unlikely – Summer event
February 1948	164	147	Recruitment unlikely – Summer event
May 1955	152	134	Potential recruitment event – Winter rain
January 1962	116	-	Recruitment unlikely
January 1963	146	125	Recruitment unlikely – Summer event
April 1966	146	-	Potential recruitment event – Winter rain
March 1968	228	130	Recruitment unlikely – Summer event
February 1978	279	172	Recruitment unlikely – Summer event
February 1980	128	118	Recruitment unlikely – Summer event
February 1981	131	120	Recruitment unlikely – Summer event
March 1988	191	138	Recruitment unlikely – Summer event
December 1994	235	133	Recruitment unlikely – Summer event
December 1995	225	218	Recruitment unlikely – Summer event
January 1997	252	130	Recruitment unlikely – Summer event
February 1998	276	341	Likely recruitment event – Multiple rains
February 1999	219	238	Recruitment unlikely – Summer event
January 2000	216	231	Recruitment unlikely – Summer event
January 2001	164	136	Recruitment unlikely – Summer event
February 2002	135	115	Recruitment unlikely – Summer event
March 2003	119	123	Recruitment unlikely – Summer event
February 2004	193	183	Documented successful recruitment
January 2006	251	213	Recruitment unlikely – Summer event
March 2007	158	155	Recruitment unlikely – Summer event
February 2011	200	186	Recruitment unlikely – Summer event
February 2013	235	150	Nesting noted but no successful recruitment
January 2014	118	116	Recruitment unlikely – Summer event
January 2017	139	133	Recruitment unlikely – Summer event
December 2017	192	190	Nesting noted but no successful recruitment

Note that nesting events (but not necessarily successful recruitment) were noted in June 2015 and February 2016, but no pond formation is modelled; this is due to the use of Telfer precipitation data (no rain was recorded at Telfer over those periods).

3.1.4 Scenario 2A

Scenario 2A was developed to assess the probability of pond forming events for a potential 30-year mine life (set at 2020 to 2050) at Lake Disappointment. The model was run using a Monte Carlo analysis for 100 realisations, with the primary stochastic input of Precipitation. Scenario 2A was completed using the same hydrologic inputs as those used in the base case in order to simulate no mining at the lake.

A realisation representing average pond water levels of all realisations is provided in Figure 3-7 and suggests that 14 ponding events are predicted for the Lake during the simulated 30-year period. Modelled pond persistence is provided in Table 3-2 for Scenario 2A and is discussed in more detail in Section 3.4.

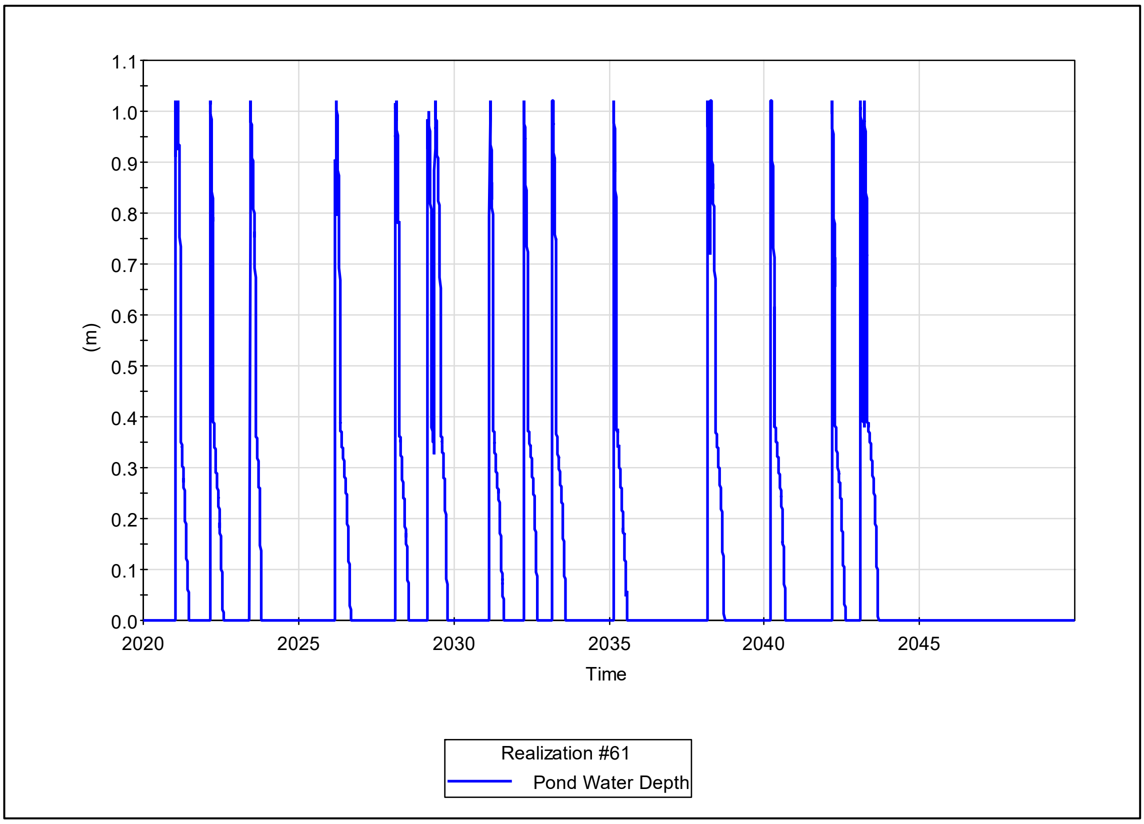


Figure 3-7: Probabilistic pond water depths for 2020–2050 for non-mining conditions

3.1.5 Scenario 2B

Scenario 2B was developed to assess the probability of pond forming events for a potential 30-year mine life (set at 2020–2050) at Lake Disappointment. The model was run using a Monte Carlo analysis for 100 realisations, with the primary stochastic input of Precipitation. Scenario 2B was completed using the same hydrologic inputs as those used in Scenario 1 in order to simulate playa hydrological response under the influence of mining activity at the lake.

A realisation representing average pond water levels for all realisations is provided in Figure 3-8 and suggests that 4 ponding events are predicted for the lake. Modelled pond persistence is provided in Table 3-2 for Scenario 2A and is discussed in more detail in Section 3.4.

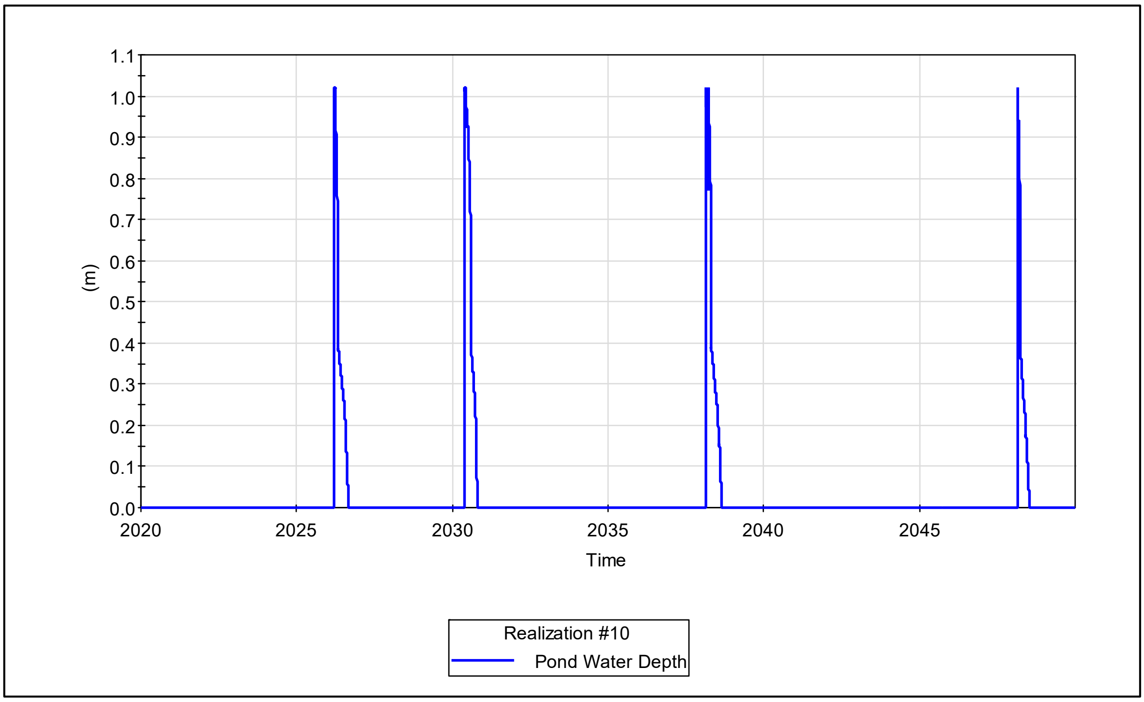


Figure 3-8: Probabilistic pond water levels for 2020–2050 for operational conditions

3.1.6 Stochastic modelling results

Results of the stochastic (predictive) modelling exercise, developed to compare non-mining conditions with potential operational conditions for the period 2020–2050 are provided in Table 3-2. Discussion of the results is provided in Section 3.4.

Table 3-2: Modelled pond persistence and potential recruitment events – 2020–2050

Event Date	Pond persistence (days)		Notes
	Scenario 2A	Scenario 2B	
March 2026	163	149	Potential recruitment event – Winter rain
May 2030	-	146	Potential recruitment event – Winter rain
April 2032	150	-	Potential recruitment event – Winter rain

3.2 Salinity

An assessment of salinity levels was completed using the deterministic model information (i.e. Scenario 1) and incorporated inputs from tributary streams ('run-on'), direct rainfall on the lake, evaporation and calculated pond volume. Upon review of the model results, it became apparent that the most frequent pond development events occurred as part of a large summer rainfall event, and conversely that the longest pond persistence events occurred after winter rains. Representative events for each of these scenarios were selected, January 2017 and July 1998 respectively, and salinity calculations developed to ascertain whether the events could support brine shrimp persistence required for successful banded stilt recruitment.

Run-on was assigned an initial salinity of 10,000 mg/L, precipitation 0 mg/L and it was assumed that dissolution and precipitation processes within the pond were constant, thus evapo-concentration was the controlling process on overall pond salinity.

Pond water levels and precipitation are provided for the January 2017 and July 1998 ponding events in Figure 3-9 and Figure 3-10, respectively. Precipitation and calculated salinity levels are provided for the January 2017 and July 1998 ponding events in Figure 3-11 and Figure 3-12. Both events have pond persistence times in excess of 100 days; however, the high evaporation rates during the summer season lead to a dramatically reduced length of time for salinities to be in the desired range (i.e. between 10,000 mg/L and 100,000 mg/L) for brine shrimp propagation for the January ponding event.

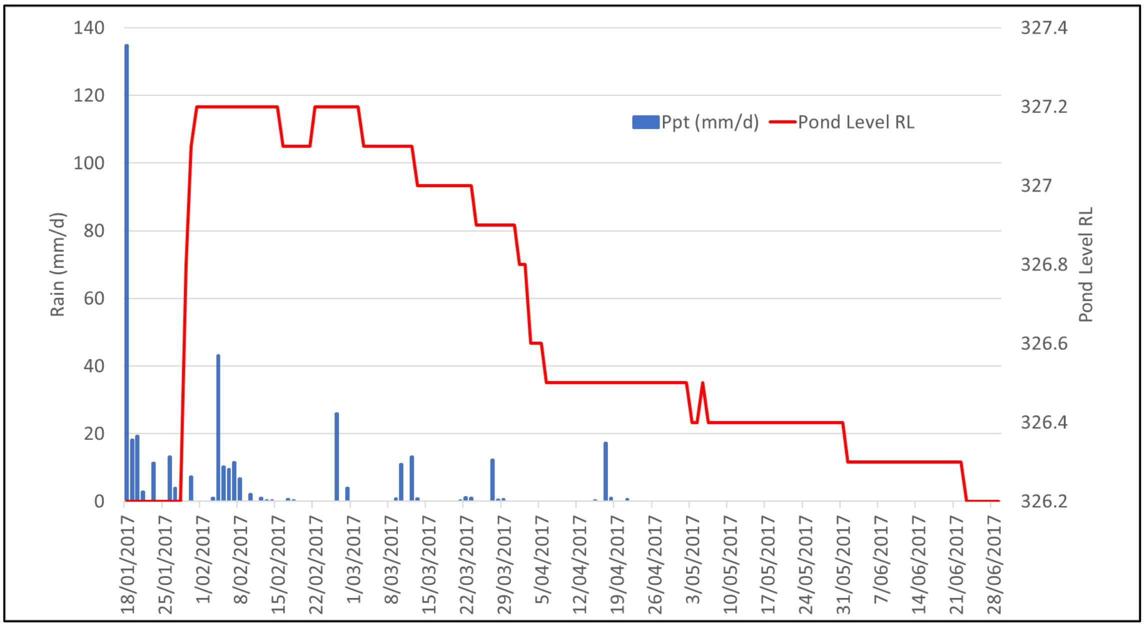


Figure 3-9: Precipitation and Pond levels for January 2017 ponding event

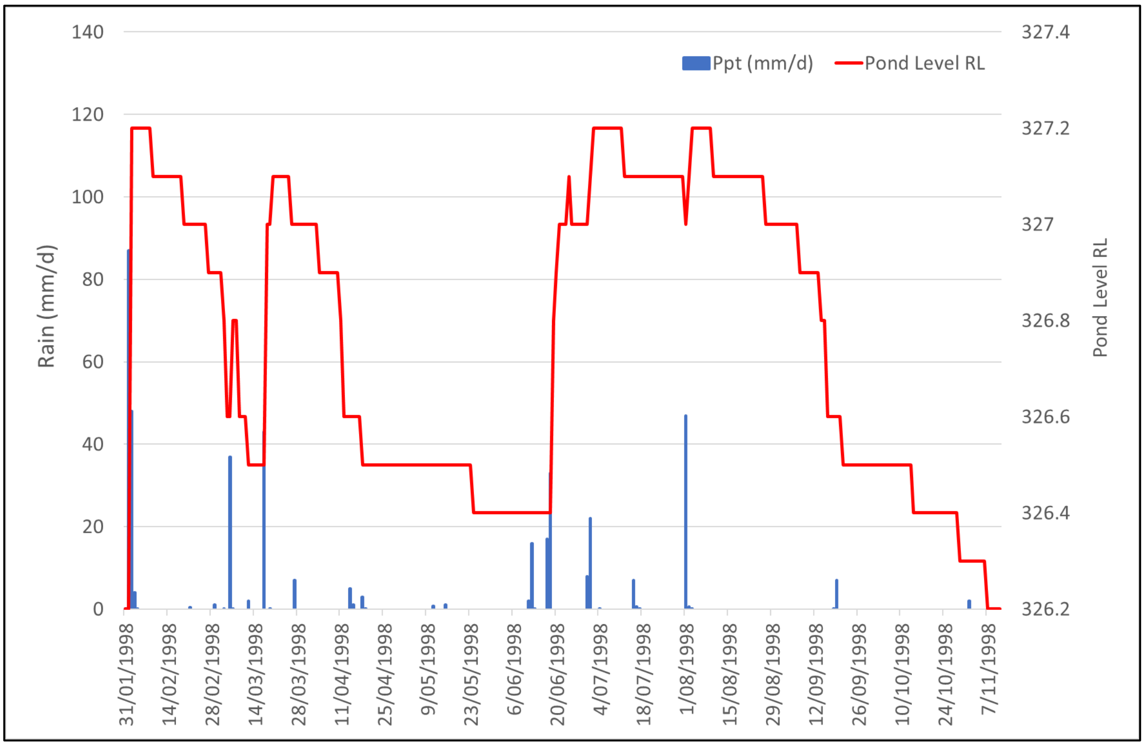


Figure 3-10: Precipitation and Pond levels for July 1998 ponding event

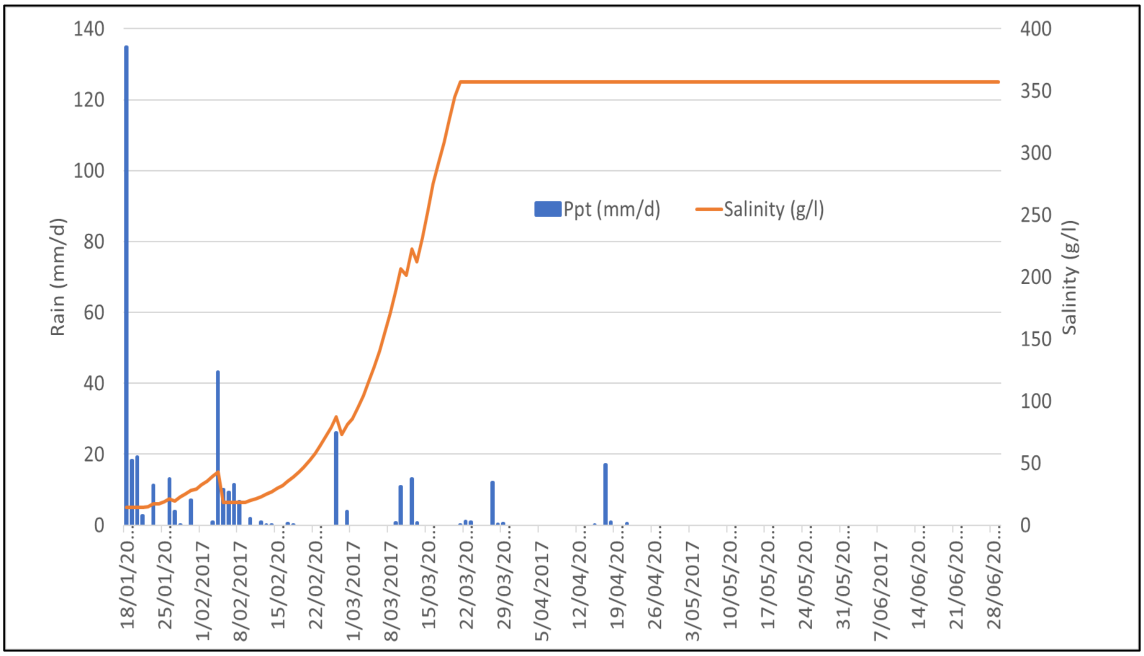


Figure 3-11: Precipitation and salinity levels for January 2017 ponding event

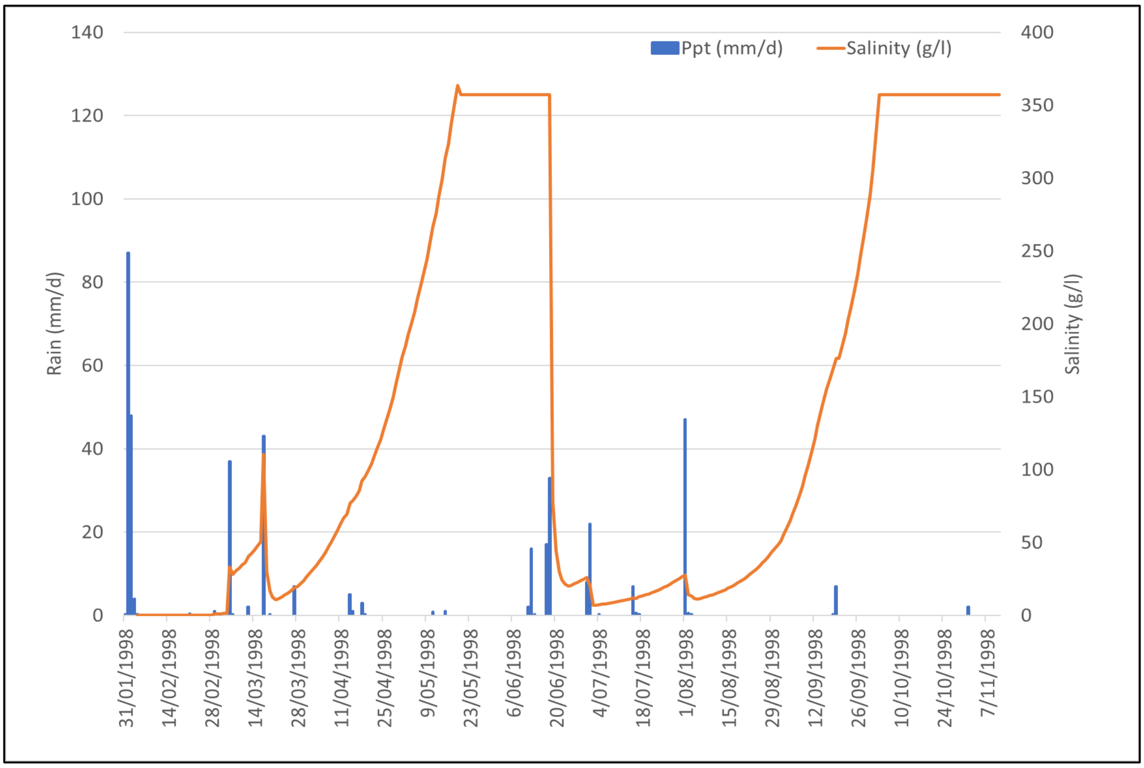


Figure 3-12: Precipitation and salinity levels for July 1998 ponding event

3.3 Climate change

Assessing the impacts of climate change can be difficult given the paucity of long-term data for Lake Disappointment. Using the available SILO rainfall data for the Telfer BOM station, an analysis of the total rainfall and number of rainfall events was completed as part of this study. Total rainfall is provided in Figure 3-13 and analysis of the data suggests that total annual rainfall is increasing. The number of rainfall events is provided in Figure 3-14 and indicates that the number of rainfall events in each year is decreasing. This implies that the precipitation patterns are changing to include less frequent, more intense events, which could reduce the number of nesting events (successful or otherwise) but could have a positive impact on pond persistence.

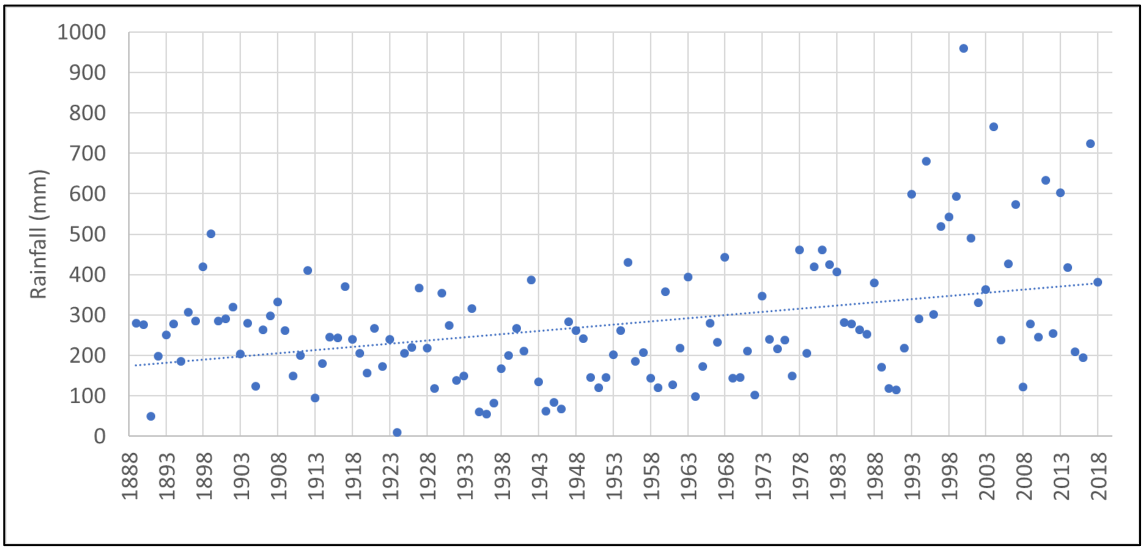


Figure 3-13: Annual average precipitation (1889–2018)

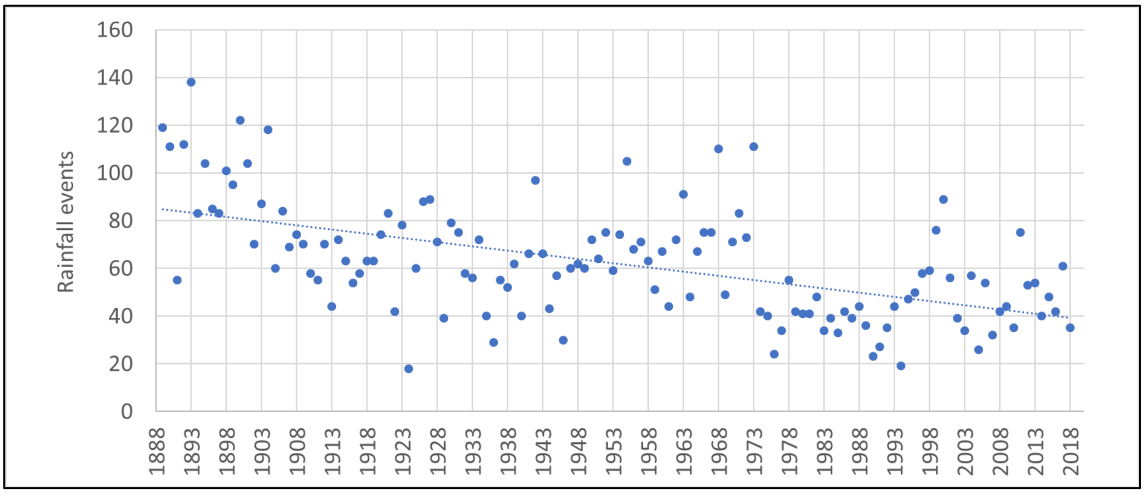


Figure 3-14: Number of rainfall events per annum (1889–2018)

3.4 Discussion

While no model can be expected to accurately represent a natural system, analysis of model results can provide some salient insights into the hydrology of the system. In the case of Lake Disappointment, some key learnings on the hydrologic system can be synthesised from the modelling exercise. These include:

- The driving processes for pond development and persistence are precipitation and evaporation, respectively.
- Precipitation is dominated by rare, large rainfall events likely associated with tropical weather systems during the summer months, with only rare rainfall events recorded during the winter.
- Water available for ponding is predominantly from direct precipitation on the lake, with run-on comprising approximately 10% of the total.
- Pond formation typically occurs after any major (i.e. >50 mm) rainfall event.
- Pond persistence during the summer months is generally short due to the flat topography of the lake and the extreme evaporation rates.
- It appears there are two potential scenarios that will lead to potential recruitment events for the Banded Stilt – a large winter rainfall event, or a series of perfectly timed summer rainfall events.
- Precipitation patterns appear to be changing to include less frequent, more intense events, which could have a positive impact on pond persistence.

These learnings can be used to inform the assessment of potential impacts of the proposed brine extraction from Lake Disappointment on potential Banded Stilt recruitment.

Modelled pond persistence is provided in Table 3-1 for the base case and Scenario 1 (mining). Pond persistence is presented as the duration (in days) where depth in the pond remains above 10 cm for any given pond development event.

With some notable exceptions, most of the recruitment events are modelled to occur in the summer/ wet season of northern Australia and are typically associated with extremely large rainfall events; this suggests a high dependency on cyclonic rainfall events. Pond formation events do occur at different times of the year but tend to be short-term events – a direct correlation with lower rainfall amounts received in winter.

In addition to the recruitment event documented in February–May 2004, base case model results have identified five additional likely recruitment events. Marginal events, those with persistence durations above the 80–90 days criterion, have also been included in Table 3-1, but uncertainty within the model has resulted in them being designated as ‘possible’. Summer rainfall events where salinities are likely to increase beyond the established range for brine shrimp propagation (10,000 mg/L to 100,000 mg/L) are nominated ‘unlikely’.

Comparing Base case and Scenario 1 conditions, there is a reduction in the overall frequency of pond-forming events. However, all pond-forming events under base case conditions for which no pond is formed under Scenario 1 conditions, are short duration events unlikely to support recruitment. There does appear to be some potential impact on pond persistence for the ‘possible’ and ‘likely’ recruitment events. In general, Scenario 1 conditions have a 5%–10% reduction in duration of pond persistence.

Analysis of the precipitation data suggests that these impacts are most notable after extended dry periods, resulting in high storage availability in the unsaturated zone. It is important to note that a highly conservative value was used for the initial unsaturated zone levels and specific yields as part of Scenario 1 (1.5 m and 0.10, respectively). In practice it is unlikely that the unsaturated zone will be reduced to that extent across the entire playa: rather it will be confined to the areas of proposed trenching which are generally located away from the expected ponds formation areas (Figure 2-4). Thus, the impacts of the operations are likely overestimated in the model.

The apparent increase in frequency of large rainfall events is also likely important when assessing potential impact on the Banded Stilt population. Although difficult to confirm given the short climatic record, there appears to be an increasing trend in large rainfall events over time which may support more frequent recruitment events. Further analysis (Figure 2-2 and Figure 3-14) also suggests that rainfall events are getting more intense with higher precipitation totals per event, which would have a positive impact on pond development and persistence.

Results of the probabilistic modelling completed for the lake using stochastic precipitation data are presented in Table 3-2. The frequency of ponding events is reduced under mining conditions (i.e. Scenario 2B); however, analysis of the data suggests that the impact on potential recruitment is not significant. Under both non-mining and mining hydrologic conditions, the simulations both predict two potential recruitment events for a nominal 30-year life of mine period (2020–2050).

3.5 Model limitations

The model is limited primarily by the quality and quantity of data inputs. Some key considerations when interpreting the results of the modelling include the following:

- Precipitation records are from the Telfer Airport BOM station, located approximately 150 km from the site and do not accurately reflect site conditions. Specifically, a pond-forming event was documented at Lake Disappointment in June of 2015, while no rainfall was recorded at the Telfer site.
- Evaporation records are also from the Telfer Airport BOM station and may underestimate evaporation at Lake Disappointment.
- No comprehensive calibration dataset is available for the model of the hydrologic input parameters or model results derived therein. Parameters were estimated using best fit data from available RML studies for the site, and modelled results correspond generally with anecdotal and historical records from the site.

4 Summary

In order to assess the potential impact on Banded Stilt recruitment from the proposed Lake Disappointment project, SRK developed a deterministic hydrology model using GoldSim (v.12) software. This model was developed using all available information for the lake, and was used to estimate daily fluxes of water, pond volumes and ultimately to determine the length of pond persistence and pond salinity, seen as critical for successful Banded Stilt recruitment.

The model was established and run in deterministic mode for the period of record (1900–2018, inclusive) and informally calibrated to existing conditions with the available data. Four scenarios were developed in order to assess pond persistence:

- Base Case scenario: Developed deterministically to represent historical and current conditions
- Scenario 1: Involved increasing the depth of the unsaturated zone to represent the drawdown effects of brine extraction
- Scenario 2A: Used stochastic rainfall to predict likely ponding events for the 30 years from 2020 using the base case hydrologic inputs
- Scenario 2B: Used the stochastic rainfall to predict likely ponding events for the 30 years from 2020 using the Scenario 1 modifications to reflect potential conditions during brine extraction.

Under operational (i.e. Scenario 1) conditions, a relatively modest reduction in pond persistence was noted. However, conservative values were incorporated into the model for the unsaturated zone levels and specific yields as part of Scenario 1, and thus it should be noted that the model likely overestimates the effect on pond persistence under mining conditions.

Probabilistic modelling suggests no significant impact on potential recruitment events for an assumed 30-year life of mine (2020–2050). Minor impacts are potentially mitigated by an increase in the frequency of large pond-forming (and recruitment) events suggested by the rainfall record and model results.

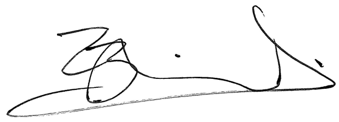
Yours faithfully

SRK Consulting (Australasia) Pty Ltd

Signed by:

Brian Luinstra
Principal Hydrogeologist

Signed by:



Zbigniew Boniecki
Senior Hydrogeologist