APPENDIX A
GROUNDWATER EVALUATIONS

APPENDIX A1
BOREHOLE LOGGING

BOREHOLE GEOPHYSICAL LOGGING OF THREE BEDROCK BOREHOLES AT THE CALLAHAN MINE SUPERFUND SITE BROOKSVILLE, MAINE

Northeast Geophysical Services
4 Union Street, Suite 3
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January, 2013

BOREHOLE GEOPHYSICAL LOGGING OF THREE BEDROCK BOREHOLES AT THE CALLAHAN MINE SUPERFUND SITE BROOKSVILLE, MAINE

Introduction

At the request of AMEC, three bedrock boreholes located at the Callahan Mine Superfund Site in Brooksville, Maine were geophysically logged by Rudy Rawcliffe of Northeast Geophysical Services (NGS). The boreholes are designated as RC-1143, RC-1144 and RC-1145. Borehole RC-1143 was logged on December 20, 2012 and boreholes RC-1144 and RC-1145 were logged on January 9, 2013.

The purpose of the geophysical logging was to identify water-bearing fractures. Caliper, temperature, fluid conductivity, and heat-pulse flowmeter measurements were collected from each of the boreholes. Single-point resistance (SPR) and spontaneous potential (SP) were also collected on RC-1144 and RC-1145. In addition, acoustic televiewer (ATV) and optical televiewer (OTV) images were generated for each borehole.

Summary of Results

Three boreholes totaling about 110 lineal feet of geophysical logging were completed. Geophysical logs of the boreholes are attached to this report (Attachments A, B and C respectively). For each borehole the data are presented in a series of logs (Plates 1-4) that show the results of the geophysical measurements. Tables that provide the depth and calculated strike and dip of each identified feature and rose and polar plots of planar features for each borehole are also presented in the attachments.

The main objective of the geophysical logging was to identify transmissive fractures in the boreholes. Plate 1 in each attachment is a composite geophysical log containing caliper, flowmeter, temperature, fluid conductivity, SPR and SP data and a tadpole plot derived from the televiewer data. Plate 1 shows the locations of potential fractures in each of the boreholes. The flowmeter results, temperature and fluid conductivity results provide indications of which of these potential fractures carry notable groundwater flow (i.e. are transmissive).

The fractures interpreted to be transmissive are highlighted in yellow on Plate 1. Dark yellow highlights indicate likely transmissive fractures. Lighter yellow highlights indicate possible transmissive fractures. The tadpole plot (far right column) on Plate 1 also shows possible and likely transmissive fractures. The blue colored tadpoles represent possible (light blue) and likely (dark blue) transmissive fractures. It is possible that there are other transmissive fractures in the boreholes but these are the ones that are most apparent based on the geophysical measurements.

Figure 1 (page 2) is a rose plot of the strike and dip angle of all 118 interpreted features measured in the three boreholes logged by NGS. This plot shows that there is a wide range of strike and dip directions in the boreholes. There does appear to be a preferential strike depending on dip angle.

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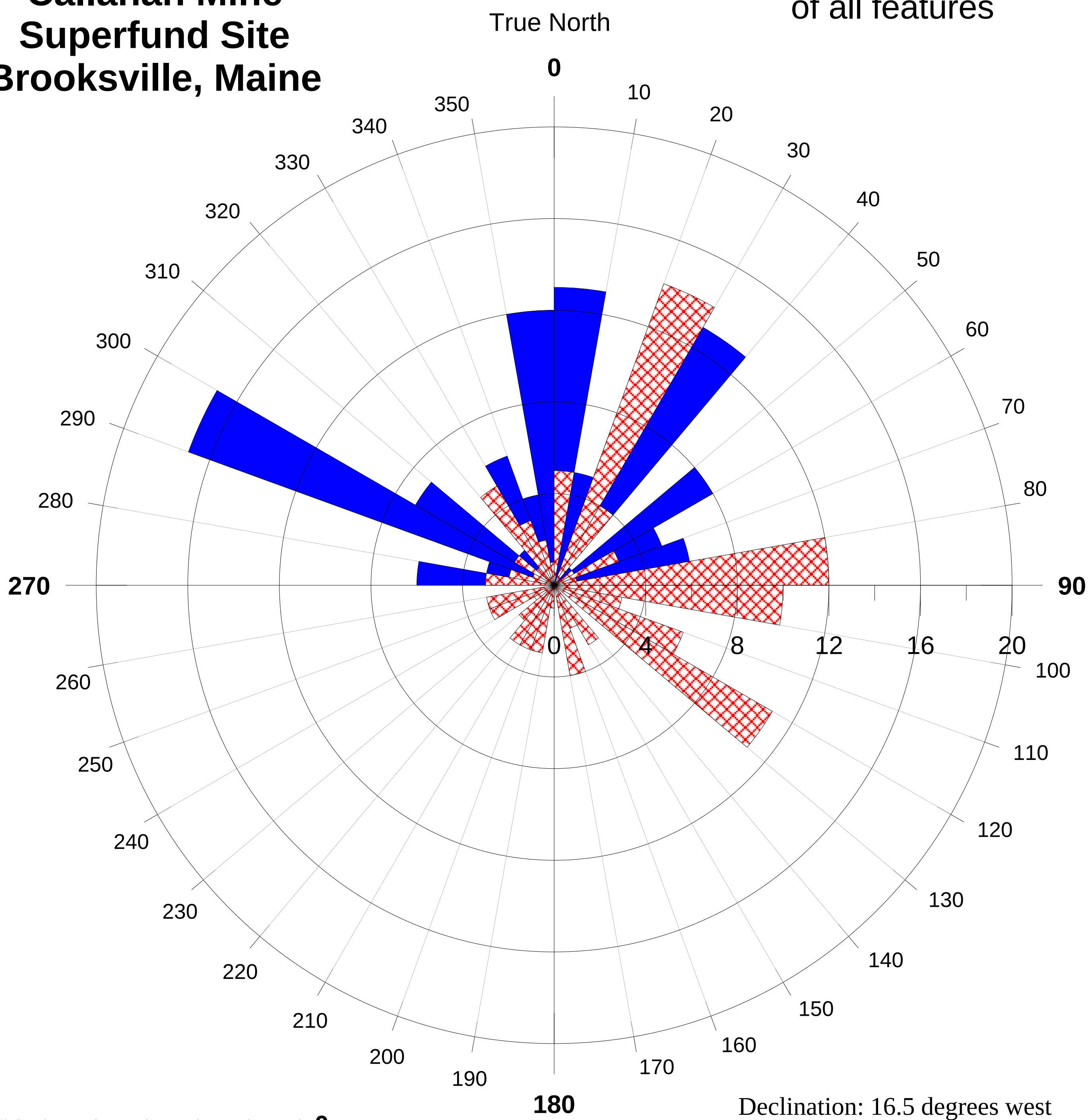
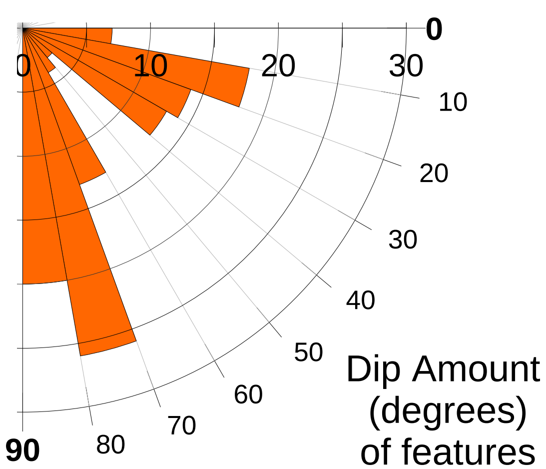
FIGURE 1
Strike and Dip Direction of all features



Declination: 16.5 degrees west



Explanation

- Dip direction of feature
- Strike of feature
- Dip Amount (Tilt)

Based on 118 measurements in RC-1143, RC-1144 and RC-1145

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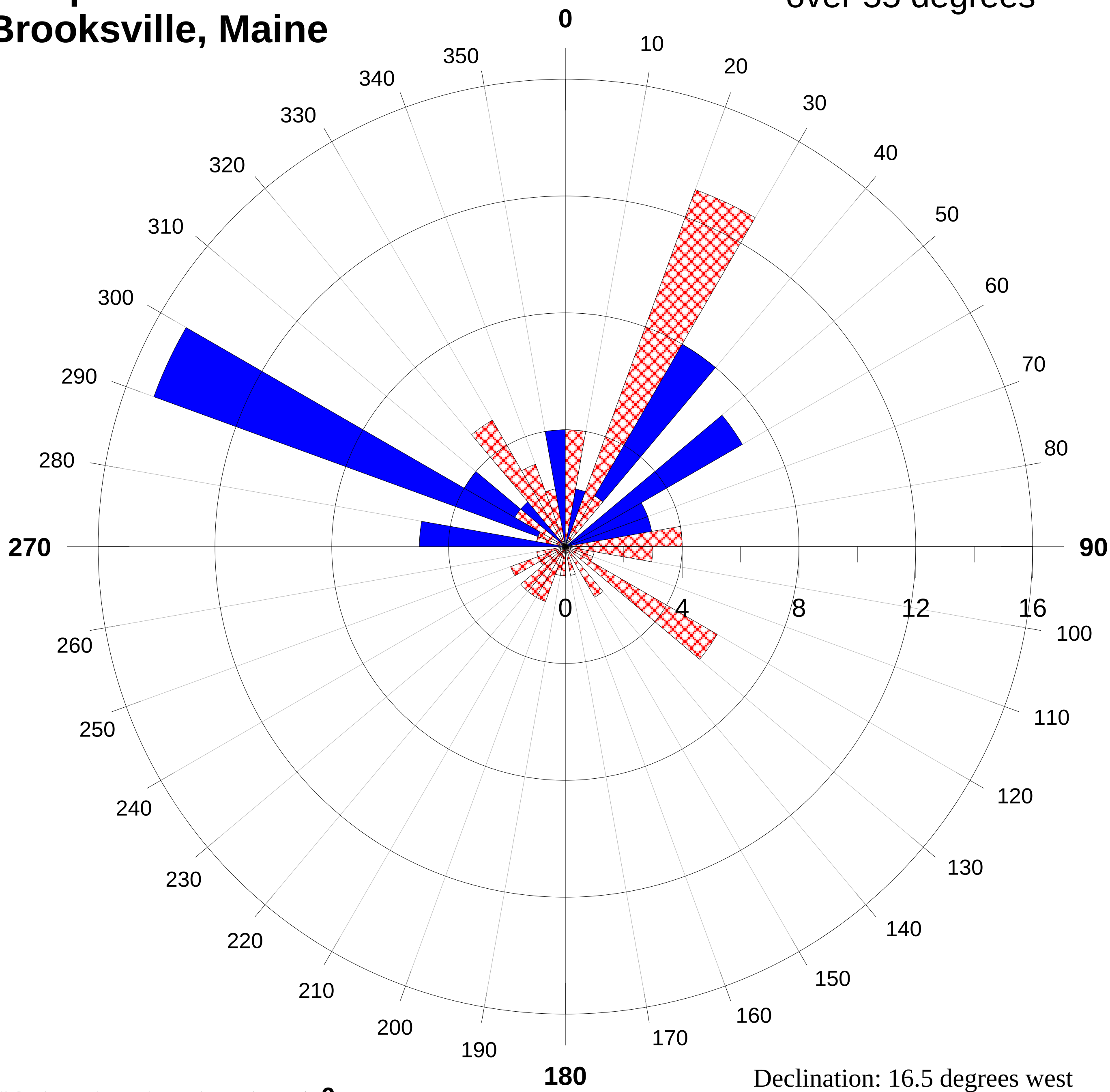
Callahan Mine Superfund Site Brooksville, Maine

FIGURE 1A
Strike and Dip Direction of all features that dip over 55 degrees



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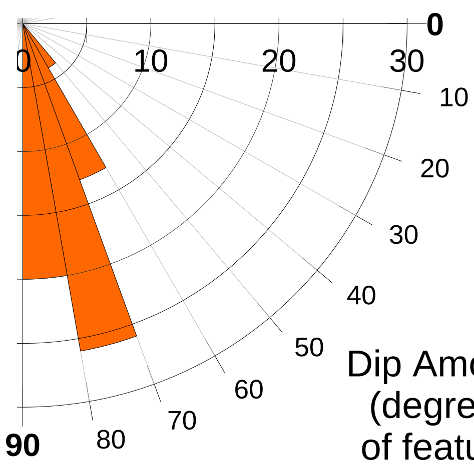


Dip Amount (degrees) of features

Explanation

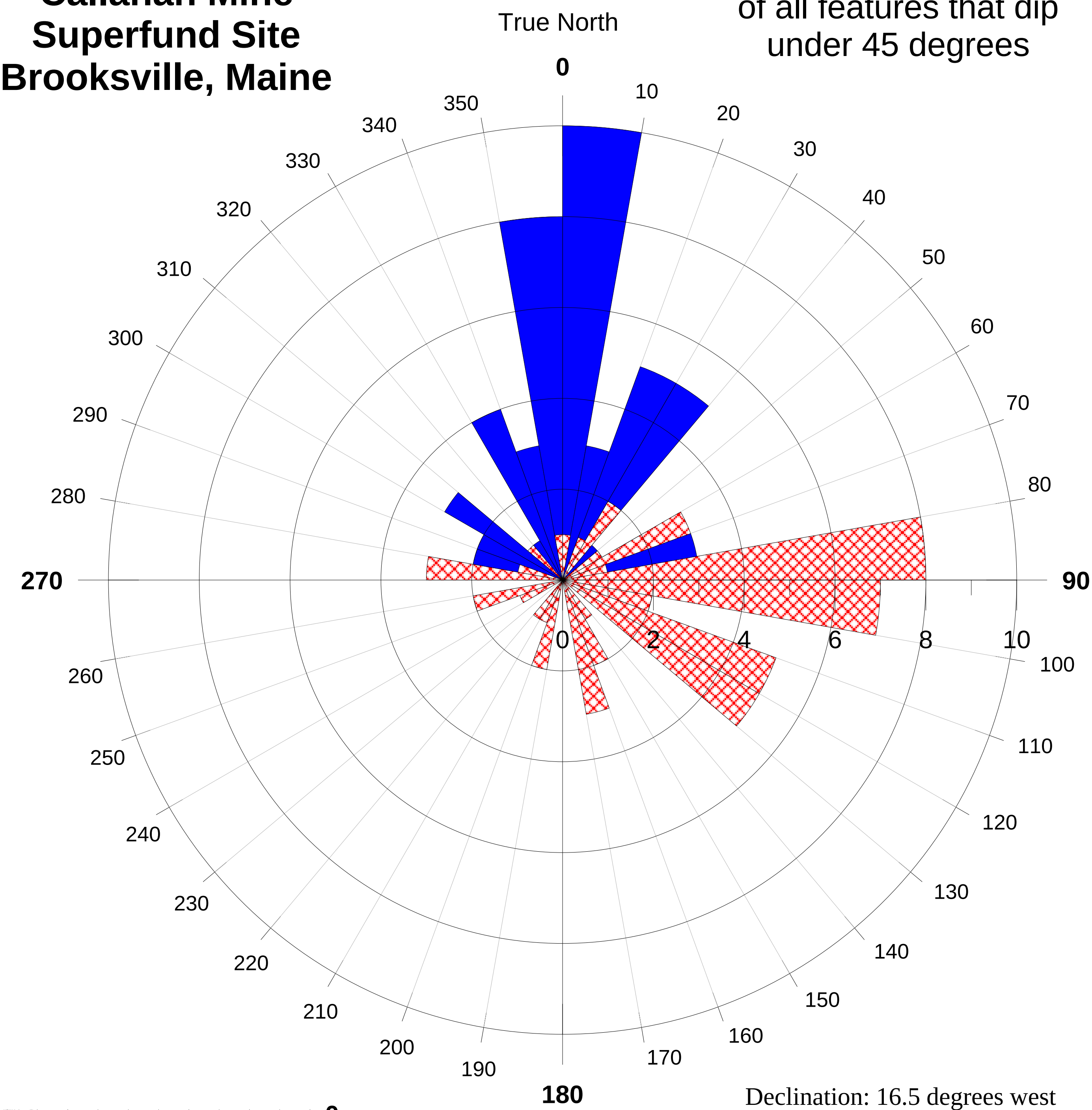
- Dip direction of feature
- Strike of feature
- Dip Amount (Tilt)

Based on 63 measurements in RC-1143, RC-1144 and RC-1145

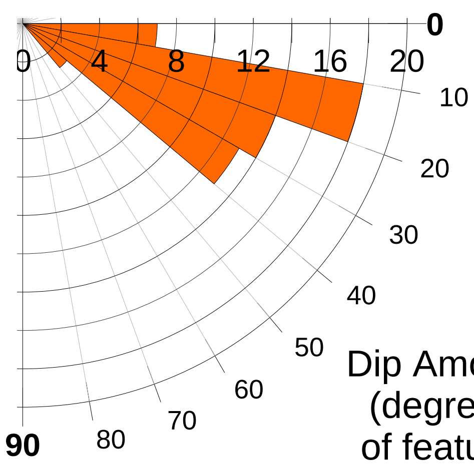
Northeast Geophysical Services

Callahan Mine Superfund Site Brooksville, Maine

FIGURE 1B
Strike and Dip Direction of all features that dip under 45 degrees



Declination: 16.5 degrees west



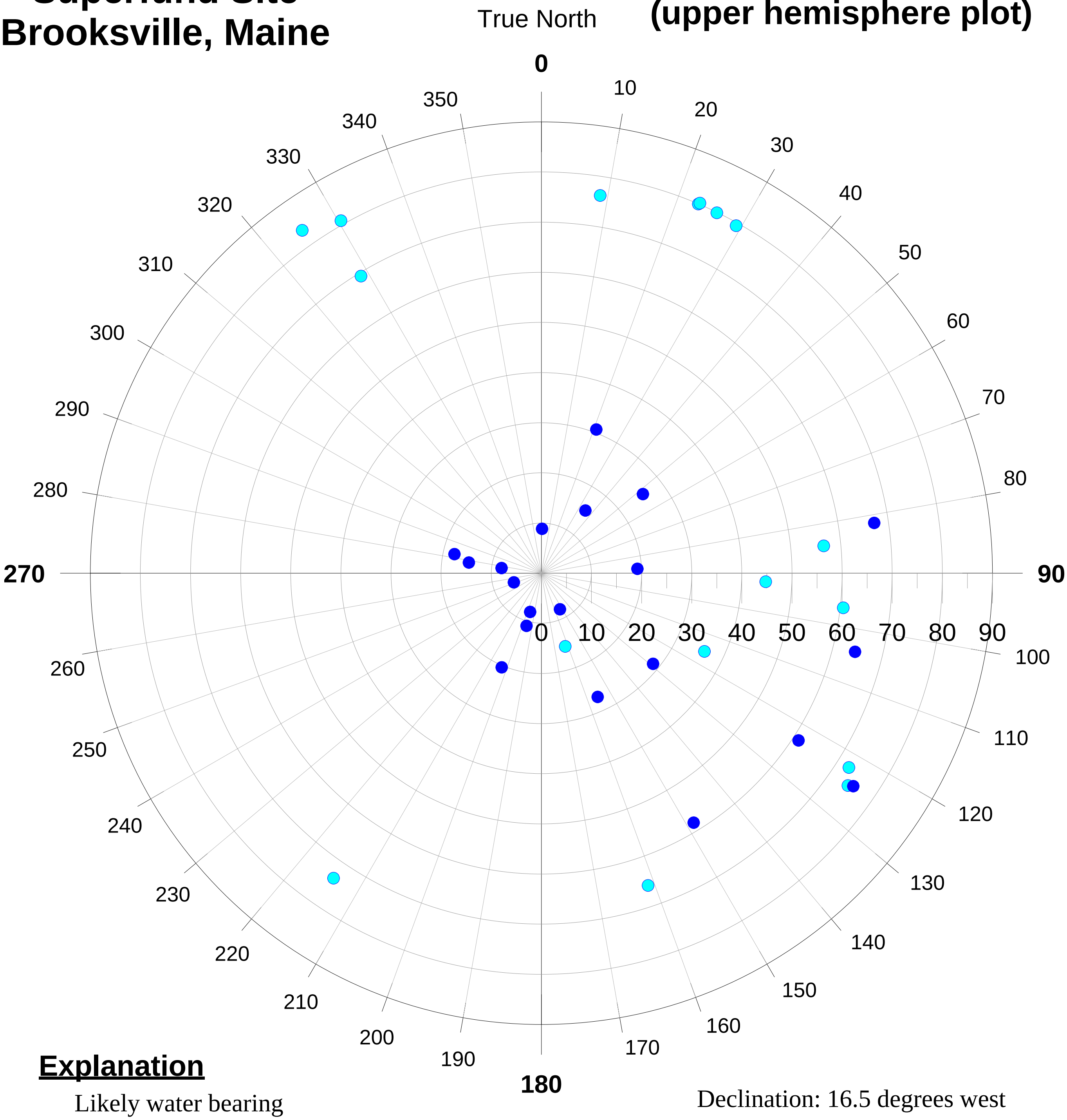
Dip Amount (degrees) of features

Explanation
- Dip direction of feature
- Strike of feature
- Dip Amount (Tilt)

Based on 55 measurements in RC-1143, RC-1144 and RC-1145

Callahan Mine Superfund Site Brooksville, Maine

FIGURE 2
Dip Amount and Dip Azimuth of fractures possibly or likely to be transmissive (upper hemisphere plot)



Explanation

- Likely water bearing
- Possibly water bearing

Declination: 16.5 degrees west

Based on 37 measurements in RC-1143, RC-1144 and RC-1145

Steeply dipping features (over 55°) generally strike to the northwest between 290 and 300° and dip to the northeast. Figure 1A (page 3) is a rose plot of the strike and dip angle of the steeply dipping (over 55°) features. Whereas shallow dipping features (less than 45°) generally strike to the north and dip to the east. Figure 1B (page 4) is a rose plot of the strike and dip angle of the shallow dipping (less than 45°) features.

Of the 118 measured features, 37 were interpreted to be likely or possibly transmissive. Figure 2 (page 5) is an upper hemisphere polar plot showing the dip amount and dip direction of the planar features in the three boreholes that are interpreted to be likely or possibly transmissive. This graph shows that there is a wide range of dips and dip directions of these interpreted fractures. However, the fractures interpreted to be most likely transmissive generally either have shallow dips of less than 30° or they dip towards the east to southeast.

Geophysical Methods and Instrumentation

The boreholes were logged with a Mount Sopris Matrix digital logger. The boreholes were logged with a caliper tool, fluid temperature/fluid conductivity tool, a SPR/SP tool and the OTV and ATV tools. The final log on each borehole was the flowmeter measurements. Following is a brief description of each parameter that was measured and how that information is used to locate possible bedrock fractures.

Temperature (in degrees Centigrade [°C]) is measured with the probe going down each hole. Generally, temperature rises smoothly with depth at a rate of about 1.0° C per 100 feet due to the local geothermal gradient. Areas where water may be entering or exiting the borehole are sometimes revealed on the temperature log as abrupt temperature changes or sometimes as temperature gradient changes. Other factors that can affect the temperature log besides transmissive fractures include variations in the thermal resistivity of the rock with depth along the borehole, surface climatic changes, thermal effects of drilling activity, and localized heat sources such as radionuclides in the rock or cement setting outside the casing.

Single-point-resistance (SPR) measures the electrical resistance (in ohms) between the probe and a surface electrode. Water-filled fractures will often appear as abrupt spikes of relatively low resistance on this log.

Spontaneous potential (SP) measures the natural electrical currents (in milli-volts) in the subsurface. Causes of SP can be due to electrochemical changes or oxidation-reduction potentials that may exist between different layers. Another cause for SP can be streaming potentials caused by fluid movement into or out of a bedrock fracture. Typically SP anomalies appear as spikes towards the left (lower voltage) on the log.

Fluid conductivity measures the conductivity (in micro Siemens) of the water in the borehole. Fluid conductivity can be useful in identifying transmissive fractures because water entering the borehole through fractures sometimes has a different conductivity than the water that is already in the borehole.

Caliper measures the borehole diameter. Fractures are often revealed on the caliper log as abrupt widenings of the borehole.

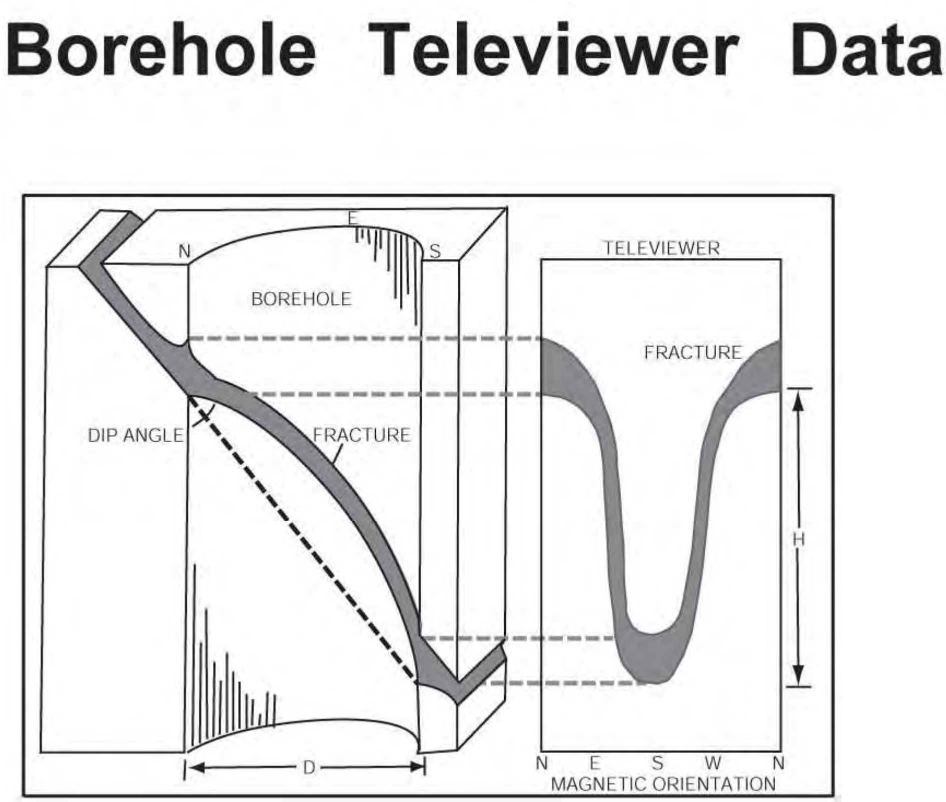
The optical televiewer (OTV) log provides a digital optical image of the borehole walls. The OTV can identify planar features such as fractures, bedding surfaces, and joints and the strike, dip direction and dip angle.

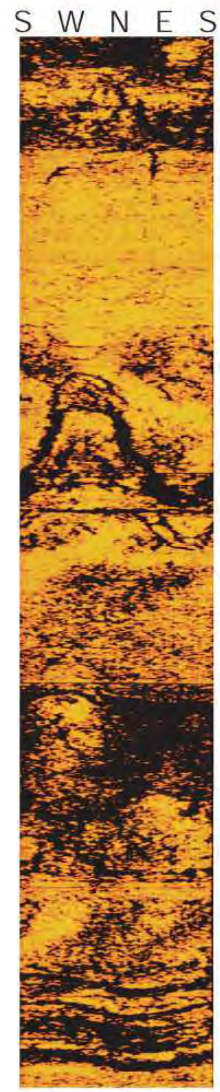
The acoustical televiewer (ATV) log provides an acoustical image of the borehole walls. The

ATV works by scanning the borehole wall with an acoustic beam that is produced by a rapidly rotating piezoelectric source. Similar to the optical televiewer, planar features such as fractures, bedding surfaces and joints can be identified with the ATV tool and the strike, dip direction and dip angle of these features can often be determined.

The optical (OTV) and acoustical (ATV) televiewer logs are somewhat duplicative in that they both can provide similar information. However, there are advantages and disadvantages to both tools. The ATV requires the borehole to be water filled and will not provide information above the water level. The OTV can work in air or water but is not effective in cloudy, turbid water whereas the ATV will work fine in cloudy water. The ATV can be better at discerning voids, cracks and fractures whereas the OTV can be better at discerning lithology. Also, sometimes water-bearing fractures are rust stained, which can be seen by the OTV.

The ATV (and OTV) data are presented as “unwrapped” images of the borehole wall that are oriented to magnetic north. The dip angle and dip direction of any planar feature that intersects the borehole can be measured from this image. The figure below illustrates this.





Each identified feature was digitized using WellCad software which then calculates the dip and dip direction of the features taking into account the borehole tilt and orientation.

The temperature, caliper, SPR, fluid conductivity, ATV and OTV logs were examined and possible bedrock fractures were identified. This information was used to select measurement locations for the flowmeter instrument. Generally, flowmeter measurements were taken in the zone above and below locations where potential fractures might exist in the boreholes.

Flowmeter Measurements

Flowmeter measurements of the vertical water flow were made in the boreholes using a Mount Sopris Heat Pulse Flowmeter. This instrument is capable of measuring flow direction in a borehole (up or down) and has a calibrated measurement range of 1.0 to 0.03 gallons per minute (gpm).

Vertical flow in a borehole is caused when two or more transmissive fractures in the borehole are at hydraulic disequilibrium with one another. When this occurs there is a hydraulic gradient developed and water will flow toward the fracture with the lower hydraulic head. When no vertical flow is measured it can mean that there are less than two transmissive fractures in the borehole or that all the fractures in the borehole are at equilibrium with each other.

Flowmeter measurements are made under ambient (unstressed) conditions and then repeated while stressing the borehole by pumping using a small pump situated near the top of the borehole. The effect of pumping is to cause inflow into the borehole from any transmissive fractures which can be identified by the flowmeter measurements.

Borehole Geophysical Results

Geophysical logs of the boreholes are attached to this report (Attachments A B and C). The geophysical data for each borehole are presented on a series of plots entitled Plates 1-4. The caliper log is plotted on plates 1 and 4 for reference. Attachment A contains data from RC-1143 Attachment B contains data from RC-1144 and Attachment C contains data from RC-1145.

The first plot for each borehole, Plate 1, is a composite log plot containing the caliper log, heat pulse flowmeter, fluid conductivity, temperature, SPR, SP logs and a tadpole plot of the dip and dip direction of the interpreted planar features interpreted from the televiewer logs. The blue colored tadpoles represent possible (light blue) and likely (dark blue) transmissive fractures. The number adjacent to each blue tadpole reference tabulated data for the borehole that provide the strike, dip direction and dip amount of each identified planar feature in the borehole.

One or a combination of anomalous geophysical responses identified physical discontinuities that may represent possible transmissive fractures. These included abrupt widenings in the caliper log, changes in the fluid conductivity log, deflections or gradient changes in the temperature log and the heat pulse flowmeter measurements. The flowmeter log and the temperature and fluid conductivity logs were mainly used to identify transmissive fractures.

Plate 2 is a rose plot of the strike and dip angle of all the interpreted planar features in each borehole.

Plate 3 is an upper hemisphere polar plot of the dip direction and dip amount of planar features in each borehole.

Plate 4 is the televiewer image log plots, caliper log and interpreted structure for each borehole. The ATV logs had very good resolution in all three boreholes. The OTV logs were very good in RC-1144 and RC-1145, however, the water in RC-1143 was too turbid for the OTV log to resolve anything.

Table 1 (A-E) provides the depth and calculated strike and dip of the planar features in each borehole that have been interpreted from the televiewer logs. These planar features may be fractures or may represent cleavage, joints or bedding planes. The results in Table 1 have been categorized and also have been color-coded on the logs to provide an interpretative range of the likelihood that the associated feature signifies a transmissive fracture as follows:

- Dark blue symbol (category 107) - multiple distinct borehole geophysical logging responses indicating borehole enlargement (caliper, SPR, acoustic signal), or evident change in the borehole fluid characteristic (temperature, fluid conductivity, discoloration on the optical log or quantified vertical flow) that provides the strongest data that the indicated bedrock feature represents a likely transmissive water-bearing fracture.
- Light blue symbol (category 108) - less amount of corroborating geophysical data to support that the indicated feature will transmit groundwater compared to the dark blue symbol. However, the televiewer logs show a fairly distinct acoustic signal or optical image that perhaps under a higher stress condition (e.g. pumping rate), vertical flow could be induced in the borehole. Less degree of confidence that the feature represents a transmissive feature.
- Black symbol (category 101) - bedrock feature not interpreted to transmit water; more likely to represent healed or filled fractures, joints, cracks or mechanical breaks in the rock matrix due to drilling advancement.
- Black symbol (category 100) - bedrock feature not interpreted to transmit water; more likely to represent planes of foliation or bedding planes or healed or filled fractures that parallel the bedding/foliation.

It is possible that there are other transmissive fractures in the boreholes but the ones indicated on the logs and tables are considered the most likely based on the geophysical measurements.

ATTACHMENT A

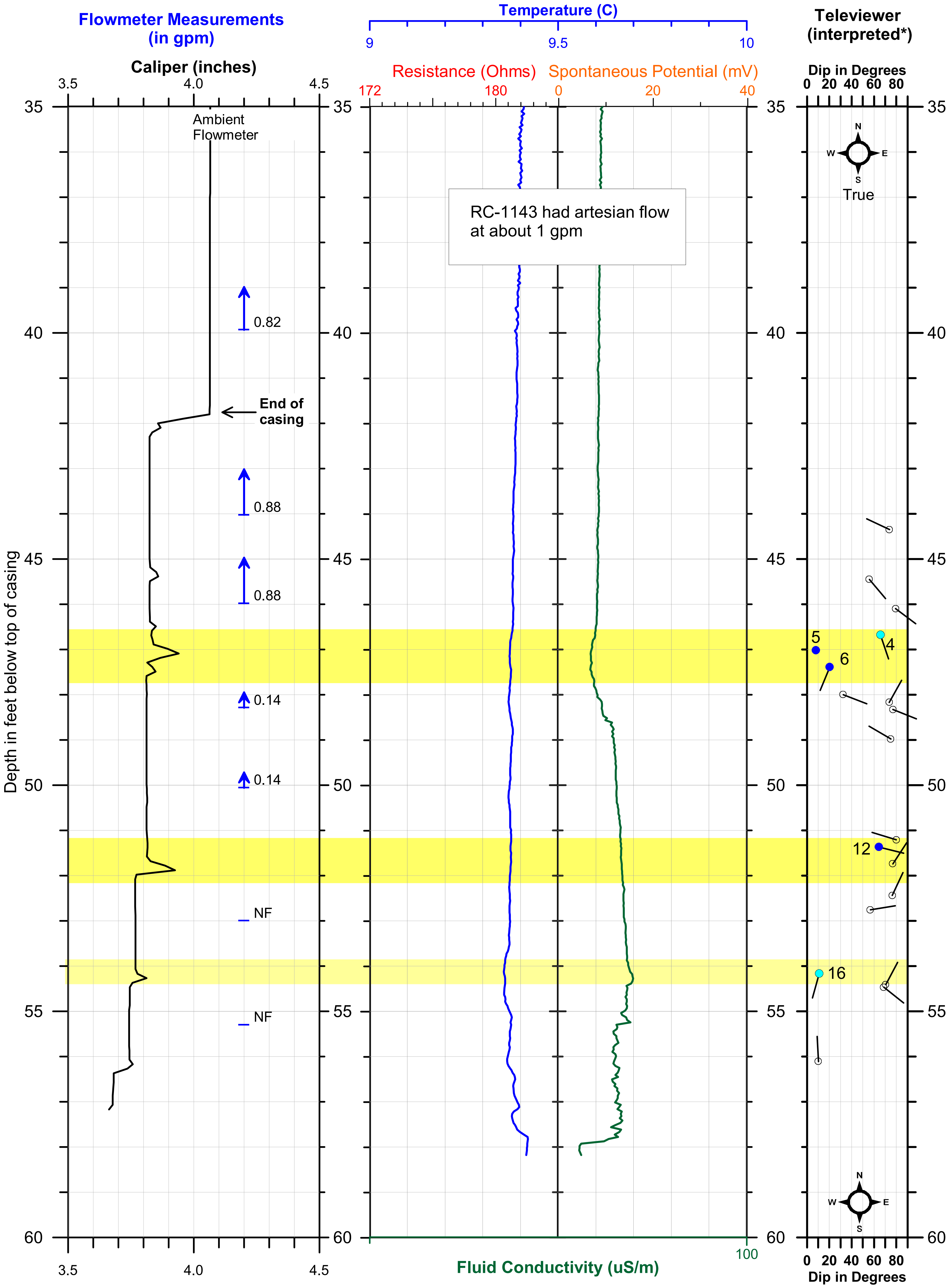
RC-1143

BOREHOLE GEOPHYSICAL LOGS

Northeast Geophysical Services

PLATE A-1
Borehole Geophysical Log
RC-1143
Callahan Mine Superfund Site
Brooksville, Maine

Date logged: 12/20/12



= Likely transmissive zone

= possible transmissive zone

The dip direction is indicated by the line extending from the circle. The strike of the feature is 90 degrees from this.

PLATE A-1
Borehole Geophysical Log
RC-1143
Callahan Mine Superfund Site

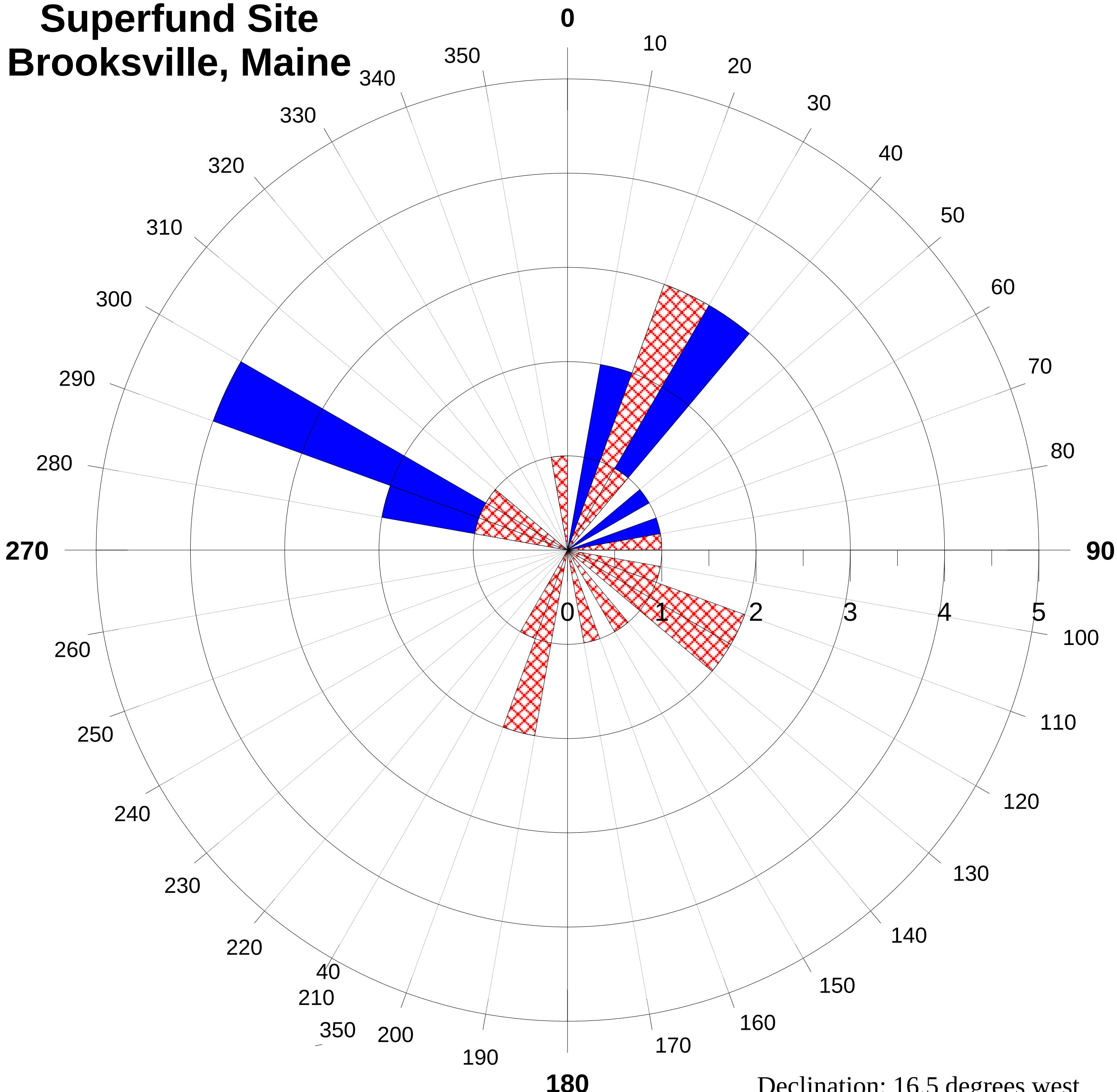
Date logged: 12/20/12

Northeast Geophysical Services

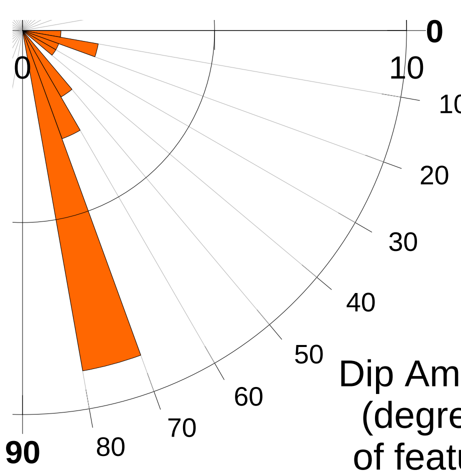
RC-1143
Callahan Mine Superfund Site
Brooksville, Maine

PLATE A-2
Strike and Dip Direction of all features

True North



Declination: 16.5 degrees west



Dip Amount (degrees) of features

Explanation

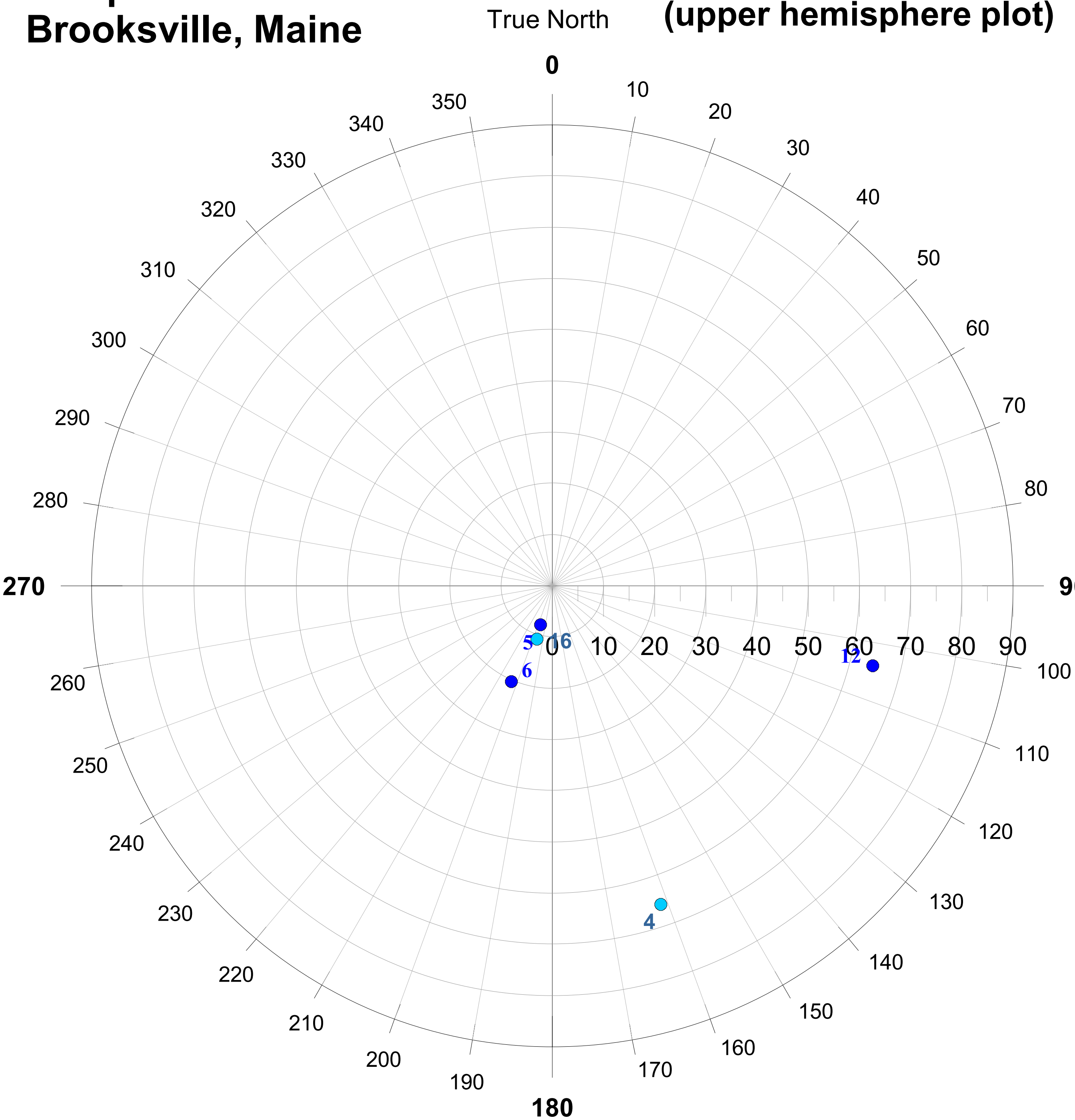
- Dip direction of feature
- Strike of feature
- Dip Amount (Tilt)

Based on 19 measurements

Northeast Geophysical Services

RC-1143
Callahan Mine Superfund Site
Brooksville, Maine

PLATE A-3
Dip Amount and Dip Azimuth of planar features likely or possibly transmissive (upper hemisphere plot)



Explanation - Fracture widths

- Possibly transmissive
- Likely transmissive

Declination: 16.4 degrees west

Based on 5 measurements

Northeast Geophysical Services	**Log:** Plate A-4 Caliper & Televiewer
	Well: RC-1143
	Site: Callahan Mine
Date: 12/20/2012	**Location:** Brooksville
Casing Depth: 42 ft	**For:** AMEC
Casing Type: 4 inch	**Logged by:** R. Rawcliffe
Boring Depth: 58.2 ft	**Orientation:** magnetic
Meas. From: toc	**Structure Plots:**
Stickup: 1.7 ft	black = planar features (faults, foliation, bedding, joints, etc) light blue = possibly transmissive fracture dark blue = likely transmissive fracture
Water Level: 0 (artesian)	

4 Union Street Bangor, Maine 04401
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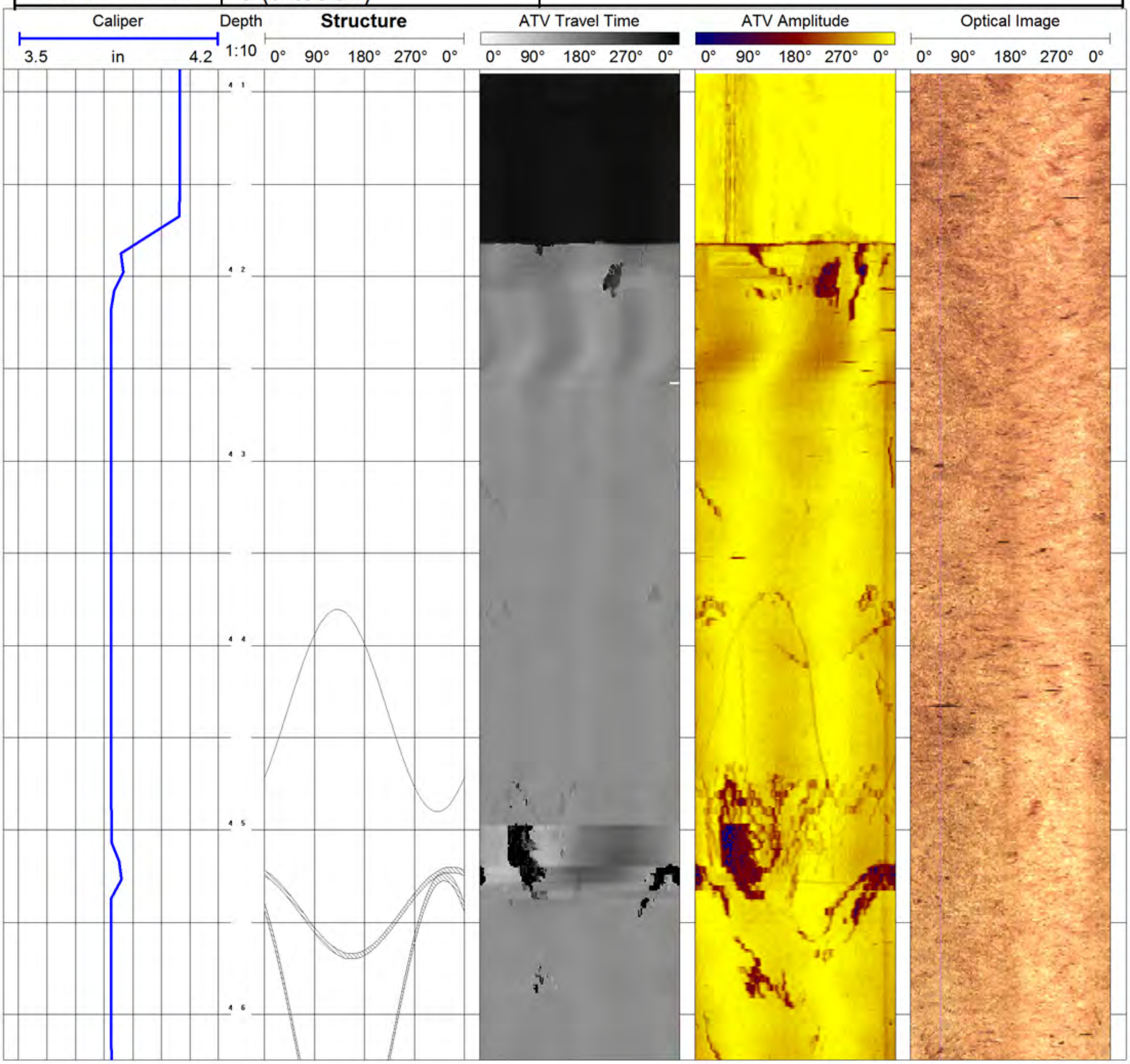
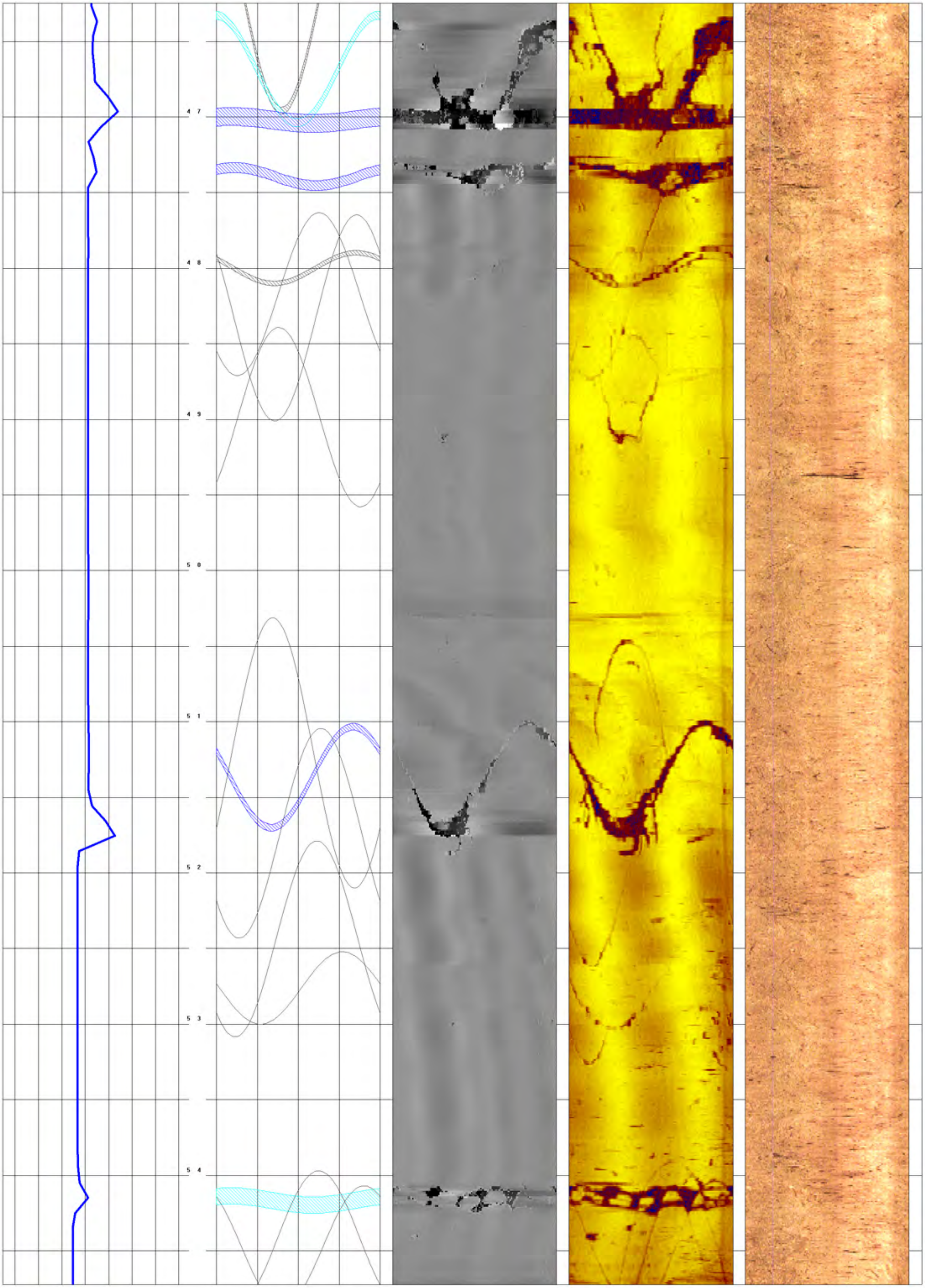
email: ngsinc@negeophysical.com

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5 1
5 2
5 3
5 4

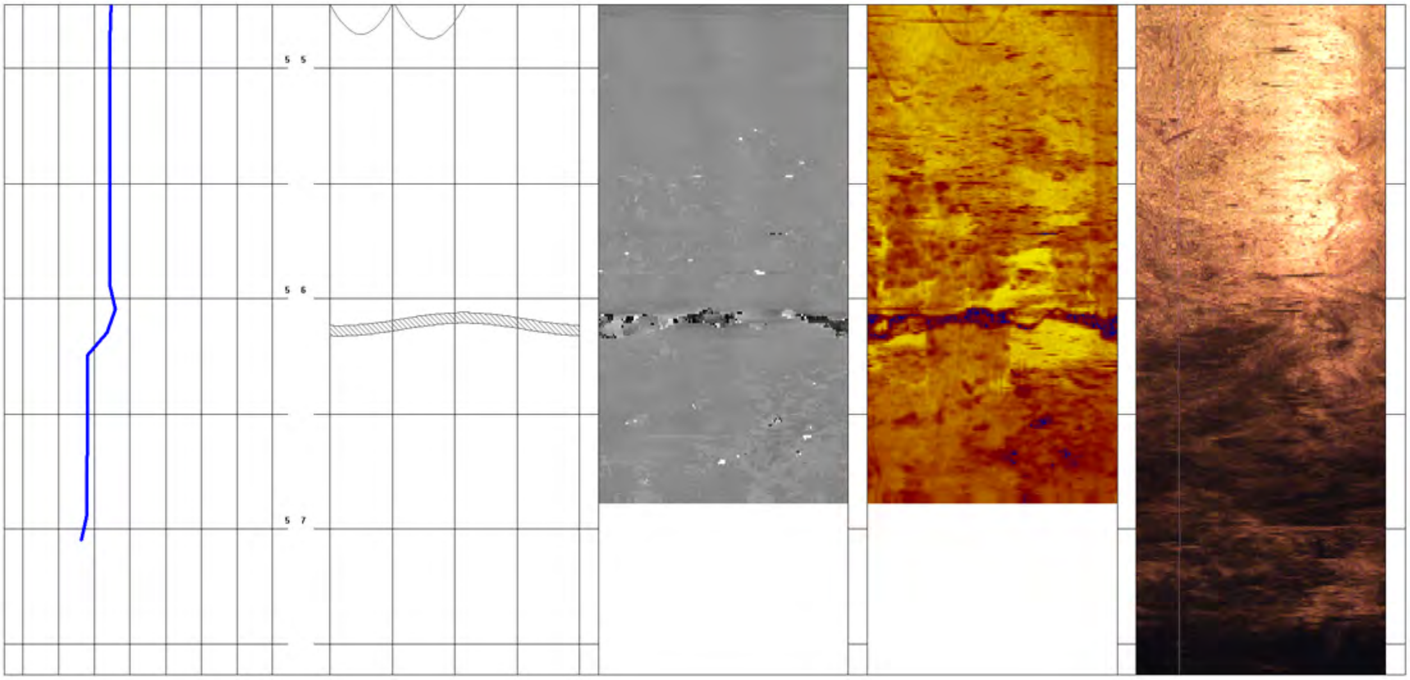
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TABLE A-1 - Planar features interpreted from acoustical and optical televiewers
RC-1143 - Callahan Mine Superfund Site - Brooksville, Maine

Logged: December 2012

Borehole	Feature # Number	Feature depth Feet	Dip Degrees	Dip Azimuth magnetic	Strike magnetic	Dip Azimuth True	Strike True	Aperture mm	Category Type
RC-1143	1	44.4	74	311	41	295	25	<1 mm	101
RC-1143	2	45.5	56	157	67	140	50	5	101
RC-1143	3	46.1	79	143	53	127	37	3	101
RC-1143	4	46.7	66	178	88	161	71	7	108
RC-1143	5	47.0	8	213	303	196	286	35	107
RC-1143	6	47.4	20	219	309	203	293	19	107
RC-1143	7	48.0	32	127	37	111	21	7	101
RC-1143	8	48.2	74	46	316	29	299	<1 mm	101
RC-1143	9	48.3	77	129	39	112	22	<1 mm	101
RC-1143	10	49.0	75	317	47	301	31	<1 mm	101
RC-1143	11	51.2	80	304	34	287	17	<1 mm	101
RC-1143	12	51.4	65	121	31	104	14	6	107
RC-1143	13	51.7	77	50	320	33	303	<1 mm	101
RC-1143	14	52.4	76	41	311	25	295	<1 mm	101
RC-1143	15	52.8	57	97	7	80	350	<1 mm	101
RC-1143	16	54.2	11	212	302	196	286	32	108
RC-1143	17	54.4	70	45	315	28	298	<1 mm	101
RC-1143	18	54.5	69	145	55	128	38	<1 mm	101
RC-1143	19	56.1	10	13	283	357	87	14	101

Explanation:

Category 100 = planar feature (possible foliation, bedding, etc.)
Category 101 = planar feature (possible fracture, joint, etc.)
Category 107 = Likely water bearing feature
Category 108 = Possible water bearing fracture

ATTACHMENT B

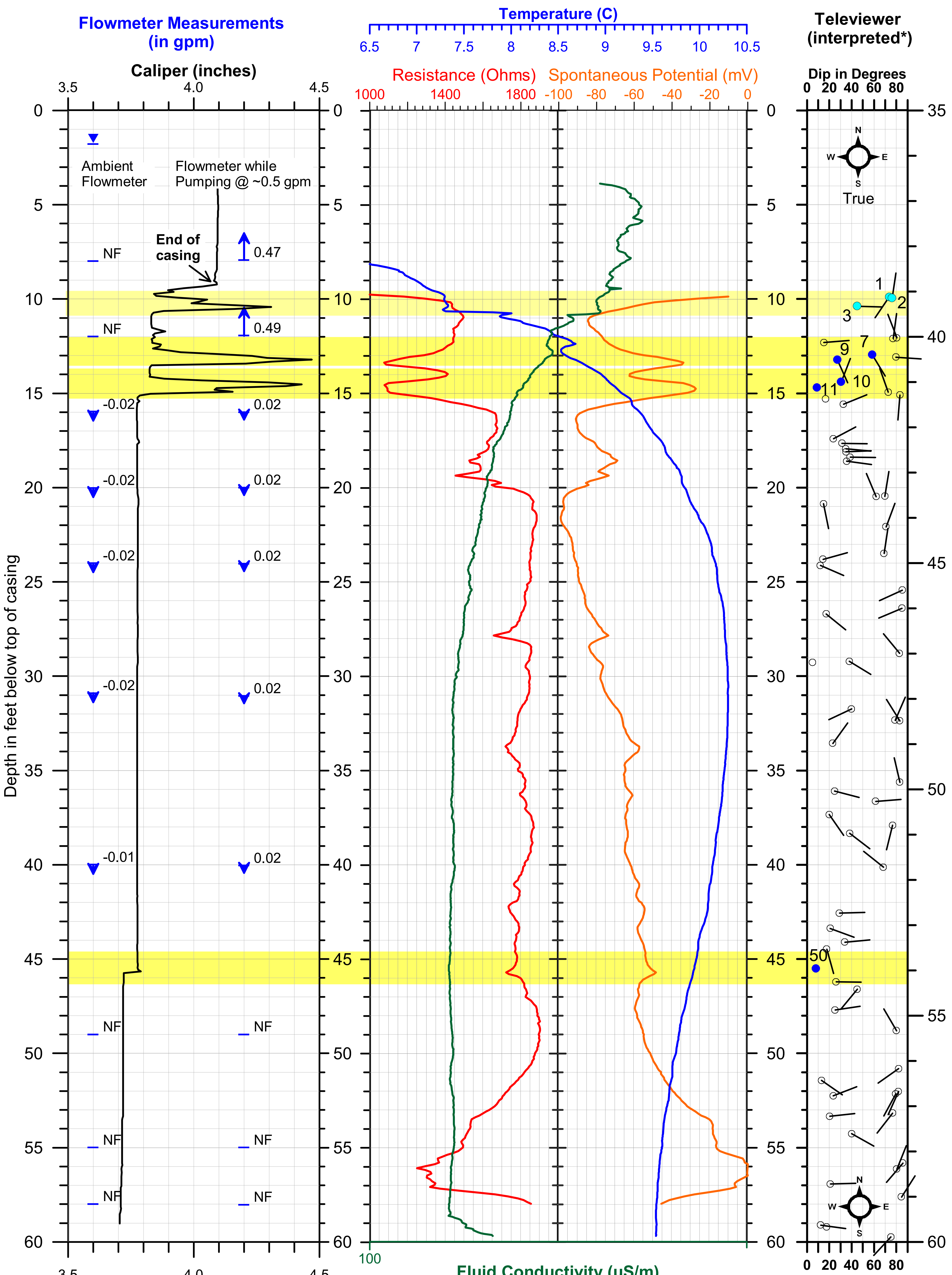
RC-1144

BOREHOLE GEOPHYSICAL LOGS

Northeast Geophysical Services

PLATE B-1
Borehole Geophysical Log
RC-1144
Callahan Mine Superfund Site
Brooksville, Maine

Date logged: 01/13/13



= Likely transmissive zone

= possible transmissive zone

PLATE B-1
Borehole Geophysical Log
RC-1144
Callahan Mine Superfund Site

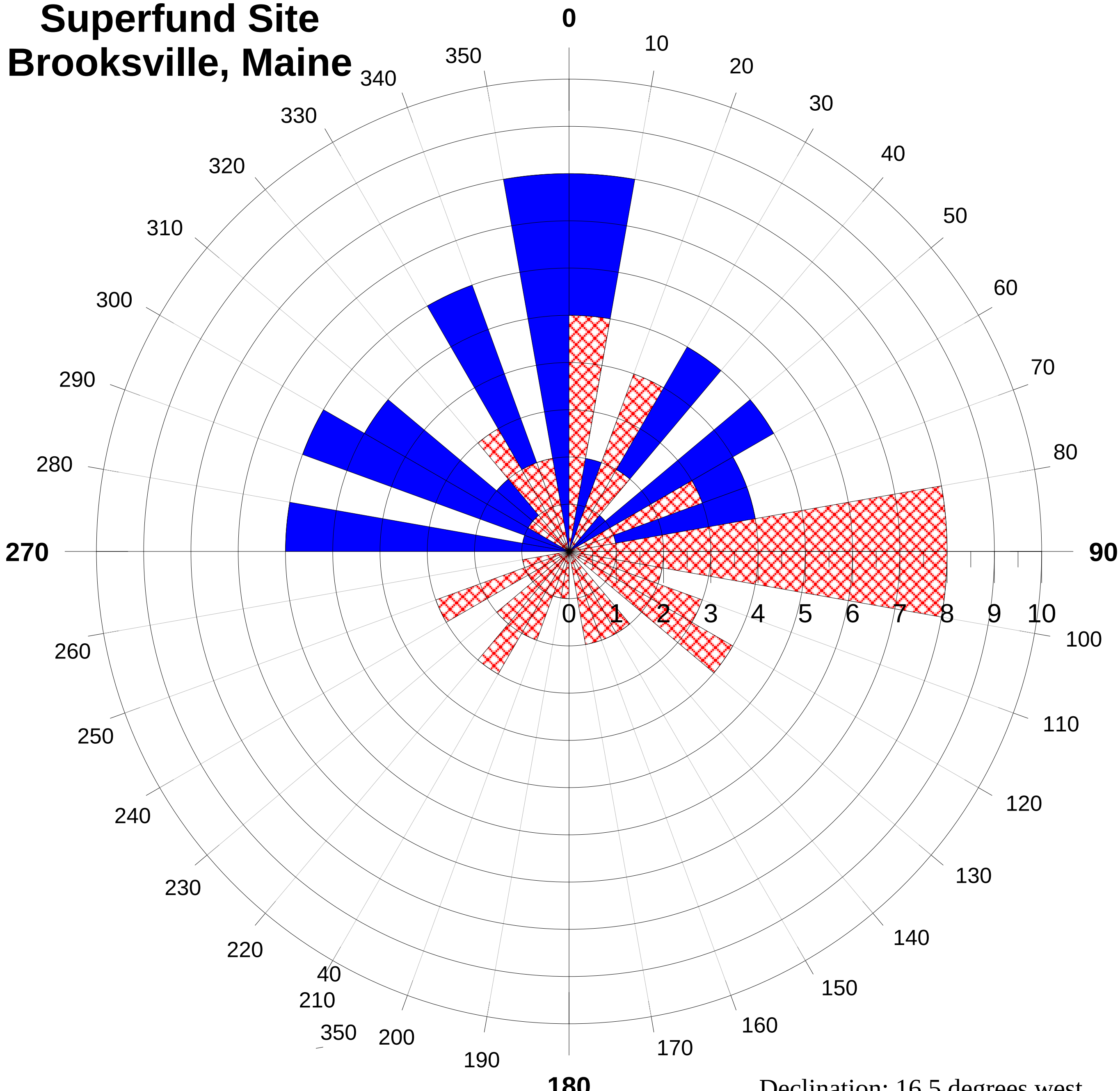
The dip direction is indicated by the line extending from the circle. The strike of the feature is 90 degrees from this.

Date logged: 01/13/13

Northeast Geophysical Services

RC-1144
Callahan Mine Superfund Site
Brooksville, Maine

PLATE B-2
Strike and Dip Direction of all features



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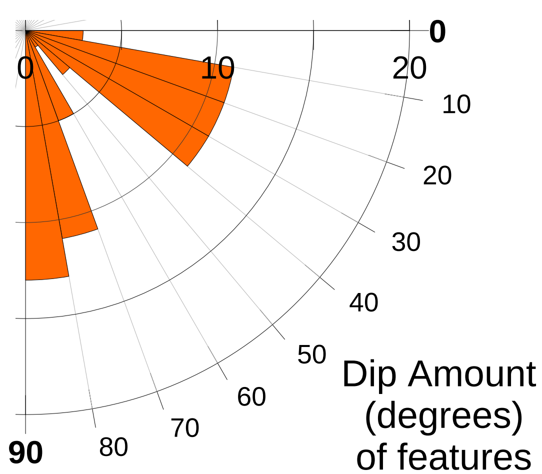


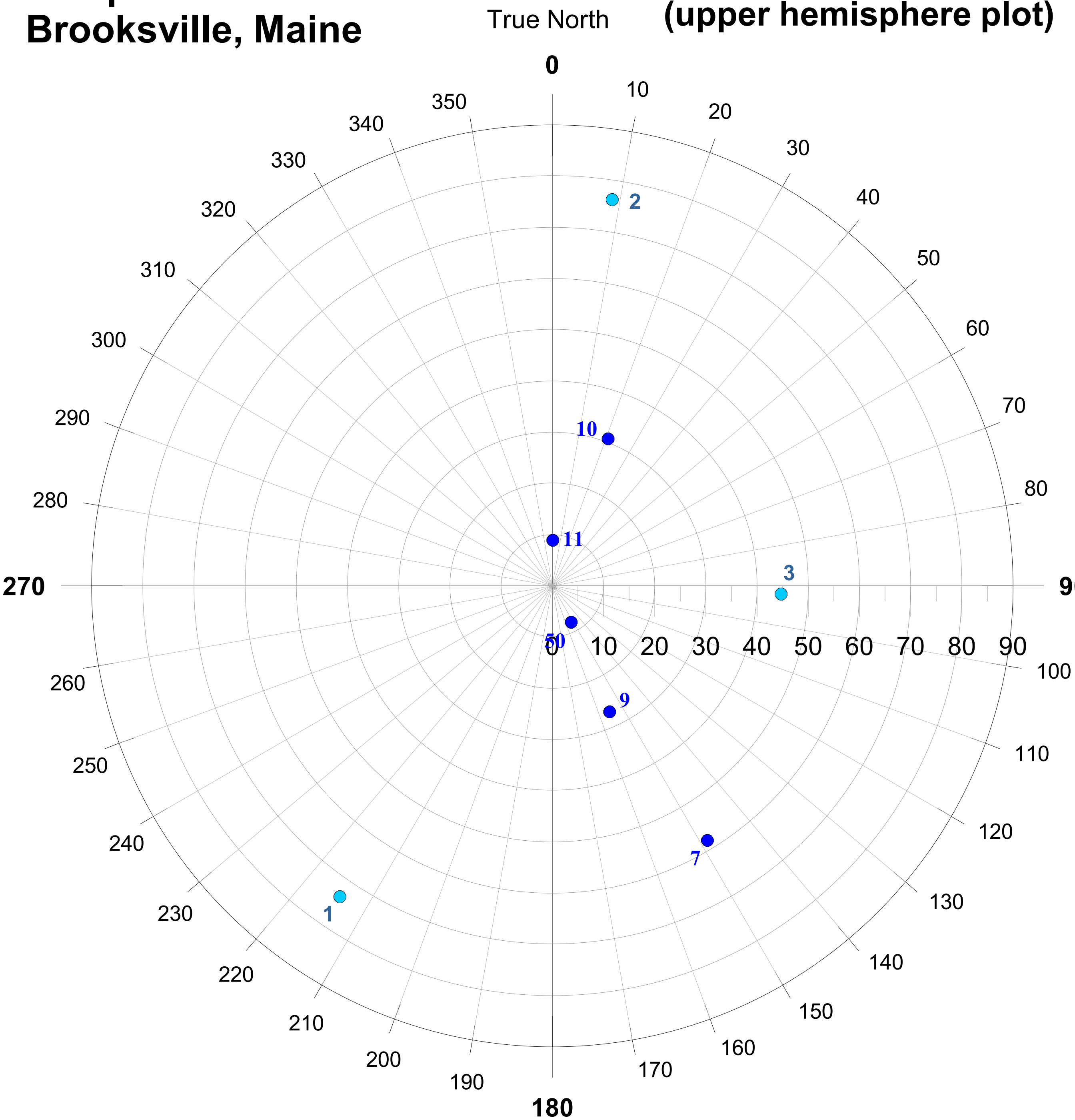
Explanation
- Dip direction of feature
- Strike of feature
- Dip Amount (Tilt)

Based on 69 measurements

Northeast Geophysical Services

RC-1144
Callahan Mine Superfund Site
Brooksville, Maine

PLATE B-3
Dip Amount and Dip Azimuth of planar features likely or possibly transmissive (upper hemisphere plot)



Explanation - Fracture widths

- Possibly transmissive
- Likely transmissive

Declination: 16.4 degrees west

Based on 8 measurements

Northeast Geophysical Services
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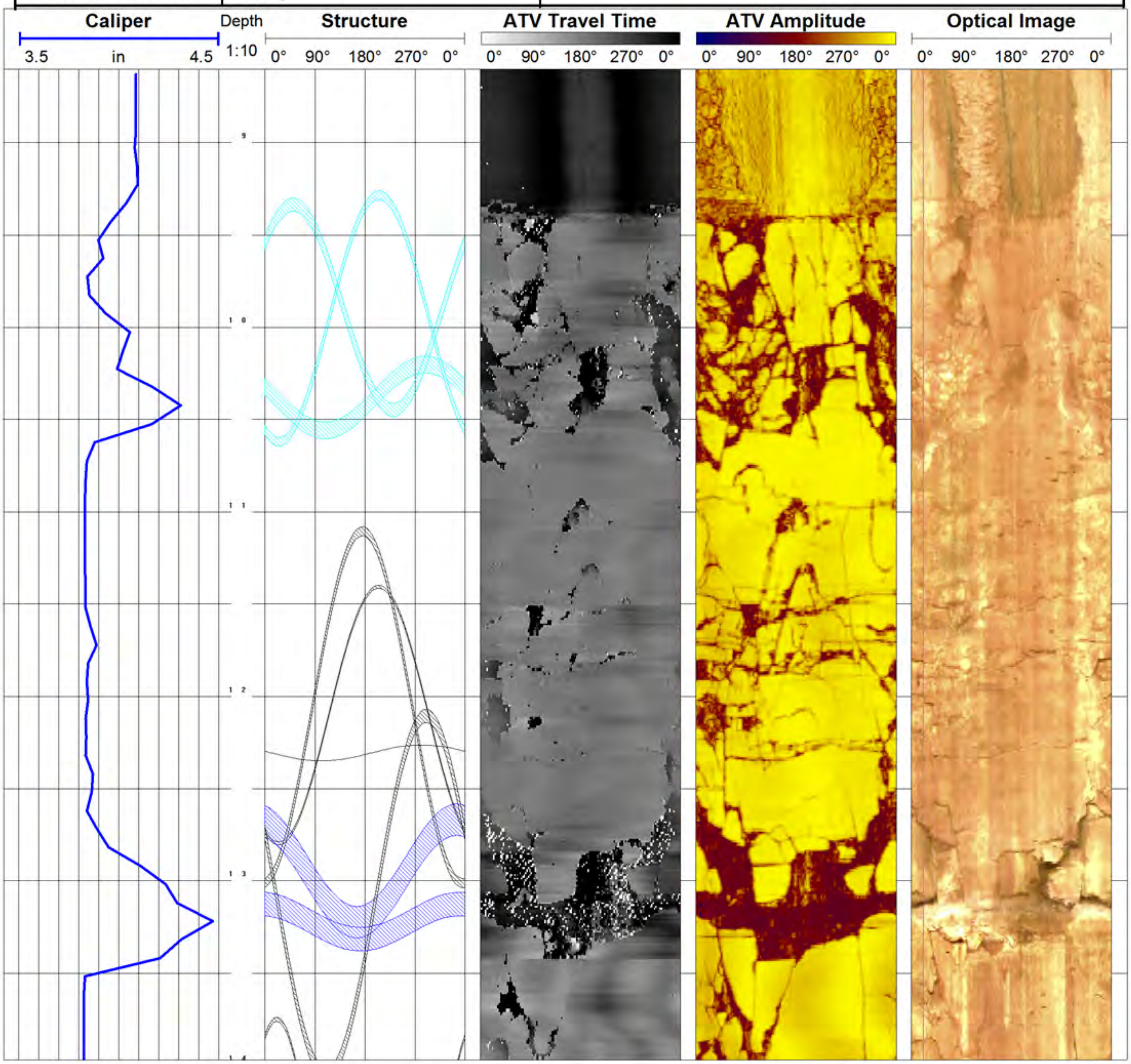
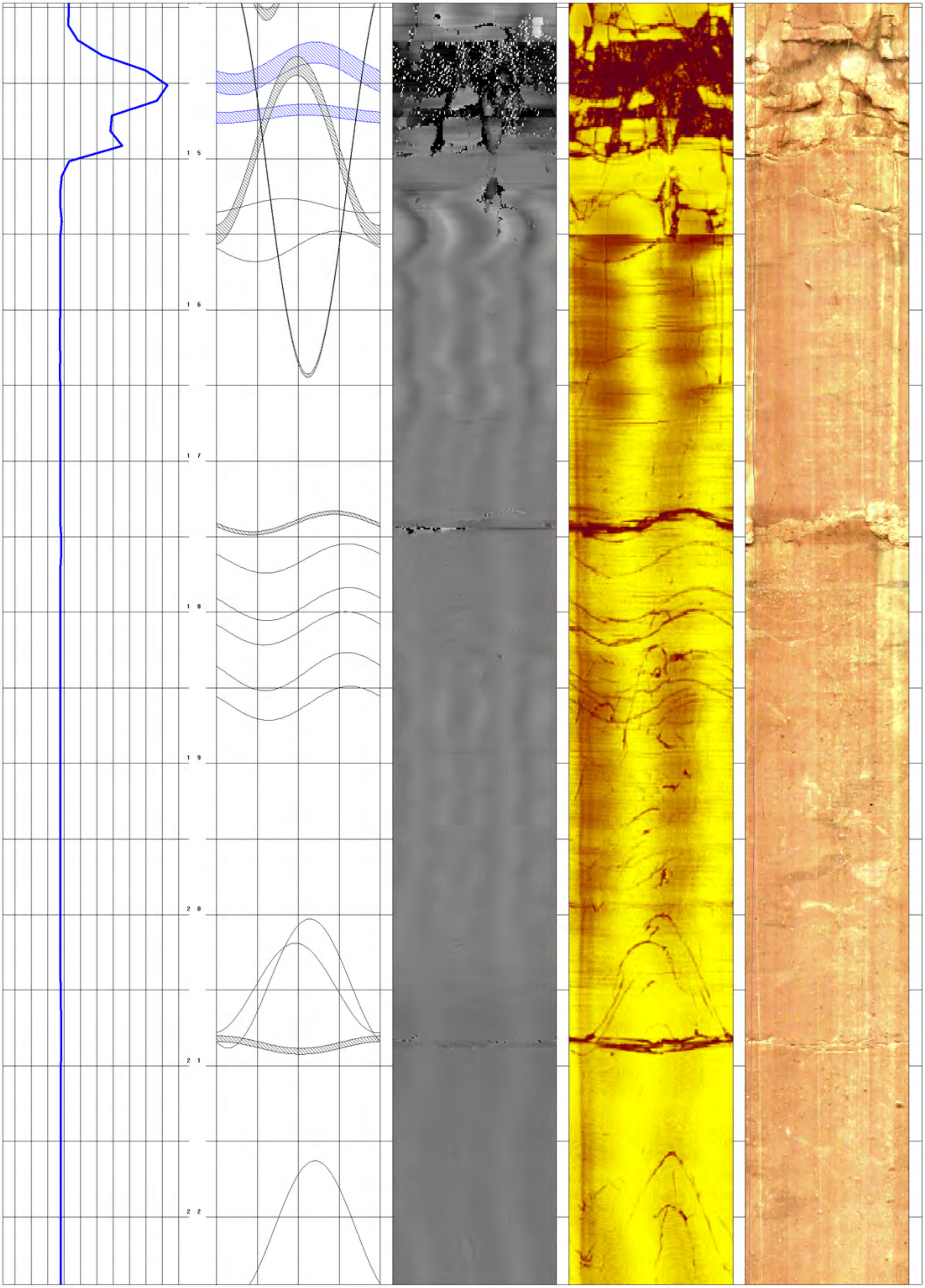
Tel. 207-942-2700
email: ngsinc@negeophysical.com

Log:	Plate B-4 Caliper & Televiewer		
Well:	**RC-1144**		
Site:	Callahan Mine		
Date:	01/09/2013	**Location:**	Brooksville
Casing Depth:	9.5 ft	**For:**	AMEC
Casing Type:	4 inch	**Logged by:**	R. Rawcliffe
Boring Depth:	60.0	**Orientation:**	magnetic
Meas. From:	toc	**Structure Plots:**	black = planar features (faults, foliation, bedding, joints, etc) light blue = possibly transmissive fracture dark blue = likely transmissive fracture
Stickup:	1.5		
Water Level:	1.79		

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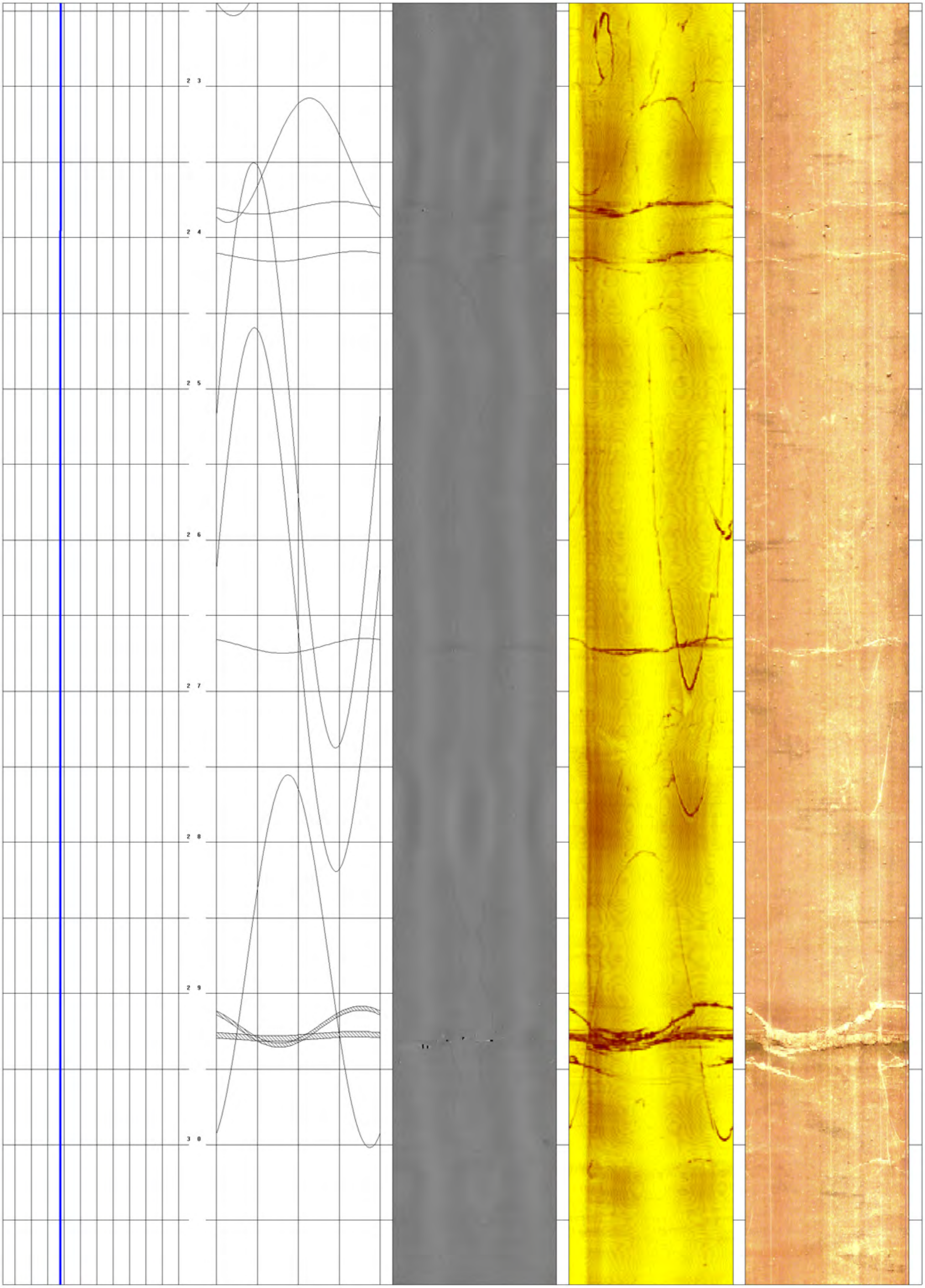
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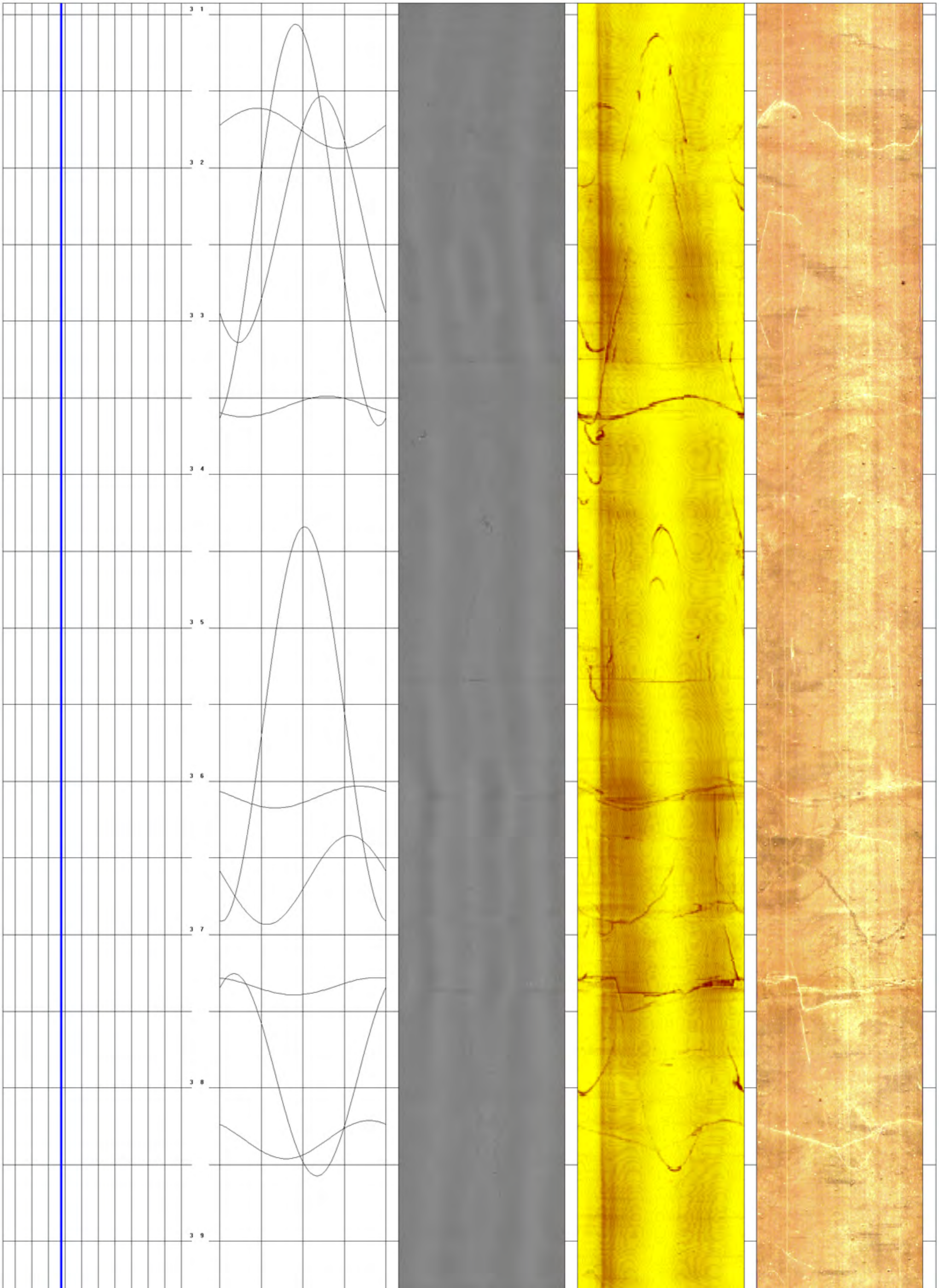
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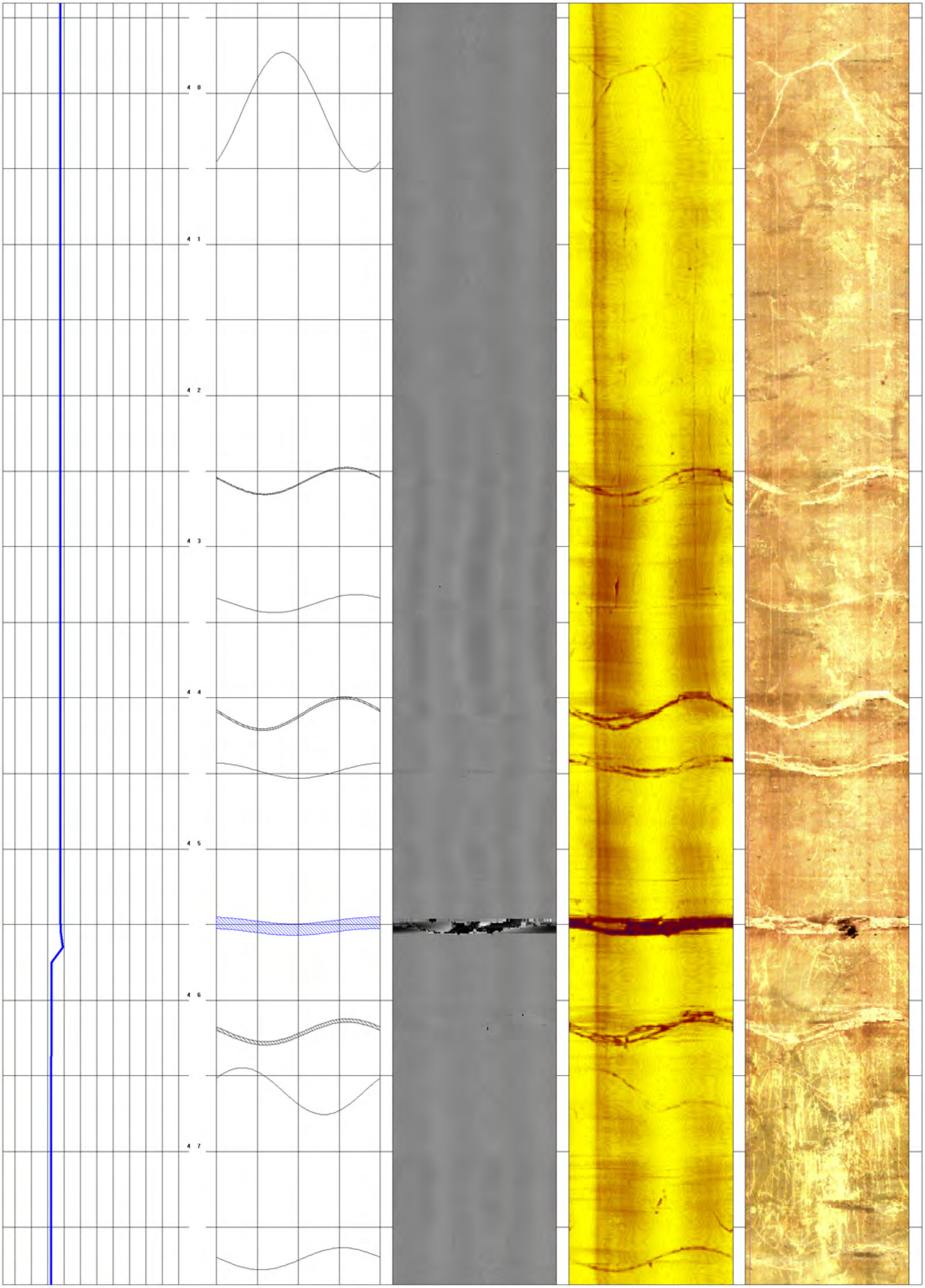
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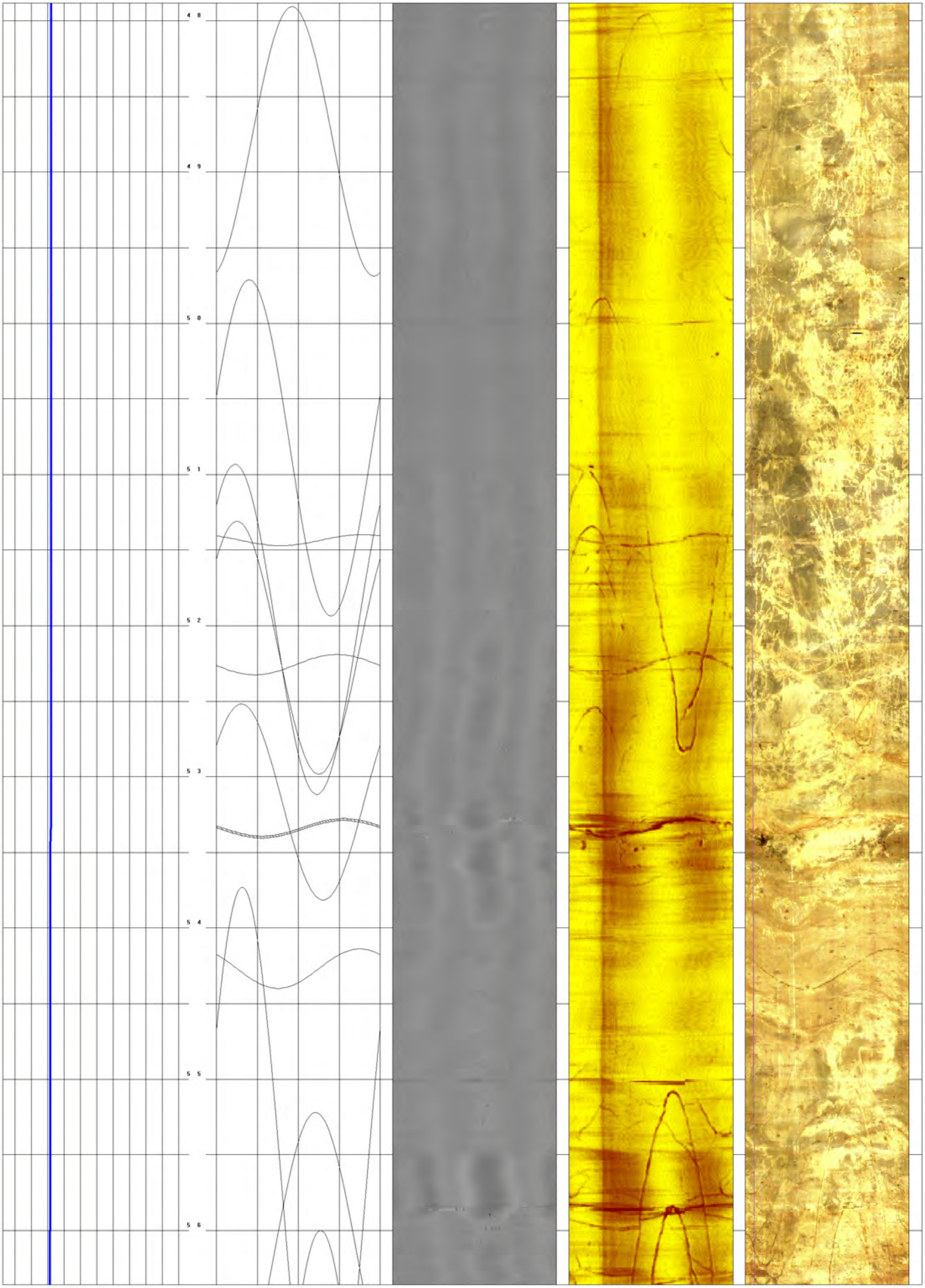
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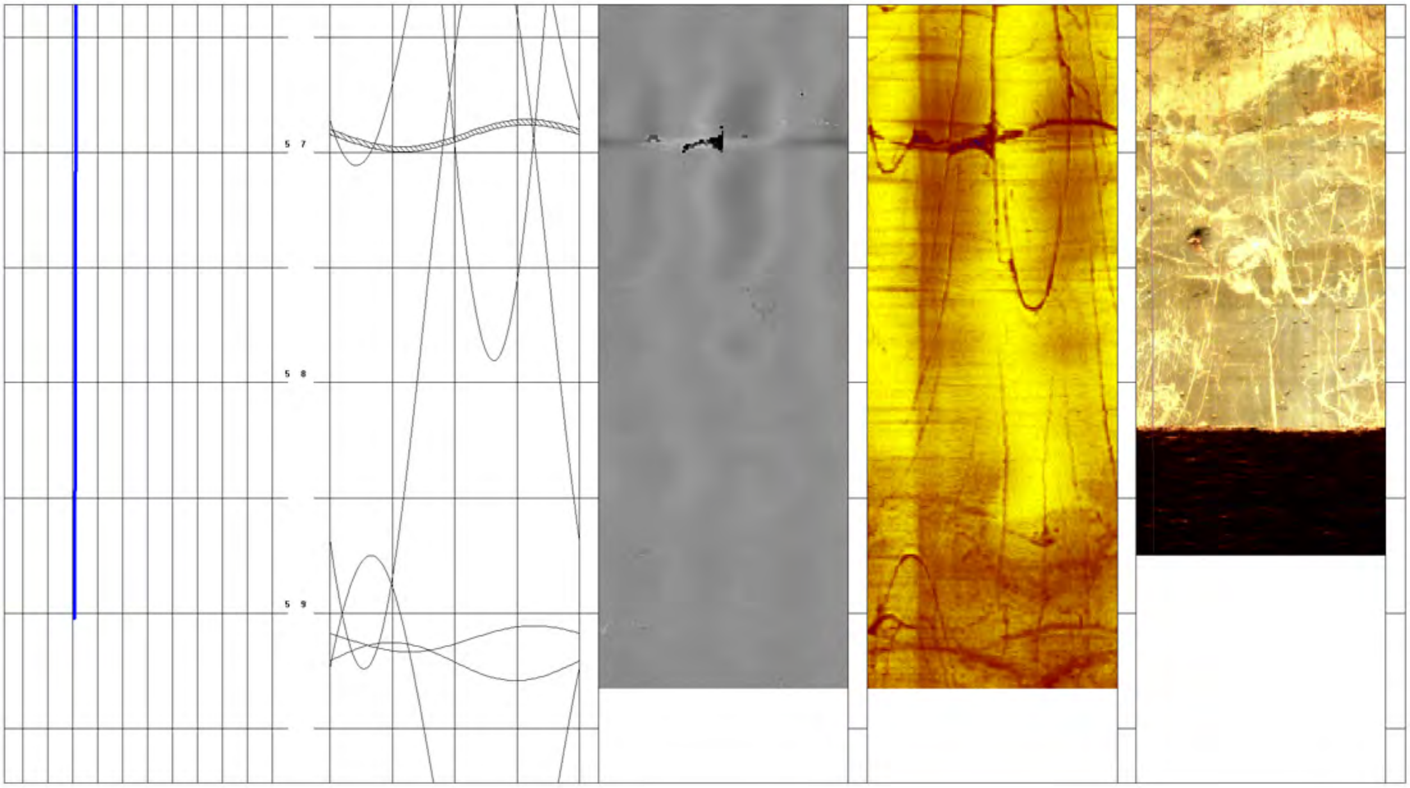
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TABLE B-1 - Planar features interpreted from acoustical and optical televiewers
RC-1144 - Callahan Mine Superfund Site - Brooksville, Maine

Logged: December 2012

Borehole	Feature # Number	Feature depth Feet	Dip Degrees	Dip Azimuth magnetic	Strike magnetic	Dip Azimuth True	Strike True	Aperture mm
RC-1144	1	9.9	74	231	321	214	304	6
RC-1144	2	10.0	76	25	295	9	279	4
RC-1144	3	10.4	45	109	19	92	2	21
RC-1144	4	12.1	80	355	85	339	69	2
RC-1144	5	12.1	77	25	295	8	278	1
RC-1144	6	12.3	15	102	12	85	355	<1 mm
RC-1144	7	13.0	58	165	75	149	59	27
RC-1144	8	13.1	80	110	20	94	4	4
RC-1144	9	13.2	27	172	82	156	66	35
RC-1144	10	14.4	31	37	307	21	291	36
RC-1144	11	14.7	9	17	287	1	271	22
RC-1144	12	14.9	73	357	87	340	70	11
RC-1144	13	15.1	83	201	291	185	275	1
RC-1144	14	15.3	17	333	63	316	46	<1 mm
RC-1144	15	15.6	33	85	355	68	338	<1 mm
RC-1144	16	17.4	24	79	349	62	332	6
RC-1144	17	17.7	31	108	18	91	1	<1 mm
RC-1144	18	18.0	35	111	21	95	5	<1 mm
RC-1144	19	18.1	35	104	14	88	358	<1 mm
RC-1144	20	18.4	39	107	17	91	1	<1 mm
RC-1144	21	18.6	35	114	24	98	8	<1 mm
RC-1144	22	20.5	70	25	295	9	279	<1 mm
RC-1144	23	20.5	62	354	84	337	67	<1 mm
RC-1144	24	20.9	15	185	275	168	78	12
RC-1144	25	22.1	71	37	307	20	290	<1 mm
RC-1144	26	23.5	69	25	295	8	278	<1 mm
RC-1144	27	23.8	14	91	1	75	345	<1 mm
RC-1144	28	24.1	12	130	40	113	23	<1 mm
RC-1144	29	25.4	85	262	352	246	336	<1 mm
RC-1144	30	26.4	85	263	353	247	337	<1 mm
RC-1144	31	26.7	17	146	56	129	39	<1 mm
RC-1144	32	28.8	83	338	68	321	51	<1 mm
RC-1144	33	29.2	38	138	48	121	31	6
RC-1144	34	29.3	5	126	36	109	19	11
RC-1144	35	31.7	40	261	351	245	335	<1 mm
RC-1144	36	32.3	79	40	310	24	294	<1 mm
RC-1144	37	32.4	83	344	74	328	58	<1 mm
RC-1144	38	33.6	23	53	323	36	306	<1 mm
RC-1144	39	35.6	83	4	274	347	77	<1 mm
RC-1144	40	36.1	25	121	31	104	14	<1 mm
RC-1144	41	36.6	62	102	12	85	355	<1 mm
RC-1144	42	37.3	20	162	72	145	55	<1 mm
RC-1144	43	37.9	77	211	301	194	284	<1 mm
RC-1144	44	38.3	38	144	54	127	37	<1 mm
RC-1144	45	40.1	68	326	56	309	39	<1 mm
RC-1144	46	42.6	29	105	15	89	359	2
RC-1144	47	43.4	21	127	37	111	21	<1 mm
RC-1144	48	44.1	34	101	11	84	354	4
RC-1144	49	44.5	18	181	271	164	74	<1 mm
RC-1144	50	45.5	8	169	79	153	63	23
RC-1144	51	46.2	26	107	17	90	0	6
RC-1144	52	46.6	45	236	326	220	310	<1 mm

TABLE B-1 - Planar features interpreted from acoustical and optical televiewers
RC-1144 - Callahan Mine Superfund Site - Brooksville, Maine

Logged: December 2012

Borehole	Feature # Number	Feature depth Feet	Dip Degrees	Dip Azimuth magnetic	Strike magnetic	Dip Azimuth True	Strike True	Aperture mm
RC-1144	53	47.7	25	98	8	81	351	<1 mm
RC-1144	54	48.8	80	346	76	330	60	<1 mm
RC-1144	55	50.8	82	252	342	236	326	<1 mm
RC-1144	56	51.4	13	141	51	124	34	<1 mm
RC-1144	57	52.0	82	221	311	204	294	<1 mm
RC-1144	58	52.2	80	225	315	209	299	<1 mm
RC-1144	59	52.3	24	85	355	69	339	<1 mm
RC-1144	60	53.2	77	235	325	218	308	<1 mm
RC-1144	61	53.3	20	100	10	84	354	3
RC-1144	62	54.3	40	135	45	119	29	<1 mm
RC-1144	63	55.8	86	237	327	220	310	<1 mm
RC-1144	64	56.1	80	38	308	22	292	<1 mm
RC-1144	65	56.9	21	105	15	88	358	7
RC-1144	66	57.6	85	49	319	33	303	<1 mm
RC-1144	67	59.1	12	114	24	98	8	<1 mm
RC-1144	68	59.2	18	268	358	252	342	<1 mm
RC-1144	69	59.7	75	240	330	223	313	<1 mm

Explanation:

Category 100 = planar feature (possible foliation, bedding, etc.)
Category 101 = planar feature (possible fracture, joint, etc.)
Category 107 = Likely water bearing feature
Category 108 = Possible water bearing fracture

ATTACHMENT C

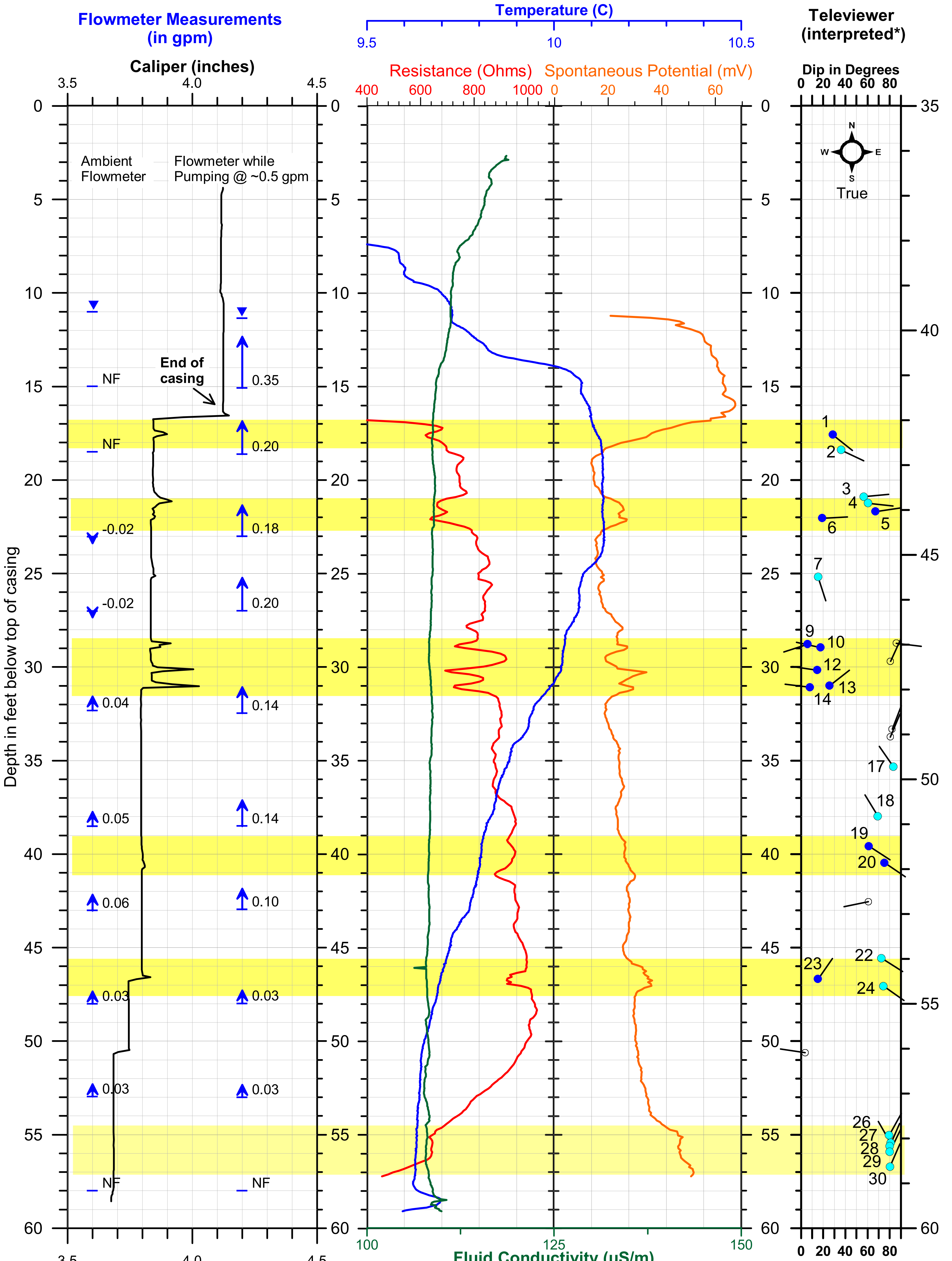
RC-1145

BOREHOLE GEOPHYSICAL LOGS

Northeast Geophysical Services

PLATE C-1
Borehole Geophysical Log
RC-1145
Callahan Mine Superfund Site
Brooksville, Maine

Date logged: 01/13/13



= Likely transmissive zone

= possible transmissive zone

The dip direction is indicated by the line extending from the circle. The strike of the feature is 90 degrees from this.

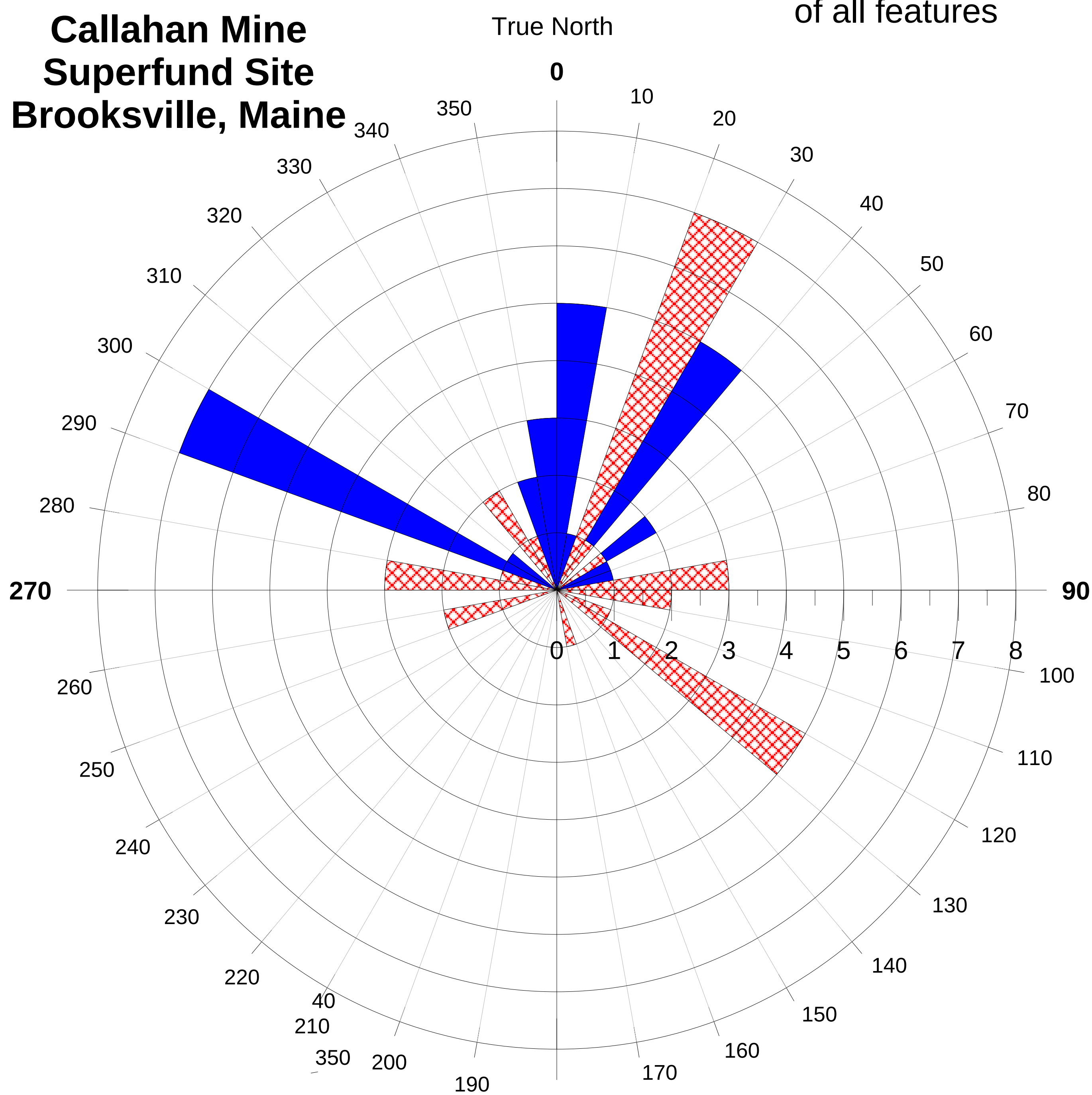
PLATE C-1
Borehole Geophysical Log
RC-1145
Callahan Mine Superfund Site

Date logged: 01/13/13

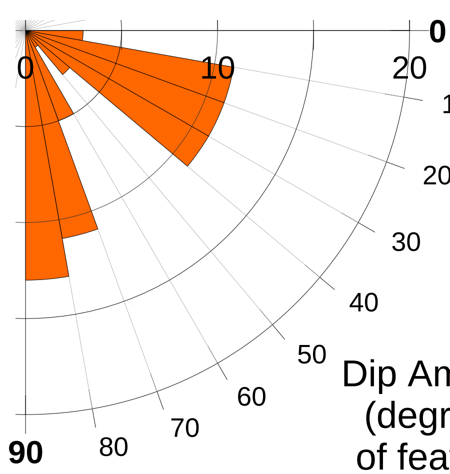
Northeast Geophysical Services

PLATE C-2
Strike and Dip Direction of all features

RC-1145
Callahan Mine Superfund Site
Brooksville, Maine



Declination: 16.5 degrees west



Dip Amount (degrees) of features

Explanation

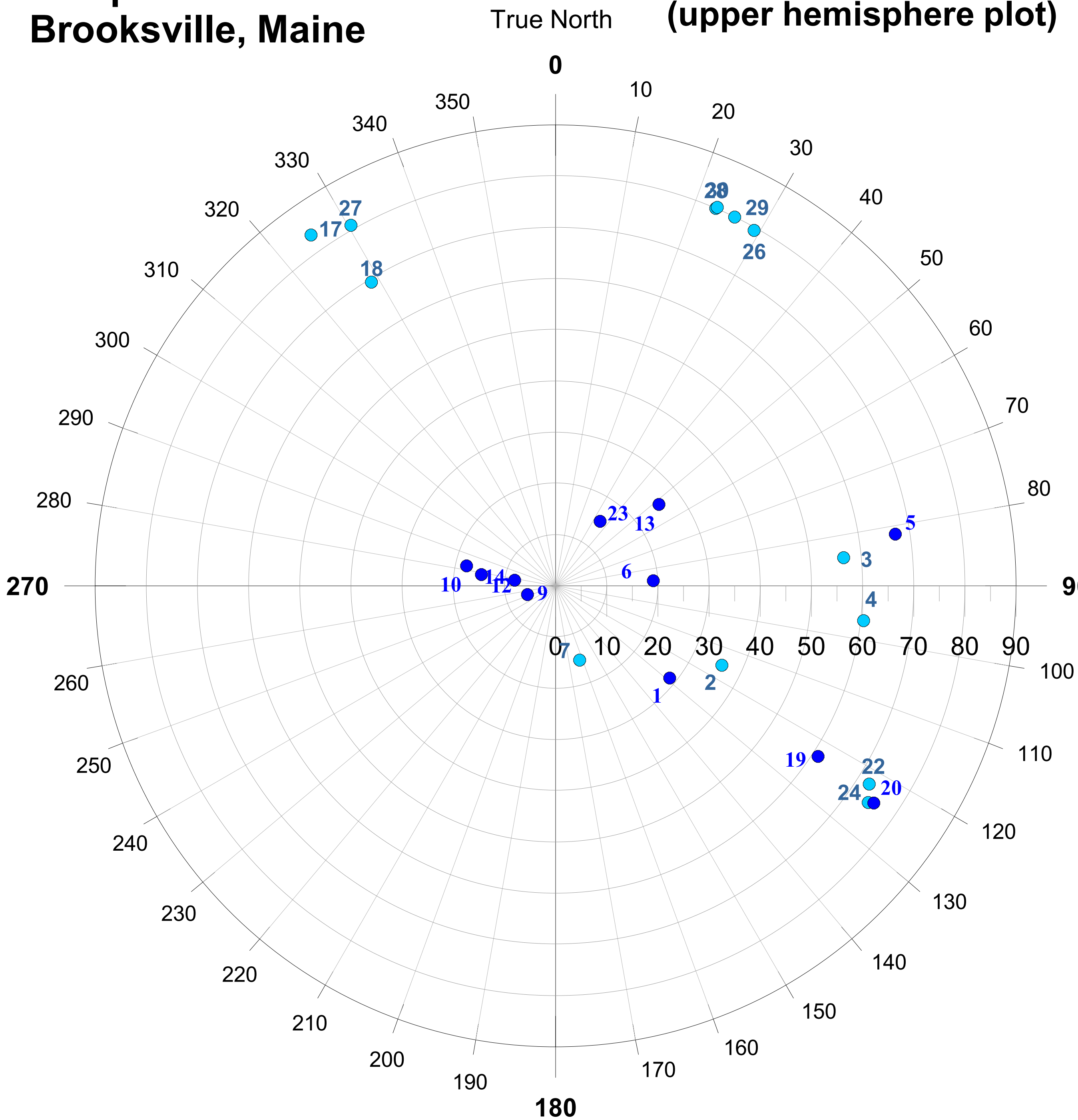
- Dip direction of feature
- Strike of feature
- Dip Amount (Tilt)

Based on 30 measurements

Northeast Geophysical Services

RC-1145
Callahan Mine Superfund Site
Brooksville, Maine

PLATE C-3
Dip Amount and Dip Azimuth of planar features likely or possibly transmissive (upper hemisphere plot)



Explanation - Fracture widths

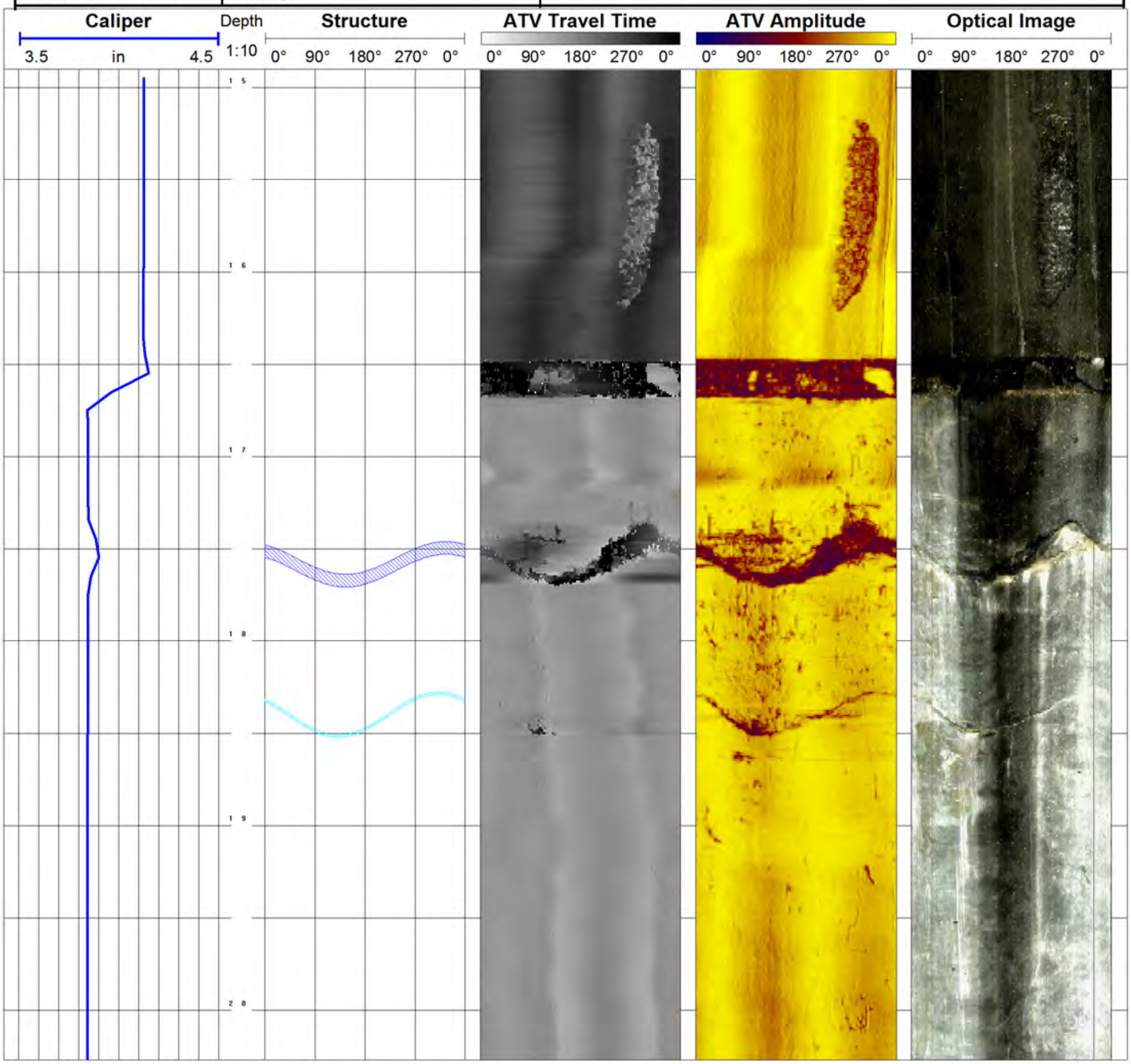
- Possibly transmissive
- Likely transmissive

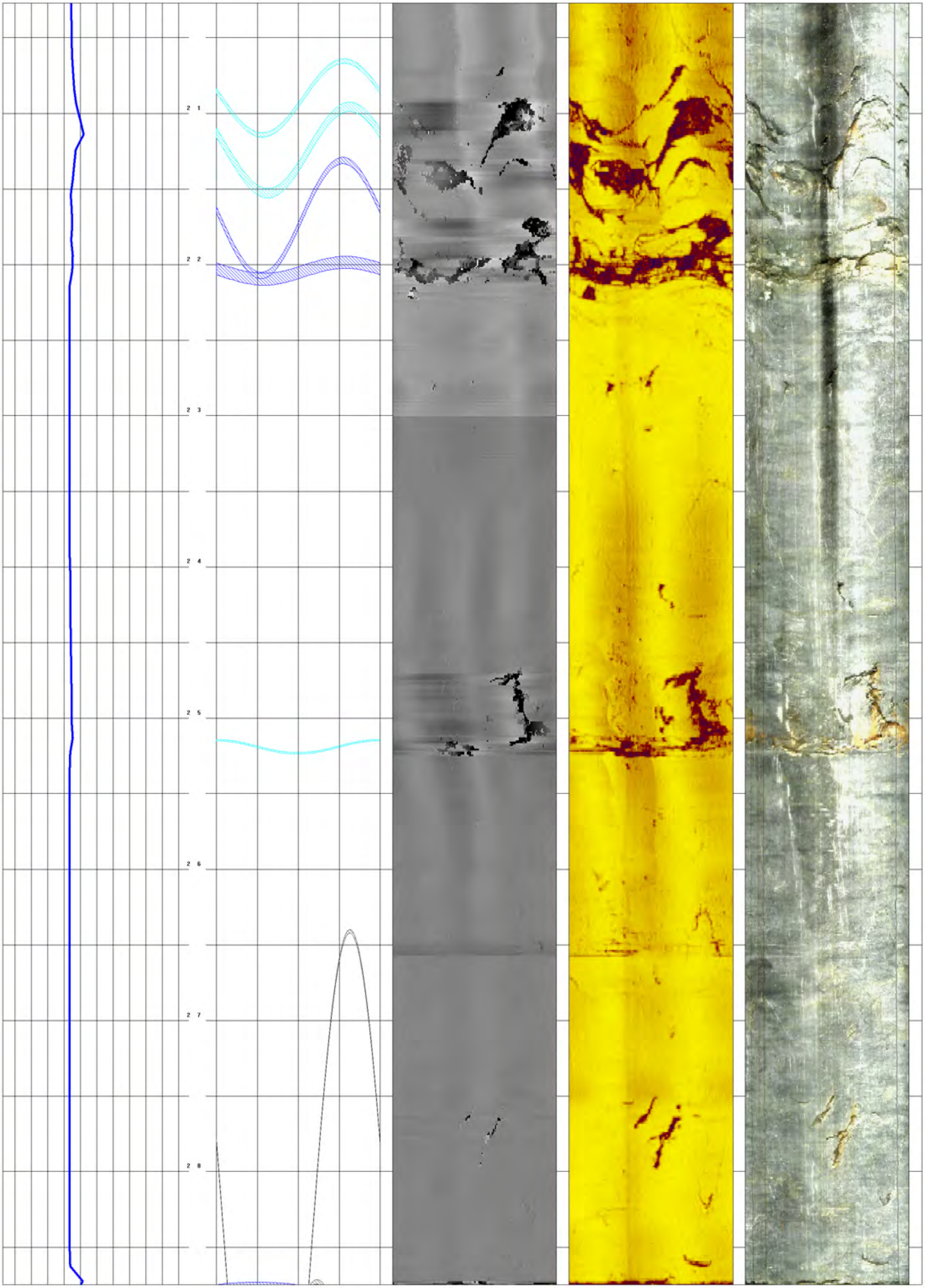
Declination: 16.4 degrees west

Based on 24 measurements

Northeast Geophysical Services
4 Union Street Bangor, Maine 04401
Tel. 207-942-2700
email: ngsinc@negeophysical.com

Log:	Plate C-4 Caliper & Televiewer		
Well:	**RC-1145**		
Site:	Callahan Mine		
Date:	01/09/2013	**Location:**	Brooksville
Casing Depth:	16.5 ft	**For:**	AMEC
Casing Type:	4 inch	**Logged by:**	R. Rawcliffe
Boring Depth:	59.6	**Orientation:**	magnetic
Meas. From:	toc	**Structure Plots:**	black = planar features (faults, foliation, bedding, joints, etc) light blue = possibly transmissive fracture dark blue = likely transmissive fracture
Stickup:	2.05		
Water Level:	11.07		

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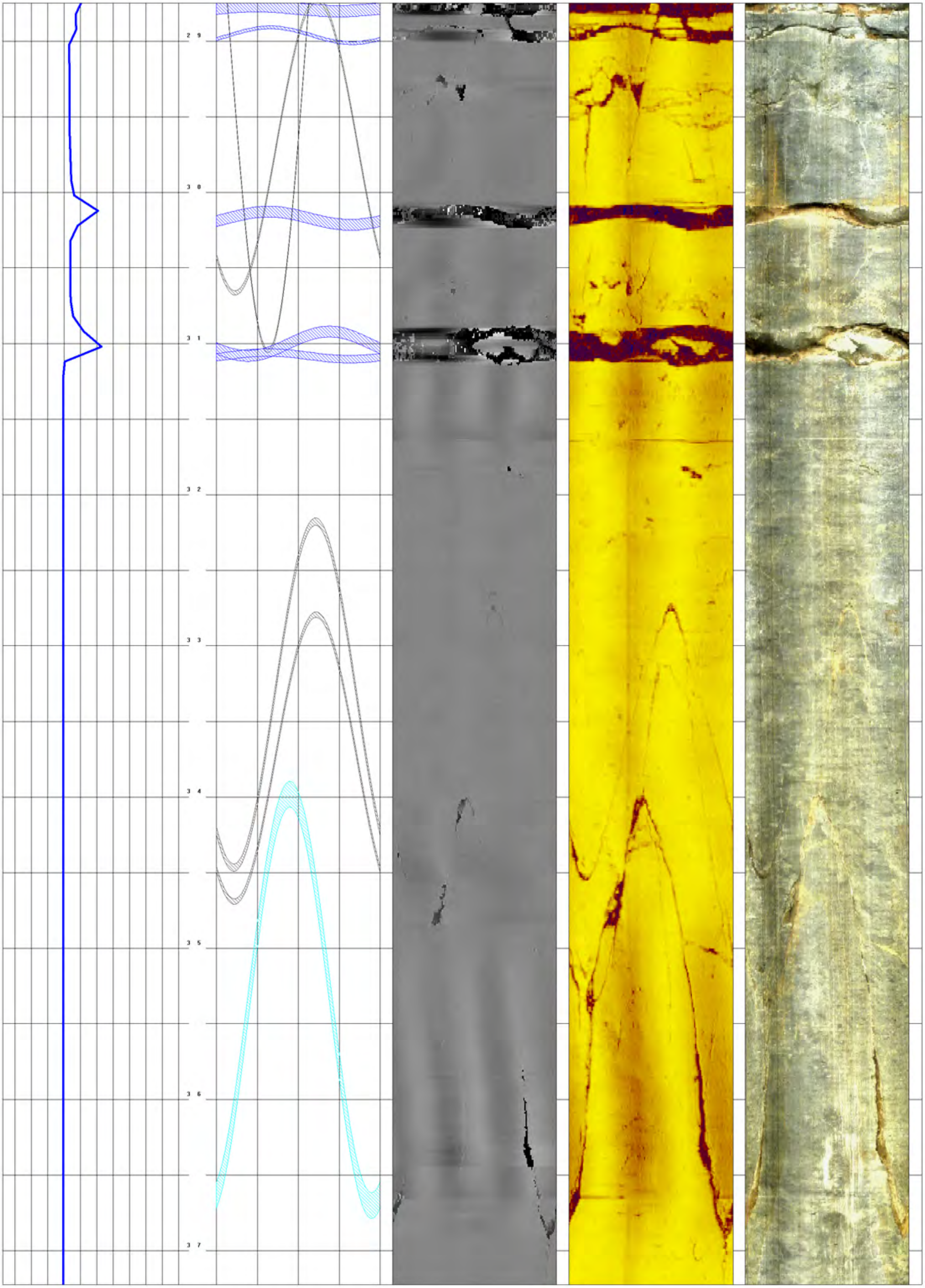
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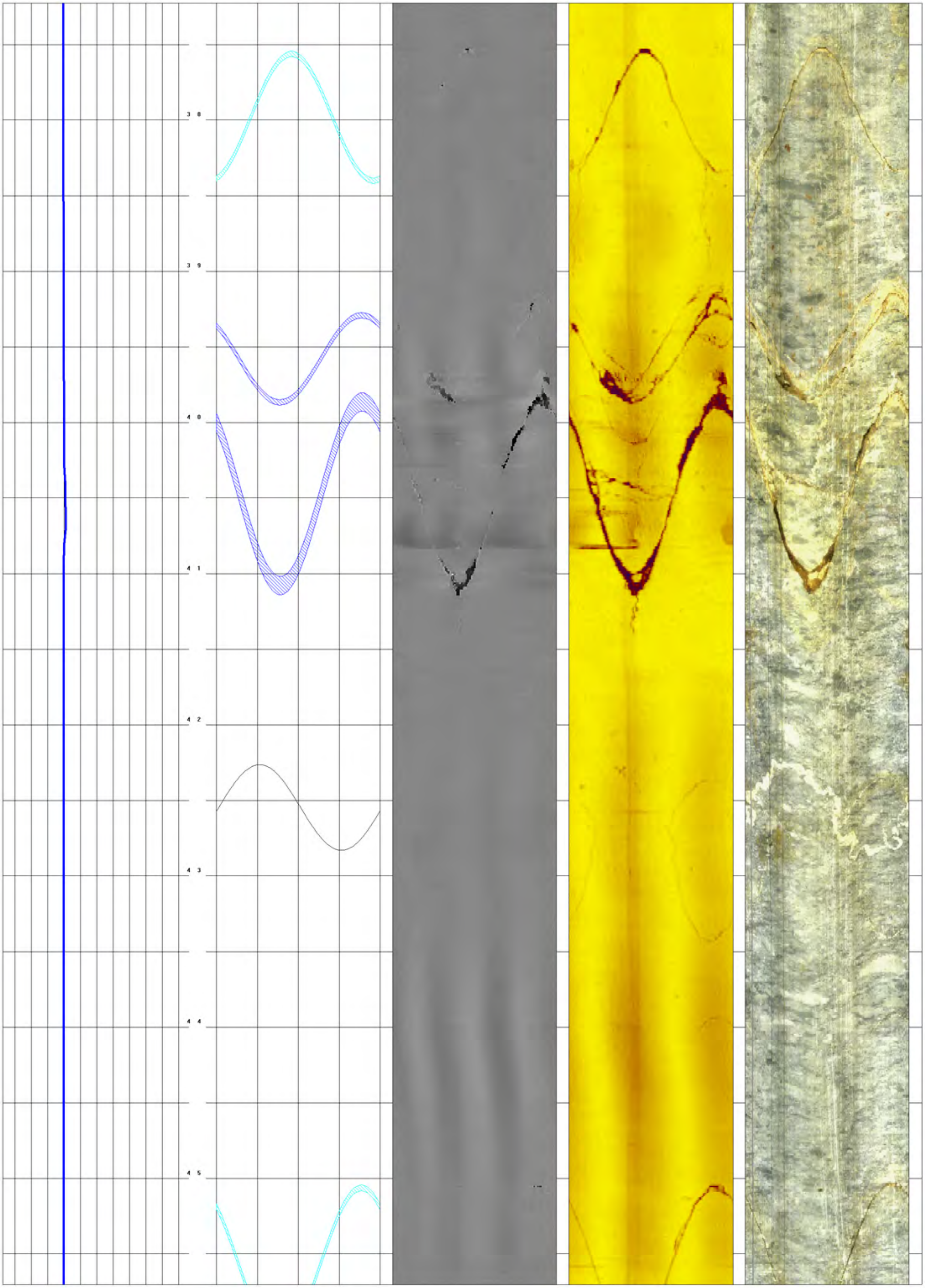
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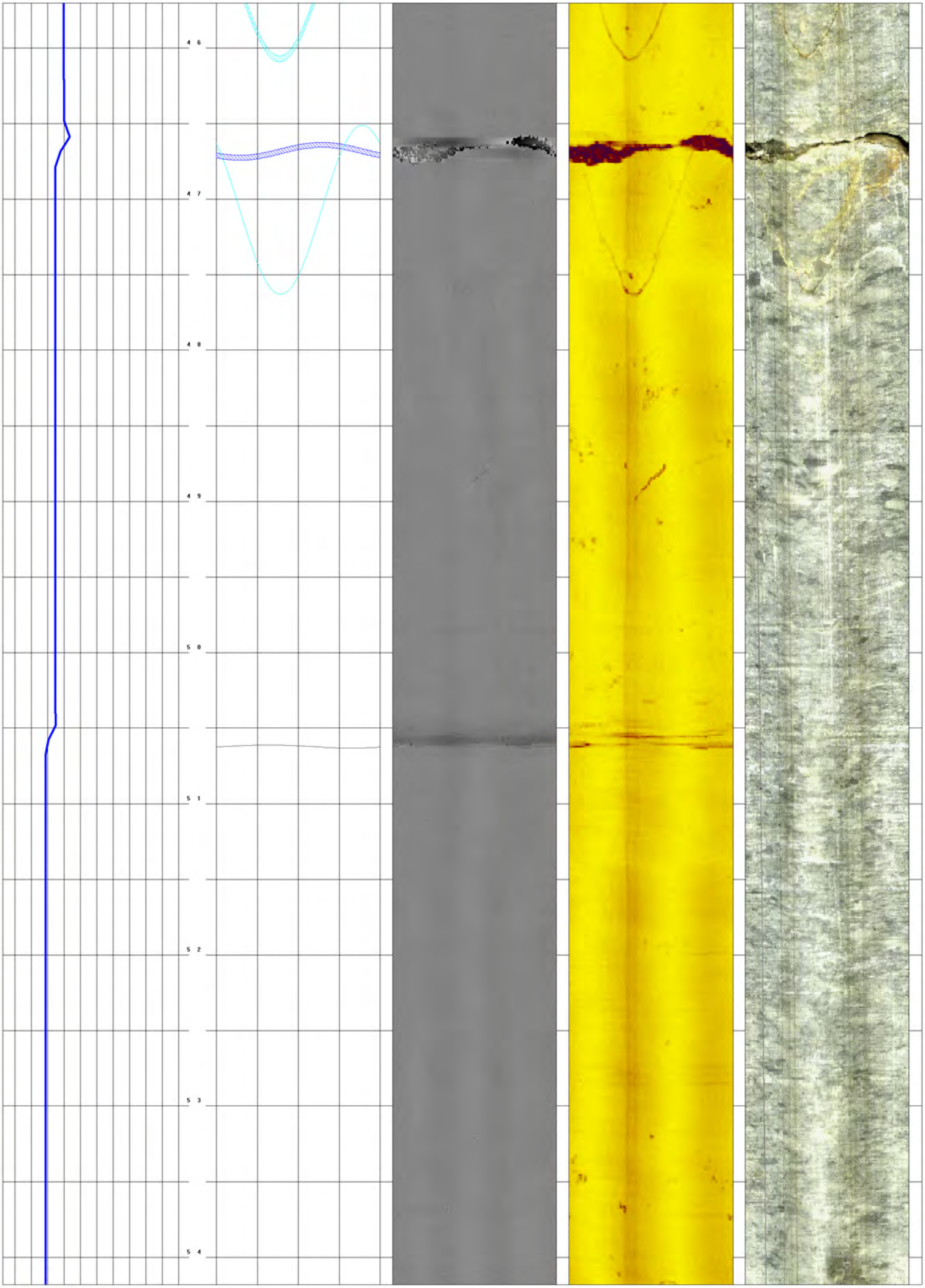
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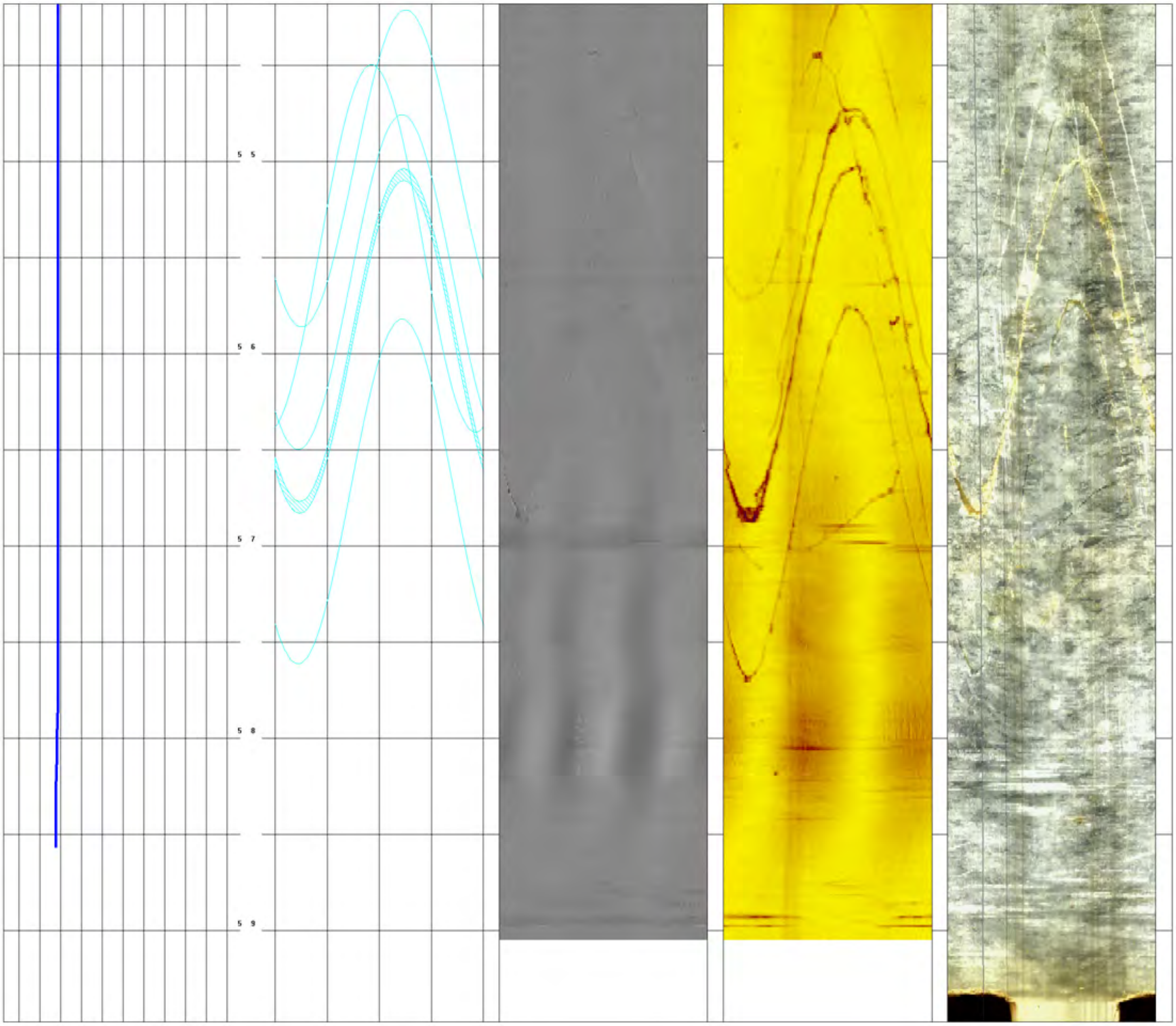
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TABLE C-1 - Planar features interpreted from acoustical and optical televiewers
RC-1145 - Callahan Mine Superfund Site - Brooksville, Maine

Logged: January 2013

Borehole	Feature # Number	Feature depth Feet	Dip Degrees	Dip Azimuth magnetic	Strike magnetic	Dip Azimuth True	Strike True	Aperture mm	Category Type
RC-1145	1	17.6	29	146	56	129	39	19	107
RC-1145	2	18.4	36	132	42	116	26	3	108
RC-1145	3	20.9	57	101	11	84	354	5	108
RC-1145	4	21.2	61	113	23	97	7	10	108
RC-1145	5	21.7	67	98	8	81	351	5	107
RC-1145	6	22.0	19	104	14	87	357	22	107
RC-1145	7	25.2	15	178	88	162	72	4	108
RC-1145	8	28.7	86	114	24	97	7	1	101
RC-1145	9	28.8	6	268	358	252	342	23	107
RC-1145	10	29.0	18	299	29	282	12	6	107
RC-1145	11	29.7	81	41	311	25	295	2	101
RC-1145	12	30.2	15	295	25	278	8	22	107
RC-1145	13	31.0	26	69	339	52	322	19	107
RC-1145	14	31.1	8	294	24	277	7	14	107
RC-1145	15	33.3	82	38	308	22	292	2	101
RC-1145	16	33.7	81	39	309	23	293	2	101
RC-1145	17	35.3	83	342	72	325	55	6	108
RC-1145	18	38.0	69	345	75	329	59	4	108
RC-1145	19	39.6	61	140	50	123	33	5	107
RC-1145	20	40.5	75	141	51	124	34	9	107
RC-1145	21	42.6	61	275	5	258	348	<1 mm	100
RC-1145	22	45.6	73	139	49	122	32	4	108
RC-1145	23	46.7	15	52	322	35	305	9	107
RC-1145	24	47.1	74	141	51	125	35	<1 mm	108
RC-1145	25	50.6	4	295	25	279	9	<1 mm	101
RC-1145	26	55.0	79	46	316	29	299	<1 mm	108
RC-1145	27	55.5	81	347	77	330	60	<1 mm	108
RC-1145	28	55.6	80	40	310	23	293	<1 mm	108
RC-1145	29	55.9	80	42	312	26	296	3	108
RC-1145	30	56.7	80	40	310	23	293	<1 mm	108

Explanation:

Category 100 = planar feature (possible foliation, bedding, etc.)
Category 101 = planar feature (possible fracture, joint, etc.)
Category 107 = Likely water bearing feature
Category 108 = Possible water bearing fracture

APPENDIX A2
PUMPING TEST

TECHNICAL MEMORANDUM

Project No: 3612112201

Date: March 20, 2013, revised August 7, 2014

To: Stephen H. Mitchell, P.E.

From: John Rand

Subject: **Pumping Test**
OU3 Draft Final Design Submission
Callahan Mine Superfund Site
Brooksville, Maine

1.0 INTRODUCTION

The pumping test was conducted to refine hydraulic parameters needed to determine a dewatering approach. The testing was completed in the eastern portion of the Tailings Impoundment where dewatering will provide the most improvement to soil stability conditions. The objective of the pumping test was to identify, through a constant rate pumping test, the extent of influence for the tested well under an extended period of pumping.

A review of boring logs and recommendations in the March 2012 Maine DEP report supported the approach that a fully penetrating well with a diameter larger than two inches would be necessary to impose a measureable hydraulic stress on tailings. The well was located between the higher permeability sandy tailings near the east perimeter road and the lower conductivity mixed tailings near the slimes in the center of the Tailings Impoundment. This location provided radial distances to existing monitoring wells of 60 to 130 feet.

2.0 METHODS

2.1 Pumping Well Installation

To facilitate the pumping test, a dewatering well (DW-1) was installed approximately 60 feet southeast of the MW-605 monitoring well cluster and approximately 90 feet west of the east perimeter access road (See Figure A2-1). The well was installed on November 28, 2012 by AMEC drilling Subcontractor Great Works Test Boring of Berwick, Maine. A truck mounted drill rig was used to advance a pilot hole to 15 feet below ground using solid stem augers. Four inch flush mount casing was then used to advance the borehole using drive and wash techniques. Split spoon samples were collected at five foot intervals starting at 15 to 17 feet bgs. The soils encountered consisted of stratified gray sand and silt grading to non cohesive stratified silt with traces of clay and fine sand. These gray "tailings" were underlain by approximately 4 feet of olive brown to light brown till consisting of traces of sand and gravel in a slightly plastic silt and clay matrix. The contact between the tailings and till was approximately 48.5 feet bgs. Weathered bedrock was encountered at approximately 52.5 feet bgs and became competent by 54 feet bgs. The boring was advanced to refusal in bedrock at 55 feet bgs. A screened interval of 14 to 49 feet bgs was selected based the stratigraphy encountered in the pilot boring. The four inch casing was removed from the borehole and six inch flush joint casing was advanced to 50 feet bgs. The casing was flushed with potable water to remove fines prior to well installation.

Pumping well DW-1 was installed using four inch diameter Schedule 80 PVC riser and a four inch x 35 foot long Schedule 80 well screen with a 0.01 inch slots from 14.2 to 49.2 feet bgs. The screen was backfilled with #2 Filpro Quartz sand from 50.0 feet to 9.5 feet bgs. A bentonite chip seal was installed from 9.5 to 6 feet bgs and the well was completed with a six inch diameter protective casing with locking cap. A boring and construction log is presented in Figure A2-2.

The newly installed well was development by purging with a submersible whale pump. The well was pumped at an average rate of approximately 1.1 gpm until nearly dry and then allowed to recharge. Measurements collected during recovery indicated a recharge rate of 0.26 gpm. The well was purged dry again after partial recovery. A total of 59 gallons were purged during development activities.

2.2 Pumping Test Setup

Set up activity included background water level measurements at monitoring wells and vibrating wire piezometers (VWPs), barometric pressure readings and deployment of the test pump in DW-1. Weather during the duration of the pumping test was partly cloudy to sunny, cold and windy with daytime temperatures in the upper 20s F and nighttime temperatures in the teens. Winds were 15 to 25 mph out of the NW.

On Wednesday, November 28, 2012, a Solinst water level meter was used to manually record water levels from several monitoring wells and piezometers in the eastern tailings to establish background trends in water levels. Another round of manual water levels was collected the following morning from the pumping well (DW-1) and other monitoring wells within 200 feet of the pumping well.

A variable speed Grundfos Redi-Flo 2 submersible pump (2”) was installed in DW-1. The Grudfos pump was powered by a Honda 2000 portable generator. On Thursday morning, November 29, additional AMEC personnel mobilized to the site with Troll 1000 transducers, a Geokon data logger for reading and recording data from vibrating wire (VWP) piezometers, and a barometer.

An initial round of data was collected manually from four VWPs located within 130 feet of DW-1 (VWP-1119, 1120, 1121, and 1122). Transducers were programmed and installed in MW-605D, OW-1123, and OW-1124 and set to record water levels at 10 minute intervals. A fourth transducer could not be deployed due to battery and programming issues with the data logger.

The fourth transducer was to be installed at PZ-MW-705, however, manual measurements were made at this location. The presentation of transducer and manually recorded data is discussed in Section 3.0.

2.3 Pumping Test Start

The pump in DW-1 was started at 1445 on Thursday November 29, 2012 and the initial rate was set at approximately 1 gpm to confirm, following development, that this rate was not sustainable, and based on the MEDEP pumping test at OW-1123 (a 2-inch diameter well) which had sustained a flow rate of 0.40 gpm. The pumping rate eventually stabilized at 0.25 gpm with about 23 feet of drawdown in the pumping well (because of the very low yielding formation, step testing was not practical). After the pump was started well measurements were recorded from the VWPs using the data reader and manually from the pumping well and monitoring wells with the Solinst water level meter. Flow rate from the pumping well and barometric pressure readings were also recorded. Once the test started, manual measurements were collected every 2 to 3 hours. All water derived from testing was discharged to vegetated areas of the tailings remote from the pumping test wells. Table A2-1 presents a summary of the locations and depths monitored during the pumping test.

2.4 Pumping Test Stop

The pump in DW-1 was shut off at 2045 Friday November 30, 2012 after 30 hours of pumping. The transducers installed in MW-605D, OW-1123, and OW-1124 continued to collect recovery data after the shutdown of the pump, and several rounds of readings were collected from the monitoring wells and VWPs on Saturday December 1, 2012 between 0843 and 1015. AMEC personnel demobilized and locked up the site by 1050.

2.5 Background Water Level Trend and Barometric Correction

Water level data from the background wells and barometric pressure readings were used to correct the manual water level data for wells within the zone of influence of the pumping well. The VWPs are vented and were reported by the vendor not to need correction for barometric pressure effects. The background monitoring wells PZ-602, MW-602S and MW-602D are located approximately 325 feet south of DW-1 and are outside the influence of the pumping test. Table A2-2 presents the data collected from the background wells and the barometric pressure, and Figure A2-3 shows the trends of these measurements.

The barometric pressure rose throughout the pumping test from 33.59 feet H2O to 34.48 feet H2O. The result was a slight decrease in the ground water levels in monitoring wells within the Tailings Impoundment. Based on the data collected from the background wells, the barometric pressure had a greater influence on the shallow groundwater (PZ-602) compared to the deeper groundwater at MW-602S and MW-602D. The barometric efficiency decreased slightly with increasing depth. The decreases in water level observed in the background wells, considered to be the combination of water level trend and barometric effects, were used as correction factors for the pumping test monitoring locations of similar depth so that only the effects of the pumping were calculated and in turn used to assess long term drawdown. Barometric pressure change and its influence on groundwater levels as measured in wells is described in Groundwater Hydrology (Todd, 1980, pgs. 235-238).

3.0 RESULTS

Results for the pumping test are provided in Table A2-1 through A2-3 and Figures A2-1 through A2-9. Pumping well DW-1 was pumped at a constant rate of 0.25 gpm with a stable drawdown between 22 and 23 feet below the top of the well casing. Drawdown at monitored locations is summarized in Table A2-2.

Based on the observed drawdown at DW-1, its well construction and the saturated thickness present at this location, the transmissivity (T) and permeability (hydraulic conductivity, K) of the tailings material were estimated using the Cooper Jacob approximation to the Theis equations (see Table A2-3). The results of the calculation was T = 7.6 gallons per day per foot (gpd/ft) and K = 0.034 feet/day (1.2 x10-5 cm/sec) respectively. A similar estimate method in Table A2-3 indicated a T = 16 gpd/ft and K = 0.073 feet/day (2.6 x 10-5 cm/sec). These results are consistent with K values obtained by MACTEC during the Remedial Investigation for this area of the Tailings Impoundment.

Observation well and vibrating wire piezometer draw down data (Table A2-2) was used to create a distance/drawdown plot (Figure A2-9). A calculation of T using distance drawdown methods in Driscoll (Groundwater and Wells, 1986, p.237) indicates a T of 15 gpd/ft (or K= 0.067 feet/day for 30 foot saturated thickness) which is consistent with the range presented in Table A2-3 (7.6 to 16 gpd/ft). The results obtained for T and K from the pumping test provided a range which was used as a starting point in calibrating the groundwater model (described in Appendix A3).

Figure A2-9 was also used to understand what scale of well spacing that would be required if vertical dewatering wells were used at the site. Based on Table A2-2, a drawdown of as much as 0.51 feet was observed in MW-605D (after correcting for background and barometric effects). A similar response was seen at MW-605S and PZ-605, but with less drawdown observed in these adjacent shallower wells. Water level plots for the MW-605 cluster wells are provided in Figure A2-4 through A2-6. Water level measurements from OW-1123 located along the east perimeter road showed a small response, but after correcting for background trend and barometer there was no significant drawdown at this location (see Table A2-2).

Data collected from vibrating wire piezometers VWP-1120 and VWP-1121 showed drawdown of approximately 0.5 feet. Table A2-2 provides readings from VWP-1120 after conversion to approximate water elevation data. The vibrating wire readings collected at the well head are multiplied by a gage factor and a temperature factor to provide a water level that is relative to the original water level reading at the time of installation. The data has been converted to an approximate water elevation using installation depths and the estimated ground elevation at the VWP location. Figure A2-7 and Figure A2-8 show the drawdown at the deep zone (Red = 40.7 ft bgs) and middle zone (Yellow = 27.6 ft bgs) respectively at the VWP-1120 location.

Data collected from VWP-1119 and VWP-1122 also indicate drawdown of approximately 0.5 feet at these locations. However, manual measurements collected at OW-1123 (adjacent to VWP-1122) and transducer readings from OW-1124 (adjacent to VWP-1119) did not show drawdown greater than background influences in these areas. Based on the manual measurement at these monitoring wells, effects from the pumping test are not interpreted to have been significant at these east perimeter road locations.

Corrected data (and considering distance drawdown data discussed below) was plotted on Figure A2-1 which indicates the interpreted extent of drawdown. The data suggests a preferential drawdown along the north/south axis of the tailings impoundment. This interpretation is consistent with the lower permeability material toward the center of the tailings. The anisotropy suggested by the observed drawdown indicates more water was produced from the tailings along a north south direction compared with an east west direction.

The results shown on Figure A2-9 for the DW-1 pumping test as well as the OW-1123 pumping test reported by the Maine DEP in March 2012 are based on tests completed at close to the maximum sustainable pumping rate for the respective wells (0.25 gm for DW-1 which is a 4 inch well; 0.40 gpm for OW-1123 which is a two inch well). Based on Figure A2-9, meaningful drawdown with respect to dewatering the tailings impoundment (i.e. greater than 10 feet) appears to only be possible at close distances to the pumping wells (i.e. on the order of feet from a pumping well). These results suggest multiple pumping wells would be needed to cause the required dewatering for the excavation and construction of the cap for the Tailings Impoundment.

FIGURES

A2-1 Tailings Impoundment Plan and Observed Drawdown (feet) During Pumping Test (Figure 4.2a from above Design Report)

A2-2 Boring and Well Construction Log for DW-1

A2-3 Background Water Level and Barometric Trends

A2-4 MW-605D Drawdown vs. Time (manual)

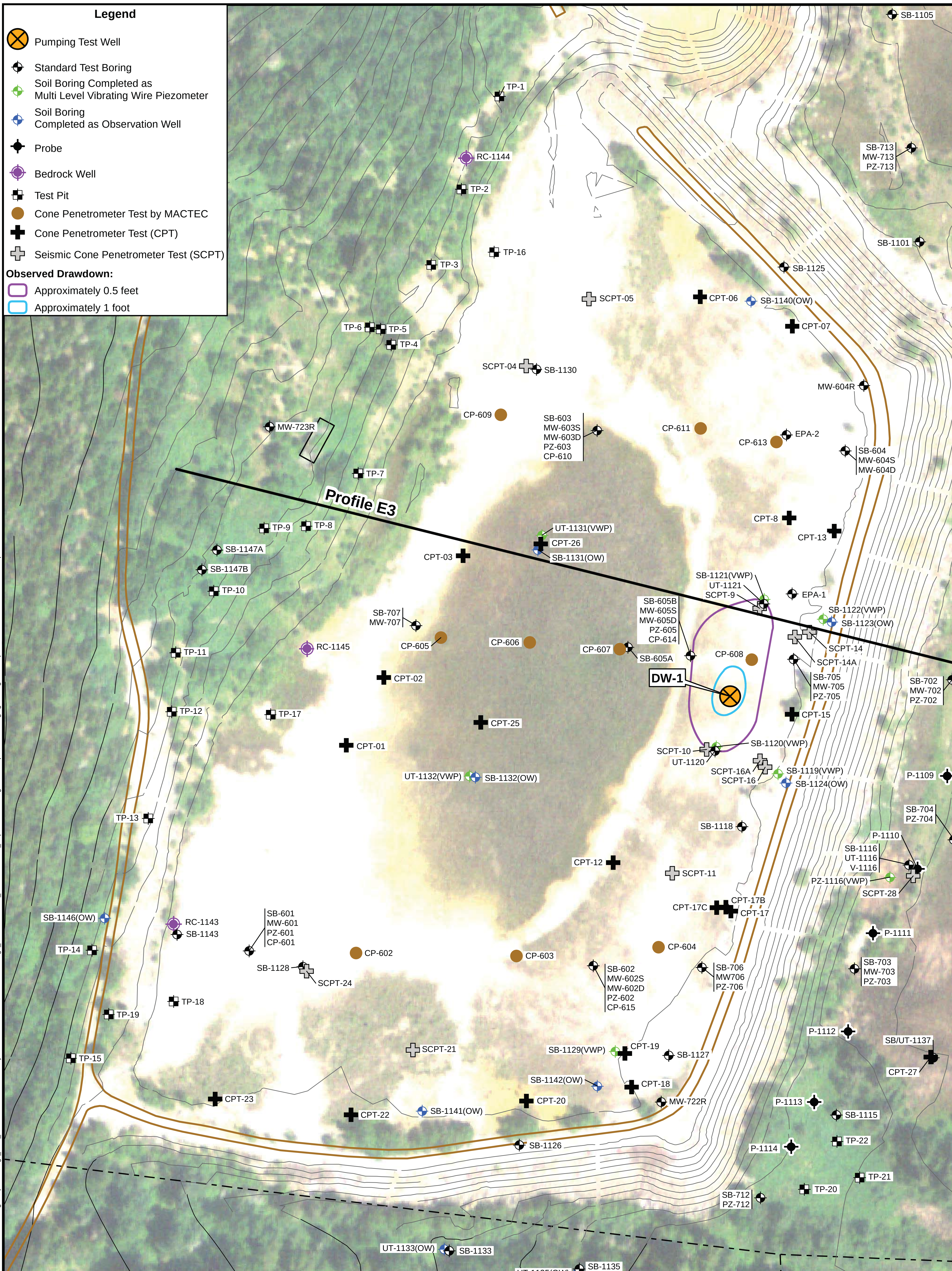
A2-5 MW-605D Drawdown vs. Time (transducer)

A2-6 MW-605S Drawdown vs. Time (manual)

A2-7 VWP-1120 Red Drawdown vs. Time

A2-8 VWP-1120 Yellow Drawdown vs. Time

A2-9 Distance vs. Drawdown



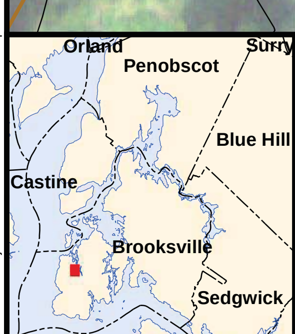


Figure A2-1
Tailings Impoundment Plan and
Observed Drawdown (Feet) During Pumping Test
OU3 Draft Final Design
Basis of Design Report
Callahan Mine Superfund Site
Brooksville, Maine

Prepared/Date: BRP 10/29/14 | Checked/Date: JBR 10/29/14

amec

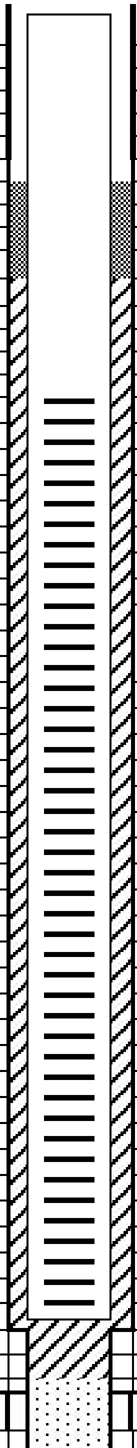
Document: P:\Projects\mdot\Callahan Mine\6.0 GIS\MapDocuments\Basis of Design Report\Tailings_Area_11x17P.mxd PDF: P:\Projects\mdot\Callahan Mine - OU3 Design_3612112014\4.0_Deliverables\4.1_Reports\90% Design\BOD-Report\Dewatering\figures\Figure 4.2a.pdf 10/29/2014 9:14 AM brian.peters

amec	Project:	Callahan Mine Tailings Pile Pumping Test	Figure
	Location:	Brooksville, Maine	A2-2
	Client:	MDOT	
Contractor: Great Works Test Boring	**Drilling Method: Drive & wash cased boring**		**Boring:**
Operator: Pete Michaud	**Bore Hole OD: 6-inch**		**DW-1**
Logged By: Jerry Rawcliffe	**Riser/Screen: Sch 80 PVC 4-inch ID - 0.01 inch slot**		
Checked By:	**Sampler: 2"X2' split spoon - 5 foot intervals 15'-55' bgs**		
Date Start/Finish: 11/28/2012	**Water Level: 21' measured in borehole with casing**		
Boring Location: Tailings Pile	**Ref. Elevation: Estimated ground elevation = 71.5' msl**		

Depth (feet bgs)

Stickup on Casing = 1.6 feet above ground surface

Top of Casing to top of riser = 0.14 feet.



Depth (feet bgs)	Well construction	Sample	Description
5			
	Bentonite Chips - 6 to 9.5 feet bgs.		
10			
15	Top of Screen = 14.2' bgs.		
		S1 15-17	Gray fine sand with some silt and medium sand . Stratified.
20		S2 20-22	Gray fine sand and silt. Stratified.
	Sand pack is #2 Filpro Quartz Sand 9.5 to ~51 feet bgs.		
25		S3 25-27	Gray fine sand and silt with a trace of medium sand. Stratified.
30		S4 30-32	Gray silt and fine sand. Well stratified.
35		S5 35-37	Gray silt with traces of clay and fine sand. Well stratified, nonplastic.
40		S6 40-42	Gray silt with traces of clay and fine sand. Well stratified, nonplastic.
45		S7 45-47	Gray silt with traces of clay and fine sand (layers). Well stratified, nonplastic.
50	Bottom of well =49.2 feet bgs.	S8 50-52	Olive brown to light olive silt and clay with traces of sand and gravel. Slightly plastic. Grades to olive to olive brown silt and clay with sand
52.5			Weathered bedrock 52.5' bgs becomes competent by 54' bgs.
55	Cave-in/cuttings ~51 to 55 feet bgs.		
	Bottom of Boring = 55 feet bgs		

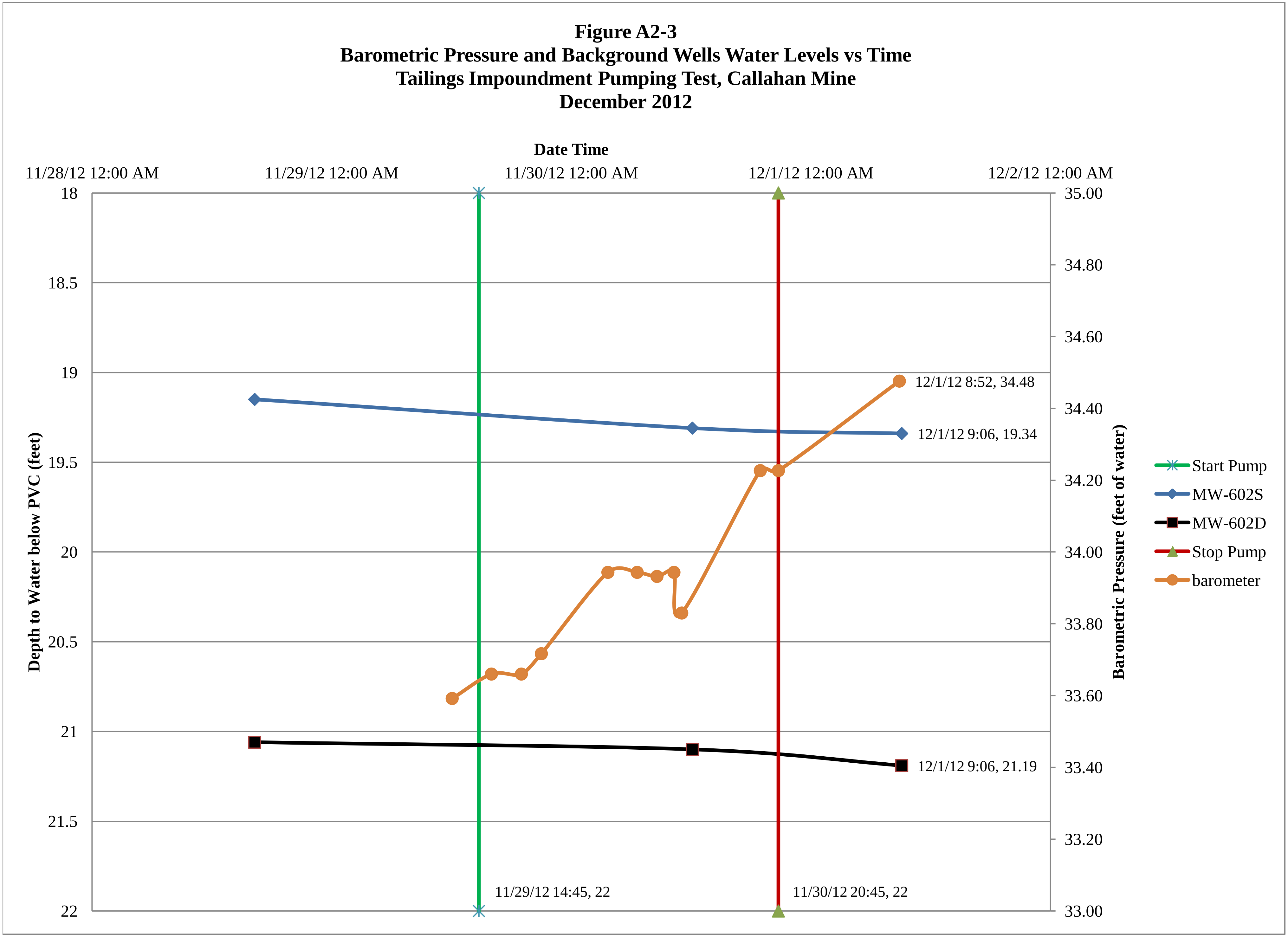


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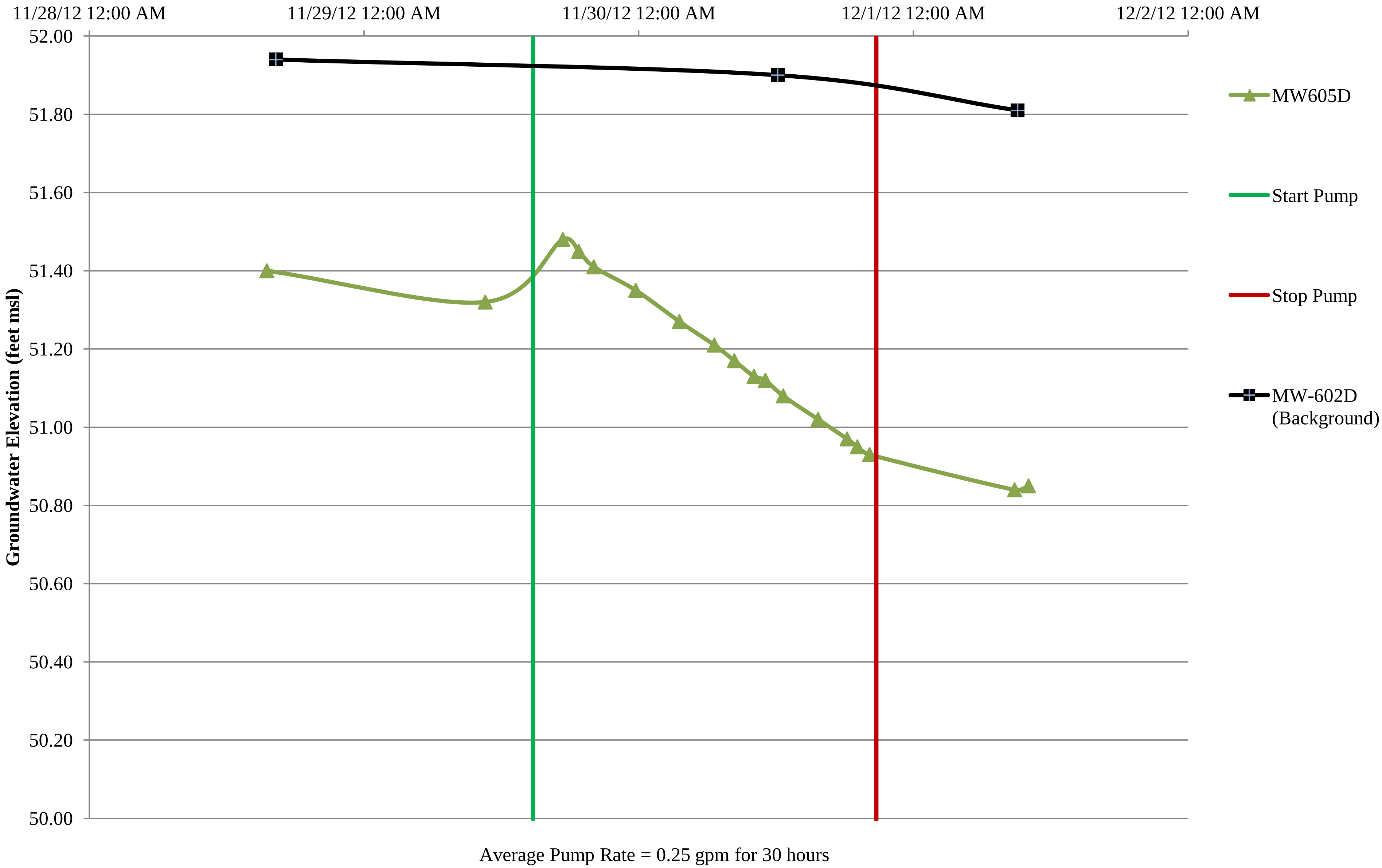
Figure A2-4
MW-605D Drawdown vs Time - Manual Water Level Measurements
Tailings Impoundment Pumping Test, Callahan Mine
December 2012



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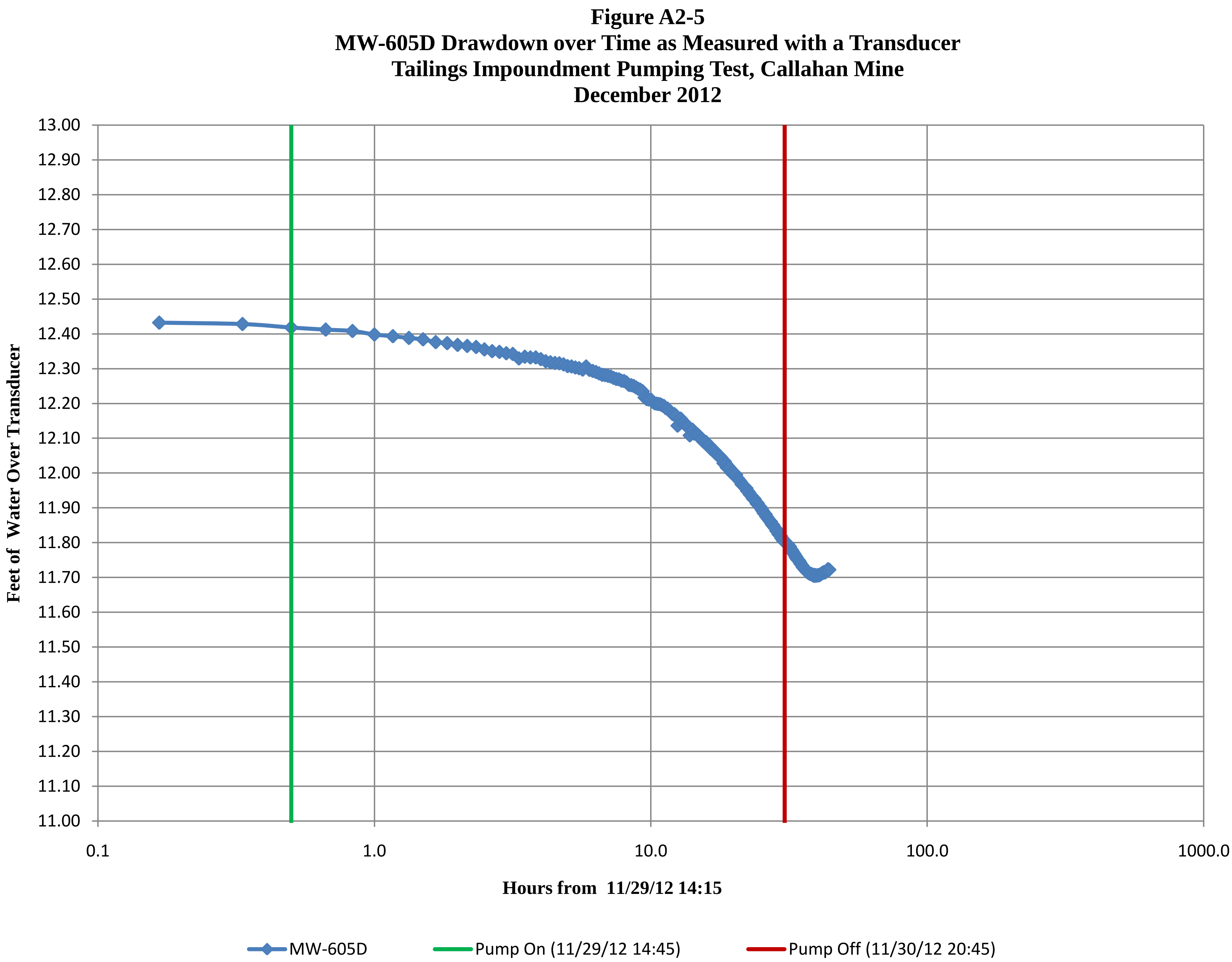

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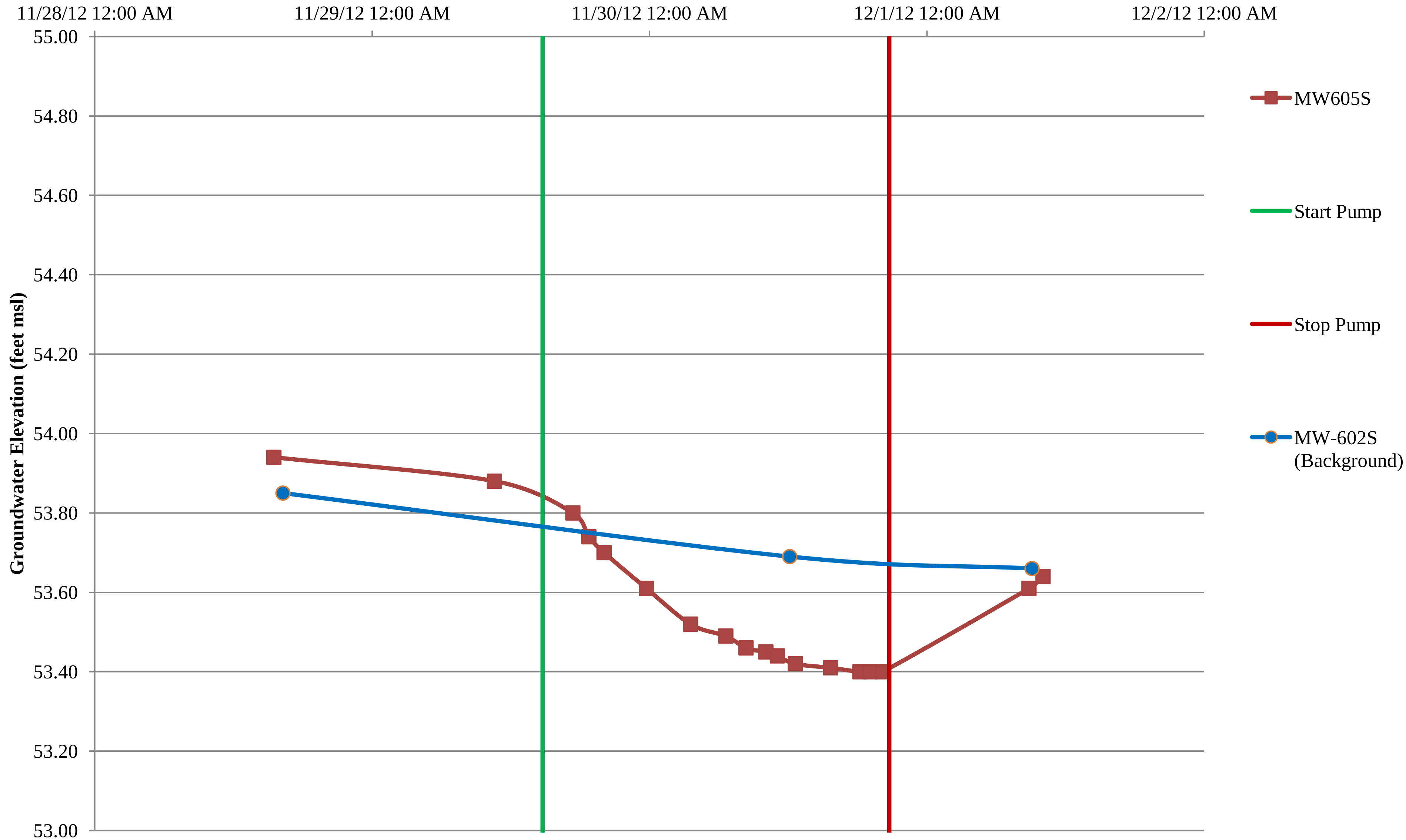
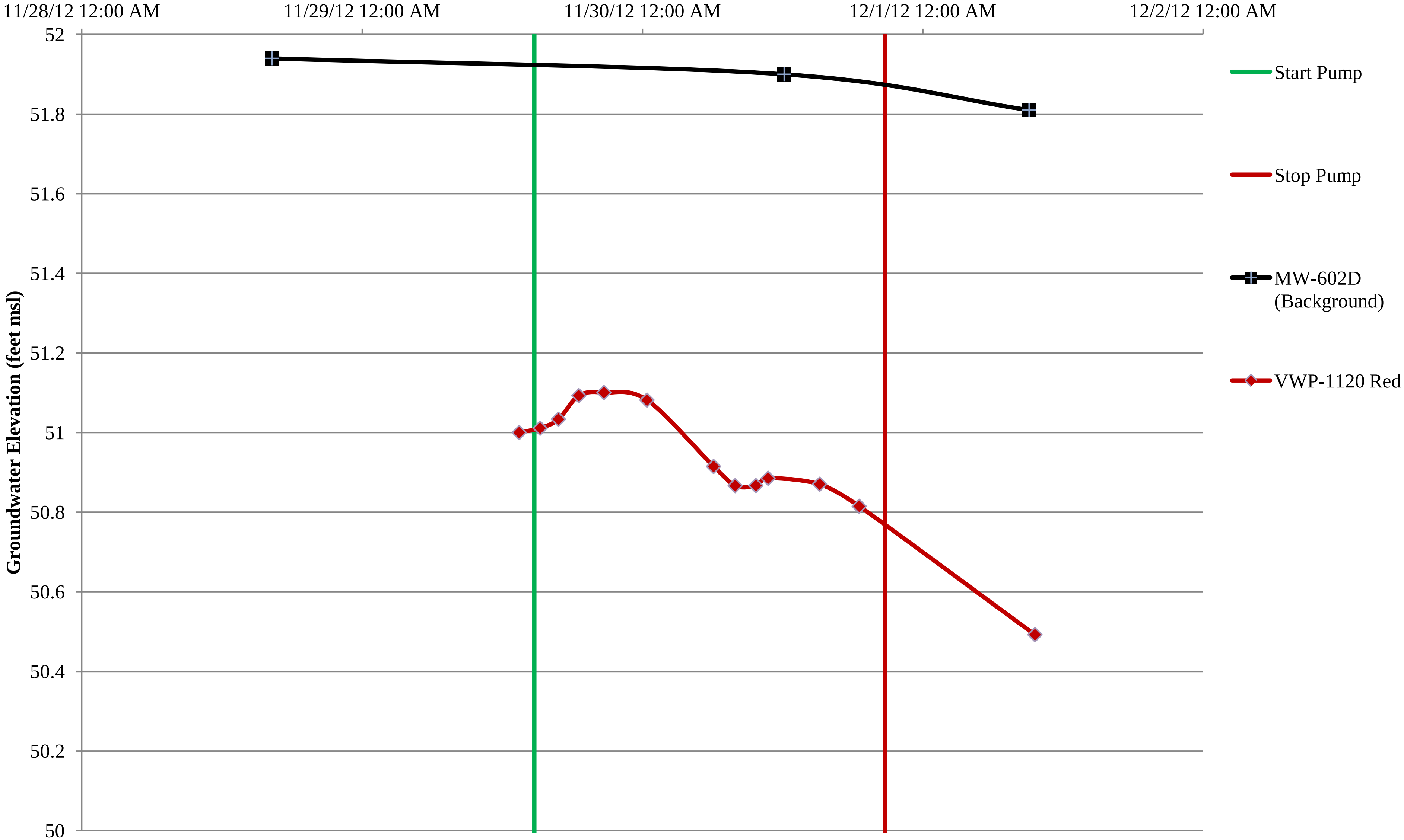
Figure A2-6
MW-605S Drawdown vs Time - Manual Water Level Measurements
Tailings Impoundment Pumping Test, Callahan Mine
December 2012



Average Pump Rate = 0.25 gpm for 30 hours

Figure A2-7
VWP-1120 Red (40.7' bgs) - Drawdown vs Time
Tailings Impoundment Pumping Test, Callahan Mine
December 2012



Average Pump Rate = 0.25 gpm for 30 hours

Figure A2-8
VWP-1120 Yellow (27.6' bgs) - Drawdown vs Time
Tailings Impoundment Pumping Test, Callahan Mine
December 2012

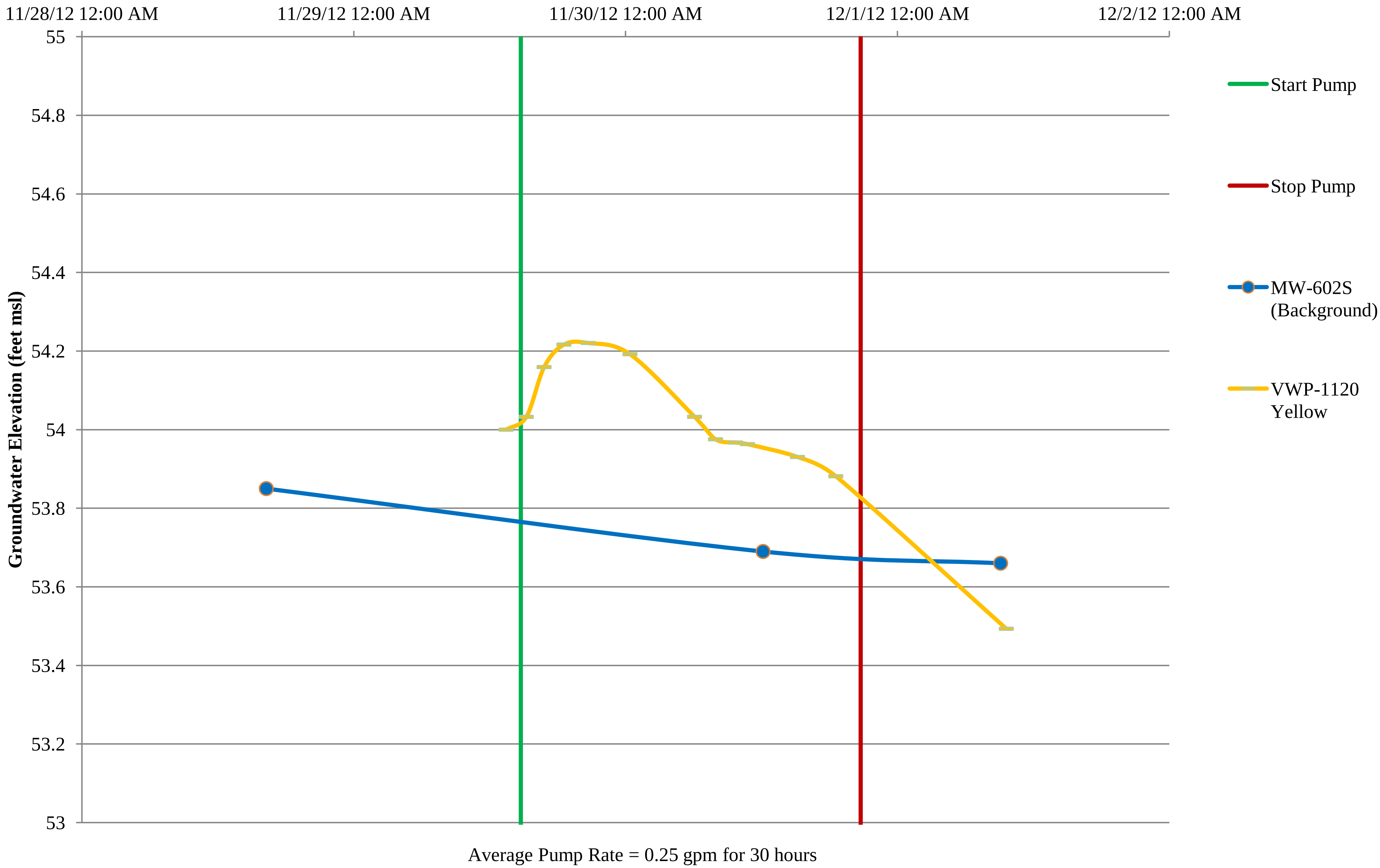
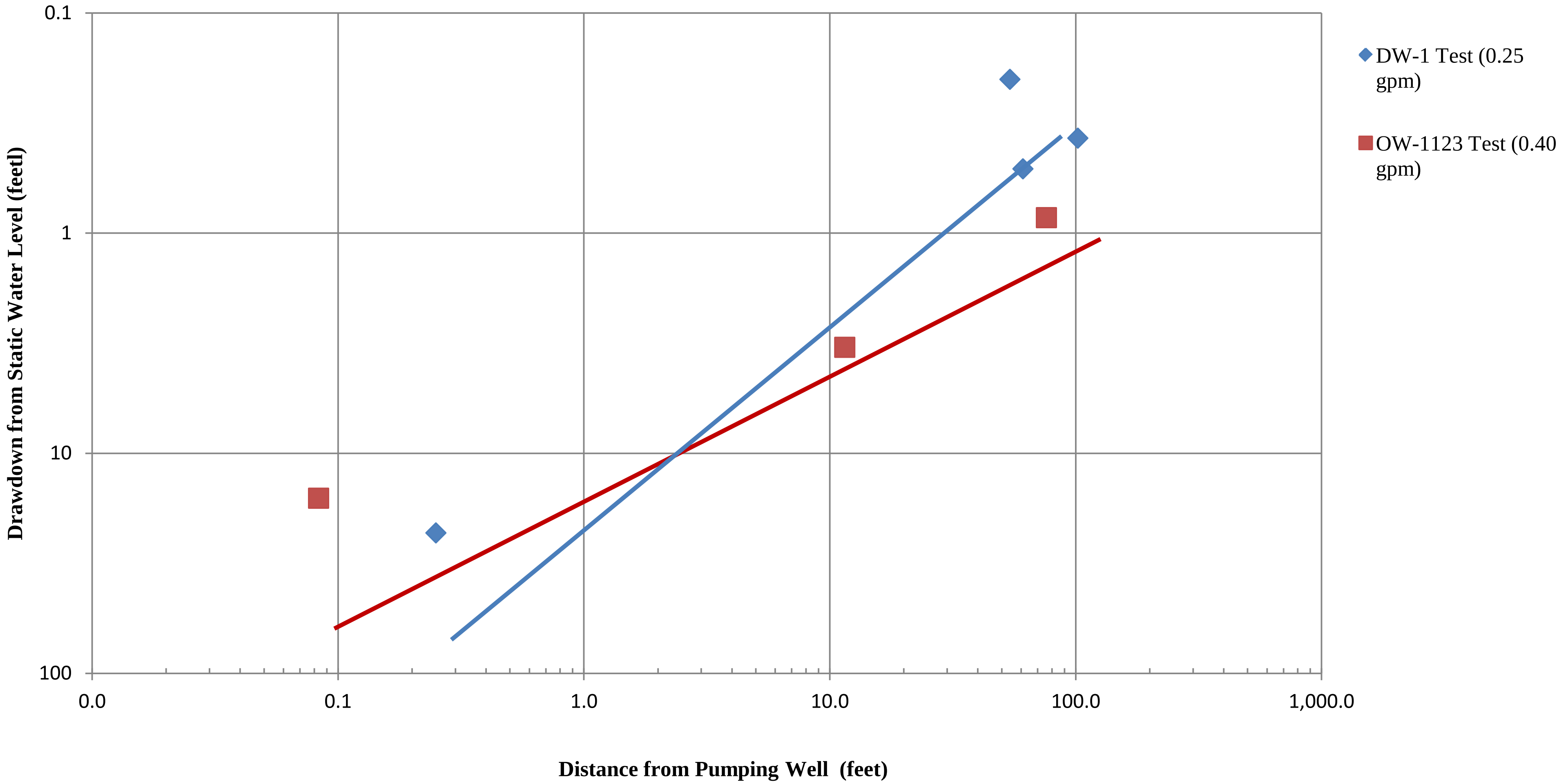


Figure A2-9
Drawdown vs Distance from Pumping Well
Tailings Impoundment Pumping Test, Callahan Mine
December 2012



Note: The following monitoring wells (and radial distances from pumping wells) were used in this plot- see Table A2-2:

DW-1 Test: MW-605D (61'); VWP-1120 (54'); VWP1121 (102')
OW-1123 Test: VWP-1122 Deep (11.5'); VWP1121 (76')

TABLES

A2-1 Well Constructions and Locations
A2-2 Tailings Impoundment Pumping Test
A2-3 Cooper Jacob Aquifer Parameter Estimator

Table A2-1
Well Constructions and Locations
OU3 Draft Final Design
Basis of Design Report
Callahan Mine Superfund Site
Brooksville, Maine

Pumping Test Well and Screen Depth (feet bgs)	Observation Wells and Monitored Zones (feet bgs)	Distance to Pumping Well DW-1 (feet)	Lithology
Dewatering Test Well - DW-1 (14.2' - 49.2')	PZ-605 - 10'-20'	61	Tailings
	MW-605S - 25'-30'	61	Tailings
	MW-605D - 33'-38'	61	Tailings
	SB-1119(VWP) 22' (G)	98	Tailings
	SB-1119(VWP) 33.5' (W)	98	Tailings
	SB-1119(VWP) 45.1' (Y)	98	Tailings
	SB-1119(VWP) 61.1' (R)	98	Clay
	SB-1120(VWP) 14.1' (W)	54	Tailings
	SB-1120(VWP) 27.6' (Y)	54	Tailings
	SB-1120(VWP) 40.7' (R)	54	Tailings
	SB-1121(VWP) 13' (W)	102	Tailings
	SB-1121(VWP) 25.4' (Y)	102	Tailings
	SB-1121(VWP) 38.1' (R)	102	Tailings
	SB-1122(VWP) 25' (G)	129	Tailings
	SB-1122(VWP) 35.4' (W)	129	Tailings
	SB-1122(VWP) 45.8' (Y)	129	Tailings
	SB-1122(VWP) 60.5' (R)	129	clay
	SB-1123(OW) 7'-55'	125	Tailings
	SB-1124(OW) 25' - 70'	111	Tailings/clay/till
	PZ-705 - 20'-30'	83	Tailings
	MW-705 - 50'-55'	83	Clay

Notes:

1. Well constructions from MACTEC 2009 and Credere 2012 reports.
2. G = green, W = white, Y = yellow, R = red

Table A2-2
Tailings Impoundment Pumping Test
OU3 Draft Final Design
Basis of Design Report
Callahan Mine Superfund Site
Brooksville, Maine

Pumping Well DW-1

		gpm
11/29/12 14:45	Start pump	1
11/29/12 15:29		0.38
11/29/12 17:29		0.25
11/30/12 20:30		0.25
11/30/12 20:45	Stop Pump	

initial depth to water	21	feet below top of casing
pumping test dtw	44	feet btoc
specific capacity	0.011	gpm/ft of drawdown

Monitoring Wells

	MW-605D		MW605S		PZ-605	
	depth to water below PVC	Groundwater elev. (feet site datum) PVC = 73.21	depth to water below PVC	Groundwater elev. (feet site datum) Approx PVC = 73	depth to water below PVC	Groundwater elev. (feet site datum) Approx PVC = 73
11/28/12 15:30	21.81	51.40	19.06	53.94	14.82	58.18
11/29/12 10:35	21.89	51.32	19.12	53.88	14.86	58.14
11/29/12 17:22	**21.73**	51.48	**19.20**	53.80	**14.82**	58.18
11/29/12 18:45	21.76	51.45	19.26	53.74	14.83	58.17
11/29/12 20:04	21.80	51.41	19.30	53.70	14.84	58.16
11/29/12 23:44	21.86	51.35	19.39	53.61	14.96	58.04
11/30/12 3:33	21.94	51.27	19.48	53.52	15.07	57.93
11/30/12 6:36	22.00	51.21	19.51	53.49	15.11	57.89
11/30/12 8:21	22.04	51.17	19.54	53.46	15.14	57.86
11/30/12 10:04	22.08	51.13	19.55	53.45	15.14	57.86
11/30/12 11:04	22.09	51.12	19.56	53.44	15.13	57.87
11/30/12 12:37	22.13	51.08	19.58	53.42	15.12	57.88
11/30/12 15:40	22.19	51.02	19.59	53.41	15.13	57.87
11/30/12 18:12	22.24	50.97	19.60	53.40	15.13	57.87
11/30/12 19:06	22.26	50.95	19.60	53.40	15.15	57.85
11/30/12 20:10	22.28	50.93	**19.60**	53.40	**15.15**	57.85
12/1/12 8:50	**22.37**	50.84	19.39	53.61	15.12	57.88
12/1/12 10:03	22.36	50.85	19.36	53.64	15.12	57.88
max dd =	**-0.64**		**-0.40**		**-0.33**	
less background	**-0.13**		**-0.19**		**-0.21**	
actual dd =	**-0.51**		**-0.21**		**-0.12**	

distance to DW-1 61 feet

Table A2-2
Tailings Impoundment Pumping Test
OU3 Draft Final Design
Basis of Design Report
Callahan Mine Superfund Site
Brooksville, Maine

	OW1123			MW-705	PZ-705
	depth to water below PVC	Groundwater elev. (feet site datum) Approx PVC = 70		depth to water below PVC	depth to water below PVC
11/29/12 12:47	29.72	40.28	11/29/12 10:39	47.54	23.98
11/29/12 17:31	**29.66**	40.34	11/30/12 15:45	47.60	24.23
11/29/12 18:53	29.68	40.32	11/30/12 18:17	47.60	24.26
11/29/12 20:22	29.67	40.33	11/30/12 20:15	47.62	24.15
11/29/12 23:57	29.70	40.30	12/1/12 8:54	47.65	24.21
11/30/12 3:38	29.75	40.25	12/1/12 10:11	47.66	24.21
11/30/12 6:36	29.79	40.21			
11/30/12 8:21	29.79	40.21			
11/30/12 10:04	29.79	40.21	max dd =	**-0.08**	**-0.17**
11/30/12 11:04	29.79	40.21			
11/30/12 12:46	29.78	40.22			
11/30/12 15:49	29.79	40.21			
11/30/12 18:20	29.79	40.21			
11/30/12 20:20	**29.80**	40.20			
12/1/12 8:55	29.80	40.20			
12/1/12 10:15	29.80	40.20			
max dd =	**-0.14**				

Background Wells

	MW-602D		MW-602S		PZ-602	
	depth to water below PVC	Groundwater elev. (feet site datum) Approx PVC = 73	depth to water below PVC	Groundwater elev. (feet site datum) Approx PVC = 73	depth to water below PVC	Groundwater elev. (feet site datum) Approx PVC = 73
11/28/12 16:17	21.06	51.94	19.15	53.85	14.79	58.21
11/30/12 12:08	21.10	51.90	19.31	53.69	15.00	58.00
12/1/12 9:06	21.19	51.81	19.34	53.66		73.00
min-max =	**-0.13**		**-0.19**		**-0.21**	
barometric eff.:	**0.15**		**0.21**		**0.24**	

Table A2-2
Tailings Impoundment Pumping Test
OU3 Draft Final Design
Basis of Design Report
Callahan Mine Superfund Site
Brooksville, Maine

Barometer

	inches Hg	feet water
11/29/12 12:04	29.64	33.59
11/29/12 16:00	29.70	33.66
11/29/12 19:00	29.70	33.66
11/29/12 21:00	29.75	33.72
11/30/12 3:40	29.95	33.94
11/30/12 6:36	29.95	33.94
11/30/12 8:35	29.94	33.93
11/30/12 10:17	29.95	33.94
11/30/12 11:04	29.85	33.83
11/30/12 18:56	30.20	34.23
11/30/12 20:45	30.20	34.23
12/1/12 8:52	30.42	34.48

min-max = **-0.88** barometric pressure increased during test
should cause extra water level decline in wells (not in VWPs)

Vibrating Wire Piezometers

	VWP-1120					
	Red (deep)		Yellow (mid)		White (shallow)	
	Reading	Groundwater elev. (feet site datum) Approx Tip = 35	Reading	Groundwater elev. (feet site datum) Approx Tip = 47	Reading	Groundwater elev. (feet site datum) Approx Tip = 58
assumed initial GW elev --->		51		54		58
11/29/12 1:27 PM	-15.52	51.00	-7.05	54.00	-0.24	58.00
11/29/12 3:14 PM	-15.51	51.01	-7.02	54.03	-0.21	58.03
11/29/12 4:48 PM	-15.49	51.03	-6.89	54.16	-0.20	58.04
11/29/12 6:33 PM	-15.43	51.09	-6.84	54.22	-0.20	58.04
11/29/12 8:42 PM	-15.42	51.10	-6.83	54.22	-0.21	58.04
11/30/12 12:23 AM	-15.44	51.08	-6.86	54.19	-0.29	57.96
11/30/12 6:05 AM	-15.61	50.91	-7.02	54.03	-0.49	57.75
11/30/12 7:56 AM	-15.66	50.87	-7.08	53.98	-0.55	57.70
11/30/12 9:42 AM	-15.66	50.87	-7.09	53.97	-0.58	57.66
11/30/12 10:45 AM	-15.64	50.89	-7.09	53.96	-0.58	57.66
11/30/12 3:10 PM	-15.65	50.87	-7.12	53.93	-0.59	57.65
11/30/12 6:33 PM	-15.71	50.81	-7.17	53.88	-0.66	57.59
12/1/12 9:36 AM	-16.03	50.49	-7.56	53.49	-0.81	57.43
max dd =	**-0.20**		**-0.15**		**-0.44**	

Table A2-2
Tailings Impoundment Pumping Test
OU3 Draft Final Design
Basis of Design Report
Callahan Mine Superfund Site
Brooksville, Maine

Distance Drawdown Data

Well	R	dd
DW-1 (pumping well)	0.25	23
MW-605D	61	0.51
VWP1120	54	0.20
VWP1121	102	0.37

MW-605D	0.8	feet dd per log cycle hours	
	0.8	feet	3.75 days
	1.6	feet	37.5 days
	2.4	feet	375 days

DW-1 Distance Drawdown T Calculation

T= 528*Q/Delta s

Q = 0.25 gpm

Delta s = 10'- 1' = 9' (change in drawdown for distances of 2.5 and 25 feet from pumping well)

T = 15 gpd/ft

(Reference: Driscoll Groundwater and Wells, 1986, p. 236)

MEDEP Pumping Test

rate =	0.40	gpm
dd =	16	feet
Specific Capacity = Q/dd	0.025	gpm/ft dd

Well	R	dd
OW1123 (pumping well)	0.083	16
VWP1122 deep	11.5	3.3
VWP1121	76	0.85

Table A2-3
Cooper-Jacob Aquifer Parameter Estimator
OU3 Draft Final Design
Basis of Design Report
Callahan Mine Superfund Site
Brooksville, Maine

Data from 11/30/13 pumping test at DW-1

Geology = fine to silty fine sand from ground to ~ 40 feet bgs, transition to silty fine sand and silt by 45 feet bgs, and clay silt at 50 feet bgs. Refusal at ~52 feet bgs.

Depth to groundwater = 21 feet btoc

Well construction: Four inch PVC w/ 0.010 inch slot screen from 49 to 14 feet bgs, installed with sand pack in 6" casing

Hydrogeology CSM: Assume upper 30 feet of saturated silty fine sand Tailings contributes large majority of water to pumping well

pumping rate, Q	enter --->	**0.25**	gpm	measured
		360	gpd	
drawdown, s	enter --->	23	ft	measured
specific capacity, Q/s		0.011	gpm/ft	
T		***7.6***	gpd/ft	estimate by adjusting *K* (and/or *S* and/or *b*) below until match with calculated T below
t	enter --->	1.25	days	measured
r	enter --->	0.25	ft	measured, includes sandpack
Storage, *S*	enter --->	0.10		estimate
b	enter --->	**30**	ft	interpreted
K	enter --->	**0.034**	ft/day	estimate
		1.2E-05	cm/sec	
T = Q/s*264*log(.3Tt/(r^2S))		**7.6**	gpd/ft	
Estimated *T* - Calculated T =		0.0		
Q = T*s/(264*log(.3Tt/(r^2S)) =		**0.25**	gpm	
u = 1.87r^2S/(Tt) =		0.00122		should be less than 0.05 for valid use of Cooper Jacob

Groundwater and Wells p. 1021 T Estimation Method

T = 1500*(Q/s)

pumping rate, Q	from above	**0.25**	gpm	measured
drawdown, s	from above	23	ft	measured
specific capacity, Q/s	from above	0.011	gpm/ft	
T = 1500*Q/s =		**16**	gpd/ft	
b	from above	**30**	ft	interpreted
K		**0.073**	ft/day	estimate
		2.6E-05	cm/sec	

APPENDIX A3
GROUNDWATER MODEL

APPENDIX A3
GROUNDWATER MODEL

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Figure 2 30% design model version. Steady-state uncapped head contours model layer 1– no drains. Initial heads for subsequent transient runs with drains.

Figure 3 Run CalM2R303 – 90% model version. Steady state recalibration. Added K zone (yellow area) in layer 1. Revised constant head along toe of impoundment. Grid refined in lower half to better represent proposed horizontal wells.

Figure 4 Run CalM2R303 – 90% model version. Steady-state existing conditions simulation to generate heads for transient runs. Heads in model layer 1 (tailings- green and yellow; slimes – purple).

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Table 2 Hydraulic Conductivity Zones and Residual Statistics for Calibrated Models

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Table 4 R302 30% Design Model With Drains - Summary Flows Capped Scenario

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Attachment A Output Figures for the 30 Percent Design Support Model Version with Added Horizontal Wells

Attachment B Output Figures for the 90 Percent Design Support Model with Added Horizontal Wells

1.0 INTRODUCTION

This Appendix describes refinements that have been made to groundwater modeling presented in the *30% DESIGN SUBMISSION, BASIS OF DESIGN REPORT CALLAHAN MINE SUPERFUND SITE* (AMEC, April 5, 2013). The reader is referred to that document for further details on the construction of the original model.

To refine the understanding of the effects of multiple deep horizontal wells, six east west drains were added to the original model (which had a single full length north south drain at elevation 35 feet), and a deep full length north to south drain was added. Simulations were performed for both uncapped and capped tailings scenarios.

Next, to support the 90 percent (%) design specification of horizontal drains proposed for the tailings, a new elevation surface representing the bottom of tailings (i.e., the top of underlying clay/till) was prepared based on a thorough interpretation of geotechnical and monitoring well boring logs. Since these data also represented a potentially significant change in the original simplified groundwater model used to support the 30 percent design, the original model was revised to incorporate the new bottom of tailings data. In addition, an interpreted top of bedrock surface was created.

When the new surfaces were ready, they were imported into the model domain, the model was revised and recalibrated, and the proposed horizontal wells were imported into the newer model. This memorandum describes the model revisions, horizontal drain placements, and simulations of drain flows under both uncapped and capped scenarios. Finally, we note the limitations of the modeling and that these simulations provide only approximate results under the conditions assumed, and are best used to compare alternatives in a relative sense.

2.0 MODEL SETUP

2.1 Summary of the 30% Design Support Model

The 30 percent design support model was a simple box model. The active portion of the model domain covered an area of approximately 750,000 square feet (680 feet in the east west direction by 1,100 feet north to south - about 17 acres) and is a grid with an origin at 904630 E and 245763 N (horizontal control based on North American Datum (NAD) of 1983, Maine State Plane, East Zone, U.S. Feet. and vertical control based North American Vertical Datum of 1988 – the same as on the original EPA site survey prepared by TRC during the SI phase). The model contained three layers – one each for tailings, clay/till, and upper (50 feet) of fractured bedrock and was based on a uniform application of a typical cross section of the impoundment (from the Remedial Investigation Report, MACTEC, 2009) that was carried across the entire north-south length of the model domain. As such it simplifies the tailings as relatively uniform whereas in reality, it is a multilayered sequence of fines and coarser materials. While there are downward vertical gradients within the tailings which drive the natural drainage of the impoundment, incorporating two or more layers within the tailings to simulate vertical gradients was beyond the objective of the three layer modeling effort. The presence of "slimes", a wet and relatively high fines volume of material, was represented as a monolithic and uniform mass in the central portion of the impoundment. Similarly, the clay/till layer was considered uniform in properties, but did vary in thickness across the section. The bedrock was conceptualized as a representative volume of constant thickness (50 feet) and treated as a porous medium of relatively low hydraulic conductivity, low porosity and, and low specific yield. Lateral boundary conditions were no-flow to the north and south, and constant heads to the east and west of the impoundment. Simulations for the 30% design considered only one horizontal well near the east toe of the impoundment at elevation 35 feet site datum (about 15 feet below the water table) to facilitate dewatering in the area where tailings would need to be excavated during cap construction. These results provided a favorable indication for the potential use of horizontal wells to dewater this eastern portion of the tailings (results discussed below).

2.2 Summary of Adjustments to the 30% Design Support Model

The 90% design support modeling included the addition of six horizontal wells that would protrude through the eastern face of the toe and extend inward into the impoundment along the bottom of the tailings surface. Invert elevations used in the model for these drains representing the horizontal wells are summarized on Table 1. The grid for the 30% design model was refined in the eastern portion of the model domain to better represent the proposed additional drains and run to yield preliminary results while the expanded bottom of tailings and top of rock surfaces were being generated. The refined grid is shown on Figure 1. The refinement of the grid in the eastern portion of the model reduces the grid block size from 10x10 feet to 5x5 feet. The change in the grid block size had negligible effect on the calibration statistics. The base, steady-state model (model run CalM2R300) was rerun to generate starting heads (see Figure 2) for the newer gridding in the transient runs for the uncapped and capped impoundment conditions.

2.3 Addition of Refined Model Layer Elevations and Other Modifications

When the new bottom of tailings and top of rock surface files were available, they were imported into the model domain. Some areas had conflicting surface elevations due to the interpolation algorithm combined with differing sets of data point locations. Most of these were repaired by increasing the ground surface elevation in the northwest corner of the model. These adjustments are not critical as the focus of attention is in the eastern portion of the model near the dam crest and toe. In addition, layer 1 of the model is considered water table conditions; ground surface elevations are not used in model calculations of head for this layer.

Two other modifications in the model were made to improve recalibration and more accurately represent conditions. These were to 1. wrap the constant head boundary on the east side of model layer 1 around the northeast and southeast corners of the tailings to more closely conform to the actual extent of the confining base rock dam and areas of observed and likely seepage, and 2. The addition of a zone of lower hydraulic conductivity (K) in the northeast corner of the tailings to aid in model calibration (see Figure 3).

2.4 Recalibration

Recalibration was accomplished with the aid of the calibration algorithm in Groundwater Vistas including calibration on all five zones of K (model run CalM2R303). Resultant calibration statistics were generally consistent with those in the original 30% design model and with respect to K, reasonably close to values obtained from the pumping test (K in the model = 0.1 feet/day; K from the pumping test = 0.034 to 0.073 feet/day). It is noted that the model calibration is intended to provide a fit over as much of the model domain as possible, and not just use values obtained from the area near, and during the short time period of, the pumping test. An exception was with residuals in the western portion of the model in model layer 1. The residuals here (as noted above) are not reliable as the newer model suggests that model layer 1 is partly dry in this area. Residuals in the critical eastern portion of model layer 1 are reasonable as indicated by the mix of positive and negative residuals shown for this area of the model in Figure 4. Table 2 summarizes K values and residual statistics for this model run.

The output heads of this recalibration run (see Figure 3) were used as initial heads for subsequent simulations of the capped and uncapped conditions including the proposed horizontal well locations. One other difficulty was encountered in that the model appeared to be unstable using these initial heads. However, using the option in Groundwater Vistas to set initial heads at 1 foot above the layer bottom, the model ran well. This has the effect of an initial amount of water to be greater in the 90% support model than in the 30% support model. As will be seen, this slightly affected the estimated initial flux to the horizontal wells, but had no significant effect in flux or volumes of water removed in longer simulation times.

3.0 MODEL OUTPUTS

This section describes model run outputs using the original 30% design support model both prior to and with the additional east-west horizontal wells, and also the newer 90% design support version with the newer layers, recalibration, and the added horizontal wells. As will be seen, these two models, despite their differences, result in very similar estimates of dewatering times and flow rates for the uncapped and capped simulations. The output from both models has been used to develop the overall horizontal well dewatering approach for the Site. As discussed in Section 5.2.3 of the BOD report, while a deep trench may potentially be more efficient at dewatering the layered tailings deposits, its installation would be cost prohibitive relative to the cost of a horizontal well system. In addition, the model as built would be anticipated to predict lower flow rates and longer dewatering times than a trench and thus may provide a conservative estimate of dewatering times.

3.1 30 % Design Support Model Runs

Pre-Construction Single Drain Dewatering Run

Run 16 from the 30% design model (uncapped with a single horizontal well) provided results that showed a lowering of the water table to about elevation 41 feet after 180 days of operation. Figure 5.2b of this 90% BOD report presents the predicted dewatering for construction in profile and Table 3 provides predicted flows. The results of this run are shown in Table 3 and indicate initial total flows for the single full length north-south drain of 6.0 gpm decreasing to 1.5 gpm at year 1 and 1.0 gpm at year 2.

Multiple Drain Runs

Attachment A contains figures associated with the use of the 30% design support model to estimate flows and conditions for the proposed full array of horizontal wells – six drains oriented east-west and two full length drains oriented north-south (note: in the model the two North-South drains lie entirely along one row of the model and one lies directly above the other; flows however for each are reported as Upper South, Upper North, Lower South, Lower North). Figure A-1 shows the resultant equilibrium heads in model layer 1 (tailings) for the uncapped condition (model run CalM2R301). Equilibrium conditions represent a balance between the amount of recharge that occurs and the amount of flow the horizontal wells are estimated to remove. Some flow still leaves the system through the clay/till and bedrock layers. Effects of several of the horizontal wells are seen in the warping of the head contours. The initial flow rate to the horizontal drains was estimated at about 26 gallons per minute (gpm), decreasing to about 2.6 gpm under equilibrium conditions.

Figure A-2 shows a cross section at column 112, about half-way across the model domain. This shows an elevated water table in the area of the slimes – as expected – because the K and the specific yield of this material is specified to be lower than the surrounding materials and takes longer to drain.

Figures A-3 through A-6 show model plan view head contours at approximately 1, 2, 5, and 10 years of simulation of the capped scenario (model run CalM2R302). These figures show successively declining heads as most of the recharge is cut off by the cap. In addition, the effects of, and flows to, horizontal wells decrease with time since the water levels within the impoundment decline as a combination of water removed and natural decline through underflow in the clay/till and shallow bedrock. In general, for later times, total flows in the model are low. Here, the initial flow to drains is again about 26 gpm, but after 10 years, the flow rate to drains has declined to about 0.1 gpm. Table 4 presents a summary of flows to individual and all drains for the capped scenario run. The decline in the water table at about 10 years into the simulation is evidenced in Figure A-7, which corresponds to Profile E-3 (Figure 5.2c of the BOD report.

3.2 90 % Design Support Model Version Runs

Multiple Drain Runs

Attachment B contains figures associated with the 90 percent design support model used to estimate flows and conditions for the proposed array of horizontal wells. Figure B-1 shows the simulated uncapped condition heads (model run CalM2R304) in model layer 1 (tailings), which indicate groundwater elevations in the vicinity of the north-south drains of 30 to 34 feet (with lower groundwater adjacent to east flowing drains, and higher groundwater to the west toward the slimes). For this scenario and a bottom of tailings elevation of approximately 20 feet, the steady state uncapped fully drained condition will leave 10 to 14 feet of groundwater saturation above the bottom of the tailings. Initial flows to the drains are 29.6 gpm (higher partly due to the added water to allow model stability as discussed previously) which decline to 2.3 gpm at steady-state conditions. These results compare favorably to 2.6 gpm in the 30% model version.

Figures B-2 through B-17 show a sequence of results at simulation times of about 1, 2, 5, and 10 years for the capped condition (model run CalM2R305). Each set of four shows the plan view of heads in model layer 1, and a set of corresponding cross sections at approximate sections E-1, E-3, and E-4. Some of the apparent jogs in the water table location correspond to places in the model where nodes may go dry, principally in the upper, west portions of the model, and become inactive and isolate some perched water. This is an artifact of the model. Heads in these locations would be expected to decline as well. Summary fluxes and accumulative volumes are summarized for individual and total drains in Table 5 for the capped simulation.

4.0 SUMMARY

The flowing summarizes the modeling completed to date for the site:

- The original 30% design model for an uncapped scenario showed that a single full length north- south horizontal well at elevation 35 feet lowered the water table to about elevation 41 feet after 180 days of operation. These results provided a favorable indication for the use of horizontal wells to dewater the eastern portion of the tailings which would be necessary for cap construction. Initial total flows for the well were 6.0 gpm, decreasing to 1.5 gpm at year 1 and to 1.0 gpm at year 2.
- In both the 30% and 90% design models there is reasonably close agreement with flux rates, volumes removed over time (within about 10 percent at 10 years), and rates of head decline.
- The function of the upper drains is limited to the first two or three years. Following that, the long, deeper north-south oriented drain in conjunction with natural water decline in response to cutting off recharge are the primary contributors to a dropping water table. There appears to be very little water flux through the system at later time.
- After 10 years of capped operation, the total flow from all drains is on the order of 0.1 gpm. Both the till and fractured bedrock underlying the tailings are expected to provide consistent under drainage while the effects of the horizontal wells decline over time. These results imply that, once dewatered, if the drains were to fail, there would not be a significant build up of water in the bottom of the tailings. This condition is supported by water level measurements for the two bedrock wells installed at the northeast and southeast corners of the tailings impoundment which show groundwater elevations at three feet below the bottom of tailings (MW-604R) to 6 feet above the bottom of tailings (MW-722R).

5.0 LIMITATIONS OF THE MODELING

In general, any model is a simplification of actual conditions and assumes homogeneity over areas where heterogeneity may prevail. More specifically, several factors may influence both the rates and durations determined through the current modeling. The more important of these are: the actual Ks, which may vary considerably over even short distances, both horizontally and vertically; the specific yield; the conductance (connectivity) of the drains with the aquifer; and the ability of the model to accurately reflect aquifer conditions, including the bedrock as a representative homogeneous medium rather than fractured medium (although the bedrock appears to have little bearing on the treatment of the dewatering of the tailings). The model has assumed a reasonable recharge rate over the existing impoundment and bedrock to the west of the model domain. These assumptions will have an influence over the Ks which come out of the calibration. Greater Ks may result in higher initial flow rates and shorter durations to lower heads, and vice-versa. The greatest factor may be the specific yield as the heads are drawn down. The modeling conducted here assumes a specific yield of 0.1 for the tailings and till and 0.01 for the slimes. If the specific yield is actually greater, then the expected volumes may be proportionately greater, but the durations may be somewhat similar. Lastly, there is an assumption that the horizontal wells can be installed approximately to the specifications included in the modeling. That is, the wells can achieve the lengths, and invert elevations contained in the model. Actual installations may result in somewhat different attained elevations depending mainly on the till surface encountered. The model also assumes that the full length of the screened portion of the well is active, that is, portions of the screen are not smeared closed, or can be developed to overcome such smearing if it occurs. The expected alternating strata of fines and more coarse materials within the tailings may also limit the flow paths of groundwater to well screens. The actual flows to horizontal wells may not be accurately known until they are installed. In general, however, the greater the length of screen installed at the bottom elevation of, or within, the tailings, the more effective will be the dewatering and the attainment of working platforms or desired stability criteria.

TABLES

Table 1
Invert Elevations for Simulated Horizontal Wells

Callahan Mine Superfund Site
Brooksville, Maine

Horizontal Well	Model Drain Reach #	Low end Feet	Upper end Feet
Shorter E-W wells			
EW-1	1	18.5	20.8
EW-2	2	15.7	18.5
EW-3	3	18.1	22.0
EW-4	4	16.1	18.8
EW-5	5	19.0	40.0
EW-6	6	17.8	27.8
Longer N-S wells			
Upper - South Half	7	33.0	48.9
Upper - North Half	8	32.8	48.9
Lower - North-South	9	20.0	20.0

Table 2
Hydraulic Conductivity Zone Values and
Resdiual Statistics for Calibrated Models

Callahan Mine Superfund Site
Brooksville, Maine

	30% Regridded Run CalM2R300	90% New Layering Run CalM2R303
K-Zone		
Bulk of tailings	0.0948	0.1
Till	0.281	0.267
Fractured rock	0.204	0.198
Slimes	0.01	0.007
New NE tailings	NA	0.019
Resdiual Stats		
Average	0.05	-0.23
Average absolute	2.47	2.8
Standard Deviation	3.1	3.98
Sum of Squares	192	317
Minimum	-6.49	-9.96
Maximum	4.71	9.33
Std Dev/range	0.042	0.054

Notes: 1. Hydraulic conductivity in feet per day.
2. Statistics based on 20 water level targets.

Table 3
Run 16 - 30% Design Model - Single Drain Uncapped

Callahan Mine Superfund Site
Brooksville, Maine

	Drain only		Reduce Tailings Sy	
Time, days	gpm	gallons	gpm	gallons
1.6	5.98	14,213	5.6	13,362
94.4	2.51	456,857	1.53	339,749
180.1	1.97	723,008	0.88	477,558
271	1.66	954,562	0.5	559,800
366	1.47	1,162,003	0.24	603,270
544	1.2	1,490,052	0.026	624,129
730	1.04	1,781,106	0	524,682

Table 4
Run 302 - 30% Design Model With Multiple Drains - Summary Flows Capped Scenario

Callahan Mine Superfund Site
Brooksville, Maine

		EW-1				EW-2				EW-3				EW-4				EW-5				EW-6			
Time - days	Time - years	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal
0.053	0.000145	64.4	3.4	0.3345	25	168	8.9	0.873	67	92	4.9	0.4779	37	144	7.6	0.748	57	355	18.8	1.844	141	371	19.6	1.927	147
31.4	0.09	48	1689	0.2494	12634	134	4556	0.696	34079	73.8	2500	0.3834	18700	97.5	3538	0.506	26464	272	9414	1.413	70417	273	9593	1.418	71756
90.5	0.25	35.9	4098	0.1865	30653	111	11664	0.577	87247	61.6	6437	0.3200	48149	71.1	8354	0.369	62488	215	23481	1.117	175638	212	23564	1.101	176259
176.9	0.48	26.4	6695	0.1371	50079	89	20094	0.462	150303	50	11153	0.2597	83424	51.7	1352	0.269	10113	168	39603	0.873	296230	163	39266	0.847	293710
379.8	1.04	15.6	10675	0.0810	79849	57.6	34265	0.299	256302	32.5	19140	0.1688	143167	30.1	21172	0.156	158367	106	66002	0.551	493695	101	64553	0.525	482856
556.3	1.52	10.9	12881	0.0566	96350	40.6	42457	0.211	317578	22.8	23759	0.1184	177717	19.5	25221	0.101	188653	72.4	80835	0.376	604646	63.9	78375	0.332	586245
740.7	2.03	7.9	14504	0.0410	108490	28.5	48395	0.148	361995	16	27095	0.0831	202671	12.9	27925	0.067	208879	47.7	91027	0.248	680882	38	86881	0.197	649870
896.3	2.45	6.2	15528	0.0322	116149	20.9	51937	0.109	388489	12	29102	0.0623	217683	8.8	29429	0.046	220129	33.1	96698	0.172	723301	23.7	90907	0.123	679984
1084.6	2.97	4.7	16484	0.0244	123300	14	54900	0.073	410652	8.5	30847	0.0442	230736	6.7	30756	0.035	230055	20.7	101130	0.108	756452	15.4	94100	0.080	703868
1921.9	5.26	1.8	18801	0.0094	140631	3.2	60191	0.017	450229	1.9	34116	0.0099	255188	2.1	33521	0.011	250737	0.66	106138	0.003	793912	1.4	98843	0.007	739346
2558.3	7.00	0.7	19455	0.0036	145523	1.9	61606	0.010	460813	0.5	34696	0.0026	259526	1.1	34403	0.006	257334	0	106170	0.000	794152	0.6	99344	0.003	743093
3745.8	10.26	0.02	19671	0.0001	147139	1	63124	0.005	472168	0.04	34870	0.0002	260828	0.7	35353	0.004	264440	0	106170		794152	0.03	99472	0.000	744051
4120.4	11.28		19671		147139	1	63487	0.005	474883	0.02	34878	0.0001	260887	0.6	35582	0.003	266153		106170		794152	0.02	99478	0.000	744095
4532.5	12.41		19671		147139		63487		474883		34878		260887		35582		266153		106170		794152		99478		744095

		Drain 7 - Upper, Southern half				Drain 8 - Upper, Northern Half				Drain 9 - Lower, Southern Half				Drain 10 - Lower, Northern Half				Total Drains				
Time - days	Time - years	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Time - yrs
0.053	0.000145	315.7	16.7	1.640	125	1712.6	90.7	8.897	678	1141	60.4	5.927	452	618	32.7	3.210	245	4980.9	263.87	25.875	1974	0.000145
31.4	0.09	159.4	6472	0.828	48411	200.7	12395	1.043	92715	360	12046	1.870	90104	275	8955	1.429	66983	1894.4	71158	9.841	532262	0.09
90.5	0.25	81.9	13062	0.425	97704	64.7	18876	0.336	141192	332	32398	1.725	242337	254	24509	1.319	183327	1439.4	166440	7.477	1244971	0.25
176.9	0.48	33.8	17465	0.176	130638	21	21888	0.109	163722	301	59518	1.564	445195	230	45214	1.195	338201	1134.6	274350	5.894	2052138	0.48
379.8	1.04	7.9	20437	0.041	152869	5.2	24013	0.027	179617	243	113806	1.262	851269	185	86597	0.961	647746	784.6	460660	4.076	3445737	1.04
556.3	1.52	2.5	21183	0.013	158449	0.72	24377	0.004	182340	205	152331	1.065	1139436	156	115853	0.810	866580	594.1	577270	3.086	4317980	1.52
740.7	2.03	0.25	21337	0.001	159601	0	24385	0.000	182400	176	186372	0.914	1394063	134	141668	0.696	1059677	461.2	669590	2.396	5008533	2.03
896.3	2.45	0	21337	0	159601		24385		182400	160	211833	0.831	1584511	121	161012	0.629	1204370	385.5	732170	2.003	5476632	2.45
1084.6	2.97		21337		159601		24385		182400	142	239341	0.738	1790271	108	182013	0.561	1361457	320.2	795290	1.663	5948769	2.97
1921.9	5.26		21337		159601		24385		182400	73.7	323527	0.383	2419982	58.5	247636	0.304	1852317	143.2	968500	0.744	7244380	5.26
2558.3	7.00		21337		159601		24385		182400	39.4	355123	0.205	2656320	31.9	273005	0.166	2042077	76.2	1029500	0.396	7700660	7.00
3745.8	10.26		21337		159601		24385		182400	7.2	375520	0.037	2808890	7.3	290493	0.038	2172888	16.4	1070400	0.085	8006592	10.26
4120.4	11.28		21337		159601		24385		182400	1.8	376187	0.009	2813879	3.4	291760	0.018	2182365					11.28
4532.5	12.41		21337		159601		24385		182400	0	376187	0.000	2813879	0.4	291814	0.002	2182769					12.41

Notes:
Model Run CalM2R302 Output Summary Flows and Accumulative Volumes - 30% Design Model - Capped Scenario
Specific yield of 0.1 in tailings and till

Table 5
Run 305 - 90% Design Model With Multiple Drains - Summary Flows Capped Scenario

Callahan Mine Superfund Site
Brooksville, Maine

		EW-1				EW-2				EW-3				EW-4				EW-5				EW-6			
Time - days	Time - years	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal
0.053	0.000145	75.8	4	0.3938	30	187	10	0.971	75	82.1	4	0.4265	30	127	7	0.660	52	406	21	2.109	157	374	20	1.943	150
31.4	0.09	57.4	2012	0.2982	15050	154	5187	0.800	38799	53.3	1945	0.2769	14549	72.4	2845	0.376	21281	314	10845	1.631	81121	248	9076	1.288	67888
90.5	0.25	43.1	4898	0.2239	36637	130	13474	0.675	100786	38.3	4553	0.1990	34056	41.4	5978	0.215	44715	249	27096	1.294	202678	179	21231	0.930	158808
176.9	0.48	31.8	8019	0.1652	59982	107	23492	0.556	175720	27.6	7287	0.1434	54507	22.1	8510	0.115	63655	194	45683	1.008	341709	134	34281	0.696	256422
379.8	1.04	19.2	12851	0.0997	96125	71.6	40808	0.372	305244	15.8	11373	0.0821	85070	9.06	11194	0.047	83731	116	75513	0.603	564837	89.7	55768	0.466	417145
556.3	1.52	13.5	15572	0.0701	116479	51.8	51172	0.269	382767	10.6	13559	0.0551	101421	5.87	12396	0.030	92722	78.1	91571	0.406	684951	68.3	69140	0.355	517167
740.7	2.03	9.8	17586	0.0509	131543	34.6	58663	0.180	438799	6.9	15009	0.0358	112267	4.45	13291	0.023	99417	53.5	102830	0.278	769168	53	79787	0.275	596807
896.3	2.45	7.68	18858	0.0399	141058	23.1	62612	0.120	468338	4.85	15858	0.0252	118618	3.36	13836	0.017	103493	38.8	109397	0.202	818290	43.1	86854	0.224	649668
1084.6	2.97	5.85	20038	0.0304	149884	15.4	65916	0.080	493052	3.43	16549	0.0178	123787	2.4	14330	0.012	107188	27.1	115020	0.141	860350	33.6	93608	0.175	700188
1921.9	5.26	2.78	22504	0.0144	168330	3.86	71747	0.020	536668	0.92	17928	0.0048	134101	1	15569	0.005	116456	4.73	124458	0.025	930946	9.3	107831	0.048	806576
2558.3	7.00	0.95	23215	0.0049	173648	1.48	73051	0.008	546421	0.37	18242	0.0019	136450	0.58	16002	0.003	119695	0.94	125632	0.005	939727	3.56	111193	0.018	831724
3745.8	10.26	0.31	23813	0.0016	178121	0.1	73528	0.001	549989	0.1	18438	0.0005	137916	0.24	16421	0.001	122829	0.06	125866	0.000	941478	0.086	112302	0.000	840019
4120.4	11.28	0.21	23893	0.0010909	147139	0.05	73546	0.000	550124	0.06	18461	0.0003	138088	0.2	16495	0.001	123383	0.034	125880	0.000	941582	0.043	112318	0.000	840139
5484.5	15.02	0.057	24020	0.0002961	147139	0.014	73576	0.000	550348	0	18476	0.0000	138200	0.09	16663	0.000	124639	0	125884	0.000	941612	0.013	112345	0.000	840341
6636.3	18.17	0.022	24053	0.0001143	147139	0.067	73585	0.000	550416	0	18476	0.0000	138200	0.037	16723	0.000	125088	0	125884	0.000	941612	0.006	112354	0.000	840408
7300	19.99	0.013	24062	6.753E-05	147139	0.006	73589	0.000	550446	0	18476	0	138200	0.037	16747	0.000	125268	0	125884	0.000	941612	0.004	112356	2.078E-05	840423

		Drain 7 - Upper, Southern half				Drain 8 - Upper, Northern Half				Drain 9 - Lower, Full Length				Total drains				
Time - days	Time - years	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Flux -cfd	Ac Vol cf	Flux - gpm	Ac Vol - gal	Time - yrs
0.053	0.000145	423	22	2.197	165	1587	84	8.244	628	2408	128	12.509	957	5670.7	300.4	29.458	2247	0.000145
31.4	0.09	254	9745	1.319	72893	147	8992	0.764	67260	566	21378	2.940	159907	1869.6	72090	9.712	539233	0.09
90.5	0.25	147	20897	0.764	156310	57.7	14204	0.300	106246	488	51933	2.535	388459	1375.3	164440	7.144	1230011	0.25
176.9	0.48	72.9	29592	0.379	221348	19.4	17004	0.101	127190	431	91083	2.239	681301	1041.2	265260	5.409	1984145	0.48
379.8	1.04	17.3	36246	0.090	271120	2.86	18330	0.015	137108	350	168669	1.818	1261644	692.4	431320	3.597	3226274	1.04
556.3	1.52	7.05	38066	0.037	284734	0.63	18561	0.003	138836	300	224708	1.558	1680816	536.4	535490	2.786	4005465	1.52
740.7	2.03	2.05	38699	0.011	289469	0	18575	0.000	138941	258	274705	1.340	2054793	423.1	620000	2.198	4637600	2.03
896.3	2.45	0.27	38794	0.0014026	290179	0	18575	0	138941	229	311463	1.190	2329743	350.9	677220	1.823	5065606	2.45
1084.6	2.97	0	38794	0	290179	0	18575	0	138941	199	350363	1.034	2620715	287.7	734270	1.495	5492340	2.97
1921.9	5.26	0	38794	0	290179	0	18575	0	138941	106	468383	0.551	3503505	128.2	887130	0.666	6635732	5.26
2558.3	7.00	0	38794	0	290179	0	18575	0	138941	63.2	516795	0.328	3865627	71.2	942950	0.370	7053266	7.00
3745.8	10.26	0	38794	0	290179	0	18575	0	138941	24.2	559048	0.126	4181679	25.2	988320	0.131	7392634	10.26
4120.4	11.28	0	38794	0	290179	0	18575	0	138941	18.9	566124	0.098	4234608	19.5	995630	0.101	7447312	11.28
5484.5	15.02	0	38794	0	290179	0	18575	0	138941	9.37	582283	0.049	4355477	9.5	1012200	0.049	7571256	15.02
6638.3	18.17	0	38794	0	290179	0	18575	0	138941	5.6	589737	0.029	4411233	5.7	1019700	0.030	7627356	18.17
7300	19.99	0	38794	0	290179	0	18575	0	138941	4.37	592640	0.023	4432947.2	4.4	1022700	0.023	7649796	19.99

Notes
Model Run CalM2R305 Output Summary Flows and Accumulative Volumes - 90% Design Model - Capped Scenario
Specific yield of 0.1 in tailings and till

FIGURES

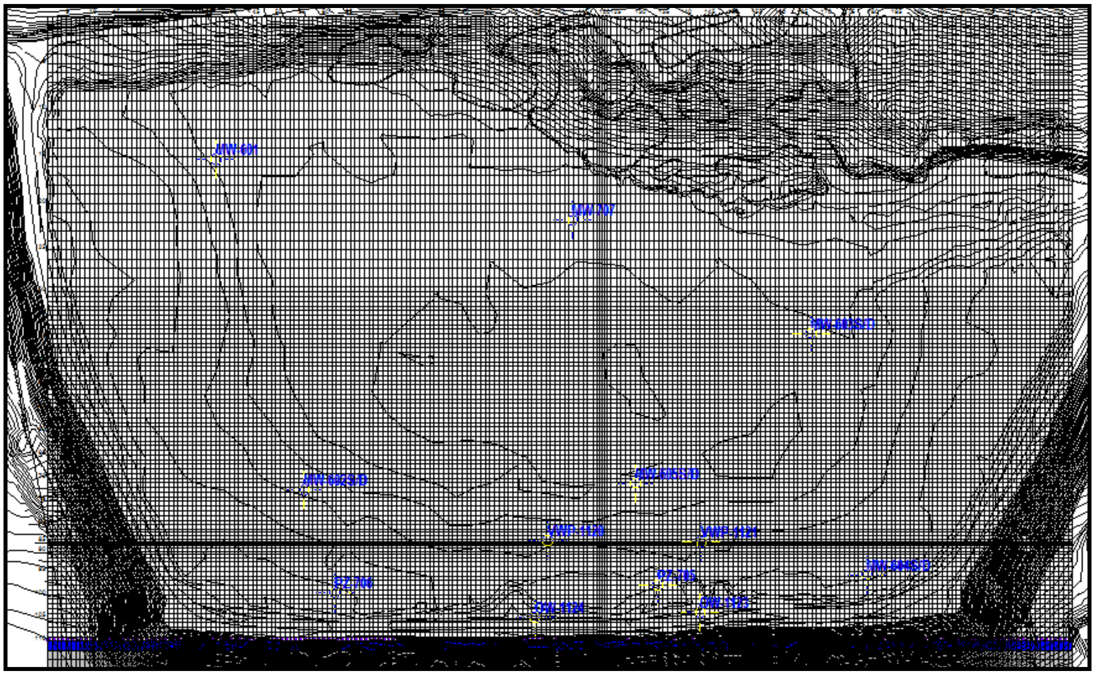

Figure 1: Refined grid: Lower model grid blocks typically 5x5 ft.

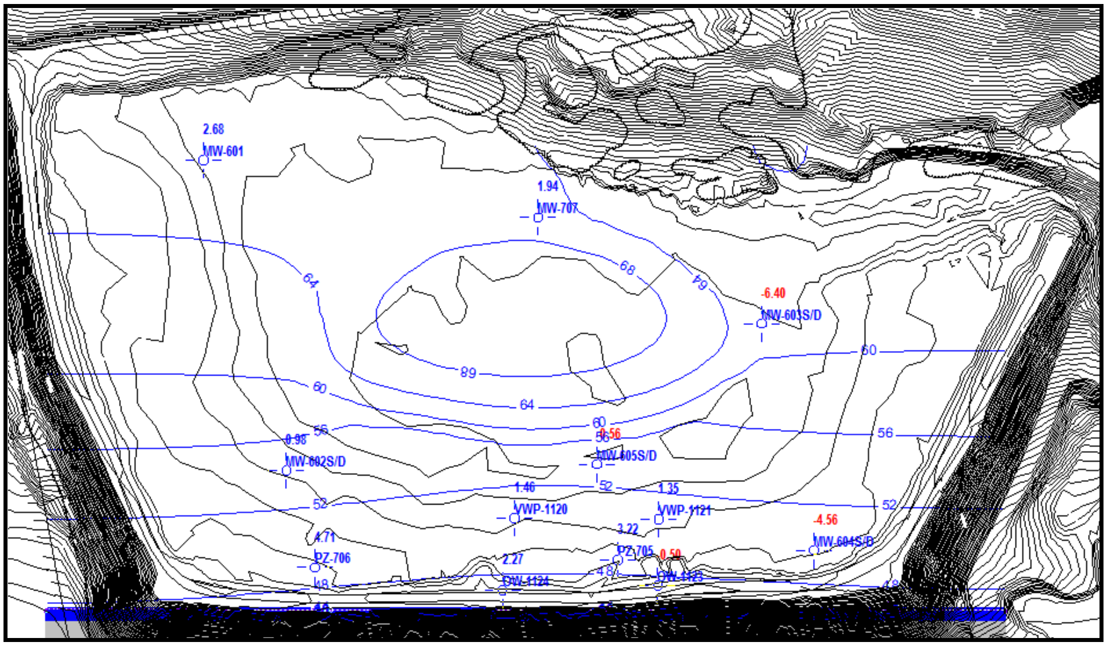

Figure 2: 30% design model version. Steady-state uncapped head contours model layer 1– no drains. Initial heads for subsequent transient runs with drains.

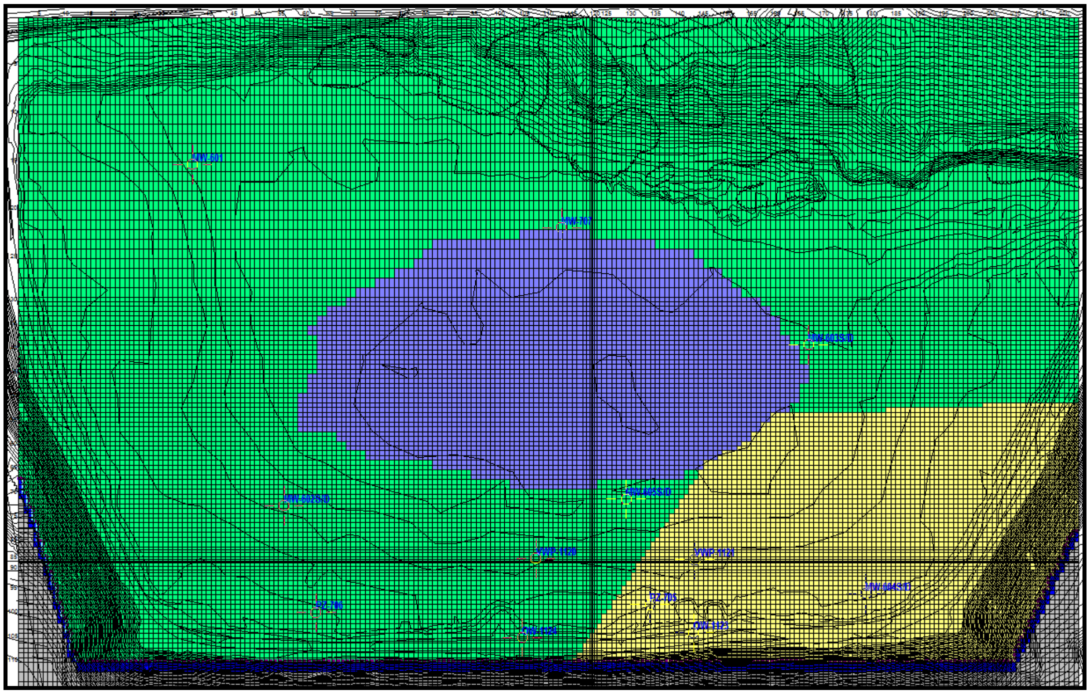

Figure 3: Run CalM2R303 – 90% model version. Steady state recalibration. Added K zone (yellow area) in layer 1. Revised constant head along toe of impoundment. Grid refined in lower half to better represent proposed horizontal wells.

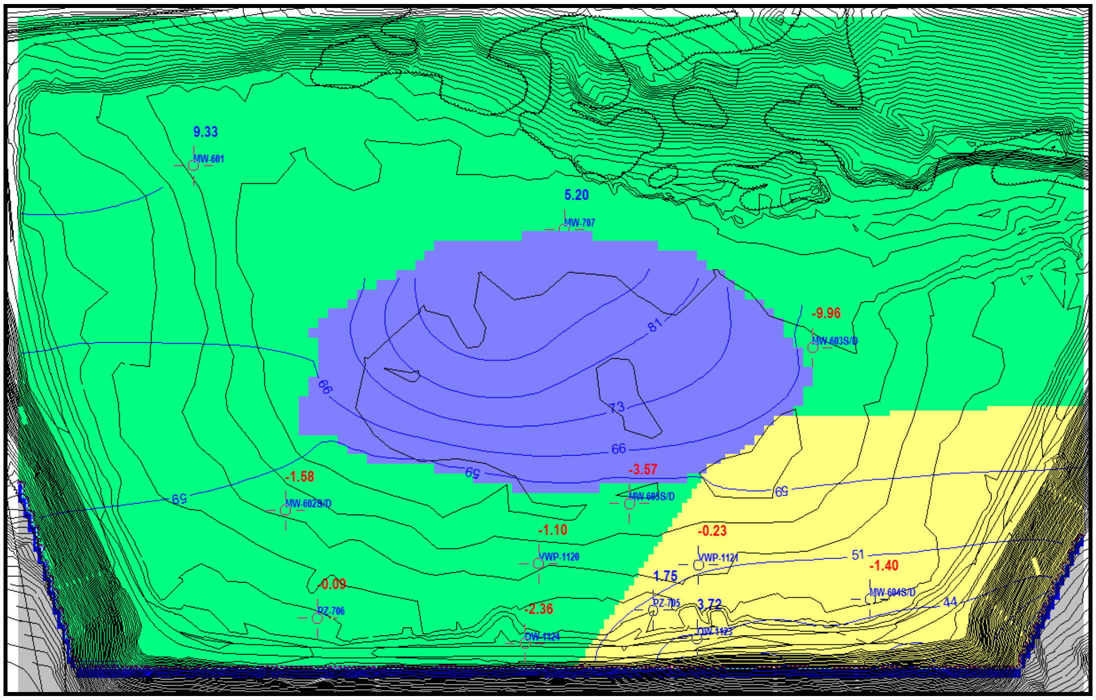

Figure 4: Run CalM2R303 – 90% model version. Steady-state existing conditions simulation to generate heads for transient runs. Heads in model layer 1 (tailings- green and yellow; slimes – purple).

ATTACHMENT A
OUTPUT FIGURES FOR THE 30 PERCENT DESIGN SUPPORT MODEL VERSION WITH ADDED HORIZONTAL WELLS

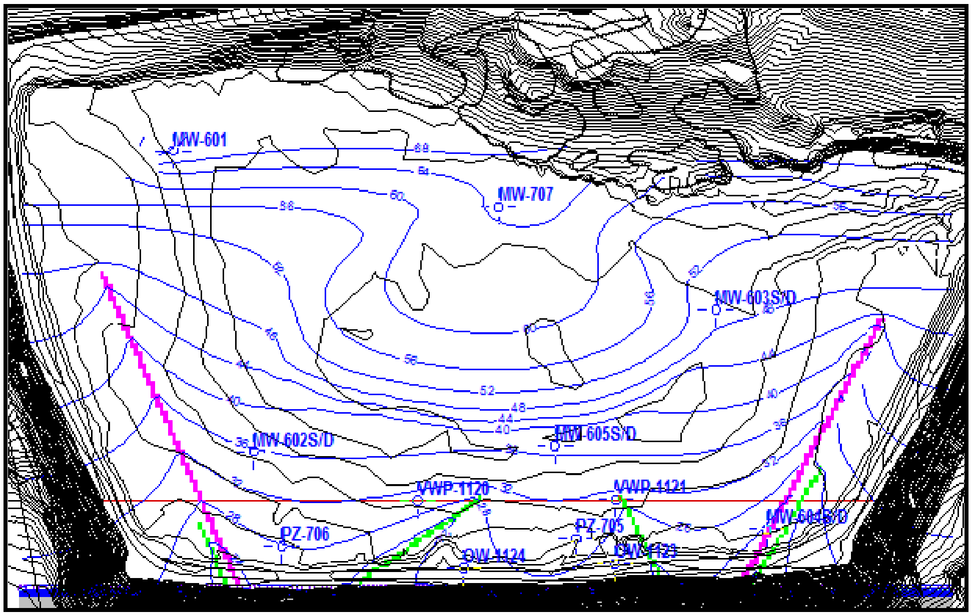

Figure A-1: Run CalM2R301 – Long-term head distribution model layer 1. Uncapped condition, drains (pink, green, red and orange lines) operating. Initial flow to all drains about 25.9 gpm; long-term average flow about 2.6 gpm.

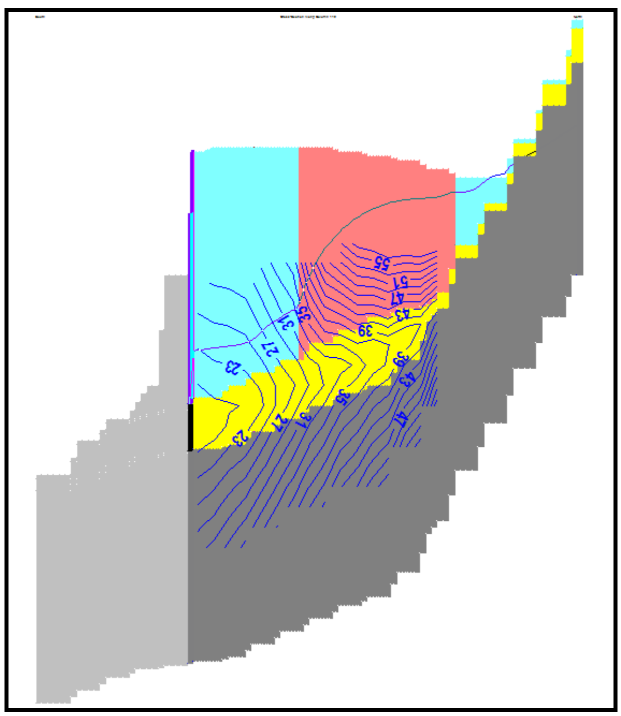

Figure A-2: Run CalM2R301 - Long-term head distribution, column 112 (mid-model) – minimum head at about 19, maximum at about 69 ft msl.

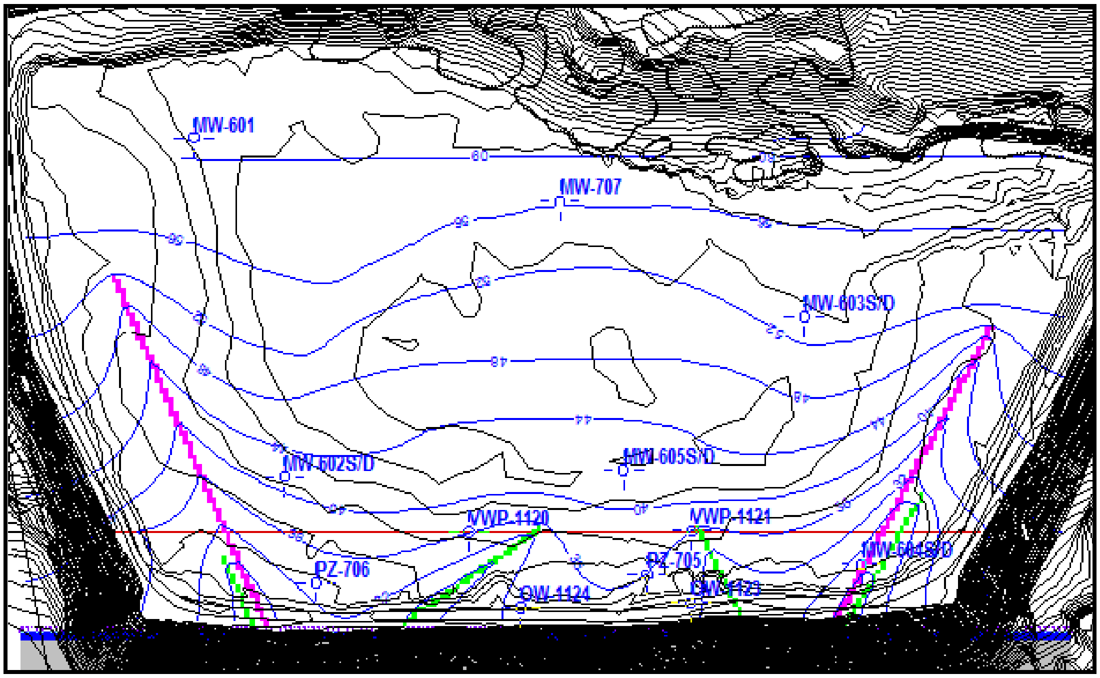

Figure A-3: Run CalM2R302 – Capped, heads in layer 1 at about 1.04 years.

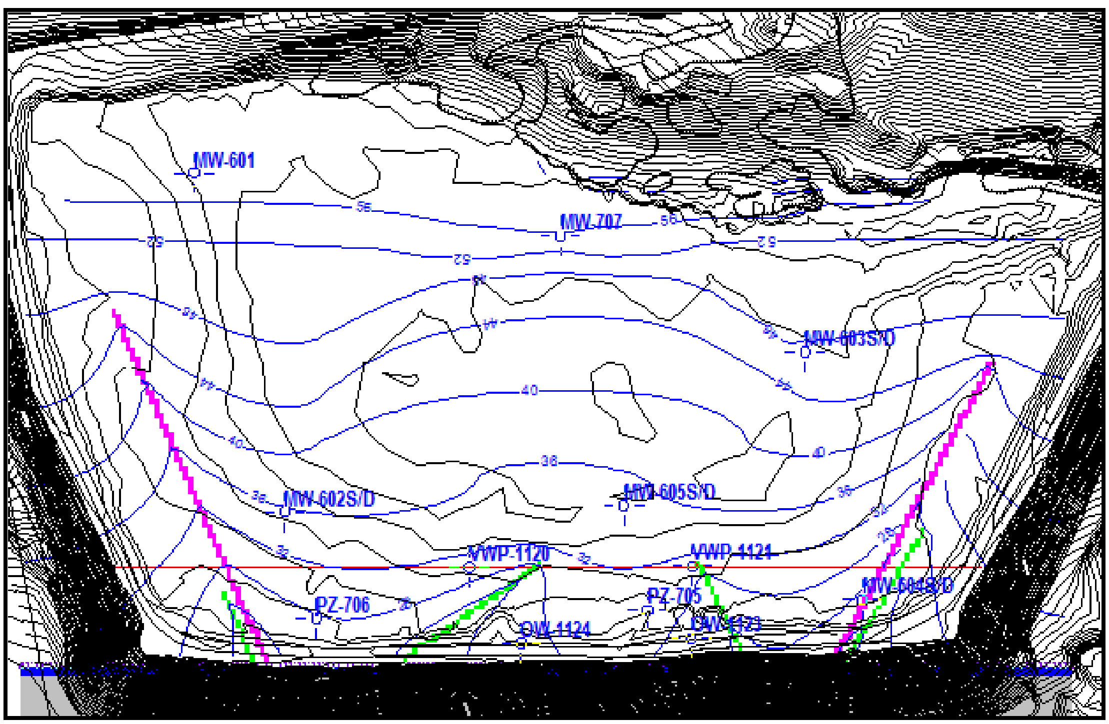

Figure A-4: Run CalM2R302 – Capped, heads in layer 1 at about 2.03 years

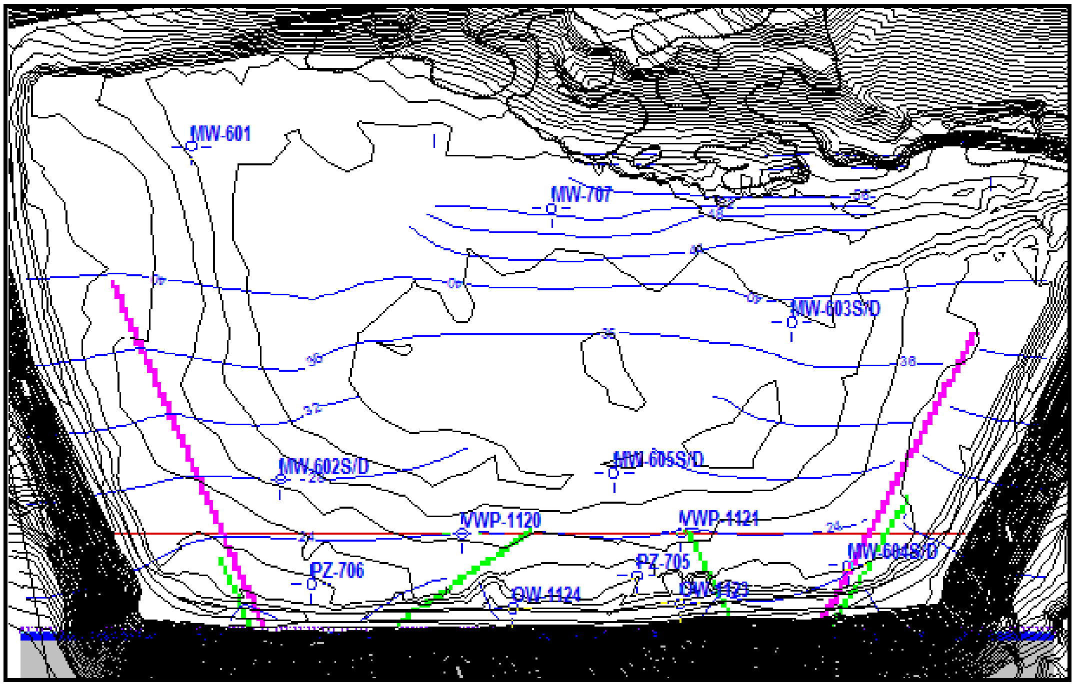

Figure A-5: Run CalM2R302 – Capped, heads in layer 1 at about 5.26 years.

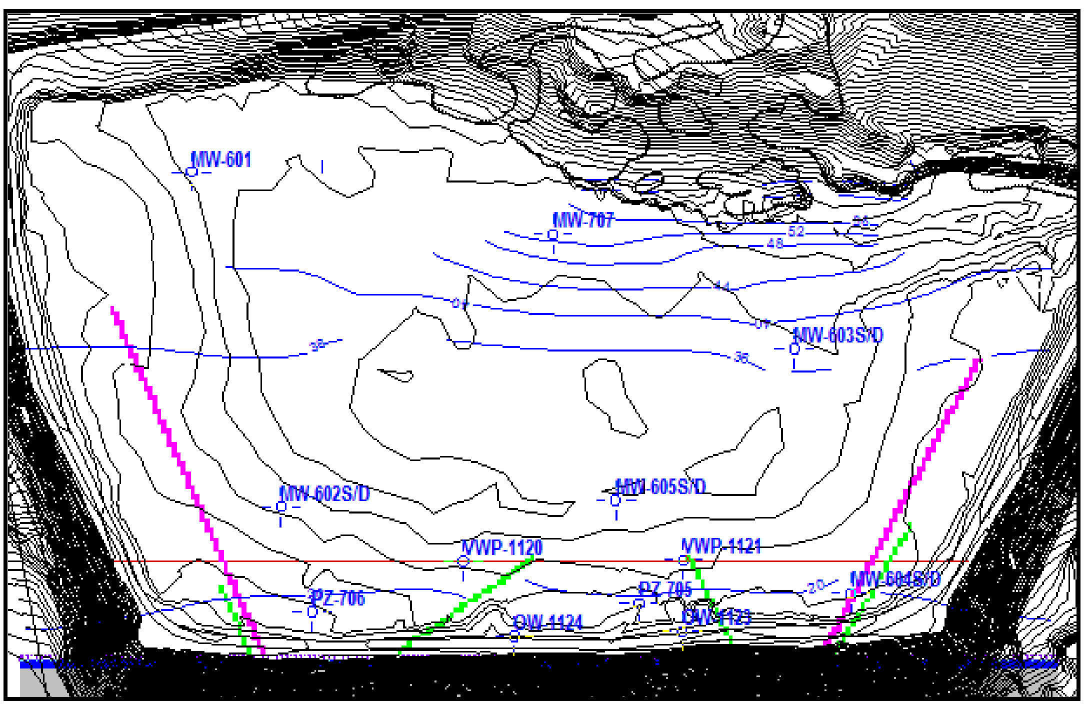

Figure A-6: Run CalM2R302 – Capped, heads in layer 1 at about 10.25 years

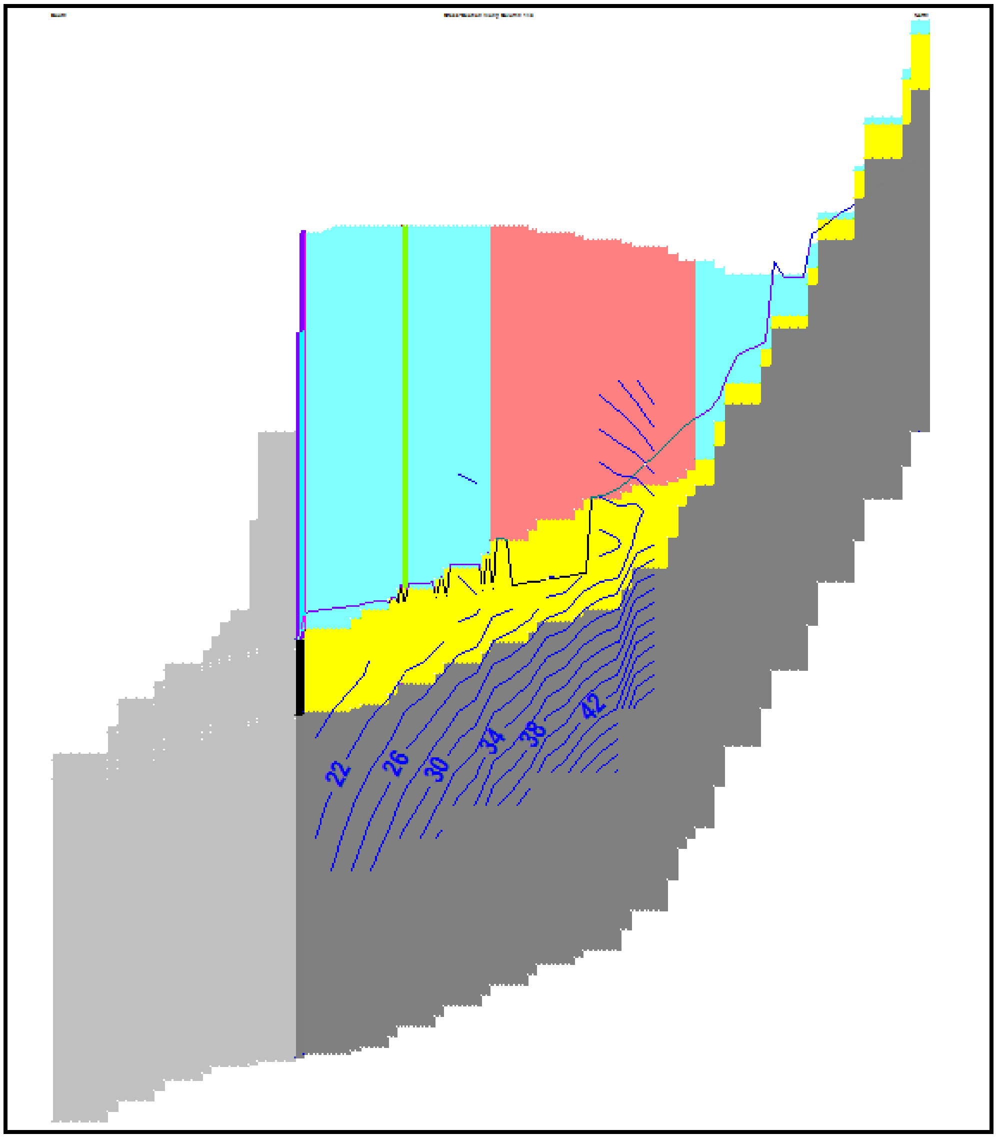

Figure A-7: Run CalM2R302 – Capped, heads in section along column 145, corresponding closely to Profile E3. Estimated water table elevation along top of till/clay along much of this section. Time about 10 years.

ATTACHMENT B
OUTPUT FIGURES FOR THE 90 PERCENT DESIGN SUPPORT MODEL WITH ADDED HORIZONTAL WELLS

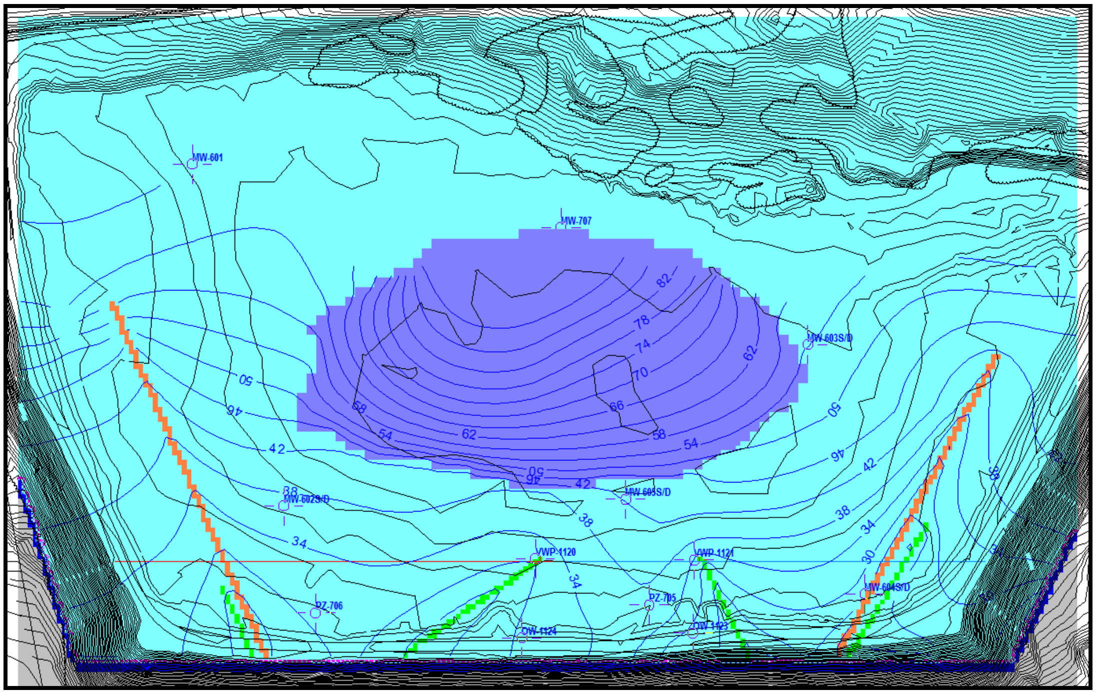

Figure B-1: Run CalM2R304 – Simulation with horizontal wells installed – uncapped condition. Heads in layer 1 at about 10.25 years (near equibibrium condition). Initial flux to drains 29.5 gpm; 2.3 gpm at equilibrium.

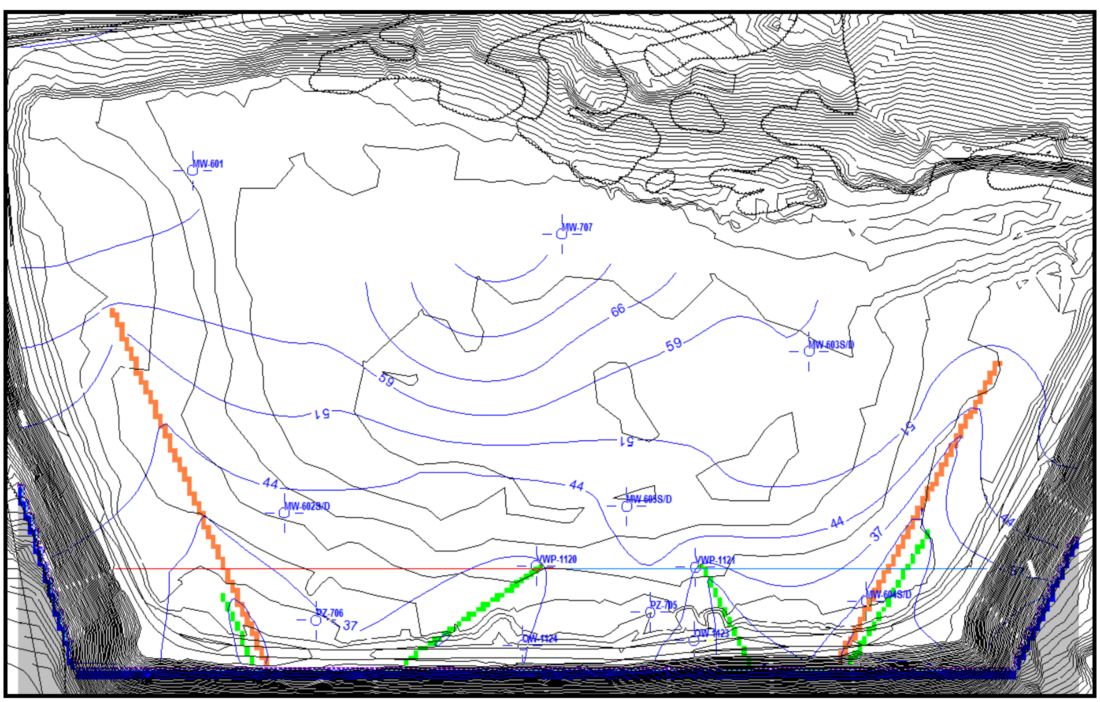

Figure B-2: Run CalM2R305 – Simulation of drains with impoundment capped. Heads in model layer 1 shown at 1.04 years. Initial flux to drains at about 29.5 gpm. Flux at 1.1 years is about 3.6 gpm.

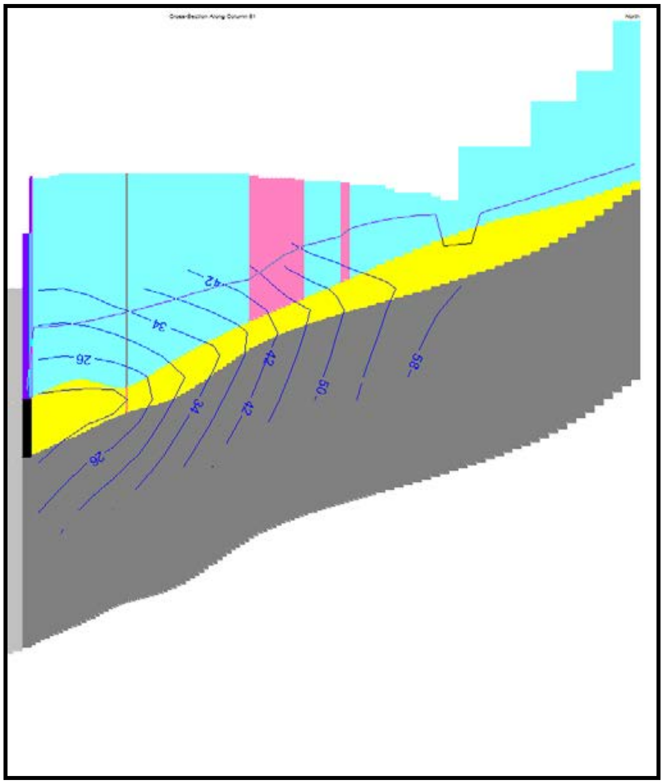

Figure B-3: Run CalM2R305 – Approximate Section E1 heads at about 1.04 years.

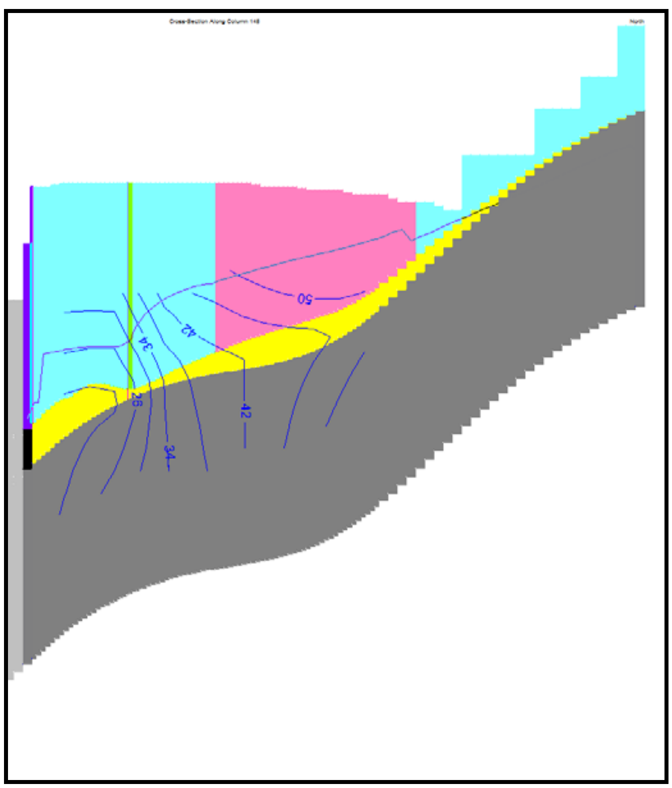

Figure B-4: Run CalM2R305 – Approximate Section E3 heads at 1.04 years

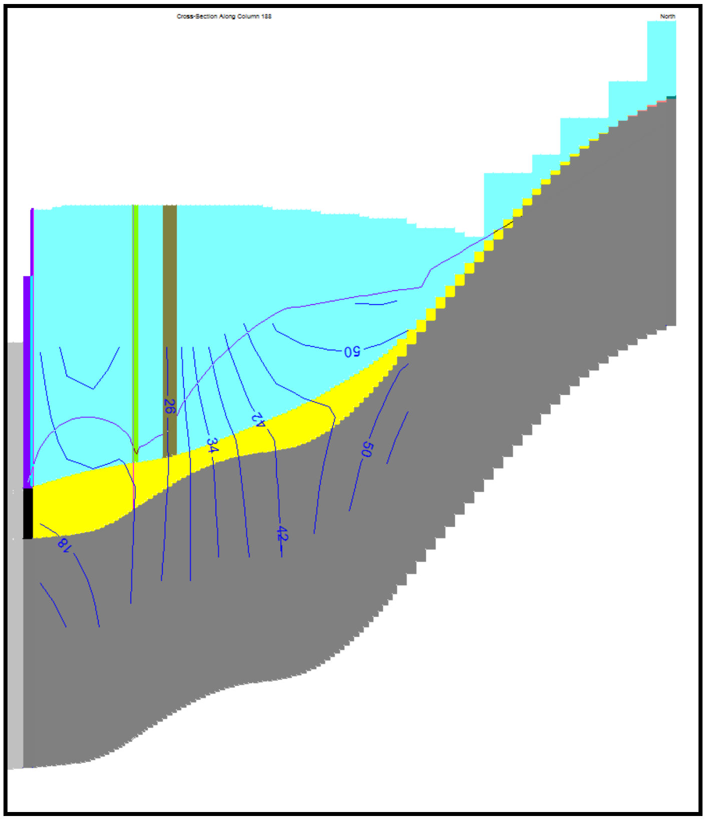

Figure B-5: Run CalM2R305 – Approximate Section E4 heads at 1.04 years

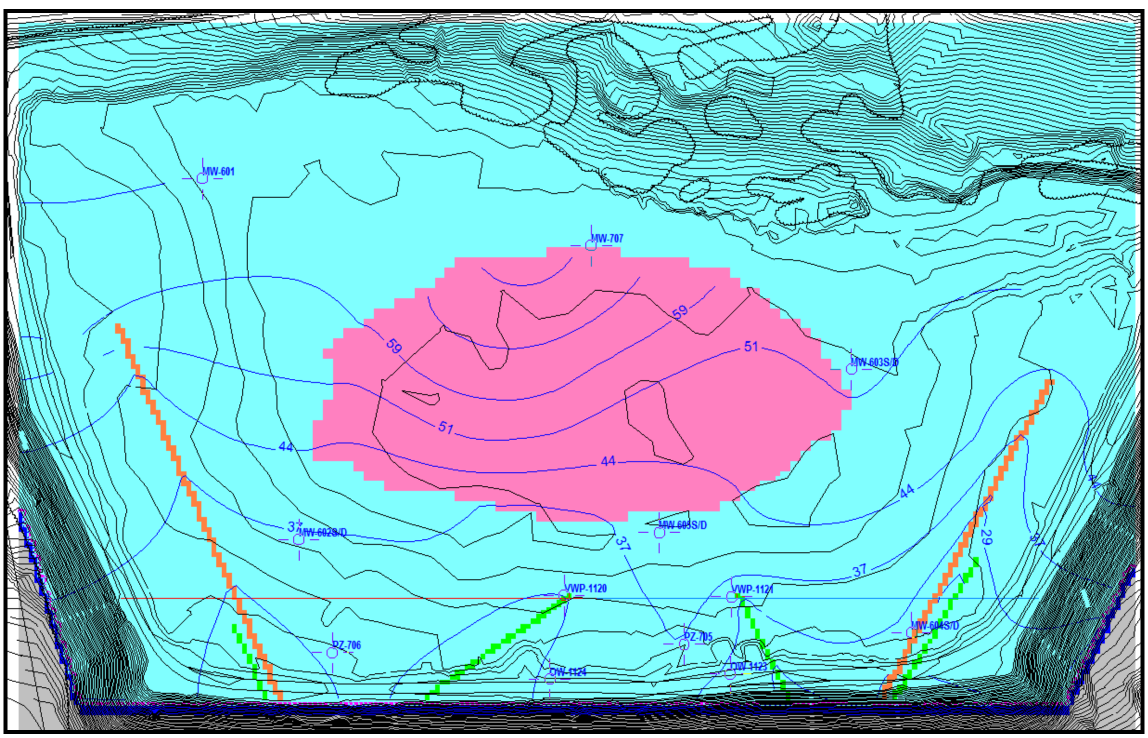

Figure B-6: Run CalM2R305 – Simulation of drains with impoundment capped. Heads in model layer 1 shown at 2.03 years. Flux to drains at 2.03 years is about 2.2 gpm.

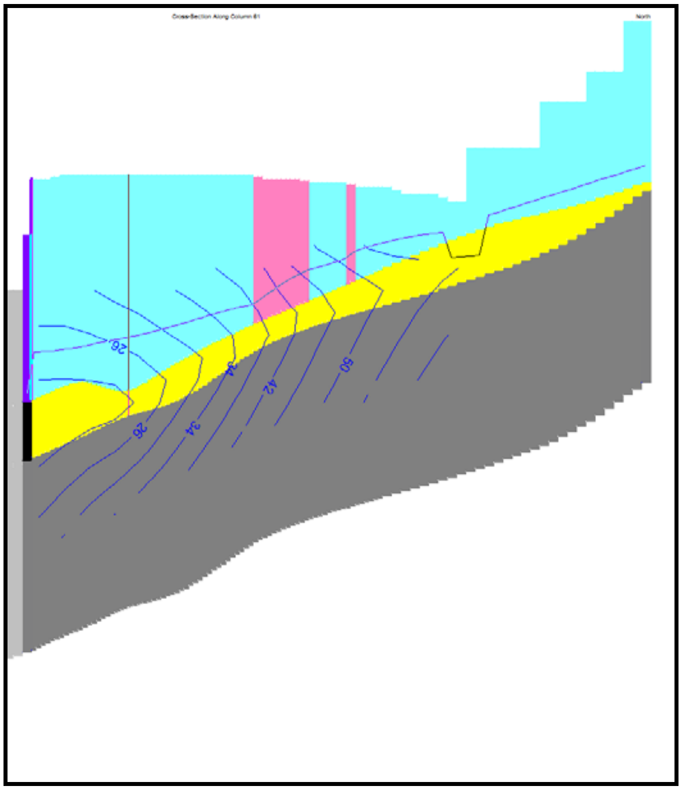

Figure B-7: Run CalM2R305 – Approximate Section E1 heads at about 2.03 years.

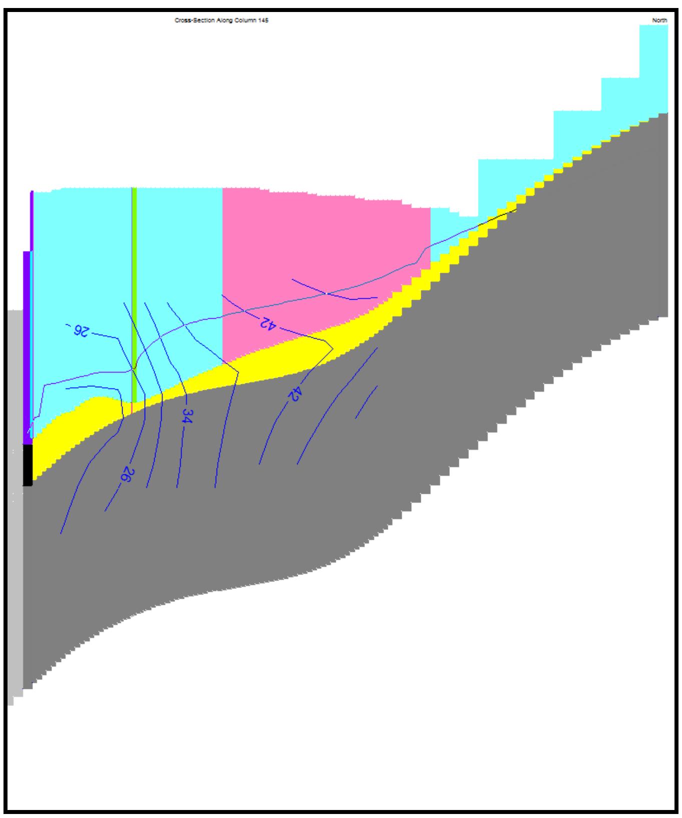

Figure B-8: Run CalM2R305 – Approximate Section E3 heads at about 2.03 years.

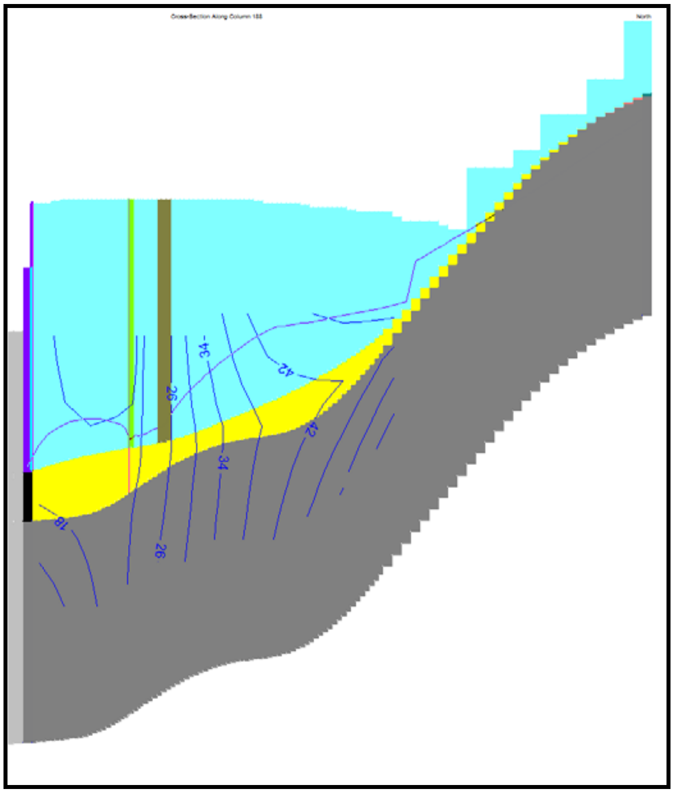

Figure B-9: Run CalM2R305 – Approximate Section E4 heads at about 2.03 years.

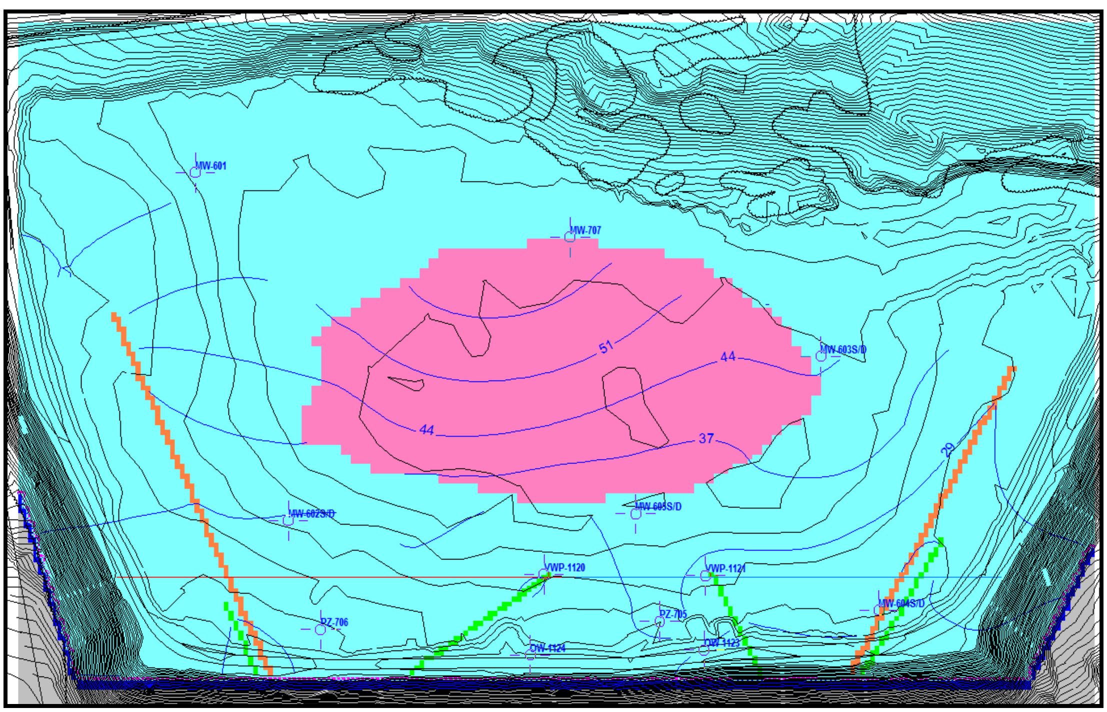

Figure B-10: Run CalM2R305 – Simulation of drains with impoundment capped. Heads in model layer 1 shown at 5.26 years. Flux to drains at 5.26 years is about 0.7 gpm.

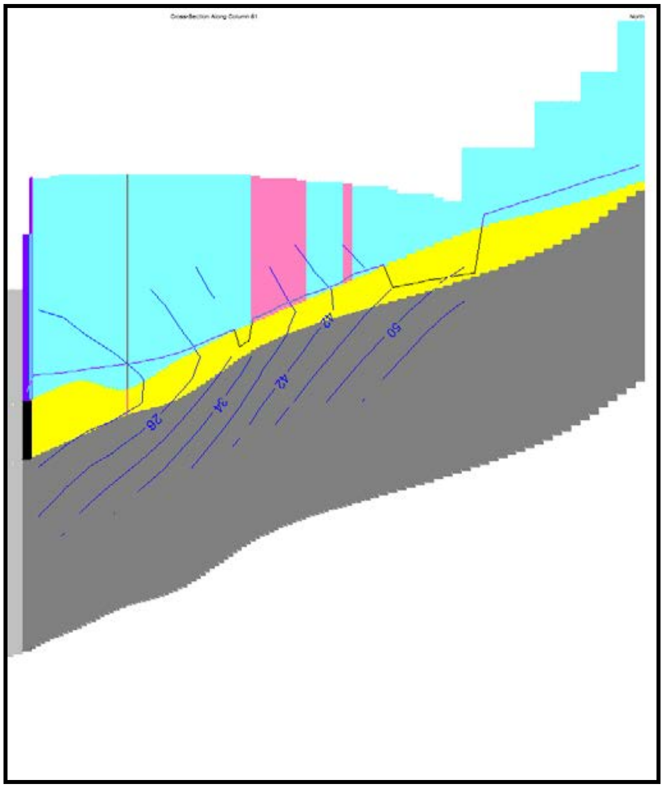

Figure B-11: Run CalM2R305 – Approximate Section E1 heads at about 5.26 years.

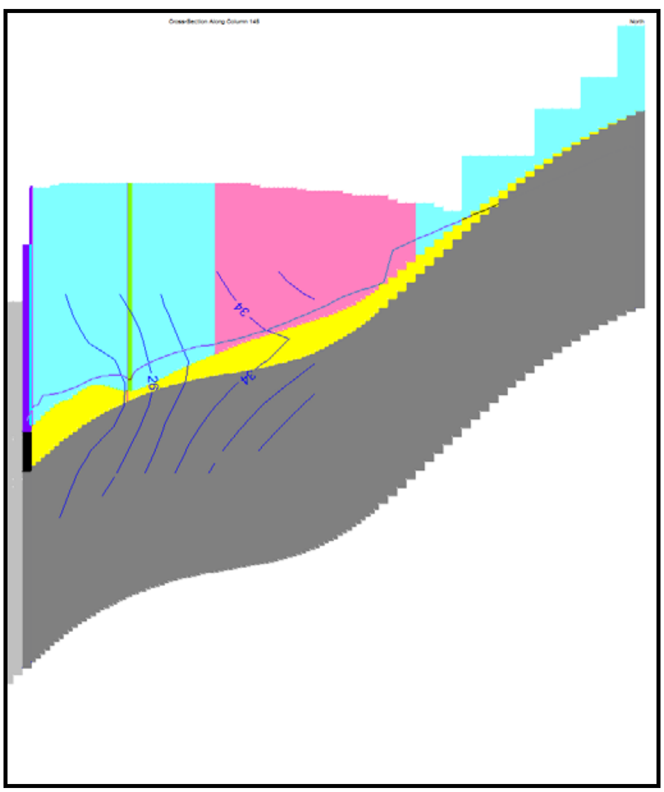

Figure B-12: Run CalM2R305 – Approximate Section E3 heads at about 5.26 years.

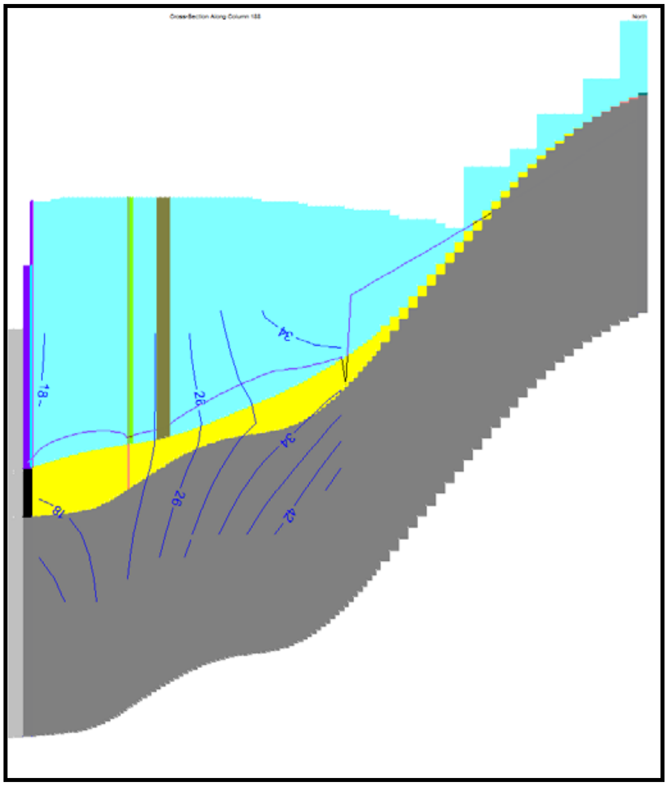

Figure B-13: Run CalM2R305 – Approximate Section E4 heads at about 5.26 years.

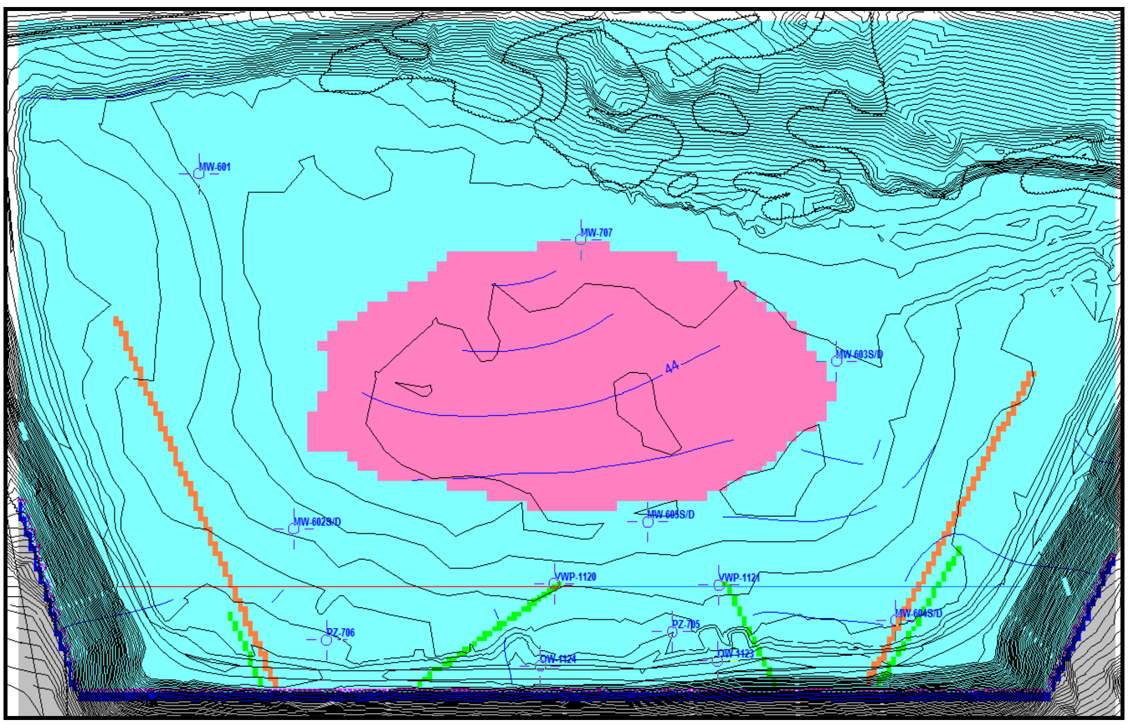

Figure B-14: Run CalM2R305 – Simulation of drains with impoundment capped. Heads in model layer 1 shown at 10.26 years. Flux to drains at 10.26 years is about 0.13 gpm.

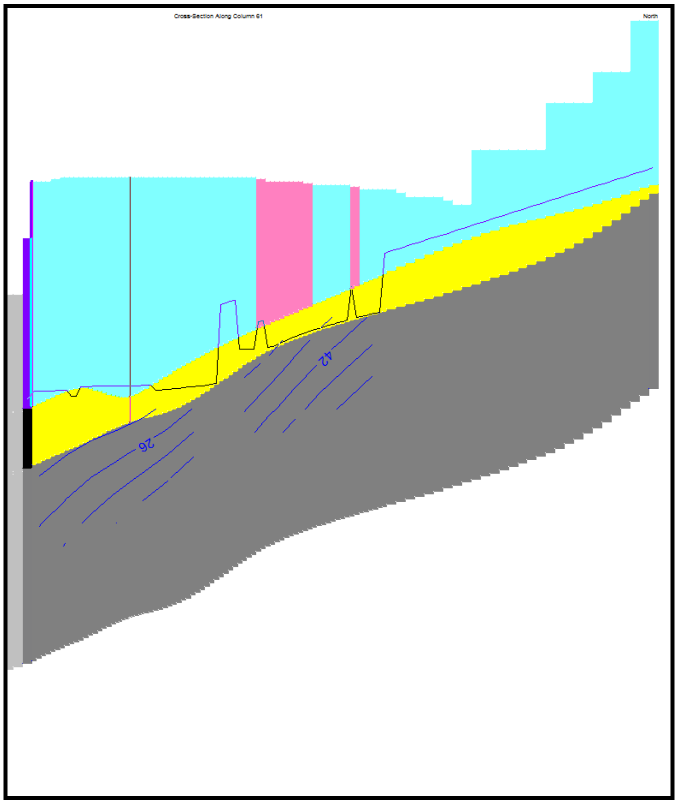

Figure B-15: Run CalM2R305 – Approximate Section E1 heads at about 10.26 years.

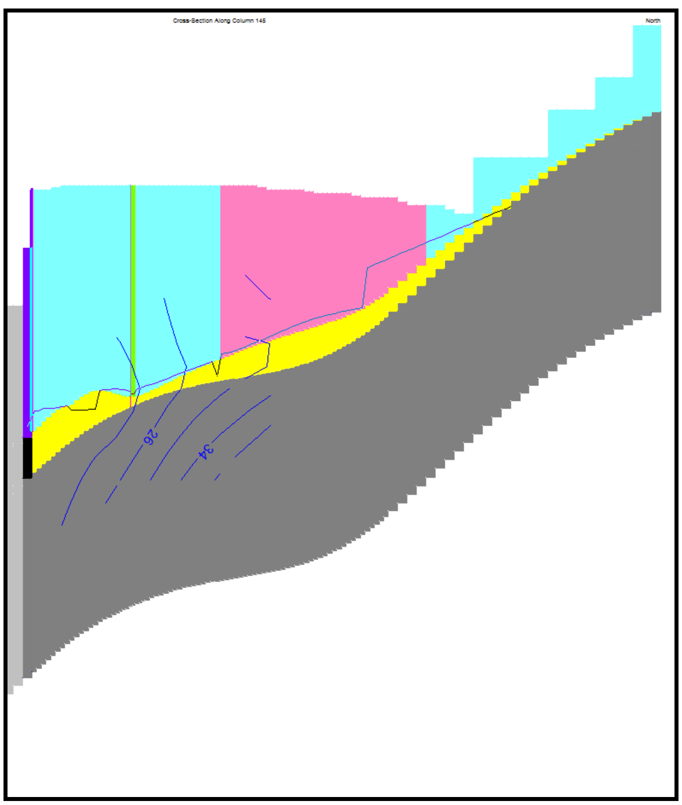

Figure B-16: Run CalM2R305 – Approximate Section E3 heads at about 10.26 years.

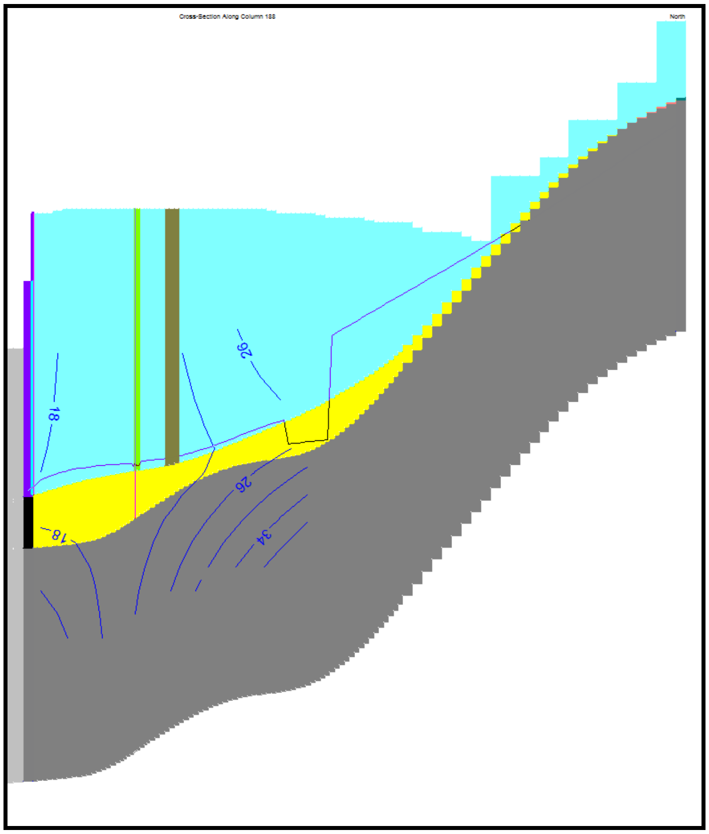

Figure B-17: Run CalM2R305 – Approximate Section E4 heads at about 10.26 years.