nhc

Memorandum

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to:	Gerry Ferris	***sent:***	by email
company:	BGC Engineering	***date:***	4 November 2004
from:	Barry Evans	***pages:***	21

subject:	Faro Mine Site: North Fork Rose Creek - Extreme flood hydrograph attenuation by Haul Road flow-through rock drain and effect on the downstream RCDC flood peak

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1. INTRODUCTION

At present, North Fork Rose Creek flows pass through the Mine Site haul road embankment by way of a flow-through rock drain (see Figure 1). Hydrotechnical studies for closure planning to date have assumed that the rock drain is removed some time in the future, allowing North Fork flows to pass unimpeded into the Rose Creek valley[1].

Retaining the rock drain would attenuate North Fork flows, thereby reducing downstream flood peaks, and, possibly, significantly reduce the cost of upgrading the downstream Rose Creek Diversion Channel (RCDC) to convey the extreme floods up to the probable maximum flood (PMF).

This memorandum assesses the attenuating affect of the Haul Road flow-through rock drain on North Fork Rose Creek extreme floods, and presents a preliminary estimate of the lowered extreme flood peaks in the downstream RCDC.

This memorandum was prepared for inclusion in the BGC Engineering Inc. (**BGC**) report on the stability of the Mine Site haul road embankment.

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[1] *Northwest Hydraulic Consultants Ltd.(**nhc**) December2002. Hydrotechnical assessment for Faro Mine Site. Prepared for BGC Engineering Inc.*
***nhc**, June 2004. Hydrotechnical study for closure planning, Faro Mine Site area,Yukon, final report. Prepared for SRK Consulting Inc.*

2. STUDY COMPONENTS

The study components herein are:

1. Develop a stage-discharge rating curve for the Stn. X2 water level recorder (see Figure 1). **BGC** used the Stn. X2 flow data and corresponding embankment pond water level records at Loc. 3, plus other data and analyses, to develop a flow-through rock drain relationship between the upstream pond elevation and downstream discharge.
2. Route extreme flood hydrographs up to the PMF through the Haul road embankment using the pond elevation versus volume relationship, and flow-through rock drain relationships provided by **BGC**. Outputs: pond water level hydrographs, and attenuated downstream discharge hydrographs.
3. Provide a preliminary estimate of the lowered extreme flood peaks in the downstream RCDC resulting from the flow-through rock drain attenuation.

2.1 STN. X2 STAGE-DISCHARGE CURVE

Photo 1 shows the North Fork Rose Creek at the Stn. X2 water level recorder installed by **BGC** in the summer of 2004.

The HEC-RAS backwater model was used to compute a preliminary stage-discharge curve for the Stn. X2 water level recorder[2]. Creek geometry model input consisted of four creek cross-sections over a 60 m length of channel that were surveyed on September 30, 2004.

The sensitivity of the backwater calculations was assessed by using channel roughness values (Manning's n) ranging from 0.040 to 0.050. The adopted rating curve is a compromise between the two roughness values, and is:

$$Q = 8.955\,3\ \text{WSE} - 9579.4$$

where:

Q = discharge in m^3/s, and

WSE = water surface elevation at Stn. X2 recorder in m.

Note: The use of the rating curve should be limited to water levels less than El. 1070.4 m. This level corresponds to a creek discharge of about 6 m^3/s.

[2] The lack of reliable discharge measurements necessitated that the stage-discharge curve be computed by backwater analysis only.

3. FLOW-THROUGH ROCK DRAIN FLOOD ROUTING

The flood hydrograph routing model used the following inputs:

1. Flood inflow hydrographs.
2. Haul Road pond elevation versus capacity data.
3. Flow-through rock drain outflow relationship.

3.1 Flood Inflow Hydrographs

The following flood hydrographs were routed through the embankment:

- mean annual, 100-year, 500-year, and 1000-year snowmelt floods; and
- probable maximum flood (PMF).

3.1.1 ***Snowmelt.*** Table 1 lists the 20-day non-dimensional hydrograph for snowmelt floods[3], and Table 2 the peak discharges[4]. Individual hydrographs for the four events were generated by multiplying the peak discharge values of Table 2 by the Table 1 values of Q_n/Q_{peak}.

3.1.2 ***PMF.*** This extreme short-duration rainfall event has a 16-hour hydrograph with the peak discharge of 504 m^3/s occurring after 4 hours[4].

3.2 Haul Road Pond Capacity

Table 3 lists the pond elevation versus capacity characteristics supplied by **BGC**.

3.3 Flow-Through Rock Drain Outflow Relationships

Two relationships were developed by **BGC** relating the flow-through drain outflow with the upstream pond water level. The relationships are:

Q-out = 0.31483(Pond El.21086.5)^1.7560 .... Rel.2004

Q-out = 0.15573(Pond El.21088.3)^211.993(Pond El.21088.3)11.2707... Rel.1993

where:

Q-out = drain outflow in m^3/s, and
Pond El = upstream pond water level in m.

[3] *From: nhc, December 2002. (See Footnote 1 on page 1.)*
[4] *From: nhc, June 2004. (See Footnote 2 on page 1.)*

The reader is referred to the main body of the report by **BGC** for the background to the two relationships.

3.4 Flood Hydrograph Routing

3.4.1 ***Initial conditions for snowmelt events.*** The mean annual flood (MAF) hydrograph was initially routed through the model and the maximum pond elevation attained was adopted as the starting level for routing the extreme snowmelt 100-, 500- and 1000-year flood hydrographs. Figure 2 presents the results of the MAF inflow hydrograph routing, and shows the maximum pond level attained was El. 1092.4 m

3.4.2 ***Initial conditions for PMF.*** A pond elevation of 1093.0 m was adopted.

3.4.3 ***Results.*** Two output sets were generated corresponding to the two rock drain outflow equations REL.2004 and REL.1993.

REL.2004 routing. Figures 3 to 6 graphically present the routing results and Table 4 summarizes the peak pond water levels and outflow discharges. As expected, the long duration snow snowmelt events with their large hydrograph volumes produce significantly higher pond water levels and smaller attenuation of peak discharges than the short duration PMF rainfall event.

REL.1993 routing. Figures 7 to10 graphically present the routing results and Table 5 summarizes the peak pond water levels and outflow discharges.

Comparison of REL.2004 and REL.1993 routing results. The following summary of the Tables 4 and 5 routing estimates show that the two routing relationships used give moderately different attenuation results.

Event/Output Parameter	Result Comparison	
	REL.2004	REL.1993
1000-year Snowmelt flood		
Peak pond water level (m)	1103.5	1101.3
Peak outflow discharge (m^3/s)	45.4	53.5
PMF		
Peak pond water level (m)	1093.9	1093.9
Peak outflow discharge (m^3/s)	10.7	17.3

4. EFFECT OF HAUL ROAD EMBANKMENT FLOW ATTENTUATION ON RCDC PMF ESTIMATES

Earlier hydrotechnical studies have assumed that the Haul Road embankment will be removed some time in the future allowing extreme flood flows to pass unimpeded down North Fork Rose Creek (**nhc,** December 2002 and June 2004).

Tables 4 and 5 show that retaining the embankment and the flow-through rock drain reduces the North Fork Rose Creek PMF peak discharge from 504 m^3/s to about 15 m^3/s[5]. This significant reduction in peak discharge will also lower the PMF peak discharge in the downstream RCDC as shown below.

RCDC PMF peak discharge with Haul Road embankment removed:	730 m^3/s
RCDC PMF peak discharge with Haul Road embankment retained:	460 m^3/s
Estimated reduction in PMF peak discharge:	270 m^3/s

5. CONCLUDING REMARK

The results presented in this memorandum are preliminary as they are based on analyses requiring many assumptions and engineering judgement because of insufficient data.

Prepared by:

B.J. Evans, P.Eng.
Senior Engineer

[5] *The attenuated discharge estimate of 15 m^3/s is the approximate average of the computed peak outflows listed in Tables 4 and 5.*

Table 1. Non-dimensional hydrograph for snowmelt floods

Day	Q_n/Q_{peak}
1	0.054
2	0.059
3	0.065
4	0.075
5	0.086
6	0.124
7	0.172
8	0.226
9	0.349
9.5	0.457
9.75	0.538
10	1.000
10.25	0.699
10.5	0.484
11	0.349
12	0.242
13	0.188
14	0.177
15	0.172
16	0.167
17	0.161
18	0.156
19	0.151
20	0.145

Where:

Q_n = Discharge at time "n"

Q_{peak} = Instantaneous peak discharge

From: **nhc**, December 2002. (See Footnote 1 on page 1.)

Table 2. Estimated mean annual to 1000-year flood peaks for North Fork Rose Creek at flow-through rock drain (Loc.3)

Return Period	Peak Discharge (m^3/s)
Mean annual flood	11
100-year	54
500-year	81
1000-year	93

From: **nhc**, June 2004. (See Footnote 2 on page 1.)

Table 3. Haul Road embankment pond capacity relationship

Elevation (m)	Area (m^2)	Incr. Volume (m^3)	Total Volume (m^3)
1086.5	0		0
1090	9,417	11,018	11,018
1092	23,496	84,238	95,256
1094	35,156	164,297	259,553
1096	57,740	256,105	515,659
1098	81,657	394,274	909,933
1100	111,037	548,702	1,458,634
1102	143,763	731,674	2,190,308
1104	179,501	934,056	3,124,365
1106	211,725	1,141,456	4,265,821
1108	244,866	1,336,634	5,602,455
1110	277,848	1,535,161	7,137,616
1112	332,929	1,777,250	8,914,866
1114	387,635	2,106,984	11,021,850
1116	457,585	2,465,710	13,487,560
1118	533,094	2,896,531	16,384,091
1120	605,118	3,342,612	19,726,703
1122	697,572	3,815,615	23,542,318
1130	1,137,570	20,261,714	43,804,032

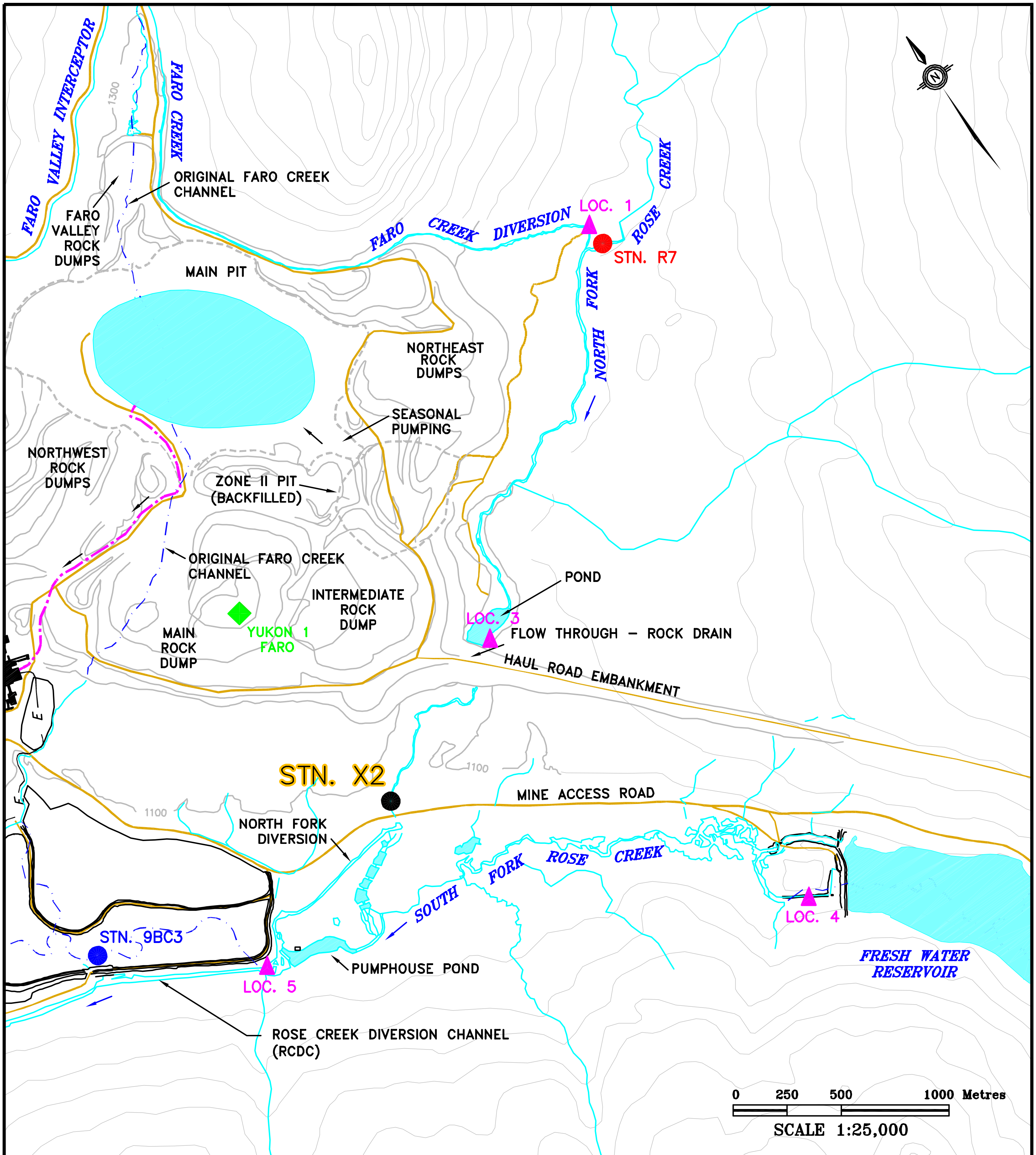
Note: Pond capacity data provided by BGC Engineering Inc.

Table 4. Estimated peak pond water level and peak rock drain outflow discharge using the REL.2004 outflow relationship

Routed Event	Peak Inflow Discharge (m^3/s)	Peak Pond Water Elevation (m)	Peak Outflow Discharge (m^3/s)
Snowmelt			
100-year	54	1099.5	28.5
500-year	81	1102.4	40.4
1000-year	93	1103.5	45.4
Rainfall			
PMF	504	1093.94	10.7

Table 5. Estimated peak pond water level and peak rock drain outflow discharge using the REL.1993 outflow relationship

Routed Event	Peak Inflow Discharge (m^3/s)	Peak Pond Water Elevation (m)	Peak Outflow Discharge (m^3/s)
Snowmelt			
100-year	54	1097.6	33.5
500-year	81	1100.3	47.5
1000-year	93	1101.3	53.5
Rainfall			
PMF	504	1093.91	17.3



LEGEND:

STN. X2 WATER LEVEL RECORDER

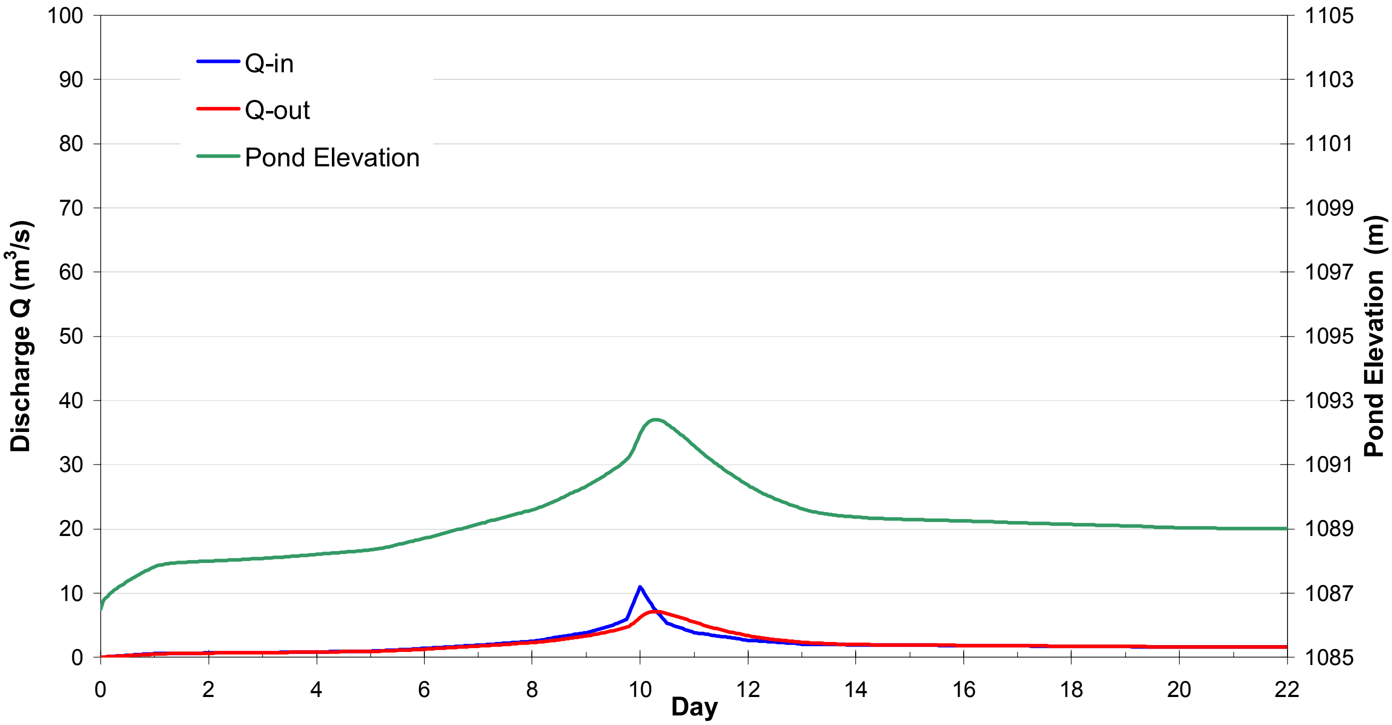
BGC ENGINEERING INC.

FARO MINE SITE 2004 STUDIES
FLOOD HYDROGRAPH ATTENUATION
BY FLOW THROUGH ROCK DRAIN

SITE MAP

Dwg. 6472–003	25 Oct 2004	**Figure 1**

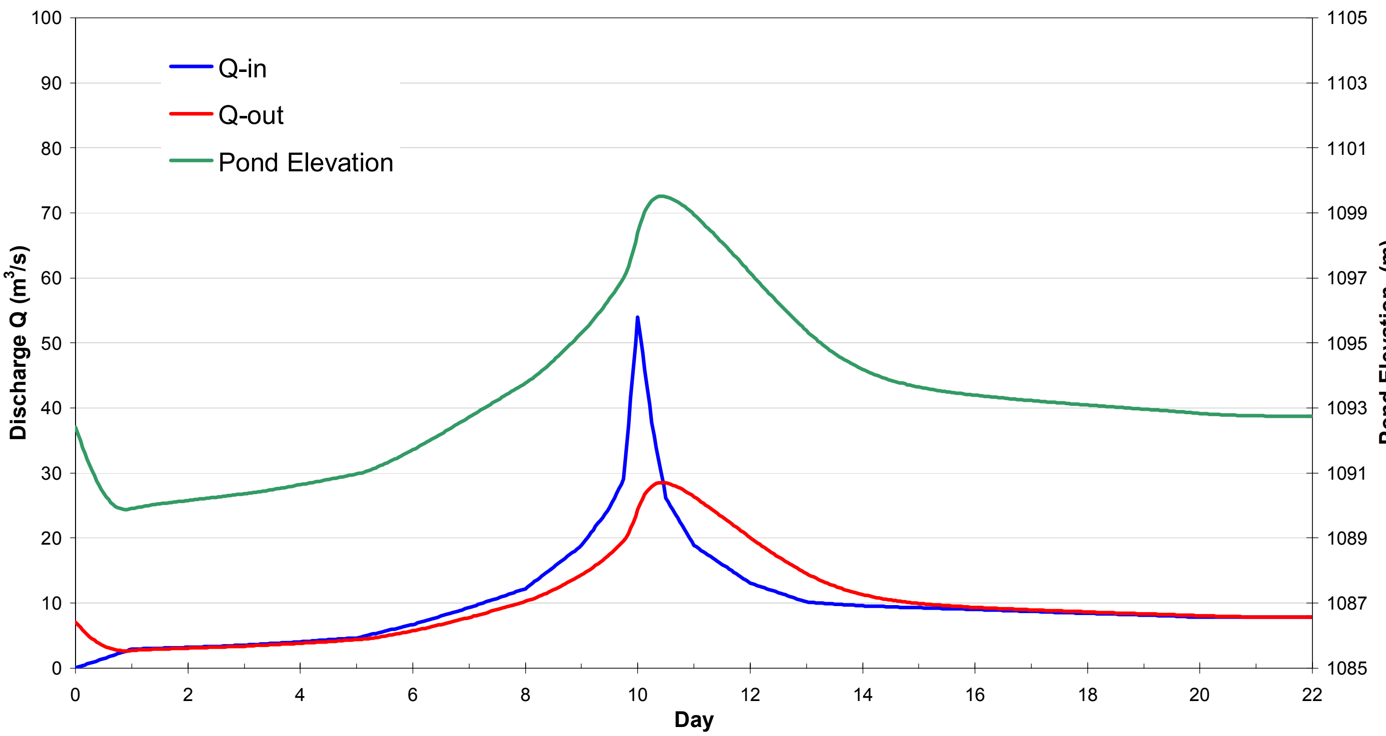
northwest hydraulic consultants ltd.



NOTE:

2004 RELATIONSHIP (REL.2004) USED TO COMPUTE DRAIN OUTFLOW:
Q-out = 0.3148 x (POND ELEVATION - 1086.5) ^ 1.756

BGC ENGINEERING INC.		
FARO MINE SITE 2004 STUDIES FLOOD HYDROGRAPH ATTENUATION BY FLOW THROUGH ROCK DRAIN **MAF HYDROGRAPH (REL.2004)**		
Dwg. 6472–004	2 Nov 2004	**Figure 2**
northwest hydraulic consultants ltd.		

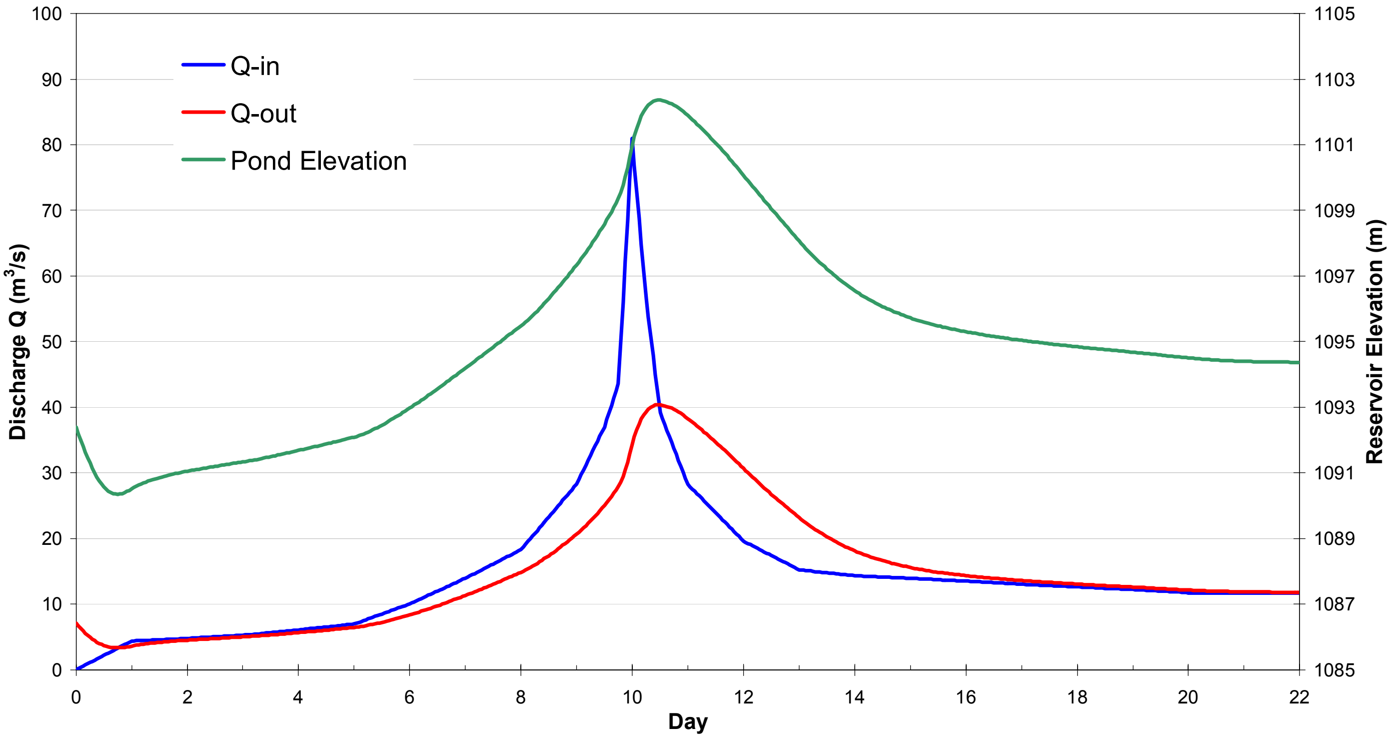


NOTE:

2004 RELATIONSHIP (REL.2004) USED TO COMPUTE DRAIN OUTFLOW:

Q-out = 0.3148 x (POND ELEVATION - 1086.5) ^ 1.756

BGC ENGINEERING INC.		
FARO MINE SITE 2004 STUDIES FLOOD HYDROGRAPH ATTENUATION BY FLOW THROUGH ROCK DRAIN **100-YEAR FLOOD HYDROGRAPH (REL.2004)**		
Dwg. 6472–004	2 Nov 2004	**Figure 3**
northwest hydraulic consultants ltd.		

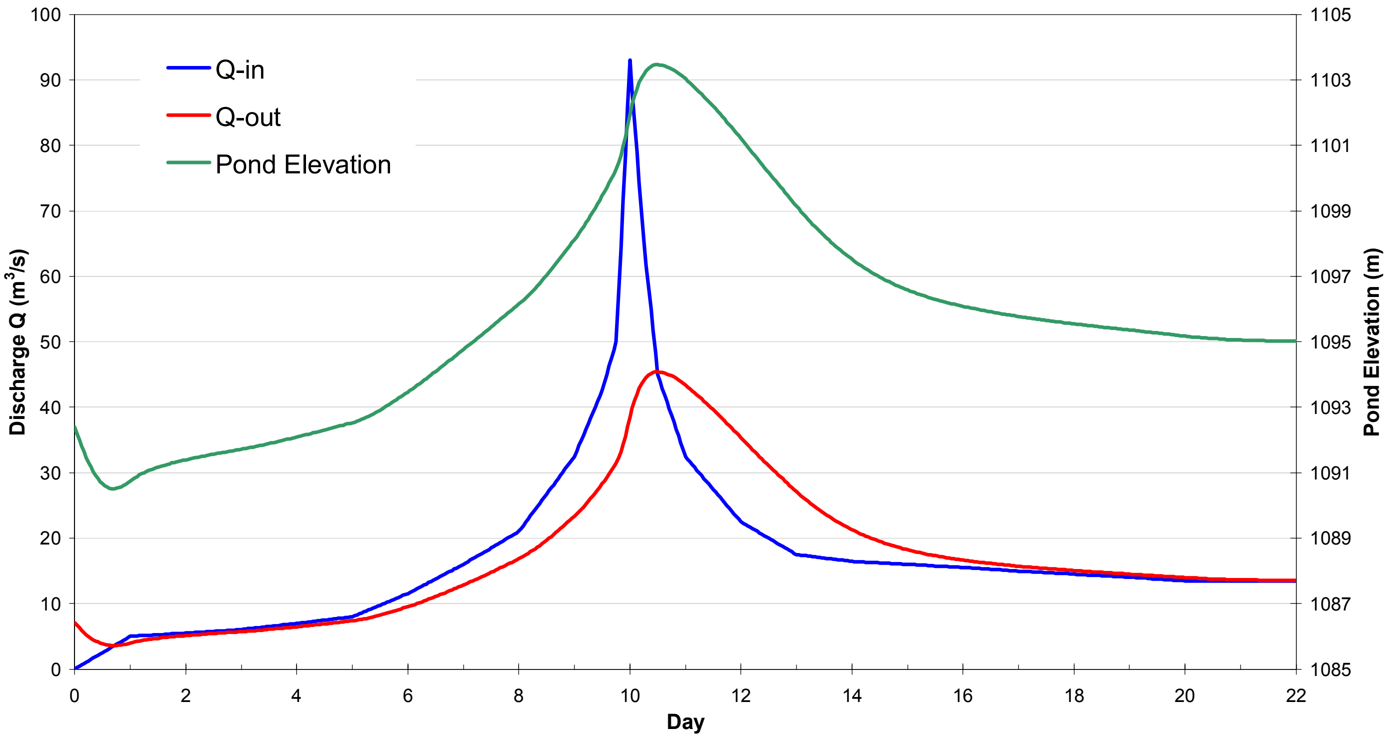


NOTE:

2004 RELATIONSHIP (REL.2004) USED TO COMPUTE DRAIN OUTFLOW:

Q-out = 0.3148 x (POND ELEVATION - 1086.5) ^ 1.756

BGC ENGINEERING INC.		
FARO MINE SITE 2004 STUDIES FLOOD HYDROGRAPH ATTENUATION BY FLOW THROUGH ROCK DRAIN **500-YEAR FLOOD HYDROGRAPH (REL.2004)**		
Dwg. 6472-004	2 Nov 2004	**Figure 4**
northwest hydraulic consultants ltd.		



NOTE:

2004 RELATIONSHIP (REL.2004) USED TO COMPUTE DRAIN OUTFLOW:

Q-out = 0.3148 x (POND ELEVATION - 1086.5) ^ 1.756

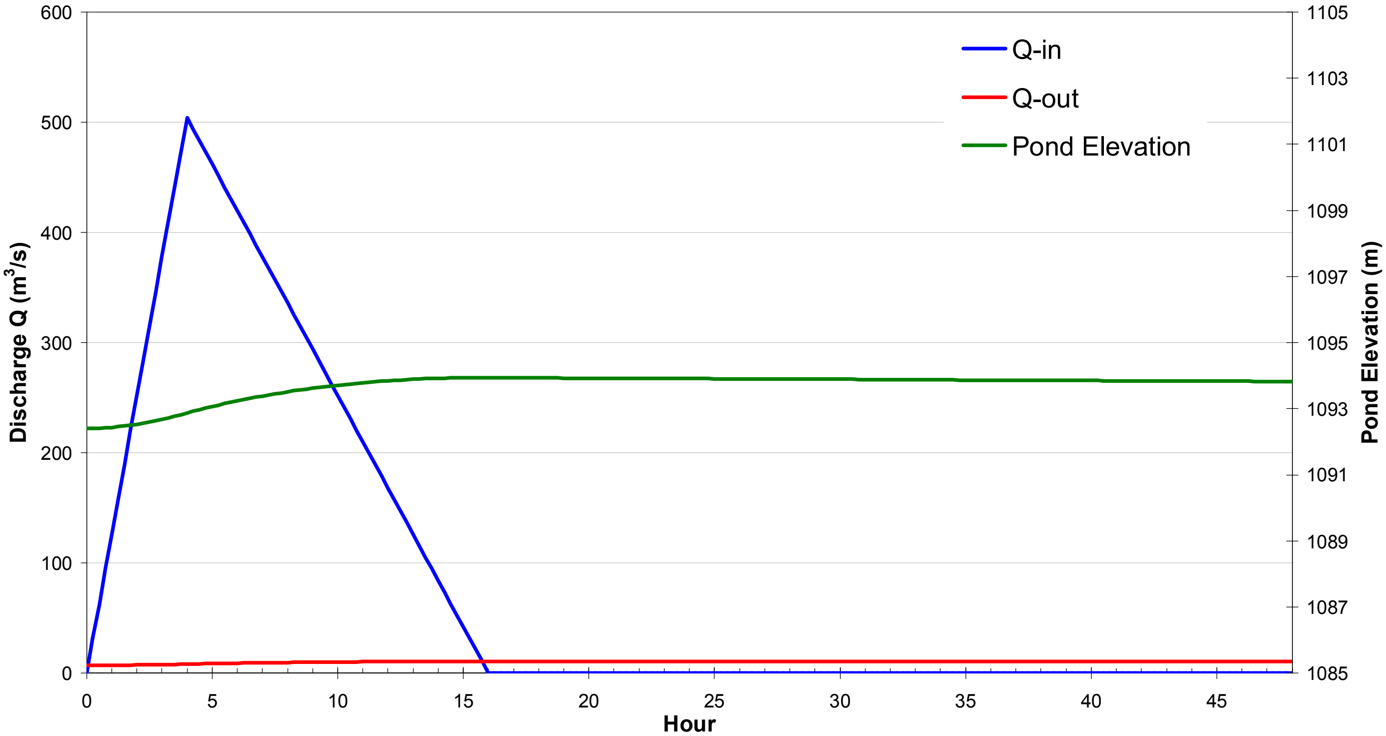
BGC ENGINEERING INC.

FARO MINE SITE 2004 STUDIES
FLOOD HYDROGRAPH ATTENUATION
BY FLOW THROUGH ROCK DRAIN

1000-YEAR FLOOD HYDROGRAPH (REL.2004)

Dwg. 6472–004	2 Nov 2004	**Figure 5**

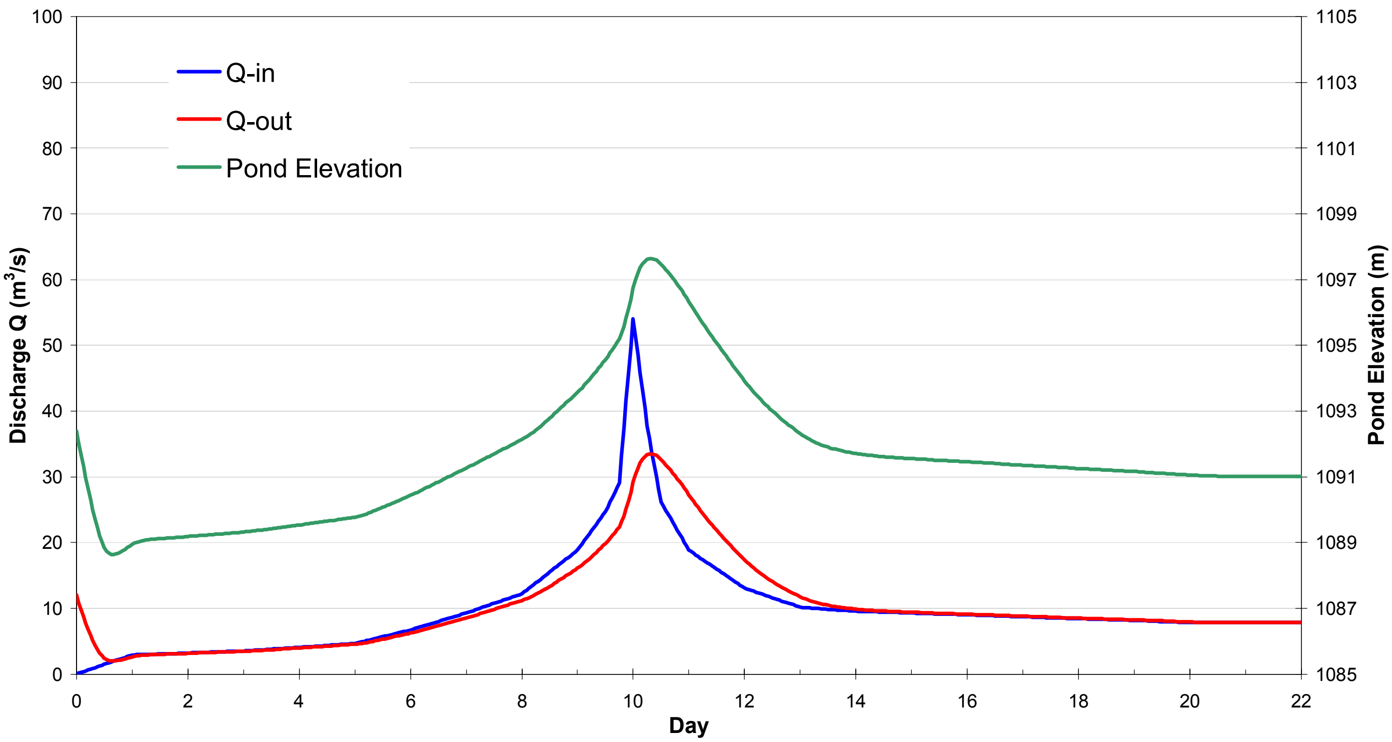
northwest hydraulic consultants ltd.



NOTE:

2004 RELATIONSHIP (REL.2004) USED TO COMPUTE DRAIN OUTFLOW:
Q-out = 0.3148 x (POND ELEVATION - 1086.5) ^ 1.756

BGC ENGINEERING INC.		
FARO MINE SITE 2004 STUDIES FLOOD HYDROGRAPH ATTENUATION BY FLOW THROUGH ROCK DRAIN **PMF HYDROGRAPH (REL.2004)**		
Dwg. 6472–004	2 Nov 2004	**Figure 6**
northwest hydraulic consultants ltd.		

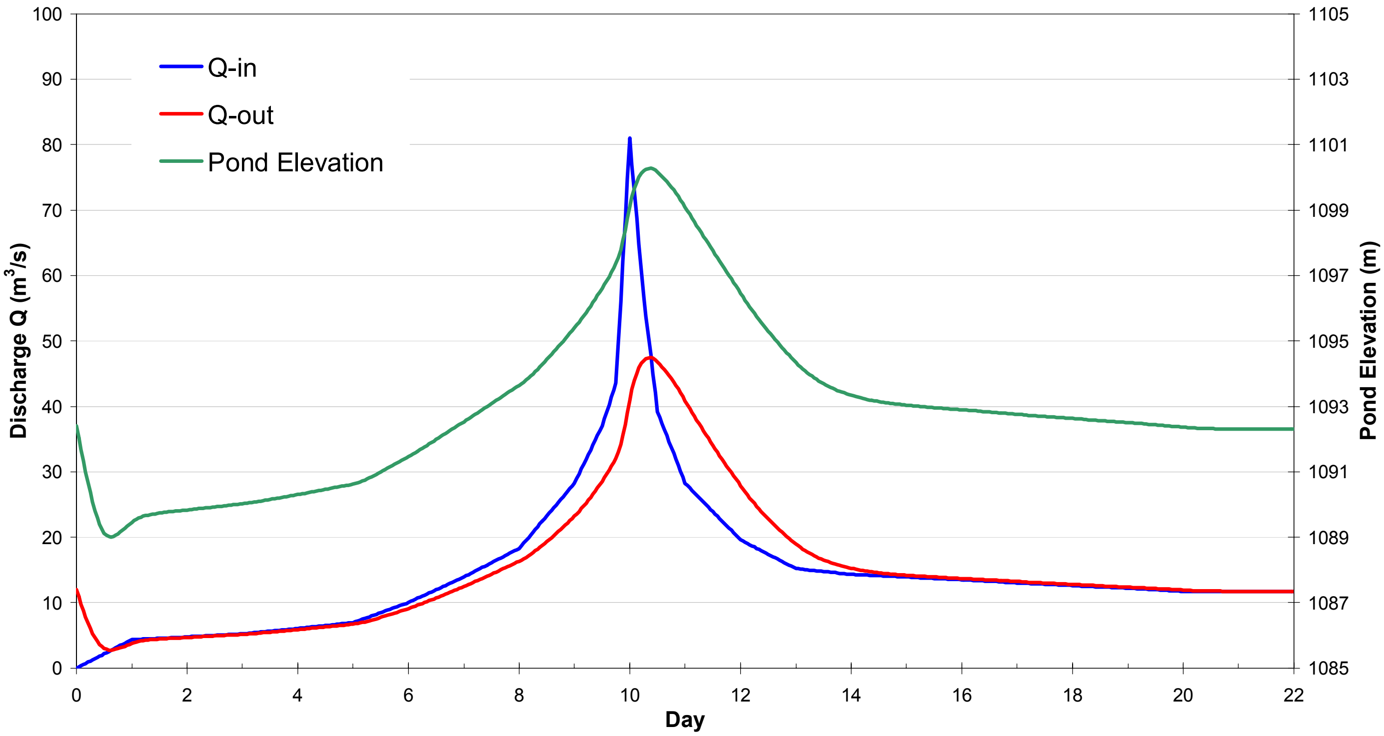


NOTE:

1993 RELATIONSHIP (REL.1993) USED TO COMPUTE DRAIN OUTFLOW:

Q-out = 0.1557 x (POND ELEVATION - 1088.3) ^ 2 + 1.99 x (POND ELEVATION - 1088.3) + 1.2707

BGC ENGINEERING INC.		
FARO MINE SITE 2004 STUDIES FLOOD HYDROGRAPH ATTENUATION BY FLOW THROUGH ROCK DRAIN **100-YEAR FLOOD HYDROGRAPH (REL.1993)**		
Dwg. 6472–004	2 Nov 2004	**Figure 7**
northwest hydraulic consultants ltd.		

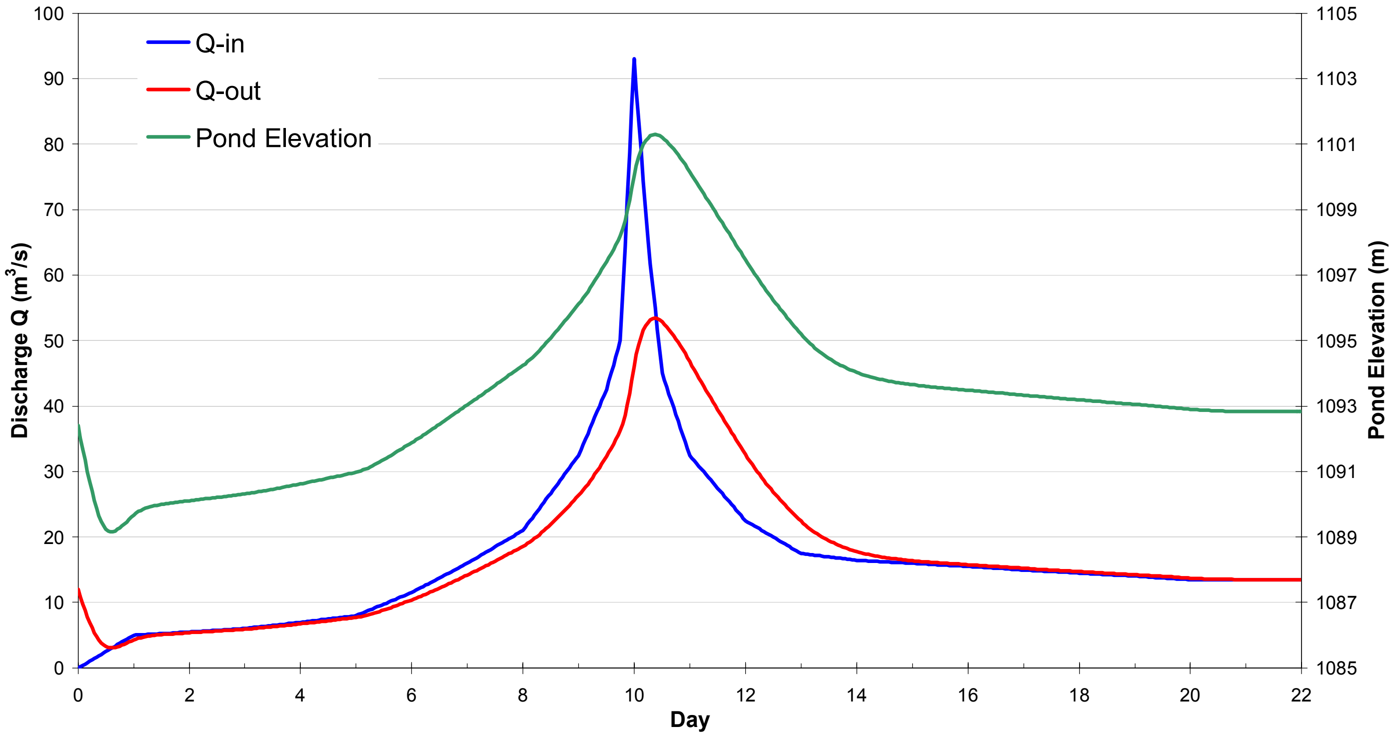


NOTE:

1993 RELATIONSHIP (REL.1993) USED TO COMPUTE DRAIN OUTFLOW:

Q-out = 0.1557 x (POND ELEVATION - 1088.3) ^ 2 + 1.99 x (POND ELEVATION - 1088.3) + 1.2707

BGC ENGINEERING INC.		
FARO MINE SITE 2004 STUDIES FLOOD HYDROGRAPH ATTENUATION BY FLOW THROUGH ROCK DRAIN **500-YEAR FLOOD HYDROGRAPH (REL.1993)**		
Dwg. 6472–004	2 Nov 2004	**Figure 8**
northwest hydraulic consultants ltd.		

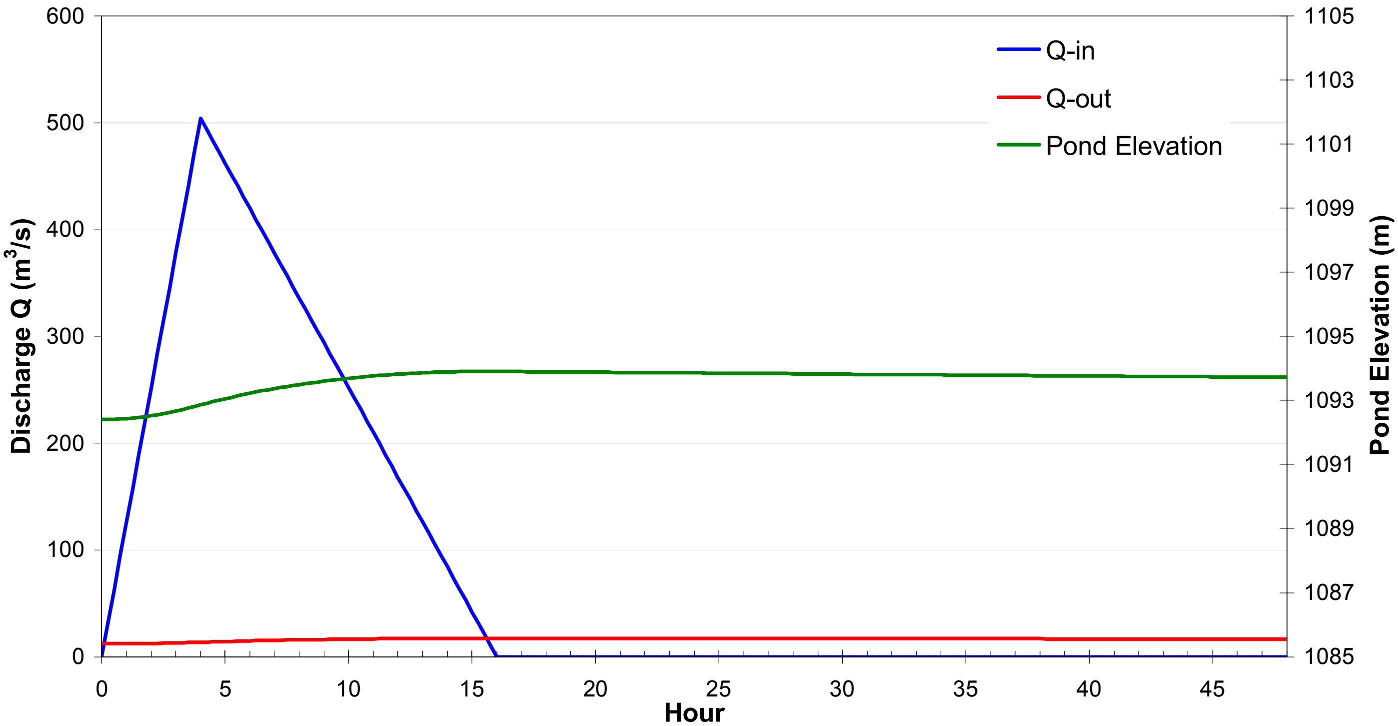


NOTE:

1993 RELATIONSHIP (REL.1993) USED TO COMPUTE DRAIN OUTFLOW:

Q-out = 0.1557 x (POND ELEVATION - 1088.3) ^ 2 + 1.99 x (POND ELEVATION - 1088.3) + 1.2707

BGC ENGINEERING INC.		
FARO MINE SITE 2004 STUDIES FLOOD HYDROGRAPH ATTENUATION BY FLOW THROUGH ROCK DRAIN **1000-YEAR FLOOD HYDROGRAPH (REL.1993)**		
Dwg. 6472–004	2 Nov 2004	**Figure 9**
northwest hydraulic consultants ltd.		



NOTE:

1993 RELATIONSHIP (REL.1993) USED TO COMPUTE DRAIN OUTFLOW:

Q-out = 0.1557 x (POND ELEVATION - 1088.3) ^ 2 + 1.99 x (POND ELEVATION - 1088.3) + 1.2707

BGC ENGINEERING INC.		
FARO MINE SITE 2004 STUDIES FLOOD HYDROGRAPH ATTENUATION BY FLOW THROUGH ROCK DRAIN **PMF HYDROGRAPH (REL.1993)**		
Dwg. 6472–004	2 Nov 2004	**Figure 10**
northwest hydraulic consultants ltd.		

Photo 1. North Fork Rose Creek viewing upstream at Stn. X2 water level recorder. Photo taken by BGC Engineering on August 30, 2004.