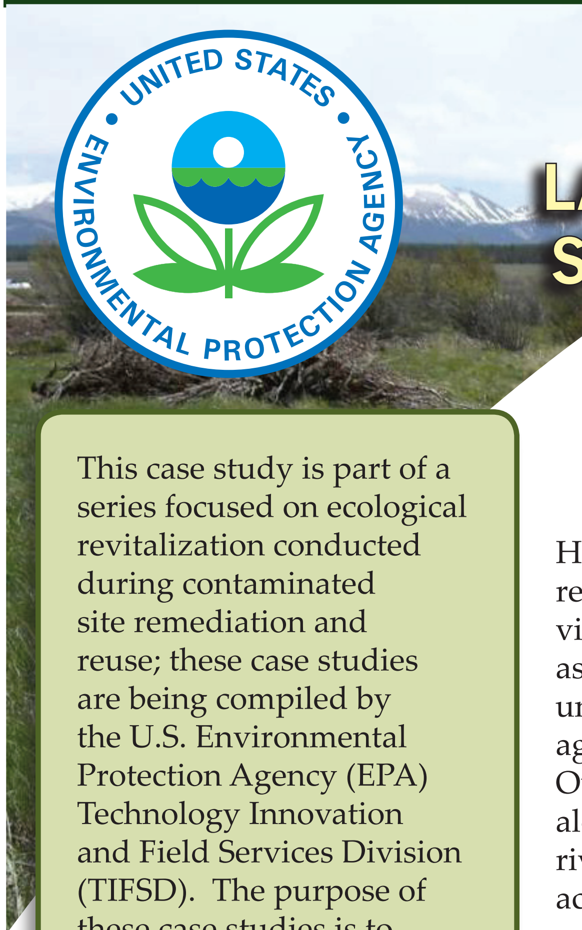

CALIFORNIA GULCH LAKE COUNTY, COLORADO SUPERFUND CASE STUDY

This case study is part of a series focused on ecological revitalization conducted during contaminated site remediation and reuse; these case studies are being compiled by the U.S. Environmental Protection Agency (EPA) Technology Innovation and Field Services Division (TIFSD). The purpose of these case studies is to provide site managers with information on ecological reuse, including principles for implementation, recommendations based on personal experiences, a specific point of contact, and a network of sites with an ecological reuse component.

A Once Toxic "Moonscape" from Mining and Smelting Is Returned to Fertile Pasture and Native Prairie

Historical mining in Lake County, Colorado, resulted in releases of tailings and water with high metals concentrations via California Gulch to the Upper Arkansas River and associated irrigation ditches. These releases created unvegetated mine waste deposits in the floodplain and agricultural land with areas of reduced or no productivity. Over the years, the tailings continued to erode and re-deposit along the Upper Arkansas River, creating a 9-mile stretch of river containing barren mine deposits. Many of these deposits accumulated along eroding stream banks and were coated with metals salts that washed into the river during storms. Vegetation and the soil community were limited by high metals concentrations, low pH, insufficient macro- and micro-nutrients, poor physical properties, and reduced water holding capacity.

During a series of demonstration projects and ultimately a remedial action, the fluvial deposits and irrigated meadows were amended with organic residuals, lime, and fertilizer and seeded with native and crop species to produce a stable vegetative cover that reduces dust, erosion, washing of metals into the river, and the availability and toxicity of metals contaminants. Testing conducted by EPA and the U.S. Department of Agriculture (USDA) showed that total concentrations of metals of concern in soil did not change, but that bioavailable lead,

Ecological Revitalization = the process of returning land from a contaminated state to one that supports functioning and sustainable habitat.

Topics Highlighted in this Case Study:

- ✓ Attractive Nuisance
- ✓ Bioavailability
- ✓ Erosion
- • Invasive Species
- • Predator Control
- ✓ Recreation
- ✓ Soil Amendments
- ✓ Use of Native Plants
- • Use of Volunteers
- • Water Management
- • Wildlife Habitat:
  - • Freshwater Wetland
  - ✓ Prairie
  - • Saltwater Wetland
  - • Savannah
  - ✓ Stream
  - • Woodland

cadmium, and zinc concentrations are now greatly reduced. Stable stream banks with minimally intrusive engineering materials that support native plants were created to replace the eroding tailings. Approximately 210 acres of the contaminated soils were converted to pasture and recreational lands. As a result of this ecological revitalization, cattle grazing has resumed on land that was barren for more than 80 years and a public recreation area with trails, river access, and fishing areas now operates on remediated fluvial tailings deposits. Fly fishing enthusiasts now enjoy a scenic panorama of native grasslands in the floodplain.

Eroding streambank prior to treatment

Background

- The California Gulch Superfund site was listed on the National Priorities List (NPL) in 1983 and consists of about 16 square miles in Lake County, Colorado. Operable Unit 11 (OU11) includes the Arkansas River from the confluence of California Gulch downstream to the confluence with Box Creek, approximately 9 miles downstream. The site encompasses both private and public lands.
- Mining, mineral processing, and smelting in and near Leadville produced gold, silver, lead, copper, manganese, and zinc for more than 130 years. Wastes generated during the mining and ore processing contained metals, such as cadmium, copper, lead, and zinc.
- Wastes were washed downstream and deposited as discrete parcels along an 11-mile stretch of the Upper Arkansas River. The fluvial deposits are pyritic soils with no natural soil structure and are characterized by lack of vegetation, low pH, and high metals.
- Over the years, the wastes eroded, re-deposited along the river, and accumulated in deposits up to 4 feet deep. The rise and fall of the water table resulted in alternating reducing and oxidizing conditions, creating an extremely acidic soil pH (1.5 to 4.5).

What are Pyritic Soils?

Pyritic soils contain pyrite, which is a mineral also known as "fool's gold." Pyrite is used to produce iron ore and sulfuric acid, and when it is present in the soil, it can cause the soil to be acidic.

The fluctuating water table and the acidic conditions, in turn, caused zinc and lead in the tailings to form soluble salts that wick to the soil surface during dry portions of the year. A metal salt crust with zinc concentrations of greater than 90,000 milligrams per kilogram (mg/kg) formed on the soil surface. The soil was toxic to riparian vegetation and became highly susceptible to continued erosion by the river.

Why Not Just Remove the Waste Deposits?

Removal of the tailings was not feasible because of (1) the potential to destabilize streambanks and cause massive changes in the river system, (2) the potential for tailings to enter the river during field activities, (3) the high cost of replacement topsoil, and (4) the difficulty of locating an acceptable repository for contaminated soil.

Streambank after treatment

- Irrigation with contaminated water from the Arkansas River impaired the productivity of adjacent ranchlands, causing reduced forage and increased exposure of livestock to toxic concentrations of metals contaminants.

Ecological Revitalization

Initial Research and Field Studies

The Region 8 Removal Program, EPA's Environmental Response Team (ERT), and USDA researchers initiated ecological revitalization at the site in 1998 by developing a recipe of biosolids and lime to be applied to the fluvial deposits. The intent of these amendments was to reduce the mobility, bioavailability, and toxicity of metals in the soil and provide a more hospitable growth environment for vegetation and soil organisms. The amendments were applied to four "demonstration areas" using a front-end loader and mixed into the top 12 inches of tailings using an industrial disc, a plow, or an excavator. The plots were seeded and in some cases irrigated because of the low precipitation. The resulting vegetation in the demonstration areas reduced the following: erosion, exposure to contaminants, formation of metals salts on the surface and subsequent leaching into the river, and transport of metals to groundwater. Subsequent demonstration areas were treated with various combinations of biosolids pellets, biosolids compost, cow manure compost, limestone, and sugar beet lime. Test plots were installed in these subsequent demonstration areas to evaluate the relative merits of various lime amendments and of adding wood chips to the treated soil.

Biosolids, or organic residuals, have been used at a wide range of sites both alone and in combination with other materials to restore disturbed sites. Research has consistently demonstrated that biosolids are highly effective, in many cases more so than topsoil replacement, for restoration of disturbed ecosystems. In addition, biosolids, applied at restoration rates of more than 50 tons per acre, provide sufficient organic matter to improve the physical properties and nutrient status of the soil, while reducing the availability of metals. Some additional examples of Superfund sites where biosolids have successfully been used include the following:

- West Page Swamp (Bunker Hill), Shoshone County, Idaho: http://faculty.washington.edu/clh/wet.html
- Palmerton Zinc Pile, Carbon County, Pennsylvania: http://www.epa.gov/aml/tech/palmerton.pdf
- Sharon Steel, Mercer County, Pennsylvania: http://www.epa.gov/reg3hwmd/npl/PAD001933175.htm
- Oronogo-Duenweg Mining Site, Jasper County, Missouri: http://www.itrcweb.org/miningwaste-guidance/cs34_oronogo_duenweg.pdf

Extensive evaluation of the physical and chemical properties, toxicity, and function of soil, and of ecosystem function suggested that the soil amendments have restored function to the fluvial deposits. After 1 year, the addition of lime and biosolids generally improved soil quality, increased pH, decreased

Consider the Potential for Attractive Nuisance Issues

Assessments such as chemical extraction tests, ecological evaluation, and modeling can be used to ensure that a remedy is protective of both humans and wildlife. At the California Gulch OU11 site, for example, a wide range of earthworm, fish, and small mammal testing was conducted to determine whether the revitalized habitat was creating an attractive nuisance to the wildlife at the site. Results showed that the bioavailability of heavy metals present on site was dramatically reduced after treatment with soil amendments and that wildlife exposure to metals is within acceptable limits. For additional details on attractive nuisance issues, please visit the following website: http://www.epa.gov/tio/download/remed/542f06003.pdf

the mobility of metals, and reduced soil toxicity; plant and soil microbial activity also increased and a plant community was established. Stakeholders were concerned that leaving the waste in place would create an attractive nuisance and be harmful to wildlife attracted to the newly vegetated area, but the treatment reduced the potential for ingestion of contaminants by wildlife by decreasing the extractable metals in the soil. Assessments during 2005, 2009, and 2010 indicate that the vegetation established on the demonstration areas is robust, reproducing, and permanent many years after it was first planted.

Revitalization Activities

As a result of the initial research and field studies, stakeholders who previously expressed concern about the viability and protectiveness of in situ treatment and revegetation of the fluvial deposits became proponents and recommended approval of EPA's plans for similar work on the remaining fluvial deposits and in contaminated irrigated meadows. In 2008, a remedial action was initiated to treat an additional 20 acres of fluvial deposits plus 160 acres of irrigated meadows located on private and public lands. The remedy was based on lessons learned during the initial field studies and on work at a similar site, the Clark Fork River NPL site in Montana.

Lime, organic material, and fertilizer application rates were identified based on a statistical evaluation of characteristics at the site for the irrigated meadows. Typical agronomic methods, including calibrated spreaders and agricultural deep till or industrial discs, were used to apply and mix soil amendments. A drill seeder was used to apply a seed mix tailored to landowner preferences such as grazing and forage production, and straw mulch was spread to protect the seed until spring germination.

A hybrid approach was taken to establish the lime application rate for each fluvial deposit. In general, one of the following two "master" application rates was assigned to each deposit, depending on lime requirement data that identified current acidity and potential acidity created by the pyritic soils: (1) 3 percent lime by weight, and (2) 6 percent lime by weight. However, a custom lime rate was selected for deposits with an extremely high lime requirement. The lime and phosphate fertilizer was applied to the full depth of tailings and mixed, and then organic matter was added and tilled to a depth of 12 inches. Initially, an excavator was used to blend the amendments into the fluvial deposits. However, the process was slow, so the excavator was replaced by an Allu mixer that is capable of precision work along uneven boundaries and can manage large (up to 12-inch) rock. The fluvial deposits were hand-seeded with a riparian seed mix approved by the land manager (either the private landowner or Colorado State Parks), raked, and mulched before winter arrived.

The streambanks adjacent to the fluvial deposits were often compromised because of the absence of vegetation caused by metals toxicity or low pH. Tilling amendments

into the tailings would further destabilize the streambanks and leave entire treatment areas open to erosion, so stream bank stabilization measures were needed. Stakeholders expressed concern over armoring banks with riprap or gabion baskets during the demonstration projects; therefore, in a few locations, bendway weirs and root wads were used protect the bank and enhance fish habitat. The remedial action used soft engineering techniques to create well-vegetated banks that protect the remediated areas in the near term, but will also accommodate natural stream migration in the long term. Streambank stabilization tools included the following:

- Excavation of contaminated soil within 10 feet of the streambank and replacement with clean fill
- Rock roll along the toe of the stream bank
- Coir roll (biolog) along the toe of the stream bank or behind the rock roll
- Sedge (*Carex* spp.) plantings
- Mature willow (*Salix* spp.) transplants
- Tipped willows that extend into the river

The *Carex* plantings and mature willow transplants

Stakeholders Involvement

- **EPA** – EPA Region 8 provided the site characterization, mapping, alternatives analysis, demonstration project funding and implementation, feasibility study, risk assessment, remedial action planning and implementation, and coordinated with a large group of agency and local stakeholders over the entire life of the project. EPA participated in a multi-agency effort that successfully coordinated Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Natural Resource Damages activities. EPA's Environmental Response Team (ERT) provided research and development assistance for the initial field studies, including contracting with the USDA for research assistance.
- **Landowners** – Community members, especially landowners in and around the California Gulch OU11 site, were actively engaged in selection, design, and implementation of the remedy to ensure private and public lands returned to beneficial use.
- **Local Government Authorities** – Lake County had a vested interest in the end use of the site and wanted ensure it met the goals of its master plan. The demonstration projects were coordinated with a Lake County Open Space Initiative project that created a fishing lake, river access, and informative trails.
- **State and Federal Natural Resource Trustees** – EPA and state and federal natural resource trustees, including the U.S. Fish and Wildlife Service, the U.S. Bureau of Land Management, the U.S. Department of Justice, the Colorado Department of Public Health and Environment, the Colorado Division of Natural Resources, and the Colorado Attorney General's Office, coordinated site assessment, remedy selection, and remedy design to ensure EPA CERCLA efforts were consistent with long-term restoration actions. Trustees also provided input to EPA during remedial design and construction to ensure the remedy protected, and in some cases enhanced, species habitat.
- **Colorado State Parks** — Colorado State Parks worked with EPA to identify access road and borrow area locations that fit with long-term land use priorities.
- **Potentially Responsible Parties (PRPs)** – A Consent Decree settlement with the PRPs provided funding for the remedial action.

were harvested from the adjacent floodplain. These tools were used in various combinations to address the diversity of streambank conditions encountered.

Performance criteria were developed to measure the success of the remediation:

- **Soil criteria** include post-treatment soil characteristics such as pH, lime requirement, organic carbon, and electrical conductivity.
- **Vegetation criteria** include seedling density (first-year measure only), cover, species richness, biomass, and evidence of reproduction.
- **Irrigated meadows criteria** were developed from the results of pre-remediation sampling in contaminated and uncontaminated meadows
- **Fluvial deposits criteria** were based on the characteristics of the demonstration areas 5 to 7 years after treatment and of riparian reference areas.
- **Streambank criteria** were based on an adaptation of the Riparian Evaluation System (RipES) developed by Reclamation Research Group for the Clark Fork River site.

The remediation areas are also monitored for erosion, bare areas, and weeds.

Fishing along the revitalized streambank

Incorporating Recreation into the Remedy

Land use changed during the lifetime of the project. Historical ranch land was purchased by a Colorado community for the water rights and was designated for recreational use, and another historically ranched property was purchased by natural resource trustees to provide critical habitat. In addition, Lake County's the High Lonesome Recreation area — which included a fishing lake, river access, and a trail through demonstration plots with paths, bridges, and signage describing the remediation and site ecological features — was developed in the project area. A portion of the site is also located in the Arkansas River Headwaters State Park. Construction roads required during remediation were located to minimize impacts to vital bird habitat, and some of the roads will be used for long-term fishing access and recreational use.

Lessons Learned

1. **Consider all aspects of the remedy in estimating costs:** During the initial demonstration project, biosolids were provided at no cost by the Denver Metro Wastewater Treatment Facility, but the cost of transportation over steep mountain roads was not covered. During the remedial action, the compost supplier was selected for a low cost and high organic content product, but the quality of the compost degraded over time and newer material was not fully composted, leading to elevated ammonia and salt content and reduced vegetation production. A quick response to changes in materials quality, identified during a construction quality assurance and quality control (QA/QC) monitoring program, saved long-term maintenance costs and headaches.
2. **Equipment tailored to site requirements:** Incorporation of soil amendments into deep and sometimes rocky fluvial deposits using

traditional construction equipment was labor-intensive and yielded inconsistent results. The construction contractor therefore identified and procured an Allu mixer that was productive, reliable, and cost-efficient; provided consistent mixing; and dealt with rock and mud. The Allu worked with precision near stream banks and around existing vegetation and could handle large (up to 12 inch) rock without breaking down, leaving very few areas unamended. Rock segregated during the Allu mixing process was used for streambank stabilization.

3. **Integrated design:** The project drew from site-specific research performed by ERT, USDA, Colorado State University and others, plus technology transfer from experience at the Clark Fork River site in Montana, thus providing high confidence in the outcome of the remedial action. The early laboratory tests, test plots, and larger-scale field demonstration projects paved the way for acceptance of the larger-scale remedial action, and experience on the Clark Fork River site provided insight into effective implementation of the design-build project.

4. **Availability of resources differs depending on the region:** The source of biosolids in the area "dried up" when a nearby mine reclamation project acquired all of the biosolids from nearby mountain communities, so the remedial action relied on cow manure compost, a plentiful resource in the Colorado Front Range. The sugar beet lime used during remediation is a waste product from the sugar beet industry in eastern Colorado and contained approximately 20 percent moisture, making it much easier to spread and less likely to produce dust than dry lime.

5. **Climate can affect the success of revitalization:** Leadville is the one of the highest elevation incorporated towns in North America, at 10,200 feet. The growing season is approximately 60 to 70 days, inhibiting the growth of new vegetation. Rainfall is approximately 17 inches, further limiting growth and allowing capillary rise of metals salts during dry periods. Vegetation stress was observed in the demonstration areas during the early years after treatment because of drought, so performance standards for the subsequent remedial action were developed to accommodate unusual weather patterns or other uncontrollable events.

6. **Incorporate stakeholder priorities when possible:** Concerns about specific streambank stabilization techniques were overcome when stakeholders suggested slight design modifications that would improve fish habitat while providing protection of remediation areas without increasing costs. Access roads in the recreation area were more acceptable when EPA agreed to leave certain roads in place for long-term recreational paths and river access.

7. **Work with the entire system:** A fluvial geomorphologic assessment of the Arkansas River provided valuable information on the vulnerability of the specific river reaches, assisting with the remedial design. The geomorphologic assessment was valuable to natural resource trustees and other stakeholders and will be used in future natural resource improvement efforts by the State of Colorado and federal agencies.

Smith Ranch vegetation assessment, 2010

Additional Information

Websites to obtain additional information on the California Gulch site and ecological revitalization include the following:

EPA Region 8 Superfund Program, California Gulch
http://www.epa.gov/region08/superfund/co/calgulch/

Wildlife Habitat Council Case Study 11, Upper Arkansas River Tailings Restoration
http://www.wildlifehc.org/ewebeditpro/items/O57F3067.pdf

University of Washington Upper Arkansas River Alluvium Remediation, Biosolids Demonstration, Leadville, Colorado
http://faculty.washington.edu/clh/leadville.html

Cost and Performance Summary Report, In Situ Biosolids and Lime Addition at the California Gulch Superfund Site, OU 11
http://www.brownfieldstsc.org/pdfs/CaliforniaGulchCaseStudy_2-05.pdf

Leadville, Colorado: Moving Beyond the Scars of Mining, Integrating Remedial Design and Site Reuse
http://www.epa.gov/superfund/programs/recycle/pdf/cal_gulch.pdf

EPA's Eco Tools Website
http://www.clu-in.org/ecotools/

Ecological Revitalization: Turning Contaminated Properties into Community Assets
http://www.clu-in.org/download/issues/ecotools/Ecological_Revitalization_Turning_Contaminated_Properties_into_Community_Assets.pdf

Frequently Asked Questions about Ecological Revitalization of Superfund Sites
http://www.clu-in.org/download/remed/542f06002.pdf

Revegetating Landfills and Waste Containment Areas Fact Sheet
http://www.clu-in.org/download/remed/revegetating_fact_sheet.pdf

Ecological Revitalization and Attractive Nuisance Issues
http://www.epa.gov/tio/download/remed/542f06003.pdf

For additional information on the California Gulch site, you can also contact these project managers:

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