RESULTS FROM THE INITIAL "ELF" INTER-MINE POOL TRANSFER TESTS[1]

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Abstract: Abandoned underground mines in the Pittsburgh coalbed continue to be a source of pollution to over 48 km of streams in the Raccoon Creek watershed. Raccoon Creek watershed is located in Western Pennsylvania and drains 176,890 ha into the Ohio River. In 2006, an evaluation of selected discharges with conceptual treatment approaches was developed that included the "ELF" project, which had the potential to substantially eliminate AMD impacts to Burgetts Fork for 5.3 km to the confluence with Raccoon Creek. For simplicity, the acronym, "ELF", is used to identify the discharge that would be created by consolidation of discharges from Erie Mine, Langeloth Mine, and Francis-Patterson Mine. This project addresses the initial physical feasibility of the "ELF" System" by identifying if the opportunity exists to combine and relocate AMD from various locations in the Burgetts Fork sub-watershed by "inter-mine pool transfer" to a single discharge point for future reuse or treatment. To evaluate the degree of hydrologic interconnectedness of the mine workings, two tests were conducted. The tests indicate that there is no apparent impediment to flow within the Erie Mine and that the Erie Mine discharge can be successfully relocated by implementation of the "ELF" system. The tests also indicate that withdrawal from the Langeloth Mine Shaft with injection into the Erie Mine may substantially decrease the discharge from the Francis mine that flows through and out of the Patterson Mine. The physical feasibility of the "ELF" system to decrease or eliminate the flow from the Patterson Mine requires additional confirmation prior to implementation.

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Introduction

Abandoned, commercial, underground mines in the Pittsburgh coalbed have been and continue to be a source of degradation to over 48 km of streams in the Raccoon Creek Watershed. Efforts to characterize and abate the impacts of this mining legacy have been on-going for almost four decades. In 2006, an evaluation of selected discharges with conceptual treatment approaches was developed that included the "ELF" System (BioMost, 2006) which had the potential to substantially reduce AMD impacts to Burgetts Fork for 5.3 km to the confluence with Raccoon Creek.

Raccoon Creek watershed is located in southwestern Pennsylvania in the Alleghany Plateau Province. The project is located near the Borough of Burgettstown on the Avella (PR1979) and Midway (PI1977) 7 ½' USGS topographic maps in Smith Township, Washington County, PA. The study area includes both the main stem of Raccoon Creek and a major tributary, Burgetts Fork. Figure 1 shows the generalized flooding status of the abandoned Eire Mine, Langeloth Mine, and Francis-Patterson Mine and other mines surrounding the project area.

The current locations for the discharges in the Burgettstown area makes it difficult to treat the mine water. The "ELF" project proposes to move mine water via abandoned underground workings from the Francis Mine through the Langeloth Mine and then by siphon into the southwestern portion of the Erie Mine. The mine water would flow through underground mine workings and discharge at the easternmost extent of the Erie Mine via horizontal bores (see Fig. 1). If successful, the project would consolidate numerous discharges from the Burgettstown area and convey the mine water out of the borough to an area where the water could be treated.

The water level in the Langeloth Mine is over 3.4 m higher than the water elevation in the Erie Mine, which would provide the driving force needed to convey water from the Langeloth Mine to the Erie Mine should the "ELF" project be completed. In order for this concept to be viable under the conditions present, the hydraulic conductivity within the mines must be large. In this project, water was either injected or withdrawn from the mines while simultaneously measuring the change in water level in the mine at two or more locations. For relatively large mine pools, the difference between the water levels at two observation points is considered inversely proportional to the hydraulic conductivity of the mine aquifer. In other words, if the water level difference is small during the injection/withdrawal process, then the mine is highly conductive; if the water level difference is large, then the hydraulic conductivity is low.

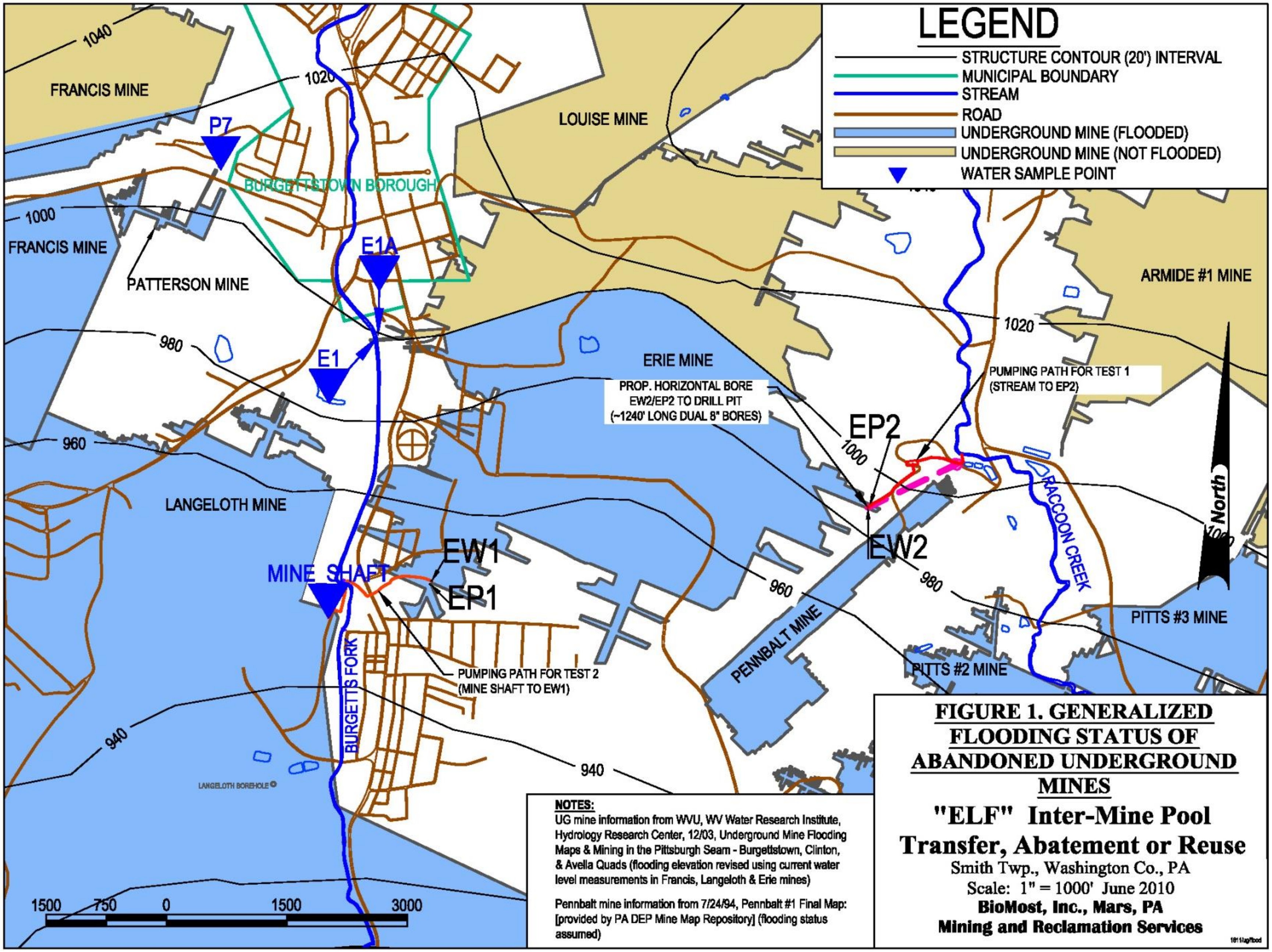

Figure 1. Generalized Flooding Status of Abandoned Underground Mines

General Methodology

Water Monitoring

In order to document conditions prior to conducting the mine pool response testing, water levels were manually measured for 16 piezometer, 90° V-notch weirs were installed and flow measurements were collected at the E1 and E1A discharges (Erie Mine), and the existing rectangular weir at the P7A discharge (Patterson Mine) was repaired and the flow was measured.

During the tests, several monitoring points were equipped with pressure transducers. These include the Mine Shaft (Langeloth Mine), piezometer 181-1 (Francis Mine), piezometer 181-14 (Langeloth Mine), and the P7A (Patterson Mine discharge weir). The effect of the pumping into Erie Mine (west) at EW1 was monitored at four locations: two observation wells/piezometers: EP1 (Erie Mine – west), EP2 (Erie Mine – east), and two AMD discharges: E1 and E1A (Erie mine – west). E1 is a culvert located under the Burgettstown football stadium and is suspected to be the primary outlet for the Erie Mine. E1A is a second culvert located next to E1 and is a surface/near surface stormwater/drainage facility related to the football stadium. Both culvert pipes were apparently installed during the construction of the football stadium (c. 2001). All except E1A were equipped with pressure transducers.

The transducers used in the ELF testing required the subtraction method. The units, called hobos, were manufactured by Onset Computing. Where high sensitivity was needed, model number U20-001-04 was used. It has a pressure range of 0 – 4 m, an accuracy of ±3 mm and a resolution of 1.5 mm. In less sensitive locations, model U20-001-01 was used. It has a pressure range of 0 to 9 m, an accuracy of 5 mm and a resolution of 2 mm. The transducers made measurements in intervals of two, ten or fifteen minutes depending on the location and the degree of sensitivity appropriate for site conditions. In all, seven transducers were used simultaneously for both tests.

Drilling Program

As part of the drilling program, underground mine maps and surface conditions were evaluated to determine the most appropriate location for the injection and monitoring wells. Injection and monitoring wells were installed on the west and east side of the Erie Mine. On the west side of the Erie Mine, injection and monitoring wells (EW1 and EP1, respectively) were installed on the site of a former drive-in theater (Drive-in). On the east side of the Erie Mine, the injection and monitoring wells (EW2 and EP2, respectively) were located near the terminus of the proposed horizontal bore holes. The drilling locations were staked in the field using a submeter-rated GPS unit at the Drive-In and subcentimeter-rated GPS unit in conjunction with an EDM survey on the east side of the Erie Mine.

Test 1. Raccoon Creek Withdrawal with Erie Mine (East) Injection

Methodology

Two Godwin CD103M diesel-powered pumps were used to convey water from Raccoon Creek to an injection well (EW2). EW2 was drilled into an entry located on the east side of the Erie Mine at the approximate location of the proposed in-mine terminus of the horizontal bores. One pump was used to convey water approximately 213 m horizontally and approximately 24 m vertically upward to a transfer pond, which can be seen in Fig. 2; the second pump conveyed the water an additional approximate 256 m horizontally and 24 m upward to the point of injection (EW2).

Figure 2. One of two CD103M pumps used for Test 1. A pickup truck located in the background provides scale.

In order to monitor the rate of flow during injection, an orifice plate, with a 152 mm diameter opening, was installed in a 3 m section of 203 mm diameter pipe placed horizontally just before the water cascaded into the borehole. A manometer was installed upstream of the orifice plate along the centerline of the 203 mm horizontal pipe (See Fig. 3). In this configuration, a 267 mm backpressure on the orifice plate is equivalent to a flow of 32 L/s. The engine speeds of the pumps were adjusted until 267 mm of backpressure was achieved. Injection begun at 15:07 hours on 2/11/2010, continued approximately 24 hours and was shut off at 15:12 on the 2/12/2010.

Figure 3. Flow rate measurement device (Test 2 installation shown) Orifice plate (in gray flange) and manometer (left of flange)

Results

Table 1 contains manual measurements from the four Test 1 monitoring locations. Prior to the start of Test 1 injection the Erie Mine (E1) was discharging at 3.1 L/s after 20.33 hours of injection the discharge was 23.5 L/s, an increase of 20.4 L/s. Based on monitoring data, E1A was not measurably affected by the injection test.

Table 1: Manual Measurements at Observation Wells EP1 & EP2 and AMD E1 & E1A

Site	Date	Time	DTW*	TSU*	WE*	L/s*
EP1 (Piezometer)	01/28/10	08:28	12.17676	317.3303	305.1536	
	02/02/10		11.64946	317.3303	305.6809	
	02/11/10	13:35	12.17066	317.3303	305.1597	
	02/12/10	09:25	12.07618	317.3303	305.2542	
	02/26/10	09:10	12.07008	317.3303	305.2602	
EP2 (Piezometer)	02/11/10	14:20	45.04639	350.1299	305.0835	
E1 (Weir)	02/01/10					3.1
	02/11/10	13:30				3.1
	02/12/10	09:40				23.5
E1A (Weir)	02/01/10					0.2
	02/11/10	13:30				0.2
	02/12/10	09:40				0.2

*All dimensions in m, unless noted; DTW – depth to water; TSU – top stick up elevation; WE – water elevation; L/s – liters per second

Figure 4 is a hydrograph illustrating changes in water elevation based on pressure transducer observations from EP2 (Erie mine – east) and EP1 (Erie mine – west) in response to pumping water into injection well EW2 (Erie Mine – east) during Test 1. This injection produced an immediate rise of 1.4 m in the nearby observation well EP2. In the same two-minute period, a rise of 2.4 mm was recorded at the EP1 observation well on the west side of the Erie Mine. This was followed by an additional rise of 4.6 mm in the next two-minute period. The response in EP1 (2,326 m away) in less than 4 minutes is indicative of a highly transmissive system.

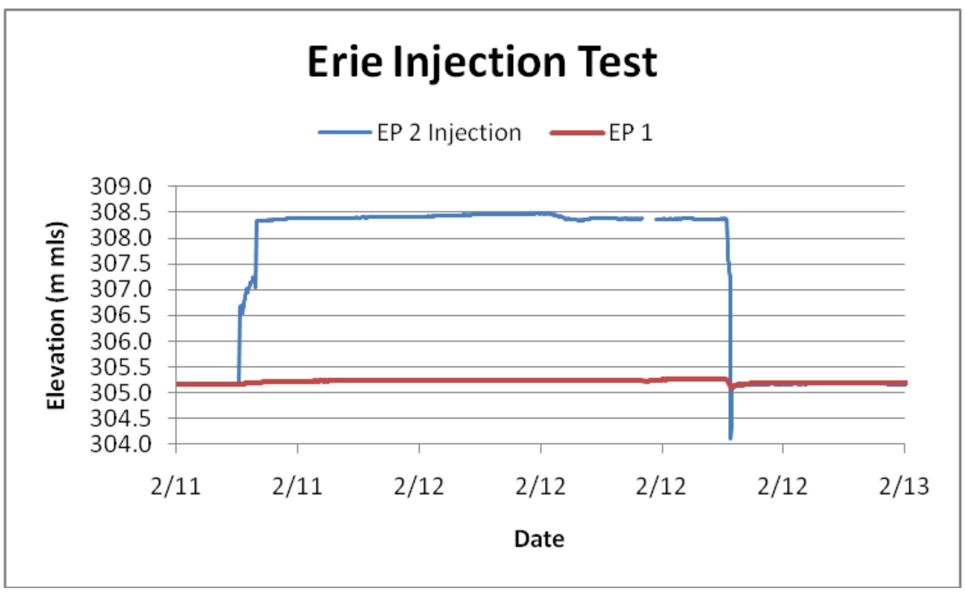

Figure 4. Hydrograph of EP1 (Erie Mine – west) and EP2 (Erie Mine – east) (pressure transducer with a 2-minute recording interval)

The water level in observation well EP2, about 12 m from the injection site (EW2), rose 3.1 m above the static water level in the mine. This head difference was needed to cause 31.5 L/s to move from the injection well (EW2) to the main entries on the west side of the mine. The water level in EP1 had a maximum rise of 91.4 mm.

Upon the termination of injection at EW2, the water level in the adjacent observation well (EP2) dropped 4.3 m in 12 minutes. This includes a drop of 1.0 m below the pre-test static water level in the mine. In addition, when injection was stopped in EW2, the water level at observation well EP1 (2,326 m away) fell 6.4 mm in the first two-minute period and an additional 36.3 mm in the next two minutes. The water level in EP1 dropped a total of 166 mm in 18 minutes, which was immediately followed by a water level recovery (rise in elevation) of 79.0 mm over a 22-minute period. This fall and recovery behavior, although less dramatic, is similar to the water level changes that were observed in observation well EP2 at the injection site. This response is subtle, but visible on the hydrograph above.

Discussion

The data from this test are somewhat conflicted. Based on these results, there does not appear to be any significant restriction along the entries that connect EW2 and the mine discharge point (E1). The rapid transmission of head across a large distance both at the beginning and at the end of the test indicates highly-connected entries. On the other hand, 3.1 m of head was needed to inject 31.5 L/s at the injection well. This change in head at the injection well was very rapid at the beginning and particularly at the end of the test where the head dropped over 4.3 m in 12 minutes. This rapid decline suggests that the area of the mine that is under these high head conditions is limited in size. This would be consistent with the injection well location at the end of a set of double entries.

The second complicating factor is the significant, unknown volume of compressed air that was stored in the mine during the test and released when the injection was shut off. The reason for this unusual event is that the injection water that was cascading down the well entrained and compressed air. This compressed air was delivered to the mine where some vented out of the observation well. This venting was observed throughout the test. In addition to venting, some of the compressed air also displaced water in the vicinity of the injection well, thus pushing the water in storage further into the mine. When the injection stopped, the compressed air was free to vent out of the injection well EW2. This left a water level that was below the static level in the mine. Water then reversed flow direction in the mine to fill the lower water level at the injection site. The compressed air and displacement of the mine pool can explain the measurements at EP2 that dipped below static pool levels. In addition, some compressed air may have moved into the mine, further complicating the analysis.

Given the rapid drop in water level at the end of the test and the concurrent release of the compressed air in the mine, the high head observed at the injection site could be an artifact of the compressed air injection. There may be some localized restriction within the mine in the vicinity of the injection well but, even so, it is not believed to be sufficient to impair the operation of the proposed horizontal drainage holes. The head in the Erie Mine is above elevation 305.2 m. The proposed discharge elevation of the horizontal boreholes is 301.8 m, providing a driving head in excess of 3.4 m, which is sufficient to overcome the localized head observed in the test. It should also be noted that during most of the year, there would be less than 31.5 L/s flowing out of the Erie Mine; hence, any restriction would offer less resistance to flow and consequently a lower head loss.

Weirs E1 and E1A are adjacent to one another and it was thought that fluctuations of the Erie mine pool might be directly reflected by the discharge rate at both E1 and E1A.However, based on monitoring data, E1A was not measurably affected by Test 1.

Based on this analysis, the Erie Mine appears to be sufficiently transmissive to allow 31.5 L/s to flow from the proposed injection site on the west side of the mine to the east side, where it would be intersected and conveyed by the proposed horizontal bores.

Test 2. Langeloth Mine Withdrawal with Erie Mine (West) Injection

Methodology

A 152 mm schedule 40 PVC pump suction line was installed into the Langeloth shaft, and the discharge was conveyed via a pipeline laid overland to injection well EW1, drilled into the Erie Mine approximately 12 m from observation well EP1. Most of the discharge line was 152 mm schedule 40 PVC pipe with solvent-welded fittings. A portion of the pipeline, about 30 m long, was 152 mm lay-flat hose used to extend the line through a new 305 mm culvert under an access road. An additional 91 m of 152mm lay-flat hose was extended through an existing 1.2 m culvert located under a parking lot. Because lay-flat hose was used during the test and a more constant discharge rate is desirable, a Godwin CD103M pump was used instead of a siphon. As with the Erie East Injection Test, the pipeline was connected to a horizontal section of 203 mm diameter PVC pipe in which a 152 mm orifice plate had been installed. The pumped discharge passed through the orifice plate into injection well EW1 and into the Erie Mine. In order to minimize the entrainment and compression of air during this test, a vertical section of 76 mm diameter pipe was connected to the bottom of the tee receiving the water from the orifice plate. The 76 mm pipe extended from the surface to below the pre-test static water level in Erie Mine. This method proved to be successful and it was observed that an insignificant amount of air was entrained during the injection into Erie mine. The pipeline location is depicted in Fig. 1.

Pumping began on February 23rd at 11:23 transducer time. The pump had been positioned adjacent to the mine shaft. On 3/3/10, it was determined that the water level in the mine shaft was getting very close to the bottom of the suction pipe. In this configuration, the center of the suction line was about 0.91 m above the shaft. At this point, the pump was shut down and repositioned so that the suction line lay on the top of the shaft. At the same time, an additional section of pipe was added to the suction line. In this new configuration, the suction lift was lower, but this was somewhat offset by a longer suction line. The pump was restarted on March 4, at 11:16 transducer time. The new configuration was able to lower the water level in the mine by an additional foot, but suction was lost due to out-gassing. This second effort lasted until March 5th, at 06:54. Water was allowed to build up in the mine for three days, when the pump was again restarted on March 8th at 08:14. This third and final pumping period lasted for not quite 30 hours. The pump was shut off on March 9th at 13:50.

<u>Results</u>

<u>Francis & Patterson Mine Pool Response from Langeloth Shaft Withdrawal</u>

The effect of the withdrawal of water from the Langeloth mine pool was monitored at the Langeloth mine shaft, piezometer 181-14 (Langeloth mine), 181-13 (Langeloth mine) and 181-1 (Francis mine) and the weir at P7A (Patterson Mine discharge).

<u>Langeloth Mine Shaft withdrawal</u>

Figure 5 is a hydrograph of the Langeloth mine shaft. During the withdrawal/injection period, the water level was lowered in excess of 2.4 m over the course of seven days. During this time, the pump discharge rate fell as the water level was lowered. This can be seen in Fig. 6, where the initial pumping was set at 31.5 L/s, which fell over time by about 50 percent. At the pumping rate of about 15.8 L/s, the pump came into dynamic equilibrium with the mine inflow rate. Pumping in this manner lowered the water level in Langeloth Mine by no less than 1.5 m and as much as 2.9 m for a period in excess of 15 days.

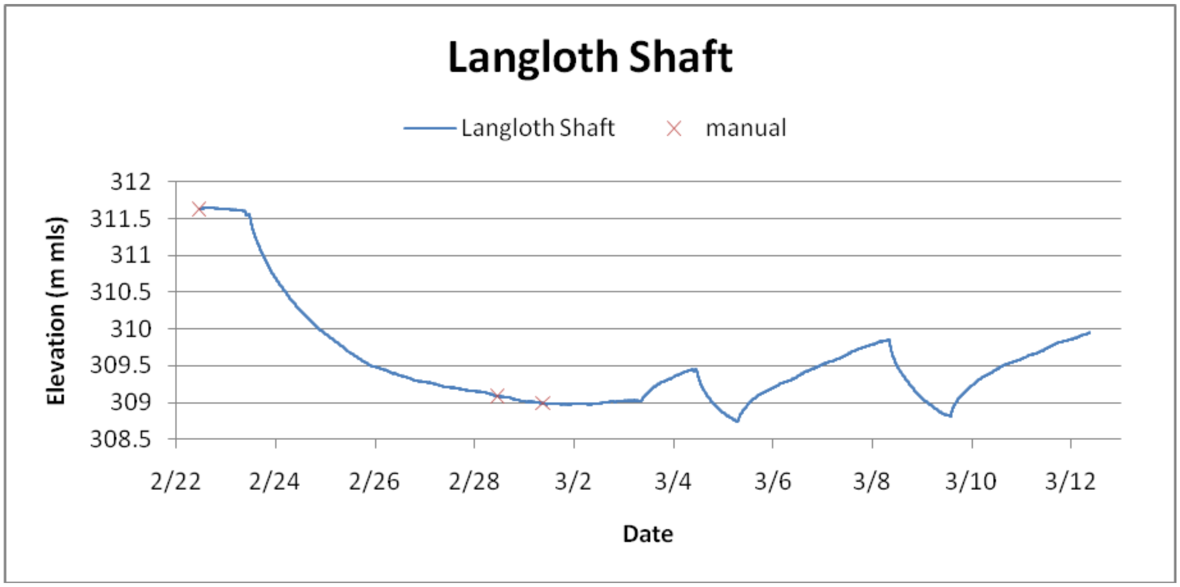

Figure 5. Hydrograph of Mine Shaft [Langeloth Mine] (pressure transducer with 2 minute recording interval)

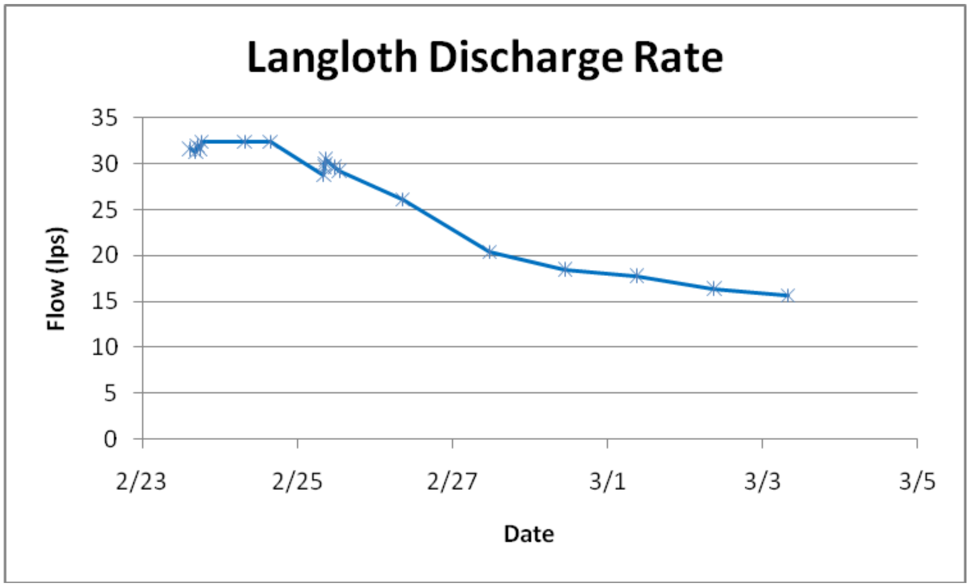

Figure 6. Pump discharge rate 2/23/10 to 3/3/10 from Mine Shaft [Langeloth Mine] (determined from manual measurements from the manometer at the injection point EW1)

Piezometer 181-14

The effect of this pumping was quickly observed at piezometer 181-14. This well was installed during a prior investigation and was still available for use. This well was selected because it was completed within a void (open mine workings), which was thought to provide a more rapid response to the pump testing. Figure 7 is a hydrograph illustrating the effect on 181-14 during pumping at the Mine Shaft.

In comparing this hydrograph with that of the shaft, the resemblance is evident; however, two differences should be noted. First, the starting water elevation is 308.6 m at the well compared to 311.7 m at the shaft, a difference of 3.2 m. Second, although the shape of the graph is similar, the magnitude of the fluctuations is reduced. The well shows a maximum drop of about 1.1 m while the shaft dropped 2.9 m.

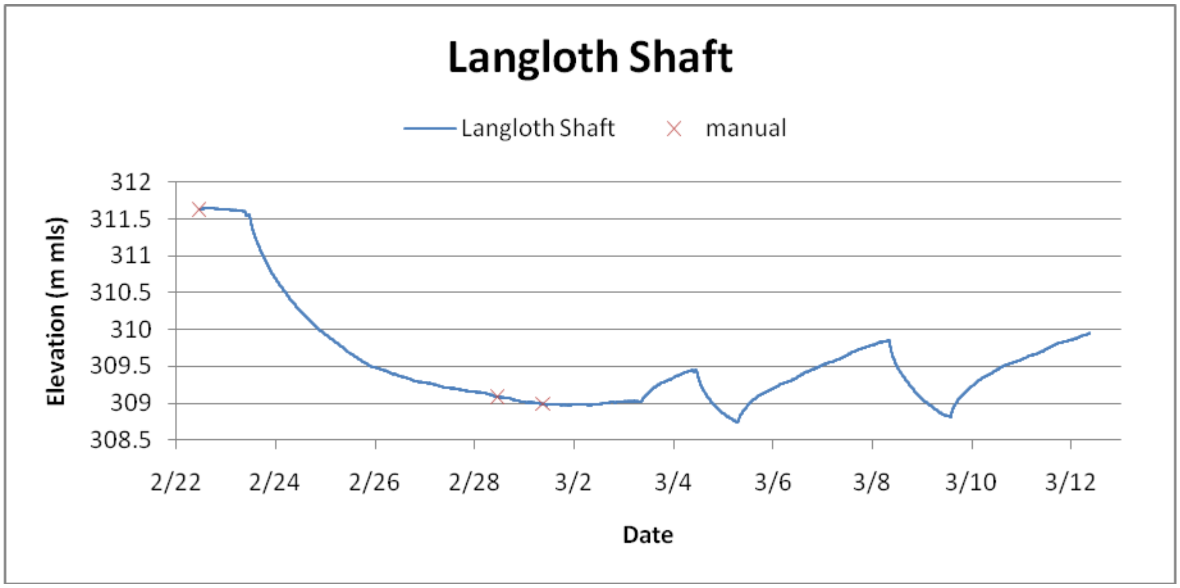

Figure 7. Hydrograph of Piezometer 181-14 [Langeloth Mine] (pressure transducer with 2-minute recording interval in blue; manual readings in red)

When the pump was turned off on March 5, a "V" shape was noted in both the Langeloth Shaft and 181-14 hydrographs. In the pumping shaft, this "V" occurred at 06:54. At well 181-14, this response was observed at 07:04. This is a rapid response by groundwater standards, not as rapid as Erie Mine, but rapid none-the-less. The straight-line distance between the shaft and the well is 686 m while the probable in-mine distance is 1,473 m.

Manual measurement of piezometer 181-13 showed a pre-pumping water level of 311.6 m, which is nearly as high as the 311.7 m observed at the shaft. This well is about 168 m away from well 181-14 and is closer to the shaft along the probable in-mine flow path. The probable reason for the water level in 181-14 to be responsive to pumping in the mine and 3.2 m lower in elevation than the shaft is that the water in this part of the mine is moving to a discharge point, which at this time is unidentified.

Piezometer 181-1

Monitoring well 181-1 is completed in the Francis Mine and is located west of the Patterson Mine. It is at a straight-line distance of 1,845 m from the Langeloth shaft but the in-mine probable flow path ranges from about 3,637 m to 6,802 m. Figure 7 is a hydrograph illustrating the effect on 181-1 during Test 2. A review of Fig. 8 does not show any trend that can be attributed to the pumping in the Langeloth Mine. The rise in water level after March 9th is attributable to infiltration resulting from snow melt. The water level was in a slight decline at the start of the pumping and it recovered to above the 312.0 meter elevation. Another slight decline persisted from March 2nd to March 6th. If this decline in water level was the result of pumping, it was completely wiped out by the recharge event.

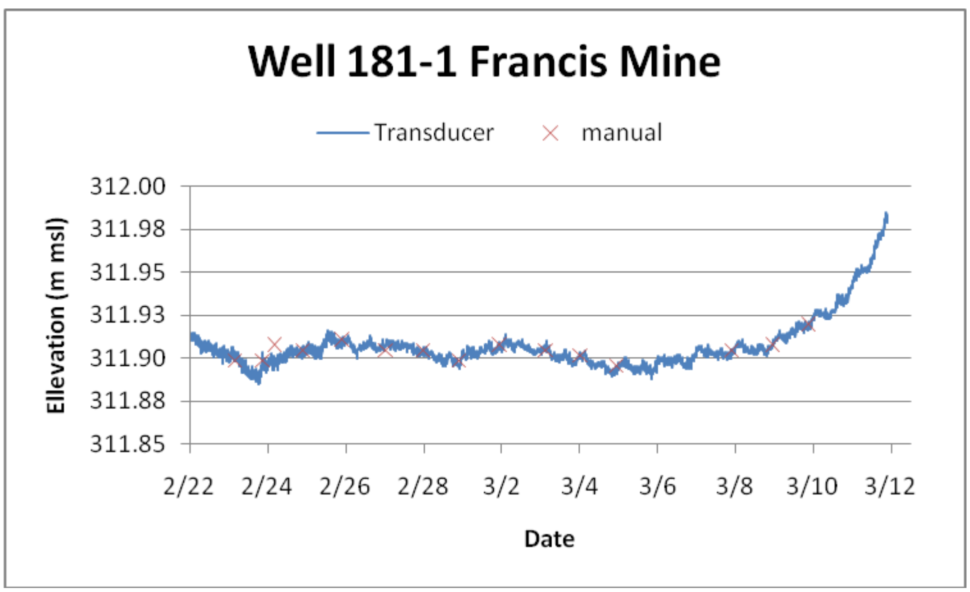

Figure 8. Hydrograph of 181-1 [Francis Mine] (pressure transducer with 2- to 10-minute recording interval)

P7A (Plum Run Discharge)

The ultimate goal of directing flow from the Langeloth Mine is to eliminate or significantly decrease the discharge from the Patterson Mine. The mine discharge is located very close to Plum Run both horizontally and vertically. The discharge pipe is inundated by the backwater of a 0.91 m rectangular weir. The overflow from the weir is only a few centimeters above the water level in the stream. Under high flow conditions, the weir readily becomes inundated.

A pressure transducer was installed at this site by laying it on the substrate behind the weir. Figure 9 is a hydrograph of the water level data after being converted to flow rate. It is evident from the hydrograph that the weir was inundated by the local stream due to snow melt on March 9th and thereafter. The inundation of the weir effectively ended the pump test as it was not possible to measure a response to the pumping.

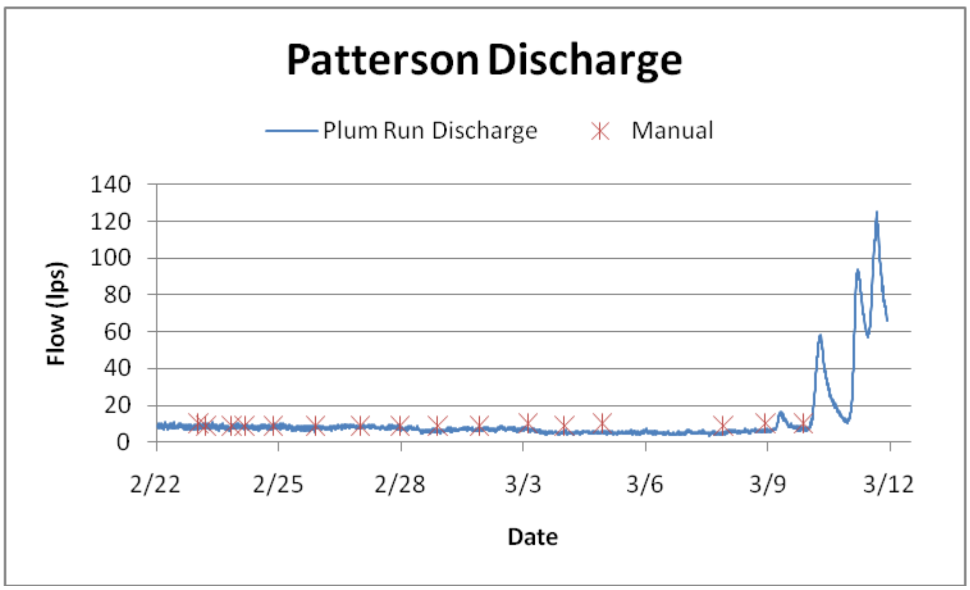

Figure 9. Hydrograph of P7A Weir (Patterson Mine discharge) (pressure transducer with 2- to 10-minute recording interval)

Two items of significance are noted. First, the manual readings do not match the transducer data. Second, the transducer data indicate a gradual reduction in flow from the Patterson mine.

The manual readings at this site are extraordinarily difficult. The water level is about 30 mm above the weir, the weir is at ankle level, and in a 0.91 m rectangular weir, 3 mm equals 1.3 L/s. As a result, errors are possible even though great care was taken in reading the weir.

The transducer data were adjusted so that the early manual readings fell within the range of observations. This is how transducer data are tied to real world elevations. In the early morning hours of March 1st, the transducer data deviated from the manual measurements. This occurred again in the late evening of March 3rd and in the early morning of March 4th. An enlarged section of Fig. 9 is shown in Fig. 10 to better see the decrease in flow measured by the transducers. Both changes were gradual and the second decrease was more gradual than the first. This "rules out" the transducer being moved by a person or an animal. The fact that the water depth over the top of the transducer decreased is also significant. If the transducer had settled by gravity into the substrate, then the depth of water over the transducer would have increased. Transducer voltage remained constant throughout these events. And the water temperature was 53.6 degrees except at midday when it rose to 53.8 degrees. A set of natural conditions has not been found that would explain the drop in water level recorded on the transducer. It may be possible that the transducer is experiencing drift, but it would be the first time in our experience with these units.

Based on this review, it is possible that pumping at Langeloth had an effect at the Patterson Mine discharge, but since the manual readings did not corroborate the transducer data, the effects of pumping cannot be confirmed.

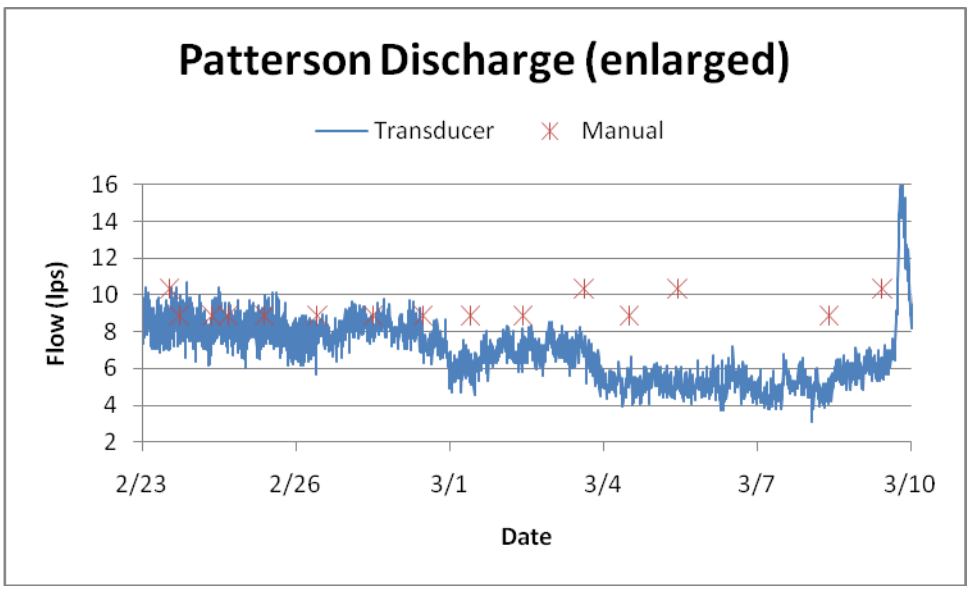

Figure 10. Enlarged View of P7A (a.k.a. Plum Run) Weir Hydrograph (Patterson Mine) (pressure transducer with 2- to 10-minute recording interval)

<u>Erie Mine Pool Response with Erie Mine (West) Injection</u>

The injection of water pumped from the Langeloth Shaft into the Erie Mine at EW1 was monitored at observation wells/piezometer EP1 (Erie Mine – west), EP2 (Erie Mine – east) and at weir E1 (Erie Mine – west).

Observation Well EP1 (Erie Mine – West)

The injection into Erie mine began on 2/23/10 at 11:34. At the beginning of the test, the pump was able to deliver 31.5 L/s. Later in the test, this capacity was reduced as the suction lift became greater. Based on these data, the 31.5 L/s injection only raised the water level at the injection monitoring well by 0.1 to 0.2 m. This low level of head is indicative of highly conductive entries between the injection point and the discharge point. The gap on 3/1/10 at 14:10 appears to be accurate. This is in the middle of a recording period, so it does not represent a change in position of the transducer.

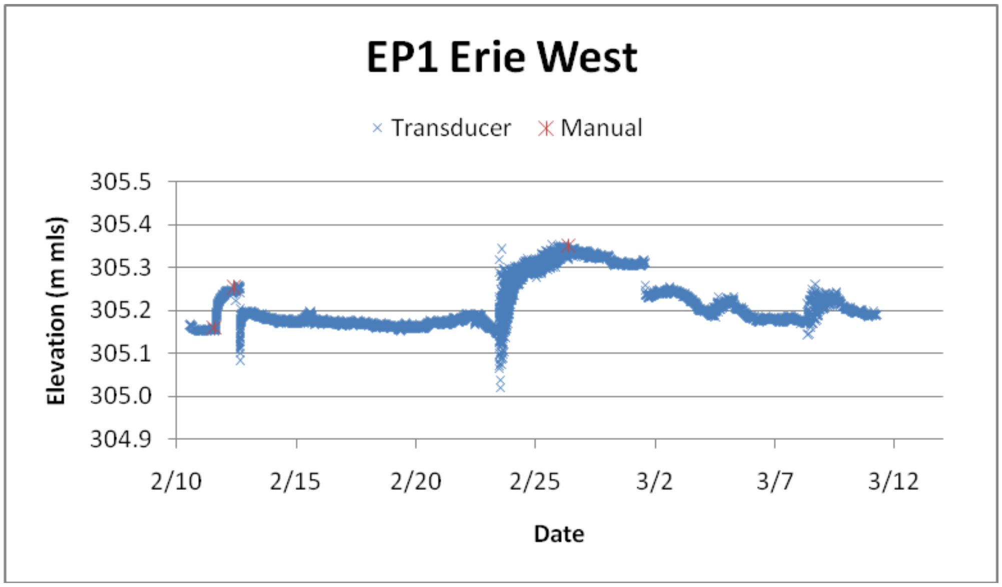

Figure 11. Hydrograph of EP1 (Erie Mine - west) (pressure transducer with 2-minute recording interval)

Erie Mine Discharge E1

Figure 12 is a hydrograph of the Erie Mine discharge (E1) during injection of the water pumped from the Langeloth Shaft into EW1 (Test 2). The injection into the Erie mine began on 2/23/10 at 11:34 and the initial increase in flow at E1 on occurred between 11:45 and noon. The flow rate did not reach 31.5 L/s because the mine was buffering some of this flow as storage in the mine which was released later. Note that the base flow had increased from about 3.2 L/s to about 8.8 L/s between March 6th and March 8th.

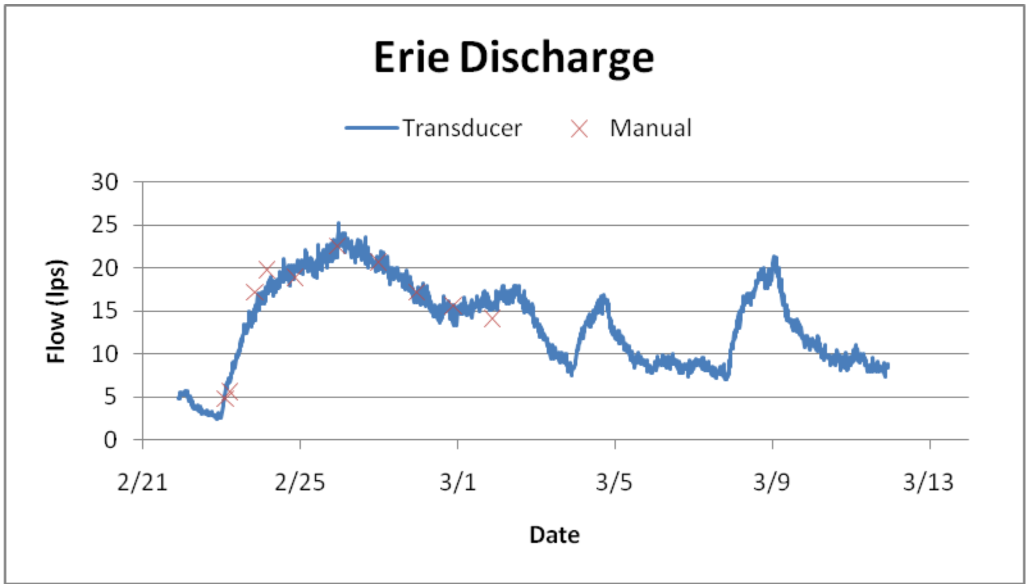

Figure 12. Hydrograph of E1 Weir (Erie Mine – west discharge) (pressure transducer with 15-minute recording interval)

Observation Well EP2 (Erie Mine – East)

The transducer at EP2 logged the injection of mine water from the Langeloth Shaft into EW1 on the east side of the Erie Mine. The injection of 31.5 L/s raised the Erie mine pool by a maximum of 0.1 m. Refer to Fig. 13.

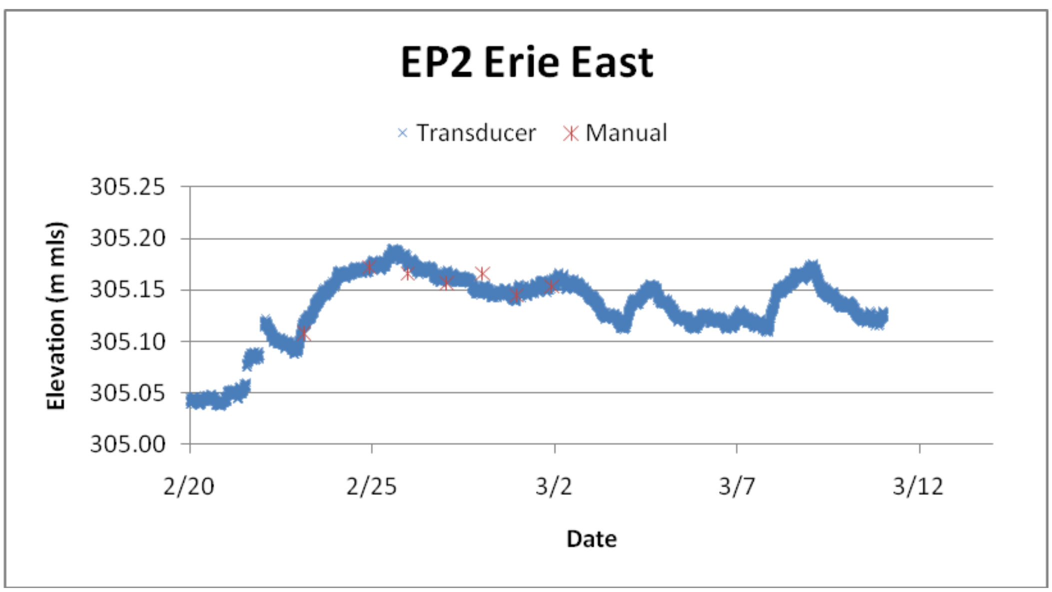

Figure 13. Hydrograph of EP2 (Erie Mine - east) (pressure transducer with 2-minute recording interval)

Discussion

Pumping of Langeloth Mine at 31.5 L/s successfully lowered the Langeloth mine pool. Pumping at a rate as low as 15.8 L/s was able to lower the pool during the weather conditions experienced in February and early March 2010.

The Langeloth Mine showed good transmissivity between the Mine Shaft and wells 181-13 and 181-14. No connectivity was observed between the Langeloth shaft (withdrawal point) and well 181-1. A gradual but significant reduction in flow was recorded by the pressure transducer at the Patterson mine discharge, but this was not corroborated by the manual flow readings. A gradual drop in flow would be consistent with the dewatering of a large gob area, as is the case in the Francis Mine. It may be necessary to keep the water level in Langeloth Mine lowered for an extended period of time before the full effects of the dewatering are expressed at the Patterson discharge. The small difference in head between the Francis and Langeloth Mines of 0.21 m suggests that dewatering of the Patterson Mine discharge (P7A) is possible.

Mine water elevations at the Langeloth shaft, well 181-13, and well 181-14 indicate that water is draining from the Langeloth Mine in the vicinity of well 181-14. The location of this discharge should be identified. Water pumped into the Erie Mine demonstrated high transmissivity between the injection well EW1 and the mine discharge E1.

Conclusion

The following is a brief outline of selected conclusions based on the results. (1) The Erie Mine is open and is not expected to present any impediment to "ELF" project construction. (2) Both injection tests into the Erie Mine have demonstrated that the average 5 L/s Erie Mine discharge E1 can be controlled and is directly hydrologically connected to both the west and east injection sites, each with a probable flow path of about 1.6 km or more. (3) The existing head in the mine is sufficient to overcome the injection head that developed at EP2 during Test 1. The magnitude of that head is likely an artifact of the unknown amount of compressed air that was injected in addition to the 31.5 L/s water injection. Under normal operating conditions, flows through this section will be less than 31.5 L/s thus, reducing the potential resistance. Measures to eliminate the entrainment and compression of air during injection on the west side of the Erie Mine were successful. (4) The water level in the Langeloth Mine was lowered by withdrawing as little as 15.8 L/s during the recharge conditions at the time of the testing. (5) The withdrawal testing also suggests that additional unidentified drainage from the Langeloth Mine exists in the vicinity of piezometer 181-14. (6) Although transducer measurements during withdrawal testing indicate a hydrologic relationship between the mine pool (as intercepted at the Langeloth Shaft) and the Patterson Mine discharge P7A, in-mine gob areas within the Francis and Langeloth Mines appear to offer resistance to flow.

Future Work

The following is a brief outline of future work proposed for further development of the "ELF" project. (1) Identify the drainage from the Langeloth Mine in the vicinity of 181-14 and install a discharge structure and measure flow rate. (2) Raise the elevation of the Patterson Mine discharge (P7A) and install a more sensitive weir or flume. (3) Conduct a second pump test of the Langeloth Mine by pumping 18.9 L/s into a set of existing treatment ponds (Langeloth Borehole passive treatment system) during dry weather conditions. This pumping should continue for a minimum of one month to confirm the hydraulic conductivity between the Langloth, Francis and Patterson Mines. (4) Two monitoring wells in each of the two in-mine gob areas are recommended: one to be located in the in-mine Langeloth gob and one to be located in the in-mine Francis gob on a line between the Langeloth Mine haulage way and the Patterson Mine cut-through. (5) Pressure transducers should be installed in all boreholes and at major discharge points during the test.

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