REPORT

Galmoy Mines TMF Independent Audit 2018

Galmoy Mines Ltd

Submitted to:

Galmoy Mines Ltd
Galmoy
County Kilkenny
Ireland

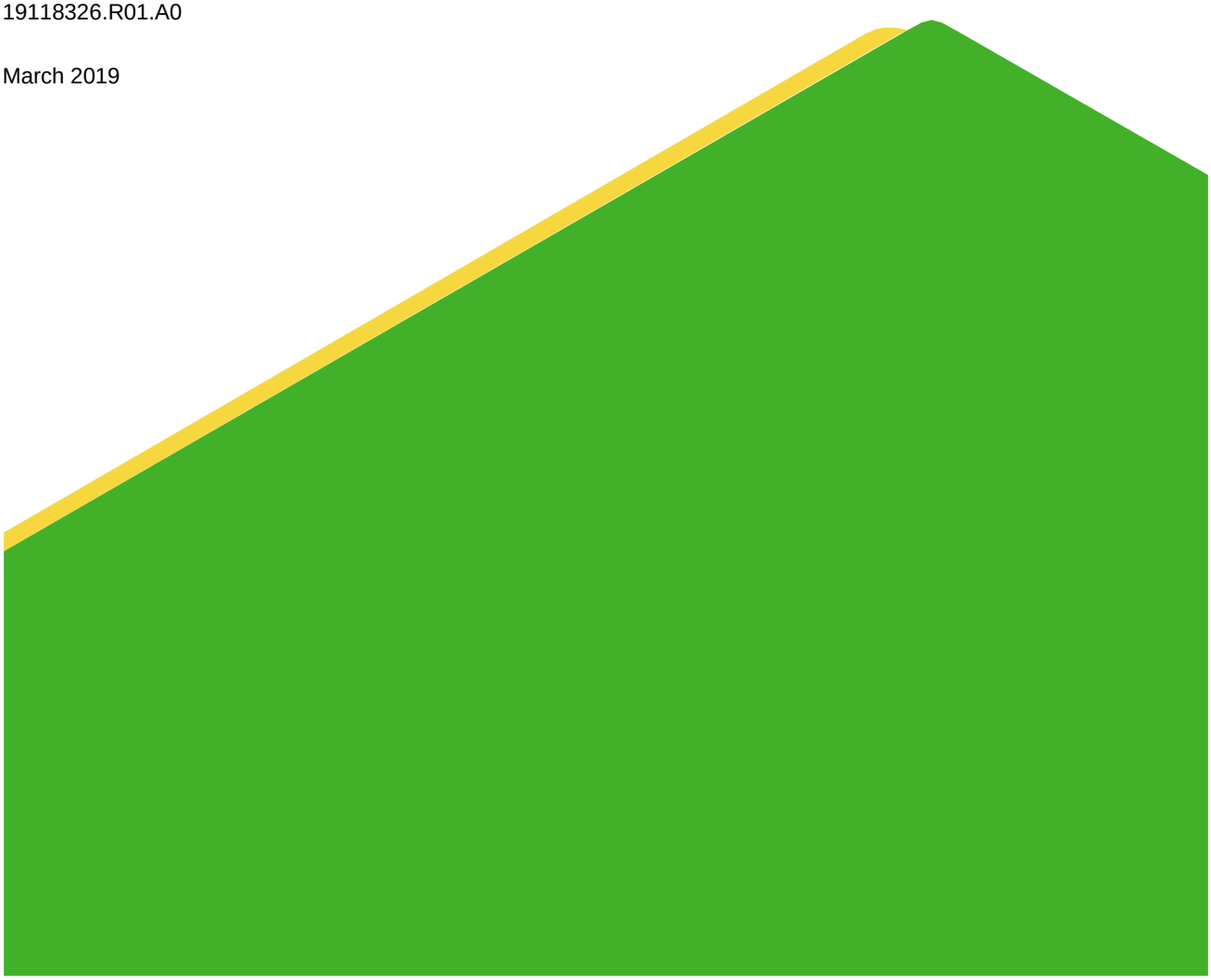
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1.0 INTRODUCTION

1.1 General

Golder Associates Ireland Ltd (Golder) were commissioned by Galmoy Mines Ltd (GML) to prepare Independent Audit Report to facilitate licensee compliance with the conditions of *Schedule C.4.2: Monitoring of the Tailings Management Facility* of the licence (IPPCL P01517-02 as amended in January and December 2015 for reductions to licence boundary) and subsequent agreements with the EPA in regard to a reduced monitoring programme, namely the 'Independent Audit' for the Galmoy Mines Tailings Management Facility (TMF).

Golder had most recently conducted the Galmoy TMF Independent Audit Report for 2016 (Golder 2017). The Galmoy TMF has been maintained in a similar condition in the intervening period:

- The TMF site is clean, tidy and the slopes well vegetated. The security of the facility is satisfactory and the electronic gate to the site is closed at all times.
- Based on the visual inspection and an evaluation of the monitoring data, Cell 1, Cell 2 and Cell 3 are performing in accordance with the design. The dam walls are in excellent condition and the piezometers installed in the dam wall are stable and/or dry for much of the year as can be seen from the readings.

1.2 TMF Location

The Galmoy Mine is located three miles west of the village of Galmoy and within the Townlands of Castletown, Whiteswall, Rathreagh, Garrylaun and Rathpatrick in north Co. Kilkenny. The surface facilities of the mine are confined largely to the Townland of Castletown on both sides of the Johnstown/Rathdowney road (R435). The TMF and the former explosives storage facilities are located to the west of this road. The TMF comprises approximately 32 ha. and is located immediately south-west of the former plant site in a broad relatively shallow valley which drains to the north-west. The maximum relief of the valley is some 66 m with a hill peak forming part of the west valley side at an elevation of 196 mOD and the valley floor attaining an elevation low of 130 mOD. The eastern and southern sections of the valley sides attain maximum elevations of 142 mOD and 145 mOD respectively.

1.3 Background

Galmoy Mine was an underground mining operation processing local zinc-lead ore bodies. A large proportion of the tailings produced were mixed with cement and pumped underground as a high density paste material for backfilling. This aided the stabilisation of worked out areas. The remaining tails not used for backfilling were pumped to the TMF, located on the west side of the site. The TMF consists of three adjacent cells:

- Cell 1, with a storage capacity of 880,000 m^3 and a surface area of approximately 9 Ha, was constructed in 1996 and was filled with tailings by 2000;
- Cell 2, with a storage capacity of 1,167,000 m^3 and a surface area of 13.4 Ha was constructed in 2000 and was filled with tailings by 2006; and
- Cell 3, with a storage capacity of 777,000 m^3 and a surface area of approx. 9 Ha was constructed in 2006 and only partially filled (60%) prior to the mill operation closing in June 2009.

During operations water within these facilities was pumped back to the concentrator for re-use or was treated and safely discharged to the River Goul. The Galmoy processing plant has been demolished and no tailings have been produced since 2009. Mining operations were ceased in October 2012 and the groundwater has recovered since March 2014. The capping and closure works for the Galmoy TMF and Plant were completed in 2015.

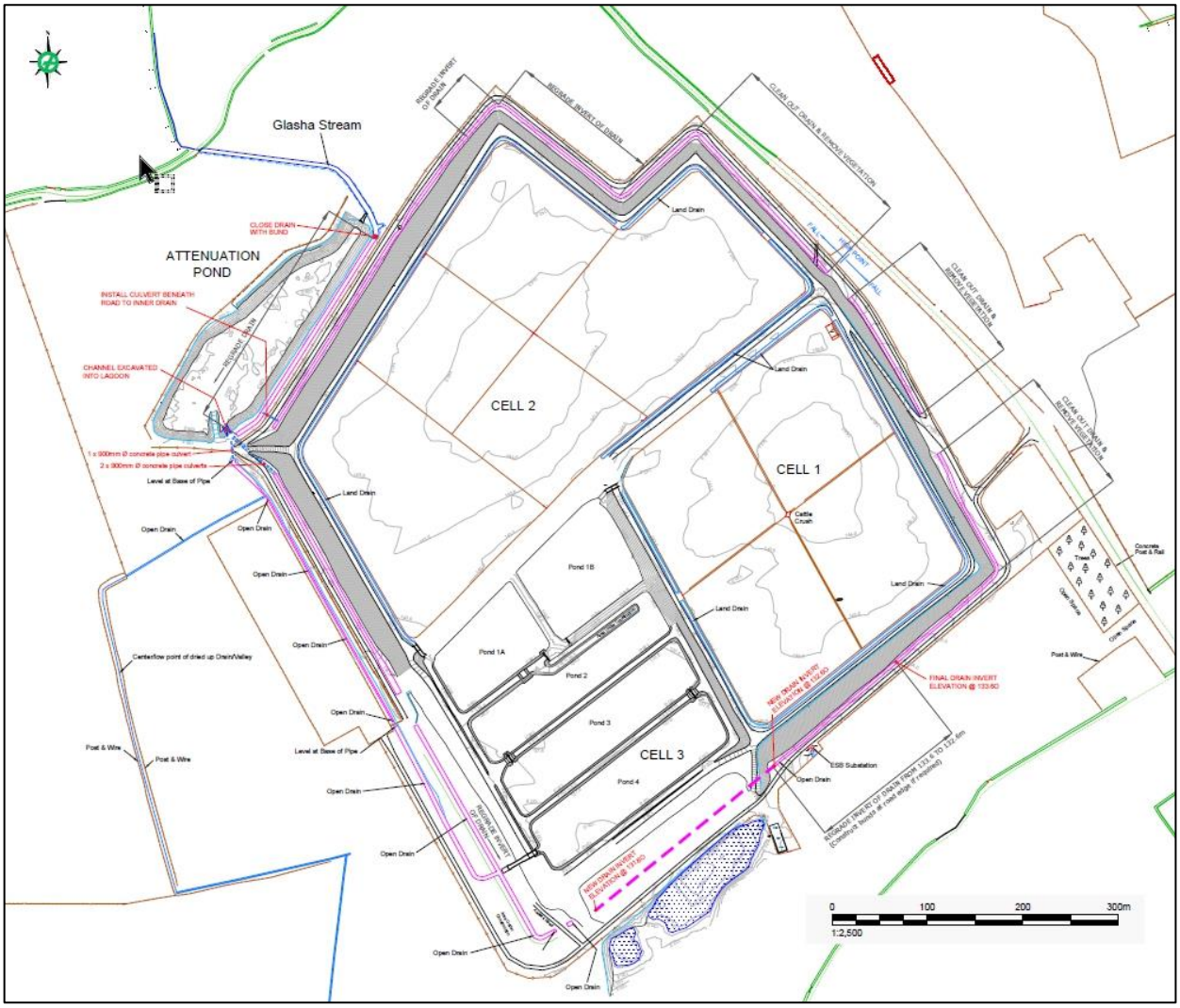


Figure 1: Galmoy TMF, June 2015 (Drawing 01)

Cell 1 and Cell 2 are completely capped and include a perimeter drainage system that decants into Cell 3 via spillways and cascade chutes. Cell 3 was partially filled with tailings, subsequently capped and a wetlands was constructed above the capping to attenuate and treat the surface water from Cells 1 and 2. The Cell 3 wetlands consists of four main pond (Ponds 1 to 4) with the uppermost pond further subdivided into two, namely Pond 1A and 1B with each pond receiving the surface waters from Cells 2 and 1, respectively.

The wetlands retain approximately 300 mm of water over the base and water migrates to the main external spillway located in the southwest corner of Pond 4, by a series of intermediate decant structures constructed in the dividing wall of each cell. A series of intermediate open concrete spillways are also provided on the dividing wall to manage water flow for a design event and to permit access for maintenance and monitoring vehicles. Currently, surface runoff water from Cells 1 and 2 is passively treated in the wetland system and discharged through the spillway and open drain system to the Attenuation Pond and then to the Glasha Stream.

The TMF embankments were constructed as earth fill walls with a central chimney drain to reduce the phreatic level within the embankments. The embankments at Cells 1,2 and 3 were constructed in 2 Stages to a crest elevation of 143.3 mOD. The outer embankments for Cell 3 were subsequently reduced to 139.0 mOD during the wetlands construction. A site location plan and typical dam wall sections are provided on Drawings 01 and 02 in Appendix A.

1.4 Scope of the Works

A site inspection visit was undertaken by Golder on the 26 February 2019 to conduct the following:

- Assessment of the TMF surroundings i.e. lower perimeter road, toe drain, surface water diversion and collection systems;
- Assessment of the TMF side slope condition, stability and integrity;
- Assessment of the TMF cap, inter-cell walls, upper perimeter road and the perimeter drainage system;
- Assessment of active piezometer and borehole installations;
- Check on select piezometer elevations, select borehole elevations and select chimney sump elevations;
- Assessment of the Cell 3 Wetlands i.e. spillways, ponds, water elevations, vegetation, overflow systems and water level control systems;
- Assessment of the Drainage Ditch and Attenuation Pond;
- Assessment of the Outfall Structure and discharge to the Glasha Stream; and
- Discussion of the initial findings with Galmoy.

Golder reviewed the TMF monitoring data supplied by Galmoy for the period 2016 to 2018 and compared with previous data. This review comprised the following monitoring locations understood be active in 2016:

- **Boreholes (9 No.) –** BH3, BH4, BH5, BH6, BH7, BH8, BH10, BH11 and BH13;
- **Piezometers (30 No.**);
  - Cell 1 (Pz4, Pz5, Pz13, Pz14, Pz15, Pz16, Pz17, Pz18, Pz20, Pz24, Pz55 and Pz56);
  - Cell 2 (Pz25, Pz26, Pz27, Pz28, Pz29, Pz30, Pz33, Pz34, Pz36, Pz37, Pz38, Pz57 and Pz58); and
  - Cell 3 (Pz45, Pz48, Pz54, Pz59 and Pz60).
- **Internal Drainage Sumps (2 No.)** – IDS1 and IDS2 (decommissioned);
- **Chimney Drain Sumps (3 No.)** – Sump 3, Sump 4 and Sump 5; and
- **Interceptor Channel Sumps (3 No.)** – IC1, IC2 and IC4 (decommissioned).

2.0 2018 MONITORING DATA

2.1 Monitoring Installations

The geotechnical monitoring system installed for facility consisted of the following:

- Standpipe Piezometers;
- Borehole Monitoring Wells;
- Internal Drainage Sumps;
- Chimney Drain Sumps; and
- Interceptor Channels Sumps

To facilitate the evaluation of the TMF, the dam area has been divided into sectors (A to I) and the original monitoring points installed are tabulated in Table 1 below and are shown on Drawing 03 in Appendix A (Figure 2).

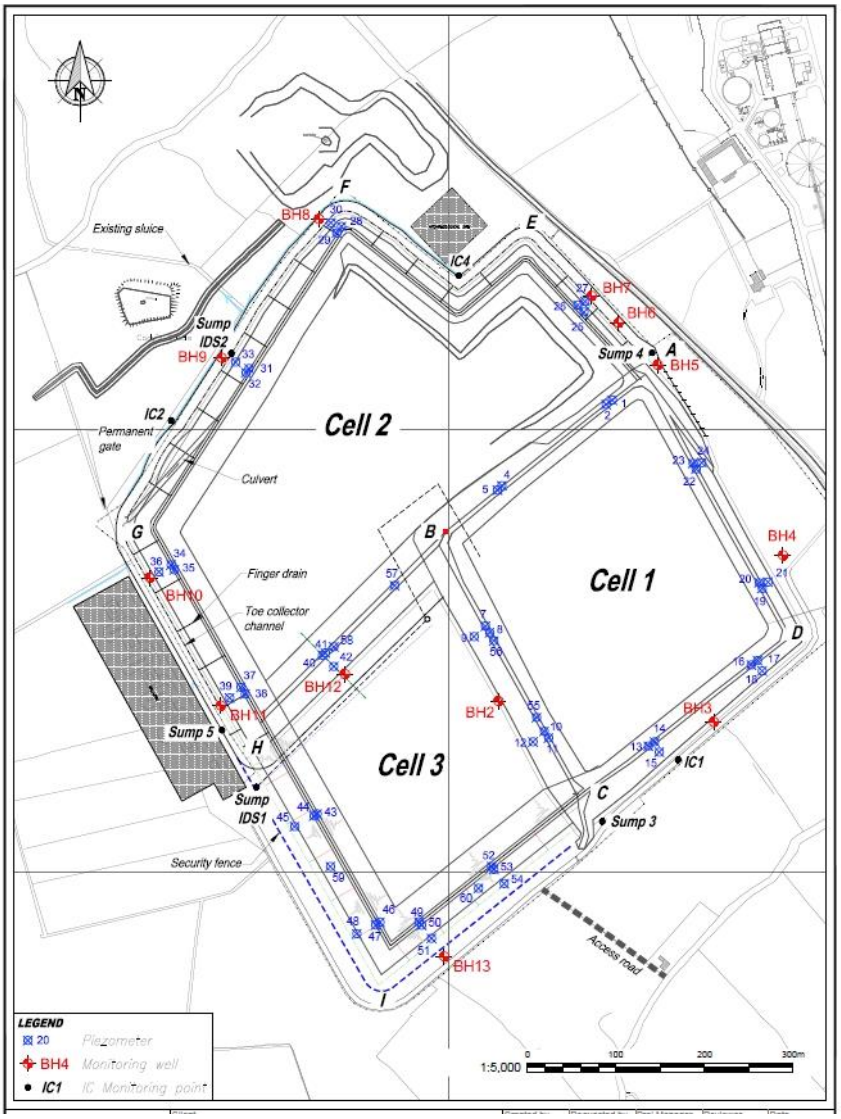


Figure 2: Galmoy TMF Original Monitoring Installations (Drawing 03)

A number of these original monitoring installations are no longer active resulting from the modifications to Cell 3, the closure works, decommissioning, damage or loss.

Table 1: Galmoy TMF Dam Sectors and Original Monitoring Installations

TMF Area	Dam Sector	Piezometers (Pz)	Monitoring Wells	Internal Drainage Sumps	Chimney Drain Sumps	Interceptor Channel Sumps
Cell 1	A to B	1, 2, 3, 4, 5 and 6				
	B to C	7, 8, 9, 10, 11, 12, 55 and 56	BH2			
	C to D	13, 14, 15, 16, 17 and 18	BH3		Sump 3	IC1
	D to A	19, 20, 21, 22, 23 and 24	BH4 and BH5		Sump 4	
Cell 2	A to F	25, 26 and 27	BH6 and BH7			IC4
	F to G	28, 29, 30, 31, 32 and 33	BH8 and BH9	IDS2		IC2
	G to H	34, 35, 36, 37, 38 and 39	BH10 and BH11		Sump 5	
	H to B	40, 41, 42, 57 and 58	BH12	IDS1		
Cell 3	H to I	43, 44, 45, 46, 47, 48 and 59				
	I to C	49, 50, 51, 52, 53, 54, 60	BH13			

Notes:

- **Installations highlighted in orange are decommissioned / removed / missing.**
- **Installations highlighted in blue are blocked.**

Cell 1

1. **Pz 1 and 2 are removed/missing and not monitored. Last readings are from Apr 2011 and Feb 2005, respectively.**
2. **Pz 3 and 6 were located on the northern downstream slope of Cell 1 and were decommissioned during the construction of Cell 2 in 1999. Last readings are from Jan 2000.**
3. **Pz 7, 8, 9, 10, 11 and 12 were decommissioned during the construction of Cell 3 in 2006. Last readings are from Feb 2006. Piezometers 55 and 56 installed as replacements, but 55 is now missing, last reading was from August 2014.**
4. **Pz 13 was noted to be blocked at a shallow during the check in Feb 2019. Last reading in Dec 2018.**
5. **Pz 19 was knocked over and blocked in May-June of 2001, last reading in Apr 2001. Check in Feb 2019 showed it to be blocked at a shallow depth.**
6. **Pz 20 was noted to be blocked during the check in Feb 2019. Last reading in Dec 2018.**
7. **Piezometer 22 was read during the check in Feb 2019. It had not been previously been read since Aug 2003.**
8. **Pz23 was recorded as blocked in December 1999, last reading in Nov 1999, and has not been monitored since. This installation could not be located during the check in Feb 2019.**
9. **BH2 was removed during the construction of Cell 3.**
10. **Interceptor Channel Sump IC1 was removed during the perimeter surface drainage works in 2015.**

Cell 2

11. **Pz 25 was located during the check in Feb 2019 and was recorded as blocked, last reading is from Feb 2018.**

12. **Pz 31 and 32 are removed / missing. Last readings are from Mar 2006 and Aug 2007, respectively.**
13. **Pz 35 was recorded as blocked in October 2001 and is no longer monitored, last reading in Sept 2001. This piezometer was not located during the check in Feb 2001.**
14. **Pz 40, 41 and 42 were decommissioned during the construction of Cell 3 in 2006. Last readings are from Mar 2006. Piezometers 57 and 58 installed as replacements.**
15. **BH6 was not found during the check in Feb 2019. It had previously been read in Nov 2018.**
16. **BH9 was read during the check in Feb 2019. It had not been previously been read in the data supplied.**
17. **BH12 was removed during the construction of Cell 3.**
18. **Interceptor Channel Sumps IC2 and IC4 have been removed during the perimeter surface drainage works in 2015.**
19. **Drainage Sumps IDS1 and IDS2 have been decommissioned by filling with concrete during 2015.**

Cell 3

20. **Pz 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, & 53 were removed during the modification of Cell 3, last readings in Mar and Jun 2013. Piezometers 59 and 60 installed as replacements.**
21. **Pz 54 was removed during the modification of Cell 3, last reading in Aug 2014.**
22. **Pz 57 was read during the check in Feb 2019. It had not been previously been read since Jun 2014.**

Table 2 below summarises the currently active monitoring installations and their locations are shown on Drawing 4 provided in Appendix A (Figure 3). There are 26 no. active Piezometers and 9 no. active Boreholes.

Table 2: Galmoy TMF Dam Sectors and Currently Active Monitoring Installations (26 Feb 2018)

TMF Area	Dam Sector	Piezometers (Pz)	Monitoring Wells	Internal Drainage Sumps	Chimney Drain Sumps	Interceptor Channel Sumps
Cell 1	A to B	4 and 5				
	B to C	56				
	C to D	14, 15, 16, 17 and 18	BH3		Sump 3	
	D to A	21, 22 and 24	BH4 and BH5		Sump 4	
Cell 2	A to F	26 and 27	BH7			
	F to G	28, 29, 30 and 33	BH8 and BH9			
	G to H	34, 36, 37, 38 and 39	BH10 and BH11		Sump 5	
	H to B	57 and 58				
Cell 3	H to I	59				
	I to C	60	BH13			

Notes:

1. **It is recommended that the blockages at Pz 13, 19, 20 and 25 be resolved. Pz13 and Pz20 were most recently read in Dec 2018.**
2. **It is recommended that BH6 be located. It was most recently read in Nov 2018.**
3. **It is recommended that covers and signage are installed at each monitoring installation to alleviate further blockages, loss of instruments and/or confusion of ID numbers.**

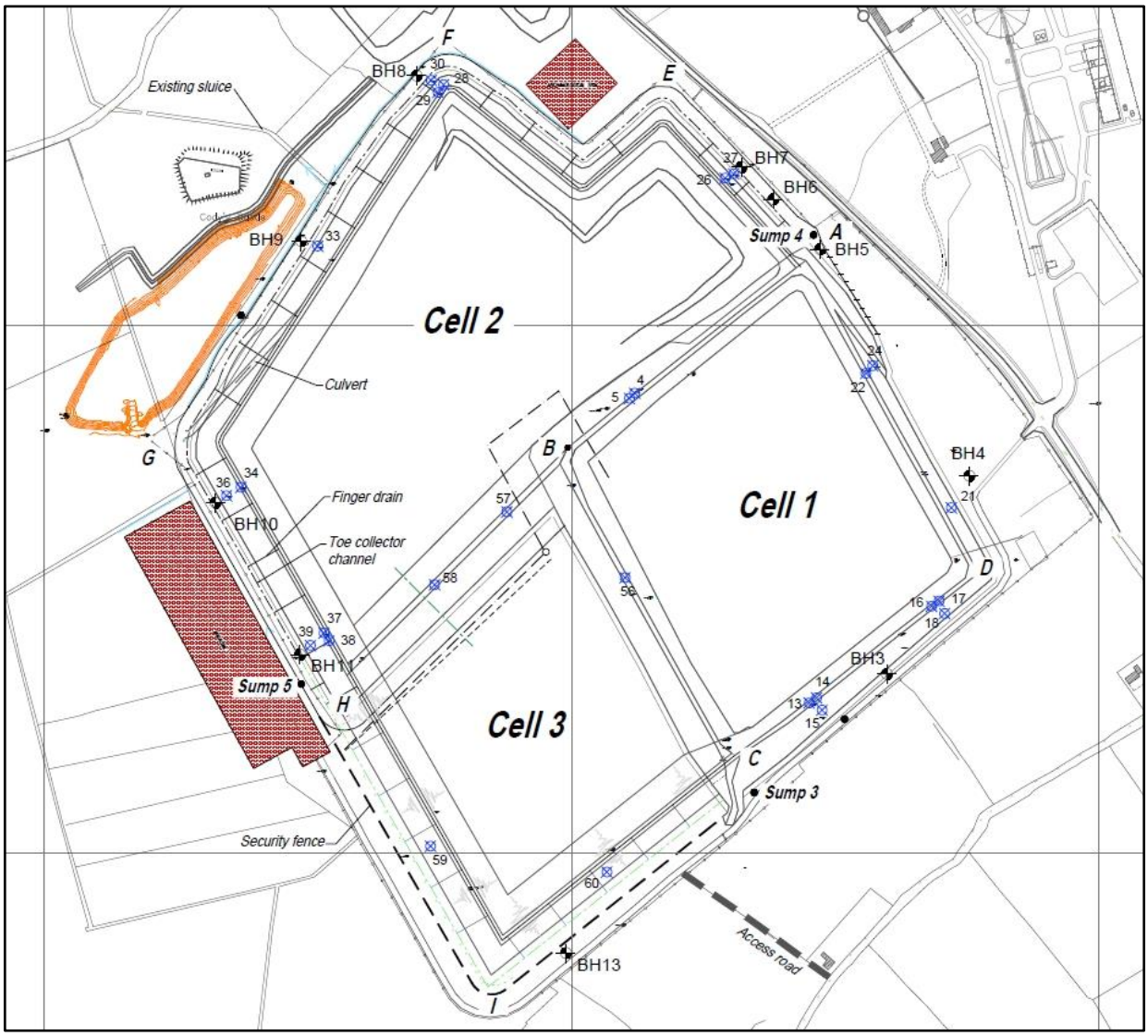


Figure 3: Galmoy TMF Currently Active Monitoring Installations (Drawing 04)

2.2 Instrumentation Data

The installation details for the piezometers and monitoring wells (boreholes) are presented in the 'TMF Environmental Monitoring Report' (Galmoy). The results of the water level readings and water quality readings from the boreholes and piezometers are provided in graphical form in Appendix B and in the Figures below.

2.2.1 Monitoring Well Borehole Data

2.2.1.1 Water Elevation

Dewatering during mining activity had reduced the groundwater level beneath the Cells of the TMF. Prior to mine dewatering, groundwater levels at the site typically varied between 0 m and 5 m BGL (135 mOD to 130mOD). Mine dewatering has ceased, and the borehole monitoring data clearly shows the water level had recovered fully by Q1 of 2014 to between 3 m and 8 m BGL (132 mOD to 127 mOD). The trend in seasonal fluctuation in water levels is apparent. It should be noted that these boreholes were drilled deep into the bedrock and reflect the phreatic surface in the rock. Water at higher elevations were recorded from the piezometers installed in the dam wall and glacial till dam foundations.

Table 3: Borehole Installations

ID	Elev. (mOD)	Depth (m)	Soil Type	ID	Elev. (mOD)	Depth (m)	Soil Type
BH3	133.47	70	Rock	BH8	136.99	70	Rock
BH4	137.09	70	Rock	BH9	-	70	Rock
BH5	136.89	70	Rock	BH10	132.79	70	Rock
BH6	135.72	70	Rock	BH11	132.56	70	Rock
BH7	138.03	70	Rock	BH13	134.50	70	Rock

Figures 4 and 5 below show the depth to water and elevation of water in the boreholes from Jan 2013 to Feb 2019. Readings for all the boreholes except BH6 (unable to be located) were taken during the site visit on 26 Feb 2019.

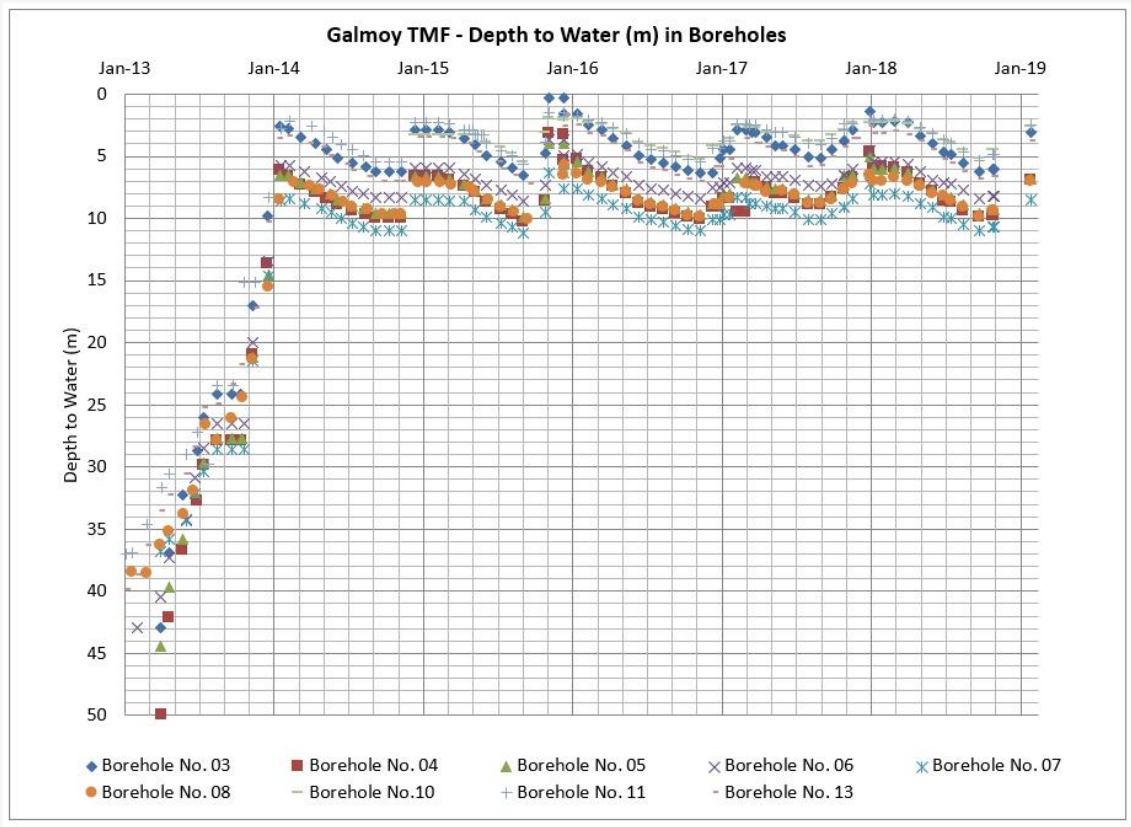


Figure 4: Depth to Water in Boreholes (2013-2018)

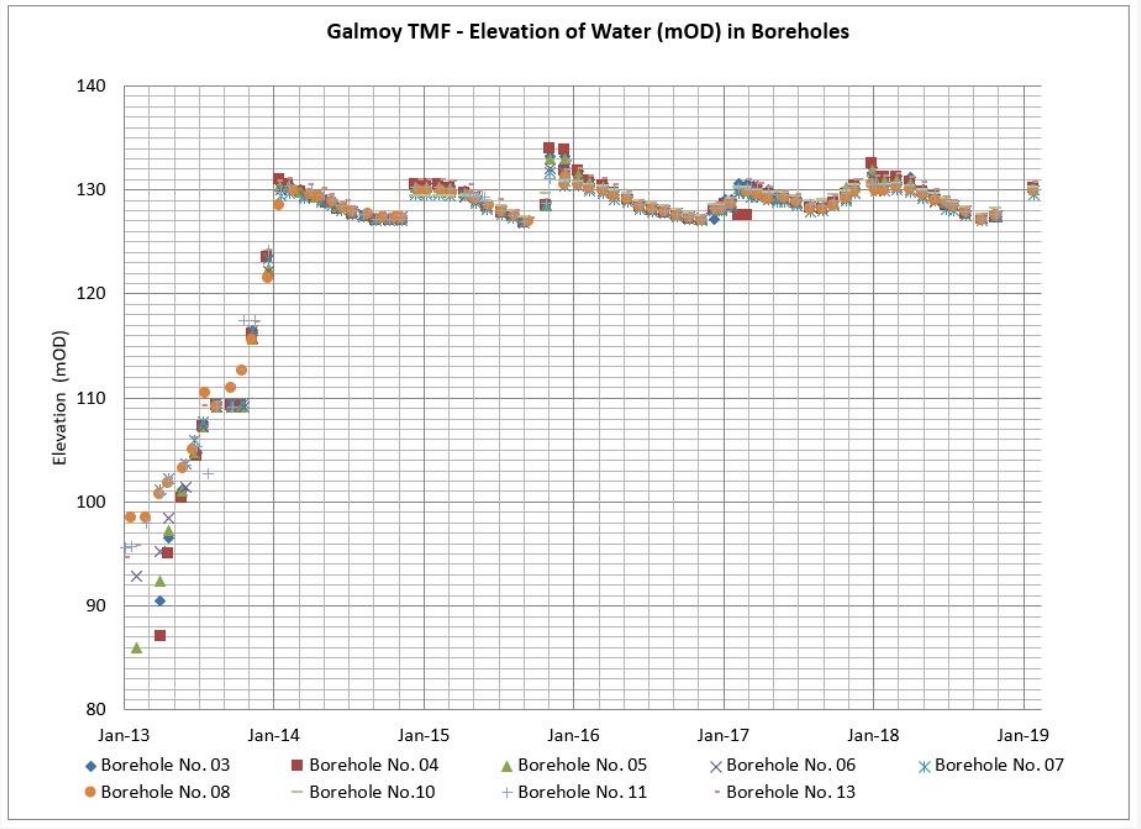


Figure 5: Elevation of Water in Boreholes (2013-2018)

- Borehole depths ranged from 1.5 m to 11.0 m from 2016 to 2018 and followed seasonal fluctuations ranges similar to previous years, since the dewatering ceased, and the groundwater has rebounded.
- BHs 3, 11 and 13, located along the southern downstream toe recorded the lowest depths to groundwater. The cover elevations for these boreholes are also at the lower end of the range of cover elevations for the boreholes present (132.56 to 134.50 mOD).
- BH4 and BH7 recorded the greatest depths to water. The cover elevations for these boreholes are also at the higher end of the range of cover elevations for the boreholes present (137.0 to 138.0 mOD).
- Borehole elevations ranged from 127 mOD to 132 mOD from 2016 to 2018 and followed seasonal fluctuations ranges similar to previous years, since the dewatering ceased, and the groundwater has rebounded.
- Groundwater elevations around the TMF are generally within 1 m of each other when monitored with those boreholes on a line running from SW to NE recording the lower elevations (BH7 and BH11) and those boreholes either side of this line recording the higher elevations i.e. BH8 and BH10 to the north and BH3, BH4 and BH13 to the south.
- BH9 was read on 26 Feb and there appears to no previous recent readings, the depth to water was approximately 2 m. No collar elevation is noted on the previous data or audit reports. It is recommended that the collar elevation is surveyed and that this monitoring well is included for future monitoring.

2.2.1.2 Water Quality

The boreholes are sampled and tested for pH, conductivity and sulphate concentration. The sulphate data from the ongoing monitoring has been used as an indicator of potential seepage paths from the base of the TMF. Sulphate has been chosen for its mobility. No water quality samples were taken during the site visit on 26 Feb.

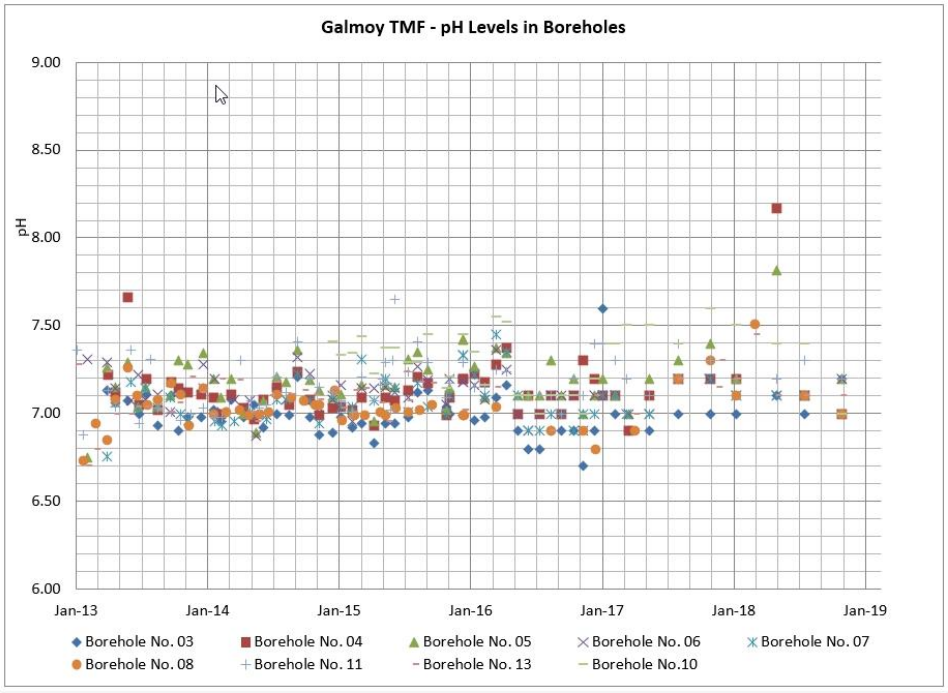


Figure 6: pH Levels in Boreholes (2013-2018)

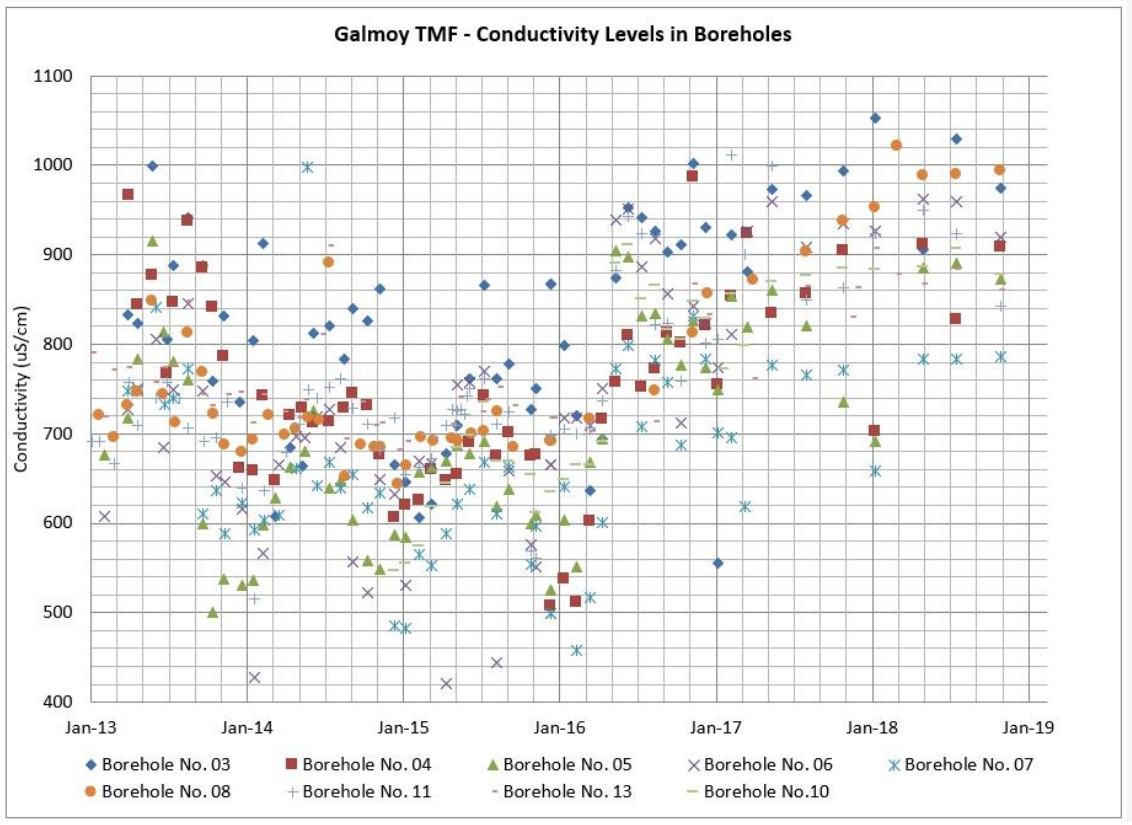


Figure 7: Conductivity Levels in Boreholes (2013-2018)

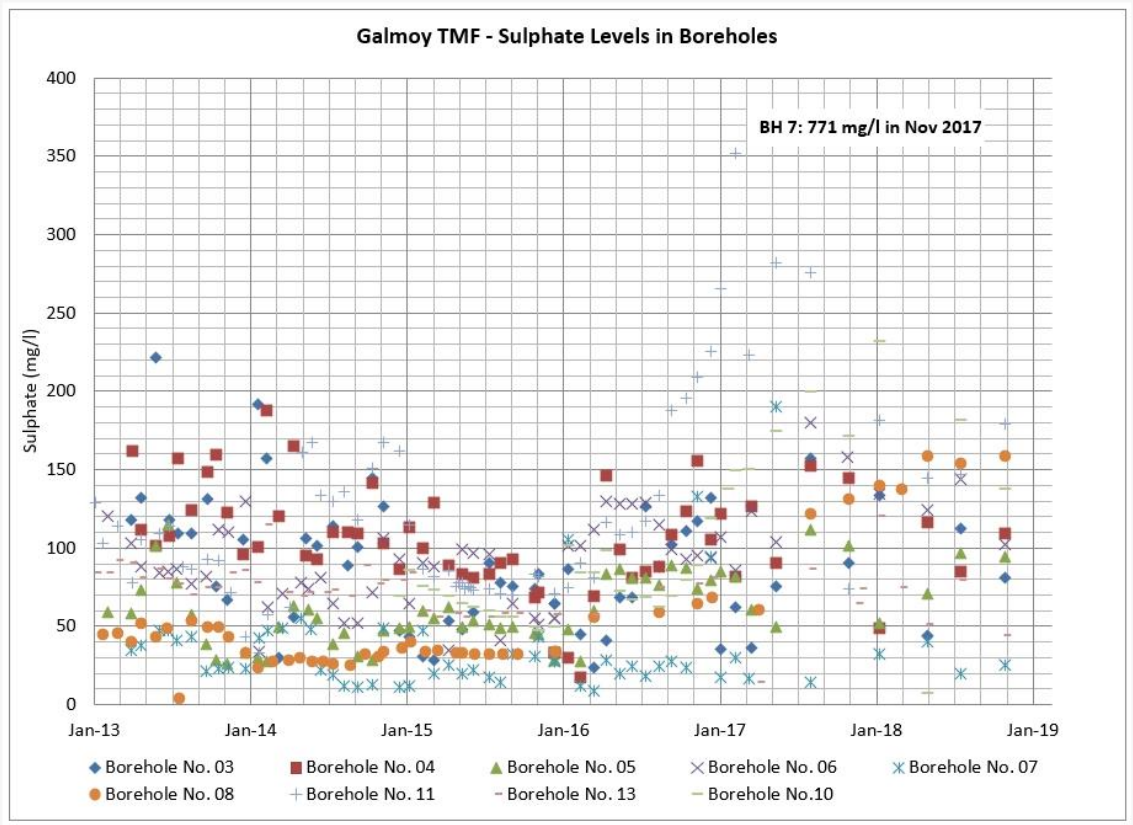


Figure 8: Sulphate Levels in Boreholes (2013-2018)

- The pre-rebound pH values are similar in range to those recorded for post-rebound and generally range from 6.7 to 7.4 pH. Anomalies present in the data only extend slightly outside of this range. Data from 2016 to 2018 is consistent with previous years.
- The range of conductivity values has increased from 2016 to 2018 from a range of 500 to 800 µS/cm pre-2016 to a range of 750 to 1,050 µS/cm. The higher values are being recorded at BH3 and BH8, but all boreholes are showing an increase in the period. This increase can be correlated to the increasing sulphate values.
- The range of sulphate values has increase from 2016 from a range of 20 to 150 mg/l pre-2016 to a range of 20 to 180 mg/l. BH6, BH8, BH11 and BH13 are all showing a noticeable increasing trend. Anomalies present in the data extend to the 200 to 300 mg/l range at BH11 and BH13. The high value noted at BH7 in Nov 2017 is the same value as the conductivity reading recorded and can be discounted from the data set.
- The background level of sulphate concentration for sites with similar geology in Ireland can be as high as 250 mg/l and the sulphate concentration levels recorded are generally below this threshold and the 187.5 mg/l threshold for EC Environmental Objectives (Groundwater) Regulations S.I. No. 9 of 2010

2.2.2 Piezometer Data

2.2.2.1 Water Elevation

Piezometers have been installed through the crest and at approximately midway on the downstream slope of the dam walls to allow measurement of the piezometric surface within the dam walls and of the groundwater table beneath in either the till foundations or the bedrock.

Piezometers into the bedrock are likely to be more impacted by changes in recharge to the fracture system into the bedrock. Piezometers into the till foundations are likely to be more stable, reflecting groundwater perching in till.

Table 4: Active Piezometer Installations

ID	Elev. (mOD)	Depth (m)	Soil Type	ID	Elev. (mOD)	Depth (m)	Soil Type
Pz 4	143.40	9.93	Till	Pz 28	134.35	11.89	Till
Pz 5	143.44	15.96	Rock	Pz 29	143.10	6.69	Dam Wall
Pz 56	143.72	13.53	Rock	Pz 30	138.49	5.35	Till
Pz 13	143.58	10.63	Dam Wall	Pz 33	135.82	6.66	Till
Pz 14	143.50	15.32	Rock	Pz 34	143.39	12.78	Till
Pz 15	136.13	7.43	Till	Pz 36	136.01	6.11	Till
Pz 16	143.34	8.33	Dam Wall	Pz 37	143.02	13.85	Till
Pz 17	143.32	10.63	Dam Wall	Pz 38	143.02	8.82	Dam Wall
Pz 18	137.64	4.73	Till	Pz 39	135.23	6.66	Till
Pz 21	139.75	4.58	Till	Pz 57	143.50	17.82	Rock
Pz 22	143.64	9.83	Till	Pz 58	143.20	18.02	Rock
Pz 24	139.76	6.23	Till	Pz 59	139.82	16.0	Rock
Pz 26	143.25	3.14	Dam Wall	Pz 60	139.71	16.0	Rock
Pz 27	139.70	5.10	Till				

The piezometer data is summarised in Table 5 below and the graphs are provided in Appendix B.

All water levels recorded are satisfactory in terms of dam wall stability.

Table 5: Summary of Piezometer Data

TMF Area	Dam Sector	Comment on Piezometer Data
Cell 1	A to B	**Pz 4** - Trend of slow increase since 2013, rising by approx. 1m from 134 to 135 mOD during this period, prior to dropping back to 134.3 mOD in late 2018. **Pz 5** - Ongoing seasonal fluctuations since 2014, averaging 4m from winter to summer. Follows similar trend and range of elevation to borehole monitoring wells installed into rock around the perimeter of the TMF (127.5 to 131.5 mOD).
	B to C	**Pz 56 –** Ongoing seasonal fluctuations since 2014, averaging 4m to 5m from winter to summer. Follows similar trend and range of elevation to borehole monitoring wells installed into rock around the perimeter of the TMF (128.0 to 133.0 mOD). Large increase in late 2018 to 135.5 mOD prior to dropping back to 134.5 mOD in Feb 2019.
	C to D	**Pz 13** - Blocked in Feb 2019 but was being read up until Dec 2018. This piezo elevation had been reading dry at approx. 133.0 mOD until 2016 and has been showing a slow increase trend since then, rising by 0.5m by Dec 2018. **Pz 14 -** Ongoing seasonal fluctuations since 2014 with a range of approx. 5m. Follows similar trend but slightly higher range of elevation to borehole monitoring wells installed into rock around the perimeter of the TMF (128.5 to 134.5 mOD). **Pz 15** - Ongoing seasonal fluctuations since 2014 with a range of approx. 3.5m between dry at 128.5 mOD (dry) and 132 mOD. **Pz 16 –** Mostly reading stable at 135.0 (dry) to 135.5 mOD , minor seasonal fluctuations **Pz 17 –** Mostly reading stable at 132.7 mOD (dry). **Pz 18 -** Mostly reading stable at 132.9 mOD (dry).
	D to A	**Pz 20 -** Blocked in Feb 2019 but was being read up until Dec 2018. This piezo elevation had been reading stable and dry at 137.2 mOD until end of 2016. **Pz 21 -** Reading stable at 135.2 mOD (dry). **Pz 22 -** First reading since 2003, 133.77 mOD (dry) **Pz 24 -** Reading stable at 133.5 mOD (dry).
Cell 2	A to F	**Pz 25 –** Blocked in Feb 2019 but was being read up until Feb 2018. This piezo elevation had been reading stable at approx. 136.5 mOD, minor fluctuations. **Pz 26 –** Reading stable at 140.1 mOD (dry). **Pz 27 –** Reading stable at 134.6 mOD (dry).
	F to G	**Pz 28 –** Large seasonal fluctuations since 2014, ranges from 122.5 mOD (dry) to 133 mOD. **Pz 29 -** Relatively stable readings at approx. 137.5 mOD, minor fluctuations. **Pz 30 -** Relatively stable readings at approx. 134.5 mOD, minor fluctuations. **Pz 33 –** Increasing trend since 2017. Previously range from 127.7 mOD (dry) to 129 mOD. Since 2017, ranging from 129 mOD to 130 mOD with seasonal fluctuations.
	G to H	**Pz 34 -** Relatively stable readings at approx. 131.5 mOD, minor seasonal fluctuations. **Pz 36 -** Relatively stable readings between dry at 130.0 mOD and 131.0 mOD, minor seasonal fluctuations.

TMF Area	Dam Sector	Comment on Piezometer Data
		Pz 37 - Relatively stable readings between dry at 129.2 mOD and 131.0 mOD, minor seasonal fluctuations. **Pz 38 -** Reading stable at 134.2 mOD (dry). **Pz 39 -** Relatively stable readings between dry at 128.6 mOD and 131.0 mOD, minor seasonal fluctuations.
	H to B	**Pz 57 –** Piezo elevation jumped 5m in Jan 2014 (dry) to 130.5 mOD and hadn't been read since June 2014. Reading in Feb 2019 was 130.9 mOD. **Pz 58 -** Piezo elevation jumped 5m in Jan 2014 (dry) to 130.5 mOD and shows seasonal fluctuations since ranging from 127.5 mOD to 131.5 mOD.
Cell 3	H to I	**Pz 59 -** Ongoing seasonal fluctuations since 2015, averaging 4m to 5m from winter to summer. Follows similar trend and range of elevation to borehole monitoring wells installed into rock around the perimeter of the TMF (127.5 to 132.0 mOD).
	I to C	**Pz 60 -** Ongoing seasonal fluctuations since 2015, averaging 4m to 5m from winter to summer. Follows similar trend and range of elevation to borehole monitoring wells installed into rock around the perimeter of the TMF (127.5 to 132.0 mOD).

2.2.2.2 Water Quality

The piezometers are sampled and tested for sulphate concentration. The sulphate data from the ongoing monitoring has been used as an indicator of potential seepage paths from the base of the TMF. Sulphate has been chosen for its mobility. No water quality samples were taken during the site visit on 26 Feb 2019.

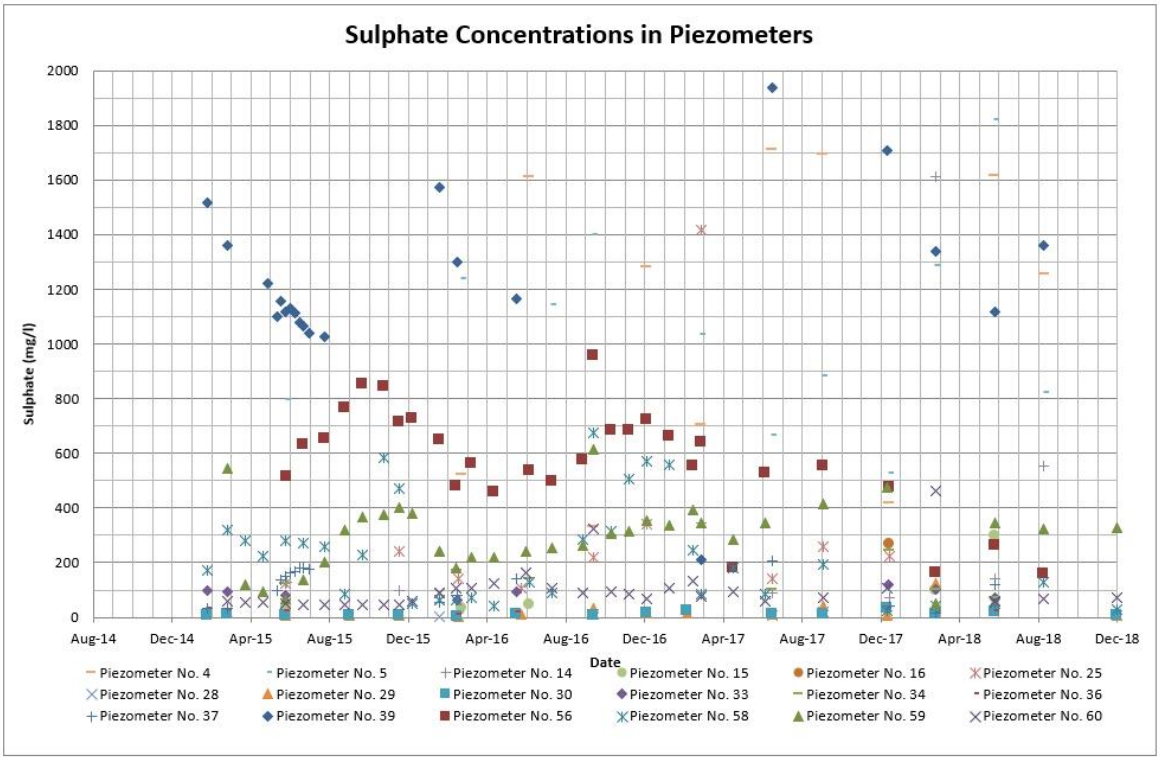


Figure 9: Sulphate Levels in Piezometers (2013-2018)

- The overall data from 2016 to 2018 shows a decreasing trend in sulphate concentration for most piezometers to a range from 0 mg/l to 350 mg/l.
- Pz 4 and Pz 5 located in Sector A – B are installed in the dam crest between Cell 1 and Cell 2, into the dam wall foundations and the underlying bedrock respectively, and report increasing sulphate levels from those recorded prior to 2016. Sulphate concentrations range from 1,200 mg/l to 1,800 mg/l. The high sulphate levels at this location reflect past issues relating to the integrity of the lining at this locality. Seepage will be controlled by the low permeability of the tailings and the level of defect in the lining and will thus be minimal.
- Pz 14 located in Sector C to D has historically reported sulphate concentration levels < 200 mg/l but has reported two significantly higher readings in 2018 at 500 mg/l and 1,600 mg/l. This piezometer is installed into rock and similarly high levels are reported in BH3 located nearby.
- Pz 39 located in Sector G – H is installed in the dam wall foundations and reports the highest levels of sulphate concentration ranges from1,100 mg/l to 1,900 mg/l and is showing an increasing trend from 2016. Pz 39 had previously shown high concentration levels of sulphate but the nearby Pz 37 was showing much lower levels for a nearby installation for a similar depth into the dam wall foundations. This is still the case with Pz 37 reporting sulphate concentrations of approximately 100 mg/l. BH11 is also located nearby and it is showing an increasing trend in concentration, though at a fraction of the concentrations evident in Pz 39. The origin of the seepage at this location is believed to emanate via a defect in the lining of Cell 3 which is being transmitted along the chimney drain and into Sump 5 as well as locally impacting Piezometer 39 though not Pz 37 or BH11. The limit of impact would indicate that seepage is minor.
- Pz 59 located in Sector H – I is installed into the bedrock and is reporting sulphate concentration levels ranging between 300 and 400 mg/l, similar to what has been recorded at this location since installation in 2015. These levels are greater than the background sulphate concentrations recorded by the perimeter boreholes and would suggest a seepage route from the Cell 3 lining at this location.

2.2.3 Internal Drainage Sumps

IDS1 and IDS2 were concrete manhole chambers which served as external sumps for the outlet pipes of the internal drainage systems installed above the cell lining systems. These sumps were pumped dry and decommissioned by filling with concrete in 2015 and are no longer monitored.

- **IDS1** - Sectors A to B and B to H contained the outlet for the internal drainage system above the lining systems of Cell 1 and Cell 3. IDS1 was located on the downstream side of the Cell 3 dam wall at Point H. The original IDS1 sump was located in Cell 2, subsequently moved to Cell 3 and then extended and located outside the footprint of Cell 3, where it was combined with the internal drainage above the lining system of Cell 3. By moving IDS1 from Cell 2 into Cell 3, the connecting pipes crossed the base of the chimney drain system; it is considered that these diversions resulted in a connection between the connecting pipes and the base of the chimney drain. All these structures are located below the lining systems of Cell 2 and Cell 3. However, there was a defect in the lining of Cell 3 and water escaping could find its way into the base of the chimney drain and subsequently into the internal drainage system. Following the filling of Cell 3 with tailings, this issue became resolved as the seepage was minimized.
- **IDS2** - Sector F to G contained the outlet for the internal drainage system above the lining system for Cell 2. IDS2 was located on the downstream side of the Cell 2 dam wall midway between Point F and Point G.

2.2.4 Chimney Drain Sumps

Chimney drains were installed in the centre-line of embankments of the Stage 2 downstream raises. Internal chimney drains are present between Cells 1, 2 and 3. Their purpose is to intercept any seepage through the geomembrane liner system and to ensure the long-term stability of the embankments. The chimney drains comprised a minimum of a 0.5 m wide zone of Type B and Type C material (coarse sand and gravel).

Sumps 3, 4 and 5 were concrete manhole chambers which served as external sumps for the outlet pipes of the chimney drain systems installed in the dam walls. The pipes were installed was to allow for camera inspections of the base of the chimney drain to be carried out. Sumps 3 and 4 were opened during the site visit on 26 Feb 2019. Sump 5 could not be located on the day.

- Sump 3 has a cover elevation of 133.23 mOD and a manhole depth of 2.1m (IL at 131.13 mOD);
- Sump 4 has a cover elevation of 137.97 mOD and a manhole depth of 2.2m (IL at 135.77 mOD); and
- Sump 5 has a cover elevation of 133.22 mOD. No data on depth.



Sump 3



Sump 4

Table 6: Chimney Drain Sumps Water Elevation

Date	Sump 3 Depth (m) / mOD	Sump 4 Depth (m) / mOD	Sump 5 Depth (m) / mOD
Feb 2019	1.62 / 131.61	1.40 / 136.57	-

Table 7: Chimney Drain Sumps Sulphate Concentration Levels

Date	Sulphate Levels (mg/l)		
	Sump 3	Sump 4	Sump 5
2016	45 to 174	75 to 168	411 to 2,543
2017	46 to 135	12 to 203	1,392 to 4,546
2018	20 to 89	88 to 162	3,465 to 5,242

- **Sump 4 and Sump 5 -** The base of the chimney drain on the dividing wall of Cell 1 and Cell 2 and on the dividing wall of Cell 2 and 3 are connected via a pipe to manholes at either end i.e. Sump 4 at Point A and Sump 5 at Point H located on the downstream toe of the dam walls. Sump 4 at Point A is several metres higher than Sump 5 at point H.

  Following the filling of Cell 3 with water, water was observed flowing into Sump 5, which was then pumped back to Cell 3. The flow rate continued to reduce over the years, and by 2013 flow had ceased into Sump 5. As discussed in Section 2.2.3, it is considered that the diversion of the outlet of the internal drainage system has resulted in a connection between the connector pipes and the base of the chimney drain. However, there was a defect in the lining of Cell 3 and water escaping could find its way into the base of the chimney drain between the dividing wall of Cell 2 and Cell 3 and discharge into Sump 5. Inspection of Sump 5 in 2016 indicated no flow of water into the manhole but the standing water level was higher than the pipe outlet level which suggested that the head was sufficient to force water to discharge from elsewhere beneath the dam wall. Sump 5 was purged during 2016 and flow returned to a similar pre-pumping water level. Samples taken reported high sulphate concentration which would be consistent with tailings water from either the internal drainage system or the defect in Cell 3.

- **Sump 3 -** The base of the chimney drain on the dividing wall between Cell 1 and Cell 3 has an external outlet on the downstream toe of the Cell 3 dam wall at Point C. The pipe was installed was to allow for camera inspection of the base of the chimney drain to be carried out.

- The water levels in Sumps 3 and 4 are lower than the outlet pipes entering the manhole chambers, which would suggest that there is minimal if any on-going seepage issues. Sump 5 should be located, have a sign installed, and be included in the monitoring plan for both elevation and water quality. Sumps 3 and 4 should also be monitored for water elevation.

2.2.5 Interceptor Channel Sumps

Finger drains was installed at approximately 50 m intervals around the perimeter of the facility connecting to the base of the chimney drains and fed into the perimeter interceptor channel at the downstream toe of the dam walls, to allow collection of seepage, sampling and return to the tailings pond, as necessary. A number of sumps were constructed in the perimeter interceptor channel for this purpose; IC1, IC2 and IC4, and concrete manhole chambers installed.

These manhole chambers were removed, and the sumps decommissioned during the re-grading of the perimeter interceptor channel in 2015.

2.3 Monitoring Dates

The instruments have been monitored and/or sampled monthly or quarterly since installation in accordance with agreements with the EPA in regard to a reduced monitoring programme.

The Annual Review Consultant shall be notified as soon as practicable of any readings above thresholds following the taking of the in-field readings or during the data processing, depending on the nature of the data recorded.

The current piezometric levels are unlikely to have any significant impact on the stability compared to previous years and this is addressed in the stability section. The majority of the Piezometers and Boreholes appear to be functioning as expected and the short-term anomalies can be correlated to seasonal fluctuations.

3.0 SITE INSPECTION

The site inspection was undertaken by Roger White, Brian Keenan and Gerd Janssens of Golder. A summary of the visual inspection and comments related to specific areas are presented below for each of the dam wall sectors.

3.1 General

The TMF site is clean, tidy and the slopes well vegetated. The security of the facility is satisfactory and the electronic gate to the site is closed at all times.

The doming of Cells 1 and 2 prevents the accumulation of water on the surface, and therefore the potential for damage from over topping of the dam walls will be eliminated or at least minimised. The slope of the dome is designed to be approximately 1%, which has resulted in isolated ponding on the surface as a result of hollows forming due to differential settlements of the underlying tailings and the cap itself. Isolated zones of ponding were evident on the caps during the site visit. This is not expected to have an impact on the structural integrity of the facility. Cell 3 restoration as a wetland appears to be thriving.

The vegetation growth on the downstream dam walls is good, although the grass should be continued maintained and managed. Gorse has been allowed to proliferate at a number of Sectors on the downstream slopes of the dam walls. It is evident that some efforts have been made to eradicate the gorse by spraying but the dead plants remain on the slopes. The gorse should be thinned out to an extent such that only isolated shrubs are present. This allows any defects in the wall to be readily observed. A program of removing the large shrubs and trees from the walls of the TMF was completed in February 2015 based on previous recommendations and as part of the closure works. It is evident that horses have been grazing on the cap and side-slopes of the facility. Although, this grazing is useful to keep the vegetation maintained, it is leading to localized sloughing on the slopes as the animals attempt to gain footing.

The crest of the HDPE liner was observed to be exposed and marginally damaged in locations. This should be covered with drainage pebble / sand to limit further damage.

3.2 Dam Sector A to B

This Sector of the dam wall is the common dividing wall between Cells 1 and 2. The lining in this section of the dam wall, close to point B, has been slightly damaged in the past and repaired some time ago. Tailings were placed against the damaged area to minimise any potential seepage. High sulphate levels are still recorded at Pz 4 and Pz 5 in this location.

The base of the chimney drains on the dividing wall of Cells 1 and Cells 2 and on the dividing wall of Cells 2 and 3 are connected via a pipe to manholes at either end i.e. Sump 4 at point A and Sump 5 at point H on the downstream toe of the dam walls. Sulphate levels recorded in Sump 4 are relatively low historically and in recent years (see Table 7).

The internal crest access road was in good repair and the upper perimeter drainage system was intact and covered over with drainage stone. Localized ponding was evident on the cap of Cell 1.



Internal crest road A to B



Ponding on Cap in Cell 1

3.3 Dam Sector B to C

This wall is now the dividing wall between Cells 1 and 3. This Sector has an internal collector drain with no finger drain outlets. The collector drain is at the base of the central chimney drain and discharges into Sump 3. Pz 56 is located in this Sector and records similarly low sulphate concentration levels to Sump 3, generally below 200 mg/l.

The internal crest access road was in good repair and the upper perimeter drainage system was intact and covered over with drainage stone. Localized ponding was evident on the cap of Cell 1.



Internal crest road B to C



Cell 1 Cap

3.4 Dam Sector C to D

The dam wall along this Sector is well vegetated with no signs of distress or surface sloughing. Gorse bushes are beginning to flourish on the slopes again. This sector has a series of finger drains connected to the collector drain at the base of the chimney drain. All the finger drains were dry, and no seepage was evident.



Downstream Slope C to D



PIC at D to C

Pz 13 to Pz 18 are located in this Sector and water quality data is reported from Pz 14, 15 and 16. Pz 14 is installed into rock, although at a higher elevation than BH3 located nearby, and has recently report elevated levels of sulphate at 500 mg/l to 1,600 mg/l. Sulphate levels at BH3 have been generally less than < 150 mg/l/. Sulphate concentration levels at Pz 15 and 16 have historically been low at < 100 mg/l but readings reported since 2017 show an increase towards 300 mg/l.

3.5 Dam Sector D to A

The wall along this Sector of the dam is well vegetated with no signs of distress or surface sloughing. Gorse bushes had been sprayed / died off on the downstream slope and require removal. This sector has a series of finger drains connected to the collector drain at the base of the chimney drain. All the finger drains were dry, and no seepage was evident.

Pz 19 to Pz 24 are located in this Sector and no water quality is reported for these piezometers. Only Pz 21, 22 and 24 were operational during the site visit. Pz 19 and Pz 20 were blocked at shallow depths and should be restored, in particular Pz 20 as it had been operational in Dec 2018.

BH4 and BH5 are located in this Sector and both report low levels of sulphate concentration at < 150 mg/l.



Point D – looking North-West



Downstream Slope D to A

3.6 Dam Sector A to F

The dam wall along this Sector is well vegetated with no signs of distress or surface sloughing. This sector has a series of finger drains connected to the collector drain at the base of the chimney drain. All the finger drains were dry, and no seepage was evident.

Pz 25 to Pz 27 are located in this Sector and water quality is reported at Pz 25, but this piezometer was blocked on the day of the site visit and has not been operational since Feb 2018. This piezometer should be restored for the 2019 monitoring. Sulphate concentration levels at Pz 25 are typically in the 200 mg/l to 350 mg/l range.

BH7 is located in this Sector reports low levels of sulphate concentration at < 40 mg/l for 2016 to 2018, similar to historic values.



Ramp at Downstream Slope at A to E



Downstream Slope at A to E



Downstream Slope at A to E



Downstream Slope at E to IC4

3.7 Dam Sector F to G

The dam wall along this Sector of the dam is well vegetated with no signs of distress or surface sloughing. Several isolated patches of gorse are present and should be removed. This sector has a series of finger drains connected to the collector drain at the base of the chimney drain. All the finger drains were dry, and no seepage was evident.

Pz 28 to Pz 33 are located in this Sector, of which Pz 31 and 32 are no longer active, and water quality is reported for the four active piezometers (Pz 28, Pz 29, Pz 30 and Pz 33). Sulphate concentration levels for 2016 to 2018 are low (generally less than 30 mg/l) with the exception of Pz29 and Pz 33 reporting values of approx. 100 mg/l.

BH9 is located in this Sector and has not been monitored or sampled in recent years. This borehole should continue to be read and sampled going forward.



Point F to Point G



Point F to Point G

3.8 Dam Sector G to H

This Sector of the dam wall had been noted to be heavily vegetated with gorse in 2016 and it is evident that the area has been sprayed and the plants are dying back. The dead vegetation should be removed from the slope. This sector has a series of finger drains connected to the collector drain at the base of the chimney drain. All the finger drains were dry, and no seepage was evident.

Pz 34 to Pz 39 are located in this Sector, of which only Pz 35 is no longer active, and water quality is reported at four piezometers (Pz 34, Pz 36, Pz 37 and Pz 39). Sulphate concentration levels for 2016 to 2018 are below 200 mg/l for Pz 34, 36 and 37 and historically have been similar. Pz 39 has reported high sulphate concentration values historically (1,000 mg/l to 1,600 mg/l) and they appear have increased slightly in 2017 prior to dropping back to previous levels in 2018.

BH10 and BH10 are located in this Sector and both reported elevated sulphate concentration levels in 2017 (250 mg/l to 350 mg/l) which dropped back to historic levels in 2018 (100 mg/l to 150 mg/l).



Sector G to H



Gorse removed from Slope

3.9 Dam Sector H to B

This sector of the dam wall forms the internal dividing wall between Cell 2 and Cell 3. The base of the chimney drains on the dividing wall of Cells 1 and Cells 2 and on the dividing wall of Cells 2 and 3 are connected via a pipe to manholes at either end i.e. Sump 4 at point A and Sump 5 at point H on the downstream toe of the dam walls. Sulphate levels recorded in Sump 5 are relatively high historically and in recent years (see Table 7).

Pz 57 and Pz 58 are located in this Sector and Pz 58 is monitored for water quality. Sulphate concentration values have shown a reduction since 2016 with the range or 400 mg/l to 600 mg/l reducing to below 200 mg/l.

The internal crest access road was in good repair and the upper perimeter drainage system was intact and generally covered over with drainage stone. There were localized sections where the drainage pipes were exposed on surface and appear to have risen.



Internal Crest at H to B



Upper Perimeter Drainage System at H to B

3.10 Dam Sector H to I

This sector of the dam wall has been modified by the construction of the wetlands on Cell 3. The original dam height has been reduced to an elevation of approximately 139.7 mOD.

The hydroseeding vegetation has not been successful on the upstream or downstream slopes and a better vegetation cover is required to alleviate erosion. No impact of constructing the wetlands is apparent on the external dam walls.

The original piezometers for the dam wall have been replaced with a single piezometer, Pz 59 which is installed to rock in 2015. Pz 59 is monitored for water quality and has shown elevated levels of sulphate concentration since installation at 200 mg/l to 400 mg/l. Similar levels were recorded from 2016 to 2018.



Downstream Slope at H to I



Downstream Slope at H to I

3.11 Dam Sector I to C

This sector of the dam wall has been modified by the construction of the wetlands on Cell 3. The original dam height has been reduced to an elevation of approximately 139.7 mOD.

The hydroseeding vegetation has not been successful on the upstream or downstream slopes and a better vegetation cover is required to alleviate erosion. No impact of constructing the wetlands is apparent on the external dam walls.

The original piezometers for the dam wall have been replaced with a single piezometer, Pz 60 which is installed to rock in 2015. Pz 59 is monitored for water quality and has shown low levels of sulphate concentration since installation at < 100 mg/l. Similar levels were recorded from 2016 to 2018.



Downstream Slope at I to C



Downstream Slope at I to C

3.12 Cell 3 Wetlands

Cell 3 was partially filled with tailings, subsequently capped and a wetlands was constructed above the capping to attenuate and treat the surface water from Cells 1 and 2. The Cell 3 wetlands consists of four main pond (Ponds 1 to 4) with the uppermost pond further subdivided into two, namely Pond 1A and 1B with each pond receiving the surface waters from Cells 2 and 1, respectively.

The wetlands retain approximately 300 mm of water over the base and water migrates to the main external spillway located in the southwest corner of Pond 4, by a series of intermediate decant structures constructed in the dividing wall of each cell. A series of intermediate open concrete spillways are also provided on the dividing wall to manage water flow for a design event and to permit plant traffic for maintenance and monitoring. Currently, surface runoff water from Cells 1 and 2 is passively treated in the wetland system and discharged through the spillway and open drain system to the Attenuation Pond and then to the Glasha Stream.

The wetlands vegetation is flourishing and the spillways, water control and overflow systems between the ponds are operating appropriately. There are no signs of erosion of the pond wall or the channels within the wetlands.



Cell 3 Wetland



Cell 3 Wetland



Spillway 3 – Discharge to Open Drain



Flow Control between Wetland Ponds

3.13 Surface Water Drainage

The surface water drainage system has an upper perimeter system for Cells 1 and 2, which decants into Cell 3 via spillways and a lower perimeter system (perimeter interceptor channel) which discharges into the Attenuation Pond.

Upper Perimeter System – surface water from the cap, and sub-surface infiltration and migrations are collected in the perimeter drainage systems of Cells 1 and 2 and directed into Cell 3 by spillways. The perimeter drainage system consists of two smooth HDPE pipes at a gradient of 0.01% and with an internal diameter of 500 mm, encased in drainage stone and positioned on the upstream side of the lining system. The pipes drain approximately 50% of each cell area so that four pipes deliver water to each spillway. The system is design for a 1 in 150-year rainfall event of 4 hrs duration. As noted above in Section 3.9, there were localized sections where the drainage pipes were exposed on surface and appear to have risen.

- **Lower Perimeter System** – surface water from the downstream slope of the dam walls, seepages from the finger drains and inflows from other sources (ramps, lower perimeter road etc.) are captured in the perimeter interceptor channel (PIC) at the downstream toe of the dam walls. The base of the channel is approximately 1 m and it varies in depth around the facility, to maintain falls, but generally has a depth of approximately 1 m to 1.5 m. The PIC has a high point slightly north-west of Point A and grades clockwise and anti-clockwise around the facility to Point G at the western corner of the facility, where the flows enter the Attenuation Pond. The west wall of the facility (Sectors G to H and H to I) has an outer open drain which collects the flows from the PICs in these sectors and transfers them to the Attenuation Pond.

The 2015 Annual Review (Golder 2016) noted that the recovery of the groundwater had highlighted some deficiencies in the lower perimeter drainage system in the south east sector of Cell 3, in particular at a low spot situated at the location of the original valley floor near Sump 3. Significant perimeter drainage works were undertaken during 2015 to re-grade and connect the perimeter drainage system at the toe of the dam walls to the Attenuation Pond, and further works were completed in 2016. No flooding was observed during the site inspection for the 2016 Annual Review in February 2017 and similarly no flooding was noted during the recent site inspection in February 2018 or signs of impacts of previous flooding. This absence may reflect the lower rainfall monitored during the winters of 2016/2017 and 2018/2019 compared to the winter of 2015/2016. Flooding, should it occur, will have no impact on the dam wall along this sector and would spill along the channel before making contact with the downstream toe of the dam wall.





Overgrown Outer Open Drain at F to G

The following items were noted in regard to the lower perimeter system during site inspection visit:

- The PIC is generally in good order and appears to be operating appropriately. Some litter was observed and should be removed to prevent accumulation which can limit flow.
- An existing inflow (Rathpatrick Stream) is connected to outer open drain along the west wall of the facility (Sectors G to H and H to I). This connection allows drainage from the fields to the west of the TMF and transfers these flows along with the TMF flows to the Attenuation Pond. This inflow poses a risk of outside sources negatively impacting on the discharge waters for the TMF.
- The outer open drain at Sectors G to H and H to I is in good order and appears to be operating appropriately.
- The outer open drain at Sectors F to G requires clean-out.

3.14 Attenuation Pond

The Attenuation Pond receives all the surface water discharging from the TMF (both upper and lower drainage systems) and dependent on elevation in the Pond, they are subsequently discharged to the Glasha Stream via the Outfall Structure.

The Attenuation Pond and Outfall Structure are operating according and appear to be in good order.





Attenuation Pond Outfall to Glasha Stream

4.0 SLOPE STABILTY (2013)

The stability of the external dams' walls was assessed in (Golder 2013) using the limit equilibrium software Slope/W and using the Morgenstern-Price method which considers both force and moment equilibrium. The analyses considered the stability of the dam wall at its elevation in 2013 of 143 mOD for Cell 1 and 2 and its final elevation of 139.0 mOD for Cell 3. A pseudo-static analysis was also carried out in both cases for a peak ground acceleration (PGA) of 0.06 g. An elevated phreatic level was used in all four models. The results of the stability assessment are tabulated below, and the figures are presented in Appendix D.

Table 8: Galmoy TMF Dam Walls Stability Assessment (2013)

Dam Wall Crest Elevation	Operating Conditions Factor of Safety (FoS)	Pseudo-Static Factor of Safety (FoS) 0.06 g
143 mOD	1.58	1.37
139 mOD	1.56	1.35

The industry standard factors of safety (FoS) for normal operating conditions are 1.5 and for during the design seismic event are 1.0 (pseudo-static) The stability assessment has shown that the external dam walls meets these requirements. The removal of a section of the chimney drain of Cell 3 in lowering the embankment to the final elevation has not had a significant impact on its stability.

5.0 CONCLUSIONS AND RECOMENDATIONS

Based on the visual inspection and an evaluation of the monitoring data, Cell 1, Cell 2 and Cell 3 are performing in accordance with the design. The dam walls are in excellent condition and the piezometers installed in the dam wall are stable and/or dry for much of the year as can be seen from the readings. The piezometers installed into the foundations of the dam wall indicate that the phreatic surface is generally below foundation level and the majority of results are between 128 mOD and 132 mOD. Where the dam wall is constructed on higher ground, as seen on the north east walls of Cells 1 and 2, water levels above 132 m were observed but generally still in the dam foundations. Many of the piezometer readings are impacted by the seasons.

The water levels in the monitoring boreholes show seasonal variation as indicated below. Levels for 2016 to 2018 are in the general range from 128 mOD and 133 mOD. The winter of 2015/2016 was very wet and showed a short-term range from 130 mOD to 134 mOD.

Recommendations have been noted throughout the text and are summarized briefly below:

- Restore the following piezometers: Pz 13, Pz 19, Pz 20 and Pz 25.
- Locate and continue to monitor BH6.
- Include Pz 22, Pz 57 and BH9 in the monitoring plan (water elevation and water quality).
- Locate and continue to monitor Sump 5.
- Monitor water elevation data in Sump 3, Sump 4 and Sump 5.
- Progress with the removal of large sections of live gorse and gorse that has died back or has been previously cut from the downstream side slopes.
- Discontinue allowing horses to graze on the downstream side slopes of the dam walls. Lighter animal such as goats or sheep would be appropriate.
- The crest of the HDPE liner was observed to be exposed and marginally damaged in locations. This should be covered with drainage pebble / sand to limit further damage.
- Encourage vegetation growth on the upstream and downstream slopes of Cell 3 (wetlands).
- The Annual Review Consultant shall be notified as soon as practicable of any readings above thresholds following the taking of the in-field readings or during the data processing, depending on the nature of the data recorded.
- It is understood that Galmoy are currently reviewing the surface water drainage system around the TMF to improve the discharge water quality.

6.0 REFERENCES

Galmoy, TMF Environmental Monitoring Report

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Signature Page

Golder Associates Ireland Limited





Brian Keenan
Project Manager, Associate

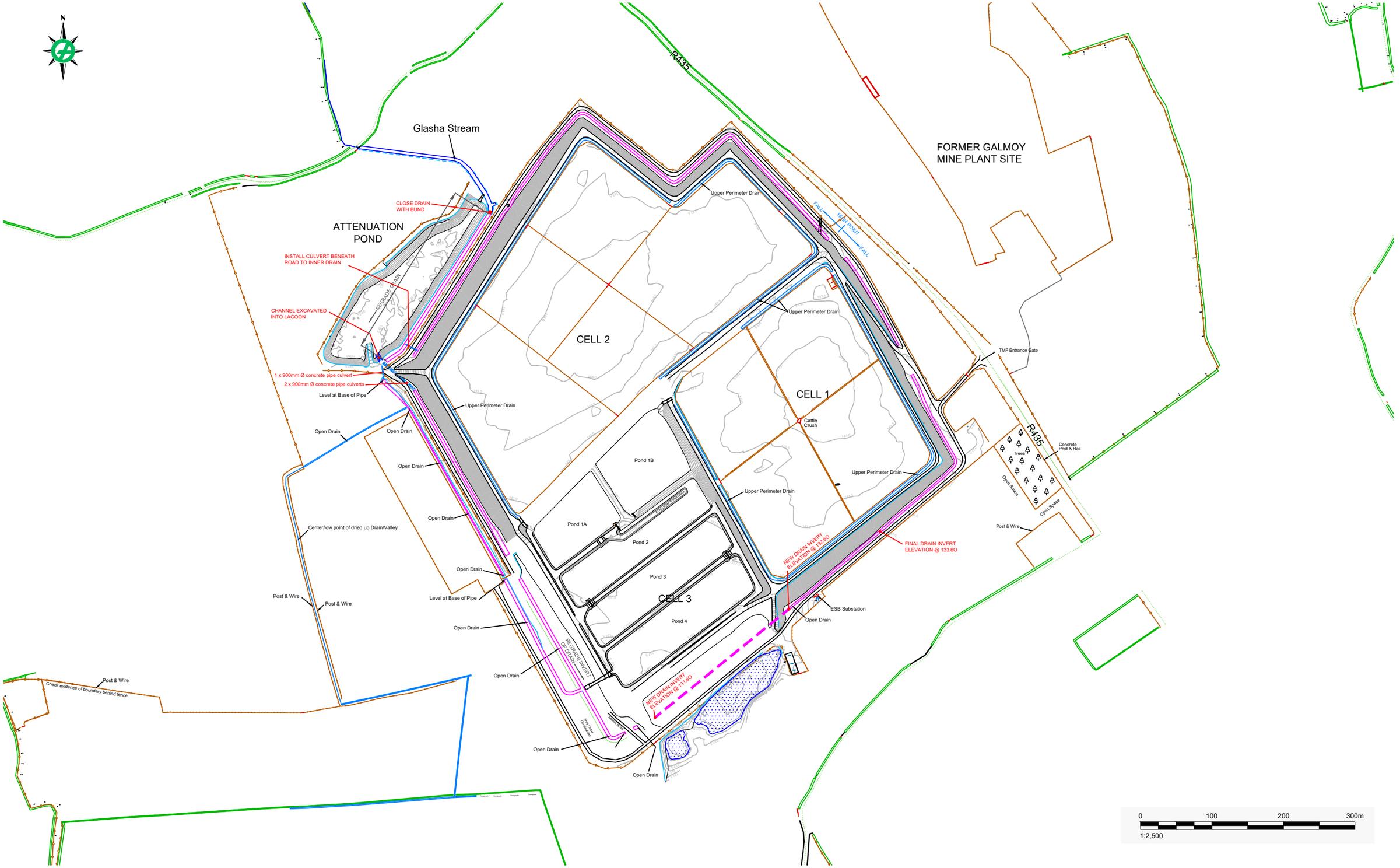
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APPENDIX A

Drawings



CLIENT

GALMOY MINES LTD.

CONSULTANT

GOLDER

YYYY-MM-DD	2019-Mar-20
PREPARED	POB
DESIGN	POB
REVIEW	BK
APPROVED	BK

PROJECT

GALMOY MINES TMF ANNUAL REVIEW 2018

TITLE

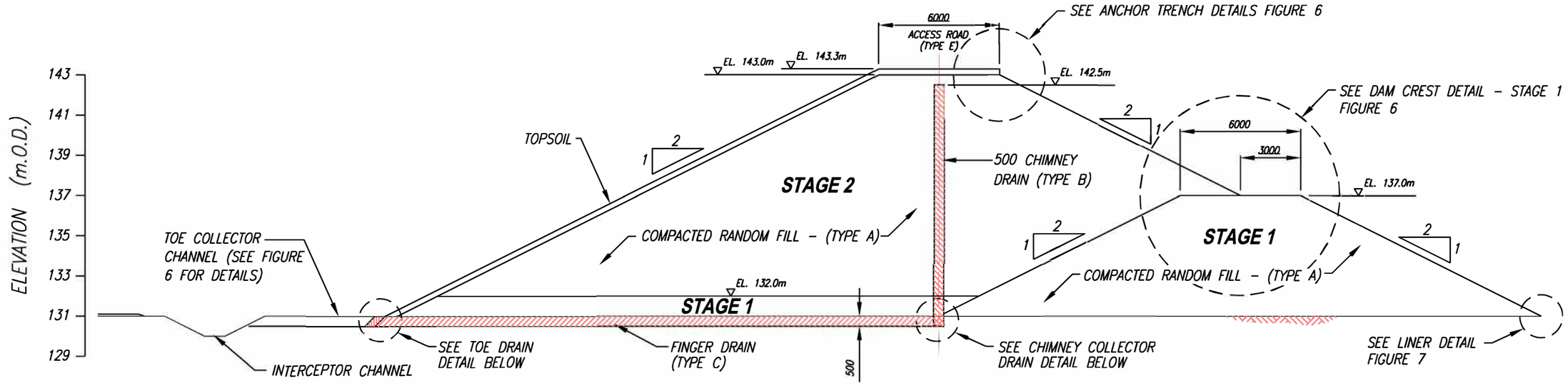
GALMOY MINES TMF LOCATION PLAN (JUNE 2015)

PROJECT No.	DRAWING No.	Rev.	SCALE
19118326	01	A	1:2,500 A1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ISO A1

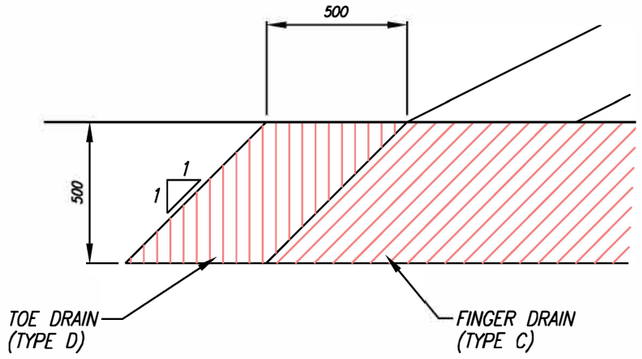
25 mm

Path: C:\Users\bkeenan\Documents\Golder\Galmoy\2018 Audit_Mar 2019\Report\Appendix A - Drawings\ | File Name: 19118326_Galmoy TMF AsBuilt_19 March 2019.dwg



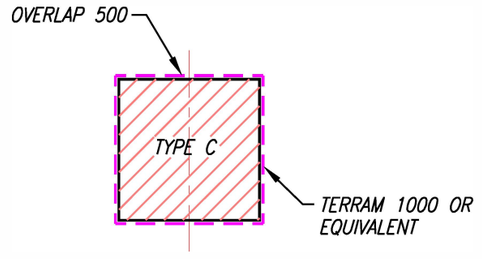
TYPICAL SECTION

SCALE: 1 : 200



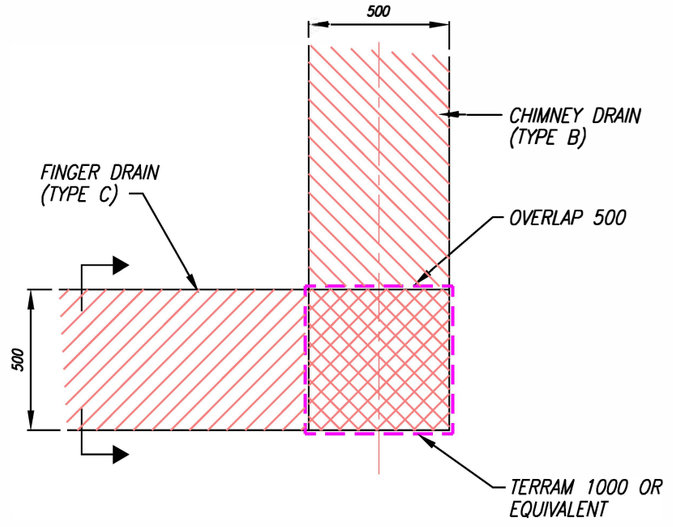
TOE DRAIN DETAIL

SCALE: 1 : 20



SECTION THROUGH FINGER DRAIN

SCALE: 1 : 20



CHIMNEY COLLECTOR DRAIN DETAIL

SCALE: 1 : 20

NOTE

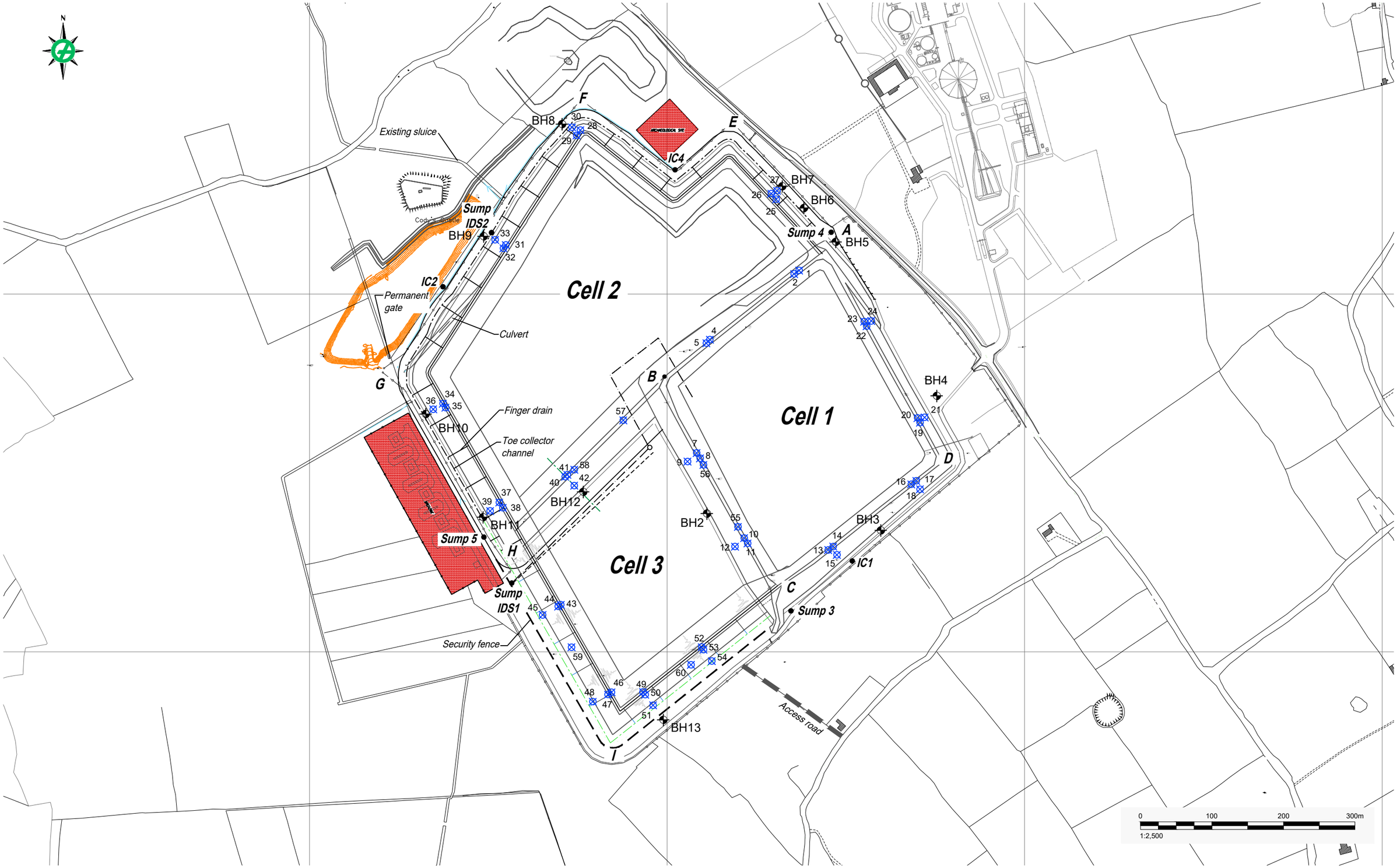
1. All dimensions in millimetres unless stated otherwise.

Date	13.03.03
Project No.	05515354
Created by	E.C.S.
File No.	515407

Title

Typical Section Through Main Dam Wall Showing Internal Drainage Details
Galmoy Mines Ltd
Tailings Dam Cell 3 Expansion, Galmoy, Ireland

Drawing **2**



LEGEND

58	STANDPIPE PIEZOMETER
BH12	BOREHOLE MONITORING WELL
Sump 5	DRAINAGE SUMPS
Sump IDS1	CHIMNEY SUMPS
IC4	INTERCEPTOR CHANNEL SUMPS

CLIENT

GALMOY MINES LTD.

CONSULTANT

GOLDER

YYYY-MM-DD	2019-Mar-20
PREPARED	POB
DESIGN	POB
REVIEW	BK
APPROVED	BK

PROJECT

GALMOY MINES TMF ANNUAL REVIEW 2018

TITLE

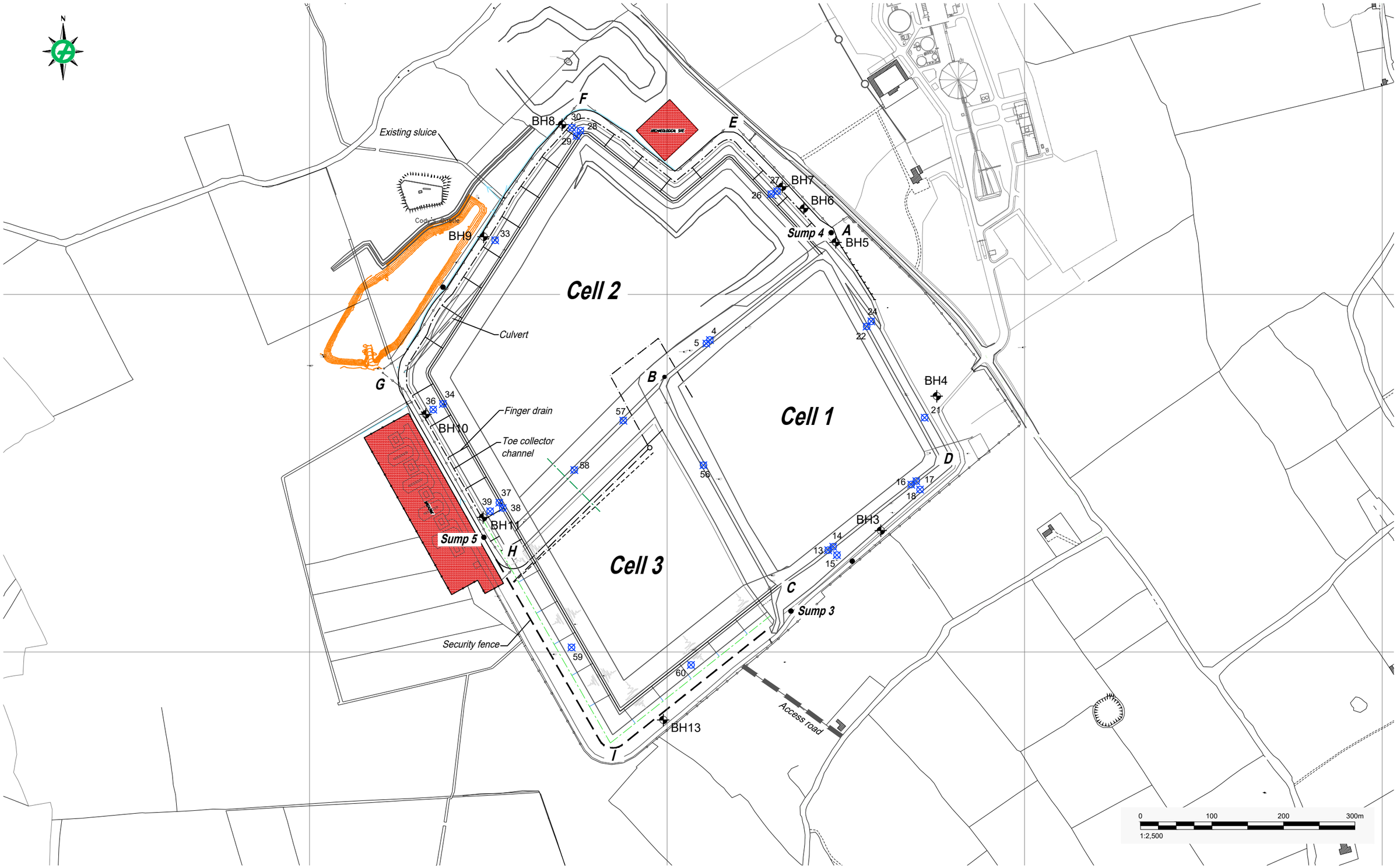
GALMOY MINES TMF
ORIGINAL MONITORING INSTALLATIONS

PROJECT No.	DRAWING No.	Rev.	SCALE
19118326	03	A	1:2,500 A1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A1

0 25 mm

Path: C:\Users\bkennan\Documents\Golder\Galmoy\2018 Audit Mar 2019\Report\Appendix A - Drawings\ | File Name: 19118326_Galmoy TMF Original Monitoring Instrument Locations_Mar 2019.dwg



LEGEND

58 ⊠	STANDPIPE PIEZOMETER
BH12	BOREHOLE MONITORING WELL
Sump 5	DRAINAGE SUMPS
Sump IDS1	CHIMNEY SUMPS
IC4	INTERCEPTOR CHANNEL SUMPS

CLIENT

GALMOY MINES LTD.

CONSULTANT

GOLDER

YYYY-MM-DD	2019-Mar-20
PREPARED	POB
DESIGN	POB
REVIEW	BK
APPROVED	BK

PROJECT

GALMOY MINES TMF ANNUAL REVIEW 2018

TITLE

GALMOY MINES TMF
ACTIVE MONITORING INSTALLATIONS

PROJECT No.	DRAWING No.	Rev.	SCALE
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A1

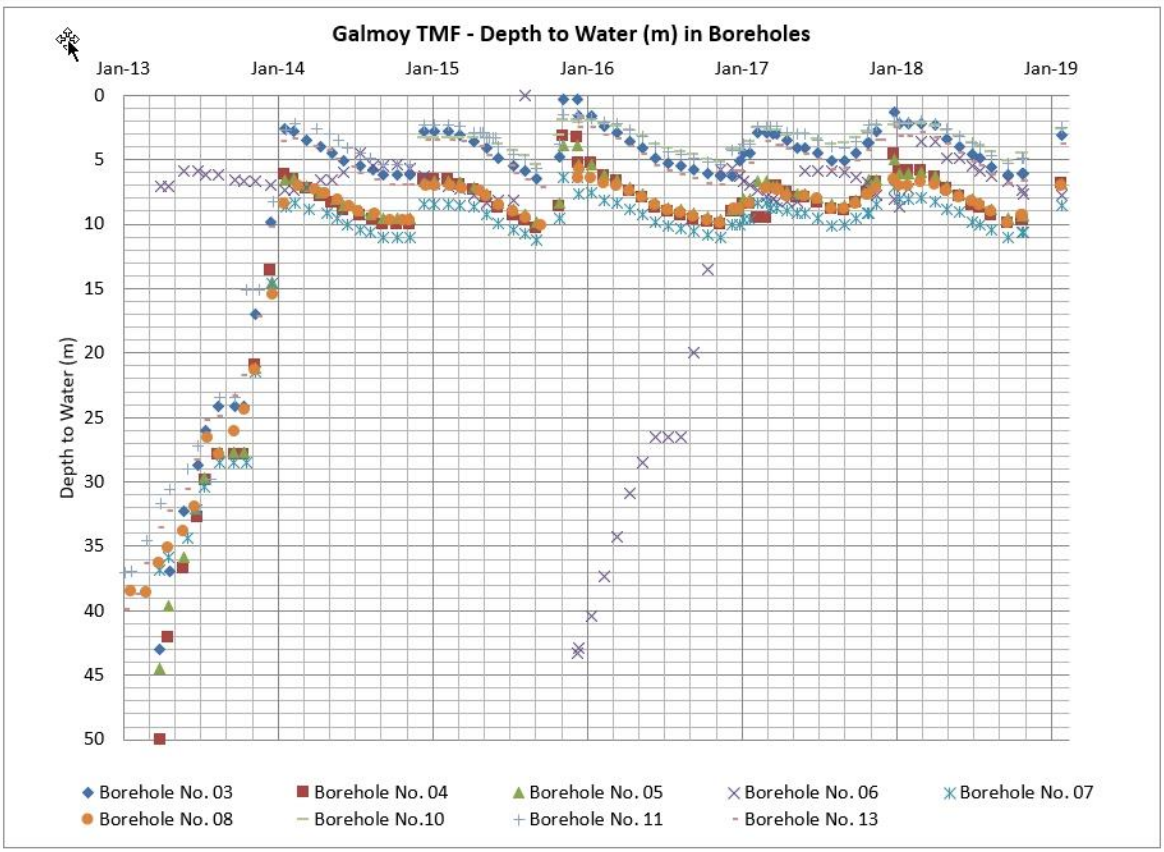
0 25 mm

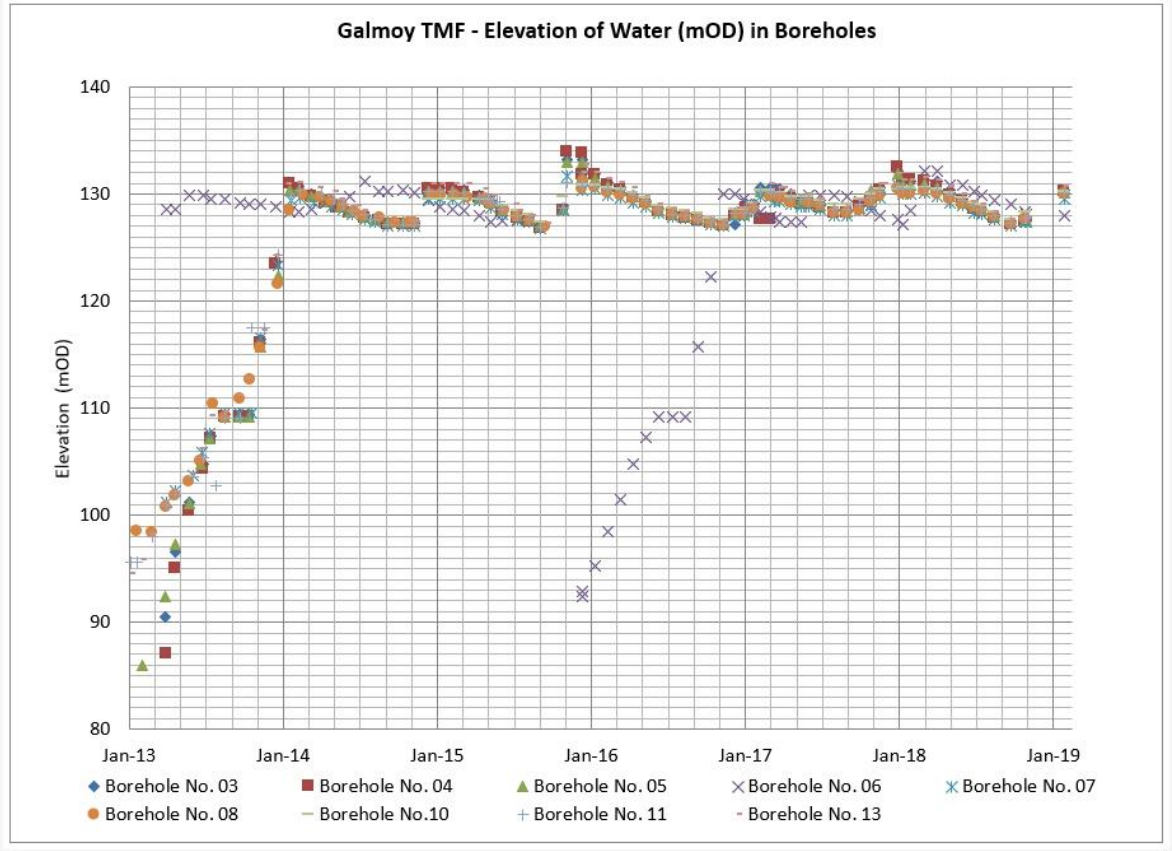
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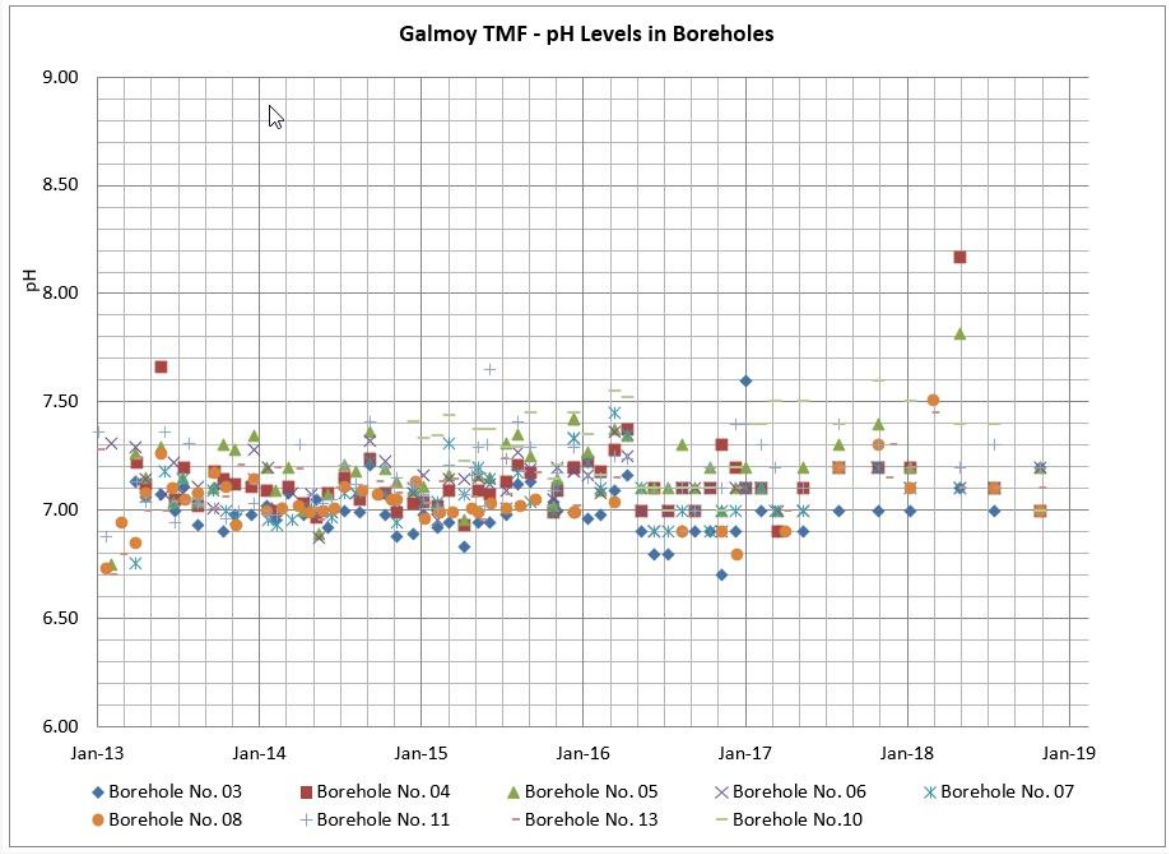
APPENDIX B

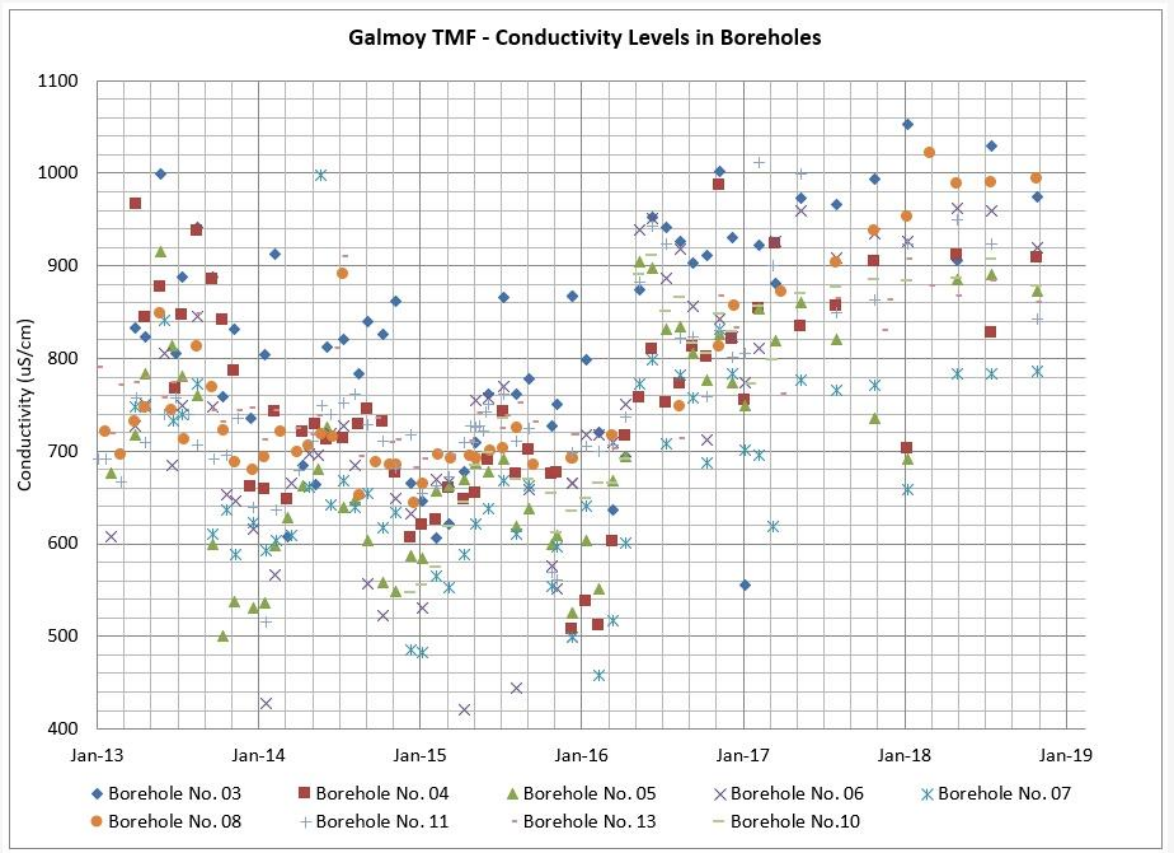
Piezometer and Boreholes Monitoring Data

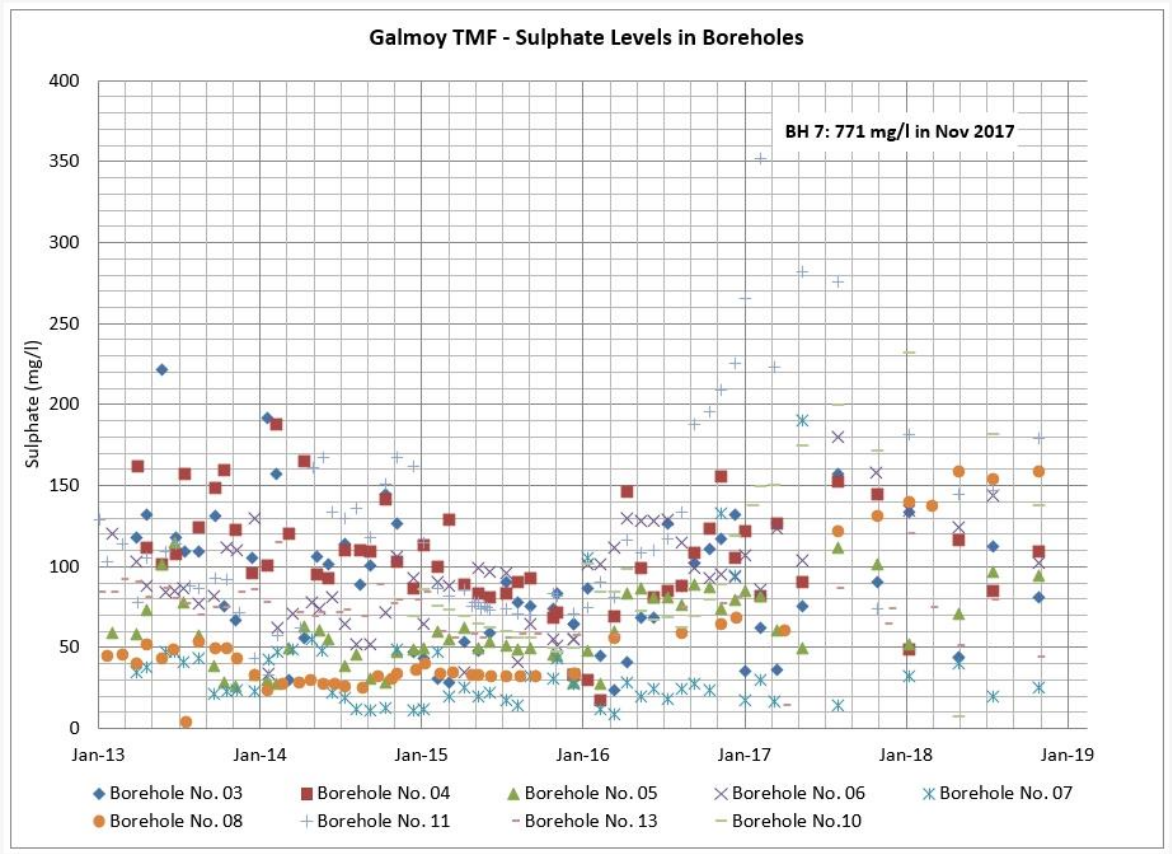
BOREHOLE DATA



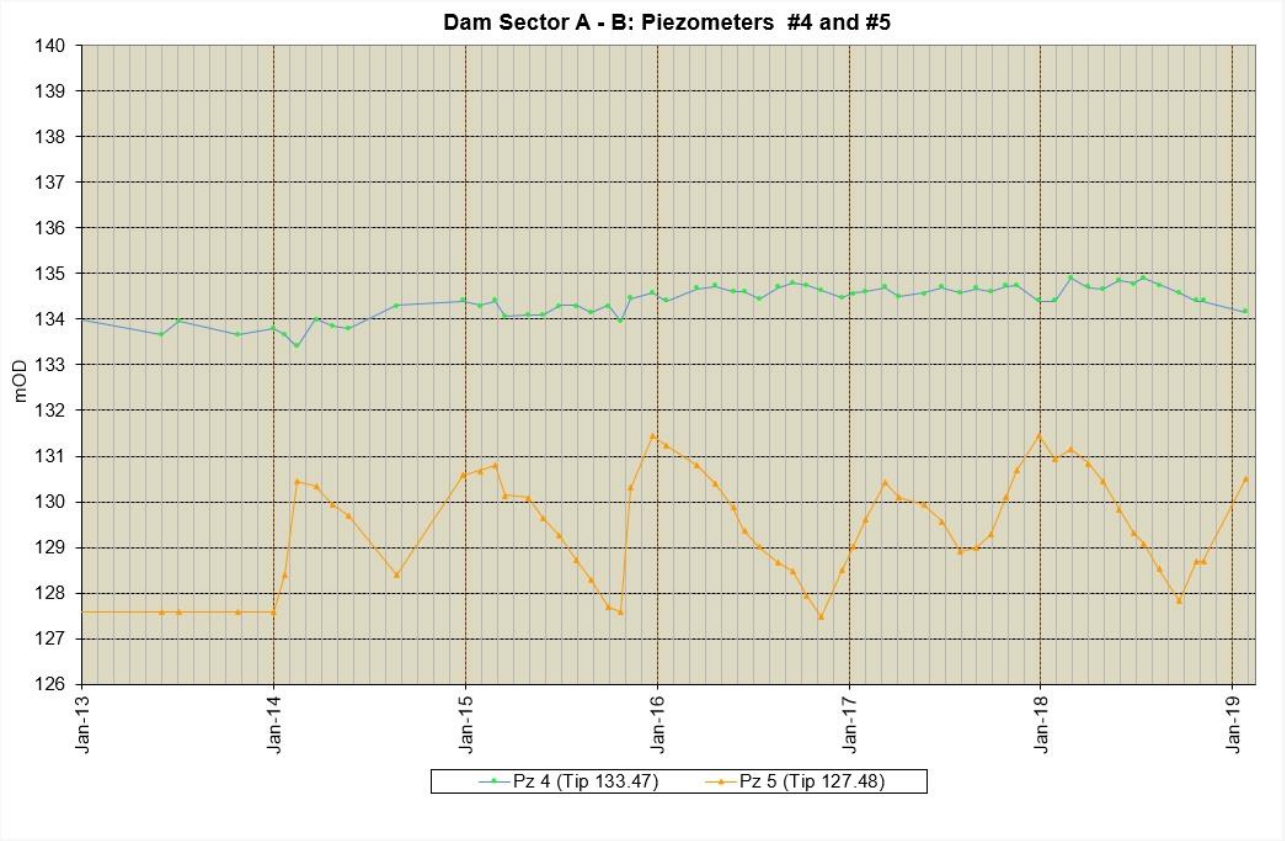


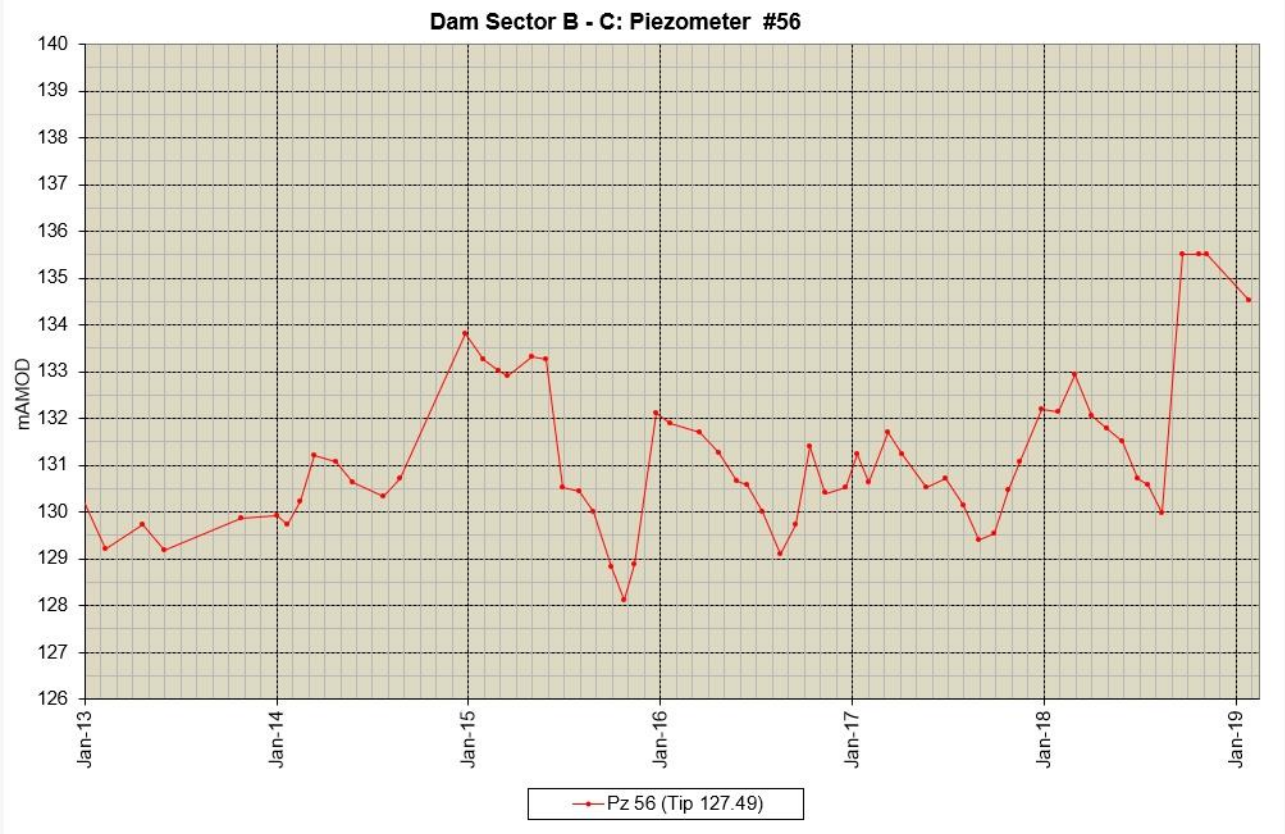

Galmoy TMF - pH Levels in Boreholes
pH
9.00
8.50
8.00
7.50
7.00
6.50
6.00
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Borehole No. 03
Borehole No. 04
Borehole No. 05
Borehole No. 06
Borehole No. 07
Borehole No. 08
Borehole No. 11
Borehole No. 13
Borehole No.10

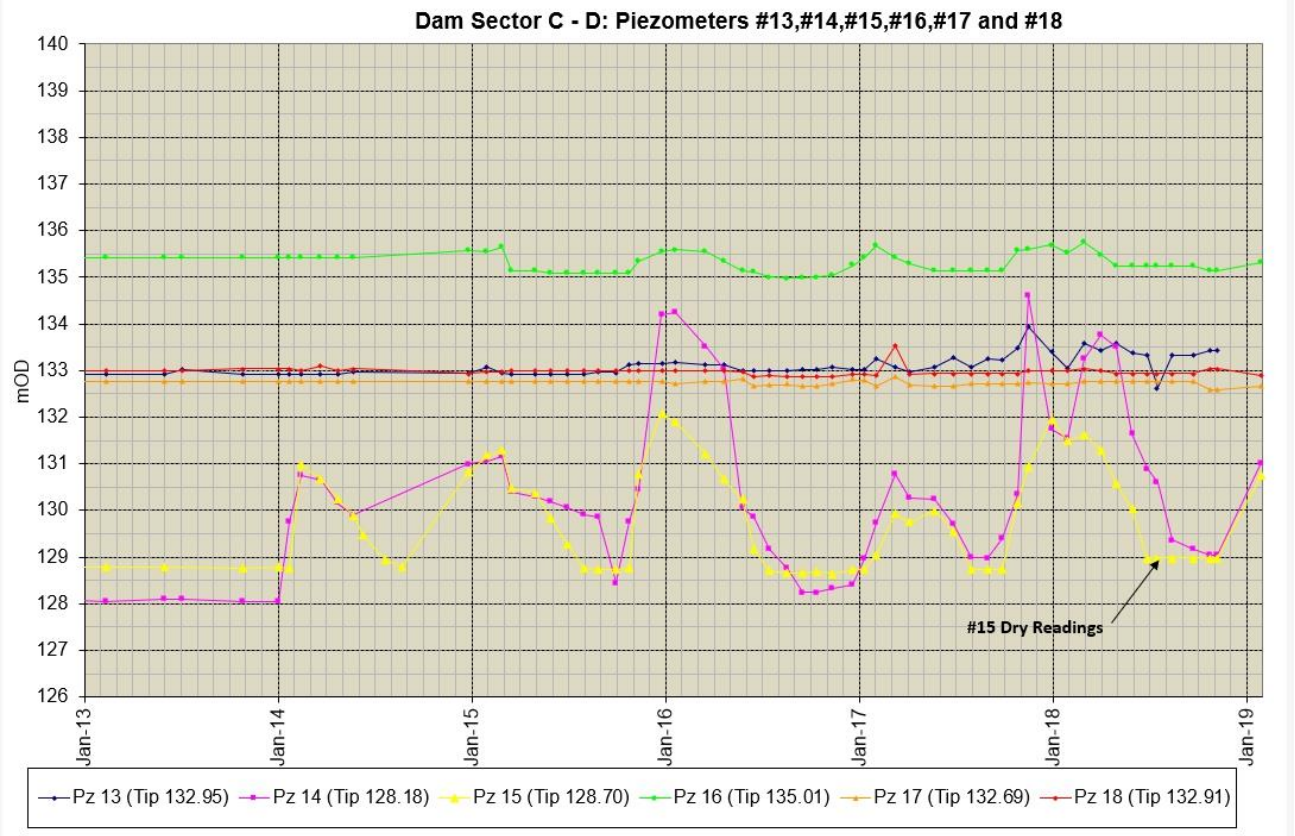

Galmoy TMF - Conductivity Levels in Boreholes
Conductivity (uS/cm)
1100
1000
900
800
700
600
500
400
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Borehole No. 03
Borehole No. 04
Borehole No. 05
Borehole No. 06
Borehole No. 07
Borehole No. 08
Borehole No. 11
Borehole No. 13
Borehole No.10

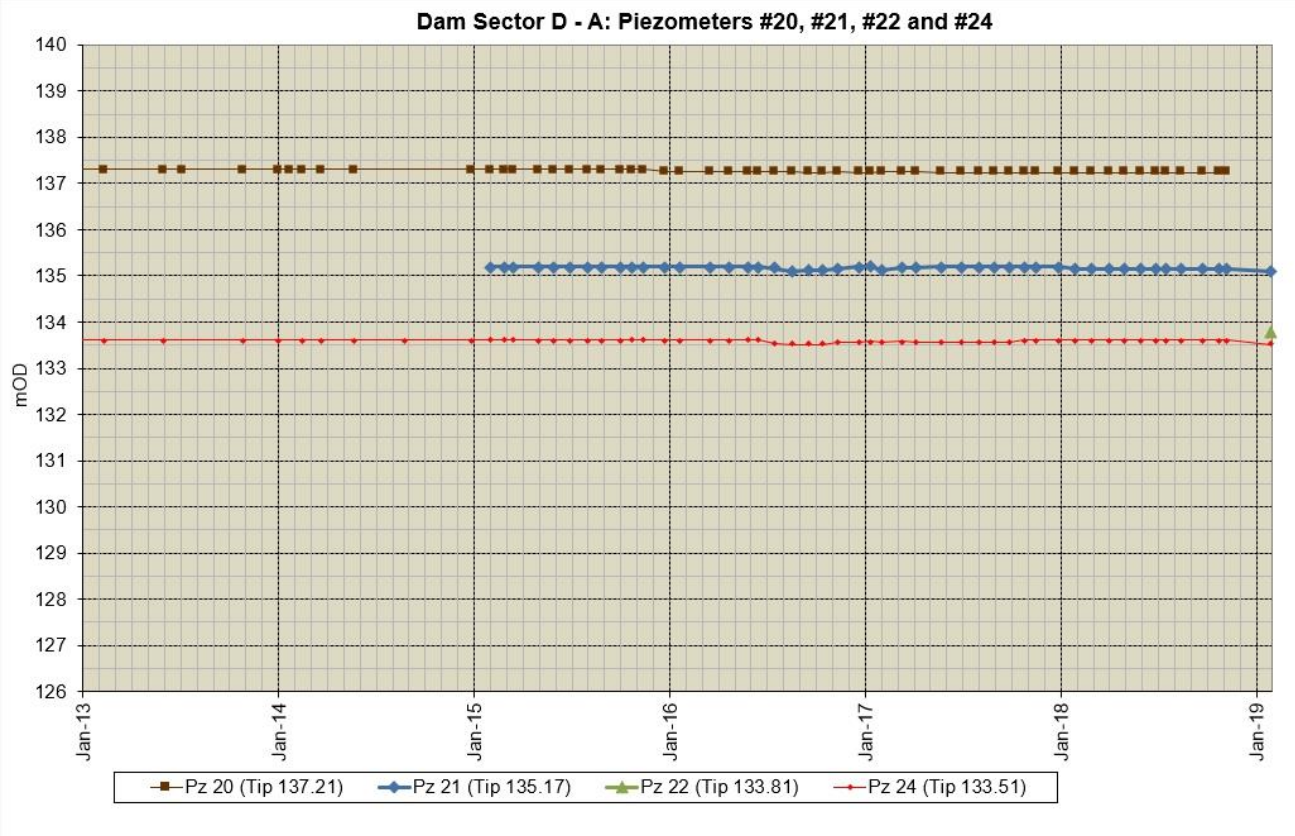

Galmoy TMF - Sulphate Levels in Boreholes
BH 7: 771 mg/l in Nov 2017
Sulphate (mg/l)
400
350
300
250
200
150
100
50
0
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Borehole No. 03
Borehole No. 04
Borehole No. 05
Borehole No. 06
Borehole No. 07
Borehole No. 08
Borehole No. 11
Borehole No. 13
Borehole No.10

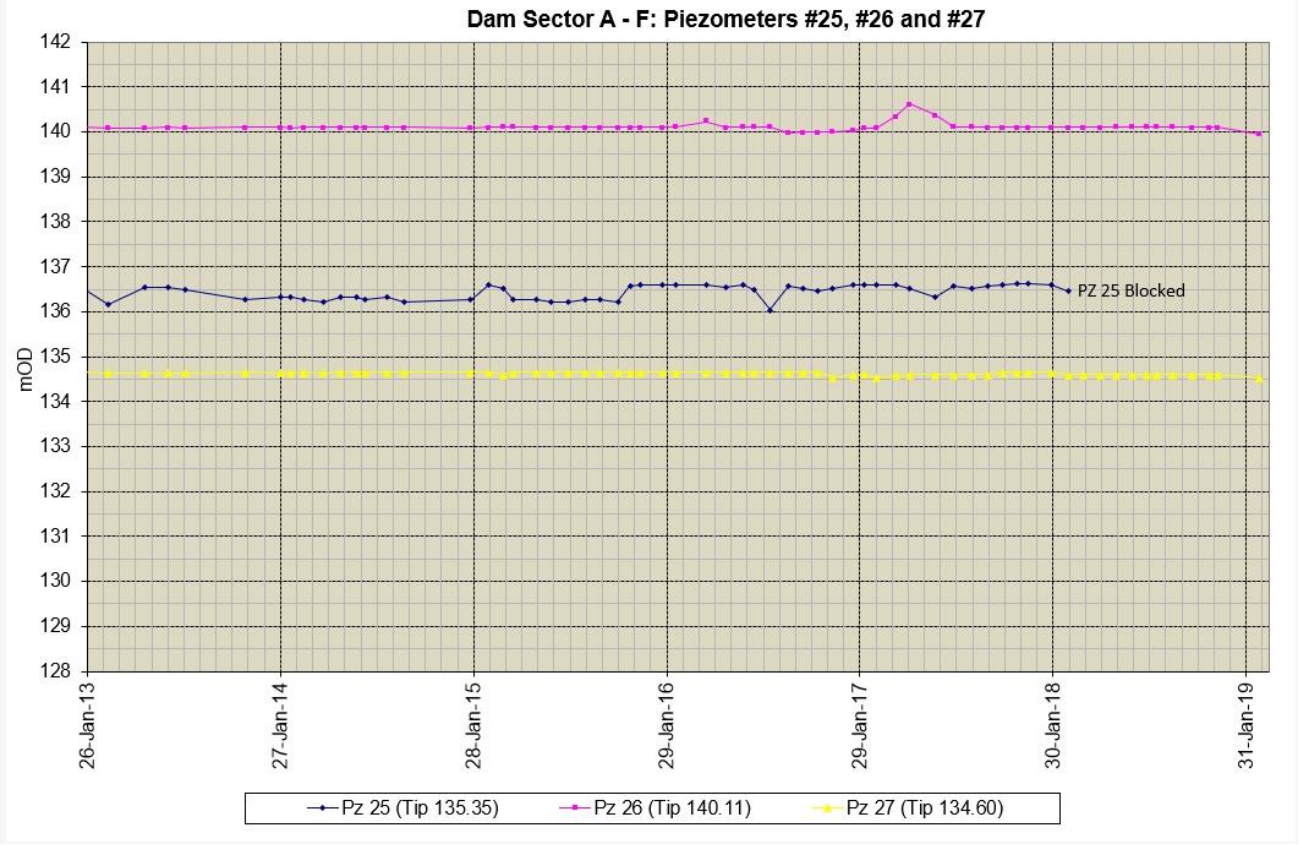
PIEZOMETER DATA

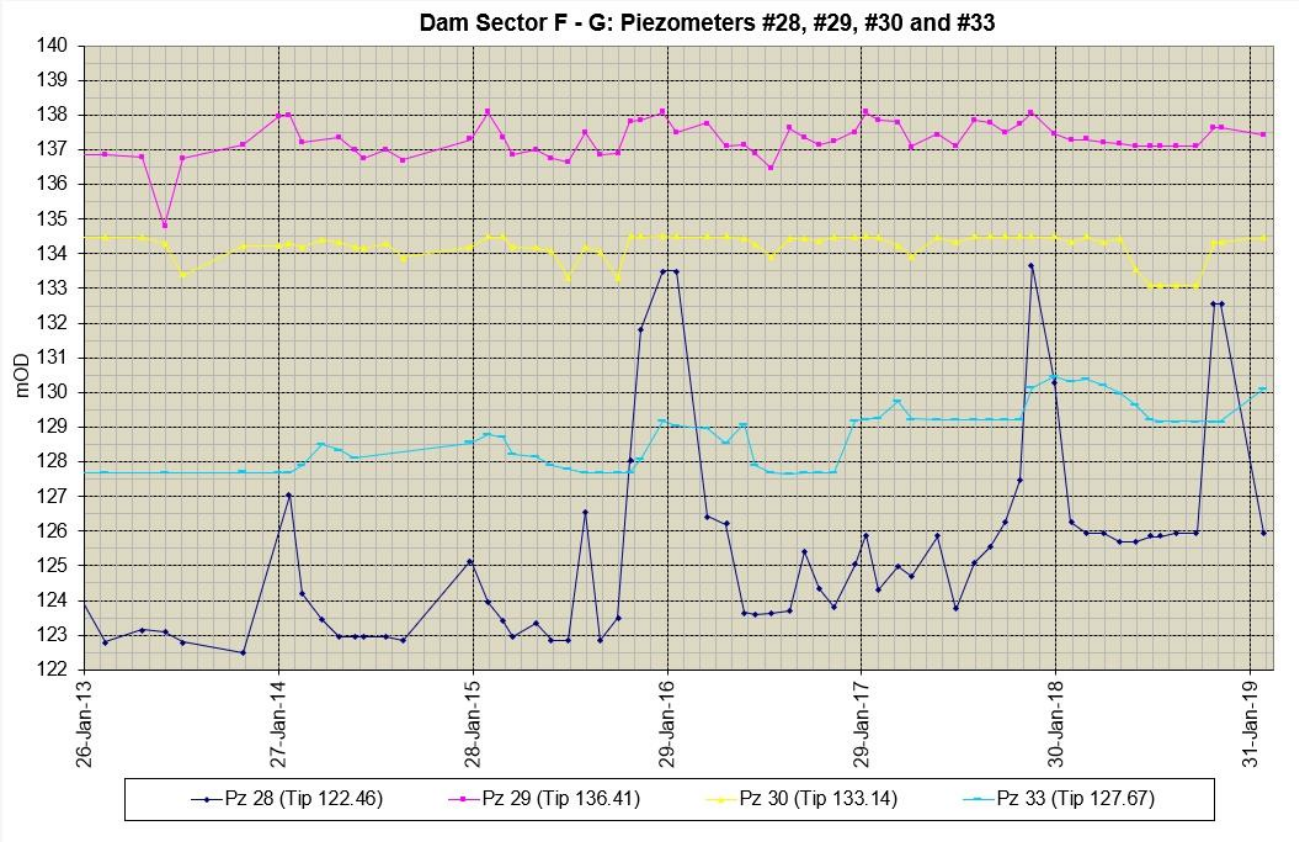


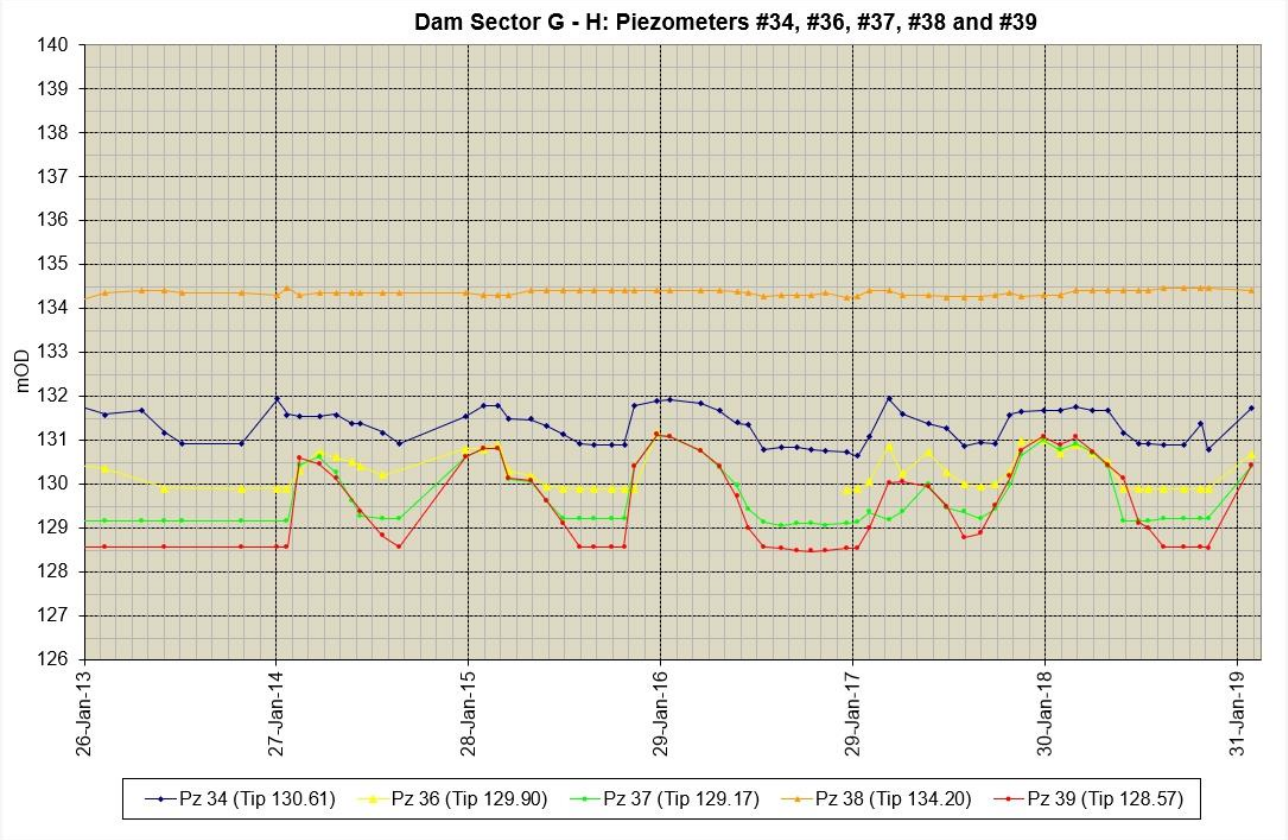


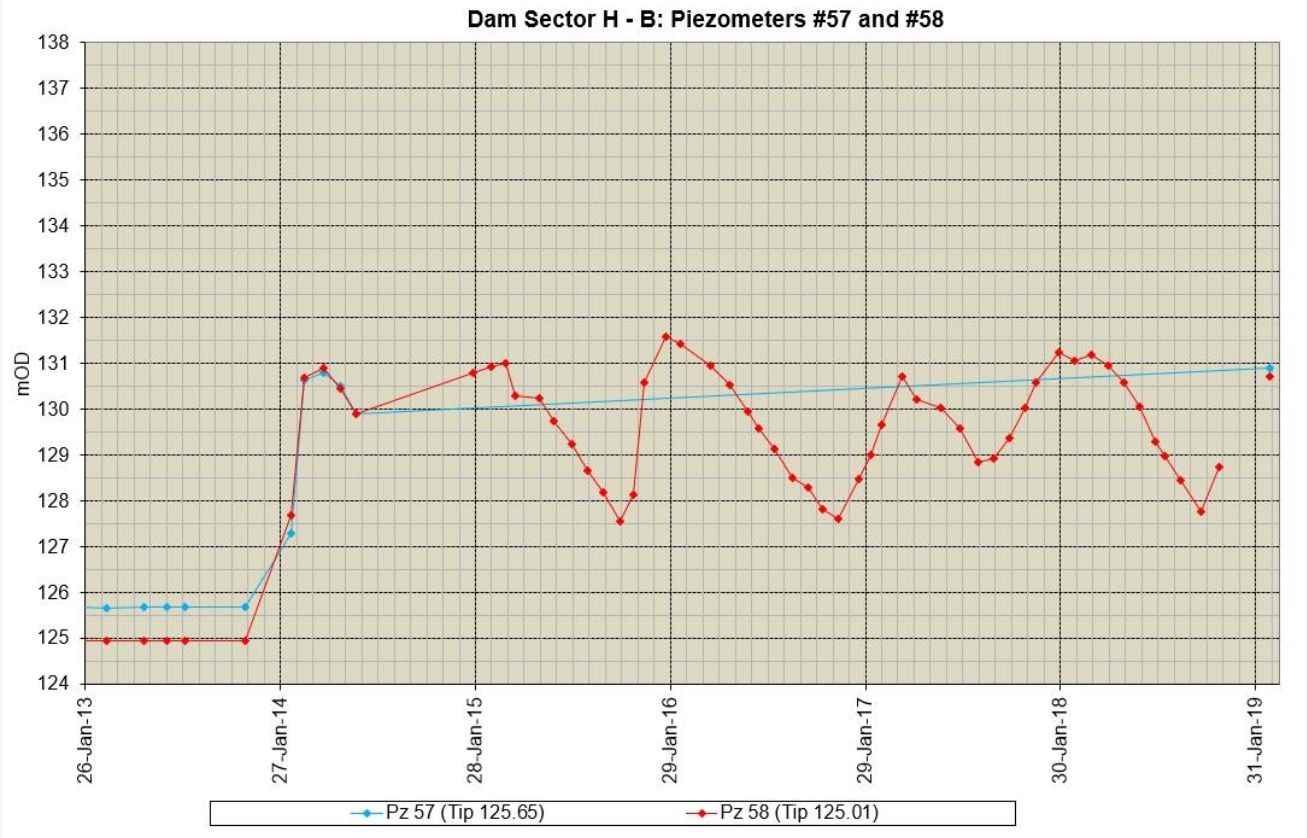

Dam Sector C - D: Piezometers #13,#14,#15,#16,#17 and #18
mOD
140
139
138
137
136
135
134
133
132
131
130
129
128
127
126
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
#15 Dry Readings
Pz 13 (Tip 132.95)
Pz 14 (Tip 128.18)
Pz 15 (Tip 128.70)
Pz 16 (Tip 135.01)
Pz 17 (Tip 132.69)
Pz 18 (Tip 132.91)

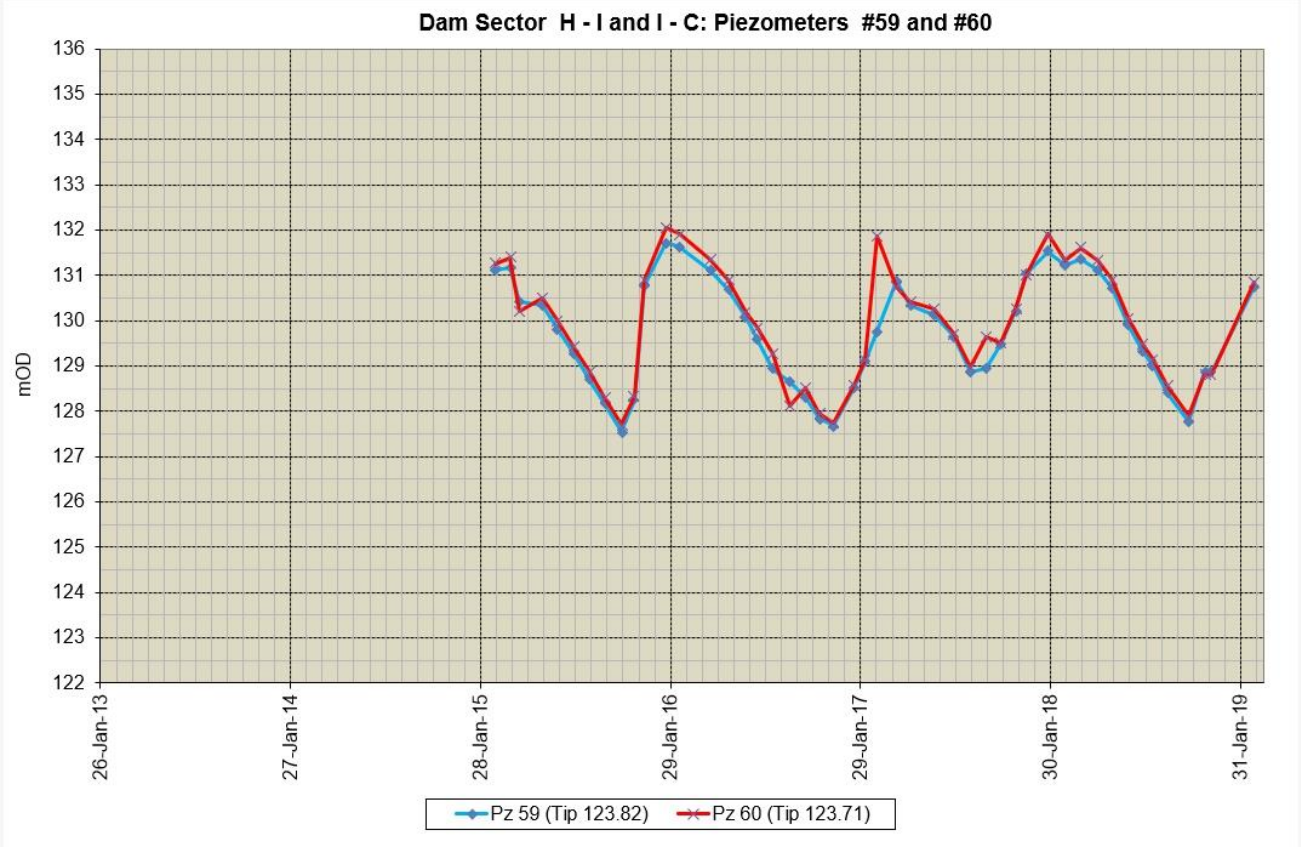

Dam Sector D - A: Piezometers #20, #21, #22 and #24
mOD
140
139
138
137
136
135
134
133
132
131
130
129
128
127
126
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Pz 20 (Tip 137.21)
Pz 21 (Tip 135.17)
Pz 22 (Tip 133.81)
Pz 24 (Tip 133.51)

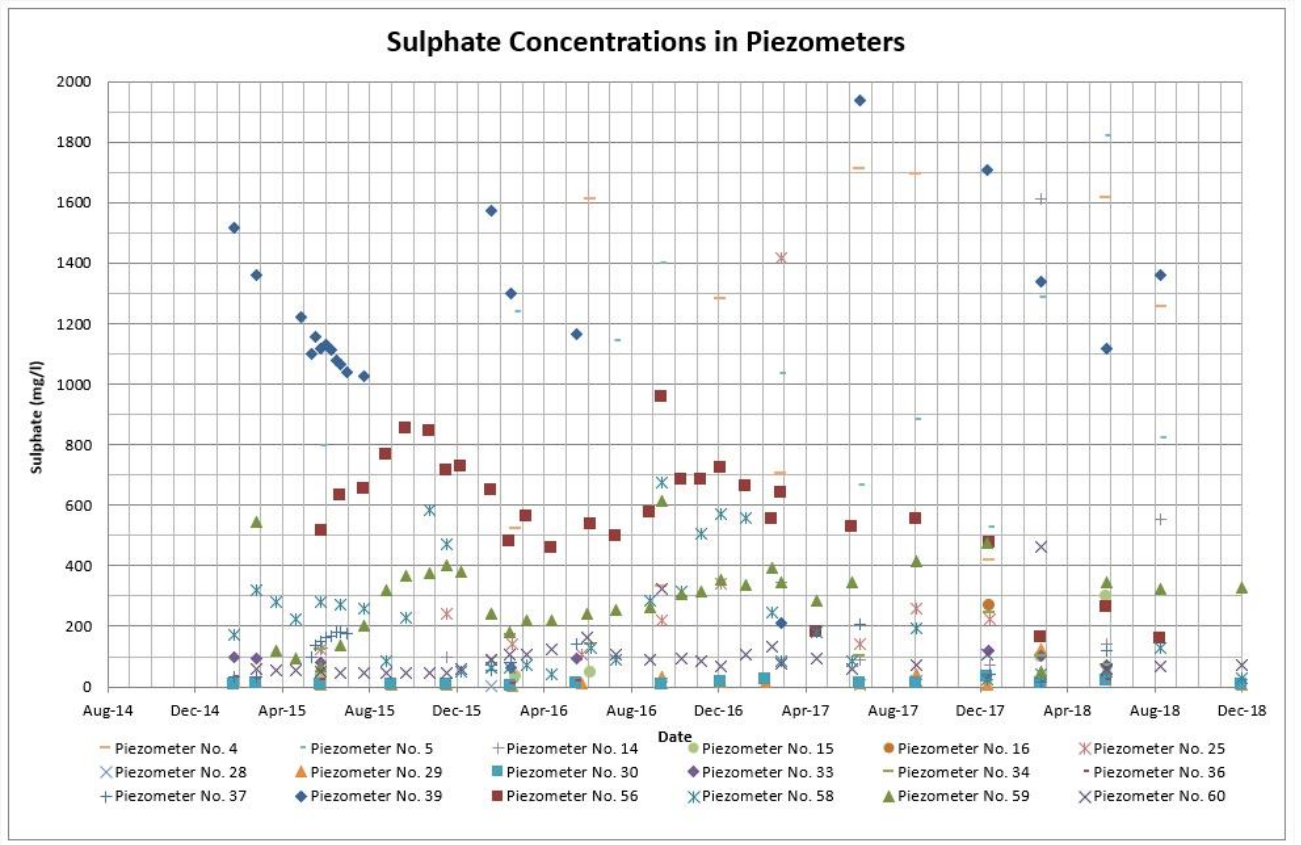

Dam Sector A - F: Piezometers #25, #26 and #27
mOD
142
141
140
139
138
137
136
135
134
133
132
131
130
129
128
PZ 25 Blocked
26-Jan-13
27-Jan-14
28-Jan-15
29-Jan-16
29-Jan-17
30-Jan-18
31-Jan-19
Pz 25 (Tip 135.35)
Pz 26 (Tip 140.11)
Pz 27 (Tip 134.60)


Dam Sector F - G: Piezometers #28, #29, #30 and #33
mOD
140
139
138
137
136
135
134
133
132
131
130
129
128
127
126
125
124
123
122
26-Jan-13
27-Jan-14
28-Jan-15
29-Jan-16
29-Jan-17
30-Jan-18
31-Jan-19
Pz 28 (Tip 122.46)
Pz 29 (Tip 136.41)
Pz 30 (Tip 133.14)
Pz 33 (Tip 127.67)


Dam Sector G - H: Piezometers #34, #36, #37, #38 and #39
mOD
140
139
138
137
136
135
134
133
132
131
130
129
128
127
126
26-Jan-13
27-Jan-14
28-Jan-15
29-Jan-16
29-Jan-17
30-Jan-18
31-Jan-19
Pz 34 (Tip 130.61)
Pz 36 (Tip 129.90)
Pz 37 (Tip 129.17)
Pz 38 (Tip 134.20)
Pz 39 (Tip 128.57)

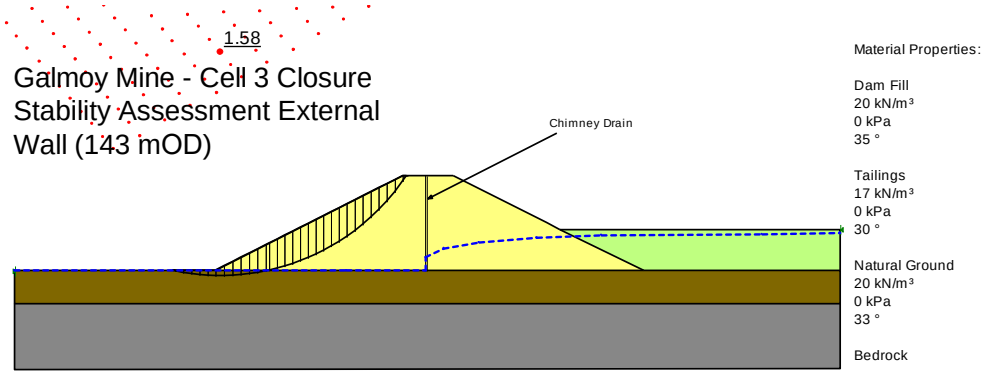

Dam Sector H - B: Piezometers #57 and #58
mOD
138
137
136
135
134
133
132
131
130
129
128
127
126
125
124
26-Jan-13
27-Jan-14
28-Jan-15
29-Jan-16
29-Jan-17
30-Jan-18
31-Jan-19
Pz 57 (Tip 125.65)
Pz 58 (Tip 125.01)

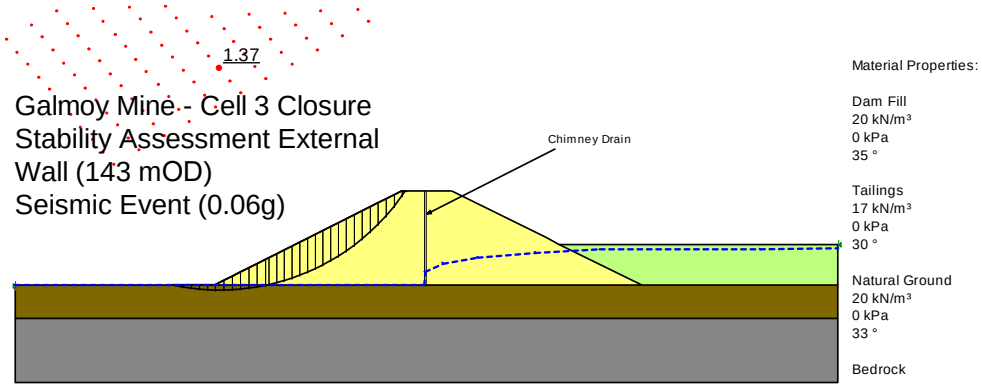

Dam Sector H - I and I - C: Piezometers #59 and #60
mOD
136
135
134
133
132
131
130
129
128
127
126
125
124
123
122
26-Jan-13
27-Jan-14
28-Jan-15
29-Jan-16
29-Jan-17
30-Jan-18
31-Jan-19
Pz 59 (Tip 123.82)
Pz 60 (Tip 123.71)

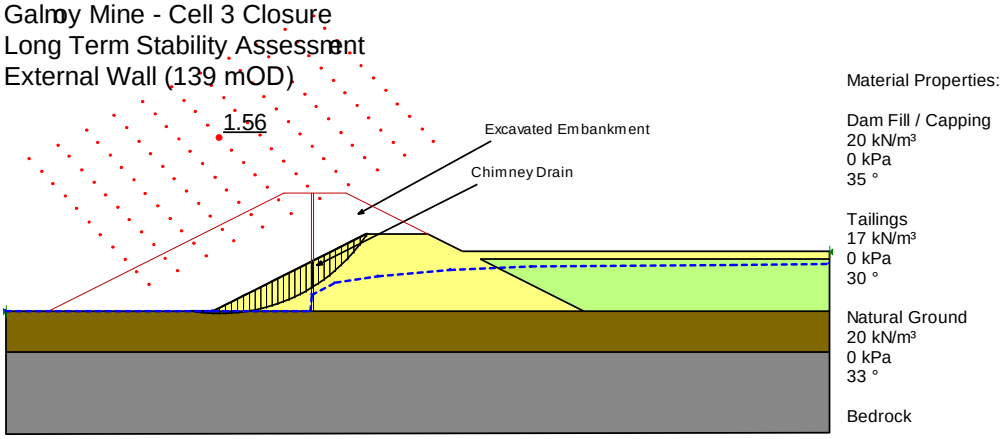

Sulphate Concentrations in Piezometers
Sulphate (mg/l)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Aug-14
Dec-14
Apr-15
Aug-15
Dec-15
Apr-16
Aug-16
Dec-16
Apr-17
Aug-17
Dec-17
Apr-18
Aug-18
Dec-18
Date
Piezometer No. 4
Piezometer No. 5
Piezometer No. 14
Piezometer No. 15
Piezometer No. 16
Piezometer No. 25
Piezometer No. 28
Piezometer No. 29
Piezometer No. 30
Piezometer No. 33
Piezometer No. 34
Piezometer No. 36
Piezometer No. 37
Piezometer No. 39
Piezometer No. 56
Piezometer No. 58
Piezometer No. 59
Piezometer No. 60

APPENDIX C

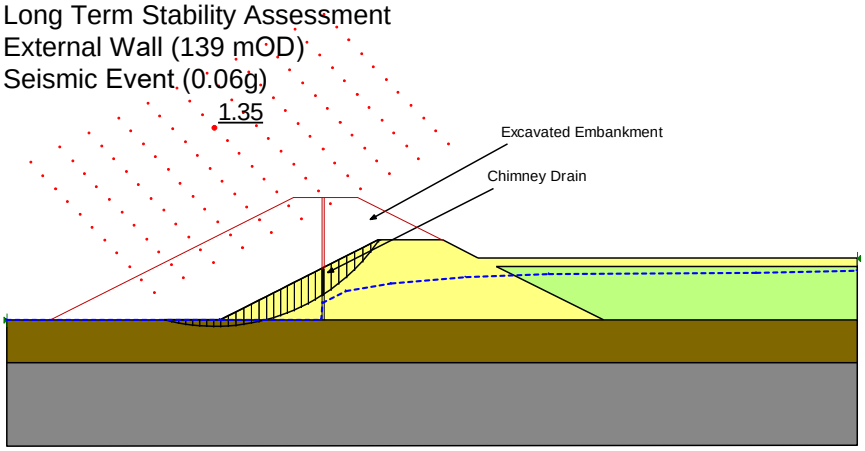
Slope Stability


1.58
Galmoy Mine - Cell 3 Closure
Stability Assessment External
Wall (143 mOD)
Chimney Drain
Material Properties:
Dam Fill
20 kN/m³
0 kPa
35 °
Tailings
17 kN/m³
0 kPa
30 °
Natural Ground
20 kN/m³
0 kPa
33 °
Bedrock


1.37
Galmoy Mine - Cell 3 Closure
Stability Assessment External
Wall (143 mOD)
Seismic Event (0.06g)
Chimney Drain
Material Properties:
Dam Fill
20 kN/m³
0 kPa
35 °
Tailings
17 kN/m³
0 kPa
30 °
Natural Ground
20 kN/m³
0 kPa
33 °
Bedrock


Galmoy Mine - Cell 3 Closure
Long Term Stability Assessment
External Wall (139 mOD)
1.56
Excavated Embankment
Chimney Drain
Material Properties:
Dam Fill / Capping
20 kN/m³
0 kPa
35 °
Tailings
17 kN/m³
0 kPa
30 °
Natural Ground
20 kN/m³
0 kPa
33 °
Bedrock

Galmoy Mine - Cell 3 Closure
Long Term Stability Assessment
External Wall (139 mOD)
Seismic Event (0.06g)



Material Properties:

Dam Fill / Capping
20 kN/m³
0 kPa
35 °

Tailings
17 kN/m³
0 kPa
30 °

Natural Ground
20 kN/m³
0 kPa
33 °

Bedrock



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