DAM BREACH MODELING FOR HAZARD CLASSIFICATION

HOMESTAKE MINING COMPANY OF CALIFORNIA

GRANTS RECLAMATION PROJECT

GRANTS, NEW MEXICO

Prepared by Alan Kuhn Associates LLC

March 23, 2016

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Introduction

At the request of the Dam Safety Bureau of the Office of the State Engineer (OSE), Homestake Mining Company of California (HMC) agreed to conduct numerical modeling to simulate breaching of each of the three evaporation ponds at the Grants Reclamation Project, the site of the former Homestake uranium mill. The breach analysis is intended to support re-assessment of the hazard classification of each pond. Alan Kuhn Associates LLC (AKA) was contracted to perform this modeling for HMC.

Each of the evaporation ponds (EP1, EP2 and EP3) was designed in accordance with the then-existing OSE standards and permitted for construction and operation by the State Engineer. In 2015, the OSE performed an inspection of the evaporation ponds and questioned the original classification of each pond as "low" hazard based on the potential for a breach that could release impounded contaminated water and the potential for that water to endanger people and property downgradient of the HMC site. This report documents the modeling that was performed to assess potential dam breach and release of impounded water. This report does not address water quality or potential impacts of water-borne contaminants.

Description of the Evaporation Ponds

The evaporation ponds are located on HMC property on or adjacent to the mill site five miles north of the Village of Milan. Ponds EP1 and EP2 are located south of the large tailing pile, and EP3 is approximately ½ mile northwest of the pile. All three ponds are similar in that they have geomembrane liners, they receive only water involved in ground water restoration and direct precipitation, and they have no pipe penetrations or spillway structures. The ponds are used primarily for evaporation of contaminated ground water as part on HMC's on-going ground water restoration program. See Figure HPA-1 for locations of the ponds and breach flow paths. See Table 1 for the numerical parameters of each pond used in the breach modeling.

EP1 was designed and constructed in 1990. It was constructed on top of the small tailing pile that was decommissioned in the 1960s. It is the only pond that sits entirely above surrounding natural grade; therefore, all impounded water is subject to release. The pond is lined with a composite

liner consisting of fabric sheets coated with Deery Oil No. 6 asphaltic emulsion. EP1 has no internal leak detection system.

EP2 was designed and constructed in 1995-1996. It is constructed partly above and partly below surrounding natural grade. Only the water impounded above the elevation of the surrounding grade can be released by a dam breach. The pond has a double geomembrane liner consisting of 60 mil HDPE over a 250 mil geonet leak detection layer over a bottom 40 mil HDPE geomembrane.

EP3 was designed in 2006 and constructed in 2010. Its design is similar to that of EP2 except that it is configured with two identical cells separated by an earthen weir berm. Only the water impounded above the elevation of the surrounding grade can be released by a dam breach.

The HEC RAS Model

The breach analyses were performed in accordance with:

1. Guidelines for Dam Breach Analysis, State of Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer Dam Safety Branch; February 10, 2010
2. HEC RAS River Analysis System User's Manual Version 4.1, U.S. Army Corps of Engineers Hydrologic Engineering Center, January 2010

Reference 1 was used in developing the breach parameters listed for each pond in Table 1. Current topography was used in AutoCAD to extract distances and elevations for model input.

The HEC RAS model described in reference 2 is the latest in a long series of hydrologic modeling software developed and made available for public use by the Corps of Engineers. Breach modeling is one of the applications for HEC RAS. HEC RAS was selected for use in this application because it is the most advanced and robust numerical model currently available. It models the progression of breach development with time and generates water stage and flow values for the entire flow path throughout the selected time period.

The selected method of breach for each pond was overtopping. Although breach by piping is possible, it is very unlikely because there are no penetrations of the perimeters berms, and each pond includes a liner.

Breach flow paths were determined by examination of a series of topographic cross sections using AutoCAD Civil 3D software. For each pond the selected flow path was tied to the lowest elevation on the crest of the perimeter dam, or berm. From that location the flow path followed the terrain to the HMC property boundary, the limit of existing current detailed topographic mapping. In most locations a clearly defined channel was not present, so the flow path was identified by connecting the low points of successive cross sections.

Flow paths for each pond were selected to begin several hundred feet upstream of the breach point. The end of each model was placed near the HMC property boundary. This end point is considered to be the point at which a reasonable assessment of downstream hazard to human safety and

property can be made. The HMC property line is also the limit of available aerial photogrammetric topography.

The breach analysis using HEC RAS yields conservative output values for stage and flow. The HES RAS model does not account for infiltration of water into the ground along the flow path, adding conservatism to the volume of water reaching the end of the modeled flow path. All flow paths have considerable vegetation cover consisting of grasses and brush, and although a Manning Coefficient value of 0.035 accounts for some surface roughness from vegetation, it underestimates the retarding effect of vegetation on flow. Stage values are also conservative because the many shallow depressions along the flow path can retain water but are not accounted for in the HEC RAS model.

The HEC RAS model does not predict the probability of breaching. The assumption for all models is that a breach occurs (assumed probability of 1). The model input includes certain conditions (such as initial pond water level, initial flow rate, and initial geometry of the breach) that must be assumed to initiate the progression of breach development and pond water flow and stage.

The HEC RAS model also does not yield a hazard ranking. That is a subjective determination based on several factors, one of which is HEC RAS output.

The following sections summarize the model for each of the HMC evaporation ponds.

EP1 Breach Analysis

Assumed Initial Conditions

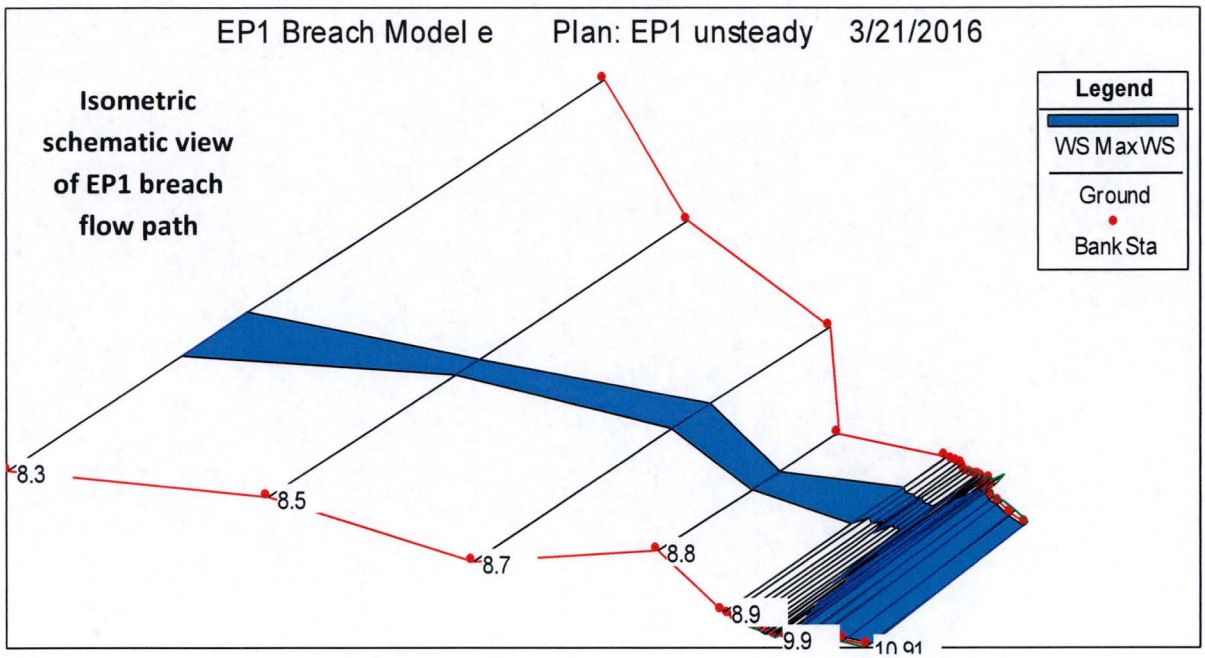
Both for conservatism and for simplification of the model, the position of EP1 in the model was rotated clockwise around the west corner of EP1 to bring the south berm alignment parallel to the southwest slope of the small tailing pile. In this position, the south berm of EP1 and the southwest slope of the small pile merge and become continuous for modeling purposes. This repositioning shortens the flow path to the south property (license) boundary and eliminates the south triangle of the small tailing pile. This triangle area would in reality retard released flow and retain some of that water for infiltration into the tailings, thereby both slowing the release of water and reducing the amount of water reaching the property boundary.

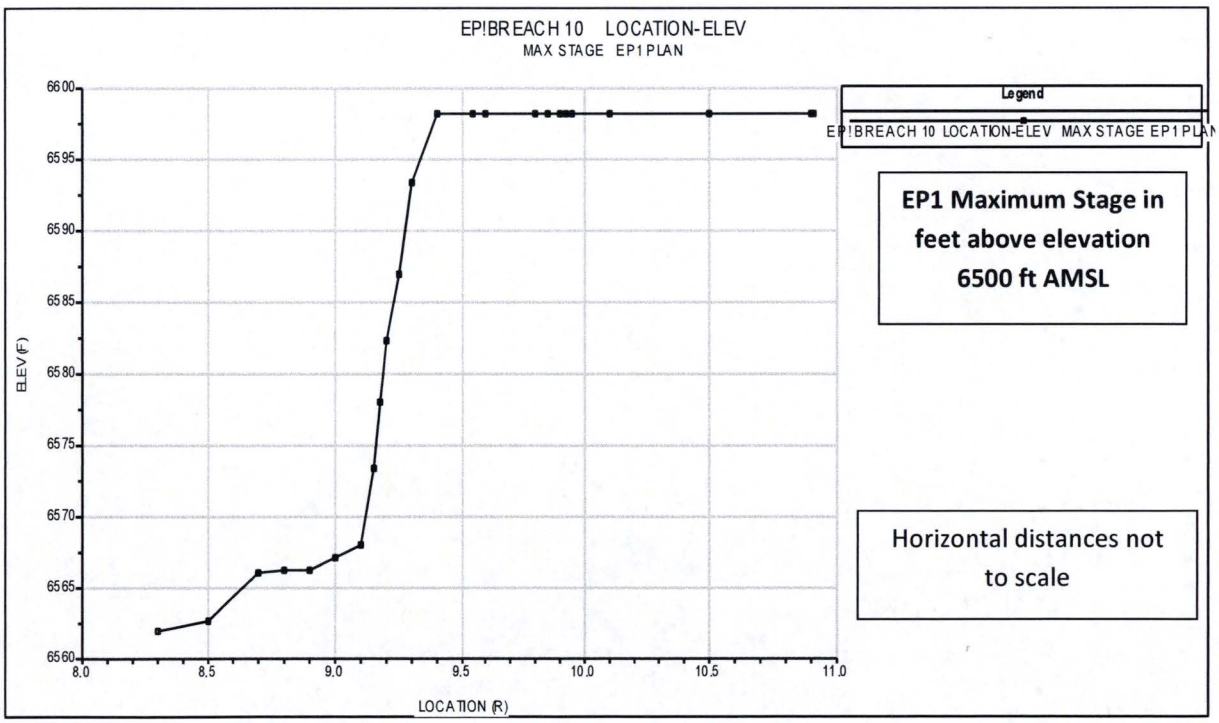
At the lowest elevation of the crest, 6598.5 ft AMSL, a breach was initiated by a pond water surface at 6598.6 along a 1.0 ft deep path where the breaching water initially moved at 0.02 cfs across the berm crest.

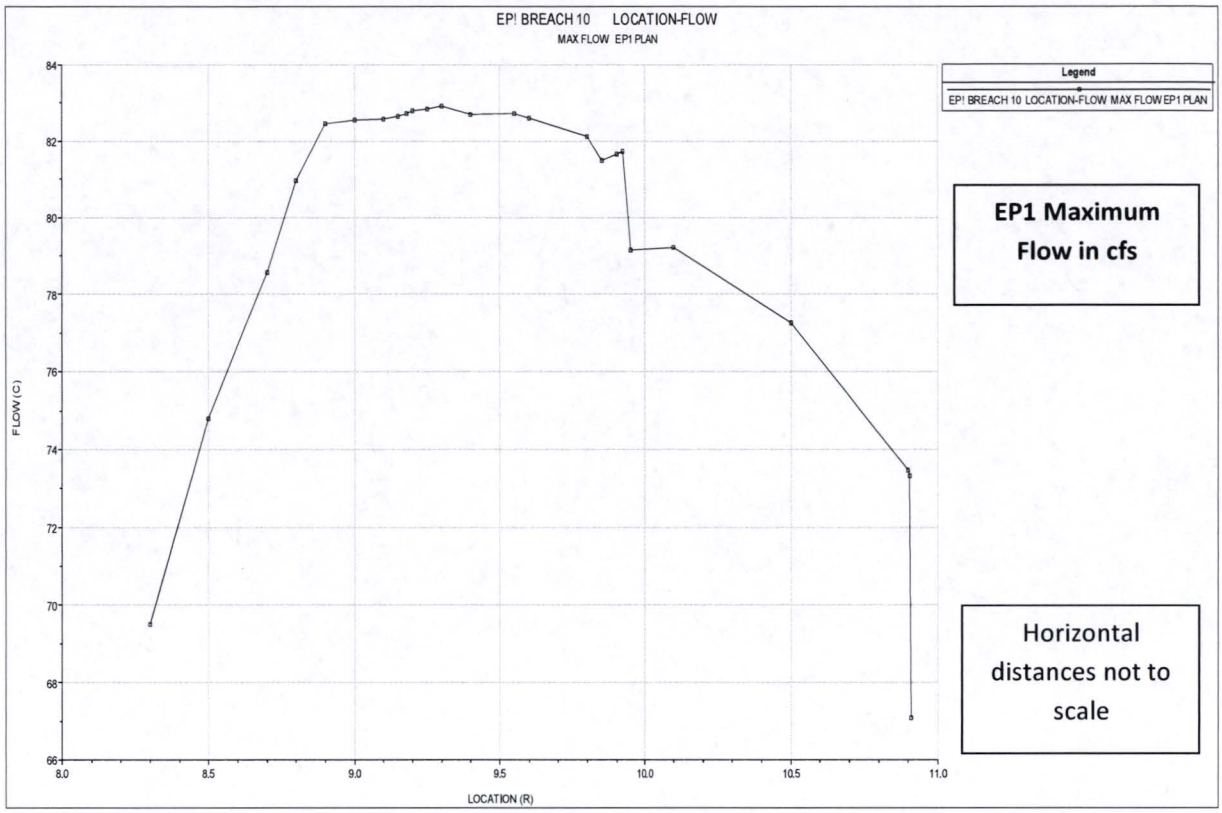
Results of Model

The results of the model (file name: EP1 Breach Model e) are illustrated by the following graphs, table and isometric image extracted from the output file of HEC RAS. As expected, the highest stages and flow rates occur as flow converges in the pond toward the breach and passes over the berm down the steep outslope. Once flow passes across the downstream toe and spreads out over the flat ground south of EP1, the flow rates and depths decrease. At the downstream end of the model flow path, near the south property boundary, the maximum flow would be 0.20 ft deep and approximately 300 ft wide.

EVAPORATION POND 1 (EP1) HEC RAS Output






EP! BREACH 10 LOCATION-FLOW
MAX FLOW EP1 PLAN
Legend
EP! BREACH 10 LOCATION-FLOW MAX FLOW EP1 PLAN
EP1 Maximum Flow in cfs
Horizontal distances not to scale
FLOW (C)
LOCATION (R)
84
82
80
78
76
74
72
70
68
66
8.0
8.5
9.0
9.5
10.0
10.5
11.0

EP1 Breach Maximum Stage Elevations

Cross Section Number	Cross Section Location	Maximum Stage Elevation
10.91	300 ft upstream of US toe	6598.27
10.90	200 ft upstream of US toe	6598.27
10.50	100 ft upstream of US toe	6598.27
10.10	50 ft upstream of US toe	6598.27
9.95	US toe at elevation 6583	6598.27
9.92	US slope at elevation 6585	6598.27
9.90	US slope at elevation 6587.5	6598.27
9.85	US slope at elevation 6590	6598.27
9.80	US slope at elevation 6592.5	6598.27
9.60	US slope at elevation 6595	6598.27
9.55	Crest US edge at elevation 6597.5	6598.27
9.50	Centerline of berm at elevation 6597.5	6598.27
9.40	Crest DS edge at elevation 6597.5	6598.27
9.30	DS slope at elevation 6593	6593.03
9.25	DS slope at elevation 6587	6587.04
9.20	DS slope at elevation 6582	6582.03
9.18	DS slope at elevation 6578	6578.29
9.15	DS slope at elevation 6573	6573.03
9.10	DS slope at elevation 6568	6568.12
9.00	DS slope at elevation 6567	6567.06
8.90	DS toe at elevation 6566	6566.24
8.80	500 ft DS from DS toe	6566.04
8.70	1070 ft DS from DS toe	6565.79
8.50	2070 ft DS from DS toe	6562.65
8.30	3070 ft DS from DS toe	6561.80
Initial ground elevation at breach		6598.5
Assumed initial breach depth		1.0 ft
Ground elevation at downstream end of model		6561.6
Maximum water depth at downstream end of model		0.20 ft

EP2 Breach Analysis

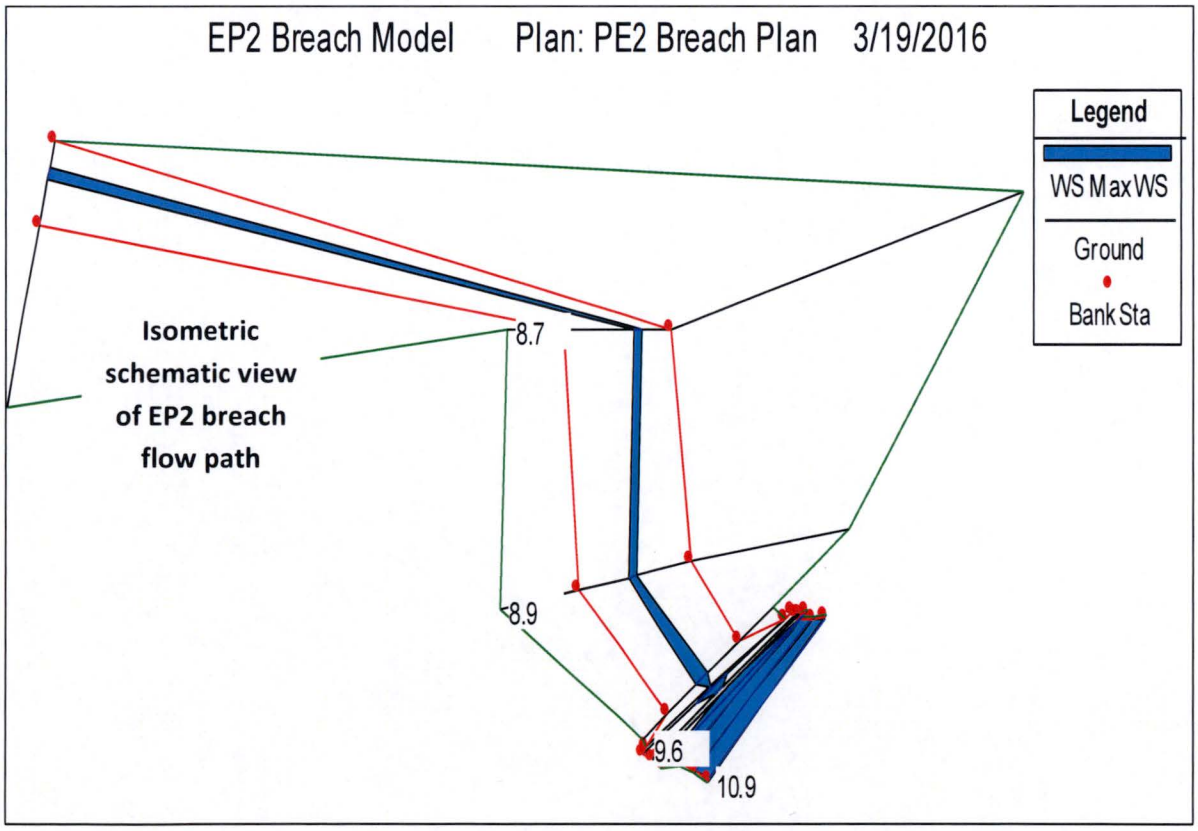
Assumed Initial Conditions

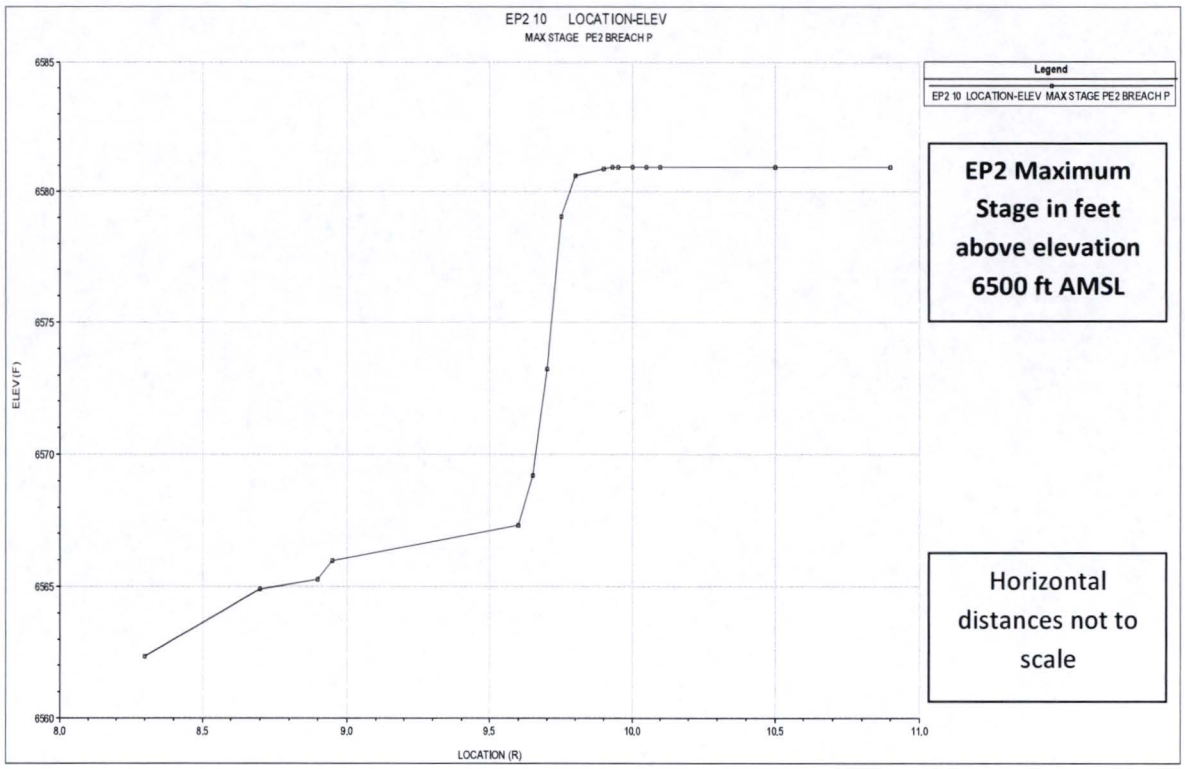
At the lowest elevation of the crest, 6581.5 ft AMSL, a breach was initiated by a pond water surface at 6581.6 along a 1.0 ft deep path of water that initially moved at 0.02 cfs across the berm crest.

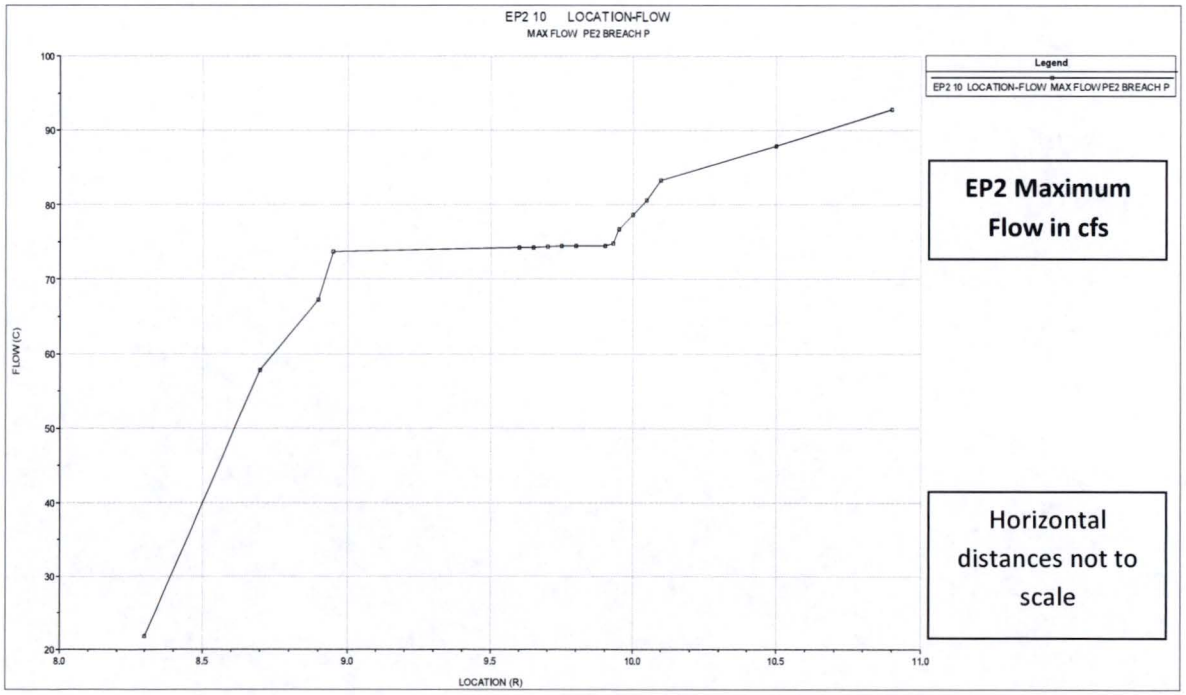
Results of Model

The results of the model (file name: EP2 Breach Model a) are illustrated by the following graphs, table and isometric image extracted from the output file of HEC RAS. Highest stages and flow rates occur as flow converges in the pond toward the breach and passes over the berm down the steep outslope. Once flow passes across the downstream toe and spreads out over the flat ground south of EP2, the flow rates and depths decrease. The flow is deflected from southwesterly to southerly flow when it encounters the old Thunderbird Road embankment. At the downstream end of the model flow path, near the south property boundary, the maximum breach flow would be 0.84 ft deep and approximately 260 ft wide.

EVAPORATION POND 2 (EP2) HEC RAS Output




EP2 10 LOCATION-ELEV
MAX STAGE PE2 BREACH P
Legend
EP2 10 LOCATION-ELEV MAX STAGE PE2 BREACH P
EP2 Maximum Stage in feet above elevation 6500 ft AMSL
Horizontal distances not to scale
ELEV (F)
LOCATION (R)
6585
6580
6575
6570
6565
6560
8.0
8.5
9.0
9.5
10.0
10.5
11.0


EP2 10 LOCATION-FLOW
MAX FLOW PE2 BREACH P
Legend
EP2 10 LOCATION-FLOW MAX FLOW PE2 BREACH P
EP2 Maximum Flow in cfs
Horizontal distances not to scale
FLOW (C)
LOCATION (R)
100
90
80
70
60
50
40
30
20
8.0
8.5
9.0
9.5
10.0
10.5
11.0

EP2 Breach Maximum Stage Elevations

Cross Section Number	Cross Section Location	Maximum Stage Elevation
10.90	100 ft US of US slope toe of berm	6580.95
10.50	50 ft US of US slope toe of berm	6580.95
10.10	US slope toe of berm	6580.95
10.05	US slope at elevation 6565	6580.95
10.00	US slope at elevation 6570	6580.95
9.95	US slope at elevation 6575	6580.95
9.93	US slope at elevation 6580	6580.95
9.90	US edge of crest at elevation 6581.5	6580.88
9.85	Centerline of berm at elevation 6581.5	6580.74
9.80	DS edge of crest at elevation 6581.5	6580.60
9.75	DS slope at elevation 6580	6579.04
9.70	DS slope at 6574	6573.23
9.65	DS slope at 6570	6569.21
9.60	DS toe	6567.31
8.95	49 ft from toe	6565.98
8.90	600 ft from toe	6565.27
8.70	1800 ft from toe	6564.89
8.30	DS end of model, 4300 ft from toe	6562.34
Initial ground elevation at breach		6581.5
Assumed initial breach depth		1.0 ft
Ground elevation at downstream end of model		6561.5
Maximum water depth at downstream end of model		0.84 ft

EP3 Breach Analysis

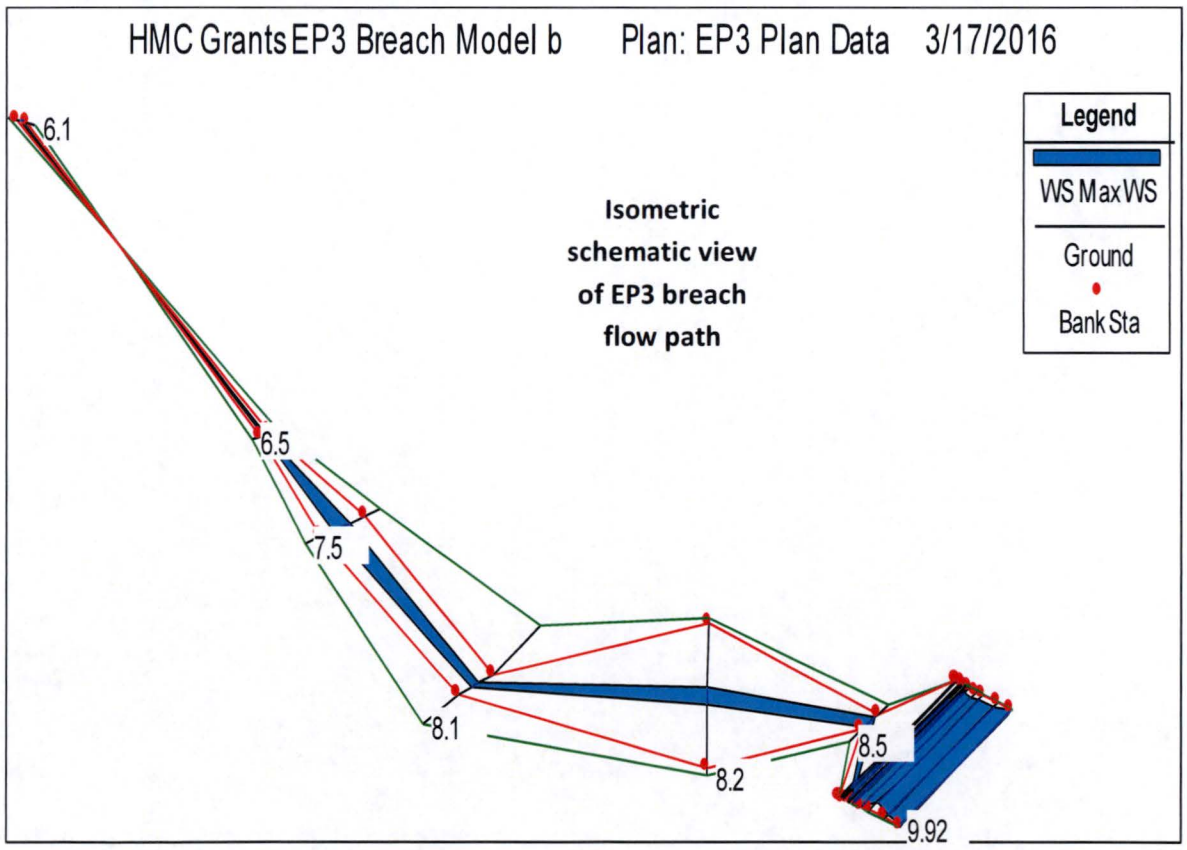
Assumed Initial Conditions

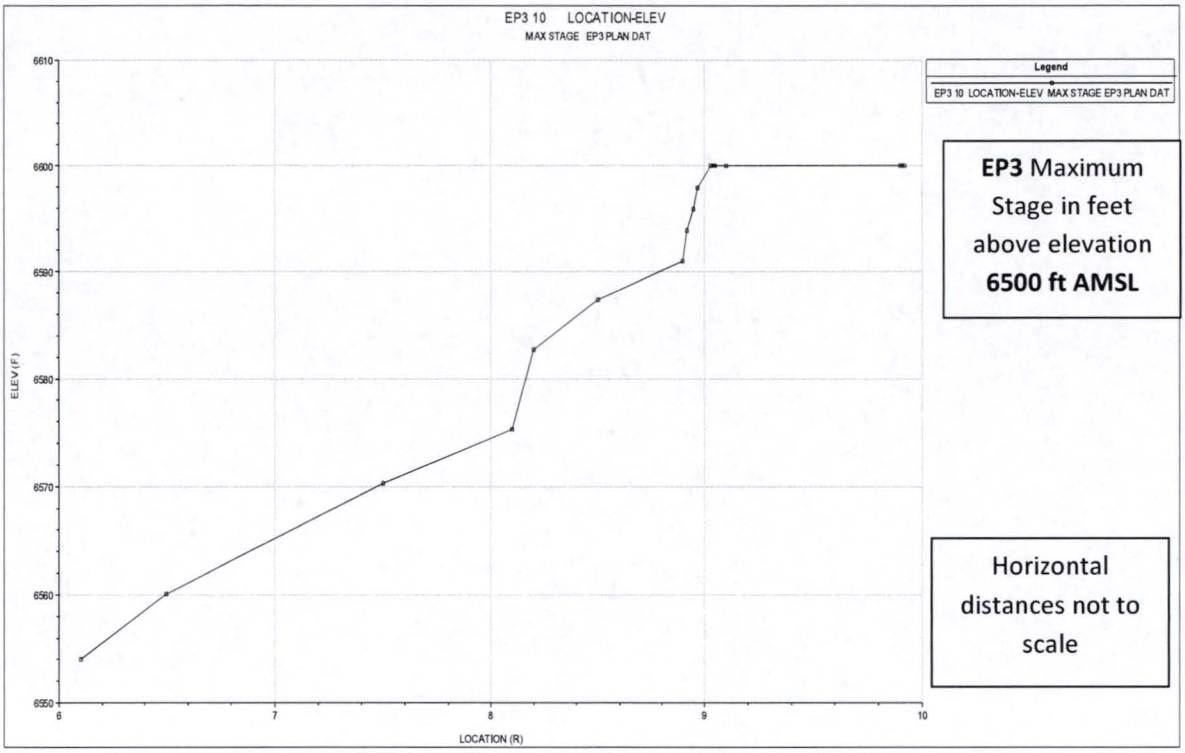
At the lowest elevation of the crest, 6600.0 ft AMSL, a breach was initiated by a pond water surface at 6581.6 along a 1.0 ft deep path of water initially moving at 0.02 cfs across the berm crest.

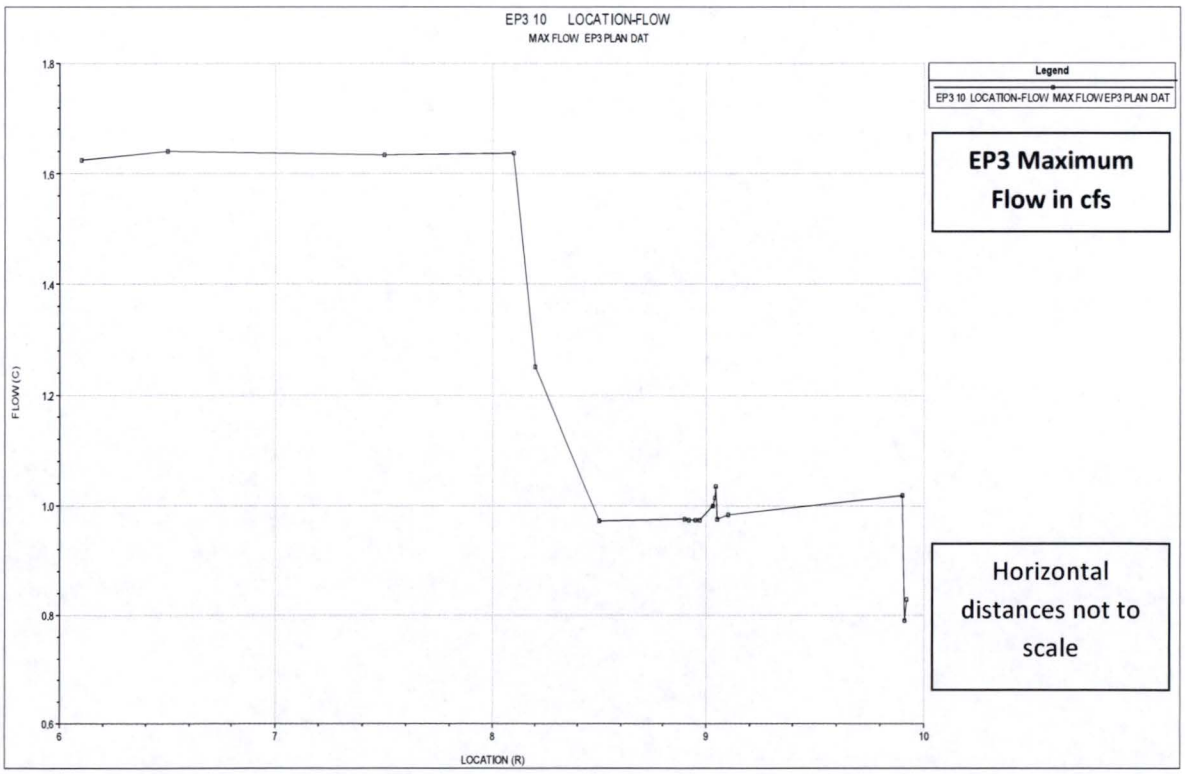
Results of Model

The results of the model (file name: EP3 Breach Model) are illustrated by the following graphs, table and isometric image extracted from the output file of HEC RAS. Highest stages occur as flow converges in the pond toward the breach and passes over the berm down the steep outslope. Once flow passes across the downstream toe, it spreads out over the flat ground south of EP3 until it intersects the PMF diversion channel off the northwest corner of the large tailing pile, then becomes more confined, causing the flow rates to increase. At the downstream end of the model flow path, near the west property boundary, the maximum breach flow would be 0.07 ft deep and approximately 20 ft wide.

EVAPORATION POND 3 (EP3) HEC RAS Output




EP3 10 LOCATION-ELEV
MAX STAGE EP3 PLAN DAT
Legend
EP3 10 LOCATION-ELEV MAX STAGE EP3 PLAN DAT
EP3 Maximum Stage in feet above elevation 6500 ft AMSL
Horizontal distances not to scale
ELEV (F)
LOCATION (R)
6610
6600
6590
6580
6570
6560
6550
6
7
8
9
10


EP3 10 LOCATION-FLOW
MAX FLOW EP3 PLAN DAT
Legend
EP3 10 LOCATION-FLOW MAX FLOW EP3 PLAN DAT
EP3 Maximum Flow in cfs
Horizontal distances not to scale
FLOW (C)
LOCATION (R)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
6
7
8
9
10

EP3 Breach Maximum Stage Elevations

Cross Section Number	Cross Section Location	Maximum Stage Elevation, ft
9.92	300 ft upstream of berm toe	6600.02
9.91	200 ft upstream of berm toe	6600.02
9.90	100 ft upstream of berm toe	6600.02
9.10	50 ft upstream of berm toe	6600.02
9.05	Upstream of berm toe	6600.02
9.045	US slope 9 ft below crest at 6591	6600.02
9.04	US slope 6 ft below crest at 6594	6600.02
9.03	US slope 3 ft below crest at 6597	6600.02
9.02	US crest at 6600	6600.01*
9.015	Crest Centerline	6600.01*
8.99	US crest at 6600	6600.00*
8.97	2 ft below crest on DS slope	6597.92
8.95	mid DS slope at 6596	6595.92
8.92	DS at elev 6594	6593.92
8.90	toe of DS slope	6591.02
8.50	200 feet S of pond	6587.35
8.20	1200 ft from toe of EP3	6582.72
8.10	bend south of county road	6575.26
7.50	1500 ft west of LTP west toe	6570.32
6.50	E end of Section 28 excavated channel	6560.06
6.10	W end of Section 28 excavated channel	6554.07
		*Interpolated, no output
Initial ground elevation at breach		6600.0
Assumed initial breach depth		1.0 ft.
Ground elevation at downstream end of model		6654.0
Maximum water depth at downstream end of model		0.07 ft.

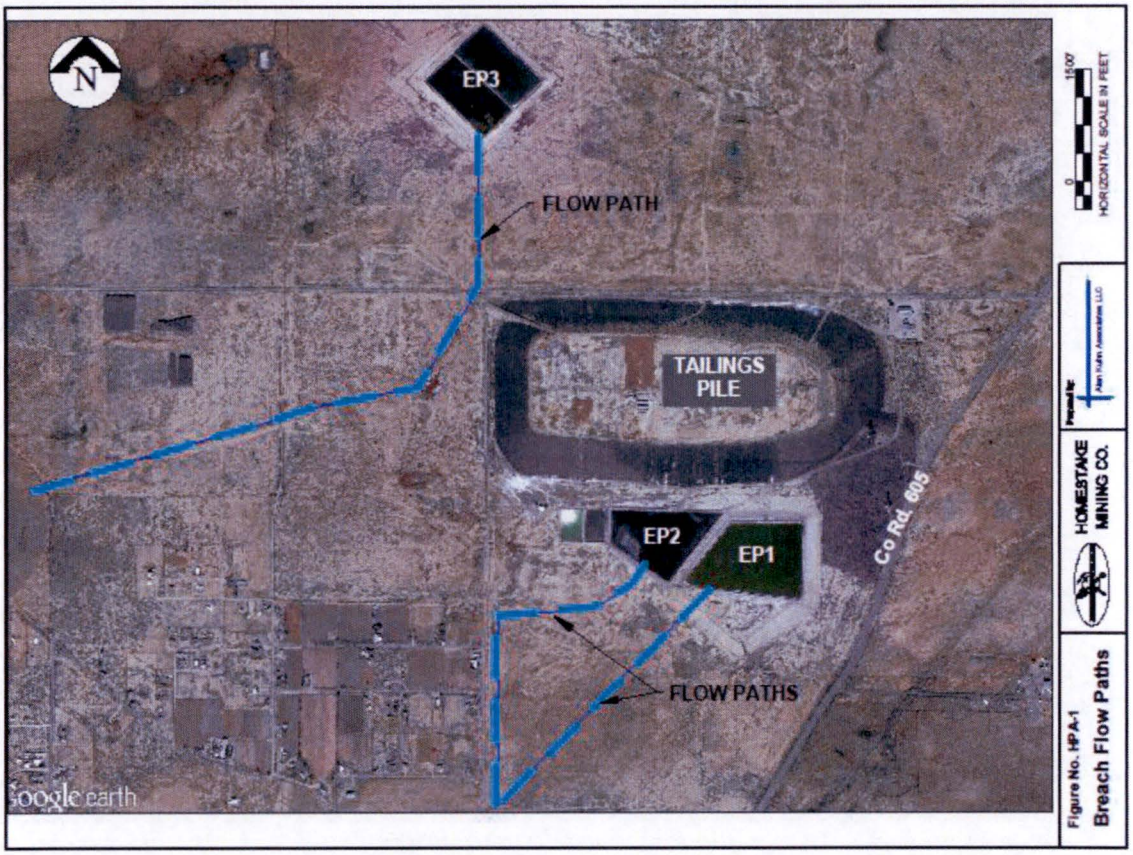

N
EP3
FLOW PATH
TAILINGS PILE
EP2
EP1
Co Rd. 605
FLOW PATHS
Google earth
0
1500
HORIZONTAL SCALE IN FEET
HOMESTAKE MINING CO.
Figure No. HPA-1
Breach Flow Paths

Table 1 Homestake Grants Pond Breach Parameters

Based on methods in Colorado "Guidelines for Dam Breach Analysis", Table 2, Table 3
All Homestake ponds are classified per this reference as "small", with capacities of <1000AF and >100AF

Parameters	Units	Equation	EP1*	EP2	EP3
Surface area of water,	Ac		25.61	17.80	26.62
Volume of water, Vw	AF		350.91	235.47	185.52
Height of water, Hw	ft		15.5	15.5	10
Storage intensity, SI	AF/ft	Vw/Hw	22.64	15.19	18.55
			high	medium	medium
Height of Breach, Hb	ft	Crest to pond bottom or ground surface	28.5	15.5	10
Breach elevation	ft AMSL				
Applicable Empirical Equation:					
MacDonald & Langridge-Monopolis (MLM)			√		
Washington					
Froehlich			√	√	√
Froehlich Failure Mode Factor, Ko, for overtopping			1.3	1.3	1.3
Breach formation factor, BFF	Acre - ft^2	Vw*Hw	5439.1	3649.9	1855.2
Volume eroded, Ver	CY	3.264*BFF^0.77	2455.3	1805.9	1072.5
Average Breach Width, Bave	ft				
Froehlich		8.239*Ko*Vw^0.32*Hb^0.04	79.89	68.62	62.47
Breach side slopes	none				
Froehlich			1.0:1	1.0:1	1.0:1
Breach Development Time, Tf	hr	3.664*((Vw/(G*Hb^2))^.5)	0.42	0.64	0.88
Erosion Rate,ER	ft/hr				
min		4Hw	62	62	40
max		200+4Hw	262	262	240
ER/Hw					
min			4	4	4
max			16.90	16.90	24.00
Bave/Hb			2.8	4.4	6.2
Manning's n, liner			0.025	0.025	0.025
Manning's n, soil surface			0.035	0.035	0.035