NEW GOLD RAINY RIVER MINE
APPENDIX O
PAG COVER TRAIL FACTUAL REPORT
2019

Rainy River PAG Cover Trial - Annual Monitoring Report

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EXECUTIVE SUMMARY

New Gold Inc. (New Gold) has developed cover system designs for the closure of the potentially acid generating (PAG) mine rock stockpiles (MRSs) at Rainy River Mine. New Gold has implemented cover system field trials to evaluate the cover system design's effectiveness to limit acid rock drainage. O'Kane Consultants Inc. (Okane) was retained to design, instrument, and interpret monitoring data collected from a performance monitoring system installed at the potentially acid generating (PAG) mine rock cover system field trial. The objective of this report is to summarize and interpret findings from data collected for the monitoring period of November 1, 2018 to October 31, 2019.

Two cover system field trials were constructed in fall 2017. Trial #1 consists of 0.50 m compacted Brenna clay (CBC), 0.75 m non-compacted clay overburden, and 0.25 m topsoil. Propagules present in the topsoil layer will provide re-vegetation on Trial #1. Trial #2 consists of 0.50 m CBC and 1.0 m non-compacted clay overburden. Re-vegetation was completed by hand-seeding an appropriate seed-mix on Trial #2 in July 2019. The primary objectives of the cover system field trials are to evaluate the ability of overburden clay to manage oxygen ingress and net percolation through altering the water and gas balances.

The ability of the cover system to manage oxygen ingress is evaluated by monitoring the degree of saturation of the CBC layer. A cover system containing a layer maintained at a degree of saturation equal to or greater than 85% is generally expected to efficiently limit oxygen ingress (McMullen et al. 1997, MEND 2004). Monitoring data recorded at the cover system field trials during the monitoring period show annual average saturation levels greater than 95% in the CBC. Maintenance of a 95% degree of saturation in the cover systems demonstrated that the compacted clay layer is retaining sufficient pore-water to prevent advection, and limit oxygen transport to diffusion through water.

Simple water balances were created for each cover system configuration to estimate net percolation of meteoric waters past the cover system into the underlying waste rock. The total estimated net percolation over the monitoring year was 10% and 12% for Trial #1 and Trial #2, respectively. Measured percolation rates align with conceptual model performance of 5 to 15% net percolation).

Fluctuating automated and manual oxygen concentration readings were observed during the monitoring period. Manual oxygen concentrations indicate an oxygen ingress pathway through Trial #2 and is attributed to insufficient thickness of the clay key surrounding the trial. Due to this pathway, monitoring of oxygen concentrations is not a definitive approach to measure the ability of the cover system to control oxygen ingress. Instead, the ability to control oxygen ingress should be evaluated on the degree of saturation maintained within the CBC. Performance monitoring of cover systems provides essential insight into cover system response

to climatic variations in terms of temperature and water storage dynamics. The monitoring systems installed at Rainy River are providing data required to assess the performance trajectories for the site. Continuous monitoring and interpretation of meteorological and water balance components is necessary for determining an accurate representation of cover system performance.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

New Gold Inc. (New Gold) has developed cover system designs for the closure of the potentially acid generating (PAG) mine rock stockpiles (MRSs) at Rainy River Mine. New Gold has implemented cover system field trials to evaluate the cover system design's effectiveness to limit acid rock drainage. O'Kane Consultants Inc. (Okane) was retained to design, instrument, and interpret monitoring data collected from performance monitoring systems installed at the PAG mine rock cover system field trial. This report summarizes and provides interpretation of monitoring data obtained between November 1, 2018 and October 31, 2019 (referred to herein as 'the monitoring period').

1.1 Project Objectives and Scope

The objectives of the PAG mine rock cover system field trials are to:

1) Evaluate overburden clay as a potential cover material for mitigation of oxygen ingress during stockpile construction (operations) due to advective airflow;

2) Evaluate the effectiveness of compacted overburden clay as a low hydraulic conductivity barrier layer and overlying protective growth medium cover borrow material for mitigation of net percolation and oxygen ingress (closure); and

3) Update and refine conceptual models of performance for the cover system field trial area through examining changes in *in situ* gas concentrations after cover system placement and water balance components (e.g., precipitation, runoff, evaporation, water storage, etc.).

1.2 Report Organization

For convenient reference, this report has been subdivided into the following sections:

- Section 2 – provides pertinent background information of the cover system field trials and a summary of activities completed during the monitoring period;
- Section 3 – presents and discusses field data collected during the monitoring period; and
- Section 4 – provides conclusions and recommendations based on key performance monitoring characteristic.

2 BACKGROUND

2.1 Description of Cover System Field Trials

Construction of the cover system field trials commenced October 2017 and was completed by early November 2017. The constructed field trials span an approximate area of 65 m × 100 m with a 1 to 2% sloping plateau of ~3,000 m^2. A 3H:1V slope was constructed on the north, east and west slopes. Two enhanced store-and-release, low permeability layer cover systems were constructed to meet the objectives stated in Section 1.1. Trial #1 consists of 0.50 m compacted Brenna clay (CBC), 0.75 m non-compacted clay overburden, and 0.25 m topsoil. Propagules present in the topsoil layer will provide re-vegetation on Trial #1. Trial #2 consists of 0.50 m CBC and 1.0 m non-compacted clay overburden. Re-vegetation was initiated by hand-seeding an appropriate seed-mix on Trial #2 in July 2019. Complete as-built details can be found in Okane Report No. 1003/08-001 (2018).

Okane installed and commissioned meteorological and *in-situ* instrumentation throughout the trial area to monitor cover system performance over time under site specific conditions. Two instrumentation nests (Primary and Secondary) were installed in both Trial #1 and Trial #2 areas. Primary nests consist of a full arrangement of sensors throughout the cover system profile. Secondary nests consist of a reduced number of sensors and was implemented to ensure data redundancy in the profile. The following *in-situ* instrumentation was installed in each trial area:

- Eleven matric suction sensors (Campbell Science International [CSI] 229) to measure suction (i.e., negative pore-water pressure) and soil temperature;
- Fourteen water content sensors (CSI 616) to measure *in situ* volumetric water content; and,
- Six oxygen sensors (Apogee SO-110) to measure differential oxygen concentrations above and below the CBC.

Two meteorological instruments were installed on Trial #2. A Texas Electronics model 525M tipping bucket rain gauge to capture trial area specific rainfall events and a Kipp & Zonen NR-LITE2 net radiometer to monitor hourly averages and daily totals of net radiation (i.e., the sum of incoming and outgoing all-wave radiation). The tipping bucket and net radiometer will be used to determine theoretical maximum potential rates of evaporation from the cover system surface. Additional site-specific meteorological data will be collected from New Gold's on-site weather station.

2.2 Conceptual Model of Cover System Performance

A conceptual model of cover system performance was developed by Okane. The conceptual model was used to identify key processes and mechanisms, and then evaluate the cover system design's control on those mechanisms under a range of potential scenarios. It was identified that weathering (oxidation) and leaching (net percolation) in the MRSs will cause acid rock drainage and have negative environmental effects on the receiving environment. The cover system designs aim to provide controls on oxygen ingress and net percolation to limit acid rock drainage.

Diffusion and advection represent the primary mechanisms for oxygen transport through a cover system. Oxygen diffusion can be restricted by decreasing the bulk diffusion coefficient of the cover system, generally by increasing the degree of saturation. A cover system containing a layer maintained at a degree of saturation equal to or greater than 85% is expected to efficiently limit oxygen ingress (McMullen et al. 1997, MEND 2004). The compacted clay layer incorporated in both cover system configurations is designed to provide higher water retention characteristics of the cover system profile. It is expected that the compacted layer will maintain a degree of saturation greater than, or close to 85% for the majority of the climate cycle. Limiting advective transport of oxygen requires that the cover restrict air flow by reducing pressure and thermal gradients or the permeability of the material. The compacted clay layer aims to reduce permeability of the material to limit advective air movement.

Net percolation is limited by taking advantage of the store-and-release properties of the one-meter thick non-compacted layer. Infiltrating water is stored within the cover system so it can be subsequently released via transpiration and evaporation. A store-and-release system uses the variability in timing, volume, and intensity of precipitation events to take advantage of available evaporative energy during summer.

The conceptual model was based on Rainy River Mine's site-specific climate, hydrogeological setting, and materials. Given the site-specific climate of Rainy River Mine, the conceptual ranges of performance could be classified as very low net percolation (5 to 15% of average annual precipitation) and very low oxygen flux (1 to 5 mol/m^2/year) according to the INAP Guidance Document (INAP 2017).

2.3 2018 – 2019 Monitoring Activities

The cover system field trials were monitored by Okane personnel throughout the monitoring period. Major activities that were completed on the field trials include installation of manual oxygen sampling probes, snow survey, Trial #2 modifications, and monthly data collection and data QA/QC (Table 2.1).

Table 2.1: Monitoring period activities.

Date	Activity
November 12, 2018	Installation of Manual Oxygen Sampling Probes
March 4, 2019	Snow Survey
July 11 – 18, 2019	Trial #2 Modifications[1]
November 2018 – October 2019	Monthly Data Collection and Data QA/QC

[1]Detailed in Section 2.3.1.

2.3.1 Trial #2 Modification

During site visits, large erosional rills were observed on the northern and eastern slopes of Trial #2. The erosional rills were attributed to the steep (3H:1V), non-vegetated slope. Okane identified the potential for advective air movement into the underlying mine rock and deeper frost penetration due to the loss of material and recommended repairing and modifying Trial #2 slopes. Approximately 2,200 m^3 of overburden material was placed on the north, east, and south slopes of Trial #2 to reduce the overall slope to approximated 4H:1V (Figure 2.1). Once extended, the new slopes were hand-seeded with appropriate seed mix to promote vegetation development and reduce erosion potential. Drawing 1003/16-001 outlines design details of the modifications.

During material placement, a small borrow investigation of the clay key surrounding the cover trials was completed on the south-east corner. It was observed that the thickness of the key at this location pinched out and is less than the minimum design thickness (Figure 2.2). It should be noted that a thin clay key could be an additional potential pathway if oxygen ingress is observed in the future.

Figure 2.1: Completed modified north slope construction. July 17, 2019.

Figure 2.2: Borrow investigation of clay key layer on southeast corner of Trial #2. July 15, 2019.

3 COVER SYSTEM PERFORMANCE MONITORING RESULTS

3.1 Meteorology

Meteorological parameters were measured at Rainy River Mine to monitor site-specific climate conditions. Rainfall, snowfall, and net radiation were measured directly on the field trial plateau while air temperature, relative humidity, and wind speed and direction was collected at Rainy River Mine's Barron weather station.

3.1.1 Air Temperature and Relative Humidity

Annual average air temperature recorded at the Barron weather station during the monitoring period was 1.7˚C. Recorded maximum and minimum daily air temperature at the Barron weather was lower than the 30-year historical average of 3.3˚C (Figure 3.1). The average winter temperature is of interest with respect to performance monitoring for the purpose of evaluated frost penetration into the cover system. During February 2019, the average air temperature was -17.8 ˚C (6.4˚C colder than average).

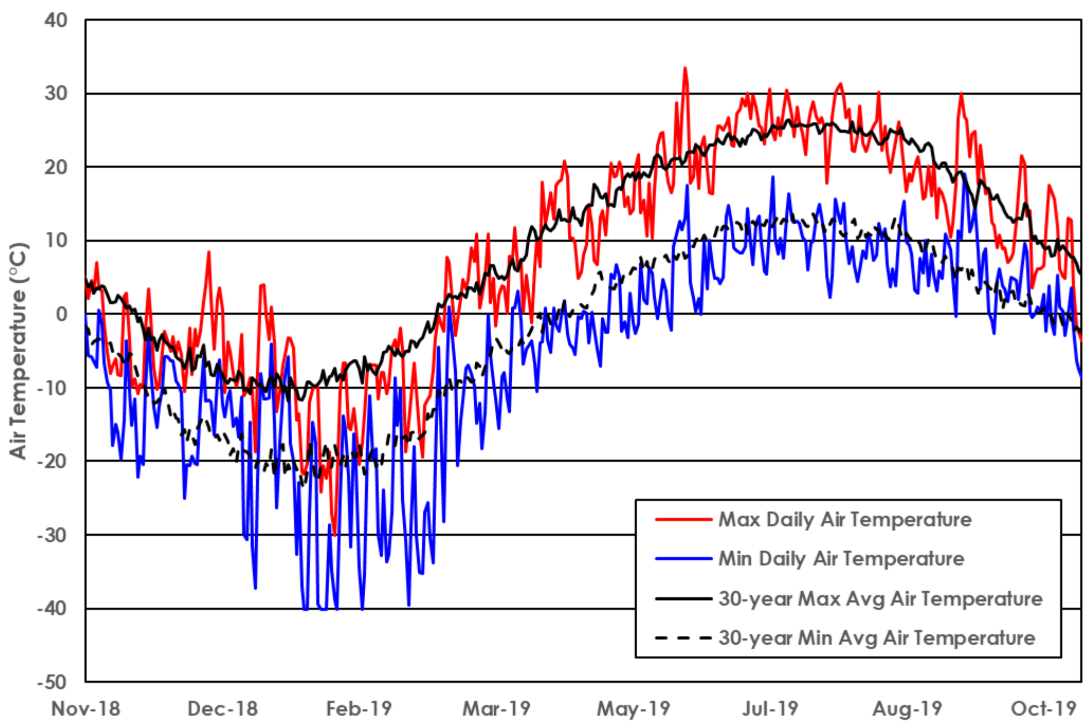

Figure 3.1: Maximum and minimum daily air temperature recorded at Barron weather station as compared to 30-year averages.

3.1.2 Rainfall

Cumulative rainfall is measured with a tipping bucket gauge located on the plateau of Trial #2 (Figure 3.2). A total of 593 mm of rainfall was recorded during the monitoring period (41 mm more than the 30-year historic average). Monthly rainfall from March to October 2019 was compared to the 30-year historic average (Table 3.1). It was observed that the spring and summer months of April to August were drier than average, while rainfall in September and October was higher than the long-term average.

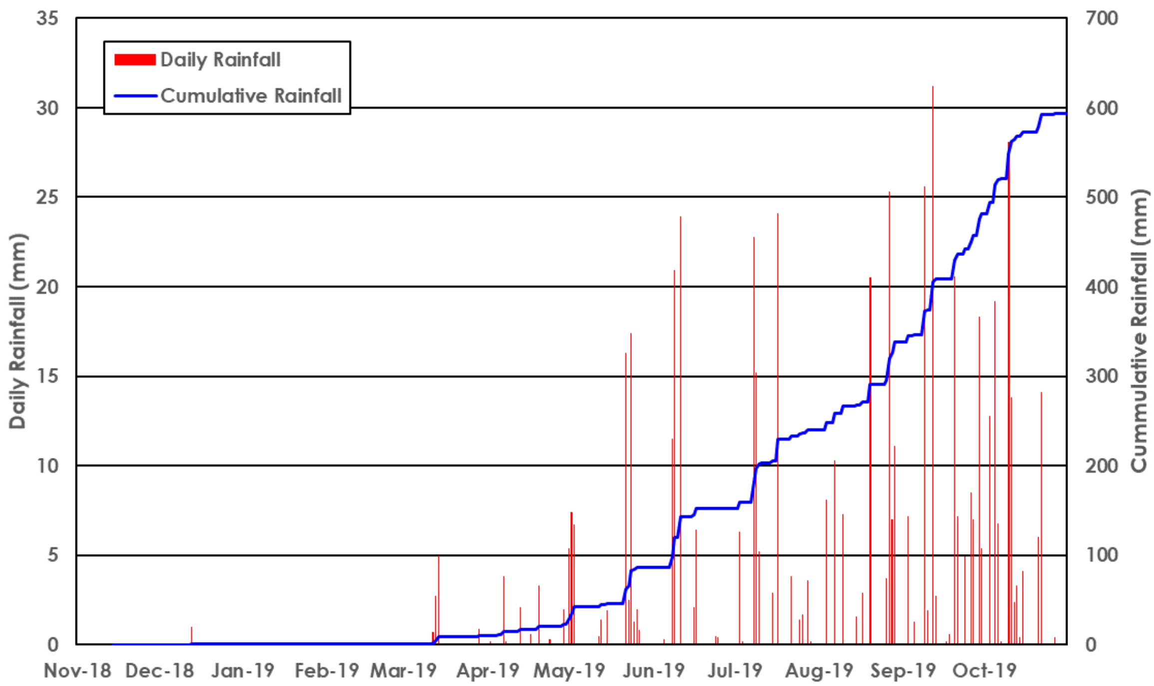

Figure 3.2: Daily and cumulative rainfall recorded at cover system field trials.

Table 3.1: April to October monthly rainfall at field trials versus 30-year historic average.

Month	2019		30-year Average	
	Rain Days	Cumulative Rainfall (mm)	Rain Days	Cumulative Rainfall (mm)
April	10	12.7	8	48.4
May	12	63.6	13	87.2
June	9	66.1	13	107.9
July	15	87.7	11	123.6
August	11	97.9	10	78.6
September	16	142.7	11	77.5
October	17	112.0	11	63.6

3.1.3 Snowfall

The tipping bucket rain gauge on the trial plateau only measures rainfall and does not directly measure snow accumulation. A snow survey was conducted by Okane to measure the depth of the snowpack on each cover system field trial on March 4, 2019 (Figure 3.3). Assuming an average snow water density of 10%, the average snow water equivalent on the plateau of Trial #1 and Trial #2 was 51 mm and 34 mm, respectively.

Overall, Trial #1 observed a greater snowpack on the plateau. The greater snowpack was attributed to the tall vegetation acting as a snow catch on Trial #1 as compared to the bare surface of Trial #2. The large snowpack observed on the east and southeast slopes can be attributed to snow blowing off the bare plateau and accumulating on the side slopes.

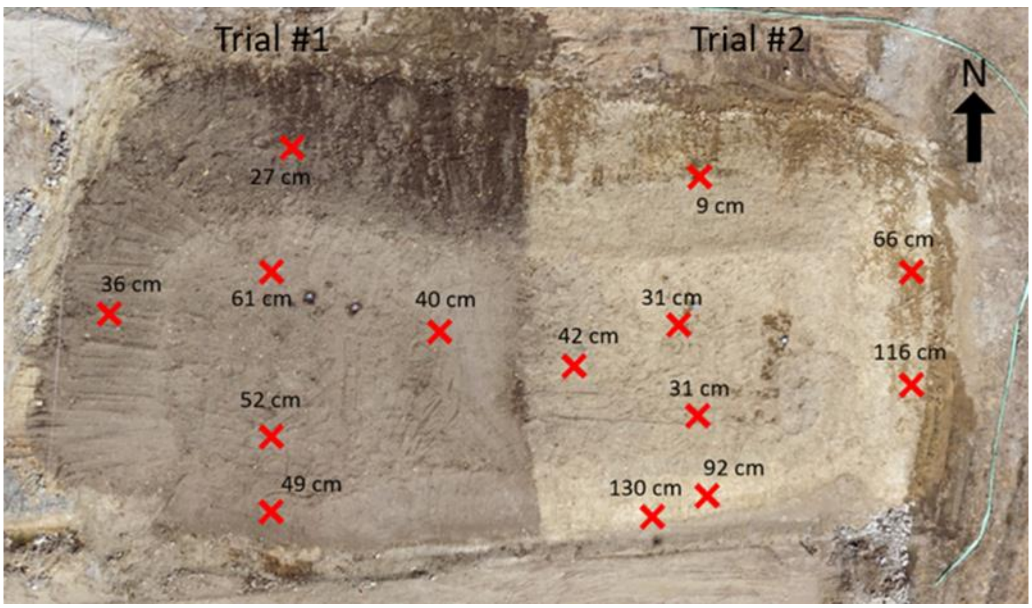

Figure 3.3: Snow survey locations and snowpack depths. March 4, 2019.

3.1.4 Reference Evapotranspiration

Key drivers of cover system performance in terms of net percolation are precipitation and energy available for evapotranspiration. Reference evapotranspiration (ET_0) was calculated using the Penman-Monteith method. The Penman-Monteith method is the sum of transpiration of water within vegetation and evaporation of free water from the surface. A hypothetical grass crop having a height of 0.12 m, 70 s m^{-1} surface resistance, and albedo of 0.23 was used (Allen *et al*. 1998). Reference evapotranspiration was calculated based on air temperature, relative humidity, and wind speed data collected at the Barron weather station and net radiation measured on the cover system surface.

Monthly ET_0 was compared to monthly rainfall for March to October (Figure 3.4). A decrease in the water stored within the upper layers of the cover system is observed in months where ET_0 is greater than rainfall (April to August). Similarly, periods where ET_0 is less than rainfall observe an increase in water storage and increased potential for net percolation into the underlying mine rock material (September and October).

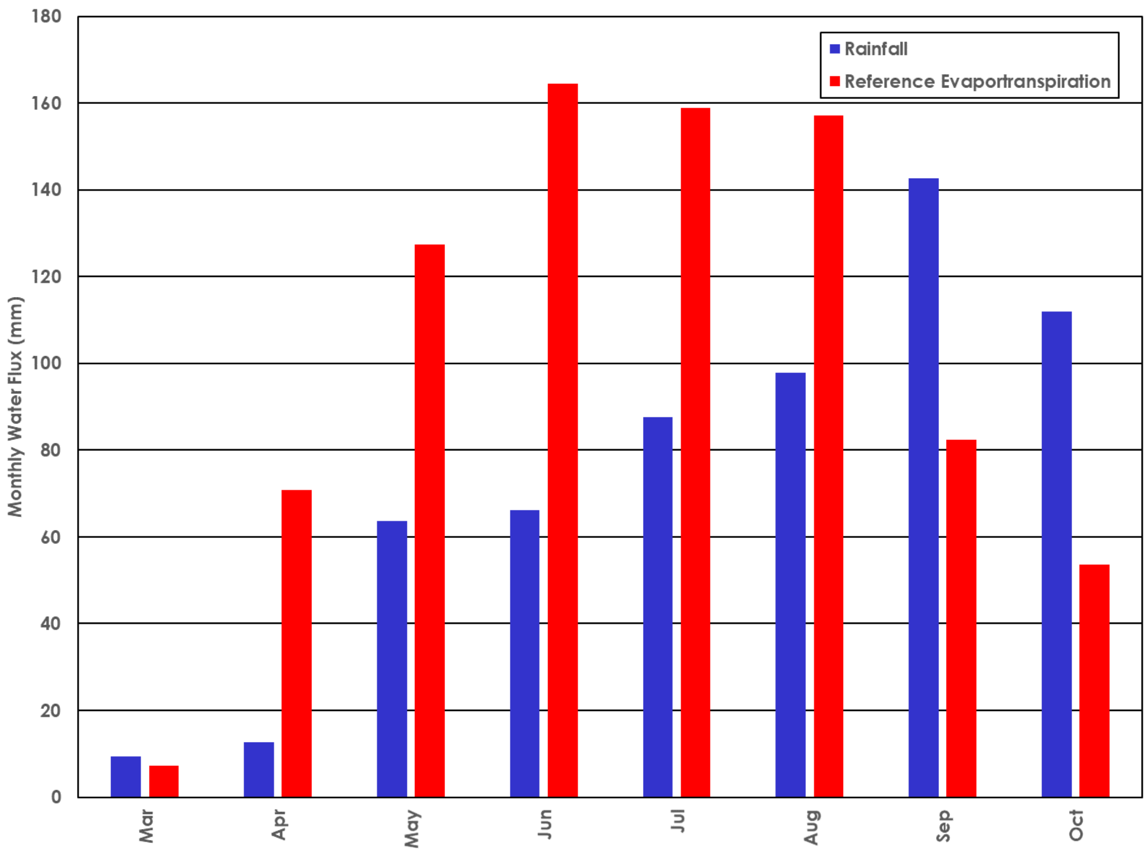

Figure 3.4: Reference Evapotranspiration and total rainfall measured at Rainy River mine during March to October 2019.

3.2 Cover System Temperature Profiles

Soil temperature was monitored over the entire cover system profile of Trial #1 and Trial #2 to observe freeze-thaw cycling and the depth of frost penetration. The largest implication of freeze-thaw cycles on cover system performance is potential changes to physical properties of the material, such as altering the hydraulic conductivity. Freezing temperatures were observed in both cover systems beginning November 25, 2018. Based on *in situ* temperature measurements the maximum freezing depth was 30 cm and 110 cm in Trial #1 (Figure 3.5) and Trial #2 (Figure 3.6), respectively. The large difference between the observed freezing depths is mainly attributed to the thicker snowpack on Trial #1 providing an insulating layer between the cover system and ambient air temperature.

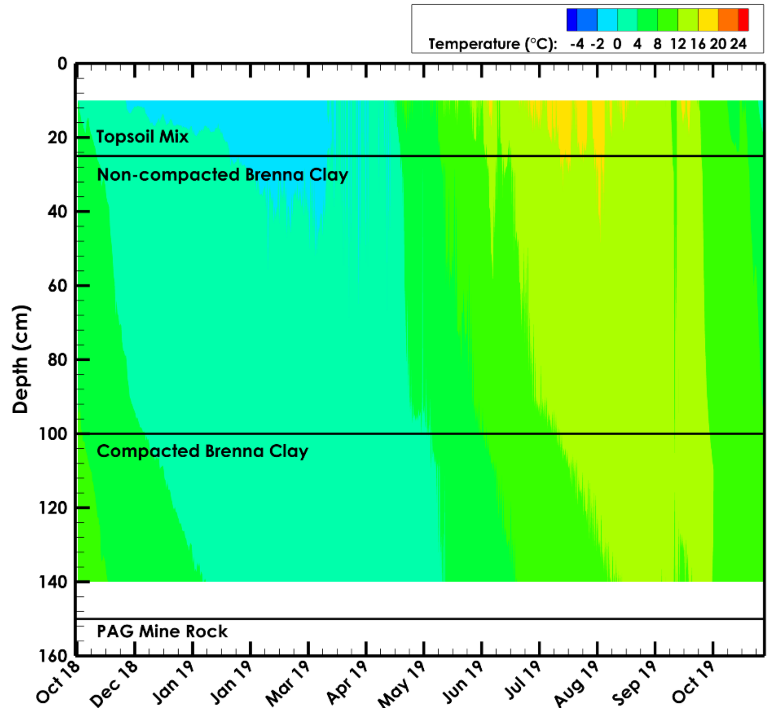

Figure 3.5: Soil temperature profile measured at Trial #1 Primary Nest during the monitoring period.

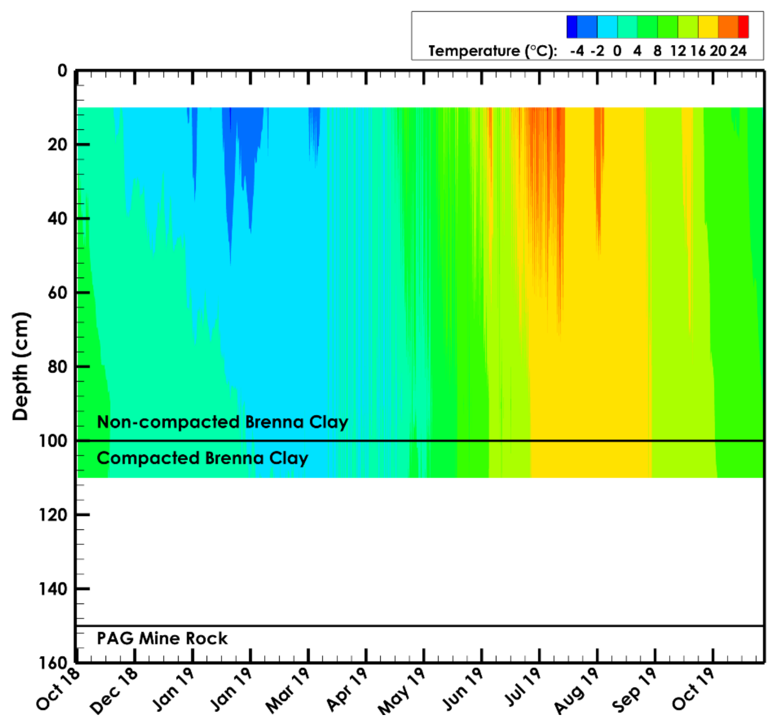

Figure 3.6: Soil temperature profile measured at Trial #2 Secondary Nest during the monitoring period.

3.3 Cover System Water Dynamics

Volumetric water content and matric suction were measured throughout each cover system profile. Volumetric water content and matric suction measurements can be further analyzed to investigate performance and water dynamics of the cover systems. This section presents the results of the data analysis, while direct *in situ* measurements are presented in Appendix B. The top of each cover system was selected as origin datum for all instrumentation depths.

3.3.1 Degree of Saturation

Volumetric water content was measured throughout each cover system profile to observe changes in the degree of saturation of the cover system material. In order to successfully mitigate the ingress of oxygen into the underlying waste rock, a material must remain at or near saturated levels. As the degree of saturation exceeds 80%, the diffusion coefficient typically decreases by several orders of magnitude. A general guideline suggests that maintaining a consistent degree of saturation of 85% or greater within a layer will effectively limit the amount of oxygen movement by diffusion (Aachib *et al*. 2004).

Water content data shows that the CBC layer in both cover system profiles maintained a high degree of saturation throughout the monitoring period, having an annual average degree of saturation greater than 95% (Table 3.2). The degree of saturation maintained in the cover systems demonstrates that the compacted clay layer is retaining sufficient pore-water to attenuate oxygen transport. The noncompacted overburden clay was also examined to assess the capability of the material to mitigate oxygen ingress during MRS construction. It was found that the top 50 cm of material had an average degree of saturation of 88%, while the bottom 50 cm of material had an average degree of saturation above 90% (Table 3.2). Although the noncompacted clay experienced periods below 85%, the noncompacted layer would be able to reduce oxygen ingress for during construction for the majority of the year. It is clear from monitoring results that the objective of mitigating oxygen ingress is effectively achieved through the maintenance of a high degree of saturation in both the compacted and non-compacted layers.

The water cycling depth of each cover system was interpolated based on changes in volumetric water content at measured depths. The water cycling depth of Trial #1 (Figure 3.7) and Trial #2 (Figure 3.8) during the monitoring period was 70 cm and 40 cm, respectively. The deeper water cycling depth seen in Trial #1 was attributed to a greater evapotranspiration depth from the established vegetation.

Table 3.2: Average degree of saturation of cover system layers

	Non-compacted Clay		Compacted Clay		
	0 – 50 cm	50 – 100 cm	Maximum	Minimum	Average
Trial #1 Primary Nest	91%	93%	100%	93%	98%
Trial #1 Secondary Nest	N/A	96%	100%	93%	98%
Trial #2 Primary Nest	89%	96%	99%	86%	97%
Trial #2 Secondary Nest	84%	86%	98%	92%	95%

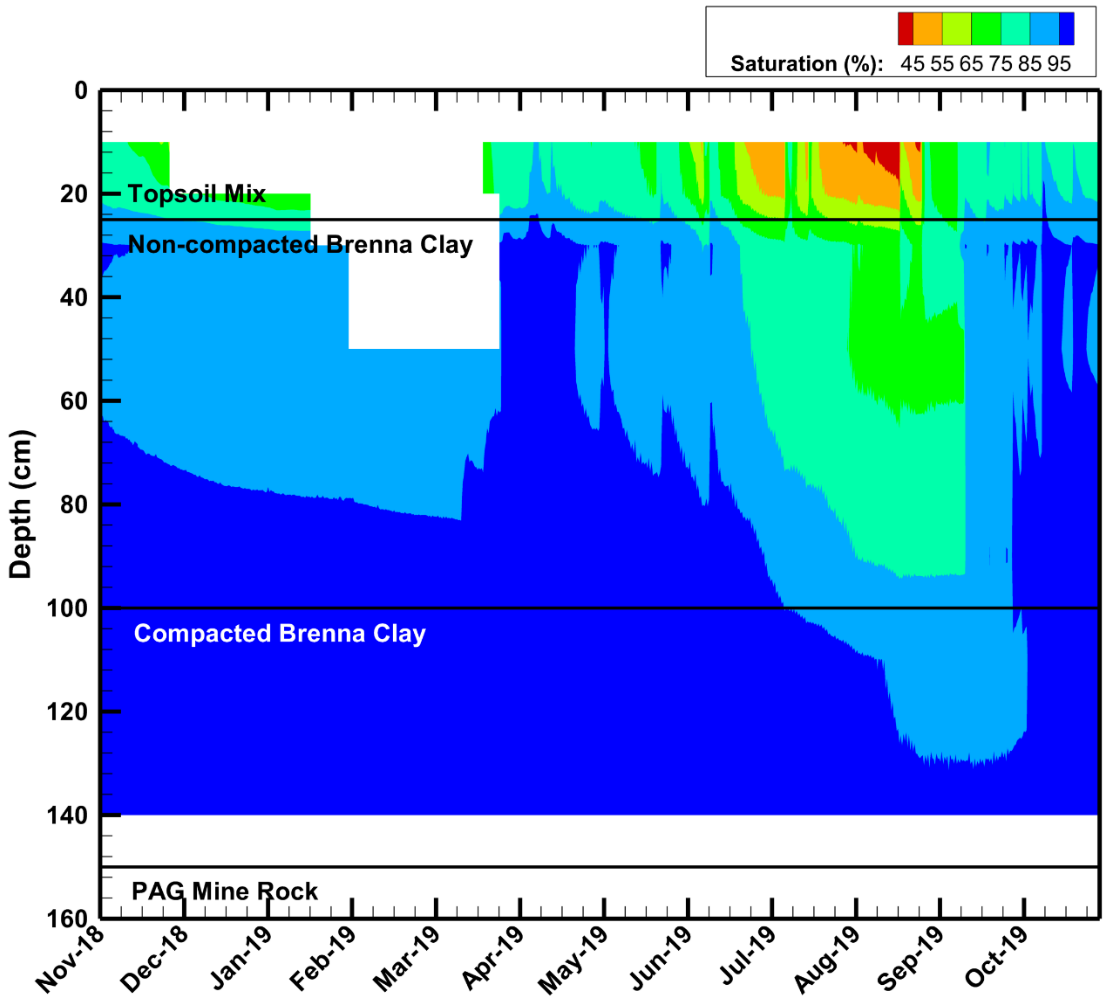

Figure 3.7: Change in degree of saturation at Trial #1 Primary Nest (white areas indicate periods of freezing temperatures).

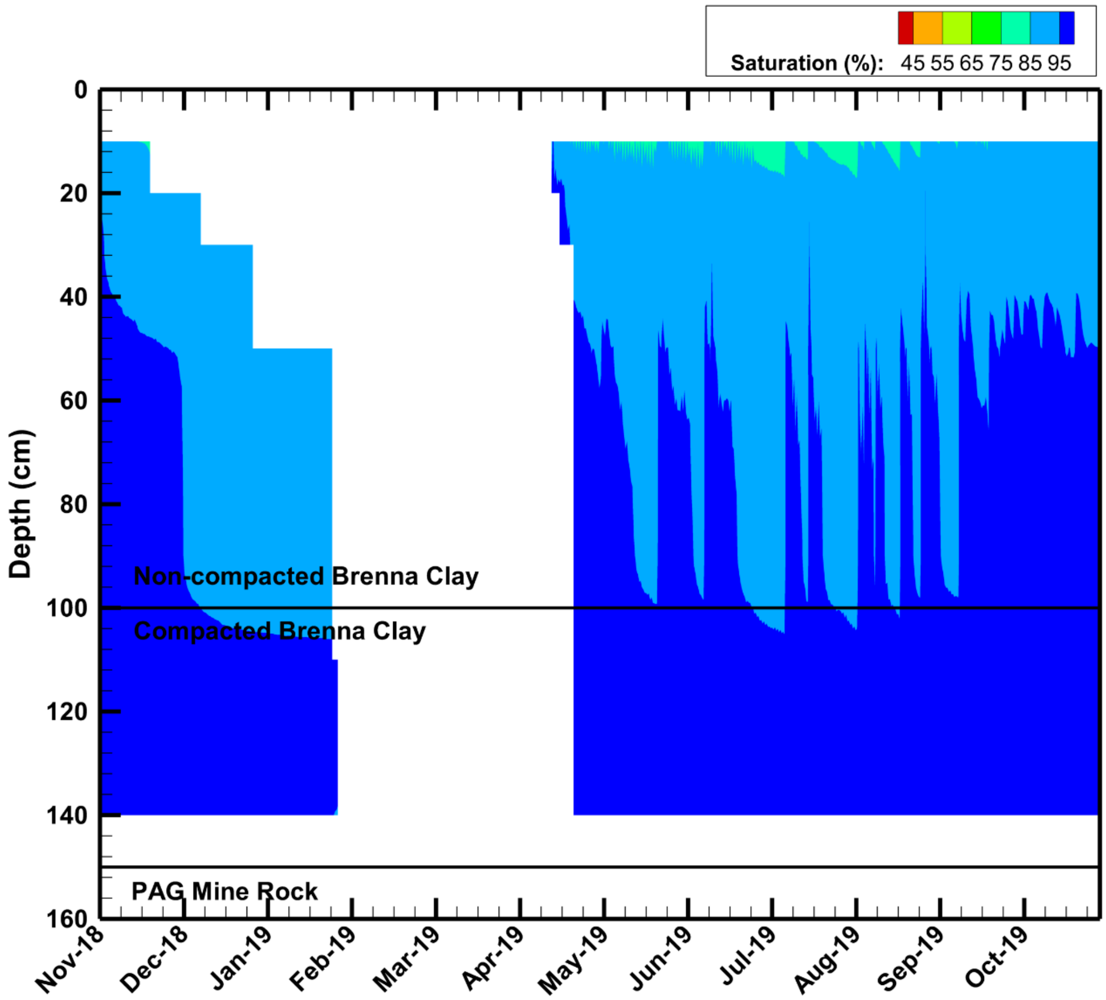

Figure 3.8: Change in degree of saturation at Trial #2 Primary Nest (white areas indicate periods of freezing temperatures).

3.3.2 *Summary of Matric Suction Data*

Matric suction sensors were installed in each cover system profile to measure negative pore-water pressure (suction). In unsaturated soils, suction provides an indication of the affinity of a soil for water, expressed as an energy potential. Measurements of less than 10 kPa are outside the sensor measurement range and are not considered to be accurate. Overall, Trial #1 (Figure 3.9) observed higher suction values deeper within the cover system than Trial #2 (Figure 3.10) (suction values > 500 kPa within the compacted layer). The higher suction values in Trial # 1 was primarily attributed to June and July being drier than normal combined with the ability of vegetation to translocate water out of the soil matrix. Although elevated suction values were recorded within the compacted layer, a high degree of saturation was still maintained indicating that compacted clay was not drying out. The relationship between matric suction and water content could be better defined through development of laboratory water retention curves. A corresponding recommendation for laboratory characterization is provided in Section 5.

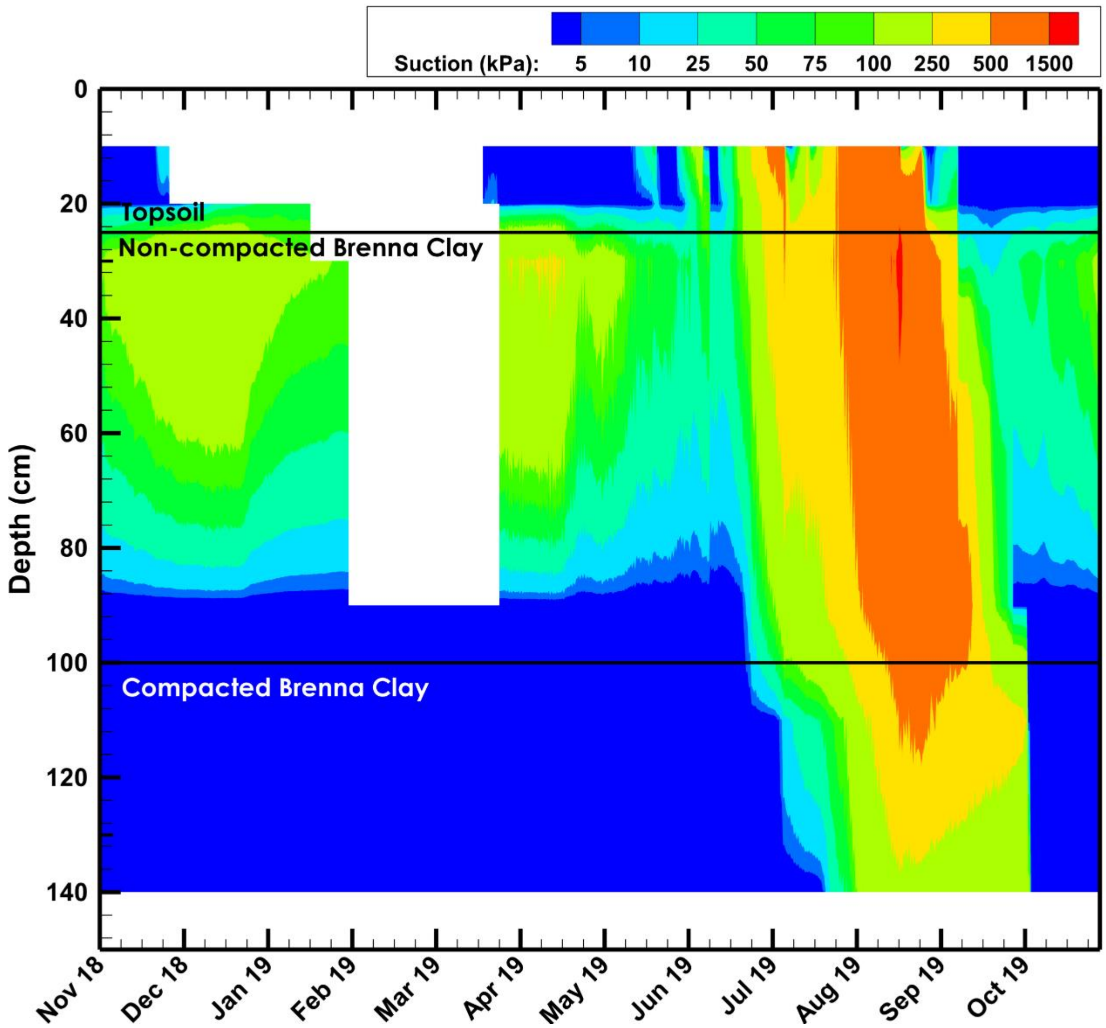

Figure 3.9: Matric suction profile measured at Trial #1 Primary Nest(white areas indicate periods of freezing temperatures).

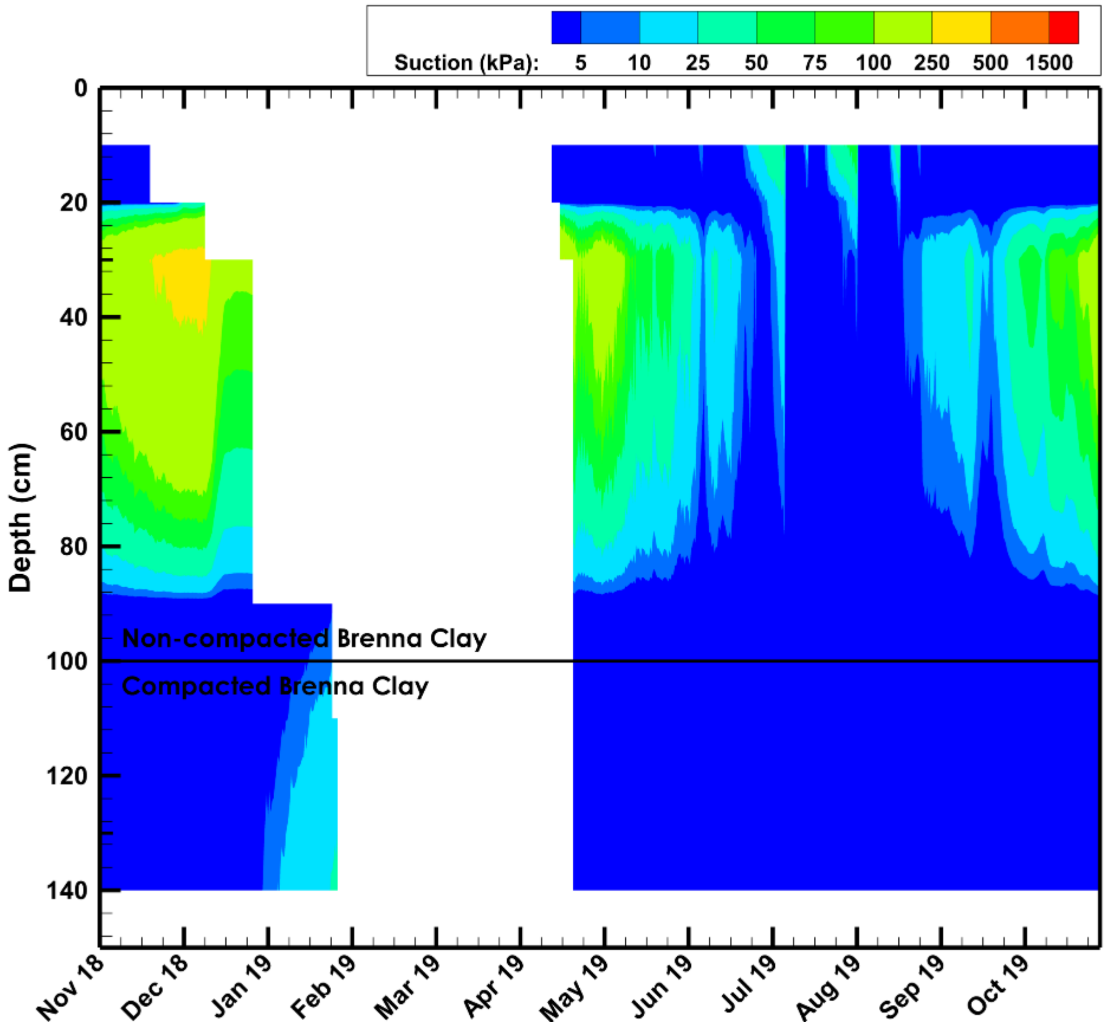

Figure 3.10: Matric suction profile measured at Trial #2 Primary Nest(white areas indicate periods of freezing temperatures).

3.3.3 Total Water Storage

The total water storage within the cover system profiles was determined by using field data to produce water retention curves (WRCs) from combined volumetric water content and suction data during the monitoring period. From the WRCs the water content at which field capacity (FC) is reached can be determined. The FC is the volume of water stored in a soil matrix after the soil is allowed to drain from saturation freely under gravity (with no evaporative loss) and typically corresponds to the water content at suction values of 33 kPa for fine grained soils. Inputs of water above FC fill the largest pores, which then quickly drain under gravity due to an inability of large macropores to exert sufficient tension to retain the water. The total storage of water below field capacity within the cover system was calculated to determine the capacity to store new precipitation within the soil matrix. The total available storage in the cover system trials was approximately 550 mm.

Volumetric water content data was used to calculate the total measured water storage within each primary nest profile. A total water storage profile was created from sectioning the cover system into representative layers, with each layer having a sensor at its centre. For example, if sensors are placed at 10 cm, 20 cm, and 30 cm the representative layers would be 0 to 15 cm and 15 to 25 cm. During periods where the measured storage is less than the total available storage, the soil has room to hold more water within the profile. Conversely, periods where the measured storage volume is greater than the total available storage the profile is not able to store new precipitation and infiltrated water will produce larger net percolation events.

Examination of measured water storage within the cover system profiles demonstrate the effect vegetation has on the capacity of the cover system to store and release water within the upper meter. Trial #1 observed a greater decrease in stored water than Trial #2 from June to August (Figure 3.11). The decrease in storage allows for new precipitation to be stored within the soil profile and not infiltrate to the underlying mine rock. If vegetation is not able to be established on the clay overburden the cover system will not be as effective as a store-and-release system.

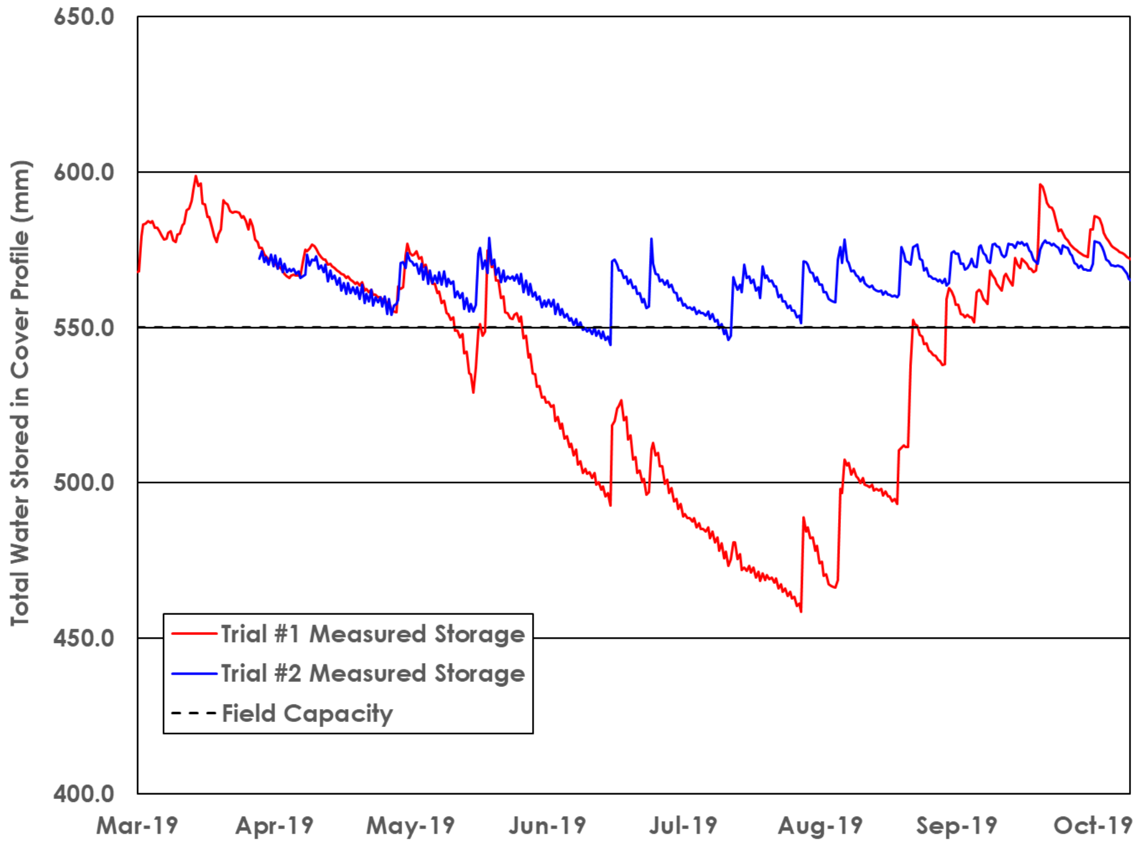

Figure 3.11: Measured storage vs. cover system field capacity.

3.4 Water Balance

3.4.1 Discussion of Water Balance Inputs

Simple water balances were created for each primary station to estimate the volume of water percolating through the cover systems to the underlying waste rock. The water balances were based on *in situ* measurements, site specific climate data, and solving the water balance equation daily (Equation 1). The estimation and application of each of these components in calculating the water balance is discussed briefly below.

$$PPT = SB + RO + ET_0 + NP + \Delta S + ITF \quad [1]$$

where:

PPT = precipitation (rainfall plus snow water equivalent);

SB = sublimation (assumed to be zero);

RO = runoff;

ET_0 = reference evapotranspiration;

NP = net percolation;

ΔS = change in water storage within the cover system profile; and

ITF = interflow (assumed to be zero).

Precipitation was measured at site with a tipping bucket rain gauge to measure rainfall and an assumed snow water equivalent (SWE) of 0.1 kg/m^2. Daily spring melt was estimated by the degree-day method with a degree-day coefficient of 2.74 mm/degree-day C and an estimated snow ripening period of 7 days (USDA 2004). Snow density measurements and sonic ranger instruments would allow for a better understanding on how the SWE contributes to the daily water balance.

Runoff is not measured at the cover trials but was estimated during spring freshet and large rainfall events based on Okane's experience at sites where runoff is monitored. At similar sites, to produce a runoff event of 1 mm, rainfall events of at least 10 mm were required in periods of ~24 hours or less. Based on these findings, runoff events were estimated for the monitoring period as approximately 10% of daily rainfall totals exceeding 10 mm during spring and summer months. As the Rainy River site experienced a wet fall, runoff events were estimated for September and October from solving the water balance equation given the response of measured change in storage. It is Okane's experience at sites with similar climatic conditions that the majority of snowmelt reports as runoff, as it occurs while the lower cover system profile is still frozen, inhibiting infiltration through the cover system profile.

The primary purpose of the water balance is to estimate net percolation rates. Net percolation was estimated based on changes in water storage in the compacted clay layer, suction gradients, and conservative flow limitations of a barrier layer (hydraulic conductivity equal to or greater than 10^{-7} cm/s).

The water balance is an indirect method of calculating net percolation. Therefore, the uncertainty associated with the individual components of the water balance are compounded when estimating net percolation. Water balance uncertainties are constrained to the extent possible using engineering judgement. The estimated net percolation rates and patterns determined using the water balance method generally support the conceptual model, and as such support the suitability of the water balance method for this site.

3.4.2 Water Balance Results

Calculated change in storage matched measured change in storage reasonably well for Trial #1 (Figure 3.12) and Trial #2 (Figure 3.13) water balances. Net percolation in each trial followed performance outlined in the conceptual model and produced low net percolation rates according to the INAP Guidance Document for the given climate region (INAP 2017). Trial #2 produced more runoff than the conceptual model outlined due to its bare surface (Table 3.3). Deep erosional rills observed on Trial #2 is evidence of the increased runoff. Continued monitoring and updated water balances will help to better understand climatic cycles and the influence of further established vegetation to modify the water fluxes.

Table 3.3: Water balance components

	ET_0 (mm)	Runoff (mm)	Net Percolation (mm)
Conceptual Model	50 – 70%	10 – 20%	5 – 15%
Trial #1	414 (64%)	166 (26%)	64 (10%)
Trial #2	312 (50%)	257 (41%)	74 (12%)

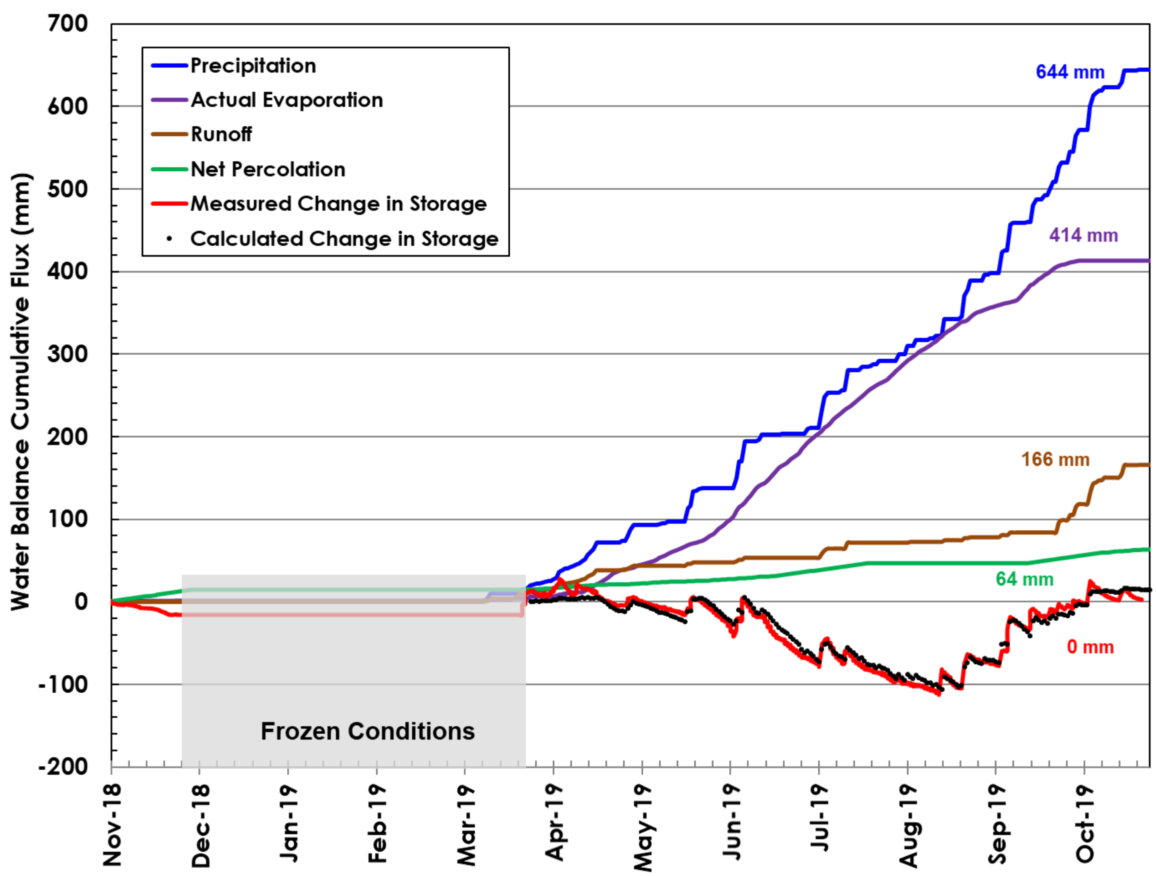

Figure 3.12: Cumulative water balance fluxes for Trial #1 for the monitoring period.

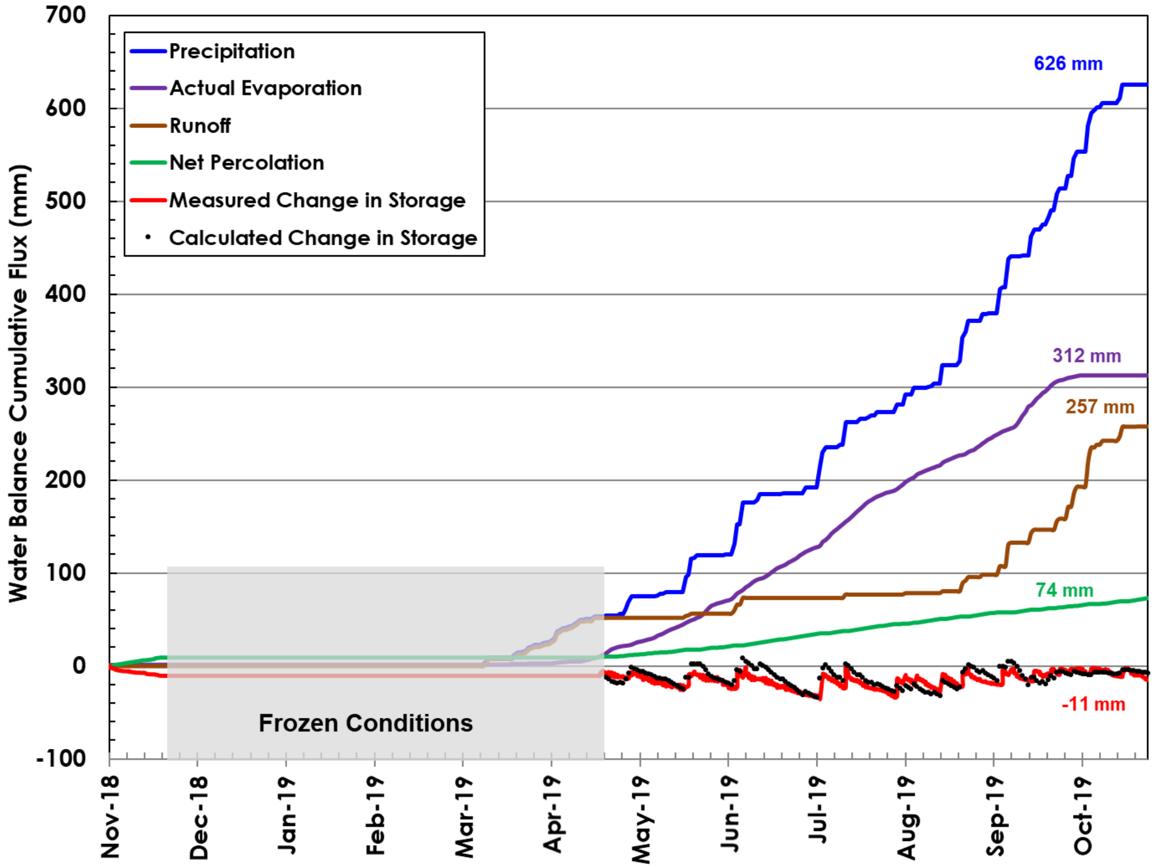

Figure 3.13: Cumulative water balance fluxes for Trial #2 for the monitoring period.

3.5 Oxygen Ingress

3.5.1 Oxygen Ingress Monitoring Results

Automated oxygen sensors were placed in the underlying waste rock and directly above the CBC layer to observe the ingress and consumption of oxygen. Fluctuations in oxygen concentrations were observed (Figure 3.14) during the monitoring period. Oxygen concentrations in the other instrumented nests showed similar trends as Trial #1 Primary Nest and are found in Appendix B.

Okane personnel installed 10 manual gas sampling stations into the waste rock to verify oxygen fluctuations read by automated sensors. When compared to automated readings, monthly manual readings (Table 3.4) correspond well confirming the automated sensor readings.

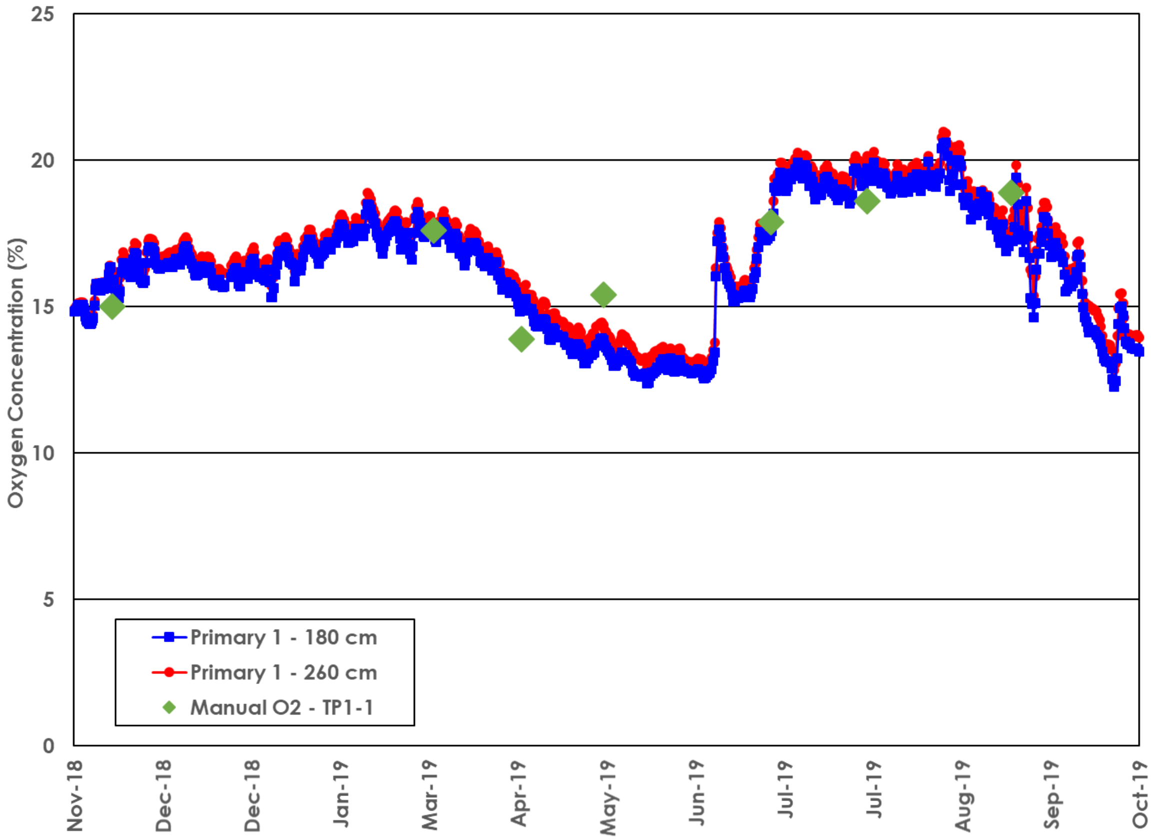

Figure 3.14: Oxygen concentration in waste rock below CBC layer at Trial #1 Primary Nest.

Table 3.4: Oxygen concentrations from manual sampling

Station ID	Oxygen Concentration (%)						
	March 2019	April 2019	May 2019	June 2019	July 2019	September 2019	November 2019
TP1-1	17.6	13.9	15.4	17.9	18.6	18.9	14.7
TP1-3	17.2	*	*	*	*	*	*
TP1-6	17.2	1.7	*	*	*	17.7	*
TP1-8	20.9	5.4	*	16.1	18.6	16.5	16.8
TP1-9	17.3	14.3	13.4	16.5	19.9	16.3	10.2
TP2-2	17.8	15.3	*	20.5	*	*	20.9
TP2-4	19.4	16	20.1	16.7	20.4	20.3	20.2
TP2-5	17.9	15.5	14.4	18.2	18	17.9	14.9
TP2-7	19.1	17.9	*	*	20.9	*	*
TP2-10	17.8	15.6	13.9	16.1	17.7	17.2	15.7

*Low flow due to water in tubing.

3.5.2 Discussion of Observed Oxygen Ingress

The manual readings also allow an understanding of spatial variability in oxygen concentrations. Oxygen concentrations fluctuated between 1.7% and 20.9% during the monitoring period. Increases in oxygen concentrations are first measured in the northeast corner of the cover trials. The observed patterns in concentration fluctuations points towards ingress pathways through Trial #2. As saturation levels of the CBC layer have remained sufficient to limit oxygen diffusion, the oxygen ingress observed is thought to be attributed to insufficient thickness of the clay key surrounding the field trials as observed during Trial #2 modifications (Section 2.3.1). Due to the observed oxygen ingress pathways, monitoring oxygen concentrations is not a definitive approach to measure the ability of the cover system to mitigate oxygen ingress. Therefore, oxygen ingress through the cover system must be evaluated entirely on the degree of saturation maintained within the CBC.

4 SUMMARY

Two cover system field trial configurations were constructed in the summer of 2017. Performance of the cover system was evaluated in terms of frost penetration, degree of saturation within the CBC layer, available water within the cover system, net percolation of precipitation, and oxygen ingress into the underlying waste rock.

Cover system temperature data shows a difference in frost penetration between Trial #1 and Trial #2. The freezing depth of Trial #2 reached 110 cm into the cover system, allowing half of the CBC to undergo freeze / thaw cycling.

Oxygen diffusion through the cover system profile can be inhibited if a high degree of saturation is maintained. The degree of saturation of the CBC layer remained over 95% for the majority of the year. The degree of saturation maintained in the cover systems demonstrated that the compacted clay layer is retaining sufficient pore-water to attenuate oxygen transport. The noncompacted overburden clay was also examined to assess the capability of the material to mitigate oxygen ingress during MRS construction. Although the noncompacted clay experienced periods below the 85% threshold, it would reduce oxygen ingress during construction for the majority of the year.

Examination of measured water storage within the cover system profiles demonstrate the effect vegetation has on the cover system's effectiveness to store and release water within the upper meter. Trial #1 observed a greater decrease in stored water than Trial #2. If vegetation is not able to be established on the clay overburden the cover system will not be as effective as a store-and-release system.

Simple water balances were created for each primary monitoring station profile to estimate the volume of water percolating through the cover systems to the underlying waste rock. Net percolation of each trial followed the expected conceptual model rates.

Monitoring of automated and manual oxygen readings show fluctuating oxygen concentrations within the underlying waste rock. Concentrations varied between 1.7% and 20.9% during the monitoring period. The observed patterns in manual readings point towards ingress pathways through Trial #2. These pathways are thought to have been created due to insufficient thickness of the clay key surrounding the field trial as described in Section 2.3.1.

5 RECOMMENDATIONS

To further understand cover system performance, the following is recommended to be completed during the upcoming monitoring period:

- Laboratory water retention curves be produced to understand and verify the ability of the compacted clay to maintain saturation levels at elevated suction levels. This will aid in evaluating cover system configuration and development of surface vegetation and the risk of inability of the compacted layer to act as an oxygen ingress barrier over the long-term.
- Installation of an SR50 on each trial to accurately measure snow melt during spring freshet. Accurately measuring snow melt will add accuracy and confidence to the water balance calculation.
- Due to the observed oxygen ingress pathways, monitoring oxygen concentrations is not a definitive approach to measure the ability of the cover system to mitigate oxygen ingress. Therefore, Okane recommends that oxygen ingress through the cover system should be evaluated on the degree of saturation maintained within the CBC rather than oxygen concentration readings.
- Generation of annual water balances to better understand climatic cycles and the influence of further established vegetation to modify the water fluxes.

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Appendix A

Photo Log

Photograph A.1: Overview of manual gas sampling stations on Trial #2. November 14, 2018.

Photograph A.2: Manual gas sampling shut-off valve. November 14, 2018.

Photograph A.3: Trial #1 vs. Trial #2 vegetation comparison. November 14, 2018.

Photograph A.4: Erosional rill on east slope. November 14, 2018.

Photograph A.5: Snowpack on south slope on Trial #2. March 4, 2018.

Photograph A.6: Material being added to east slope. July 15, 2019

Photograph A.7: Completed east slope construction. July 16, 2019.

Photograph A.8: Completed north slope construction. July 17, 2019.

Photograph A.9: Hand-seeding on Trial #2 slope. July 17, 2019.

Photograph A.10: Fresh vegetation on north slope of Trial #2 from hand seeding. August 13, 2019.

Photograph A.11: Borrow investigation of clay key layer on southeast corner of Trial #2. July 15, 2019.

Appendix B

In Situ Instrumentation Measurements

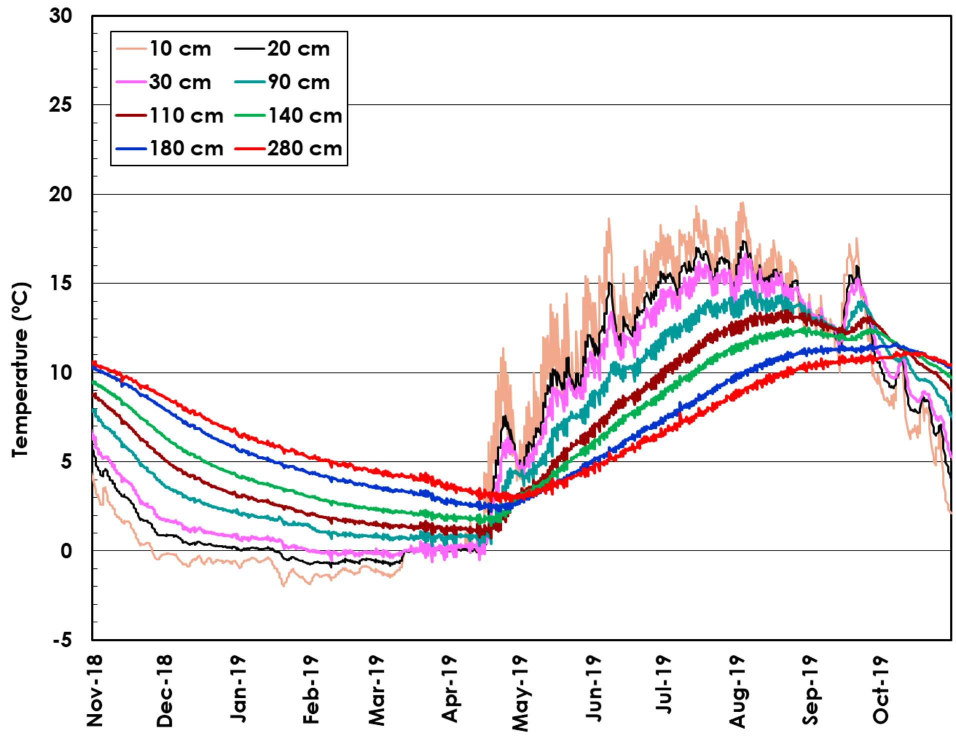

Figure B.1: *In situ* temperature at Trial #1 Primary Nest during the monitoring period.

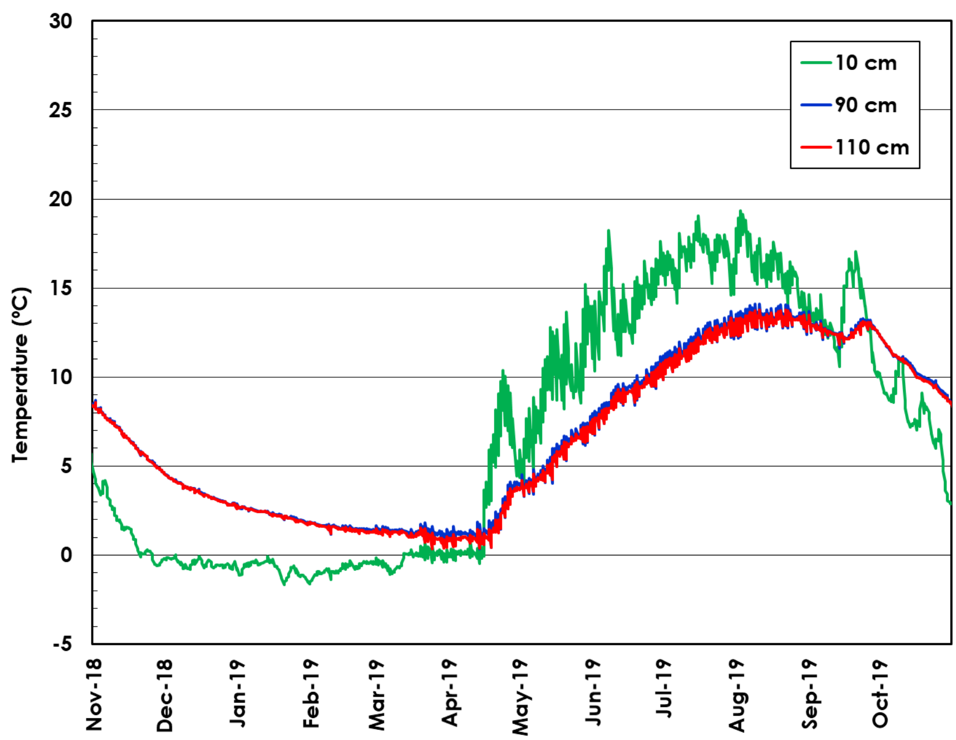

Figure B.2: *In situ* temperature at Trial #1 Secondary Nest during the monitoring period.

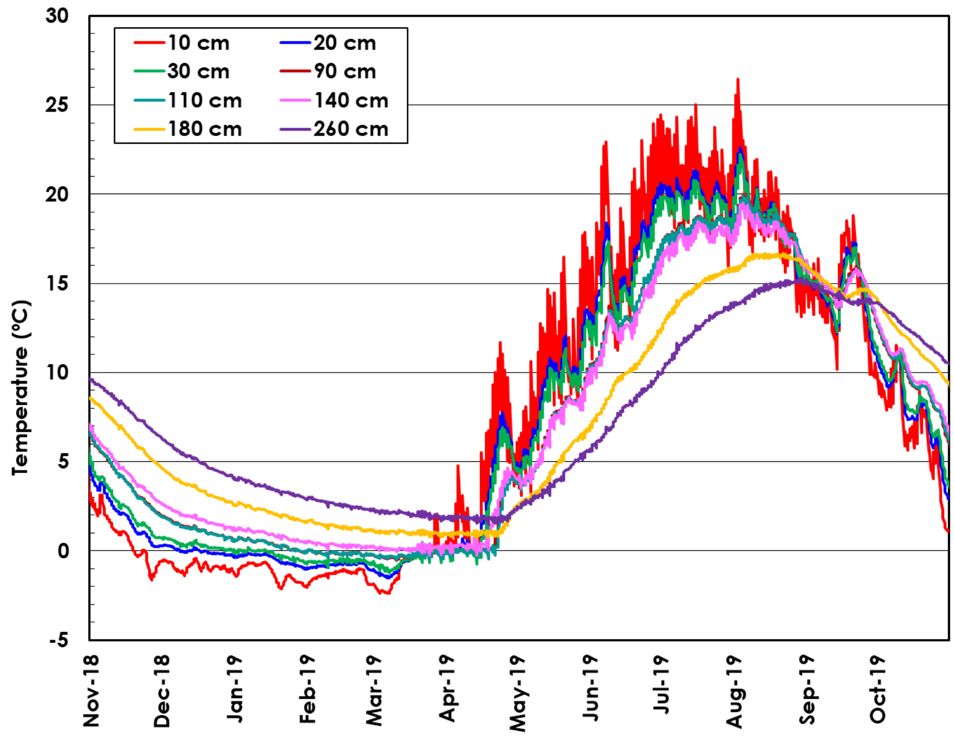

Figure B3: *In situ* temperature at Trial #2 Primary Nest during the monitoring period.

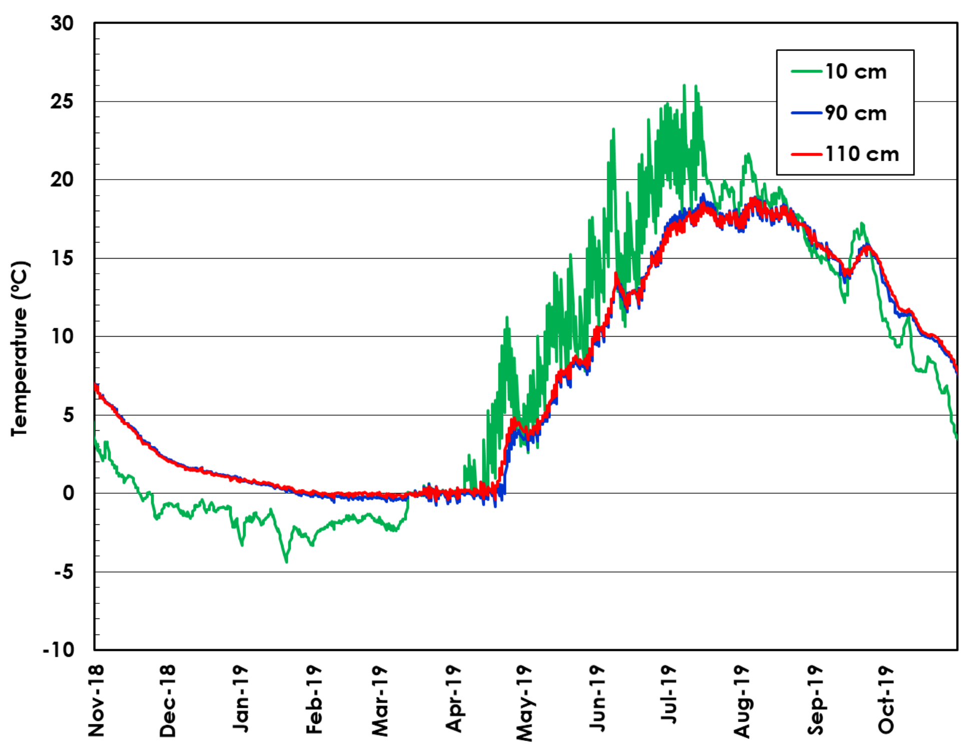

Figure B.4: *In situ* temperature at Trial #2 Secondary Nest during the monitoring period.

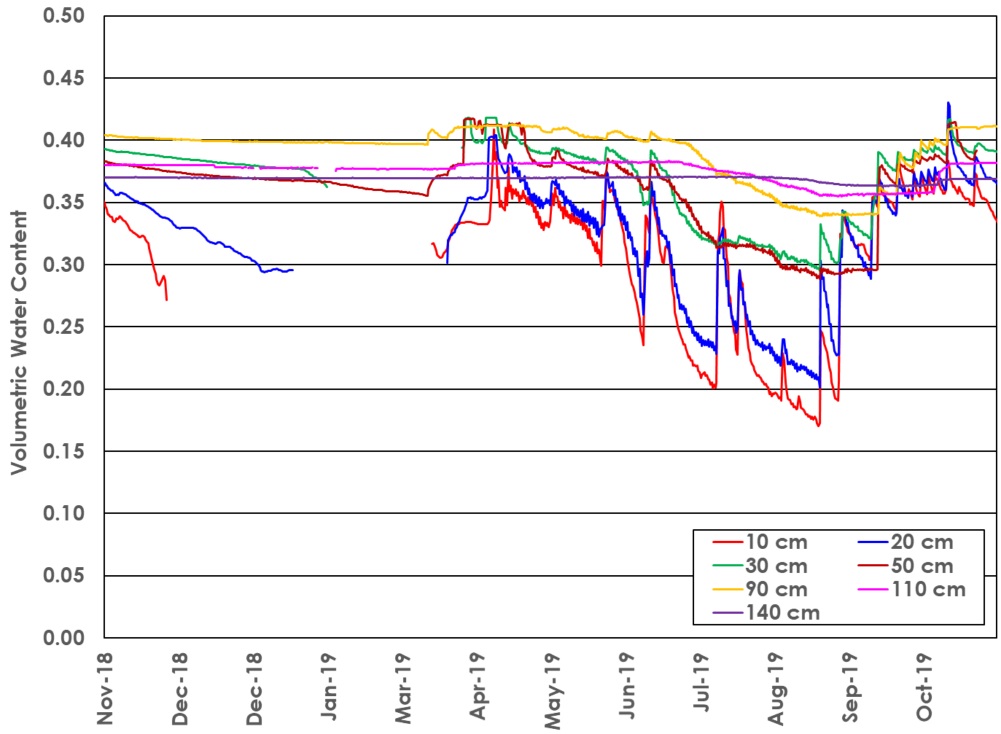

Figure B.5: Volumetric water content at Trial #1 Primary Nest during the monitoring period.

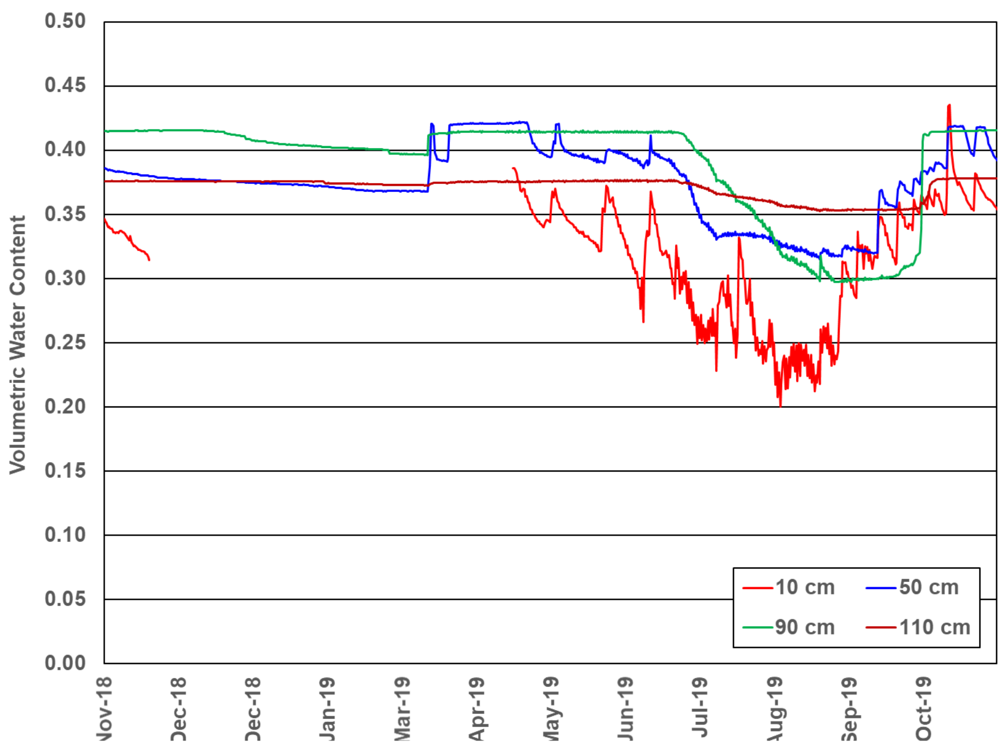

Figure B.6: Volumetric water content at Trial #1 Secondary Nest during the monitoring period.

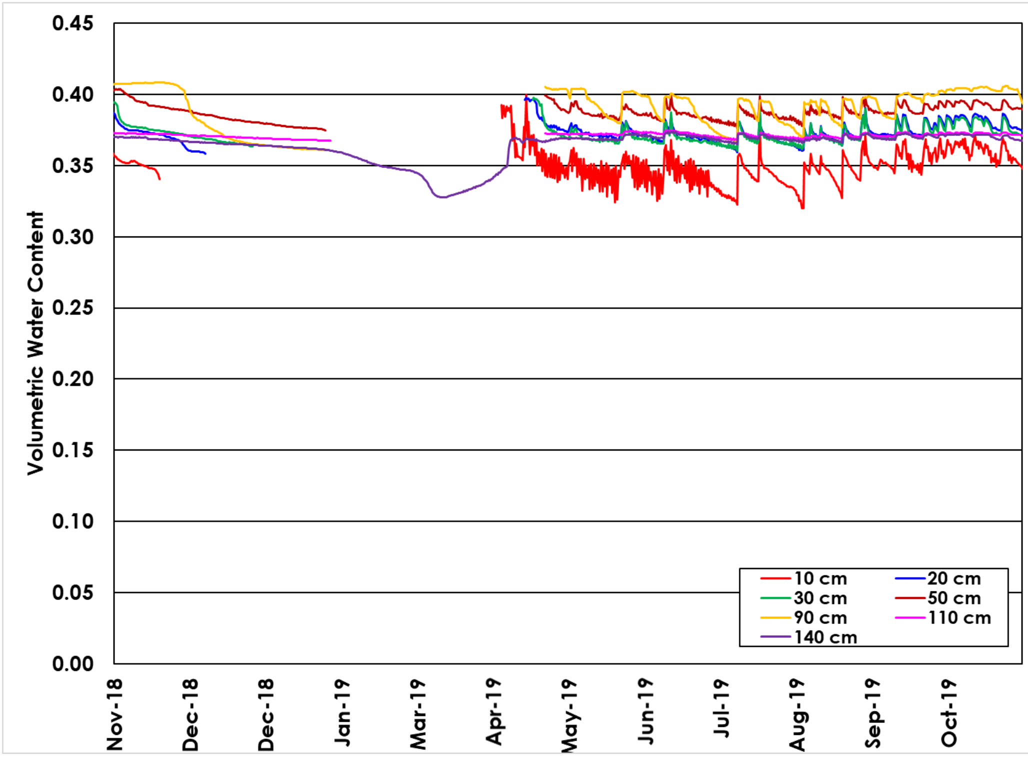

Figure B.7: Volumetric water content at Trial #2 Primary Nest during the monitoring period.

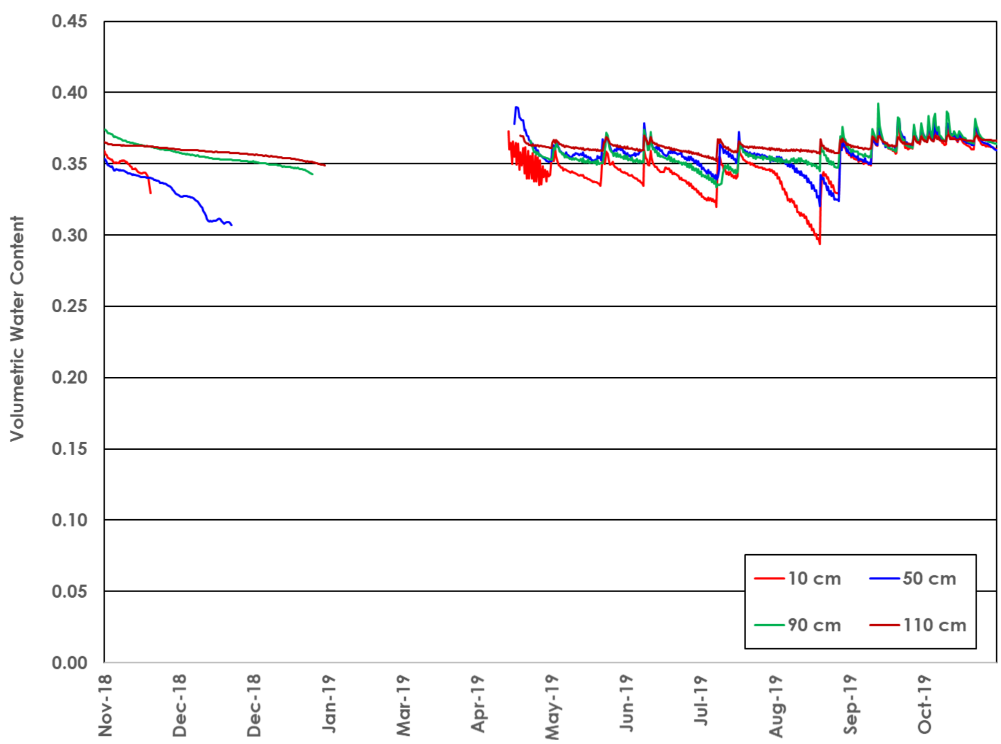

Figure B.8: Volumetric water content at Trial #1 Secondary Nest during the monitoring period.

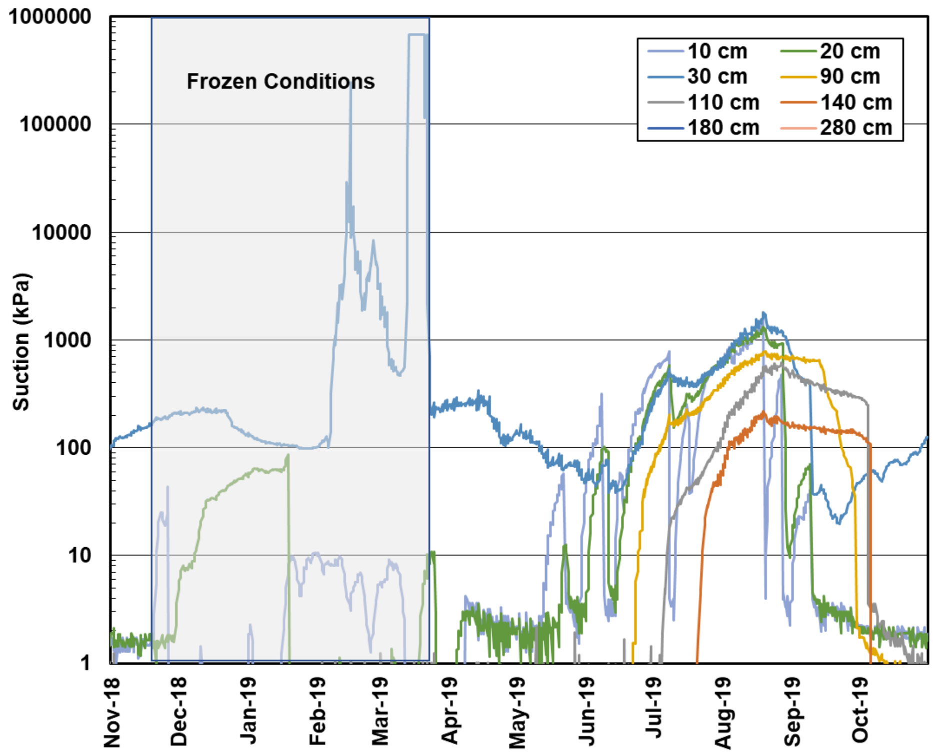

Figure B.9: Matric suction at Trial #1 Primary Nest during the monitoring period.

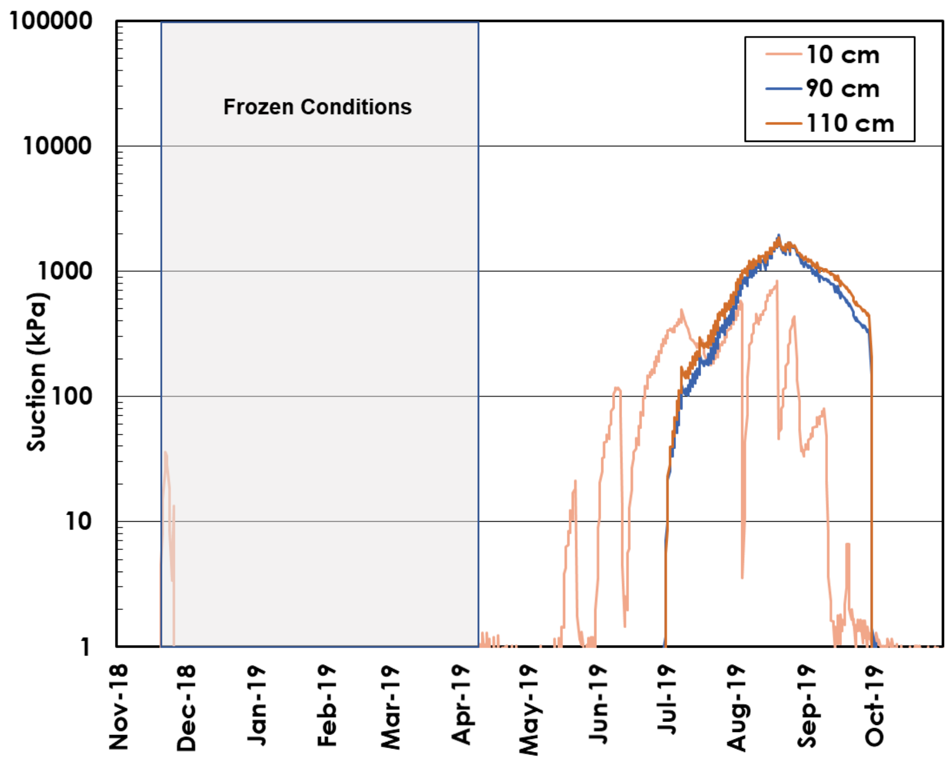

Figure B.10: Matric suction at Trial #1 Secondary Nest during the monitoring period.

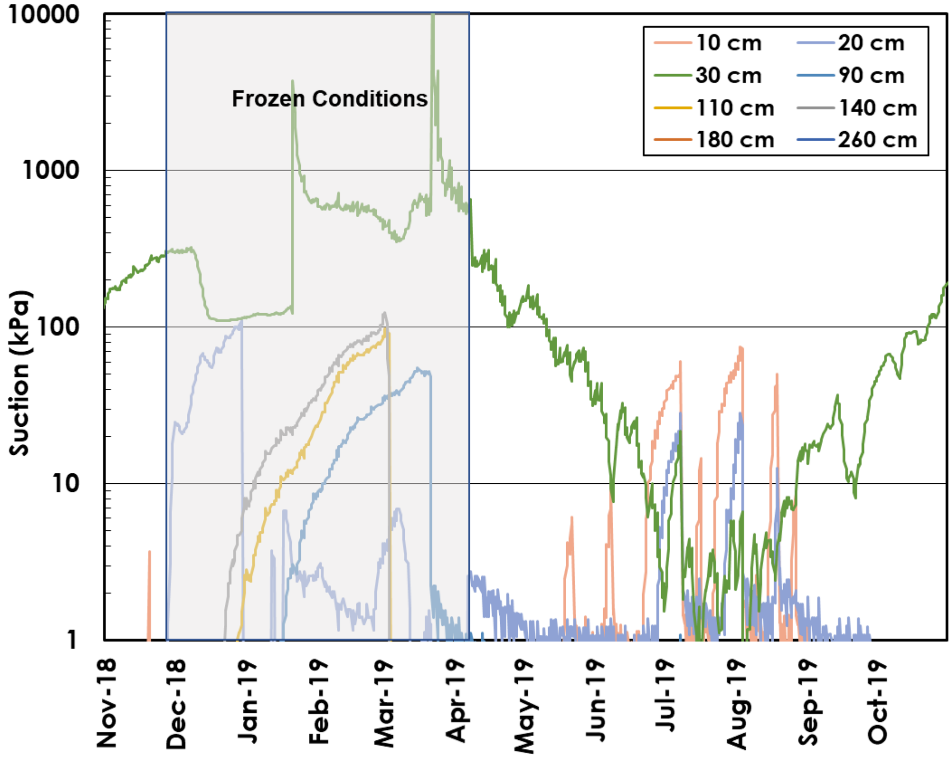

Figure B.11: Matric suction at Trial #2 Primary Nest during the monitoring period.

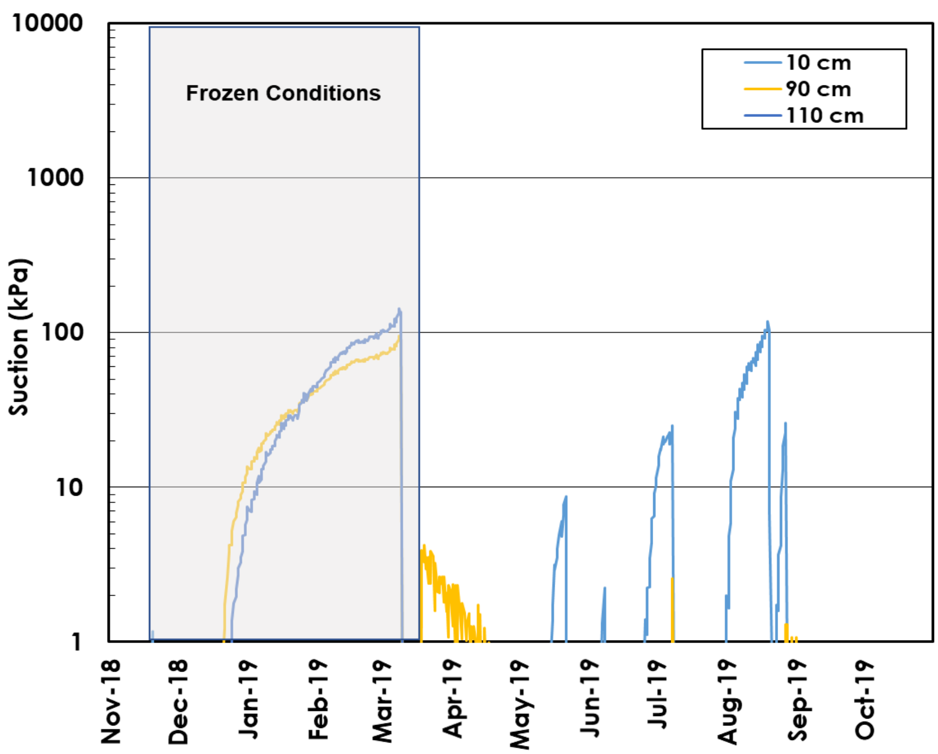

Figure B.12: Matric suction at Trial #2 Secondary Nest during the monitoring period.

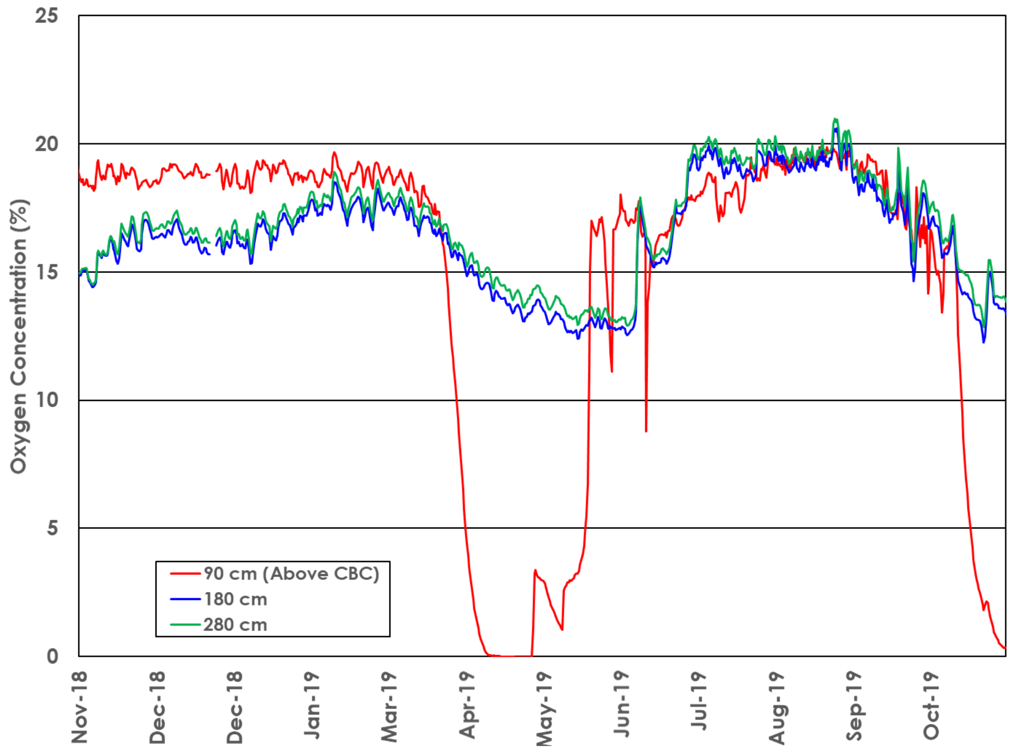

Figure B.13: Oxygen concentration at Trial #1 Primary Nest during the monitoring period.

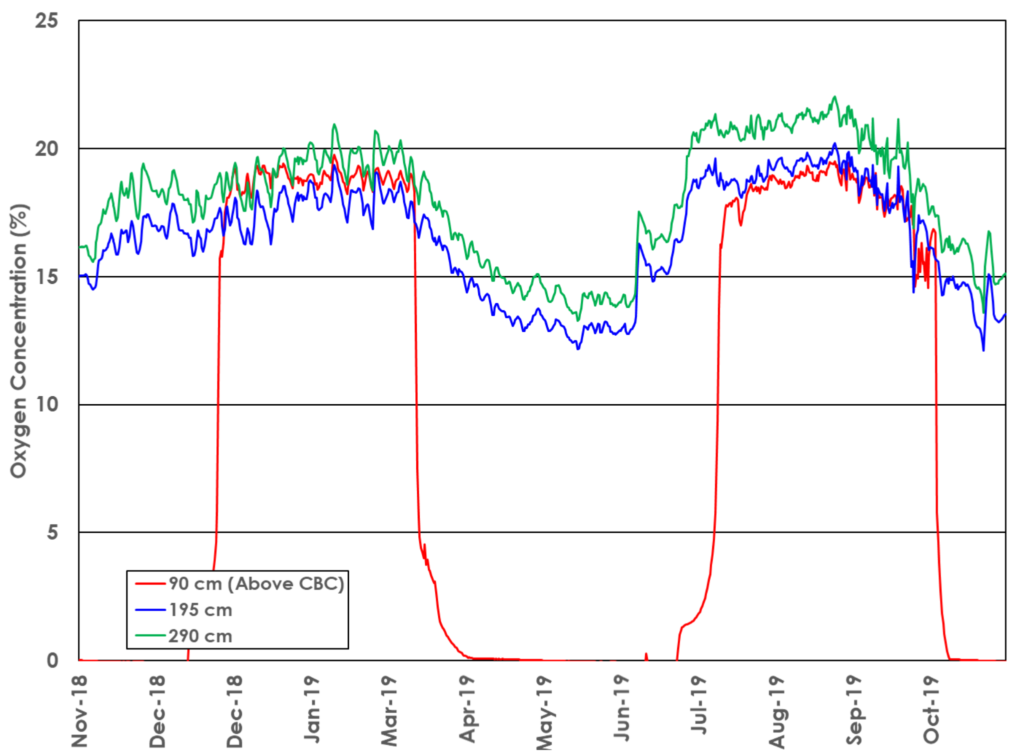

Figure B.14: Oxygen concentration at Trial #1 Secondary Nest during the monitoring period.

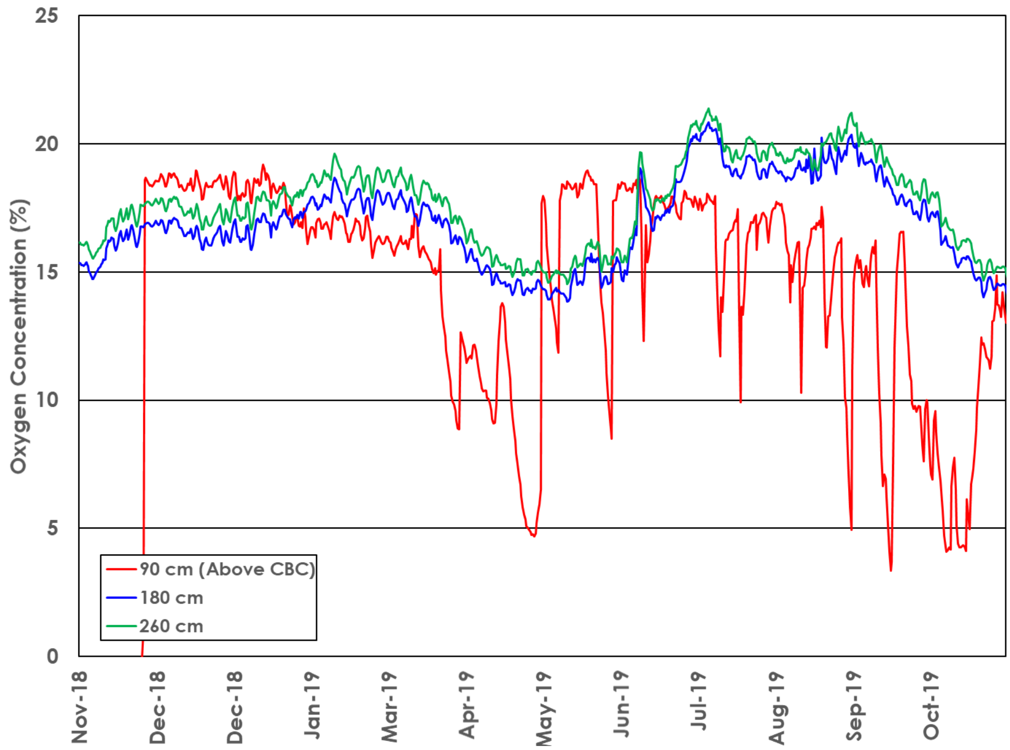

Figure B.15: Oxygen concentration at Trial #2 Primary Nest during the monitoring period.

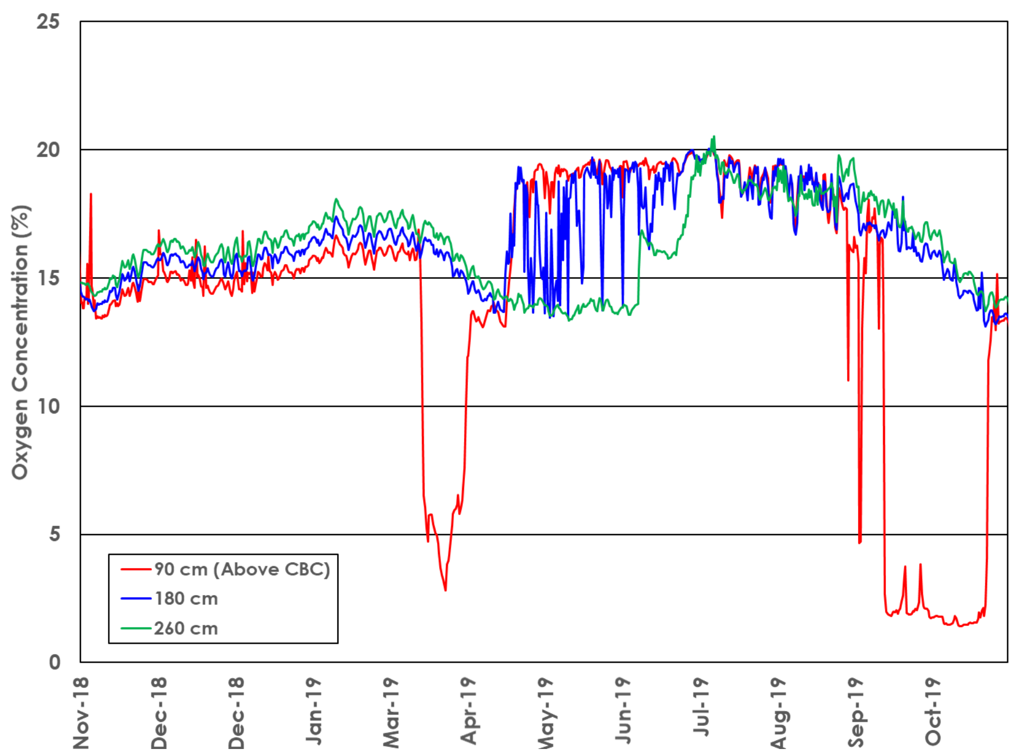

Figure B.16: Oxygen concentration at Trial #2 Secondary Nest during the monitoring period.