# APPENDIX B

# ALTERNATIVE SCREENING AND CLEAN WATER ACT SECTION 404(B)(1) ALTERNATIVE ANALYSIS

# ALTERNATIVES SCREENING AND CLEAN WATER ACT SECTION 404(b)(1) ALTERNATIVES ANALYSIS

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# ASARCO LLC RAY MINE PROPOSED TAILINGS STORAGE FACILITY

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# 1. INTRODUCTION

## 1.1. DOCUMENT PURPOSE AND ORGANIZATION

ASARCO LLC (Asarco or the Applicant) has identified the need for additional tailings storage to support ongoing mining operations at the Ray Mine in Pinal County, Arizona (***Figure 1***). The construction of a tailings storage facility (the Project) will require the discharge of fill material to surface drainage features that are considered waters of the United States (waters of the U.S. or waters) by the U.S. Army Corps of Engineers (Corps).

An analysis of alternatives is required by the Corps and the U.S. Environmental Protection Agency (EPA) to demonstrate compliance with guidelines established under the Clean Water Act (CWA) Section 404(b)(1) (40 C.F.R. Part 230) (the Guidelines) for the avoidance and minimization of impacts to jurisdictional waters. The alternatives analysis is intended to ensure that no discharge is permitted "if there is a practicable alternative to the proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences" (40 C.F.R. § 230.10(a)). An alternative is deemed practicable if it is "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes" (40 C.F.R. § 230.10(a)(2)). The National Environmental Policy Act (NEPA) also requires a discussion of alternatives (40 C.F.R. § 1502.14). The Corps is preparing an Environmental Impact Statement (EIS) under NEPA as part of its review of Asarco's application for a Section 404 permit for impacts to waters of the U.S. associated with the Project. The analysis contained herein will inform the development of alternatives for the EIS for the Project. NEPA policy directs that federal agencies should identify and assess reasonable alternatives to the proposed action (40 C.F.R. § 1500.2(e)). The Council on Environmental Quality identifies *reasonable* alternatives as "those that are practical or feasible from the technical and economic standpoint and using common sense" (CEQ 1981). In the context of both NEPA and the CWA Section 404(b)(1) requirements, this alternatives analysis identifies the range of reasonable alternatives to be considered in the Corps' NEPA analysis of the proposed project. The screening provided in this analysis identifies alternatives that are practicable and brought forward for analysis in the EIS. Other alternatives evaluated herein that are not considered practicable will not be analyzed in detail in the EIS.

While the Corps is required to select the least environmentally damaging practicable alternative (LEDPA) which as described above is normally based on impacts to the aquatic system, it must also consider other consequences of its action when making a determination of LEDPA. Even where a practicable alternative exists that would have less adverse impact on the aquatic ecosystem, the Guidelines allow it to be rejected if it would have "other significant adverse environmental consequences" 40 CFR 230.10(a). In practice, these factors can be identified in the 404(b)(1) alternatives analysis as well as in the NEPA document utilized by the Corps to evaluate the consequences of its action (issuance of a CWA Section 404 permit) on the human environment. A preliminary evaluation of other environmental factors that may affect the Corps identification of the LEDPA is included in this 404(b)(1) alternatives analysis. The Corps will consider these and other factors in its NEPA analysis to make its final determination of the LEDPA.

Tailings disposal and storage options evaluated in detail in this document include conventional tailings disposal or slurry deposition and dewatered tailings disposal ("dry-stack" tailings). Six (6) potential tailings storage facility (TSF) locations are analyzed in detail in this document; 3 different configurations are analyzed within one of the locations and 2 different configurations at another location, for a total of 9 conventional tailings alternatives. The practicability of each alternative (in terms of cost, technology, and logistics) is evaluated. The expected impacts to potential jurisdictional waters for each alternative are presented, the LEDPA for the Project that fulfills the Project purpose is identified, and other adverse environmental consequences are discussed for each practicable alternative.

This alternatives analysis is presented in 8 sections:

**Section 1: Introduction.** This section includes background information, a description of the purpose and need for the Project, and a description of the proposed Project.

**Section 2: Initial Screening Analysis and Formulation of Alternatives for Practicability Analysis.** This section describes the initial screening process that was used to determine which potential TSF locations would be evaluated (including a discussion of how alternatives that are clearly not feasible or do not meet the project purpose and need were eliminated from further consideration) and provides a description of the general approach taken in formulating alternatives that meet the Applicant's project purpose.

**Section 3: Identification of Evaluation Criteria.** This section identifies the practicability criteria used in the analysis. It also describes how impacts to aquatic ecosystems will be assessed for each practicable alternative and briefly identifies the types of other potential adverse environmental consequences that will be evaluated when considering practicable alternatives.

**Section 4: Description of Alternatives and Practicability Analysis for Each Alternative.** This section provides a description of each alternative that survived the initial screening process and presents an evaluation of the practicability of those alternatives.

**Section 5: Practicable Alternatives – Identification of Impacts to Waters of the U.S. and Other Adverse Environmental Consequences.** This section provides a discussion of the impact of each practicable alternative on the aquatic ecosystem and identifies other adverse environmental consequences potentially associated with each practicable alternative. The LEDPA is identified in this section.

**Section 6: Ripsey Wash Alternative 3 Project Element Alternatives Analysis.** This section evaluates alternatives for the realignment of the Florence-Kelvin Highway and the tailings delivery and reclaim water pipelines that would be associated with Ripsey Wash Alternative 3.

**Section 7: Summary.** This section provides a summary of the alternatives analysis and the basis for the identification of the LEDPA and the NEPA-preferred alternative.

**Section 8: References**. This section lists the references that are cited in the analysis.

## 1.2. PROJECT HISTORY AND BACKGROUND

Asarco is the owner and operator of the Ray Mine in Pinal County, Arizona, a copper mine with an onsite concentrator and leaching facilities. Asarco also owns associated concentrating and smelting facilities located in Hayden, Gila County, Arizona.

The Ray Mine was founded by Ray Copper Company in 1882. Originally, silver was mined at Ray, with the mining of copper beginning somewhat later. The Ray Mine facilities closed during the Depression, but reopened in 1937, operating under the ownership of Kennecott Copper. The Ray open pit was established in 1947, and continuous open pit mining operations have been ongoing since. Asarco purchased the Ray Mine and Kennecott's associated facilities in Hayden from Kennecott Copper in 1986 and constructed the Ray Mine Concentrator and Elder Gulch Tailings Impoundment in 1992. A CWA Section 404 permit was issued for the construction of the Elder Gulch tailings impoundment in 1991; modifications to that permit were issued in 1996, 1997, and 1998 for ongoing mining and mitigation activities.

In May 2011, a new Section 404 permit was obtained that authorizes: (1) continued operation and expansion of the Elder Gulch tailings facility to the height (2,590 feet) authorized in the facility's original aquifer protection permit (APP) issued on September 25, 1991, by the State of Arizona; (2) construction of a stormwater diversion system upgradient of the tailings facility, as required by the facility's APP and the original 1991 Section 404 permit; and (3) continued placement of rock into rock deposition areas previously authorized in the 1991 Section 404 permit (as modified by the subsequent amendments). Prior to the May 2011 Section 404 permit that authorized expansion of the Elder Gulch impoundment, that facility was expected to reach capacity in approximately 2013. Raising the crest elevation of the impoundment to the 2,590-foot level authorized in the Elder Gulch APP, as authorized by the May 2011 Section 404 permit, will allow the existing Elder Gulch tailings impoundment to be used for an anticipated 5 to 7 additional years. The Ray Mine has mineral resources that will allow mining to continue well past that timeframe, and any substantial expansion of the Elder Gulch facility is not feasible because the safety and stability of the Elder Gulch facility would be compromised.

The Ray Mine is one of the largest sources of copper production in Arizona. Current world copper demand averages approximately 5 pounds (2.2 kilograms) of copper per capita per year (Snider 2010), requiring approximately 15.9 million tons of production each year worldwide. Demand for copper, and commodity resources in general, has recently been driven primarily by the growth of the middle class in developing countries such as Brazil, Russia, India, and China, as well as Mexico and South Korea. The rate of growth in developing countries has been nearly 3 times that in developed countries (Grantham 2011), leading to predictions that the increase in per capita consumption over the next 20 years (Snider 2010) will require the production of between 36.6 and 42.1 million tons of copper per year, an increase of 2.3 to 2.65 times current production, More recent predictions are consistent: in a long-term outlook analysis conducted in September 2016, total annual copper consumption is estimated between 35 and 40 million tons by 2035 (Wood Mackenzie 2016). Despite higher production yields from new technologies, the extensive time involved in developing new mines, including exploration, environmental impact studies, and permitting, requires the full utilization of known resources in existing mines to help meet the predicted global demand.

Currently, sulfide ore from the Ray Mine is processed and milled at 2 different facilities, the onsite Ray Concentrator and the offsite Hayden Concentrator located approximately 20 miles away. For planning purposes, the amount of tailings storage required is estimated to be the amount of sulfide ore resource that would be processed through the life of mine (850 million tons; ***Table 1***). [1]

The Elder Gulch facility at the Ray Mine has the capacity to accept approximately 100 million more dry tons of tailings before it reaches capacity. The Hayden tailings facilities have approximately 200 million tons of remaining capacity. This leaves a need for approximately 550 million dry tons of additional tailings storage capacity based on current projections of ore resources (***Table 1***).

Considering the trends of the past 40 years, which generally have allowed for lower cost recovery of ore and thus have resulted in an increase in resources by allowing lower grade ore to be processed profitably, considering that the resource at Ray has not yet been fully defined, [2] and considering the world copper demand as discussed above, it is reasonable and prudent to predict that additional resources will be delineated at the Ray Mine and that additional tailings storage capacity will be required. In addition, a tailings facility generally requires the construction of a starter dam or embankment using rock as an initial step prior to tailings deposition. In order to allow for possible additional resources identified in the future, and to account for starter dam or embankment construction, the Applicant has estimated for the purposes of this analysis that the new TSF would need to accommodate an additional 200 million dry tons of material, for a total capacity of roughly 750 million tons. ***Table 1*** summarizes the need for tailings storage capacity for the Ray Mine and ***Exhibit 1*** shows the Ray Mine resource curve based on current mining practices and the price of copper.

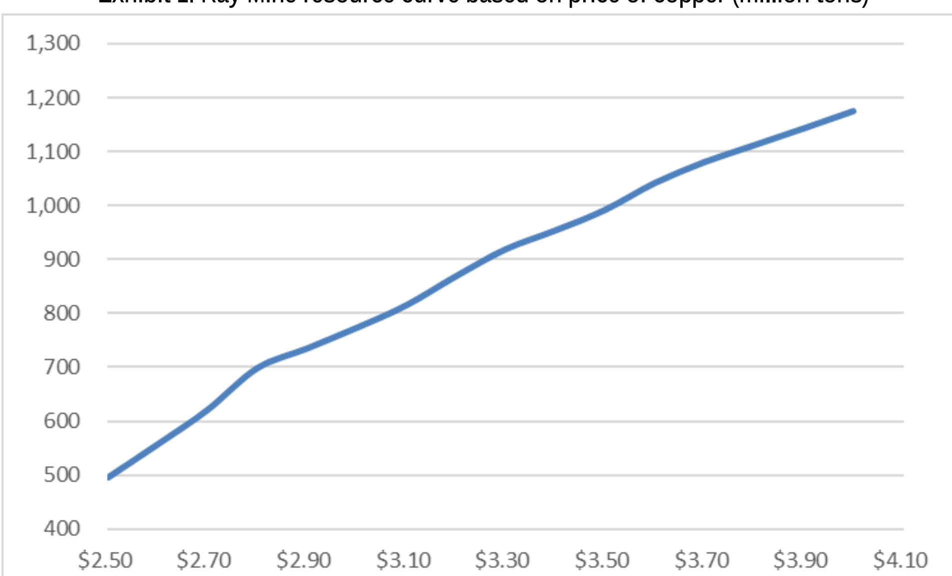
1 The milling of approximately 850 million tons of sulfide ore is anticipated to result in the production of approximately 850 million dry tons of tailings, less the minerals extracted (less than 1 percent of total).

2 The resource at the Ray Mine has not been fully defined at depth or in the northern portions of the pit (comm. James Stewart, ASARCO LLC)

Table 1. Future tailings storage capacity needs for the Ray Mine

| Storage Requirement | Amount (million tons) |
|---|---|
| **Total Estimated Sulfide Ore Resource**:<br>Key Points:<br>1. Based on a $3.20 price of copper (consistent with long term price projections).<br>2. Not based on the rate of mining.<br>3. $3.20 was the price of copper at the time of application.<br>4. The long-term plan for mining is based on reasonable and prudent copper price projections, not short-term fluctuations in copper prices. | **850** |
| Remaining tailings storage capacity at Elder Gulch (100M tons) and Hayden (200M tons) | (300) |
| **Additional Tailings Storage Capacity Needed Based on Current Projections and Resource Identification** | **550** |
| Contingency of 200 million tons is added for changed market conditions, identification of additional resource through future drilling, and/or future technologies for mining and to account for the starter dam and embankment construction. This is a reasonable and prudent estimate because:<br>1. Long term projections for copper are higher than $3.20. (Wood Mackenzie 2016)<br>2. Extent of resource has not been fully explored or defined, even at $3.20 copper.<br>3. Even a modestly higher long-term price significantly increases the identified resource. For example, the resource identified at $3.50 copper is 985 million tons (See **Exhibit 1**). | 200 |
| **Total Capacity Requirement** | **750** |

Exhibit 1. Ray Mine resource curve based on price of copper (million tons)




Source: ASARCO LLC

The resource-based life of the Ray Mine is a function of:

1. Resource definition of 850 million tons (with 200 million tons of contingency)
2. Mill capacity and production
   a. Design capacity of the Ray Concentrator is 45,000 tpd

b. The current average mill production is 30,000 tpd, which is a result of rock characteristics and other operational considerations.

Subject to changes based on economics, technology, and new identification of resource, the resource-based life of mine is estimated to be between 45.6 years at 45,000 tpd and 68.5 years at 30,000 tpd.

### 1.3. Purpose and Need for the Project

The Applicant's purpose and need for the Project is to create additional tailings storage for up to approximately 750 million tons of mill tailings produced by the Ray Mine Concentrator and starter dam and embankment material. This capacity is required to allow for the full utilization of the identified sulfide mineral resource at the Ray Mine.[3]

The Applicant's basic project purpose is mine tailings storage, which is not water-dependent.[4] The Applicant's overall project purpose is the development of tailings storage capacity that will allow the full utilization of the identified sulfide mineral resource at the Ray Mine, using infrastructure and processes already in existence at the mine.[5] The Corps has identified the overall project purpose as being to create additional tailings storage to support up to approximately 750 million tons of material.

## 2. INITIAL SCREENING ANALYSIS AND FORMULATION OF ALTERNATIVES FOR PRACTICABILITY ANALYSIS

This section describes the initial screening process used to identify potential TSF locations and eliminate alternatives from further evaluation if they were obviously not feasible or did not meet Asarco's purpose and need.

### 2.1. Initial Screening Process – Tailings Placement Technologies and Storage Options

The purpose of the initial screening process is to eliminate an alternative if it is clearly not feasible or does not meet Asarco's purpose and need for tailings storage.

Initially, various tailings placement technologies and storage options were evaluated. The identification of feasible placement technologies helps determine potential TSF locations.

[3] The Ray Mine also produces oxide ore, from which copper is extracted through leaching rather than milling and smelting. The production of copper from oxide ore through leaching does not result in the generation of tailings.

[4] As a general rule, the basic purpose of the project must be known to determine if the project is water-dependent (i.e., requires access to, or siting within, a special aquatic site in order to fulfill its basic purpose). If a proposed project is not water-dependent and would impact a special aquatic site (e.g., a wetland), then there is a strong regulatory presumption that practicable alternatives that do not involve special aquatic sites are available, and that such alternatives have less adverse impact on the aquatic ecosystem. 40 C.F.R. § 230.10(a)(3); Army Corps of Engineers Standard Operating Procedures for the Regulatory Program, p. 15 (July 2009).

[5] See U.S. Army Corps of Engineers Standard Operating Procedures (SOP) for the Regulatory Program, p. 15 (July 2009). The Corps SOP states that "the overall project purpose is used to evaluate less environmentally damaging practicable alternatives" and "must be specific enough to define the applicant's needs, but not so restrictive as to constrain the range of alternatives that must be considered under the 404(b)(1) guidelines."

Tailings placement and storage options considered as part of this screening included:

1. Conventional tailings placement – slurry deposition (as currently used by the Ray Mine);
2. Dewatered tailings placement ("dry-stack" tailings);
3. In-pit placement and storage of tailings at the Ray Mine;
4. Underground placement and storage of tailings;
5. Placement and storage of tailings at multiple sites; and,
6. Offsite shipment and processing of ore material, with remote tailings storage.

#### 2.1.1. Conventional Tailings Placement – Slurry Deposition

Asarco has proposed this method of tailings placement, so it will be considered as the proposed action in the draft EIS. The typical solids densities of Asarco tailings, after passing through a thickener, range from 40 to 50 percent. Tailings would be discharged from spigots that surround the perimeter of the tailings storage facility and a tailings "beach" would be created using thin-layer, sub-aerial deposition techniques. The tailings discharge operations would focus on directing water to the rear of the facility to allow a pool of water to form, which would be reclaimed and pumped back to the Ray Mine Concentrator. As tailings beaches are formed, spigot discharges would progress around the perimeter of the facility, and this action would promote drying and consolidation of the tailings. This method of tailings placement is considered feasible and consistent with the Applicant's purpose and need, and is the current method of tailings storage at the Ray Mine.

#### 2.1.2. Dewatered Tailings Placement

This technique is typically referred to as "dry-stack" deposition. In this process, water would be "filtered" from the tailings using a mechanical device such as a vacuum or pressure filter system. Filtered tailings would have solid densities of 80 to 90 percent, which would be too thick to pump. Therefore, these tailings would need to be transported to the tailings placement site by trucks, railroad, or a conveyor system (or conveyed as slurry and then dewatered by an entirely separate plant constructed at the tailings storage site). At the placement site, these tailings would be "dry-stacked" by placing, spreading, and compacting the materials to form a relatively unsaturated (dense) and stable stockpile. Filtered tailings would not be totally "dry," but would have a typical delivered moisture content of 10 to 20 percent. This method of tailings storage is carried forward through the initial screening and is evaluated further below in ***Section 4.1***.

#### 2.1.3. In-pit Placement and Storage of Tailings at the Ray Mine

The Ray Mine is a surface open-pit mine. ***Figure 2*** provides a cross section of the Ray Mine pit showing elevations from 2016 and life of mine under a $3.20 copper price scenario (copper price used in the determination of the purpose and need) and a $4.00 copper price scenario. Because future mining involves deepening and widening of the current pit as shown in ***Figure 2***, the placement of tailings into the pits would preclude ongoing mining at the Ray Mine. Future mining of the ore requires access to the bottom and outer edges of the pit and there are no areas within the pit that could be used for tailings storage that would not inhibit future mining. Therefore, this method of tailings placement and storage was eliminated from further consideration.

### 2.1.4. Underground Placement and Storage of Tailings

Although it is sometimes possible to place tailings into mined-out underground workings, this technique is not available at the Ray Mine, which is a surface mine. No underground workings exist at the mine. Therefore, this method of tailings placement and storage was eliminated from further consideration.

### 2.1.5. Tailings Placement at Multiple New Sites

The placement of tailings from a single concentrator at multiple new sites is sometimes feasible. An example of multiple new tailings storage sites would be at an underground mine where a portion of the tailings materials could be backfilled underground into mined-out areas. However, as explained in ***Sections 2.1.3 and 2.1.4***, this situation does not exist at the Ray Mine Concentrator.

Another example where multiple new tailings placement sites might be considered would be at a mining operation where multiple and distinct milling processes are used, such as flotation and cyanidation.[6] In this situation, an operator may choose to segregate the flotation tailings (which would typically represent the larger tailings volume) from those tailings generated in a cyanidation circuit. The operator may decide to segregate the tailings into different sites because of the different containment, control, and monitoring technology required for flotation versus cyanide tailings streams. However, because the Ray Mine Concentrator involves the singular milling process of flotation, there is no need to have separate new tailings facilities.

The other situation where an operator might choose to have multiple new tailings storage sites is when insufficient surface areas are available for a single storage facility. This is not the case at the Ray Mine, where there are several sites that would contain the total anticipated volume of tailings to be produced at the Ray Mine Concentrator. Given extensive infrastructure requirements for a tailings facility (e.g., roads, pipelines, power, pumping stations, and various environmental-management measures such as cut-off trenches, pumpback wells, and diversion structures), and the need for providing starter dam, embankment, and capping materials at multiple locations, the management of multiple facilities when compared to a single facility fails to meet the project purpose and need, and is considered logistically impracticable.

From a site selection and environmental perspective, using multiple sites for tailings storage compared to a single site can be problematic. A single facility allows the project's TSF footprint to be at one location, rather than having multiple TSF footprints dispersed over a larger area and requiring additional infrastructure at each location. Environmental effects such as impacts to waters of the U.S., visual impacts, land use compatibility, ground and surface water quality, and air quality would occur at a single location. The use of multiple, smaller sites might result in reduced environmental effects at one of those locations because of the smaller footprint; however, these effects would be spread over a much larger area when considering all the separate storage facilities. For example, there may be substantial visual impacts at a single large facility, but when you split those adverse effects over multiple locations, a much larger area

[6] Cyanidation is the main process for gold and silver recovery and is not used at the Ray Mine.

may now be subject to visual impacts compared to the single facility site. From the perspective of waters of the U.S., the multiple sites approach would likely result in disruptions in multiple watersheds, compared to impacts in a single watershed for a single facility.

Without considering economics, three alternatives, the West Dam, Hackberry Gulch, and Ripsey Wash, were specifically evaluated in a screening level analysis to provide further demonstration that the development of multiple smaller TSFs meeting the project purpose is not feasible and/or clearly would not constitute the LEDPA (***Table 2***).

Table 2. Evaluation of Multiple TSFs at West Dam, Hackberry Gulch, and Ripsey Wash

| Multiple TSF Alternative | Practicability Constraints/LEDPA Considerations |
|---|---|
| West Dam – Hackberry Gulch | As described in ***Section 4.3.2***., a smaller TSF at West Dam placed to avoid SR-177 and the existing leaching areas at the Ray Mine would require an embankment height of 1,100 ft (see ***Figure 5b*** for a cross section of a conceptually designed TSF with a capacity of approximately 640 million tons), which is not feasible given the side-hill construction that would be required. In addition, the increased embankment raise rate required by the steeper topography at West Dam may compromise the stability of the TSF.<br><br>A smaller TSF could be placed at Hackberry Gulch, but the geotechnical and geologic conditions at the Hackberry Gulch site make it likely that even a smaller facility at this site will have seepage, as described in Sections 5.1.2 and 5.2.2. In addition, the side slope construction required by the land forms at the Hackberry Gulch site and the requirement to integrate post-closure stormwater controls associated with the existing Elder Gulch TSF pose significant design, operation and maintenance challenges and increase the risk of failure at both facilities should a large, infrequent storm event occur. |
| Hackberry Gulch - Ripsey Wash | Given the constraints of the terrain, even a smaller TSF at the Ripsey Wash site would result in the same impacts to waters as the proposed alternative due to the need to locate upstream stormwater diversion detention and conveyance facilities in the same location and the resulting dewatering (loss) of downstream waters. The upgradient stormwater diversion dam is designed to use the adjacent topography, would be placed where the Ripsey Canyon narrows just downstream from the convergence of 3 drainages, and uses an existing ridgeline in the design of the dam spillway. Stormwater diversion around a smaller Ripsey Wash TSF would therefore result in dewatering any waters avoided by a smaller TSF footprint. Because the Corps considers dewatered waters to be lost, the total impact to waters of the U.S. from a smaller Ripsey Wash TSF would be the same as for a larger one, to which would have to be added the impacts from a TSF at the Hackberry site as well. This multiple TSF configuration therefore would result in even greater impacts to waters than does the applicant's proposed alternative (Ripsey Wash option 3).<br><br>Moreover, as noted above, the geotechnical and geologic conditions at the Hackberry Gulch site make it more likely that this alternative will have seepage, as described in ***Sections 5.1.2 and 5.2.2***. |
| Ripsey Wash – West Dam | As discussed above, even a smaller TSF at the Ripsey Wash site would result in the same impacts to waters as the proposed alternative due to the need to locate upstream stormwater diversion detention and conveyance facilities in the same location and the resulting dewatering (loss) of downstream waters. When impacts to waters from West Dam are added, this multiple TSF configuration therefore would result in even greater impacts to waters than does the applicant's proposed alternative (Ripsey Wash option 3).<br><br>A smaller TSF at West Dam (avoiding SR-177 and existing leaching areas) would require an embankment height of 1,100 ft, which is not feasible given the side-hill construction that would be required at West Dam. In addition, the increased embankment raise rate required by the steeper topography at West Dam may compromise the stability of the TSF.<br>Even if a smaller TSF were feasible at West Dam, the impacts to waters associated with this alternative would include impacts equal to those of the Preferred Alternative, Ripsey Wash 3, plus the impacts associated with a smaller TSF at West Dam. |

For these reasons, the management of multiple sites is eliminated from further consideration for tailings produced at the Ray Mine Concentrator.

#### 2.1.6. Offsite Shipment and Processing of All Ore, with Remote Tailings Storage

Offsite processing of the entire sulfide ore resource produced at the Ray Mine theoretically could be accomplished at the Hayden Concentrator (if a new TSF were constructed at or near Hayden), or at new milling facilities at a new location. Neither option is feasible and the exclusive use of the Hayden facilities would impact more waters of the U.S. than the practicable alternatives identified here.

As noted in ***Section 1.2***, Asarco currently sends a portion of the ore produced at the Ray Mine by rail to the Hayden Concentrator, located roughly 20 miles away. This practice is expected to continue. However, the tailings storage facilities at Hayden have only approximately 200 million tons remaining capacity. This capacity has been factored into the calculation of the necessary additional tailings storage capacity (750 million tons) needed to process the remaining identified sulfide ore resource at the Ray Mine.

Shipping all the sulfide ore from the Ray Mine to Hayden for processing was eliminated from further consideration because: (1) shutting down the Ray Mine Concentrator is not consistent with the Applicant's purpose and need to utilize existing infrastructure at the Ray Mine to process the ore produced at the Ray Mine; and (2) the remaining tailings storage capacity at Hayden is limited (roughly 200 million tons), so a new large tailings storage facility would still be required if all the ore were processed at Hayden (likely the E Dam alternative discussed in ***Section 4.2.1***), and preliminary analysis (see ***Section 4.2.2***) suggests that this facility would impact twice the amount of waters as the LEDPA identified below.

To construct new processing facilities at a different location would require Asarco to identify and secure another remote site, where the company would have to construct new off-loading facilities and an entirely new milling complex (while simultaneously mothballing an existing milling complex at the mine that is just over 20 years old) in addition to a new tailings storage facility. Since the Ray Mine is an existing operation, with existing infrastructure and milling facilities, this option was eliminated from detailed evaluation. Further, this option would not meet Asarco's purpose and need, which is to use existing infrastructure in the processing of the ore produced at Ray.

#### 2.1.7. Results of Initial Screening

Tailings placement technologies and storage options to be considered further in the alternatives analysis are:

- Conventional tailings placement– slurry deposition (proposed action); and
- Dewatered tailings placement (commonly referred to as "dry-stack" placement).

Tailings placement technologies and storage options eliminated from further consideration during the initial screening process are:

- Placement and storage of tailings within the Ray Mine open pit;
- Underground placement and storage of tailings;

- Tailings placement at multiple new sites; and
- Offsite shipment and processing of all ore, with remote tailings storage.

## 2.2. ALTERNATIVES DEVELOPMENT

Asarco has conducted numerous studies for the evaluation of tailings storage alternatives for the Ray Mine. Several of the locations considered in this analysis were initially evaluated during the permitting effort for the Elder Gulch tailings dam in 1990 (SPL 1990-4008400-RJD). AMEC Foster Wheeler Environment & Infrastructure, Inc. (AMEC), reviewed and evaluated these earlier studies, as well as additional information, and provided analysis of potential TSF locations considering the previous studies and the current design criteria for the Project (***Appendix A***).

Identifying potential alternative locations for the development of a TSF was based largely on the need for storage of up to approximately 750 million tons of material within a reasonable distance of the Ray Mine Concentrator to allow for the delivery of the tailings in an efficient manner. Generally, areas within approximately 10 miles of the mine were evaluated (although one option discussed below, E Dam, is roughly 20 miles away). Within this general area, areas excluded from consideration as potential TSF sites were the active Ray Mine operations (including expanded pits and rock deposition areas); areas with slopes that prohibit the construction and operation of a TSF; environmentally sensitive areas (e.g., the White Canyon Wilderness area); and existing residential areas, including the communities of Kelvin, Riverside, Kearny, Hayden, and Winkelman (***Figures 3a and 3b***).

A combination of slope percentage and average drainage slope percentage (the average slope of National Hydrography Database-mapped drainages in an area) were evaluated in conducting a slope analysis of the region and potential alternatives therein (***Figure 3b***). The construction of a TSF northwest of the existing Ray Mine and north of State Route (SR) 177 (Region A as shown in ***Figure 3b***) or east of the mine operations in the Dripping Spring Mountains (Regions B, C, and D as shown in ***Figure 3b***) is not practicable because of the steepness of the terrain and the lack of areas that can provide the necessary 750 million tons of tailings storage capacity. These areas have average drainage slopes of approximately 20 percent or greater and are largely dominated by slopes that are 4:1 or steeper.

Other regions evaluated (Regions E, F, and G) are located south of the Gila River and were eliminated from further evaluation as potential alternatives for a variety of reasons. Region E may provide terrain that would allow for the construction of a TSF, but it lacks existing access and the terrain between the region and the Ray Mine is very rugged (***Figure 3b***), making conveyance of the tailings by pipeline to the TSF extremely difficult. Region F is not practicable because of the steepness of the terrain and the absence of areas that can provide the necessary 750 million tons of tailings storage capacity (***Figure 3b***). Region G may provide terrain that would allow for the construction of a TSF, but it too lacks existing access and would encroach upon some of the rural communities surrounding Kearny and Riverside (***Figure 3b***).

Six (6) areas that were available and capable of supporting a 750-million-ton TSF were identified for further practicability analysis. Five (5) of the 6 alternative locations for the TSF evaluated in this analysis are in the general vicinity of the Ray Mine near Kearny, Pinal County, Arizona. One (1) site, E Dam, is located near the

Hayden Smelter Complex near Hayden, Pinal County, Arizona (***Figure 3a***). With the exception of the Devils Canyon Alternative (with a 12.5 percent average drainage slope in Devils Canyon), the alternatives evaluated in this analysis have a less than 12 percent average drainage slope, meaning that the drainages where the tailings would be deposited have an overall average slope that is less than 12 percent (***Figure 3b***).

All alternatives analyzed below are accessed via SR 177, then from secondary roads. These 6 alternative locations will be detailed and analyzed in ***Section 4*** using the criteria discussed in ***Section 3***. The 6 alternative locations to be further analyzed are as follows:

- E Dam
- West Dam
- Granite Mountain
- Devils Canyon
- Hackberry Gulch
- Ripsey Wash

# 3. CRITERIA FOR ANALYSIS OF ALTERNATIVES

The Guidelines only require analysis of practicable alternatives (45 Fed. Reg. 85336, 85339 [December 24, 1980]; U.S. Army Corps of Engineers Standard Operating Procedures (SOP) for the Regulatory Program, p. 20 [July 2009]). This section: (1) explains the criteria that will be used to determine if alternatives that survived the initial screening are practicable (i.e., available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes, see 40 C.F.R. § 230.10(a)(2)); (2) explains how impacts to the aquatic ecosystem resulting from practicable alternatives will be assessed, and (3) identifies the other types of adverse environmental consequences that are considered in evaluating each practicable alternative. Impacts to the aquatic ecosystem as well as other adverse environmental consequences are used to identify which among the practicable alternatives represent the LEDPA.

Using the criteria explained in this section, the remainder of this document will identify practicable alternatives for the new TSF (***Section 4***) and the LEDPA (***Sections 5 and 7***).

## 3.1. PRACTICABILITY CRITERIA

The Guidelines provide that "an alternative is practicable if it is available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes" (40 C.F.R. § 230.10(a)(2)). In terms of practicability, therefore, the Guidelines require consideration of the following general components when evaluating whether an alternative is practicable: (1) availability, (2) cost, (3) existing technology, (4) logistics, and (5) ability to fulfill the overall project purpose. The manner in which these general considerations translate to a particular project, and the relative significance of each consideration, will vary based on the type of project being evaluated.

For purposes of evaluating additional tailings storage to allow full utilization of the mineral resource at the Ray Mine, the following are the primary factors used to assess practicability (the bracketed language at the end of each factor description ties that factor back to 1 or more of the 5 components of practicability as set forth in the Guidelines and listed above):

1. **Availability:** The site must be available for the development of a TSF. For the purposes of this analysis, “available” is defined as owned by Asarco, privately owned and available for purchase by Asarco, state-owned and available for purchase by Asarco, or federally owned and available for development as a TSF. Also included within this factor is whether there are known and potentially developable mineral resources underlying a potential TSF location. If there are, the site may not be considered available for the development of a TSF because construction of the TSF would preclude the subsequent development of those mineral resources. The active area of the Ray Mine where the current open pits, rock deposition areas, leach facilities, Ray Mine Concentrator, Elder Gulch TSF, and general infrastructure are located was also excluded as a site for possible future tailings storage because this infrastructure is necessary for future mining activities [availability, logistics].

2. **Capacity:** The site must have sufficient capacity for the deposition of approximately 750 million tons of tailings and embankment material. The size (i.e., footprint) to capacity ratio is used to determine the efficiency of each alternative. A lower size-to-capacity ratio is an indication of a more efficient space for use as a TSF (i.e., of the ability for a designated volume of tailings to be stored in a smaller footprint) [project purpose, logistics, technology].

3. **Geologic and Hydrogeologic Characteristics:** The site must have geologic and hydrogeologic conditions that are favorable for tailings storage. For example, areas that are unstable, highly permeable, or subject to fissures are generally not favorable for tailings storage. Because Asarco is proposing conventional tailings slurry deposition, geologic and hydrogeologic conditions that limit seepage and/or facilitate the reliable control of seepage are preferred over conditions that do not limit seepage and/or facilitate the control of seepage [logistics, technology, cost].

4. **Constructability:** The site must be able to be developed in a safe and stable manner that meets the requirements of current codes, standards, and regulations described by ASTM International, the U.S. Mine Safety and Health Administration, the Geosynthetic Research Institute, the National Sanitation Federation, the American Association of State Highway and Transportation Officials, Federal Test Method Standards, the Soil Conservation Service, the Arizona Mine Inspector’s Office, and the Arizona Department of Environmental Quality. The pipeline delivery system associated with the tailings facility must be able to be constructed to allow for the delivery of tailings slurry and the return of reclaim water in a reliable, safe, and cost-effective manner. The further the distance from the concentrator, the greater the support infrastructure, transport logistics, potential for environmental effects, and energy required for tailings transport. Pipeline systems that require pumping significantly uphill (i.e., that have a significant elevation gain), that would have to traverse rough and uneven terrain, that would contain numerous low spots that could prohibit the pipeline from operating reliably, or that may be prohibitively expensive or geographically or physically constrained (i.e., through distance or terrain) may not be practicable for the transport of tailings slurry. The TSF must be placed on terrain that allows for the facility to be constructed and operated in a safe and cost-effective manner. Areas dominated by steep

terrain and floodplains could make the development and/or operation of a TSF logistically or cost prohibitive [logistics, technology, cost].

The dry-stack tailings storage method and 9 alternatives within 6 sites that would use a conventional slurry tailings method are evaluated further for practicability in ***Section 4*** based on the criteria described above. Additional discussion is also provided to specifically evaluate the dry stack storage method at 3 of the alternative sites evaluated.

## 3.2. IMPACTS TO AQUATIC ECOSYSTEM

For those alternatives determined to be practicable, an analysis of impacts to the aquatic ecosystem is provided in ***Section 5***. The Guidelines require that the practicable alternative with the least adverse impact on the aquatic ecosystem be selected, unless that alternative has other significant adverse environmental consequences (40 C.F.R. § 230.10(a)).

Estimated impacts to waters of the U.S., measured in acres of waters to be filled, are often used as a surrogate for assessing impacts to the aquatic ecosystem in the absence of a more detailed assessment of the functions and values of impacted waters. Because of the large size of any TSF and the widespread presence of (largely ephemeral) stream channels at all locations considered, all the potential alternatives would impact features that would be considered (or potentially considered) waters.

WestLand Resources, Inc. (WestLand), has evaluated approximately 5,548 acres of land in proximity to Ripsey Wash for the presence of waters. A formal Jurisdictional Determination (JD) request was submitted by WestLand on behalf of Asarco. This JD was approved by the Corps in September 2013. The JD evaluation was conducted in accordance with the joint December 2008 Corps/EPA guidance entitled *Clean Water Act Jurisdiction Following the U.S. Supreme Court's Decision in Rapanos v. United States and Carabell v. United States* (Guidance) and the June 5, 2007 *U.S. Army Corps of Engineers Jurisdictional Determination Form Instructional Guidebook* (the Guidebook) and its attachments. Analysis was based on site reconnaissance, aerial photography, and topographical maps.

At the other alternative sites, potentially jurisdictional waters delineation was conducted by aerial analysis and limited field verification utilizing the same general approach used in the approved delineation at Ripsey Wash.

The methods described above were used to estimate total acres of waters that would be affected in each alternative. Overall impacts to the aquatic ecosystem also depend on the type of water impacted. Different types of waters provide different types and/or levels of aquatic functions and values. The presence of any special aquatic sites or other features unusual in an arid environment (e.g., springs or perennial or intermittent flows) were evaluated for each practicable alternative as part of the assessment of potential adverse effects on the aquatic ecosystem. An alternative that affects fewer total acres of waters may be determined to have greater adverse impacts to the aquatic ecosystem if the alternative impacts special aquatic sites or features with persistent surface water.

### 3.3. OTHER POTENTIAL ADVERSE ENVIRONMENTAL CONSEQUENCES

For those alternatives determined to be practicable, ***Section 5*** includes a discussion of other potential adverse environmental consequences associated with the development of the alternative. Examples of such other adverse environmental consequences are potential adverse impacts to biological resources, groundwater and surface water quality, and visual resources. Seepage potential is also evaluated as part of this discussion due to potential impacts to groundwater or surface water quality. The environmental consequences associated with each practicable alternative was evaluated in the "Draft Environmental Impact Statement, Proposed Tailings Storage Facility, Ray Mine – Pinal County, Arizona" (U.S. Army Corps of Engineers 2016).

## 4. DESCRIPTION OF ALTERNATIVES AND PRACTICABILITY ANALYSIS OF EACH ALTERNATIVE

### 4.1. DRY-STACK TAILINGS

The Applicant retained AMEC (***Appendix B***) to conduct an evaluation of the feasibility of using dry-stack tailings for the new TSF at the Ray Mine, and a summary of AMEC's findings is provided here.

After production of the copper concentrate in the milling process, the resulting tailings are passed through thickeners where the pulp density (weight of solids per unit weight of slurry) is typically 40 to 50 percent. The tailings slurry produced by this traditional method is typically abrasive and of high viscosity, requiring special consideration in piping and transport. Notwithstanding the viscosity of tailings traditionally produced in copper mining, the tailings still behave as a liquid, and impoundment design, transport, and management are based on that behavior. Dry-stack disposal of tailings requires the use of filtration methods to remove additional water from the tailings before they are deposited so that they can be handled in essentially solid form.

The efficacy of dry tailings disposal methods is affected by the characteristics of the ore body (high gypsum or clay ores can make it impossible to cost effectively filter the concentrator byproduct). In addition, the need for extensive capital expenditures as well as substantially increased energy costs can make the implementation of the dry disposal method cost prohibitive. Only a small number of copper mines worldwide have implemented or proposed the practice of dewatering tailings using vacuum or pressure filters so that the tailings can then be handled as a solid material. There are no operating facilities in Arizona currently using this practice. Moreover, the dry-stack technology to date has not been demonstrated to be viable at sites with a production rate as high as the design capacity of the Ray Concentrator (45,000 tpd) (***Appendix B***). The Rosemont Copper Project in Pima County, Arizona, has proposed to use the dry-stack tailings disposal process at a site where the projected mill throughput is larger than that of the Ray Operations. Rosemont, however, will be a new facility with the flexibility to construct the concentrator adjacent to the tailings facility, which avoids many of the challenges discussed below that would exist in trying to implement this technology at the Ray Mine. The other facilities at which the dry-stack technology has been implemented or proposed were also new facilities where the concentrator and disposal sites were in close proximity. Research revealed no case in which dry-stack technology has been proposed for a conventional mill like the Ray Mine Concentrator with the additional filtration provided at a distant tailings placement site.

Given the distance of the Ray Mine Concentrator from any of the potential TSF locations and the difficulty in transporting dry material over those distances via pipeline (or by any other means, such as conveyor or truck), implementing a dry-stack tailings approach at the Ray Operations would require transporting the tailings via pipeline as conventional slurry to the TSF, followed by filtering the tailings at the TSF site at an entirely new plant that would be constructed adjacent to the TSF. This filtration would be followed by the placement of the tailings by mechanical method (likely involving the use of conveyors and heavy equipment). The water recovered in the filtration process would have to be stored in a new water retention structure prior to being pumped back to the mine complex for reuse. These considerations would necessitate the construction of significant additional facilities adjacent to the TSF and greatly increase the cost of the project (both initial construction costs and future operating costs, given the higher energy usage needed to provide further filtration at the TSF and then disposal of the resulting tailings by mechanical method).

Dry-stack tailings are placed, spread, and compacted to form an unsaturated, dense tailings stack requiring no dam for water or slurried tailings retention, and generally are expected to require a smaller footprint for tailings storage than a traditional slurry tailings facility (Davies 2011). AMEC performed a study to evaluate the potential gain in tailings density through the use of dry-stack tailings deposition for the Ray Mine (***Appendix C***). The study concluded that dry-stack tailings deposition provides an increase in density of 2.8 pounds per cubic foot versus conventional tailings. This represents an approximately 3 percent reduction in total volume, which would result in the final elevation of an ultimate dry-stack impoundment that would be approximately 3 percent less than the final elevation of the proposed slurry tailings impoundment. This reduction in elevation may result in a minor reduction in impacts to waters associated with the lower order streams that occur in the upper elevations of the proposed TSF; however, the need for stormwater diversion around the TSF would likely result in the dewatering of any such avoided waters within the upper elevation of the TSF. In addition, as described above, a dry-stack TSF would necessitate significant additional infrastructure that would not be required for a conventional TSF, thereby increasing the overall footprint of a dry-stack TSF.

Extensive earthwork would be required to keep the retention dikes to a reasonable height and result in embankment construction similar to that envisioned for conventional slurry containment. While a smaller supernatant pond would result from dry-stack technology, the potential seepage would be contained in the same fashion as conventional tailings slurry, with geologic and engineering controls. Currently, the existing TSF supernatant pond at Elder Gulch is used for the mine water balance and stores water for mill water make-up. Eliminating this storage for a new TSF would require constructing a separate water-retention structure to hold water for use in the mill system.

A dry-stack TSF at the Ray Mine is not considered practicable for the following primary reasons:

1. Historically, filtered tailing technologies have not been demonstrated to be viable for a facility with a production rate as high as the design capacity of the Ray Concentrator (45,000 tpd).
2. Substantial infrastructure at the TSF (filter plant, conveyor system, heavy equipment, water storage facility) is required to accommodate dry-stack tailings production. This would significantly increase the costs of constructing and operating a dry-stack TSF in comparison to the costs of constructing and operating a conventional slurry TSF. No existing dry-stack facilities involve the construction of filtering systems at a TSF site located miles away from a traditional concentrator, as would be required at Ray.
3. Although the area needed for tailings placement at a dry-stack TSF can be expected to be approximately 3 percent smaller than at a conventional TSF, a dry-stack TSF would require the construction of significant additional infrastructure adjacent to the TSF that would not be required at a conventional TSF. This additional infrastructure would increase the overall footprint of the dry-stack TSF to a degree where any potential trade-offs from the reduced surface disturbance for the tailings placement would be offset by the increased surface disturbance required for this infrastructure; thus, only a minimal reduction in waters of the U.S., if any, would be realized.
4. Tailings being deposited in dry stack TSF are dewatered using filter presses or vacuum technologies to moisture contents ranging from 15 to 20 percent by weight, depending on the gradation and plasticity of the material. Dust generation from dry stack tailings is a common problem, particularly in arid environments, due to the low moisture content of the placed tailings. Control of dust during transport, handling, and construction of a dry stack facility is challenging.

Dry stack tailings placement in a site-specific context is considered further in Sections 4.3, 4.6, and 4.7(as part of the discussion of the practicability of the West Dam, Hackberry Gulch, and Ripsey Wash alternatives, respectively).

## 4.2. E DAM

### 4.2.1. Alternative Description

The E Dam alternative is located near Hayden, approximately 20.3 miles from the Asarco Ray facility, on privately owned, state, and Bureau of Land Management (BLM) lands (***Figure 4***). It is on the eastern bajada of the Tortilla Mountains at an elevational range of 2,135 to 2,633 feet above mean sea level (amsl). The area of the TSF footprint is estimated at 2,363 acres.

The E Dam site differs geologically and topographically from the other sites under consideration. It is located on a gently sloping bajada extending from the Tortilla Mountains down to the Gila River near its confluence with the San Pedro River. Compared to the other sites evaluated in this document, E Dam is by far the most level, with a higher size-to-capacity ratio. Additionally, the site is underlain by fine-grained alluvial material rather than bedrock. Surface hydrology is influenced by the gently sloping nature of the site and the alluvial nature of the soil. Surface water within this alternative flows generally northeast toward the San Pedro River in a braided network of ephemeral channels that is common to alluvial fans.

This alternative requires a 20.3-mile-long tailings pipeline; 6 containment ponds along the pipeline route for the containment of tailings or reclaim water in case of pipeline failure; and an estimated 22,557 feet (4.3 miles) of diversion channel to divert upstream flows around the facility (***Figure 4***). The embankment would be constructed using a fill starter embankment for initial containment and then cyclone centerline construction, possibly transitioning to upstream construction, for the remainder of the life of the facility.

#### 4.2.2. Practicability

Development of the E Dam alternative has been determined to be logistically impracticable due to its distance from the Ray Mine as well as other constraints associated with the Project pipelines. Owing to the natural topography, the TSF embankment would have to be constructed along 3 sides of the facility, giving it the largest (i.e., least efficient) size-to-capacity ratio of any of the alternatives. The primary concern in terms of constructability is the 20.3-mile length of the tailings and reclaim water pipelines. The pipelines would be constructed alongside the Gila River for approximately 13.5 miles, passing through the towns of Kearny and Hayden. They would cross 46 washes and have many low points. In addition to being prohibitively expensive to operate, the lengthy pipelines would be much more prone to operational difficulties than a shorter pipeline. It would be necessary to construct containment ponds and booster pump stations at intervals along the length of the pipelines. A vertical lift of 720 feet would be required to deliver the tailings slurry from the thickeners at the Ray Mine to the ultimate 2,650-foot TSF crest (***Appendix A***).

Due to the length of the pipeline (the primary factor); the containment measures that would have to be put into place along it; the associated power requirements; and the overall embankment volume, this alternative is deemed to be logistically impracticable.[7]

### 4.3. WEST DAM

#### 4.3.1. Alternative Description

The West Dam alternative is located immediately west of the Ray Mine Complex, partly on Asarco lands that are currently being used for mining purposes and partly on privately owned and BLM lands (***Figure 5a***). It is situated along approximately 2 miles of the current alignment of SR 177. The footprint is at an elevational range of 2,100 to 2,979 feet amsl, and the area of the footprint is estimated at 1,333 acres (***Figure 5a and Figure 3a***). This alternative would require the rerouting of SR 177 around the TSF, necessitating the construction of approximately 7 miles of new roadway built to rural highway standards, through rough terrain, primarily on BLM land. This alternative would also interfere with operations at Ray by precluding the use of (i.e., covering) existing rock deposition and leaching areas and the 7F stormwater diversion channel, constructed in 2015 at a cost of over $11 million (comm. Duane Yantorno, ASARCO LLC) to prevent stormwater affected by mining operations from entering the 7F drainage and Mineral Creek.

[7] The E Dam alternative would result in approximately 276 acres of impacts to potential waters of the U.S., approximately 140 more acres than the proposed Ripsey Wash Alternative 3. Therefore, in addition to being impracticable, this alternative would not be the LEDPA.

The area is sited on the eastern side of the Tortilla Mountains on moderately to steeply east-dipping slopes draining into Mineral Creek, which is located approximately 0.8 mile downstream of the site. The major drainages on the site are structurally controlled and flow under SR 177 through culverts.

This alternative requires 1.6 miles of tailings pipeline (***Figure 5a***). No secondary containment ponds would be required for this pipeline because there are existing ponds at the Ray Mine at the low point of the pipeline route. West Dam requires an estimated 17,051 feet (3.2 miles) of diversion channel to divert upstream flows around the facility (***Figure 5a***).

For this alternative, the embankment would be constructed using a fill starter embankment for initial containment and then cyclone centerline construction and transitioning to upstream construction, for the remainder of the life of the facility.

#### 4.3.2. Practicability

Development of the West Dam alternative has been determined to be impracticable due to availability and logistical concerns, given that a portion of the alternative footprint is currently used as rock deposition and leaching areas and that the alternative would require the rerouting of SR 177 to develop the site. Locating this alternative to avoid SR 177 and the existing operations at the Ray Mine was not possible due to steep slopes in the areas south and west of the alternative (***Figure 5b***).

The eastern and northern portions of the footprint of this alternative would preclude the use of current rock deposition and leaching areas. Overburden, rock that does not contain economically viable levels of copper, and leachable ore are transported in large volumes by truck and thus must be placed close to the point of generation (i.e., the pit) because truck transport is expensive. The areas that would be infringed upon by the footprint of the West Dam alternative are essential for these purposes because of their proximity to the pit. The West Dam TSF embankment would extend above the leaching areas to the east (the 1 and 7 series leach dumps) by about 300 feet (***Figure 5b***). The leaching areas contain an estimated 500 million pounds of recoverable copper that would not be recoverable with the development of this alternative (comm. James Stewart, ASARCO LLC).

The West Dam site is also constrained by a drop-in topography to the south. The rockfill starter dam required for the West Dam Alternative is 342 feet, 152 feet taller than the starter dam of the Preferred Alternative at Ripsey Wash. This alternative would involve construction of an 870-foot-high embankment, exceeding the Preferred Alternative at Ripsey Wash by 245 feet. The 870-foot required height of the West Dam embankment would place it amongst the tallest tailings impoundments in the world. A listing of the current tallest tailing dam heights is presented in ***Table 3***.

Table 3. Current Tallest Tailing Dam Heights

| Site | Height | Construction Method |
|---|---|---|
| Bagdad Mammoth Dam | 750 ft | Cycloned sands, improved upstream construction |
| Thompson Creek (Bruno) | 750 ft | Cycloned sands, centerline raising |
| Antimina Dam | 787 ft | Concrete faced rockfill |
| Mauro Dam | 813 ft | Cycloned sands |

(Please note that all these facilities consist of valley fill dams. There are no side hill construction facilities that meet these heights)

It is important to recognize that these listed tall dams are valley fill dams rather than side hill construction (which would be required at the West Dam alternative), where the embankment lengths are shorter and three-dimensional corner effects on stability are not present. There are pending designs for dams approaching 985-foot (300 meter) heights, but again these are valley fill configured TSFs. Risk of failure and consequence of failure are generally increased with increased embankment heights, particularly with the side-hill construction that would be required at West Dam.

The option of avoiding the existing leaching operation and SR 177 was also evaluated, and determined to be infeasible due to the resulting requirement for an embankment that is approximately 1,100-ft in height, with accompanying stability concerns (***Figure 5b, Section B***). In addition, this alternative would not meet the capacity requirement (only approximately 640 million tons can be placed before the TSF would crest over the existing ridgeline to the west). Shifting the alignment of the West Dam TSF to the west, to avoid both the SR 177 highway and the existing leaching area, is not feasible due to the reduced storage capacity, requirement for an embankment that is approximately 1,100 ft in height (with accompanying stability concerns), and the increased embankment raise rate required by the steeper topography.

While not the principal reason for deeming this alternative impracticable, the availability of this alternative is uncertain because it would require multiple state and federal agency approvals for the realignment of SR 177, an Arizona Department of Transportation- (ADOT-) designated scenic road. Approximately 7.2 miles of 2-lane roadway realignment would be required in mountainous terrain for SR 177 as part of this alternative. This would require the approvals of multiple agencies and trigger additional approval processes, which may or may not be obtainable. Even if such approvals could be secured, relocating the State Highway would impose significant costs, estimated at a minimum of $48 million.[8]

Using the dry stack method of tailings disposal at this site would meet the same challenges as using conventional tailings slurry. A dry-stack TSF at the West Dam alternative is not considered practicable for the primary reasons discussed in ***Section 4.1***. In addition, there are site-specific factors that preclude use of a dry stack method at West Dam. The West Dam is constrained to the north and east by the mining activities at Ray, and to the south and west by steep topography and there is no reasonable place within or adjacent the site for the additional infrastructure required at the TSF (filter plant, conveyor system, heavy equipment, water storage facility). Moreover, a dry stack TSF at West Dam placed to avoid SR-177 would require embankment height that is not feasible given current technology, particularly with the side-hill construction that would be required at West Dam. The raise rate and embankment height required for this alternative are not feasible for using the dry stack method.

[8] It has been estimated by AMEC (comm. Tony Freiman), based on the terrain west of Granite Mountain where SR 177 would be relocated as part of the West Dam alternative, that the SR 177 relocation would cost approximately $48 million based on the conceptual alignment provided and a review of Arizona Department of Transportation bid tabulations of comparable projects, assuming that no unusually difficult conditions were encountered. This cost estimate is consistent with Association for the Advancement of Cost Engineering concept-level screening criteria. The actual cost based on final design could range from approximately half this estimate to twice the cost estimate provided.

## 4.4. GRANITE MOUNTAIN

### 4.4.1. Alternative Description

The Granite Mountain alternative is located approximately 2 miles west of the Ray Mine Complex at an elevational range of 2,200 to 2,885 feet amsl (***Figure 6 and Figure 3a***). It is located on privately owned and BLM lands (***Figure 6***). The disturbance area of the footprint is estimated at 1,568 acres.

Ephemeral drainages flow in a northeast-to-southwest direction across the site, ultimately discharging to the Gila River, which is located approximately 1.9 miles downstream.

This alternative requires an 8.0-mile-long tailings pipeline (***Figure 6***). An evaluation was not conducted to determine how many secondary containment ponds would be required for this pipeline because this alternative was deemed impracticable and the conceptual design was not completed. An estimated 17,744 feet (3.4 miles) of diversion channel would be required to divert upstream flows around the facility (***Figure 6***).

This alternative would be constructed using a fill starter embankment for initial containment and then cyclone centerline construction for the remainder of the facility life.

### 4.4.2. Practicability

Development of the Granite Mountain alternative is not considered practicable due to the presence of known mineral resources at the site that would be rendered unavailable for future mining should the site be developed as a TSF. Mining claims and previously proposed mine uses[9] have been identified within a large portion of this alternative (***Figure 6***). In previous studies, over 80 exploration drill holes were evaluated and approximately 115 million tons of oxide resource was identified (comm. James Stewart, ASARCO LLC). The approximate location of this resource is provided in ***Figure 6***. Locating this alternative to avoid the known mineral resource and areas required for the future mining of that resource was not possible due to the extreme topography to the east of the alternative and the location of the White Canyon Wilderness Area to the northwest of the alternative (***Figure 3b***).

This alternative's pipeline corridor would also pose some construction and operation issues due to its length (8 miles) and the mountainous terrain along the corridor. Additional pump capacity with increased energy requirements would be required for the development of this alternative.

## 4.5. DEVILS CANYON

### 4.5.1. Alternative Description

The Devils Canyon alternative is located approximately 0.6 mile north of the Ray Mine Complex. It is located on privately owned, state, and BLM lands (***Figure 7***). The facility footprint has an elevational range of 2,200 to 3,200 feet amsl, and the area of the footprint is estimated at 1,222 acres (***Figure 7***). Devils

[9] Proposed mine uses were mapped in a Mine Plan prepared in 1994 and subsequently submitted to the BLM. This mine plan has since been withdrawn and there is no current pending application for mine uses at the site. This mapping is shown merely to illustrate the location of the mineral resource and potential surrounding land uses that would be required to recover that resource.

Canyon requires 3 diversion channels totaling an estimated 53,817 feet (10.2 miles) to divert upstream flows around the facility (***Figure 7***).

This site lies within a mountainous region characterized by rugged mid-elevation peaks and hills cut by Devils Canyon. Within the site, flows are perennial and intermittent in the northwestern reach of the canyon and ephemeral in the lower reach. Special aquatic sites (wetlands) may be present. The site is located 0.2 mile upstream of the impounded surface water created by Big Box Dam at the confluence of Mineral Creek, an area that provides mitigation associated with a prior CWA Section 404 permit for Ray Mine activities.

This alternative requires a 7.6-mile-long tailings pipeline. Much of the pipeline would run through the Ray Mine, within areas that have been disturbed and are isolated from flows upstream and downstream of the Ray Operations.

This alternative would be constructed using a fill starter embankment for initial containment and then cyclone centerline construction for the remaining life of the facility.

#### 4.5.2. Practicability

Development of the Devils Canyon alternative is not considered practicable due to its proximity and potential for adverse impacts to a mitigation site covered by a restrictive covenant as well as constructability issues.

The site is located immediately upstream of an area covered by a restrictive covenant that precludes mining. This area serves as a mitigation site for past impacts authorized in a Section 404 permit (***Figure 7***). Construction and operation of a TSF immediately upstream of this area could adversely impact the mitigation site through dewatering and changes in sediment transport downstream, thereby adversely affecting the projected development of wetland and riparian habitat within the mitigation area. Therefore, this alternative is not considered logistically practicable.

The site presents additional constructability constraints. Its remoteness offers accessibility challenges; the dam would need to be constructed in a steep-walled canyon setting; the design and construction of stormwater conveyances around the facility would be difficult because of the large size of the Devils Canyon watershed (33.6 square miles); and precipitation depths are higher at this site than at the other alternatives due to orographic effects (***Appendix A***). Lastly, the required tailings transport pipeline would have to be 7.6 miles long, would require a vertical lift of 1,280 feet to the ultimate TSF crest elevation of 3,180 feet, and would have a number of low spots, making it difficult to construct and operate in a reliable and cost-effective manner (***Appendix A***).

### 4.6. HACKBERRY GULCH ALTERNATIVES

Hackberry Gulch is located southeast of the Ray Mine Complex, adjacent to the Elder Gulch tailings facility. The use of this site as shown and identified in this document would require the redesign and relocation of a diversion channel to be constructed at the closure of the Elder Gulch facility, pursuant to that facility's current Section 404 permit. Asarco and AMEC have evaluated in greater detail the design and/or feasibility of this potential alternative given its interference with the planned Elder Gulch diversion channel. Asarco and AMEC have also evaluated more generally the options for the diversion of upstream flows at this facility.

Steep slopes and deeply incised washes characterize the topography of this site.

This alternative location requires a 0.9-mile-long tailings pipeline. No additional secondary containment ponds are proposed for the pipeline because there are ponds at the existing thickener at the pipeline low point.

This analysis includes 2 designs for the Hackberry Gulch area: Hackberry Gulch Alternative 1 was the initial design; Hackberry Gulch Alternative 2 represents a refinement of the original design intended to reduce impacts to waters of the U.S. and the risk of potential seepage by creating a somewhat smaller (but higher) footprint for the impoundment. Potential issues created by raising the height of the impoundment require further analysis.

### 4.6.1. Hackberry Gulch Alternative 1

#### *4.6.1.1. Alternative Description*

Hackberry Gulch Alternative 1 is a side-hill facility using an embankment starter dam, transitioning to centerline raises using cyclone sand, and finally transitioning to upstream construction for the remainder of the impoundment operation. The Hackberry Gulch Alternative 1 TSF footprint has an elevational range of 1,900 to 2,500 feet amsl (***Figure 8***). This alternative is located mostly on privately owned and BLM lands; a very small portion of the alternative to the southwest is on State Trust land (***Figure 8***). The area of the footprint is estimated at 2,125 acres.

Hackberry Gulch Alternative 1 would require approximately 23,912 feet (4.5 miles) of diversion channel to divert upstream flows around the facility, as well as 2 retention basins designed to capture and hold water upstream of the TSF (***Figure 8***). This alternative would be constructed using a fill starter embankment for initial containment and then cyclone centerline construction for the remaining life of the facility. The upper raises of the impoundment could possibly be accomplished by upstream raises, similar to the adjacent Elder Gulch facility. The cyclone construction will utilize the coarse portion of the tailings.

The Gila River is located approximately 0.4 mile (2,000 feet) downstream of the toe of this alternative and approximately 0.1 mile (750 feet) downstream of the closest seepage collection pond.

#### *4.6.1.2. Practicability*

Hackberry Gulch Alternative 1 is considered practicable, although the development of a 750-million-ton-capacity facility would pose considerable logistical difficulties. Another alternative, Hackberry Gulch Alternative 2, discussed below, was developed at this site to reduce the footprint of the facility and expansion southward, thus reducing the potential for seepage points and impacts to potential waters.

While the Hackberry Gulch site has some favorable characteristics due to its proximity to the Ray Mine and the existing Elder Gulch tailings facility, it would be difficult to expand vertically higher at this site due to its adjacency to the current Elder Gulch embankment.

To accommodate a storage capacity of 750 million tons, the facility would have to expand laterally to the south. As the facility expands southerly, it crosses additional deeply incised wash areas in bedrock, which increases the impacts to waters as well as the potential for multiple underground seepage points. Hackberry Gulch Alternative 1 crosses 18 drainages, including 7 major drainages (***Appendix A***). Since many of these wash areas are independent of each other, it is anticipated that multiple (12) cut-offs, monitoring stations, and pumpback wells (if feasible) would need to be included in the design to try to address potential seepage concerns. Alluvial cut-offs and subsurface drains will be required to collect under-drainage and excess water from the cyclone underflow. Toe berms would control sediment erosion from the face of the dam and divert stormwater and underflow to collection ponds. The proximity of the toe of the embankment to SR 177 would require that 4 of the collection ponds be located south of the highway (***Appendix A***).

The bedding of the conglomerate within the site footprint generally dips to the southwest toward the Gila River at between 10 to 20 degrees. Studies conducted for the design of the adjacent Elder Gulch TSF revealed the presence of coarser grained, more permeable zones within the Big Dome Formation that could provide preferential pathways for seepage (***Appendix D***). Examination of exposures of the Big Dome Formation within the proposed Hackberry TSF footprint revealed similar coarse gradations. These pathways present a challenge for seepage control at the Hackberry site (***Appendix D***).

There are also numerous high-angle, northwest-striking faults within the site footprint that are potential seepage avenues. As many as 12 deeply incised channels along the downstream toe of the site will require individual cut-offs to prevent seepage from migrating toward the Gila River. Since each drainage is independent, it is anticipated that multiple cut-off walls and pumpback wells would be required to control seepage (***Appendix A***).

Paleo-channels paralleling the existing drainage pathways within the Hackberry Gulch site also present potential seepage pathways to the Gila River (***Appendix A***). The geologic environment along the facility embankment centerline, in which a mantle of colluvium overlies the conglomerate, could conceal ancestral drainages. These might prove difficult to identify without extensive investigations, and hinder the development of seepage countermeasures (***Appendix A***).

The toe of this TSF is within 500 feet of SR 177, requiring the construction of 4 seepage collection ponds on the opposite side of the highway; support facilities within the highway right-of-way (i.e., lined channels or headwalls and piping to convey collected fluids to these seepage collection points under the highway); and an overpass to provide a connection between the project activities on both sides of the highway. Based on previous conversations with ADOT, it would be very difficult to obtain authorization for this level of mining infrastructure within the SR 177 right-of-way. The inability to construct these facilities within the right-of-way would require the relocation of about 15,000 feet (2.85 miles) of SR 177. The relocated highway would cross the recently reclaimed Belgravia tailings site south of the existing highway. The relocation of SR 177 would also require the relocation of the Ray Mine water pipeline from the Hayden well field and portions of a Salt River Project 115-kV line.

This alternative would require a borrow source for the embankment in excess of the cyclone-generated sands, and the Ray Mine does not have additional volume of non-mineralized materials. Approximately

8 million tons of additional material, at a rate of up to 1.5 million tons per year, would be needed for the embankment to support the required rate of rise of the facility. This material would be excavated from within and upstream of the Hackberry Gulch impoundment footprint and/or brought in from an offsite source. Because the extra embankment material is required during Years 5 through 16.5 of the operational life (***Appendix A***), the use of a borrow source within the impoundment footprint would require the construction of a haul road around the outside perimeter of the facility.

The Hackberry Gulch alternative location would require the shortest pipeline of all the alternatives (roughly 0.9 mile), but would involve a significant elevation gain. This elevation gain means that the power needed to pump the tailings through the pipeline would be relatively high despite its short length.

The footprint of the Hackberry Gulch alternative covers the proposed location of a diversion channel to convey upgradient flows to the Gila River that Asarco is required to build at the closure of the Elder Gulch TSF under the terms of its aquifer protection permit from the State of Arizona. This channel is authorized in Corps permit SPL-1990-4008400. If a TSF were constructed in Hackberry Gulch, an alternative approach for conveying this water would be required. The tentative location of this alternative diversion would be between the Elder Gulch and Hackberry Gulch Impoundments (***Figure 8***). The diversion would require bank protection (e.g., concrete, riprap) along the full length of the drainage downstream, Belgravia Wash, to the Gila River and improvements to the Belgravia Wash drainage crossings of SR 177, the Pinal County-maintained Ray Junction Road, and the Copper Basin Railroad. An energy dissipation structure would be required at the terminus of the stormwater diversion channel at the Gila River outfall (***Figure 8***).

The control of stormwater runoff from the Hackberry Gulch TSF embankment, in a side-hill configuration where the embankment toe tends to follow a constant elevation contour, would be more challenging than the control of runoff from a valley fill TSF embankment, such as the Ripsey Wash alternatives, where the embankment toe follows a positive gradient to the seepage collection pond.

Unlike the Ripsey Wash site, which is characterized by a basin-like land form that simplifies the design and operations of stormwater management facilities, the side slope construction required by the land forms at the Hackberry Gulch site and the requirement to integrate post-closure stormwater controls associated with the existing Elder Gulch TSF pose significant design, operation and maintenance challenges and increase the risk of failure at both facilities should a large, infrequent storm event occur. The following illustrates the significant challenges associated with managing stormwater at the Hackberry Gulch site:

- The site is located in steep terrain. More than 50 percent of the site has slopes that are 25 percent or greater (**Figure 3b**). Slope analysis shows 50 percent more of the Hackberry Gulch basin lies within the extreme terrain area (30 percent to greater than 50 percent slopes) relative to the Ripsey Wash basin (AMEC 2016). By comparison, 35 percent more of the Ripsey Wash basin lies within flatter terrain characterized by slopes less than 16 percent (AMEC 2016).
- The Hackberry Gulch Diversion channel intercepts and conveys runoff around the TSF from approximately 2.5 square miles of upstream watershed area. Integration of the post-closure stormwater controls associated with the existing Elder Gulch TSF would increase this to approximately 5.1 square miles (AMEC 2016). By comparison the East Diversion channel at the

Ripsey site intercepts runoff from approximately 1.6 square miles, and stormwater flows from the Ripsey Wash watershed would be collected above the upstream diversion dam and diverted to the west via a diversion pipeline to Zelleweger Wash and ultimately the Gila River.To have a stable channel slope, 40-foot cuts and 30-foot fills will be required along the centerline increasing the channel footprint due to the daylighting of proposed channel geometry with the existing ground. In some areas, it is likely that retaining walls may be required adjacent to the Elder Gulch TSF. Up to 30% of the total channel length will be constructed on engineered fill and much of the channel will require heavy armoring to mitigate high velocity and erosive forces through steep channel reaches (AMEC 2016).

- Based on the existing terrain, conveyance of incoming runoff is extremely uncertain where incoming washes must turn sharply in order to get into the diversion channel. In some cases, flow must turn close to 90 degrees. There will be a potential that the flow would overtop these transitions and enter the TSF impoundment (AMEC 2016).
- To maintain a stable channel slope, the diversion alignment follows existing contours effectively traversing the mountain. In some locations, this requires tight radii turns where incoming washes are intercepted resulting in larger cuts and fills (AMEC 2016).
- The Hackberry diversion channel will be required to convey additional discharge from the watershed up-gradient of the Elder Gulch TSF (directly adjacent on the west) at the time of that facility's closure (i.e., at the time of the Elder Gulch TSF Closure), as required by the Aquifer Protection permit and Section 404 permit issued for the Elder Gulch TSF. This would increase channel discharges by over 30% (requiring an additional 2,300 cfs of capacity) (AMEC 2016).
- The Hackberry Gulch diversion channel/combined Elder Gulch post-closure channel must drop 640' over a length of approximately 1,900' and is limited to the corridor formed by the area between both the east Elder Gulch (west) and the Hackberry Gulch TSF facility fill slopes. This will likely require significant structural elements such as vertical walls in order to provide the necessary conveyance capacity, and the channel must be lined and the adjacent TSF facilities protected from scour/erosion hazards associated with large, combined stormwater discharge running through a steep, narrow area (AMEC 2016).

Using the dry stack method of tailings disposal at this site is not feasible for the reasons that are specific to the Ray Mine discussed in **Section 4.1**. Impacts to the aquatic ecosystem as well as other potential adverse environmental consequences of this alternative are evaluated further in ***Section 5***.

### 4.6.2. Hackberry Gulch Alternative 2

#### *4.6.2.1. Alternative Description*

Hackberry Gulch Alternative 2 was developed to reduce the expansion of the TSF in Hackberry Gulch to the south, thereby decreasing the potential for seepage points. Like Hackberry Gulch Alternative 1, Hackberry Gulch Alternative 2 is a side-hill facility using an embankment starter dam, transitioning to centerline raises using cyclone sand, and finally transitioning to upstream construction for the remainder of the impoundment operation. The upper raises of the impoundment could possibly be accomplished by upstream raises, similar to the Elder Gulch facility. The cyclone construction will utilize the coarse portion of the tailings.

The Hackberry Gulch Alternative 2 TSF footprint has an elevational range of 1,900 to 2,540 feet amsl (***Figure 9a***). This alternative is located on privately owned and BLM lands (***Figure 9a***). The area of the footprint is estimated at 1,971 acres.

Hackberry Gulch Alternative 2 would require approximately 22,071 feet (4.2 miles) of diversion channel, 9 detention basins, and approximately 11,091 feet (2.1 miles) of stormwater diversion pipeline to divert upstream flows around the facility (***Figure 9a***).

The Gila River is located approximately 0.4 mile (2,000 feet) downstream of the toe of this alternative and approximately 0.1 mile (750 feet) downstream of the closest seepage collection pond.

#### *4.6.2.2. Practicability*

The development of Hackberry Gulch Alternative 2 is considered practicable. This alternative offers the same challenges as described for Hackberry Gulch Alternative 1, except that the smaller footprint is expected to reduce somewhat the potential for seepage. Hackberry Gulch Alternative 2 crosses 16 drainages, including 6 major drainages, and would require 7 seepage collection points (***Appendix A***).

From a geologic and hydrogeologic standpoint, the site still presents significant challenges in terms of seepage control. The bedding of the conglomerate that underlies the site footprint generally dips to the southwest toward the Gila River at between 10 to 20 degrees. Studies conducted for the design of the adjacent Elder Gulch TSF revealed the presence of coarser grained, more permeable zones within the Big Dome Formation that could provide preferential pathways for seepage (***Appendix D***). Examination of exposures of the Big Dome Formation within the proposed Hackberry TSF footprint revealed the presence of similar coarse gradations. These pathways present a challenge for seepage control at the Hackberry site (***Appendix D***).

There are also numerous high-angle, northwest-striking faults within the site footprint that are potential seepage avenues. As many as 6 deeply incised channels along the downstream toe of the site will require individual cut-offs to prevent seepage from migrating toward the Gila River. Since each of these drainages is independent, it is anticipated that multiple cut-off walls and pumpback wells would be required to control seepage (***Appendix A***). Cross sections of the Hackberry Gulch Alternative 2 main embankment and TSF illustrate its side hill construction and deeply incised channels at the site (***Figure 9b***).

Paleo-channels paralleling the existing drainage pathways within the Hackberry Gulch site also present potential seepage pathways to the Gila River (***Appendix A***). The geologic environment along the facility embankment centerline, in which a mantle of colluvium overlies the conglomerate, could conceal ancestral drainages. These might prove difficult to identify without extensive investigations, and hinder the development of seepage countermeasures (***Appendix A***).

Hackberry Gulch Alternative 2 is similar in its constructability to Hackberry Gulch Alternative 1. This alternative was developed to decrease the lateral expansion of the TSF south to minimize the potential for seepage points. The starter dam length at the required 2,150-foot crest elevation is 9,700 feet versus a starter dam crest length of 3,700 feet for the preferred Ripsey Wash Alternative 3.

The embankment staging and materials mass balance analyses, using a 36 percent cyclone underflow split for the embankment sand generation, reveal a deficiency of sand in Years 4 through 16.5, requiring a borrow source to provide up to 1.5 million tons of material per year to meet embankment raise requirements (AMEC Foster Wheeler, Inc. 2015). The availability of embankment borrow within the Hackberry Gulch TSF footprint is limited in comparison to the Ripsey Wash TSF alternative. The Hackberry Gulch borrow would initially be developed from a source west of the Kane Springs drainage within the footprint of the starter dam impoundment. When the supplemental embankment material needs to be supplied beginning in Year 4, access to this borrow source would be inundated by the deposited tailings. A new borrow source outside the footprint of the Hackberry Gulch TSF would be required (AMEC Foster Wheeler Inc. 2015). The conceptual locations of these borrow sources are provided in ***Figure 9a***.

The requirement of 7 cut-off trenches, monitoring stations, and pumpback wells (if feasible) create challenges for controlling seepage (although to a lesser degree than Hackberry Gulch Alternative 1, which would require 12 such trenches and pumpback systems) and would increase the cost of construction and operation. In comparison, the Ripsey Wash Alternative 3 requires 2 cut-offs and seepage collection ponds, one downstream from the main embankment and one downstream from an eastern embankment. The Hackberry Gulch Alternative 2 main embankment is approximately 1.3 miles in length compared to the Preferred Alternative (Ripsey Wash Alternative 3) main embankment of approximately 0.7 miles in length. A comparison of the cross sections for the Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3 main embankments is shown in ***Figure 9c***.

The toe of this TSF is within 500 feet of SR 177, requiring the construction of 4 seepage collection ponds on the opposite side of the highway; support facilities within the highway right-of-way (i.e., lined channels or headwalls and piping to convey collected fluids to these seepage collection points under the highway); and an overpass to provide connection between the project activities on both sides of the highway. Based on previous conversations with ADOT, it would be very difficult to obtain authorization for this level of mining infrastructure within the SR 177 right-of-way. The inability to construct these facilities within the right-of-way would require the relocation of about 15,000 feet (2.85 miles) of SR 177. The relocated highway would cross the recently reclaimed Belgravia tailings site south of the existing highway. The relocation of SR 177 would also require the relocation of the Ray Mine water pipeline from the Hayden well field and portions of a Salt River Project 115-kV line.

As with Hackberry Gulch Alternative 1, this TSF would cover the proposed location of a diversion channel to convey upgradient flows to the Gila River that Asarco is required to build at the closure of the Elder Gulch TSF under the terms of its aquifer protection permit from the State of Arizona. If a TSF were constructed in Hackberry Gulch, an alternative approach for conveying this water would be required. The tentative location of this alternative diversion would be between the Elder Gulch and Hackberry Gulch Impoundments (***Figure 9a***). This channel would require improvements to the Belgravia Wash drainage crossings of SR 177, the Pinal County-maintained Ray Junction Road, and the Copper Basin Railroad. The necessity of this channel restricts the ultimate height of the Hackberry Gulch TSF site. An energy dissipation structure would be required at the terminus of the stormwater diversion channel at the Gila River outfall (***Figure 9a***).

The control of stormwater runoff from the Hackberry Gulch TSF embankment, in a side-hill configuration where the embankment toe tends to follow a constant elevation contour, would be more challenging than the control of runoff from a valley fill TSF embankment, such as the Ripsey Wash alternatives, where the embankment toe follows a positive gradient to the seepage collection pond. A comparison of the TSF cross sections for Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3 is provided in ***Figure 9d***.

In addition, as discussed above, construction of the required upgradient stormwater diversion channels would be complicated by the steep and rugged terrain that is immediately upgradient of the Hackberry Gulch TSF impoundment footprint and the requirement to integrate post-closure stormwater controls associated with the existing Elder Gulch TSF.

As discussed in ***Sections 4.1 and 4.6.1***, the use of the dry stack tailings method is not a feasible alternative for this site.

Impacts to the aquatic ecosystem as well as other potential adverse environmental consequences of this alternative are evaluated further in ***Section 5***.

## 4.7. RIPSEY WASH ALTERNATIVES

The Ripsey Wash Project area is located about 4 miles south of the Ray Mine Complex, south of the Gila River (***Figures 1 and 3a***). It is located on state lands that Asarco is seeking to acquire. A formal JD was approved by the Corps in September 2013.

The dominant geomorphic features of this site are Ripsey and Zelleweger Washes, both of which are relatively large xeroriparian corridors. The potential waters are ephemeral, flowing only in response to storm events. The washes in the Project area flow to the Gila River, located approximately 0.3 mile downstream of the Project area. There are no special aquatic sites within the Project area.

### 4.7.1. Seepage Control Methods

There are 2 basic options for controlling seepage, retaining the seepage within the impoundment and capturing the seepage downstream from the impoundment. The proposed Ripsey Wash TSF would implement both of these options by selective placement of finer-grained tailings slimes within the TSF footprint and construction of embankment barriers and seepage collection ponds.

The amount of earthwork required for subgrade preparation precludes the practicality of a fully geomembrane lined TSF and is without precedent in Arizona in the base metal industry. The ADEQ APP Program recognizes this in Section 3.5.1 of the Mining BADCT Guidance Manual (ADEQ 2004):

> "*Tailings disposal in the base metal industry typically involves hydraulic deposition of very large volumes of waste slurries. Based on practical operating experience, theoretical studies and performance monitoring, a philosophy of design has emerged wherein adequate discharge control has been achieved in unlined basins employing control technologies which take advantage of the large net evaporation in the prevailing arid and semi-arid climate in Arizona.*"

The Ripsey Wash site geological setting, including the extent of low permeability bedrock below the impoundment and the presence of alluvial filled drainages that would serve as underdrains, allow for the primary discharge control of the facility at the downstream edge of the TSF. Additional discharge control would be achieved by selective placement of a geomembrane liner and finer-grained tailings slimes over the potentially more conductive Hackberry Fault trace. The groundwater modeling work performed as a part of the Ripsey Wash facility design further supported an unlined facility.

#### 4.7.2. Construction Methods

The proposed Ripsey Wash TSF would entail the construction of a fill starter dam for initial containment, cyclone centerline construction for the first approximately 15 years of tailings deposition, then upstream construction for the remainder of the life of the facility.

The selection of the construction method of the embankment is based on the embankment raise rate, freeboard and flood storage requirements, percent solids, and particle size distribution of the whole tailings. The method of construction nomenclature is based on the direction of which the raised embankment crest moves in relation to the starter dam position (downstream, centerline or upstream).

The starter dam, constructed using rockfill and filter zones, akin to a traditional water retention dam, is required to contain the initial two years of tailing production at half-rate (one-half deposited in the current Elder Gulch TSF). The starter embankment establishes centerline, acts to support infrastructure, and provides a structural buttress for the remaining embankment raises. The starter dam can accommodate the high tailings impoundment raise rates that occur early in the operational life of the facility.

The selected alternative for raising the Ripsey Wash TSF embankments during the initial stage of construction is with a centerline technique using cycloned sands derived from the whole tailings. Control of the phreatic surface within the embankment is provided by the permeability of cycloned tailings and the specification that a minimum beach distance is maintained. Compaction of the lower zones of the cyclone sand embankment shell can be readily accomplished using tracked or rubber tired tractors to achieve materials that would not be prone to liquefaction during a seismic event. This construction technique can accommodate embankment raise rates up to 50 feet per year. Centerline construction early in the TSF construction is preferred because it does not require a wide beach (minimizing the surface disturbance), allows for a faster raise rate, and allows for greater stability of the dam when coupled with sufficient compaction.

As the embankment height increases and the surface area of the TSF grows, transitioning to an upstream raise technique would accommodate the reclamation of the lower embankment slopes. The increased size of the TSF impoundment would allow the longer beach lengths that are required to control the location of the phreatic line. The arid conditions and low seismic risk of the Ripsey Wash site are amenable to the transition to an upstream raise technique.

The downstream method of embankment construction was not selected for the project as this method requires ever increasing amounts of embankment materials as the TSF is raised and also sufficient space downstream to accommodate the future raises. The main advantage of this raise technique, where water can be impounded directly against the embankment, is not required for the Ripsey Wash TSF project because of the available area for tailings beach development.

Three (3) alternatives of varying configurations are evaluated at this alternative location.

### 4.7.3. Ripsey Wash Alternative 1

#### *4.7.3.1. Alternative Description*

The approximate facility footprint has an elevational range of 1,800 to 2,350 feet amsl and the area of the tailings footprint is estimated at 2,356 acres (***Figure 10***).

All the Ripsey Wash alternatives would use the preferred tailings delivery and reclaim water system (discussed in ***Section 6.2***), which is 3.0 miles long and, because of favorable topography, requires only one containment pond along the pipeline route for the containment of tailings or reclaim water in case of pipeline failure. The tailings and reclaim water pipelines are proposed to allow for a reduction in greenhouse gas emissions through the use of a gravity alignment north of the Gila River and run beside the Florence-Kelvin Highway south of the river. The pipelines would cross the Gila River on a bridge to be constructed immediately upstream of the Florence-Kelvin Highway bridge constructed by Pinal County.

This option requires 2 diversion channels that total approximately 34,543 feet (6.5 miles) to divert upstream flows around the facility, along with an upstream detention structure to temporarily detain stormwater during very large events (***Figure 10***).

Ripsey Wash Alternative 1 would be built with cyclone centerline and upstream construction methods. The starter embankment would be constructed with onsite materials.

This alternative requires relocating approximately 1.75 miles of an existing graded county road (the Florence-Kelvin Highway), a portion of the Arizona Trail, and a powerline that currently traverses the area.

#### *4.7.3.2. Practicability*

This alternative is practicable.

The tailings foundation at the Ripsey Wash site is primarily low- to very-low-permeability Ruin granite, which is expected to minimize potential impacts to groundwater (***Appendix A***). Seepage from the tailings along the major xeroriparian corridors in the Ripsey Wash project area would be managed by surface water diversion upgradient of the tailings footprint; drainage channels; seepage collection trenches; and interceptor pumpback wells downgradient of the impoundment. The risk of foundation instability is low and would be mitigated by excavating loose surface soils prior to the construction of the starter embankment. The main channel of Ripsey Wash is filled with sandy materials to depths of over 80 feet. This material is not expected to provide a barrier against seepage, but the basement rocks are relatively impermeable. Seepage is expected to occur primarily along 3 wash corridors for Ripsey Wash Alternative 1 (Zelleweger Wash, Ripsey Wash, and an unnamed wash), where sandy materials overlie bedrock, and possibly 2 mapped faults within the footprint. This seepage is expected to be contained within the sandy materials above the bedrock and could reliably be intercepted downstream of the embankment using seepage collection trenches and a series of dewatering pumpback wells located across the washes.

This alternative is practicable from a logistical standpoint when considering the distance from the Ray Mine Concentrator. The proposed pipeline for this alternative would be 3.0 miles long with one containment pond along the pipeline route for the containment of tailings or reclaim water in case of pipeline failure. There is only one low spot along the preferred pipeline corridor (which is where the containment pond will be located), thus allowing for reliable and cost-effective pipeline operation.

Using the dry stack method of tailings disposal at this site is not feasible and would not result in fewer impacts to the environment, as discussed in ***Section 4.1***. An approximately 3 percent reduction volume may result in a minor reduction in impacts to waters associated with the lower order streams that occur in the upper elevations of the proposed TSF; however, the need for stormwater diversion around the TSF would result in the dewatering of any such avoided waters within the upper elevation of the TSF.

### 4.7.4. Ripsey Wash Alternative 2

#### *4.7.4.1. Alternative Description*

This alternative represents a refinement of Ripsey Wash Alternative 1. The primary changes in the design of this alternative are a smaller TSF footprint and the avoidance of Zelleweger Wash. The approximate facility footprint has an elevational range of 1,800 to 2,388 feet amsl and the area of the tailings footprint is estimated at 2,073 acres (***Figure 11***).

All the Ripsey Wash alternatives would use the preferred tailings delivery and reclaim water system (discussed in ***Section 6.2***), which is 3.0 miles long and, because of favorable topography, requires only one containment pond along the pipeline route for the containment of tailings or reclaim water in case of pipeline failure. The tailings and reclaim water pipelines are proposed to allow for a reduction in greenhouse gas emissions through the use of a gravity alignment north of the Gila River and run beside the Florence-Kelvin Highway south of the river. The pipelines would cross the Gila River on a bridge immediately upstream of the Florence-Kelvin Highway bridge constructed by Pinal County.

This option requires 2 diversion channels that total approximately 20,453 feet (3.9 miles) to divert upstream flows around the facility, along with an upstream detention structure to temporarily detain stormwater during very large events (***Figure 11***).

Ripsey Wash Alternative 2 would be built with cyclone centerline and upstream construction methods. The starter embankment would be constructed with onsite materials.

This alternative requires relocating approximately 1.75 miles of an existing graded county road (the Florence-Kelvin Highway), the Arizona Trail, and a powerline that currently traverses the area.

#### *4.7.4.2. Practicability*

This alternative is practicable.

The geologic and hydrogeologic characteristics of this alternative are similar to those of Ripsey Wash Alternative 1. The primary difference is that Zelleweger Wash will be avoided. Therefore, there would only be 2 potential pathways for seepage along wash corridors for Ripsey Wash Alternative 2 (Ripsey Wash and an unnamed wash). The constructability of this alternative is comparable to that of Ripsey Wash Alternative 1.

Using the dry stack method of tailings disposal at this site is not feasible and would not result in fewer impacts to the environment, as discussed above in ***Sections 4.1 and 4.7.3.2***.

### 4.7.5. Ripsey Wash Alternative 3

#### *4.7.5.1. Alternative Description*

This alternative represents a refinement of Ripsey Wash Alternatives 1 and 2, with the goal of reducing impacts to waters. The primary differences between Ripsey Wash Alternative 3 and Ripsey Wash Alternatives 1 and 2 are a smaller TSF footprint and the avoidance of BLM lands. The approximate facility footprint has an existing elevational range of approximately 1,800 to 2,400 feet amsl and the ultimate area of the tailings footprint is estimated at 2,129 acres (***Figure 12a***).

All the Ripsey Wash alternatives would use the preferred tailings delivery and reclaim water system (discussed in ***Section 6.2***), which is 3.0 miles long and, because of favorable topography, requires only one containment pond along the pipeline route for the containment of tailings or reclaim water in case of pipeline failure.

This option requires a diversion channel measuring approximately 17,624 feet (3.3 miles), 7 detention basins, and approximately 9,330 feet (1.8 miles) of stormwater diversion pipeline to divert upstream flows around the facility, along with an upstream detention structure to temporarily detain stormwater during very large events (***Figure 12a***). This alternative also requires the relocation of the San Carlos Irrigation Project powerline (***Figure 13***).

The TSF is designed for an overall storage capacity of 751.3 million tons of tailings and embankment materials with a final crest elevation of 2,440 feet. The proposed TSF would be built with cyclone centerline and upstream construction methods. The starter embankment would be constructed with onsite materials.

This alternative requires relocating approximately 1.75 miles of an existing graded county road (the Florence-Kelvin Highway), the Arizona Trail, and a powerline that currently traverses the area.

#### *4.7.5.2. Practicability*

Ripsey Wash Alternative 3 is practicable. As discussed below in ***Sections 5 and 7***, it also represents the LEDPA for this project.

The geologic and hydrogeologic characteristics of this alternative are similar to those of Ripsey Wash Alternative 2. There would be only 2 potential pathways for seepage along wash corridors for Ripsey Wash Alternative 3 (Ripsey Wash and an unnamed wash). The constructability of this alternative is comparable to that of Ripsey Wash Alternatives 1 and 2. The Ripsey Wash site is characterized by a basin-like land form that simplifies the design and operation of stormwater management facilities as illustrated in the cross sections provided in ***Figure 12b***.

Using the dry stack method of tailings disposal at this site is not feasible and would not result in fewer impacts to the environment, as discussed above in ***Sections 4.1 and 4.7.3.2***.

### 4.8. RESULTS OF THE PRACTICABILITY ANALYSIS

Hackberry Gulch Alternatives 1 and 2 and Ripsey Wash Alternatives 1, 2, and 3 using conventional tailings deposition methods are deemed practicable for the proposed TSF. These alternatives are analyzed further below in ***Section 5***.

The dry-stack tailings disposal method was deemed impracticable for the proposed TSF. Dry tailings disposal has not yet been demonstrated to be viable for a facility with the design capacity of the Ray Mine Concentrator (peak production of 45,000 tpd). Nor do any existing dry-stack facilities involve a disposal location miles away from a conventional mill, a scenario that would require piping slurry to the TSF location and then filtering it there (which would necessitate the construction and operation of substantial infrastructure—filter plant, conveyor system, heavy equipment, water storage facility—at the TSF). Dry-stack technology is thus not a demonstrated practicable technology for the Ray tailings disposal scenario. Although the area needed for tailings placement at a dry-stack TSF can be expected to be approximately 3 percent smaller than at a conventional TSF (***Appendix C***), a dry-stack TSF would require the construction of substantial infrastructure at the TSF (filter plant, conveyor system, heavy equipment, water storage facility) to accommodate dry-stack tailings production. This additional infrastructure would increase the overall footprint of the dry-stack TSF. In addition, dust generation from dry stack tailings is a common problem, particularly in arid environments, due to the low moisture content of the placed tailings. Control of dust during transport, handling, and construction of a dry stack facility at the Ray Mine would be challenging. Assuming the tailings were not transported as slurry and filtered in new infrastructure at the TSF, longer conveyor runs would be required for the Ripsey Wash TSF project than are required at facilities currently utilizing dry-stack techniques, and involve numerous conveyor transfer points which would increase the transit moisture content losses and further generate fugitive dust.

E Dam, West Dam, Granite Mountain, and Devils Canyon were deemed impracticable locations for the proposed TSF.

E Dam is not practicable from a logistical perspective. The site is located approximately 20 miles from the Ray Mine, making transport of the tailings impracticable.

West Dam is not practicable from a logistical perspective given that it would preclude the use of existing rock deposition and leach areas, thereby interfering with mining operations and resulting in the inability to recover approximately 500 million pounds of copper contained in the 1 and 7 series leach dumps. This alternative would involve construction of an 870-foot-high embankment, exceeding the Preferred Alternative at Ripsey Wash by 245 feet and placing it amongst the tallest tailings impoundments in the world, all of which are valley fill dams rather than side hill construction, where the embankment lengths are shorter and three-dimensional corner effects on stability are not present. The risk of failure and consequence of failure would be greatly increased with an embankment height of this magnitude at this site. This alternative would also require relocation of SR 177, an ADOT-designated scenic road.

The Granite Mountain site overlies a known mineral resource. It is considered unavailable because placement of a TSF on the site would preclude the development of those mineral resources.

Devils Canyon is not practicable primarily for logistical reasons; it is located immediately upstream of a restrictive covenant and mitigation area. Lands immediately downstream of this site have been placed under a restrictive covenant and provide mitigation set-aside for previously permitted Ray Mine activities. The development of the site as a TSF would result in the dewatering of this mitigation area to some extent. The site also would require a 7.9-mile-long pipeline through unfavorable terrain. Such a pipeline would be difficult and costly to operate. The development of a TSF at this site is also expected to impact intermittent or perennial waters, riparian areas, and possibly wetland areas (i.e., special aquatic sites).

# 5. PRACTICABLE ALTERNATIVES – IDENTIFICATION OF IMPACTS TO WATERS OF THE U.S. AND OTHER ADVERSE ENVIRONMENTAL CONSEQUENCES

## 5.1. HACKBERRY GULCH ALTERNATIVE 1

### 5.1.1. Impacts to the Aquatic Ecosystem

Potentially jurisdictional waters were mapped on the Hackberry Gulch site using a 2007 National Agriculture Imagery Program aerial image analysis and field reconnaissance. ESRI online aerial imagery (2010) was used to further refine the potential jurisdictional delineation.

Potential waters identified within the Hackberry Gulch Alternative 1 project area are dominated by relatively confined ephemeral channels with functions and values typical of desert ephemeral systems. However, unlike the other sites being evaluated, intermittent and perennial surface water flows have been identified within this footprint, including special aquatic sites (wetlands), although no formal detailed wetland delineation has been submitted to the Corps for review and approval. For the purposes of this analysis, special aquatic sites, in the form of wetlands, are presumed to exist within the footprint of this alternative. The estimated total permanent impacts to waters associated with this alternative are provided in ***Table 4*** and depicted in ***Figure 8***. This alternative impacts more jurisdictional area than Hackberry Gulch

Alternative 2. Approximately 2.3 acres of intermittent or perennial waters (including wetland areas) would be impacted by this alternative.

Table 4. Hackberry Gulch Alternative 1 impacts to potentially jurisdictional waters

| Drainage Type | Impact Area (acres) |
|---|---|
| Wetland | 0.62 |
| Perennial/intermittent | 1.65 |
| Ephemeral | 100.88 |
| **Total Impacts** | **103.15** |

Pursuant to the Guidelines, the presence of special aquatic sites (wetlands) within the impact footprint of this alternative, combined with the fact that the proposed TSF is not water-dependent, results in a presumption that other sites not involving impacts to wetlands are available and that those alternatives have a less adverse impact on the aquatic ecosystem unless clearly demonstrated otherwise (40 C.F.R. § 230.10(a)(3)). Asarco has evaluated the possibility of avoiding the wetlands within the impact footprint of this alternative, and the required storage capacity and topography within the TSF footprint do not allow for their avoidance. Moving the TSF southeasterly to avoid wetland areas would impact more drainages, require even more environmental controls and potential for seepage, result in a larger TSF footprint due to steep terrain and narrow drainages, and require moving the TSF closer to residential areas within and surrounding Kearny.

#### 5.1.2. Other Adverse Environmental Consequences

**Biological Resources:** This alternative would result in approximately 2,450 acres of surface disturbance associated with the TSF and pipeline construction. Steep slopes and deeply incised washes characterize the topography of this site and probably influence the vegetation. Upland vegetation is characteristic of the Arizona Upland subdivision of the Sonoran Desertscrub biotic community (Brown and Lowe 1980). Dominant plants noted in the uplands during the site visit include palo verde, mesquite, ocotillo, jojoba, and cholla. During field visits conducted in 2012 and 2013, it was determined that within this alternative footprint there are areas of riparian vegetation supported by above-ground flowing water (i.e., wetland areas). In addition, some areas appear to support perennial and intermittent flows. Meso- and hydroriparian vegetation is present at these locations, including cottonwood, ash willow, monkeyflower, netleaf hackberry, seepwillow, and cattail.

Impacts to designated and proposed critical habitats for the southwestern willow flycatcher (*Empidonax traillii extimus*) and yellow-billed cuckoo (*Coccyzus americanus*) associated with this alternative would be the same as those for Hackberry Gulch Alternative 2 (permanent impacts to approximately 1.5 acres), as described in ***Appendix F***. Within the footprint of the TSF, this alternative would disturb potentially suitable habitat for Sonoran desert tortoise (*Gopherus morafkai*), a species that is a candidate for listing under the ESA. This alternative would also disturb intermittent and perennial surface water features, including wetland areas, and riparian areas that likely support wildlife to a greater extent than nearby ephemeral waters.

The Gila River is located approximately 0.4 mile (2,000 feet) downstream of the toe of this alternative and approximately 0.1 mile (750 feet) downstream of the closest seepage collection pond.

**Visual Resources:** Hackberry Gulch Alternative 1 would be highly visible from SR 177, an ADOT-designated scenic road. This alternative would also be highly visible from Kearny and other residential areas along portions of SR 177. It would have substantially greater visual impacts than Hackberry Gulch Alternative 2 due to the larger footprint of the TSF. Based on this and a viewshed assessment conducted for Hackberry Gulch Alternative 2, this alternative would be visible from more than 8 miles of SR 177, more than 5 miles of the Arizona Trail, and more than 5 miles of the Florence-Kelvin Highway. It would be visually prominent along most of the viewsheds from SR 177 and the Arizona Trail.

**Seepage Potential:** The foundation material at Hackberry Gulch is Big Dome Formation conglomerate rather than crystalline bedrock. Beds of this conglomerate have a coarser gradation that could provide lateral seepage pathways (***Appendix D and E***), as opposed to the Ripsey Wash site, which is underlain or surrounded by low- to very-low-permeability granite (***Appendix A***). The topography of the area would require a very long embankment crossing numerous washes, each one providing a potential pathway for seepage to travel and thus requiring individual controls. In addition, the presence of numerous high-angle, northwest-striking faults and paleo-channels within the site footprint potentially provides pathways for seepage to move to the Gila River. These could prove difficult to control (***Appendix A***). The number of potential pathways for seepage (multiple drainages, paleo-channels, and layers of more permeable material within the Big Dome Formation) complicates the ability to contain seepage at this location. Given the site's proximity to the Gila River, it would be difficult to prevent at least some seepage at Hackberry Gulch from eventually reaching the river.

In summary and as outlined in ***Appendix E***, the following Hackberry Gulch site geotechnical and geologic conditions make it likely that a TSF built at this location would experience seepage that could not be prevented or captured:

1. Presence of beds of coarser gradation within the tilted Big Dome Formation Conglomerate that underlies the Hackberry Gulch site could provide lateral and vertical seepage pathways.
2. Possible presence of one or more paleo-channels that could be potential avenues of seepage.
3. Layered heterogeneity resulting in increased hydraulic connectivity with depth and uncertain migration pathways for tailings fluid seepage in the Big Dome Conglomerate.
4. Numerous unnamed faults that have the potential to act as conduits for seepage of tailings fluids into the subsurface.
5. High potential for discontinuous heterogeneity of subsequent increased lateral and vertical cross-connectivity through the network of Tertiary-age normal faults.
6. Elder Gulch studies of seepage migration travel times suggest that the closer proximity of the Hackberry site to the Gila River presents an even greater challenge to seepage control.

This alternative requires the construction and monitoring of 12 seepage collection points (***Figure 8***). Other alternatives evaluated require fewer seepage collections points: 7 at Hackberry Gulch Alternative 2; 3 at Ripsey Wash Alternative 1; and 2 at Ripsey Wash Alternatives 2 and 3.

**Reclamation:** This alternative would be constructed using a fill starter embankment for initial containment and then cyclone centerline construction for most of the remaining life of the facility; it would not provide an opportunity for concurrent reclamation early in the life of the project.

**Conclusion:** Because of the challenges associated with controlling seepage; impacts to perennial and intermittent water sources, including special aquatic sites in the form of wetlands; greater visual resource impacts along SR 177 and in the community of Kearny; and the inability to perform concurrent reclamation early in the project life cycle, Hackberry Gulch Alternative 1 is not considered the LEDPA when compared to Ripsey Wash Alternative 3 (see below).

#### 5.1.3. Cumulative Analysis

The 404(b)(1) Guidelines require an analysis of the cumulative effects of alternatives on the aquatic system. To accomplish this, the Corps reviewed previously permitted project records from within each practicable alternative's respective 10-digit hydrologic unit code (HUC) to determine the magnitude of past permitted impacts to waters of the U.S. To estimate the extent of waters within the watershed, the U.S. Geological Survey's National Hydrography Database (NHD) was used to provide an estimate of the linear feet of potential waters of the U.S. within the watershed. Within each alternative, the average of the ratio of linear feet of waters to linear feet of mapped NHD drainages was used to convert the total length of mapped NHD drainages within the watershed to the total length of waters within the watershed. The Hackberry Gulch alternatives are located in the Mineral Creek-Gila River watershed (HUC 1505010002). Using this method, it was estimated that 10,166,500 linear feet of potential waters of the U.S. are present in this watershed.

Based on previous CWA Section 404 permitting records, the Corps has authorized the fill of 105.6 acres of waters in this watershed, 29.7 acres of which were jurisdictional wetlands. Permitting records were reviewed to determine the linear extent of 105.3 acres of the total 105.6 acres that were previously permitted by the Corps (records for the remaining 0.3 acre of fill were not available).

This alternative would impact 260,990 linear feet of waters. Based on this assessment, it would impact 2.6 percent of the total estimated linear feet of waters within the watershed. These impacts in addition to the previously permitted impacts within the watershed equal 3.9 percent of the total estimated waters within the watershed.

### 5.2. HACKBERRY GULCH ALTERNATIVE 2

As noted above, Hackberry Gulch Alternative 2 was developed to reduce the expansion of the TSF in Hackberry Gulch to the south, thereby decreasing the potential for seepage points. This design results in a TSF with a somewhat smaller footprint, but one that is higher than that envisioned under Hackberry Gulch Alternative 1.

### 5.2.1. Impacts to the Aquatic Ecosystem

Potentially jurisdictional waters were mapped on this site using aerial image (NAIP 2007) analysis and field reconnaissance. ESRI online aerial imagery (2010) was used to further refine the potential jurisdictional delineation at the Hackberry Gulch site.

Potential waters identified within the Hackberry Gulch Alternative 2 project area are dominated by relatively confined ephemeral channels with functions and values typical of desert ephemeral systems. However, unlike the other sites being evaluated, intermittent and perennial surface water flows have been identified within this footprint, including wetland areas, although at the time of this writing a formal detailed wetland delineation has not yet been submitted to the Corps for review and approval. The estimated total permanent impacts to waters associated with this alternative are provided in ***Table 5*** and depicted in ***Figure 8***. Approximately 2.3 acres of intermittent or perennial waters, including special aquatic sites in the form of wetlands, would be impacted by this alternative.

Table 5. Hackberry Gulch Alternative 2 impacts to potentially jurisdictional waters

| Drainage Type | Impact Area (acres) |
|---|---|
| Wetland | 0.62 |
| Perennial/intermittent | 1.65 |
| Ephemeral | 69.23 |
| **Total Impacts** | **71.50** |

Pursuant to the Guidelines, the presence of wetlands within the impact footprint of this alternative, combined with the fact that the proposed TSF is not water-dependent, results in a regulatory presumption that other sites not involving impacts to wetlands are available and that those alternatives have a less adverse impact on the aquatic ecosystem (40 C.F.R. § 230.10(a)(3)). Asarco has evaluated the possibility of avoiding the wetlands within the impact footprint of this alternative, and the required storage capacity and topography within the TSF footprint do not allow for their avoidance. Moving the TSF southeasterly to avoid wetland areas would impact more drainages, require even more environmental controls and potential for seepage, result in a larger TSF footprint due to steep terrain and narrow drainages, and require moving the TSF closer to residential areas within and surrounding Kearny.

### 5.2.2. Other Adverse Environmental Consequences

**Biological Resources:** This alternative would result in approximately 2,290 acres of surface disturbance associated with the TSF and pipeline construction. Steep slopes and deeply incised washes characterize the topography of this site and probably influence the vegetation. Upland vegetation is characteristic of the Arizona Upland subdivision of the Sonoran Desertscrub biotic community (Brown and Lowe 1980). Dominant plants noted in the uplands during the site visit include palo verde, mesquite, ocotillo, jojoba, and cholla. During field visits conducted in 2012 and 2013, it was determined that within this alternative footprint there are areas of riparian vegetation supported by above-ground flowing water (i.e., wetland areas). In addition, some areas appear to support perennial and intermittent flows. Meso- and hydroriparian vegetation is present at these locations, including cottonwood, ash willow, monkeyflower, netleaf hackberry, seepwillow, and cattail.

This alternative would result in permanent impacts to approximately 1.5 acres of hydroriparian vegetation within designated and proposed critical habitats for the southwestern willow flycatcher and yellow-billed cuckoo (***Appendix F***). Within the footprint of the TSF, this alternative would disturb potentially suitable habitat for Sonoran desert tortoise, a species that is a candidate for listing under the ESA. This alternative would also disturb intermittent and perennial surface water features, including wetland areas, and riparian areas that likely support wildlife to a greater extent than nearby ephemeral waters.

The Gila River is located approximately 0.4 mile (2,000 feet) downstream of the toe of this alternative and approximately 0.1 mile (750 feet) downstream of the closest seepage collection pond.

**Visual Resources:** This alternative would be highly visible from SR 177, an ADOT-designated scenic road. It would also be visible from Kearny and other residential areas along portions of SR 177. Based on a viewshed assessment conducted for this alternative, Hackberry Gulch Alternative 2 would be visible from approximately 8 miles of SR 177. This alternative would also be seen from the Arizona Trail (a National Scenic Trail) along approximately 5 miles of the trail and from the Florence-Kelvin Highway along approximately 5 miles of the road. This TSF would be visually prominent along most of the viewsheds from SR 177 and the Arizona Trail.

**Seepage Potential:** The seepage potential for this alternative would be similar to that of Hackberry Gulch Alternative 1. The beds of Big Dome Conglomerate that underlie the site have a coarser gradation that could provide lateral seepage pathways (***Appendix D***), as opposed to the Ripsey Wash site, which is underlain or surrounded by low- to very-low-permeability granite (***Appendix A***). This alternative requires the construction and monitoring of 7 separate seepage control points (as compared to the 12 required under Hackberry Gulch Alternative 1). Other alternatives evaluated require fewer seepage collection points: 3 at Ripsey Wash Alternative 1 and 2 at Ripsey Wash Alternatives 2 and 3. In addition, the presence of numerous high-angle, northwest-striking faults and paleo-channels within the site footprint potentially provides pathways for seepage to move to the Gila River. These could prove difficult to control (***Appendix A***). The number of potential pathways for seepage (multiple drainages, paleo-channels, and layers of more permeable material within the Big Dome Formation) complicates the ability to contain seepage at this location. Given the site's proximity to the Gila River, it would be difficult to prevent at least some seepage at Hackberry Gulch from eventually reaching the river. As described in ***Section 5.1.2*** and in ***Appendix E,*** the geotechnical and geologic conditions at this site suggest a strong likelihood for seepage.

**Reclamation:** This alternative would be constructed using a fill starter embankment for initial containment and then cyclone centerline construction for most of the remaining life of the facility; it would not provide an opportunity for concurrent reclamation earlier in the life of the project.

**Conclusion:** Because of the challenges associated with controlling seepage; greater visual resource impacts; the inability to perform concurrent reclamation earlier in the life of the project; and impacts to perennial and intermittent flows, including special aquatic sites in the form of wetlands, the Hackberry Gulch alternative is not considered the LEDPA when compared to Ripsey Wash Alternative 3 (see below).

#### 5.2.3. Cumulative Analysis

As described in ***Section 5.1.3***, the Corps reviewed previously permitted project records from within each practicable alternative's respective 10-digit HUC to determine the magnitude of past permitted impacts to waters of the U.S. Based on previous CWA Section 404 permitting records, the Corps has authorized the fill of 105.6 acres of waters in this watershed, 29.7 acres of which were jurisdictional wetlands. Permitting records were reviewed to determine the linear extent of 105.3 acres of the total 105.6 acres that were previously permitted by the Corps (records for the remaining 0.3 acre of fill were not available).

This alternative would impact 228,325 linear feet of waters. Based on this assessment, it would impact 2.3 percent of the total estimated linear feet of waters within the watershed. These impacts in addition to the previously permitted impacts within the watershed equal 3.6 percent of the total estimated waters within the watershed.

### 5.3. RIPSEY WASH ALTERNATIVE 1

#### 5.3.1. Impacts to the Aquatic Ecosystem

The estimated total permanent impacts to waters associated with this alternative are provided in ***Table 6*** and depicted in ***Figure 10***. This alternative impacts substantially more jurisdictional area than Ripsey Wash Alternative 3, the Preferred Alternative. All impacts would be to ephemeral waters. No special aquatic sites would be impacted.

Table 6. Ripsey Wash Alternative 1 impacts to jurisdictional waters

| Drainage Type | Impact Area (acres) |
|---|---|
| Wetland | 0 |
| Perennial/intermittent | 0 |
| Ephemeral | 212.48 |
| **Total Impacts** | **212.48** |

#### 5.3.2. Other Adverse Environmental Consequences

**Biological Resources:** This alternative would result in approximately 2,730 acres of surface disturbance associated with the TSF, the realignment of the Florence-Kelvin Highway, and pipeline construction. There is no designated critical habitat within the footprint of this TSF, but critical habitat for southwestern willow flycatcher and proposed critical habitat for yellow-billed cuckoo is present along the Gila River downstream of this alternative. Impacts to those habitats associated with this alternative are similar to those associated with Ripsey Wash Alternative 3, as described in ***Appendix F***.

This alternative would also disturb suitable habitat for Sonoran desert tortoise, a species that is a candidate for listing under the ESA. Both Zelleweger and Ripsey Washes would be impacted by this alternative.

The habitat on this site is consistent with that described for the Arizona Upland subdivision of the Sonoran Desertscrub biotic community (Brown and Lowe 1980). Two (2) major washes, Ripsey and Zelleweger, both of which would be impacted by this alternative, run the entire length of the proposed site, and numerous smaller drainages are tributary to these washes from the surrounding subbasins. The habitat in the washes can be characterized as xeroriparian. The vegetation is predominately scattered mesquite, acacia, palo verde, and hackberry thickets, with additional shrubs such as canyon ragweed and desert broom also present. The scattered and patchy nature of the riparian community suggests a dynamic hydrologic system in which flooding occurs frequently. Dominant species in the uplands include palo verde, cholla, and prickly pear, with some saguaros present. Additional plants noted in the uplands include ocotillo, jojoba, brittle bush, and acacia.

**Visual Resources:** This alternative is not highly visible from any public areas except the Florence-Kelvin Highway, a county road, and the Arizona Trail, a National Scenic Trail. Portions of both of these facilities would need to be relocated. Because this alternative has a larger TSF footprint, it would have substantially greater visual impacts than Ripsey Wash Alternative 3, which would be visible from approximately 8 miles along the Arizona Trail and approximately 5 miles along the Florence-Kelvin Highway.

**Seepage Potential:** Seepage is expected to occur primarily along 3 wash corridors (Ripsey Wash, Zelleweger Wash, and an unnamed wash), where sandy materials overlie bedrock. It is anticipated that this seepage will be contained within the sandy materials above the bedrock and could reliably be intercepted downstream of the embankment using seepage collection trenches and a series of dewatering pumpback wells located across the washes. A high-angle fault is present on the western side of the site that has the potential to be a seepage pathway. If the fault is determined to be such, then controls (including cut-offs and/or pumpback wells) would be designed to intercept the seepage. Because of the smaller number of drainage features requiring seepage control and the differences in the underlying materials between the Ripsey and Hackberry sites (the Ripsey site is underlain or surrounded by low- to very-low-permeability granite, while the geologic and geotechnical conditions at the Hackberry site provide for seepage potential), the ability to reliably control seepage at the Ripsey Wash site is significantly greater than at the Hackberry Gulch site.

**Reclamation:** This alternative would be constructed using a fill starter embankment with cyclone centerline construction initially, and then an upstream construction method would be used for the remaining life of the facility. This construction method provides an opportunity for concurrent reclamation early in the life of the project.

**Conclusion:** Although practicable, this alternative is not considered the LEDPA because another alternative (Ripsey Wash Alternative 3) impacts fewer waters and does not have other significant adverse environmental consequences as compared to this alternative.

### 5.3.3. Cumulative Analysis

The Corps reviewed previously permitted project records from within each practicable alternative's respective 10-digit HUC to determine the magnitude of past permitted impacts to waters of the U.S. The Ripsey Wash alternatives are located in the Box O Wash-Gila River watershed (HUC 1505010003). Based on previous CWA Section 404 permitting records, the Corps has authorized the fill of 3.03 acres of waters in this watershed. Permitting records were not available to determine the linear extent of those 3.03 acres. This alternative would impact 212,650 linear feet of waters. Based on this assessment, this alternative would impact 2.2 percent of the total estimated linear feet of waters within the watershed.

## 5.4. RIPSEY WASH ALTERNATIVE 2

### 5.4.1. Impacts to the Aquatic Ecosystem

The estimated total permanent impacts to waters associated with this alternative are provided in ***Table 7*** and depicted in ***Figure 11***. The reduction in impacts as compared to Ripsey Wash Alternative 1 is attributable largely to avoiding impacts to Zelleweger Wash. This alternative impacts more jurisdictional area than Ripsey Wash Alternative 3, the Preferred Alternative. All impacts would be to ephemeral waters. No special aquatic sites would be impacted.

Table 7. Ripsey Wash Alternative 2 impacts to jurisdictional waters

| Drainage Type | Impact Area (acres) |
|---|---|
| Wetland | 0 |
| Perennial/intermittent | 0 |
| Ephemeral | 148.58 |
| **Total Impacts** | **148.58** |

### 5.4.2. Other Adverse Environmental Consequences

**Biological Resources:** Impacts to biological resources resulting from Ripsey Wash Alternative 2 are similar to those for Ripsey Wash Alternative 1, with the exception that the xeroriparian habitat in Zelleweger Wash would be avoided under this alternative. This alternative would also result in approximately 150 acres less surface disturbance than Ripsey Wash Alternative 1. Effects to mapped designated and proposed critical habitats associated with this alternative are the same as those described for Ripsey Wash Alternative 3, as described in ***Appendix F***.

**Visual Resources:** This alternative is not highly visible from any public areas except the Florence-Kelvin Highway, a county road, and the Arizona Trail, a National Scenic Trail. Portions of both of these facilities would need to be relocated. Because this alternative has a larger TSF footprint, it would have greater visual impacts than Ripsey Wash Alternative 3, which would be visible from approximately 8 miles along the Arizona Trail and approximately 5 miles along the Florence-Kelvin Highway.

**Seepage Potential:** Seepage is expected to occur primarily along 2 wash corridors (Ripsey Wash and an unnamed wash), where sandy materials overlie bedrock, as opposed to 3 wash corridors for Ripsey Wash Alternative 1. The seepage potential for Ripsey Wash Alternative 2 is similar to that for Alternative 1, with the exception that Zelleweger Wash will be avoided and therefore would not be a potential seepage point (meaning that there are only 2 potential seepage pathways along washes to control). Because of the smaller number of drainage features requiring seepage control and the differences in the underlying materials between the Ripsey and Hackberry sites (the Ripsey site is underlain or surrounded by low- to very-low-permeability granite, while the geologic and geotechnical conditions at the Hackberry site provide for seepage potential), the ability to reliably control seepage at the Ripsey Wash site is significantly greater than at the Hackberry Gulch site.

**Reclamation:** This alternative would be constructed using a fill starter embankment with cyclone centerline construction initially, and then an upstream construction method would be used for the remaining life of the facility. This provides an opportunity for concurrent reclamation early in the life of the project.

**Conclusion:** Although practicable, this alternative is not considered the LEDPA because another alternative (Ripsey Wash Alternative 3, see below) impacts fewer waters and does not have other significant adverse environmental consequences as compared to this alternative.

#### 5.4.3. Cumulative Analysis

The Corps reviewed previously permitted project records from within each practicable alternative's respective 10-digit HUC to determine the magnitude of past permitted impacts to waters of the U.S. The Ripsey Wash alternatives are located in the Box O Wash-Gila River watershed (HUC 1505010003). Based on previous CWA Section 404 permitting records, the Corps has authorized the fill of 3.03 acres of waters in this watershed. Permitting records were not available to determine the linear extent of those 3.03 acres. This alternative would impact 159,645 linear feet of waters. Based on this assessment, this alternative would impact 1.7 percent of the total estimated linear feet of waters within the watershed.

### 5.5. RIPSEY WASH ALTERNATIVE 3

#### 5.5.1. Impacts to the Aquatic Ecosystem

The estimated total permanent impacts to waters associated with this alternative are provided in ***Table 8*** and depicted in ***Figure 12a***. All impacts would be to ephemeral waters. No special aquatic sites would be impacted.

Table 8. Ripsey Wash Alternative 3 impacts to jurisdictional waters

| Drainage Type | Impact Area (acres) |
|---|---|
| Wetland | 0 |
| Perennial/intermittent | 0 |
| Ephemeral | 134.65 |
| **Total Impacts** | **134.65** |

#### 5.5.2. Other Adverse Environmental Consequences

**Biological Resources:** Impacts to biological resources resulting from Ripsey Wash Alternative 3 are similar to those for Ripsey Wash Alternative 2. This alternative would result in an estimated 50 acres less surface disturbance than Ripsey Wash Alternative 2. The proposed pipeline bridge associated with this alternative would permanently impact approximately 0.2 acre and temporarily impact approximately 0.5 acre of hydroriparian vegetation within southwestern willow flycatcher critical habitat and yellow-billed cuckoo proposed critical habitat (***Appendix F***)[10].

[10] There are also approximately 12.2 acres of mapped critical habitat for southwestern willow flycatcher and 3.6 acres of proposed critical habitat for yellow-billed cuckoo containing xeroriparian and upland vegetation adjacent to the riparian corridor along the Gila River. These areas do not contain the dense riparian vegetation described by USFWS (2013, 2014) as primary constituent elements for these birds (*Appendix F*).

The Hackberry Gulch alternatives are closer to the Gila River than this alternative. The Gila River is located approximately 0.6 mile (3,200 feet) downstream of the toe of this alternative and approximately 0.3 mile (1,600 feet) downstream of the closest seepage collection pond located in Ripsey Wash compared to the 0.4 mile (2,000 feet) downstream of the toes of Hackberry Gulch Alternatives 1 and 2, and approximately 0.1 mile (750 feet) downstream of the closest seepage collection ponds at Hackberry Gulch Alternatives 1 and 2.

**Visual Resources:** This alternative is not highly visible from any public areas except a county roadway, the Florence-Kelvin Highway, and the Arizona Trail, a National Scenic Trail. Portions of both of these facilities would need to be relocated. Ripsey Wash Alternative 3 would be visible from approximately 8 miles along the Arizona Trail and approximately 5 miles along the Florence-Kelvin Highway. This alternative would also be visible along approximately 2.6 miles of SR 177, but the views would be largely broken up by the terrain. The TSF is not expected to be visually prominent from SR 177.

**Seepage Potential:** The seepage potential for Ripsey Wash Alternative 3 is expected to be comparable to that of Ripsey Wash Alternative 2. Because of the smaller number of drainage features requiring seepage control and the differences in the underlying materials between the Ripsey and Hackberry sites (the Ripsey site is underlain or surrounded by low- to very-low-permeability granite, while the geologic and geotechnical conditions at the Hackberry site lead to a likelihood for seepage (as discussed above in ***Section 5.1.2*** and in ***Appendix E***), the ability to reliably control seepage at the Ripsey Wash site is significantly greater than at the Hackberry Gulch site. The Hackberry Fault has been investigated and engineering controls have been developed to mitigate potential seepage through the fault zone as part of the permitted design for Ripsey Wash Alternative 3 under Asarco's State of Arizona Aquifer Protection Permit (Permit No. P-511395) for the project (***Appendix A***).

**Reclamation:** This alternative would be constructed using a fill starter embankment with cyclone centerline construction initially, and then an upstream construction method would be used for the remaining life of the facility. This provides an opportunity for concurrent reclamation early in the life of the project.

**Conclusion:** Ripsey Wash Alternative 3 is the least environmentally damaging practicable alternative. It impacts fewer waters than either Ripsey Wash Alternatives 1 or 2 and has no other significant adverse environmental consequences compared to those 2 alternatives. Although Hackberry Gulch Alternative 2 would impact fewer acres of waters, some of the impacted waters under that alternative are perennial or intermittent. Wetland areas (i.e., special aquatic sites) would also be impacted. In addition, Hackberry Gulch Alternative 2 is considered to have other significant adverse environmental consequences when compared to Ripsey Wash Alternative 3. These include a greater difficulty to control seepage into groundwater, greater visual impacts to the public, and the inability to perform concurrent reclamation earlier in the life of the project due to the construction method required at the Hackberry site.

### 5.5.3. Cumulative Analysis

The Corps reviewed previously permitted project records from within each practicable alternative's respective 10-digit HUC to determine the magnitude of past permitted impacts to waters of the U.S. The Ripsey Wash alternatives are located in the Box O Wash-Gila River watershed (HUC 1505010003). Based on previous CWA Section 404 permitting records, the Corps has authorized the fill of 3.03 acres of waters in this watershed. Permitting records were not available to determine the linear extent of those 3.03 acres. This alternative would impact 170,840 linear feet of waters. Based on this assessment, this alternative would impact 1.7 percent of the total estimated linear feet of waters within the watershed.

### 5.6. RESULTS OF ASSESSMENT OF IMPACTS TO THE AQUATIC ECOSYSTEM AND ANALYSIS OF OTHER ADVERSE ENVIRONMENTAL CONSEQUENCES

The Ripsey Wash location is considered the LEDPA in comparison to the Hackberry Gulch location because it has less potential for seepage escaping the facility and potentially impacting groundwater and surface water (i.e., less pathways for potential seepage). Because of the smaller number of drainage features requiring seepage control and differences in the geologic and geotechnical conditions, the ability to reliably control seepage at the Ripsey Wash site is significantly greater than at the Hackberry Gulch site. In addition, although the Ripsey Wash alternatives would impact more acres of ephemeral waters than the Hackberry Gulch alternatives, the construction of a TSF at Hackberry Gulch would impact some higher functioning perennial and intermittent waters as well as special aquatic sites. Impacts to special aquatic sites trigger the regulatory presumption (40 C.F.R. § 230.10(a)(3)) that other sites not involving impacts to special aquatic sites have less adverse impact to the aquatic ecosystem. Finally, the Hackberry Gulch alternatives would have other adverse environmental consequences in comparison to the Ripsey Wash alternatives. These include significantly greater visual resource impacts from the Hackberry Gulch site because of its proximity to SR 177 and visibility from residences in Kearny and the inability to perform concurrent reclamation earlier in the life of the project. Of the Ripsey Wash alternatives, Alternative 3 is the LEDPA because it impacts the fewest acres of waters without creating other adverse environmental effects.

## 6. RIPSEY WASH ALTERNATIVE 3 PROJECT ELEMENT ALTERNATIVES ANALYSIS

### 6.1. ALTERNATIVES FOR THE RELOCATION OF THE FLORENCE-KELVIN HIGHWAY

Asarco has evaluated 2 alternatives for the relocation of approximately 1.75 miles of the Florence-Kelvin Highway (***Figure 14; Table 9***).

Table 9. Summary of Florence-Kelvin Highway relocation alternatives (*Figure 14*)

| Alternative | Length (feet) | Total Area (acres) | Impacts to Waters (acres) |
|---|---|---|---|
| Alternative 1 | 10,800 | 22 | 0.52 |
| Preferred Alternative | 9,500 | 37 | 0.69 |

Both alternatives would be constructed north (downstream) of the Ripsey Wash TSF alternatives. Alignments running to the south (upstream) of the proposed TSF and associated diversion and detention structures were determined to be impracticable because of their significantly greater length and associated costs. In addition, alignments running to the south of the proposed facility would have to cross unimpacted waters of the United States, whereas the proposed alignments to the north only cross washes mostly already considered to be dewatered by the proposed TSF. While precise impacts to waters along the southern alignments were not evaluated, it is clear that the impacts would be greater than those associated with the northern alignments.

Two (2) northern alignment options were evaluated, both with a design speed of 35 mph. The preferred alignment avoids visual impacts to the users of the Arizona Trail north of the Gila River, and based on preliminary discussions with Pinal County staff regarding this road relocation, it is the preferred alternative. Because impacts to waters of the U.S. are comparable under both alternatives (***Table 9***), the preferred alternative can be considered the LEDPA.

### 6.2. ALTERNATIVES FOR RIPSEY TAILINGS DELIVERY AND RECLAIM WATER PIPELINES

The tailings generated from the mill at the Ray Mine would be pumped in slurry form in a pipeline to the final impoundment location. Hydraulic calculations were performed to determine the pumping, pipe, and power requirements for cyclone underflow transport along the crest of the tailings embankment and for return reclaim water for each alternative. The pipeline for each alternative would be constructed of 28-inch-diameter steel and HDPE pipe. A peak production rate of approximately 45,000 tpd, representing the maximum design capacity of the current Ray Mine Concentrator, has been assumed in evaluating tailings transport requirements.

Asarco has evaluated 5 pipeline alternatives for the delivery of tailings to the Ripsey Wash Project (***Figure 15; Table 10***). Alternative 5, with the lowest impact to waters of the U.S., is considered to be the LEDPA. It would allow for reduction of greenhouse gas emissions through use of a gravity alignment north of the Gila River, follow the Florence-Kelvin Highway south of the river, and cross the Gila River on a new bridge that is to be constructed immediately upstream of the new Florence-Kelvin Highway Bridge. Wetlands associated with the Gila River would be avoided during the construction of the pipeline. Where it crosses the Gila River, the tailings pipeline will be carried within a second pipeline designed to contain any leaks or spills from the primary pipeline. A secondary containment pond (double-lined with leak detection) will be placed upstream of the Gila River north of the bridge. The pipeline pressure and flow rates will be continuously monitored to detect any pressure drops, at which time the pipeline could be shut down.

Table 10. Summary of proposed Ripsey Project pipeline alternatives

| Alternative | Length (feet) | Length (miles) | No. of Drainage Crossings | Impacts to Waters (acres) | Description of Route |
|---|---|---|---|---|---|
| 1 | 15,063 | 2.9 | 5 | 0.46 | Follows the Florence-Kelvin Highway, then north-northeast to the discharge point. |
| 2 | 25,234 | 4.8 | 10 | 0.57 | Follows the Florence-Kelvin Highway and the Copper Basin Railway along the Gila River, and then travels south and east to the discharge point. |
| 3 | 23,104 | 4.4 | 15 | 1.29 | Travels across undeveloped lands southwest to the Copper Basin Railway, then south and east to the discharge point. |
| 4 | 21,032 | 4.0 | 11 | 0.59 | Travels across undeveloped lands southwest and crosses the Gila River upstream of the Copper Basin Railway bridge, then southwest to the discharge point. This alternative would avoid public lands and not require right of way authorization from BLM. |
| 5 | 16,011 | 3.0 | 7 | 0.44 | Allows for reduction in greenhouse gas emissions through use of a gravity alignment north of the Gila River and follows the Florence-Kelvin Highway south of the Gila River. This is the Preferred Alternative. |

The construction of the pipeline bridge crossing of the Gila River may temporarily impact some perennial flows within the river during construction; however, no piers would be placed directly within the ordinary high-water mark of the Gila River. Other impacts to waters of the U.S. associated with the pipeline construction would be temporary impacts to ephemeral waters.

# 7. SUMMARY AND CONCLUSIONS

Asarco has identified the need for additional tailings storage to support ongoing mining operations at the Ray Mine in Pinal County, Arizona. The Applicant's purpose and need for the Project is to create additional tailings storage to support up to approximately 750 million tons of mill tailings and embankment material. The deposition of 750 million tons of tailings and embankment material is required to allow for the full utilization of the identified sulfide mineral resource at the Ray Mine.

The Applicant's basic Project purpose is mine tailings storage, which is not water-dependent. The Applicant's overall project purpose is the development of a TSF that will allow the full utilization of the mineral resource at the Ray Mine using infrastructure already in existence at the mine. In the public notice for this project, the Corps identified the overall project purpose as the creation of additional tailings storage to support up to approximately 750 million tons of material.

Asarco has evaluated numerous alternatives for the proposed TSF for the Ray Mine. Eight (8) alternatives (at 5 locations) are in relative proximity to the Ray Mine near Kearny, Pinal County, Arizona, including 3 TSF configurations at the Ripsey Wash site and 2 alternative configurations at the Hackberry Gulch site. One (1) alternative, E Dam, is located near the Hayden Smelter Complex near Hayden-Winkelman, Pinal County, Arizona, approximately 20 miles from the Ray Mine. Each of the alternatives considered is briefly discussed below. Hackberry Gulch Alternatives 1 and 2 and Ripsey Wash Alternatives 1, 2, and 3 are deemed practicable for the proposed TSF. The Ripsey Wash location is considered the LEDPA in comparison to the

Hackberry Gulch location because it has less potential for seepage escaping the facility and potentially impacting groundwater and surface water (i.e., less pathways for potential seepage). In addition, although the Ripsey Wash alternatives would impact more acres of waters than the Hackberry Gulch alternatives, the construction of a TSF at Hackberry Gulch would impact some higher functioning waters (i.e., special aquatic sites and perennial and intermittent waters). Finally, the Hackberry Gulch alternatives would have other adverse environmental consequences in comparison to the Ripsey Wash alternatives (i.e., significantly greater visual resource impacts because their proximity to SR 177 and visibility from residences in Kearny and the inability to perform concurrent reclamation earlier in the life of the project). Of the Ripsey Wash alternatives, Alternative 3 is the LEDPA because it impacts the fewest acres of waters. ***Table 11*** summarizes a number of key factors for the alternatives that were determined to be impracticable and ***Table 12*** summarizes key factors for the practicable alternatives.

The key conclusions of this alternatives analysis are as follows:

- **Dry-stack Tailings Disposal Method:** Dry tailings disposal has not yet been demonstrated to be viable for a facility with the design capacity of the Ray Mine Concentrator (i.e., a peak production of 45,000 tpd). Nor do any existing or proposed dry-stack facilities involve a disposal location miles away from a conventional mill, a scenario that would require piping slurry to the TSF location and then filtering it there (which would necessitate the construction and operation of substantial infrastructure—filter plant, conveyor system, heavy equipment, water storage facility—at the TSF). Dry-stack technology thus has not been demonstrated to be a practicable technology for the Ray tailings disposal scenario. A dry-stack facility would not likely result in fewer impacts to waters. Dry-stack tailings deposition at the Ray Mine would provide an increase in density of 2.8 pounds per cubic foot versus conventional tailings (***Appendix C***). This represents only a 3 percent reduction in total volume, which would result in the final elevation of an ultimate dry-stack impoundment that would be approximately 3 percent less than the final elevation of the proposed slurry tailings impoundment. This reduction in elevation may result in a minor reduction in impacts to waters associated with small drainages in the upper elevations of the TSF; however, the need for stormwater diversion around the TSF would likely result in the dewatering of any such avoided waters within the upper elevation of the TSF. In addition, a dry-stack TSF would necessitate significant additional infrastructure that would not be required for a conventional TSF, thereby increasing the overall footprint of a dry-stack TSF.
- **E Dam:** This alternative is not practicable from a logistical perspective. The site is located approximately 20 miles from the Ray Mine, making transport of the tailings impracticable.
- **West Dam:** This alternative is not practicable from a logistical perspective because it precludes the use of existing rock deposition and leach areas, thereby interfering with mining operations and resulting in the inability to recover approximately 500 million pounds of copper contained in the 1 and 7 series leach dumps. This alternative would involve construction of an 870-foot-high embankment, exceeding the Preferred Alternative at Ripsey Wash by 245 feet placing it amongst the tallest tailings impoundments in the world, all of which are valley fill dams rather than side hill construction, where the embankment lengths are shorter and three-dimensional corner effects on stability are not present. The risk of failure and consequence of failure would be greatly increased

with an embankment height of this magnitude at this site. Shifting the alignment of the West Dam TSF to the west, to avoid both the SR 177 highway and the existing leaching area, is not feasible due to the reduced storage capacity, requirement for an embankment that is approximately 1,100-ft in height (with associated stability concerns), and the increased embankment raise rate required by the steeper topography.

- **Granite Mountain:** This site overlies a known mineral resource. It is considered unavailable because the placement of a TSF on the site would preclude the development of this resource.
- **Devils Canyon:** This alternative is not practicable primarily for logistical reasons; it is located immediately upstream of a restrictive covenant and mitigation area. Lands immediately downstream of this site have been placed under a restrictive covenant and provide mitigation set-aside for Ray Mine activities that have been permitted under Section 404 of the CWA. To some extent, the development of the site as a TSF would result in the dewatering of this mitigation area. The site would also require a 7.9-mile-long pipeline through unfavorable terrain. This pipeline would be difficult and costly to operate. The development of a TSF at this site is also expected to impact intermittent or perennial waters, riparian areas, and possibly wetland areas as well (i.e., special aquatic sites).
- **Hackberry Gulch Alternative 1:** The development of Hackberry Gulch Alternative 1 is currently considered practicable, but not the LEDPA. The number of potential pathways for seepage (numerous faults, multiple drainages, paleo-channels, layers of more permeable material within the Big Dome Formation, layered heterogeneity resulting in increased connectivity with depth and uncertain migration pathways for seepage, and high potential for discontinued heterogeneity of subsequent increased lateral and vertical cross-connectivity through a network of Tertiary-age normal faults) complicates the ability to effectively prevent or capture seepage at this location. Given the site’s proximity to the Gila River, it would be difficult to prevent at least some seepage at Hackberry Gulch from eventually reaching the river. Because of the challenges associated with controlling seepage; impacts to perennial and intermittent water sources, including wetland areas; greater visual resource impacts along SR 177 and in the community of Kearny; greater impacts to critical habitat for southwestern willow flycatcher and proposed critical habitat for yellow billed cuckoo containing dense hydroriparian vegetation, a higher percentage of cumulative impacts on a watershed level, and the inability to perform concurrent reclamation early in the project life cycle, Hackberry Gulch Alternative 1 is not considered the LEDPA when compared to Ripsey Wash Alternative 3.
- **Hackberry Gulch Alternative 2:** The development of Hackberry Gulch Alternative 2 is currently considered practicable, but not the LEDPA. While this alternative has fewer areas of potential seepage than Hackberry Gulch Alternative 1 due to its smaller footprint, the number of potential pathways for seepage (numerous faults, multiple drainages, paleo-channels, layers of more permeable material within the Big Dome Formation, layered heterogeneity resulting in increased connectivity with depth and uncertain migration pathways for seepage, and high potential for discontinued heterogeneity of subsequent increased lateral and vertical cross-connectivity through a network of Tertiary-age normal faults) complicates the ability to effectively prevent or capture contain seepage at this location. Given the site’s proximity to the Gila River, it would be difficult to prevent at least some seepage at Hackberry Gulch from eventually reaching the river. Because of the challenges

associated with controlling seepage; impacts to perennial and intermittent water sources, including wetland areas; greater visual resource impacts along SR 177 and in the community of Kearny; greater impacts to critical habitat for southwestern willow flycatcher and proposed critical habitat for yellow billed cuckoo containing dense hydroriparian vegetation, a higher percentage of cumulative impacts on a watershed level, and the inability to perform concurrent reclamation early in the project life cycle, Hackberry Gulch Alternative 2 is not considered the LEDPA when compared to Ripsey Wash Alternative 3.

- **Ripsey Wash Alternative 1:** This alternative is practicable, but it is not the LEDPA. It would impact substantially more acres of waters (approximately 78 acres more) than Ripsey Wash Alternative 3, the Preferred Alternative.
- **Ripsey Wash Alternative 2:** This alternative is practicable, but it is not the LEDPA. It would impact more acres of waters (approximately 14 acres more) than Ripsey Wash Alternative 3, the Preferred Alternative.
- **Ripsey Wash Alternative 3:** This alternative is the LEDPA. Hackberry Gulch Alternatives 1 and 2 and Ripsey Wash Alternatives 1, 2, and 3 are all currently considered practicable for the proposed TSF. Ripsey Wash Alternative 3 has fewer impacts to waters than Ripsey Wash Alternatives 1 and 2 based on the acreage of impact. Although Ripsey Wash Alternative 3 impacts more acres of waters than do the Hackberry Gulch alternatives, all impacted waters at Ripsey Wash are ephemeral, and no special aquatic sites would be affected. In contrast, the development of Hackberry Gulch Alternatives 1 and 2 would impact 2.3 acres of perennial and intermittent waters and Hackberry Alternative 2, including wetland areas (special aquatic sites). Pursuant to the Guidelines, the presence of wetlands within the impact footprint of the Hackberry Gulch alternatives, combined with the fact that the proposed TSF is not water-dependent, results in a regulatory presumption that other sites not involving impacts to wetlands, such as Ripsey Wash Alternative 3, are available and that those alternatives have a less adverse impact on the aquatic ecosystem (40 C.F.R. § 230.10(a)(3)).

  Ripsey Wash Alternative 3 would result in a smaller percentage of cumulative impact on a watershed level than the Hackberry Gulch alternatives. In addition, the Hackberry Gulch alternatives are considerably less favorable for minimizing and controlling seepage from a tailings impoundment given the number of potential pathways for seepage at their location. Seepage is more likely to occur— and would be more difficult to capture or contain—at Hackberry Gulch than at Ripsey Wash. Finally, the Hackberry Gulch alternatives would have other adverse environmental consequences in comparison to the Ripsey Wash alternatives. These include substantially greater visual resource impacts because of their proximity to SR 177 and visibility from residences in Kearny, greater impacts to designated critical habitat for southwestern willow flycatcher and proposed critical habitat for yellow-billed cuckoo containing dense hydroriparian vegetation, and the inability to perform concurrent reclamation earlier in the life of the project.

Table 11. Alternatives that are not practicable – summary of key findings

| Criteria | E Dam | West Dam | Granite Mountain | Devils Canyon |
|---|---|---|---|---|
| Overall facility capacity (million tons) | 750.9 | 757.6 | 748.6 | 766.7 |
| Embankment volume (million tons) | 174.3 | 239.6 | 183.0 | 158.9 |
| Tailings volume (million tons) | 576.6 | 518.0 | 565.6 | 607.8 |
| Crest elevation (feet) | 2,620 | 2,970 | 2,880 | 3,180 |
| Embankment height (feet) | 493 | 870 | 710 | 890 |
| Tailings pipeline length (feet [miles]) | 107,325 (20.3) | 8,491 (1.6) | 42,171 (8.0) | 40,345 (7.6) |
| Total length of diversion channel (feet [miles]) | 22,557 (4.3) | 17,051 (3.2) | 17,744 (3.4) | 38,742 (7.3) |
| Tailings impoundment footprint (acres) | 2,363 | 1,333 | 1,568 | 1,222 |
| Total estimated surface disturbance | 2,400 | 1,620 | 1,580 | 1,220 |
| Direct impacts to water (acres) | 169.40 | 52.88 | 61.81 | 46.75 |
| Impacts from dewatering (acres) | 106.46 | 2.81 | 4.81 | 3.17 |
| Special aquatic sites (yes or no) | No | No | No | Yes |
| **Total impacts to Waters of the U.S. (acres)** | **275.86** | **55.69** | **66.62** | **49.92** |
| **Total impacts to Waters of the U.S. (linear feet)** | **355,505** | **125,990** | **135,685** | **73,360** |
| Size-to-capacity ratio (acres / overall capacity) | 3.2:1 | 1.8:1 | 2.1:1 | 1.6:1 |
| Embankment ratio (embankment volume / tailings volume) | 0.3:1 | 0.4:1 | 0.3:1 | 0.2:1 |
| Functions and values of jurisdictional waters | Ephemeral drainages with xeroriparian vegetation consistent with the Arizona Upland subdivision of the Sonoran Desertscrub biotic community (Brown 1982). Woody species commonly noted along washes also found in upland habitats. | Ephemeral drainages with xeroriparian vegetation consistent with the Arizona Upland subdivision of the Sonoran Desertscrub biotic community (Brown 1982). Woody species commonly noted along washes also found in upland habitats. | Ephemeral drainages with xeroriparian vegetation consistent with the Arizona Upland subdivision of the Sonoran Desertscrub biotic community (Brown 1982). Woody species commonly noted along washes also found in upland habitats. | Waters support xeroriparian, mesoriparian, and hydroriparian vegetation communities. Portions of the site support perennial and intermittent surface water, potentially including wetlands (i.e., special aquatic sites). |
| Distance to nearest intermittent or perennial water | 1.1 miles to the San Pedro River | 0.8 mile to Mineral Creek | 1.9 miles to the Gila River | 0.2 mile to impounded surface water created by Big Box Dam at confluence with Mineral Creek (mitigation area under prior Section 404 permit) |

Table 11. Alternatives that are not practicable – summary of key findings

| Criteria | E Dam | West Dam | Granite Mountain | Devils Canyon |
|---|---|---|---|---|
| Other considerations | More than 20 miles from the Ray Mine | Requires realignment of SR 177. | Conflicts with mineral estate rights and foreseeable uses of mining. | Lands immediately downstream of the site are covered by a restrictive covenant and provide mitigation set-aside for Ray Mine activities. |
| Practicability | No – This alternative is not practicable from a logistical perspective; it is approximately 20 miles from the Ray Mine. | No – This alternative is not practicable from a logistical perspective; footprint impinges on existing leach operations; the embankment height, side hill construction, and rate of rise increase the risk and consequence of failure; would also require relocation of approximately 7 miles of SR 177 in rough terrain. | No – This alternative is not logistically practicable; the alternative's foreseeable uses include mining, and the area is in mineral estate. | No – The area is upstream of a restrictive covenant that provides mitigation set-aside for Ray Mine activities. This alternative would result in some dewatering of that mitigation site. |

Table 12. Practicable alternatives – summary of key findings

| Criteria | | Hackberry Gulch Alternative 1 | Hackberry Gulch Alternative 2 | Ripsey Wash Alternative 1 | Ripsey Wash Alternative 2 | Ripsey Wash Alternative 3 (Preferred Alternative) |
|---|---|---|---|---|---|---|
| Overall facility capacity (million tons) | | 755.2 | 746.2 | 769.5 | 791.7 | 751.3 |
| Embankment volume (million tons) | | 224.0 | 158.4 | 97.2 | 126.0 | 67.4 |
| Tailings volume (million tons) | | 531.2 | 590.7 | 672.4 | 665.7 | 683.7 |
| Crest elevation (feet) | | 2,500 | 2,535 | 2,350 | 2,390 | 2,440 |
| Embankment height (feet) | | 640 | 610 | 560 | 540 | 625 |
| Tailings pipeline length (feet [miles]) | | 4,622 (0.9) | 4,622 (0.9) | 16,011 (3.0) * | 16,011 (3.0) * | 16,011 (3.0) * |
| Total length of diversion channel (feet [miles]) | | 23,912 (4.5) | 22,071 (4.2) | 34,543 (6.5) | 20,453 (3.9) | 17,624 (3.3) |
| Total length of diversion pipeline (feet [miles]) | | N/A | 11,091 (2.1) | N/A | N/A | 9,330 (1.8) |
| Tailings impoundment footprint (acres) | | 2,125 | 1,971 | 2,356 | 2,140 | 2,129 |
| Total estimated surface disturbance | | 2,450 | 2,290 | 2,791 | 2,641 | 2,636 |
| Direct impacts to water (acres) | | 53.43 | 51.70 | 167.98 | 135.48 | 130.91 |
| Impacts from dewatering (acres) | | 49.72 | 19.80 | 44.50 | 13.10 | 3.74 |
| Special aquatic sites (yes or no) | | Yes | Yes | No | No | No |
| Total impacts to Waters of the U.S. (acres) | | 103.15 | 71.50 | 212.48 | 148.58 | 134.65 |
| Total impacts to Waters of the U.S. (linear feet) | | 260,990 | 228,325 | 212,650 | 159,645 | 170,840 |
| Impact by drainage type (acres) | Wetland | 0.62 | 0.62 | 0 | 0 | 0 |
| | Perennial/intermittent | 1.65 | 1.65 | 0 | 0 | 0 |
| | Ephemeral | 100.88 | 69.23 | 212.48 | 148.58 | 134.65 |
| Cumulative impacts to waters | | This alternative would impact an estimated 2.6 percent of the waters within the HUC10 watershed. These impacts in addition to the previously permitted impacts within the watershed equal 3.9 percent of the total estimated waters within the watershed. | This alternative would impact an estimated 2.3 percent of the waters within the HUC10 watershed. These impacts in addition to the previously permitted impacts within the watershed equal 3.6 percent of the total estimated waters within the watershed. | This alternative would impact an estimated 2.2 percent of the waters within the HUC10 watershed. No data were available to estimate the percent of the impacts within the watershed associated with previously permitted areas. | This alternative would impact an estimated 1.7 percent of the waters within the HUC10 watershed. No data were available to estimate the percent of the impacts within the watershed associated with previously permitted areas. | This alternative would impact an estimated 1.7 percent of the waters within the HUC10 watershed. No data were available to estimate the percent of the impacts within the watershed associated with previously permitted areas. |
| Acres of impact to mapped proposed and designated critical habitat | Southwestern Willow Flycatcher critical habitat | 1.5 acres associated with the stilling basin at Belgravia Wash and the Gila River. This area contains dense hydroriparian vegetation providing the primary constituent elements identified by USFWS (2013) for this species. | 1.5 acres associated with the stilling basin at Belgravia Wash and the Gila River. This area contains dense hydroriparian vegetation providing the primary constituent elements identified by USFWS (2013) for this species. | 0.7 acre (0.2 acre of permanent and 0.5 acre of temporary impacts) associated with the pipeline bridge crossing of the Gila River and an additional 12.2 acres within areas that do not provide primary constituent elements identified by USFWS (2013) for this species. | 0.7 acre (0.2 acre of permanent and 0.5 acre of temporary impacts) associated with the pipeline bridge crossing of the Gila River and an additional 12.2 acres within areas that do not provide primary constituent elements identified by USFWS (2013) for this species. | 0.7 acre (0.2 acre of permanent and 0.5 acre of temporary impacts) associated with the pipeline bridge crossing of the Gila River and an additional 12.2 acres within areas that do not provide primary constituent elements identified by USFWS (2013) for this species. |
| | Yellow-billed Cuckoo proposed critical habitat | 1.6 acres associated with the stilling basin at Belgravia Wash and the Gila River. Approximately 1.5 acres in this area is dense hydroriparian vegetation providing the primary constituent elements identified by USFWS (2014) for this species. | 1.6 acres associated with the stilling basin at Belgravia Wash and the Gila River. Approximately 1.5 acres in this area is dense hydroriparian vegetation providing the primary constituent elements identified by USFWS (2014) for this species. | 0.7 acre (0.2 acre of permanent and 0.5 acre of temporary impacts) associated with the pipeline bridge crossing of the Gila River and an additional 3.6 acres within areas that do not provide primary constituent elements identified by USFWS (2014) for this species. | 0.7 acre (0.2 acre of permanent and 0.5 acre of temporary impacts) associated with the pipeline bridge crossing of the Gila River and an additional 3.6 acres within areas that do not provide primary constituent elements identified by USFWS (2014) for this species. | 0.7 acre (0.2 acre of permanent and 0.5 acre of temporary impacts) associated with the pipeline bridge crossing of the Gila River and an additional 3.6 acres within areas that do not provide primary constituent elements identified by USFWS (2014) for this species. |
| Size-to-capacity ratio (acres / overall capacity) | | 2.8:1 | 2.6:1 | 3.1:1 | 2.7:1 | 2.8:1 |
| Embankment ratio (embankment volume / tailings volume) | | 0.3:1 | 0.2:1 | 0.1:1 | 0.2:1 | 0.1:1 |

Table 12. Practicable alternatives – summary of key findings

| Criteria | Hackberry Gulch Alternative 1 | Hackberry Gulch Alternative 2 | Ripsey Wash Alternative 1 | Ripsey Wash Alternative 2 | Ripsey Wash Alternative 3 (Preferred Alternative) |
|---|---|---|---|---|---|
| Distance to Gila River | The TSF toe is about 2,000 feet upstream of the Gila River at its closest point and the closest seepage collection pond is about 750 feet upstream of the river. | The TSF toe is about 2,000 feet upstream of the Gila River at its closest point and the closest seepage collection pond is about 750 feet upstream of the river. | The TSF toe is about 1,900 feet upstream of the Gila River at its closest point. The locations of the seepage collection ponds were not determined as part of this conceptual plan. | The TSF toe is about 2,000 feet upstream of the Gila River at its closest point. The locations of the seepage collection ponds were not determined as part of this conceptual plan. | The TSF toe is about 3,200 feet upstream of the Gila River at its closest point and the closest seepage collection pond is about 1,600 feet upstream of the river. |
| Other considerations | This alternative requires the use of borrow sources outside the TSF footprint. The toe of this TSF would be within 500 feet of SR 177, requiring either the placement of seepage collection ponds and other project infrastructure on both sides of the highway or the relocation of approximately 3 miles of the highway. This alternative requires side-hill construction, and the control of stormwater runoff from this TSF embankment is challenging compared to the control of runoff from a valley fill TSF embankment, where the embankment toe follows positive gradient to the seepage collection ponds. | This alternative requires the use of borrow sources outside the TSF footprint. The required starter dam length for this alternative is 9,700 feet compared to a starter dam length of 3,700 feet for the preferred alternative (Ripsey Wash Alternative 3). The toe of this TSF would be within 500 feet of SR 177, requiring either the placement of seepage collection ponds and other project infrastructure on both sides of the highway or the relocation of approximately 3 miles of the highway. This alternative requires side-hill construction, and control of stormwater runoff from this TSF embankment is challenging compared to the control of runoff from a valley fill TSF embankment, where the embankment toe follows positive gradient to the seepage collection ponds. | Requires the realignment of the Florence-Kelvin Highway, San Carlos Irrigation Project powerline, and Arizona Trail. | Requires the realignment of the Florence-Kelvin Highway, San Carlos Irrigation Project powerline, and Arizona Trail. | Requires the realignment of the Florence-Kelvin Highway, San Carlos Irrigation Project powerline, and Arizona Trail. |
| Practicability | Currently considered practicable, but is not the LEDPA because of a comparable alternative at the same location with fewer impacts to waters. The Hackberry site has numerous potential pathways for seepage (numerous faults, multiple drainages, paleo-channels, layers of more permeable material within the Big Dome Formation, layered heterogeneity resulting in increased connectivity with depth and uncertain migration pathways for seepage, and high potential for discontinued heterogeneity of subsequent increased lateral and vertical cross-connectivity through a network of Tertiary-age normal faults),, as opposed to the Ripsey Wash site, which is underlain or surrounded by low- to very-low-permeability granite. This alternative would have 12 potential drainage pathways for seepage; special aquatic sites would be impacted, as would perennial and intermittent waters; and concurrent reclamation would not be possible early in the life of the project. Not carried forward in the EIS. | Currently considered practicable, but not the LEDPA. The Hackberry site has numerous potential pathways for seepage (numerous faults, multiple drainages, paleo-channels, layers of more permeable material within the Big Dome Formation, layered heterogeneity resulting in increased connectivity with depth and uncertain migration pathways for seepage, and high potential for discontinued heterogeneity of subsequent increased lateral and vertical cross-connectivity through a network of Tertiary-age normal faults), as opposed to the Ripsey Wash site, which is underlain or surrounded by low- to very-low-permeability granite. This alternative would have 7 potential drainage pathways for seepage; special aquatic sites would be impacted, as would perennial and intermittent waters; and concurrent reclamation would not be possible early in the life of the project. | Practicable, but is not the LEDPA because of comparable alternatives at the same location with fewer impacts to waters and no other significant adverse environmental consequences. Not carried forward in the EIS. | Practicable, but is not the LEDPA because of comparable alternatives at same location with fewer impacts to waters and no other significant adverse environmental consequences. Not carried forward in the EIS. | Practicable – Ripsey Wash Alternative 3 is identified as the LEDPA. This alternative would have only 2 seepage collection points and the site is underlain by low- to very-low-permeability granite; only ephemeral waters would be impacted (no special aquatic sites or perennial or intermittent waters would be impacted); and concurrent reclamation would be possible earlier in the life of the project. |

* There are 5 alternatives for the delivery of tailings to the Ripsey Wash Project. The value shown here represents the length of the preferred tailings delivery pipeline alternative.

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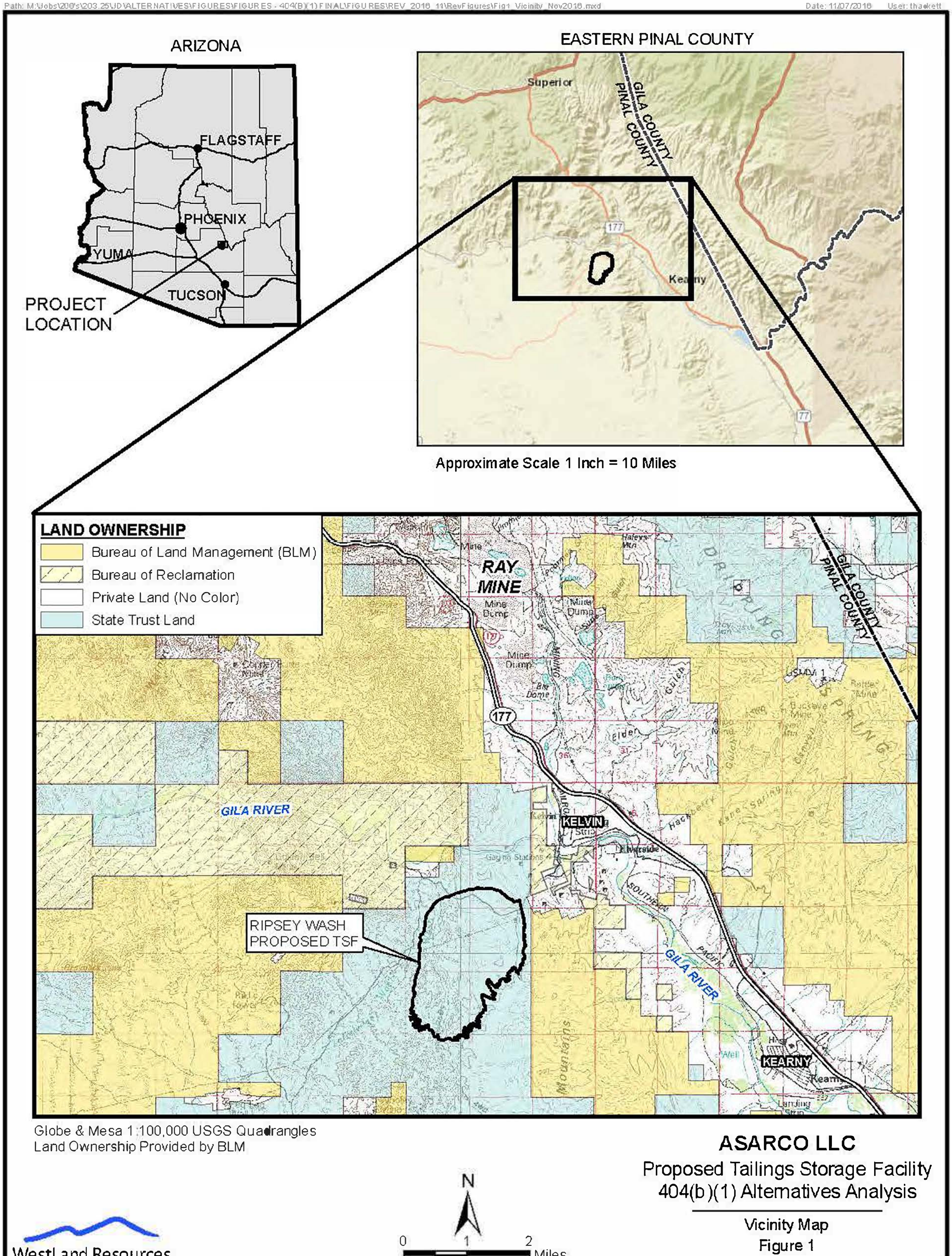
# FIGURES




Globe & Mesa 1:100,000 USGS Quadrangles
Land Ownership Provided by BLM

**ASARCO LLC**

Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Vicinity Map
Figure 1

WestLand Resources

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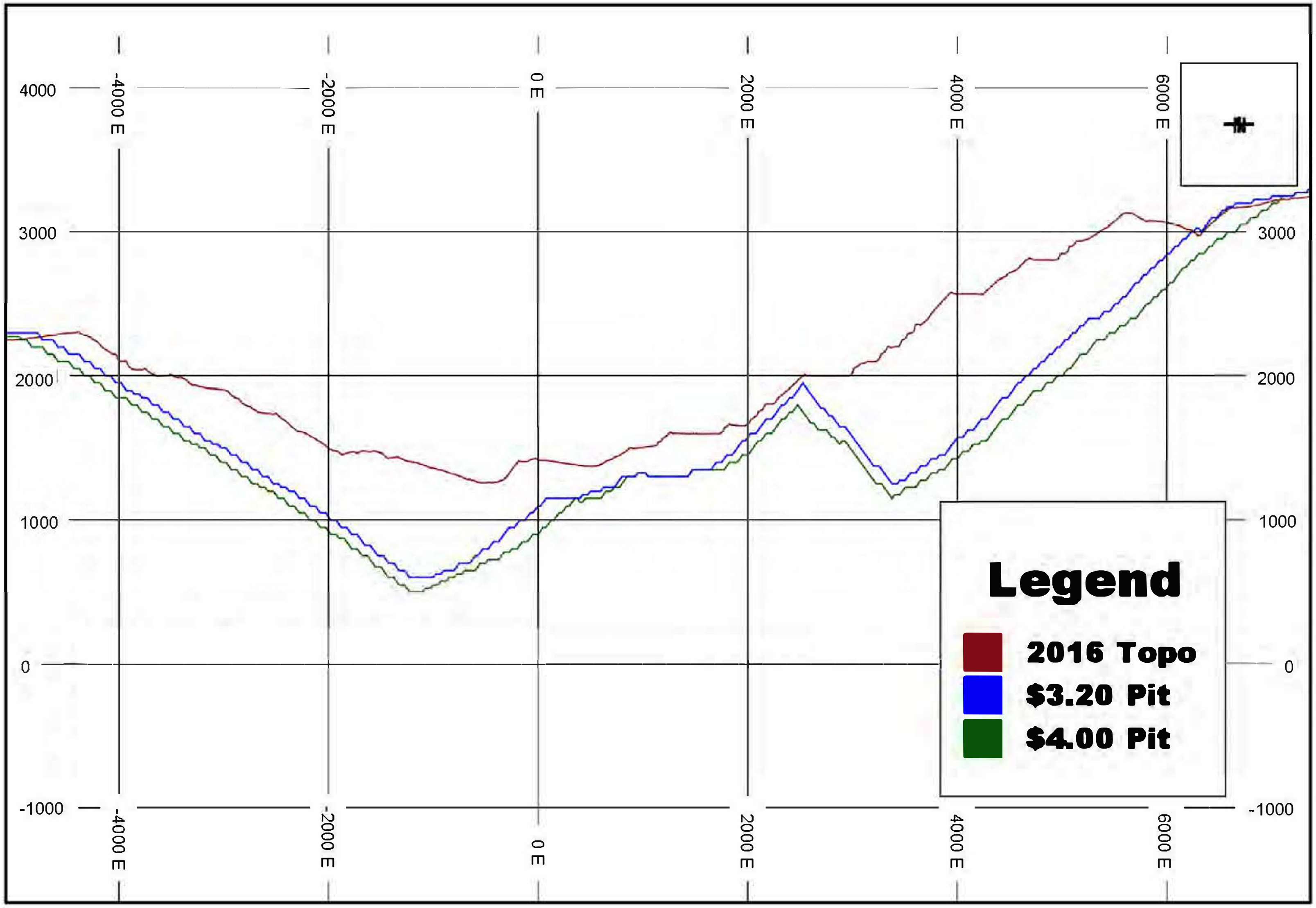


Ray Mine W/E Cross Section 3000 N
2016/11/10
(N.T.S.)

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Ray Life of Mine
Cross Section
Figure 2

WestLand Resources

Source: ASARCO LLC

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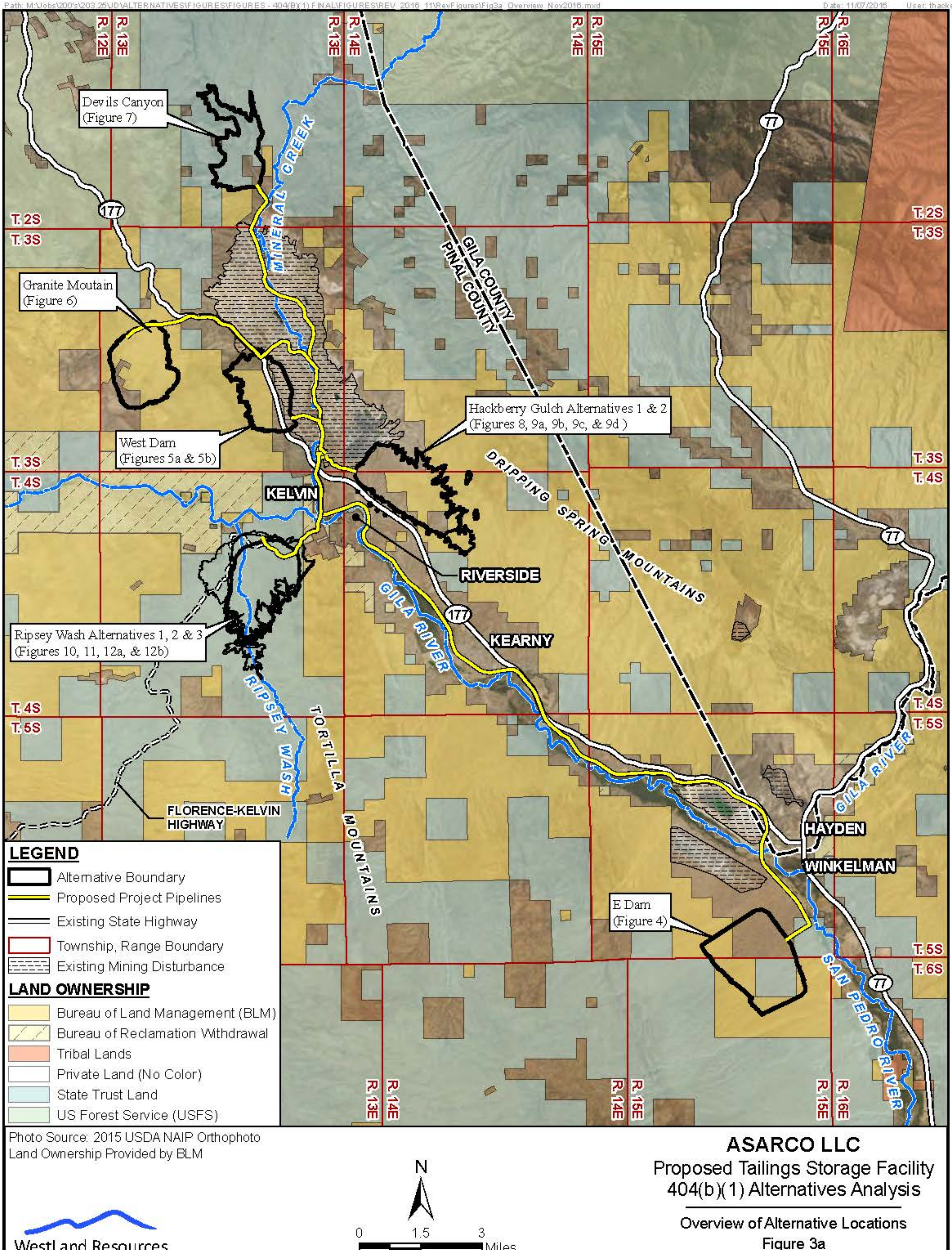
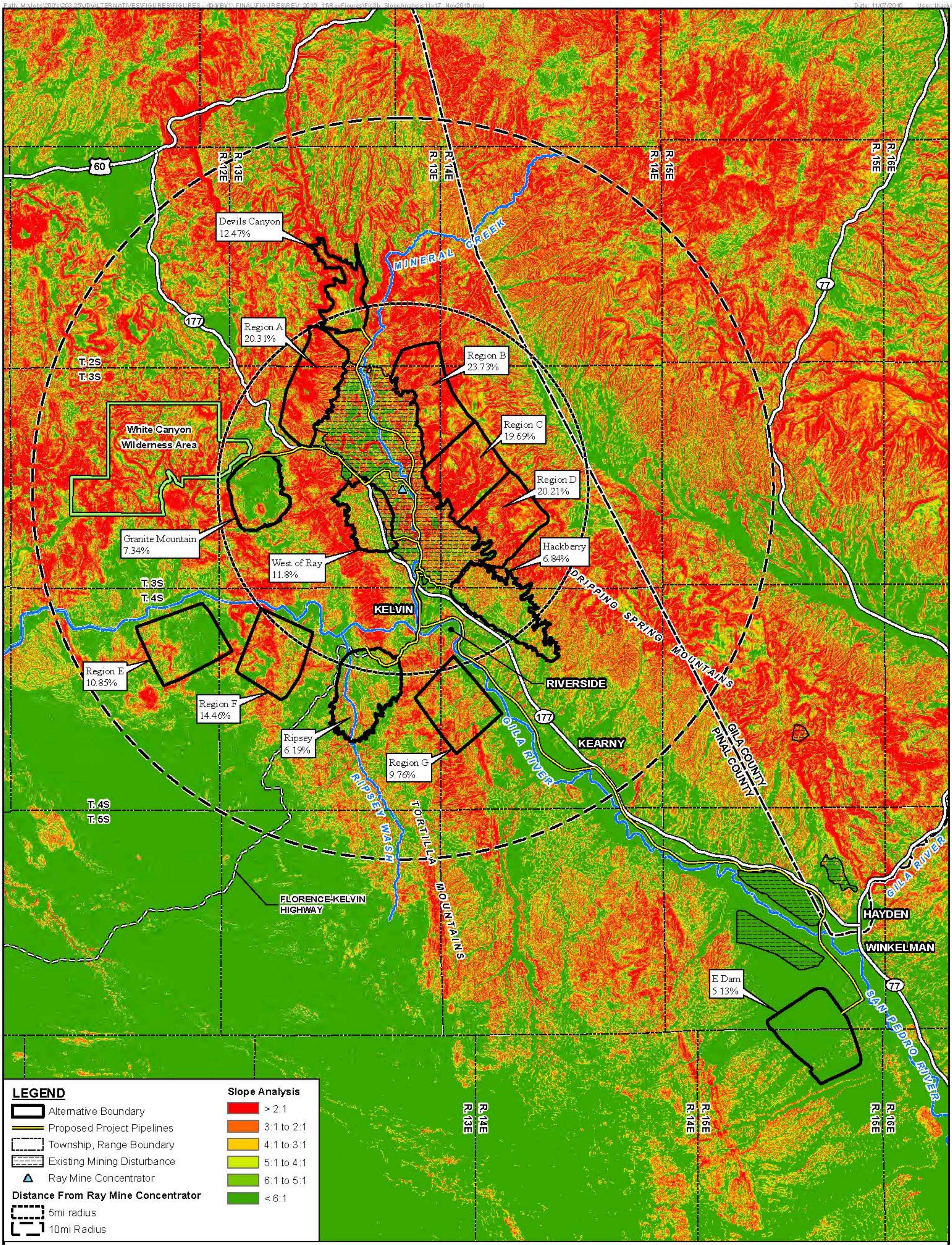



Photo Source: 2015 USDA NAIP Orthophoto
Land Ownership Provided by BLM

WestLand Resources

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Overview of Alternative Locations
Figure 3a




Elevation Source: USGS NED

**10 Meter Digital Elevation Model Slope Class as Percent of Regional Alternative Total**

| Regional Tailings Alternative | Slope Percentage | | | | | | Drainage Slope Percentage (Average Slope Percentage of NHD-mapped Drainages) |
|---|---|---|---|---|---|---|---|
| | > 2:1 | 3:1 to 2:1 | 4:1 to 3:1 | 5:1 to 4:1 | 6:1 to 5:1 | < 6:1 | |
| Region A | 45.57 | 31.86 | 11.14 | 4.66 | 2.18 | 4.60 | 20.31 |
| Region B | 48.42 | 31.43 | 10.95 | 4.18 | 1.68 | 3.33 | 19.69 |
| Region C | 50.32 | 28.21 | 10.29 | 4.42 | 1.96 | 4.79 | 20.21 |
| Region D | 40.40 | 36.15 | 12.06 | 4.90 | 2.10 | 4.39 | 23.73 |
| Region E | 4.34 | 12.96 | 10.48 | 8.66 | 6.80 | 56.76 | 10.85 |
| Region F | 19.50 | 27.66 | 14.46 | 8.78 | 5.51 | 24.09 | 14.46 |
| Region G | 20.71 | 33.15 | 15.58 | 8.14 | 4.24 | 18.18 | 9.76 |
| Devils Canyon | 16.24 | 4.45 | 7.05 | 10.84 | 21.95 | 39.46 | 12.47 |
| E Dam | 0.10 | 0.54 | 0.67 | 0.85 | 0.82 | 97.03 | 5.13 |
| Granite Mountain | 3.78 | 10.74 | 8.58 | 6.66 | 5.63 | 64.61 | 7.34 |
| Hackberry | 6.65 | 26.40 | 19.47 | 11.43 | 6.34 | 29.70 | 6.84 |
| Ripsey | 4.27 | 17.06 | 15.49 | 10.65 | 6.87 | 45.66 | 6.19 |
| West of Ray | 8.12 | 24.23 | 16.85 | 11.55 | 6.80 | 32.45 | 11.80 |

N

0 1.25 2.5
Miles

**ASARCO LLC**

Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Overview of Alternative Locations with Slope Analysis
Figure 3b

WestLand Resources

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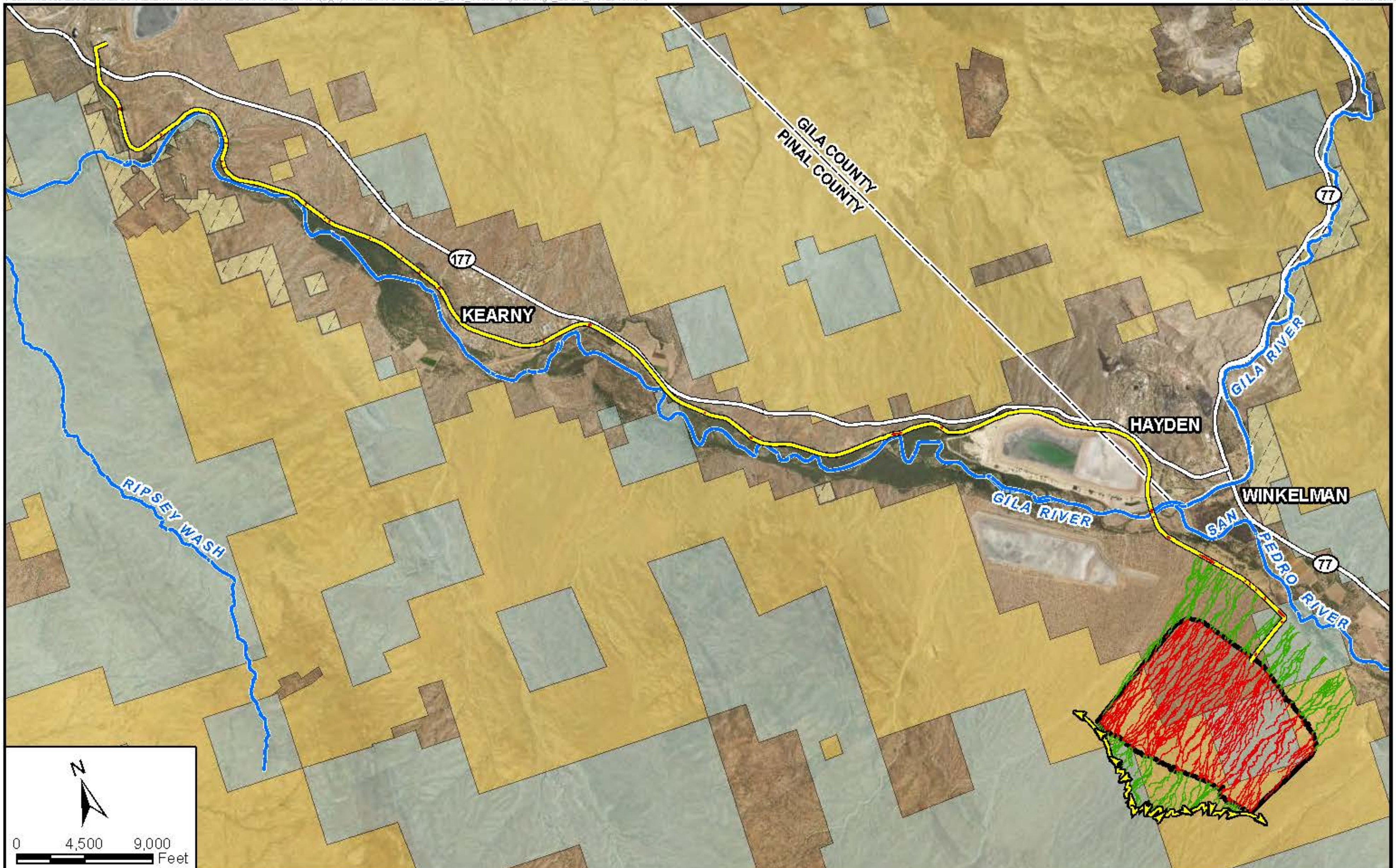


Photo Source: 2015 USDA NAIP Orthophoto
Land Ownership Provided by BLM

**LEGEND**

- Alternative Footprint
- Directly Impacted Waters of the U.S.
- Indirectly Impacted Waters of the U.S.
- Proposed Diversion Channel and Flow Direction
- Proposed Project Pipelines

**LAND OWNERSHIP**

- Bureau of Land Management (BLM)
- Bureau of Reclamation Withdrawal
- Indian Lands
- Private Land (No Color)
- State Trust Land

WestLand Resources

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

E Dam
Figure 4

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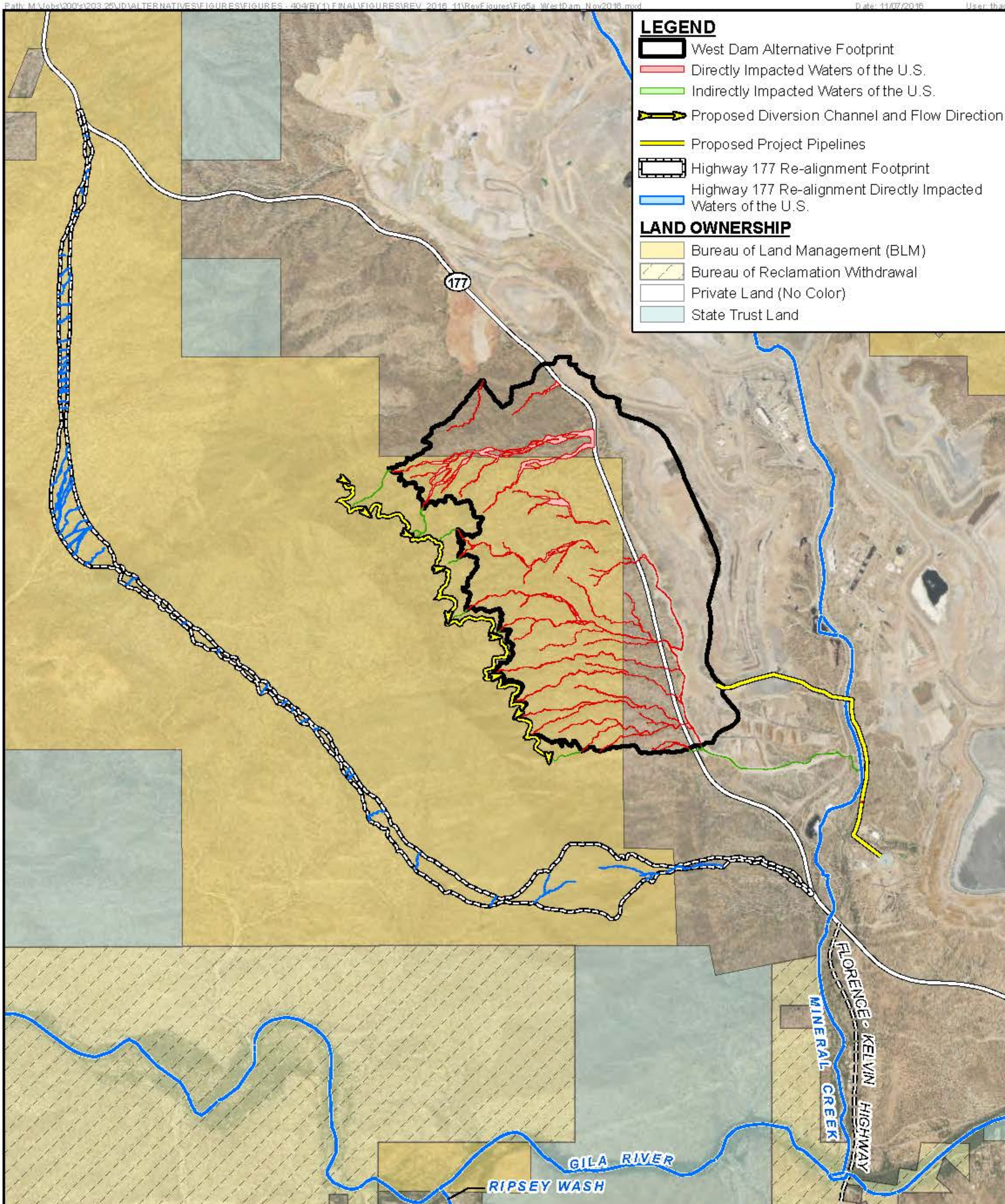


Photo Source: 2015 USDA NAIP Orthophoto
Land Ownership Provided by BLM

N

0 1,750 3,500 Feet

WestLand Resources

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

West Dam
Figure 5a

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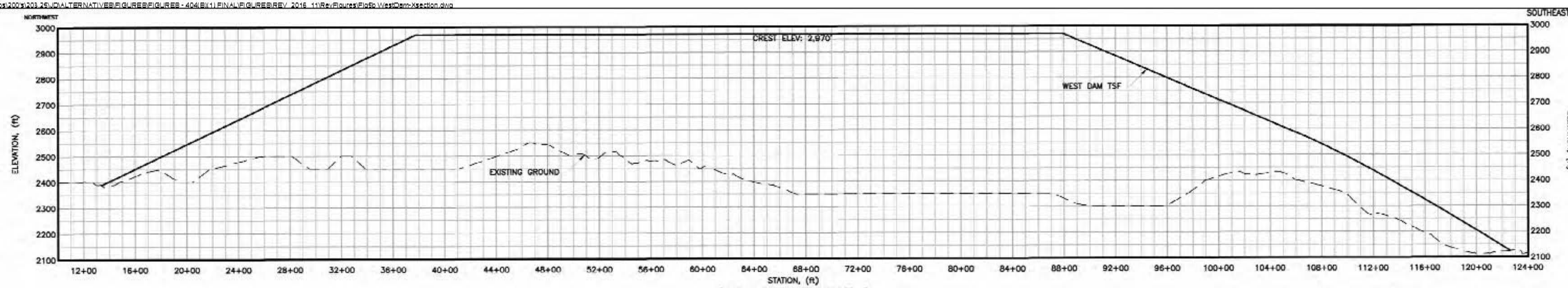
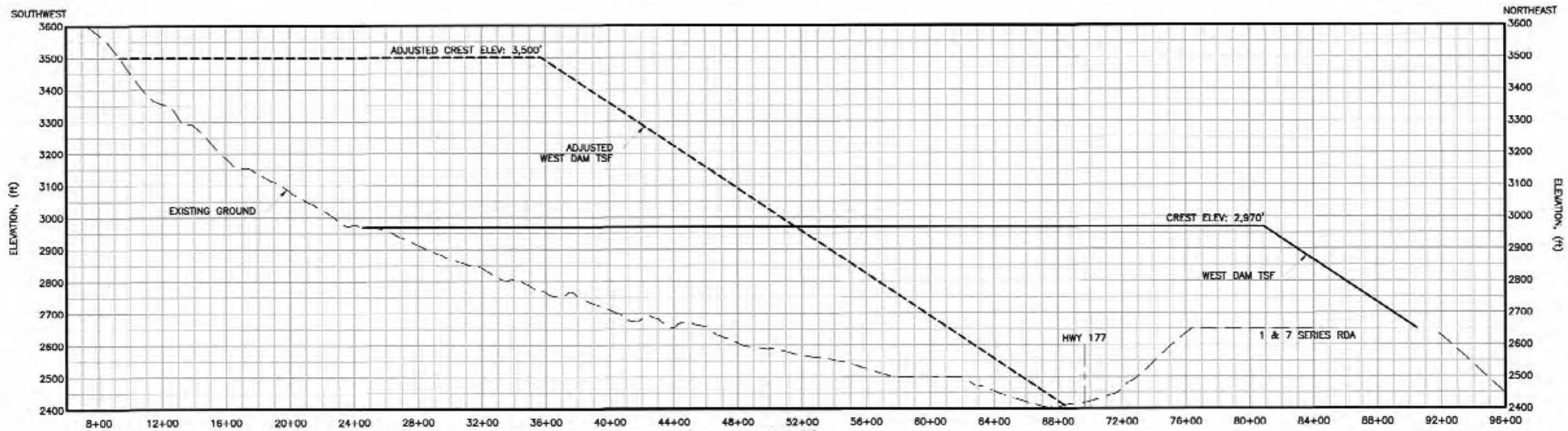



**WEST DAM–SECTION A**

SECTION LOOKING NORTH

400 0 400 800 FT HORIZONTAL

200 0 200 400 FT VERTICAL

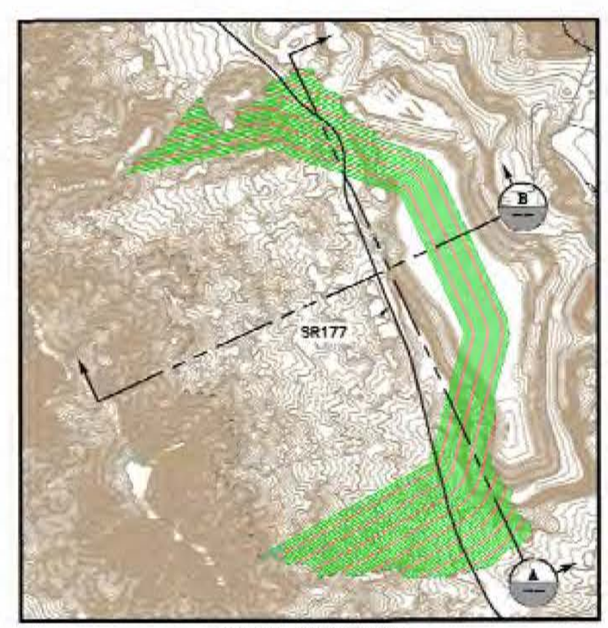



**WEST DAM–SECTION B**

SECTION LOOKING NORTH

400 0 400 800 FT HORIZONTAL

200 0 200 400 FT VERTICAL




**WEST DAM TSF**

**LEGEND:**

- 100 EXISTING GROUND SURFACE CONTOUR EL, FEET
- 100 PROPOSED GROUND SURFACE CONTOUR EL, FEET
- EXISTING GROUND
- ORIGINAL WEST DAM
- WEST DAM ADJUSTED TO AVOID HWY 177

amec

**ASARCO LLC**

Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

West Dam Embankment and
Avoidance of SR-177
Cross Sections

Figure 5b

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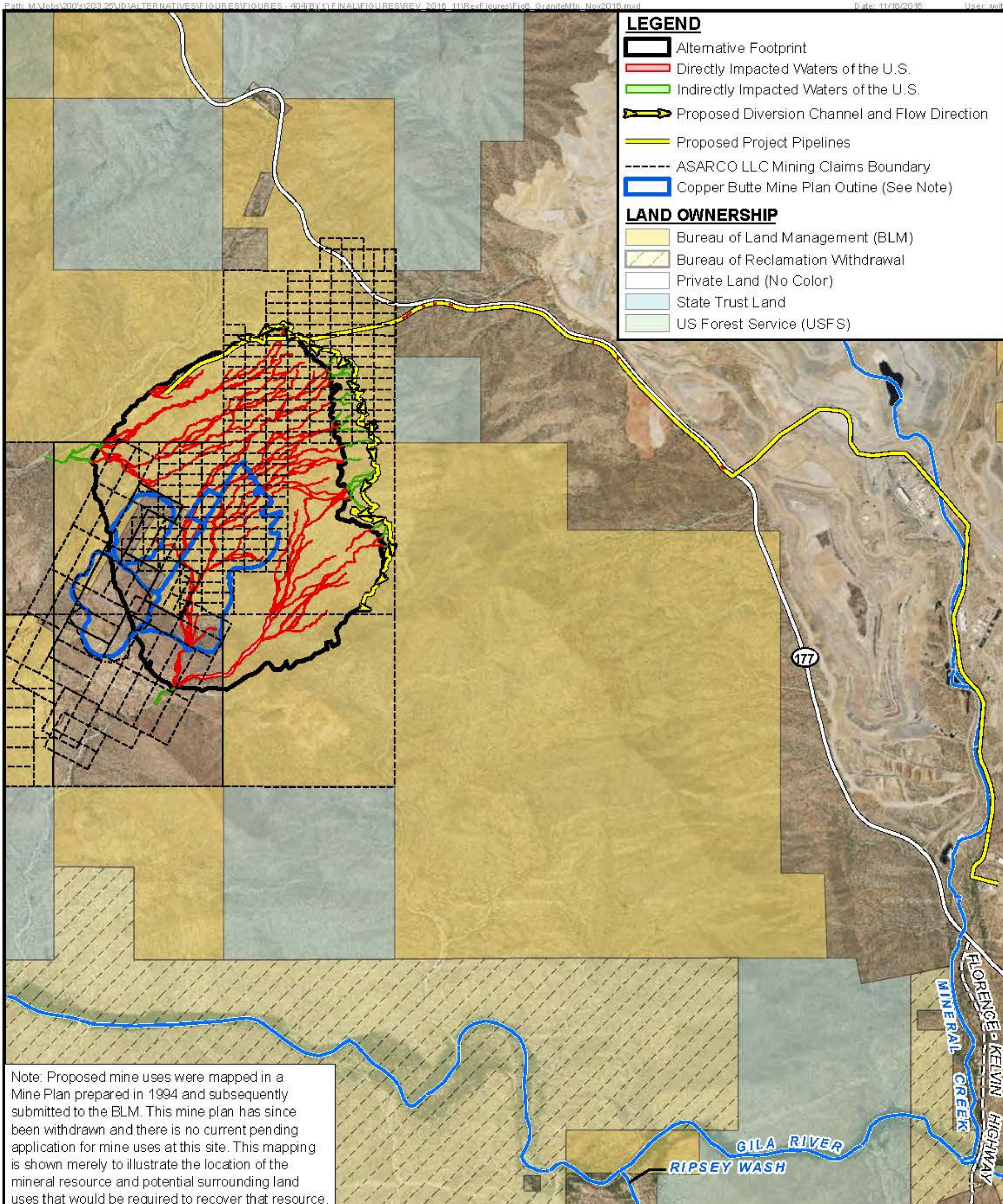


Photo Source: 2015 USDA NAIP Orthophoto
Land Ownership Provided by BLM

WestLand Resources

N

0 2,000 4,000 Feet

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

**Granite Mountain**
**Figure 6**

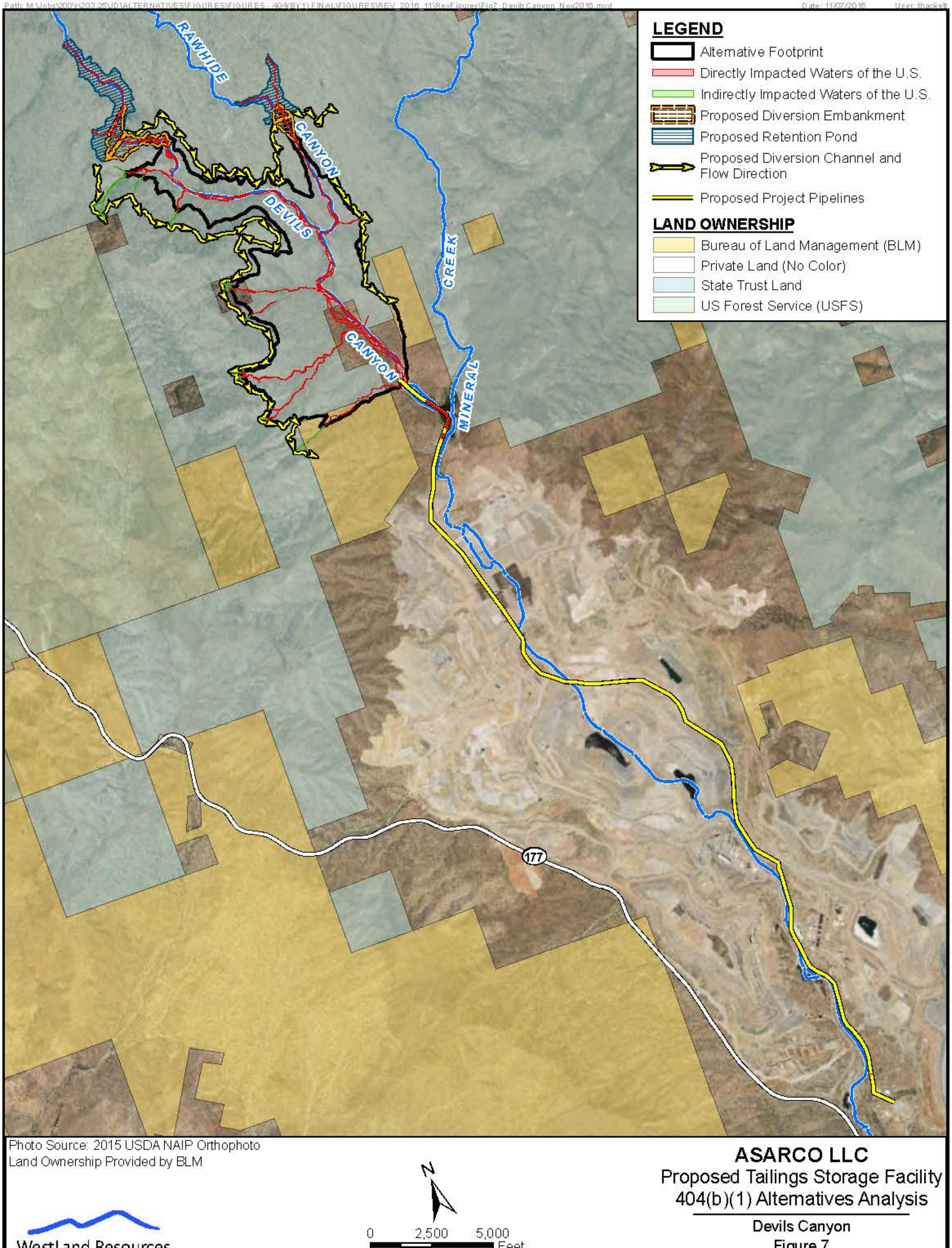


Photo Source: 2015 USDA NAIP Orthophoto
Land Ownership Provided by BLM

WestLand Resources

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

**Devils Canyon**
**Figure 7**

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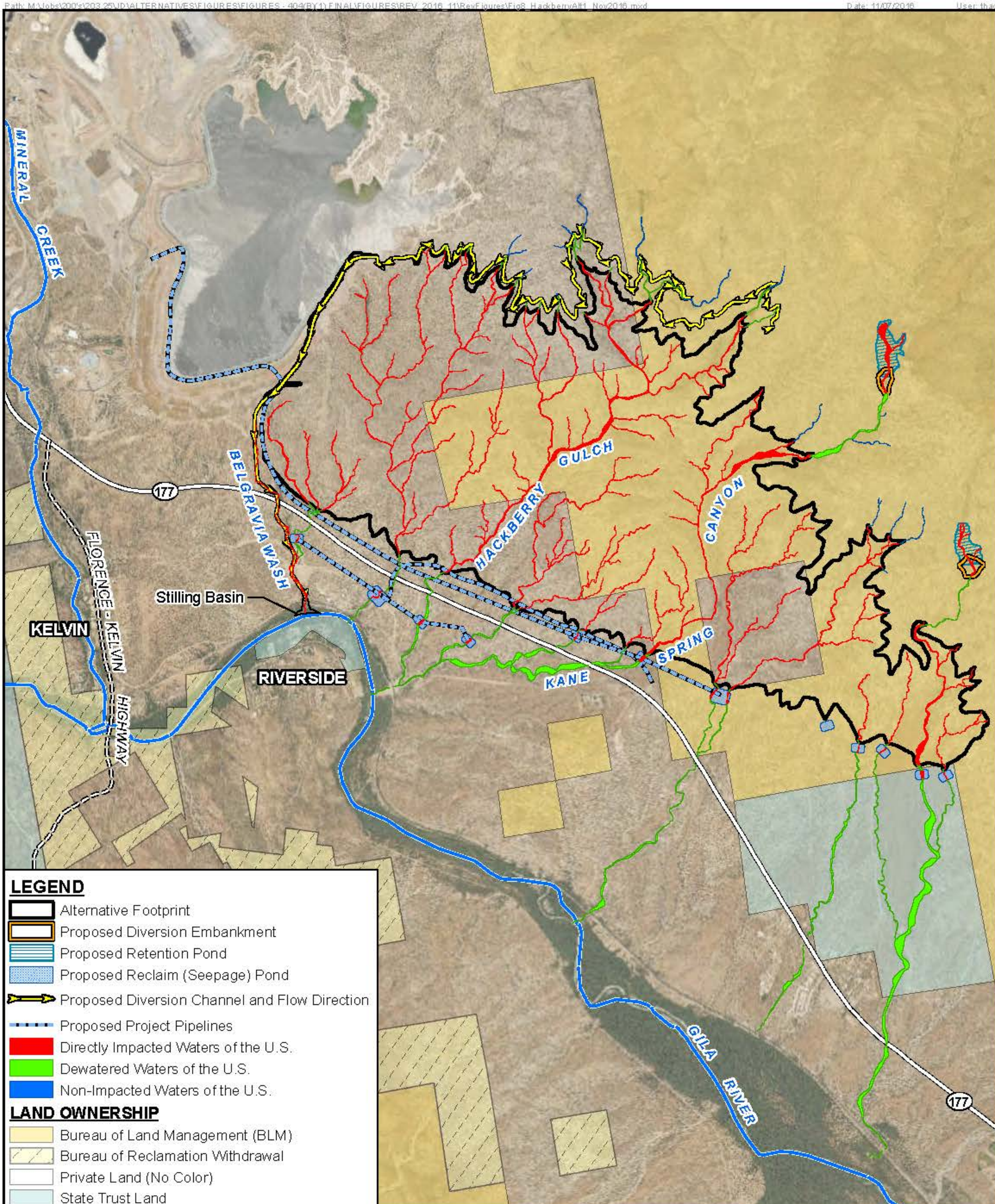


Photo Source: 2015 USDA NAIP Orthophoto
Land Ownership Provided by BLM

WestLand Resources

N

0 1,500 3,000 Feet

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Hackberry Gulch Alternative 1
Figure 8

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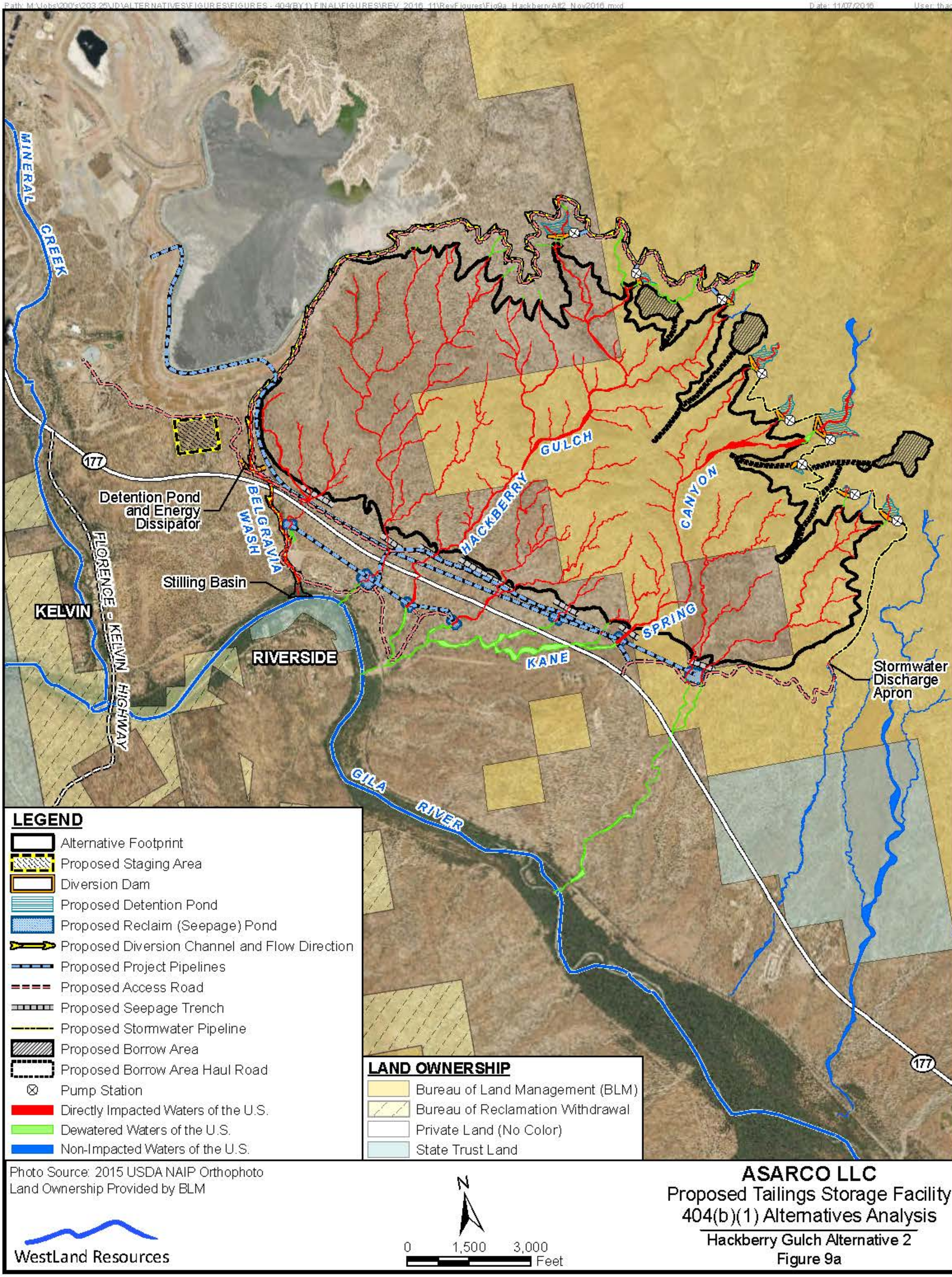

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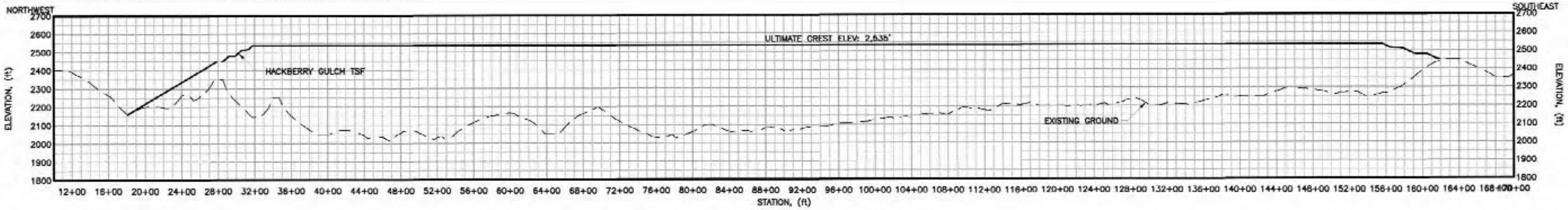
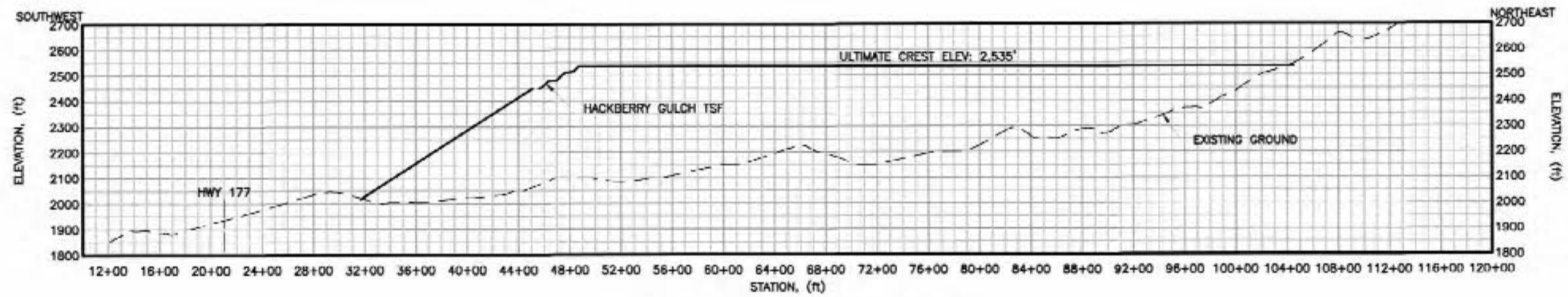



## HACKBERRY GULCH–SECTION A

SECTION LOOKING NORTH

600 0 600 1200 FT HORIZONTAL

300 0 300 600 FT VERTICAL

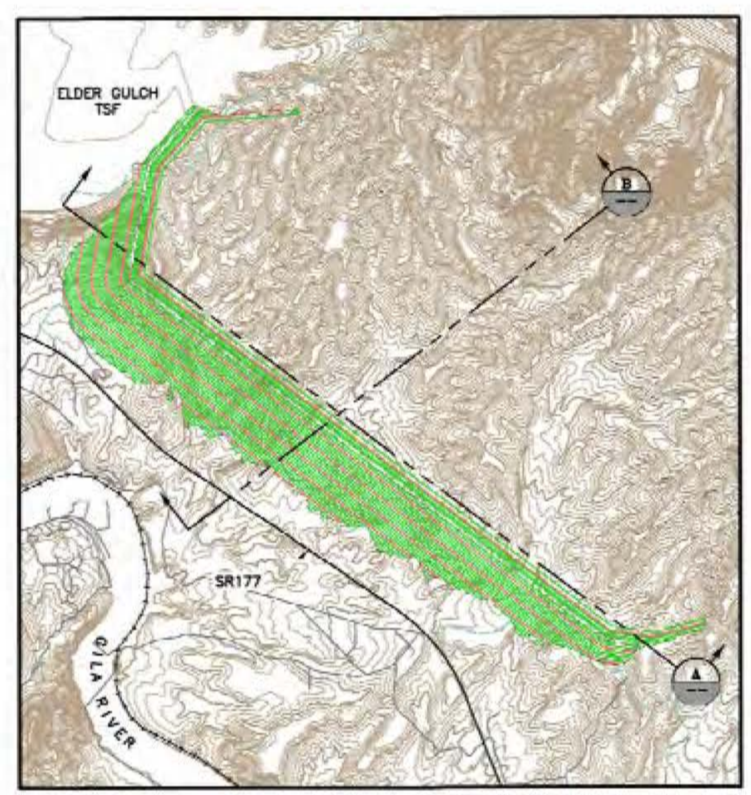



## HACKBERRY GULCH–SECTION B

SECTION LOOKING NORTH

600 0 600 1200 FT HORIZONTAL

300 0 300 600 FT VERTICAL




HACKBERRY GULCH TSF

**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET
- PROPOSED GROUND SURFACE CONTOUR EL, FEET
- EXISTING GROUND
- PROPOSED TSF

amec

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Hackberry Gulch Alternative 2
Main Embankment and
TSF Cross Sections

Figure 9b

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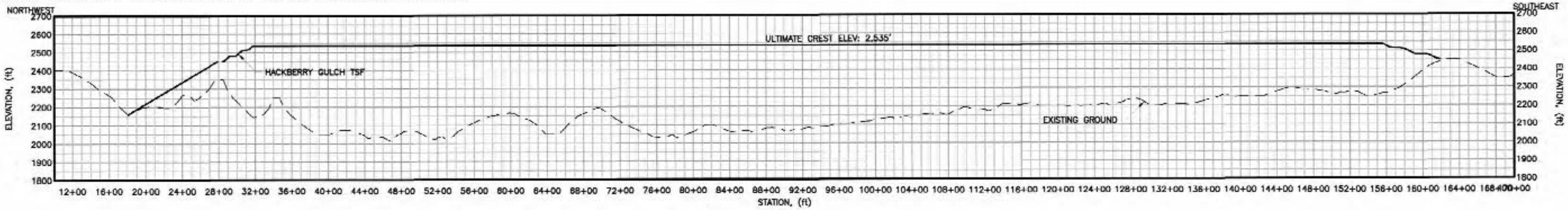
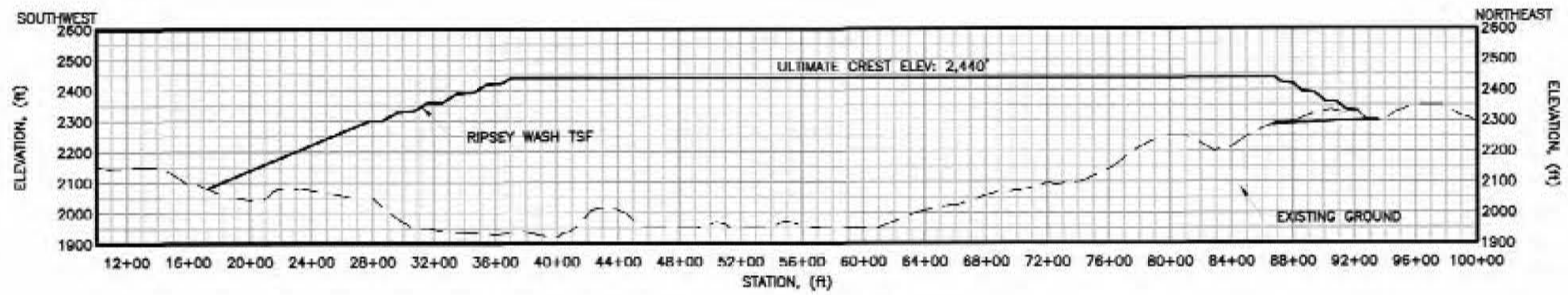



HACKBERRY GULCH–SECTION A
SECTION LOOKING NORTH

600 0 600 1200 FT HORIZONTAL
300 0 300 600 FT VERTICAL




RIPSEY WASH–SECTION A
SECTION LOOKING NORTH

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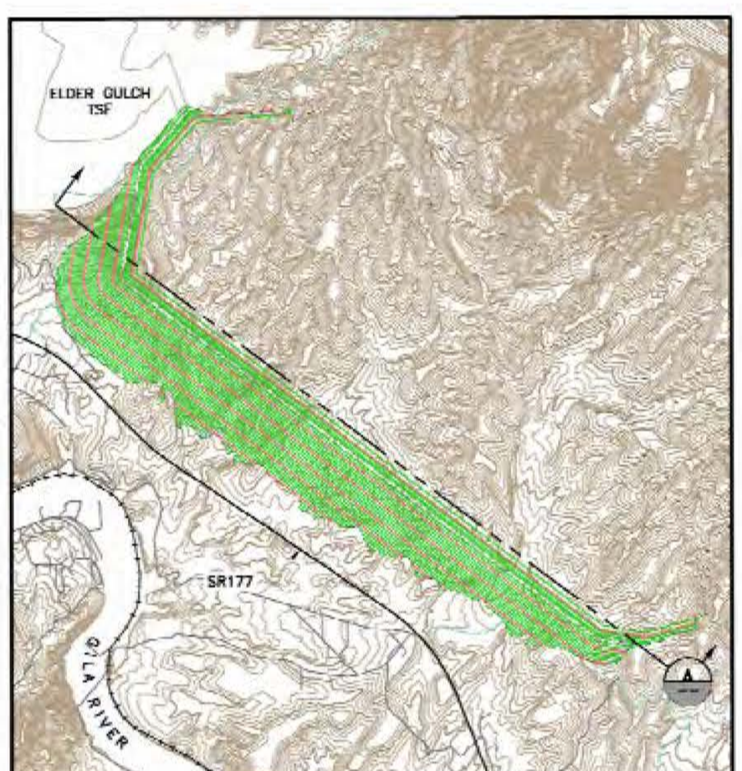
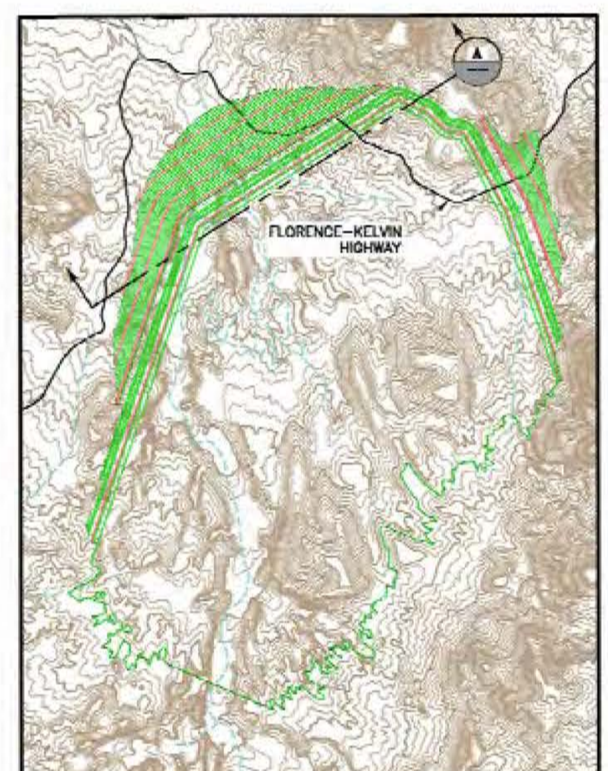



HACKBERRY GULCH TSF




RIPSEY WASH TSF

**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET
- PROPOSED GROUND SURFACE CONTOUR EL, FEET
- EXISTING GROUND
- PROPOSED TSF

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Comparison of Main Embankment Sections-Hackberry Gulch Alternative 2 and Ripsey Wash Alternativer 3

Figure 9c

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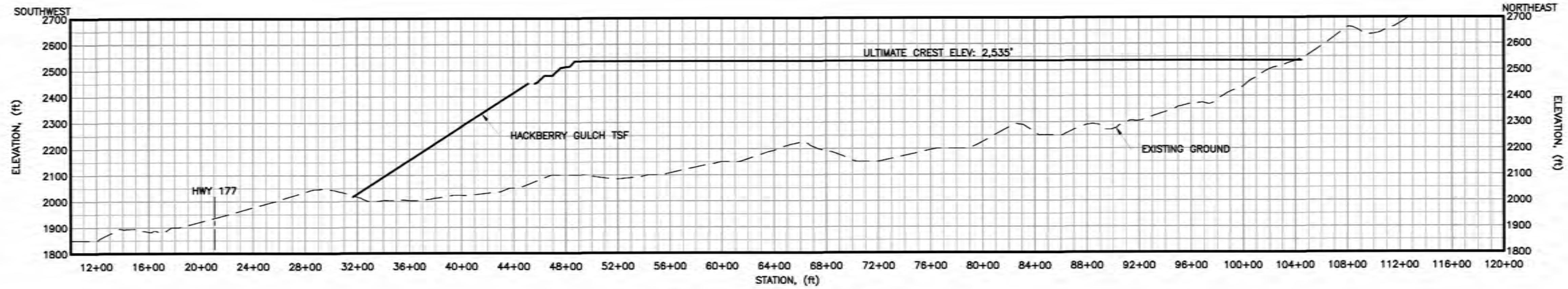
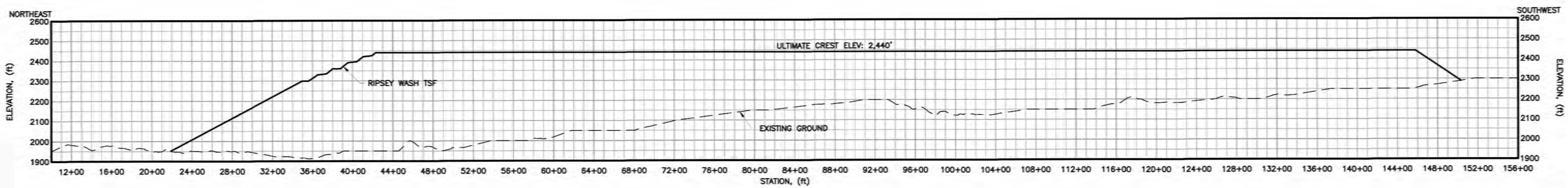



**HACKBERRY GULCH–SECTION B**

SECTION LOOKING NORTH

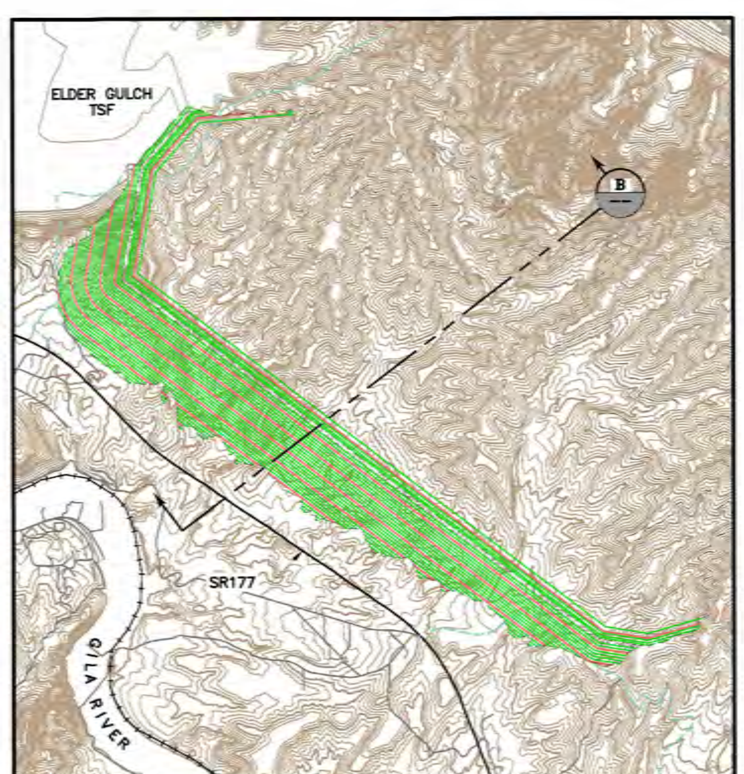
500 0 500 1000 FT HORIZONTAL — 250 0 250 500 FT VERTICAL



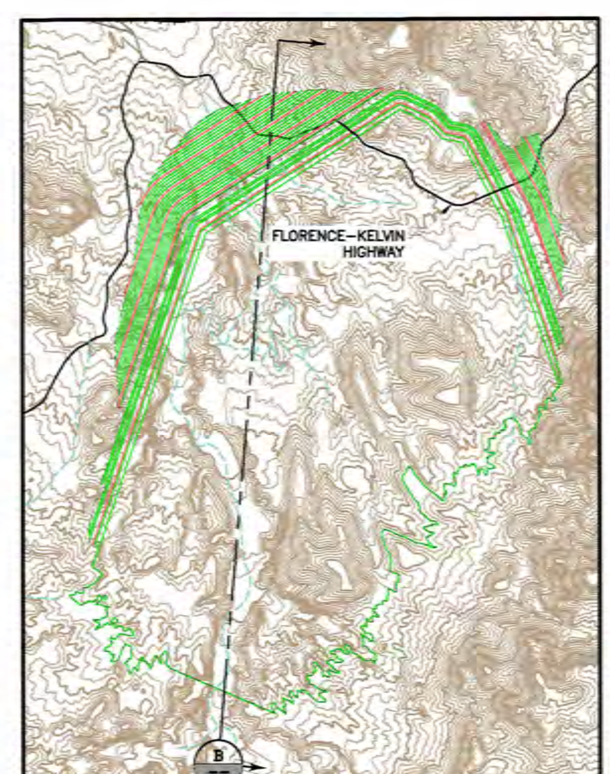

**RIPSEY WASH–SECTION B**

SECTION LOOKING NORTH

500 0 500 1000 FT HORIZONTAL — 250 0 250 500 FT VERTICAL




**HACKBERRY GULCH TSF**




**RIPSEY WASH TSF**

**LEGEND:**

- 100 EXISTING GROUND SURFACE CONTOUR EL, FEET
- 100 PROPOSED GROUND SURFACE CONTOUR EL, FEET
- — — — EXISTING GROUND
- ——— PROPOSED TSF

amec

**ASARCO LLC**

Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Comparison of TSF Cross Sections-Hackberry Gulch Alternative 2 & Ripsey Wash Alternative 3

Figure 9d

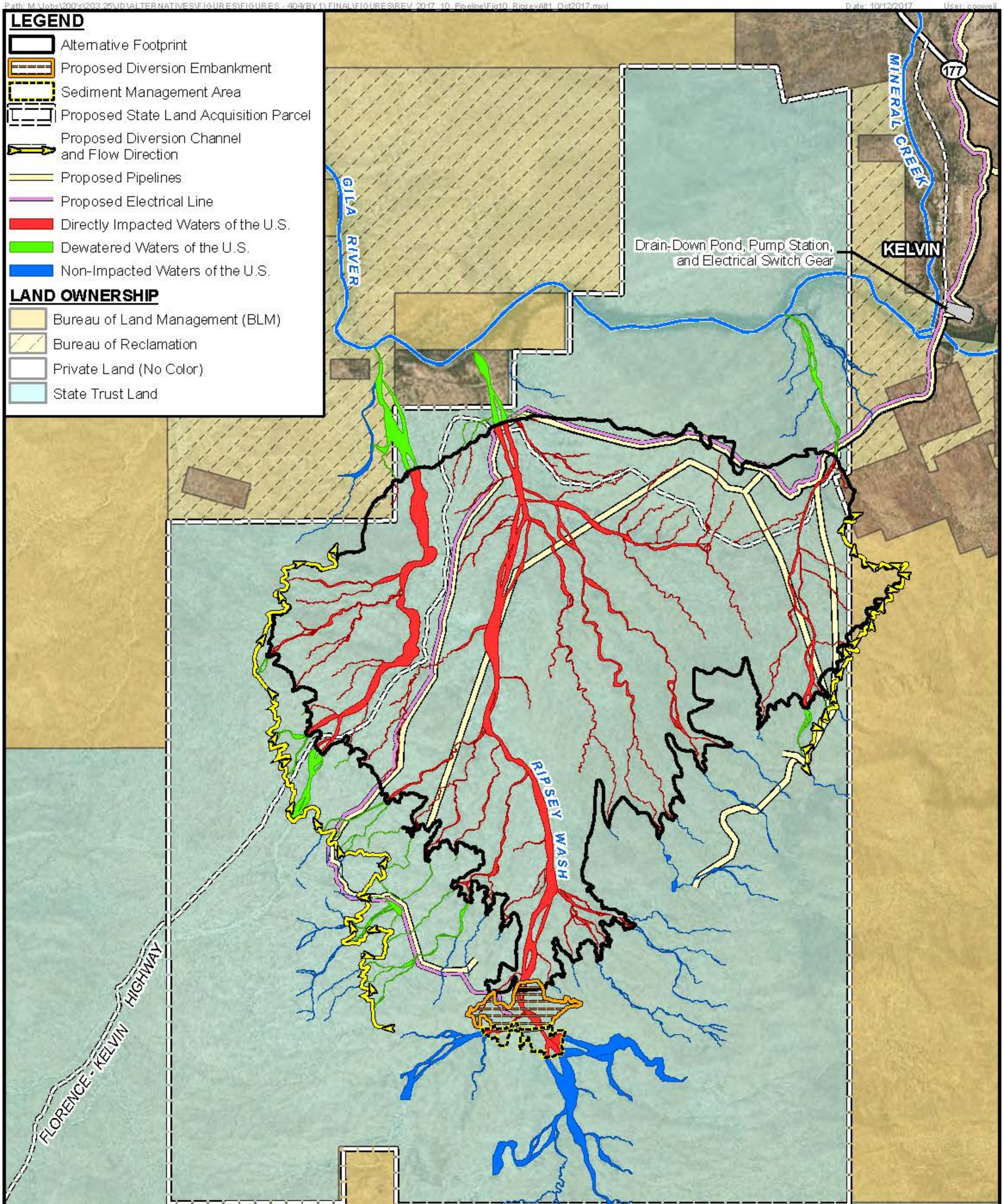



Photo Source: 2015 USDA NAIP Orthophoto
Land Ownership Provided by BLM 2017

WestLand Resources

N

0 1,500 3,000 Feet

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Ripsey Wash Alternative 1
Figure 10

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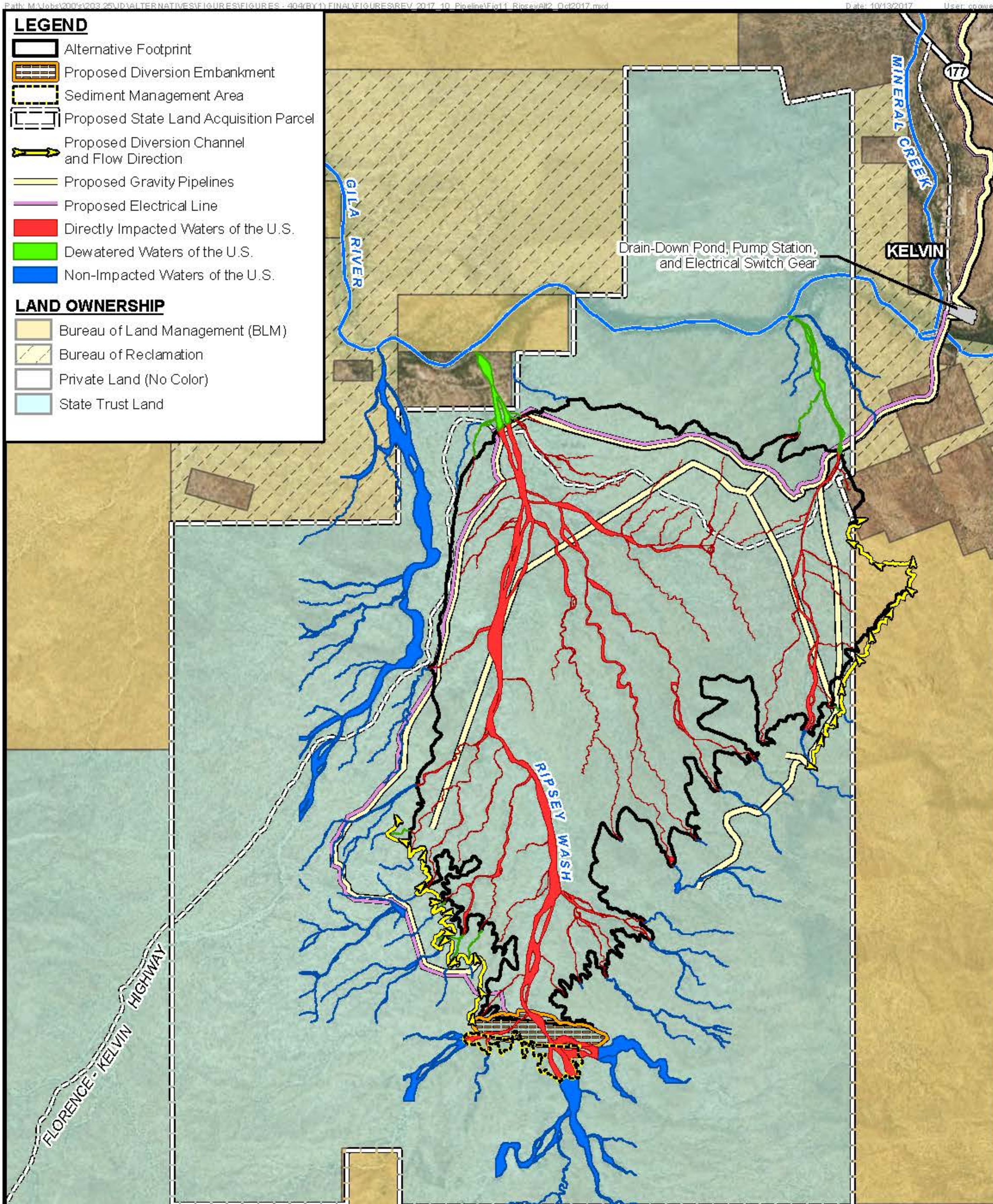


Photo Source: 2015 USDA NAIP Orthophoto
Land Ownership Provided by BLM 2017

WestLand Resources

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Ripsey Wash Alternative 2
Figure 11

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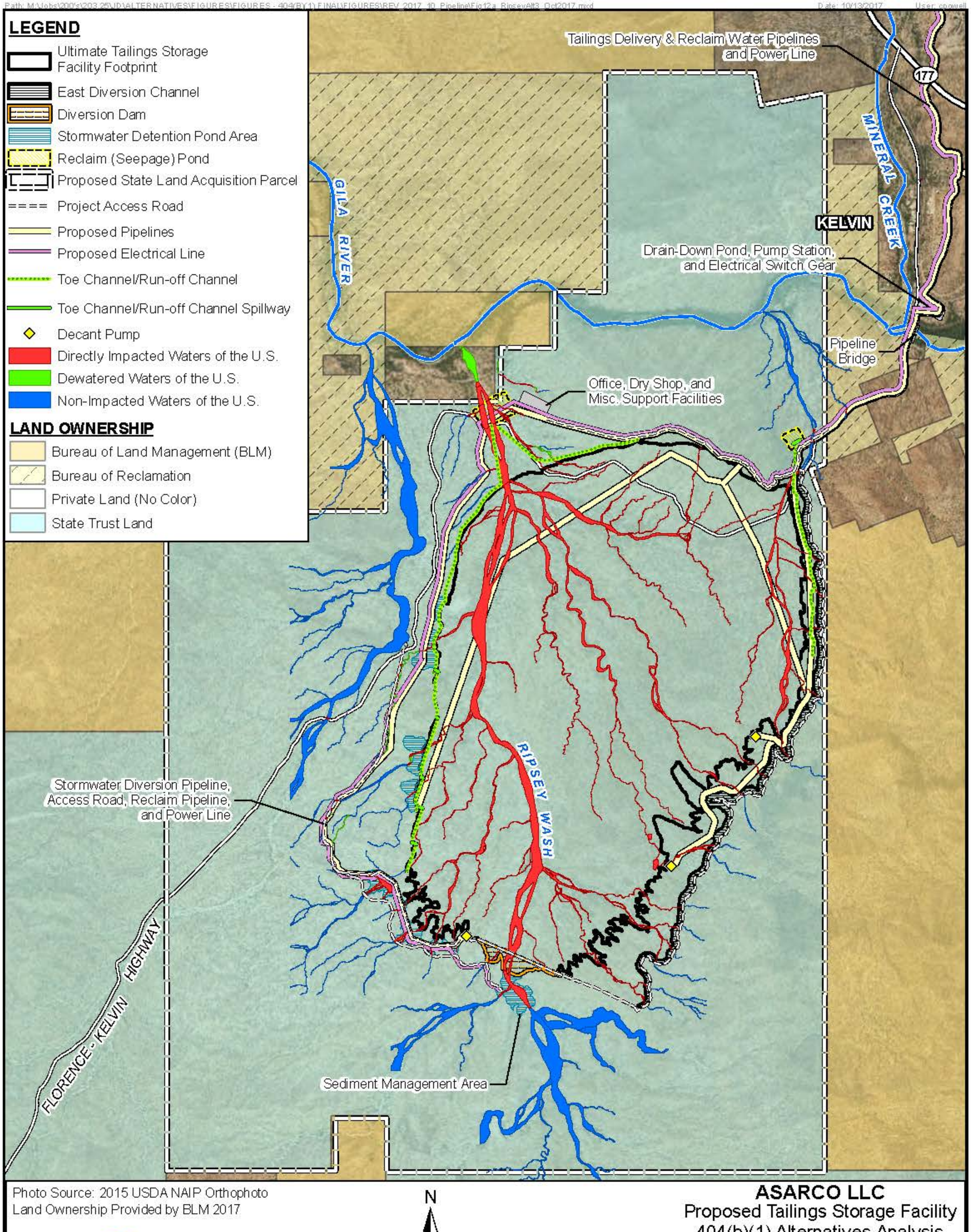


Photo Source: 2015 USDA NAIP Orthophoto
Land Ownership Provided by BLM 2017

WestLand Resources

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

**Ripsey Wash Alternative 3**
**Figure 12a**

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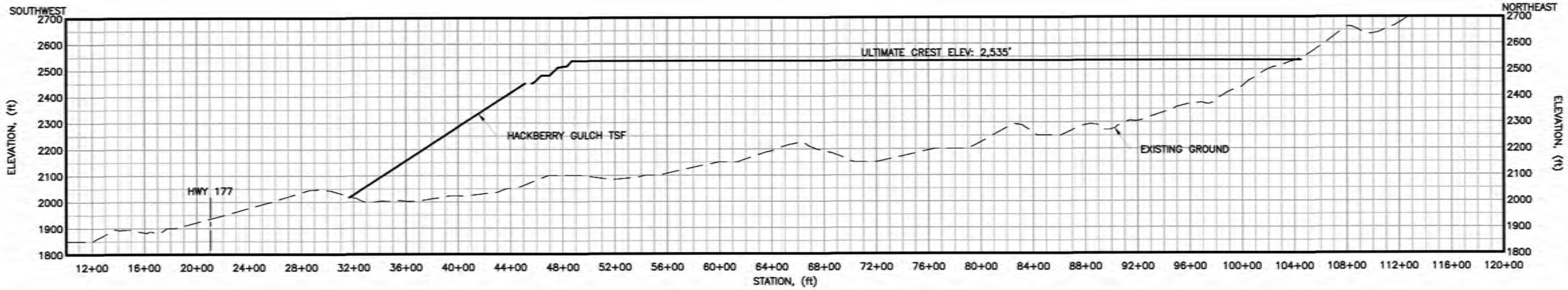
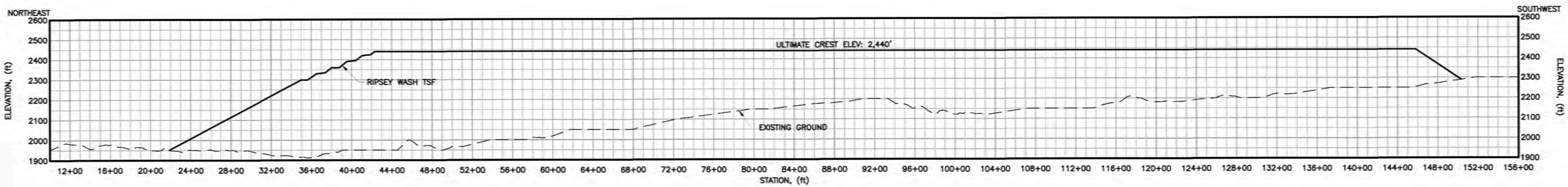



**HACKBERRY GULCH–SECTION B**

SECTION LOOKING NORTH

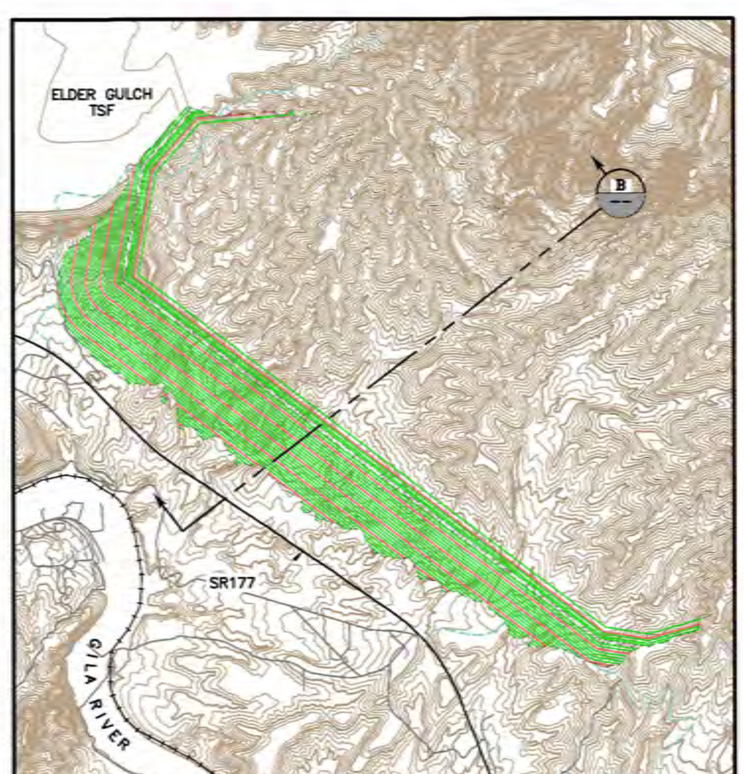
500 0 500 1000 FT — HORIZONTAL; 250 0 250 500 FT — VERTICAL



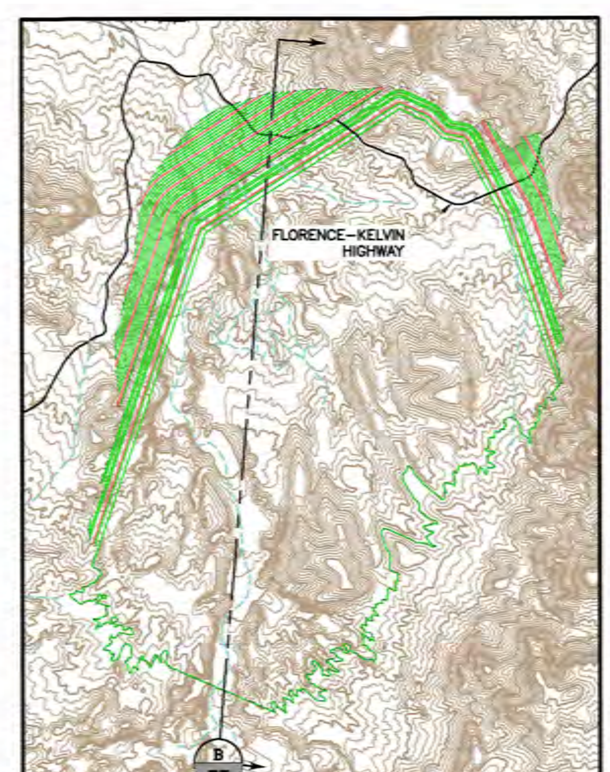

**RIPSEY WASH–SECTION B**

SECTION LOOKING NORTH

500 0 500 1000 FT — HORIZONTAL; 250 0 250 500 FT — VERTICAL




**HACKBERRY GULCH TSF**




**RIPSEY WASH TSF**

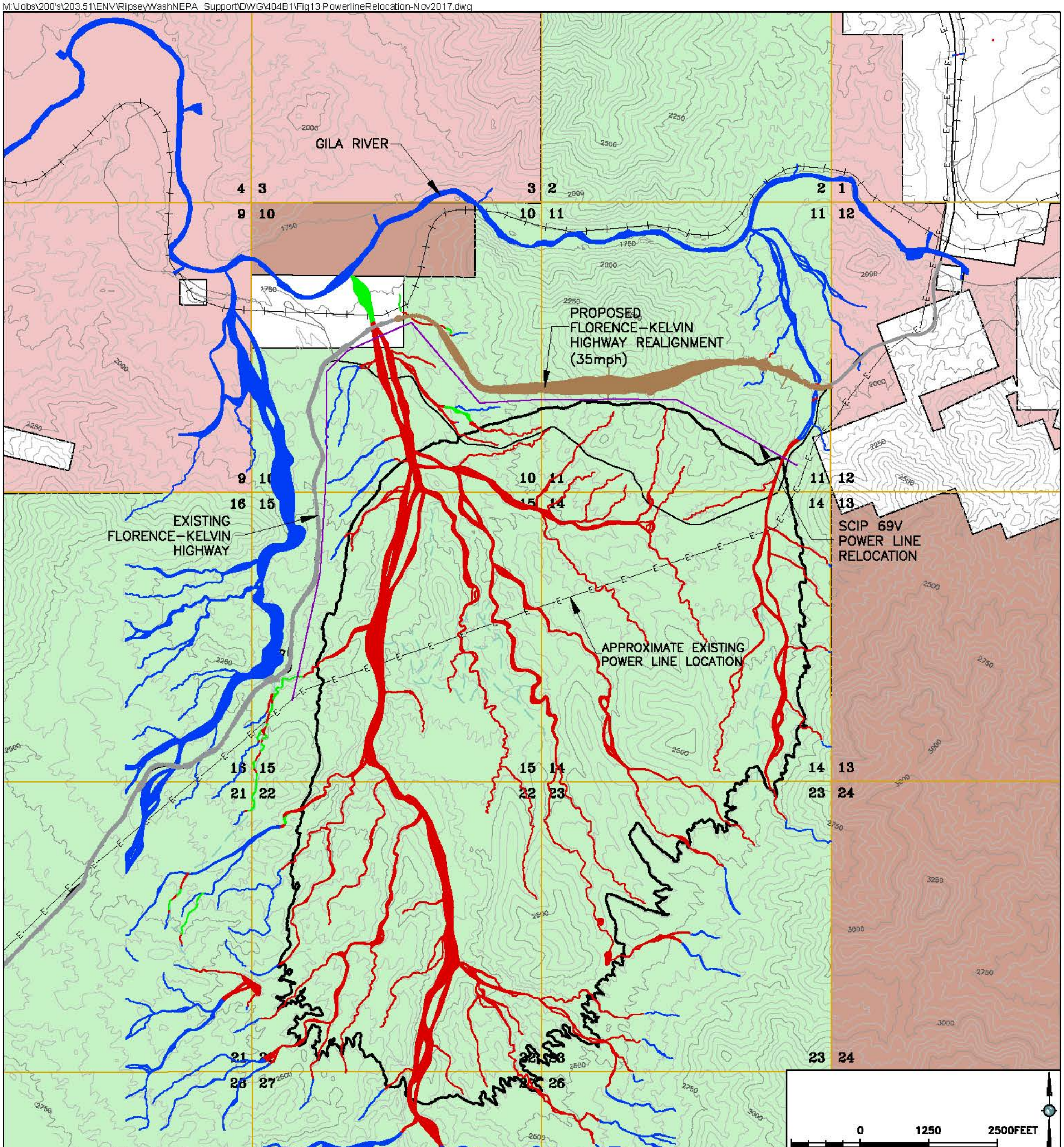
**LEGEND:**

- 100 EXISTING GROUND SURFACE CONTOUR EL, FEET
- 100 PROPOSED GROUND SURFACE CONTOUR EL, FEET
- — — — EXISTING GROUND
- ——— PROPOSED TSF

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Ripsey Wash Alternative 3
Main Embankment and
TSF Cross Sections

Figure 12b




REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

amec

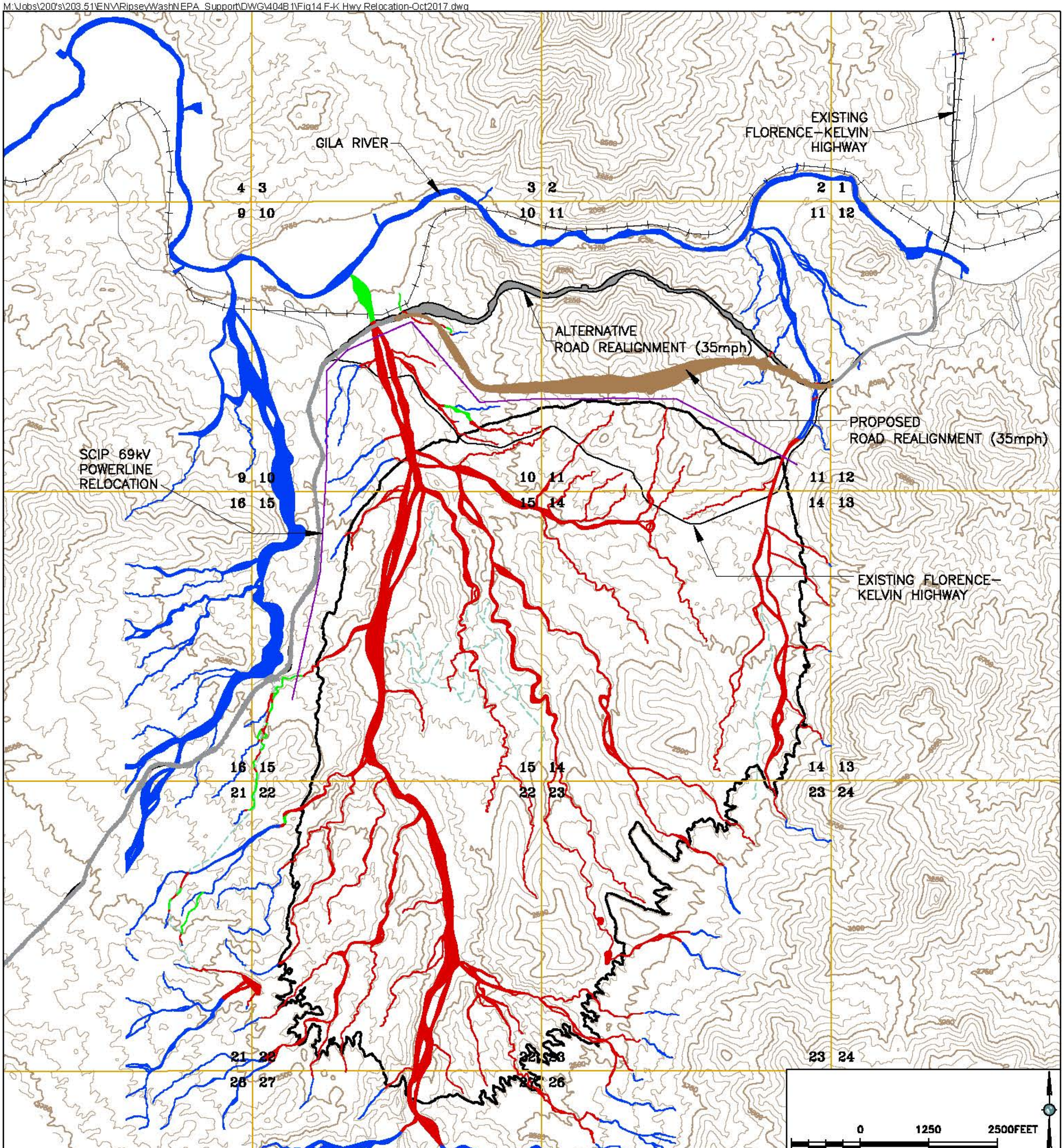
**LEGEND:**

- 100 EXISTING GROUND SURFACE CONTOUR EL, FEET
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- E EXISTING POWER LINE
- SCIP POWER LINE RELOCATION
- 21 22 / 28 27 SECTION QUADRANTS
- BUREAU OF LAND MANAGEMENT (BLM)
- BUREAU OF RECLAMATION
- STATE TRUST LAND
- PRIVATE LAND (NO COLOR)
- TAILINGS IMPOUNDMENT
- DIRECTLY IMPACTED WATERS OF THE U.S.
- DEWATERED WATERS OF THE U.S.
- NON-IMPACTED WATERS OF THE U.S.

**ASARCO LLC**
Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

SCIP Power Line Relocation
Figure 13

M:\Jobs\200's\203.51\ENV\RipseyWashNEPA_Support\DWG\404B1\Fig14 F-K Hwy Relocation-Oct2017.dwg




REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

amec

**LEGEND:**

- 100 — EXISTING GROUND SURFACE CONTOUR EL, FEET
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- 21|22 / 28|27 — SECTION QUADRANTS
- CUT/FILL AREA FOR PROPOSED NEW ROAD ALIGNMENT (35MPH)
- TAILINGS IMPOUNDMENT
- DIRECTLY IMPACTED WATERS OF THE U.S.
- DEWATERED WATERS OF THE U.S.
- NON–IMPACTED WATERS OF THE U.S.

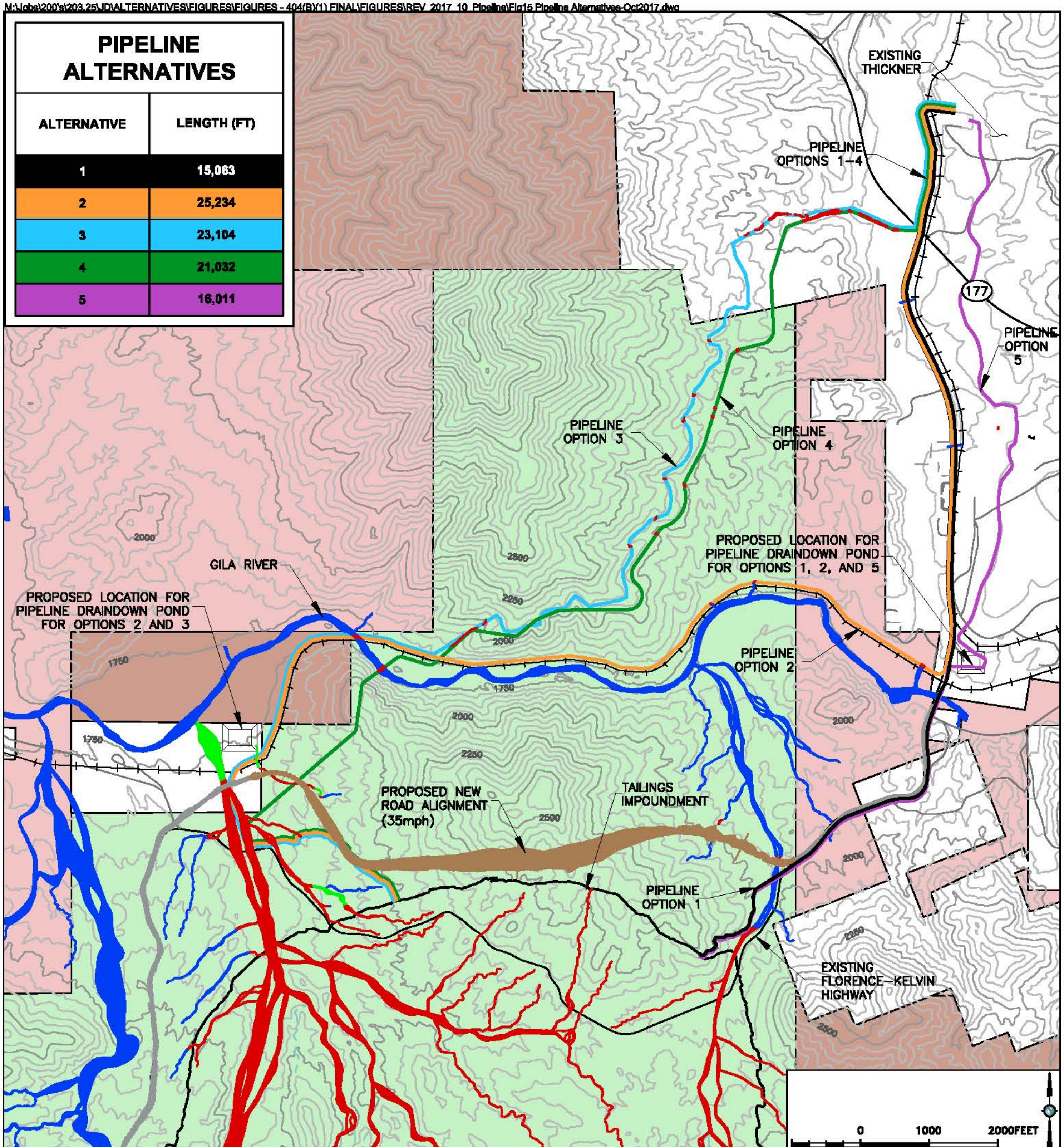
**ASARCO LLC**

Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Florence - Kelvin Highway Relocation
Figure 14

**PIPELINE ALTERNATIVES**

| ALTERNATIVE | LENGTH (FT) |
|---|---|
| 1 | 15,063 |
| 2 | 25,234 |
| 3 | 23,104 |
| 4 | 21,032 |
| 5 | 16,011 |




REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

amec

**LEGEND:**

- 100 — EXISTING GROUND SURFACE CONTOUR EL, FEET
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- BUREAU OF LAND MANAGEMENT (BLM)
- BUREAU OF RECLAMATION
- STATE TRUST LAND
- PRIVATE LAND (NO COLOR)
- TAILINGS IMPOUNDMENT
- DIRECTLY IMPACTED WATERS OF THE U.S.
- DEWATERED WATERS OF THE U.S.
- NON-IMPACTED WATERS OF THE U.S.

**ASARCO LLC**

Proposed Tailings Storage Facility
404(b)(1) Alternatives Analysis

Ripsey Wash Pipeline Alternatives

Figure 15

# APPENDIX A

**Tailings Impoundment Alternatives ASARCO Ray Mine Complex (Technical Memorandum Prepared by AMEC Environment & Infrastructure, Inc.)**

# Technical Memorandum

amec foster wheeler

**To:** James Stewart - Asarco **Project No.:** 17-2013-4034

**From:** Tony Freiman, PE **Reviewed by:** Wayne Harrison, PG

**Date:** November 16, 2016

**Subject:** Technical Memorandum
Tailings Impoundment Alternatives
Asarco Ray Operations

Registered Professional Engineer (Civil)
Certificate No.
23982
TONY J.
FREIMAN
Date Signed 11/16/2016
ARIZONA, U.S.A.
Expires 12/31/2017

Registered Geologist
Certificate No.
42910
WAYNE A.
HARRISON
Date Signed 11/16/16
ARIZONA U.S.A.
Expires 06/30/2017

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) was tasked by Asarco LLC with reviewing the characteristics of potential sites for a new tailings storage facility (TSF) for the Asarco Ray Operations and providing a recommendation for the preferred location of such a facility based on geologic, geotechnical, hydrogeological, and engineering considerations. Our recommendation is based on a review of previous analyses performed by other consultants and the results of our own independent analysis using current design criteria for the facility.

## 1.0 OVERVIEW OF PREVIOUS ANALYSES

Analyses of potential TSF locations completed by other consultants included the following:

1. *Tailings Dam Engineering Project Order of Magnitude Study (SRK 2005).*This study considered seven TSF alternatives with an assumed ultimate capacity of 400 million tons, and identified four of these alternatives as worthy of further analysis.
2. *Tailings Dam Alternative Project - Preliminary Engineering Design (SRK 2006).*This study focused on the four primary TSF alternatives identified in the 2005 study, and assumed an ultimate capacity of 400 million tons.
3. *Tailings Dam Alternatives Project – Tailings Alternative Reanalysis Report (SRK 2008).*This study also focused on the same four primary TSF alternatives identified in the

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2005 analysis and studied in the 2006 report, but the sites were reevaluated for an assumed ultimate capacity of 200 million tons rather than 400 million tons.

As discussed further in Section 1.4, the SRK reports contained several assumptions that are no longer valid. In addition, unlike this report, the SRK reports also included as a key component of the analysis an assessment of the estimated costs of various alternatives.

Despite these limitations, the three SRK reports included technical information that remains valid for the current assessment. The following is a brief summary of the information contained in the SRK reports.

### 1.1 SRK 2005 Report

SRK Consulting (U.S.), Inc. (SRK) and Smith Williams Consultants, Inc. (SWC) evaluated seven potential TSF sites. The TSF sites reviewed in the report were:

- E Dam (located west of Hayden).
- West Dam (located west of State Route (SR) 177).
- Granite Mountain (located east of the West Dam location);
- Devils Canyon (located north of the Ray open pit);
- Hackberry Gulch (located immediately south of the Elder Gulch impoundment);
- Ripsey Wash (located south of the mine and the Gila River); and
- North Area Dump.

The SRK 2005 report does not indicate a preferred alternative but does show that Ripsey Wash has the lowest embankment size to capacity ratio. Four TSF sites were recommended for further study based on an evaluation of technical and economic factors.

### 1.2 SRK 2006 Report

SRK (2006) performed a detailed engineering evaluation of the four preferred TSF alternatives. Based on the results of its 2005 report, the four preferred TSF alternatives were Ripsey Wash, Hackberry Gulch, West Dam and E Dam. Each of these four sites was evaluated based on the following criteria:

- Storage volume
- Storage ratio
- Disturbance
- Pipeline corridor impacts
- Geology
- Hydrogeology
- Surface water impacts
- Cost ($/ton)

Each of these criteria were assigned numerical values and the values were then added together to provide an overall rating of the alternatives. Results are presented in the following ratings table.

**Tailings Dam Engineering Project – Preliminary Engineering Design (SRK 2006 Report)**
**Comparative Ranking of Sites and Alternatives**

| Site | Construction Alternative | Storage Volume | Storage Ratio | Disturbance (acres) | Pipeline Corridor Impacts | Environmental Containment | | | Cost | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Geology | Hydrogeology | Surface Water | | |
| Ripsey Wash | Fill/Centerline Cyclone Tailings | 5 | 5 | 5 | 2.5 | 4.5 – Ideal granite and consolidated conglomerate foundation. Fault along Rispsey Wash has no indication of Holocene movement. | 4 – Nonpermeable crystalline rock; seepage control required for alluvial washes | 2 | 10 | 38 |
| Hackberry Gulch | Fill/Centerline Cyclone Tailings | 3 | 2 | 2.5 | 4.5 | 3 – Consolidated conglomerate foundation. Several faults noted along basin front. No indication of Holocene movement | 3 – Seepage potential along faults | 3 | 9 | 30 |
| West Dam | Fill/Centerline Cyclone Tailings for Downstream Embankment, Fill for Upstream Embankment | 2.5 | 2 | 2.5 | 5 | 5 – Ideal granite foundation, minimal faulting | 3 – nonpermeable crystalline rock; upgradient of Mineral Creek and open pit mine | 5 | 2 | 27 |
| E Dam | Upstream Construction | 3 | 5 | 4 | 0 | 4 – Unconsolidated and consolidated basin fill and lakebed sediments; absence of faulting | 3 – Thick lakebed sediments will act as aquitard to minimize impact to groundwater | 4 | 3 | 26 |

The Ripsey Wash TSF alternative ranked the highest, followed by the Hackberry Gulch alternative. The overall storage capacity of the Ripsey Wash alternative could readily be increased to handle more than the proposed 400 million ton design criterion used in the report, thus earning it a five out of five on the rating scale compared to the other three alternatives.

If cost were not included as an evaluation factor, the 2006 SRK report would rank Ripsey Wash the highest, followed by West Dam, E Dam and Hackberry Gulch.

### 1.3 SRK 2008 Report

SRK (2008) updated its 2006 report to reflect changes to the design criteria and estimated costs. The primary change in design criteria was that the ultimate capacity of the TSF was reduced from 400 million tons to 200 million tons. The capital cost for each facility also was updated to reflect the change in size and the rate of inflation. Results are presented in the following ratings table.

**Tailings Dam Engineering Project – Preliminary Engineering Design (SRK 2008 Report)**
**Comparative Ranking of Sites and Alternatives**

| Site | Construction Alternative | Storage Volume | Storage Ratio | Disturbance (acres) | Pipeline Corridor Impacts | Environmental Containment | | | Cost | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Geology | Hydrogeology | Surface Water | | |
| Ripsey Wash | Fill/Centerline Cyclone Tailings | 5 | 5 | 5 | 2.5 | 4.5 – Ideal granite and consolidated conglomerate foundation. Fault along Ripsey Wash has no indication of Holocene movement. | 4 – Non-permeable crystalline rock; seepage control required for alluvial washes | 2 | 10 | 38 |
| Hackberry Gulch | Fill/Centerline Cyclone Tailings | 3 | 2 | 2.5 | 4.5 | 3 – Consolidated conglomerate foundation. Several faults noted along basin front. No indication of Holocene movement | 3 – Seepage potential along faults | 3 | 10 | 31 |
| West Dam | Fill/Centerline Cyclone Tailings for Downstream Embankment, Fill for Upstream Embankment | 2.5 | 2 | 2.5 | 5 | 5 – Ideal granite foundation, minimal faulting | 3 – non-permeable crystalline rock; upgradient of Mineral Creek and open pit mine | 5 | 5 | 30 |

| Site | Construction Alternative | Storage Volume | Storage Ratio | Disturbance (acres) | Pipeline Corridor Impacts | Environmental Containment | | | Cost | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Geology | Hydrogeology | Surface Water | | |
| E Dam | Upstream Construction | 3 | 5 | 4 | 0 | 4 – Unconsolidated and consolidated basin fill and lakebed sediments; absence of faulting | 3 – Thick lakebed sediments will act as aquitard to minimize impact to groundwater | 4 | 6 | 29 |

Even with the ultimate capacity reduced to 200 million tons, the Ripsey Wash site retained the highest ranking as the preferred alternative. As with the 2005 report, if cost were not included as an evaluation factor, the 2008 SRK report would rank Ripsey Wash the highest, followed by West Dam, E Dam and Hackberry Gulch.

### 1.4 Changes Since Completion of Previous Studies

The first two SRK analyses were based on an assumed ultimate storage capacity of 400 million tons (SRK 2005, 2006). The third SRK analysis, performed during the height of the 2008 financial crisis and global recession, was based on an assumed ultimate storage capacity of 200 million tons (SRK 2008).

Several changes have been made to the design criteria of the TSF and other aspects of the project since these earlier studies were performed. Based on a detailed evaluation of mineral reserves of the Asarco Ray Mine, it was determined that a TSF with a capacity of roughly 750 million tons (including embankment volume) would be needed to allow full development of the currently identified resource at Ray, with a contingency. This obviously results in somewhat different facility configurations than were projected by SRK, which was assessing 200 million or 400 million ton facilities.

In addition, subsequent to performing these earlier studies, the geometry of the West Dam alternative, which considered using the existing 7 Series Rock Deposition Area as the eastern embankment of the TSF, was determined to be incompatible with the current Asarco Ray mine plan. We also note that some assumptions regarding facility construction techniques have changed somewhat since the preparation of the SRK reports. The embankment configuration, starter dam heights and point of transition from centerline embankment construction to upstream construction techniques were revised to account for the increase in storage capacity and, where feasible, to provide opportunity for reclamation of the facility during the operational life.

In Amec Foster Wheeler’s judgment, the above changes do not alter the validity of the earlier analyses’ evaluation and conclusions regarding the hydrogeological aspects of the various sites.

Lastly, as noted above, the SRK reports included as a significant component an assessment of the estimated costs of constructing and operating various tailings facility options. By contrast, this analysis focuses solely on engineering, geologic and hydrogeologic considerations, and does not include an assessment of costs. Nevertheless, in reviewing the SRK analysis of costs, we note that in addition to being 5-8 years old, some of the assumptions used in generating the cost estimates may be questionable (e.g., the use of the same unit costs for activities at all of the sites). If cost is to be examined, some of these assumptions may need to be re-evaluated.

## 2.0 AMEC FOSTER WHEELER ANALYSIS

### 2.1 Criteria for Siting

Amec Foster Wheeler was requested to reanalyze the potential TSF locations based on the changes described above. As a result, Amec Foster Wheeler developed new impoundment layouts based on an ultimate capacity of 750 million tons. The tailings impoundment and associated facilities would be designed and operated to meet all regulatory obligations.

The foundation of the starter dam would be prepared by removing unconsolidated alluvial and/or colluvial soils from the dam footprint. The starter dam would be constructed as an engineered soil and rockfill embankment with material borrowed from within the tailings impoundment footprint. The starter dam was sized to accommodate between 18 and 24 months of tailings production.

The tailings embankments of the alternatives would be raised above the starter dam elevations by centerline methods using the sand fraction of cycloned tailings. The E Dam, Hackberry Gulch, West Dam and Ripsey Wash alternatives were designed to then transition from the centerline raise method to an upstream method of dam construction. The upstream raises were restricted to a maximum 10 foot per annum rate of rise.

Bench test studies performed in 2012 by Krebs Engineers, Inc., a cyclone system engineer and manufacturer, demonstrated that about 36 percent of the tailings would be available as the sand fraction. For this analysis, the dry unit weight of cycloned tailings overflow fraction was considered to be 83 pounds per cubic foot (pcf), cycloned sands underflow was assigned a dry density of 100 pcf. Whole tailings were assigned a dry density of 85 pcf and the earthen/rockfill embankments considered a 120 pcf dry unit weight.

The cycloned sand embankment dam will be designed with an underdrain system to capture water draining from the material. In addition a toe berm will be designed to control sediment and stormwater runoff during the operation of the facility.

Upgradient stormwater diversion channels and associated detention features, or retention structures if detention and diversion are not feasible, would be sized for a 100-year storm recurrence event. For closure, the upstream diversion channels would be sized for a 500-year storm event. The flow rates resulting from the higher of the 6-hour or the 24-hour storm duration would be used to design the channels.

Sufficient freeboard would be provided to contain the probable maximum precipitation event within the tailings impoundment or combined with upgradient detention or retention dam capacity.

The sites considered in this analysis are as follows:

- E Dam (located west of Hayden);
- West Dam (located on a portion of the leaching operation at the Ray Mine and requires relocation of SR 177);
- Granite Mountain (located west of the West Dam site and east of the White Canyon Wilderness area);
- Hackberry Gulch Option 1 (located immediately south of the Elder Gulch TSF and east of SR 177);
- Hackberry Gulch Option 2 (with the footprint reduced to avoid crossing the easternmost drainage);
- Devils Canyon (located north of the Ray mine pit in a tributary drainage of Mineral Creek);

- Ripsey Wash Option 1 (located southwest of the mine and south of the Gila River spanning both Ripsey Wash and Zelleweger Wash and incorporating Bureau of Land Management (BLM) lands);
- Ripsey Wash Option 2 (located southwest of the mine and south of the Gila River spanning only Ripsey Wash and incorporating BLM lands on the east end of the site); and
- Ripsey Wash Option 3 (located southwest of the mine and south of the Gila River spanning only Ripsey Wash and avoiding BLM lands).

These potential TSF locations are presented in Figure 1.

For the analysis, the sites were given a low to high rating based on their overall technical and engineering attributes. Each site was evaluated using the following criteria:

- Site Conditions
  - Geomorphic setting
  - Site geology
  - Site hydrogeology
- Design Considerations
  - Total tailings capacity
  - Size to capacity ratio
  - Embankment ratio
  - Other engineering and constructability considerations

The following sections highlight the aspects of each site and configuration considered:

## 2.2 E Dam

### 2.2.1 Site Conditions

The E Dam site is located near the confluence of the Gila and San Pedro Rivers. The Tortilla Mountains are located to the west of the site and the Dripping Springs Mountains are located to the east of the site. Most of the site is located within Sections 2 and 3 (and minor portions of 1, 4, 10, 11 and 12) of Township 6 South, Range 15 East and Sections 34 and 35 (and minor portions of 26, 27 and 33) of Township 5 South, Range 15 East. The site is situated near the distal end of an alluvial fan complex located along the eastern flank of the Tortilla Mountains. Romero Wash would form the northwest boundary of the facility and the facility would be constructed across Sample Wash and two unnamed washes. These washes originate in the Tortilla Mountains and flow into the San Pedro River.

As shown on Figure A-1, surficial deposits exposed within the site footprint predominantly consist of early to middle Pleistocene deposits of alluvial sand and gravel. These deposits are unconsolidated and largely composed of granitic material (Krieger 1974). The thickness of these deposits is unknown, but the deposits probably range from several 10s of feet to a hundred feet or more in thickness. These unconsolidated materials are underlain by the Quiburis Formation. These semi-consolidated to consolidated alluvial and fine-grained lakebed deposits are considered to be middle Pliocene in age (Kreiger 1974) and appear to have been deposited in a long, narrow closed basin. Some interfingering of the two facies occurs, although the alluvial deposits generally occur along the sides of the basin and the fine-grained lakebed deposits are generally confined to the central portion of the basin. Kreiger (1974) identifies the western contact between the two facies as crossing the uppermost portion of the E-dam site. In other words, approximately 90 percent of the E-Dam site is underlain at depth by lakebed deposits.

In general, the alluvial facies consist of a sandy pebble-conglomerate with interbedded sandy and silty beds. The lakebed facies consist of thin beds of clay, silt, marl and very fine-grained sand that form vertical cliffs where exposed in washes. The Quiburis Formation may be as thick as 600 feet (Kreiger 1974). No faults have been identified within the footprint of the site. The presence of marl within the Quiburis Formation and the presence of lime cementation within the Quiburis Formation and the overlying sand and gravel deposits may provide some chemical attenuation capacity.

Groundwater is probably present within both the unconsolidated sand and gravel deposits and the Quiburis Formation. Water levels in two shallow wells drilled in Sections 3 and 12 of Township 6 South, Range 15 East (within the footprint of the site and about one-half mile to the southeast of the site, respectively) are on the order of 25 feet deep or less, whereas water levels in two wells drilled in Section 28 or Township 5 South, Range 15 East (about one mile north of the site) were on the order of 250 feet deep. The two shallow wells were likely completed in the sand and gravel deposits that overlie the Quiburis Formation and the deeper wells were likely completed within the Quiburis Formation.

The watershed upgradient of the E tailings impoundment site is about 5320 acres, ranging in elevation from 4080 feet to the dam crest elevation of 2620 feet. The natural ground alluvial fan setting of the tailings impoundment is favorable for the construction of a diversion channel.

### 2.2.2 Design Considerations

The E Dam site is underlain by alluvial sands and gravels, which in turn are underlain by interfingered deposits of alluvial and fine-grained lakebed facies of the Quiburis Formation (Krieger 1974). Because the near-surface materials at the site consist of sand and gravel, the impoundment can be expected to seep. Seepage from the impoundment could be reduced by slime sealing beneath the tailings pond, installing a system of granular finger or blanket drains to supplement natural subdrainage, and/or lining the main underdrains. Seepage downstream of the TSF could be controlled with a cutoff system below the dam, trench drains with downstream geomembranes, or a slurry wall with upstream pumpback wells. The seepage control system would be facilitated by the presence of fine-grained lakebed deposits at relatively shallow depths that would act as a lower boundary for seepage control system.

### 2.2.3 Discussion

The E Dam site is seen as a medium-low feasibility design. Both the geological and hydrogeological makeup of the area receives a medium feasibility grade; however, this average grade is the highest it receives in any category. Due to the relatively flat topography at the site, the TSF embankment would have to be constructed in a side hill configuration, with an embankment along three sides of the facility, giving the site the largest size to capacity ratio of any of the alternatives.

The most significant consideration with this alternative is the length of the tailings slurry and reclaim water pipelines. The 20.3-mile-long tailings pipeline corridor would travel alongside the Gila River for about 13.5 miles, crossing 43 drainages and passing through the towns of Kearny and Hayden. It would be necessary to construct containment ponds at intervals along the length of the pipeline to accommodate power outages and mill shutdowns. The ultimate tailings impoundment crest is 2620 feet, requiring a vertical lift of the tailings slurry from the existing Elder Gulch thickener pump station (elevation 1900) of 720 feet. Booster pump stations would be required for the slurry and reclaim lines.

A tailings impoundment footprint of 2,363 acres, with a maximum dam height of 480 feet, would provide the required total impoundment capacity of 750 million tons. The size to capacity ratio for the impoundment is 3.15 (2,363 acres/750.9 million tons). Figure 2 presents the layout of the facility. The facility would be constructed with an embankment starter dam, transitioning to centerline and ultimately upstream construction methods. Detailed staging of the impoundment was not completed to determine the required starter dam crest elevation and the point in time when a transition from centerline to an upstream method of construction was feasible.

## 2.3 West Dam

### 2.3.1 Site Conditions

The West Dam alternative is located to the west of the Ray Mine and is presented on Figure 3. The Dripping Springs Mountains and Mineral Creek are located to the east of the site. The rugged topography to the west of the site includes a number of mountains, buttes and canyons, including Granite Mountain about a mile to the northwest of the site. The site straddles about 2 miles of SR 177 and impinges upon existing and planned dumps on the east. The site is located within Sections 22, 23, 26 and 27 of Township 3 South, Range 13 East. As shown on Figure A-2, most of the site is underlain by Precambrian Ruin granite cut by Cretaceous and Tertiary dikes and sills. The northwest portion of the site is underlain by Pinal Schist and Madera diorite and a narrow band of Tortilla quartz diorite is exposed near the eastern margin of the site. The eastern edge of the site is underlain by conglomerate of the Big Dome Formation. Cornwall et al (1971) describes the conglomerate as consisting of poorly consolidated fragments of Tortilla quartz diorite and Ruin granite. These bedrock units are locally overlain by erosional surfaces consisting of thin deposits of soils and gravel. The pediment deposits commonly occur along or adjacent to drainages.

The ground surface slopes downward to the east-northeast and several small drainages flow eastward across the site, underneath SR 177 and into Mineral Creek. There is limited information regarding groundwater conditions. Two wells drilled within the footprint of the site near SR 177, one in Section 23 and one in Section 26 of Township 3 South, Range 13 East, have recorded water levels of 23 feet and 56 feet, respectively. It is anticipated that the crystalline rock units (Ruin granite, Madera diorite, Tortilla quartz diorite and Pinal Schist) that underlie most of the site have a very low permeability. The poorly consolidated conglomerate along the eastern margin of the site probably has a moderate permeability. Cornwall et al (1971) identifies several north-south striking faults within the Ruin granite in the southern portion of the site.

The watershed above the West Dam alternative measures 469 acres, extending to the Granite Mountain ridge line. The watershed runoff coefficient would be high because of the exposed rock between the impoundment and the ridge crest.

### 2.3.2 Design Considerations

Seepage from beneath the impoundment would be minimized by the presence of low permeability crystalline bedrock below much of the impoundment. Seepage could be further reduced by installing subdrainage beneath the impoundment to minimize hydraulic head, installing granular finger or blanket drains to supplement natural subdrainage, and/or lining the main underdrains. Seepage controls would be required downstream of the dam in the area underlain by poorly consolidated conglomerate to prevent seepage from migrating toward Mineral Creek. Two seismic refraction lines completed across the proposed embankment as part of the 2006 SRK study indicated the depth to competent bedrock ranged from 20 to 120 feet below the ground surface (bgs). Seepage downstream of the TSF could be controlled with cut-off systems such as a slurry wall or grout curtain with upgradient pumpback wells or a trench drain with downstream geomembrane.

### 2.3.3 Discussion

Most of the site is underlain by low permeable crystalline bedrock with poorly consolidated conglomerate exposed along the eastern margin of the site. The presence of low-permeability crystalline bedrock beneath the site should help minimize seepage into the groundwater system. However, the presence of poorly consolidated conglomerate beneath the eastern margin of the site is of concern since a large portion of the embankment will be constructed in this area and Mineral Creek is located less than a mile to the east of the site.

The West Dam alternative embankment volume required to raise the impoundment above the starter dam crest elevation is larger than could be provided solely by cycloned sand construction. Mine waste rock or locally derived rockfill borrow would be required to meet the necessary embankment build rates. Abutting the downstream edge of the impoundment against the 7 Series Oxide Leach Rock Deposition Area would result in intermingling of tailings underflow and the cycloned sands bleed water with the pregnant leach solution of the leach facility, making the leach facility inoperable.

The West Dam site is constrained by the extension of the 5 Series Rock Deposition Area to the north and the drop in topography to the south. The developed alternative for the site involves construction of an 870 foot high embankment, exceeding the preferred Ripsey Wash TSF site by 245 feet. The West Dam TSF embankment would extend above the 7 Series RDA by about 300 feet. The 870 foot required height of the West Dam would place it amongst the tallest tailings impoundments in the world.

An elevation-capacity relationship was developed for the West Dam alternative to meet the 750 million ton tailings storage requirement. The side hill configuration of the TSF and steep terrain would require construction of a rockfill starter dam of 342 feet to mitigate against the development of excess pore pressures within the embankment. A starter dam crest elevation of 2442 feet was determined. The construction would transition to centerline methods to keep embankment construction raise rates of the TSF in within an acceptable range of less than 30 feet per year, until an elevation of 2670 feet was reached. Upstream construction embankment raising techniques would be used to the ultimate dam crest elevation of 2970 feet.

Arizona State Highway 177 traverses about 2 miles of the West Dam impoundment footprint. The only practical means to relocate the highway would be to route it west of the Granite Mountain ridge line. This realignment would involve construction of 7.2 miles of two-lane rural highway in mountainous terrain, designed to meet current Arizona Department of Transportation (ADOT) and American Association of State Highway and Transportation Officials (AASHTO) requirements.

The tailings impoundment ranges in elevation from 2500 to 2970 feet, requiring a vertical lift of the tailings slurry, from the existing Elder Gulch thickener pump station of between 600 to 1070 feet.

Shifting the alignment of the West Dam TSF to the west, to avoid both the SR 177 highway and the existing 7 Series RDA is not feasible due to both the reduced storage capacity reduction, required 1,100-ft embankment with a side-hill construction, and the increased embankment raise rate required by the steeper topography.

The West Dam is seen as a medium feasibility design from a geological and hydrogeological perspective and a low feasibility design from an engineering perspective. Construction of this facility would adversely impact current and proposed mining operations in this area. In addition, due to the location of this site, SR 177 would have to be completely re-routed through the rugged terrain to the west of the site, at significant cost.

## 2.4 Granite Mountain

### 2.4.1 Site Conditions

The Granite Mountain site is located in the mountainous terrain to the west of the Ray Mine and to the southwest of SR 177. The site is located within Sections 17, 18, 19, 20, 29 and 30 of Township 3 South, Range 13 East. The rugged topography in this area contains a number of mountains, buttes and canyons, including Granite Mountain about a mile east of the site, Copper Butte immediately southwest of the site, and Walnut Canyon immediately northwest of the site (Figure A-3). The White Canyon Wilderness is located to the west and northwest of the site. The ground surface generally slopes to the southwest and large embankments would be required to the northwest and southeast of Copper Butte. A small drainage in the northern portion of the site flows into Walnut Canyon, whereas the remaining drainages converge near the toe of the southern embankment and this unnamed wash then flows into the Gila River about 2 miles to the southwest of the site.

As shown on Figure A-3, most of the site is underlain by a large stock of Tertiary Granite Mountain porphyry that was intruded into Precambrian Schist. The western margin of the site is underlain by Tertiary rock units consisting of Apache Leap tuff, Whitetail conglomerate and Teapot Mountain porphyry. Large talus and landslide deposits are present on the north and east sides of Copper Butte and thin alluvial deposits are present along the drainages that flow into Walnut Canyon and the drainages beneath the southern embankment. Much of the contact between the Granite Mountain porphyry and Pinal schist is a thrust fault. The Pinal schist forms the upper plate of the fault and the fault generally dips to the west toward Walnut Canyon. As shown on Figure A-3, this fault, referred to as the Copper Butte Fault, underlies large portions of the both the northwestern and southern embankments.

The crystalline rock units that underlie most of the Granite Mountain site are anticipated to have a low permeability. The Apache Leap tuff and Whitetail conglomerate are anticipated to have a low to medium permeability. Several deep exploration holes (up to 850 feet deep) have been drilled within the site footprint; however, no groundwater level data are available for these borings. Several shallower borings drilled near the southwest portion of the site in Section 30 of Township 3 South, Range 13 East have recorded water levels ranging from approximately 150 to 300 feet in depth. A spring is present at the confluence of two drainages that meet near the toe of the southern embankment.

The watershed above the Granite Mountain alternative is relatively small, measuring 531 acres. The watershed runoff coefficient would be high because of the exposed rock conditions.

### 2.4.2 Design Considerations

Most of the impoundment would be underlain by low permeable crystalline bedrock, which should minimize seepage into the groundwater system. The northwestern embankment would primarily be underlain by low permeability crystalline bedrock, whereas the southern embankment would primarily be underlain by low to moderate permeability Apache Leap tuff and Whitetail conglomerate. However, the presence of talus and landslide deposits adjacent to Copper Butte and the presence of the Copper Butte Fault, a large-scale regional thrust fault, beneath both embankments are of concern. The toe of the northwestern embankment impinges upon Walnut Canyon and a cut-off system would be needed to prevent seepage from migrating into this drainage. Cut-off systems would also be needed downstream of the southern embankment. A spring at the toe of this embankment indicates the presence of shallow groundwater in this area.

### 2.4.3 Discussion

The Copper Butte Fault located along the western margin of the site generally separates the Granite Mountain porphyry from the Pinal Schist, Apache Leap tuff and Whitetail conglomerate. The northwest and southern embankments would be constructed on top of the Copper Butte Fault for much or their lengths. Talus and landslide deposits located adjacent to Copper Butte would need to be addressed, since these materials would be located within the footprint of the dam embankment. In general, the presence of low permeable igneous and metamorphic bedrock beneath the site will minimize the potential for seepage to enter the groundwater system; however, the Copper Butte Fault, a thrust fault of regional scale, has the potential to be a major seepage pathway and would require detailed investigation.

Figure 4 presents the configuration of the Granite Mountain alternative. The required embankment volume to raise the impoundment above the starter dam crest elevation is higher than could be provided solely by cycloned sand construction. Locally derived rockfill borrow would be required to meet the necessary embankment build rates. The distance from the Ray Mine and the lack of suitable material being generated make the use of mine generated waste rock to provide the additional embankment volume infeasible.

The 8 mile long tailings slurry pipeline corridor would pose an issue due to the rugged terrain. The pipeline would cross the Granite Mountain ridge line at an elevation of about 3000 feet before dropping back down to the impoundment elevation, which varies between 2170 and 2880 feet. The overall elevation lift requirement for the slurry pipeline would be 1100 feet.

In addition, the impoundment is located above a known mineral resource that is in Asarco's mine plan. The construction of this alternative would preclude access to this resource.

The site scores medium-high for geology but low for hydrogeology due to the presence of talus and landslide deposits adjacent to Copper Butte and the presence of the Copper Butte Fault.

## 2.5 Devils Canyon

### 2.5.1 Site Conditions

The Devils Canyon site is located within Devils Canyon north of the Ray Mine, approximately ¼ mile north of the confluence of Devils Canyon and Mineral Creek. Most of the site is located in Sections 22 and 27 of Township 2 South, Range 13 East, with minor portions of the site extending into Sections 15, 16, 21, 23, 26, 28 and 34 of the same township and range. The upper portions of the site are located within the deeply incised Devils Canyon and Rawhide Canyon; the western side of Devils Canyon broadens out and is less steep as it approaches Mineral Creek. Several drainages flow into Devils Canyon from the west and Rawhide Canyon flows into Devils Canyon from the north. An embankment would be constructed across Devils Canyon approximately ¼ mile upstream of the confluence of Devils Canyon and Mineral Creek. Figure 5 presents the layout of the Devils Canyon alternative.

As shown on Figure A-4, the site is predominantly underlain by Tertiary Apache Leap tuff and Whitetail conglomerate. Younger, unconsolidated deposits of alluvium occur along the floor of Devils Canyon, and on the western slope of Devils Canyon in the southern portion of the site. Talus and landslide blocks occur in the western portions of the site and are derived from the Apache Leap Tuff (Creasey et al 1983). The southern portion of the embankment would be constructed on Whitetail conglomerate consisting of monolithic breccias that originated as landslides and/or mudflows.

The eastern portion of the embankment would overlie several faults and the area between the downstream toe of the embankment and the confluence of Devils Canyon and Mineral Creek is characterized by a highly faulted sequence of diabase and Apache Group sediments. Sell (1995, 1996) indicates the presence of a northwest-trending fault underlying Devils Canyon that can be traced to the vicinity of the confluence of Devils Canyon and Mineral Creek. Based on available drill data, the fault dips approximately 60 degrees to the west and displays more than 6,000 feet of separation.

The Apache Leap tuff and Whitetail conglomerate are anticipated to have a low to medium permeability. ADWR records indicate the presence of two wells within the footprint of the proposed facility; in the southwest quarter of Section 27. Water levels in these wells are reported to be approximately 150 and 200 feet deep. Two wells located in Section 34 to the south of the site had recorded water levels of approximately 70 and 200 feet. Grapevine Spring in the southeast quarter of Section 21 is located within the site footprint.

The watershed of the Devil's Canyon alternative is considerable, measuring about 21,500 acres [33.6 square miles], extending north to the Fortuna Peak ridge of Haunted Canyon. The highest point in the watershed is at elevation 5528 feet, skirts the east edge of Oak Flat and captures the area between the Apache Leap and Mineral Creek. Rock is exposed in a large percentage of the watershed. The percentage of rainfall reporting as runoff is much higher than in the preferred Ripsey Wash alternative watershed. The precipitation depths in this watershed are higher due to orographic effects.

### 2.5.2 Design Considerations

The tuff and conglomerate are anticipated to have a low to medium permeability. The presence of large blocks of talus and landslide materials within the footprint of the facility and the presence of breccias and faults beneath the embankment are of concern and would need to be investigated. Seepage downstream of the TSF could be controlled with a cut-off system below the dam, trench drains with downstream geomembrane, or a slurry wall with upstream pumpback wells. The investigation and design of these systems would need to consider the presence of several faults between the toe of the embankment and the confluence of Devils Canyon and Mineral Creek. Mineral Creek is located approximately ¼ mile downstream of the facility.

The facility would be constructed with an embankment starter dam, transitioning to centerline construction methods. Detailed staging of the impoundment was not completed to determine the required starter dam crest elevation and the timing which a transition to centerline construction was feasible.

This site presents numerous engineering challenges, including accessing the site, potential differential settlement of the dam in the steep walled canyon setting, and the design and construction of conveyances of stormwater around the facility. The ultimate tailings impoundment crest elevation is 3180 feet, requiring a vertical lift of the tailings slurry of 1280 feet over the 7.6 mile pipeline length.

### 2.5.3 Discussion

The Devils Canyon site scores medium for geology and hydrogeology. However, there are significant challenges in terms of constructability at this location, including challenges in site access during construction (the only access is through the operating mine), potential differential settlement of the dam in the steep walled canyon setting, and the difficulty of constructing and maintaining the approximately 7.6 mile long pipeline needed to convey tailings. In addition, the location is immediately upgradient of a Section 404 mitigation area covered by a restrictive covenant, and it is unclear if the TSF could be constructed at this location without impacting that mitigation area. For all these reasons, Amec Foster Wheeler concurs with the earlier SRK studies that the Devils Canyon site is not a feasible location for a tailings impoundment.

## 2.6 Hackberry Gulch Options 1 & 2

### 2.6.1 Site Conditions

The Hackberry Wash site is located southeast of the Elder Gulch Tailings Facility on the western flank of the Dripping Springs Mountains. Most of the site is located in Sections 31 and 32 (with a small portion located in Section 33) of Township 3 South, Range 14 East and in Sections 4, 5, 6, 8 and 9 (with small portions in Sections 10, 15 and 16) of Township 4 South, Range 14 East. The area is characterized by a large number of deeply incised drainages that flow from the upper reaches of the Dripping Springs Mountains southwestward into the Gila River located along the base of the mountain range. SR 177 is located immediately southwest of the site between the site and the Gila River.

As shown on Figure A-5, the Hackberry Gulch site is predominantly underlain by conglomerate of the Big Dome Formation (Cornwall and Krieger 1975a). The conglomerate in the uppermost reaches of the site is dominated by clasts of Paleozoic limestone, whereas the remainder of the conglomerate is made up of a diverse variety of clast types. The westernmost portion of the site contains some sandstone beds. The Big Dome Formation was deposited during the late Miocene when debris was shed into the Gila River basin from the surrounding highlands. The Big Dome has been moderately deformed by tilting along northwest-striking normal faults (Cornwall and Kreiger 1975a). The faults dip to the northeast and southwest at angles ranging from vertical to 45 degrees. Bedding within the conglomerate generally dips to the southwest at between 10 to 20 degrees.

Detailed geologic investigations at the adjacent Elder Gulch tailings facility, within the same geologic setting as the Hackberry Gulch alternatives, identified a concealed paleo-channel within a terrace of the main drainage channel. The investigation revealed that the channel merged with the main Elder Gulch drainage within the impoundment footprint and did not present a seepage pathway beyond the embankment footprint.

ADWR imaged records were reviewed to characterize the depth to groundwater at the site and in surrounding areas. The records identify one well within the footprint of the Hackberry Wash site; however, there are no data for this well. Depths to groundwater in wells in areas surrounding the site vary considerably. Two wells downgradient from the site on the west side of SR 177 in Section 8 of Township 4 South, Range 14 East had recorded water levels of 335 feet bgs and 400 feet bgs, whereas a dozen wells located in Section 6, also downgradient of the site, had water levels ranging from 5 to 20 feet bgs. These later wells were located closer to the Gila River. Three wells located approximately 1 mile upgradient of the site had water levels ranging from 48 to 56 feet bgs, whereas a fourth well in this area had a recorded water level of 340 feet bgs.

The watershed above the Hackberry Gulch alternatives measure 4154 acres for Option 1 and 3133 acres for Option 2. The natural drainages upgradient of the impoundment, average about 25 percent gradients, with a short time of flow concentration resulting in very high peak flow rates in the drainages. Retention dams would be required in the major drainages to reduce these peak rates to the diversion channel.

### 2.6.2 Design Considerations

For this alternative, the TSF would be constructed using an embankment starter dam, transitioning to centerline raises using cyclone sand and finally transitioning to upstream construction for the remainder of the impoundment operation. The layouts of these alternatives are presented on Figures 6 and 7.

The Hackberry Option 1 would require an embankment height of 640 feet with a crest elevation of 2500 feet and would result in an impoundment with a total capacity of 755.2 million tons. The impoundment footprint area would be about 2125 acres.

An elevation-capacity staging relationship was developed for the Hackberry Gulch Option 2 alternative using the project topographic mapping. An embankment height of 610 feet with a crest elevation of 2530 feet would allow for an impoundment with a total capacity of 746.2 million tons. The impoundment footprint area would be about 1971 acres.

The Hackberry Gulch alternatives require significantly higher amounts of embankment borrow materials than the Ripsey Wash alternatives. A study of the Option 2 embankment build rates reveals a deficiency of cyclone sand being generated to build the embankment. The cyclone sand embankment would need to be supplemented with additional rockfill materials, at a rate of up to 1.5 million tons per year during Years 5 through 16.5 of the facility operation. The mine is not able to provide the additional volume of suitable non-mineralized material and it would need to be locally produced at the impoundment site. The amount of embankment borrow required would be 21.5 million tons, including the starter dam (13.5 million tons).

A configuration with a starter dam, constructed of earth and rockfill borrowed from within the impoundment footprint would be constructed to elevation 2150 feet, with a maximum height of about 180 feet. The starter dam for the Hackberry Option 2 alternative would require about 8.3 million cubic yards (13.5 million tons) of material. Detailed analysis has not been performed on a possible Hackberry Option 1 starter dam, but a preliminary estimate of starter dam volume is 19.1 million tons.

The size to capacity ratio for Hackberry Gulch Option 1 is 2.8:1 (2,125 acres/755.2 million tons) and for Option 2 is 2.6:1 (1971 acres/746.2 million tons).

The ultimate tailings impoundment crest elevation is for Option 1 is 2500 feet, requiring a vertical lift of the tailings slurry of 600 feet over the 0.9 mile pipeline length. For Option 2, the required vertical lift of the tailings slurry is 635 feet.

The toe of the cyclone sand embankment would be within 450 feet of State Route 177 at the end of the centerline raise construction phase. Reclamation of the downstream face of the embankment could not commence until this point.

Control of upgradient stormwater would be a challenge for the Hackberry alternatives. Positive stormwater controls will be necessary to prevent encroachment of the supernatant pool on the dam crest.

The conceptual design considers an upgradient channel extending from the Hackberry Gulch drainage eastward to drain between the new TSF and the existing Elder Gulch impoundment.

Additionally, the post closure upgradient stormwater diversion channel, currently permitted as a component of the Elder Gulch TSF reclamation, shown on Figure 7, would need to be connected to the Hackberry Gulch diversion channel. The combined flow would be routed between the two impoundments, cross State Route 177, and travel through the Belgravia Wash to the Gila River. This would necessitate changes to the location and design of the currently permitted Elder Gulch diversion channel. Control of upgradient stormwater for the eastern portion of the impoundment would necessitate construction of either one (Option 2) or two (Option 1) retention ponds.

The Hackberry Gulch Option 1 crosses 18 drainages, including 7 major drainages and Option 2 crosses 16 drainages, including 6 major drainages. Alluvial cutoffs and subsurface drains will be required to collect under drainage and excess water from the cyclone underflow. Toe berms would control sediment erosion from the face of the dam and divert stormwater and underflow to collection ponds located in the major drainages. The proximity of the toe of the embankment to SR 177 would require that four of the collection ponds be located south of the highway.

The elongate arrangement of the Hackberry Gulch alternatives would require at least four or five separate supernatant decant points. The reclaim water pipeline would cross deeply incised drainages.

The Big Dome formation is anticipated to have a low to moderate permeability. Seepage from the impoundment could be reduced by installing a system of granular finger or blanket drains to supplement natural subdrainage and/or lining the main underdrains. Studies conducted for the design of the adjacent Elder Gulch TSF revealed the presence of coarser grained, more permeable zones within the Big Dome Formation that could provide preferential pathways for seepage. Examination of exposures of the Big Dome Formation within the proposed Hackberry TSF footprint revealed similar coarse gradations.

The stormwater diversion channel would require energy dissipation structures as the channel drops from the between the Hackberry Gulch and Elder Gulch TSFs to the Gila River. A new highway bridge or series of box culverts would be required at the SR 177 crossing. Belgravia Wash would need to be channelized the entire length. The Copper Basin Railroad and Ray Junction Road crossings of the drainage would require improvements due to the increased flows.

The channel alignment would cross through the site of historic Belgravia tailing site, which has been recently reclaimed.

### 2.6.3 Discussion

The bedding of the conglomerate within the site footprint generally dips to the southwest toward the Gila River at between 10 to 20 degrees. The bedding planes may act as preferential seepage pathways. There also are approximately two dozen high-angle, northwest-striking faults within the site footprint that are potential seepage avenues. As many as twelve deeply incised channels along the downstream toe of the site will require individual cutoffs to prevent seepage from migrating toward the Gila River. Since each of these drainages is independent of one another, it is anticipated that multiple cut-off walls and pumpback wells would be required to control seepage.

The potential presence of paleo-channels paralleling the existing drainage system could result in pathways for seepage to move to the Gila River. The geologic environment, where a mantle of colluvium overlies the conglomerate, along with the number of drainages that the facility embankment intersects, could prove difficult for the identification of concealed ancestral drainages and the development of appropriate seepage countermeasures.

The toe of the facility is so close to the road that construction of support facilities (i.e, cutoff walls, pumpback wells, seepage collection ponds, etc.) would be difficult to construct. In some drainages, seepage collection ponds and ancillary equipment would likely need to be located on the river side of SR 177 and seepage would need to be piped through culverts beneath the highway; and an overpass to provide a connection between the project activities on both sides of the highway. Based on previous conversations with ADOT, it would be very difficult to obtain authorization for this level of mining infrastructure within the SR 177 right-of-way.

Hackberry Gulch is considered to be a medium to low feasible design. Hackberry Gulch ranked in the medium-high feasibility range in the 2006 and 2008 SRK Reports based on cost per ton. Due to its close proximity to the existing Elder Gulch TSF, there is minimal impact from the tailings pipeline corridor. However, whereas the Hackberry Gulch site has some favorable characteristics, it isn't without issue. Due to its close proximity to the existing Elder Gulch TSF, it would be difficult to expand vertically higher than the current Elder Gulch embankment height. To accommodate a storage capacity of 750 million tons the facility would have to expand laterally to the south. In doing so the medium geological and hydrogeological ranking it received from the 2006 SRK Report becomes an important consideration. As the facility expands south, it crosses more washes, which increases the possibility of multiple underground seepage pathways.

Another significant disadvantage to the site is the amount of additional embankment borrow material that is required because the necessary embankment volumes exceed the amounts that would be available from cycloned sands generated from the tailings.

## 2.7 Ripsey Wash Options 1, 2, and 3

### 2.7.1 Site Conditions

The Ripsey Wash site is located south-southwest of the Ray Mine at the northern end of the Tortilla Mountains. The area is characterized by hilly terrain with moderately incised washes. There are three options (footprints) for this alternative. The footprint of Option 1 encompasses portions of Ripsey Wash, Zelleweger Wash and an unnamed wash, all of which flow northward into the Gila River, and the easternmost portion of this option extends onto the BLM land. The footprint of Option 2 avoids Zelleweger Wash, but still extends onto BLM land on the east. The footprint of Option 3, the preferred option, avoids both Zelleweger Wash and BLM land. The footprint of Option 3 is located within Sections 10, 11, 14, 15, 22 and 23 of Township 4 South, Range 13 East. Two embankments would need to be constructed for the Ripsey Wash alternative, a primary embankment across Ripsey Wash and a secondary embankment across the unnamed wash. The layouts of these alternatives are presented on Figures 8, 9, and 10.

As shown on Figure A-6, much of the Ripsey Wash site is underlain and surrounded by Ruin granite locally cut by diabase dikes. A compound half-graben (troughs bounded by faults on one side) is filled with Tertiary deposits; primarily conglomerate and breccias with lesser amounts of tuff and tuffaceous sandstone. These units typically dip to the east at between 25 and 40 degrees. The bedrock units are locally mantled with deposits of sand, gravel and reddish-brown soil and the washes are typically filled with thick deposits of alluvium predominantly consisting of silt, sand and gravel. The crystalline bedrock units are cut by two primary faults related to the development of the half-grabens within the Ruin granite: the Hackberry Fault on the west side of the site and the Ripsey Wash Fault in the central portion of the site. Neither of these faults is considered active according to the USGS Earthquake Hazards Program (2010).

A review of available groundwater records indicates that the depth to groundwater in and around the site ranges from about 25 to 150 feet bgs and is generally on the order of 100 feet bgs. The permeability of the Ruin granite is low to very low, whereas the permeability of the Tertiary deposits is probably low to moderate. The yields of wells completed in the Ruin granite ranged from less than 0.5 gallons per minute (gpm) to 3 gpm, with most wells yielding less than 1 gpm.

The Ripsey Option 1, extending across Zelleweger Wash has an upgradient watershed of 12,190 acres [19.0 square miles]. The longest flow length is about 6 miles within Ripsey Wash, with a 1060 foot elevation drop, and 3.5 miles in Zelleweger Wash, with a 1040 foot elevation drop.

Ripsey Options 2 and 3 have similar upgradient watersheds, covering about 9887 acres [15.5 square miles]; neither of these options impinge upon Zelleweger Wash. The Ripsey Wash Option 3, by not extending completely to the Tortilla Mountains, provides a better channel alignment opportunity to convey upgradient water from the east watershed (1044 acres) past the facility. In addition, the toe of the Ripsey Wash Option 3 impoundment is further removed from the Gila River than the other two options, providing better conditions for construction of a downgradient cutoff between the impoundment and the Gila River.

### 2.7.2 Design Considerations

Ripsey Wash is filled with alluvial deposits of silt, sand and gravel that exceed a thickness of 100 feet in the vicinity of the planned embankment. Alluvial deposits in the unnamed wash in the eastern portion of the site are anticipated to be on the order of 10 to 20 feet thick. Seepage controls will be required in both of these washes. It is anticipated that the seepage control in Ripsey Wash will consist of a trench drain that extends into the Ruin granite. The lower portion of the downgradient wall of the trench will be lined with a geomembrane that is tied into bedrock along the bottom and sides of the trench. The trench will be backfilled with drain rock, as well as several riser pipes with submersible pumps to remove fluids that collect within the trench. The seepage control in the unnamed wash will likely consist of a cutoff wall or grout curtain within the Ruin granite, possible supplemented with pumpback wells.

The ultimate tailings impoundment crest elevation is for Option 1 is 2350 feet, requiring a vertical lift of the tailings slurry of 450 feet over the 3.9 mile pipeline length. For Option 2, the vertical lift of the tailings slurry is 490 feet. For Option 3, the required vertical lift of the tailings slurry is 540 feet.

The impoundment ultimate crest elevation of the Ripsey Wash alternatives and relative proximity to the existing Elder Gulch tailings thickener allow for most efficient pumping of tailings and reclaim water of all the studied alternatives. The supernatant reclaim water pipeline would be routed along the east edge of the impoundment. The low point of the tailings pipelines would be adjacent to the Gila River, requiring a drain down pond of sufficient size to contain both the slurry and decant pipe volumes. Double containment of the pipelines adjacent to Mineral Creek and the Gila River would be provided.

A portion of the Pinal County Florence-Kelvin Highway, a two lane gravel surfaced roadway with limited drainage improvements, would require relocation around the TSF. In addition, a portion of the Arizona Trail would require relocation around the impoundment.

The Ripsey Wash Option 3 alternative embankment raising was evaluated over the life of the facility. The embankment would be raised from the starter dam crest elevation of 2000 feet by centerline construction using cycloned sands to elevation 2200 feet. The impoundment would then be raised by upstream methods to the planned ultimate height of elevation 2440 feet. The volume of cyclone sands that can be produced is in excess of that required to raise the embankment, which would result in the development of a sand beach developing within the impoundment, providing additional stability to the embankment.

Reclamation of the embankment can commence at the conclusion of the centerline raising phase, providing opportunity to complete the reclamation activities once the transition to upstream raising occurs. The Ripsey Wash options allow for reclamation activities to commence earlier than do the Hackberry options.

### 2.7.3 Discussion

Essentially the entire site is underlain or surrounded by low to very low permeability granite. The Tertiary deposits that overlie the Ruin granite in the southeast portion of the site and in the western portion of the site along Ripsey Wash dip toward the east, a favorable orientation for preventing seepage from moving along bedding planes toward Zelleweger Wash. There are two drainages that will require cutoffs; probably a seepage collection trench in Ripsey Wash and a cutoff wall in the unnamed wash. A high-angle fault on the west side of the site between Ripsey Wash and Zelleweger Wash was investigated and engineering controls were developed to mitigate potential seepage through the fault zone. As previously noted, this is not an active fault.

The Ripsey Wash areas are seen to be highly feasible design options. The 2006 and 2008 SRK Reports concluded that the Ripsey Wash site had the most favorable hydrogeological conditions. Our analyses confirm these findings and also find the areas to have the most favorable geological conditions.

## 3.0 RESULTS OF SITE RANKING

Table 1 presents a summary of the data used to evaluate and select a preferred site for the new TSF. Basic data included embankment volume, embankment height, embankment ratio, area to capacity ratio, tailings pipeline length and elevation change, and total length of diversion channels needed. Each of the sites was also ranked with regard to geological and hydrogeological conditions. The rankings ranged from low (least favorable conditions) to high (most favorable conditions). The ranking of geological conditions was primarily based on the presence of stable foundation conditions, particularly beneath the embankments, the presence and location of geological hazards such as landslide deposits within the footprint of the embankments, and the availability of borrow materials for construction of rockfill embankments. The ranking of hydrogeological conditions was primarily based on the permeability of the geologic materials underlying the sites, the number and type of potential seepage pathways including faults and unconsolidated materials such as alluvial and colluvial deposits and their locations within the impoundment, and potential type, number and length of downgradient cutoffs that may be needed to prevent seepage from the facility.

As previously discussed, the E Dam alternative is considered to be a medium feasibility design, considering geologic and hydrogeological factors. The alternative ranks lower in overall feasibility primarily due to the length of the slurry and reclaim water pipelines.

The West Dam is considered to be a medium feasibility design from a geological and hydrogeological perspective. The realignment of State Highway 177 and the potential impacts of the TSF on current mine operations reduce the overall feasibility of the alternative to a low level.

The Granite Mountain alternative is located above a proven mineral resource that is in Asarco's mine plan. The site scores medium-high for geology but low for hydrogeology due to the presence of talus and landslide deposits adjacent to Copper Butte and the presence of the Copper Butte Fault. The site has been determined to be not feasible.

The Devils Canyon site scores medium for geology and hydrogeology. However, there are significant challenges in terms of constructability at this location. Among other issues, the site is located immediately upgradient of an area covered by a restrictive covenant. It was determined that the Devils Canyon site is not a feasible alternative

Hackberry Gulch is considered to be a medium to low feasible design considering geologic and hydrogeological factors. A significant disadvantage to the site is the amount of additional embankment borrow materials required over that which can be generated using cycloned sands. In addition, there are challenges in controlling potential seepage from the site.

Based on our review of the previously completed alternative analyses and our current analysis (as summarized in Table 1), Ripsey Wash Options 1, 2 and 3 are considered highly feasible and are the preferred locations for the new TSF.

The advantages of the Ripsey Wash Options include:

- The most favorable geologic and hydrogeologic conditions to control seepage within the impoundment footprint.
- The lowest embankment volume to tailings storage ratio.
- Relative proximity to the existing Elder Gulch tailings thickener and favorable topography for pipeline construction and operation, resulting in pipelines that are expected to be relatively easy to construct and maintain and efficient to operate.
- The lowest dam crest elevations, reducing the slurry and reclaim water pumping power requirements.
- The impoundment is drained by only two natural drainages, providing better means to control any seepage from the base of the impoundment.

- The impoundment location does not affect any other mine operations.
- Topography allowing for relatively easy conveyance of upstream flows around the impoundment.

A summary of the analysis is presented in Table 1, attached.

G:\Geotechnical\2013 Projects\17-2013-4034 ASARCO Ripsey Wash TSF APP Support\DEIS Comments\TSF Impoundments Alternatives Updated Memo\AMEC Technical Memo_Alternative TSF Sites (11-16-2016).docx

## 4.0 REFERENCES

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**TABLES**

**Table 1-Summary of Impoundment Alternatives**

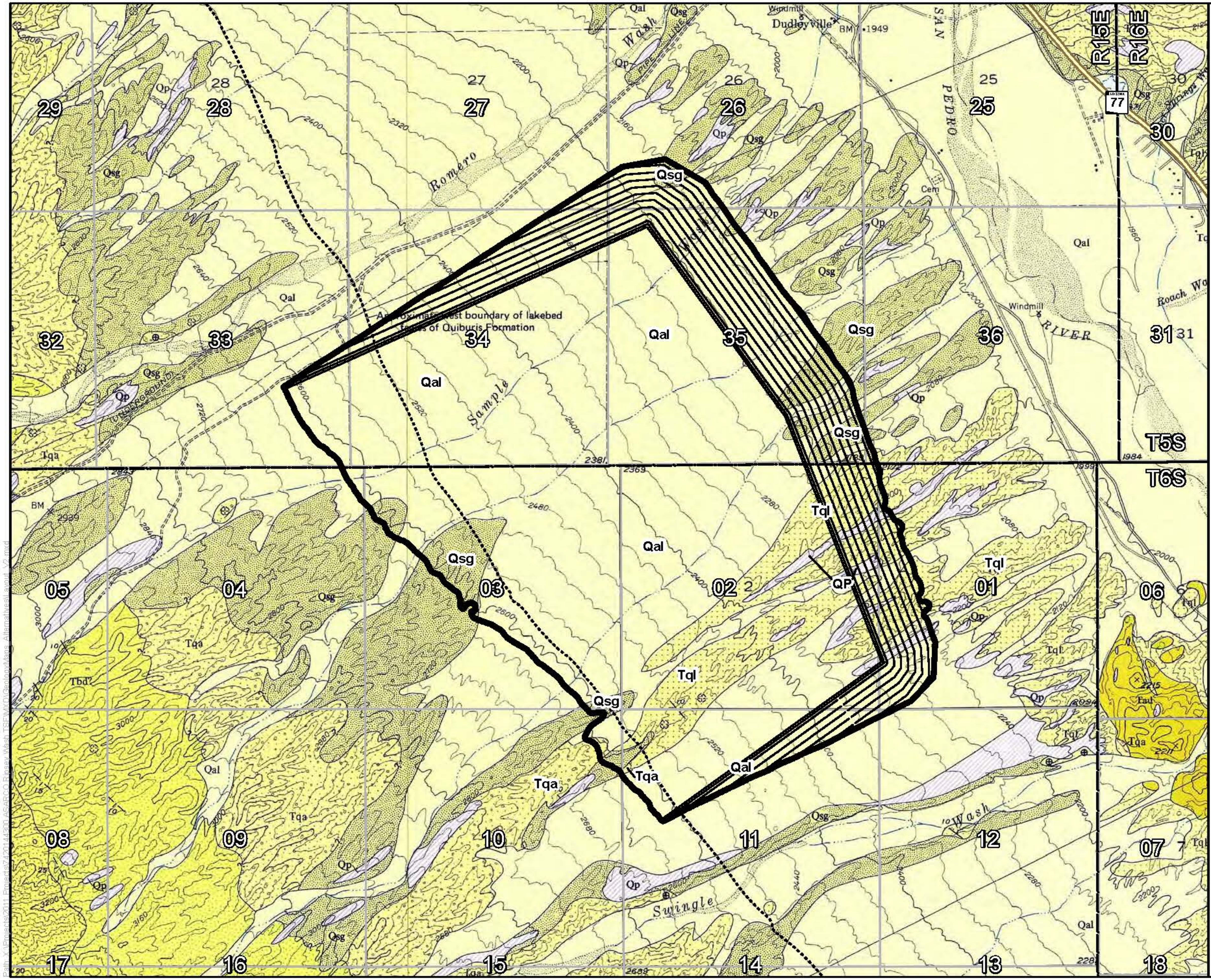
| Criteria | E Dam | West Dam | Granite Mountain | Devils Canyon |
|---|---|---|---|---|
| Overall Facility Capacity (million tons) | 750.9 | 757.6 | 748.6 | 766.7 |
| Embankment Volume (million tons) | 174.3 | 239.6 | 183.0 | 158.9 |
| Tailings Volume (million tons) | 576.6 | 518.0 | 565.6 | 607.8 |
| Crest Elevation (ft) | 2620 | 2970 | 2880 | 3180 |
| Embankment Height (ft) | 493 | 870 | 710 | 890 |
| Tailings Pipeline Length (ft [miles]) | 107,325 [20.3] | 8,491 [1.6] | 42,171 [8.0] | 40,345 [7.6] |
| Total Length of Diversion Channel (ft[miles]) | 22,557 [4.3] | 17,051 [3.2] | 17,744 [3.4] | 38,742 [7.3] |
| Tailings Impoundment Footprint (acres) | 2,363 | 1,333 | 1,568 | 1,222 |
| Area to Capacity Ratio (Acres/Overall Capacity) | 3.2:1 | 1.8:1 | 2.1:1 | 1.6:1 |
| Embankment Ratio (Embank Vol./Tailings Vol.) | 0.3:1 | 0.4:1 | 0.3:1 | 0.2:1 |
| Geological Ranking | Medium | Medium-High | Medium-High | Medium |
| Hydrogeological Ranking | Low-Medium | Medium | Low | Medium |
| Other Considerations | More than 20 miles from the Ray Mine. | Requires realignment of State Route 177. Conflicts with current mine operations. | Conflicts with the mineral estate rights and foreseeable uses for mining. | Lands immediately downstream from this site are covered by a restrictive covenant and provide mitigation set aside for Ray Mine activities. |

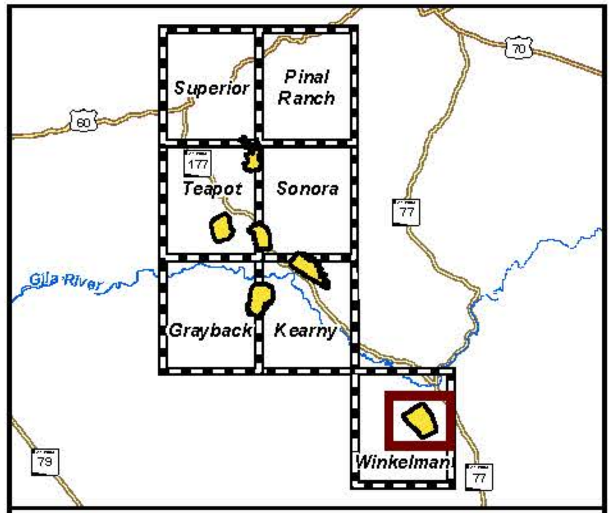
**Table 1-Summary of Impoundment Alternatives**

| Criteria | Hackberry Gulch Option 1 | Hackberry Gulch Option 2 | Ripsey Wash Option 1 (including Zelleweger Wash and BLM lands) | Ripsey Wash Option 2 (including BLM lands) | Ripsey Wash Option 3 (Preferred Alternative) |
|---|---|---|---|---|---|
| Overall Facility Capacity (million tons) | 755.2 | 746.2 | 769.5 | 791.7 | 751.3 |
| Embankment Volume (million tons) | 224.0 | 158.4 | 97.2 | 126.0 | 67.4 |
| Tailings Volume (million tons) | 531.2 | 590.7 | 672.4 | 665.7 | 683.7 |
| Crest Elevation (ft) | 2500 | 2535 | 2350 | 2390 | 2440 |
| Embankment Height (ft) | 640 | 610 | 560 | 540 | 625 |
| Tailings Pipeline Length (ft [miles]) | 4,622 [0.9] | | 20,359 [3.9]* | | |
| Total Length of Diversion Channel and Diversion Pipeline (ft [miles]) | 23,912 [4.5] | 33,162 [6.3] | 34,543 [6.5] | 20,453 [3.5] | 26,954 [5.1] |
| Tailings Impoundment Footprint (acres) | 2,125 | 1,971 | 2,356 | 2,140 | 2,129 |
| Area to Capacity Ratio (Acres/Overall Capacity) | 2.8:1 | 2.6:1 | 3.1:1 | 2.7:1 | 2.8:1 |
| Embankment Ratio (Embank Vol./Tailings Vol.) | 0.3:1 | 0.2:1 | 0.1:1 | 0.2:1 | 0.1:1 |
| Geological Ranking | Medium | Medium | High | High | High |
| Hydrogeological Ranking | Medium | Medium | Medium-High | High | High |
| Other Considerations | Dam construction would be required immediately adjacent to State Route 177.The western underflow collection ponds would need to be located south of the highway. | | Requires realignment of portion of Florence-Kelvin Highway | | |

* There are 5 alternatives for the delivery of tailings to the Ripsey Wash Alternative. The value shown here represents the length of the preferred tailings delivery pipeline alternative.

**FIGURES**




**Alternatives Location Overview**

## Explanation

- TSF Alternative Location
- USGS Geologic Quadrangle Map Boundary
- Fault
- Approximate boundary between lakebed facies and alluvial facies of Quiburis Formation
- Township and Range Lines
- Section Lines
- Waterways

**Geologic Map Units**

**Winkelman Quadrangle**

| | |
|---|---|
| Qal | Alluvium |
| Qp | Soil and gravel veneer on pediments and younger terraces |
| Qsg | Sand and Gravel |
| Tqa | Quiburis Formation - Alluvial facies |
| Tql | Quiburis Formation - Lakebed facies |

**Note:**

The geology shown on this figure is from the Winkelman (Krieger 1974) Geologic Quadrangle Map published by the U.S. Geological Survey. The explanation provided on this figure only provides the symbols and names of the geologic units that are exposed within the footprint of the TSF site.

0 1,000 2,000 Feet

N

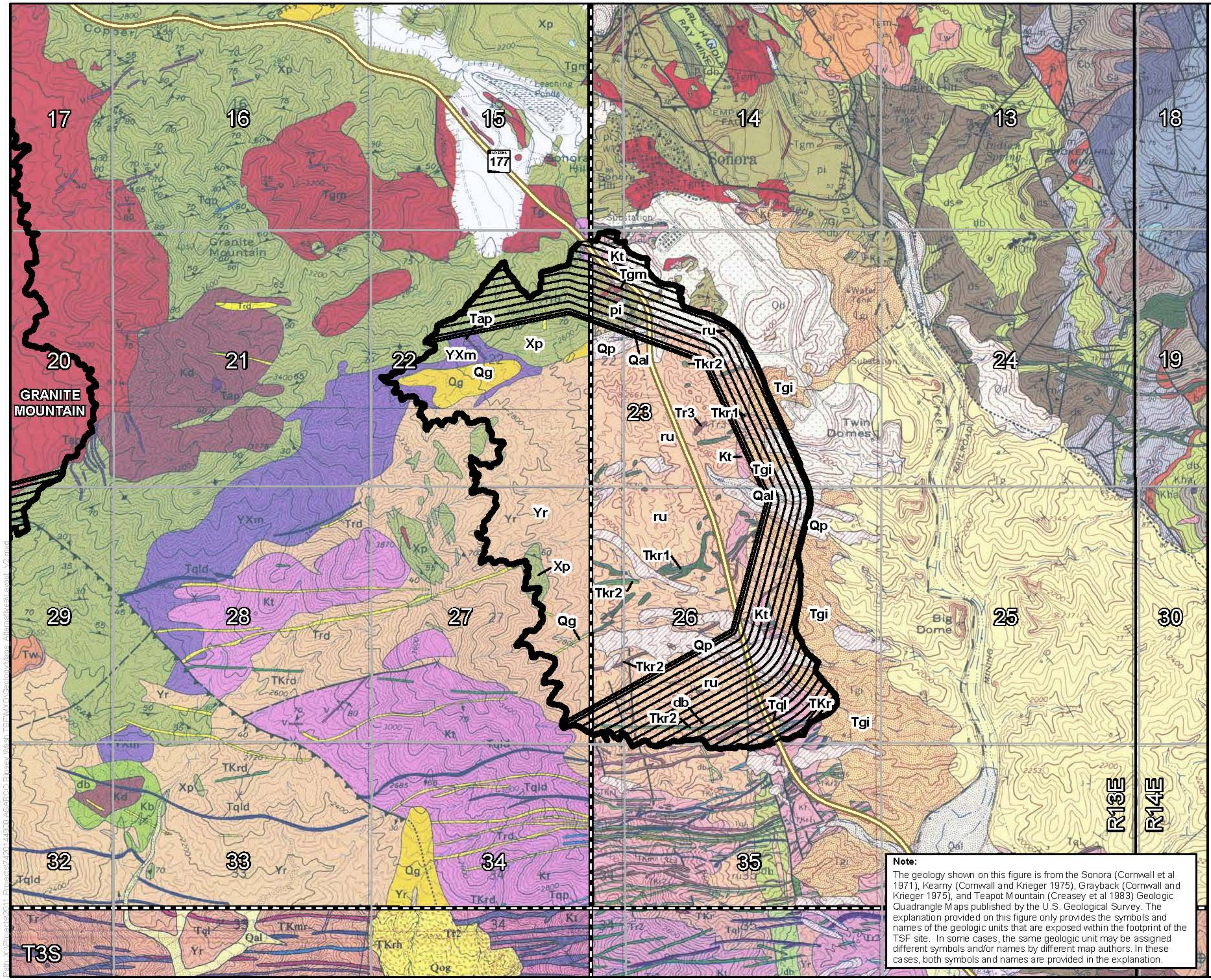
TSF Alternatives Analyses Review
ASARCO Ray Mine Complex

E Dam

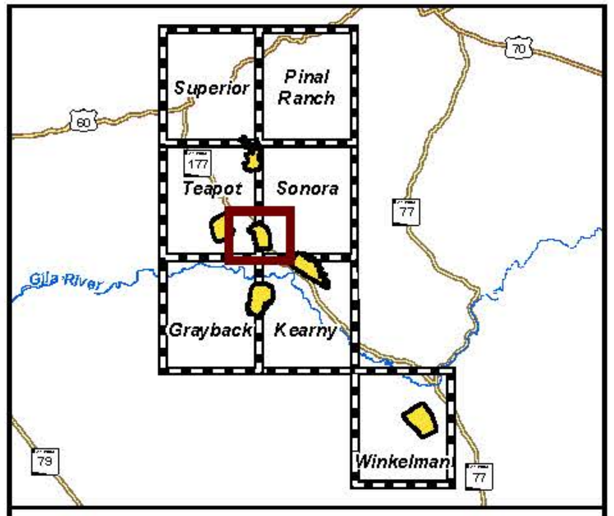
FIGURE A-1

| | |
|---|---|
| Job No. | 74-2014-4300 |
| PM: | RB |
| Date: | 6/24/2013 |
| Scale: | 1" = 2000 feet |

amec




**Note:**
The geology shown on this figure is from the Sonora (Cornwall et al 1971), Kearny (Cornwall and Krieger 1975), Grayback (Cornwall and Krieger 1975), and Teapot Mountain (Creasey et al 1983) Geologic Quadrangle Maps published by the U.S. Geological Survey. The explanation provided on this figure only provides the symbols and names of the geologic units that are exposed within the footprint of the TSF site. In some cases, the same geologic unit may be assigned different symbols and/or names by different map authors. In these cases, both symbols and names are provided in the explanation.




**Alternatives Location Overview**

## Explanation

- TSF Alternative Location
- USGS Geologic Quadrangle Map Boundary
- Fault
- Township and Range Lines
- Section Lines
- Waterways

### Geologic Map Units

**Teapot Mountain Quadrangle**

| | |
|---|---|
| Qg | Older Alluvium |
| Tap | Aplite and Pegmatite Dikes |
| Yr | Ruin Granite |
| YXm | Madera Diorite |
| Xp | Pinal Schist |

**Sonora Quadrangle**

| | |
|---|---|
| Qal | Alluvium |
| Qp | Pediment with soil and gravel veneer |
| Tgi | Conglomerate with angular igneous clasts |
| Tr3 | Rhyodacite porphyry |
| Tql | Quartz latite porphyry |
| Tgm | Granite Mountain Porphyry |
| TKr1 | Rhyodacite porphyry |
| TKr2 | Rhyodacite porphyry |
| TKr | Rhyodacite porphyry |
| Kt | Tortilla Quartz Diorite (new) |
| db | Diabase |
| ru | Ruin Granite |
| pi | Pinal Schist |

0 1,000 2,000 Feet

N

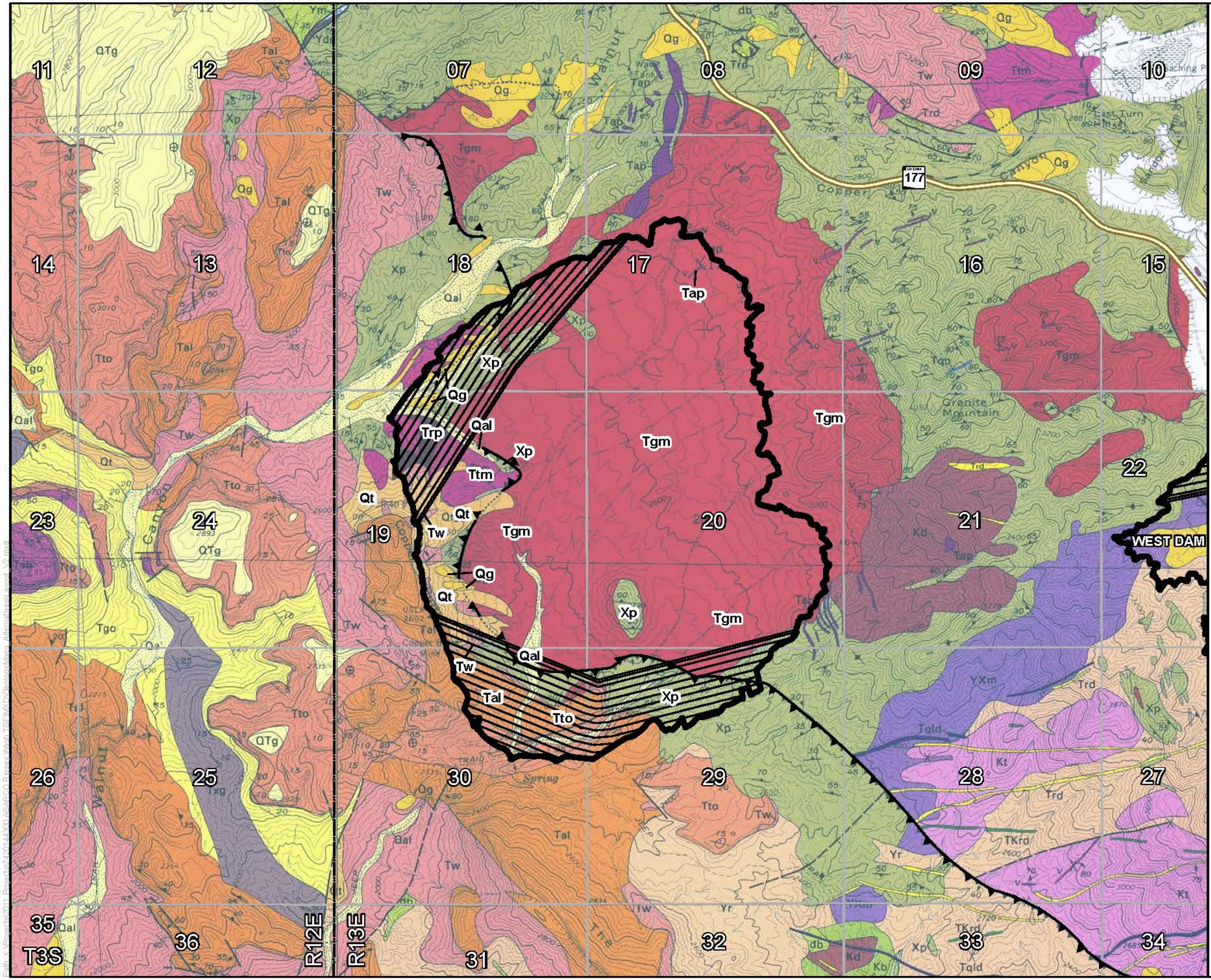
TSF Alternatives Analyses Review
ASARCO Ray Mine Complex

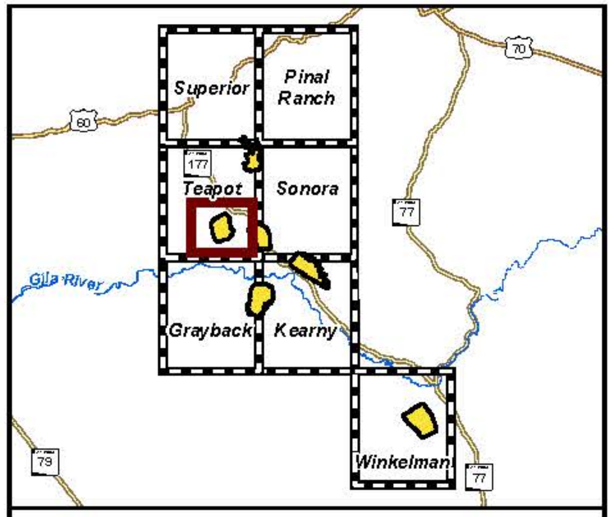
**West Dam**

FIGURE **A-2**

| | |
|---|---|
| Job No. | 74-2014-4300 |
| PM: | RB |
| Date: | 6/24/2013 |
| Scale: | 1" = 2000 feet |

amec




**Alternatives Location Overview**

## EXPLANATION

- TSF Alternative Location
- USGS Geologic Quadrangle Map Boundary
- Fault
- Low-Angle Fault; Sawteeth on Upper Plate; dotted where concealed
- Township and Range Lines
- Section Lines
- Waterways

### Geologic Map Units

**Teapot Mountain Quadrangle**

| | | | |
|---|---|---|---|
| Qal | Alluvium | Trp | Ryhodacite porphyry |
| Qt | Talus and landslides | Tap | Aplite and Pegmatite Dikes |
| Qg | Older alluvium | Tgm | Granite Mountain Porphyry |
| Tto | Older tuff | Yr | Ruin Granite |
| Tal | Apache Leap tuff | YXm | Madera Diorite |
| Tw | Whitetail conglomerate | Xp | Pinal Schist |
| Ttm | Teapot Mountain Porphyry | | |

**Note:**

The geology shown on this figure is from the Teapot Mountain (Creasey et al 1983) Geologic Quadrangle Map published by the U.S. Geological Survey. The explanation provided on this figure only provides the symbols and names of the geologic units that are exposed within the footprint of the TSF site.

0 1,000 2,000 Feet

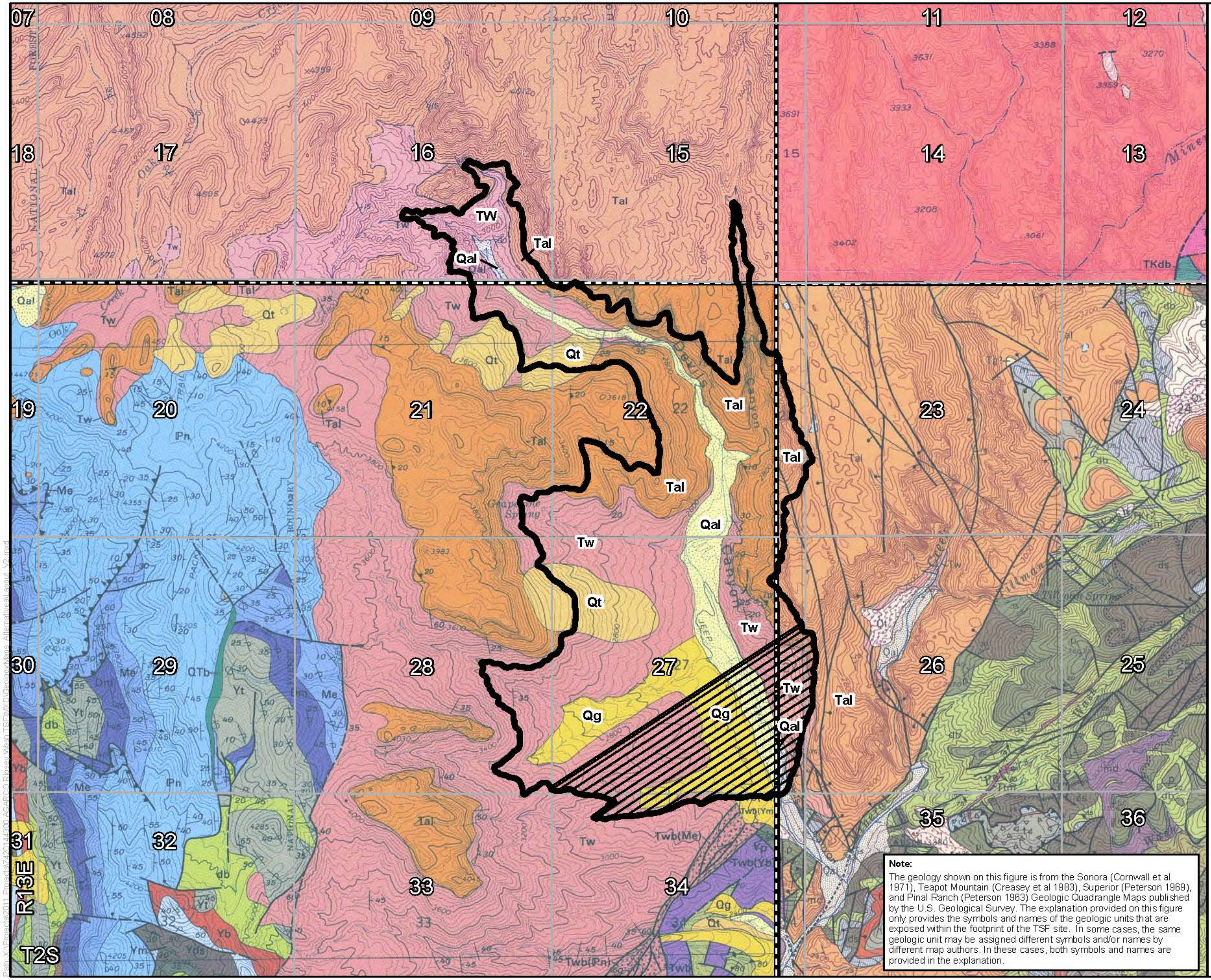
N

TSF Alternatives Analyses Review
ASARCO Ray Mine Complex

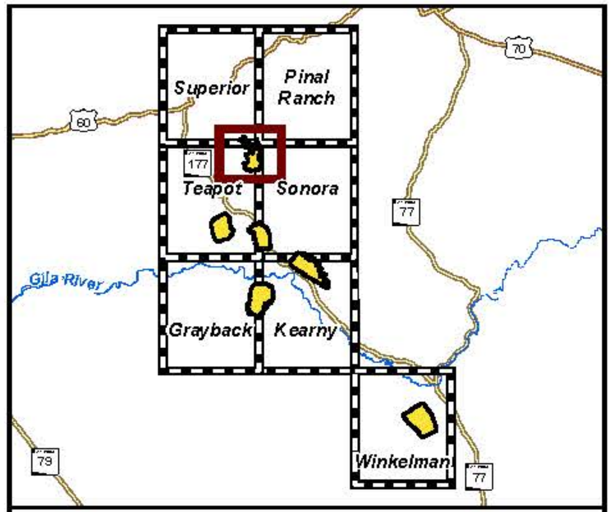
**Granite Mountain**

FIGURE A-3

| | |
|---|---|
| Job No. | 74-2014-4300 |
| PM: | RB |
| Date: | 6/24/2013 |
| Scale: | 1" = 2000 feet |




Note:
The geology shown on this figure is from the Sonora (Cornwall et al 1971), Teapot Mountain (Creasey et al 1983), Superior (Peterson 1969), and Pinal Ranch (Peterson 1963) Geologic Quadrangle Maps published by the U.S. Geological Survey. The explanation provided on this figure only provides the symbols and names of the geologic units that are exposed within the footprint of the TSF site. In some cases, the same geologic unit may be assigned different symbols and/or names by different map authors. In these cases, both symbols and names are provided in the explanation.




**Alternatives Location Overview**

## Explanation

- TSF Alternative Location
- USGS Geologic Quadrangle Map Boundary
- Fault
- Township and Range Lines
- Section Lines
- Waterways

### Geologic Map Units

**Superior Quadrangle**
- Qal Alluvium
- Tal Apache Leap Tuff
- Tw Whitetail Conglomerate

**Sonora Quadrangle**
- Qal Alluvium
- Tal Apache Leap Tuff
- Tw Whitetail Conglomerate

**Teapot Mountain Quadrangle**
- Qal Alluvium
- Qg Older alluvium
- Qt Talus and landslides
- Tal Apache Leap Tuff
- Tw Whitetail Conglomerate

0 1,000 2,000 Feet

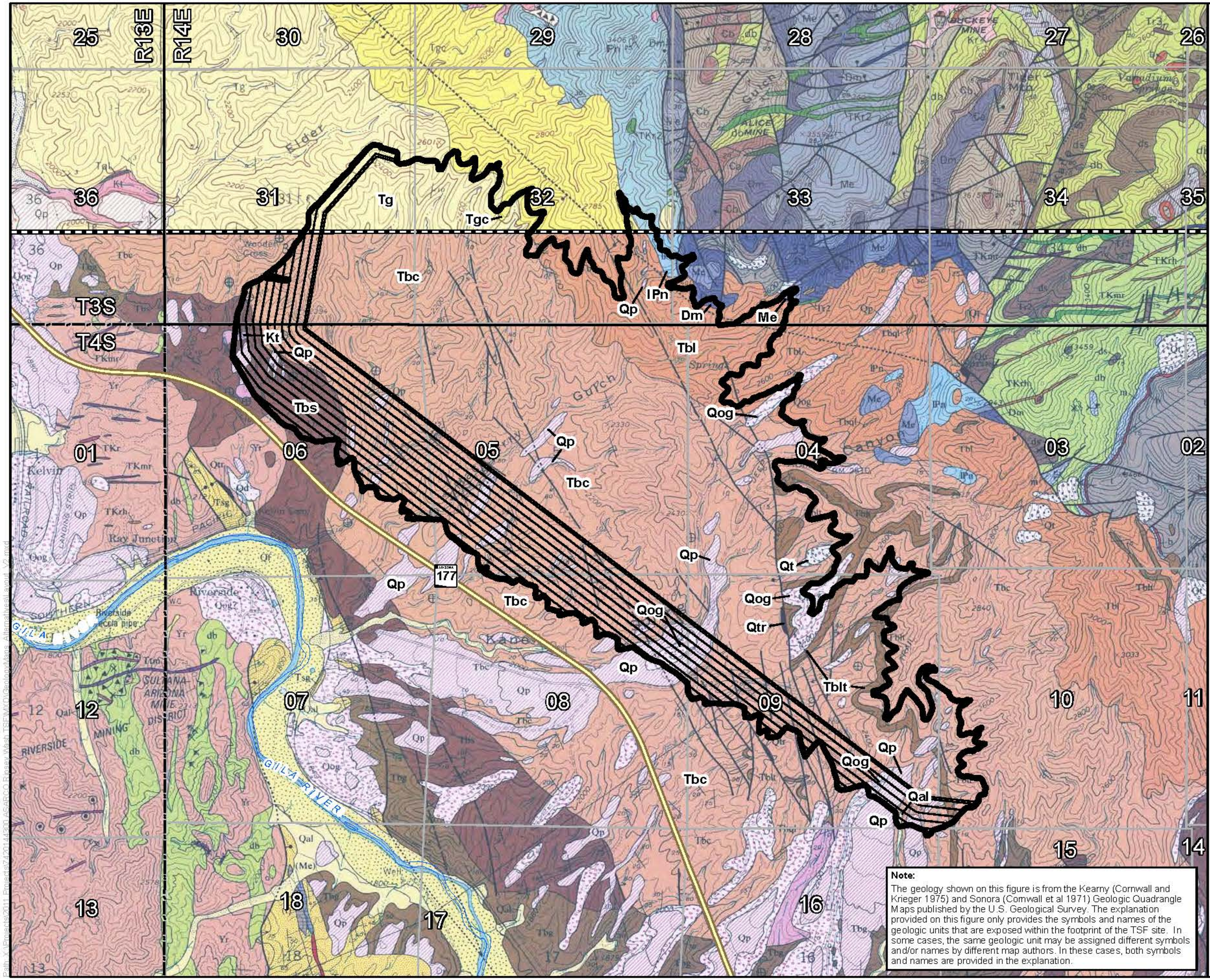
N

TSF Alternatives Analyses Review
ASARCO Ray Mine Complex

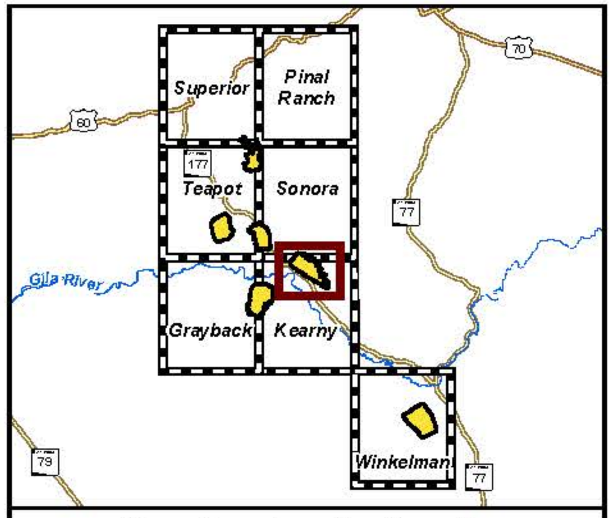
**Devils Canyon**

FIGURE A-4

| | |
|---|---|
| Job No. | 74-2014-4300 |
| PM: | RB |
| Date: | 6/25/2013 |
| Scale: | 1" = 2000 feet |




**Note:**
The geology shown on this figure is from the Kearny (Cornwall and Krieger 1975) and Sonora (Cornwall et al 1971) Geologic Quadrangle Maps published by the U.S. Geological Survey. The explanation provided on this figure only provides the symbols and names of the geologic units that are exposed within the footprint of the TSF site. In some cases, the same geologic unit may be assigned different symbols and/or names by different map authors. In these cases, both symbols and names are provided in the explanation.




**Alternatives Location Overview**

**EXPLANATION**

- TSF Alternative Location
- USGS Geologic Quadrangle Map Boundary
- Fault
- Township and Range Lines
- Section Lines
- Waterways

**Geologic Map Units**

**Sonora Quadrangle**

| | |
|---|---|
| Tgc | Conglomerate with mainly carbonate clasts |
| Tg | Conglomerate with diverse types of clasts |

**Kearny Quadrangle**

| | | | |
|---|---|---|---|
| Qal | Alluvium | Tblt | Lapilli tuff |
| Qt | Talus | Tbs | Sandstone and conglomerate |
| Qtr | Travertine | Kt | Tortilla Quartz Diorite |
| Qp | Pediment gravels | IPn | Naco Limestone |
| Qog | Older gravels | Me | Escabrosa Limestone |
| Tbl | Limestone conglomerate | Dm | Martin Limestone |
| Tbc | Conglomerate | | |

0 1,000 2,000 Feet

N

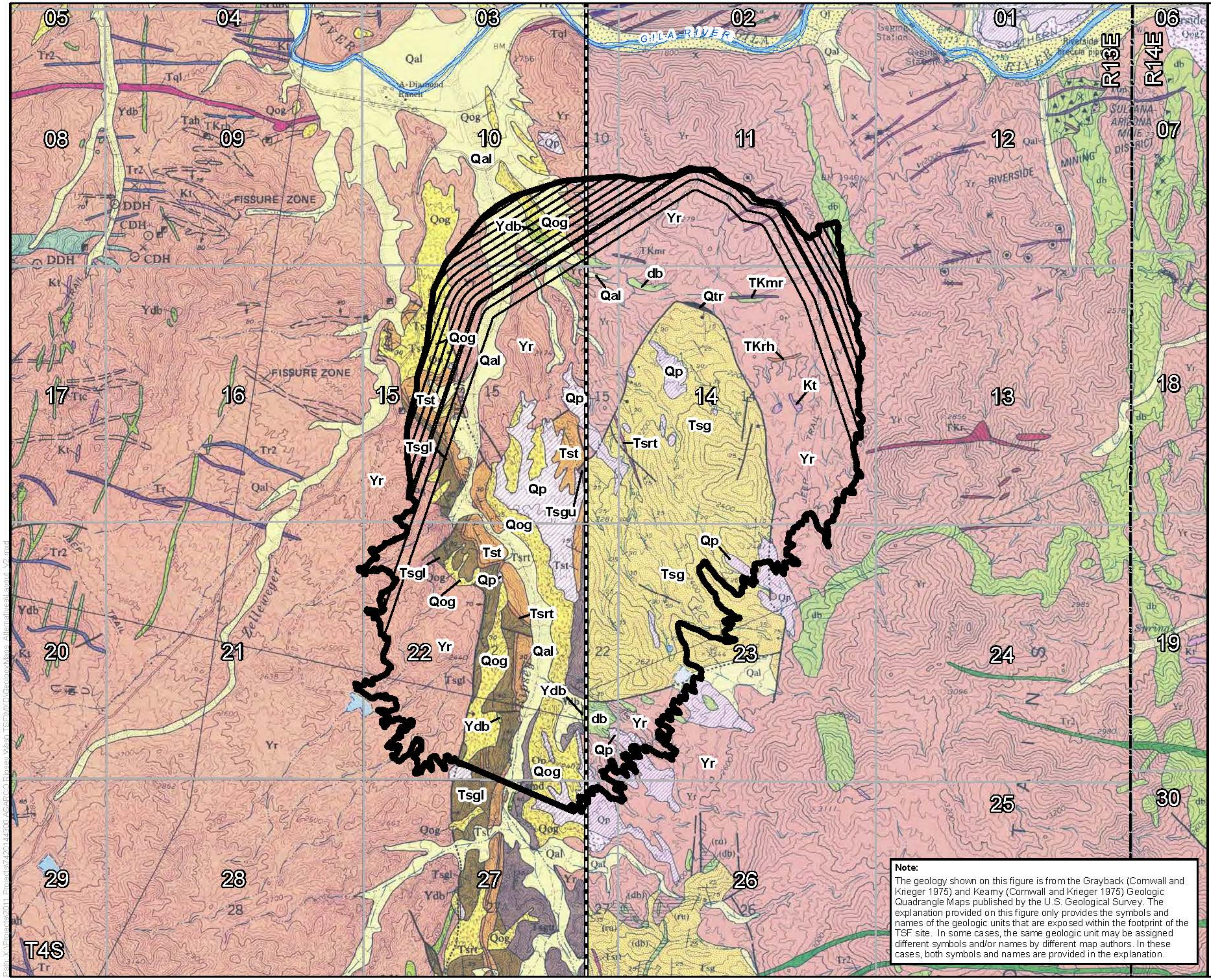
TSF Alternatives Analyses Review
ASARCO Ray Mine Complex

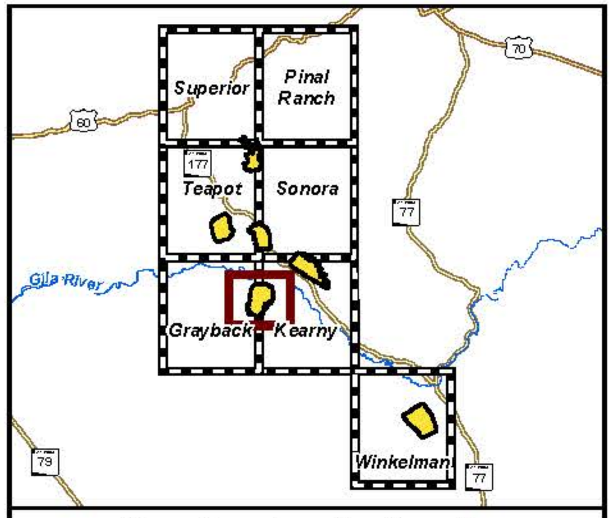
**Hackberry Wash**

FIGURE A-5

| | |
|---|---|
| Job No. | 74-2014-4300 |
| PM: | RB |
| Date: | 6/25/2013 |
| Scale: | 1" = 2000 feet |

amec




**Alternatives Location Overview**

## EXPLANATION

- TSF Alternative Location
- USGS Geologic Quadrangle Map Boundary
- Fault
- Township and Range Lines
- Section Lines
- Waterways

### Geologic Map Units

**Grayback Quadrangle**

| | |
|---|---|
| Qal | Alluvium |
| Qp | Pediment veneer |
| Qog | Older gravel |
| Tsgu | Upper granitic conglomerate |
| Tst | Tuffaceous sandstone and conglomerate |
| Tsrt | Tuff |
| Tsgl | Lower granitic conglomerate |
| Ydb | Diabase |
| Yr | Ruin granite |

**Kearny Quadrangle**

| | |
|---|---|
| Qal | Alluvium |
| Qtr | Travertine |
| Qp | Pediment gravels |
| Tsg | Granitic conglomerate |
| Tsrt | Rhyolitic to dacitic tuff |
| TKmr | Melanocratic rhyodacite porphyry |
| TKrh | Rhyodacite porphyry |
| Kt | Tortilla Quartz Diorite |
| db | Diabase |
| Yr | Ruin granite |

0 1,000 2,000 Feet

N

**Note:**
The geology shown on this figure is from the Grayback (Cornwall and Krieger 1975) and Kearny (Cornwall and Krieger 1975) Geologic Quadrangle Maps published by the U.S. Geological Survey. The explanation provided on this figure only provides the symbols and names of the geologic units that are exposed within the footprint of the TSF site. In some cases, the same geologic unit may be assigned different symbols and/or names by different map authors. In these cases, both symbols and names are provided in the explanation.

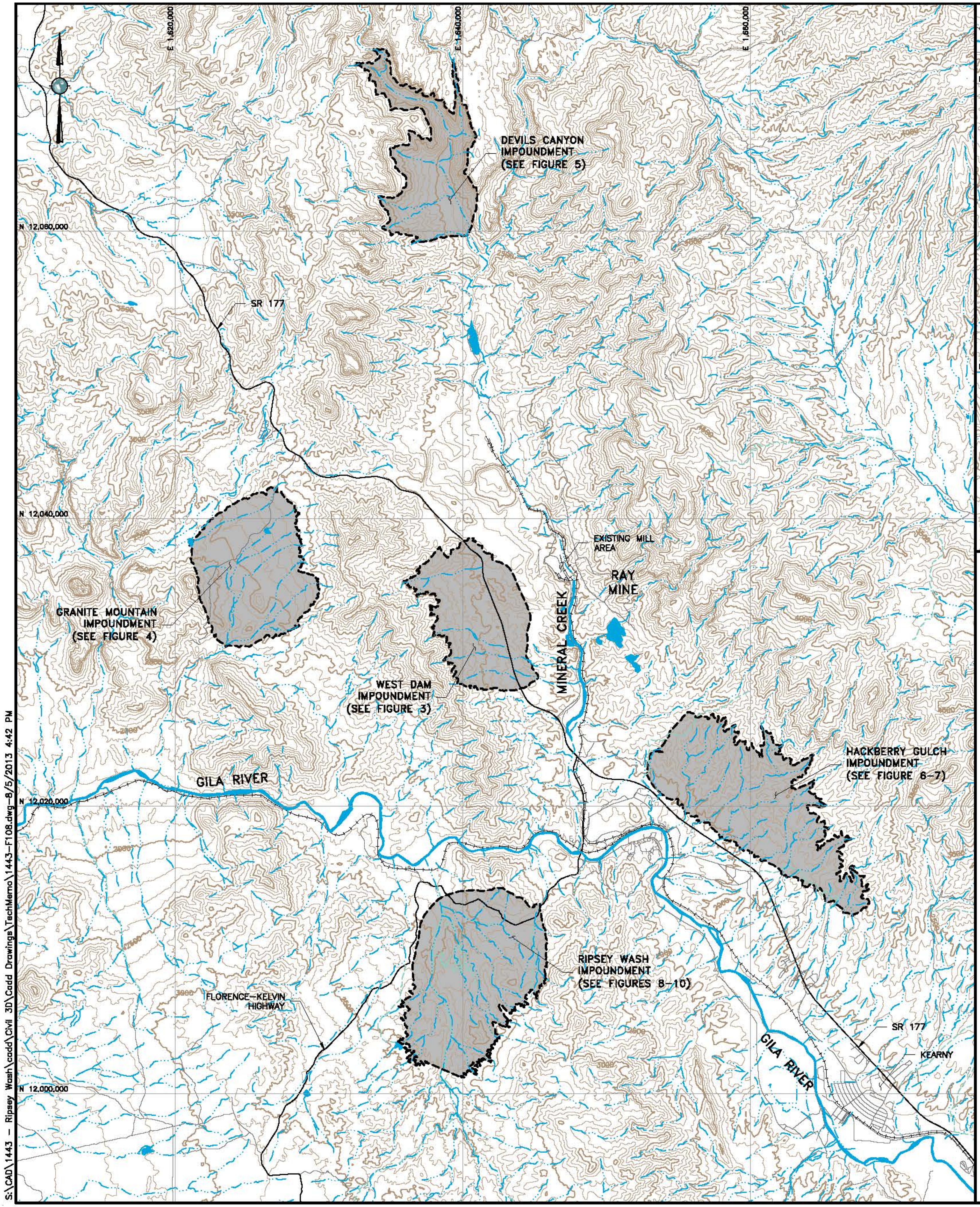
TSF Alternatives Analyses Review
ASARCO Ray Mine Complex

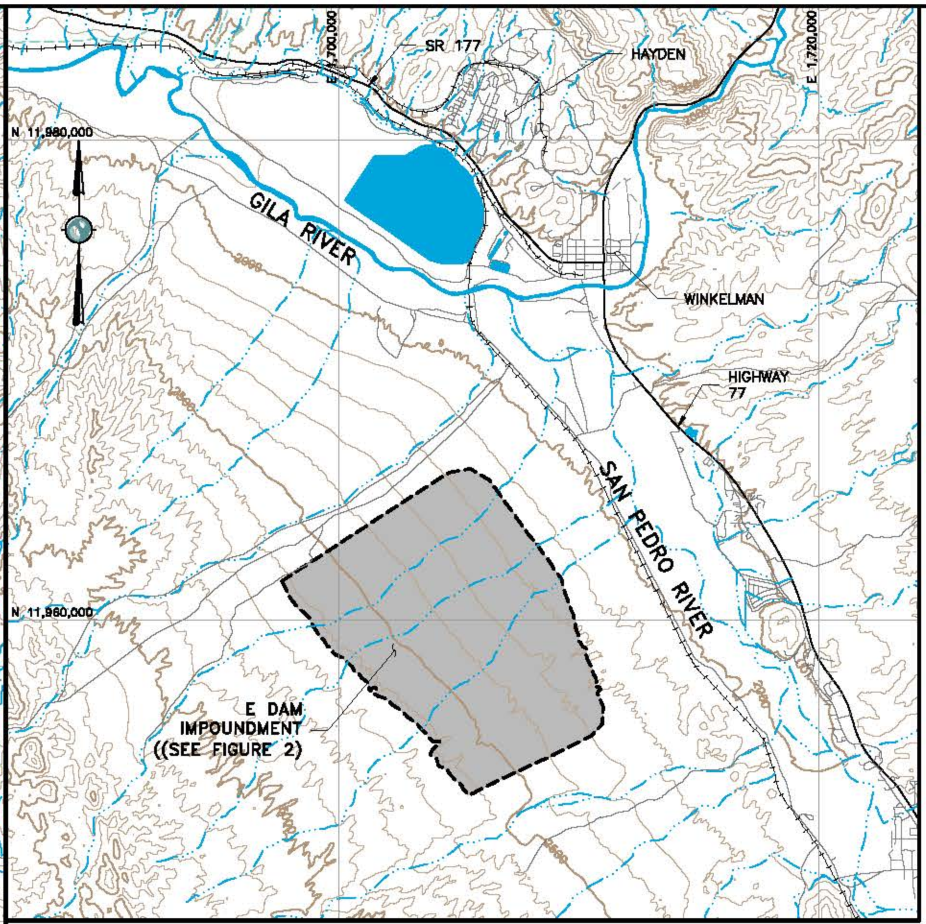
**Ripsey Wash**

FIGURE A-6

| | |
|---|---|
| Job No. | 74-2014-4300 |
| PM: | RB |
| Date: | 6/25/2013 |
| Scale: | 1" = 2000 feet |

amec




**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- TAILINGS AREA

4000 0 4000 8000 FEET

| | |
|---|---|
| CLIENT | ASARCO, LLC. |
| PROJECT | TAILINGS DAM ENGINEERING PROJECT |
| TITLE | 750 MILLION TON ALTERNATIVES OVERALL VIEW |

amec

| DESIGNED BY | TJK | CHECKED BY | TJF | DATE |
|---|---|---|---|---|
| DRAWN BY | JAS | APPROVED BY | LAH | 06/26/13 |
| FILENAME | | | FIGURE No. | REV |
| 1443-F108 | | | 1 | A |

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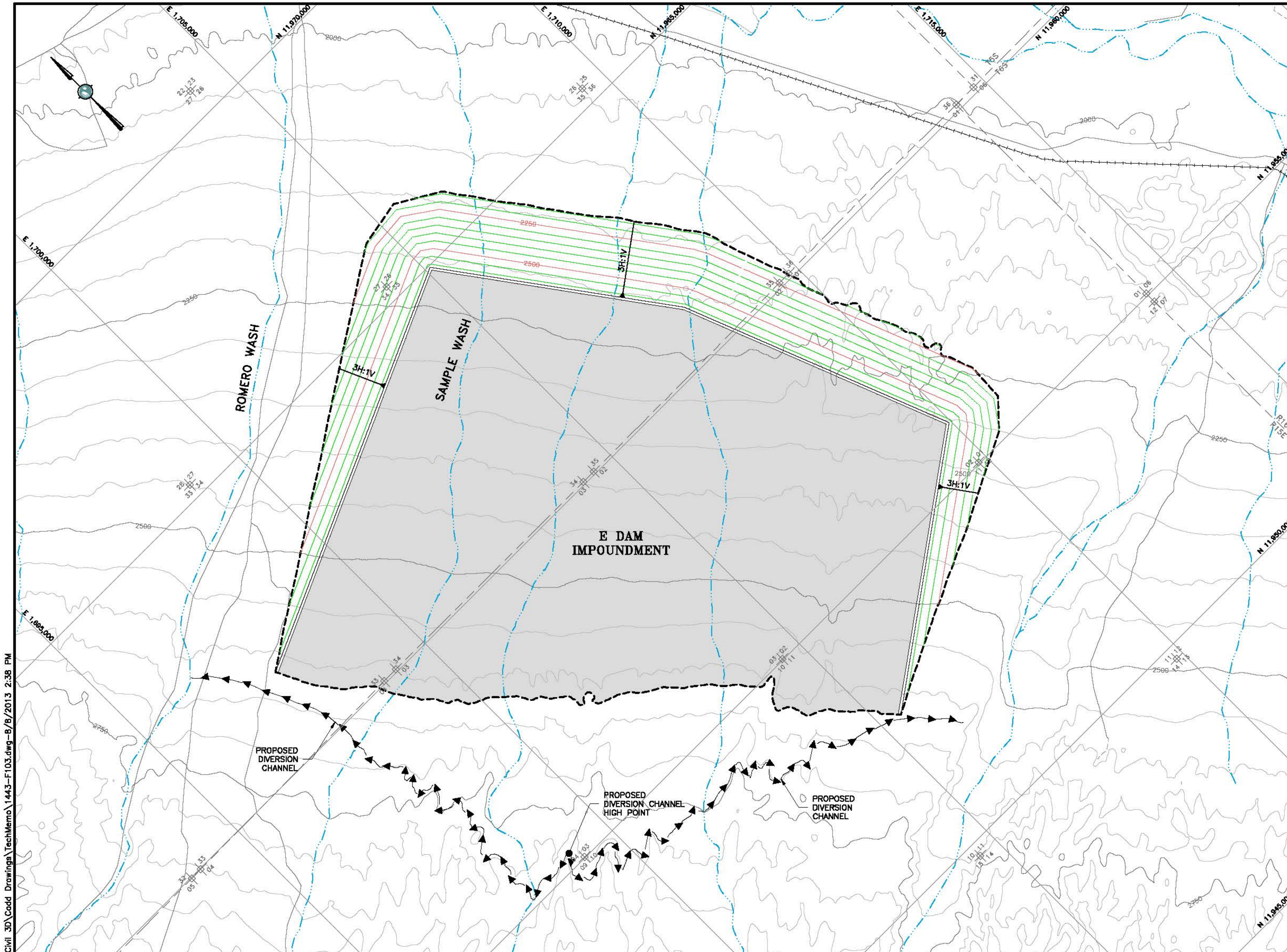


**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET (USGS)
- PROPOSED EMBANKMENT CONTOUR EL, FEET
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- PROPOSED DIVERSION CHANNEL
- TAILINGS AREA

**NOTE:**

1. DESIGN CRITERIA ARE AS STATED IN THE ALTERNATIVES ANALYSIS TECHNICAL MEMORANDUM.

REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

1000 0 1000 2000 FEET

E DAM

| CAPACITY (MILLION TONS) | EMBANKMENT VOLUME | | TAILINGS VOLUME | | TSF FOOTPRINT ($FT^2$) | CREST ELEVATION (FT) | EMBANKMENT HEIGHT (FT) | DIVERSION CHANNEL LENGTH (FT) |
|---|---|---|---|---|---|---|---|---|
| | $YD^3$ | TONS | $YD^3$ | TONS | | | | |
| ~750 | 129,102,785 | 174,288,760 | 514,568,014 | 576,573,460 | 102,913,431 | 2,620 | 493 | 22,557 |

CLIENT
ASARCO, LLC.

PROJECT
TAILINGS DAM ENGINEERING PROJECT

TITLE
E DAM TSF LAYOUT
FILL/CYCLONE METHOD

amec

| DESIGNED BY | TJK | CHECKED BY | TJK | DATE |
|---|---|---|---|---|
| DRAWN BY | TJK | APPROVED BY | LAH | 06/26/13 |

FILENAME 1443-F103 | FIGURE No. 2 | REV A

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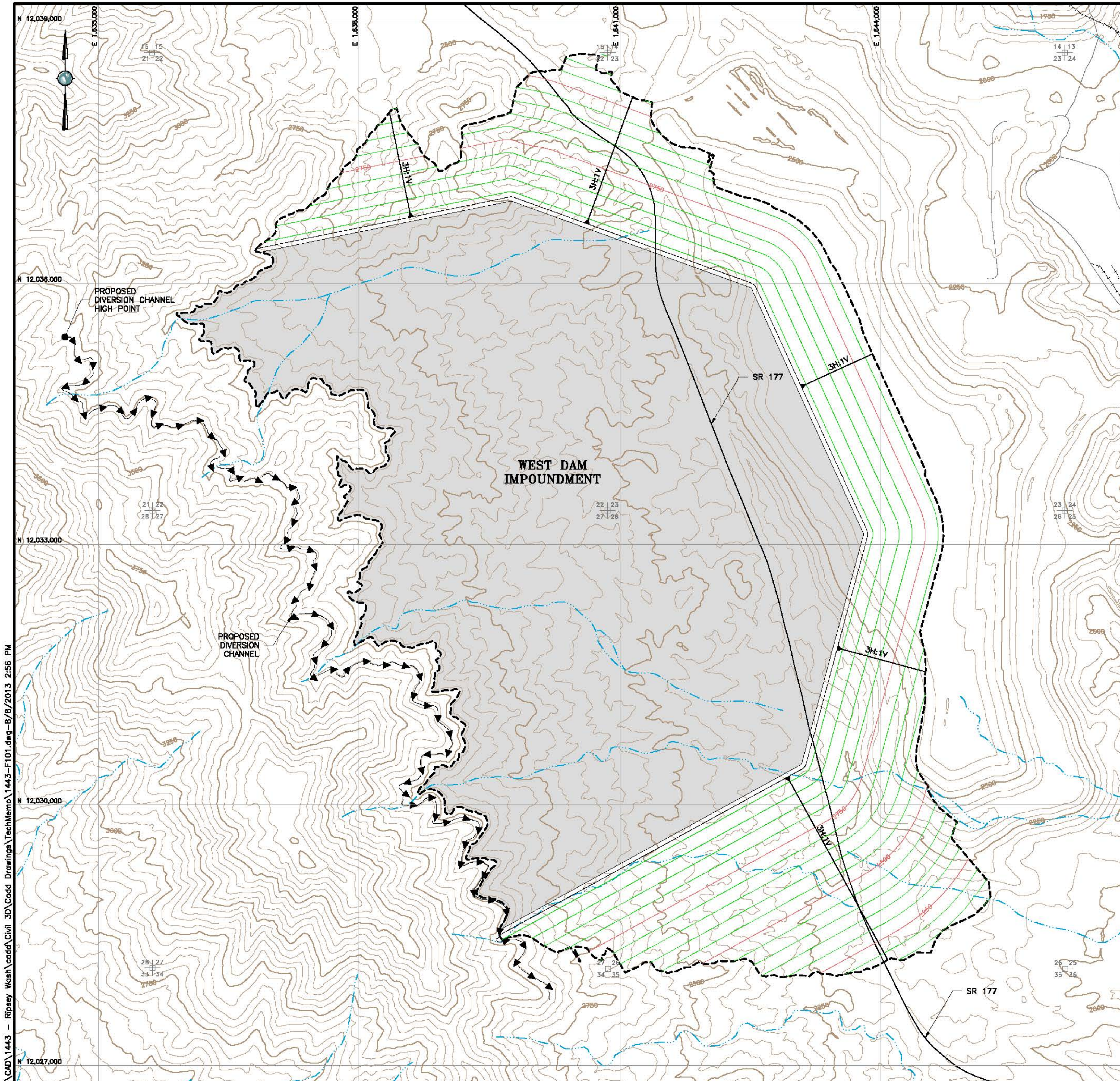


**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET
- PROPOSED EMBANKMENT CONTOUR EL, FEET
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- PROPOSED DIVERSION CHANNEL
- TAILINGS AREA

| WEST DAM | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CAPACITY (MILLION TONS) | EMBANKMENT VOLUME | | TAILINGS VOLUME | | TSF FOOTPRINT ($FT^2$) | CREST ELEVATION (FT) | EMBANKMENT HEIGHT (FT) | DIVERSION CHANNEL LENGTH (FT) |
| | $YD^3$ | TONS | $YD^3$ | TONS | | | | |
| ~750 | 177,499,211 | 239,623,935 | 462,260,181 | 517,962,533 | 58,060,325 | 2,970 | 870 | 17,051 |

**NOTE:**

1. DESIGN CRITERIA ARE AS STATED IN THE ALTERNATIVES ANALYSIS TECHNICAL MEMORANDUM.

REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

CLIENT: ASARCO, LLC.

PROJECT: TAILINGS DAM ENGINEERING PROJECT

TITLE: WEST DAM TSF LAYOUT FILL/CYCLONE METHOD

| DESIGNED BY | TJK | CHECKED BY | TJK | DATE |
|---|---|---|---|---|
| DRAWN BY | TJK | APPROVED BY | LAH | 06/26/13 |
| FILENAME: 1443-F101 | | FIGURE No.: 3 | | REV: A |

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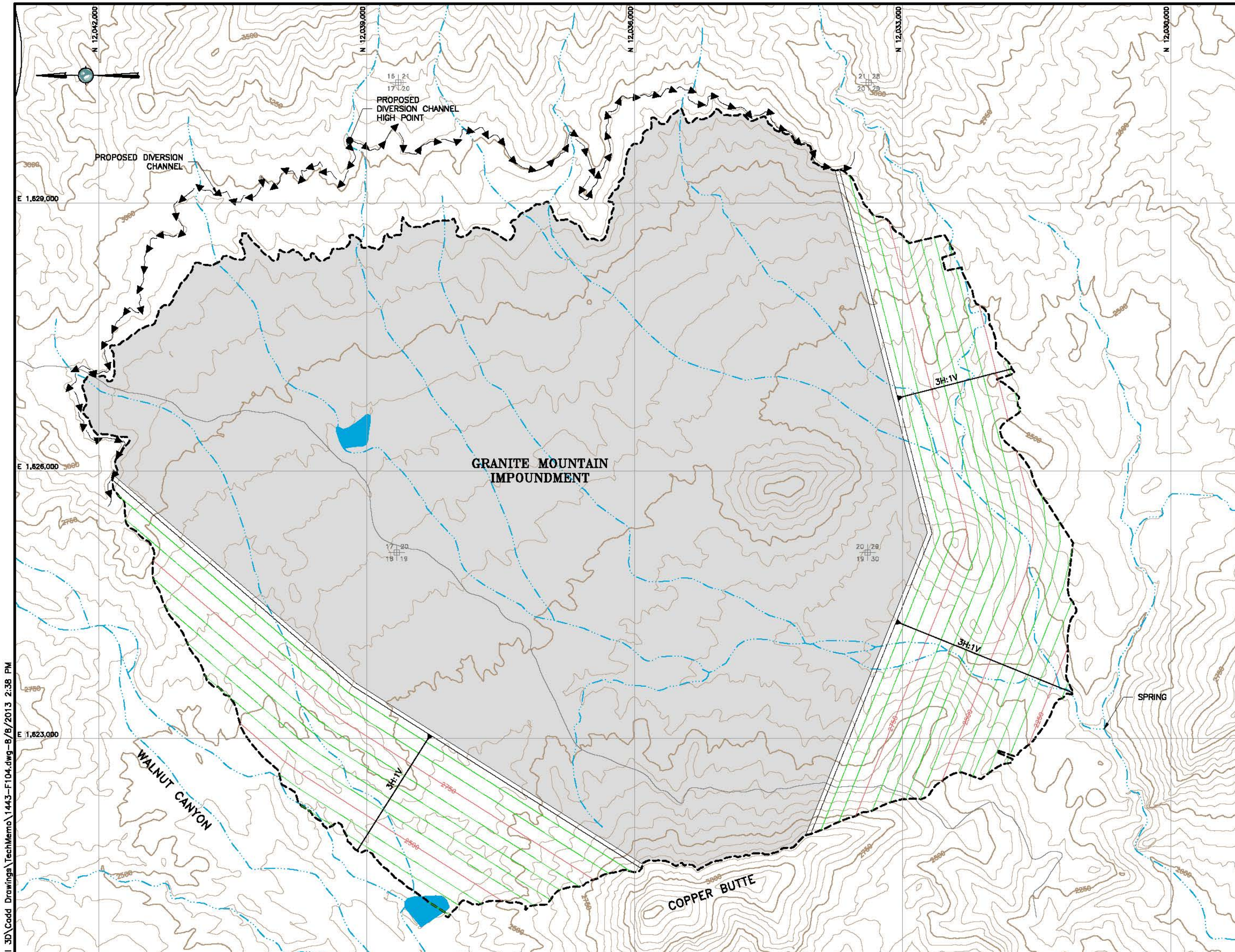


**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET
- PROPOSED EMBANKMENT CONTOUR EL, FEET
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- PROPOSED DIVERSION CHANNEL
- TAILINGS AREA

**NOTE:**

1. DESIGN CRITERIA ARE AS STATED IN THE ALTERNATIVES ANALYSIS TECHNICAL MEMORANDUM.

REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

600 0 600 1200 FEET

**GRANITE MOUNTAIN**

| CAPACITY (MILLION TONS) | EMBANKMENT VOLUME | | TAILINGS VOLUME | | TSF FOOTPRINT ($FT^2$) | CREST ELEVATION (FT) | EMBANKMENT HEIGHT (FT) | DIVERSION CHANNEL LENGTH (FT) |
|---|---|---|---|---|---|---|---|---|
| | $YD^3$ | TONS | $YD^3$ | TONS | | | | |
| ~750 | 135,533,947 | 182,970,829 | 504,736,663 | 565,557,431 | 68,294,764 | 2,880 | 710 | 17,744 |

CLIENT: ASARCO, LLC.

PROJECT: TAILINGS DAM ENGINEERING PROJECT

TITLE: GRANITE MOUNTAIN TSF LAYOUT FILL/CYCLONE METHOD

amec

| DESIGNED BY | TJK | CHECKED BY | TJF | DATE |
|---|---|---|---|---|
| DRAWN BY | TJK | APPROVED BY | LAH | 06/26/13 |
| FILENAME: 1443-F104 | | FIGURE No.: 4 | | REV: A |

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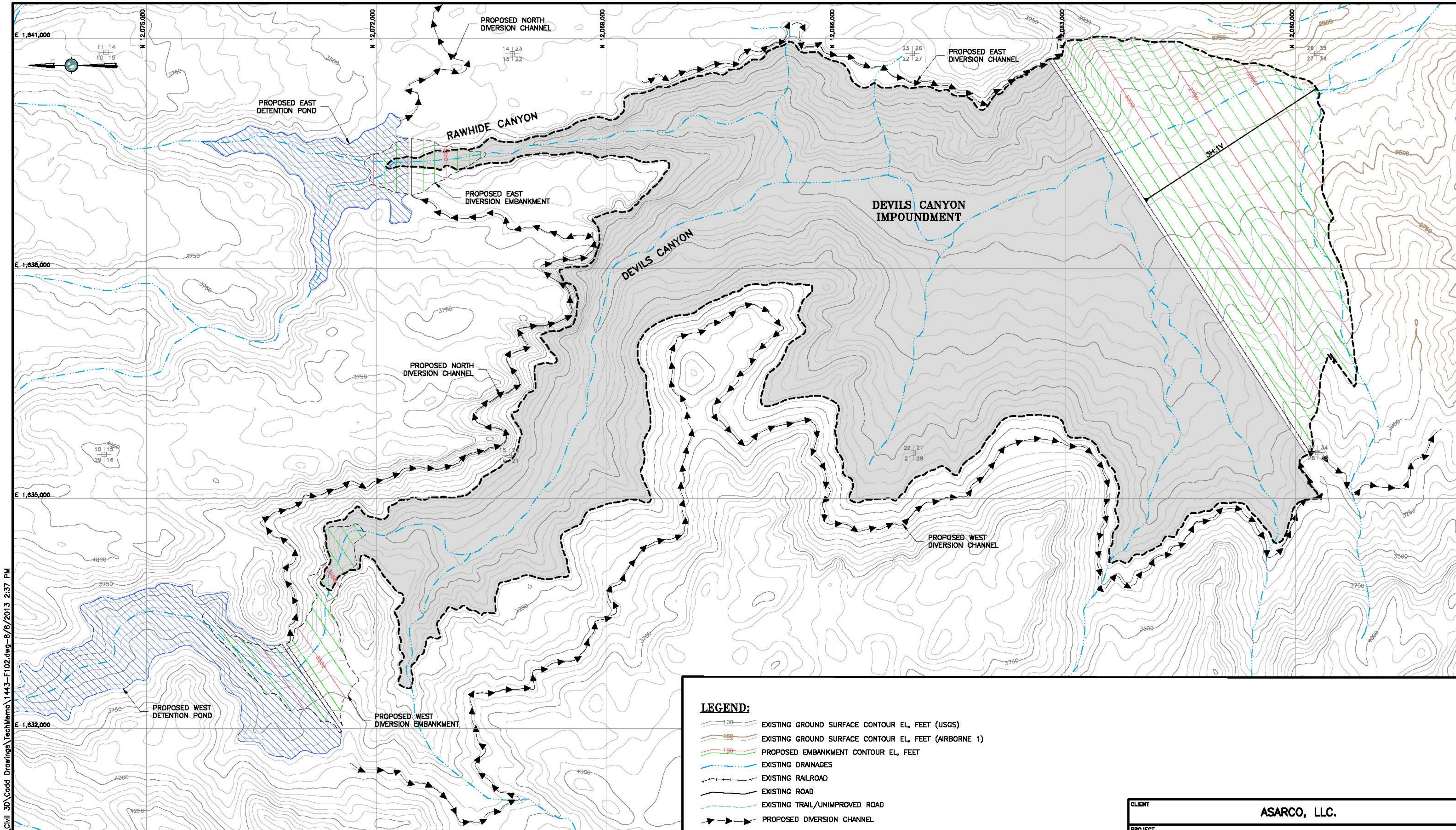


**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET (USGS)
- EXISTING GROUND SURFACE CONTOUR EL, FEET (AIRBORNE 1)
- PROPOSED EMBANKMENT CONTOUR EL, FEET
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- PROPOSED DIVERSION CHANNEL
- TAILINGS AREA

REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

600 0 600 1200 FEET

**NOTE:**

1. DESIGN CRITERIA ARE AS STATED IN THE ALTERNATIVES ANALYSIS TECHNICAL MEMORANDUM.

**DEVILS CANYON**

| CAPACITY (MILLION TONS) | EMBANKMENT VOLUME | | TAILINGS VOLUME | | TSF FOOTPRINT ($FT^2$) | CREST ELEVATION (FT) | EMBANKMENT HEIGHT (FT) | NORTH DIVERSION CHANNEL LENGTH (FT) | EAST DIVERSION CHANNEL LENGTH (FT) | WEST DIVERSION CHANNEL LENGTH (FT) |
|---|---|---|---|---|---|---|---|---|---|---|
| | $YD^3$ | TONS | $YD^3$ | TONS | | | | | | |
| ~750 | 117,702,768 | 158,898,737 | 542,472,271 | 607,840,180 | 53,246,082 | 3,180 | 890 | 15,724 | 7,009 | 31,084 |

CLIENT: ASARCO, LLC.

PROJECT: TAILINGS DAM ENGINEERING PROJECT

TITLE: DEVILS CANYON TSF LAYOUT FILL/CYCLONE METHOD

amec

| DESIGNED BY | DS | CHECKED BY | TJK | DATE |
|---|---|---|---|---|
| DRAWN BY | DS | APPROVED BY | LAH | 06/26/13 |

FILENAME: 1443-F102 | FIGURE No.: 5 | REV: A

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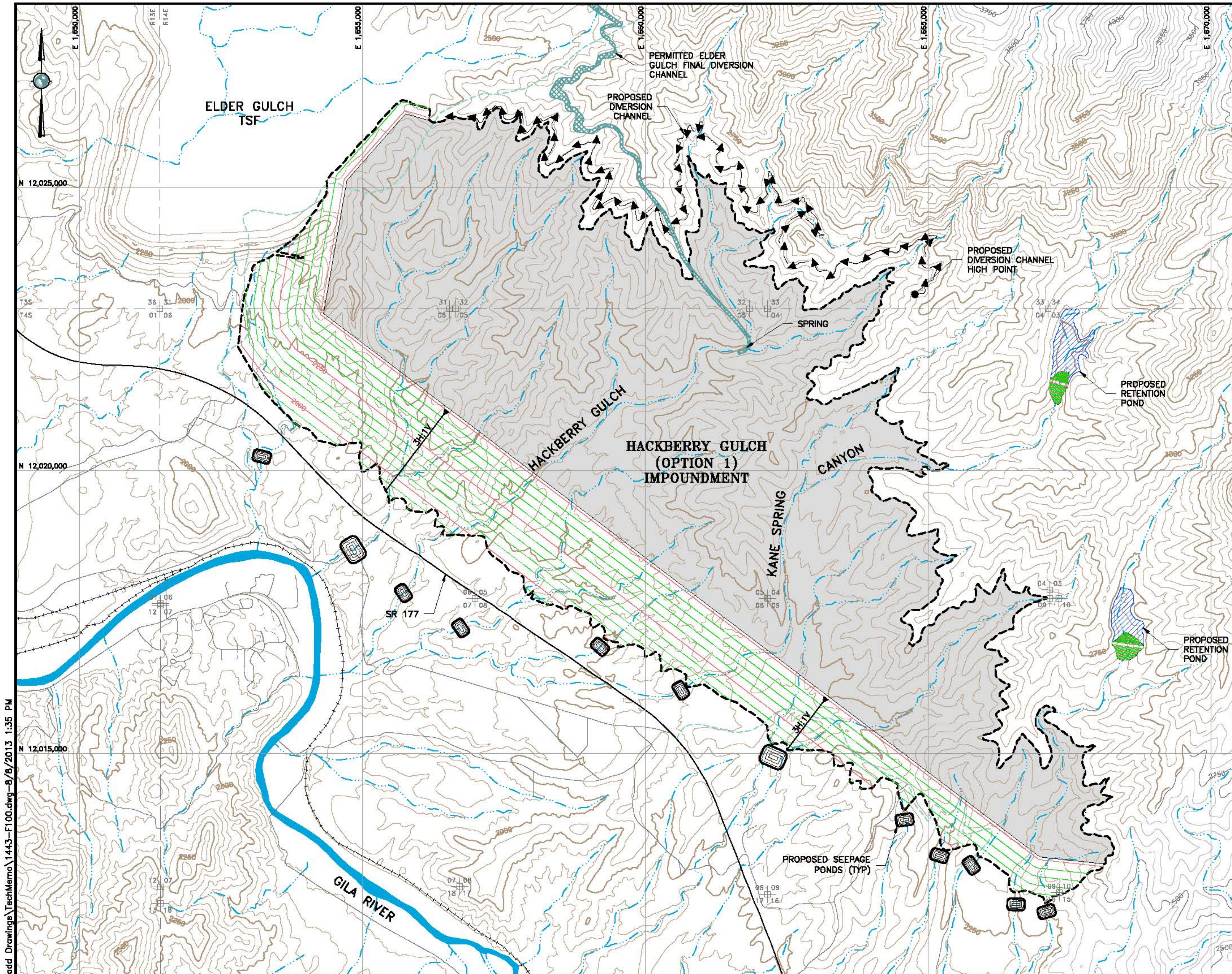


## LEGEND:

- EXISTING GROUND SURFACE CONTOUR EL. FEET (USGS)
- EXISTING GROUND SURFACE CONTOUR EL. FEET (AIRBORNE 1)
- PROPOSED EMBANKMENT CONTOUR EL. FEET
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- PROPOSED DIVERSION CHANNEL
- TAILINGS AREA

## NOTE:

1. DESIGN CRITERIA ARE AS STATED IN THE ALTERNATIVES ANALYSIS TECHNICAL MEMORANDUM.

REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

1000 0 1000 2000 FEET

**HACKBERRY GULCH**

| CAPACITY (MILLION TONS) | EMBANKMENT VOLUME | | TAILINGS VOLUME | | TSF FOOTPRINT ($FT^2$) | CREST ELEVATION (FT) | EMBANKMENT HEIGHT (FT) | DIVERSION CHANNEL LENGTH (FT) |
|---|---|---|---|---|---|---|---|---|
| | $YD^3$ | TONS | $YD^3$ | TONS | | | | |
| ~750 | 165,905,487 | 223,972,407 | 474,104,069 | 531,233,609 | 92,565,262 | 2,500 | 640 | 23,912 |

| | |
|---|---|
| CLIENT | ASARCO, LLC. |
| PROJECT | TAILINGS DAM ENGINEERING PROJECT |
| TITLE | HACKBERRY GULCH (OPTION 1) TSF LAYOUT FILL/CYCLONE METHOD |

| amec | DESIGNED BY | TJK | CHECKED BY | TJK | DATE |
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| | DRAWN BY | JAS | APPROVED BY | LAH | 06/26/13 |
| | FILENAME: 1443-F100 | | | FIGURE No.: 6 | REV: A |

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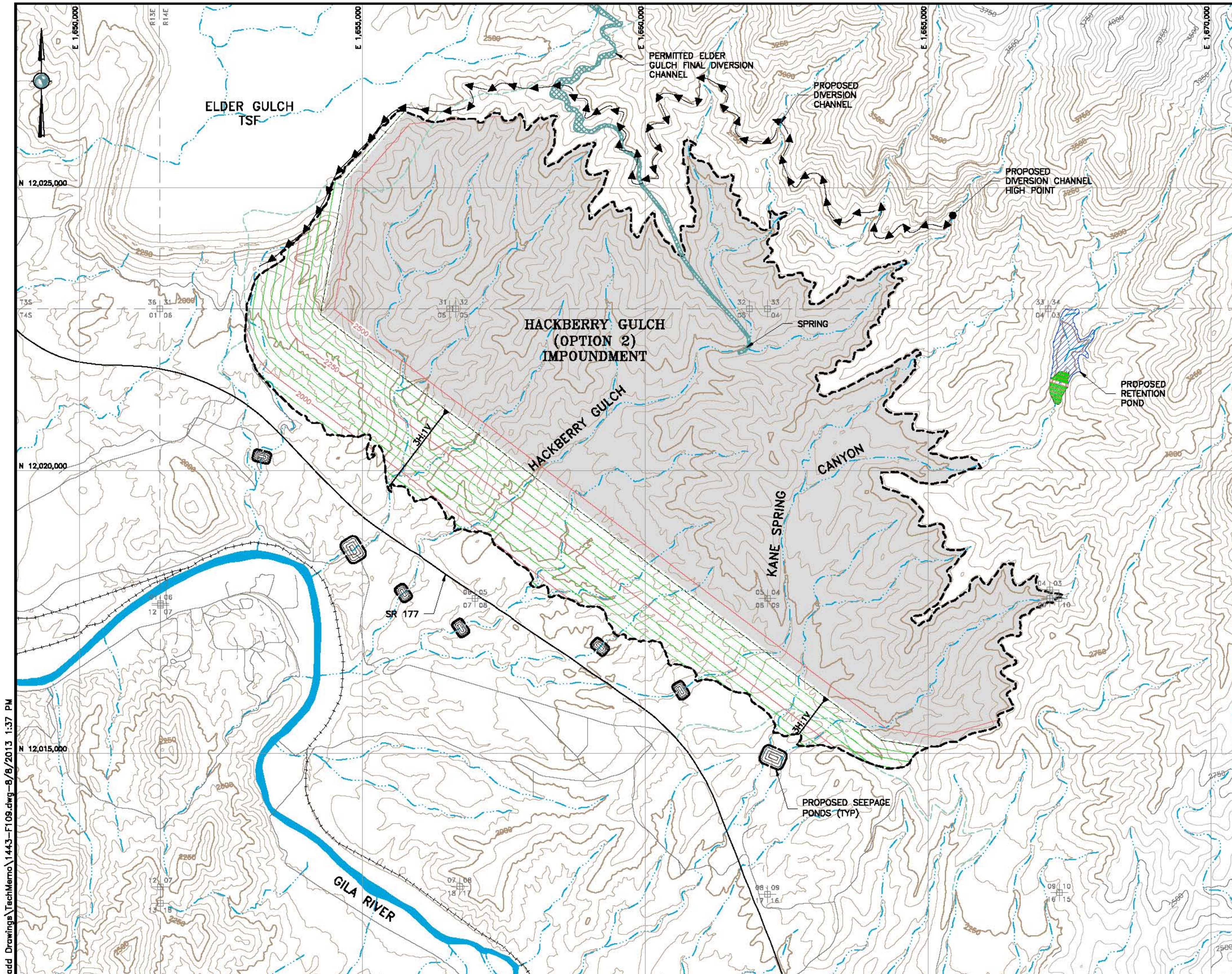


## LEGEND:

- EXISTING GROUND SURFACE CONTOUR EL. FEET (USGS)
- EXISTING GROUND SURFACE CONTOUR EL. FEET (AIRBORNE 1)
- PROPOSED EMBANKMENT CONTOUR EL. FEET
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- PROPOSED DIVERSION CHANNEL
- TAILINGS AREA

## NOTE:

1. DESIGN CRITERIA ARE AS STATED IN THE ALTERNATIVES ANALYSIS TECHNICAL MEMORANDUM.

REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

1000 0 1000 2000 FEET

**HACKBERRY GULCH**

| CAPACITY (MILLION TONS) | EMBANKMENT VOLUME | | TAILINGS VOLUME | | TSF FOOTPRINT ($FT^2$) | CREST ELEVATION (FT) | EMBANKMENT HEIGHT (FT) | DIVERSION CHANNEL LENGTH (FT) |
|---|---|---|---|---|---|---|---|---|
| | $YD^3$ | TONS | $YD^3$ | TONS | | | | |
| ~750 | 117,322,366 | 158,385,194 | 523,105,400 | 590,729,311 | 85,846,843 | 2,535 | 610 | 22,071 |

CLIENT: ASARCO, LLC.

PROJECT: TAILINGS DAM ENGINEERING PROJECT

TITLE: HACKBERRY GULCH TSF LAYOUT FILL/CYCLONE METHOD

amec

| DESIGNED BY | TJK | CHECKED BY | TJF | DATE |
|---|---|---|---|---|
| DRAWN BY | JAS | APPROVED BY | LAH | 06/27/13 |

FILENAME: 1443-F109 | FIGURE No.: 7 | REV: A

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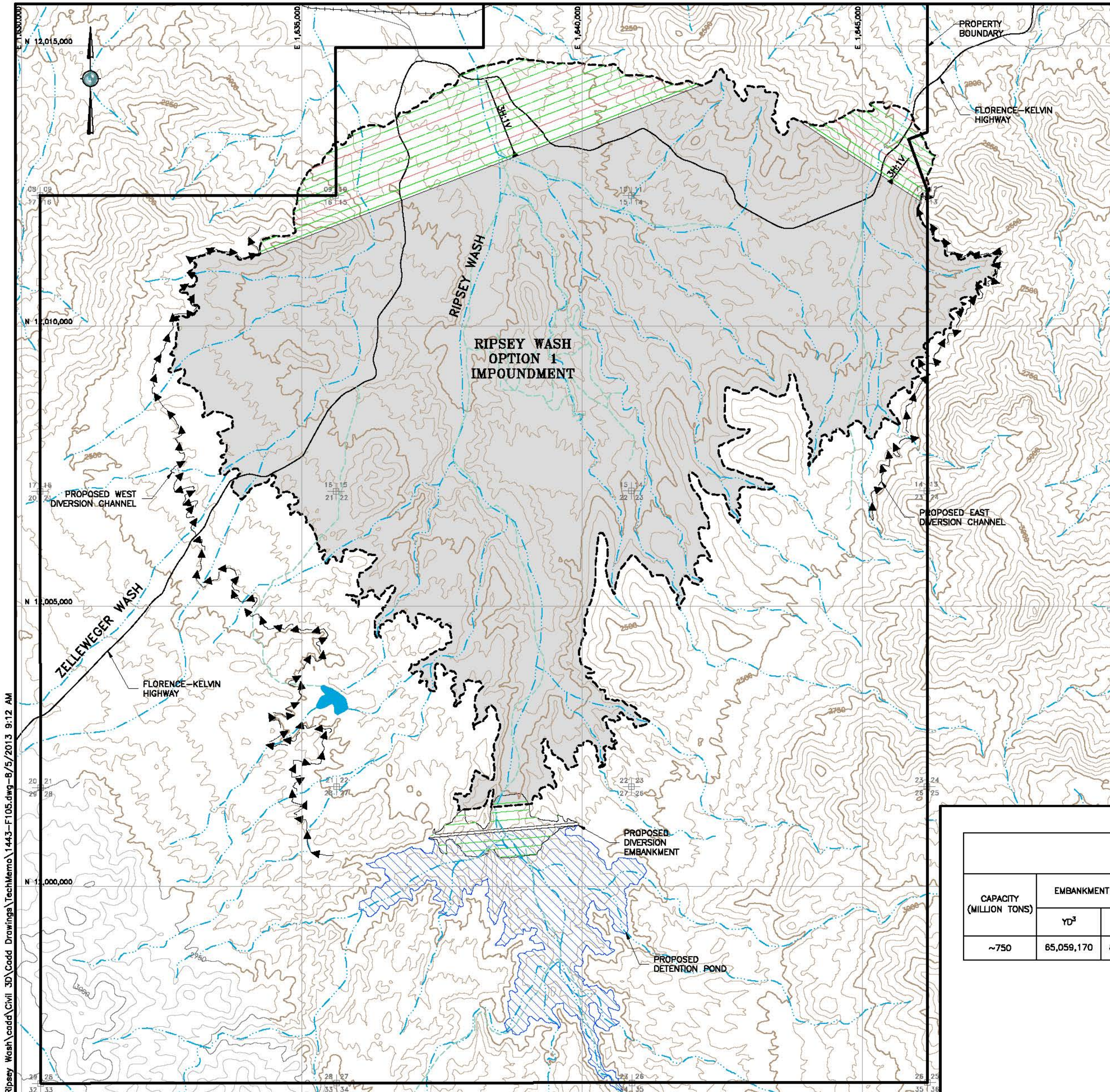


**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET (USGS)
- EXISTING GROUND SURFACE CONTOUR EL, FEET (AIRBORNE 1)
- PROPOSED EMBANKMENT CONTOUR EL, FEET
- PROPERTY BOUNDARY
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- PROPOSED DIVERSION CHANNEL
- TAILINGS AREA

**NOTE:**

1. DESIGN CRITERIA ARE AS STATED IN THE ALTERNATIVES ANALYSIS TECHNICAL MEMORANDUM.

RIPSEY WASH OPTION 1
(INCLUDING ZELLEWEGER WASH & BLM ENCROACHMENT)

| CAPACITY (MILLION TONS) | EMBANKMENT VOLUME | | SECONDARY EMBANKMENT VOLUME | | TAILINGS VOLUME | | TSF FOOTPRINT ($FT^2$) | CREST ELEVATION (FT) | EMBANKMENT HEIGHT (FT) | SECONDARY EMBANKMENT HEIGHT (FT) | EAST DIVERSION CHANNEL LENGTH (FT) | WEST DIVERSION CHANNEL LENGTH (FT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $YD^3$ | TONS | $YD^3$ | TONS | $YD^3$ | TONS | | | | | | |
| ~750 | 65,059,170 | 87,829,880 | 6,879,015 | 9,286,670 | 600,077,912 | 672,387,300 | 102,619,410 | 2,350 | 560 | 390 | 10,316 | 24,227 |

REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

CLIENT: ASARCO, LLC.

PROJECT: TAILINGS DAM ENGINEERING PROJECT

TITLE: RIPSEY WASH OPTION 1 (INCLUDING ZELLEWEGER GULCH & BLM ENCROACHMENT) TSF LAYOUT FILL/CYCLONE METHOD

| DESIGNED BY | TJK | CHECKED BY | TJF | DATE |
|---|---|---|---|---|
| DRAWN BY | TJK | APPROVED BY | LAH | 06/27/13 |
| FILENAME | 1443-F105 | FIGURE No. | 8 | REV A |

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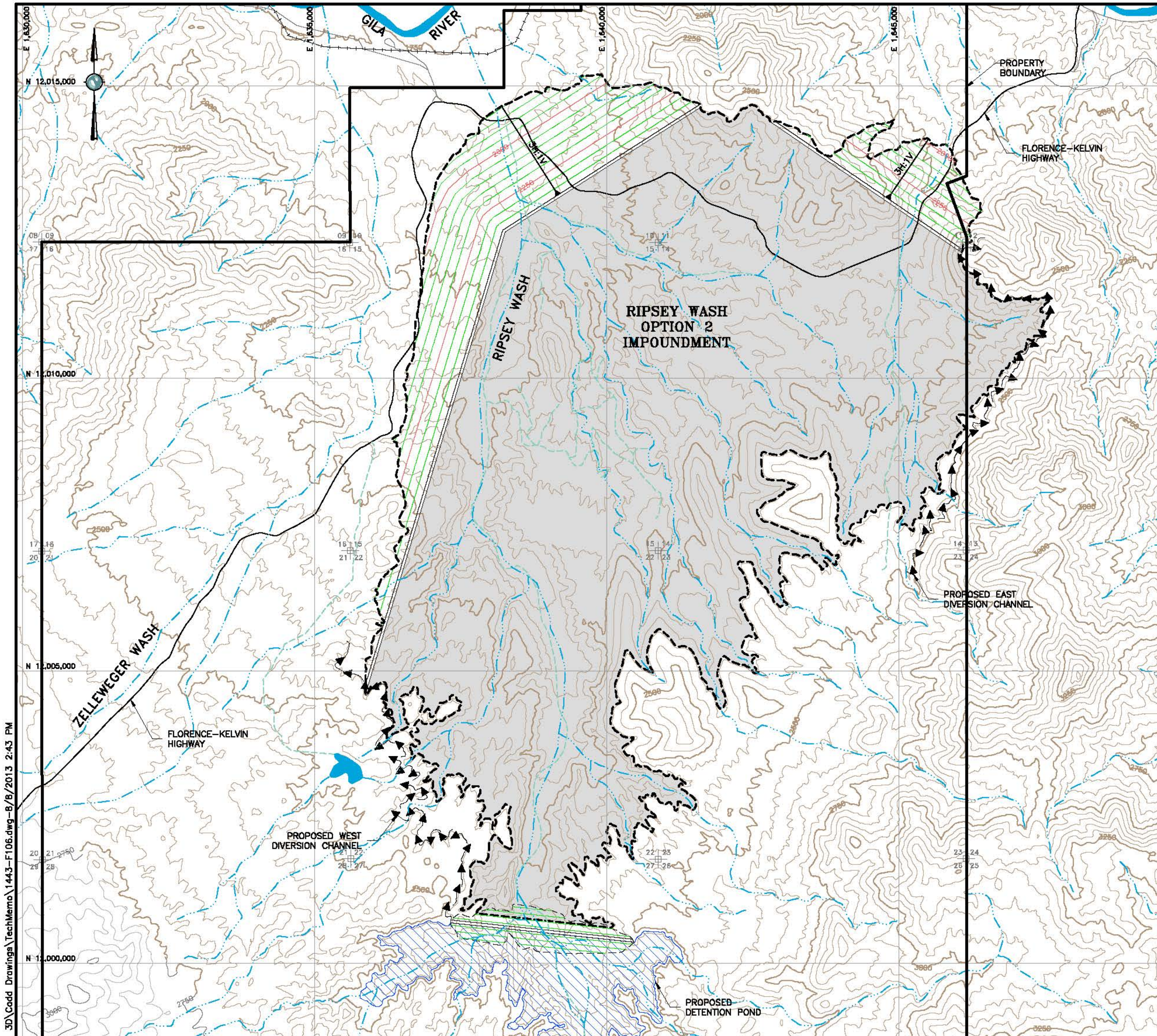


**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET (USGS)
- EXISTING GROUND SURFACE CONTOUR EL, FEET (AIRBORNE 1)
- PROPOSED EMBANKMENT CONTOUR EL, FEET
- PROPERTY BOUNDARY
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- PROPOSED DIVERSION CHANNEL
- TAILINGS AREA

**NOTE:**

1. DESIGN CRITERIA ARE AS STATED IN THE ALTERNATIVES ANALYSIS TECHNICAL MEMORANDUM.

REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

1000 0 1000 2000 FEET

**RIPSEY WASH OPTION 2 (INCLUDING BLM ENCROACHMENT)**

| CAPACITY (MILLION TONS) | EMBANKMENT VOLUME | | SECONDARY EMBANKMENT VOLUME | | TAILINGS VOLUME | | TSF FOOTPRINT ($FT^2$) | CREST ELEVATION (FT) | EMBANKMENT HEIGHT (FT) | SECONDARY EMBANKMENT HEIGHT (FT) | EAST DIVERSION CHANNEL LENGTH (FT) | WEST DIVERSION CHANNEL LENGTH (FT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $YD^3$ | TONS | $YD^3$ | TONS | $YD^3$ | TONS | | | | | | |
| ~750 | 83,086,728 | 112,167,083 | 10,256,374 | 13,846,105 | 594,130,325 | 665,723,029 | 93,210,490 | 2,390 | 600 | 440 | 9,668 | 10,785 |

CLIENT: ASARCO, LLC.

PROJECT: TAILINGS DAM ENGINEERING PROJECT

TITLE: RIPSEY WASH OPTION 2 (INCLUDING BLM ENCROACHMENT) TSF LAYOUT FILL/CYCLONE METHOD

amec

| DESIGNED BY | TJK | CHECKED BY | TJF | DATE |
|---|---|---|---|---|
| DRAWN BY | TJK | APPROVED BY | LAH | 06/27/13 |

| FILENAME | FIGURE No. | REV |
|---|---|---|
| 1443–F106 | 9 | A |

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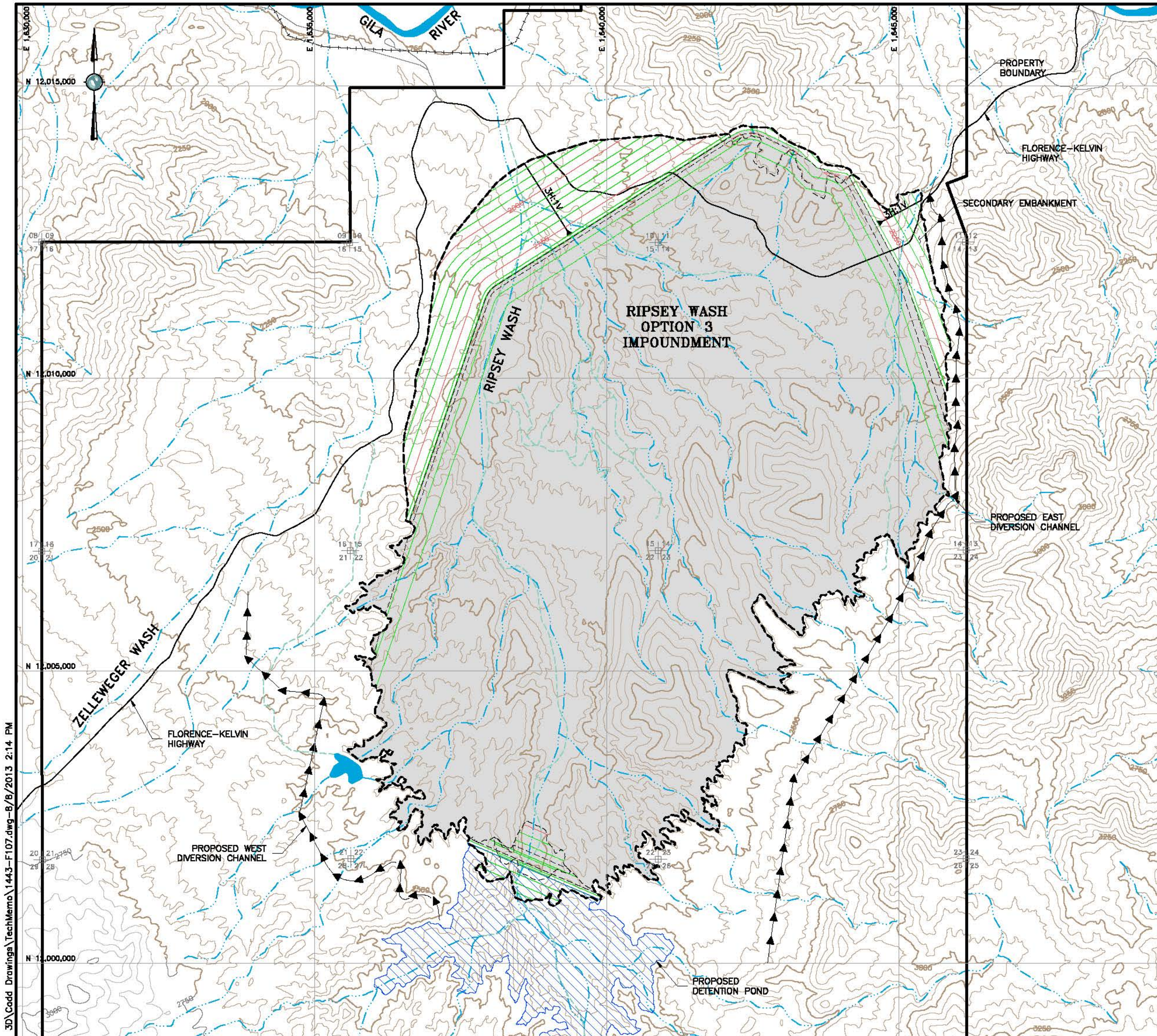


**LEGEND:**

- EXISTING GROUND SURFACE CONTOUR EL, FEET (USGS)
- EXISTING GROUND SURFACE CONTOUR EL, FEET (AIRBORNE 1)
- PROPOSED EMBANKMENT CONTOUR EL, FEET
- PROPERTY BOUNDARY
- EXISTING DRAINAGES
- EXISTING RAILROAD
- EXISTING ROAD
- EXISTING TRAIL/UNIMPROVED ROAD
- PROPOSED DIVERSION CHANNEL
- TAILINGS AREA

**NOTE:**

1. DESIGN CRITERIA ARE AS STATED IN THE ALTERNATIVE ANALYSIS TECHNICAL MEMORANDUM.

REFERENCE:
TOPOGRAPHIC MAPPING AND EXISTING FEATURE DATA PROVIDED BY AIRBORNE 1, INC.; COORDINATE SYSTEM IS IN UTM ZONE 12 NAD 83 DATUM FOR HORIZONTAL AND NAVD 88 DATUM FOR VERTICAL.

1000 0 1000 2000 FEET

## RIPSEY WASH OPTION 3

| CAPACITY (MILLION TONS) | EMBANKMENT VOLUME | | SECONDARY EMBANKMENT VOLUME | | TAILINGS VOLUME | | TSF FOOTPRINT ($FT^2$) | CREST ELEVATION (FT) | EMBANKMENT HEIGHT (FT) | SECONDARY EMBANKMENT HEIGHT (FT) | EAST DIVERSION CHANNEL LENGTH (FT) | WEST DIVERSION CHANNEL LENGTH (FT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $YD^3$ | TONS | $YD^3$ | TONS | $YD^3$ | TONS | | | | | | |
| ~751 | 42,686,100 | 58,538,662 | 6,423,850 | 8,947,585 | 603,139,820 | 683,679,798 | 92,756,779 | 2,440 | 625 | 440 | 7,272 | 8,693 |

CLIENT: ASARCO, LLC.

PROJECT: TAILINGS DAM ENGINEERING PROJECT

TITLE: RIPSEY WASH OPTION 3 TSF LAYOUT FILL/CYCLONE METHOD

| DESIGNED BY | JAS | CHECKED BY | TJF | DATE |
|---|---|---|---|---|
| DRAWN BY | JAS | APPROVED BY | LAH | 06/27/13 |

FILENAME: 1443–F107 | FIGURE No.: 10 | REV: B

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# APPENDIX B

**Evaluation of Dry Stack Tailings Disposal Method ASARCO Ray Mine Complex (Technical Memorandum Prepared by AMEC Environment & Infrastructure, Inc.)**

amec

**To:** Chris Pfahl, PE
Senior Mine Engineer
ASARCO LLC
Ray Operations

**Project No.:** 74-2014-4300

**From:** Tony Freiman, PE

**Reviewed by:** Lawrence A. Hansen, PhD, PE

**Date:** January 7, 2014

Registered Professional Engineer (Civil) Certificate No. 23982 TONY J. FREIMAN Date Signed 1/7/2014 ARIZONA, U.S.A. Expires 12/31/14

Registered Professional Engineer (Civil) Certificate No. 13872 LAWRENCE A. HANSEN Date Signed 1/7/14 ARIZONA, U.S.A. Expires 03/31/2015

**Subject:** Technical Memorandum
Evaluation of Dry Stack
Tailing Disposal Method
ASARCO Ray Mine Complex

AMEC Environment & Infrastructure, Inc. (AMEC) was tasked by ASARCO LLC with the evaluation of using dry stack tailings deposition techniques for the planned new tailings storage facility (TSF) at the ASARCO Ray Complex. Our recommendation is based on a review of mining engineering literature, AMEC's experience with dry stack tailing facility design and operation, and an understanding of the existing Ray Concentrator operations.

## 1.0 INTRODUCTION

An evaluation was performed to determine the feasibility of using the dry stack tailings disposal method for the planned new TSF at the ASARCO Ray Complex. The evaluation is based on a review of the state of the practice in the mining industry, and especially within the copper mining segment of that industry. Most of the world's mineral milling and concentrating operations use conventional milling processes. In a conventional milling process, after production of the concentrate, the resulting tailings are passed through thickeners where the pulp density (weight of solids per unit weight of slurry) is typically between 40 to 50 percent. The tailings slurry produced by this traditional method requires special engineering considerations in the design of slurry transport. Notwithstanding, the viscosity of tailings traditionally produced in copper mining, the tailings still behave as a liquid and impoundment design, transport and management are based on that behavior. The tailings impoundment is designed and constructed to manage both the water used to transport the tailings and the water reporting to the impoundment as a result of precipitation.

There has been an impetus to develop alternative tailings disposal methods that reduce the amount of water required for the tailings disposal process. With advances in dewatering technologies, such as vacuum and pressure filters, there is the potential, on some projects, for placing tailings in an unsaturated state rather than as slurry. Filtered tailings would be placed by conveyor or truck, spread and compacted to form a dense and stable tailings stack (often termed a "dry stack").

AMEC Environment & Infrastructure, Inc.
4600 East Washington Street, Suite 600
Phoenix, Arizona 85034-1917
Tel (602) 733-6000
Fax (602) 733-6100

## 2.0 SELECTION CRITERIA FOR THE DRY STACK TAILING DISPOSAL METHOD

The most applicable projects for incorporating a dry stack tailings facility are those that have one or more of the following attributes:

- There is insufficient water available to operate a conventional tailings process.
- The recovery of fluids from the tailings during the filtration process enhances economic recovery of the mineral resource.
- The site is located in an area of very high seismicity where the design of conventional tailing impoundments is not feasible.
- The site is located in a cold region that would create water handling issues.
- The TSF site has topographic limitations that would exclude conventional dam construction or the dam embankment volume to tailings storage ratio is unfavorable.
- The operating and closure costs associated with a conventional tailings facility are in excess of the increased costs associated with tailings filtration and dry stack placement.
- The TSF is located in an area where material for use at the TSF starter dam or for embankment raises is not present or would be expensive to produce.
- The mill is in very close proximity to the potential dry stack disposal location, given the difficulty of transporting dry tailings.

The efficacy of dry tailings disposal methods is also affected by the characteristics of the ore body (high gypsum or clayey ores can make it impossible to cost effectively filter the concentrator byproduct), and requirements for extensive capital expenditures and substantially increased energy costs can make implementation of dry tailings disposal methods cost prohibitive.

## 3.0 APPLICABILITY OF THE DRY STACK METHOD TO ASARCO RAY COMPLEX TSF PROJECT

Only a small number of mines worldwide have implemented or proposed the practice of dewatering tailings using filters so tailings can then be handled as a solid material, and the majority of those are precious metal mines. There are no operating facilities in Arizona that currently utilize this practice. Moreover, the dry stack technology to date has not been proven to be viable at sites producing the peak volume of tailings that the Ray Mine is designed to generate 45,000 tons per day (tpd). The largest production volume currently being deposited by dry stack is approximately 17,600 tpd, at the La Copia gold facility, located around 12,500 feet above sea level in the Atacama Desert, a very arid area of northern Chile. At that facility the tailings are being filtered to recover cyanide from leach tailings.

The proposed Rosemont Copper Project in Pima County, Arizona has proposed to use the dry stack tailings disposal process at a site where the peak production rate exceeds that at Ray. Rosemont, however, will be a new facility with the flexibility to construct the concentrator adjacent to the tailings facility, which avoids many of the challenges discussed below that would exist in trying to implement this technology at the Ray Mine.

The other higher volume facilities at which dry stack technology has been implemented or proposed were also new facilities where the concentrator and disposal sites were in close proximity. One such project was the Spinifex Ridge molybdenum project in Australia, with a planned mill throughput of 154,000 tpd. This project was suspended in 2008 and put on an indefinite hold due to economic factors.

A review of the mining engineering literature also revealed no case where dry stack technology had been proposed for a conventional mill such as the Ray Concentrator, with the additional filtration provided at a distant tailings placement site.

Dry stack tailings technology is considerably more expensive per ton of tailings stored than conventional slurry systems (Davies, 2011)[i]. AMEC evaluated the planned ASARCO TSF project using the previously presented listing of attributes which would make the TSF a candidate for the dry stack disposal.

Attribute 1 - There is insufficient water available to operate a conventional tailings process.

> ASARCO has significant decreed water rights available to support a conventional tailings process, and such a process has been utilized at Ray for the last 20 years. The proposed new TSF is not dependent on an increase in milling capacity or water consumption at the Ray Mine. A water supply infrastructure and water management system have been developed to support the milling operations. This factor is not applicable to the Ray TSF project.

Attribute 2 – The recovery of fluids from the tailings during the filtration process enhances economic recovery of the mineral resource.

> There would be no economic enhancement to using tailings filtration in the copper floatation milling process. This factor is usually only applicable for tailings generated from a leaching process, where an incremental increase in the pregnant leach solutions could be economically beneficial.

Attribute 3 – The site is located in an area of very high seismicity where the design of conventional tailings impoundments is not feasible.

> The Ray TSF locations being evaluated are not located within a seismically active area. Seismic hazard assessment studies and stability evaluations of the planned tailing embankment geometries at the applicant's preferred site have been conducted that demonstrate that the use of conventional tailings impoundments is appropriate for the site.

Attribute 4 – The site is located in a cold region that would create water handling issues.

> This is not applicable to the Ray TSF project.

Attribute 5 – The TSF site has topographic limitations that would exclude conventional dam construction or result in excessively high dam embankment volume requirements.

> The sites analyzed by Asarco for a new TSF possess different embankment to storage volume ratios (with the preferred Ripsey Wash location generally having the most

favorable ratios), but all are considered suitable for conventional tailings dam construction.

Attribute 6 – The operating and closure costs are in excess of the increased costs associated with tailings filtration and dry stack placement.

The Ray Concentrator is an existing facility that was designed and is operating using conventional milling and tailings slurry transportation and impoundments. The costs to convert the operations for the use of tailing filtration would be prohibitive to the project. The developed Ray Mine TSF impoundment configurations were designed to transition from centerline construction raises to an upstream raise technique to allow reclamation activities to commence during the operational life of the facility.

Attribute 7 – The TSF is located in an area where material for use at the TSF starter dam or for embankment raises are not present or would be expensive to produce.

The preferred Ripsey Wash TSF impoundment basin footprint can be developed to supply the embankment material and drain blanket materials. The volumes required for raising the embankment over the operational life of the TSF can be generated by the use of cycloning of the tailings material and using the generated sand fraction to construct the TSF embankments. This factor may be present to some degree at the other locations considered for the TSF. The Hackberry Gulch alternatives, which require higher embankment borrow volumes than the preferred alternative, are capable of being developed for the required borrow volumes.

Attribute 8 - The mill is in very close proximity to the potential dry stack disposal location, given the difficulty of transporting dry tailings.

Given the distance from the Ray concentrator to any of the potential TSF locations, and the difficulty of transporting the necessary volume of dry material over those distances via pipeline (or by any other means, such as truck or conveyor), implementing a dry stack tailings approach at Ray would require transporting the tailings via pipeline as conventional slurry to the TSF, followed by filtering the tailings at the TSF site at an entirely new plant that would be constructed adjacent to the TSF. This filtration would be followed by placement of the tailings by mechanical method (likely involving use of conveyors and heavy equipment). The water recovered in the filtration process would have to be stored in a new water retention structure prior to being pumped back to the mine complex for re-use. These considerations would necessitate construction of significant additional facilities adjacent to the TSF, and would significantly increase the cost of the project (both initial construction costs and future operating costs, given the higher energy usage needed to provide further filtration at the TSF and then dispose of the resulting tailings by mechanical method). At some of the sites considered, site topography make the placement of these sorts of ancillary facilities adjacent to a new TSF impractical.

Few if any of the attributes that make a project appropriate for implementation of dry stack tailings are present at the Ray Mine.

## 4.0 CONCLUSIONS OF DRY STACK APPLICABILITY EVALUATION

Generally, dry stack tailings require a somewhat smaller footprint for tailings storage than would a traditional slurry tailings facility (Davies, 2011). However, as described above, a dry stack TSF for the ASARCO Ray Complex TSF project would necessitate significant additional infrastructure for the filtration process that would not be required for a conventional TSF, thereby increasing the overall footprint of a dry stack TSF.

While a smaller supernatant pond would result from dry stack technology, the potential seepage would be controlled in the same fashion as if conventional tailings slurry containment were implemented, with geologic and engineering controls. Extensive land use would be required to keep the retention dikes to a minimal size and would result in embankment construction similar to that envisioned for conventional slurry containment. Currently, the existing TSF supernatant pond at Elder Gulch is used for the mine water balance and stores water for mill water make-up. Eliminating this storage for a new TSF would require constructing a separate water retention structure to hold water for use in the mill system.

A dry stack TSF is not being proposed for the ASARCO Ray Complex TSF for the following primary reasons:

1. Filtered tailing technologies are unproven for a facility with a production rate as high as 45,000 tpd.

2. Substantial infrastructure at the TSF (filter plant, conveyor system, heavy equipment, water storage facility) is required to accommodate dry stack tailings production. This would significantly increase the costs of constructing and operating a dry stack TSF in comparison to the costs of constructing and operating a conventional TSF. No existing or proposed dry stack facilities involve construction of filtering systems at a TSF site located a significant distance away from a traditional concentrator, as would be required at Ray.

3. Although the area needed for tailings placement at a dry stack TSF would be smaller than at a conventional TSF, a dry stack TSF would require construction of significant additional infrastructure adjacent to the TSF that would not be required at a conventional TSF. This additional infrastructure would increase the overall footprint of the dry stack TSF.

On the basis of the results of this evaluation, it was determined that the use of dry stack tailings disposal methods is not practical or feasible for the ASARCO Ray TSF. Therefore all of the developed TSF alternatives for the project consider the use of conventional tailings disposal processes.

G:\Geotechnical\2011 Projects\74-2014-4300 ASARCO Ripsey Wash TSF\AMEC Alternatives Analyses Memo\Dry Stack Tailings Memo\Current Version\Dry Stack Tailings - Technical Memorandum_ver4_format.docx

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[i] Davies, M., 2011, Filtered Dry Stack Tailings – The Fundamentals, Proceedings Tailings and Mine Waste 2011, Vancouver, BC.

# APPENDIX C

**Evaluation of
Dry Stack Tailings
Density, Tailings
Storage Project,
Ray Mine
(Technical Memorandum
Prepared by AMEC Foster
Wheeler Environment &
Infrastructure, Inc.)**

April 14, 2015

# Memo

**To:** Asarco, LLC

**Attn:** Duane Yantorno
Environmental Manager

**From:** Tony J Freiman, PE

**Ref:** 7420144300

**Re:** Evaluation of Dry Stack Tailings Density
Tailings Storage Project
Ray Mine

A study was conducted to evaluate the potential gain in tailings density through the use of filtered dry stack tailings deposition for the Asarco Ray Mine Tailings Storage project.

The processing of copper ore in a milling operation results in the generation of tailings that must be disposed in a safe and efficient manner. The milling of ore results in tailings slurry at a range of solids contents of 25 to 45 percent. Conventional thickeners are used to increase the solids contents to the range of 45 to 60 percent where the material is pumped to tailings impoundments in slurry form using centrifugal pumps and stored within tailings impoundments formed by embankments. The majority of the world's current active and planned new mines use this conventional method for tailings management.

Deep bed compression thickeners can be used to increase the solids content of mill tailings. The solids content can be increased to the 65 to 75 percent range, resulting in a non-segregating tailings paste. Positive displacement pumps are typically required to transport the paste material. The material is stored behind embankments, similar to conventionally placed tailing impoundments.

Filtration can be used to remove water from tailings to result in a solids content in the 80 to 90 percent solids range. The filters use pressure or a vacuum and can be in a drum, stacked plate or belt configuration. The resulting wet cake tailings cannot be pumped. Haulage equipment or conveyors will be needed to stack the material.

In general, decreasing water content results in higher operating expense for the transporting and placement of mill tailings.

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A comparison was made to evaluate the density of the tailings stored in a conventional tailings storage facility to a filter dried and stacked tailings storage facility. This analysis was conducted by comparing the resulting void ratio of tailings using these two techniques. The volumetric ratio of the volume of voids divided by the volume of solids is defined as the void ratio. The void ratio is expressed as a decimal value.

The void ratio (e) is related to the dry density of the tailings by the following relationship:

$$\gamma_{dry} = \frac{Gs}{1+e}\gamma_w$$

Where: $\gamma_{dry}$ = Tailings Dry Density, pounds per cubic foot
$\gamma_w$ = Unit Density of Water, pounds per cubic foot
$Gs$ = Specific Gravity of Tailings, dimensionless

The specific gravity of tailings from the Ray Concentrator was tested at 2.82. The unit weight of water is 62.4 pounds per cubic foot.

The results of geotechnical drilling, sampling and testing of the tailings at the currently operating Asarco Ray Mine Elder Gulch tailings storage facility were reviewed. This facility is operated using conventional whole tailings slurry deposition. The average dry density in the upper 50 feet of the impoundment is 100.8 pound per cubic foot. The void ratio is calculated to be 0.75.

One dimensional consolidation tests can be used, if drained conditions develop in the tailings storage facility, to evaluate the decrease in the tailings void ratio with the increasing tailings storage depth. A relationship between the applied effective vertical stress and the decrease in the void ratio of conventionally placed tailings is defined by the Compression Index ($C_c$). From a series of ten consolidation tests of the Ray Mine Elder Gulch tailings, the average Compression Index value was 0.183.

The compression index is related to void ratio and the effective overburden pressure by the following relationship.

$$C_c = \frac{e_{1-}e_2}{\log \quad \sigma_2' - \log \quad \sigma_1'}$$

The initial void ratio of tailings deposited on the surface of the storage facility is typically about 1.1, corresponding to a dry density of 85 pounds per cubic foot. As the thickness of successive tailings increase and compress the underlying material, the density is increased as presented in the following table.

**Summary of Placement Density – Conventionally Deposited Tailings**

| Effective Vertical Stress, Pounds per Square Foot | Tailings Void Ratio | Tailings Dry Density, pounds per cubic foot |
|---|---|---|
| 1 | 1.06 | 85.4 |
| 1,000 | 0.88 | 93.6 |
| 10,000 | 0.70 | 103.5 |
| 50,000 | 0.57 | 111.9 |

Continued.

The initial placement density of dry stack tailings is most typically specified as a percentage of the density defined by moisture-density compaction relationship. Considering a 90 percent of the maximum standard proctor of 102.9 pounds per cubic at initial placement, that equates to an initial dry density of 92.6 pounds per cubic foot. The effects of increased vertical overburden stress on increasing the density of the tailings, using one-dimensional consolidation theory is presented in the flowing table.

**Summary of Placement Density – Dry Stack Deposited Tailings**

| Effective Vertical Stress, Pounds per Square Foot | Tailings Void Ratio | Tailings Dry Density, pounds per cubic foot |
|---|---|---|
| 1 | 0.90 | 92.6 |
| 1,000 | 0.80 | 97.8 |
| 10,000 | 0.65 | 106.6 |
| 50,000 | 0.55 | 113.5 |

The increase in the density achieved by dry stack tailings placement over conventional tailings deposition is as follows:

**Increase in Tailings Density –**
**Dry Stack Deposited Tailings over Conventional Placed Tailings**

| Effective Vertical Stress, Pounds per Square Foot | Increase in Tailings Dry Density, pounds per cubic foot |
|---|---|
| 1 | 7.2 |
| 1,000 | 4.2 |
| 10,000 | 3.1 |
| 50,000 | 1.6 |

Considering a 350 foot deep average tailing thickness, the mid-level effective vertical stress within drained tailings mass would be about 18,500 pounds per square foot. The average increase in density achieved by using dry stack tailings over conventionally placed tailings would be 2.8 pounds per cubic foot.

# APPENDIX D

**Fault Reconnaissance, Hackberry Gulch TSF Site, ASARCO Ray Mine Complex (Technical Memorandum Prepared by AMEC Foster Wheeler Environment & Infrastructure, Inc.)**

# Memo

| | | | |
|---|---|---|---|
| **To:** | Duane Yantorno<br>Corporate Manager Permitting<br>Environmental Manager<br>ASARCO LLC.<br>Ray Operations | **Project No.:** | 17-2013-4034 |
| **From:** | Wayne Harrison, PG | **Reviewed by:** | Richard Bansberg, PG<br>Tony Freiman, PE |
| **Date:** | June 2, 2015 | | |
| **Re:** | Technical Memorandum<br>Fault Reconnaissance<br>Hackberry Gulch TSF Site<br>ASARCO Ray Mine Complex | | |

## 1.0 INTRODUCTION

ASARCO LLC (Asarco) proposes to construct and operate a new tailings storage facility (TSF). Several potential sites and/or configurations of the TSF have been identified. Because construction of the TSF will involve ephemeral washes that are considered "waters of the United States", the U.S. Army Corps of Engineers has determined that an Environmental Impact Statement (EIS) is needed to analyze effects of the project and to be compliant with the National Environmental Policy Act (NEPA). As part of the NEPA process a 404(b)(1) alternatives analysis is also being performed.

AMEC Environment & Infrastructure, Inc. (now known as Amec Foster Wheeler Environment & Infrastructure, Inc.) was tasked by ASARCO LLC with performing a limited field reconnaissance to observe and document previously mapped faults within the footprint of the Hackberry Gulch TSF site (the Site), one of the alternative sites for constructing the TSF. As shown on Figure 1, only a portion of the Site was visited during the reconnaissance due to time constraints. In addition, the results of previous investigations at the adjacent Elder Gulch TSF site were reviewed and summarized within this memorandum.

## 2.0 SCOPE OF WORK

The following bullets summarize the scope of work associated with this study:

- Review U.S. Geological Survey (USGS) geologic quadrangle map GQ-1188 (Cornwall and Krieger 1975).
- Review USGS satellite aerial photographs and Google Earth imagery to confirm the locations of previously mapped faults.

- Overlay the Cornwall and Kreiger (1975) geologic map (including faults) on aerial imagery to facilitate a one-day field reconnaissance to observe selected points of interest along drainages where intersecting fault exposures are more likely to be observed.

- Perform a one-day field reconnaissance and document observations at each location visited.

- Review information from Elder Gulch report (SHB 1989) on seepage characteristics of Big Dome conglomerate.

- Observe exposures of Big Dome conglomerate in the field to evaluate seepage characteristics.

- Prepare a technical memorandum with maps and annotated photographs.

## 3.0 GEOLOGY

The Hackberry Gulch Site is located southeast of the Elder Gulch TSF on the western flank of the Dripping Springs Mountains. Most of the site is located in Sections 31 and 32 (with a small portion located in Section 33) of Township 3 South, Range 14 East and in Sections 4, 5, 6, 8 and 9 (with small portions in Sections 10, 15 and 16) of Township 4 South, Range 14 East. The area is characterized by a large number of deeply incised drainages that flow from the upper reaches of the Dripping Springs Mountains southwestward into the Gila River located along the base of the mountain range (Figure 1). SR 177 is located immediately southwest of the Site between the Site and the Gila River.

As shown on Figure 2, the Hackberry Gulch Site is predominantly underlain by conglomerate of the Big Dome Formation (Cornwall and Krieger 1975). The conglomerate in the uppermost reaches of the site is dominated by clasts of Paleozoic limestone, whereas the remainder of the conglomerate is made up of a diverse variety of clast types. The westernmost portion of the site contains some sandstone beds. The Big Dome Formation was deposited during the late Miocene when debris was shed into the Gila River basin from the surrounding highlands. The Big Dome has been moderately deformed by tilting along northwest-striking normal faults (Cornwall and Kreiger 1975). The faults dip to the northeast and southwest at angles ranging from vertical to 45 degrees. Bedding within the conglomerate generally dips to the southwest at between 10 to 20 degrees.

Review of the USGS Quaternary Fault and Fold Database (USGS 2014) indicate that no active Quaternary faults or folds have been mapped at the site.

### 3.1 Seepage Characteristics of Big Dome Conglomerate

Seepage analyses conducted during the design of the Elder Gulch TSF indicated that seepage through coarser-grained, more permeable zones of the Big Dome Formation may travel as much as 6,000 feet from the TSF impoundment during the planned 25-year operational life of the facility (SHB 1989). While site-specific in-situ hydraulic conductivity testing was not conducted at the Hackberry Gulch site, examination of exposures of the Big Dome Formation in the drainages at the site reveals similar coarse gradations in beds of the conglomerate. The closer proximity of the Hackberry Gulch site to the Gila River than the Elder Gulch TSF presents a challenge to seepage control given the potential for seepage to travel 6,000 feet in 25 years, as determined during a previous study utilizing in-situ hydraulic conductivity testing conducted within the Big Dome Formation conglomerate at the Elder Gulch TSF (SHB 1989). Field observations documented on Photograph No. 41 of Appendix A visually depicts this bedding characteristic and exhibits the lateral seepage potential described above.

## 4.0 FIELD RECONNAISSANCE METHODOLOGY

The primary objectives of the reconnaissance were to observe and document the characteristics of the faults and assess potential fault-related impacts on the design, permitting and operation of a tailings storage facility. To optimize the one-day field reconnaissance, an area in the southeast portion of the potential footprint was selected. This area of focus was selected due to the concentration of numerous northwest-striking normal faults previously mapped by Cornwall and Kreiger (1975) and to efficiently exploit dissected drainages and existing road cuts that may advantageously expose intersecting faults. The reconnaissance was carried out on foot from various locations along North Old Ray Road accessed by truck.

To provide spatial documentation of the reconnaissance and facilitate creation of GIS maps to accompany this memorandum, a Garmin Montana 650t, WAAS-enabled, hand-held recreational-grade GPS unit was utilized in gathering points and tracks. The unit was set to record position in decimal degrees format, using a map datum of NAD83, and a default map spheroid GRS80. The estimated positional accuracy of these points and tracks is approximately 10 feet. Twenty-six target locations were selected to confirm and observe previously mapped faults intersecting drainages and road cuts.

## 5.0 OBSERVATIONS

Observations at these target locations were written in a bound field notebook. Annotated photographs are presented in Appendix A and are used to highlight items of interest. The photographs are numbered and presented in the order they were observed on April 1, 2014. The locations and direction of photographs are shown on Sheet 1. A summary of observations for each location are provided in the following sections, listed by location number corresponding to a mapped observational target location shown on the map.

### 5.1 Location 01

This location was accessed along North Old Ray Road from the intersection with highway 177. This location was chosen on a northwest-striking mapped fault trace. No geomorphic indication of faulting was observed in the low slope adjacent to and east of the road, and no photograph was taken. Exposure was poor, weathered colluvium at the surface, and there was no outcrop to observe. This mapped fault trace is also intersected by Location 24 and the reader is referred to the detailed photographs and observations made in Section 5.24 - Location 24 of this memorandum. The trace is also coincident with Locations 06 and 09, which were not visited during this reconnaissance due to time constraints.

### 5.2 Location 02

This location was accessed along North Old Ray Road. This location was chosen at the northern terminus of a north-northwest-striking mapped fault trace. No geomorphic or visual indication of faulting was observed in the approximately 25-feet-high, steeply inclined cut slope south of the road (Photograph No. 01). The exposure is well indurated, moderately weathered Big Dome conglomerate with some tafoni weathering on the cut face. This mapped fault trace is also coincident with Locations 13, 14 and 15, which were not visited during this reconnaissance due to time constraints.

### 5.3 Location 03

This location was selected at a discontinuous mapped fault trace on the same north-northwest -striking fault splay also intersected by Location 16, and is mapped by Cornwall and Krieger (1975) projecting to the north of Location 16 at the intersection of an ephemeral drainage where it terminates a short distance beyond the drainage in the Big Dome Formation. The north-northwest striking fault had a dip of 75 to 85 degrees to the northeast. The exposure was weathered and the interpretation is uncertain as no clear contact was evident. The exposure was too steep and loose rocks made unassisted climbing unsafe. The fault was observed in a northeast facing road cut in the Big Dome Formation. The fault zone appears to be about 5 feet wide (Photograph Nos. 09, 10 and 11). No open framework was observed. A view of the ridge and road cut at this location as seen from a distance is provided in Photograph No. 43.

### 5.4 Location 04

This location was accessed along North Old Ray Road cut into the hillside as the grade gains elevation eastward. This location was chosen on a northwest-striking mapped fault trace (Map Sheet C1). No geomorphic or visual indication of faulting was observed in the weathered cut slope adjacent south of the road, and no photograph was taken. No bedrock exposure was present to observe, with only weathered colluvium derived from the Big Dome Formation and desert vegetation at the surface. This mapped fault trace is also coincident with Locations 25 and 26 with a northerly projection across the drainage intersecting between Locations 16 and 17.

### 5.5 Location 05

This location was accessed along North Old Ray Road. This location was chosen at the southern end of a north-northwest-striking mapped fault trace. No geomorphic or visual indication of faulting was observed in the approximately 10-foot-high, 3H:1V cut slope north of the road (Photograph Nos. 02, 03 and 04). The exposure is poor, highly weathered, Big Dome conglomerate on the cut face. Absence of laterally-traceable bedding in the interpreted fault zone approximately 50-feet wide, flanked by traceable bedding on both sides, is the main indication of a fault at this location. This mapped fault trace is also coincident with Location 18 (Section 5.18). Apparent seepage potential exists along the interpreted fault at this location.

## 5.6 Location 06

This location was selected on the same northwest-striking fault trace intersected by Locations 01, 09 and 24. This location was not visited due to time constraints. See Section 5.24 for observation of Location 24.

## 5.7 Location 07

This location was selected at the northern end of a discontinuous mapped fault trace where it terminates at unit Qp, and is on the same northwest-striking fault also intersected by Location 10. This location was not visited due to time constraints.

## 5.8 Location 08

This location was selected at the northern end of a discontinuous mapped fault trace where it terminates within unit Tbc, and is on the same northwest-striking cross-fault splay also intersected by Locations 11 and 12. This location was not visited due to time constraints.

## 5.9 Location 09

This location was selected on the same northwest-striking fault trace intersected by Locations 01, 06 and 24. This location was not visited due to time constraints. See Section 5.24 for observations made at Location 24.

## 5.10 Location 10

This location was selected at the northern end of a discontinuous mapped fault trace where it terminates at unit Qp, and is on the same northwest-striking fault also intersected by Location 07. This location was not visited due to time constraints

## 5.11 Location 11

This location was selected at the northern end of a discontinuous mapped fault trace where it terminates within unit Tbc, and is on the same northwest-striking cross-fault splay also intersected by Location 08. This location was not visited due to time constraints.

## 5.12 Location 12

This location was selected at the northern end of a discontinuous mapped fault trace where it terminates within unit Tbc, and is on the same northwest-striking fault splay also intersected by Location 08. This location was not visited due to time constraints.

## 5.13 Location 13

This location was selected on the same northwest-striking fault trace intersected by Locations 02, 14 and 15. This location was not visited due to time constraints. See Section 5.2 for observations made at Location 02.

### 5.14 Location 14

This location was selected on the same northwest-striking fault trace intersected by Locations 02, 13 and 15. This location was not visited due to time constraints. See Section 5.2 for observations made at Location 02.

### 5.15 Location 15

This location was selected on the same northwest-striking fault trace intersected by Locations 02, 13 and 14. This location was not visited due to time constraints. See Section 5.2 for observations made at Location 02.

### 5.16 Location 16

This location was accessed on foot from the North Old Ray Road, entering the drainage and hiking in the upstream direction. This location was selected at a discontinuous mapped fault trace on the same north-northwest-striking fault splay also intersected by Location 03, and is mapped by Cornwall and Krieger (1975) projecting to the north of Location 16 at the intersection of an ephemeral drainage where it terminates a short distance beyond the drainage in the Big Dome Formation. A sharp fault contact was observed in the drainage bottom (Photograph Nos. 12, 13, 14 and 15). The fault varies from tight to partially-open. The upstream side of the fault has been eroded and scoured creating a dam and a narrow ‘weir’ eroded into the rock along the thalweg of the drainage, focusing the water into a narrow downstream channel 3 to 5 feet wide cut into the Big Dome Formation conglomerate, with near-vertical sidewalls as high as 10 feet. Another possible fault 20 feet upstream may be the full extent of a larger zone up to 20 feet wide, but the upstream fault interpretation is suspect due to the poor exposure quality and scour fill obscuring clear observations. No open framework was observed. The Big Dome Formation is tilted 20 degrees to the west at this location.

### 5.17 Location 17

This location was accessed by hiking in the upstream direction in the drainage. This location was selected at the intersection of a fault with a relatively small discontinuous extent mapped by Cornwall and Krieger (1975) crossing an ephemeral drainage where it terminates a short distance beyond the drainage in the Big Dome Formation to the north and south. The fault is approximately 50 feet wide at his location, with a dramatic cliff forming footwall of Big Dome Formation conglomerate reaching a height of 60 feet above the base level of the drainage on the east side of the fault zone (Photograph Nos. 16, 17, 18 and 19). The hanging wall on the west side of the fault zone is eroded and heavily vegetated. The contact of the fault is obscured by the erosion and vegetation. The normal fault dips west from 75 to 85 degrees judging from the footwall cliff angle viewed along strike. The vertical upstream face of the large outcrop shows evidence of scour. The drainage bends nearly 90 degrees from south to west and flows with apparent high velocity and significant bed load of cobbles and boulders have contacted and scoured the bedrock face to a height of about 6 feet. The Big Dome Formation is tilted 20 degrees to the west at this location. Tafoni and differential weathering are present on the Big Dome formation cliff face.

### 5.18 Location 18

This location was accessed by hiking in the upstream direction in the drainage. This location was selected at the intersection of a fault with a relatively long, continuous extent as mapped by Cornwall and Krieger (1975) crossing the ephemeral drainage and continuing northward beyond the drainage in the Big Dome Formation. However, no fault was observed at this location. Tafoni weathering and stream scour were observed (Photograph No. 20).

### 5.19 Location 19

This location was accessed by hiking in the upstream direction in the drainage. This location was selected at the intersection of a fault with a relatively small discontinuous extent mapped by Cornwall and Krieger (1975) crossing an ephemeral drainage where it terminates a short distance beyond the drainage in the Big Dome Formation to the north. The location was adjusted in the field as presented on Map Sheet C2. The fault is approximately 10 to 15 feet wide at this location (Photograph Nos. 21 and 22). This normal fault dips west from 65 to 80 degrees. The fault contact is eroded and partially vegetated. Where the fault intersects the drainage bottom, the aperture is 4 to 6 inches wide. The fault is partially-cemented with white calcite lining the fault fractures. Partially open to open fractures in the fault zone are potential seepage pathways to the subsurface.

### 5.20 Location 20

This location was accessed by hiking in the upstream direction in the drainage. This location was selected at the intersection of a fault mapped by Cornwall and Krieger (1975) crossing an ephemeral drainage and terminating in the Big Dome Formation to the north. Several faults are present between Locations 19 and 21 (Photograph Nos. 23, 24, 42 and 43). One fault is approximately 2 to 4 feet wide at his location. The normal fault dips west from 75 to 85 degrees. The fault contact is healed and no open framework was observed. One fault is partially-cemented with a white calcite lining. Another fault a bit further upstream (Photograph No. 25) is a high angle normal fault with a gouge and rubble zone 15 to 20 feet wide, with partially open fractures. This faults exhibit a dip to the west of 65 to 85 degrees. These faults are in the Big Dome Formation. Partially open to open fractures in the fault zone are potential seepage pathways to the subsurface.

### 5.21 Location 21

This location was accessed by hiking in the upstream direction in the drainage and is the furthest point observed in the northeast extent for this reconnaissance. This location was selected at the intersection of north-northeast striking fault splay mapped by Cornwall and Krieger (1975) crossing an ephemeral drainage and terminating in the Big Dome Formation a relatively short distance to the north. Cliff forming Big Dome Formation is faulted down to the west at a high angle dip with a zone approximately 100 feet wide (Photograph Nos. 26 through 40). The eroded fault contact contains a 10-foot-side zone of very soft rock flour, gouge and rubble with partially open fractures and frameworks observed at the margins for the fault zone. Tafoni and differential weathering are present in the footwall cliff comprised of Big Dome Formation that is tilted approximately 20 degrees dipping to the west. Partially open to open fractures in the fault zone are potential seepage pathways to the subsurface.

### 5.22 Location 22

This location was selected at a discontinuous mapped fault trace which may be a continuation of the north-northwest-striking fault also coincident with Locations 15,14,13, and 02, and is mapped by Cornwall and Krieger (1975) projecting to the northwest at the northernmost point of the Kane Spring Canyon explored in this field reconnaissance. This Location was observed from the south side of the steep drainage looking to the north. Three faults in the Big Dome Formation were observed in the Kane Spring Canyon wall in a zone approximately 50 feet wide. One fault appears closed and healed with a very thin tight, 'knife-blade' contact. Another has open fractures to several inches. The third appears cemented with calcite and partially-healed, with some voids of missing weathered gouge material (Photograph Nos. 45 through 48). The southeast dipping faults range from 60 degrees to vertical. Partially open to open fractures in the fault zone are potential seepage pathways to the subsurface.

### 5.23 Location 23

This location was selected at a discontinuous fault trace mapped by Cornwall and Krieger (1975) projecting to the northwest a central portion of the Kane Spring Canyon explored in this field reconnaissance. This Location was observed from the south side of the steep drainage looking to the north (Photograph Nos. 49 through 51). A single closed, down to the west, normal fault was observed dipping west at angle of about 50 degrees, with a thin 'knife-blade' contact. There was possible subtle geomorphic expression of faulting at the surface, but it also could be a drainage tributary. The interpretation based on limited observation is equivocal. The view of the location was obscured by vegetation. Better observations could be made from the canyon drainage bottom during future reconnaissance.

### 5.24 Location 24

This location was chosen on a relatively continuous, northwest-striking fault trace mapped by Cornwall and Krieger (1975) (Map Sheet C1). This mapped fault trace connection is inferred under the Quaternary pediment gravels unit, and is also intersected by Location 01 and coincident with Locations 06 and 09, which were not visited during this reconnaissance due to time constraints. This Location was observed from the southeast side of the steep drainage looking to the north. Four discrete, high angle faults in the Big Dome Formation were observed in the Kane Spring Canyon north wall in a zone approximately 100 feet wide. One fault appears closed and healed with a very thin tight, 'knife-blade' contact. The westernmost fault has open fractures from 2 to 6-inches in aperture. The others appear partially-closed, within a discrete fault/gouge contact several inches wide (Photograph Nos. 53 through 57). The southeast dipping faults range from 60 degrees to vertical. Partially open to open fractures in the fault zone are potential seepage pathways to the subsurface.

### 5.25 Location 25

This location was selected at a discontinuous mapped fault trace on the same north-northwest-striking fault splay also intersected by Locations 04 and 26, and is mapped by Cornwall and Krieger (1975) projecting to the north between Locations 16 and 17 at the intersection of an ephemeral drainage where it terminates a short distance beyond the drainage in the Big Dome

Formation. A single fault was observed in a south facing road cut. The fault zone is a closed brecciated gouge zone a few inches wide, healed with calcite cementation (Photograph Nos. 05 and 06). The dip of the high-angle fault ranges from 7 to 85 degrees to the northwest.

### 5.26 Location 26

This location was selected at a discontinuous mapped fault trace on the same north-northwest - striking fault splay also intersected by Locations 04 and 25, and is mapped by Cornwall and Krieger (1975) projecting to the north between Locations 16 and 17 at the intersection of an ephemeral drainage where it terminates a short distance beyond the drainage in the Big Dome Formation. Multiple faults were observed in a southwest facing road cut in the Big Dome Formation. The fault zone is approximately 2-feet wide, closed and healed with quartz and calcite veins several inches thick (Photograph Nos. 07 and 08). The dip of the high-angle fault ranges from 75 to 85 degrees to the southeast.

## 6.0 SUMMARY

The field reconnaissance was conducted by the author on April 1, 2014. Observed faults are high-angle normal faults in the Miocene-age Big Dome Formation, often with little to no geomorphic expression at the surface. The faults are most easily observed in side-wall exposures where they intersect drainages. Many of the faults can be traced between drainages. Most of the faults shown on the Kearny geologic quadrangle map within the area reconnoitered were confirmed. The observed fracture aperture on the faults ranged from zero to 6 inches. Several of the faults observed were closed, healed or cemented with calcium carbonate. Where present, lapilli tuff outcrops adjacent to faulting exhibited open fractures, disrupted and parted bedding planes, and partially-open fractures. Tafoni and differential weathering was observed at many locations in the Big Dome Formation conglomerate. It is not known how or if these features may extend into the subsurface acting as possible conduits or if they present a potential seepage pathway.

Field observations of Big Dome Formation conglomerate exposures reveal beds with coarse gradations that present potential lateral seepage pathways. The closer proximity of the Hackberry Gulch site to the Gila River than the Elder Gulch TSF presents a challenge to seepage control given the potential for seepage to travel 6,000 feet in 25 years, as determined during a previous study utilizing in-situ hydraulic conductivity testing conducted within the Big Dome Formation conglomerate at the Elder Gulch TSF (SHB 1989).

The topographic relief created by the downcutting action of ephemeral water within the Kane Spring Canyon was steep and covered by loose rock and colluvial debris such that it could not be assessed without ropes and anchors. For safety reasons, these exposures were viewed from a vantage point across the steep walled canyon. Additional observation and measurements of open fractures on faults could be made at locations in this drainage by entering and hiking the drainage bottom given additional time and after addressing the safety concerns by finding a safe entry point and route to hike down to the drainage bottom.

This reconnaissance identified several unnamed faults that have the potential to act as conduits for seepage of tailings fluids into the subsurface. It is not known how deep, persistent or connected these faults may be. The seepage potential of these faults may present design challenges for seepage control. These faults should be studied further to provide a more thorough assessment of their characteristics.

Limitations to keep in mind regarding this one-day field reconnaissance:

- The area of the reconnaissance was relatively small compared to the design footprint of the potential Hackberry Gulch TSF and future investigation or fault assessments should be scaled up accordingly to provide coverage of the entire Site.
- A limited number of observations were made in this reconnaissance. Not every fault was visited or observed. There are potentially unmapped faults in the Site area.
- Observations of faulting were limited to the locations visited indicated by the recorded GPS tracks shown on the attached fault reconnaissance map.

## 7.0 REFERENCES

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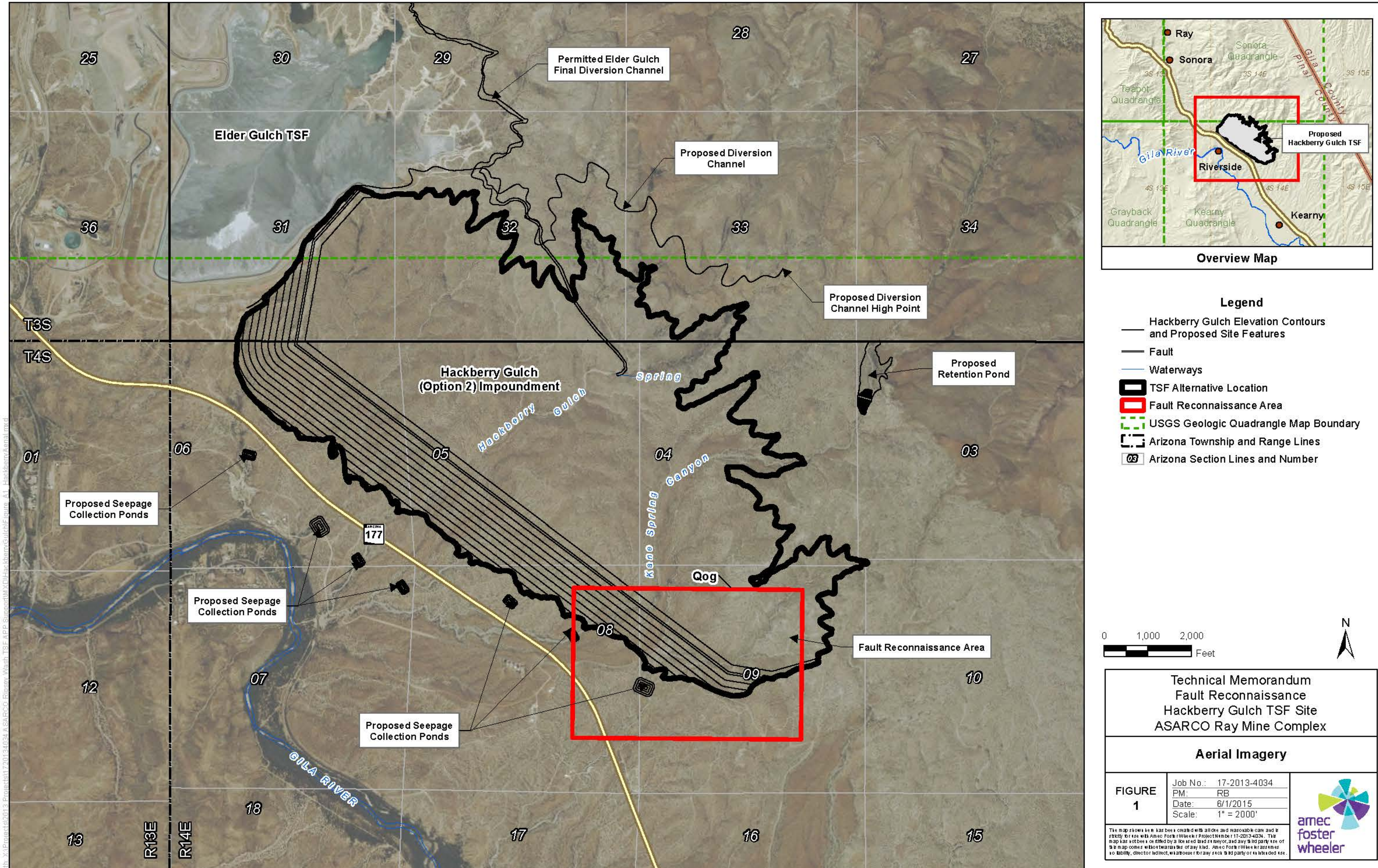
U.S. Geologic Survey, 2010, Quaternary Fault and Fold Database for the United States, http://earthquake.usgs.gov/hazards/qfaults/, accessed July 2013.

**FIGURES**



Permitted Elder Gulch Final Diversion Channel
Elder Gulch TSF
Proposed Diversion Channel
Proposed Diversion Channel High Point
Hackberry Gulch (Option 2) Impoundment
Spring
Hackberry Gulch
Kane Spring Canyon
Proposed Retention Pond
Proposed Seepage Collection Ponds
Proposed Seepage Collection Ponds
Proposed Seepage Collection Ponds
Fault Reconnaissance Area
Qog
177
GILA RIVER
T3S
T4S
R13E
R14E
25
30
29
28
27
36
31
32
33
34
01
06
05
04
03
12
07
08
09
10
13
18
17
16
15
Ray
Sonora
Sonora Quadrangle
Teapot Quadrangle
Gila County
Pinal County
Proposed Hackberry Gulch TSF
Gila River
Riverside
Grayback Quadrangle
Kearny Quadrangle
Kearny
3S 13E
3S 14E
3S 15E
4S 13E
4S 14E
4S 15E
Overview Map
Legend
Hackberry Gulch Elevation Contours and Proposed Site Features
Fault
Waterways
TSF Alternative Location
Fault Reconnaissance Area
USGS Geologic Quadrangle Map Boundary
Arizona Township and Range Lines
03 Arizona Section Lines and Number
0 1,000 2,000 Feet
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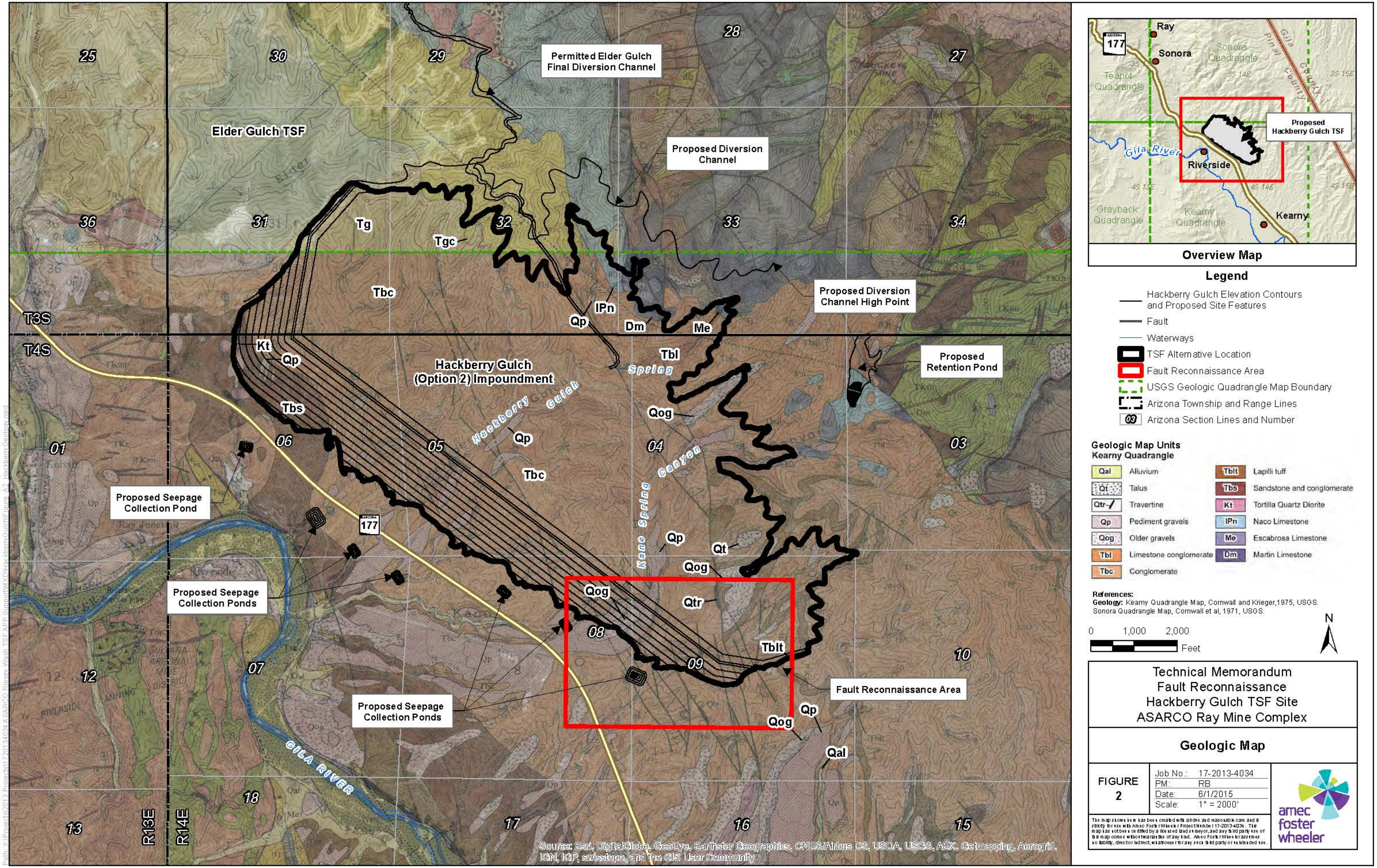
Technical Memorandum
Fault Reconnaissance
Hackberry Gulch TSF Site
ASARCO Ray Mine Complex
Aerial Imagery
FIGURE 1
Job No.: 17-2013-4034
PM: RB
Date: 6/1/2015
Scale: 1" = 2000'
amec foster wheeler


Permitted Elder Gulch Final Diversion Channel
Elder Gulch TSF
Proposed Diversion Channel
Proposed Diversion Channel High Point
Proposed Retention Pond
Hackberry Gulch (Option 2) Impoundment
Hackberry Gulch
Kane Spring Canyon
Spring
Proposed Seepage Collection Pond
Proposed Seepage Collection Ponds
Proposed Seepage Collection Ponds
Fault Reconnaissance Area
GILA RIVER
177
T3S
T4S
R13E
R14E
25
30
29
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36
31
32
33
34
01
06
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Tg
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Qog
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Tblt
Qal
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Ray
Sonora
Teapot Quadrangle
Sonora Quadrangle
Gila River
Riverside
Proposed Hackberry Gulch TSF
Grayback Quadrangle
Kearny Quadrangle
Kearny
Pinal County
Gila County
Overview Map
Legend
Hackberry Gulch Elevation Contours and Proposed Site Features
Fault
Waterways
TSF Alternative Location
Fault Reconnaissance Area
USGS Geologic Quadrangle Map Boundary
Arizona Township and Range Lines
03 Arizona Section Lines and Number
Geologic Map Units Kearny Quadrangle
Qal Alluvium
Qt Talus
Qtr Travertine
Qp Pediment gravels
Qog Older gravels
Tbl Limestone conglomerate
Tbc Conglomerate
Tblt Lapilli tuff
Tbs Sandstone and conglomerate
Kt Tortilla Quartz Diorite
IPn Naco Limestone
Me Escabrosa Limestone
Dm Martin Limestone
References:
Geology: Kearny Quadrangle Map, Cornwall and Krieger,1975, USGS.
Sonora Quadrangle Map, Cornwall et al, 1971, USGS.
0 1,000 2,000
Feet
N
Technical Memorandum
Fault Reconnaissance
Hackberry Gulch TSF Site
ASARCO Ray Mine Complex
Geologic Map
FIGURE 2
Job No.: 17-2013-4034
PM: RB
Date: 6/1/2015
Scale: 1" = 2000'
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**PHOTO-LOG**

# Appendix A - Photographs

Fault Reconnaissance

Hackberry Gulch TSF

4/1/2014

Photo No. 01 – Location 02: Tafoni weathering in exposure of conglomerate member of the Miocene-age Big Dome Formation along Old Ray Road cut (approximately 25 feet high); no obvious signs of faulting observed in cut.


Photo No. 02 – Southeast of Location 05: View of Elder Gulch TSF to Northwest along Old Ray Road.


Photo No. 03 – Location 05: West edge of fault zone; unfaulted bedding on left side of view.

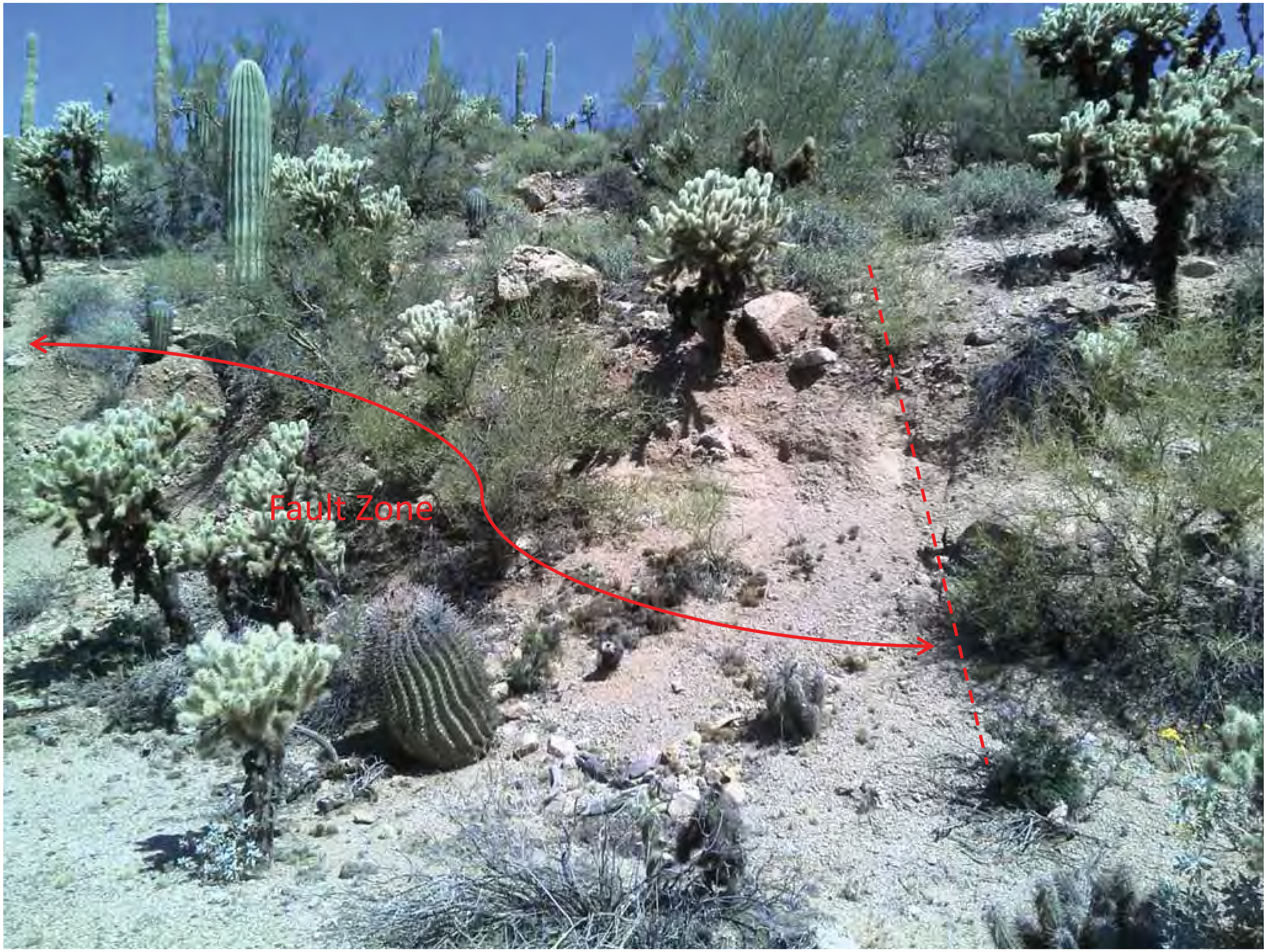


Photo No. 04 – Location 05: East edge of fault zone.

Photo No. 05 – Location 25: Healed fault, filled with calcium carbonate cementation.

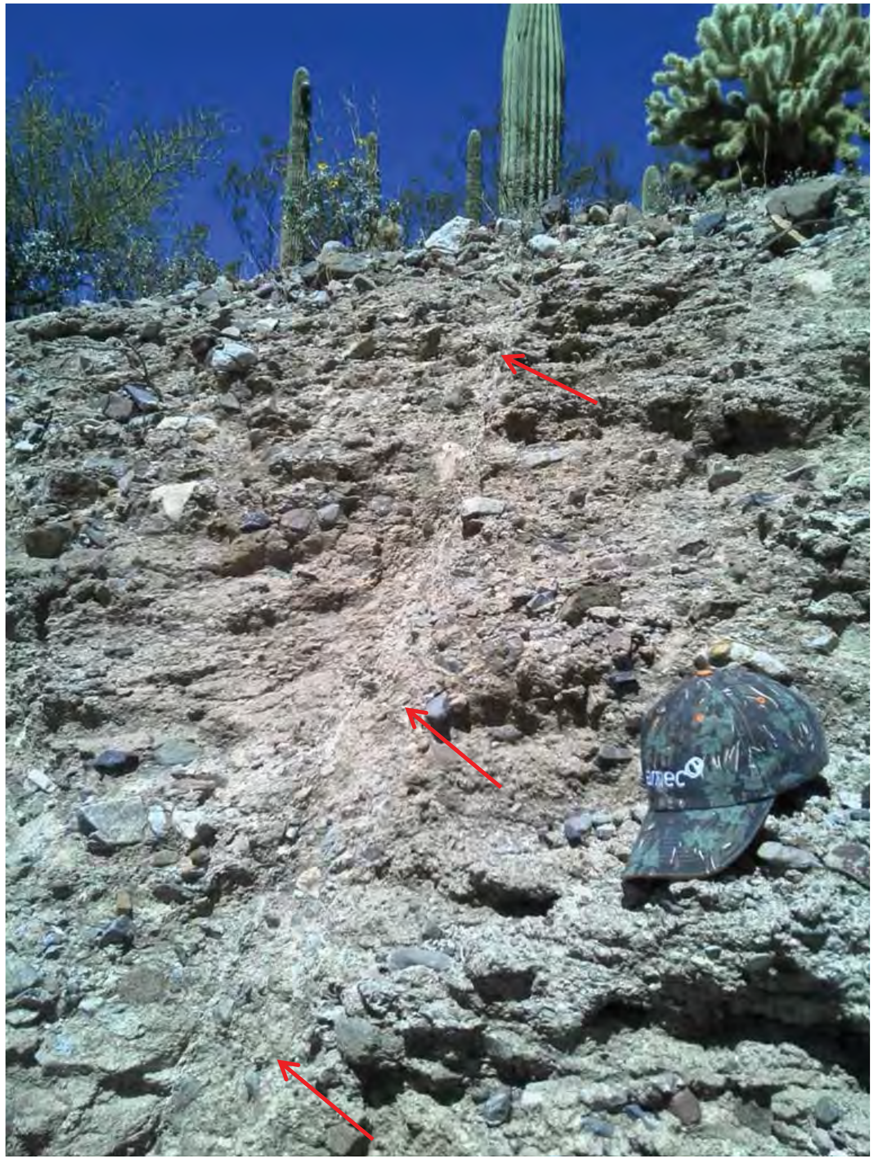

Photo No. 06 – Location 25: Close-up of healed fault breccia, filled with calcium carbonate cementation.

Photo No. 07 – Location 26: Calcite veining in fault (hat for scale).


Photo No. 08 – Location 26: Close-up of calcite veining in fault.

Photo No. 09 – Location 03: Fault exposure, closed, weathered.

Photo No. 10 – Location 03: Possible fault, weathered, poor exposure.

Photo No. 11 – Location 03: Poor exposure, possible fault?

Photo No. 12 – Location 16: Partially closed, sharp fault contact in Big Dome across drainage.

Photo No. 13 – Location 16: Looking down at partially closed to several inch aperture, sharp fault contact in Big Dome Formation crosses drainage; eroded by scour.

Photo No. 14 – Location 16: Looking down vertically at partially closed to several inch aperture, sharp fault contact in Big Dome Formation crosses drainage; eroded by scour.

Photo No. 15 – Location 16: Weathered Big Dome Formation exposed in drainage walls.

Photo No. 16 – Location 17: Tafoni weathering in Big Dome Formation; arrows indicate approximate location of high-angle normal fault striking perpendicular to direction of photograph.

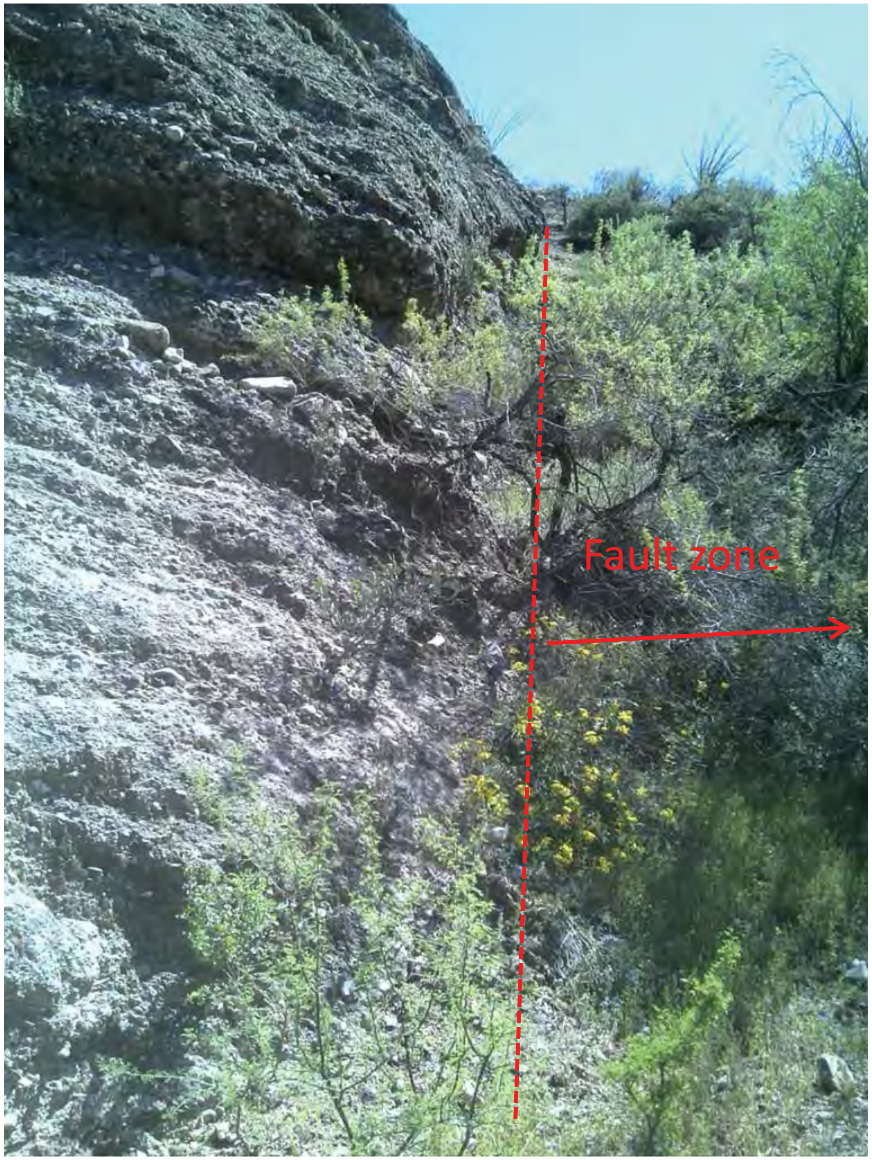


Photo No. 17 – Location 17: Faulted Big Dome Formation; weathered, heavily vegetated exposure of fault zone.

Photo No. 18 – Location 17: Scoured face of Big Dome Formation exposure.


Photo No. 19 – Location 17: Faulted and tilted Big Dome Formation.

Photo No. 20 – Location 18: Tafoni weathering and scour in drainage sidewall.


Photo No. 21 – Location 19: Faulted Big Dome Formation with several inches of open fracture where it intersects the drainage floor.

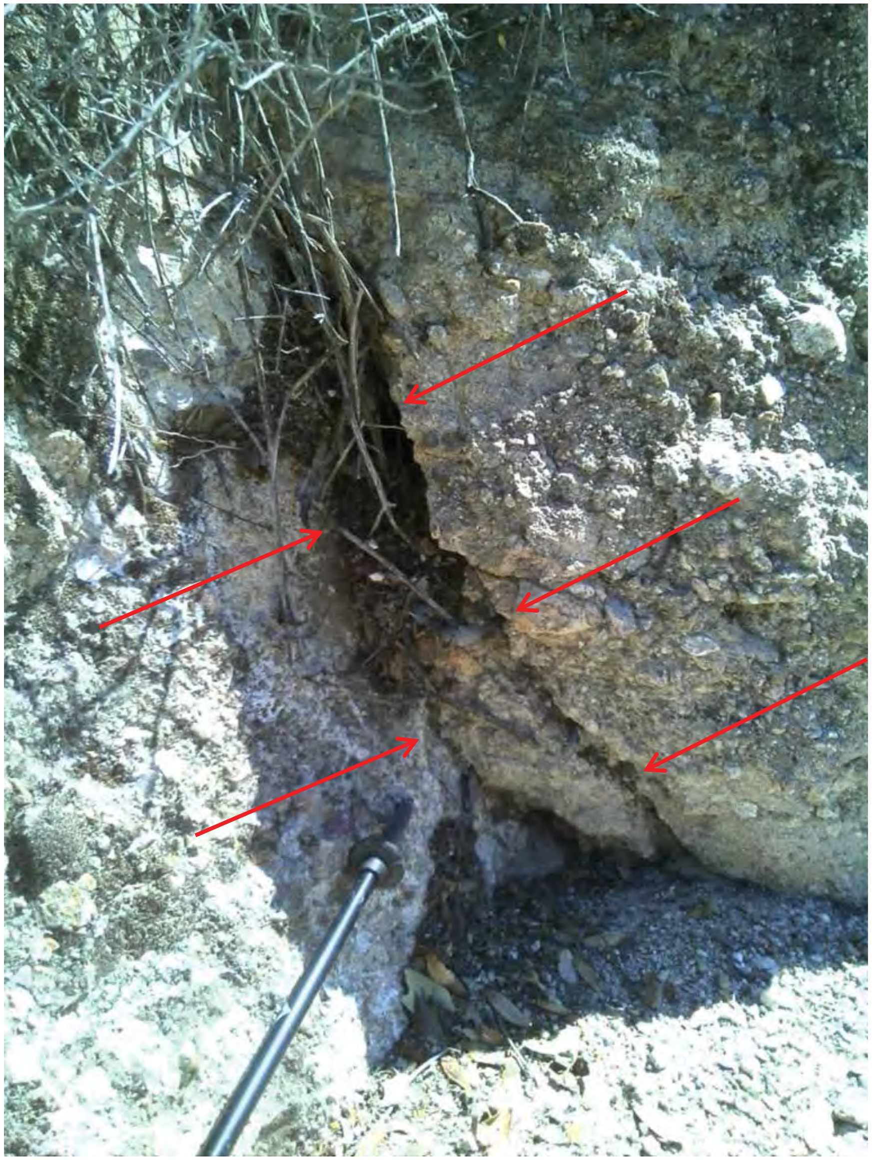

Photo No. 22 – Location 19: close-up of open fracture (hiking pole for scale).

Photo No. 23 – Location 20: Healed fault in Big Dome Formation.

Photo No. 24 – Location 20: Close up of fault zone breccia (hiking poles for scale).


Photo No. 25 – Location 20: Faulted Big Dome Formation; 15-20 feet wide, with partially open fractures and rubble.

Photo No. 26 – Location 21: Tafoni weathering along bedding planes in Big Dome Formation.

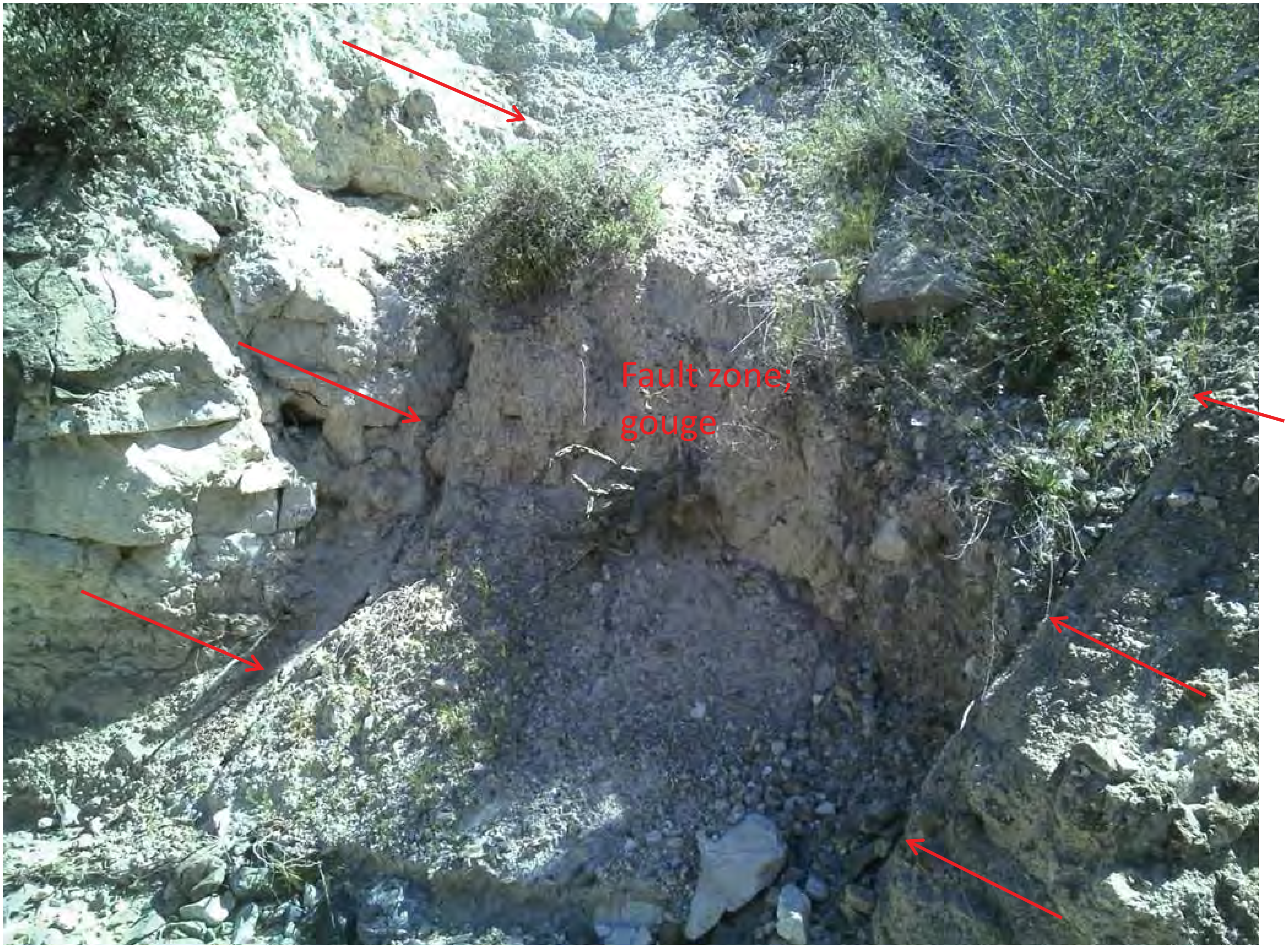


Photo No. 27 – Location 21: Faulted Big Dome Formation; some open fractures, breccia and gouge zone approximately 10 feet wide; parted and fractured bedding adjacent to fault on left side of picture.


Photo No. 28 – Location 21: Another view of faulted Big Dome Formation.


Photo No. 29 – Location 21: Faulted Big Dome Formation, close view.

Photo No. 30 – Location 21: Vertical partially open fractures and horizontal bedding in the Big Dome Formation.

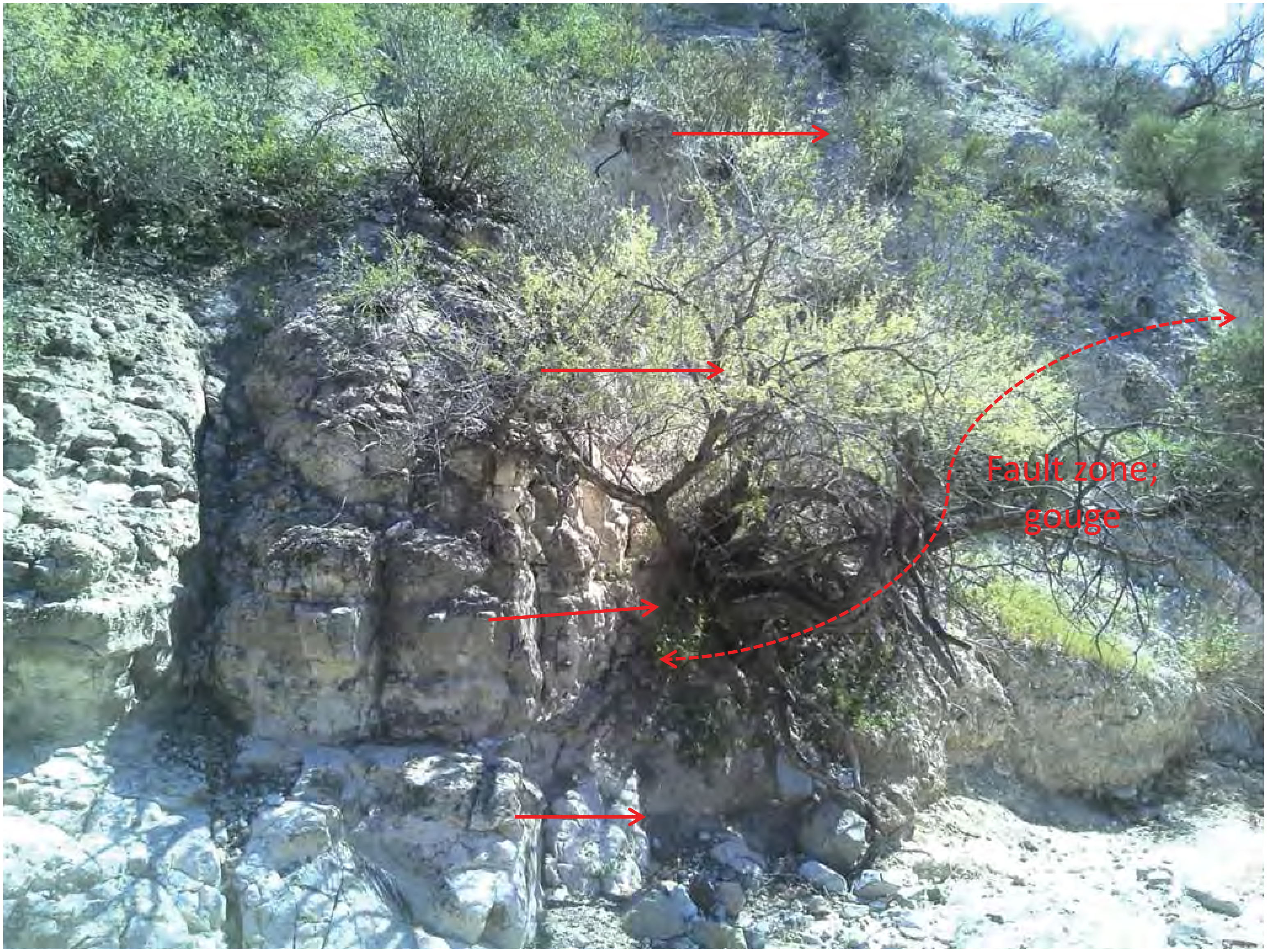


Photo No. 31 – Location 21: Close view of vertical, partially open fractures and horizontal bedding in the Big Dome Formation, adjacent to fault on right.

Photo No. 32 – Location 21: Close view of partially-open vertical fractures and horizontal bedding in the Big Dome Formation, adjacent to fault on right.

Photo No. 33 – Location 21: Tafoni and differential weathering along bedding planes in Big Dome Formation.

Photo No. 34 – Location 21: Tafoni weathering along bedding planes in Big Dome Formation.

Photo No. 35 – Location 21: Typical conglomerate clasts in Big Dome Formation.

Photo No. 36 – Location 21: Partially-open vertical fracture in tuffaceous member of Big Dome Formation (hiking poles for scale).

Photo No. 37 – Location 21: Partially-open vertical fracture in tuffaceous member of Big Dome Formation.

Photo No. 38 – Location 21: Partially-open vertical fracture in tuffaceous member of Big Dome Formation (hiking poles for scale).

Photo No. 39 – Location 21: Partially-open vertical fracture in tuffaceous sandstone member of Big Dome Formation, adjacent to fault on right  (hiking poles for scale).

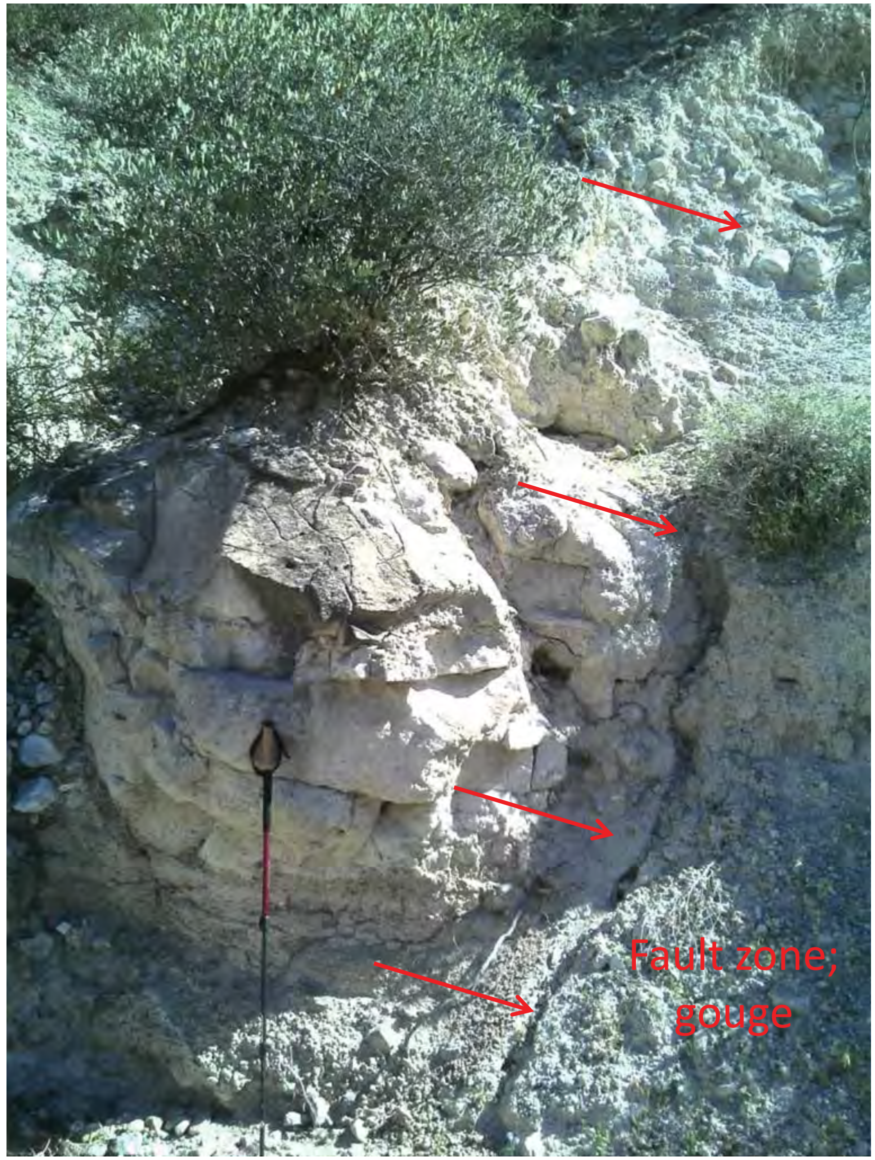


Photo No. 40 – Location 21: Faulted Big Dome Formation; close view (hiking pole for scale).

Photo No. 41 – Between Locations 20 & 21: Bank and channel scour in drainage channel carved into Big Dome Formation.


Photo No. 42 – North of Location 20: High-angle fault in the Big Dome Formation, striking N35E to N40E, with zone approximately 5-feet wide. East side of drainage.


Photo No. 43 – North of Location 20: Weathered fault exposure of same
fault as in Photograph No. 43, in opposite side of drainage (west).


Photo No. 44 – View towards Location 03: Geomorphic expression of faulting at surface is subtle to none. Old Ray Road cut visible along the ridge.

Photo No. 45 – Location 22: Fault scarp viewed across deep Kane Spring Canyon drainage; arrows indicate width of fault zone at surface.

Photo No. 46 – Location 22: Faulted Big Dome Formation viewed across steep drainage of Kane Spring Canyon.

Photo No. 47 – Location 22: Subtle geomorphic expression of faulting at surface; more easily observed on canyon wall exposures into Big Dome Formation.


Photo No. 48 – Location 22: Faulted Big dome Formation observed across steep drainage exposed in Kane Spring Canyon walls.

Photo No. 49 – Location 23: Subtle geomorphic expression of faulting at surface in Big Dome Formation.

Photo No. 50 – Location 23: Subtle geomorphic expression of faulting at surface; tafoni weathering in steep canyon walls of Kane Spring Canyon; Elder Gulch TSF visible in distance.

Photo No. 51 – Location 23: Subtle to no geomorphic expression of faulting at surface.

Photo No. 52 – East of Location 24: Side-tributary to Kane Spring Canyon.

Photo No. 53 – Location 24: Faulted Big Dome Formation; viewed across steep-sided drainage of Kane Spring Canyon .

Photo No. 54 – Location 24: Faulted Big Dome Formation.

Photo No. 55 – Location 24: Faulted Big Dome Formation, filled with cementation.

Photo No. 56 – Location 24: Faulted Big Dome Formation, partially open to about 6 inches.


Photo No. 57 – Location 24: Faulted Big Dome Formation; open high-angle faults with several inches aperture; fault zone approximately 100 feet wide; viewed across steep-sided Kane Spring Canyon. Height of rock exposed in sidewall approximately 20 feet.

**SHEETS**


Tbc
Qp
Qog
Proposed Seepage Pond
Qp
Tbc
Qtr
Tblt
Qog
Qog
Tblt
Tblt
Qog
Tbc
08
09
Qog
Tbc
Proposed Seepage Pond
Propoosed Tailings Impoundment Footprint
Tbc
Qog
Tblt
177
Proposed Hackberry Gulch TSF
Reconnaissance Area
Ray
Sonora
Riverside
Kearny
Overview Map
EXPLANATION
Geologic Units
Kearny Quadrangle
Qal Alluvium
Qt Talus
Qtr Travertine
Qp Pediment gravels
Qog Older gravels
Tbl Limestone conglomerate
Tbc Conglomerate
Tblt Lapilli tuff
Tbs Sandstone and conglomerate
Kt Tortilla Quartz Diorite
IPn Naco Limestone
Me Escabrosa Limestone
Dm Martin Limestone
Photo Location and Direction
Fault Observation Target
Hackberry Gulch Elevation Contours and Proposed Site Features
TSF Alternative Location
Arizona Section Line and Number
Reference:
Geology: Kearny Quadrangle Map, Cornwall and Krieger, 1975, USGS
Technical Memorandum
Fault Reconnaissance
Hackberry Gulch TSF Site
ASARCO Ray Mine Complex
Sheet - 1 Fault Reconnaissance Map
0 75 150 300 Feet
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# APPENDIX E

**Hackberry Gulch**
**Site Considerations**
**(Technical Memorandum**
**Prepared by AMEC Foster**
**Wheeler Environment &**
**Infrastructure, Inc.)**

# TECHNICAL MEMORANDUM

amec foster wheeler

| | | | |
|---|---|---|---|
| **To:** | James Stewart<br>Technical Services Manager<br><br>Duane Yantorno<br>Corporate Manager Permitting<br>Environmental Manager<br>ASARCO LLC.<br>Ray Operations | **Project No.:** | 17-2013-4034 |
| **From:** | Wayne Harrison, PG | **Reviewed by:** | Tony Freiman, PE |
| **Date:** | November 28, 2016 | | |

**Re:** **Draft Environmental Impact Statement – Comment Response**
**Hackberry Gulch TSF Site Considerations**
**ASARCO Ray Mine Operations**

## 1.0 BACKGROUND AND PURPOSE

The Ray Mine Tailings Storage Facility Draft Environmental Impact Statement (DEIS) was released on January 29, 2016 (USACE 2016). In their review of the DEIS, the US Environmental Protection Agency (EPA) has commented that the information presented in the Ray Mine Tailings Storage Facility Alternatives Screening and Clean Water Act Section 404(b)(1) Alternatives Analysis (404(b)(1) Alternatives Analysis) and the DEIS, does not clearly present the "other significant environmental consequences" that make the Hackberry Gulch Tailings Storage Facility (TSF) Alternative more environmentally damaging than the Ripsey Wash TSF Alternative.

This technical memorandum (TM) addresses this comment by reiterating and clarifying the information presented in the 404(b)(1) Alternatives Analysis (Appendix B of the DEIS) regarding the potential for seepage and the uncertainties posed by the geologic and geotechnical conditions at the Hackberry Gulch site.

## 2.0 HACKBERRY GULCH GEOLOGICAL AND GEOTECHNICAL CONSIDERATIONS

The following sections discuss the geological, and geotechnical issues that would be encountered in the development of the Hackberry Gulch TSF Alternative. This information has been provided as part of the Ray Mine Tailings Storage Facility Alternatives Screening and Clean Water Act Section 404(b)(1) Alternatives Analysis (Appendix B of the DEIS).

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## 2.1 Site Conditions

The Hackberry Gulch site is located southeast of the Elder Gulch Tailings Facility on the western flank of the Dripping Springs Mountains. Most of the site is located in Sections 31 and 32 (with a small portion located in Section 33) of Township 3 South, Range 14 East and in Sections 4, 5, 6, 8 and 9 (with small portions in Sections 10, 15 and 16) of Township 4 South, Range 14 East. The area is characterized by a large number of deeply incised drainages that flow from the upper reaches of the Dripping Springs Mountains southwestward into the Gila River located along the base of the mountain range. SR 177 is located immediately southwest of the site between the site and the Gila River.

## 2.2 Site Geologic and Geotechnical Considerations

Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) was tasked by ASARCO LLC with performing a field reconnaissance to observe and document previously mapped faults within the footprint of the Hackberry Gulch TSF site. In addition, the results of previous investigations at the adjacent Elder Gulch TSF site were reviewed and summarized within this memorandum.

A separate technical memorandum presenting the results of an initial geologic reconnaissance of faulting within the Hackberry Gulch TSF footprint (Amec Foster Wheeler, 2015) has been submitted and is included as an Appendix in the 404(b)(1) Alternatives Analysis. The key findings of the survey include the determination that the faulting has the potential to act as a conduit for seepage and the likely presence of unidentified faults in the impoundment footprint.

The following bullets summarize the scope of previous work (AMEC 2015) with respect to geologic and geotechnical considerations analyzed in the DEIS (USACE 2016):

- Reviewed U.S. Geological Survey (USGS) geologic quadrangle map GQ-1188 (Cornwall and Krieger 1975).
- Reviewed USGS satellite aerial photographs and Google Earth imagery to confirm the locations of previously mapped faults.
- Overlaid the Cornwall and Kreiger (1975) geologic map (including faults) on aerial imagery to facilitate a one-day field reconnaissance to observe selected points of interest along drainages where intersecting fault exposures are more likely to be observed.
- Performed a field reconnaissance and documented observations at each location visited.
- Reviewed information from Elder Gulch report (SHB 1989) on seepage characteristics of Big Dome conglomerate.
- Observed exposures of Big Dome conglomerate in the field to evaluate seepage characteristics.
- Prepared a technical memorandum with maps and annotated photographs. (AMEC 2015)

The Hackberry Gulch site is predominantly underlain by conglomerate of the Big Dome Formation (Cornwall and Krieger 1975). The conglomerate in the uppermost reaches of the site is dominated by clasts of Paleozoic limestone, whereas the remainder of the conglomerate is made up of a diverse variety of clast types. The westernmost portion of the site contains some sandstone beds.

The Big Dome Formation was deposited during the late Miocene when debris was shed into the Gila River basin from the surrounding highlands.

### 2.2.1 Faulting

The Big Dome Formation has been moderately deformed by tilting along northwest-striking normal faults (Cornwall and Kreiger 1975). The faults dip to the northeast and southwest at angles ranging from vertical to 45 degrees. Bedding within the conglomerate generally dips to the southwest at between 10 to 20 degrees.

Observed faults within the southern end of the Hackberry Gulch site footprint are characteristic high-angle normal faults in the Miocene-age Big Dome Formation, often with little to no geomorphic expression at the surface. The faults are most easily observed in side-wall exposures where they intersect drainages. Many of the faults can be traced between drainages. Most of the faults shown on the Kearny geologic quadrangle map within the area reconnoitered were confirmed. The observed fracture aperture on the faults ranged from zero to 6 inches. Several of the faults observed were closed, healed or cemented with calcium carbonate. Where present, lapilli tuff outcrops adjacent to faulting exhibited open fractures, disrupted and parted bedding planes, and partially-open fractur*es. Cavernous weathering* [1] was observed at many locations in the Big Dome Formation conglomerate (BDC). These features may extend into the subsurface and act as possible conduits and a potential seepage pathway.

This reconnaissance identified several unnamed faults that have the potential to act as conduits for seepage of tailings fluids into the subsurface. It is not known how deep, persistent or connected these faults may be. The seepage potential of these faults present design challenges for seepage control.

### 2.2.2 Paleo-channels

A review of aerial imagery indicates the presence of one or more paleo-channels that could be potential avenues of seepage. The older gravel deposits are present in unknown thicknesses (some areas over 50 feet thick exposed in the side walls of the deeply incised channels) and geologic reasoning applied to the understanding of the depositional environment and the spatial relationship of these surficial units lead the author to believe that these units may constitute paleo-channels cut into the early BDC as the regional uplift, tilting of the BDC, and incision and deposition of the paleo-channel sediments on the BDC. The stranded remnants of the paleo-channels are merely now subtle traces due the subsequent erosion over geologic time which has left isolated the once connected channels that may extend to significant depths and may connect in the subsurface acting as preferential seepage pathways that will make mitigation for stability and appropriate engineering seepage control strategy impractical.

[1] Cavernous weathering features, also called *Tafoni*, are a cavernous rock decay phenomena expressed as small cave-like features found in granular sedimentary rock created by the physical and chemical forces of weathering of dissolved minerals by water, consisting of rounded entrances and smooth concave walls, often connected, adjacent, and or networked, and usually occurring in groups visible in hillsides, cliffs, steep sided drainages and outcrops.

### 2.2.3 Coarser Gradation Beds within the Big Dome Conglomerate

Based on review of studies conducted for the design of the adjacent Elder Gulch TSF (SHB 1989) and field reconnaissance mapping (Amec Foster Wheeler 2015), the presence of beds of coarser gradation within the tilted Big Dome Conglomerate (BDC) that underlies the Hackberry Gulch TSF could provide lateral and vertical seepage pathways.

### 2.2.4 Big Dome Conglomerate Heterogeneity

Hydraulic conductivity (K) values usually exhibit variation through space within a geologic formation which is a property known as *heterogeneity*[2]. [Conversely, *homogeneity* [3]is the opposite of heterogeneity]. When these values also vary with the direction of measurement at any point within the formation it is a property known as *anisotropy*[4]. Geologic processes involved at the time of deposition in differing geologic environments control the characteristic development of these formation properties (Freeze and Cherry, 1979). These properties greatly influence flow of water (or seepage fluids) within a geologic formation.

Along with direct measurements (exploratory borings, testing, mapping), geologic reasoning can be applied to account for the anisotropy arising from the layered heterogeneity observed within the sedimentary BDC from an understanding of how these initial geologic processes at the time of formation (referred to by geologists as the *depositional environment*) are preserved within the BDC unit, and how they control the characteristics of seepage flow through the formation.

Geological environments naturally evolve many heterogeneous configurations. In nature, homogeneous geological formations are the rare exception rather than the rule. A property common among many sedimentary rocks is *layered heterogeneity* where individual beds of an interlayered geologic formation can be considered homogeneous, but each bed can have a different hydraulic conductivity value. *Trending heterogeneity* is a property observed whereby hydraulic conductivity is dependent upon position within the geologic formation *and* is increasing or decreasing on a trend in that direction. Trending heterogeneity is common to many types of sedimentary rocks and can attain gradients of 2 to 3 orders of magnitude within several miles (Freeze and Cherry, 1979). *Discontinuous heterogeneity* can be caused by the presence of faults, large stratigraphic features, or the overburden bedrock contact, where the discontinuities are characterized by a large contrast in hydraulic conductivity. Understanding these characteristics is important to the design and implementation of an appropriate engineering seepage control strategy. As the analysis of data from Elder Gulch reveals in the following discussion, the BDC exhibits characteristics of two of the three properties of heterogeneities, and all three properties are likely present at the Hackberry Gulch site.

Analysis of Elder Gulch data (SHB 1989) provides a geologic analog for the conditions that would be expected at Hackberry Gulch TSF site due to their proximity and the predominance of the Big Dome conglomerate common to both sites. Results of the packer testing in BDC from Elder Gulch are summarized on attached **Figure 1** as a site analog for Hackberry Gulch. The chart in **Figure 2** shows the subsurface relationship of hydraulic conductivity (K) with depth measured from packer

[2] *Heterogeneity* is a characteristic of a medium in which material properties *vary* from point to point.
[3] *Homogeneity* is a characteristic of a medium in which material properties are *identical* everywhere.
[4] *Anisotropy* is the condition of having *different properties* in *different directions* (AGI, 1980).

tests performed within boreholes encountering the BDC within the Elder Gulch TSF footprint. The problematic aspect of the seepage pathways in the BDC are illustrated in an analysis of the 24 hydraulic packer tests conducted in eight boreholes advanced to depths of up to 300 feet into the BDC which indicate a general trend of increasing hydraulic conductivity with depth to the maximum depth explored. A hydraulic conductivity of $1x10^{-4}$ cm/sec measured at the deepest test location in boring R-5 at a depth of 301 feet (SHB 1989). **Figure 2** illustrates a trending heterogeneity where K increases with depth at several locations tested below 75 feet to over 300 feet, the maximum depth tested, which is an example of layered heterogeneity defined in the in the preceding discussion. This potential for increased K with depth and uncertain migration pathways for tailings fluid seepage in the BDC make it a less desirable alternative from an environmental seepage control perspective.

In addition to the issue of seepage control in a formation with dipping layered heterogeneity such as the BDC, is the high potential for discontinuous heterogeneity of subsequent increased lateral and vertical cross-connectivity through the network of Tertiary-age normal faults mapped in this unit, such as at the Hackberry Gulch site.

## 3.0 ELDER GULCH INITIAL STUDIES, SEEPAGE MIGRATION

During the initial Elder Gulch studies, a seepage wetted front migration of about 6,000 feet over a time of 25 years was calculated (SHB 1989). While site-specific in-situ hydraulic conductivity testing was not conducted at the Hackberry Gulch site, examination of exposures of the Big Dome Formation in the drainages at the site reveals similar coarse gradations in beds of the conglomerate. The closer proximity of the Hackberry Gulch site to the Gila River than the Elder Gulch TSF presents a challenge to seepage control given the potential for seepage to travel 6,000 feet in 25 years.

Given the estimated design life of the new Ray Mine TSF is over 25 years, and the Hackberry Gulch TSF site is within 4,000 feet of the Gila River, extensive hydrogeologic characterization would be required to evaluate and to design necessary engineering controls. Given the conditions and the uncertainties posed by the geologic and geotechnical conditions at the site described above, these conditions may preclude a positive engineering solution.

## 4.0 SUMMARY

The following Hackberry Gulch site conditions contribute to the potential for seepage:

1. Presence of beds of coarser gradation within the tilted Big Dome Formation Conglomerate that underlies the Hackberry Gulch site could provide lateral and vertical seepage pathways

2. Possible presence of one or more paleo-channels that could be potential avenues of seepage

3. Layered heterogeneity resulting in increased hydraulic connectivity with depth and uncertain migration pathways for tailings fluid seepage in the Big Dome Conglomerate

4. Numerous unnamed faults that have the potential to act as conduits for seepage of tailings fluids into the subsurface

5. High potential for discontinuous heterogeneity of subsequent increased lateral and vertical cross-connectivity through the network of Tertiary-age normal faults

6. Elder Gulch studies of seepage migration travel times suggest that the closer proximity of the Hackberry site to the Gila River presents an even greater challenge to seepage control

## ATTACHMENTS

**Figure 1** – K (cm/s) versus Depth, Elder Gulch Packer Tests in Conglomerate

**Figure 2** – K Summary By Lithology, Elder Gulch Packer Test Results

## 5.0 REFERENCES

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Cornwall, H.R., Banks, N.G. and Phillips, C.H., 1971, *Geologic Map of the Sonora Quadrangle*, *Pinal and Gila counties, Arizona.* US Geological Survey Geologic Quadrangle Map GQ-1021. Map Scale 1:24,000.

Freeze, R.D., and Cherry, J.A., 1979, *Groundwater.* Englewood Cliffs, New Jersey, Prentice-Hall, Inc.

Sergent, Hauskins, & Beckwith (SHB), 1989. Consulting Geotechnical Engineers, *Geotechnical & Hydrogeological Investigation Report, ASARCO Elder Gulch Tailings Facility & Ray Concentrator, Pinal County, Arizona.* Project No. E89-123, Letter No. 31, dated November 15.

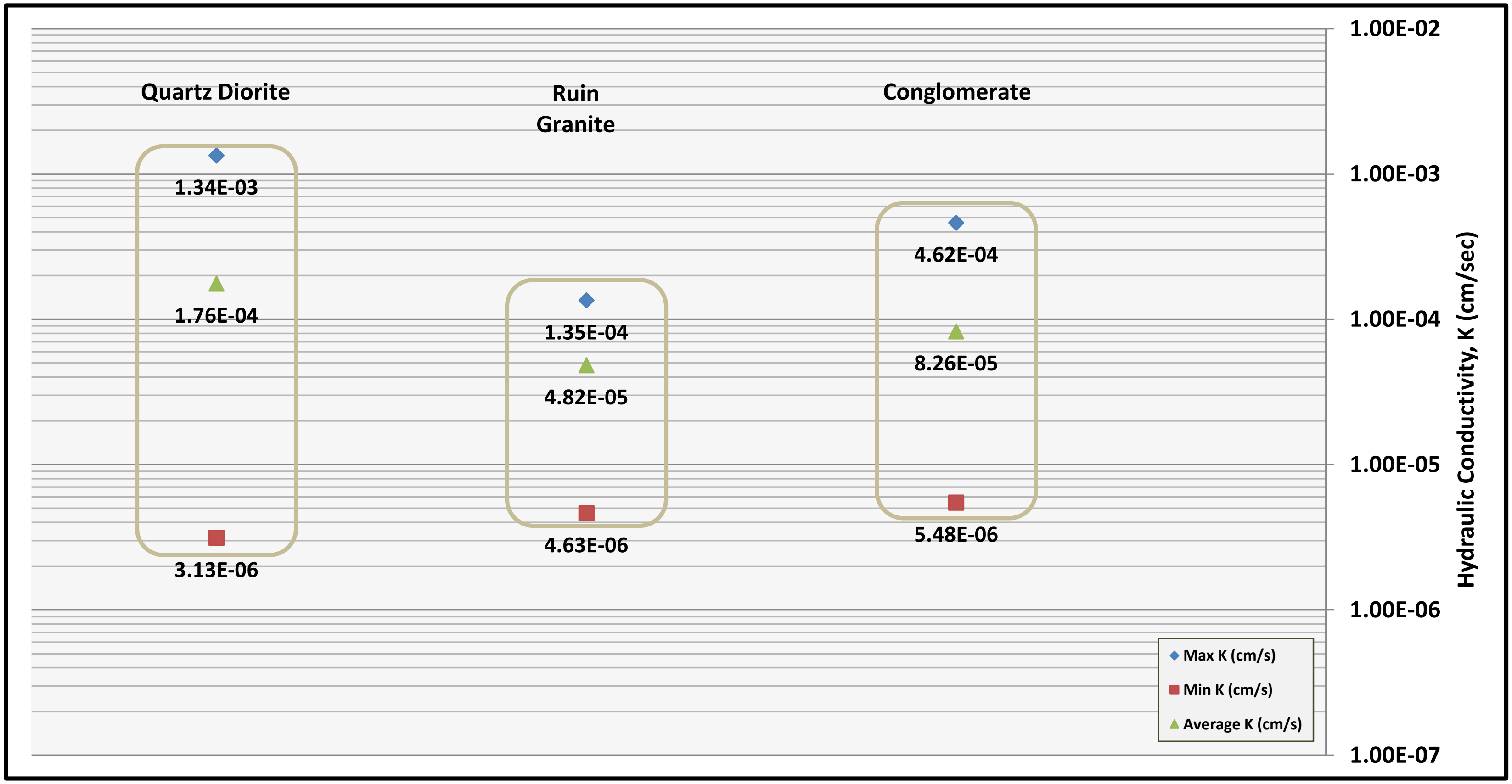
US Army Corps of Engineers (USACE), 2016. *Draft Environmental Impact Statement, Proposed Tailings Storage Facility, Ray Mine - Pinal County, Arizona, File No. SPL-2011-1005-MWL*. Dated January 29, signed by Michael W. Langley.

# ATTACHMENTS

**FIGURE 1 - K Summary by Lithology (Packer Test Results)**

**Packer Tests Results for Elder Gulch - (SHB 1989)**

| Rock Type | Average K (cm/s) | Max K (cm/s) | Min K (cm/s) | No. of Test Results |
|---|---|---|---|---|
| **Conglomerate** | 8.26E-05 | 4.62E-04 | 5.48E-06 | 24 |
| **Ruin Granite** | 4.82E-05 | 1.35E-04 | 4.63E-06 | 7 |
| **Quartz Diorite** | 1.76E-04 | 1.34E-03 | 3.13E-06 | 34 |
| **Combined Results** | 1.28E-04 | 1.34E-03 | 3.13E-06 | 65 |



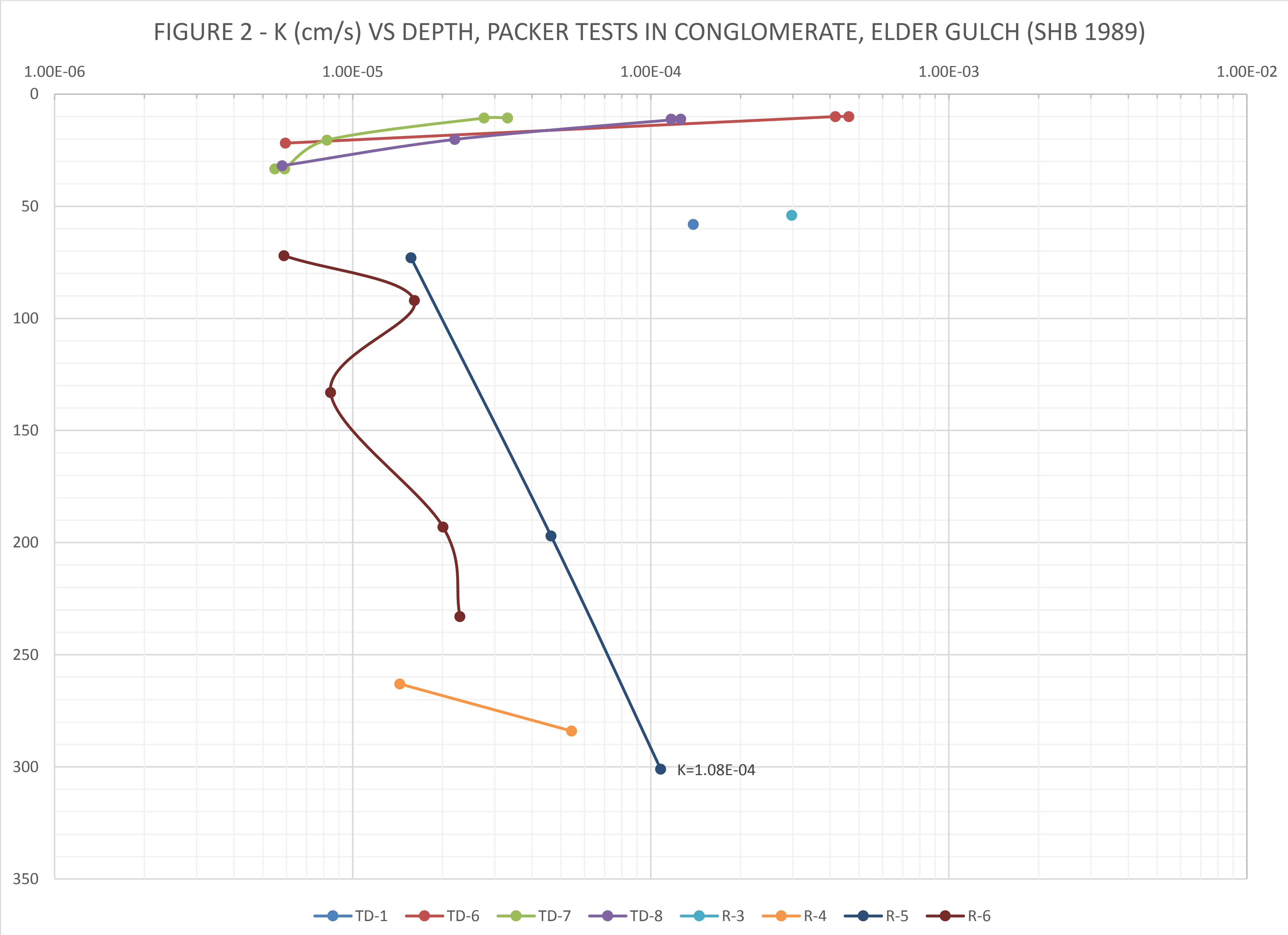


FIGURE 2 - K (cm/s) VS DEPTH, PACKER TESTS IN CONGLOMERATE, ELDER GULCH (SHB 1989)
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-02
0
50
100
150
200
250
300
350
K=1.08E-04
TD-1
TD-6
TD-7
TD-8
R-3
R-4
R-5
R-6

# APPENDIX F

## Ray Mine Tailings Storage Facility Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3 Analysis of Impacts to Proposed and Designated Critical Habitats (Technical Memorandum Prepared by WestLand Resources, Inc.)

# REVISED
# RAY MINE TAILINGS STORAGE FACILITY
# HACKBERRY GULCH ALTERNATIVE 2 AND RIPSEY WASH ALTERNATIVE 3
# ANALYSIS OF IMPACTS TO PROPOSED AND DESIGNATED CRITICAL HABITATS

| | |
|---|---|
| **Prepared for:** | U.S. Army Corps of Engineers |
| **Prepared by:** | WestLand Resources, Inc. |
| **On Behalf of:** | ASARCO LLC |
| **Date:** | November 22, 2017 |
| **Corps File No.:** | SPL-2011-1005-MWL |

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## FIGURES

(*follow text*)

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## APPENDIX

## 1. INTRODUCTION

ASARCO LLC (Asarco) has identified the need for an additional tailings storage facility to support ongoing mining operations at the Ray Mine in Pinal County, Arizona. The construction of a new tailings storage facility and associated infrastructure (the Project) would require the discharge of fill to surface drainage features that have been identified as waters of the United States by the U.S. Army Corps of Engineers.

Screening analyses were conducted by WestLand Resources, Inc. (2014a and b), to determine whether species listed or proposed for listing under the Endangered Species Act or designated or proposed critical habitat occurs within the Hackberry Gulch and Ripsey Wash sites. Two species, the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) and the threatened yellow-billed cuckoo (*Coccyzus americanus*), are known to occur along the Gila River in proximity to the Hackberry Gulch and Ripsey Wash alternatives. In addition, this stretch of the Gila River is designated critical habitat for southwestern willow flycatcher and proposed critical habitat for yellow-billed cuckoo (***Figures 1 and 2***).

This technical memorandum has been prepared to support the 404(b)(1) Alternatives Analysis prepared for the Project. The purpose of this technical memorandum is to provide an analysis of potential impacts to designated critical habitat for southwestern willow flycatcher and proposed yellow-billed cuckoo critical habitat associated with Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3. This analysis does not consider the effects from proposed mitigation activities associated with the Project. The sections below compare the acreage of mapped critical habitat areas impacted by Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3, and consider the presence or absence of the primary constituent elements for southwestern willow flycatcher and yellow-billed cuckoo, as defined by the U.S. Fish and Wildlife Service (USFWS), within those impacted areas.

Primary constituent elements are physical or biological features essential to the conservation of a species for which its designated or proposed critical habitat is based on, such as space for individual and population growth, and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal; and habitats that are protected from disturbance or are representative of the species' historical geographic and ecological distribution (USFWS 2004).

## 2. SOUTHWESTERN WILLOW FLYCATCHER CRITICAL HABITAT

### 2.1. PRIMARY CONSTITUENT ELEMENTS

There are two defined primary constituent elements for the southwestern willow flycatcher: riparian habitat along a dynamic river or lakeside and the presence of suitable insect prey populations (USFWS 2013). These primary constituent elements as defined by USFWS (2014) are provided below:

1) Riparian habitat along a dynamic river or lakeside, in a natural or manmade successional environment (for nesting, foraging, migration, dispersal, and shelter) that is comprised of trees and shrubs (that can include Gooddings willow, coyote willow, Geyer's willow, arroyo willow, red willow, yewleaf willow, pacific willow, boxelder, tamarisk, Russian olive, buttonbush, cottonwood, stinging nettle, alder, velvet

ash, poison hemlock, blackberry, seep willow, oak, rose, sycamore, false indigo, Pacific poison ivy, grape, Virginia creeper, Siberian elm, and walnut) and some combination of:

a) Dense riparian vegetation with thickets of trees and shrubs that can range in height from about 2 to 30 meters (m) (about 6 to 98 feet [ft]). Lower-stature thickets (2 to 4 m or 6 to 13 ft tall) are found at higher-elevation riparian forests and tall-stature thickets are found at middle- and lower-elevation riparian forests;

b) Areas of dense riparian foliage at least from the ground level up to approximately 4 m (13 ft) above ground or dense foliage only at the shrub or tree level as a low, dense canopy;

c) Sites for nesting that contain a dense (about 50 to 100 percent) tree or shrub (or both) canopy (the amount of cover provided by tree and shrub branches measured from the ground);

d) Dense patches of riparian forests that are interspersed with small openings of open water or marsh or areas with shorter and sparser vegetation that creates a variety of habitat that is not uniformly dense. Patch size may be as small as 0.1 hectare (ha) (0.25 acre [ac]) or as large as 70 ha (175 ac).

2) Presence of suitable insect prey populations (USFWS 2013). These include a variety of insect prey populations found within or adjacent to riparian floodplains or moist environments, which can include flying ants, wasps, and bees (Hymenoptera); dragonflies (Odonata); flies (Diptera); true bugs (Hemiptera); beetles (Coleoptera); butterflies, moths, and caterpillars (Lepidoptera); and spittlebugs (Homoptera) (USFWS 2013). It should be noted that USFWS (2013) does not explicitly measure insect prey populations and implicitly concludes that the dense riparian vegetation described in primary constituent element 1 supports suitable insect prey populations that meet primary constituent element 2.

## 2.2. Comparison of Impacts – Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3

Hackberry Gulch Alternative 2 permanently impacts approximately 1.5 ac of designated critical habitat for southwestern willow flycatcher that provide primary constituent elements, while Ripsey Wash Alternative 3 permanently impacts approximately 0.2 ac of this habitat (***Table 1***).

Table 1. Impacts to Mapped Southwestern Willow Flycatcher Designated Critical Habitat, Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3

| Mapped Critical Habitat | Hackberry Gulch Alternative 2 (see Figure 3) | Ripsey Wash Alternative 3 (see Figures 4–6) |
|---|---|---|
| Impacts Within the Gila River Hydroriparian Corridor | The footprint of the stilling basin, a permanent feature within the Gila River hydroriparian corridor, is 1.5 ac.<br>Construction impacts would lead to the temporary loss of additional vegetation surrounding the stilling basin. Riparian vegetation within the construction areas outside the stilling basin footprint is expected to recover. | The placement of the approximately 14-foot-wide pipeline bridge would result in approximately 0.2 ac of permanent impact along the Gila River.<br>Construction impacts would lead to a temporary loss of 110 ft of vegetation upstream from the pipeline resulting in 0.5 ac of temporary impact. Riparian vegetation within the bridge construction area is expected to recover. |
| Impacts Outside the Gila River Hydroriparian Corridor | There are no mapped critical habitat areas within the footprint of Hackberry Gulch Alternative 2 that do not provide primary constituent elements for southwestern willow flycatcher. | Approximately 12.2 ac of mapped critical habitat contain xeroriparian and upland vegetation adjacent to the riparian corridor along the Gila River. These areas do not contain the dense riparian vegetation described by USFWS (2013) as primary constituent element 1 and thus likely do not support the suitable insect prey population contemplated as primary constituent element 2 by USFWS (2013). |

***Figures 3 through 6*** depict the areas within Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3 that impact mapped southwestern willow flycatcher critical habitat and provide aerial imagery within that mapped critical habitat. The dense corridor of riparian vegetation containing salt cedar, cottonwood, and willow along the Gila River provides the primary constituent elements identified for this bird. Areas outside that riparian corridor include upland and xeroriparian vegetation dominated by mesquite and desert broom that either do not support or do not provide the optimal conditions for the primary constituent elements of southwestern willow flycatcher critical habitat.

Primary constituent element 1 (Riparian Vegetation): Areas outside the hydroriparian corridor along the Gila River that contain xeroriparian or upland vegetation neither provide the species composition nor the dense structure identified by the USFWS as primary constituent element 1.

Primary constituent element 2 (Insect Prey Populations): It is expected that xeroriparian and upland vegetation likely provides less insect prey than the hydroriparian zone along the Gila River. The density and vertical structure of the hydroriparian vegetation along the Gila River affect light and temperature, and the presence of surface water along the river affects temperature and moisture availability. This dense vegetation could also act as protection from wind. Because insects are known to respond to temperature, moisture, and wind (Willmer 1982), it is expected that the hydroriparian zone along the Gila River that meets primary constituent element 1 provides more favorable conditions for insects and thus more optimal foraging habitat for southwestern willow flycatcher. As such, the areas outside the hydroriparian zone that do not contain dense riparian vegetation are not likely to contain the suitable prey populations described by USFWS (2013) as primary constituent element 2.

### 2.2.1. Summary of Impacts Associated with Hackberry Gulch Alternative 2

A stilling basin would be placed on the northern bank of the Gila River at its confluence with Belgravia Wash for the discharge of stormwater that would be diverted around the Hackberry Gulch and Elder Gulch facilities (***Appendix A*** and ***Figure 3***). The stilling basin footprint is approximately 1.8 ac along the Gila River, approximately 1.5 ac of which are within mapped critical habitat for southwestern willow flycatcher that supports dense hydroriparian vegetation (meeting the definition for primary constituent element 1). The stilling basin would be about 225 ft wide at its widest point and bank protection would extend along approximately 450 ft of the north bank of the Gila River channel (***Appendix A***). Construction impacts would lead to the temporary loss of additional vegetation surrounding the stilling basin. Riparian vegetation within the construction areas outside the stilling basin footprint would be expected to recover.

The remaining activities, including the construction of the tailings storage facility, would occur outside critical habitat for southwestern willow flycatcher.

### 2.2.2. Summary of Impacts Associated with Ripsey Wash Alternative 3

A proposed pipeline bridge will cross the Gila River and pass through designated critical habitat for the southwestern willow flycatcher (***Figure 4***). The construction of the pipeline bridge would require vegetation clearing within approximately 0.7 ac. The placement of the approximately 14-ft-wide pipeline bridge would result in approximately 0.2 ac of permanent impact along the Gila River (WestLand 2015). Construction impacts would lead to a temporary loss of 110 ft of vegetation upstream from the pipeline (0.5 ac). Riparian vegetation within the bridge construction area is expected to recover. The proposed pipeline bridge is planned for construction after the planned construction of a new highway bridge for the Florence-Kelvin Highway proposed by the Arizona Department of Transportation (ADOT) and Pinal County, and a portion of the pipeline bridge construction area would overlap with approximately 0.3 ac previously disturbed by the new highway bridge construction (***Figure 4***).

Approximately 5.8 ac of impact to mapped critical habitat north of the Copper Basin Railway and east of the proposed drain down pond, pump station, and electrical switchgear would be impacted by Project activities (***Figure 5***). This area is dominated by velvet mesquite and other upland plant species, and it does not provide the dense shrub and/or tree cover described as primary constituent element 1 (***Figure 5***). In addition, this upland vegetation is likely to provide less insect prey primary constituent element 2 (Insect Prey Populations) than the hydroriparian zone adjacent to the Gila River.

There will also be impacts to mapped critical habitat with the construction of the pipeline bridge, relocation of the Florence-Kelvin Highway, relocation of the San Carlos Irrigation Project (SCIP) power line, and construction of the seepage collection system near the confluence of Ripsey Wash and the Gila River (***Figure 6***). However, the approximately 6.4 ac shown as mapped critical habitat in this area are dominated by velvet mesquite, desert broom, and other xeroriparian plant species (***Figure 6***). There is no mesoriparian or hydroriparian vegetation in this area, and the vegetation that is present is not the dense riparian vegetation described by USFWS (2013) as primary constituent element 1. As such, the vegetation that is present is unlikely to support the insect prey populations described as primary constituent element 2 (Insect Prey Populations).

The remainder of Ripsey Wash Alternative 3, including the construction of the tailings storage facility, would occur outside critical habitat for southwestern willow flycatcher.

# 3. YELLOW-BILLED CUCKOO PROPOSED CRITICAL HABITAT

## 3.1. PRIMARY CONSTITUENT ELEMENTS

There are three defined primary constituent elements for the yellow-billed cuckoo: the presence of suitable riparian woodlands, the presence of suitable large insect populations, and dynamic riverine processes (USFWS 2014). These primary constituent elements as defined by USFWS (2014) are provided below:

1) Riparian woodlands with mixed willow-cottonwood vegetation, mesquite-thorn forest vegetation, or a combination of these that contain habitat for nesting and foraging in contiguous or nearly contiguous patches that are greater than 325 ft (100 m) in width and 200 ac (81 ha) or more in extent. These habitat patches contain one or more nesting groves, which are generally willow dominated, have above-average canopy closure (greater than 70 percent), and have a cooler, more humid environment than the surrounding riparian and upland habitats.

2) Presence of a prey base consisting of large insect fauna (e.g., cicadas, caterpillars, katydids, grasshoppers, large beetles, dragonflies) and tree frogs for adults and young in breeding areas during the nesting season and in post-breeding dispersal areas.

3) River systems that are dynamic and provide hydrologic processes that encourage sediment movement and deposits that allow seedling germination and promote plant growth, maintenance, health, and vigor (e.g., lower-gradient streams and broad floodplains, elevated subsurface groundwater table, and perennial rivers and streams).

It is important to note that USFWS (2014) mapped proposed critical habitat using only primary constituent element 1, implicitly concluding that the other primary constituent elements were present in the areas mapped. As such, we focus our discussion below on primary constituent element 1.

## 3.2. COMPARISON OF IMPACTS – HACKBERRY GULCH ALTERNATIVE 2 AND RIPSEY WASH ALTERNATIVE 3

Hackberry Gulch Alternative 2 permanently impacts approximately 1.5 ac of proposed critical habitat for yellow-billed cuckoo that provide primary constituent elements, while Ripsey Wash Alternative 3 permanently impacts approximately 0.2 ac of this habitat (***Table 2***).

Table 2. Impacts to Mapped Yellow-billed Cuckoo Proposed Critical Habitat, Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3

| Mapped Critical Habitat | Hackberry Gulch Alternative 2 (see Figure 7) | Ripsey Wash Alternative 3 (see Figures 8–10) |
|---|---|---|
| Impacts Within the Gila River Hydroriparian Corridor | The footprint of the stilling basin, a permanent feature within the Gila River hydroriparian corridor, is 1.5 ac.<br><br>Additional temporary impacts to vegetation surrounding the stilling basin would occur during construction. | The placement of the approximately 14-ft-wide pipeline bridge would result in approximately 0.2 ac of permanent impact along the Gila River.<br><br>Construction impacts would lead to a temporary loss of 110 ft of vegetation upstream from the pipeline (0.5 ac). Riparian vegetation within the bridge construction area is expected to recover. |
| Impacts Outside the Gila River Hydroriparian Corridor | A 0.1-ac portion of the stilling basin occurs within mapped habitat that does not support or does not provide the optimal conditions for the primary constituent elements for this species. | Approximately 3.6 ac of mapped critical habitat contain xeroriparian and upland vegetation adjacent to the riparian corridor along the Gila River. These areas do not contain dense riparian vegetation and thus likely do provide the dense, contiguous riparian woodland described by USFWS (2014) as primary constituent element 1. |

***Figures 7 through 9*** depict the areas within Hackberry Gulch Alternative 2 and Ripsey Wash Alternative 3 that impact mapped proposed yellow-billed cuckoo critical habitat and provide aerial imagery within that mapped critical habitat. The dense corridor of riparian vegetation containing salt cedar, cottonwood, and willow along the Gila River provides the primary constituent elements identified for this bird. Areas outside that riparian corridor include upland and xeroriparian vegetation dominated by mesquite and desert broom that do not provide the broad riparian woodlands identified as primary constituent element 1 of yellow-billed cuckoo proposed critical habitat.

Primary constituent element 1 (Riparian Woodlands): The riparian woodland primary constituent element is described as willow-cottonwood vegetation, mesquite-thorn forest vegetation, or a combination of these types that contains habitat for nesting and foraging in contiguous or nearly contiguous patches greater than 325 ft in width and greater than 200 ac in extent. Areas outside the hydroriparian corridor along the Gila River that contain xeroriparian or upland vegetation may provide foraging habitat, but they do not appear to contain the contiguous, dense, riparian woodland identified as primary constituent element 1.

Primary constituent element 2 (Insect Prey Base): The insect prey base primary constituent element includes large caterpillars, cicadas, katydids, large beetles, and dragonflies. It is expected that xeroriparian and upland vegetation likely provides less insect prey than the hydroriparian zone along the Gila River. The density and vertical structure of the hydroriparian vegetation along the Gila River affect light and temperature, and the presence of surface water along the river affects temperature and moisture availability. This dense vegetation could also act as protection from wind. Because insects are known to respond to temperature, moisture, and wind (Willmer 1982), it is expected that the hydroriparian zone along the Gila River provides more favorable conditions for insects and thus more optimal foraging habitat for yellow-billed cuckoo. It is possible that yellow-billed cuckoo forage in the upland and xeroriparian areas that are mapped as proposed critical habitat, but these areas are not expected to provide the same amount of prey that occurs immediately along the river in the dense, broad riparian woodlands identified as primary constituent element 1.

Primary constituent element 3 (Dynamic River Systems): The dynamic riverine process primary constituent element includes those hydrologic processes that encourage sediment movement and deposition, allow seedling germination, and promote plant growth, maintenance, health, and vigor. These processes are typically present in low-gradient streams with broad floodplains, an elevated subsurface water table, and perennial surface flow (USFWS 2014). The areas outside the hydroriparian corridor along the Gila River that contain upland vegetation and the xeroriparian areas within Ripsey Wash do not provide perennial surface flow and thus do not meet the criteria described by the USFWS for primary constituent element 3.

### 3.2.1. Summary of Impacts Associated with Hackberry Gulch Alternative 2

A stilling basin would be placed on the northern bank of the Gila River at its confluence with Belgravia Wash for the discharge of stormwater that would be diverted around the Hackberry Gulch and Elder Gulch facilities (***Appendix A*** and ***Figure 3***). The stilling basin footprint is approximately 1.8 ac along the Gila River, approximately 1.5 ac of which are within the Gila River hydroriparian corridor and approximately 0.1 ac is outside that corridor. The stilling basin would be about 225 ft wide at its widest point and bank protection would extend along approximately 450 ft of the north bank of the Gila River channel (***Appendix A***). Construction impacts would lead to the temporary loss of additional vegetation surrounding the stilling basin. Riparian vegetation within the construction areas outside the stilling basin footprint is expected to recover.

The remainder of Hackberry Gulch Alternative 2, including the construction of the tailings storage facility, would occur outside proposed critical habitat for yellow-billed cuckoo.

### 3.2.2. Summary of Impacts Associated with Ripsey Wash Alternative 3

The pipeline bridge will cross the Gila River and pass through proposed critical habitat for the yellow-billed cuckoo (***Figure 8***). The construction of the pipeline bridge would likely require surface disturbance on both sides of the river within approximately 0.7 ac. Construction impacts would lead to a temporary loss of habitat along approximately 110 ft of proposed critical habitat. Riparian vegetation within the bridge construction area is expected to recover. As stated above, approximately 0.3 ac within the pipeline bridge construction corridor would be previously disturbed from the planned construction of a new highway bridge for the Florence-Kelvin Highway proposed by ADOT and Pinal County that would be located immediately downstream from the Project pipeline bridge.

Approximately 3.6 ac of mapped proposed critical habitat would be impacted by the Florence-Kelvin Highway relocation, SCIP power line relocation, and seepage collection system in Ripsey Wash. However, this area is dominated by velvet mesquite, desert broom, and other xeroriparian plant species; there is no mesoriparian or hydroriparian vegetation (***Figure 9***); and it does not contain the dense, contiguous riparian vegetation described as primary constituent element 1.

The remainder of Ripsey Wash Alternative 3, including the construction of the tailings storage facility, would occur outside proposed critical habitat for yellow-billed cuckoo.

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# FIGURES

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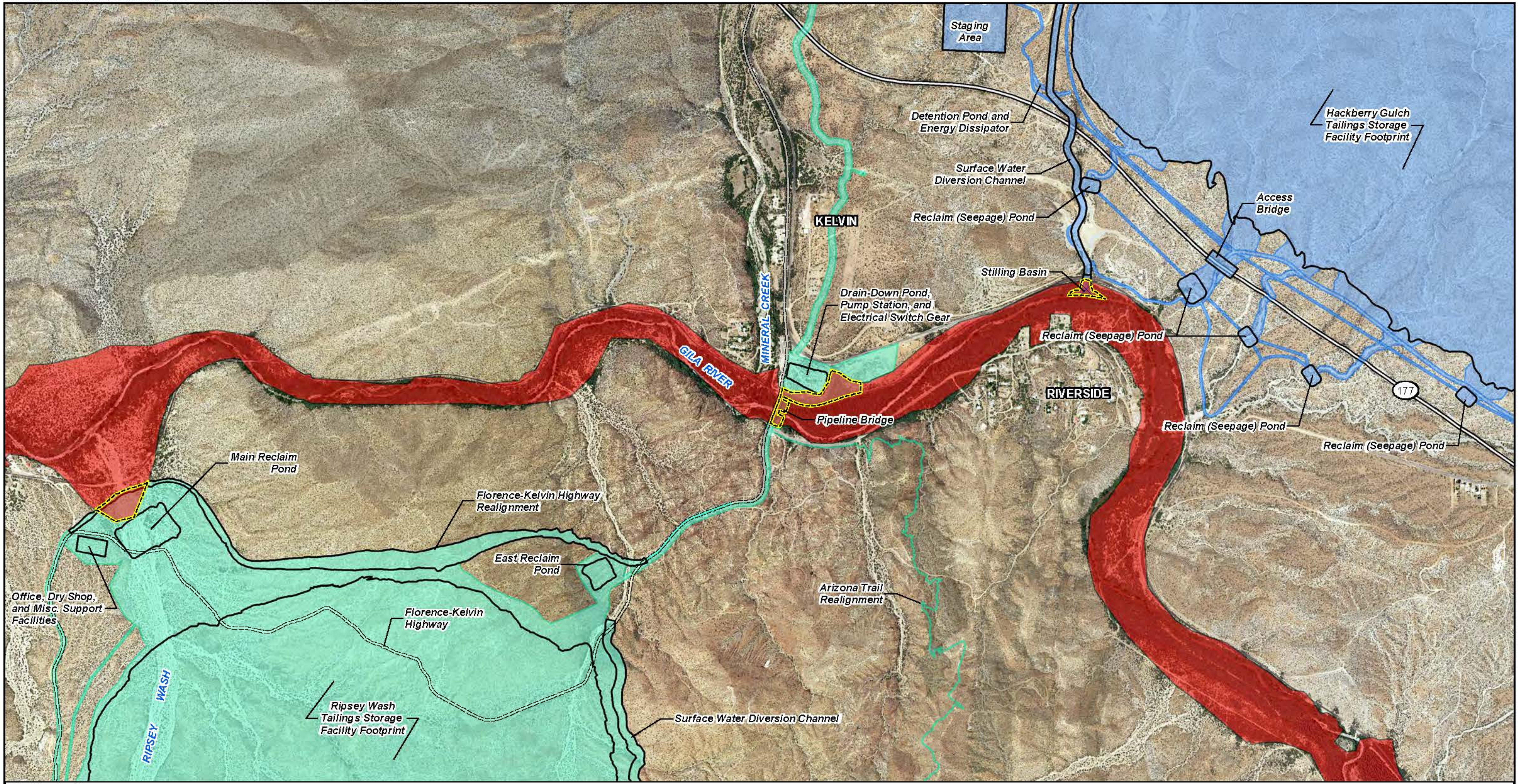


Pinal County, Arizona
Image Source: National Agricultural Imagery Program (NAIP)
Image Date: 2015 USDA NAIP Orthophoto

Southwestern Willow Flycatcher Final Critical Habitat:
Provided by U.S. Fish and Wildlife
Publication Date: Jan-3-2013
Effective Date: Feb-4-2013

WestLand Resources

N

0 750 1,500 Feet

**LEGEND**

- Southwestern Willow Flycatcher Critical Habitat as Mapped by U.S. Fish and Wildlife Service
- Mapped Critical Habitat Impacted by Surface Disturbance
- Ripsey Wash Alternative 3 Surface Disturbance
- Hackberry Gulch Alternative 2 Surface Disturbance

**ASARCO LLC**

Ray Mine Tailings Storage Facility
Analysis of Critical Habitat Impacts

Overview of Mapped Southwestern Willow Flycatcher Critical Habitat
Figure 1

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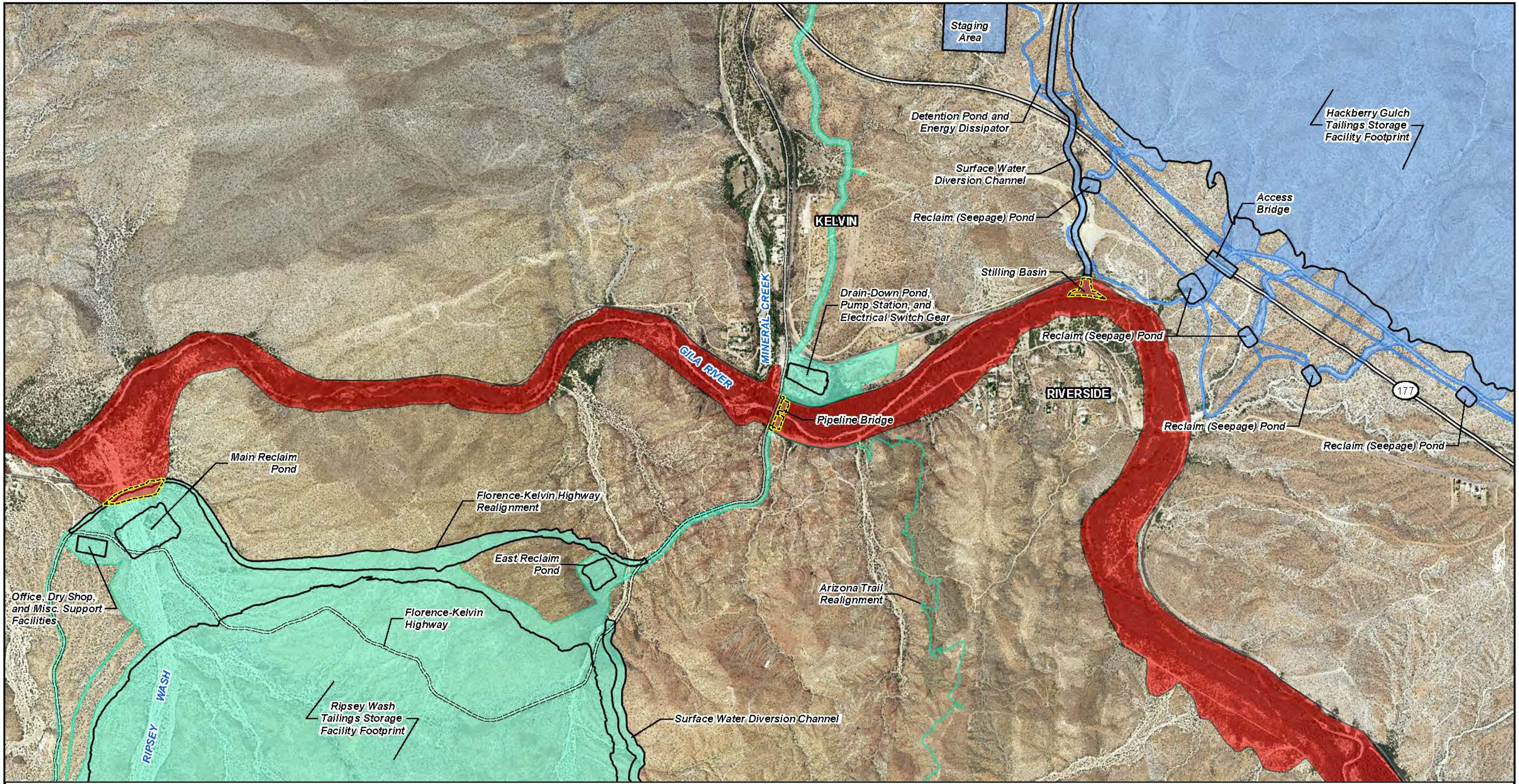


Pinal County, Arizona
Image Source: National Agricultural Imagery Program (NAIP)
Image Date: 2015 USDA NAIP Orthophoto

**LEGEND**

- Yellow-Billed Cuckoo Proposed Critical Habitat as Mapped by U.S. Fish and Wildlife Service
- Mapped Proposed Critical Habitat Impacted by Surface Disturbance
- Ripsey Wash Alternative 3 Surface Disturbance
- Hackberry Gulch Alternative 2 Surface Disturbance

WestLand Resources

Yellow-Billed Cuckoo Proposed Critical Habitat:
Provided by U.S. Fish and Wildlife
Publication Date: Aug-15-2014

N

0 750 1,500 Feet

**ASARCO LLC**

Ray Mine Tailings Storage Facility
Analysis of Critical Habitat Impacts

**Overview of Mapped Proposed Yellow-Billed Cuckoo Critical Habitat**

**Figure 2**

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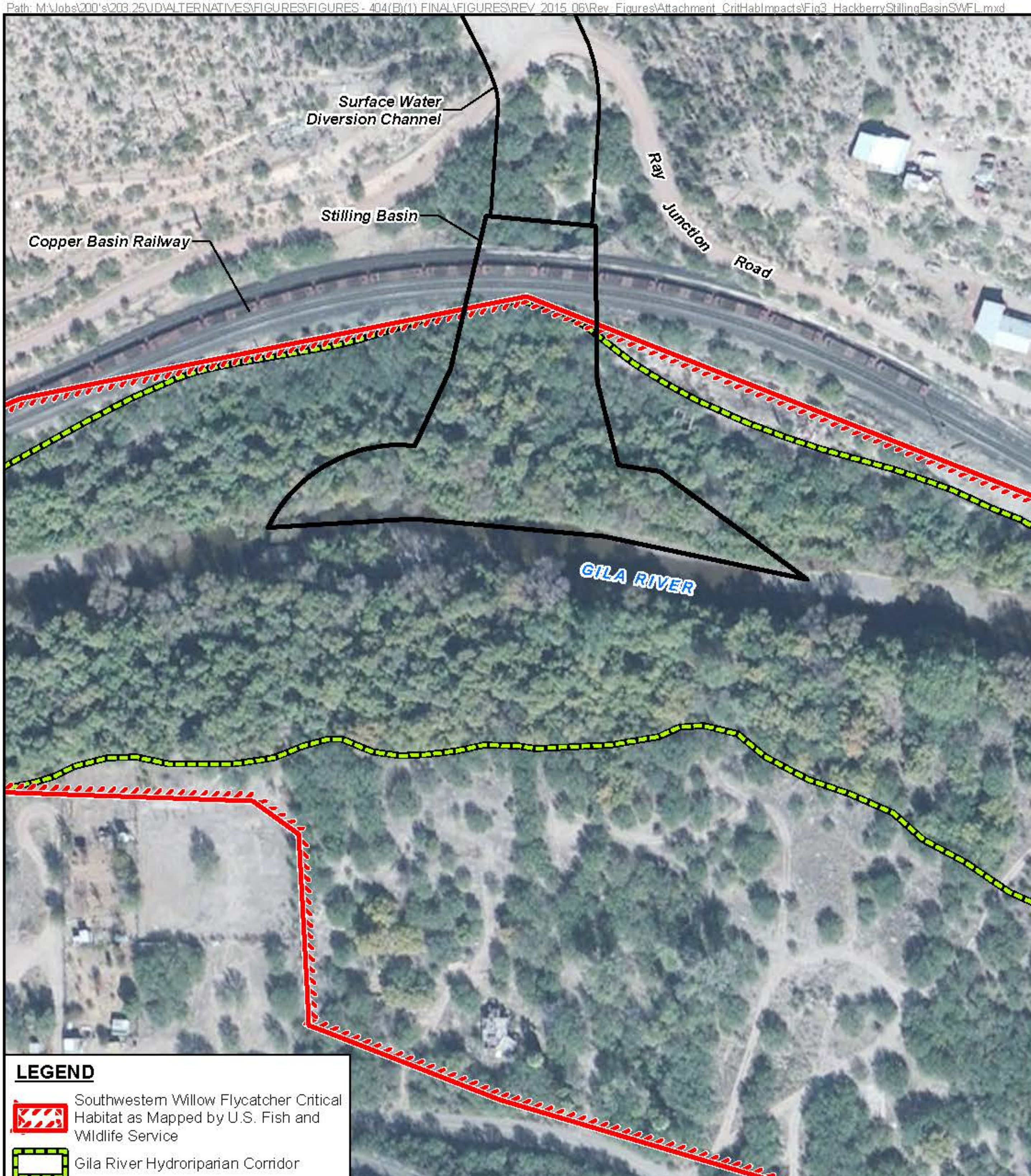


Pinal County, Arizona
Image Source: National Agricultural Imagery Program (NAIP)
Image Date: June-8-2013

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Tucson, Arizona 85712 (520) 206-9585

Southwestern Willow Flycatcher
Final Critical Habitat:
Provided by U.S. Fish and Wildlife
Publication Date: Jan-3-2013
Effective Date: Feb-4-2013

N
0 75 150 Feet

**ASARCO LLC**
Ray Mine Tailings Storage Facility
Analysis of Critical Habitat Impacts

**Hackberry Gulch Alternative Stilling Basin and Mapped Southwestern Willow Flycatcher Critical Habitat**
**Figure 3**

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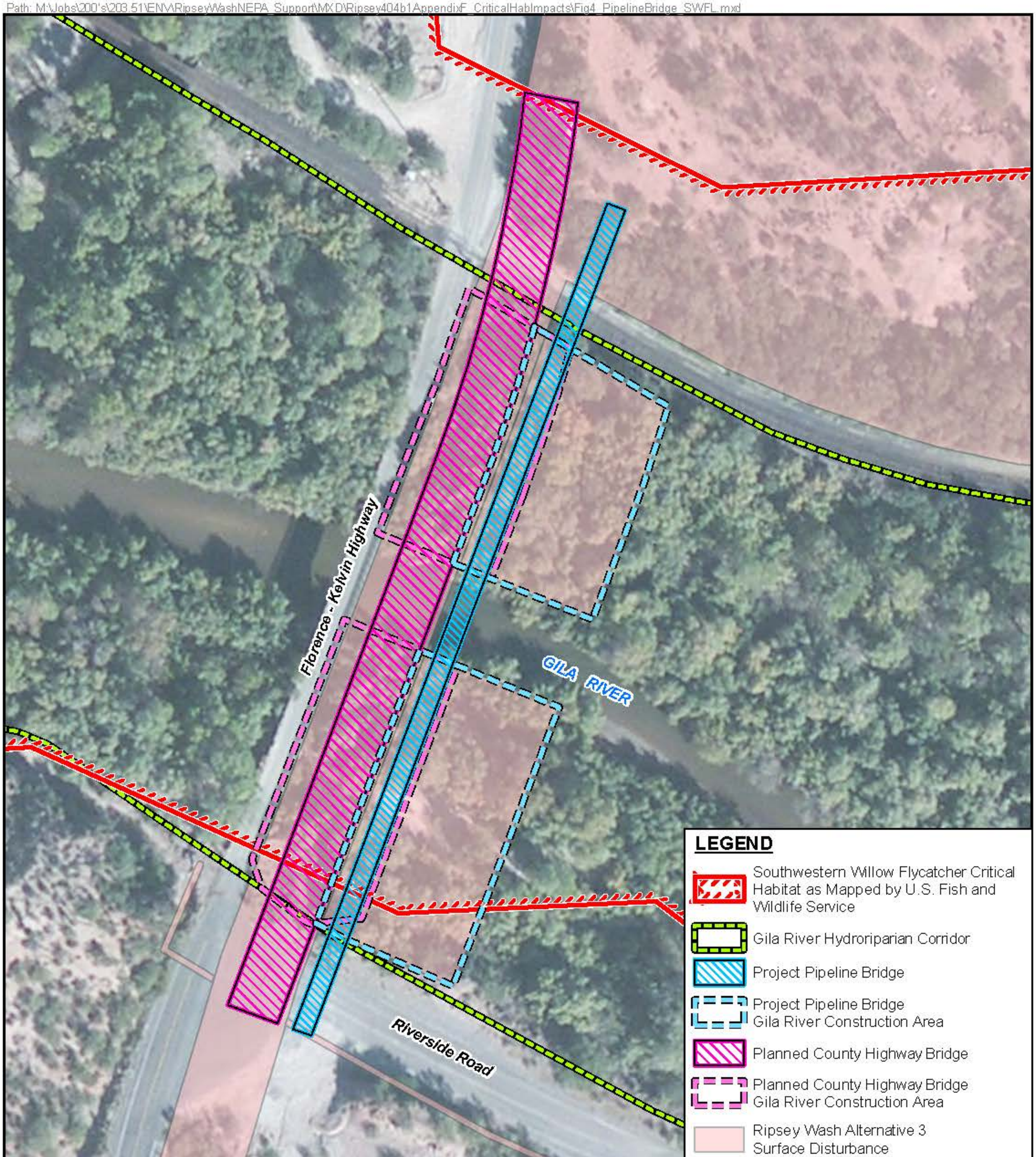


Pinal County, Arizona
Image Source: ESRI Online World Imagery
Image Date: November 1, 2010
Planned County Highway based on ADOT State Highway Florence-Kelvin Highway BR-PPN-0(169)A, 60% Design Submittal dated July 2013
Pipeline Bridge Linework Provided by AMEC.

WestLand Resources

Southwestern Willow Flycatcher
Final Critical Habitat:
Provided by U.S. Fish and Wildlife
Publication Date: Jan-3-2013
Effective Date: Feb-4-2013

N
0 50 100 Feet

**ASARCO LLC**

Ray Mine Tailings Storage Facility
Analysis of Critical Habitat Impacts

**Ripsey Wash Tailings Delivery and Reclaim Water Pipeline Bridge and Mapped Southwestern Willow Flycatcher Critical Habitat**

**Figure 4**

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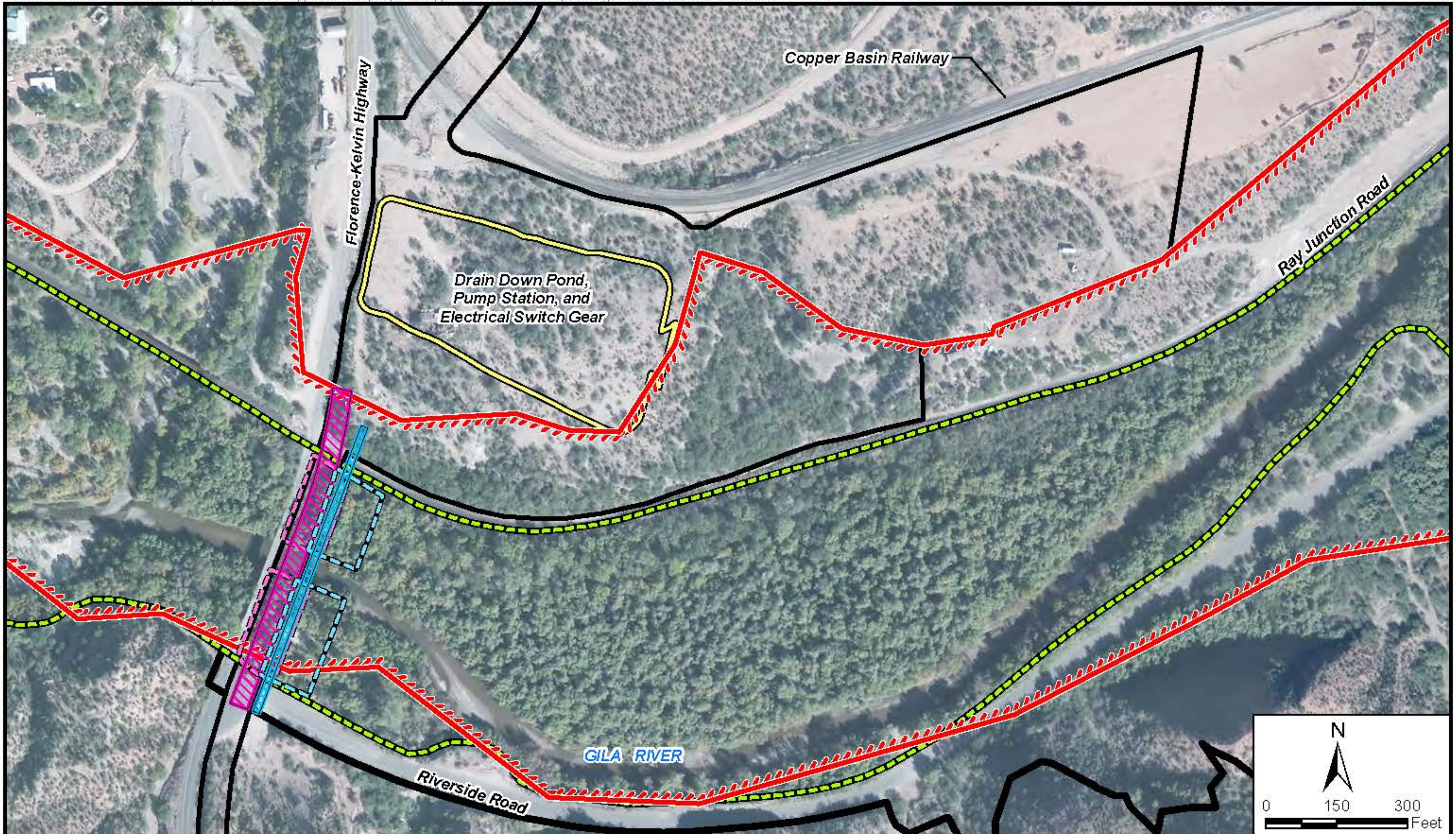


Pinal County, Arizona
Image Source: ESRI Online World Imagery
Image Date: November 1, 2010
Southwestern Willow Flycatcher
Final Critical Habitat:
Provided by U.S. Fish and Wildlife
Publication Date: Jan-3-2013
Effective Date: Feb-4-2013

WestLand Resources

**LEGEND**

- Southwestern Willow Flycatcher Critical Habitat as Mapped by U.S. Fish and Wildlife Service
- Gila River Hydroriparian Corridor
- Surface Disturbance Associated with Drain Down Pond and Pipeline Infrastructure
- Project Pipeline Bridge
- Project Pipeline Bridge Gila River Construction Area
- Planned County Highway Bridge
- Planned County Highway Bridge Gila River Construction Area

**ASARCO LLC**

Ray Mine Tailings Storage Facility
Analysis of Critical Habitat Impacts

**Ripsey Wash Drain Down Pond and Pipeline Infrastructure and Mapped Southwestern Willow Flycatcher Critical Habitat**

**Figure 5**

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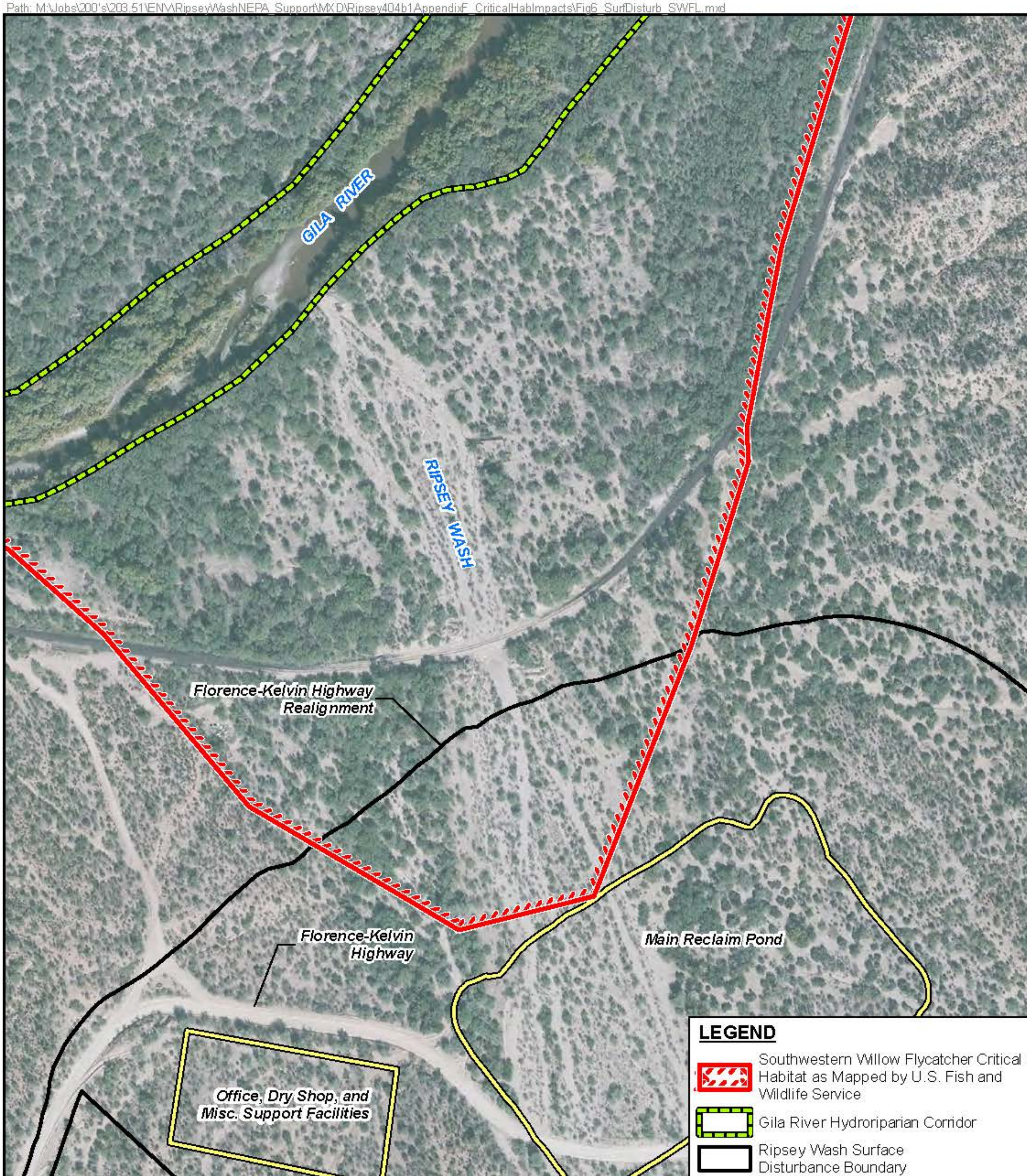



Pinal County, Arizona
Image Source: ESRI Online World Imagery
Image Date: November 1, 2010

WestLand Resources

Southwestern Willow Flycatcher
Final Critical Habitat:
Provided by U.S. Fish and Wildlife
Publication Date: Jan-3-2013
Effective Date: Feb-4-2013

N

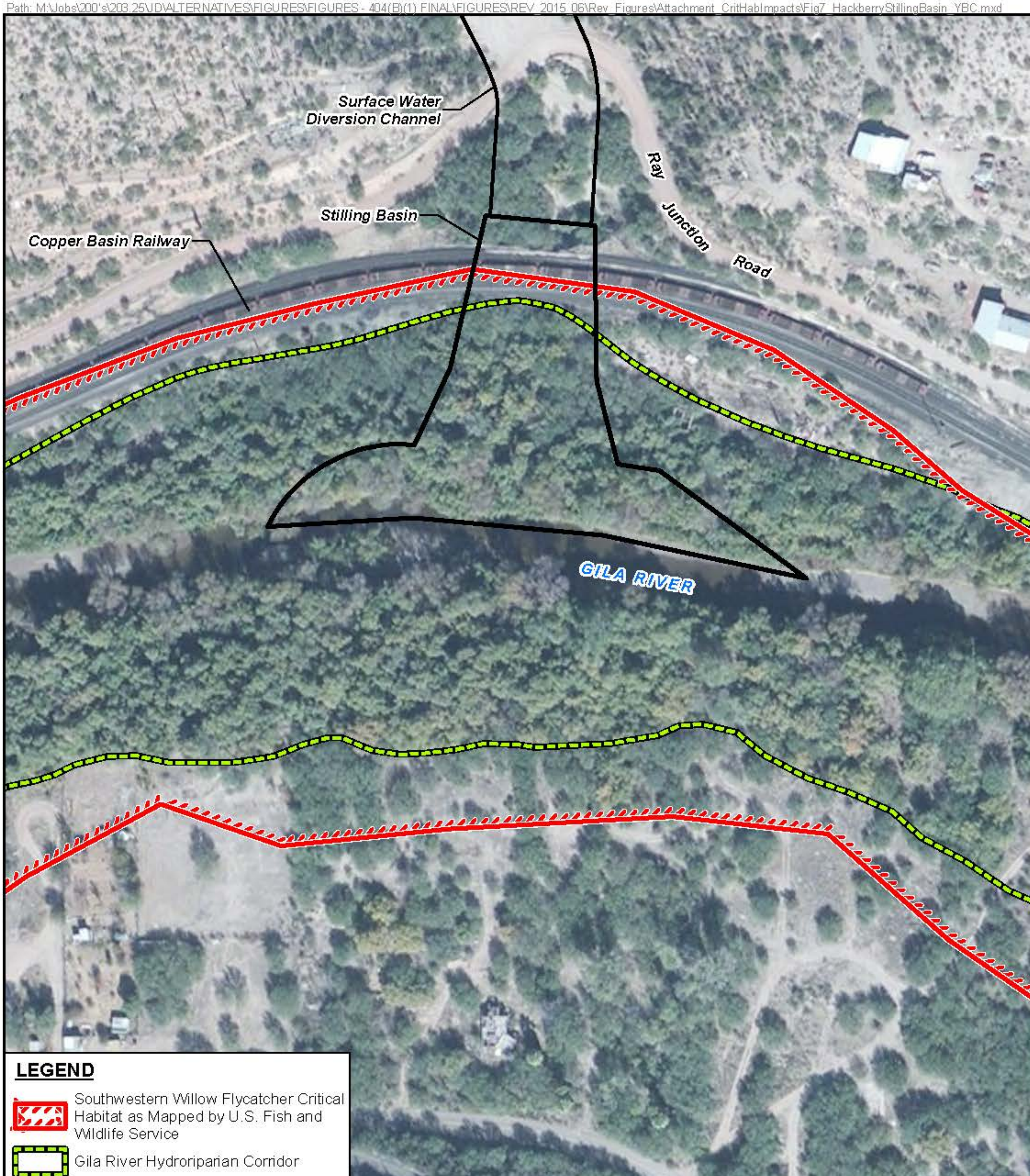
0 150 300 Feet

**ASARCO LLC**

Ray Mine Tailings Storage Facility
Analysis of Critical Habitat Impacts

**Ripsey Wash Alternative 3**
**Surface Disturbance in Ripsey Wash and Mapped Southwestern Willow Flycatcher Critical Habitat**
**Figure 6**

Path: M:\Jobs\200's\203.25\JD\ALTERNATIVES\FIGURES\FIGURES - 404(B)(1) FINAL\FIGURES\REV_2015_06\Rev_Figures\Attachment_CritHabImpacts\Fig7_HackberryStillingBasin_YBC.mxd




Pinal County, Arizona
Image Source: National Agricultural Imagery Program (NAIP)
Image Date: June-8-2013

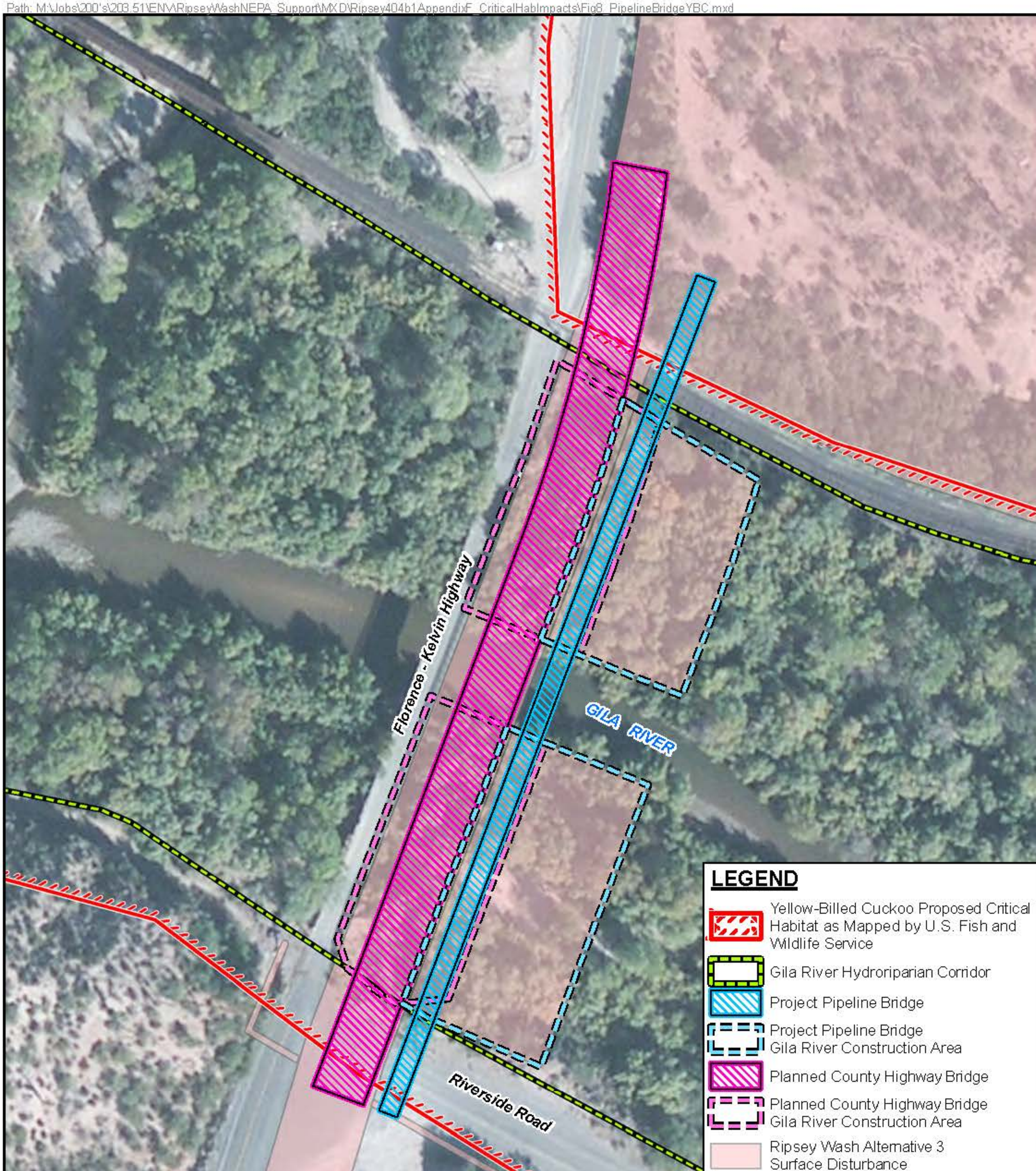
WestLand Resources, Inc.
Tucson • Phoenix • Flagstaff
4001 E. Paradise Falls Drive
Tucson, Arizona 85712 (520) 206-9585

Southwestern Willow Flycatcher
Final Critical Habitat:
Provided by U.S. Fish and Wildlife
Publication Date: Jan-3-2013
Effective Date: Feb-4-2013

**ASARCO LLC**
Ray Mine Tailings Storage Facility
Analysis of Critical Habitat Impacts

**Hackberry Gulch Alternative Stilling Basin and Mapped Yellow-Billed Cuckoo Proposed Critical Habitat**
**Figure 7**

Path: M:\Jobs\200's\203.51\ENV\RipseyWashNEPA_Support\MXD\Ripsey404b1AppendixF_CriticalHabImpacts\Fig8_PipelineBridgeYBC.mxd




Pinal County, Arizona
Image Source: ESRI Online World Imagery
Image Date: November 1, 2010
Planned County Highway based on ADOT State Highway Florence-Kelvin Highway BR-PPN-0(169)A, 60% Design Submittal dated July 2013
Pipeline Bridge Linework Provided by AMEC.

WestLand Resources

Yellow-Billed Cuckoo
Proposed Critical Habitat:
Provided by U.S. Fish and Wildlife
Publication Date: Aug-15-2014

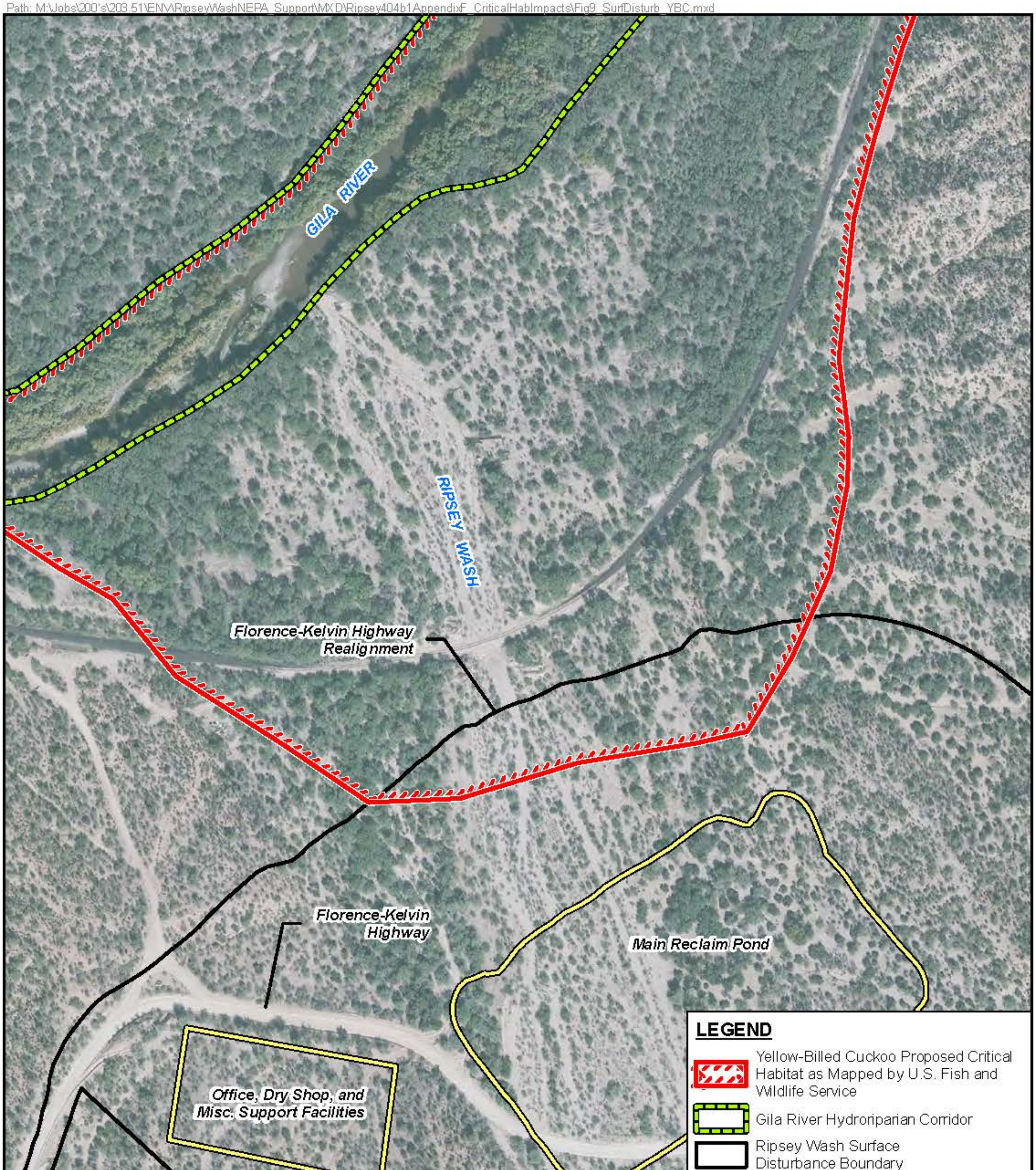
N

0 50 100 Feet

**ASARCO LLC**
Ray Mine Tailings Storage Facility
Analysis of Critical Habitat Impacts

**Ripsey Wash Tailings Delivery and Reclaim Water Pipeline Bridge and Mapped Yellow-Billed Cuckoo Proposed Critical Habitat**
**Figure 8**

Path: M:\Jobs\200's\203.51\ENV\RipseyWashNEPA_Support\MXD\Ripsey404b1AppendixF_CriticalHabImpacts\Fig9_SurfDisturb_YBC.mxd




Pinal County, Arizona
Image Source: ESRI Online World Imagery
Image Date: November 1, 2010

WestLand Resources

Yellow-Billed Cuckoo
Proposed Critical Habitat:
Provided by U.S. Fish and Wildlife
Publication Date: Aug-15-2014

N

0 150 300 Feet

**ASARCO LLC**

Ray Mine Tailings Storage Facility
Analysis of Critical Habitat Impacts

**Ripsey Wash Alternative 3**
**Surface Disturbance in Ripsey Wash**
**and Mapped Yellow-Billed Cuckoo**
**Proposed Critical Habitat**
**Figure 9**

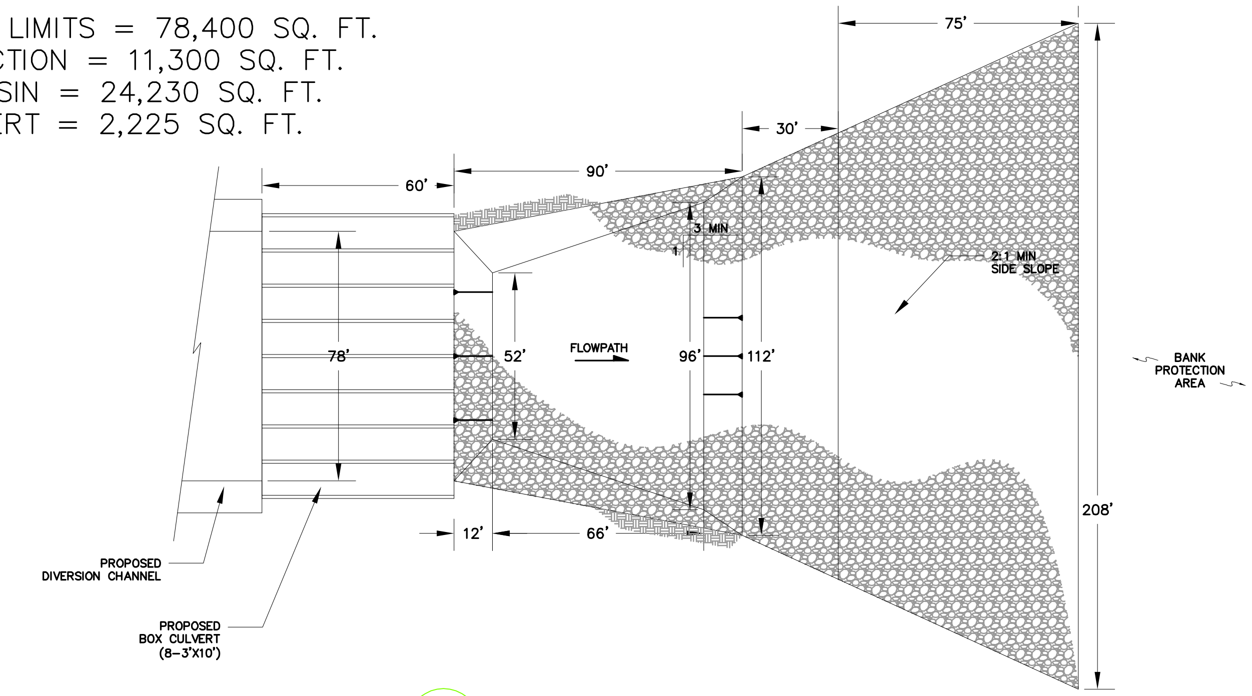
# APPENDIX A

## BELGRAVIA WASH
## STILLING BASIN EXHIBIT

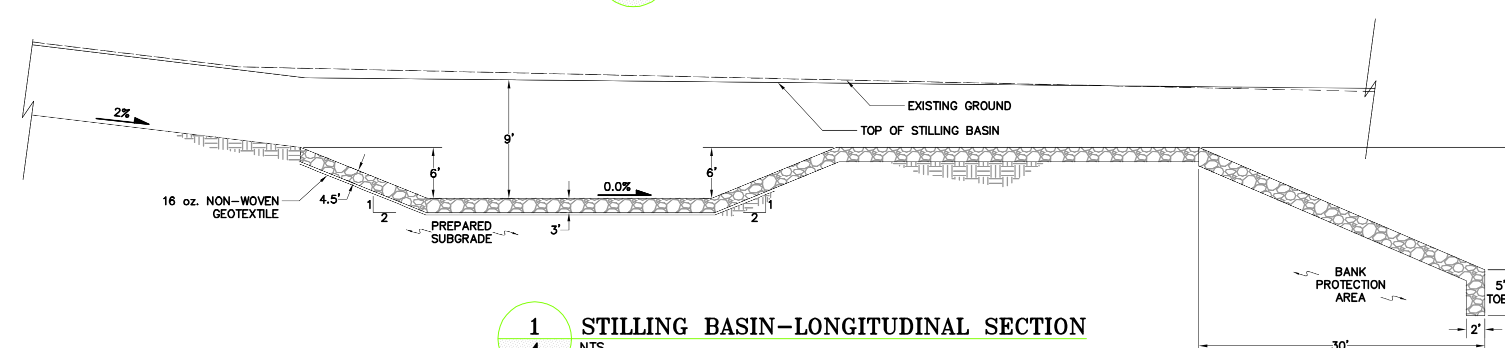
S:\CAD\1443 - Ripsey Wash\cadd\cadd drawings\1443-F013-Ripsey Wash Stilling Basin Exhibit TEST.dwg-4/14/2015 1:44 PM


## SUMMARY

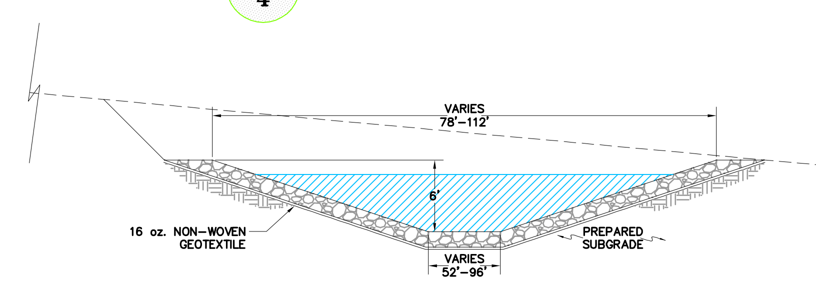
CLEAR & GRUB LIMITS = 78,400 SQ. FT.
BANK PROTECTION = 11,300 SQ. FT.
STILLING BASIN = 24,230 SQ. FT.
BOX CULVERT = 2,225 SQ. FT.




E/1 RIPRAP STILLING BASIN-PLAN
NTS




1/4 STILLING BASIN-LONGITUDINAL SECTION
NTS




2/4 STILLING BASIN-TRANSVERSE SECTION
NTS

50 0 50 100 FT
1" = 50"

| 04/14/15 | ISSUED FOR..... | RW |
|---|---|---|

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CLIENT: ASARCO, LLC.

PROJECT: TAILING DISPOSAL PROJECT

TITLE: BELGRAVIA WASH STILLING BASIN EXHIBIT

| DESIGNED BY | YX | CHECKED BY | TF | ISSUED FOR |
|---|---|---|---|---|
| DRAWN BY | RW | APPROVED BY | | DRAFT |
| FILENAME: StillingBasinExhibit | DRAWING No. 1 | REV A | PROJECT NO. 74-2014-4300 | |

amec foster wheeler