

#### **4.0 IDENTIFICATION AND SCREENING OF RESTORATION APPROACHES**

The identification of restoration approaches is intentionally limited to primary restoration of the impaired resources of the 11-Mile Reach (i.e., physical actions to improve conditions within the boundaries of the 11-Mile Reach). Approaches that potentially involve actions outside of the 11-Mile Reach, such as acquisition or replacement, have not been considered. The information on primary restoration alternatives, including relative costs, presented in the RAR could be used as a basis for evaluating those alternative approaches. However, acquisition or replacement alternatives are best considered jointly by the MOUP and various stakeholders of the UARB. Approaches for restoration of resources within the 11-Mile Reach have been identified by the Resource Categories presented in Section 3. The Resource Categories with identified restoration needs include:

- Fluvial Mine-Waste Deposits;
- Agricultural/Floodplain Lands;
- Channel Morphology/In-Stream Habitat; and
- Riparian Areas.

A hierarchical approach was utilized for the identification of specific types of actions to be considered for restoration alternatives development. For each Resource Category identified as needing restoration, General Response Actions were selected for consideration. General Response Actions reflect a broad category of restoration measures that should be considered (e.g., Institutional Controls). For a given General Response Action, Restoration Technology options were identified for consideration. Restoration Technologies identify the types of technical approaches available for a given Response Action Category. For example, for the Riparian Areas, General Response Action of Streambank Restoration, the Restoration Technology of Bioengineering/Soft Treatments was identified. For each Restoration Technology, a list of specific Process Options was then identified for screening. Process Options are the specific restoration actions that apply to a Restoration Technology (e.g., fencing is a Process Option for the Grazing Control Restoration Technology).

The restoration needs categories of Riparian Areas and Channel Morphology/In-Stream Habitat are closely related and thus contain Technologies that are applicable to both categories. In particular, Streambank Stabilization Technologies provide benefits specific to Riparian Areas as well as Channel Morphology/In-Stream Habitat. However, this overlap is appropriate at the screening level to assure that an acceptable set of actions is identified, to address the varying conditions along the 11-Mile Reach.

The range of Process Options for each Resource Category has been identified utilizing the following sources:

- Feasibility Studies or comparable reports for individual OUs within the California Gulch Superfund Site: OU4-Upper California Gulch (Shepard Miller, Inc. [SMI]/Terra Matrix 1998); OU5-Smelter Sites (MFG 2000b); OU6-Stray Horse Gulch (HDR 2002); OU7-Apache Tailings Impoundments (MFG 2000a); OU8-Lower California Gulch (SMI/Terra Matrix 1997b); and OU-10 Oregon Gulch Tailing Impoundment (SMI/Terra Matrix 1997a);
- Final Screening Feasibility Study for Remediation Alternatives at the California Gulch Superfund Site (USEPA 1993b);
- EPA START, Draft Alternatives Analysis for the Year 2000 UAR Fluvial Tailings TDD No 9702-0025 (URS 1999);
- Effects of Remediation on Geochemistry and Hydrology of the Unsaturated Area of Fluvial Tailings Deposits in the Floodplain of the Upper Arkansas River, Colorado (Walton-Day et al. 2000);
- Identifying sites for riparian wetland restoration: Application of a Model to the Upper Arkansas River Basin (O'Neill et al. 1997);
- December 13, 2001 Memo [including Attachments A through E] to the CT from Colorado Division of Natural Resources re: Restoration Alternatives;
- Memos from Resurrection and ASARCO re: Restoration Alternatives; and
- Experience of the CT at numerous other mining sites including:
  - The Bunker Hill Superfund Site in Kellogg, ID;
  - The Clark Fork Superfund Site in Butte/Anaconda, MT;
  - The Eagle Mine Superfund Site in Minturn, CO;
  - The Summitville Mine Superfund Site in Summitville, CO;
  - The Jasper County Superfund Site in Jasper, MI;
  - The Idarado Mine Site in Telluride and Ouray, CO;
  - The Coeur d' Alene Basin Superfund Site in northern ID; and
  - The Las Animas Basin in Silverton, CO.

## 4.1 OTHER CONSIDERATIONS

Although not identified as a General Response Action for screening, improved management of flows in the Arkansas River was identified as an applicable action that on its own could improve bank stability and the quality of in-stream fish habitat. Certain augmented flow conditions (i.e., above optimal bankfull conditions, rapid drawdown) have led to significant changes in bank stability and channel morphology and have seasonally reduced the quality and availability of in-stream habitat. It is beyond the scope of the RAR to develop an array of flow management options for screening and inclusion in restoration alternatives. Broad analyses of flow management have been conducted in the past (Smith & Hill 1999) that shed some light on the complexities of this issue. However, it has been noted by the CT and others (InterFluve 1999) that the success of many of the identified Technologies for improving the riparian area, channel stability and in-stream habitat are also dependent upon future management of flows.

Implementation of a flow management plan that strives to achieve optimal flows based on attaining a stable channel form will effectively improve in-stream habitat. A stable channel will lead to increased overhanging vegetation and shade, improved riffle and pool habitat through more effective scouring and active sediment transport, and improved survival and recruitment by providing optimal flows during critical life-stages. The effectiveness of flow management is dependent upon the flexibility that is available to water regulators to consistently meet optimal flows necessary to facilitate natural channel recovery. This will require the identification of optimal channel bankfull discharge and sufficient frequency and duration of channel forming flows. In addition, although recently improved, optimal increases and decreases in flow (i.e. ramping rates) need to be identified and implemented to maintain channel stability.

Legal and political concerns and physical capabilities may preclude full implementation of a flow management plan. There are multiple up- and downstream water users and regulators that influence river flow along the 11-Mile Reach. The needs and desires for water may or may not coincide with flows that are optimal for a stable channel form and the brown trout fishery. The current primary source of flow augmentation that affects the 11-Mile Reach is from Turquoise Reservoir through Lake Fork. Because of physical limitations that affect storage capacity, a flow-management plan that is optimal for the fishery may not be possible. However, over the long-term, strategic flow management could provide a substantial benefit to channel stability and riparian area recovery, as well as influencing the success of any constructed improvements.

General Response Actions have not been included for improving water quality in the UARB. As discussed in Chapter 3, the primary impacts to water quality originate within the California Gulch

Superfund Site. Substantial improvements in water quality would currently provide the largest benefit to the aquatic biota within the 11-Mile Reach, including the brown trout fishery. A variety of source control measures are currently being implemented to reduce surface water metals loading within California Gulch. It is expected that, over time, these actions will result in further improvements in water quality in the UARB. It would not be appropriate to consider surface water quality restoration measures until the California Gulch remedies have been fully implemented and adequate time has been allowed for those remedies to be fully effective.

## 4.2 SCREENING

Drawing upon the identification of Resource Categories for restoration, and the development of corresponding General Response Actions, the list of Restoration Technologies was broken down into specific Process Options that were then identified for screening.

A qualitative screening of the appropriateness of each restoration alternative was based upon a blend of USEPAs EECA and the DOIs Restoration Planning Process. The following criteria were considered for screening of each Process Option:

- Implementability/Applicability to Site Conditions;
- Effectiveness/Applicability to Restoration Objectives; and
- Cost.

The implementability of a Process Option was considered to encompass both the technical and administrative feasibility of implementing an action, the ability to handle the estimated areas and volumes of media, and how proven and reliable the action is with respect to conditions at the site.

The effectiveness of a process option was evaluated based upon the ability to meet the goals and objectives of the restoration alternative, potential impacts to human health and the environment during construction, and how proven and reliable the action is over the long-term with respect to the site conditions.

The cost of a Process Option was based on actual costs in other areas, standard estimating references and engineering judgment. Costs are evaluated as to whether costs for a specific Process Option are high, medium or low relative to other Process Options in that Restoration Technology category. During the initial screening, cost was considered to be relative capital cost and operation and

maintenance costs. When two or more Process Options provided the same or similar levels of expected benefits, cost effectiveness was considered to be a distinguishing factor and the least costly alternative noted.

#### **4.2.1 FLUVIAL MINE-WASTE DEPOSITS**

Several General Response Actions, Restoration Technologies and Process Options were identified for screening-level evaluation (Table 4-1) for fluvial mine-waste deposits. The implementability, effectiveness and cost of these Process Options varied depending upon location, setting and priority of a given deposit. The following discussion provides a summary of the relevant screening considerations. Where appropriate, the Technologies/Process Options relationship to the different priorities (high, moderate and low) of fluvial mine-waste deposits is discussed.

##### **4.2.1.1 INSTITUTIONAL CONTROLS**

Institutional controls are measures that limit exposure by restricting access to, usage of, or activity in areas with residual contamination. The institutional control considered as a Restoration Technology for fluvial mine-waste deposits is Access Control. Fencing to restrict cattle access to fluvial mine-waste deposits is the screened Process Option.

##### **Access Control**

**Fences to Restrict Cattle Access** - Fences are an easily implementable and low cost restoration measure, if access from the property owner can be obtained. Fences could be multi-strand barbed wire or electric. However, land access and long-term maintenance requirements limit the implementability of small segments of fencing to restrict cattle access to the individual fluvial mine-waste deposits as a remedy.

Using small segments of fencing as an institutional control to restrict cattle access to the fluvial mine-waste deposits does not effectively provide long-term protection of deposits from the potentially erosive effects of intensive grazing, protection of vegetation or a reduction in direct exposure to cattle. The durability of fences in this environment without maintenance is an important consideration. Fences for fluvial mine-waste deposits would be most effective as a temporary measure following restoration activities.

Fencing fluvial mine-waste deposits to restrict cattle access is not retained as a Process Option, except as a temporary measure. Continuous fencing may be appropriate for other settings, such as riparian areas. However, fencing of fluvial mine-waste deposits offers no benefits as a stand-alone action and is not applicable to situations where causes other than cattle are limiting vegetative cover.

#### **4.2.1.2 CONTAINMENT/ENGINEERING CONTROLS**

Containment/Engineering Controls are measures that limit exposure by preventing direct contact. The types of controls considered as Restoration Technologies to be screened for fluvial mine-waste deposits are Cover/Barrier Placement and Surface Water Controls.

##### **Cover/Barrier Placement**

The cover/barrier placement Process Options considered during the screening analysis are a Simple Soil Cover and a Multi-Layer Cover.

**Simple Soil Cover and Revegetation** - A simple soil cover was identified as being an applicable Process Option for fluvial mine-waste deposits. Soil covers have been used as a remedy for mine-wastes at many sites around the country, including California Gulch. The primary implementability concern for soil covers relates to the availability of local suitable capping material (e.g., topsoil), because availability of topsoil in the UARB is limited. Import of topsoil greatly reduces the cost effectiveness. However, local alternative sources, such as pond sediment from Mt. Massive Lakes (Mt. Massive Lakes Community Development is located approximately 6 miles south of Leadville, along Highway 24), would greatly increase implementability, especially in Reach 3 where transport distances are minimal. Access should pose limited implementability concerns, as most deposits could be accessed with conventional construction equipment.

Soil covers are effective at eliminating direct exposure and with grading and vegetation they can reduce infiltration and subsequent leaching. At thicknesses of 6 inches or greater, the barriers prove to be adequate for most shallow rooted vegetation. Limitations on effectiveness are related to the types of vegetation to be restored and future land use. If deep-rooted vegetation is to be restored, a thicker soil cover may be required to address the potential for phytotoxicity and metals transfer to vegetation. This effectiveness issue could in part be addressed with the addition of metals-stabilizing amendments (e.g., lime) to the fluvial mine-waste deposits, prior to placement of a soil cover. This would be especially

important for deposits containing the highest metal concentrations and lower pH values, such as the high priority deposits.

Durability of soil covers is also an effectiveness concern. Most fluvial mine-waste deposits are located in settings where grazing or other agricultural activities could occur. A thicker soil cover (e.g., 12 inches) may be required to provide long-term durability in these areas. Soil covers alone generally would not be as effective for fluvial mine-waste deposits potentially subject to erosion (i.e., stream-side deposits); however, establishment of woody vegetation would reduce this concern.

Overall, simple soil covers are retained for consideration during restoration alternative development. Direct application would be most effective for low and moderate priority deposits. Amendment of low pH (high priority) deposits may be required in conjunction with soil covers to improve effectiveness.

**Multi-Layer Cover** - A multi-layer cover was identified as being an applicable Process Option for fluvial mine-waste deposits. Multi-layer covers consist of layers of material with different properties. Typically, at mining sites, a low permeability material, such as a geotextile or geofabric or clay, is covered directly with topsoil or a suitable growth medium and revegetated. Depending upon conditions, designs may also include intermediate layers, such as a gravel blanket for drainage. Using multi-layer covers is technically implementable, however, ease of implementation decreases as the number of small isolated deposits increases. Additionally, multi-layer covers may not be applicable to site conditions, as additional infiltration control is not necessary and the relative cost is high. Multi-layer covers would be most appropriate for consolidated fluvial mine-waste deposits/repositories.

Multi-layer covers have been used as a remedy for mine-waste repositories at many sites around the country (e.g., Bunker Hill Superfund Site). Multi-layer covers can be effective in preventing erosion of and direct contact to mine wastes and are also effective in reducing infiltration. The root depth of vegetation used for multi-layer covers should not exceed the growth medium depth of the multi-layer cover.

As a Process Option, the multi-layer cover will not be retained because in this setting the effectiveness would be similar to the simple soil cover Process Option, but at a higher cost. The multi-layer cover may be considered for repository design.

## **Surface Water Controls**

Surface water controls are a Restoration Technology identified to reduce the potential for erosion of and infiltration through fluvial mine-waste deposits. As the fluvial mine-waste deposits are within the relatively flat UARB floodplain between valley terraces, the primary concerns for erosion are related to overbank flows. Overbank flows within the UAR are usually associated with spring runoff during years of well above average snowpack. Flow in overbank areas is of limited velocity and does not present significant erosion potential. The surface water control Process Option considered during the screening analysis is diversion ditches (run-on control).

**Diversion Ditches (Run-On Control)** - Diversion ditches are readily constructed with conventional equipment and are relatively low cost. However, the flat grades and the lateral extent of some of the deposits may limit the applicability of diversion ditches to the site. The large number of small individual deposits further limits implementability.

Diversion ditches are potentially effective in reducing direct contact with stormwater from upgradient areas. However, the actual effectiveness of diversion ditches at the site is likely to be low, due to the relatively flat grades of the deposits. Run-on is not a significant exposure pathway.

Diversion ditches to provide run-on control for fluvial mine-waste deposits is not a Process Option that will be retained for this site. Surface water management technologies are most appropriately considered in conjunction with the design process for other engineering options (e.g., soil covers).

### **4.2.1.3 IN-SITU STABILIZATION**

Long-term in-situ or “in place” physical stabilization of fluvial mine-waste deposits is best achieved through the development of a healthy, low maintenance vegetation that meets the objectives for acceptable habitat/forage. Because the discrete fluvial mine-waste deposits cover a relatively small portion of the floodplain, exposure related to plant consumption by deer and elk is not a primary concern.



## Vegetation

**Direct Revegetation with Metals Tolerant Species** - Direct revegetation is technically implementable for all priorities of deposits. The process of direct revegetation would include light tilling of the soil and the addition of a planting mixture and mulch. The planting mixture used would correspond to the intended land use and surrounding areas.

An important effectiveness consideration for direct revegetation is plant-available moisture. USEPA has identified plant-available moisture as a controlling factor in revegetation efforts (Personal Communication with Jan Christner, URS Greiner). Mulch would be added to help retain moisture.

Direct revegetation of the fluvial mine-waste deposits is a Process Option that has limited effectiveness for high metals and low pH deposits, because of the limited tolerance of vegetation to those soil conditions, and because of exposure concerns for livestock from metals transferred to vegetation.

The cost of direct revegetation is low. Direct revegetation as a stand-alone Process Option is retained only for the low priority mine-waste deposits.

**Lime Addition, Deep Tilling and Direct Revegetation** –The combination of lime addition, deep tilling and direct revegetation is technically implementable for all priorities of fluvial mine-waste deposits. Lime would be added to the deposits and tilled to a depth of 18-inches and the direct revegetation process would include the addition of a planting mixture and mulch. The planting mixture used would correspond to the intended land use and surrounding areas. Mulch would be added to help retain moisture.

The combination of lime addition, deep tilling and direct revegetation would be most effective for low priority deposits. The lack of organic matter may limit the effectiveness for moderate and high priority deposits, however it would be more effective in conjunction with a soil cover and/or organic amendments. Because the average depth of most deposits is less than 12-inches, deep tilling to a depth of 18-inches is expected to result in a reduction of the surficial metals concentration.

The cost of this combination is low to medium. Lime addition, deep tilling and direct revegetation will be retained as a Process Option for the low priority deposits.

**Revegetation with Organic (biosolids) and Lime Amendments** - Revegetation with the addition of organic matter and lime amendments is technically implementable for all priorities of deposits. The rate of biosolids and lime application can be matched with the conditions of a specific fluvial mine-waste deposit, based on its priority (i.e., high, moderate or low priority). However, the implementability of this combination for near bank deposits is reduced because non-composted biosolids cannot be used within 10 feet of the river channel.

Revegetation with organic and lime amendments offers restoration of vegetation and potential for reduction of metals transfer. Although listed under stabilization technologies, USEPA (2002b) has noted some treatment benefits related to reduced bioavailability of metals. In addition, because the average depth of most deposits is 12-inches or less, deep tilling to a depth of 18-inches is expected to result in reduced surficial metals concentrations.

The cost of this combination can be high depending upon the source of biosolids. Revegetation with organics and lime amendments will be retained as a Process Option.

**Lime Addition, Deep Tilling, Soil Cover and Revegetation** - The combination of lime addition, deep tilling, soil cover and revegetation has a high level of implementability where a soil source is readily available, and offers the greatest flexibility for restoration of vegetation and potential for reduction of metals transfer. The haul distance required will most likely be the most significant cost influence. For this site, the availability of stockpiled pond sediment from Mt. Massive Lakes may provide a high implementability for Reach 3.

The effectiveness of this proven option is achieved through neutralization of low pH deposits and a corresponding reduction in metals availability. Liming of the riparian mine-waste deposits and integration of the lime through the deposit profile by deep tilling, addresses metals mobility/pH concerns for high priority deposits. The soil cover provides the organic matter and rooting zone needed for most plant species. Placement of the soil cover provides long-term durability and allows for a wide range of vegetation/habitat to be developed. Vegetation can be matched to adjacent areas, restoring full use of the area.

The cost of this combination is medium to high depending upon the source of cover soil. The combination of lime addition, deep tilling, soil cover and revegetation will be retained as a Process Option.

#### **4.2.1.4 REMOVAL/REPLACEMENT**

This General Response Action involves the removal of mine waste and replacement to grade with soil, or suitable growth medium. The primary distinction for Removal/Replacement Process Options is the fate of the excavated material.

#### **Excavate & Truck Hauling with Replacement of Soils and Vegetation**

##### **Consolidate with Other Deposits Within a Reach (Multiple Small Repositories) -**

Consolidated removal is technically implementable, however, if a repository cannot be located outside the floodplain, floodplain considerations of final grade of consolidated deposits may limit applicability. For each reach, a suitable location for a repository would have to be identified. The repository location would ideally be outside the 500-year floodplain and away from any tributary drainage. The ability to acquire private lands for this purpose may limit implementability. In addition, consolidated materials may require some level of amendments, such as a simple soil cover with revegetation, to provide an adequate reduction in infiltration and the necessary durability for long-term protection. Multiple repositories also increase maintenance efforts.

Removal of fluvial mine-waste deposits with nearby consolidation outside of the floodplain adjacent to a reach is effective at limiting potential exposure routes, and with soil backfill as necessary, it offers the ability to restore appropriate vegetation/habitat. Removal with nearby consolidation greatly reduces the footprint of mine waste and correspondingly the potential for future transport/erosion of metals from the fluvial mine-waste deposits. The effectiveness of this Process Option is greatest for high priority deposits with diminishing applicability for deposits that have both lower metals concentrations and lower potential for erosion in the future.

The relative cost for removal of fluvial mine-waste deposits with nearby consolidation within each reach is medium to high. This Process Option will be retained for further consideration.

**On-Site Single Repository (within the 11-Mile Reach) -** The ability to acquire suitable property for a single on-site repository within the 11-Mile Reach greatly influences the implementability of this Process Option. The cost for hauling mine waste to a single repository would be substantially larger than for multiple repositories. Long-term operation and maintenance (O&M), however, would be more straightforward than for multiple repositories.

Removal and consolidation of fluvial mine-waste deposits with transport to an on-site (within the 11-Mile Reach) repository is effective at eliminating all potential exposure routes, and with soil backfill it offers the ability to restore appropriate vegetation/habitat. Removal and consolidation of individual fluvial mine-waste deposits with transport to a single on-site repository eliminates the potential for future transport/erosion of metals within the fluvial mine-waste deposits. The applicability of this Process Option is highest for high priority deposits with diminishing applicability for deposits that have lower metals concentrations and lower potential for erosion.

The relative cost for removal of consolidated fluvial mine-waste deposits with transport to an on-site (within the 11-Mile Reach) repository is medium to high. This Process Option will be retained for further consideration.

**California Gulch NPL Site Repository** - A site-wide repository location is being established for the Superfund site at the Black Cloud Mine tailings impoundment, and is assumed to be of adequate capacity. Using this repository is technically implementable and applicable to site conditions.

Removal of consolidated fluvial mine-waste deposits with transport to a repository within the California Gulch NPL Site is effective at eliminating all potential exposure routes, and with soil backfill it offers the ability to restore appropriate vegetation/habitat. Consolidated removal eliminates the potential for future transport/erosion of metals within the fluvial mine-waste deposits. The applicability of this Process Option is highest for high priority deposits with diminishing relative applicability for deposits that have lower metals concentrations and lower potential for erosion.

Closure and O&M costs would be proportional to the total volume of material and would therefore be less than a single repository or multiple new repositories. This Process Option is most cost effective for deposits within the upper reaches, as increasing haul distance increases costs.

The relative cost for removal of consolidated fluvial mine-waste deposits with transport to a repository within the California Gulch NPL Site is low to medium. This Process Option will be retained for further consideration.

**Distant Off-Site Repository** - Removal of consolidated fluvial mine-waste deposits with transport to a distant off-site repository is technically implementable and applicable to site conditions.

The applicability of this process option is highest for high priority deposits with diminishing applicability for deposits that have lower metals concentrations and lower potential for erosion.

Removal of consolidated fluvial mine-waste deposits with transport to a distant off-site repository is effective at eliminating all potential exposure routes, and with soil backfill, it offers the ability to restore appropriate vegetation/habitat. Consolidated removal eliminates the potential for future transport/erosion of metals within the fluvial mine-waste deposits.

The relative cost for removal of consolidated fluvial mine-waste deposits with transport to a distant off-site repository is very high. The haul costs are prohibitive and therefore, this process option will not be retained.

#### **4.2.1.5 TREATMENT**

Chemical and biological treatment technologies have been considered for numerous mining sites across the country. Other than the addition of lime, these technologies have not proven to be both effective and implementable. Also, there are several limitations for these technologies when considered for in-situ application in a floodplain setting.

#### **Chemical**

**Alkali Addition (lime)** - Alkali addition is readily implementable depending upon the depth of deposits and the required depth of incorporation.

One-time application of relatively large quantities of lime may be required to produce long-term effectiveness for the most acidic deposits. The chemical treatment of alkali addition (lime) may be effective at raising soil pH and reducing metals availability, but this alone may not meet restoration objectives. Addition of lime may reduce the formation of highly soluble metal-rich salts and buffer acid generation resulting from water contact with the deposits. Alkali addition is effective and appropriate as a soil amendment for vegetation restoration activities.

The relative cost of alkali addition is medium. Alkali addition is not retained as a stand-alone treatment Process Option for the fluvial mine-waste deposits.

**Passivation/Micro-Encapsulation** - The long-term effectiveness of coating the surface of deposits with reactive minerals (e.g., phosphate) is questionable for highly mineralized low pH mine-waste deposits. Depending upon the depth of the mine-waste deposit, the thorough degree of mixing necessary to promote encapsulation may be difficult to achieve. The relative cost of this Process Option is high.

The passivation/micro-encapsulation process option is not being retained for in-situ application to fluvial mine-waste deposits.

**Chemical Addition to Enhance Precipitation/Adsorption** - There is no proven effectiveness of using chemical addition to enhance precipitation/adsorption for conditions consistent with the environmental setting of the fluvial deposits within the 11-Mile Reach (e.g., wet dry cycles in conjunction with extreme temperature swings). The implementability and relative cost of this Process Option for a floodplain setting is unknown. Chemical addition to enhance precipitation/adsorption is not retained as a Process Option.

## **Biological**

**Bio-Mineralization (in-situ sulfate reduction; insoluble sulfide precipitation)** - There is no proven effectiveness of using bio-mineralization for conditions consistent with the setting of the fluvial deposits. This technology has only been proven in relatively stable environments (e.g., wet closure of tailings impoundments) and/or where an organic carbon source is readily and consistently available. The implementability and relative cost of this option for a floodplain setting is unknown. Bio-mineralization is not retained as a Process Option.

**Bactericides (sodium laurel sulfate)** - There is no proven effectiveness of using bactericides for restoration of conditions consistent with the environmental setting of the fluvial deposits. Examples of successful large-scale in-situ application were not identified. Therefore, the implementability and relative cost is unknown. Use of bactericides is not retained as a Process Option.

**Phytoremediation** - There is no proven effectiveness of using phytoremediation for restoration of tailings deposits. Also, it is likely that this technology would meet restoration objectives in a timeframe similar to natural recovery. This Process Option would require the harvest and disposal of

high metal content vegetation and land-use would have to be restricted for grazing until replanting with low metals uptake species occurs. Overall, the implementability of this Process Option is low and the relative cost is unknown. Phytoremediation is not retained as a Process Option.

## **4.2.2 AGRICULTURAL/FLOODPLAIN LANDS**

Several General Response Actions, Restoration Technologies and Process Options were identified for screening-level evaluation for Agricultural/Floodplain Lands (Table 4-2). The applicability, implementability and effectiveness of these Technologies vary depending upon location, setting and land ownership.

### **4.2.2.1 INSTITUTIONAL CONTROLS**

Institutional controls are measures that limit exposure by restricting activity, use and access to areas with residual contamination. This institutional control considered as a Restoration Technology for fluvial mine-waste deposits is Agricultural Best Management Practices (BMPs). Seeding with metal tolerant/low uptake species, nutritional supplements, grazing rotation and irrigation management are the screened Process Options.

#### **Agricultural BMPs**

**Seed with Metals Tolerant/Low Uptake Species** - This Process Option entails seeding agricultural lands with metals tolerant species that would also have the characteristic of low accumulation of metals in above ground plant parts. These species may be effective in increasing plant cover and making these sites more productive. The implementation of this Process Option would require some tillage to prepare a seedbed and reduce the abundance of existing species that may not be productive under current soil conditions or may accumulate metals at concentrations that could be problematic for livestock.

However, the species that would be used for this Process Option may not have high forage value and therefore may not meet the restoration objectives for these lands. The effectiveness of this Process Option is questionable depending upon the landowner's preference and planned land use. This Process Option may be more implementable on non-private land where livestock use is not a designated land use

or may not be a high priority. Seeding with metals tolerant/low uptake species is retained for site-specific consideration.

**Nutritional Supplements** - The logic behind this Process Option is to supplement livestock with minerals, such as Zn, with salt blocks. The increase in dietary Zn could offset the potential toxicity effects associated with elevated cadmium in forage (Church 1988). This approach is commonly used on rangelands where mineral deficiencies occur among cattle or horses when forages are low in certain elements (Holechek et al. 1998).

This is an effective Process Option in areas where mineral deficiencies occur or where the problem is limited to one element. However, its effectiveness in this setting is unknown. The probability of effectively implementing this strategy in an area where the problem is an excess of certain elements (e.g. Cd and Zn) is low. The agricultural lands have elevated Zn and Cd. Elevated Zn can bring about a Cu deficiency in some livestock. Zn can also work in a positive way by reducing the toxicity effect of Cd. Because of these complex interactions this Process Option is not retained for further consideration.

**Grazing Rotation** - The implementation of a grazing management plan that will rotate livestock through pastures at stocking rates that will not over utilize the forage and will be timed in a way to allow adequate regrowth will increase forage production and plant cover. Proper grazing management limits the amount of forage that is used at any one point in time, uses forage during times when adequate carbohydrate reserves are available for regrowth, and uses forage at the end of the growing season when plants are ready to senesce. Properly grazed vegetation will be more productive and the higher production may lead to lower metal concentrations. In addition, if livestock can be rotated among pastures with different metal concentrations in the soil and vegetation, it may be possible to reduce the overall uptake of metals by livestock and reduce the potential for any toxicity problems. This option is easily implementable provided the landowner agrees, and has the potential to be effective with the long-term commitment of the land manager.

The short and long-term effectiveness of this option will be dependent upon landowners and their willingness to implement and maintain a system of rotating animals through a series of pastures. There would be cost associated with fencing and with moving animals at designated times of the year. Properly implemented grazing systems are highly effective in improving and maintaining healthy plant communities and have good potential to reduce metal concentrations in forage and therefore in the animal's diet.



Because of the uncertainty of voluntary implementation by the landowner, this Process Option is not retained for further consideration.

**Irrigation Management** - Once an option is implemented to improve forage quality and production, it will be important that any future irrigation be done with water of adequate quality such that substantial metals loads are not re-introduced into the system. Water quality has improved in the UAR and this should continue over time, thus making this management practice readily implementable. Management would involve the rate and timing of irrigation water application. This process is currently managed by landowners and would require some additional effort. Head gates would need to be closed during exceptional periods of runoff from the California Gulch Superfund Site (e.g., when restoration activities are occurring upstream that could result in an increase of metals bearing sediment). Correspondingly, this Process Option is retained for consideration for downstream areas during the periods of active upstream restoration construction.

#### **4.2.2.2 SOIL MIXING**

##### **Plowing**

**Deep Tilling** - This option would require plowing to a depth of about 12 inches to remove the existing vegetation and mixing the soil to reduce metal concentrations in those areas where surface soils have elevated metal concentrations. Seeding with native and/or introduced species that would meet the land use objectives of livestock grazing would then follow plowing. This approach of soil mixing to reduce metal concentrations through the process of dilution has been used at other Superfund sites (e.g. Anaconda) and is highly effective where the concentration of metals is in the upper 6 inches. It will be effective in sites dominated by herbaceous vegetation, but is less effective in areas dominated by woody vegetation.

This option is more implementable on grassland sites. Sites that are dominated by shrubs (for example in riparian corridors) would be difficult to plow. However, it is possible to treat these areas with an implement that would mulch the vegetation in place and then plow the site after the shrubs have been turned to mulch. This Process Option is retained for further consideration.

#### 4.2.2.3 IN-SITU STABILIZATION

##### Soil Amendments

**Application of Lime** - The addition of lime to agricultural lands would be used to raise soil pH and immobilize the COCs. The result will be a more productive soil that will support greater plant cover and forage with metal concentrations in normal ranges. This option could be used on soils with a pH below 5.5 and the objective would be to raise the soil pH to 6.5 or 7.0. Within this pH range the metals of concern would become complexed and unavailable for plant uptake. This option would require soil tillage to incorporate the lime into the root area and then reseeded to establish new species that will meet the desired land use.

The option would be highly effective in reducing the bioavailability of metals and re-establishing vegetation that would support livestock use. This option is more implementable on grassland sites. Sites that are dominated by shrubs (for example in riparian corridors) would be difficult to till. It is possible to treat these areas with an implement that would mulch the vegetation in place and then till the site after the shrubs have been turned to mulch to incorporate the lime amendment. This Process Option is retained for further consideration.

**Application of Phosphate Rich Amendment (Organic Matter)** - Phosphate rich material can be utilized within the agricultural lands to reduce the availability of certain metals in a circumneutral soil pH environment. This option is physically similar to the addition of lime, in that the source of phosphate is applied at a set rate and tilled in. However, the effectiveness of this approach for the COCs is unknown. There is limited information on the long-term effectiveness of this Process Option, and in particular, for a floodplain/irrigated meadows setting. This Process Option is not retained for further consideration.

#### 4.2.3 RIPARIAN AREAS

Several General Response Actions, Restoration Technologies and Process Options were identified for screening-level evaluation of Riparian Areas (Table 4-3). The applicability, implementability and effectiveness of these Technologies vary depending upon location, accessibility, land ownership and engineering controls.

#### 4.2.3.1 INSTITUTIONAL CONTROLS

Institutional controls are measures that limit exposure by restricting activity, use and access to areas with residual contamination. The institutional control considered as a restoration technology for riparian areas is land-use management. Fencing to restrict livestock access, grazing management and conservation leases are the screened Process Options.

##### **Land-Use Management**

**Fencing to Restrict Livestock Access** - The use of fencing (e.g., barbed wire or electric) to restrict livestock access would be an institutional control to keep cattle out of riparian areas where historical grazing has been a primary cause of streambank instability. The implementability of fencing will depend upon cooperation of landowners. Fencing will be more implementable on public lands subject to grazing than on private land.

Fencing to restrict livestock access is a common and effective management practice in riparian areas that are subject to overgrazing. Riparian systems are relatively resilient and recovery will occur once animals are excluded.

The cost of fencing is low. This Process Option is retained for further consideration.

**Grazing Management** - Rotation and agricultural BMPs would not be effective for limited acreage without physical restrictions. Grazing management for riparian areas is only implementable through fencing. Grazing management is not retained as a stand-alone Process Option for riparian areas.

**Conservation Leases** - Conservation leases would not be effective as a stand-alone option for riparian areas and are not as effective as fencing. Conservation leases are highly implementable if landowners are willing. The cost of conservation leases on private land is uncertain. Conservation leases are retained as a Process Option for further consideration.

#### 4.2.3.2 STREAMBANK RESTORATION

Streambank restoration involves repairing and stabilizing bank segments that have been, or are being, impacted by erosion, livestock, vehicle crossings or other disturbances. Process Options typically include repair of the bank structure and protection of that bank segment. Protection may range from soft treatments (e.g., root wads) to hardened structures (e.g., rip-rap). Vegetation is typically enhanced in these areas, in conjunction with bank protection, to restore habitat.

#### **Bioengineering/Soft Treatments**

There are several Process Options within the Restoration Technology category of bioengineering/soft treatments. Each should have similar applicability, effectiveness and implementability. Costs for portions of a stream segment can range from \$15 to \$150 per linear foot of channel. The most unpredictable variables influencing costs are a large rock source and hauling costs. The average cost of \$35 per linear foot of channel used in developing restoration alternatives was based on experience at other sites and CT confirmation with a local stream restoration contractor (Rick Dornfeld-Intermountain Habitat Restoration, LLC). Screening of the following Process Options will be performed at the Technology level. Design activities will determine the most appropriate Process Option for a specific area and a more specific cost.

**Revegetation** - Revegetation within the riparian corridor is a common practice to reestablish vegetation in areas that are either void of vegetation or where the plant community needs to be improved. Streambanks must be physically stable before plant establishment from seed will occur. Therefore, revegetation would be most effective when done in combination with soft or hard engineering treatments. Engineering treatments would provide the bank stability necessary for plant establishment to occur. Once vegetation does become established, it will effectively control erosion. Revegetation can occur through reseeding or from willow cuttings. Reseeding would include light tilling of the soil and the addition of mulch. Willow cuttings can be easily obtained from willows native to the area. Establishment success from cuttings is normally effective. The ultimate effectiveness of these treatments will depend on suitable soil conditions for planting, which includes adequate moisture for root development.

Revegetation would be readily implementable on public or private land and should not vary with location along the 11-Mile Reach. Revegetation is retained as a Process Option for further consideration.

**Willow Waddling, Anchored logs, Root Wads** - Bioengineering soft treatment approaches like willow waddling, anchored logs, and root wads are commonly used to stabilize steep, eroding banks. The Colorado Division of Wildlife (CDOW) lists soft treatment approaches in their River Channel and Trout Habitat Treatments table. According to their table, the expected benefits of soft treatment approaches include reduced bank erosion, increased trout habitat and increased pool and run river habitat (CDOW 2002). Examples of soft treatment approaches include using a single log (cover log), at least 16 inches in diameter, anchored parallel to the base of the eroding streambank at water level. An alternative to this technique is to drive two or three abutment logs at least 4 to 6 feet into the unstable soil of the streambank, and then anchor the cover log parallel. This process can also be repeated with multiple overlapping layers (cribbing). The specific approach selected would be based on the availability of materials.

Implementability of soft treatments will require access and engineering controls during construction to avoid impacts to the river. This Process Option is retained for further consideration.

## **Hard Treatments**

There are several Process Options within the Restoration Technology category of hard or pure engineering treatments. Each should have similar applicability, effectiveness and implementability. Screening of the following Process Options will be performed at the Technology level. Design activities will determine the most appropriate Process Option for a specific area.

**Rock Structures (Vanes, J-Hook, Cross Vanes, Deflector)** –There are several rock structure techniques that have successfully been used to reduce channel widening. The CDOW lists rock structures treatment in their River Channel and Trout Habitat Treatments table. According to their table, the expected benefits of rock structure treatments include improvements in the river channel, reduced bank erosion, increased trout habitat and improved river habitat in the upper end of the pools (CDOW 2002). Strategic placement of rock structures (Vanes, J-Hook, Cross Vanes, Deflector) within a reach is a proven effective technique for reducing the development of over-width channels by slowing the bank erosion process by concentrating flow in the middle of the stream, narrowing the flow path and reducing stress to the banks. The appropriate technique or combination of techniques to use depends upon the specific characteristics of the river reach and the desired restoration effects. The implementability of rock structures depends on various factors such as the channel size of the reaches, the vicinity of a quarry or rock supply, the accessibility of the reaches for heavy equipment to place boulders and the seasonal

timing of construction (i.e., to avoid impacts to spawning fish and high flow conditions). Rock structures also are an effective technology for enhancing fish habitat (See Section 4.2.4.2).

The cost of rock structures is greatly impacted by the distance of the rock supply. Engineering controls would also be required during construction to avoid impacts to the river. Design and installation must be carefully considered because inappropriate placement of rock structures can drastically alter streamflow and cause bank failure. The Process Option of rock structures is retained for further consideration.

**Gabion Riprap and Retaining Walls** - Hard treatments like rock gabions and riprap are commonly used for bank stabilization. The specific technique selected would be based on the availability of materials. These approaches should be done in combination with plant establishment to provide a more natural functioning streambank system and to improve the aesthetics of the river. This approach is more expensive than soft treatments but could be appropriate in areas where erosion is active and bank instability is high.

Implementability of hard treatments will require access and engineering controls during construction to avoid impacts to the river. Using gabion riprap and retaining walls as a Process Option for bank stabilization is retained for further consideration.

#### **4.2.4 CHANNEL MORPHOLOGY/IN-STREAM HABITAT**

General Response Actions addressing Channel Morphology and In-Stream Habitat Improvements can be closely related. For this reason, these Restoration Technology categories are combined during the screening process (Table 4-4). It should also be noted that these categories of General Response Actions overlap with certain Process Options being considered for Riparian Areas. These relationships/overlaps will be further considered in the development of alternatives.

##### **4.2.4.1 RIVER CHANNEL ALTERATION**

There are several Process Options within the Restoration Technology category of river channel alteration. River channel alteration treatments are considered as a means to restore natural river functions, improve channel and bank stability and enhance aquatic habitat. Each should have similar

applicability, effectiveness and implementability. Screening of the following Process Options will be performed at the technology level. Design activities will determine the most appropriate Process Option for a specific area.

River channel alterations involve significant modification of the current channel. These actions range from movement of the existing channel, to channel modification and channel movement constraints.

**Restore Flow to Abandoned Channel** - Restoration of flow to an abandoned channel is an option where the current active main channel is unstable (e.g., “perched”), or is unacceptably threatening a feature (e.g., fluvial mine-waste deposits) in its current configuration. This alternative can be effective if properly applied. However, even with substantial studies, it is difficult to evaluate the potential for long-term success. Changes in flow regime may result in failure of the channel relocation and creation of unanticipated channel morphology. It is also extremely difficult to accurately predict upstream and downstream impacts on channel stability, and extensive studies may be required to understand the potential for long-term effectiveness.

The implementability of this option is limited by many factors including: access; engineering controls; and short construction seasons. The cost of such an option is considered to be very high. Channel relocation is not retained as a Process Option because the applicability is very limited.

**Reduce Channel Braiding by Confining River to a Single Channel** - This option involves consolidation of existing braided channel segments to a single channel and eliminating or utilizing existing channels for overbank flow. The new consolidated main channel would either be an expansion of an existing channel or a newly created channel. The channel would, at a minimum, have capacity for base flows. This option has the same group of effectiveness and applicability/implementability considerations as described above. The long-term effectiveness of channel constraints over short reaches is uncertain. Braided reaches are not uncommon for high mountain valley streams and reduced braiding may therefore not be considered restoration. The Process Option of reducing channel braiding by confining the river to a single channel is not retained because the applicability is limited.

**Create Channel Migration Corridor** - Creation of a channel migration corridor involves the placement of hardened structures at a set dimension within the floodplain. The hardened structures limit

migration of the channel. This option can be used to constrain channel migration away from areas of concern (e.g., structures and/or tailings deposits). Without tailings removal within the original migration corridor, this option is not fully effective and flood effects could be more focused and/or channel migration could intercept deposits.

In general, the same effectiveness and implementability considerations apply. The applicability of this alternative is limited when considering both the setting and the potential benefits. The cost is very high. This Process Option is not retained for further consideration.

**Reduce Channel Width** - The river channel through portions of the 11-Mile Reach (especially below the confluence of Lake Fork) has widened compared to the historic channel. However, the channel width appears to be stabilizing in response to better management of augmented flows in recent years.

If flows are managed appropriately, reducing channel width could be effective in facilitating natural recovery of a stable channel form. The CDOW lists treatments reducing channel width in their River Channel and Trout Habitat Treatments table. According to their table, the expected benefits of reducing channel width include improvements in the river channel, increased trout habitat and improved pool, run and riffle river habitat (CDOW 2002). Reducing channel width will also lead to reduced sediment deposition, increased bank stability, reduced lateral movement, and as noted by CDOW, improved in-stream habitat. The long-term effectiveness of a constructed narrow channel is not known, nor the upstream and downstream impacts on bank stability. Construction of a narrow channel may require armoring to improve effectiveness.

Reducing channel width to handle optimal bankfull discharge is applicable to the 11-Mile Reach, where a width/depth ration of between 20 and 30 can be achieved. Reducing channel width is physically implementable where the river is accessible to an excavator. This Process Option is not retained given other similar options have fewer effectiveness and implementability concerns.

**Channel Relocation** - The channel relocation option involves the creation of a new channel and elimination of the existing channel. This option is typically considered when the current channel morphology unacceptably threatens a structure or feature (e.g., mine-waste deposits). The effectiveness and implementability concerns raised for other river channel alteration Process Options can be magnified for this option.



The channel relocation Process Option is not applicable to the conditions of the UARB and the restoration objectives, and is not retained for further consideration.

#### **4.2.4.2 IN-STREAM HABITAT ENHANCEMENT**

There are several Process Options within the Restoration Technology category of in-stream habitat enhancement. Each should have similar applicability, effectiveness and implementability. Screening of the following Process Options will be performed at the technology level. Design activities will determine the most appropriate Process Option for a specific area.

#### **Habitat Enhancement**

**Enhance Riffles (gravel & cobble placement)** - Enhancement of riffle habitat through the placement of imported gravel and cobble is a common in-stream habitat improvement technique; however, it is not applicable to the 11-Mile Reach. Currently the 11-Mile Reach has a less than optimal pool to riffle ratio due to the lack of pools, yet abundant riffle habitat.

Enhancing riffle habitat would not be effective at improving the overall quality of in-stream habitat in the 11-Mile Reach due to the abundance of riffle habitat already present. Enhancement of riffles is not applicable to the conditions of the UARB and the restoration objectives, and therefore is not retained as a Process Option for further consideration.

**Boulder Placement (e.g., random boulders, boulder clusters)** - Placement of random boulders and boulder clusters is an applicable treatment for improving mid-stream habitat by dissipating energy and deflecting flow which leads to increased overhead cover, shelter from high-flows, and increased in-stream habitat through long runs of riffles. This treatment is readily implementable in locations where an excavator can access the river. The CDOW lists boulder placement treatments in their River Channel and Trout Habitat Treatments table. According to their table, the expected benefits of boulder placement include reduced bank erosion, increased trout habitat (boulder clusters only) and improved pool, run and riffle (random boulders) or run and riffle (boulder clusters) river habitat (CDOW 2002).

Boulder placement would be an effective treatment for the 11-Mile Reach especially in areas of monotonous riffle habitat and where the river is entrenched or confined by physical barriers (i.e. railroad,

highway). Boulder placement would provide several in-stream habitat types that are currently limited in many sections of the 11-Mile Reach (i.e. shelter from high-flows, mid-channel habitat, overhead cover).

The cost of boulder placement is medium based on the distance of a boulder supply. Large boulders are available in most sections of the 11-Mile Reach. Boulder placement is retained as a Process Option for further consideration.

**Mid-Channel Root Wads, Stumps** - Placement of root wads and stumps is applicable for improving mid-stream habitat such as overhead and resting cover, both of which are somewhat limited in sections of the 11-Mile Reach.

Root wads and stumps would be effective in the 11-Mile Reach and would increase the quantity and diversity of in-stream habitat. This treatment would create habitat similar to the placement of boulders. The CDOW lists root wad and stump treatments in their River Channel and Trout Habitat Treatments table. According to their table, the expected benefits of root wad and stump placement includes reduced bank erosion, increased trout habitat and improved pool and run (root wads) or riffle and run (stumps) river habitat (CDOW 2002).

Placing root wads and stumps in the stream may not be implementable due to the lack of readily available root wads and stumps of sufficient size. In addition, anchoring root wads and stumps in the stream bottom may be difficult to complete. The cost of root wad and stump placement is medium, dependent upon the availability of materials. Root wad and stump placement is retained as a Process Option for further consideration.

**Log Placement (log spurs, horizontal logs)** – Placement of logs is applicable for improving in-stream habitat such as overhead and resting cover, both of which are somewhat limited in sections of the 11-Mile Reach (Riley and Fausch 1995; Gowan and Fausch 1996).

Log placement techniques, such as log spurs and horizontal log placement, would be effective in the 11-Mile Reach and would increase the quantity and diversity of in-stream habitat. This treatment would create habitat similar to the placement of boulders and mid-channel root wads and stumps. The CDOW lists log placement treatments in their River Channel and Trout Habitat Treatments table. According to their table, the expected benefits of log placement include reduced bank erosion, increased trout habitat and improved pool, run and riffle (log spurs) or riffle (horizontal logs) river habitat (CDOW

2002). This treatment would create habitat similar to the placement of boulders and mid-channel root wads and stumps. The cost of log placement is medium and dependent upon the availability of logs and river access. Log placement is retained as a Process Option for further consideration.

**Excavation of Pools** - Excavation of pools is applicable for improving in-stream habitat where the pool to riffle ratio is very low. Pools provide over-wintering habitat and help to reduce flow velocity.

Given the low ratio of pools to riffles, pool excavation would be an effective treatment in some portions of the 11-Mile Reach, especially in conjunction with boulder placement to achieve increased in-stream habitat diversity.

Pool excavation is readily implementable where the river can be accessed by an excavator and where engineering controls can be implemented to reduce negative impacts to the river. Costs of pool excavation are medium. Pool excavation is retained as a Process Option for further consideration.

**Drop Structures/Weirs** - Drop structures/weirs are commonly used for stream improvement and are designed to dissipate energy and increase pool habitat. They are an applicable treatment for improving in-stream habitat in the 11-Mile Reach.

Drop structures and weirs are effective at dissipating energy and creating pool and riffle habitat. In some instances, drop structures and weirs can have a negative effect on bank stability and channel form.

Drop structures and weirs are readily implementable where the river can be accessed by an excavator for construction, and where engineering controls can be implemented to reduce negative impacts to the river. The cost of drop structures/weirs is high and they will not be retained as a Process Option for further consideration.

Table 4-1

Technology Identification and Screening for  
Fluvial Mine-Waste Deposits

General Response Action	Restoration Technology	Process Option	Implementability / Applicability to Site Conditions	Effectiveness / Applicability to Restoration Objectives	Relative Cost	Retain
No Action (no restoration actions, but considers any ongoing or planned response actions)	Natural Recovery			Required alternative	\$0	
Institutional Controls	Access Control	Fences to restrict cattle access	Low – easily implemented as a temporary measure provided access from property owner is obtained, but land access and long term maintenance requirements limit use as a remedy. Not applicable to situations where causes other than cattle are limiting vegetative cover.	Not effective long term in protecting deposits from potentially erosive effects of intensive grazing, protecting vegetation, and reducing direct exposure to cattle. Most effective as a temporary measure following restoration activities.	Low	No-offers no benefits as a stand-alone action
Containment/Engineering Controls	Cover/Barrier Placement	Simple Soil Cover (E-T barrier) and revegetation	Availability of local soil borrow area is a limiting factor. Higher implementability where a soil source is available. Availability of stockpiled pond sediment from Mt. Massive Lakes may provide high implementability for Reach 3.	Effective at eliminating direct exposure and reducing infiltration. Soil cover alone would not be effective for deposits potentially subject to erosion. Appropriate vegetation can be established. Plant metals uptake may occur depending upon soil depth and nature of underlying deposits. Deep-rooted vegetation needs a thicker soil cover to effective. Most effective for low to moderate priority deposits that are not streamside.	Medium-dependent upon transport distance.	Yes
		Multi-layer Cover (e.g., CCL, gravel, soil composite)	Technically implementable, however may not be applicable to site conditions (additional infiltration control not necessary). Most appropriate for consolidated deposits/repositories.	Effective in preventing erosion of and direct contact to mine wastes, and reducing infiltration. The root depth of vegetation used for multi-layer covers should not exceed the soil cover depth.	High	No-redundant with simple soil cover process option but higher cost. Consider for repository design.
		Surface Water Controls	Diversion Ditches (run-on control)	Medium – readily constructed with conventional equipment. Not applicable to site conditions.	Potentially effective in reducing direct contact with stormwater from upgradient areas. However, actual effectiveness is likely to be low, due to relatively flat grades of deposits (run-on not a significant pathway)	Low
In-Situ Stabilization	Vegetation	Direct revegetation with metals tolerant species	Technically implementable, but may only be applicable at deposits with moderate pH and relatively low metals availability.	Limited effectiveness based on previous work. Vegetation type/habitat restoration may be limited. Metals transfer to vegetation may present exposure concerns for deer and elk.	Low	Yes-for low priority deposits with small surfaces.
		Lime addition, deep tilling and direct revegetation	Technically implementable, but may only be applicable at deposits with moderate pH and relatively low metals availability.	Most effective for low priority deposits. Lack of organic matter may limit effectiveness for moderate and high priority deposits. Would be effective in conjunction with soil cover.	Low/Med	Yes-for low priority deposits.
		Organic (biosolids) and lime amendments, deep tilling and Revegetation	Non-composted biosolids cannot be used within 10 feet of the river channel, which reduces the implementability of this treatment option for near bank deposits.	Offers restoration of vegetation and potential for reduction of metals transfer.	High	Yes
		Lime addition, deep tilling, soil cover and revegetation	Higher implementability where soil source is available. Availability of stockpiled pond sediment from Mt. Massive Lakes may provide high implementability for Reach 3.	Offers restoration of vegetation and potential for reduction of metals transfer.	Med/High-dependent upon source of soil cover	Yes
Removal/replacement	Excavate & Truck Hauling with replacement of soils and vegetation	Consolidate with other deposits within a reach (multiple small repositories)	Technically implementable. However, floodplain considerations of final grade of consolidated deposits and land acquisition within a reach may limit applicability. Multiple repositories increase maintenance efforts.	Removal effective at eliminating all potential exposure routes and with soil backfill it offers the ability to restore appropriate vegetation/habitat. Eliminates the potential for future transport/erosion of metals within deposits. Applicability highest for high priority deposits with diminishing applicability for deposits that have lower metals	Med/High	Yes

Table 4-1

Technology Identification and Screening for  
Fluvial Mine-Waste Deposits

General Response Action	Restoration Technology	Process Option	Implementability / Applicability to Site Conditions	Effectiveness / Applicability to Restoration Objectives	Relative Cost	Retain
				concentrations and lower potential for erosion.		
		On-site single repository (within 11-mile reach)	Implementability affected by the ability to acquire suitable property for a repository within the 11-Mile Reach. Long-term O & M required.	Removal effective at eliminating all potential exposure routes and with soil backfill it offers the ability to restore appropriate vegetation/habitat. Eliminates the potential for future transport/erosion of metals within deposits. Applicability highest for high priority deposits with diminishing applicability for deposits that have lower metals concentrations and lower potential for erosion.	Med/High	Yes
		Cal Gulch NPL Site repository	A site-wide repository location is being established for the Superfund Site at the Black Cloud Mine tailings impoundment. Process Option is technically implementable and applicable to site conditions. Most implementable for deposits within upper reaches as increasing haul distance increases cost effectiveness. Capacity of site wide repository is assumed to be adequate.	Removal effective at eliminating all potential exposure routes and with soil backfill it offers the ability to restore appropriate vegetation/habitat. Eliminates the potential for future transport/erosion of metals within deposits. Effectiveness highest for high priority deposits with diminishing relative effectiveness for deposits that have lower metals concentrations and lower potential for erosion.	Low/Med	Yes
		Distant off-site repository	Technically implementable and applicable to site conditions. Highest applicability for high priority deposits.	Removal effective at eliminating all potential exposure routes and with soil backfill it offers the ability to restore appropriate vegetation/habitat. Eliminates the potential for future transport/erosion of metals within deposits. Effectiveness highest for high priority deposits with diminishing relative effectiveness for deposits that have lower metals concentrations and lower potential for erosion.	High	No
Treatment	Chemical	Alkali Addition (lime)	Technically implementable depending on depth of deposit and desired depth of incorporation. May require large quantities of lime to produce long-term effectiveness.	May be effective at raising soil pH and reducing metals availability, but this alone may not meet the restoration objectives. May reduce the formation of highly soluble metal-rich salts and buffer acid generation resulting from water contact with the deposits. Effective and appropriate as a soil amendment for vegetation activities.	Med	No-not as a stand-alone treatment
		Passivation / Micro-encapsulation	Depending on depth of waste deposit, effective mixing may be difficult.	Long-term effectiveness is questionable for highly mineralized low pH deposits	High	No-not proven to be effective
		Chemical addition to enhance precipitation/adsorption	Unknown	No proven effectiveness for site conditions	Unknown	No-not proven to be effective
	Biological	Bio-mineralization (in-situ sulfate reduction; insoluble sulfide precipitation)	Unknown	No proven effectiveness for site conditions	Unknown	No-not proven to be effective
		Bactericides (sodium laurel sulfate)	Unknown	No proven effectiveness for site conditions	Unknown	No-not proven to be effective
		Phytoremediation	Low - would have to harvest and dispose of high metals content vegetation. Land-use would be restricted for grazing until replanting with low metals uptake species occurs. Overall implementability would be low.	No proven effectiveness for site conditions	Unknown	No-not proven to be effective

Table 4-2

Technology Identification and Screening for  
Agricultural/Floodplain Lands

General Response Action	Restoration Technology	Process Option	Implementability / Applicability to Site Conditions	Effectiveness / Applicability to Restoration Objectives	Relative Cost	Retain
No Action (no restoration actions, but considers any ongoing or planned response actions)	Natural Recovery			Required alternative	\$0	
Institutional Controls	Agricultural BMPs	Seed with metals tolerant/low uptake species (revegetation)	Readily implementable, provided landowner consents. Most implementable on public lands.	May be effective in increasing vegetative cover, but may not meet restoration objectives for agricultural lands, depending on land owner preferences or planned land use.	Med	Yes
		Nutritional supplements (salt blocks)	Readily implementable, provided landowner consents. Most implementable on public lands.	Complex interactions in areas where the problem is an excess of certain elements (i.e., Cd, Zn and Cu) limit effectiveness.	Low	No
		Grazing rotation	Readily implementable, provided landowner consents. Most implementable on public lands. There is uncertainty associated with voluntary implementation by private landowners.	May be effective in reducing metal uptake by cattle and horses and in increasing forage production and plant cover.	Low	No
		Irrigation management	Readily implementable, provided landowner consents. Most implementable on public lands.	See above, may be considered for post remedy protection depending upon UAR water quality.	Low	Yes
Soil Mixing	Plowing	Deep tilling	Easily implemented in conjunction with standard agricultural practices for preparing land for planting. Not readily implementable for areas of dense woody vegetation (i.e. riparian corridors).	Effective in reducing metals concentrations in areas where only surficial metals concentrations present a problem. May be effective in over soil profile in conjunction with soil amendments.	Med	Yes
In-Situ Stabilization	Soil Amendments	Application of ag-lime	Readily implementable, but will require tilling and reseeded. Not readily implementable for areas of dense woody vegetation.	Effective in reducing the bioavailability of metals and re-establishing vegetation that would support livestock use. Over liming can adversely affect vegetation growth.	High	Yes
		Application of phosphate rich amendment (Organic Matter)	Readily implementable, but will require tilling and reseeded. Not readily implementable for areas of dense woody vegetation.	Limited information on the effectiveness with time in a floodplain/irrigated meadows setting. Can be effective in reducing bioavailability. Particularly effective for lead and not as effective for zinc.	High	No

**Table 4-3**

**Technology Identification and Screening for the Riparian Zone**

General Response Action	Restoration Technology	Process Option	Implementability / Applicability to Site Conditions	Effectiveness / Applicability to Restoration Objectives	Relative Cost	Retain
No Action (no restoration actions, but considers any ongoing or planned response actions).	Natural Recovery			Required alternative	\$0	Yes
Institutional Controls	Land Use Management	Fencing to restrict cattle access	Readily implementable. Requires cooperation of landowner. Highly implementable on public lands subject to grazing.	Effective and applicable in areas where cattle grazing are the primary cause of bank instability.	Low	Yes
		Grazing management (rotation){Agricultural BMPs}	Readily implementable. Requires cooperation of landowner. Highly implementable on public lands subject to grazing.	Effective and applicable in areas where cattle grazing are the primary cause of bank instability. Difficult to enforce/control. Not as reliable as fencing.	Low	No
		Conservation Leases	Highly implementable if landowner is willing.	Effective in conjunction with fencing, but not as reliable as fencing alone. Not effective as a stand-alone option.	Uncertain-on private land	Yes
Streambank Restoration	Bioengineering/Soft Treatments	Screening performed at technology level. Specific soft treatment options may include those listed below. Design activities will determine most appropriate option for specific areas.	Technically implementable but will require access, and engineering controls during construction to avoid impacts to the river. Implementability/ applicability also dependent on having soil conditions suitable for planting.	Effective in reducing bank erosion and the development of over-width channel; and providing overhead trout cover. Effectiveness may be increased in areas where mine waste has been removed and replaced with soil suitable for planting.	Low/Med	Yes
		Revegetation	Technically implementable but will require access, and engineering controls during construction to avoid impacts to the river. Implementability/ applicability also dependent on having soil conditions suitable for planting.	Ineffective unless done in combination with hard or soft treatments or some form of bank stabilization. Effective in controlling erosion away from the streambank.	Low	Yes
		Willow waddling	Technically implementable but will require access, and engineering controls during construction to avoid impacts to the river.	Effective in reducing bank erosion and the development of over-width channel. May need to be done in combination with hard or additional soft treatments.	Med	Yes
		Anchored logs	Technically implementable but will require access, and engineering controls during construction to avoid impacts to the river.	Effective in reducing bank erosion and the development of over-width channel. May need to be done in combination with hard or additional soft treatments.	Med	Yes
	Root wads	Technically implementable but will require access, and engineering controls during construction to avoid impacts to the river.	Effective in reducing bank erosion and the development of over-width channel. May need to be done in combination with hard or additional soft treatments.	Med	Yes	
	Hard Treatments	Screening performed at technology level. Specific hard treatment options may include those listed below. Design activities will determine most appropriate option for specific areas.	Technically implementable but will require access, and engineering controls during construction to avoid impacts to the river.	Effective in reducing bank erosion and the development of over-width channel. Hard treatments may increase flow velocities and create undesirable effects downstream. Unless application is limited to small areas, it can be counter productive to habitat restoration objectives.	Med/High	Yes
		Rock Structures (Vanes, J-Hook, Cross Vanes, Deflector)	Technically implementable, but will require access, and engineering controls during construction to avoid impacts to the river. Dependent on factors such as channel size and vicinity of quarry or rock supply.	Effective in reducing bank erosion and development of over-width channel. Maintains a "natural" look.	Med	Yes
Gabion retaining walls		Technically implementable but will require access, and engineering controls during construction to avoid impacts to the river. Applicable to areas of active erosion & high bank instability.	Effective in reducing bank erosion. Most effective in combination with plant establishment to establish a more natural functioning bank system that is also aesthetically more acceptable.	High	Yes	

**Table 4-3**

**Technology Identification and Screening for the  
Riparian Zone**

<b>General Response Action</b>	<b>Restoration Technology</b>	<b>Process Option</b>	<b>Implementability / Applicability to Site Conditions</b>	<b>Effectiveness / Applicability to Restoration Objectives</b>	<b>Relative Cost</b>	<b>Retain</b>
		Riprap	Technically implementable but will require access, and engineering controls during construction to avoid impacts to the river. Applicable to areas of active erosion & high bank instability.	Effective in reducing bank erosion. Most effective in combination with plant establishment to establish a more natural functioning bank system that is also aesthetically more acceptable.	Med/High	Yes



Table 4-4

Technology Identification and Screening for Channel Morphology/In-Stream Habitat

General Response Action	Restoration Technology	Process Option	Implementability / Applicability to Site Conditions	Effectiveness / Applicability to Restoration Objectives	Relative Cost	Retain
No Action (no restoration actions, but considers any ongoing or planned response actions).	Natural Recovery			Required Alternative	\$0	
Channel Morphology Restoration (See also Riparian Areas)	River Channel Alteration (River channel alteration treatments are considered as a means to restore natural river functions, improve channel and bank stability and enhance aquatic habitat).	Screening performed at technology level. Specific channel alteration options may include those listed below. Design activities will determine most appropriate option for specific segments.	Intensive supporting engineering studies would be required. May not be acceptable to landowners.	Uncertain it would be effective in this environment. May not present long-term effectiveness without a large engineering effort. Effectiveness of individual treatments will be highly dependent on the selection of appropriate locations for implementation and detailed evaluation and design of specific treatments.	High	No
		Restore flow to abandoned channel.	Substantial engineering and construction controls required. Other implementability considerations include water rights, easements, rights-of way, land use, and maintaining/improving trout habitats. Limited applicability.	May be effective in limiting migration of channel(s) through tailings deposits. Restoring flow to abandoned channels can be effective in areas where the abandoned channel offers stable riverbanks and riparian vegetation, and good trout habitat. However, perched channel is considered to be stable so beneficial effects would not be achieved.	High	No
		Reduce channel braiding by confining low river flows to a single channel and utilizing secondary channels as high flow channels.	Substantial engineering and construction controls required. Other implementability considerations include water rights, easements, rights-of way, land use, and maintaining/improving trout habitats. Overall, applicability is limited.	May be effective in limiting migration of channel(s) through tailings deposits. Reducing braided channels could effectively reduce total channel width and possibly increase the river's effectiveness at transporting sediment. The long-term effectiveness of channel constraints over short reaches is uncertain. Furthermore, the need for additional sediment transport has been identified.	Very High	No
		Create hard/armored channel migration corridor bordering within which the channel could migrate.	Requires a large volume of materials to be handled. Tailings within channel migration corridor require removal. Substantial engineering and construction controls required. Other implementability considerations include water rights, easements, rights-of way, land use, and maintaining/improving trout habitats.	May be effective in limiting migration of channel(s) towards tailings deposits. Not fully effective and flood effects could be more focused and/or channel migration could intercept deposits. Depending upon the degree of hard armoring required it could also result in improved fish habitat.	Very High	No
		Reduce channel width	Applicable in areas where a width/depth ratio of between 20 and 30 can be achieved. Physically implementable where the river is accessible to an excavator.	May be effective in limiting migration of channel(s) towards tailings deposits. May be effective in improving lateral channel stability, reducing sediment deposition, and improving fish habitat. However, long-term effectiveness without hardened structures is uncertain.	Medium	No
		Channel relocation	Can be considerable logistical and physical obstacles to relocation. Not applicable to conditions of the UARB.	May be effective in isolation of fluvial tailings deposits. May not be compatible with riparian and in-stream habitat restoration.	Very High	No
In-stream Habitat Restoration	Habitat Enhancement	Screening performed at technology level. Specific fish habitat restoration options may include those listed below. Design activities will determine most appropriate option for specific segments.	Type of actions, and correspondingly costs, are usually based on professional judgment.	Restoration not specific to release of mining wastes, but would improve current condition of fishery.	Medium/High	Yes
		Enhance riffles (gravel & cobble placement)	Readily implementable, but not applicable.	Adequate gravel/cobble substrate present.	Medium	No
		Boulder placement (e.g. random boulders, boulder clusters)	Readily implementable and appropriate for this river system.	Effective at increasing in-stream fish habitat. Applicable to this river system.	Medium	Yes

**Table 4-4**

**Technology Identification and Screening for  
Channel Morphology/In-Stream Habitat**

<b>General Response Action</b>	<b>Restoration Technology</b>	<b>Process Option</b>	<b>Implementability / Applicability to Site Conditions</b>	<b>Effectiveness / Applicability to Restoration Objectives</b>	<b>Relative Cost</b>	<b>Retain</b>
		Mid-channel root wads, stumps	Applicable to site conditions, but may not be readily implementable due to lack of large rood wads and stumps.	Effective at increasing in-stream fish habitat.	Medium	Yes
		Log placement (log spurs, horizontal logs)	Readily implementable and appropriate for this river system.	Effective at increasing in-stream habitat including overhanging areas.	Medium	Yes
		Excavate pool habitats	Readily implementable in areas with access. Most applicable to Reach 3.	Effective in creating pool to riffle relationships. Providing resting and over-wintering areas.	Medium	Yes
		Drop structures/weirs	Intensive supporting engineering studies would be required. May not be acceptable to landowners. Not as applicable as other habitat improvement options.	Could be effective in creating pool habitat and improving pool to riffle relationships. Provides resting habitat. Uncertain it would be effective in this environment. May not present long-term effectiveness without a large engineering effort.	High	No