RECLAMATION

Managing Water in the West

Comment Response Document

Leadville Mine Drainage Tunnel Risk Assessment

Leadville Mine Drainage Tunnel Project, Colorado
Great Plains Region

For Official Use Only

U.S. Department of the Interior
Bureau of Reclamation

October 2008

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Comment Response Document
Leadville Mine Drainage Tunnel

Leadville Mine Drainage Tunnel Project, Colorado
Great Plains Region

prepared by

Technical Service Center

Authors

Michael Gobla, P.E.

Mark Vandeberg, Geologist, P.G.

Peer Reviewer

Lloyd G. Crutchfield, P.G., Manager
Engineering Geology Group

Acronyms and Abbreviations

ARD	Acid Rock Discharge.
CDPHE	Colorado Department of Public Health & Environment
CRB	Consultant Review Board
EAP	Emergency Action Plan
ECAO	Eastern Colorado Area Office
EPA	Environmental Protection Agency
EWS	Early Warning System
LMDT	Leadville Mine Drainage Tunnel
OU6	Operable Unit 6
PFMEA	Potential Failure Modes Effects Analysis
ROD	Record of Decision
TSC	Technical Service Center
USACE	United States Army Corps of Engineers

Contents

Page

Introduction *2*

Consultant Review Board Comments *3*

Mark R. Cole Comments *14*

Lake County Board of County Commissioners Comments *16*

U.S. Army – Corps of Engineers *22*

Summary Review Memorandum by B.J. Bailey, P.G. **23**

Review Comments from Steven Jirousek, R.G. (Attachment 1) **25**

Review Comments from Joseph A. Kissane, P.G. (Attachment 2) **32**

Review Comments from B.J. Bailey, P.G. (Attachment 3) **37**

United States Environmental Protection Agency Comments *46*

Introduction

The Lake County Board of County Commissioners passed a resolution declaring the existence of a disaster emergency on Feb. 13, 2008 due to concerns about the stability of blockages that had developed in the Leadville Mine Drainage Tunnel (LMDT). The resolution stated that "*…this elevated groundwater level is an imminent threat to the citizens of Lake County Colorado, public and private property, local domestic water supply, local wastewater treatment plant and the water quality of the Arkansas River Basin…*"

Reclamation's Technical Service Center (TSC), with participation by the Great Plains Region and Eastern Colorado Area Office (ECAO), responded by attending public meetings and initiating a risk assessment relating to the stability of blockages in the LMDT. A final draft risk assessment report was released in June 2008 and the public was invited to comment. The scope of this effort was limited to an evaluation of the potential for a sudden failure of the blockage and potential impacts to downstream infrastructure and populations in the event of a rapid release of water.

An independent board of consultants was assembled to review Reclamation's draft risk assessment of the LMDT. A Consultant Review Board (CRB) Meeting was held in Denver, Colorado on June 20, 2008. The CRB was comprised of:

Dr. John F. Able, retired rock mechanics and mining engineering professor from the Colorado School of Mines.

Robert L. Elder, mining engineer from Leadville, CO.

Dr. Randall W. Jibson, geologic hazards specialist from the U.S. Geological Survey

The risk assessment study consists of the following three documents for the Leadville Mine Drainage Tunnel which Reclamation provided to the CRB for their review and comment:

1. Existing Conditions

2. Results of the Geotechnical and Structural Analysis

3. Potential Failure Modes and Effects Analysis

The risk assessment was released in final draft form on June 30, 2008 after addressing the CRB comments and suggestions.

The public and government agencies were then invited to submit technical comments on the final draft risk assessment to Reclamation. Comments were received from:

- Mark R. Cole
- Lake County Board of County Commissioners
- United States Army Corps of Engineers (USACE)
- United States Environmental Protection Agency

This report contains responses to all of the comments in the order they were received. The comments from the CRB are presented first, followed by comments from the public and government agencies. Reclamation questions to the CRB are in bold text. The CRB's responses to these questions are in plain text. Other comments are presented in plain text, and Reclamation's responses immediately follow each comment and are presented in bold and italicized text.

Consultant Review Board Comments

The CRB was asked to consider four questions in preparation of their report. Comments are organized according to the four questions posed to the CRB.

Question 1. Are Reclamation's interpretations of the existing hydrogeology, geotechnical, and structural information reasonable and sound?

The overall interpretations regarding the existing conditions in and around the LMDT appear reasonable and sound. Reclamation's review of the history of the LMDT is detailed and complete, and it provided a valuable framework for the review. The description of the difficult conditions encountered during construction and the intermittent efforts to rehabilitate the tunnel provides a basis for understanding the structural geology and how the current hydrogeologic condition has developed.

The data collected by the multiple monitoring wells have made it possible to reasonably conclude that the LMDT is submerged except on the portal side of the porous bulkhead at Station 4+61. The Pendery Fault and the collapsed-rock bulkhead immediately downstream partially hydrologically separate the tunnel into two parts. Upstream is the mining area, which forms a single interconnected mine pool. The collapse bulkhead greatly retards free flow of water from the mine pool toward the portal. The downstream part of the tunnel contains another collapse zone that was evidenced by a number of chimney collapses to the surface in the roughly 600+ feet from the portal. It is impossible to physically inspect either of the two parts. The data show that the water head in the lower section of

the tunnel has been increasing somewhat, and the water head in the upper section has been increasing considerably more. The water table in the upper section of the tunnel is very close to the level of the rock/terrace gravel contact, which could prevent any further rise in the mine pool because of the higher permeability of the terrace gravels.

Specific comments in response to this question include:

Comment 1. The lack of measured engineering properties (unit weight, shear strength, etc.) of the materials being analyzed in both the tunnel blockages and the slopes at the portal renders the analyses based on these properties somewhat tentative. Are there any geotechnical data from past construction projects for the portal, the treatment plant, or any of the pipelines? Use of conservative strength values to bracket limiting conditions is a reasonable approach to deal with lack of directly measured data, but direct measurement would be preferable.

Reclamation agrees with the CRB and recognizes the lack of measured engineering properties. The first step in the assessment program was to collect available information. The search for data included archives from the Bureau of Mines as well as Reclamation files from the Eastern Colorado Area Office, the Great Plains Regional Office, and the Denver Office. No laboratory testing results were found that would provide direct information for strength determination. Reclamation briefly considered a data collection program to sample and test the critical materials. The presence of numerous cobbles and boulders in the gravels and the lack of access to the terrace gravels and Weber Formation would necessitate collecting very large samples at significant depth to accurately characterize the material properties. Given the perception of potentially imminent failure and the subsequent public concern, Reclamation determined the public would be best served by rapidly determining the potential risk and concluded the only feasible alternative was to evaluate the tunnel using a range of strength values, including multiple layers of conservative assumptions to overcome the lack of site specific information.

Comment 2. There is the lack of consistency in reporting units of water flow: gallons/minute, gallons/day, and cubic feet/second are all used. One unit of measure should be selected, and all reported values should be converted to those units. Alternatively, a parenthetical system could be used to provide consistent unit conversion for flows originally reported in various types of units.

Reclamation agrees with the CRB. The reports have been modified to present units of flow in gallons/minute.

Comment 3. Wherever possible it would be valuable to have the approximate date of the pictures presented. The month and year would be good, but even the approximate year would help in understanding of the gradual changes in the LMDT.

Reclamation agrees with the CRB. Dates have been added to the photograph captions in the final versions of the reports.

Comment 4. If the data exist, extend the January 2008 water-table line on the geologic cross section to the portal from LDT 10+25 by including data from LDT 06+35, LDT 04+70, LDT 03+00, and the water level at the bulkhead at Station 4+61.

Reclamation agrees with the CRB. Construction details (i.e., influence zones, depths of completion, etc.) have been evaluated. Only the well at Station 06+35 penetrates the tunnel—the others are off of the tunnel alignment with influence zones outside the tunnel. The drawing in appendix A of the Existing Conditions Report was updated to show the water level at Station 06+35 and at the tunnel bulkhead.

Comment 5. A critical question is what maximum differential head is physically possible at the upper blockage, and that can only be ascertained by additional geological investigation to determine the geological controls of the local hydrology ([Potential Failure Modes Effects Analysis] PFMEA report, p. 10-12; Results report, p. 9).

One controlling hydrologic condition that might currently exist (posited by [Environmental Protection Agency] EPA hydrologist Mike Wireman) is that part of the Mine Pool discharge could be migrating to outlet points south of the Mining District. This theory is based, in part, on dye-tracer studies in which much of the dye was not recovered in the LMDT discharge. Occasional recovery of dye from the Gaw shaft and surrounding springs in California Gulch further supports this theory. If the southward water migration could be confirmed, it would reduce concerns regarding potential increases in Mine Pool recharge rates. The lower reach of Iowa Gulch is in line with the southerly projection of the Pendery fault complex. Surface elevations in lower Iowa Gulch are quite low relative to present Mine Pool elevations.

Reclamation does not know precisely what the maximum water table level would be, but believes the control on this elevation may be the geologic contact between pervious zones in the bedrock and the overlying gravels. The rate of rise of the mine pool would be limited by the gravel's large water carrying capacity and by the fact that some shafts will experience artesian flow. SourceWater Consulting has noted that seeps and flow from shafts begin in California Gulch when the water level in the LMDT mine pool reaches an elevation of 10,147. The Bureau of Mines previously suggested that a water elevation of 10,160 may be the maximum based upon this level being measured in the Pyrenees shaft prior to the excavation of the LMDT. It is believed that present water levels are near the maximum likely to occur as the hydrologic system is able to overflow out of the top of the mine pool. Placing an exact

value on this elevation is not essential, given the finding that the lower plug and bulkheads can resist considerably higher water levels and the historic evidence that the upper limit is somewhere near elevation 10,160.

Comment 6. The potential for a change in the physical conditions, particularly the rate of recharge of the Mine Pool, should perhaps be addressed in the risk assessment. For example, future periods of high precipitation could increase recharge rates in the Mine Pool. If this occurs, the relief-well pumping rate might need to be increased. The presently planned pumping rate corresponds with the estimated rate at which the LMDT Treatment Plant can process the pump output, and so it seems prudent to find ways to increase Plant throughput or to eliminate a portion of the recharge water.

Reclamation agrees in theory with the CRB that there is potential for change in the current physical conditions and that rate of recharge and rate of pumping/treatment of the Mine Pool may become significant issues in the future. However, Reclamation's goal in the risk assessment program was to assess the risk(s) to the public and others under current conditions. Reclamation recognizes the limitations of the LMDT Water Treatment Plant capacity. However, with the newly installed relief well, proportionally more water from the mine pool is being pumped and treated than in the past. Reclamation supports any effort(s) to reduce or eliminate recharge water from the Mine Pool system.

Question 2. Have the critical potential failure modes been identified, and have the risks for those potential failure modes been reasonably assessed and portrayed?

The critical failure modes have been adequately identified, and the associated risks have been rationally assessed and portrayed in most respects. Specific comments regarding this question are as follows:

Comment 1. At the portal, the slope stability of the west flank of the slope is most critical from a life-safety standpoint because houses are located near the base of this slope. Page 20 of the PFMEA report states that slope profiles at the portal are basically the same regardless of the downslope direction. This should be verified by comparing the analyzed slope profile to at least one profile measured in a westerly direction toward the houses.

The slope profile presented in the analysis is considered to be the steepest, and therefore least stable, slope. Drawing the profile further to the west results in profiles which are similar to or slightly less steep, and therefore equal to or more stable than the slope for analysis. Profiles were sketched in the risk assessment meeting using available topographic contours to verify this conclusion.

Comment 2. A better rationale is needed for the earthquake scenarios analyzed as described on p. 43 of the Results report. It is unclear why each of the three ground-shaking levels are not analyzed for each of the three groundwater levels. The groundwater levels near the portal are relatively insensitive to changes in groundwater levels upslope; therefore, it seems reasonable simply to model the highest groundwater levels (which provides an argument of conservatism) for each of the three earthquake scenarios.

Reclamation agrees with the CRB. In response to this comment, Reclamation reworked the slope stability cases to include an analysis of the three seismic loading conditions using the highest groundwater levels as suggested. The result of the revised analysis is that the hillside will remain stable even under the worst loading conditions.

Comment 3. Some discussion of the seismic performance of the tunnel plugs (collapse bulkheads) should be presented. How will they perform in an earthquake? What are the possible failure modes? Since ground shaking is far less underground, the seismic coefficients used in the surface slope-stability analysis could be reduced significantly in any analysis of the underground bulkheads. The fact that the bulkheads are submerged is also significant. Because of the differential head across the tunnel blockages, the peak predicted earthquake accelerations would apply a smaller design load to the upstream face of a bulkhead that is submerged in water on both sides. Normally, engineered reinforced concrete bulkheads will impound water only on the upstream side. The non-engineered collapse bulkhead downstream of the Pendery Fault, and any other collapse bulkheads except the Station 4+61 porous bulkhead, will be resisted by water pressure on the downstream side.

Reclamation agrees in theory with the CRB. As noted by the CRB, the seismic loading in the underground tunnel will be considerably less than that felt by a soil slope above bedrock. Reclamation ruled out the need for a detailed analysis of earthquake loading on the blockages for two reasons. First, the additional loading to the plugs due to an earthquake would be minimal, far less than what was analyzed for hydrostatic water pressure loading. Second, although there could be some more stress on the blockages due to an earthquake, with water on both sides they are not likely to fail. However, Reclamation decided to consider the worst case which is that the upper blockage could rapidly fail, perhaps as a result of earthquake loading. If failure was due to an earthquake, it would take a minimum of a few minutes for the water pressure to be transmitted down to the lower plug and bulkheads. The severe shaking would be over by the time that the water pressure loading would be seen downstream. Therefore, the analysis performed for the lower plug is a valid representation of the expected response.

Comment 4. Concrete bulkheads, and probably also collapse bulkheads, subject to overloading by whatever cause fail slowly but progressively by erosion after an

initial fracture allows leakage along either the contact between the bulkhead and the adjacent rock or by propagation of fractures induced in the adjacent rock or in the bulkhead. If a leak develops as the result of earthquake loading on any caved-rock bulkhead, it will not be possible to directly observe post-earthquake leakage and erosion or attempt to grout off the leak. However, monitoring wells should provide an indication of any significant increase in leakage through or around the bulkhead downstream of the Pendery Fault. Thus, failure of this type would involve a long time period and gradual increase in water pressure on the portal side of the bulkhead.

Reclamation agrees with the CRB. Reclamation is currently monitoring the water levels on both sides of the blockage near the Pendery Fault. Additionally, Reclamation is monitoring wells in and around the lower tunnel. Reclamation is confident that any significant change in the geohydrologic conditions could be detected and evaluated long before a significant increase in risk could occur.

Comment 5. The Early Warning System (EWS) discussed in the PFMEA report (p. 13-15) needs to be better fleshed out and specified. Specifically, a rigorous protocol should be put in place that specifies objective criteria that dictate issuing a warning. On-call personnel making the final decision should have enough technical expertise to exercise independent judgment, but if the specified criteria are met, the procedure should dictate when to sound the alarm, not just the responsible party's judgment. The technical expertise should be used primarily to verify that the instruments appear to be working correctly and that the reported data are accurate. Auto-dialer and call-down procedures should be reviewed and checked for adequate performance and redundancy, and the time between the auto-dialer being activated and the possible activation of an alarm should be quantified. Local emergency-response personnel should be notified before a warning is sounded so that they can be prepared to assist in the evacuation and overall response. Community exercises should be held at regular intervals to assure that local residents know how to respond to a warning. A planned evacuation route to the west exit from the community should be put in place to avoid coming in proximity to the path of possible water or debris flow from the tunnel or surrounding slopes. Also, both east and west entrances to the community should be kept snow-free to assure access and egress at any time of the year.

Reclamation agrees with the CRB. Reclamation developed and put into use criteria for two interim alarm response levels for use until the Emergency Action Plan (EAP) can be finalized. The initial alarm level activates when relatively minor changes in the piezometric surface, seepage rates, turbidity, or rate of change in parameters occurs. The response for the initial alarm level is the immediate callout of Reclamation personnel to evaluate the change in conditions. The second alarm level activates when very significant changes in the geohydrologic conditions occur. The indicators for this alarm level are based on surface observation and misinterpretation is very unlikely. The

response for the second level is evacuation of everyone in the vicinity of the lower tunnel. Reclamation has completed installation of, and tested, an alarm siren to notify local residents of adverse conditions.
Reclamation is working toward finalizing the Emergency Action Plan (EAP). The EAP will provide detailed information regarding the items identified in the comments, will be exercised as soon as possible after completion, and all site workers will be trained in the procedures once it is available. An in-house tabletop exercise has been conducted and plan finalization and exercise are expected in the near future.

Comment 6. An opportunity for risk reduction that could prove beneficial is the restoration of previous water flow from the Canterbury Tunnel. Parkville Water District is exploring measures to recover water from their adjudicated rights at the Canterbury, either through an intersecting well or by partial rehabilitation of the adit itself. The Colorado Department of Public Health & Environment (CDPHE) has obtained an appropriation from the Colorado Legislature to study possible water flow connections between the Canterbury Tunnel and the Mine Pool. When driven in the 1920's, the Canterbury Tunnel intercepted a water flow in the vicinity of the Pendery fault averaging 1300 gpm throughout the year. As a result, mine operators in the District recognized a marked reduction in recharge rate to both the Graham Park and Downtown basins. Should retapping of the Canterbury water flow be accomplished, the Mine Pool could very well experience a reduction in recharge rate, and the LMDT might receive an additional benefit in reduced saturation of the moraine surrounding its downstream segment.

Reclamation supports others efforts to reduce or eliminate recharge water to the Mine Pool system.

Question 3. Do the analyses adequately represent the expected behavior of the various tunnel components and the LMDT portal slopes?

In general, the analyses adequately model the expected behavior of the tunnel and portal slopes. Addressing the following issues could improve the value of the report and the predictions:

Comment 1. As stated above, the lack of measured shear strengths for materials in the tunnel plugs and the portal slopes somewhat limits the confidence of the results. Is there any potential to measure site-specific physical properties or back-calculate physical properties from site- specific field evidence? Also, when geologic materials are broken or otherwise disturbed, they can swell, which could affect their unit weight, friction angle, cohesion, and bulk permeability. The assumed values used in the analyses are reasonable and most likely represent the actual range of material properties, but direct measurement would increase the overall confidence in the results.

As discussed earlier, Reclamation agrees with the CRB and recognizes the lack of measured engineering properties. Given the perception of potentially imminent failure and the subsequent public concern, Reclamation determined the public would be best served by rapidly determining the potential risk and concluded the only feasible alternative was to evaluate the tunnel using a range of strength values including multiple layers of conservative assumptions to overcome the lack of site specific information.

Comment 2. The maximum height that any collapse chimney breached the overburden above the tunnel to produce a sinkhole at the ground surface could be used in conjunction with the underlying tunnel height to back-calculate a percent swell for the terrace gravel and glacial moraine. See attached figure from Piggott and Eynon (1977).

Using this for the area around Highway 91 the following is calculated: $S_{\%} = 2h(100)/H = 2 \times 12 \times 100) / 100 = 24$ percent, meaning the swell was less than 24 percent because a sinkhole occurred. The Bureau of Mines reported a zone of collapse further up in the tunnel where the overburden was 270 feet above the tunnel, but no surface sinkhole formed. For this are, the calculation is $S = 2 \times 12 \times 100/270 = 9$ percent. Since a sinkhole did not occur, the swell would have been somewhat greater than this value. So the swell is somewhere between 9 percent and 24 percent; it is difficult to be more precise than this.

Comment 3. Figure 14 in the Results report is a picture demonstrating the high effective angle of friction and probable cohesion for the glacial-moraine material above the LMDT.

Reclamation agrees with the CRB. The caption points out that the steep slopes indicated high soil shear strength. However, Reclamation chose to use more conservative assumptions in regards to the shear strength and friction due to the lack of test data from these materials.

Comment 4. The mass permeability along the tunnel axis of the combined terrace gravels and glacial moraine might be roughly measured during one period of pumping from LDT 10+25 by monitoring the water levels in LDT 25+15 and LDT 06+35 and by monitoring the volume of water withdrawn from LDT 10+25. Figure 4 (Water Levels in the Downstream Tunnel) in the PFMEA report appear to show a relationship between the temporary lowering of the water table in LDT 10+25 with a smaller lowering in the closest monitoring well LDT 06+34.

Reclamation considered creating a <u>very rough</u> estimate of permeability by analyzing pumping rates at Station 10+25 and surrounding wells but elected not to present that data due to significant concerns regarding the accuracy of such analysis. The pumped well at Station 10+25 and monitoring wells at 6+35 and 25+15 are directly in the tunnel. Reclamation feels that analysis of the pumping and drawdown would most likely be primarily influenced by the flow

regime of the tunnel and fractured bedrock system rather than the terrace gravels and glacial deposits.

Comment 5. Much of the information regarding flow paths within the collapsed tunnel is conjectural, such as whether surviving vent lines or compressed air lines are still capable of carrying significant water flow after almost 60 years of deterioration. The actual flow path could be a mixture of surviving pipe lines, sub-track drainage-ditch segments, and piping through voids in surrounding rock formations or moraine.

Reclamation agrees with the CRB that flow path(s) are not completely understood. Reference to open vent lines was taken out of the risk assessment document. However, this does not change the overall evaluation.

Comment 6. There is logical inconsistency in one aspect of the characterization of the material behavior. Page 9-10 of the PFMEA report and page 9 of the Results report state that the material forming the upper blockage likely was deposited in standing water in the tunnel and therefore is in a loose condition. Pages 13 and 15 of the Results then state that, if and when this material begins to shear, the relative movement of angular particles will cause dilation of the mass. This is not true if the material was, in fact, deposited in a loose condition. Loose materials contract when sheared; only dense materials dilate when sheared. Is there direct evidence that the upper plug materials are in a loose state? If not, then perhaps this statement should be deleted.

Reclamation agrees with the CRB. The statement describing the upper plug materials as in a loose state was deleted from the final draft report.

Comment 7. The Results report states (page 44) that even with a factor of safety less than 1.0 in seismic conditions, very little deformation is likely to occur. This assertion is difficult to defend without further analysis. If the claim is going to be made that even if FS<1, it will not fail, then why run the analysis? What result would have been cause for concern? The best way to rectify this is to run a simplified displacement analysis to estimate actual slope displacements during the specified earthquake shaking, and then to evaluate the significance of these displacements. Running such an analysis would require no additional information and could be done rather quickly using published empirical models (Jibson, 2007). Fully documenting likely coseismic displacements, and then evaluating the significance of those displacements, will greatly strengthen the conclusions regarding the effects of earthquakes on the stability of the slopes.

Reclamation agrees with the CRB. An analysis of expected displacements was completed and the results are presented in the report. The calculated movements were small (less than an inch), indicating the slopes are likely to remain stable during and following a major earthquake in the area.

Question 4. Are the risk assessment's conclusions and recommendations comprehensive, reasonable, and supported by the studies?

The conclusions and recommendations of the risk analysis are reasonable and, in general, well supported. However, the following significant issues should be addressed:

Comment 1. The PFMEA report states that "*collapses in the mine workings…likely limit the amount of water actually stored in the Mine Pool, and which would be available to raise downstream water levels*…" (p. 11). Analysis of data from USBM Circular 7125 suggests a possible water volume of 937.2 billion gallons above the LMDT invert at the Robert Emmet shaft when the Mine Pool was at 120 feet above the invert. The current Mine Pool elevation of 167 feet above the invert suggests an even larger water volume. However, if the lower collapse bulkhead is stable, as the risk analyses show, then the volume of water in the Mine Pool should not be the overriding concern.

Reclamation removed the statement from the risk assessment report. However, Reclamation feels that the issue is not central to the risk analysis and that the exact size of the mine pool does not affect the results of the evaluation.

That said, Reclamation feels the statement regarding the mine pool is correct. Reclamation believes collapses within the mines would fill spaces in the mine openings which formerly contained water. The collapses would also have completely blocked some of the flow pathways to the LMDT and partially blocked others. For example, a minor fall creating a pile three feet high would result in a three-foot deep pool of water which would not drain out if this part of the mine pool were lowered. Therefore, it is very unlikely that the entire 937+ billion gallons could suddenly drain out if the LMDT blockages were removed. There would likely be many places in the mine workings where water would be retained due to collapse and partial collapse. Reclamation agrees there is likely still a large volume of mine pool water which could drain out and that flow connection from the LMDT to the Robert Emmet Shaft area is still likely intact.

Comment 2. The following statement in PFMEA report (p. 11) is only correct in the absolute sense that it cannot be wrong as worded: "It is unlikely that all the mine workings are interconnected enough (especially with the possibility of additional collapses) such that the entire Mine Pool would drain quickly as the result of breaching a blockage near the Pendery Fault." The breaching of a blockage near the Pendery Fault would develop slowly because of the flow resistance from downstream collapse blockages, the bulkhead at Station 4+61 and 4+66, and the backfill injected to fill voids in the multiple collapses of terrace gravels and glacial moraine into the tunnel that produced sinkholes for more than 500 feet upstream from the portal. This positive statement appears to be unduly confident, particularly in view of the extremely close connection between water-

table elevations along the LMDT between Station 46+66 and the Robert Emmet Shaft. Historically, rapid drainages of as much as 3765 gpm occurred when fissures were encountered during tunneling operations (USBM LMDT Second Project Report, 1956). These sudden high water flows were accompanied by a steady drop in the Mine Pool level under adjacent areas, which is evidence of extensive flow connections between much, if not all, of the Mine Pool. These high flows that occurred when the LMDT approached adjacent mine workings in the upstream part of the tunnel suggest that the mine pool could drain rapidly. Again, however, the main issue is the stability of the lower collapse bulkhead, which the analyses show to be quite stable. Also, a hypothetical failure of the upper collapse bulkhead (below the Pendery fault) would most likely occur very slowly, which would retard a rapid draining of the Mine Pool.

Reclamation agrees with the CRB that water levels indicate a connection between the mine workings and the LMDT, and that section of the PFMEA report was modified. The text has been changed to the following:
"***There is no reason to believe the LMDT is completely open in other areas." Additional collapsed areas and blockages of the tunnel would limit flows to the downstream tunnel reaches from the Mine Pool even if a blockage near the Pendery Fault were to breach. For example, based on the water level data in Figure 4, there may be resistance to flow between Stations 10+25 and 6+34 (both intercept the tunnel but appear to record different elevations, although the well at 10+25 is pumped). In addition, in 1979 a well at Station 6+65 was drilled to 98 feet into the tunnel where water 6 feet deep was seen to be flowing. While waiting for well screen, a sinkhole appeared adjacent to the drill rig and the hole was lost.***

Comment 3. The justification for ruling out slope failure during an earthquake needs to be strengthened. If the upper blockage fails and higher pore pressures are transmitted downslope, the higher resulting groundwater conditions could persist for some time. If earthquake shaking is considered a highly unlikely event, then don't analyze it. It appears inconsistent to do a detailed analysis of seismic slope stability and then to dismiss it because it is so unlikely.

Reclamation agrees with the CRB that analysis of a failure mode that has been deemed "ruled out" is generally considered unnecessary and can be confusing for the report's audience. As in other aspects of the analysis, Reclamation preferred to err on the side of conservatism. Reclamation felt maintaining thoroughness of the overall analysis was worth the risk of confusion. Additionally, Reclamation felt it important to be transparent in its analysis and show all of its work. In the extremely unlikely event that a large remote earthquake were to occur immediately after a catastrophic failure of the tunnel blockage, the analysis shows that risk of hillside failure would be minimal. The minimum factor of safety of 0.87 was obtained by combining the extreme conditions of maximum seismic loading with minimum soil properties and elevated groundwater in the downstream hillside. Although a result with a

Factor of Safety of less than 1.0 was calculated for this case, it does not automatically follow that the hillside will fail even if these conditions occur. The amount of ground deformation that would occur was estimated and presented in the report. The analysis indicates maximum displacements would be on the order of 0.7 inches. It is generally accepted that it takes predicted displacements at least on the order of 6 to 12 inches before stability is considered to be threatened.

Comment 4. Conservative to very conservative assumptions were made at every step of the geotechnical and risk analyses. The cumulative conservatism of the overall analysis supports the conclusion that rapid, catastrophic failure of the collapse bulkheads and resulting rapid drainage of the Mine Pool through the portal are extremely unlikely events.

Reclamation agrees with this observation. No additional response required.

Mark R. Cole Comments

Comment 1. The Assessment should be reorganized. You have the three reports in the wrong order. You have data, conclusions, data. I suggest that you place the second chapter "Potential Failure Modes and Effects Analysis Leadville Mine drainage Tunnel" at the end of the report so the organization is data, data, conclusions. It would then appear to be a more professionally done document.

Reclamation agrees with the suggested format. Potential Failure Modes and Effects Analysis has been relocated as suggested.

Comment 2. In the "Potential Failure Modes and Effects Analysis Leadville Mine Drainage Tunnel" I do not know what the Risk categorization means. What does low, moderate and high mean? What is the time frame? A low category may become high if expressed over a long enough time frame. These need to be expressed in some mathematical fashion (probabilities) so the reader has some sense of the risk probabilities involved. Until you express these mathematically they have no meaning.

Assessment of Risk in the PFMEA looked at both likelihood and consequences in a qualitative sense. The consequence descriptors and likelihood descriptors are defined on pp. 7 and 8 of the report. Reclamation believes that the qualitative assessment provided a reasonable estimate of risks associated with the project and that a quantitative risk assessment resulting in numerical values was not practicable at this site.

Comment 3. The consequences should be more detailed. The focus in the Assessment is on the Village at East Fork with little regard to the impacts on the riparian habitat -- erosion, fish, insects, wildlife, drinking water quality down stream. Even though it is a low probability event, if a blowout should occur the impacts are substantially understated in your report because there is approximately a billion gallons of high metal, low pH waters in the mine pool.

This risk assessment focused only on potential impacts to downstream populations and property. Assessment of potential environmental impacts is beyond the scope of this study.

Comment 4. If the height of the mine pool is limited by the bed rock/terrace gravel interface then the flow into the mine pool vs. the flow through the gravels could limit the mine pool height. However, you did not present data to indicate that this is happening. The size of the pipe is very important in this assertion, the volume of flow into the mine pool and the volume of out flow through the gravels will then control the mine pool height. You present no data to show the inflow vs. outflow. As I read the Assessment this assertion is not support by data.

Reclamation does not know precisely what the maximum water table level would be. However, Reclamation believes the control on this elevation may be the geologic contact between pervious zones in the bedrock and the overlying gravels. The rate of rise of the mine pool would be limited by the gravel's large water carrying capacity and by the fact that some shafts will experience artesian flow. Source Water Consulting has noted that seeps and flow from shafts begin in California Gulch when the water level in the LMDT mine pool reaches an elevation of 10,147. The Bureau of Mines previously suggested that a water elevation of 10,160 may be the maximum based upon this level being measured in the Pyrenees shaft prior to the excavation of the LMDT. It is believed that present water levels are near the maximum likely to occur as the hydrologic system is able to overflow out of the top of the mine pool. Placing an exact value on this elevation is not essential given the finding that the lower plug and bulkheads can resist considerably higher water levels, and the historic evidence that the upper limit is somewhere near elevation 10,160.

Comment 5. On page 13 in the "Potential Failure Modes and Effects Analysis Leadville Mine drainage Tunnel" You suggest restoring drainage from the Canterbury Tunnel. There is an assertion that the tunnel flowed "1300 gal/min throughout the year, and the mine operators in the district recognized a marked reduction in recharge rate". What is the source of this data? I had not heard this before.

The source for the flow volume from the Canterbury Tunnel is the "Report on the Leadville District and Adjoining Territory" by Edward P. Chapman and Frank M. Stephens dated 1929. The authors spent 1½ years examining 359 properties, including a detailed examination of the Canterbury Tunnel. Pages

181 through 187 is a detailed discussion of the Canterbury Tunnel including the geology and observed flow of 1300 gpm during the dry part of the year.

Comment 6. The earthquake data is fine as far as it goes. Since earthquakes usually accompany fault movement, what would be the results of movement on the Pendery or associated faults. We are living the Rio Grande Rift Valley where post Pleistocene fault movement is recorded by moraine offset south of Leadville.

Movement along the Pendery Fault would likely cause additional collapse and could reduce the hydraulic connectivity along the LMDT. This would tend to help contain the mine pool.

Comment 7. In the "Results of Geotechnical and Structural Analysis Leadville Mine Drainage Tunnel" you assert that the Pendery Fault is a flow barrier; however, in other sections it is stated that the Pendery Fault will transport water. What "Geologic Data" (p.8) indicates fluid flow along the fault in the vicinity of the tunnel? The drilling records for the tunnel indicate that there was "some" water flow when the fault was crossed. Else where the drillers experienced very large water flows. The Pendery water flow should be consistent between sections of the report.

Construction records state that a significant amount of clayey gouge was encountered at the Pendery fault. This gouge would tend to restrict flow across the fault. The associated fractured zones adjacent to the fault provide a conduit to transmit water. In summary, water flow across (perpendicular to) the fault would be restricted and flow along (parallel to) the fault would be expected.

Lake County Board of County Commissioners Comments

Comment 1. The risk assessment appears to be limited to examining potential failure modes of the LMDT and the potential impact to loss of life and property damage. The BOCC is very concerned about the potential impacts that the impounded mine pool may have elsewhere in the mining district such as seeps and springs into California Gulch and the Arkansas River with associated environmental pollution and degradation of water quality. Little if any attention was paid in the draft risk assessment to the potential environmental consequences of the elevated mine pool. Shouldn't the BOR include an analysis of potential environmental damage resulting from the elevated mine pool for the entire mining district area and surrounding ecosystem, rather than the existing narrow focus on public safety and property damage from a possible catastrophic release/tunnel blowout?

This risk assessment focused only on potential impacts to downstream populations and property. Assessment of potential environmental impacts is beyond the scope and intent of this study.

Comment 2. Page 46, "Results of Geotechnical and Structural Analysis" and subsequent discussion in "Potential Failure Modes" discusses the idea that the likelihood of the blockage remaining stable decreases with increased head differential. It is suggested that though failure may occur it will not likely result in a blowout. It is further suggested that such a failure, though not a catastrophic blowout, may result in property damage but not loss of life. What about environmental damage to the Arkansas River ecosystem and potential effect on drinking water supplies should such a failure occur? Again, the risk assessment is too narrowly focused to the exclusion of environmental concerns.

This risk assessment focused only on potential impacts to downstream populations and property. Assessment of potential environmental impacts is beyond the scope of this study.

Comment 3. It appears the risk assessment conclusions are based upon the current blockage scenario. Additional collapses would surely be expected in the future, which could further affect the risk scenario. Shouldn't the analysis anticipate future collapses and their potential effect on the mine pool? What does BOR intend to do if further collapses occur? Does the BOR intend to perform maintenance of the tunnel to prevent or minimize such future collapses?

Reclamation agrees that additional collapses are likely to occur in the future. However, Reclamation believes that this would reduce the risks of a sudden release of water from the tunnel, which was the focus of this assessment.

Comment 4. The Sherman Tunnel in the Leadville mining district apparently experienced a blowout just this past week. This is an example that such events do actually occur in the mining district. Perhaps the risk assessment team should be informed of this event and may wish to examine it to see if any lessons might be derived from that occurrence.

Engineered bulkheads and placed fill material were not present in the Sherman Tunne; therefore, Reclamation believes that conditions of the tunnel are not similar enough to draw meaningful comparisons.

Comment 5. The risk assessment does not define the safe level of the impounded mine pool behind the blockage. It would seem this is an important component of the risk analysis especially for decision-making concerning future action. The Independent Review Board made a similar recommendation to which the BOCC concurs.

Reclamation believes that unacceptable risk of a sudden release of mine pool water is not present in any mine pool elevation that could reasonably occur. Reclamation does not know precisely what the maximum water table level would be. However, Reclamation believes the control on this elevation may be the geologic contact between pervious zones in the bedrock and the overlying gravels. The rate of rise of the mine pool would be limited by the gravel's large water carrying capacity and by the fact that some shafts will experience artesian flow. SourceWater Consulting has noted that seeps and flow from shafts begin in California Gulch when the water level in the LMDT mine pool reaches an elevation of 10,147. The Bureau of Mines previously suggested that a water elevation of 10,160 may be the maximum based upon this level being measured in the Pyrenees shaft prior to the excavation of the LMDT. It is believed that present water levels are near the maximum likely to occur as the hydrologic system is able to overflow out of the top of the mine pool. Placing an exact value on this elevation is not essential, given the finding that the lower plug and bulkheads can resist considerably higher water levels, and the historic evidence that the upper limit is somewhere near elevation 10,160.

Comment 6. Since direct observation of the collapse(s) is not possible, the BOCC is still uncertain how stability can be so easily assumed?

Although no direct observation of the Pendery blockage is possible, Reclamation believes the assumptions presented in the analysis are reasonable based on considerable engineering expertise. Additionally, some of the potential failure modes assumed that the upper blockage did indeed fail and even with this conservative assumption analysis showed that the engineered bulkheads would resist the forces and not fail. It is important to emphasize that the lower blockage associated with the engineered bulkheads was observed in the tunnel and by drilling five holes along the collapse fill and injecting gravel to create a stable fill mass.

Comment 7. A continuing theme in the report is that BOR never intended to maintain the tunnel upon acquisition from USBM. This really has no bearing on the actual assessment of risk and is concerning because it seems to indicate a continuing pervasive attitude in the BOR that the tunnel is not fully BOR's responsibility. The history section of the report describes the upstream portion, but then completely ignores it in the analyses and review.

This risk assessment focused only on potential impacts to downstream populations and property. Assessment of issues beyond these potential impacts is beyond the scope of this study.

Comment 8. It appears that BOR considers the contamination problem, which is probably in progress right now, a level 1, no economic impact other than local water use impacts. Actually this impact is greater. Contaminated water reports to the Arkansas River over time. From there it affects area fisheries, tourism and others' judgments of our area from stigmatization due to contamination. The damage to the local economy from contamination could be significant.

This risk assessment focused only on potential physical impacts to downstream populations and property. Assessment of potential environmental impacts from the mine pool is beyond the scope of this study.

Comment 9. Review of upstream water level data indicates there are major blockages above 75+00. BOR will need to include an analysis of these blockages for planning future action, including the permanent fix. Perhaps this was not mentioned in the report because BOR did not deem it relevant to the scope of this risk assessment. Does the BOR intend to perform further analysis of these blockages in regards to the effect on mine pool drainage?

Although Reclamation is not aware of a major blockage near Station 75+00, Reclamation believes that this would have no impact on the conclusions of the risk analysis and does not intend on performing additional analysis in these areas.

Comment 10. It appears measured data was not used for soil properties. All were assumed, and optimistically assumed. For example, the report states that the 25 foot high unsupported vertical slopes in the till near the highway indicate a very strong material. Not necessarily. It does not require high strength to form an unsupported vertical trench face. It definitely indicates a high fines content (silt and clay) and depending on size distribution a higher fines content can create a much weaker material, right at the low end of the assumed strengths or even lower. For the long term, will BOR actually obtain real numbers and adjust the report accordingly, rather than use optimistic assumptions?

Reclamation used a wide range of soil strengths in their slope stability analysis. Assumed soil friction angles were varied from 32 to 45 degrees, which Reclamation believes accurately brackets reasonable soil strengths for the types of soils present. As additional supporting evidence, EPA constructed a temporary reservoir for a pump test using these soils. The very steep slopes of the EPA embankment did not fail when saturated. This behavior is consistent with a mixed soil (containing both granular and cohesive material) and suggests that the actual strength is well above the 32 degree value used in the analysis.

Comment 11. The flow calculation of 7500 gpm in bullet 2, page 17 should be 450,000 gpm. This is a minor unit conversion error. The 1000 cfs is correct.

Reclamation agrees with the BOCC and has corrected the mistake in conversion.

Comment 12. The tunnel analyses indicate the concreted portions near the portal, which hold back the main bulkhead, should already be in failure, and that no additional groundwater pressures can be supported by the tunnel. What are the factors of safety? What will BOR do about it? Will it reinforce the lining? Will BOR open up the Canterbury to relieve the local groundwater pressures? Or does BOR just plan to rely on their assertions that groundwater levels are under control and probably will remain so? Lining instability threatens several of the assumptions for various scenarios.

There is no evidence elevated water pressure is acting against the tunnel liner. At the bulkhead at station 4+61, the hydraulic head is directly observable and is approximately 2.5 feet above the tunnel invert. At the portal, groundwater monitoring wells indicate that there is no head against the liner. Elevated water levels seen in the observation well at station 3+00 does not reflect the head acting against the tunnel liner. The well is offset 20 feet from the alignment and there are weep holes along the tunnel; therefore, the head against the liner is low. We continue to monitor the facility; there is no basis for change.

Comment 13. The assumptions in the report regarding earthquake analyses are not backed up by data or discussion. Again these assumptions affect several areas of the report. Figures developed for the Sugarloaf Dam are used. What were the threat sources for that dam? If it is the Mosquito fault, then this site is a lot closer to the source than the dam is, with resulting seismic potential higher, though the return period would still be low.

The maximum loading is not from the Mosquito fault. The values for Sugarloaf Dam are slightly higher than what would be used at the tunnel location if site-specific seismic loading curves were generated for the LMDT location; therefore, the analysis is appropriate.

Comment 14. The statements about clay and iron hydroxides helping to cement and stabilize the soils are grossly optimistic. It has been observed in old mines that iron hydroxides are simply very weak mush, with a very thin layer of slightly stiffer crust where exposed to air. Clays deposited in a saturated water environment require physical pressure to consolidate, which would not be present to any significant degree in the tunnel environment. If anything, they will form weak layers that inhibit good frictional strength development.

The report statement about "clay-sized particles" forming due to chemical precipitation is misunderstood in this comment. Reclamation is referring to the slow but constant buildup of mineral precipitates formed when lower pH water mixes with higher pH water. These mineral precipitates act to fill voids in the collapsed material, increasing its density and do have a mild cementing effect

over the course of years as the precipitates crystallize. The blockage area below the Pendery Fault is in a chemical mixing zone. Reclamation has observed this cementation effect in other old mines where pH and neutral pH waters mix. This is different than the weak precipitates which form when acid water is exposed to air; however, even those will tend to crystallize and solidify given enough time.

Comment 15. As touched on earlier, the report does not attempt to predict what may physically be the ultimate maximum height of the mine pool or the Canterbury Hill water table for a worst-case analysis. Nor does the current analysis determine how deep a mine pool or water table can safely be handled. Such an analysis could provide guidance for future decisions on what additional actions may need to be taken. Will BOR perform such an analysis?

Reclamation does not know precisely what the maximum water table level would be. However, Reclamation believes the control on this elevation may be the geologic contact between pervious zones in the bedrock and the overlying gravels. The rate of rise of the mine pool would be limited by the gravel's large water carrying capacity and by the fact that some shafts will experience artesian flow. Source Water Consulting has noted that seeps and flow from shafts begin in California Gulch when the water level in the LMDT mine pool reaches an elevation of 10,147. The Bureau of Mines previously suggested that a water elevation of 10,160 may be the maximum based upon this level being measured in the Pyrenees shaft prior to the excavation of the LMDT. It is believed that present water levels are near the maximum likely to occur as the hydrologic system is able to overflow out of the top of the mine pool. Placing an exact value on this elevation is not essential given the finding that the lower plug and bulkheads can resist considerably higher water levels, and the historic evidence that the upper limit is somewhere near elevation 10,160. It should be noted that Reclamation is closely monitoring the differential head at the upper blockage as a part of the LMDT plant operations. If conditions change, evaluation will be made and actions taken such as reducing the pumping rate Station 10+25 and increasing pumping rate from the new well at Station 46+96 to reduce the differential head.

Comment 16. There should be a time line for the emergency action plan to be implemented, including table tops. It has been discussed that table tops be conducted twice a year due to the Village at East Fork mobile home park being so transient. Further, the information distributed by the BOR might possibly also be handled through the school system so the children who are English speaking can interpret the information for their parents.

Reclamation agrees with the BOCC; a timeline for the completing and implementing the emergency action plan is being developed and will be shared with all stakeholders.

Comment 17. Chemicals being stored at the plant need to be addressed in the emergency action plan and the evacuation plan.

Reclamation agrees with the BOCC; storage of hazardous materials is addressed in the Emergency Action Plan.

Comment 18. It may be advisable to have an employee of the plant become a member of the Lake County emergency services council.

Reclamation is looking into the possibility of a staff member becoming a member of the council.

Comment 19. Summary comment: The BOR seems quite intent on not looking at the mine pool problem as a whole in the risk assessment, but rather parceling out one issue of the overall problem involving the LMDT. The dangers of contamination and other issues are given short shrift. The utility of the risk assessment is questionable since it is only looking at one piece of the puzzle. Many assumptions are made without actual data. The agencies, particularly BOR, appear to continue to be very much defending turf rather than demonstrating a willingness to fix the totality of the problem. Does BOR intend to continue to gather better data and to further supplement this report when such data is obtained? Although perhaps given the narrow focus of the report, such additional monies would be better spent on actual physical improvements.

Reclamation does not intend to collect additional data prior to finalizing the Risk Assessment Report. The Final Risk Assessment will be issued with this comment response document attached in September 2008. If Reclamation conducts any additional studies, they will be carried out under subsequent agreements.

U.S. Army – Corps of Engineers

EPA Region 8 asked the USACE to review Reclamation's Final Draft Leadville Mine Drainage Tunnel Risk Assessment report dated June 30, 2008. EPA also had provided the USACE with other EPA documents/reports for background information.

The USACE provided EPA Region 8 with a Review Memorandum dated August 25, 2008. This Review Memorandum included a two-page summary review memorandum by B.J. Bailey, P.G., and three attached individual review memorandums by: Steven Jirousek, R. G.; Joseph A. Kissane, P.G.; and B.J. Bailey, P.G. The review comments provided in these four review memorandums are each restated below and Reclamation's response (in bold italics) to each of the review comments is given below the review comment where judged necessary

and appropriate. It appears that EPA Region 8 asked the USACE to respond to four specific questions, which are included in the summary review memorandum.

Summary Review Memorandum by B.J. Bailey, P.G.

Summary of Conclusions: Based on our review of Risk Assessment, we believe that the remedy selected by the Record of Decision (ROD) appears to be the most acceptable approach to understanding and managing potential risks posed by the Leadville Mine Drainage Tunnel (LMDT). Although all reviewers came to the conclusion that a catastrophic failure of the collapsed portion of the tunnel resulting in the rapid release of mine pool water and collapse debris out of the LMDT is unlikely, it is most probable that the LMDT will continue to deteriorate resulting in less than catastrophic releases.

Reclamation agrees that catastrophic failure of the collapsed portion of the tunnel resulting in the rapid release of Mine Pool water and collapse debris out of the LMDT is unlikely (extremely low). Reclamation also agrees that additional collapses are likely to occur in the future but believes that this could reduce the risks of a sudden release of water from the tunnel, which was the focus of the risk assessment.

Question 1: Determine if implementing the 2003 ROD remedy – engineered plugs and backfilling the tunnel – is still appropriate.

The reviewers believe that the solution of engineered plugs and backfilling the tunnel is still appropriate. The remedy would provide a known engineered structure from which to form the basis of any future risk assessments or evaluations.

Judgment regarding the appropriateness of the selected remedy in EPA's 2003 ROD for Operable Unit 6 (OU6) was not part of Reclamation's Risk Assessment study. Reclamation previously had received a copy of EPA's 2002 Draft OU6 Focused Feasibility Study and had provided EPA with review comments in June 2002. EPA released the OU6 ROD in September 2003 and notified Reclamation of the OU6 remedy selection in a February 2004 letter from EPA. Since then, Reclamation has interacted with EPA a number of times concerning their selected OU6 remedy and the potential effects on Reclamation's Leadville Water Treatment Plant; these interactions included transmittal of Reclamation's February 2006 "Assessment of Remedial Design Concept"(which comments in detail on the engineered tunnel plug and backfilling the lower portions of the LMDT) to EPA.

Question 2: Identify any fatal flaws or poor assumptions in the USBR study.

All reviewers agree that no fatal flaws were noted in the USBR study.

All of the data used in the analyses were based on assumptions. Most appear to be conservative but all of the reviewers agree that the assumptions made concerning the location, length, degree of filling, and the geotechnical properties of the material within the collapsed section of the tunnel on which the Risk Assessment is based, are questionable and not necessarily conservative. Numerous inconsistencies concerning the dynamics of the groundwater within the LMDT and the surrounding area were also identified and present a major concern.

The Risk Assessment report documents the data used in Reclamation's study and the basis for the assumptions made. The independent CRB commented that* "The lack of measured engineering properties (unit weight, shear strength, etc.) of the materials being analyzed in both the tunnel blockages and the slopes at the portal renders the analyses based on these properties somewhat tentative." ***and*** **"Conservative to very conservative assumptions were made at every step of the geotechnical and risk analyses."** ***Reclamation recognizes the lack of measured engineering properties for the soil and rock materials associated with the LMDT and the uncertainty associated with the analysis results. The CRB's second comment seems to disagree with the*** **"questionable and not necessarily conservative"** ***comment made by the USACE. Reclamation agrees with the CRB's conclusion regarding the risk assessment results being conservative. Reclamation agrees that there are numerous inconsistencies associated with the groundwater system beneath OU6 and that it is not completely understood at this time. However, Reclamation believes that this groundwater system, especially the connection between the Mine Pool in the mine workings and the LMDT, is understood to a sufficient degree to support the Risk Assessment's conclusions.***

Question 3: Determine if there is another, better, model out there to evaluate the risk at the site.

The reviewers agree that the models used in the Risk Assessment are representative of models currently in use in the mining industry. There was insufficient time to perform market research to evaluate more recent models that may be capable of a more dynamic analysis.

Reclamation agrees that the risk analysis methodology used for this study was appropriate.

Question 4: Evaluate the USBR's conservative assumptions – are they conservative enough?

Although the degree of conservatism varies, the reviewers determined that, with the exception of the collapsed plug, the assumptions were generally conservative. Because there is no actual data collected from the site, the evaluation of the degree of conservatism could change based on future findings.

Reclamation agrees that the assumptions made for this risk assessment study were (generally) conservative. Reclamation also believes that the assumed length of the collapsed tunnel plug just below the Pendery Fault (a minimum of 20 to 50 feet) was relatively conservative as the actual length of the plug could range from 80 to over 200 feet based on tunnel maintenance observations.

Review Comments from Steven Jirousek, R.G. (Attachment 1)

Question 1. Determining if implementing the 2003 ROD remedy - Engineered Plugs and backfilling the tunnel - is still appropriate.

It is my opinion that the risks and consequences presented in the USBR documents do not alter the validity of Final Record of Decision, OU6 California Gulch Superfund Site, Leadville, Colorado (ROD) Alternative 2g. Implementation of a feasible engineered plug design in the LMDT would reduce, although not eliminate the risk of adverse consequences due to changes in the LMDT or mine pool over time. Specific facets of that alternative need to be addressed to ensure the concept is constructible and functions as intended.

Judgment as to the appropriateness of the selected remedy in EPA's 2003 ROD for OU6 was not part of Reclamation's Risk Assessment study. Reclamation has provided EPA with information about concerns and comments on its 2002 Focused Feasibility Study and the 2003 ROD's selected remedy for OU6 at various times since June 2002.

The following comments are regarding the ROD selected alternative 2g.

Comment 1. The USBR Risk Assessment did not directly address compliance with the EPA ROD and focused instead on the immediate concerns expressed by EPA and the local community (USBR's Existing Conditions report refers to a letter from EPA to USBR dated Nov 8, 2007) regarding risks of an uncontrolled potentially catastrophic release of water from LMDT that could endanger human life and the environment. This was USBR's stated purpose for the risk assessment. Based on the request for review the Corps received from EPA, it seems the EPA may have intended a broader view of the assessment of risk from the LMDT than the USBR approach.

Reclamation agrees that the Risk Assessment study focused on concerns regarding the potential for an uncontrolled catastrophic release of water from the LMDT that could endanger the public (life and property loss); these concerns were expressed collectively by EPA in its letter dated November 8, 2007, by the State of Colorado, and by the local community. EPA's 2003 ROD and its selected remedy for OU6 were not addressed by Reclamation's Risk Assessment study.

Comment 2. 2003 Record of Decision referred to discharge of contaminated surface water to the Marion Shaft and ultimately to the LMDT via the Robert Emmet Shaft. The addition of contaminated surface discharge to the mine pool, as a means to convey those waters to the USBR waste water treatment plant at the downstream end of the LMDT, may not be effective due to the known and suspected LMDT blockages. The mine pool may provide temporary storage capacity for diversion of contaminated surface water via the Marion Shaft, but the practice exacerbates the problem of rising mine pool water elevations and may prove to be counterproductive if the mine pool rises high enough that contaminated water moves from the bedrock into the overlying soils and is discharged to the surface untreated.

Reclamation agrees that the discharge of contaminated OU6 surface water to the Marian Shaft and ultimately to the LMDT Mine Pool via the Robert Emmet Shaft exacerbates the existing problem and is probably counterproductive.

Comment 3. Final Record of Decision, OU6 California Gulch Superfund Site, Leadville, Colorado Alternative 2g (selected) calls for construction of a concrete bulkhead in sound bedrock upstream of the Pendery Fault to permanently isolate the mine pool from the LMDT and to then reduce the mine pool elevation by pumping from wells. The ROD does not address in any detail how such a bulkhead is to be constructed. There are significant challenges associated with design and construction of a bulkhead under the conditions present at the site. The feasibility of constructing a bulkhead at the proposed location must be thoroughly considered before advancing to design phases.

Reclamation agrees that there are significant challenges associated with the design and construction of an engineered bulkhead (plug) in the LMDT. Reclamation provided EPA with an assessment of its Remedial Design Concept for the engineered plug and backfilling of the lower portions of the LMDT in a February 2006 document.

Comment 4. Final Record of Decision, OU6 California Gulch Superfund Site, Leadville, Colorado Alternative 2g (selected) calls for lowering the mine pool elevation by pumping from wells after construction of the concrete bulkhead. The contaminated pump discharge would then be conveyed to the USBR waste water treatment plant at the lower end of the LMDT by a buried pipeline. It seems as

though the USBR has mandated limits on the quantity and source of water it can treat. The ROD does not appear to recognize this constraint. Furthermore, the USBR waste water treatment plant has a limited capacity and may not be capable of processing the quantity of contaminated water from the mine pool at the rate necessary during efforts to drawdown the mine pool water elevation. The ROD does suggests modifications could be conducted on the USBR waste water treatment plant to accommodate the significant processing rate needed during mine pool drawdown but the issue of USBR's ability to treat mine pool water remains to be addressed.

Reclamation agrees. One mine pool well and buried pipeline to Reclamation's Leadville Water Treatment Plant have been constructed by EPA with input and assistance from Reclamation.

Comment 5. *Draft Water Hydrology in the Vicinity of the Leadville Mine Drainage Tunnel OperableUnit 6 and Affected Areas* maps of bedrock groundwater elevations for 1992 and 1996 do not show groundwater elevations in the vicinity of the Robert Emmet Shaft (RES) or the upper LMDT that can be compared to the conceptual pre-mining groundwater elevations or those for 1944, 1946, and 1951. It is not possible from the data provided to assess potential changes in the bedrock ground water elevations and their affect on the LMDT in the mine pool area after a suspected blockage occurred in the LMDT near Pendery Fault. I suspect the EPA has this information but was not apparent in the documents reviewed.

This risk assessment focused only on potential impacts to downstream populations and property. Assessment of issues beyond these potential impacts is beyond the scope of this study.

Comment. 6. It is not clear how recent mine pool groundwater elevation increases relate to current measured discharge rates at seeps and springs, and at the timber-lattice bulkhead in the LMDT.

It is not clear from these documents that there has been a commensurate increase in the rate of discharge from any of these points or an increase in the number of discharge locations.

This risk assessment focused only on potential impacts to downstream populations and property. Assessment of issues beyond these potential impacts is beyond the scope of this study.

Question 2. Identifying any fatal flaws or poor assumptions in the USBR Study

No fatal flaws or poor assumptions were identified that would alter the conclusions presented in the USBR risk assessment.

Reclamation agrees.

Question 3. Determining if there is another, better, model out there to evaluate the risk at the site

The process of determining the state of existing conditions in the LMDT, the Potential Failure Modes and Effects Analysis, and the Geotechnical and Structural Analysis of the plausible failure modes seems to be a comprehensive means of identifying and evaluating risks and consequences. The PFMEA process focuses on existing conditions and as implemented has limited application to conditions over long time periods.

Reclamation agrees that its risk assessment process focused on the existing LMDT situation and was appropriate for this study. Reclamation does not believe that the level (pressure head) of the mine pool will rise significantly above the level at the time of the Risk Assessment study, and that the degree of conservatism used in the study should minimize the potential for a dramatically different situation and risk assessment result.

Comment 1. Potential Failure Modes and Effects Analysis is a formal process of assessing risk and their consequences whereby a multi-disciplinary team reviews design, construction, and operations/maintenance documents, etc., and then brain-storms possible failure scenarios and their consequences. Each possible scenario is evaluated and its credibility determined. It is a process the USBR has been using on their facilities for sometime and the Corps of Engineers is beginning to adopt for assessing risk on its dams.

Reclamation agrees.

Comment 2. The Potential Failure Modes and Effects Analysis followed accepted procedure and identified what seem to be the most likely failure modes and addressed the primary safety concerns regarding the LMDT structural failures that were raised in the ROD.

Reclamation agrees that the PFMEA analysis followed accepted procedure and identified the most likely failure modes.

Comment 3. The potential failure modes that were identified and the risk matrix with consequences and likelihood descriptions for each potential failure mode were reasonable.

Reclamation agrees.

Question 4. Evaluating the USBR's conservative assumptions - are they conservative enough?

It is my opinion that the level of conservatism applied by USBR in each aspect of their risk assessment of the LMDT has been appropriate overall.

Reclamation agrees.

Comment 1. The geotechnical and structural analysis of the LMDT as part of the risk assessment was satisfactory. The assumptions made were reasonable based on available information. An appropriate level of conservatism was applied based on the level of uncertainty for each failure mode analysis.

Reclamation agrees.

Comment 2. The analysis of stability of the blockage in the vicinity of the Pendery Fault was reasonable. It seems as though there may be more collapses along the LMDT than just this one and the one near the timber-lattice bulkhead. That condition would make the likelihood of the blockages failing even less and diminish the consequences if any did fail.

Reclamation agrees.

Comment 3. The analysis of the flow blockage above the timber-lattice bulkhead was also reasonable. The amount of water that may be by-passing the lower blockage by flowing out of the LMDT and into the soil could have been more thoroughly described.

Reclamation agrees. Reclamation is not able to directly measure the seepage potentially bypassing the lower blockage in the LMDT. Reclamation believes the terrace gravel deposit probably collects and conveys most of the seepage that may be bypassing the lower blockage in the LMDT. As noted in the PFMEA report on page 21 (under Favorable Factors), a pump test was performed on the well at Station 6+35 and it indicated a terrace gravel permeability of 50 feet/day, which is relatively high. While a two- or three-dimensional seepage analysis to estimate the amount of water that may be bypassing the lower blockage by flowing through the terrace gravel has not been conducted, Reclamation believes that the physical orientation, thickness, and relatively high permeability of the terrace gravel deposit (confined by the overlying lower permeability glacial moraine) should be able to convey a relatively large amount of seepage out toward the East Fork beneath the LMDT Portal.

Comment 4. It seems likely that water impeded by the lower blockage near the timber-lattice bulkhead may flow through the tunnel walls into the gravel soils that make up the walls in that vicinity. It is not clear where that water goes after moving into the soils. If that water were to discharge at the surface as a seep or spring, it does not seem likely that a piping condition or slope instability condition would develop due to the coarse granular nature of the soils; but potentially

contaminated groundwater may discharge to the ground surface or to surface waters in the area.

Reclamation agrees – see the response to Comment. 3 above. Since the last LMDT Portal modifications in 1990-92, no surface seepage or slope instability has been observed. LMDT water not captured by the well at Station 10+25 or flowing through the timber bulkhead could become groundwater and could travel into and through the terrace gravel and glacial moraine deposits beneath the ground surface at the Portal and could then join the surface water in the East Fork.

Comment 5. The effectiveness of weep holes in the concrete tunnel lining was not adequately addressed in the analysis of the stability of the concrete lining. Photographs of the concrete lining indicate significant clogging of some weep holes by mineral deposition. It was not entirely clear if the analysis considered a reduced weep hole efficiency. It is clear however, that even if a segment of the concrete tunnel lining failed, the blockage near the timber-lattice bulkhead would remain stable. The soil above a failed segment of concrete lined tunnel would likely collapse into the tunnel and result in a sink-hole at the ground surface.

Some of the weep holes in the concrete tunnel lining were observed to be clogged as shown in Figure 22 of the Existing Condition report. The Existing Condition report recommended that these weep holes be cleaned out in Section 2.12 (Inspection March 25, 2008) on p. 54. Reclamation is planning to do so. Reclamation agrees that the lower blockage would likely remain stable in the event the concrete tunnel lining failed.

Comment 6. The analysis of the stability of the hillside in the vicinity of the portal was reasonable. The extreme case of high ground water elevation, weak soil strengths, and large seismic event occurring simultaneously is indeed remote. Displacement of the slope toe of less than one foot in the unlikely event the extreme case occurred probably would not result in a catastrophic failure of the slope.

Reclamation agrees.

Comment 7. The primary observations to make are that the Leadville Mine Drainage Tunnel (LMDT) was hurriedly constructed by US Bureau of Mines as part of the war effort in the 1940's and 1950's. It was apparently not designed or constructed for long-term stability as it was constructed using mining techniques for advancing the LMDT and temporary roof support rather than using tunneling methods available at the time. The type of roof support used, wooden timbers and light steel sets, are generally used to provide temporary support and are prone to deterioration in a relatively short time. Consequently, the overall roof stability in the LMDT should be anticipated to deteriorate significantly over time as the support members deteriorate.

Reclamation agrees.

Comment 8. There is ample description of poor roof conditions and difficulties advancing the LMDT during construction and of roof stability maintenance efforts after construction. A cursory assessment of the station by station description in *Existing Condition of the Leadville Mine Drainage Tunnel, Final Draft June 2008*, indicates only about 2,500 feet of LMDT length does not appear to be prone to partial or full collapse based on reported construction problems and anticipated deterioration of roof support members. It seems likely that there are more tunnel blockages present in the LMDT than the two assessed by USBR. Over time much of the length of the LMDT should be anticipated to at least partially collapse. The hydraulic connection between the mine pool and the timber-lattice bulkhead may be anticipated to further diminish as a result.

Reclamation agrees.

Comment 9. Based on descriptions of LMDT construction, there are numerous locations where significant groundwater inflow to the LMDT may be possible downstream of the upper blockage near the Pendery Fault. It is possible much of that water would be unrelated to the mine pool.

Reclamation agrees.

Comment 10. The description of the construction station by station was very helpful in grasping the LMDT condition and geologic setting. There is some question as to the significance of the karst feature that runs sub-parallel to the LMDT near station 29+63 to 32+00. A karst solution opening 60 feet long, 15 feet wide and 20 feet high was encountered. The opening apparently narrowed and plunged into the tunnel floor near station 32+00. What affect, if any does that feature have in the movement of water in the LMDT? How stable is the roof at that location due to the greater span from wall to wall through that section?

The Geologic Cross-Section along the LMDT (four figures) included in Appendix A of the Existing Condition report indicates the bedrock along the Station 29+63 to 32+00 portion of the LMDT is Dyer Dolomite (Dcd). When two closely spaced faults were encountered at Station 29+63, the tunnel construction experienced the largest inflow of water recorded for the LMDT (5,700 gallons per minute). The large cavern that followed the side of the constructed tunnel may or may not be a continuous feature connected to other such features in the Dyer Dolomite. It could be part of a groundwater conduit within the dolomite, bringing some of the water noted under No. 9 above to the LMDT. The report notes that the cavern sides were hard and that 156 feet of the tunnel length was "slabbed off" to create a siding for the track. This would appear to indicate that the rock along this cavern was sufficiently hard and strong to create a relatively stable roof for the tunnel.

Review Comments from Joseph A. Kissane, P.G. (Attachment 2)

The general concept of the 2003 ROD appears to be appropriate, given the parameters and goals of the ROD.

This risk assessment focused only on potential impacts to downstream populations and property. Assessment of issues beyond these potential impacts is beyond the scope of this study.

Comment 1. The U.S. Bureau of Reclamation studies of the conditions include geotechnical considerations and assumptions, some of which are based on the available information, without proposal for subsequent verification. The Bureau of Reclamation's failure mode analysis contains many assumptions to account for unknowns, and most are reasonably conservative. Some of the assumptions are not as likely as others. Among the assumptions, the most significant unverified assumption is the location and extent of the presumed collapse. Some efforts have been made to identify the location using remote camera imagery and borings; however, there is still a level of uncertainty as to the extent of the collapse/plug and the nature of the material that composes it (its composition,) its degree of compaction, and the size distribution of the materials within it.

Because of the Risk Assessment's conclusion that catastrophic failure of the collapsed portion(s) of the tunnel resulting in rapid release of mine pool water and collapse debris out of the LMDT is unlikely (extremely low), Reclamation has determined verification of the various assumptions made is unnecessary. That verification effort would be very expensive and would likely leave many questions unanswered. Reclamation recognizes that it has made many assumptions in the various studies conducted and believes that they were appropriately conservative. The independent CRB commented that "Conservative to very conservative assumptions were made at every step of the geotechnical and risk analyses." Reclamation believes that the length of the upper collapse/plug near the Pendery Fault is not a critical issue, primarily due to the fact that the better characterized lower collapse/blockage above Station 4+61 should be more than capable of preventing the rapid release of water out of the LMDT in the event the upper blockage did breach and release the Mine Pool. Reclamation has significant experience with rockfill and well-graded glacial moraine materials throughout the West and believes that the Risk Assessment has appropriately characterized these materials and how they will perform under the postulated loadings.

Comment 2. The USBR Risk Assessment addresses static conditions as they are believed to exist at present, and it is apparent from the collapse plug that the overall condition of the tunnel is not static in the reasonable future. The majority of the tunnel being unlined and the continued action of environmental stresses on it will continue to act against the long term integrity of the structures. Without

further investigation, it is not known what impacts are likely from collapses or changes in the groundwater regimes, and without further stabilization measures it is very likely that such things will occur.

Reclamation's goal in the Risk Assessment study was to assess the risk(s) to the public and others under current conditions. Reclamation agrees that in the future, the condition of the LMDT, the elevation of the Mine Pool, and groundwater levels around the LMDT in general may change. Reclamation believes that collapses in the LMDT and in the mine workings will continue to occur. However, Reclamation believes that such collapses, especially in the LMDT, would help limit flows to the downstream tunnel reaches from the Mine Pool, even if a blockage near the Pendery Fault were to breach.

Comment 3. In the Section of Major Findings and Understandings of the failure mode analysis, there is a discussion that states: "It is unlikely that the Pendery Fault or any of the rock units of this section are pervious enough to drain the water from this section of the tunnel." Later in the same paragraph, it is stated that: "Increased leakage into California Gulch, presumably along fractured rock associated with the Pendery Fault, is further evidence that the tunnel collapse is downstream of the fault zone." These statements appear to be in conflict, or at least require more explanation.

Reclamation agrees; that portion of the report has been modified.

Comment 4. The discussion of limits on the height of piezometric head within the Mine Pool implies that the head cannot rise above the bedrock/overburden contact, because the relatively high permeability of the overburden gravels. The variable nature of typical moraine deposits and the potential for highly fractured zones within bedrock in faulted areas makes this less than a universal certainty – in spite of the conditions immediately adjacent to the tunnel. In locations that are exclusively terrace gravels, this is likely, as stated; however, it is possible that the head might be greater in some locations under some conditions, and the discussion does state that the location of the water level controls remains unknown.

There are a lot of geologic data regarding the significant extent and thickness of the terrace gravel deposit. The permeability of the terrace gravel was determined by Reclamation using a pump test on the well at Station 6+35 near the LMDT Portal. While that permeability of 50 feet/day for the terrace gravel is only valid for that one location, it is considered representative of the material. Reclamation does not know precisely what the maximum water table level would be, but believes the control on this elevation may be the geologic contact between pervious zones in the bedrock and the overlying gravels. The rate of rise of the mine pool would be limited by the terrace gravel's large water carrying capacity and by the fact that some shafts would experience artesian flow. Source Water Consulting has noted that seeps and flow from shafts begin

in California Gulch when the water level in the LMDT Mine Pool reaches an elevation of 10,147. The Bureau of Mines previously suggested that a water elevation of 10,160 may be the maximum based upon this level being measured in the Pyrenees Shaft prior to the construction of the LMDT. It is believed that present water levels are near the maximum likely to occur as the hydrologic system is able to overflow out of the top of the Mine Pool. Placing an exact value on this elevation is not essential given the finding that the lower collapse/plug and lattice-timber bulkheads can resist considerably higher water levels, and the historic evidence that the upper limit is somewhere near elevation 10,160.

Comment 5. The Risk Assessment addresses static conditions as they are believed to exist in the LMDT at present, and it is apparent from the collapse plug that the overall condition of the tunnel is not static in the reasonable future. The Risk Assessment also tends to reflect an evaluation of the LMDT with little or no evaluation of the conditions of nearby mine shafts and adits and drifts, that may or may not impact the LMDT as conditions change (which they will, to an undetermined extent). The majority of the tunnel being unlined and the continued action of environmental stresses on it will continue to act against the long term integrity of the structure. Without further investigation, it is not known what impacts are likely from collapses or changes in the structural conditions of the LMDT or other nearby mine structures, and/or groundwater regimes, and without further stabilization measures it is very likely that such things will occur.

Reclamation's goal in the Risk Assessment study was to assess the risk(s) to the public and others under current conditions. Reclamation agrees that in the future, the condition of the LMDT, the elevation of the Mine Pool, and groundwater levels around the LMDT in general may change. Reclamation believes that collapses in the LMDT and in the mine workings will continue to occur. However, Reclamation believes that such collapses, especially in the LMDT, would help limit flows to the downstream tunnel reaches from the Mine Pool, even if a blockage near the Pendery Fault were to breach.

Comment 6. The discussion of Major Findings and Understandings uses terms that are subjective when it comes to safety, e.g.: "In addition, the coarser gravels adjacent to the tunnel will convey a *lot* of water without moving particles" and "With recent improvements to the Early Warning System (EWS), there should be *plenty* of advance warning of dangerously developing conditions."

Correct – the study was not a quantitative risk analysis.

Comment 7. A simplified stability analysis was done using a conservative approximation of the size of the collapse plug and the prediction is that the plug is not likely to fail rapidly in a fashion that will cause the engineered plug near the downstream portal to fail. Without additional verification as to the extent and composition of the collapse plug, it is difficult to assess its permanence or

durability. The analysis of failure modes include an assumption that the blockage materials may be materials that may somehow be "cemented" by metal precipitates. Given the acidic nature of the waters, it is also quite possible that the materials are susceptible to leaching or defloculation of clay minerals present. It may be possible that should the collapse plug be composed of material that will lose its integrity in time, that mass movement in a confined debris-flow may occur causing a plunger effect that could result in heads being applied to the engineered plug that are not anticipated in the risk evaluation done by U.S. Bureau of Reclamation.

Reclamation recognizes the uncertainty associated with the upper collapse plug. However, Reclamation believes that its judgment about the piping failure mechanism for the upper collapse plug is reasonable and appropriate. The CRB agreed with Reclamation's assessment that even in the unlikely event the upper bulkhead did collapse, it would "…* fail slowly but progressively by erosion …" *and* "Thus, failure of this type would involve a long time period and gradual increase in water pressure on the portal side of the bulkhead."

Comment 8. The reports and assessments of the Bureau of Reclamation appear to address the risks and likelihood of catastrophic failure of the collapse plug and implications to the engineered plug downstream and the portal area structures in the short term, if conditions remain essentially as they are, within the parameters of the scenarios presented. The geotechnical and structural conclusions may be valid if the conditions are as modeled – and however likely the assumptions are at the present time, there are possible, even somewhat likely scenarios that could alter those conditions, and thereby alter the outcomes.

Reclamation's engineering evaluation of the lower collapse plug and the lattice-timber bulkhead included the assumption that the upper collapse plug had breached and that the Mine Pool had been released down the LMDT. The evaluation of the lower collapse plug therefore assumed dramatically higher groundwater levels (up to 100 feet above the tunnel invert at Station 10+25) around the Portal area than have existed since Reclamation constructed the Leadville Water Treatment Plant facility in 1992, as well as three assumed seismic (pseudo-static) loadings with separate slope stability analyses performed. Reclamation believes that these analyses have conservatively estimated how the LMDT Portal area would perform under present conditions as well as possible altered conditions.

Comment 9. The assessments are primarily based on geotechnical and structural consequences of possible movement of material from the collapse plug, and not so much the hydrogeologic or environmental consequences or the consequences beyond the tunnel and associated structures of deviating from the ROD-prescribed action. The majority of the tunnel is unlined. It is very possible that there will be other collapses in the tunnel. Faults and unconformable geologic contacts may contain materials susceptible to erosion in the long term that may not result in

large-scale short-term changes in conditions, but may slowly cause wedges or blocks of rock to move or collapse into the tunnel at other locations. The impact of these collapses goes beyond the impact on the engineered plug and the structures at the portal. Surface subsidence, opening of migration pathways for untreated Mine Pool water, and the connection of the tunnel with previously unconnected sources of other mine-impacted water are just a few possible negative impacts should more collapses occur.

This Risk Assessment focused only on potential impacts to downstream populations and property. Assessment of potential environmental impacts was beyond the scope of this study. Reclamation agrees that additional collapses in the mine workings and the LMDT are likely to occur in the future but believes that this would reduce the risk of a sudden release of water from the tunnel, which was the focus of this risk assessment.

Comment 10. Groundwater regimes are variable – and the Bureau of Reclamation evaluation does not appear to consider the potential changes in groundwater demand, or changes in mining activities and how these might impact the groundwater chemistry or the overall environment if the ROD-prescribed action is not executed.

This Risk Assessment focused only on potential impacts to downstream populations and property. Assessment of potential environmental impacts was beyond the scope of this study.

Comment 11. Risk Reduction Opportunities:

The USBR Failure Modes and Effects Analysis discusses a list of "Opportunities for Risk Reduction, Monitoring Enhancement, Data Collection and/or Analysis", but includes the caveat that this "is not to say they are all recommended for implementation, but rather they form a list of ideas that can be considered during any future risk mitigation." Among these that are closest to achieving the apparent goals of the ROD are:

- Drill large diameter holes into the tunnel and examine the extent of blockage with a remote crawler camera (or other remote device).

- Construct a permanent concrete bulkhead upstream of the Pendery Fault designed to take the load from a maximum level Mine Pool.

- Drill holes into the tunnel near the Pendery Fault blockage zone through which gravel and grout are injected to form a tunnel plug capable of withstanding the differential head with more certainty.

Reclamation agrees.

Comment 12. Evaluation of Early Warning System

Regardless of the approach taken, in addition to the improvements in the Early Warning System, the system should include an alarm to signal that any of the automated systems is not operational. Self-tests and manned tests should be included in the O&M, along with calibration checks for all measured parameters.

Reclamation agrees that such non-operational alarms should be included in the Early Warning System, and is working to make such improvements.

Review Comments from B.J. Bailey, P.G. (Attachment 3)

Comment 1. "Existing Condition of the Leadville Mine Drainage Tunnel"

Page 6. Sinkholes are discussed here and throughout the document. It is unclear if the seismic refraction work was concentrated only over the LMDT. The document leads me to believe there is a one-to-one correlation between sinkhole formation and LMDT drainage. I was left with the following questions: are there other sinkholes in the area not related to the LMDT alignment; are the sinkholes predominantly within areas underlain by the limestone units; and are sinkholes located near any other tunnels or shafts within the drainage basin? The fact that a large cavern was discovered adjacent to the tunnel at Sta. 29+63 may indicate the presence of others in the area.

As noted on p. 42 (under 2.8 Modifications 1978-1980), the seismic refraction surveys performed by Reclamation in 1976* "were made along the surface overlying the tunnel from Station 4+55 to 10+00 …" *Experience with the LMDT Portal area since the first sinkhole was discovered in 1956 is a direct correlation between sinkhole development and the flow of drainage water through the LMDT. The glacial moraine material appears to be highly erodible, but the terrace gravel deposit probably filters the glacial moraine material, which probably limits the development of sinkholes at other locations further up the tunnel. The landscape around the Leadville Mining District is populated with prospect holes, numerous mine clams, and related shafts, making it difficult to differentiate between them and any sinkhole features. There may be sinkholes associated with the limestone areas, which appear to be overlain by terrace gravel and glacial moraine materials according to the "Geologic Cross-Section along the Leadville Mine Drainage Tunnel" included in Appendix A and the surface mapping included in the 1927 Emmons report. There may be other limestone unit caverns around the Leadville Mining District besides the one encountered in the Dyer Dolomite at Station 29+63 in the LMDT.

Comment 2. Limestone dissolution is apparently a problem given the condition of the weep holes in the LMDT and the relatively rapid formation of stalactites along cracks (p.51, 52). Clogging of the weep holes could lead to rapid destabilization of the tunnel liner and could also account for the relatively fast deterioration of other support systems. There is no indication that any studies have been done to address the impact of [Acid Rock Discharge] ARD on the dissolution of limestone in particular or on any other rock types such as the shale found in/around the LMDT, including gouge material, has been done.

Correct. The report recommended that these weep holes be cleaned out in Section 2.12 (Inspection March 25, 2008) on p. 54. Reclamation is planning to do so. Reclamation is not planning to conduct such ARD-effect studies.

Comment 3. Page 9. It was mentioned that in 2004 that the Bureau participated with Lake County in a functional exercise to practice for a potential problem at the LMDT Water Treatment Plant and to test the EAP and that no audible test was performed at that time. On p. 11 it states that the warning system was retested in 2008 but does not indicate that an audible test was performed. Was this test ever performed?

Yes - the warning system test performed on February 22, 2008 (mentioned on p. 11) was an audible test. Reclamation has been working with the local community to improve the collective understanding of the Early Warning System and the appropriate responses by our staff at the Leadville Water Treatment Plant, by the public, and by the community's emergency responders.

Comment 4. Page 9. The inadequacy of the treatment plant is mentioned here and elsewhere in the reviewed documents as well as the limited storage in the .5 acre holding pond. This issue needs to be addressed and remedied in the OU12 (Hydrologic OU) document. Much of the water draining from the LMDT is influent from both the alluvial and bedrock aquifers which is diluting the ARD.

Reclamation's Leadville Water Treatment Plant has a long history of operational success for the designed purpose. The facility is currently treating quantities of contaminated water well in excess of sustained historic flows from the LMDT.

Comment 5. Page 10. The result of the 2006 study of ground water in the LMDT area titled "Hydrogeologic Characterization of Ground Waters, Mine Pools, and the Leadville Mine Drainage Tunnel, Leadville, Colorado" done by Source-Water Consulting and the University of Colorado concluded that the LMDT drains only a small volume of mine pool water and a very large volume of regional bedrock and adjacent alluvial groundwater. This has two implications. The first is that the treatment Plant is being overburdened by water that is being contaminated after entering the LMDT and the second is that when ground water falls below a certain level there is potential for mine pool water to leave the tunnel and contaminate

surrounding areas as well as undermine alluvium on surrounding slopes. This is especially true since the first 635 feet of the tunnel is within alluvium.

Reclamation agrees with the first stated implication. The LMDT functions well as a groundwater collection and drainage system. The relatively small amount of LMDT water that is not collected by the well at Station 10+25 or flows through the lattice-timber bulkhead at Station 4+61 for treatment by the Leadville Water Treatment Plant probably flows into the terrace gravel and/or the glacial moraine deposits, which would then convey the groundwater to the East Fork of the Arkansas River. The glacial moraine overlying the terrace gravel around the LMDT Portal has been stable with no evidence of seepage exiting the slope or toe areas since the plant was constructed in 1992. Hence, no undermining of the portal area slopes appears to be occurring and the slope stability analyses have indicated these slopes should remain stable under the very conservative conditions analyzed. Reclamation's monitoring of the LMDT Portal area includes periodic examinations of the slope and toe areas around the portal.

Comment 6. Page 37. Paragraph states "In June, 1956 the Bureau of Mines reports 'There is a small cave in tunnel about 150 or 200 feet from the portal. There is small hole up on top of the Hill.'" This relates to comment above (p.9)

Correct. However, since the LMDT Portal area modifications constructed by Reclamation in 1978-80 and 1990-92, no additional sinkholes have been found at the portal area or along the LMDT.

Comment 7. Page 42. Statement that additional sink holes had formed between the 1973 and 1976 inspections for a total of 12 sinkholes observed. "Since the more recent sinkholes were away from the highway, Reclamation began a program of erecting safety fencing around the holes rather than backfilling them as had been done in the past." There is no indication that additional monitoring was done to evaluate the growth of these sinkholes.

Correct. However, since the LMDT Portal area modifications constructed by Reclamation in 1978-80 and 1990-92, no additional sinkholes have been found at the portal area or along the LMDT.

Comment 8. Page 43. Sta. 6+65 a well drilled 98 feet into tunnel observed 6-ft. of water flowing in tunnel. A sinkhole formed adjacent to drill rig and hole was lost.

Correct. However, since the LMDT Portal area modifications constructed by Reclamation in 1978-80 and 1990-92, no additional sinkholes have been found at the portal area or along the LMDT.

Comment 9. Page 44. This paragraph is a good illustration of my general concerns with all three documents. It refers to "likely" collapse zones which indicates the actual locations of collapsed areas and the quantity of collapsed material within the LMDT is unknown. Also the statement that the tunnel is more than adequate to handle the estimated hydraulic pressure based upon the most likely tunnel, soil, and groundwater conditions. … is extremely vague. This statement was made in 1988 and makes me question what other assumptions have been carried through as fact.

Reclamation's stability analyses performed for the Portal area slopes assumed a groundwater condition with the water level 100 feet above the invert at Station 10+25 and almost at the ground surface downstream of that location. This is believed to be a reasonably conservative assessment of possible future conditions in the event the upper collapse blockage were to breach and release the Mine Pool. An appropriate range of material properties was assumed in these analyses. These parameters are believed to reasonably assess the existing and future LMDT Portal conditions with sufficient specificity to allow others like the CRB and the USACE to review and concur with the result of Reclamation's Risk Assessment study. Reclamation's various LMDT studies since 1988 have not been based on that earlier evaluation or its information.

Comment 10. Page 47. Table 5 list the material properties assumed for the 2005 bulkhead study. There is no indication of how many values were collected to determine the range, whether or not the average value was a weighted average, and whether or not outliers were included in the calculations. This type of data needs to include this type of information. The paragraph also states that no references were found and that no strength tests were done. This study was done in 2005 so this information should be available. My concern is that this type of unsupported information is carried forward as fact without confirmation.

The "average value" data given in Table 5 do not appear to be the average of the range low and high values, so a better term than "average value" may be appropriate here. Some of the engineers and geologists who authored the 2005 Valve Controlled Bulkhead Study report also participated in this Risk Assessment process; the information from the 2005 study was reevaluated and used in the current study. Reclamation believes the assumed material properties given in Table 5 for the materials encountered by the LMDT's construction are reasonable and appropriate for this Risk Assessment study. The CRB concurred with Reclamation's opinion.

Comment 11. Page 69. High quantities of sludge are referenced at the treatment plant. This seems to be an indication that erosion is occurring within the zone the tunnel is draining.

There is no evidence erosion is occurring within the LMDT's groundwater source areas. The water flowing into the plant is monitored and no eroded

sediments have been found since its startup in 1992. The seepage at the lattice-timber bulkhead has remained clear with no suspended sediments visible, which indicates that the backfill and cobble material placed upstream of the two timber-lattice bulkheads is functioning as a good filter. The sludge is material produced by the Leadville Water Treatment Plant as a result of chemical reaction of sodium hydroxide reagent which is blended with the mine water. The chemical reaction forms a precipitate which is referred to as "sludge".

Comment 12. "Results of Geotechnical and Structural Analysis, Leadville Mine Drainage Tunnel"

Page 4. The last sentence of the paragraph under "Description" touches on one of my main concerns which is the potential collapse of the concrete tunnel liner downstream of the bulkheads and the potential for sinkhole formation. One of the figures included is a photograph of the partially CaCO3 filled weep holes and stalactites forming along the crown. The deposition is apparently occurring rather rapidly yet there is no indication in the documents that any type of inspection and response plan is either in place or proposed. I am under the impression that inspections tend to occur at irregular intervals with no set plan in place.

Based on the Risk Assessment's conclusions and recommendations, Reclamation has instituted a more detailed periodic LMDT monitoring program that includes the interior of the concrete tunnel section. Section 2.12, p. 54 of The Existing Condition Report recommended that these weep holes be cleaned out in (Inspection March 25, 2008). Reclamation is planning to do so. The water level at the lattice-timber bulkhead has remained steady with a height of about 2½ feet since it was constructed. It is believed that the terrace gravel collects and conveys the water that doesn't flow through the bulkhead downward and toward the river. It would take a significantly higher water level/pressure to create concern about the possibility of collapse of the concrete tunnel liner.

Comment 13. After reviewing the documents, I determined that the best way to present my comments was to discuss my general concerns rather that a paragraph by paragraph discussion. My general comments are:

1. Inconsistency of information. For example, the highest head is usually stated to be 119-ft. but there are also references to the highest head being 163-ft. This is higher than the highest number used in the analysis (150-ft.). In this case, it is apparent that a conservative approach may not have been followed in all cases.

While the groundwater in the Leadville Mining District is very complicated, the Risk Assessment's three reports have attempted to clearly recap the LMDT's history and to convey the monitoring data associated with it and the Mine pool. The 163-foot head was mentioned in the Results report in the fourth paragraph on p. 9. This head value (elevation 10,150) was stated as being the highest

measured head above the tunnel invert at the monitoring well located at Station 96+44. The highest head value of 119 feet was stated in the Results report in the first paragraph under "1.3 Summary of Results" on p. 6 as being the maximum differential head across the upper blockage near the Pendery Fault, as indicated by the monitoring wells at Stations 36+77 and 46+66. As shown in the Existing Condition report, Appendix A (Cross-Section along the Leadville Mine Drainage Tunnel, 2nd figure, the water in the LMDT below the upper blockage was located at elevation 10,028.47, according to the monitoring well at Station 36+77. (The water in the LMDT above the upper blockage was located at elevation 10,144.37, according to the monitoring well at Station 46+66, which calculates to a differential head of 115.90 feet.) The Results report assumed differential heads of 100 and 150 feet to evaluate the stability of the upper blockage, and the value of 150 feet is 30 feet higher than the maximum value observed in these upper blockage monitoring wells so far – a conservative approach.

Comment 14. Numerous inconsistencies make it apparent that the documents were written by multiple writers, which is not unusual, but that no one person was responsible for bringing the documents together into a unified whole. The use of a good technical editor would result in the elimination of many of the inconsistencies noted. It is of particular concern when these inconsistencies occur in the evaluation data.

The Risk Assessment's three draft reports were written by the Risk Team members. The schedule for producing the draft reports was fairly aggressive and a technical editor was not used at that time. Reclamation plans to perform an appropriate technical review and editing on the final Risk Assessment report, which should eliminate any inconsistencies in how the rather complex data are presented.

Comment 15.

2. Ground water issues: It becomes apparent in the documents that the groundwater within and surrounding the LMDT is either not completely understood or not utilized to its fullest extent.

Information gained from the Mike Wireman Reports clarified many issues. In the Reclamation's Risk Assessment there is no unified concept of flow into or out of the LMDT or through the blockages. Inconsistencies in their discussions concerning the role of the Pendry fault vary from it being a flow path to a semi-impermeable boundary. Inflow quantities from fracture zones within the Parting quartzite vary from one document to another, inflow being high within the background document to low to nonexistent in the technical analysis document. The potential drainage of the mine pool into the glacial deposits is of particular concern.

The documents indicate that this may be a good thing because it serves as an additional safety factor to reduce the driving force when looking at a potential "blowout" of the tunnel blockages.

EPA's report by Mike Wireman conveys a lot of information about the groundwater around the Leadville Mining District, primarily the groundwater found below OU6. There remains considerable uncertainty regarding the amounts of water flowing into and out of the LMDT and through the upper blockage near the Pendery Fault. It appears that more water flows parallel to the fault than across the Pendery Fault, except for areas where the fault has been penetrated by mine workings. This has been discussed more thoroughly in Reclamation's earlier responses to USACE comments in this document. These flow quantities are not a critical aspect of the analysis of the stabilities of the upper and/or lower LMDT collapse blockages or the potential for sudden, catastrophic release of the Mine Pool out the LMDT Portal, which was the primary focus of Reclamation's Risk Assessment. While Reclamation has stated that it is uncertain as to the maximum elevation to which the Mine Pool may rise, the historic (pre-LMDT) maximum elevation of the Mine Pool in the vicinity of the Robert Emmet Shaft appears to have been about 10,160. Reclamation believes this may be due to the ability of the terrace gravel deposit to drain away Mine Pool water that might otherwise rise above elevation 10,160, thereby creating a greater head differential across the Pendery Fault. Reclamation agrees that limiting the differential head across the Pendery Fault, controlling the potential for a "blowout" of the upper blockage, is a good thing.

Comment 16. The potential for destabilization of the hillside is dismissed by assuming that the flow of the escaping mine pool is toward the river and that the distribution of the water within the surrounding soil/glacial deposits is relatively uniform. These are unsupported assumptions. There is no discussion of the metal loading in the water flow through the LMDT that could contaminate material surrounding the LMDT.

The results of Reclamation's stability analyses are presented in the Results report and they conservatively indicate little to no potential for static or seismic slope instability of the LMDT Portal hillside. Beyond the LMDT water removed by the well at Station 10+25 and flowing through the lattice-timber bulkhead at Station 4+61, none of the remaining groundwater has exited as seeps on the hillside or along its toe during the 16 years since the concrete lined tunnel and the water treatment plant were completed in 1992. The other monitoring well water levels around the LMDT Portal also show this groundwater situation is under control – this is not an assumption. While the glacial moraine material around the LMDT may have become contaminated by groundwater flow, this may have existed before the tunnel was constructed, and it may still be occurring. However, that potential concern was not included as a task in Reclamation's Risk Assessment as has been noted earlier in this response document.

Comment 17. There is limited discussion of potential seepage and or piping issues. They do state that no seepage or piping was noted during an inspection but there is no indication that these inspections occur on a regular basis.

This response document has already addressed the USACE's seepage and piping comments. Based on the Risk Assessment's conclusions and recommendations, Reclamation has instituted a more detailed periodic LMDT monitoring program.

Comment 18. Assumptions: While most of the assumptions used appear conservative, some are not. The assumptions I am most uncomfortable with are:

There was no data directly applicable to the site used in the analyses. Apparently the rock within the tunnel was never tested so typical values for that rock type were used. At least some of these estimates need to be confirmed by actual testing of the rock types at the site.

Reclamation recognizes the lack of measured engineering properties for the rock and soil materials associated with the LMDT. Reclamation believes that it has appropriately and conservatively characterized these materials based on the geologic and geotechnical site information available. The lack of access to obtain suitable samples of the rock materials would require time and money to perform the sampling and testing program. Given the perception of potentially imminent failure and the subsequent public concern, Reclamation determined that the public would be best served by rapidly determining the potential risk and concluded the only feasible alternative was to evaluate the tunnel using a range of strength values and multiple layers of conservative assumptions to overcome the lack of site specific information. Given the Risk Assessment results, actual testing of rock (and soil) materials from the site does not appear warranted. The CRB accepted Reclamation's position on this concern.

Comment 19. The actual volume and configuration of the existing blockage of the tunnel is unknown. Some of the analyses used the assumption that quite a bit of the blockage was continuous in length and filled the tunnel from floor to crown which is not a conservative approach. The document discussing the results of the analysis states this directly on page 11, first paragraph of Section 1.3. There is also a statement of page 20 that the extent of the consolidation grouting that was performed is unknown because of missing records.

Reclamation recognizes the uncertainty associated with the upper collapse blockage near the Pendery Fault. The resulting conservative approach was to assume the unlikely event that the blockage failed catastrophically. This conservative assumption was carried forward to all other failure modes analyzed. Catastrophic failure of the blockage would likely greatly increase the pressure in the water-filled tunnel below the blockage. Since the upper collapse

blockage still exists and impounds the Mine Pool, Reclamation's Results report in Section 2.1.3 discusses the likely situation at this upper collapse blockage. Reclamation also recognizes the uncertainty associated with the lower blockage near the LMDT Portal. The Results report statement about the uncertainty regarding the consolidation grouting on page 20 is associated with the remedial measures constructed in 1978-80 below the LMDT's lower collapse blockage.

Comment 20. The assumptions concerning slope failure are unclear but seem to include gradient with no reference to how this was determined. The document gives the general impression that slope failure was not seriously considered.

Figure 7 in the Results report on p. 19 shows the groundwater table indicated by the monitoring wells installed in 1968. The configuration of that groundwater table generally follows the interface between the terrace gravel and the overlying glacial moraine, as well as the ground surface above. The slope stability analyses assumed various groundwater elevations at the well at Station 10+25 and then assumed the groundwater surface sloped toward the river generally following the historic groundwater table noted in 1968. As a conservative assumption, the maximum (worst case) groundwater surface was only a few feet below the sloping ground surface above the tunnel. Results report Section 2.5 presents "Stability of Hillside in Vicinity of Portal", including the material assumptions, piezometric levels assumed (see Table 13), and the stability factor of safety results in Table 14. The lowest static factor of safety, assuming the weakest soil material properties, is a factor of safety of 1.54, which Reclamation considers to be adequate. Only the extremely conservative seismic pseudo-static analysis that assumed the weakest soil material properties and a 0.35g earthquake loading produced a factor of safety below 1.0.

Comment 21. Seismicity is dismissed as of no consequence but the analysis parameters did not include the duration or the range of durations that were used for the analysis. This information needs to be included in the document.

The pseudo-static seismic stability analysis and the empirical correlations between yield acceleration and deformation used to estimate the likely maximum amount of movement (less than one inch) as discussed on p. 43 of the Results report do not involve the duration of earthquake shaking when performing the calculations.

Comment 22. In the conclusions for the analysis document, the third paragraph states that the surrounding terrace gravels would serve to attenuate rising groundwater levels but there is no mention on what effects this would have on the surrounding slopes. It would also be wise to perform a seepage analysis as part of the risk assessment. It would also be important to know the metal loading of the potential seep water.

When Reclamation has turned off the well pump at Station 10+25 for maintenance, the water level has risen to as much as 70 feet above the LMDT invert. During such situations, the level of the water flowing through the lattice-timber bulkhead at Station 4+61 has remained at approximately 2.5 feet above tunnel invert. This information appears to indicate the terrace gravel deposit is capable of handling the seepage flow caused by much higher groundwater levels. The overlying glacial moraine deposit helps to confine the groundwater seepage to remain within the terrace gravel, which must convey it toward the river. The monitoring wells around the LMDT Portal are instrumented and Reclamation would be alerted to a higher groundwater table that might adversely affect the slope stability. A seepage analysis would not refine these groundwater table observations to any great degree. The metals content of the groundwater around the LMDT Portal has already been discussed in this document.

Comment 23. I feel it unlikely that a catastrophic failure would send water and rock shooting out of the portal but it is highly likely that portions of the tunnel will continue to fail. The risk analysis is addressing static conditions but this is a dynamic condition which will change over time. I was disappointed to see that there was no discussion of periodic inspections included as part of the document.

Reclamation agrees that a catastrophic failure with water and rock shooting out of the portal is unlikely. Reclamation agrees that in the future, the condition of the LMDT, the elevation of the Mine Pool, and groundwater levels around the LMDT in general may change. Reclamation believes that collapses in the LMDT and in the mine workings will continue to occur. However, Reclamation believes that such collapses, especially in the LMDT, would help limit flows to the downstream tunnel reaches from the Mine Pool, even if a blockage near the Pendery Fault were to breach. Reclamation has instituted a more detailed periodic LMDT monitoring program.

United States Environmental Protection Agency Comments

Comment 1. The Reclamation Risk Assessment calls for: 1) increased monitoring of water pressure in the tunnel and the hillside soils, 2) connecting water pressure monitoring equipment to the existing Early Warning System, and 3) updating Reclamations's Emergency Action Plan.

EPA supports these recommendations and their implementation.

No response required

Comment 2. The Risk Assessment also provides lists of "possible actions to be considered during future risk mitigation activities." Included in this list is the installation of permanent plugs in the tunnel.

> EPA supports the installation of permanent plugs in the tunnel as well as back filling the first 2000 feet of the tunnel. This would: 1) permanently stabilize the LMDT; 2) ensure that residents and property at the mouth of the tunnel are protected from release; 3) minimize contamination of the Arkansas River water supply and fishery; and 4) protect EPA's restoration work along the Upper Arkansas River.

No response required

Comment 3. The models used by Reclamation for the Risk Assessment are generally accepted, used by the Industry, and considered appropriate for discerning initial site conditions. However, given the unstable and changing nature of conditions in the LMDT, the use of a more dynamic approach, as well as the use of a probabilistic analysis, would greatly improve the confidence level concerning the findings.

Reclamation believes mine pool levels are reaching their maximum height. Reclamation also believes it is unlikely continued deterioration of the LMDT and other tunnels in the mining district will have an adverse impact on tunnel stability in the lower portion of the LMDT. Reclamation feels attempts to take a more dynamic approach to risk assessment are unwarranted. Additionally, Reclamation believes a probabilistic analysis would be misleading in this case. Reclamation has significant experience in probabilistic risk analysis and believes there must be a large database of similar structural evaluations and experience with their failures for probabilistic analysis to have meaning. No such data base exists.

Comment 4. The Risk Assessment may adequately address conditions in the tunnel as they now exist. However, it does not consider that conditions within the tunnel will worsen with time. There is a significant likelihood that more collapses and dams will form in the tunnel to the point that it will not be effective in conveying water to the tunnel portal.

Reclamation agrees that additional collapses are likely to occur in the future but believes that this would reduce the risks of a sudden release of water from the tunnel which was the focus of this assessment.

Comment 5. The Risk Assessment does not adequately consider the potential for the dewatering well at 10+25 to be damaged or become non-operational by hydraulic pressure associated with a failure of the upper blockage (near the Pendery fault). Failure of the 10+25 dewatering well would reduce the ability to manage tunnel water should the upper blockage fail.

Reclamation agrees and acknowledged that failure of the upper blockage could render the dewatering wells at 10+25 inoperable (see conclusions on page 45 of the Results of Geotechical and Structural Analysis). Even if this were to occur, Reclamation found the risk of a sudden release of water from the mine pool to be extremely low.

Comment 6. The Risk Assessment in general underestimates the volume of groundwater entering the tunnel above the Pendery fault. It also incorrectly assumes that the water levels will stop rising when the bedrock/glacial sediment boundary is reached, should the upper blockage fail and cause water levels to rise.

Reclamation did not attempt to quantify the volume of groundwater entering or existing in the mine pool. Although these volumes were taken by reference from other documents and not verified, Reclamation does not believe they relate to the risk of a sudden release of water from the mine pool.

Reclamation did recognize that water level in the lower portion of the tunnel is likely to rise above the bedrock/glacial sediment if the upper blockage were to fail. Refer to the conclusions section of the Results of Geotechnical and Structural Analysis Report that states, **"If the blockage near the Pendary Fault were to fail,……..The well at Station 6+35 is likely to also to experience artesian flow. The artesian flow condition at one or possibly two wells could last for a significant period of time (days to weeks) until the head in the mine pool is lowered".**

Reclamation does not know precisely the maximum potential mine pool elevation, but believes the control on this elevation (assuming upper blockage remains in place) may be the geologic contact between pervious zones in the bedrock and the overlying gravels. The rate of rise of the mine pool would be limited by the gravel's large water carrying capacity and by the fact that some shafts will experience artesian flow. Source Water Consulting has noted that seeps and flow from shafts begin in California Gulch when the water level in the LMDT mine pool reaches an elevation of 10,147. The Bureau of Mines previously suggested that a water elevation of 10,160 may be the maximum based upon this level being measured in the Pyrenees shaft prior to the excavation of the LMDT. It is believed that present water levels are near the maximum likely to occur as the hydrologic system is able to overflow out of the top of the mine pool. Placing an exact value on this elevation is not essential given the finding that the lower plug and bulkheads can resist considerably higher water levels, and the historic evidence that the upper limit is somewhere near elevation 10,160.

Comment 7. The Risk Assessment concluded that there was a low risk of adverse impacts if the upper blockage failed. This was based on the assumption that the tunnel, the Reclamation timber-lattice bulkheads, and the glacial till surrounding the lower reaches of the tunnel would effectively contain and diffuse the water released from the upper tunnel. However, this assumption can not be proven and was not based on site specific data. There is no test data to determine if the glacial till could handle the large inflow of ground water if the upper blockage failed.

Although no specific data regarding the ability of the till to transmit water was available, Reclamation disagrees that specific data was not used. The amount of cover (glacial till) above the tunnel was examined and determined to be capable of withstanding the pressures that would result if the upper blockage were to fail.

Comment 8. The Reclamation Risk Assessment concludes that a blockage length of 55 feet would be required to resist the force required for movement, given a differential hydraulic head of 120 feet (currently at 119 feet). It is impossible to determine the length of the collapse zone below the Pendery fault – there is no sound basis for estimating the length. This significantly constrains the certainty of the conclusions reached in the Risk Assessment.

The assessment states,* "The actual length of collapsed material forming a flow blockage is not known, as the differential head increases, the length of blockage required to resist movement increases. However, given that about 40 timber sets exhibiting dry rot were not replaced, the length of collapsed tunnel could easily approach 80 or more feet". *This being said, we disagree that* "This significantly constrains the certainty of the conclusions reached in the Risk Assessment". *Reclamation concluded that even if this upper blockage fails that a sudden release of water from the mine pool is highly unlikely.