NEW GOLD RAINY RIVER MINE
APPENDIX C
PAG COVER TRIAL FACTUAL DATA REPORT

Rainy River Mine - PAG Cover Trial 2021 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. Okane Consultants (Okane) was retained to design, instrument, and interpret monitoring data collected from performance monitoring systems installed at the cover system field trials. The objective of this report is to summarize and interpret findings from data collected during the monitoring period of November 1, 2020 to October 31, 2021, and a comprehensive three-year monitoring period between November 1, 2018 and October 31, 2021.

Two cover system field trials were constructed in fall of 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 aided 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 both hand-seeding an appropriate seed-mix on Trial #2 in July 2019 as well as hydroseeding in late 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). During the 2020-2021 monitoring period, the annual average saturation levels measured for both Trial #1 and Trial #2 was greater than 93% in the CBC layer. Maintenance of a 93% degree of saturation in the cover system demonstrated that the compacted clay layer is retaining sufficient pore-water to prevent advective oxygen transport, and limit oxygen ingress through diffusion. The 2020-2021 monitoring period observed the degree of saturation of the CBC drop to 90% and 83% at Trial #1 and Trial #2, respectively. The drop in degree of saturation resulted from a dry period with greatly below normal rainfall observed from June to August 2021. Precipitation following this period allowed saturation levels in the CBC to rebound to historically maintained levels.

Oxygen diffusion into the waste rock was estimated using the collected field performance data within a numerical gas flow model. Using cover system material properties and the degree of saturation measured over a three-year monitoring period, oxygen diffusion was estimated to be approximately 2 mol/year for Trial #1 and 2.5 mol/year for Trial #2. This is considered a very low oxygen flux as outlined by the INAP Guidance Document (INAP 2017). Oxygen diffusion rates increased to around 1 mol/month at Trial #2 after the extended dry period experienced in June, July, and August 2021 as the water content and associated degree of saturation of the cover system compacted and non-compacted overburden layers was reduced. This rate represents the maximum measured thus far in the trials monitoring period, but corresponds to a substantial period of hot and dry conditions. September rainfall restored water contents within the cover system, which was effective in reducing predicted oxygen diffusion rates.

Simple water balances were created for each cover system configuration to estimate net percolation of meteoric waters into the underlying waste rock. The total estimated net percolation over the monitoring year was 15% and 24% for Trial #1 and Trial #2, respectively. The difference in net percolation rates in the current monitoring year was attributed to Trial #1 having a greater capacity to store large incoming rainfall events that occurred in September and October.

Performance monitoring of cover system provides essential insight into cover system response to climatic variation 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. Continued monitoring and reporting offers insight to field-derived material properties and the opportunity to optimize future closure activities at site.

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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. Okane Consultants (Okane) was retained to design, instrument, and interpret monitoring data collected from performance monitoring systems installed at the PAG mine rock cover system field trials. This report summarizes and provides interpretation of both the monitoring data obtained between November 1, 2020 and October 31, 2021 (referred to herein as 'the monitoring period'), as well as a three-year period between November 1, 2018 and October 31, 2021 (referred to herein as 'the three-year 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 water balance components (e.g., precipitation, runoff, evapotranspiration, water storage, etc.).

1.2 Report Organization

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

- 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, as well as discusses the performance of the cover system over a three-year monitoring period;
- Section 4 – provides recommendations for the following monitoring period.

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 provided 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, and later hydroseeded in autumn 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 1 m 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. Additionally, the compacted layers form a barrier-type cover system which limits net percolation by reducing the hydraulic conductivity within the layer.

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 2020 – 2021 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 monthly automated data collection and data QA/QC, manual oxygen readings, field inspections, snow survey, and cover system performance updates (Table 2.1).

Table 2.1: Monitoring period activities

Activity	Date
Automated Data Download and QA/QC	March 8, May 5, June 23, July 28. August 27, November 2, 2021
Snow Survey	March 8, 2021
Site Visit & Instrumentation Maintenance	March 8, June 22, August 17, November 1, 2021

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 were monitored at Rainy River Mine's Barron weather station. An equipment malfunction was observed at the Barron weather station from January 6, 2021, to March 4, 2021. The missing hourly and daily wind, rainfall, humidity, and temperature data from the Barron weather station has been backfilled by weather data from the Government of Canada weather station 6022474 located in Fort Frances for purposes of completing water balances. Maximum and minimum daily air temperatures from November 20, 2020, to January 5, 2021 were estimated from hourly average data from the Barron weather station, as daily data was not available.

3.1.1 Air Temperature

Annual average air temperature recorded at the Barron weather station during the monitoring period was 4.8 °C (Figure 3.1), warmer than the 30-year historical average of 3.3 °C. The average winter temperature is of interest with respect to performance monitoring for the purpose of evaluating frost penetration into the cover system. Between December and March 2021, ambient air temperature ranged from -43 °C to 17 °C and had an average temperature of -8.9 °C. The average maximum daily air temperature in the first week of March was 4.3 °C, much warmer than the 30-year average of -2.8 °C. A maximum peak temperature of 6.8°C was recorded during the first week of March, which on average, does not experience temperatures above freezing. The unseasonably warm temperatures likely contributed to there being no snow present during the March 8 snow survey.

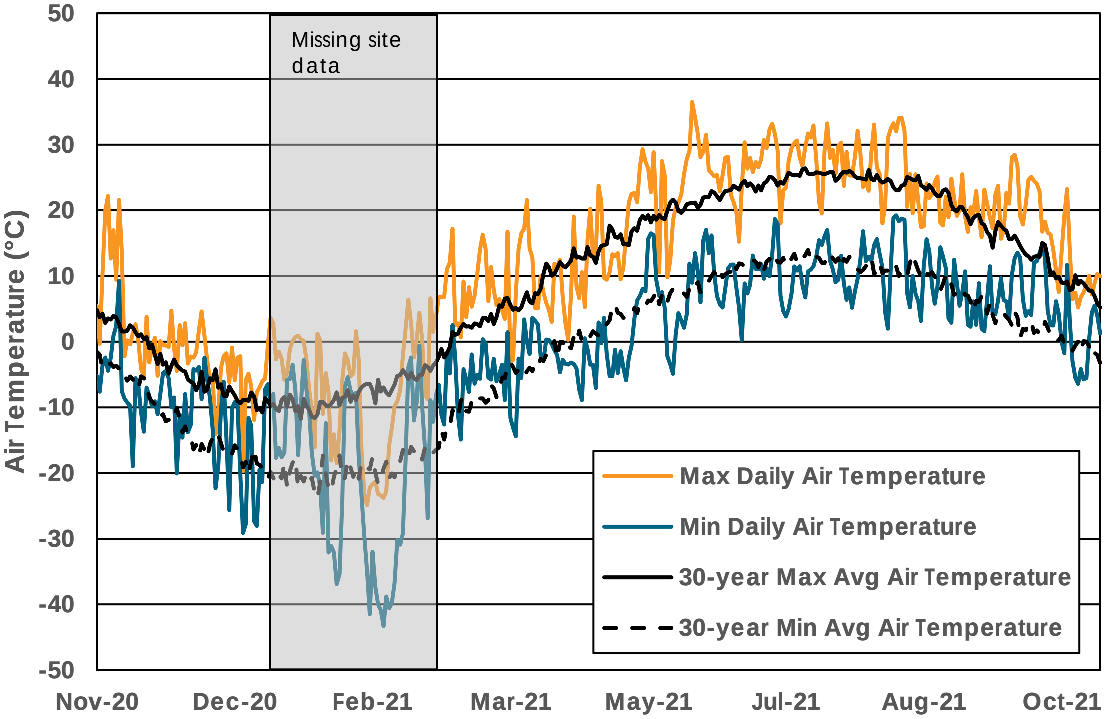

Figure 3.1: Maximum and minimum daily air temperatures recorded at Barron weather station as compared to 30-year averages (amended with Government of Canada data).

Ambient air temperatures over the three-year monitoring period were also compared (Figure 3.2). Average air temperature recorded at the Barron weather station during the three-year monitoring period was 3.0 °C, compared to the 30-year historical average of 3.3 °C. The average winter temperature between December and March for each monitoring year are provided below (Table 3.1).

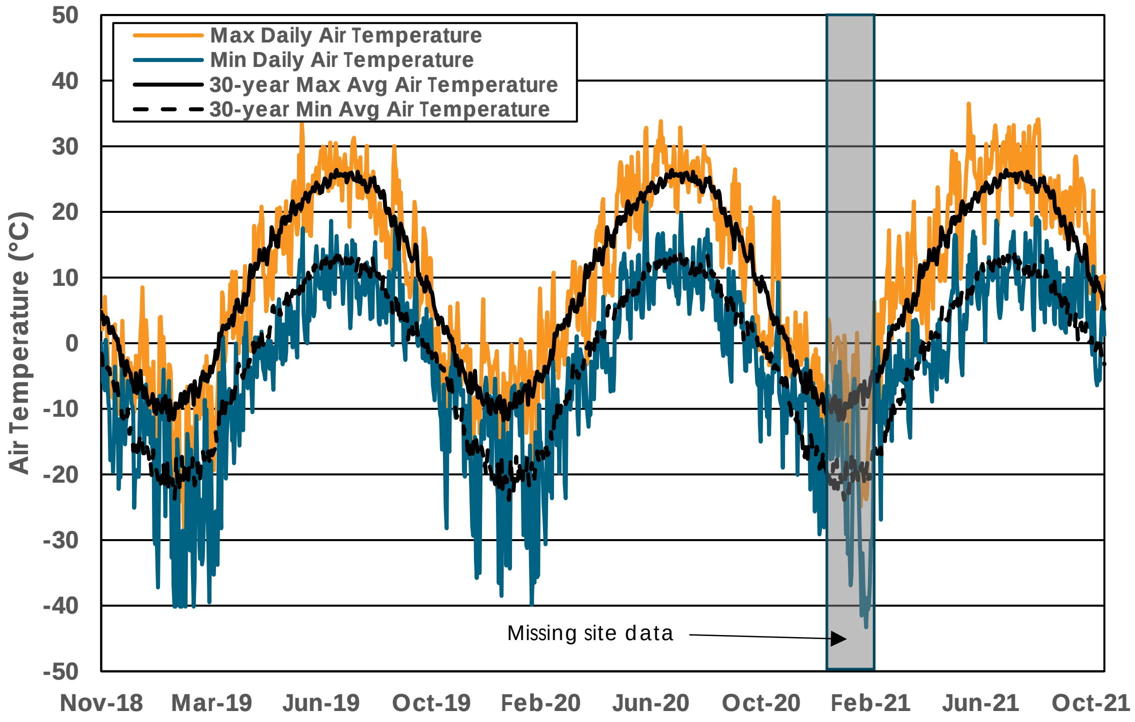

Figure 3.2: Maximum and minimum daily air temperatures over a three-year monitoring period recorded at Barron weather station as compared to 30-year averages (amended with Government of Canada data).

Table 3.1: Ambient winter air temperature over a three-year monitoring period.

Monitoring Period	2018-2019	2019-2020	2020-2021
Lowest Winter Temperature (°C)	-40.1	-39.9	-43.0
Highest Winter Temperature (°C)	10.9	12.4	17.0
Average Winter Temperature (°C)	-13.2	-10.5	-8.9

3.1.2 Rainfall

Rainfall is collected directly on site with a Texas Electronics TE-525M tipping bucket gauge. The tipping bucket gauge was installed on Trial #2 and has been collecting rainfall data since June 2018. During a site visit conducted on November 2, 2021, it was noted a that the tipping bucket lid had been blown off. Due to the lid being removed, there was an observed discrepancy between the rainfall measurements recorded on Trial #2, and the Barron weather station on site. Analysis of the raw data determined that the lid of the tipping bucket had been removed sometime in late September, as the discrepancy in rainfall data could no longer be attributed to spatial variability of the site. The Trial #2 rainfall data has been amended with the Barron monitoring station data from September 21, 2021 to October 31, 2021. The Barron monitoring station did not record a large rainfall event that occurred on September 20th, 2021, therefore the rainfall measurement from this day was amended with data from the Fort Frances weather station. These amendments will be used in the analysis of this document.

A total of 467 mm of rainfall was recorded during the monitoring period (85 mm less than the 30-year historic average). Monthly rainfall from April to October 2021 was compared to the 30-year historic average (Table 3.2). It was observed that May, June, and July were substantially drier than average. Rainfall activity was also considered over a three-year period (Figure 3.4).

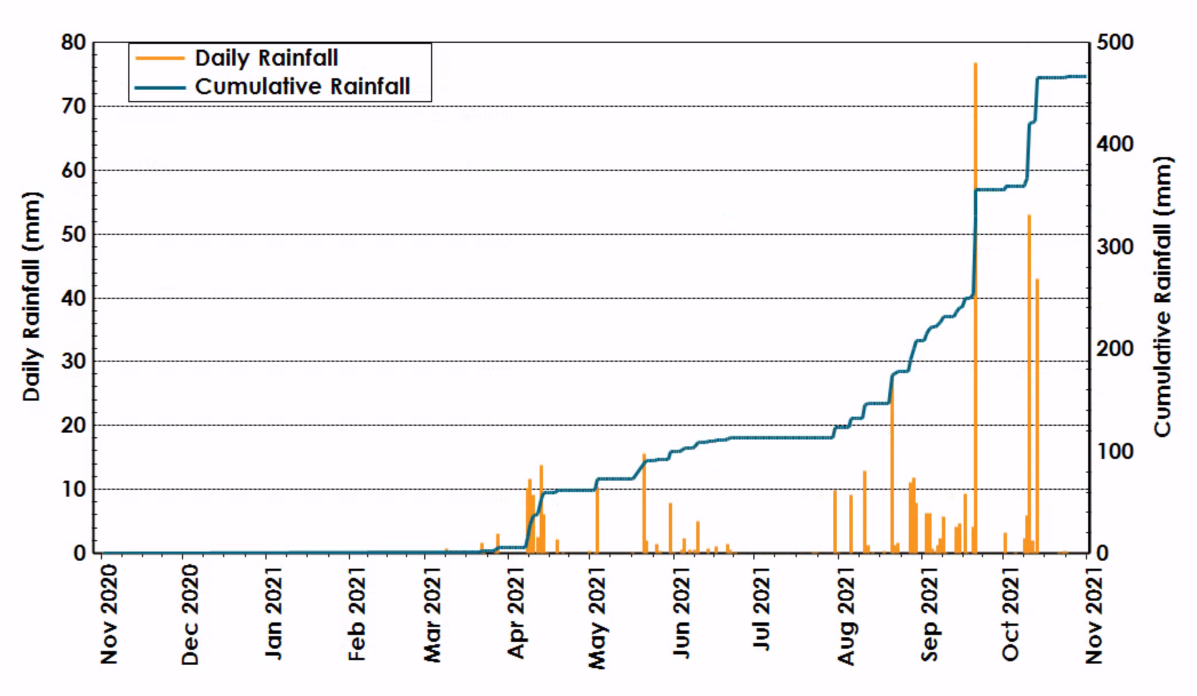

Figure 3.3: **Daily and cumulative rainfall recorded at cover system field trials.**

Table 3.2: April to October monthly rainfall.

Month	2021		30-year Average	
	Rain Days	Rainfall (mm)	Rain Days	Rainfall (mm)
April	10	56.1	8	48.4
May	9	37.9	13	87.2
June	11	12.9	13	107.9
July	4	10.3	11	123.6
August	11	85.2	10	78.6
September	16	147.9	11	77.5
October	12	110.3	11	63.6

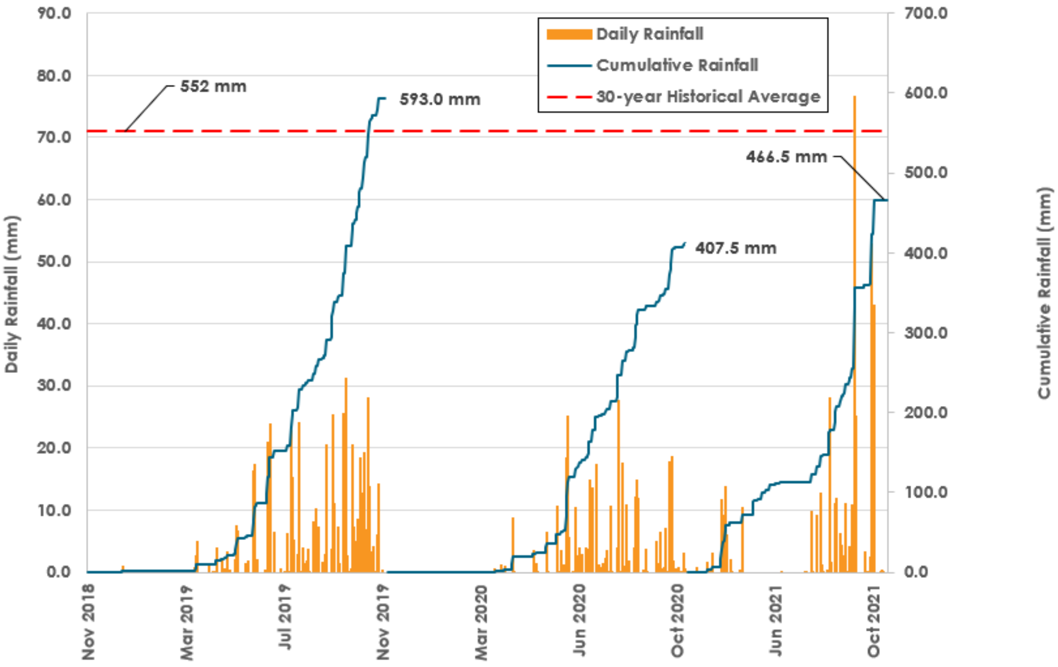

Figure 3.4: Daily and cumulative rainfall recorded at the cover trials over a three-year period.

3.1.3 *Snowfall*

The tipping bucket rain gauge on the trial plateau only measures rainfall and does not directly measure snow accumulation. Typically, snowfall is measured on the field trails through a snow survey conducted in early March. A snow survey was conducted by Okane to measure the depth of the snowpack on each cover system field trial on March 7th, 2021. During the March 7th site visit, no snow was present on the PAG cover trials (Figure 3.5 and Figure 3.6).

Figure 3.5: Trial #1 plateau at time of snow survey.

Figure 3.6: Trial #2 plateau at time of snow survey.

An estimated snow water equivalent (SWE) for Trial #1 and Trial #2 was developed. Using the maximum air temperatures to determine when snow melt would begin occurring in combination with the knowledge that all snow was gone prior to March 7, total snow depth and SWE could be calculated. The maximum snow depth was calculated to be 150 mm on February 18, 2021. Snow densities were assumed to be the same as 2020 densities. Snow water equivalent for Trial #1 and Trial #2 were calculated to be 22 mm and 33 mm, respectively.

Snow surveys were conducted on March 4, 2019 and March 3, 2020 (Table 3.3). The snow density in 2019 was estimated, whereas the density in 2020 was measured. The 2021 snow survey had no snow present either due to warmer than average late winter temperatures as described in Section 3.1.1, less snowfall over the course of the winter, or a combination of both.

Table 3.3: Three-year monitoring period snow survey results.

Measured Parameter	2019		2020		2021	
	Trial #1	Trial #2	Trial #1	Trial #2	Trial #1	Trial #2
Snow Density (kg/m^3)	100	100	150	220	150	220
Snow-water Equivalent (SWE)	51 mm	34 mm	60 mm	66 mm	22 mm	33 mm

3.1.4 Reference 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 amended with the Fort Frances weather station 6022474. Net radiation was measured on Trial #2 cover system surface.

Monthly ET_0 was compared to monthly rainfall for March to October (Figure 3.7). 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 (e.g., March to August). During these months there is higher potential for drying of the compacted layer resulting in a reduction in maintained degree of saturation. 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 (e.g., September and October).

When compared to the 30-year average, higher drying rates were observed in May, June, and July indicating more water was removed from the system than normal due to a dry and warm summer (Table 3.4). An increase in storage was observed in September, and October, which helped prevent the drying front from further impacting the compacted layer.

The 2021 monitoring year had a large decrease in stored water within the upper non-compacted store and release layer due to lack of rainfall and high evapotranspiration rates. Late season rainfall helped to recover stored water loss and reduce the drying front, discussed in more detail in Section 3.3.1.

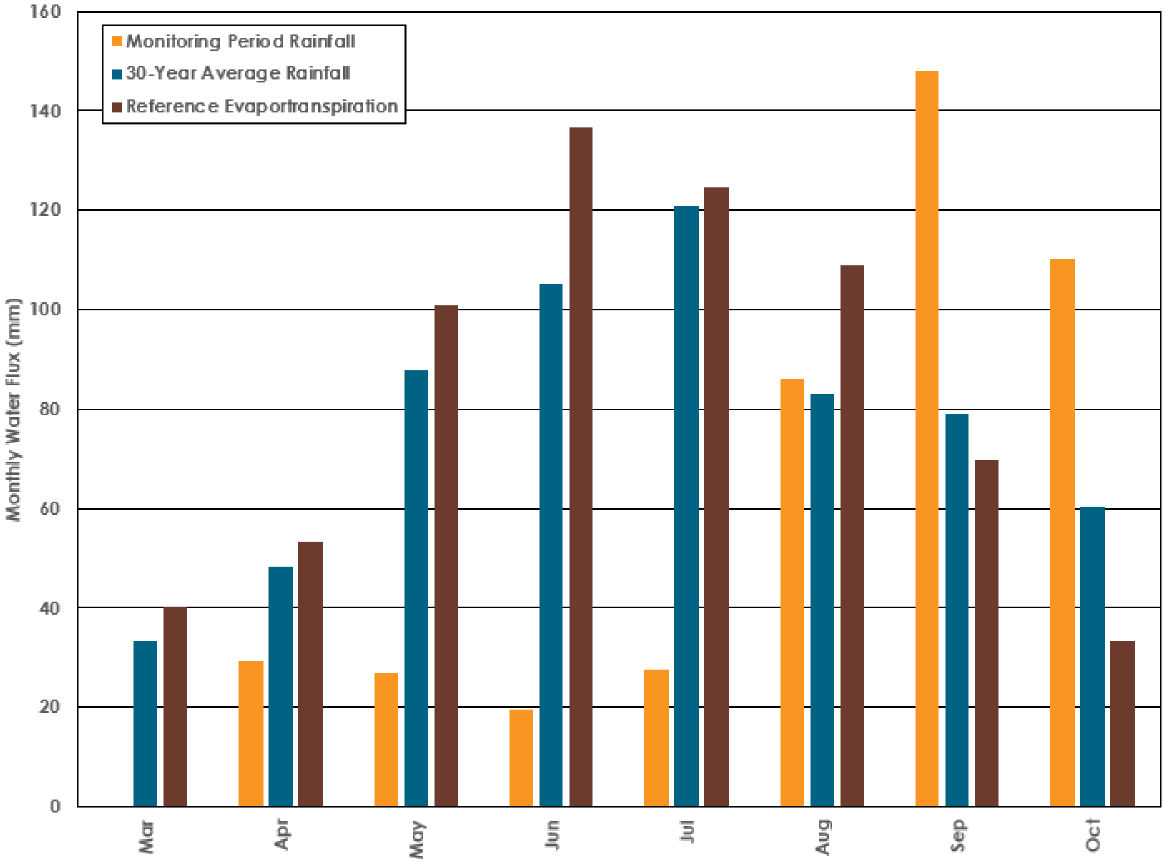

Figure 3.7: Reference evapotranspiration and total rainfall measured at Rainy River Mine during March to October 2021.

Table 3.4: Three-year summary of monthly rainfall and reference evapotranspiration.

Month	2019		2020		2021	
	Rainfall (mm)	ET_0 (mm)	Rainfall (mm)	ET_0 (mm)	Rainfall (mm)	ET_0 (mm)
March	9.3	7.3	18.8	12.1	5.8	40.2
April	12.7	70.8	4.9	42.9	56.1	53.3
May	63.6	127.5	89.1	97.8	37.9	100.8
June	66.1	164.5	64.6	115.6	12.9	136.7
July	87.7	158.9	68.9	117.7	10.3	124.6
August	97.9	157.2	82.3	107.2	85.2	108.9
September	142.7	82.5	26.5	64.7	147.9	69.8
October	112	53.4	56.4	24.2	110.3	33.3
Total	**592.0**	**822.1**	**411.5**	**582.2**	**466.4**	**667.7**

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 system configurations during the monitoring period. Trial #1 first observed freezing temperatures beginning December 14, 2020 and reach a maximum freezing depth of 30 cm (Figure 3.8). Freezing temperatures in Trial #2 was first observed February 6, 2021 and reached a maximum freezing depth of 20 cm (Figure 3.9).

During the 2018-2019 winter, freezing temperatures in Trial #2 reached depths of 110 cm. The reduction in freezing depths, and delayed freezing dates observed during the current monitoring period is likely attributed to vegetation growth on the Trial #2 plateau creating a thicker snowpack to provide an insulating layer between the cover system and ambient air temperatures. As vegetation has become established on both cover trials, freezing depths have become more consistent between the two trials (Table 3.5).

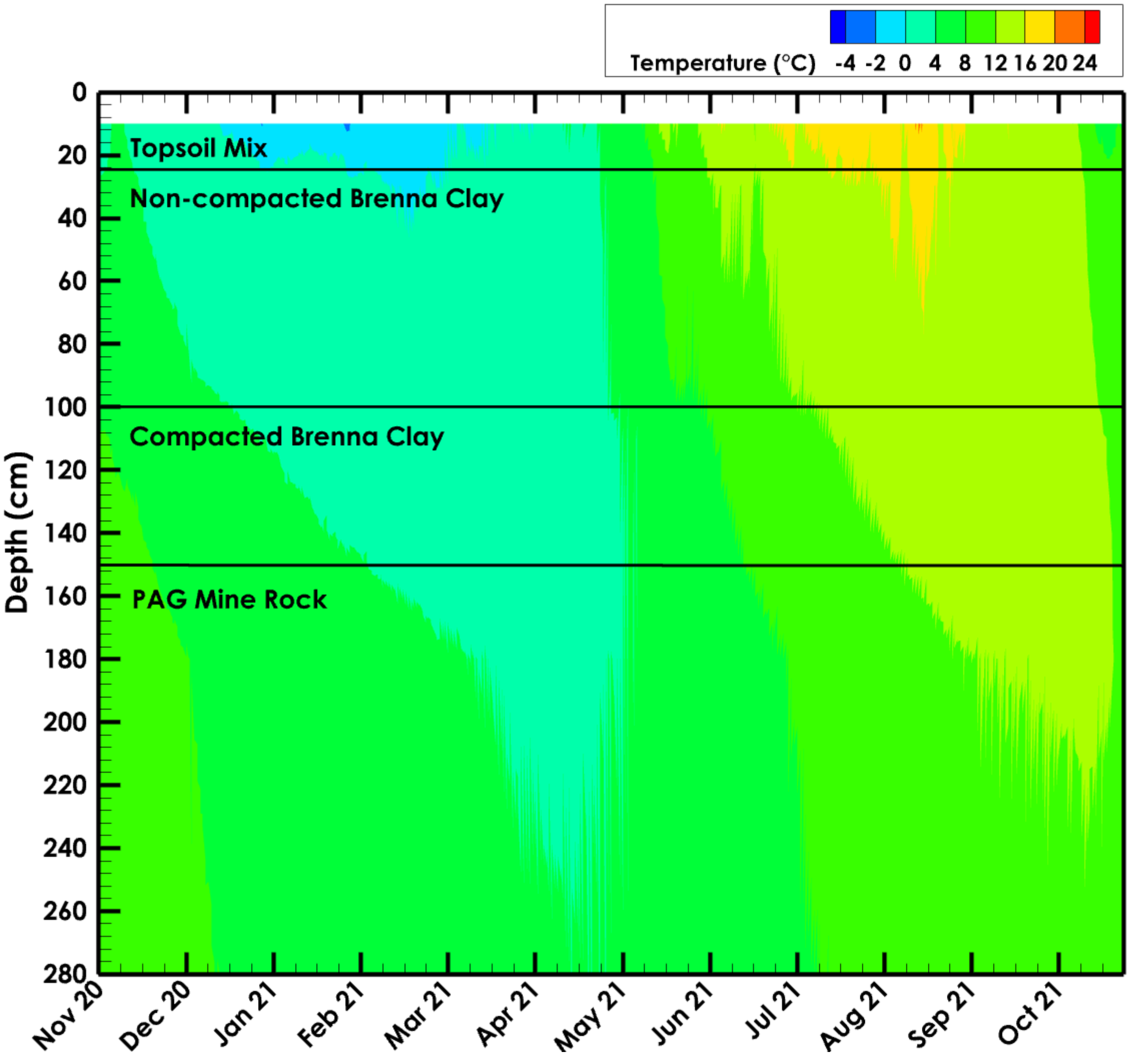

Figure 3.8: Soil temperature profile measured at Trial #1 Primary Nest during the monitoring period.

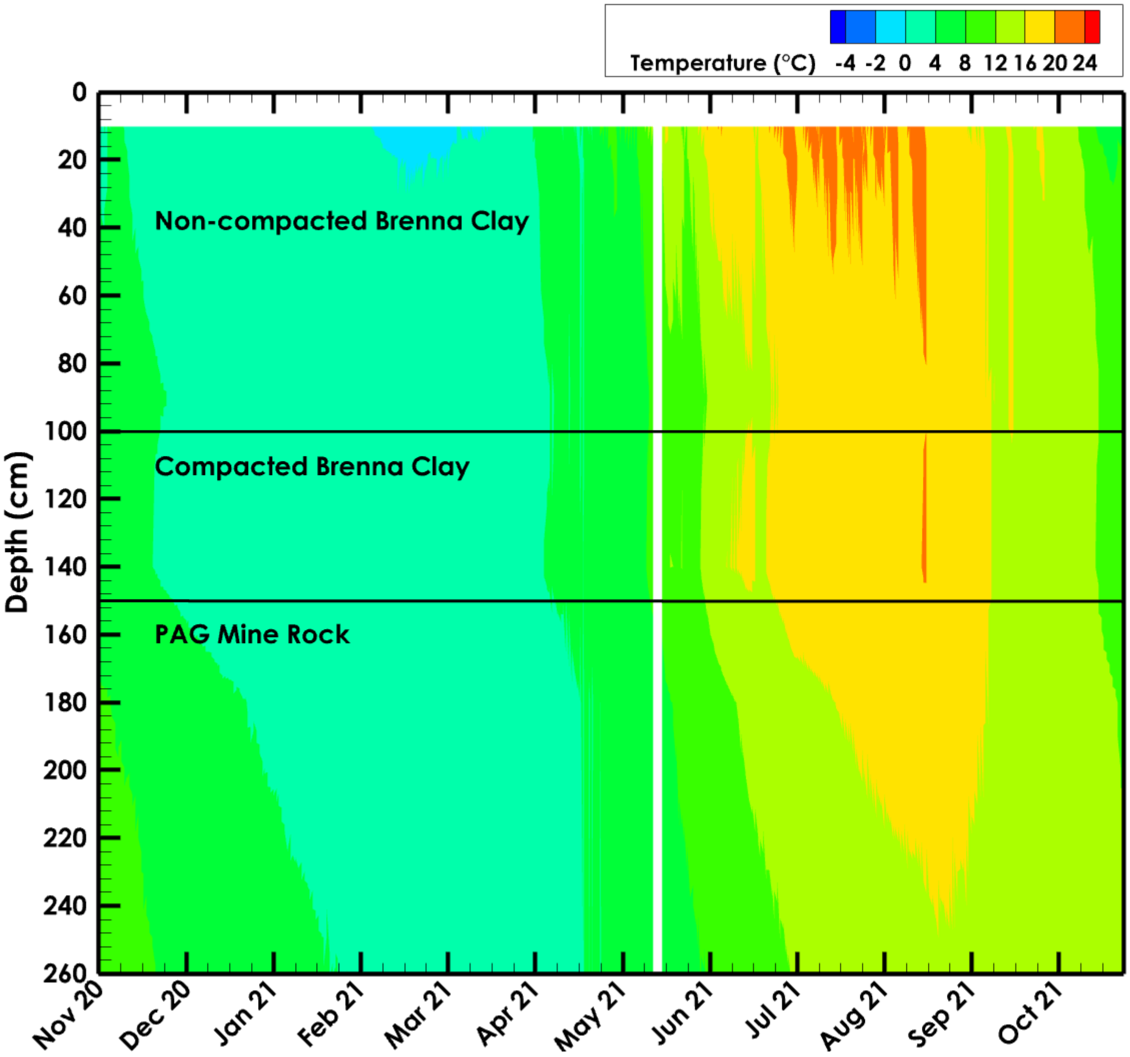

Figure 3.9: Soil temperature profile measured at Trial #2 Primary Nest during the monitoring period.

Table 3.5: Three-year summary of freezing depths and dates.

Measure Parameter	2018-2019		2019-2020		2020-2021	
	Trial #1	Trial #2	Trial #1	Trial #2	Trial #1	Trial #2
Date of freezing	Nov 25, 2018	Nov 25, 2018	Dec 9, 2019	Dec 17, 2019	Dec 15, 2020	Feb 6, 2021
Depth of freezing (cm)	30	110	30	10	30	20

Temperature within the PAG waste rock was measured over a three-year period. Annual temperatures within the waste rock vary between 3°C and 12°C for Trial #1 (Figure 3.10) and 1°C and 16°C for Trial #2 (Figure 3.11). Waste rock temperatures follow similar atmospheric heating and cooling patterns as the cover system. There is no clear additional source of heating within the waste rock mass.

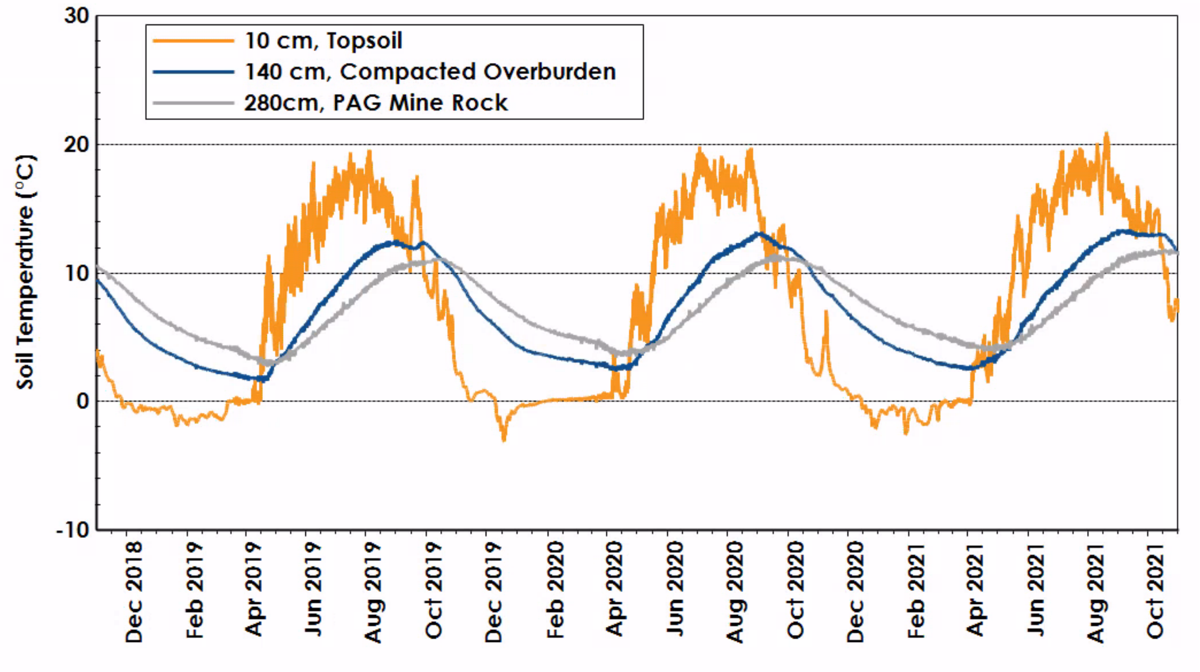

Figure 3.10: Trial #1 PAG waste rock temperatures over a three-year monitoring period.

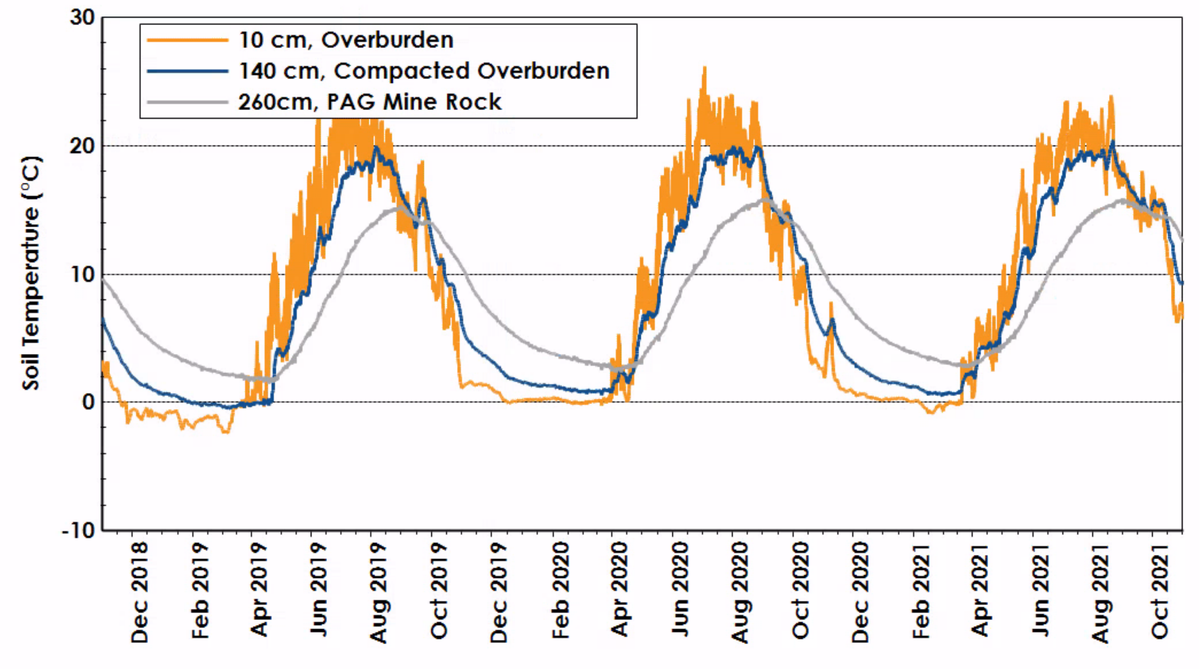

Figure 3.11: Trial #2 PAG waste rock temperatures over a three-year monitoring period.

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 system. 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. 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 compacted clay layer in both cover system profiles maintained a high degree of saturation throughout the monitoring period, having an annual average degree of saturation of 93% (Table 3.6). The degree of saturation maintained in the cover system demonstrates that the compacted clay layer is retaining sufficient pore-water to attenuate oxygen transport. The 2020-2021 monitoring period observed the degree of saturation of the CBC drop to 90% and 83% at Trial #1 and Trial #2, respectively. The drop in saturation results from a dry period observed from June to August 2021. Precipitation following this period allowed degree of saturation in the CBC to rebound to the level historically maintained. The drying front that reached both the Trial #1 (Figure 3.12) and Trial #2 (Figure 3.13) compacted layer receded with the late September – early October rainfall events, and an appropriate degree of saturation was establishing going into the winter months. It can be determined from monitoring results that the objective of mitigating oxygen ingress is effectively achieved through the maintenance of an adequate degree of saturation in both the compacted and noncompacted layers throughout extended periods of dry and warm weather. Estimated oxygen diffusion modelling is further quantified and discussed in Section 3.5.

Table 3.6: Average degree of saturation of cover system layers.

	Noncompacted Clay		Compacted Clay		
	0 – 50 cm	50 – 100 cm	Maximum	Minimum	Average
Trial #1 Primary Nest	71%	83%	100%	90%	93%
Trial #1 Secondary Nest	75%	85%	100%	90%	93%
Trial #2 Primary Nest	82%	88%	98%	83%	94%
Trial #2 Secondary Nest	83%	86%	100%	75%	93%

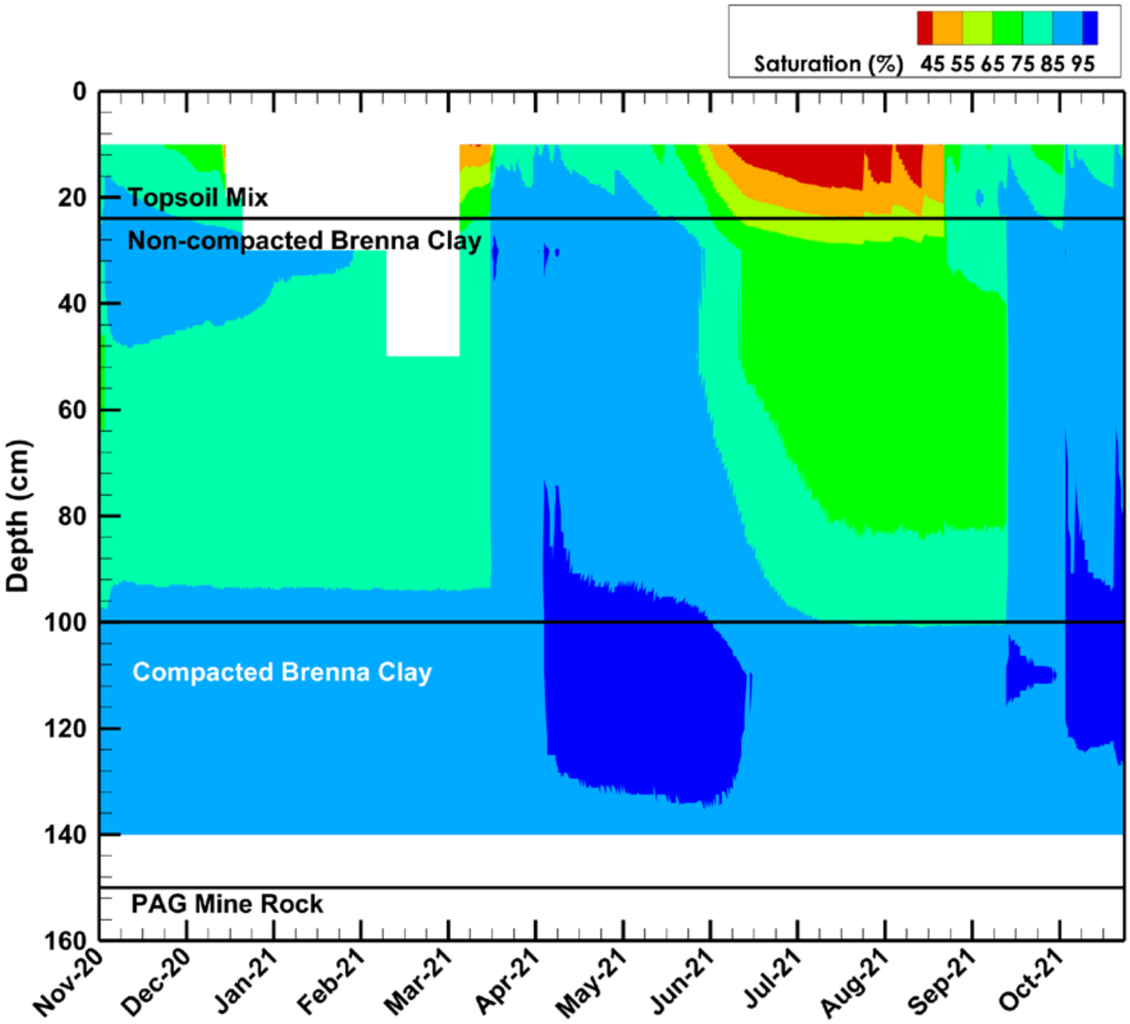

Figure 3.12: Change in degree of saturation at Trial #1 Primary Nest (white areas indicate periods of freezing temperatures).

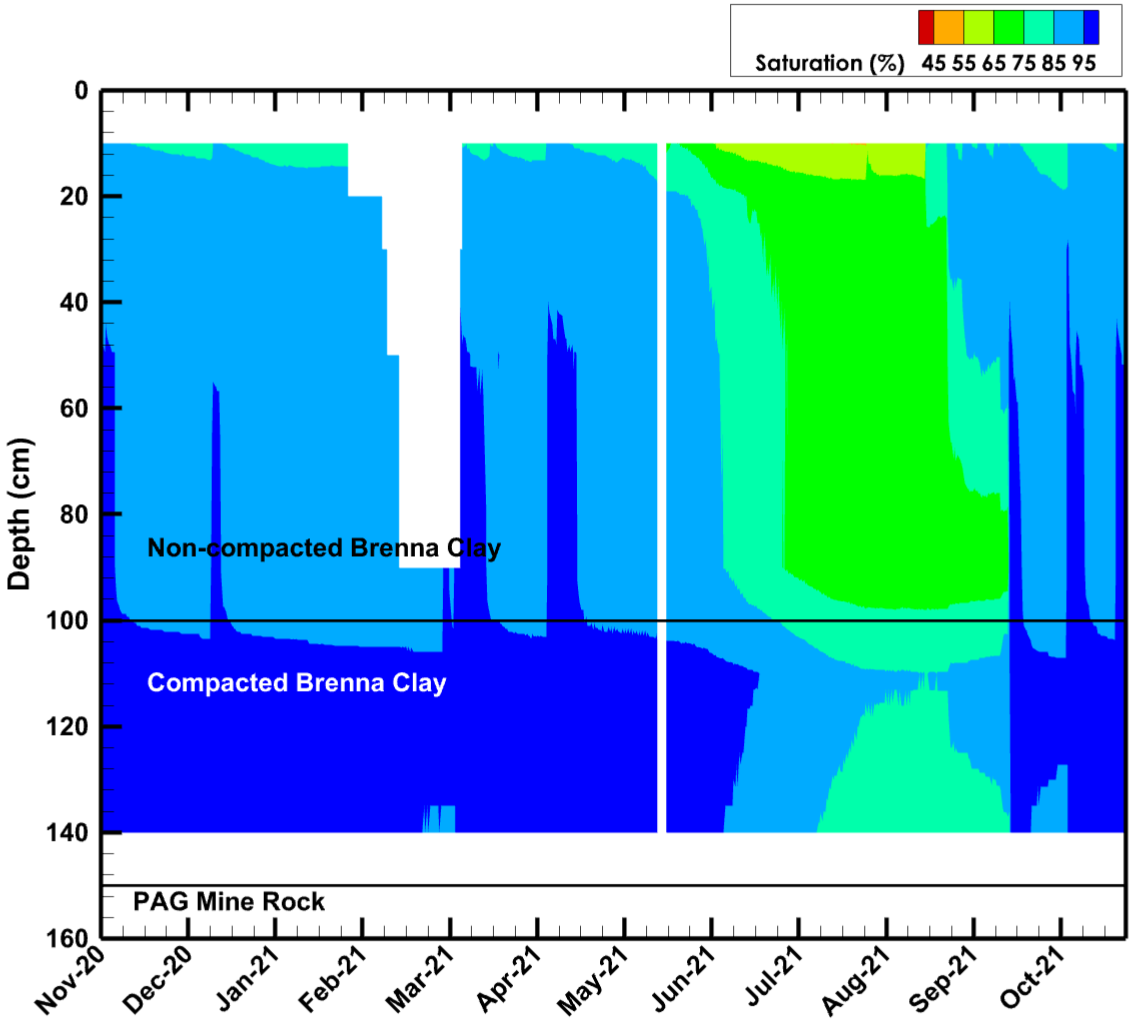

Figure 3.13: Change in degree of saturation at Trial #2 Primary Nest (white areas indicate periods of freezing temperatures).

The three-year monitoring period was also analyzed for degree of saturation and the results of the Trial #1 (Figure 3.14) and Trial #2 (Figure 3.15) primary nests are provided below. The 2020-2021 monitoring period experienced the lowest degree of saturation throughout the entire cover system for both Trial #1 and Trial #2 when compared to the 2018-2019 or 2019-2020 monitoring years. This is attributed to the lack of precipitation throughout the summer months, which allowed the drying front to extend.

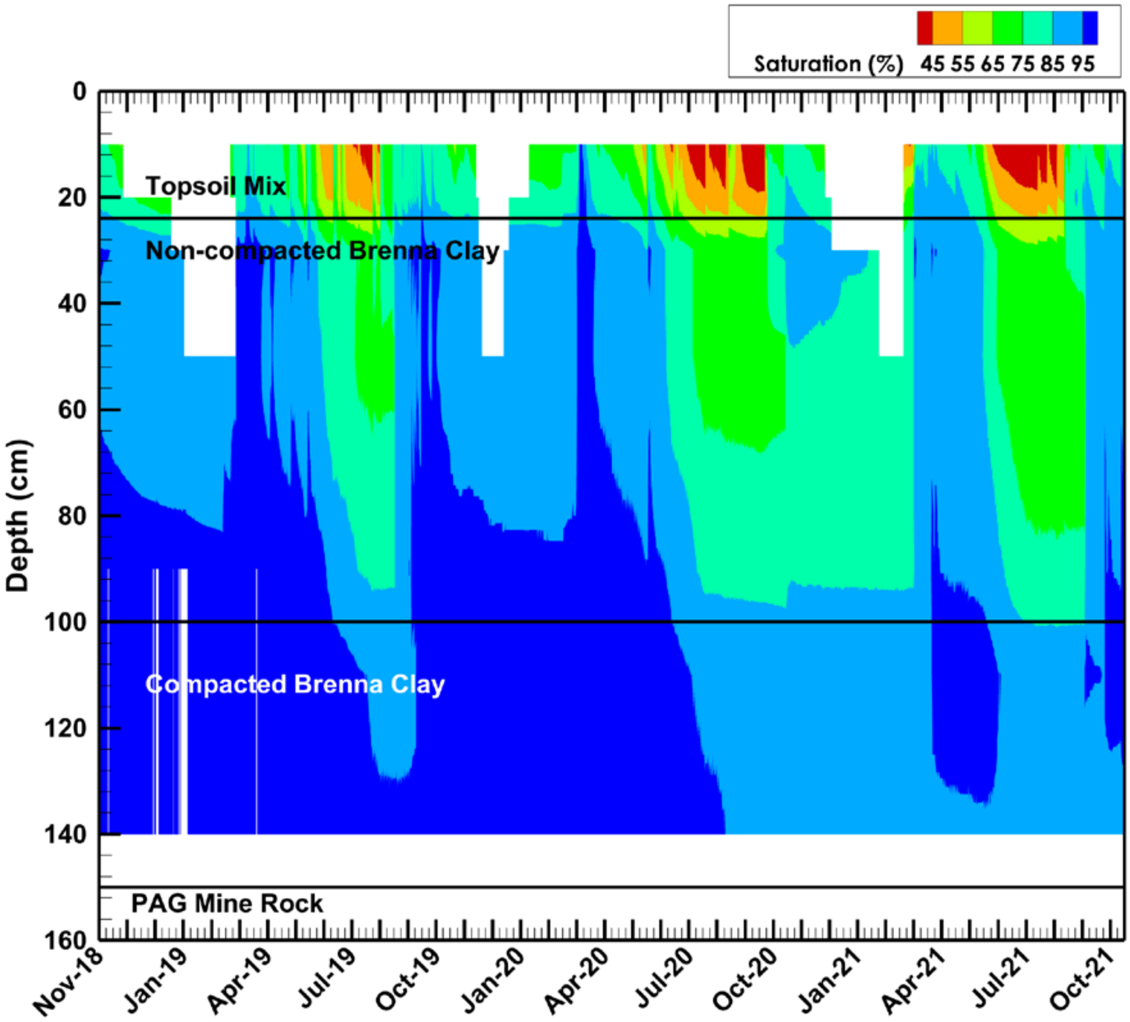

Figure 3.14: Change in degree of saturation over a three-year monitoring period at Trial #1 Primary Nest (white areas indicate periods of freezing temperatures).

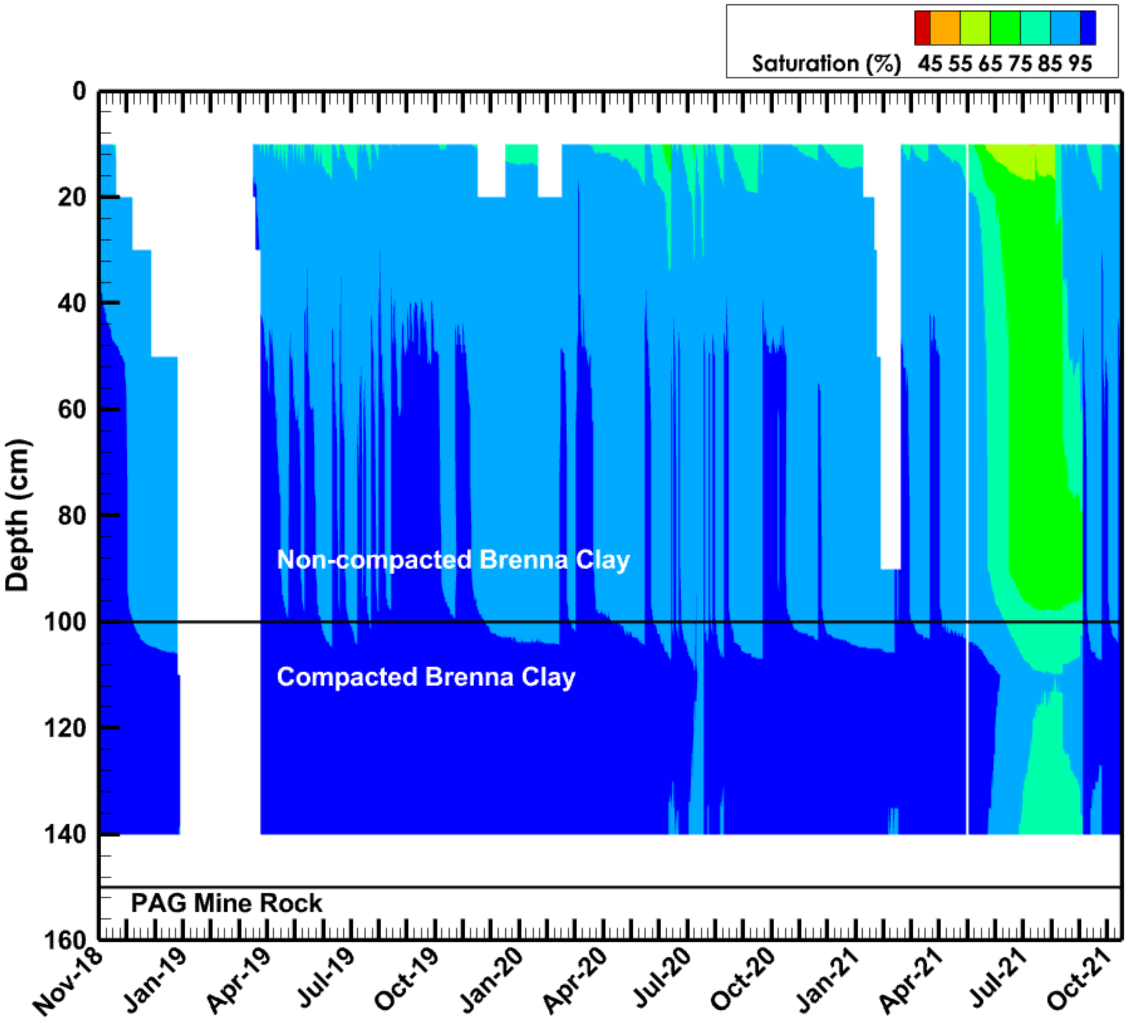

Figure 3.15: Change in degree of saturation over a three-year monitoring period at Trial #2 Primary Nest (white areas indicate periods of freezing temperatures).

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 installed sensor measurement range as the resolution of measurements in this range cannot be specifically measured and can considered as any value between 0 to 10 kPa. Suction values greater than about 400 kPa are calculated from laboratory calibrations completed with salt brines generating osmotic suction. Calibration of individual sensors in this suction range can be challenging and therefore values greater than 400 kPa can be considered as high suctions but the trend in estimated suction value is likely more valuable than the absolute value. Overall, Trial #1 (Figure 3.16) observed higher suction values deeper within the cover system than Trial #2 (Figure 3.17) (suction values measured >1,500 kPa within the compacted layer). a The higher suction values in Trial #1 were primarily attributed to the established vegetation's ability 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 showing that the compacted clay has a high permanent wilting point (PWP) and that even under high suction values water is unable to be pulled from the soil matrix.

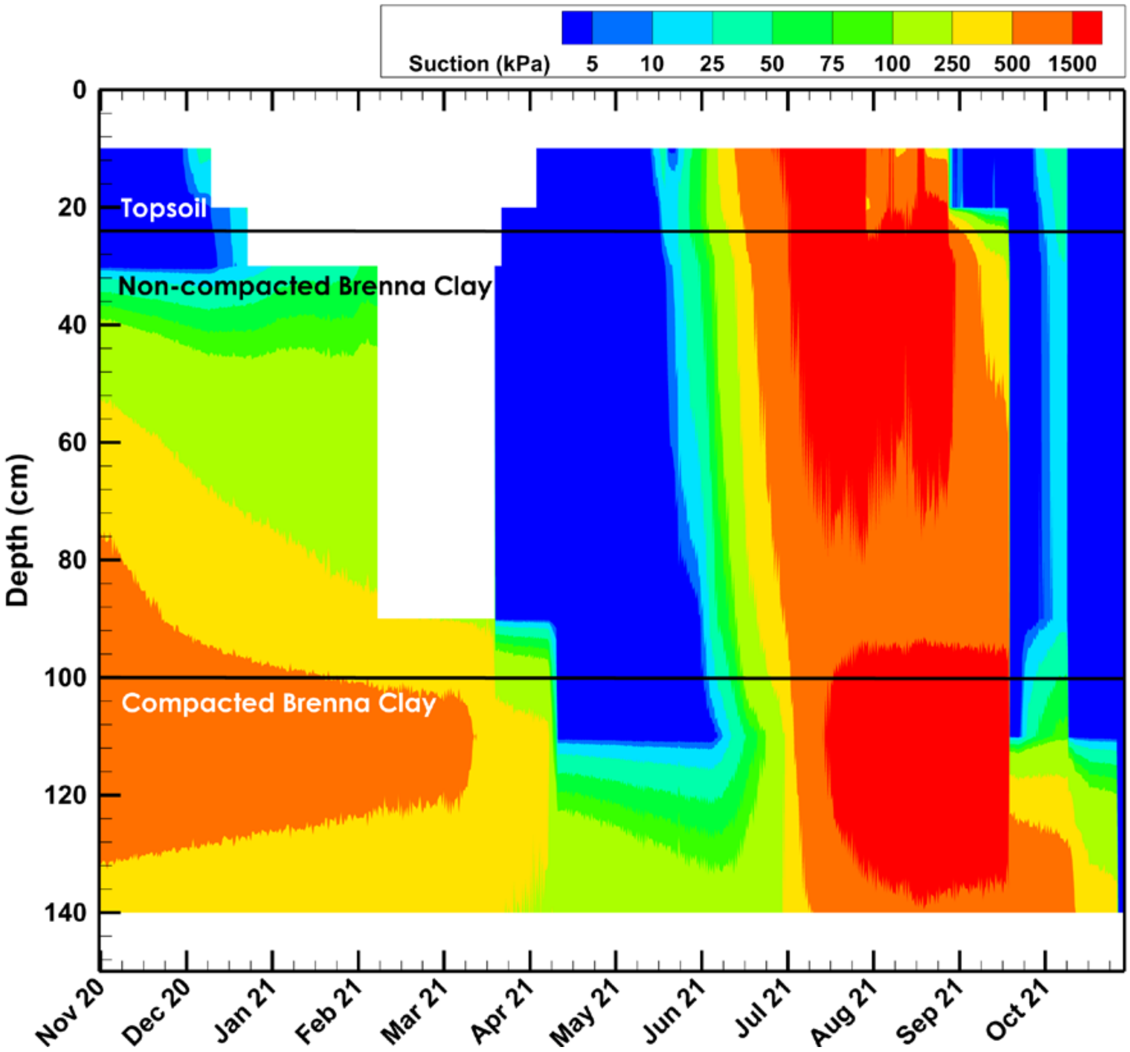

Figure 3.16: Matric suction profile measured at Trial #1 Primary Nest (white areas indicate periods of freezing temperatures).

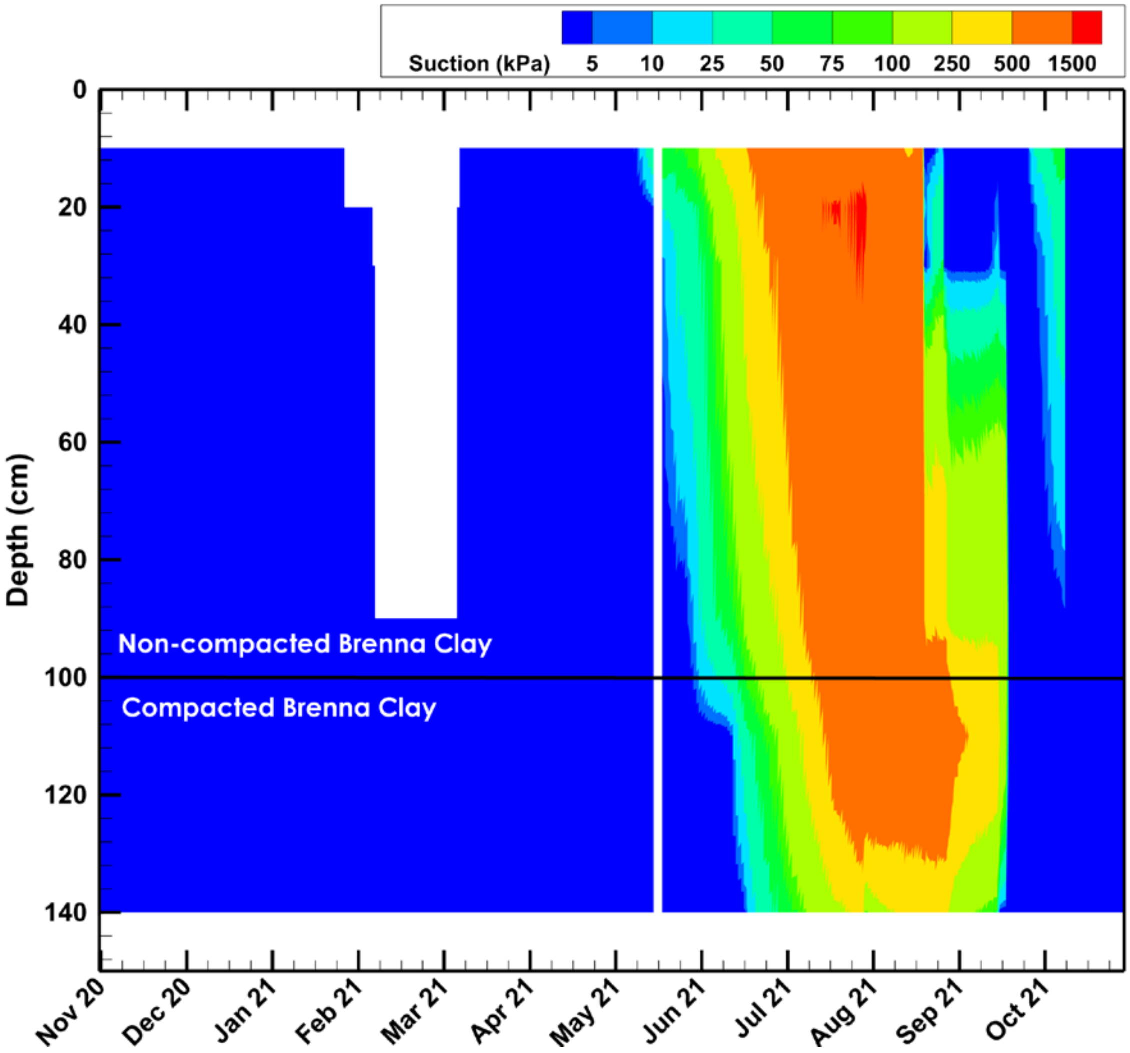

Figure 3.17: Matric suction profile measured at Trial #2 Primary Nest (white areas indicate periods of freezing temperatures).

The three-year monitoring period analysis of Trial #1 (Figure 3.18) and Trial #2 (Figure 3.19) is provided below. The 2020-2021 monitoring year showed the highest matric suctions of all three years in both trials. This was expected due to the lack of rainfall and warm temperatures. Although the compacted layer observed periods of high suction, the compacted layer was still able to maintain a sufficient degree of saturation as outlined in Section 3.3.1.

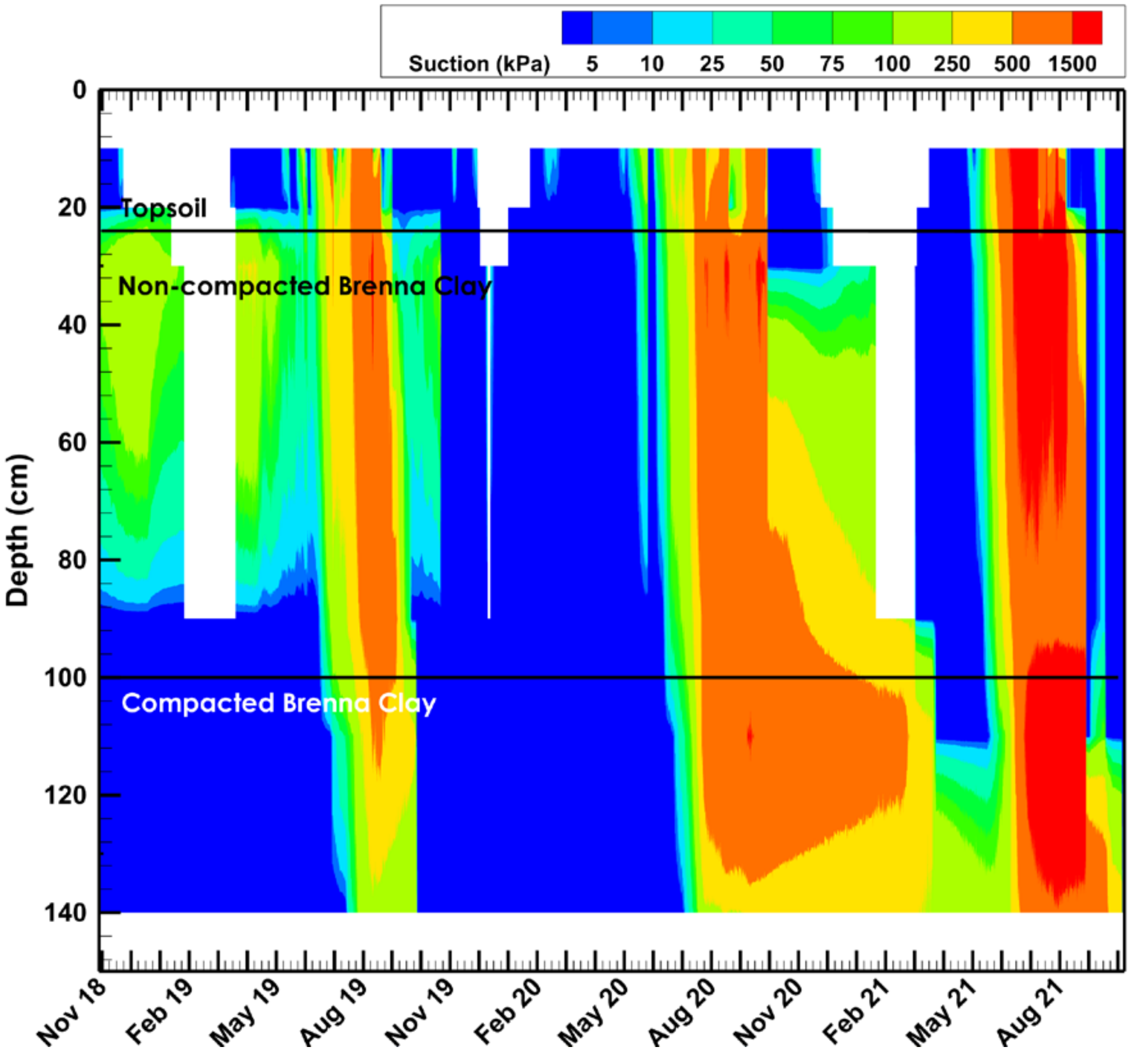

Figure 3.18: Matric suction profile measured at Trial #1 Primary Nest over a three-year monitoring period (white areas indicate periods of freezing temperatures).

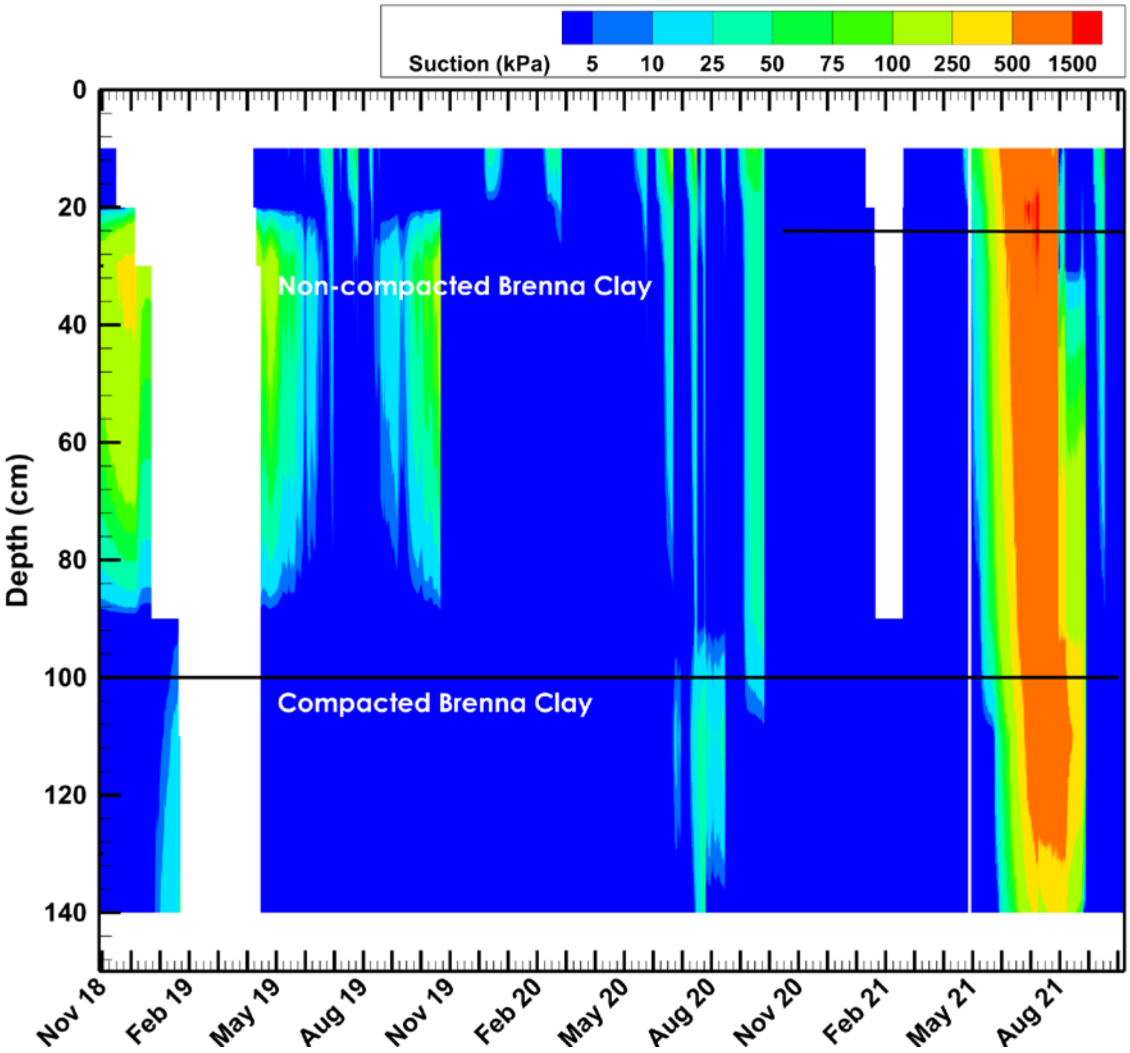

Figure 3.19: Matric suction profile measured at Trial #2 Primary Nest over a three-year monitoring period (white areas indicate periods of freezing temperatures).

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 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 sensors placed at 10 cm, 20 cm, and 30 cm the representative layers are 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 had less water stored within the soil matrix in March, as compared to Trial #2. This allowed for incoming precipitation to be stored more effectively, which assists in reducing overall net percolation into the underlying waste rock. Trial #1 and Trial #2 stored water capacity showed similar trends from April to September (Figure 3.20). 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.

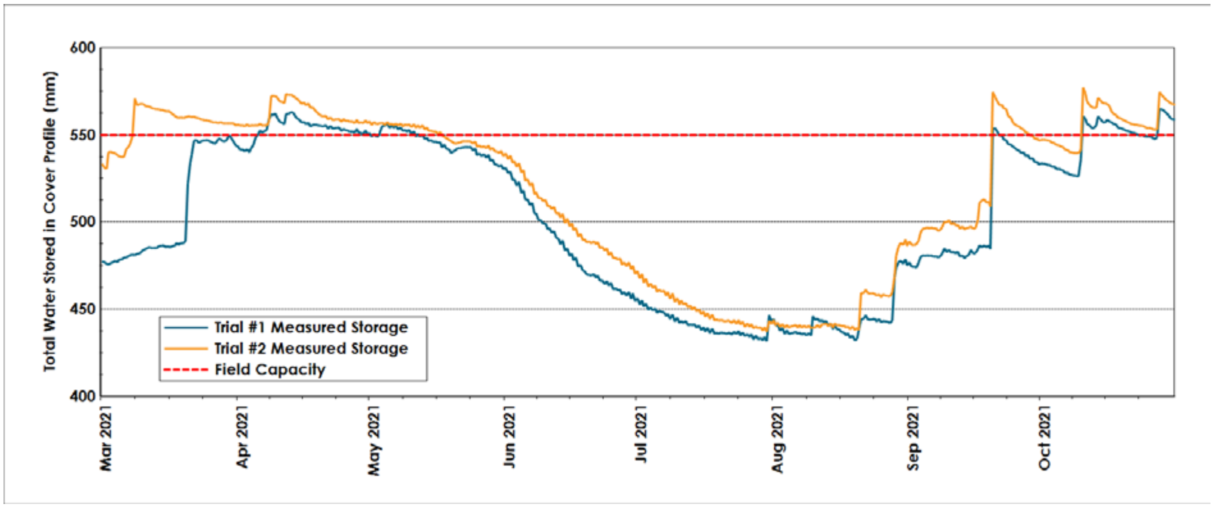

Figure 3.20: Measured storage vs. cover system field capacity.

The three-year monitoring period between March 2019 and October 2021 was also evaluated below (Figure 3.21). Both the 2019 and 2020 monitoring year showed significantly less total water stored in the Trial #1 cover compared to the Trial #2 cover, whereas the 2021 monitoring year showed similar water storage losses from May to August between both trial covers. This is likely because vegetation has been reasonably established on both cover systems over the previous 3 years, and both Trial #1 and Trial #2 are seeing more consistent results related to storing and releasing water. 2021 was also the most significant year for stored water losses due to the excessive lack of precipitation that occurred during the monitoring period.

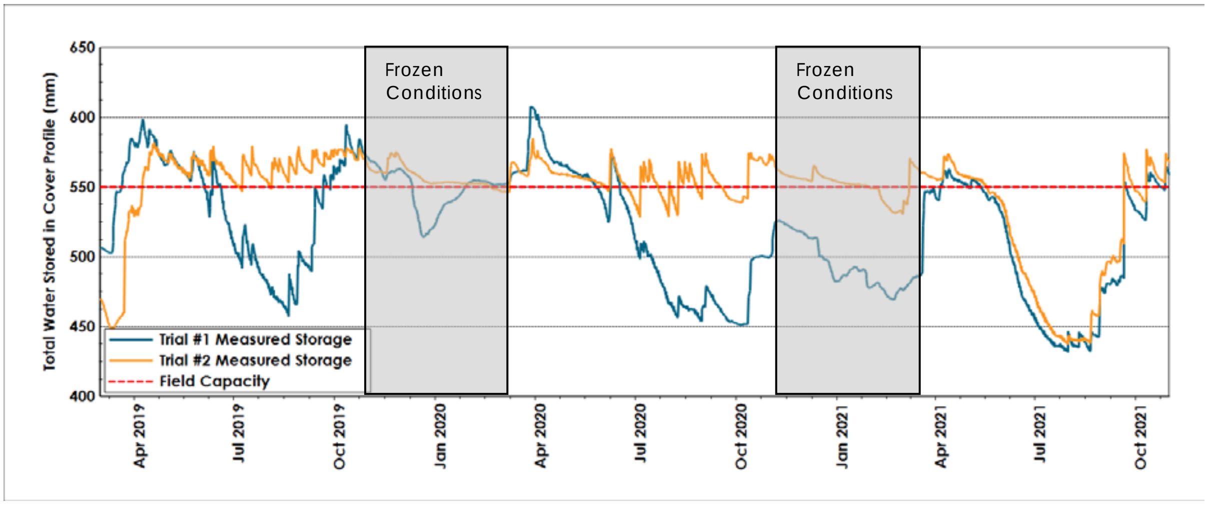

Figure 3.21: 3-year period of measured storage vs. cover system field capacity.

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 system 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.

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

where:

PPT = precipitation (rainfall plus snow water equivalent)

SB = sublimation (assumed to be zero)

RO = runoff;

ET_0 = 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 at tipping bucket rain gauge to measure rainfall and measured SWE of 0.15 and 0.22 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 seven days (USDA, 2004).

Runoff is not measured at the PAG field 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. Snowmelt is also considered to be runoff when ground conditions are still frozen.

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 lesser 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. Numerical modelling methods were used in development of the water balance

3.4.2 Water Balance Results

Calculated change in storage matched measured change in storage for Trial #1 (Figure 3.22) and Trial #2 (Figure 3.23) water balances. Net percolation in Trial #1 was 75mm (15% of annual precipitation). This net percolation follows the 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). Net percolation in Trial #2 was 120mm (24% of the annual precipitation) (Table 3.7) resulting in moderate net percolation rates. The primary component resulting in the difference in net percolation rates is the difference in storage between the two configurations. The large rainfall events late in the season caused an increase in net percolation for Trial #2. Trial #2 had more stored water in early October, prior to these rainfall events, meaning that Trial #1 had more of a capacity to hold the incoming precipitation, whereas it forced a flushing event in Trial #2. Net percolation on Trial #2 was increased because the storage capacity was insufficient in mitigating the late season rainfall events.

Table 3.7: Water balance components

	ET_0 mm (% PPT)	Runoff mm (% PPT)	Net Percolation mm (% PPT)	Change in Storage mm (% PPT)
Conceptual Model	50 – 70%	10 – 20%	5 – 15%	N/A
Trial #1	239 (49%)	122 (25%)	75 (15%)	60 (13%)
Trial #2	240 (48%)	139 (28%)	120 (24%)	-2 (-0.4%)

PPT = Annual Precipitation

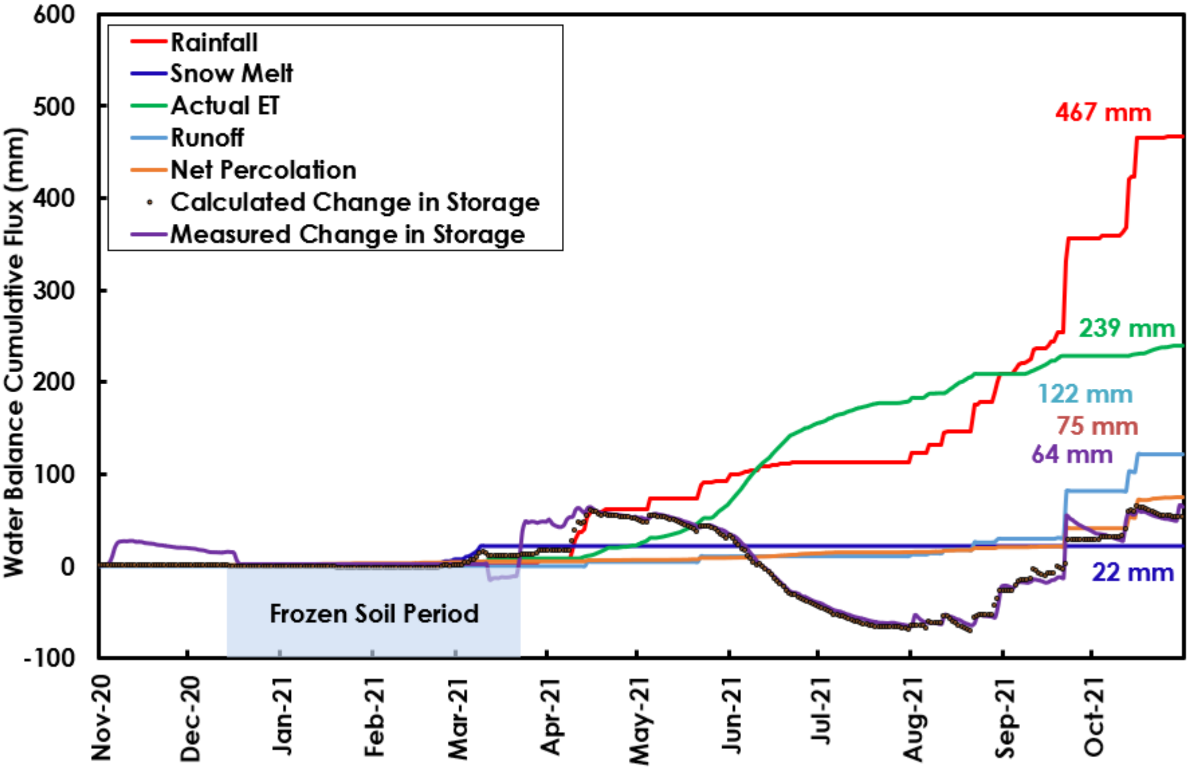

Figure 3.22: Cumulative water balance fluxes for Trial #1 for the monitoring period.

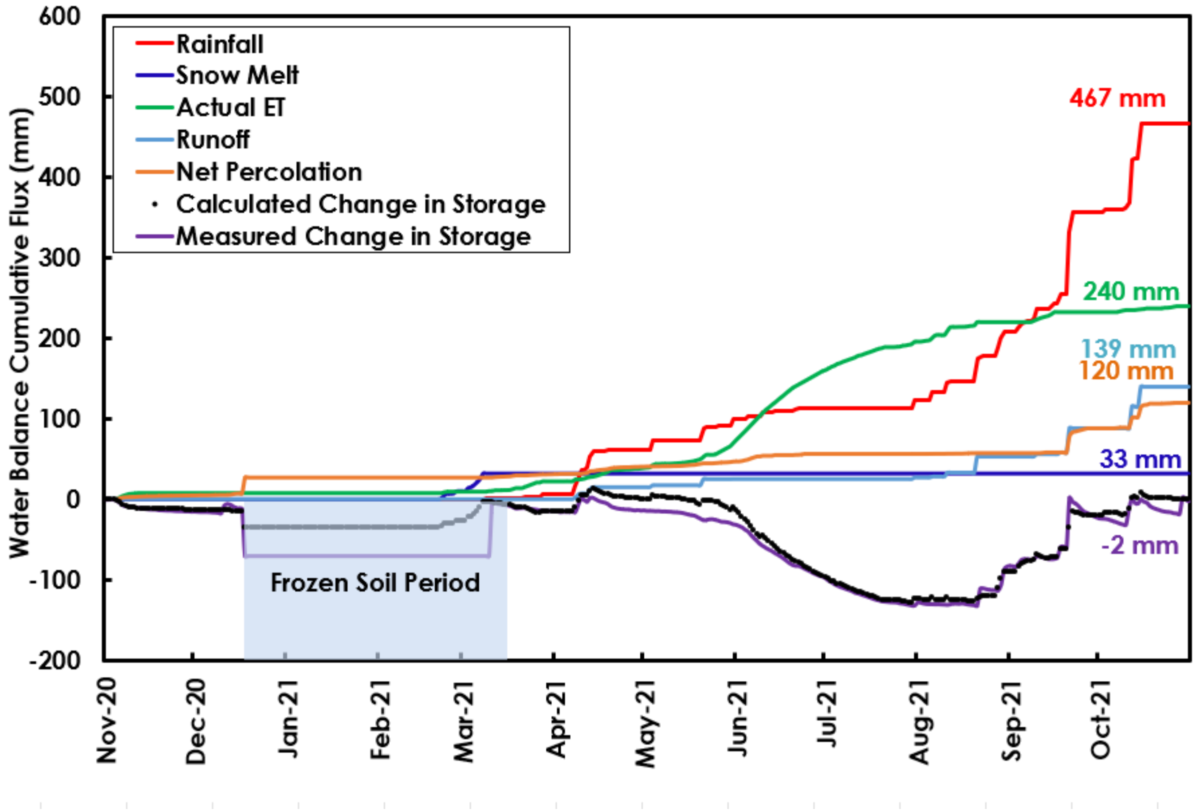

Figure 3.23: Cumulative water balance fluxes for Trial #2 for the monitoring period.

A three-year water balance was completed, and the results are included below for both Trial #1 and Trial #2 (Table 3.8). Trial #1 has shown a higher rate of AET, and lower rates of runoff and net percolation, which can be attributed to the presence of thicker, more established vegetation as compared to Trial #2 throughout the three-year monitoring period.

Table 3.8: Water balance components over the three-year monitoring period.

	ET_0 mm (% PPT)	Runoff mm (% PPT)	Net Percolation mm (% PPT)	Change in Storage mm (% PPT)
Conceptual Model	50 – 70%	10 – 20%	5 – 15%	N/A
Trial #1	985 (62%)	311 (19%)	277 (17%)	28 (2%)
Trial #2	796 (49%)	405 (25%)	384 (24%)	27 (2%)

3.5 Estimated Oxygen Ingress

Automated oxygen sensors located in the underlying waste rock were monitored to observe the ingress and consumption of oxygen. Fluctuation in oxygen concentrations have been observed since the construction of the trials. These fluctuations have been attributed to insufficient thickness of the clay key surrounding the field trials allowing oxygen to bypass the cover system through advection. Due to this ingress pathway, monitoring oxygen concentrations is not a definitive approach to measure the ability of the cover system to mitigate oxygen ingress.

To quantitatively estimate oxygen diffusion into the waste rock through the cover materials, a Monte Carlo simulation has been completed separately for both trials. The simulation used the degree of saturation as provided in Section 3.3.1, and varied the following material properties as a sensitivity analysis to estimate both best- and worst-case scenarios:

- Dry density of CBC between 1,600 kg/m^3 and 1,700 kg/m^3;
- Dry density of non-compacted clay overburden between 1,450 kg/m^3 and 1,550 kg/m^3;
- Dry density of topsoil between 1,400 kg/m^3 and 1,500 kg/m^3 (Trial #1 only); and
- Initial oxidization rate (IOR) of the waste rock between 1x10^{-11} kg/tonne/s and 1x10^{-7} kg/tonne/s.

The simulation was repeated 1,000 times, with the above parameters varied for each simulation. The results of the simulation for Trial #1 show that the median results predicts over 4 mol of oxygen had diffused into the waste rock over the three-year monitoring period (Figure 3.24). Approximately 2 mol of oxygen was predicted to ingress during 2021 while annual rates were closer to 1 mol / year during 2019 and 2020. The 95th percentile oxygen ingress estimation was approximately 8 mol over the three-year monitoring period. The results for Trial #2 indicate over 6 mol of oxygen had diffused into the waste rock over the three-year monitoring period, with approximately 10 mol of oxygen diffusion occurring in the 95th percentile estimate (Figure 3.25). Trial #2 shows an increase in oxygen diffusion rates after July 2021 of up to 1 mol/month (median case). This was caused by the decrease in the degree of saturation during the summer months where little rainfall was recorded. September rainfall reduced the drying front, which restored the water content within the cover system, and decreased the rate of oxygen diffusion into the waste rock.

The results of the modelling indicate a very low oxygen flux through the cover system (1 to 5 mol/m^2/year) according to the INAP Guidance Document (INAP 2017). The oxygen flux through the cover system was able to stay within conceptual performance expectations, even during dry periods, as experienced in June, July, and August 2021.

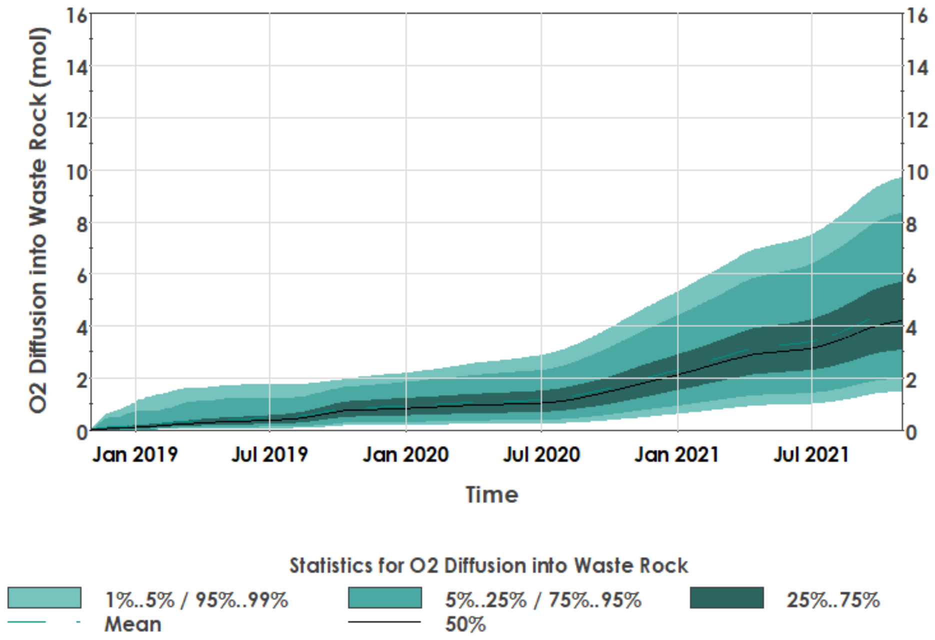

Figure 3.24: Oxygen diffusion simulation through cover materials on Trial #1 over a three-year monitoring period.

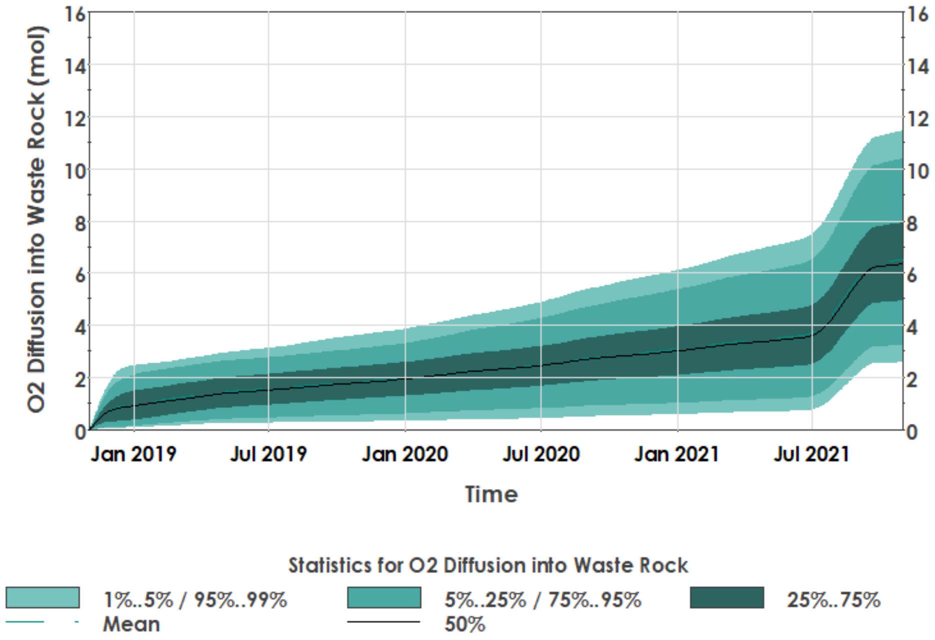

Figure 3.25: Oxygen diffusion simulation through cover materials on Trial #2 over a three-year monitoring period.

4 RECOMMENDATIONS

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

- Continued performance monitoring as the cover trials are easily accessible, not infringing on mine operations, and require little maintenance and further investments. The learnings from the performance of the cover trials in response to varying climate conditions allow for better understanding of cover system performance at the Rainy River site.
- Generation of annual water balances to better understand climatic cycles and the influence of further established vegetation to modify the water fluxes.

4.1 Opportunities

Automated performance monitoring data has been collected at the field trials for approximately 3.5 years, which represents a substantial database of material properties and soil response to wet/dry and freeze/thaw cycling. The PAG cover trial database provides New Gold with a better understanding of cover system performance under varying climatic and vegetative conditions. The database will foster additional confidence in the results from the EMRS progressive reclamation cover construction, which started in late 2020.

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Appendix A

Photo Log

Photo A.1: Traces of snow present during March 7, 2021 snow survey.

Photo A.2: Traces of snow present during March 7, 2021 snow survey.

Photo A.3: Trial #1 overview showing established vegetation, looking West. June 22. 2021.

Photo A.4: Trial #2 overview showing established vegetation, looking East. June 22, 2021.

Photo A.5: Comparison of vegetation on Trial #1 (left) and Trial #2 (right) slope, looking West. June 22, 2021.

Photo A.6: Trial #1 slope overview showing established vegetation, looking West. November 1, 2021.

Photo A.7: Trial #2 slope overview showing established vegetation, looking East. November 1, 2020.

Appendix B

In Situ Instrumentation Measurements

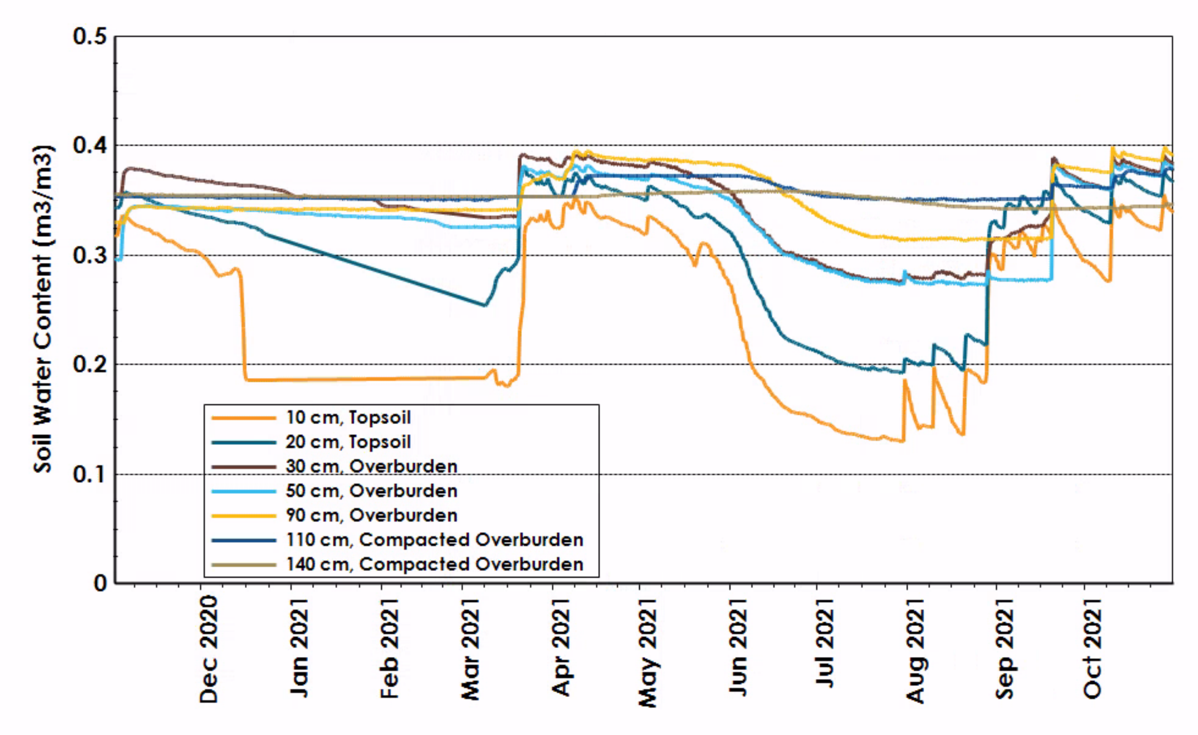

Figure B.1: VWC profile at Trial #1 primary station during the monitoring period.

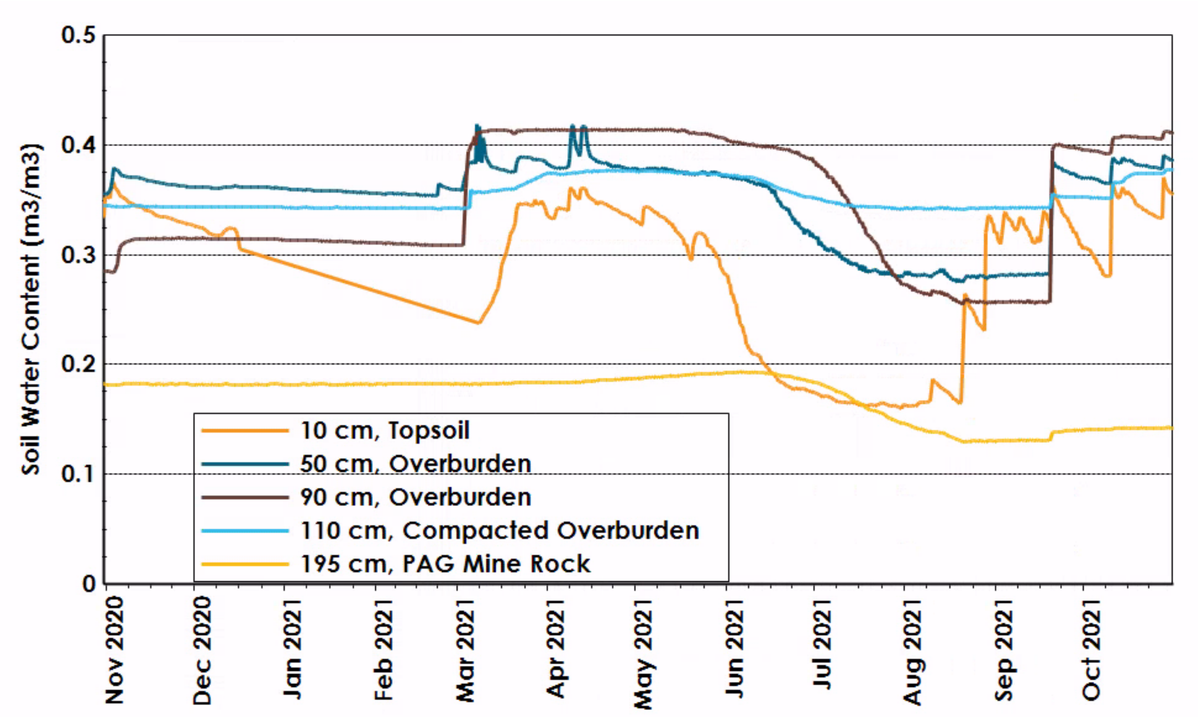

Figure B.2: VWC profile at Trial #1 secondary station during the monitoring period.

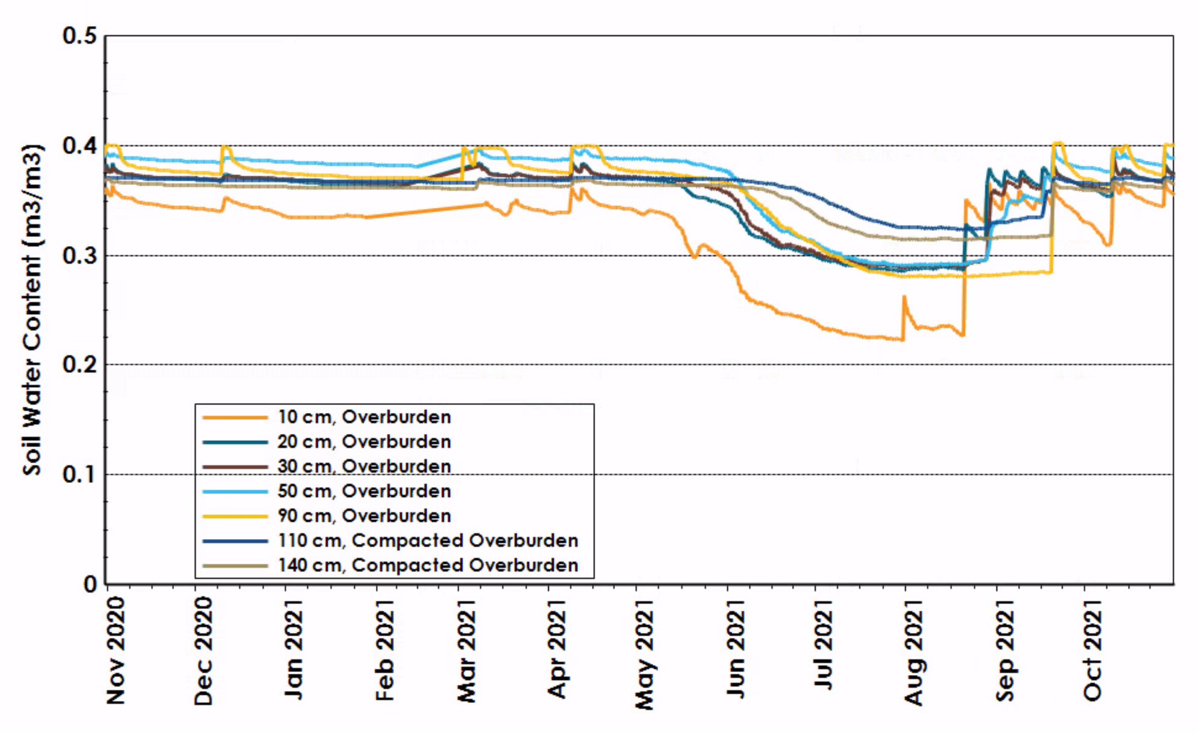

Figure B.3: VWC profile at Trial #2 primary station during the monitoring period.

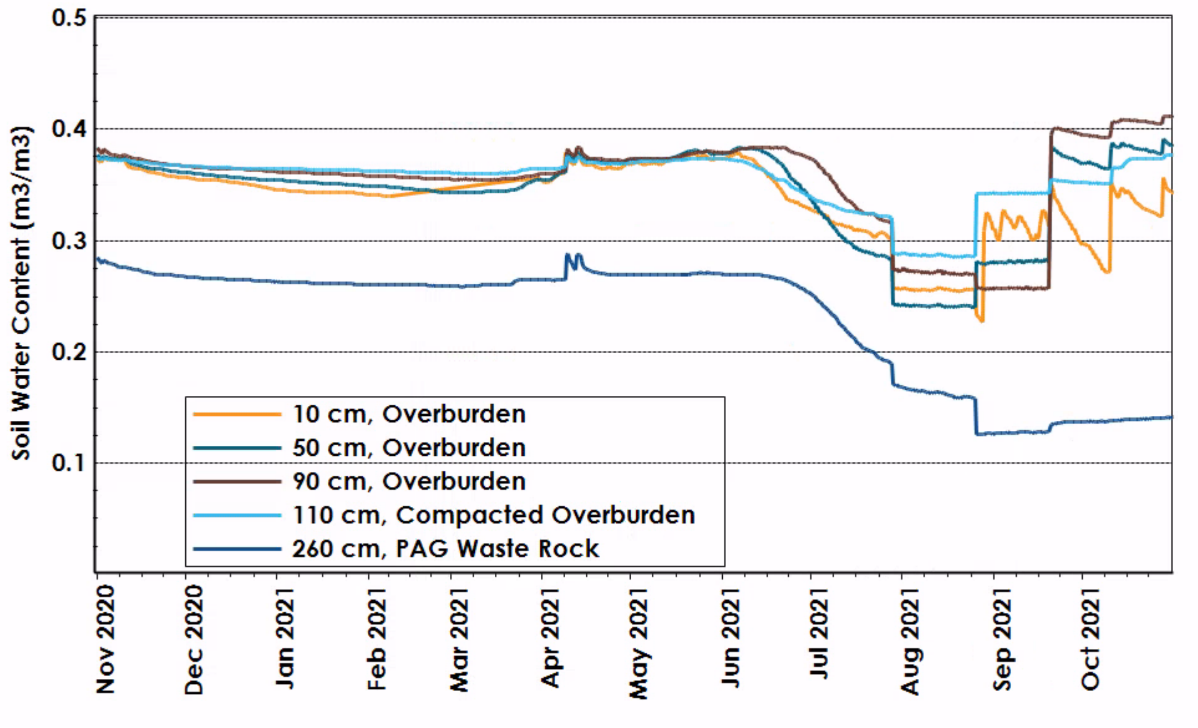

Figure B.4: VWC profile at Trial #2 secondary station during the monitoring period.

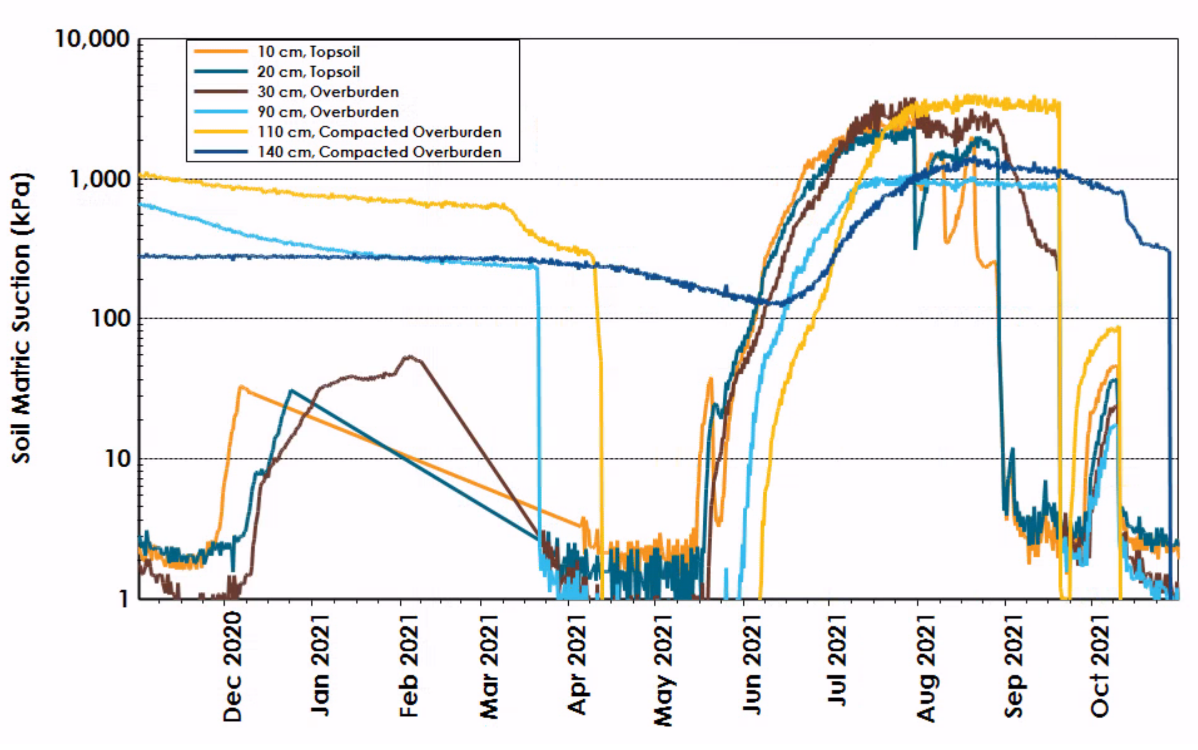

Figure B.5: Suction profile at Trial #1 primary station during the monitoring period.

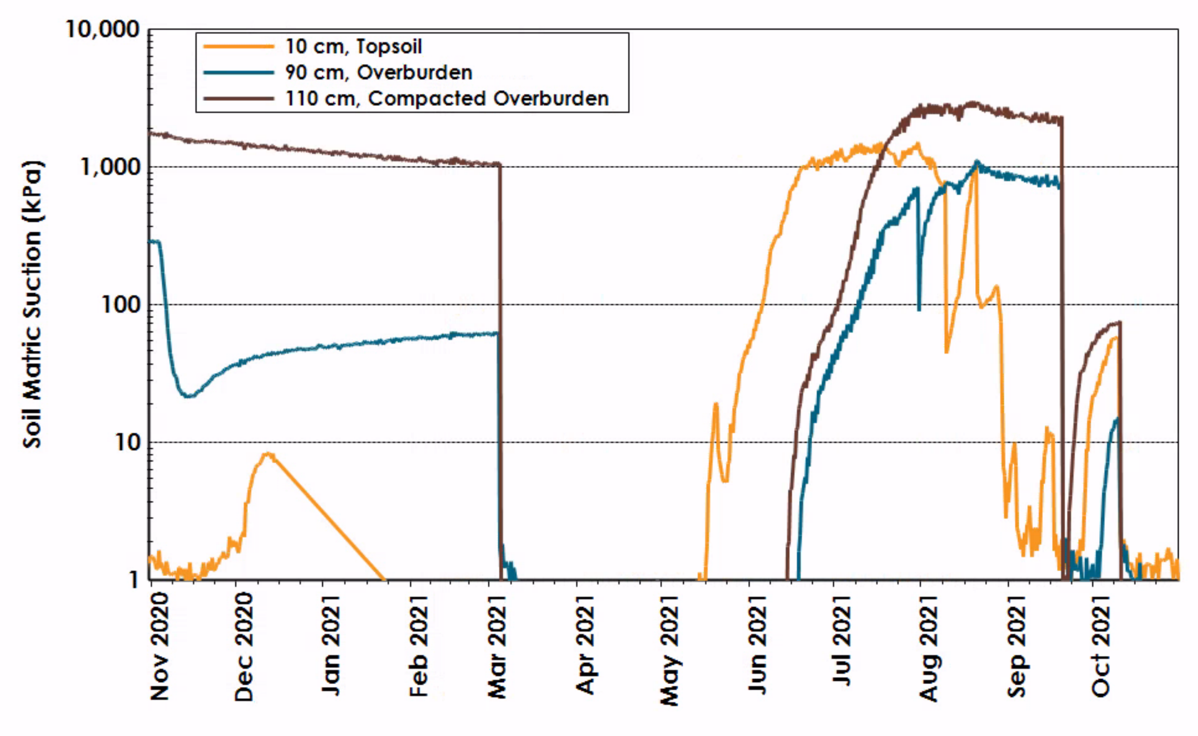

Figure B.6: Suction profile at Trial #1 secondary station during the monitoring period.

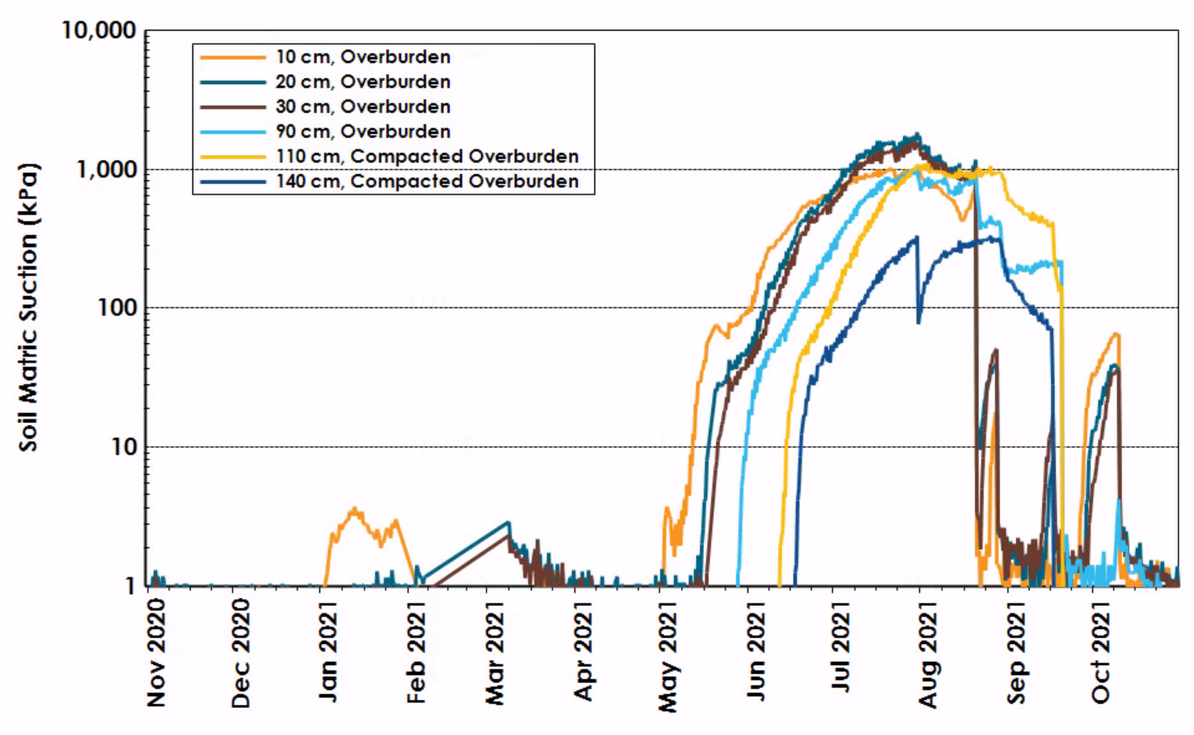

Figure B.7: Suction profile at Trial #2 Primary Station during the monitoring period.

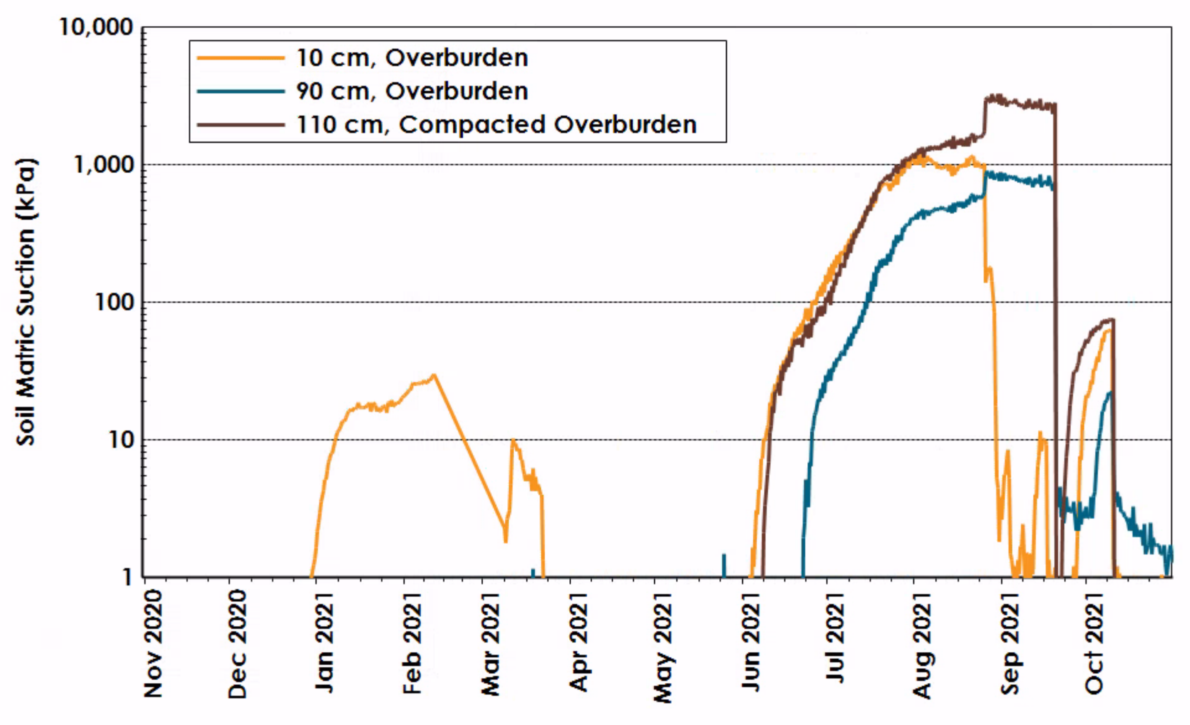

Figure B.8: Suction profile at Trial #2 Secondar Station during the monitoring period.

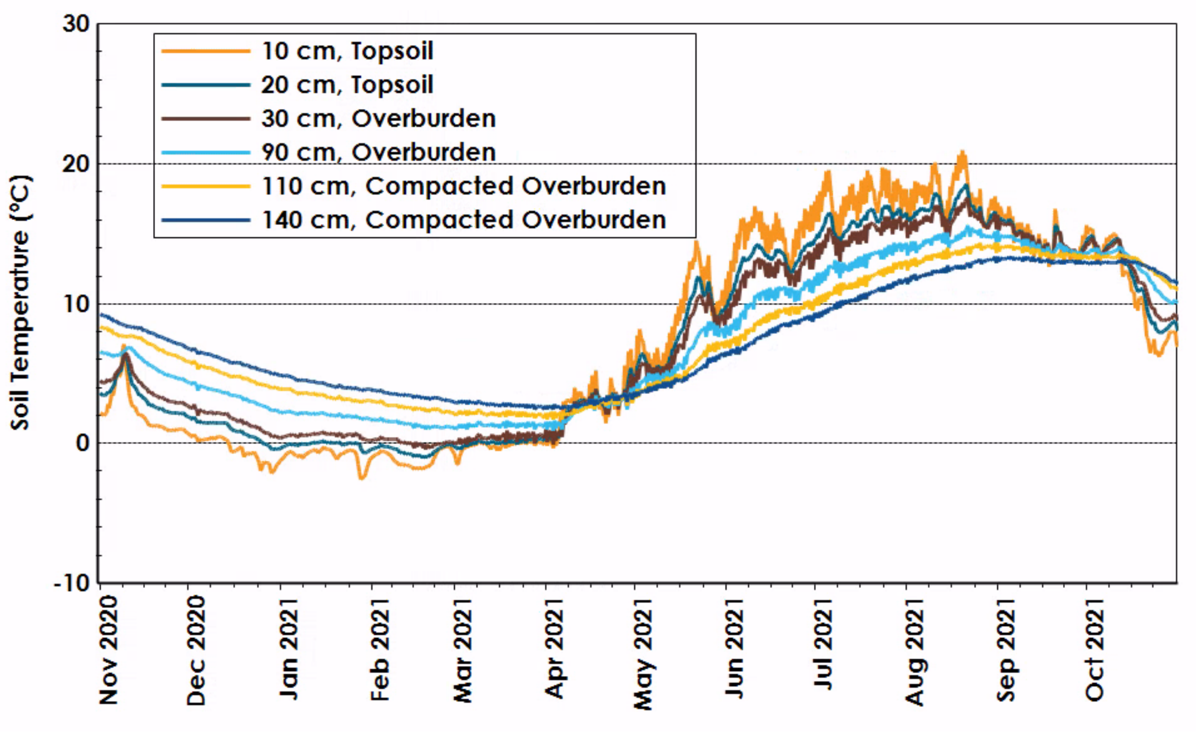

Figure B.9: Temperature profile at Trial #1 primary station during the monitoring period.

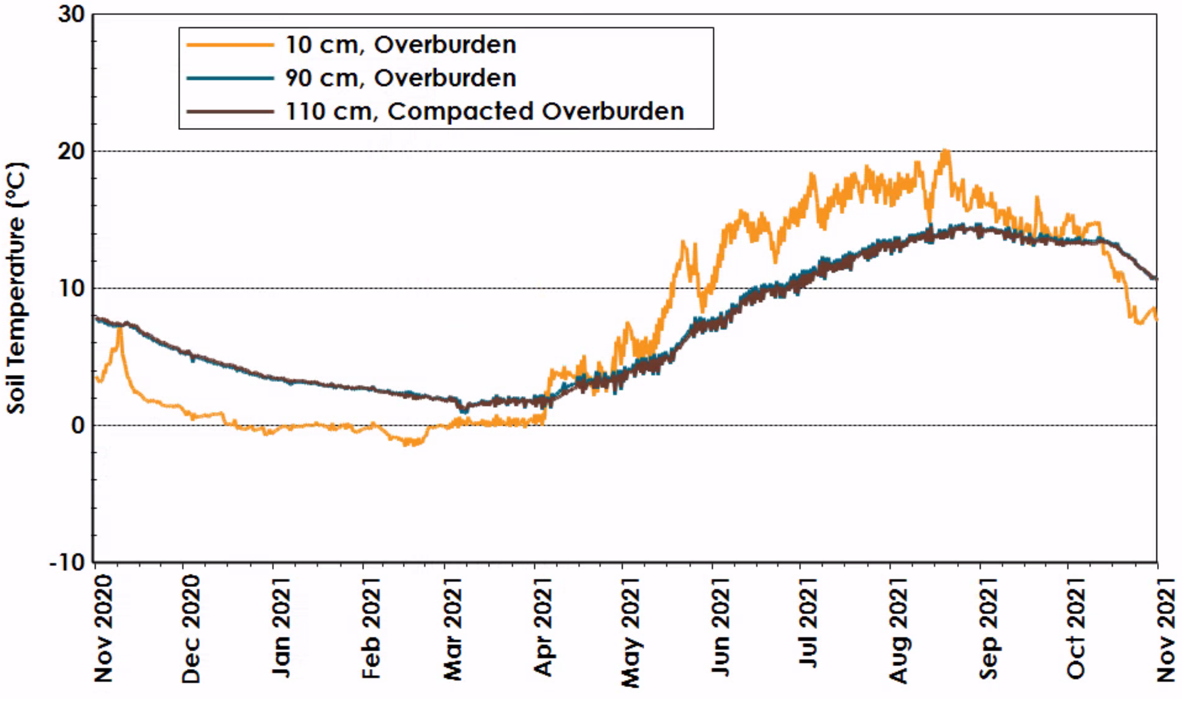

Figure B.10: Temperature profile at Trial #1 secondary station during the monitoring period.

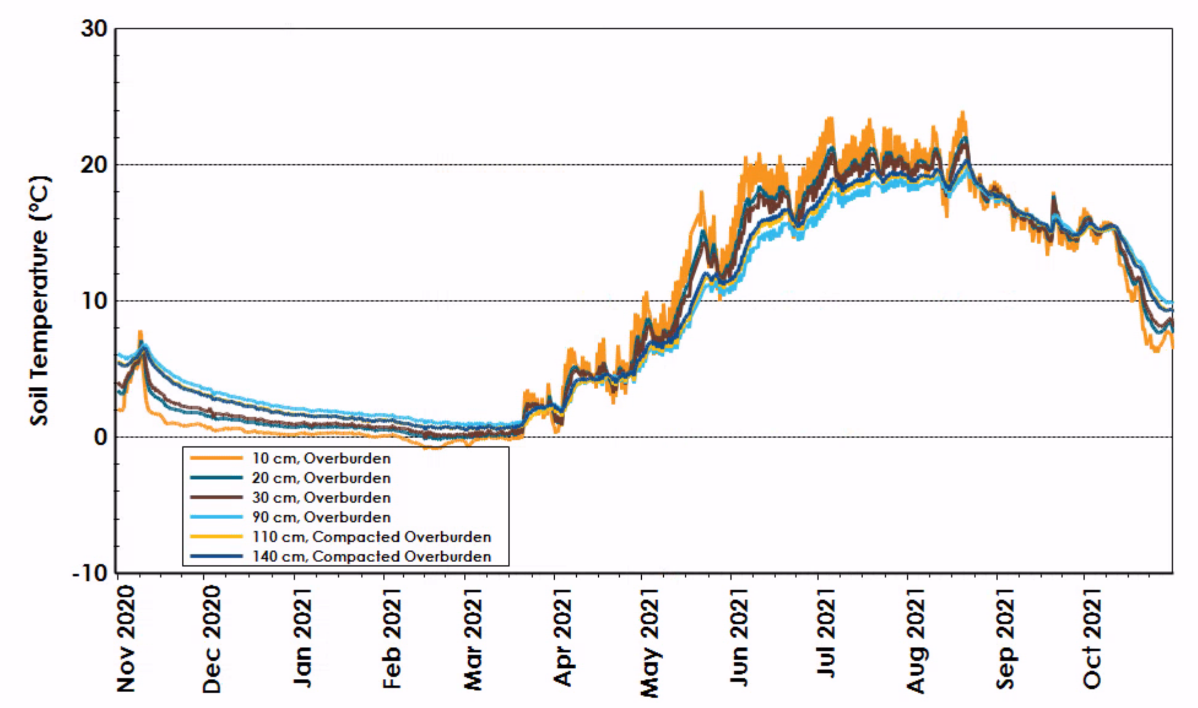

Figure B.11: Temperature profile at Trial #2 primary station during the monitoring period.

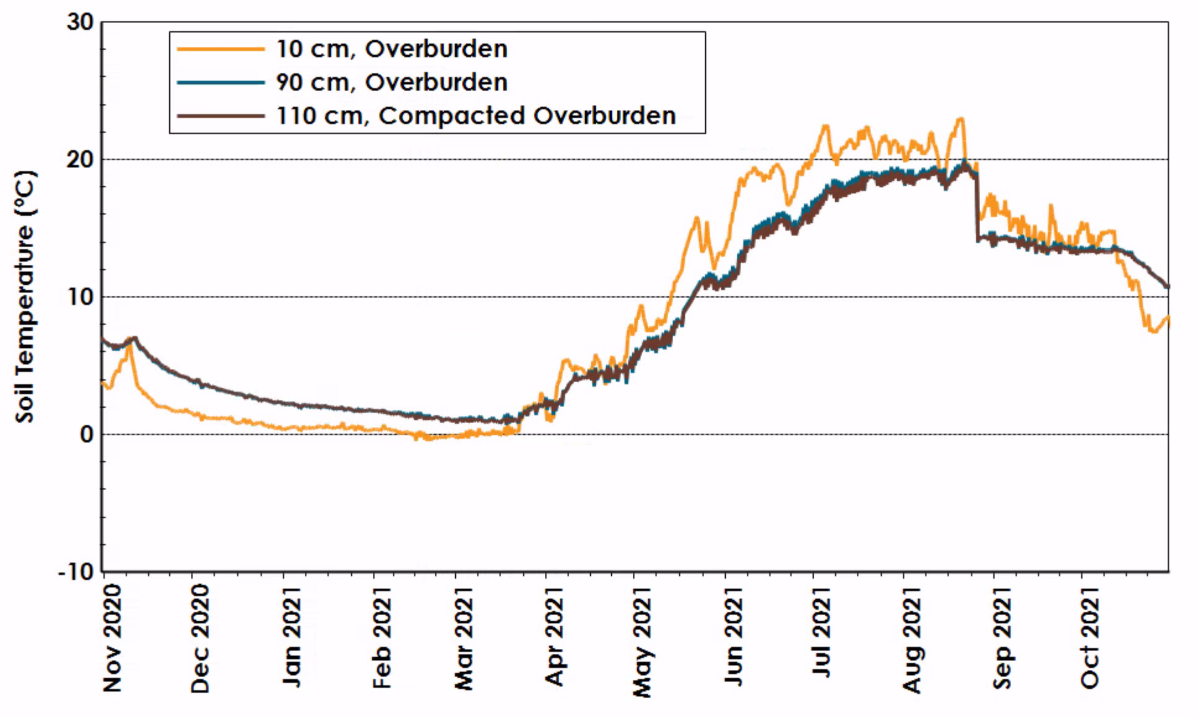

Figure B.12: Temperature profile at Trial #2 secondary station during the monitoring period.