

**RAI Volume 2, Chapter 2.1.1.3, Third Set, Number 17:**

- (a) Justify why the doors of the emplacement drifts, discharge pump, construction barrier, and shotcrete seal would not be classified as items important to safety in SAR Table 1.9–1 Preclosure Safety Classification of SSCs. As part of the screening argument for internal flooding in the subsurface facilities, DOE has identified emplacement drift doors that would prevent water splash from contacting waste packages, barriers at the front of each emplacement drift, a discharge pump that would pump water out of the tunnel, a construction barrier, and shotcrete seal (BSC, 2008). In addition, on page 101 of BSC (2008), DOE indicates that, “In the event of a flood, portal security personnel can isolate flow to the tunnel (underground communications are provided during construction operations).”
- (b) Explain what anecdotal information was obtained on water pipe breaks in construction tunnels and define what was meant by “unusual” in terms of performance requirements in BSC, 2008 (page 101, 3rd full paragraph).
- (c) Justify the conclusion that the amount of water available for internal flooding is insufficient to rise to the waste package elevation in the emplacement drifts. This is needed to assess whether failure of water supply pipes to the Tunnel Boring Machine could cause water build up high enough on the construction side of the isolation barrier. The accumulated water may flow down the access main to the emplacement side and enters the drifts with emplaced waste packages. Calculations provided in BSC, 2008, Section 6.04 seems to assume that the isolation barrier is always at the intersection of the emplacement drift and access main, which is inconsistent with the information in SAR Section 1.3.1.2.7 and SAR Figure 1.3.1–12. The calculations could have underestimated the potential maximum water levels as a result of this assumption.
- (d) Justify why a loaded Transportation and Emplacement Vehicle (TEV) near the intersection of the access main and emplacement drift would not be affected during an internal flooding event. This is needed to assess whether an internal flooding event can affect a loaded TEV during transit in the subsurface facility.

**1. RESPONSE**

The access doors of the emplacement drifts, discharge pump, construction barrier, and shotcrete seal are not important to safety because they are not relied upon to prevent or mitigate an event sequence. Also, the internal flooding event in the subsurface facility does not cause a radiological dose consequence.

This response includes six figures and two attachments. Four of the six figures summarize design information presented in several subsections within SAR Section 1.3. The figures illustrate the

physical setting of the waste packages within an emplacement drift and identify the spatial information (distances and relative elevations) in the area of the intersection of the access main and the turnout, and in the vicinity of a development area–emplacement area Type B isolation barrier (or “construction barrier” as identified in this RAI).

Figures 1 and 2 illustrate a typical configuration of a Type B isolation barrier separating the emplacement area from the development area, distances from the barrier to the other adjacent repository openings, corresponding terminology as used in the SAR, and access main grade for the Panel 1 and Panel 2 access main. Depiction of the water supply line in Figure 1 is representational, as the SAR does not include such design information for construction activities. The Type B isolation barrier consists of two bulkheads forming an airlock compartment between the development and emplacement sides of the emplacement panel being developed. Figure 1 also shows the location of the emplacement access doors that are installed within a single bulkhead at the entrance to the turnout, as described in SAR Section 1.3.5.

Figure 3 represents the transport and emplacement vehicle (TEV) physical setting in the access main at its closest point of approach (approximately 118 ft) to the nearest isolation barrier bulkhead, as identified in Figure 1. This figure also provides the location of the waste package inside the TEV relative to the access main top-of-invert and top-of-rail elevations.

Figure 4 illustrates the waste package elevation when placed on a pallet in an emplacement drift and its position relative to the top-of-invert elevations for the emplacement drift, turnout, and access main.

### **1.1 JUSTIFICATION OF SAFETY CLASSIFICATION FOR EMPLACEMENT DRIFT DOORS, DISCHARGE PUMP, CONSTRUCTION BARRIER, AND SHOTCRETE SEAL**

The emplacement access doors, discharge pump, isolation barrier, and bulkhead shotcrete seals are classified as not important to safety in SAR Table 1.9-1, *Preclosure Safety Classification of SSCs*, because they are not relied upon to prevent or mitigate an event sequence. A flooding event in the subsurface does not cause a breach of the waste package or release of radioactive materials as a consequence.

The bulkheads associated with the emplacement access doors and the isolation barriers are similar in construction but serve different purposes and are located apart from each other. Also, any actions that may be taken by portal security personnel, as described in the categorization analysis (BSC 2008, p. 101) in response to subsurface flooding, are not relied upon in determining the impact of flooding on the TEV or the waste package or in establishing the safety classification for the structures, systems, and components in question.

### **1.2 EXPLANATION OF ANECDOTAL INFORMATION ON WATER PIPE BREAKS IN CONSTRUCTION TUNNELS**

The RAI refers to the following excerpt from *Subsurface Operations Reliability and Event Sequence Categorization Analysis* (BSC 2008, Section 6.0.4, emphasis added):

As a part of this effort, existing databases (including publicly available databases associated with the mining industry) were searched and no information was obtained concerning the frequency of water pipe breaks in construction tunnels; *however, anecdotal information indicates that such breaks are unusual*. If a pipe were to break during construction of Panels 1 or 2, water would begin to accumulate at the construction barrier (near the TBM)...

As used, the term “anecdotal” indicates that the information is not directly citable and the term “unusual” indicates that such breaks are infrequent. The attached assessments show that flooding due to a construction water pipe break and the consequential effects do not lead to an event sequence; accordingly, the “anecdotal information” was not relied upon in developing a frequency of occurrence for the initiating event.

### **1.3 INSUFFICIENT VOLUME OF WATER FROM AN INTERNAL FLOODING EVENT TO RISE TO THE WASTE PACKAGE ELEVATION IN THE EMPLACEMENT DRIFTS AND LACK OF EFFECT ON A LOADED TRANSPORT AND EMPLACEMENT VEHICLE NEAR THE INTERSECTION OF THE ACCESS MAIN AND EMPLACEMENT DRIFT**

Given the calculated water depths, the water would not contact the waste package being transported inside the TEV (Figure 3). This depth of water at the intersection of the access main and the turnout would not be sufficient to overcome the elevation rise to the emplacement drift level (Figure 4); therefore, the water would not enter the emplacement drift.

The emplacement access door is part of the turnout bulkhead located near the intersection of the turnout and access main. The term “access door” used in the categorization analysis (BSC 2008, Section 6.0.4, fifth paragraph) refers to a personnel access door for emergency egress located in the Type B isolation barrier bulkheads and is not the emplacement access door located in the turnout bulkhead near the intersection of the turnout and access main.

SAR Section 1.3.5.1.3.2 discusses the Type B isolation barriers, and SAR Figure 1.3.5-8 identifies the isolation barrier as consisting of two bulkheads with an airlock chamber between the two bulkheads. The door that corresponds to the access door discussed in the categorization analysis (BSC 2008, Section 6.0.4) refers to the airlock door in either of the two bulkheads, as shown in SAR Figure 1.3.5-8. Further, SAR Figures 1.3.5-6 and 1.3.5-7 illustrate typical isolation barrier locations in the access mains. An isolation barrier separating the development side from the emplacement side is typically located along the access main at approximately the midpoint between two adjacent turnouts (Figure 1). A corresponding isolation barrier would also be located in the exhaust main. These isolation barriers are relocated as the emplacement advances within a panel. SAR Section 1.3.5.1.3.3 discusses the turnout bulkheads and emplacement access doors, and SAR Figure 1.3.5-9 depicts the emplacement access door located near the intersections of the turnout and access mains.

The flooding scenario described in this response is unique to Panels 1 and 2, where the emplacement side of the panels is located down-gradient (access main grade) of the development

side. In Panels 3 and 4, the emplacement side is up-gradient (access main grade) of the development side, so water would flow away from the isolation barriers and stay within the development area.

With respect to a potential conservative flooding scenario in the development side of the repository that could possibly impact the emplacement side waste packages or emplacement operations, the categorization analysis (BSC 2008, Section 6.0.4) postulates that the water supply sources for dust control operations for a Tunnel Boring Machine unexpectedly drain their contents into the subsurface due to a leak or a break in a component of the water supply system. These sources consist of three 10,000-gallon water tanks located at the surface and feeding a water line going underground. The complete drainage of the three water tanks and supply piping would result in a total accumulation of water of up to 46,000 gallons. The access main for Panels 1 and 2 slopes to the north; therefore, the released water would flow down the access main until the first bulkhead of the isolation barrier is reached. Assuming that the bulkhead is initially intact, water could accumulate against the bulkhead, forming an impoundment that could reach a height of 3.5 ft at its deepest point (at the bulkhead location).

This accumulated volume of water could reach the emplacement side of the isolation barrier if both bulkheads are breached in some manner. Water could cross the isolation barrier in one or a combination of the following ways:

- Leakage around the bulkheads
- Cracks in the shotcrete or small areas where the shotcrete seal may fail
- Through an open bulkhead door
- Structural failure of the bulkheads due to water pressure.

The rate of flow entering the emplacement side of the isolation barrier would depend on the type of breach, and it would vary from insignificant in the case of leakage, to considerable (but short-lived) due to a sudden failure of the bulkheads.

Breaches through small or moderate size openings would result in orifice flow with corresponding flow velocity and magnitude depending on the depth of water at the location of the opening. Using a breach at midpoint of the 3.5-ft depth, orifice flow would produce moderate water velocities of approximately 11 ft/sec (Figure A-1). The water jet resulting from this water velocity would dissipate most of its energy in a distance of 3.5 ft, much less than the 118 ft to the closest location where a TEV may be impacted. The corresponding assessment is included as Attachment A.

In the case of a sudden collapse of the isolation barrier bulkheads in the access main or a structural failure of a large portion of the isolation barrier bulkhead steel plates, it is assumed for purposes of this assessment that the entire volume of accumulated water at a depth of 3.5 ft would be instantaneously released to the emplacement side of the isolation barrier (Attachment B). This slug of water would be similar to the release of water from a dam break (Figure B-1), except that in this case, the amount of water would be limited to the accumulated 46,000 gallons, so the flow conditions into the emplacement side would be transient. The resulting flow would go through transitional hydraulic conditions resulting from the conversion of the potential energy

of the impounded water into kinetic energy once the barrier is overcome, from unsteady rapidly-varied flow to uniform "open channel" flow conditions. Hydraulic assessments for the dam break analogy are included in Attachment B, which yields an estimate of the depth of flow at the location of the TEV initiated by a sudden collapse of the bulkheads. The bulkhead thickness is very small compared to the width of a dam, so the critical depth would occur in the immediate vicinity (i.e., within a few feet) of the failed bulkhead. The maximum flow rate after the sudden collapse of the bulkheads has been estimated as 194.5 ft<sup>3</sup>/sec (1,455 gallons/sec), which is the critical flow rate calculated based on the critical depth of flow and the channel cross-sectional area of flow. The critical depth of flow is calculated as 1.56 ft (18.72 in.). The uniform depth for the same flow rate and geometry is calculated as 1.52 ft (18.24 in.). Therefore, regardless of the location of the transition from critical flow to uniform flow, the water depth at the TEV location would likely not exceed 1.56 ft and would most likely be the uniform flow depth of 1.52 ft. The assessments indicate that, for the hydraulic conditions analyzed, the depth of critical flow and the depth of uniform flow are almost the same downstream from the failed structure. The slug of water would quickly dissipate past the TEV. For example, at one third of the maximum flow rate, or 485 gallons/sec, the total volume of 46,000 gallons of water would be exhausted in approximately 95 seconds. The maximum calculated water depth downstream from the breach of approximately 18 to 19 in. would reach the bottom of the TEV shielded compartment but would stay below the elevation of the bottom of the pallet.

The TEV fails safe upon loss of power, and there is no unacceptable interaction of the flood water with the waste package being transported. Flooding of the third-rail system would trip the overcurrent protection device on the TEV, remove power, and set the TEV brakes. The TEV electrical components will be designed to preclude the introduction of water, and the grounding system prevents adverse effects on the TEV from underwater electrical currents. The water volume and velocity, and any potential water-borne debris are not sufficient to have any physical effect on the TEV because of its weight and structural rigidity. The depth of the flood water (approximately 18 to 19 in.) cannot cause TEV derailment. None of these incidents would cause degradation of the TEV shielding (see response to RAI 2.2.1.1.3-3-018) and no release of radionuclides (BSC 2008, Sections 6.2.2.1.3 and B1.4.5).

## **2. COMMITMENTS TO NRC**

None.

## **3. DESCRIPTION OF PROPOSED LA CHANGE**

None.

## **4. REFERENCES**

BSC (Bechtel SAIC Company) 2008. *Subsurface Operations Reliability and Event Sequence Categorization Analysis*. 000-PSA-MGR0-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0034.

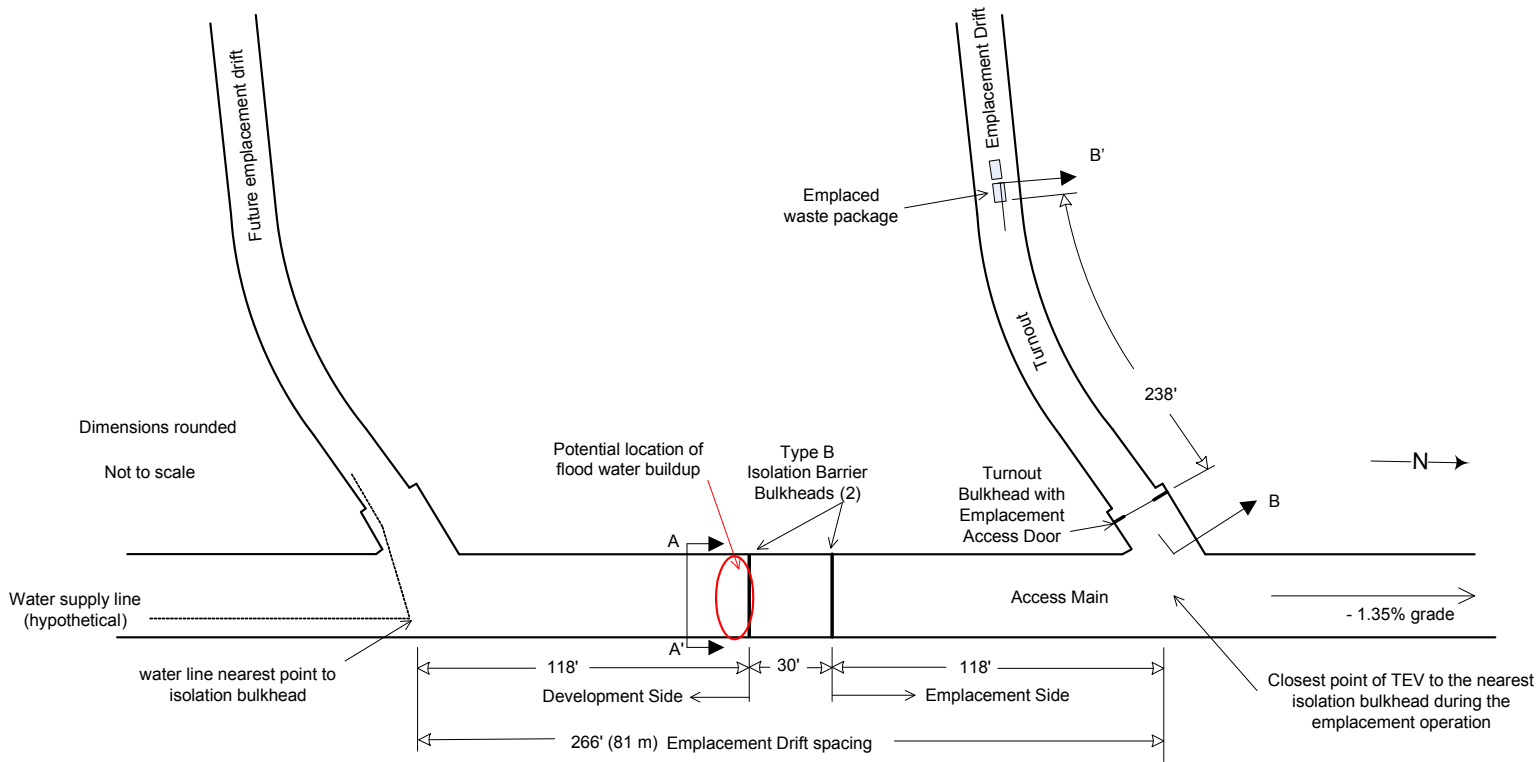
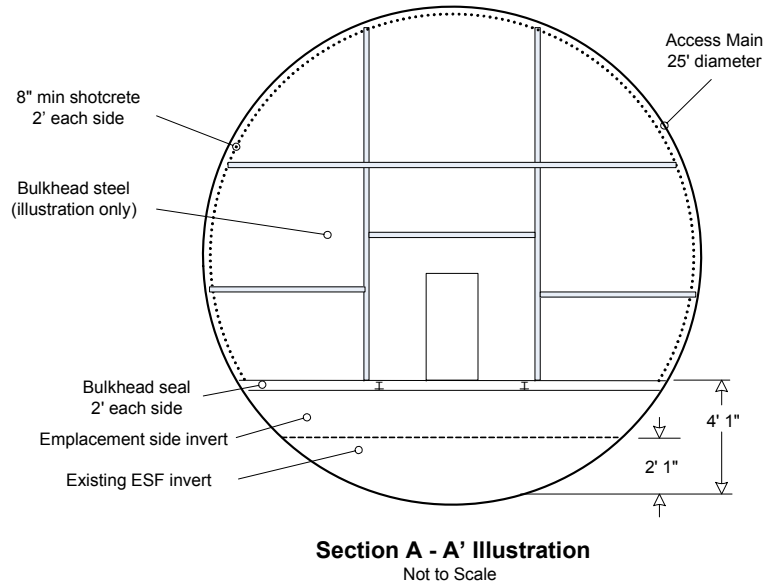


Figure 1. Location of Potential Flood Water Buildup and Subsurface Facility Features in Immediate Vicinity

NOTE: Conditions shown are representative for Panels 1 and 2.



Title	See SAR Figure
Access Main	1.3.1-4, 1.3.3-9, 1.3.3-31, and 1.3.4-3
Turnout	1.3.1-4, 1.3.4-3, and 1.3.5-9
Emplacement Drift	1.3.1-4, 1.3.3-13, 1.3.3-34, 1.3.4-3, 1.3.4-4, and 1.3.4-13
Isolation Barrier	1.3.5-6, 1.3.5-7, and 1.3.5-8
Isolation Barrier Bulkheads	1.3.5-8
Access Door	1.3.1-4, 1.3.4-3, and 1.3.5-9
TEV	1.3.1-4, 1.3.3-40, and 1.3.4-20

Figure 2. Typical Access Main Bulkhead Cross-Section and Overall Cross-References to SAR Figures for Other Subsurface Facility Features

NOTE: The access main invert is built a distance past the isolation barrier into the development side, to minimize construction activities when ready to relocate the isolation barrier bulkheads during commissioning of the expanded emplacement area. The existing Exploratory Studies Facility (ESF) invert is shown for illustration purposes only and becomes part of the final access main invert.

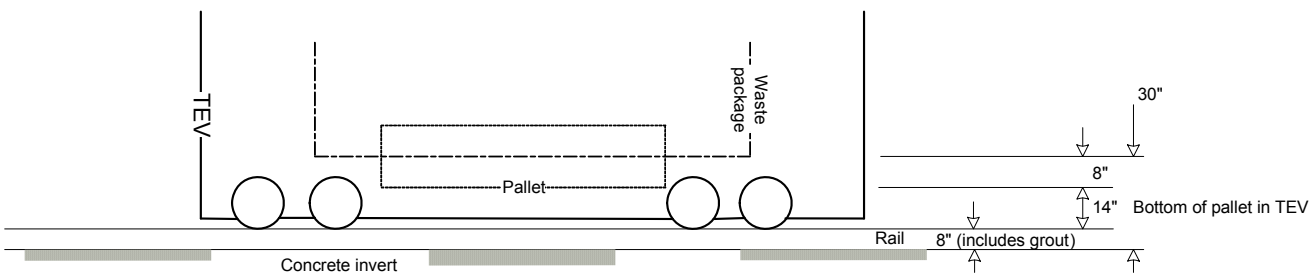


Figure 3. Waste Package Location in TEV during Transportation for Emplacement



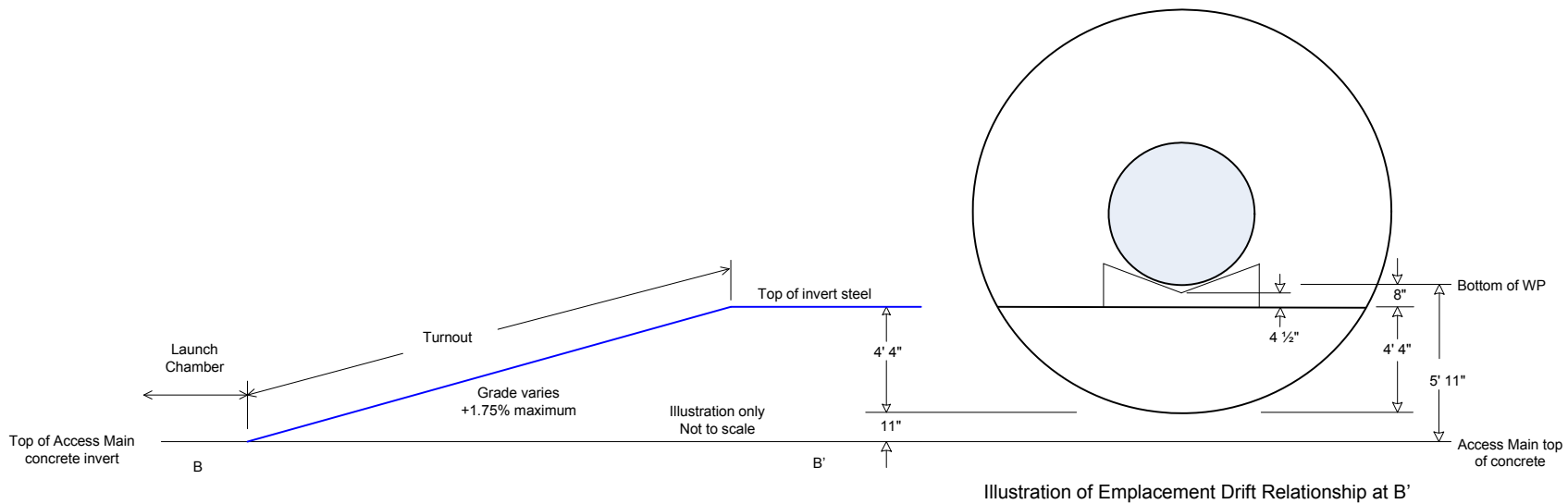


Figure 4. Placement Drift Relationship at Location B–B' Referenced in Figure 1

## ATTACHMENT A: FLOW CONDITIONS FOR SMALL BULKHEAD BREACH (ORIFICE FLOW)

### 1. ASSESSMENT

Velocity through an orifice is given by:

$$V_o = C_v \sqrt{2gh}$$

where

- $V_o$  is the water velocity through the orifice (ft/sec)
- $C_v$  is the orifice velocity coefficient,  $\leq 1$  (assume  $C_v = 1$  for maximum velocity)
- $g$  is acceleration of gravity (32.2 ft/sec<sup>2</sup>)
- $h$  is the hydraulic head at the elevation of the orifice (ft)

Assume the orifice is located at the midpoint of the submerged section of the bulkhead (Figure A-1), then  $h = 1.75$  ft.

$$V_o = (1) \sqrt{(2)(32.2)(1.75)} = 10.62 \text{ ft/sec}$$

To determine the distance at which the water jet contacts the ground:

$$x = V_o \cdot t$$

$$x = (10.62)(t)$$

$$y = \frac{1}{2}gt^2$$

where (Figure A-1)

- $x$  is the horizontal distance traveled by the water jet (ft)
- $y$  is the vertical distance from the orifice to the ground (ft)
- $t$  is the time of travel from the orifice to the ground (sec)

or

$$t^2 = \frac{2y}{g} = \frac{2(1.75)}{32.2} = 0.1087$$

$$t = 0.33 \text{ sec}$$

then

$$x = (10.62)(0.33) = 3.5 \text{ ft}$$

For any other height of the orifice, the resulting water jet would contact the ground at a shorter distance because of reduced head or because the orifice is closer to the ground.

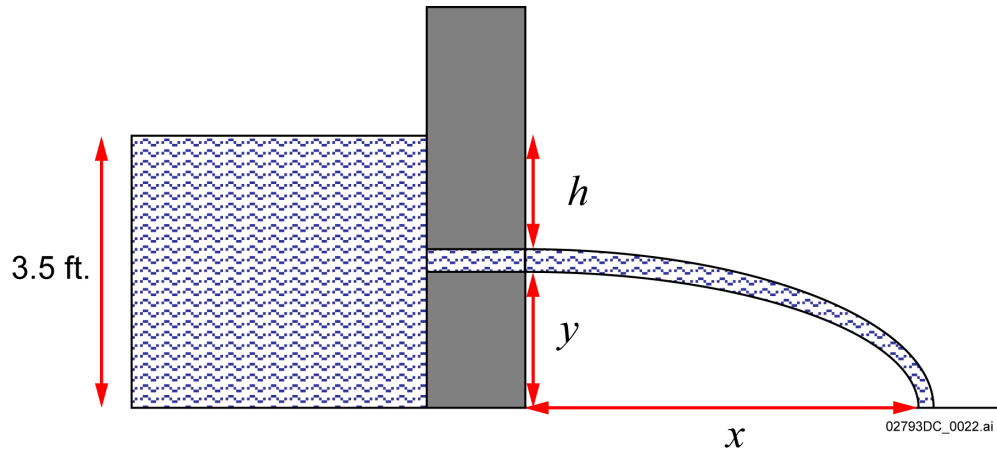


Figure A-1. Isolation Barrier Bulkhead

## ATTACHMENT B: FLOW CONDITIONS IN ACCESS MAIN AFTER SUDDEN COLLAPSE OF ISOLATION BARRIER

### 1. ASSESSMENT

Utilize a dam break problem as an analogue for the sudden failure of the isolation barrier (Figure B-1). A calculation established the depth of flow at the bulkheads as 3.5 ft (BSC 2008, Section 6.0.4).

Establish the flow rate at the critical depth (Chow 1959, p. 568):

$$y_c = \frac{4y_2}{9} = \frac{4(3.5)}{9} = 1.56 \text{ ft } (\approx 19 \text{ inches})$$

where

$y_c$  is the critical depth (ft)

$y_2$  is the depth of water at the dam (ft)

Calculate the flow velocity at the critical depth (Chow 1959, p. 43):

$$\frac{V_c^2}{2g} = \frac{D}{2} \quad (\text{Chow 1959, Eq. 3-10})$$

where

$g$  is acceleration of gravity (32.2 ft/sec<sup>2</sup>)

$V_c$  is the velocity (ft/sec)

$D$  is the hydraulic depth =  $\frac{A}{T}$ , where

$A$  is cross-sectional area of flow at flow depth (ft<sup>2</sup>)

$T$  is top width at flow depth (ft)

Assume the access main cross-sectional area of flow above the concrete invert approximates a trapezoid with side slopes of 1:1 ( $z = 1$ ); bottom width,  $b = 16.78$  ft; and, depth of flow  $y$  (ft). The small area of the cross section taken up by the rail and rail attachments above the concrete invert (Figure 1.3.3-31) has been ignored for purposes of simplifying the calculation.

Area and top width for trapezoidal section (Chow 1959, Table 2-1):

$$A = (b + zy)y = [16.78 + (1)(1.56)](1.56) = 28.61 \text{ ft}^2$$

$$T = b + 2zy = 16.78 + (2)(1)(1.56) = 19.90 \text{ ft}$$

$$D = \frac{28.61}{19.90} = 1.438 \text{ ft}$$

$$V_c^2 = \frac{2gD}{2}$$

$$V_c = \sqrt{gD} = \sqrt{(32.2)(1.438)} = 6.80 \text{ ft/sec}$$

Calculate the equivalent flow rate:

$$Q = V \times A = (6.80)(28.61) = 194.5 \text{ ft}^3/\text{sec}$$

Calculate the uniform flow at location of TEV for maximum rate of flow released at collapse of bulkheads:

Use Manning's formula (Chow 1959, p. 99):

$$V_n = \frac{1.49}{n} R^{2/3} S^{1/2} \quad (\text{Chow 1959, Eq. 5-6})$$

where

$n$  is 0.03 (+/-0.005) (Chow 1959, Table 5-6(B)(B-2)(d))

$S$  is 1.35% = 0.0135 ft/ft (Panels 1 and 2 access main slope)

$V_n$  is  $\frac{Q}{A} = \frac{194.5 \text{ ft}^3/\text{sec}}{(b + zy_n)y_n}$

$y_n$  is the depth of uniform flow (ft)

$R$  is the hydraulic radius;  $R = \frac{(b + zy_n)y_n}{b + 2y_n\sqrt{1 + z^2}}$  (Chow 1959, Table 2-1)

Substituting values in Equation 5-6:

$$\frac{(194.5)}{[16.78 + (1)y_n]y_n} = \frac{1.49}{0.03} \left[ \frac{16.78y_n + y_n^2}{16.78 + 2(1.4142)y_n} \right]^{2/3} (0.0135)^{1/2}$$

$$\frac{(194.5)(0.03)}{(1.49)(0.1162)} = \frac{(16.78y_n + y_n^2)(16.78y_n + y_n^2)^{2/3}}{(16.78 + 2.8284y_n)^{2/3}}$$

$$33.70(16.78 + 2.8284y_n)^{0.6667} = (16.78y_n + y_n^2)^{1.6667}$$

Solve for  $y_n$  by trial and error:

$$33.70A^{0.6667} = B^{1.6667}$$

$y_n$	A	$A^{0.6667}$	B	$B^{1.6667}$		$33.70A^{0.6667}$
1.5	21.0226	7.6171	27.42	249.33	<	256.70
1.6	21.3054	7.685	29.40	280.18	>	258.98
1.55	21.164	7.651	28.41	264.54	>	257.84
1.52	21.079	7.631	27.816	255.36	<	257.16*

\* sufficient approximation to a solution

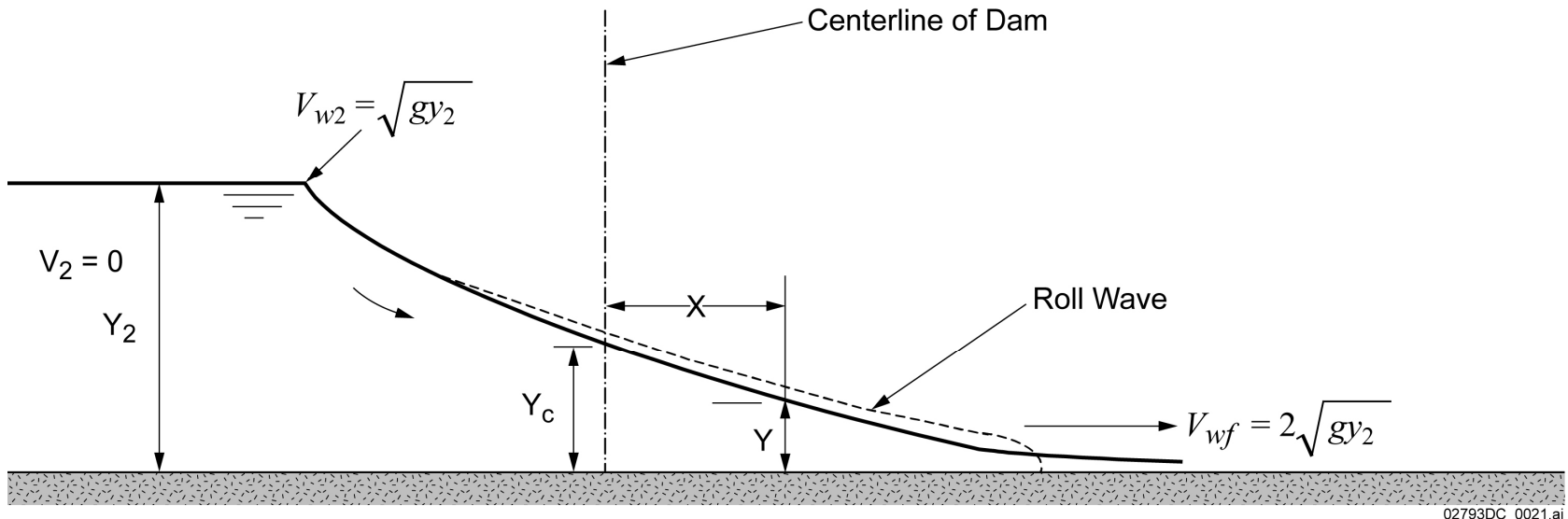
Uniform flow depth at TEV location:

$$y_n = 1.52 \text{ ft } (\approx 18 \text{ inches})$$

## 2. REFERENCES

BSC 2008. *Subsurface Operations Reliability and Event Sequence Categorization Analysis*. 000-PSA-MGR0-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080312.0034.

Chow, V.T. 1959. *Open-Channel Hydraulics*. New York, New York: McGraw-Hill Book Company.



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Figure B-1. Analogous Representation of a Hydraulic Problem Similar to a Dam Break

NOTE:  $Y$  = flow depth at distance  $x$  from failed structure;  $Y_c$  = critical depth;  $wf$  = wave front.