Medcalf Hydrogeological and Hydrological Study

Characterisation of *Marianthus* Habitat

Prepared for

Audalia Resources Limited

Level 1, 1139 Hay Street

WEST PERTH WA 6005

Report Distribution

No. Copies

1	Audalia Resources Limited (electronic copy)
1	Groundwater Resource Management Pty Ltd

Report J1843R02b June 2020

T: (+61 8) 9433 2222 **F:** (+61 8) 9433 2322 **ABN**: 97 107 493 292 **A:** 15 Harborne Street, Wembley, WA 6014
P: Po Box 442, Bayswater, WA 6933

Audalia Resources Limited (Audalia) is developing the Medcalf Vanadium/Titanium Project. The site is located in the Bremer Range, some 470 km east of Perth and 100 km south west of Norseman, near Lake Johnson.

A threatened species under Part 2 of the Biodiversity Conservation Act 2016 (*Marianthus aquilonaris*) has been identified in the project area. Ecological assessment of the mine site has identified six sub-populations with the extent of the plant mapped. Further work is underway to determine critical habitat for the species. The Environmental Scoping Document (ESD) for the Project identifies a series of study requirements; the part relevant to this hydrology study is item 6:

> "Hydrological assessments of surface water flows/hydrological regimes of the Bremer Range and influence of ironstone ridge microhabitats."

This study characterises the surface water hydrology of the project area to assist in understanding the microhabitat of the species current area of occupancy. The study focuses on areas of soil mapped as 'shallow gravel over indurated mottled zone' as the plants appear to be associated with this soil type. The results will be used to help identify any unique characteristics of the area of occupancy that contribute to the existence of the community and to provide guidance for other areas in the region that may be able to support *Marianthus aquilonaris* communities.

The mine site is located in an arid area with low, variable rainfall and high evaporation. Average annual rainfall is approximately 294 mm/year. Evaporation exceeds rainfall in every month of the year. Rainfall occurs all year round, but more rain tends to be received during winter (May to September). Large events tend to occur in summer, mainly from January to March.

Drainage through the area of the *Marianthus aquilonaris* communities is defined by a line of low hills trending in an east-west direction. Drainage from the hills is generally either toward the north or south in a number of small catchments.

Soil mapping in other studies indicates that all the *Marianthus aquilonaris* populations occur on soils referred to as shallow gravel over indurated mottled zone. Of 13 discrete areas of the soil type identified, five contain *Marianthus aquilonaris* populations. The areas that contain *Marianthus aquilonaris* populations all lie across a ridge line and down north east or north west trending slopes. Of the areas without *Marianthus aquilonaris* populations, most lie on ridgelines and on slopes with aspects ranging from northerly to southerly. One lies mid-slope. One lies in the upper reaches of a small drainage line.

The area of catchment above the mapped soils that contain *Marianthus aquilonaris* populations is smaller than the soil area in all catchments. The area of catchment above the populations is smaller than the population area in Catchments 3, 4 and 6 and marginally larger in Catchment 5. The area of soils containing *Marianthus aquilonaris* populations is a small proportion of the total catchment area, varying from 1-7%.

Modelling indicates that all of the mapped soil areas have a high runoff rate, which is consistent with their shallow soil profile and rocky surface. All of the areas receive some runoff from upslope; the amount varies depending on the location of the area in the landscape, local topography and surrounding soils. The water balance for the soil areas is dominated by evapotranspiration, which accounts for 60-80% of rainfall. This means that most of the rainfall is taken up by plants and transpired or evaporated from soil, rock and vegetation surfaces.

For the whole project area, the amount of runoff reduces from that predicted for the soil areas, consistent with the effects of higher rates of infiltration into the deeper red and gravely loams. While runoff from upper rocky areas can be high, much of this is infiltrated in the colluvial zone downslope. Runoff is predicted to account for 3% of rainfall over the project area.

Total seepage below the root zone, which could recharge groundwater, is low relative to the other components of the water balance. Recharge is likely to be highly episodic, with much occurring during extended wet periods. Evaporation still dominates the water balance at the site scale.

Regional groundwater level in the area is typically greater than 45 m below surface and the groundwater is hypersaline. Consequently the *Marianthus aquilonaris* plants are unlikely to have direct interaction with the regional groundwater table. *Marianthus aquilonaris* plants may benefit from underlying geological structures, such as vughs, iron stained fracture surfaces, quartz veining and bleached shearing, in terms of persistent soil moisture.

There are two larger rock holes in the area of the mapped *Marianthus aquilonaris* community. Both are small, shallow irregular depressions located on low ridgelines in exposed rock. The rock holes pond water for relatively short periods after larger rainfall events. Water in the holes is probably sourced from direct rainfall and runoff from a small catchment and lost mainly to evaporation.

GLOSSARY OF HYDROLOGICAL TERMS

Annual Exceedance Probability (AEP)

The probability of an event being equalled or exceeded within a year. For rainfall, an event is a total accumulated over a given duration. For floods, an event is typically the annual maximum flow rate. The relationships in terminology between AEP and ARI for specific event probabilities are (Ball *et al.* 2016):

Frequency descriptor	AEP %)	ARI (1 in *x*)
Frequent	63.21	1
Frequent	50	1.44
Frequent	20	4.48
Frequent	18.13	5
Rare	10	9.49
Rare	5	20
Rare	2	50
Rare	1	100

Antecedent Soil Moisture

Water present in the soil prior to a rainfall event.

Average Recurrence Interval (ARI)

The average time period between occurrences of an event equalling or exceeding a given value.

Australian Rainfall and Runoff (ARR)

National guideline document, data and software suite that can be used for the estimation of design flood characteristics in Australia. Currently in its 4th edition it is commonly referred to as ARR2016.

Australian Hydrological Geospatial Fabric (AHGF)

The Australian Hydrological Geospatial Fabric (Geofabric) is a specialised Geographic Information System (GIS). It identifies and registers the spatial relationships between important hydrological features such as watercourses, water bodies, canals, aquifers, monitoring points and catchments.

Backwater

Water backed-up or retarded in its course as compared with its normal or natural condition of flow.

Baseflow

The component of streamflow supplied by groundwater discharge.

Basin

A tract of country, generally larger catchment areas, drained by a river and its tributaries.

Catchment

The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.

Channel

An artificial or constructed waterway designed to convey water. Often described as open channels to distinguish them from pipes.

Control

Physical properties of a cross-section or a reach of an open channel, either natural or artificial, which govern the relation between stage and discharge at a location in the open channel.

Dead Storage

In a water storage, the volume of water stored below the level of the lowest outlet (the minimum supply level). This water cannot be accessed under normal operating conditions.

Discharge

Volume of liquid flowing through a cross-section in a unit time.

Drainage Division

Representation of the catchments of the 12-major surface water drainage systems across Australia, generally comprising a number of river basins.

Endorheic Basin

A closed surface water drainage basin that retains water and has no outflow to the sea.

Environmental Flow

The streamflow required to maintain appropriate environmental conditions in a waterway or water body.

Ephemeral	Something which only lasts for a short time. Typically used to describe rivers, lakes and wetlands that are intermittently dry.
Evapotranspiration (ET)	The sum of evaporation and plant transpiration from the earth's land surface to the atmosphere.
Evaporation	A process that occurs at a liquid surface, resulting in a change of state from liquid to vapour.
Floodplain	Flat or nearly flat land adjacent to a stream or river that experiences occasional or periodic flooding.
Flood Risk	The combination of the probability (likelihood or chance) of a flood event happening and the consequences (impact) if it occurred. Flood risk is dependent on there being a source of flooding, such as a sufficiently large upstream catchment, and something that is affected by the flood, such as a mine pit.
Full Supply Level (FSL)	The normal maximum operating water level of a water storage when not affected by floods. This water level corresponds to 100% capacity.
Generalised Short-Duration Method (GSDM)	Appropriate for estimating probable maximum precipitation for durations up to six hours and for an area of less than 1000 square kilometres.
Generalised Tropical Storm Method – Revised (GTSMR)	Appropriate for estimating probable maximum precipitation in regions of Australia affected by tropical storms.
Intensity-Frequency-Duration (IFD)	Design rainfall intensities (mm/h) or design rainfall depths (mm) corresponding to selected standard probabilities, based on the statistical analysis of historical rainfall.
Minimum Supply Level (MSL)	The lowest water level to which a water storage can be drawn down (0% full) with existing outlet infrastructure; typically, equal to the level of the lowest outlet, the lower limit of accessible storage capacity.
Precipitation	All forms in which water falls on the land surface and open water bodies as rain, sleet, snow, hail, or drizzle.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation (PMP, and coupled with the worst flood producing catchment conditions.
Probable Maximum Precipitation (PMP)	The theoretically greatest depth of precipitation for a given duration under modern meteorological conditions for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends.
Rainfall	The total liquid product of precipitation or condensation from the atmosphere, as received and measured in a rain gauge.
Riparian	An area or zone within or along the banks of a stream or adjacent to a watercourse or wetland; relating to a riverbank and its environment, particularly to the vegetation.
Stage	Water level relative to a datum, typically measured at a water monitoring site.
Storage	A pond, lake or basin, whether natural or artificial, for the storage, regulation and control of water.
Surface Runoff	Water from precipitation or other sources that flows over the land surface. Surface runoff is the fraction of precipitation that does not infiltrate at the land surface and may be retained at the surface or result in overland flow toward depressions, streams and other surface water bodies.
Sustainable Yield	The level of water extraction from a particular system that would compromise key environmental assets, or ecosystem functions and the productive base of the resource, if it were exceeded.
Total Suspended Solids (TSS)	The sum of all particulate material suspended (i.e. not dissolved) in water. Usually expressed in terms of milligrams per litre (mg/L). It can be measured by filtering and comparing the filter weight before and after filtration.

Transpiration	Evaporative loss of water from the leaves of plants through the stomata; the flow of water through plants from soil to atmosphere.
Watercourse	A river, creek or other natural watercourse (whether modified or not) in which water is contained or flows (whether permanently or from time to time).
Wind Run	The product of the average wind speed and the period over which that average speed was measured.

Terms referenced from BoM (2018a).

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

1.0 INTRODUCTION

1.1 BACKGROUND

Audalia Resources Limited (Audalia) is proposing to develop their Medcalf Vanadium/Titanium Project. The site is located some 470 km east of Perth and 50 km south west of Norseman, near Lake Johnson. The site is located in the Bremer Range.

The site location and overall project layout is shown on Figure 1. Proposed preliminary and indicative mine site layout is given in Figure 2.

Shallow open pit mining for vanadium and titanium is planned from three separate open pits - Vesuvius, Fuji and Egmont. Site infrastructure includes waste rock dumps, tailings storage facility, beneficiation plant, administration and camp. A 73 km haul road will be constructed connecting the site to the Esperance Highway to the east. A transfer depot will be built near the highway.

The ore production rate is likely to be in the order of 1.5 Mtpa over a 13 year life of mine with beneficiation processing at the mine site. The concentrate will be transported by haul trucks along the haul road to the transfer depot. The concentrate will then be transferred to smaller road trains for transport to the Esperance Port.

Audalia has been granted mining lease M63/656, and have submitted an Environmental Scoping Document (ESD, Audalia 2019) that defines the required studies for impact assessment. Item 6 of the ESD defines the study requirements relevant to hydrology:

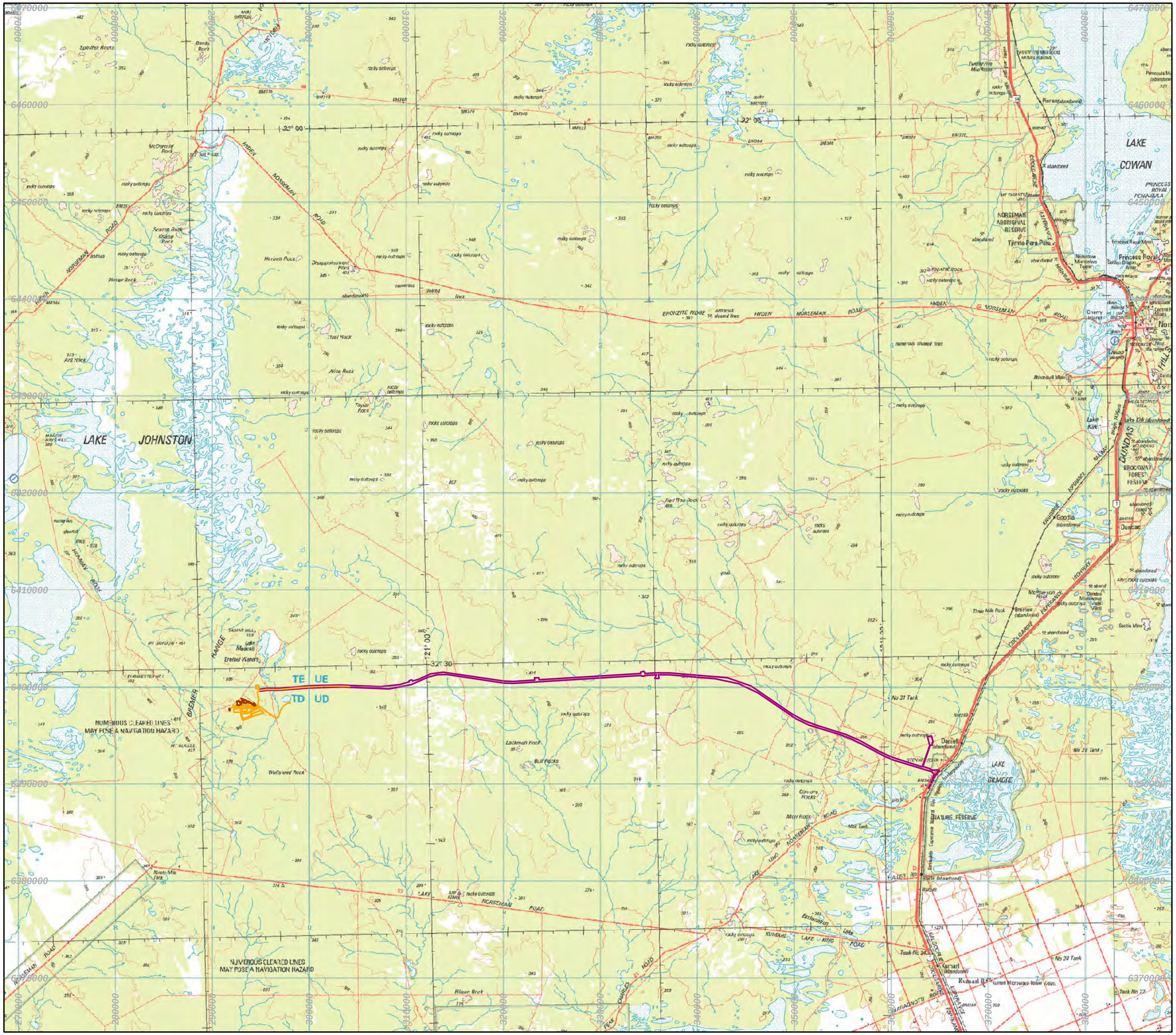
> "Hydrological assessments of surface water flows/hydrological regimes of the Bremer Range and influence of ironstone ridge microhabitats."

A rare flora (*Marianthus aquilonaris*) has been identified in the project area which will require further assessment to understand the habitat of the species. *Marianthus aquilonaris* was declared as Threatened under the WC Act in 2002 and is currently listed as 'critically endangered' under the World Conservation Union (IUCN) criteria.

Substantial ecological and landform assessment of the community at the mine site has already been undertaken. Four communities have been identified and a general extent of the plant at the mine site mapped (Botanica, 2017a, 2018). A soil investigation (Lantzke 2019) mapped a soil type (Shallow gravel over indurated mottled zone) that consistently occurs where *Marianthus aquilonaris* has been observed to occur. Lantzke (2019) suggests that the location of these soils may assist in determining the boundaries of critical *Marianthus aquilonaris* habitat. Accordingly, the location and characteristics of these soils are a focus for this hydrologic investigation.

Characterisation of surface water hydrology for the area of *Marianthus aquilonaris* is required to satisfy the ESD requirements for hydrological assessments. This study will be used to help identify any unique characteristics of this site that contribute to the existence of the community and to provide guidance for other areas in the region that may be able to support *Marianthus aquilonaris* communities.

This report presents the results of the hydrological study. The work presented here includes a review of the plant's characteristics, description of the physical environment as related to surface water and groundwater hydrology, and water balance modelling.



Legend

- Pits
- Project Disturbance Footprint
- Transport Development Envelope

Data Sources:
Project Disturbance Footprint, Transport Development Envelope, Pits - Audalia Resources Limited
250K topography - Geoscience Australia

Location

1:100 000 Map Sheet Location

Lake Percy 2934	Diamond Rock 3034	Cave Hill 3134	Cowan 3234
Roundtop 2933	Johnston 3033	Bronzite Ridge 3133	Norseman 3233
Hope 2932	Tay 3032	Peak Charles 3132	Dundas 3232

N

SCALE 1:400,000

0 2.5 5 10 15 20 Km

GDA 1994 MGA Zone 51

audalia resources limited

GROUNDWATER RESOURCE MANAGEMENT

Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 1
Project Location

Additional Information

COMPILED: Gaia Resources	DATE: 5/03/2020	LOCN: PERTH	A3	SCALE 1:400,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig1.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig1.mxd				

Legend

Pits

Project Disturbance Footprint

Data Sources:
Project Disturbance Footprint, Pits
Imagery - Audalia Resources Limited

Location

Map Area

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133
Hope 2932	Tay 3032	Peak Charles 3132

N

SCALE 1:25,000

0 0.25 0.5 1 1.5 Km

GDA 1994 MGA Zone 51

audalia resources limited

GROUNDWATER RESOURCE MANAGEMENT

Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 2
Site Layout

Additional Information

COMPILED: Gaia Resources	DATE: 7/05/2020	LOCN: PERTH	A3	SCALE 1:25,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig2.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig2.mxd				

1.2 SCOPE OF WORK

The scope of work is to undertake a hydrological assessment of surface water flows and hydrological regimes of the *Marianthus aquilonaris* communities at the Medcalf Project site.

The deliverable is this report.

1.3 SUMMARY OF METHODOLOGY

The work was undertaken in the following stages:

- Data collation and review;
- Site visits;
- Characterisation of the hydrology of the area supporting *Marianthus aquilonaris* communities; and
- Reporting.

1.3.1 Data Review

The data review involved sourcing available data and undertaking a preliminary review of local and catchment conditions.

The following information was used in this study:

- 1 m contour data and high resolution aerial imagery across the site, supplied by Audalia;
- Proposed indicative site layout across the mine site, supplied by Audalia;
- Mapping of *Marianthus aquilonaris* communities, supplied by Audalia;
- Site weather station data (incomplete record for the period 4 April 2014 to 12 June 2018), supplied by Audalia;
- Regional topographic and satellite imagery data, supplied by Geoscience Australia;
- Regional weather and design rainfall data, supplied by the Bureau of Meteorology; and
- Reports as referenced throughout the report.

1.3.2 Site Visit

A site visit was undertaken on 29-30 November 2018 by R. Connolly (Principal Hydrologist). During the visit the landscape and drainage through the areas of *Marianthus aquilonaris* habitat were inspected. Drainage lines crossing the haul road alignment were inspected.

An assessment of the hydrogeological conditions associated with the plant communities was undertaken in September 2019 by R. Toll (Senior Hydrogeologist), as part of the project's water supply investigations.

1.3.3 Characterise Hydrology of *Marianthus aquilonaris* Communities

The microclimate of the communities was described using a combination of data analysis and modelling. This included:

- Characterisation of the climate of the area, using site and regional weather records;

- Identifying catchments and topographic, terrain and soil features for the area;
- Modelling the water balance of the community area, including identifying major flow pathways and sources of water that may influence the presence of communities; and
- Interpreting possible relationships relevant to the presence of *Marianthus aquilonaris* communities.

Stations recording long term weather in the area are sparse, so it is difficult to determine reliable averages at the site. Also, the site weather station data is not a continuous record. Accordingly the data used for analysis of site climate and for input into the water balance model data were derived from a number of sources and should be considered to be indicative but sufficient to characterise the environment.

Daily weather data from the site station and generated data using the Bureau of Meteorology's (BoM's) Data Drill (Queensland Government 2018) were used. The site rainfall data covered the period 2014-2018 with a 0.5 or 1 h time step but is not complete. The Data Drill data for a number of locations was tested and it was found that data generated at the location of the BoM Salmon Gums Station, located some 90 km to the southeast of the mine site, gave the best overall representation of weather at the site compared with BoM stations in the area. Design rainfall was also derived for the site using the BoM's online data tool (BoM 2018b). These data were used in the assessment of site climate and in the water balance modelling.

Surface water catchments and drainage lines through the community area were defined using the 1 m contour data sourced from Audalia.

A catchment water balance model was setup using the Mike SHE software (DHI 2018). MIKE SHE is an advanced, flexible framework for modelling major processes in the hydrologic cycle. It includes process models for evapotranspiration, overland flow, unsaturated flow, groundwater flow, channel flow and their interactions. Each of these processes can be represented at different levels of spatial distribution and complexity, according to the goals of the modelling study, the availability of field data and the modeller's choices.

The Mike SHE model was used to help assess the water balance for the catchments through the *Marianthus aquilonaris* community area and for the rock holes. The water balance is predicted for the root zone for the period 2014-2017, which is the period of site rainfall monitoring.

The model was parameterised using the available data. Site rainfall data and daily Data Drill rainfall and evaporation data were used in the model for different model scenarios. Topography was represented in the model as a rectangular grid (5 m by 5 m cell), derived from the contour data. Soil information was based on observations made during the site visit and using information in Lantzke (2019). No mapping of soils across the site, other than for the shallow gravel over indurated mottled zone soil group, was available. The distribution of soils other than the shallow gravel over indurated mottled zone soil group was assumed. Based on site observations at the areas occupied by *Marianthus aquilonaris* and the soil type shallow gravel over indurated mottled zone, the modelling assumes hard rock occurs below the soil profile.

Vegetation characteristics were varied spatially across the site approximately based on soil type and from interpretation of topography and aerial imagery.

Two scenarios were modelled:

- Rainfall events, using the site data; and
- Catchment and rock hole water balance, 2014-2017, using daily weather data.

The catchment and rock hole model was set up with minimal data and run for a short period (four years), so the results should be considered indicative but sufficient to characterise the microhydrological environment where *Marianthus aquilonaris* grows. The site data indicates that a number of heavy rainfall events were received during the 2014-2017 period, which may not be representative of a longer term record. The water balance was calculated for the soil area that falls within the model domain and for the total domain. The total domain represents the main catchments through the project area.

Two rock holes (east and west) were included in the water balance model. Rock holes were represented by lowering the elevation of a single cell at each site by 0.5 m below ground surface. This gave an effective depth of 0.26 m for the western and 0.12 m for the eastern rock hole. This is an approximation, as the model grid size (5 by 5 m) is larger than the size of the actual rock holes and shape of the rock holes is not represented in detail. The model represents overland flow into the rock hole and evaporation and seepage. There may be other losses (such as animal use) and local factors (such as variable runoff patterns at the micro scale or variable vegetation use) that are not included in the model and could affect the actual water balance of the rock holes. Nevertheless the model helps characterise the rock hole water balance, including the contributing catchment and likely rate and mechanisms of loss of water ponded in the holes.

1.4 LIMITATIONS

This report has been prepared by Groundwater Resource Management Pty Ltd (GRM) for Audalia and may only be used and relied on by Audalia for the purpose agreed between GRM and Audalia as set out in Section 1.2 of this report.

GRM otherwise disclaims responsibility to any person other than Audalia arising in connection with this report. GRM also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GRM in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GRM has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GRM described in this report (refer Section 1.3 of this report). GRM disclaims liability arising from any of the assumptions being incorrect.

GRM has prepared this report on the basis of information provided by Audalia and others who provided information to GRM (including Government authorities), which GRM has not independently verified or checked beyond the agreed scope of work. GRM does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2.0 DESCRIPTION OF THE *MARIANTHUS AQUILONARIS* ENVIRONMENT

2.1 REVIEW OF HABITAT REQUIREMENTS

A number of comprehensive studies of the distribution and characteristics of the *Marianthus aquilonaris* populations through the project area have been undertaken by Audalia. Detailed flora and vegetation survey for the mining area and haul road, including a comprehensive regional description and landform assessment, has been undertaken (Botanica 2017a, 2018, 2019). A detailed soil investigation has also been recently undertaken (Lantzke 2019).

Typical habitat for *Marianthus aquilonaris* has been defined by DEC (2011) as: "Ironstone ridges (ca. 400 m above sea level) with a laterite capping and exposed iron oxide (commonly referred to as limonite). Plants tend to be located within shallow drainage lines on the ridge, on rocky red-orange sandy loam. Habitat is Open Low Woodland dominated by *Eucalyptus livida* over Dwarf Scrub dominated by *Eremophila clavata*, *Pultenaea arida*, *Acacia erinacea*, *Westringia cephalantha* var. *caterva*, *Waitzia fitzgibbonii*, *Asteridea athrixioides* and *Lepidosperma* sp."

Botanica Consulting (Botanica 2017b) conducted regional targeted searches for *Marianthus aquilonaris* populations in areas of similar topography/geology outside of the Medcalf area but to date have not identified regional populations.

Based on a number of studies, Botanica (2019) describe the following habitat preferences for *Marianthus aquilonaris*:

- Low salinity soils (<200 mS/m);
- Shallow brown to orange/ red-brown sandy-clay loam soils/ loamy earths (≤58 mm depth);
- Areas of exposed bedrock (predominately limonite ≥8%) with high percentage plant litter (≥20%) and bare ground (≥53%);
- Elevations ranging from 380 to 425 m with the north-eastern populations (Population 1a and 1b) occurring lower in the landscape of the Bremer Range (380-405 m) and the north-western populations (Population 1c, 1d and 1e) occurring higher in the landscape (400 to 425 m);
- North-eastern and north-western face of rocky slopes which is likely associated with the surface drainage of the hills which generally drains toward the north.

A typical plant is shown in Photo 1 and landscape in Photo 2.

Photo 1 ***Marianthus aquilonaris*** **Plant**

Photo 2 ***Marianthus aquilonaris*** **Community Landscape**

Source: Botanica (2017a).

A detailed soil investigation for the Medcalf site was undertaken by Western Horticultural Consulting (Lantzke 2019). This study indicated that all the *Marianthus aquilonaris* communities at the site occur on 'Shallow gravel over indurated mottled zone' soils. Surrounding soils have different properties – they tend to be deeper colluvial soils, do not contain limonite outcrops and are neutral to alkaline. Lantzke (2019) suggests that the location of the 'shallow gravel over indurated mottled zone' soils may assist in determining the boundaries of critical *Marianthus aquilonaris* habitat. More details of soil types are given in 2.3.

2.2 CLIMATE

The site is located in an arid area with low and variable rainfall year round and with high evaporation. The climate is classified by the modified Köppen system (BoM 2018c) as Grassland, warm (persistently dry). Summers are warm to hot and winters mild.

Key aspects of the climate that affect the hydrology of the *Marianthus aquilonaris* communities are rainfall and evaporation. The timing and magnitude of rainfall affects infiltration of rainfall into the soil and availability for uptake by plants, as well rates of runoff. Evaporation from the soil and transpiration by plants affects the rate that the soils dry out.

A summary of rainfall statistics derived for the site is given in Figure 3. A summary of larger events observed at site is given in Table 1.

Observed annual rainfall at Norseman (BoM station 012009 Norseman Aero, data from 1999-2020) is 294 mm/year. Annual rainfall has varied during the observation period between 183 and 454 mm/year. Rainfall occurs all year round, but more rain tends to be received, on average, during winter (May to September). However, rainfall is variable and large rainfall events can occur. Large events tend to occur in summer, mainly January to March. However large events have occurred in September to December and in June.

Rainfall in the period before large events is variable. Table 1 shows data for the 10 days prior, with totals tending to vary from almost no rain to around 30 mm, but sometimes much more.

Rainfall at the site occurs generally as a result of regional rain-bearing depressions in winter, or in summer from thunderstorms and occasionally as a result of tropical cyclones that track far enough south (BoM 2018d). The influence of cyclones, though, is weak and generally results in only small rainfall events.

Mean annual pan evaporation is some 1,500 mm/year with little variation from year-to-year. Mean monthly evaporation exceeds mean rainfall in every month of the year. Evaporation rates are much lower in winter than in summer. This pattern of variation in evaporation combined with rainfall distributed during the year in variable falls suggests that the soil profile prior to larger events is likely to be relatively dry in summer but could be moist to saturated in winter.

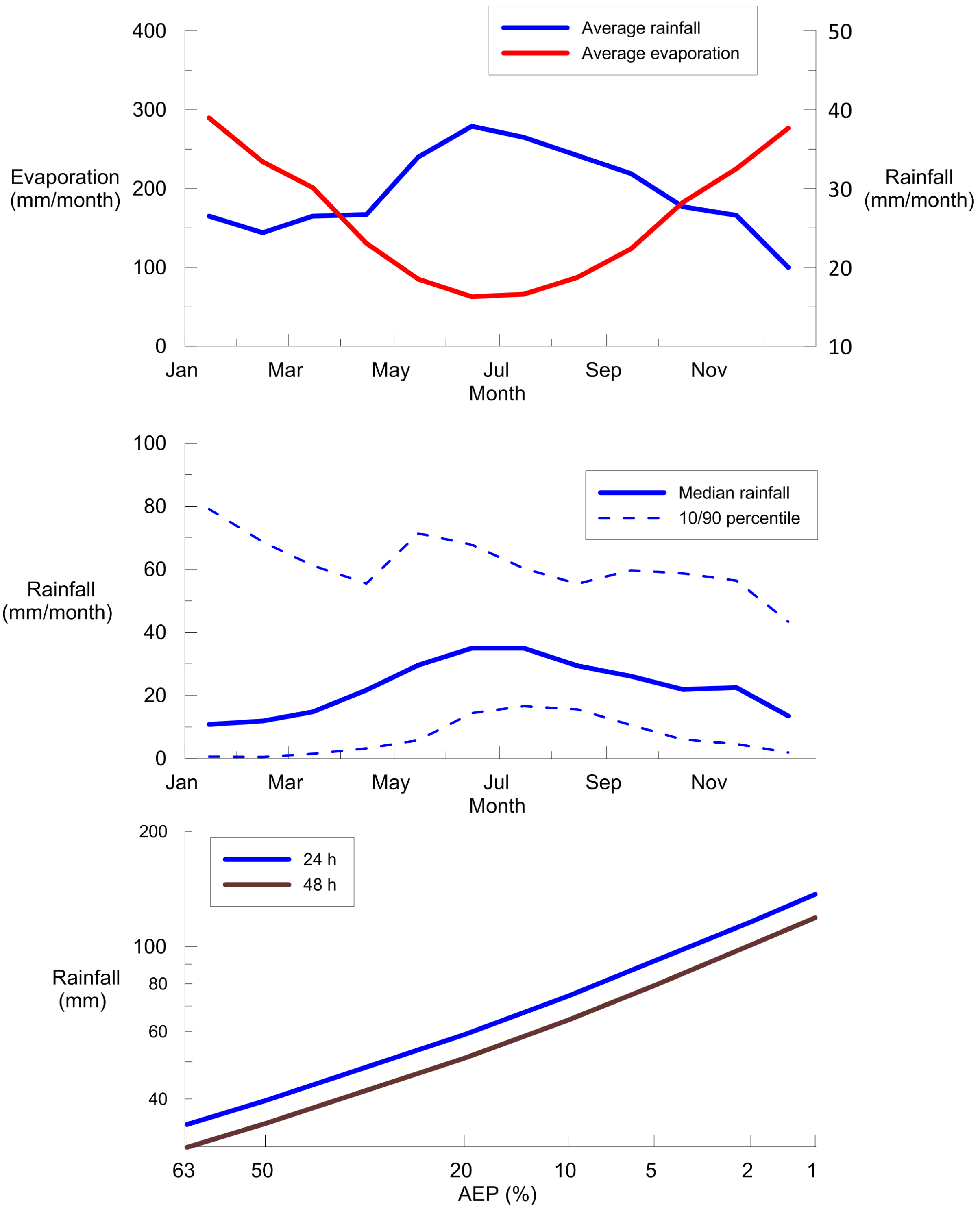


Figure 3 **Site Climate Details**

GROUNDWATER RESOURCE MANAGEMENT

Table 1 Site Rainfall Events

Date	Duration (h)	Rainfall (mm)	Average rainfall intensity (mm/h)	Rain in previous 10 days (mm)	AEP
21/09/2017	9.5	97.5	10.3	1.2	1 in 200
7-8/02/2017	10.0	78.3	7.8	24.6	2%
26/10/2017	6.0	59.4	9.9	9.9	2%
10/06/2018	5.0	49.2	9.8	5.1	5%
18/12/2017	5.0	24.9	5.0	31.2	50%
18/02/2018	1.0	23.1	23.1	11.4	10%

Data are observed at the site, 0.5 h or 1 h time step. AEP is approximate.

2.3 LAND SYSTEMS AND SOILS

Land systems, soils and geology through the project area have been mapped by a number of agencies. Most though, are at regional scales, which are hard to interpret at the scale of the project footprint. The Lanktze (2019) study is the only report specific to the Medcalf site.

One regional dataset, surface geology (GA 2018) has sufficient resolution to provide some background to the soils and landscape that occurs through the area of the mine site. The surface geology mapping shows a band of rock corresponding to the low hills and mine resource areas. Off the hills to the north and south is mapped as colluvium.

The Lantzke study undertook field investigations at the project site in April and August 2019. The aim of the study was to determine the range of soil types on which *Marianthus aquilonaris* and other selected species grow. Because of difficulties with access, a limited area of the site was surveyed directly.

Five main soil groups were identified:

1. Alkaline red shallow loamy duplex;
2. Loamy gravel;
3. Shallow gravel over indurated mottled zone;
4. Stony soils; and
5. Shallow gravel.

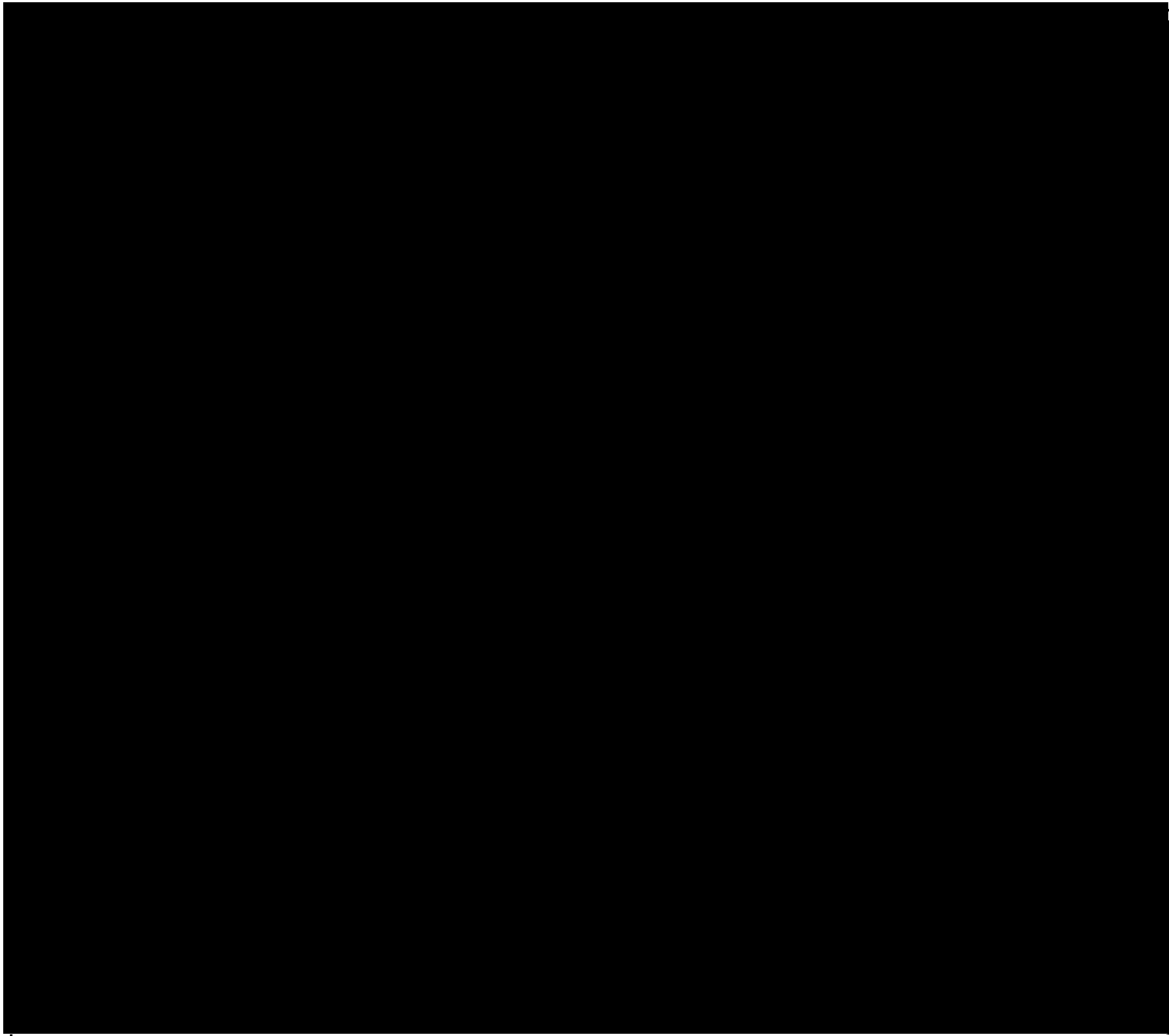
This study indicates that *Marianthus aquilonaris* grows on gravelly, shallow loamy soils with an indurated, mottled zone layer that occurs within 30 cm of the soil surface (soil type 3). The occurrence of the shallow gravel over indurated mottled zone and *Marianthus aquilonaris* populations are mapped in Figure 4.

The shallow gravel over indurated mottled zone soils are acidic, occurring on low ridges that typically have outcrops of limonite. It is a minor soil type in the district. Between 70 and 90% of the surface is covered with a scree of dark lateritic gravels and fragments of limonite rock. Limonite outcrops are common and in areas may compose up to 50 % of the soils surface. The subsoil is impermeable. As a result, infiltration rates of rainfall for these soils are low and runoff rates will be high. Topsoil is prone to erosion by shallow overland flow. Plant available water holding capacity (the water holding capacity of the soil that is available to plants) is low.

The alkaline red shallow loamy duplex soil is a major soil group in the project area. This group includes a range of red coloured, loamy duplex soils. These soils occur below the gravelly lateritic plateau and extend towards the valley floor. It can be found on the upper, mid and lower slopes. The soil profile can contain up to 60 % gravel and rocks. Soils typically have a 0.1-0.15 m thick topsoil and a deep subsoil. Plant roots can extract water to some 1 m deep and the plant available water holding capacity of the soil is relatively high.

The loamy gravel is also a major soil group. It occurs on the lateritic plateau at the top of the landscape, and on the upper, mid and lower slopes. The soil surface contains gravel that can cover up to 70 % of the soils surface. A 0.1-0.15 m deep topsoil grades into a subsoil to a depth of 1 m. Plant water holding capacity is reduced by the presence of gravels and is considered to be moderate.

The stony sols and shallow gravels are minor soil groupings. Both occur at the top of the landscape in association with rock outcrops and breakaway faces. Up to 90 % of the soil surface can be covered by rocks and gravel. The topsoil is 0.1 to 0.25 m deep with an effective plant rooting depth of approximately 0.3 m and low plant available water holding capacity. Rainfall-runoff from these areas would be high.



Legend

- Pits
- Project Disturbance Footprint
- Mapped soils
- *Marianthus* populations

Data Sources:
Project Disturbance Footprint, *Marianthus* populations, Imagery, Mapped Soils, Pits - Audalia Resources Limited

Location

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133
Hope 2932	Tay 3032	Peak Charles 3132

N

SCALE 1:25,000

0 0.25 0.5 1 1.5 km

GDA 1994 MGA Zone 51

audalia resources limited

GROUNDWATER RESOURCE MANAGEMENT

Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 4
Shallow gravel over indurated mottled zone soils

Additional Information

COMPILED: Gaia Resources	DATE: 10/06/2020	LOCN: PERTH	A3	SCALE 1:25,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig4.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig4.mxd				

2.4 VEGETATION AND LAND USE

Vegetation through the area of the *Marianthus aquilonaris* is generally Eucalypt and Mallee woodlands and shrublands (Botanica 2017a).

Land use is native vegetation on unallocated crown land overlain with Mining Act tenements.

2.5 DRAINAGE AND TOPOGRAPHY

Topography, drainage lines and catchments are shown in Figure 5. Note that the available topographic data does not cover the area of *Marianthus aquilonaris* Population 1e nor the area of shallow gravel over indurated mottled zone soils are acidic referred to as Site 8. The area of Population 1c is truncated by the boundary of the available topographic data.

Drainage around the area of the *Marianthus aquilonaris* communities is defined by a line of low hills trending in an east-west direction. Drainage from the hills is generally either toward the north or south. The *Marianthus aquilonaris* communities tend to extend mainly from the top of the hills toward the north (i.e. on north-facing slopes).

Rock is generally exposed on the top of the hills and there is little vegetation cover, litter or dead timber in contact with the ground surface (Photo 3). These areas include the shallow gravel over indurated mottled zone, stony soils, and shallow gravels mapped by Lantzke (2019). See Section 2.3 for a description of these soils.

These areas are likely to be high runoff zones as infiltration into the rock and rocky soil will be low and there is little impediment to stormwater moving across the ground surface. Runoff from even small rainfall events would occur as shallow overland flow.

In smaller events, most runoff would reinfiltrate in areas downstream with a deeper soil profile.

Photo 3 Overland Flow Area on Hills

Moving downslope below the areas of occupancy, a soil profile gradually forms, either as alkaline red shallow loamy duplex or loamy gravels (Lantzke 2019). The soil profile increases in depth with distance downstream and the infiltration capacity of the soil profile increases. Occasional small erosion gullies tend to form about mid-slope and then dissipate (Photo 4).

Photo 4 Mid-Slope Erosion Gully

Defined streamlines form toward the bottom of the catchments – well below the zone of occupancy (Photo 5). Runoff from the deeper soil areas would occur in more intense events and move as overland flow concentrating into drainage lines then defined streams as flow rates increase with distance downstream. Vegetation density increases as the soil profile increases and in proximity to drainage lines. The larger drainage lines tend to have heavy vegetation growth and fallen debris that restricts stormwater flow.

Photo 5 Streamline in the Lower Catchment

Flow in drainage lines through the site is generally relatively shallow (less than 0.3 m deep) and there are few depressions or pools. Large, incised drainage lines do not form until some distance downstream of the site.

[redacted]

Legend

- Rock Holes
- Critical Habitat
- Drainage Lines
- Pits
- Project Disturbance Footprint
- Contours (1m)
- Mapped soils
- Catchments

Data Sources:
Pits, Mapped Soils, Critical Habitat,
Project Disturbance Footprint,
Marianthus Locations - Audalia Resources Limited
Rock Holes, Drainage Lines, Catchments,
Contours - GRM

Location

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133
Hope 2932	Tay 3032	Peak Charles 3132

N

SCALE 1:15,000

0 150 300 600 900 m

GDA 1994 MGA Zone 51

Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 5
Drainage and topography

Additional Information

COMPILED: Gaia Resources	DATE: 11/05/2020	LOCN: PERTH	A3	SCALE 1:15,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig5.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig5.mxd				

2.6 Groundwater

The description of the hydrogeological conditions, with respect to the *Marianthus aquilonaris* communities is provided in the following sections, and is based on information obtained during the recent water supply investigation (GRM 2019).

2.6.1 Regional Hydrogeology

The project area is located on the western flank of a northerly draining palaeotributary of the regionally extensive Lefroy Palaeodrainage system. The main hydrogeological sequences within the project tenements are shown in Figure 6 and comprise a palaeochannel sand aquifer in the east of the project area, and fractured bedrock aquifers in the western portion of the tenements, away from the palaeochannel. The identified *Marianthus aquilonaris* communities are located within the fractured bedrock domain.

The palaeochannel and bedrock sequences are overlain by a veneer of Quaternary deposits comprising lacustrine deposits, aeolian deposits, alluvium, colluvium and laterite. The water supply investigations indicate that these units are unsaturated in the project area. However, more regionally, the Quaternary cover may be partially saturated in the larger drainage lines and the small playa lakes.

Rainfall recharge to the fractured rock and palaeochannel aquifers is low, and is via direct rainfall infiltration through the soil profile or by stream flow (in the drainage lines) during episodic rainfall events.

2.6.2 Groundwater Levels

Groundwater level measurements collected during the water supply investigations are provided in Figure 6 and indicate that the depth to groundwater ranges from around 6 m below ground level in the low-lying eastern portion of the site (MWH003 and MWH008) to 45 m below ground level in the central portion of the site (MWH011). The groundwater flow direction is expected to be towards the north east, i.e. towards the palaeochannel.

The closest monitoring bores to the identified *Marianthus* communities is MWH010 and MWH010. The measured groundwater level in MWH011 is 45 m below ground level. Monitoring bore MWH010 was constructed to 66 m below ground level and remained dry after construction, indicating that either the water level in this area is greater than 66 m below surface, or that the permeability is so low that the bore did not recover within the timeframe of the field investigations. It is considered more likely that the groundwater level is greater than 66 m below surface, given that MWH010 is located at approximately 50 m higher elevation than MWH011. However, ongoing water level measurements of this bore will be necessary to confirm this.

2.6.3 Groundwater Quality

The water supply investigations indicate that the groundwater is hypersaline, ranging from 54,000 to 170,000 mg/L total dissolved solids (TDS). The pH of the groundwater is circum neutral in the fractured bedrock aquifer and acidic (3.7) in the palaeochannel aquifer.

2.6.4 Site Visit

A site inspection of the hydrogeological conditions associated with a selection of the *Marianthus aquilonaris* plants was conducted by Mr Richard Toll (GRM Senior Hydrogeologist) during the water supply investigations.

The *Marianthus aquilonaris* plants visited and a description of observations is provided in Table 2 below, and the locations shown in Figure 6.

The site inspection identified indicators of underlying geological structures, such as vughs, iron stained fracture surfaces, quartz veining and bleached shearing in outcrops adjacent to *Marianthus aquilonaris* communities, which may be of benefit to the *Marianthus aquilonaris* plants, in terms of persistent soil moisture from within discrete fractured bedrock zones underlying the indurated mottled zone soils.

Table 2 ***Marianthus Aquilonaris*** **Plants Visited**

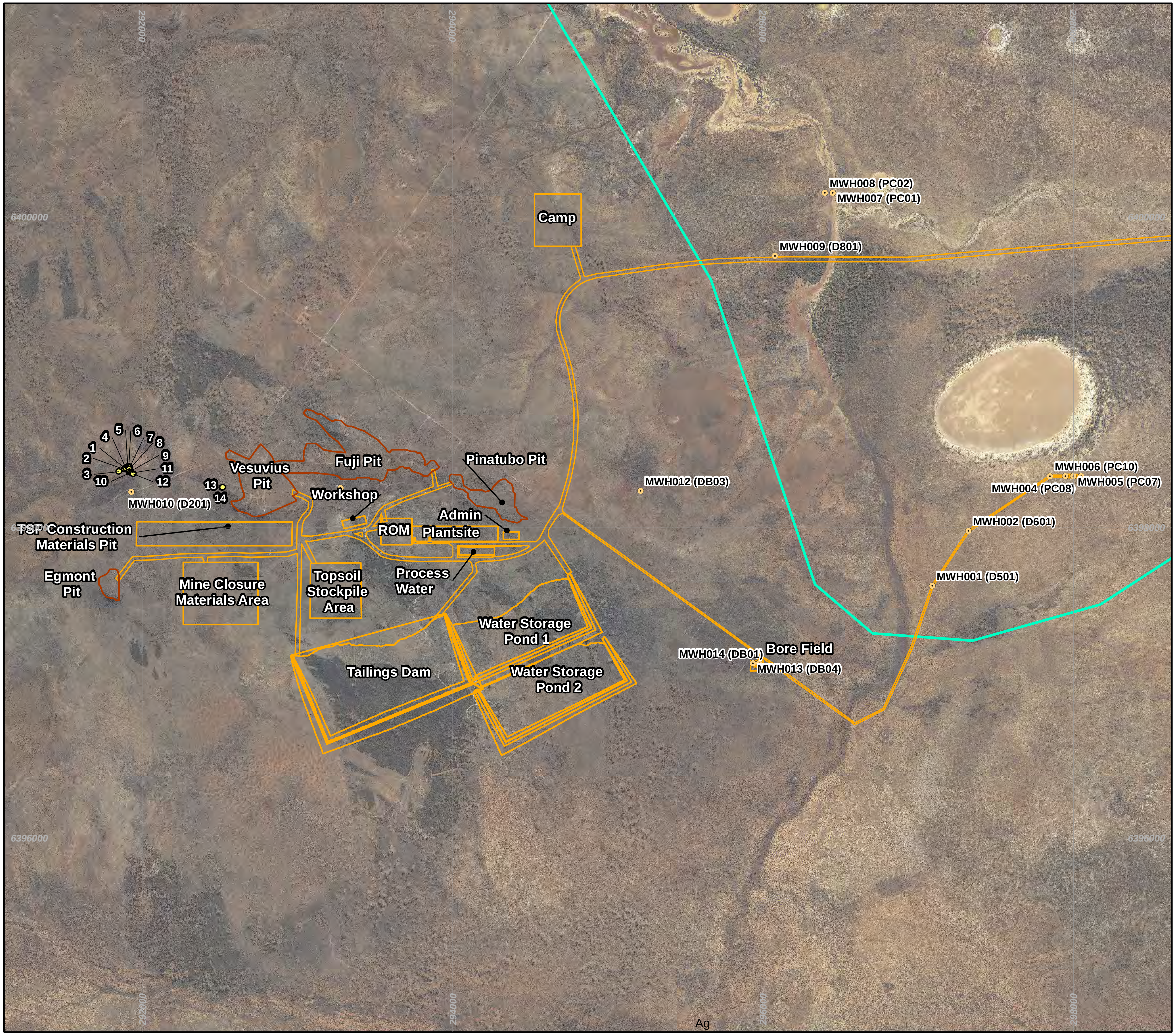
[redacted]

2.6.5 Marianthus Relationship with Groundwater

The information collected to date indicates that the *Marianthus aquilonaris* plants rely on rain water within the soil profile, and not the regional groundwater table, given that the groundwater is hypersaline and that the depth to groundwater is in excess of 45 m.

Consequently, groundwater drawdown associated with the projects proposed water supply bores is unlikely to impact the *Marianthus aquilonaris* communities. Similarly, the proposed mine pits do not extend below the water table, hence mining will not impact the groundwater environment.

The *Marianthus aquilonaris* plants may benefit from underlying geological structures, such as vughs, iron stained fracture surfaces, quartz veining and bleached shearing, in terms of persistent soil moisture.



Legend

- Drill Holes
- Geological Structures
- Pits
- Project Disturbance Footprint
- Palaeovalley

Data Sources:
Project Disturbance Footprint, Imagery,
Pits - Audalia Resources Limited
Geological Structures, Drill Holes, Palaeovalley - GRM

Location

Map Area

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133
Hope 2932	Tay 3032	Peak Charles 3132

N

SCALE 1:25,000

0 0.15 0.3 0.6 0.9 1.2 Km

GDA 1994 MGA Zone 51

audalia resources limited

GROUNDWATER RESOURCE MANAGEMENT

Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 6
Geological Structures

Additional Information

COMPILED: Gaia Resources	DATE: 8/05/2020	LOCN: PERTH	A3	SCALE 1:25,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig6.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig6.mxd				

2.7 CHARACTERISTICS OF THE SHALLOW GRAVEL OVER INDURATED MOTTLED ZONE SOILS

The mapped areas of shallow gravel over indurated mottled zone extend from the south west of the site to the north. These areas are mapped in Figure 4. Characteristics of each area are summarised in Table 3. The mapped soils have highly variable areas but are all small compared to even the size of local catchments. The areas generally lie close to or across low ridgelines, which is consistent with characteristics of this soil grouping.

The areas that contain *Marianthus aquilonaris* populations all lie across a ridge line and down north east or north west trending slopes.

Of the areas without *Marianthus aquilonaris* populations, most lie on ridgelines and on slopes with aspects ranging from northerly to southerly. One lies mid-slope (Site 1). One lies in the upper reaches of a small drainage line (Site 3).

Table 3 Soil Area Characteristics

Name	Area (m^2)	Description
Population 1a	43,470	Contains a large *Marianthus aquilonaris* population. Lies across a ridge line and on the north west slopes. Level 378-397 m AHD.
Population 1b	13,556	Contains a smaller *Marianthus aquilonaris* population. Lies across a ridge line and on the north east slopes. Level 411-397 m AHD. Includes the eastern rock hole.
Population 1c	27,597	Contains a large *Marianthus aquilonaris* population. Lies across a ridge line and on the north west slopes. Level 401-425 m AHD.
Population 1d	52,340	Contains a large *Marianthus aquilonaris* population. Lies across a ridge line and on the north east slopes. Includes the western rock hole. Level 406-416 m AHD.
Population 1e	3,461	Outside of topographical data. Contains a small *Marianthus aquilonaris* population. Lies in what appears to be the upper reaches of a northerly trending drainage valley.
Site 1	8,160	Lies mid-slope with a north west aspect. Level 372-382 m AHD.
Site 2	19,814	Lies across a ridge line and on the northern slopes. Level 373-383 m AHD.
Site 3	31,184	Lies in the upper reaches of a small drainage line. Easterly aspect. Level 347-366 m AHD.
Site 4	346	Small area on a north-south ridgeline. Level 361 m AHD.
Site 5	4,802	Small area to the south that lies across a ridgeline, near of Sites 7 and 8. Level 410-413 m AHD. Easterly and westerly aspect.
Site 6	8,730	Small area to the south on a low ridgeline, upslope of Site 8. Level 405-411 m AHD. South westerly aspect.
Site 7	1,106	Small area to the south on a low ridgeline. Level 397-399 m AHD. South westerly aspect.
Site 8	2,786	Lies outside of the topographic data.

A predicted water balance for all of the soil areas through the *Marianthus aquilonaris* area and for the whole area is given in Table 4.

The soil areas have a high runoff fraction of the water balance, which is consistent with their shallow soil profile and rocky surface. All of the areas receive some runoff from upslope; the amount varies depending on the location of the area in the landscape, local topography and the assumed surrounding soils.

However, the predicted water balance for the soil areas is still dominated by evapotranspiration, which accounts for 60-80% of rainfall. This means that most of rainfall is taken up by plants and transpired or evaporated from soil, rock and vegetation surfaces.

For the whole project area, the amount of runoff reduces, consistent with the effects of higher rates of infiltration into the deeper red and gravely loams. While runoff from upper rocky areas can be high, much of this is infiltrated in the colluvial zone downslope. Runoff is predicted to account for 3% of rainfall over the project area.

Total seepage below the root zone, which could recharge groundwater, is low relative to the other components of the water balance. Recharge is likely to be highly episodic, with much occurring during extended wet periods. Accordingly, wetter periods than observed during the simulation period (2014-2017) may have higher seepage rates. Presence of deeper soil profiles could also affect rates of seepage to and from the plant root zone.

Evapotranspiration still dominates the water balance at the project scale (96%).

Table 4 Predicted Soil Area Water Balance

Area	Inflows (mm/year)		Area water balance (mm/year)			Area water balance (% of rainfall + runoff inflow)		
	Rainfall	Runoff from upslope	Evapo-transpiration	Runoff leaving the area	Seepage below the root zone	Evapo-transpiration	Runoff leaving the area	Seepage below the root zone
Population 1a	390	10	321	74	0	81%	19%	0%
Population 1b	390	34	322	97	0	76%	24%	0%
Population 1c	390	84	322	147	0	63%	37%	0%
Population 1d	390	7	321	71	0	82%	18%	0%
Site 1	390	63	327	121	0	70%	30%	0%
Site 2	390	17	321	81	0	80%	20%	0%
Site 3	390	86	322	150	0	63%	37%	0%
Site 4	390	39	367	68	0	83%	17%	0%
Site 5	390	10	331	66	0	84%	16%	0%
Site 6	390	14	331	71	0	82%	18%	0%
Site 7	390	52	336	104	0	74%	26%	0%
All catchments	390	0	375	12	0	96%	3%	0%

Water balance is presented for the unsaturated zone (root zone). Simulation period – 2014-2017. Rainfall and evaporation data are for the location of the BoM Salmon Gums station, derived using BoM data drill. Areas are shown on Figure 5.

2.8 AREAS TO CATCHMENT DIVIDE

An assessment of the location of the *Marianthus aquilonaris* communities in the catchments across the site was made by considering the area of catchment above the communities (i.e. the catchment area that would drain through the actual area occupied by *Marianthus aquilonaris*), and also the mapped shallow gravel over indurated mottled zone soils and the catchment area above this soil type (i.e. the catchment area that would drain through the shallow gravel over indurated mottled zone soil type). A summary of these areas is given in Table 5 and mapped in Figure 7. Site drainage and the overall catchments are described in Section 2.5. Mapped soil areas without *Marianthus* *aquilonaris* populations are not considered in this assessment. Catchments 1, 2 and 7 do not contain populations.

The analysis shows that most of the communities and soils lie across or close to ridge lines. The populations in Catchment 5 have the largest upslope area of all the catchments at the site. The area of catchment above the mapped soil is smaller than the soils area in all catchments. The area of catchment above the populations is smaller than the population area in Catchments 3, 4 and 6 and marginally larger in Catchment 5.

The area of soils containing *Marianthus aquilonaris* populations is a small proportion of the total catchment area, varying from 1-7%.

Table 5 Areas to Catchment Divide

Catchment	Catchment area (m^2)	Soils area (m^2)[a]	Area above soils to catchment divide (m^2)	Population area of occupancy (m^2)	Area above population to catchment divide (m^2)	Area below population (m^2)[b]
1	93,377	-	-	-	-	-
2	151,262	-	-	-	-	-
3	748,565	10,307	0	1,975	177	748,389
4	1,217,245	46,718	1,432	17,126	3,862	1,213,383
5	947,938	67,813	14,989	12,788	13,467	934,471
6	653,620	15,625	1,871	2,966	802	652,818
7	630,950	-	-	-	-	-

a = area of mapped shallow gravel over indurated mottled zone soils; and b = catchment area – area above population to catchment divide. Analysis is given for mapped soils areas that contain *Marianthus aquilonaris*.

[redacted]

Legend

- Rock Holes
- Critical Habitat
- Drainage Lines
- Pits
- Project Disturbance Footprint
- Mapped soils
- Catchments
- Area Above Soils to Ridge
- Area Above Population to Ridge
- *Marianthus* Populations

Data Sources:
Pits, Mapped Soils, Critical Habitat,
Project Disturbance Footprint,
Marianthus Populations - Audalia Resources Limited
Rock Holes, Drainage Lines, Catchments,
Contours, Area Above Soils to Ridge,
Area Above Population to Ridge - GRM

Location

1:100 000 Map Sheet Location

Roundtop 2933	Johnston 3033	Bronzite Ridge 3133
Hope 2932	Tay 3032	Peak Charles 3132

N

SCALE 1:8,000

0 100 200 400 600 m

GDA 1994 MGA Zone 51

audalia resources limited

GROUNDWATER RESOURCE MANAGEMENT

Project: Lake Medcalf Hydrogeological and Hydrological Study
Job no: J1843

Figure 7
Areas to catchment divide

Additional Information

COMPILED: Gaia Resources	DATE: 10/06/2020	LOCN: PERTH	A3	SCALE 1:8,000
GDA 1994 MGA Zone 51	PLAN No: GR604-06_Lake_Medcalf_Fig5.pdf			
DOCUMENT NAME: GR604-06_Lake_Medcalf_Fig7.mxd				

2.9 Rock Hole Water Balance

A number of rock holes occur in the area. The two largest occur in the west (Photos 6 and 7) and east (Photo 8) of the site. Both are located on low ridgelines in exposed rock. The holes have been observed to hold water and have also been seen dry.

Photo 6 Western Rock Hole – No Ponded Water

Photo 7 Western Rock Hole – With Ponded Water

Photo 8 Eastern Rock Hole

The two rock holes were included in the water balance model, as summarised in Table 6. Figure 8 shows variation in predicted depth of water in the two rock holes.

The modelling indicates that inflow to the rock holes comes from direct rainfall and variable overland flow from a small catchment. The eastern rock hole appears to have a larger catchment than the western rock hole. Both holes readily fill and then overflow in larger events. Water is then lost mainly to evaporation over the following one to two months.

Table 6 Predicted Rock Hole Water Balance

Catchment	Inflow to rock hole (mm/year)		Water balance (mm/year)			Water balance (% of inflows)		
	Rainfall	Runoff inflow from catchment	Evapo-transpiration	Overflow from the rock hole	Seepage below the root zone	Evapo-transpiration	Runoff leaving the catchment	Seepage below the root zone
Rock hole W	390	341	318	411	0	44%	56%	0%
Rock hole E	390	811	318	881	0	27%	73%	0%

Water balance is presented for the rock hole pond. Simulation period – 2014-2017. Rainfall and evaporation data are for the BoM Salmon Gums station, derived using BoM data drill. Pond representation in the model is approximate. Location of the rock holes is shown on Figure 5.

GROUNDWATER RESOURCE MANAGEMENT

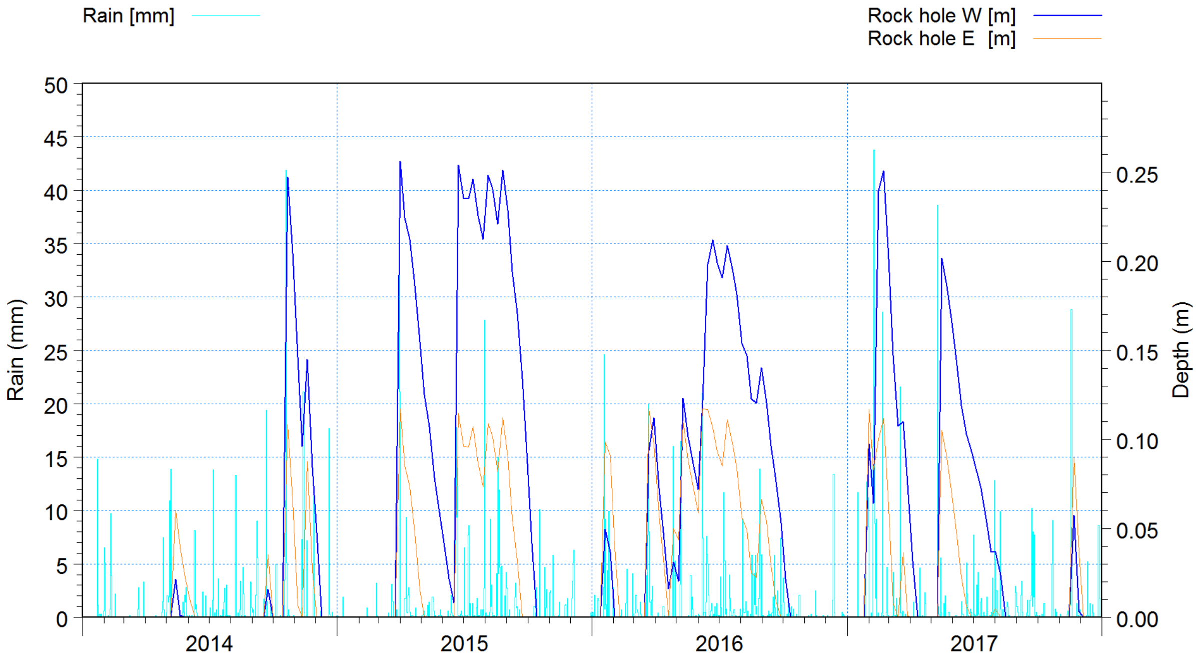


Figure 8 **Predicted Depth of Water in the Rock Holes**

3.0 SUMMARY AND CONCLUSIONS

The landscape through the area of the *Marianthus aquilonaris* community is characterised by low hills with exposed rock at the surface changing to deeper sandy and loamy soils with distance downslope. A number of small catchments drain to the north and south from a central, east-west trending line of hills.

There are occasional, discontinuous erosion gullies in the mid slopes. Broad, heavily vegetated drainage lines with no defined channel tend to form in the mid to lower parts of the local catchments.

Of 13 discrete areas of the soil shallow gravel over indurated mottled zone, five contain *Marianthus aquilonaris* populations. The areas that contain *Marianthus aquilonaris* populations all lie across a ridge line and down north east or north west trending slopes. Of the areas without *Marianthus aquilonaris* populations, most lie on ridgelines and on slopes with aspects ranging from northerly to southerly. One lies mid-slope. One lies in the upper reaches of a small drainage line.

Modelling indicates that all of the mapped soil areas have a high runoff rate, which is consistent with their shallow soil profile and rocky surface. All of the areas receive some runoff from upslope; the amount varies depending on the location of the area in the landscape, local topography and surrounding soils. The water balance for the soil areas is dominated by evapotranspiration, which accounts for 60-80% of rainfall. This means that most of the rainfall is taken up by plants and transpired or evaporated from soil, rock and vegetation surfaces.

As modelled, the catchment water balance is dominated by evapotranspiration, with a small proportion of rainfall reporting to the catchment outlet as runoff in the drainage lines. Total seepage below the root zone, which could recharge groundwater, is generally low. Any significant groundwater recharge is likely to occur in very wet years.

The current understanding of the hydrogeological conditions indicate that the *Marianthus aquilonaris* plants are very unlikely to draw water from the regional groundwater table, given that the groundwater is hypersaline and the depth to groundwater is in excess of 45 m (the plant roots are thought to only extend 1 m). Similarly groundwater drawdown associated with the projects proposed water supply bores is unlikely to impact the plant communities. *Marianthus aquilonaris* plants may benefit from underlying geological structures, such as vughs, iron stained fracture surfaces, quartz veining and bleached shearing, in terms of persistent soil moisture.

The two larger rock holes in the area pond water for relatively short periods after larger rainfall events. Water in the holes is probably sourced from direct rainfall and runoff from a small catchment and probably lost mainly to evaporation.

Groundwater Resource Management Pty Ltd

Robin Connolly

PRINCIPAL HYDROLOGIST

Kathy McDougall

PRINCIPAL HYDROGEOLGOIST

Doc Ref: J1843R02b.doc

This report has been printed on paper that contains a proportion of recycled material as a gesture of Groundwater Resource Management's commitment to sustainable management of the environment.

4.0 REFERENCES

Audalia (2019). Medcalf Project. Environmental Scoping Document. Prepared for Audalia Resources Limited by Preston Consulting. 26 March 2019.

Botanica (2017a). Detailed Flora & Vegetation Survey. Medcalf Vanadium Mining Project and Proposed Haul Road. Prepared for Audalia Resources Limited. October 2017. Version 2.

Botanica (2017b). Memorandum: *Marianthus aquilonaris*. Memorandum prepared for Audalia Resources Limited by Botanica Consulting. 9 November 2017.

Botanica (2018). *Marianthus aquilonaris* Landform Monitoring: Spring 2018. Report prepared for Audalia Resources Limited.

Botanica (2019). Memorandum: *Marianthus aquilonaris* Critical Habitat. Memorandum prepared for Audalia Resources Limited by Botanica Consulting. 6 February 2019.

BoM (2018a). Glossary of Terms. http://www.bom.gov.au/lam/glossary/?ref=ftr. Australian Government: Bureau of Meteorology.

BoM (2018b). Design Rainfall Data System (2016). http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016. Australian Government: Bureau of Meteorology.

BOM (2018c). Köppen system. http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp.

BOM (2018d). Cyclone tracks southern hemisphere. http://www.bom.gov.au/cyclone/history/tracks/index.shtml.

DEC (2011), Implementing Recovery Actions for Bremer *Marianthus* (*Marianthus aquilonaris*). Department of Environment and Conservation, Western Australia.

DHI (2018). Mike SHE. https://www.mikepoweredbydhi.com/products/mike-she. Danish Hydraulics Institute, Denmark.

GA (2018). Surface Geology of Australia (1:1M scale dataset). https://data.gov.au/dataset/c45023db-d207-4806-9f50-b38fcff0b5df. Australian Government: Geoscience Australia.

GRM (2019). Medcalf Project. Groundwater Supply Investigation. Unpublished report prepared for Audalia Resources Limited. November 2019. J1843R03.

Kern, A.M. (1995). Hydrogeology of the Kalgoorlie 1:250,000 Sheet. Geological Survey of Western Australia.

Lantzke (2019). Soils of the Audalia Medcalf area. Report prepared by Western Horticultural Consulting for Audalia Resources Limited. December 2019.

Queensland Government (2018). SILO Data Drill. https://silo.longpaddock.qld.gov.au/.