Enhanced Conceptual Site Model (ECSM) - Overview of the Lower Basin of the Coeur d'Alene River (OU3)

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Purpose

This technical memorandum provides an overview of an enhanced conceptual site model (ECSM) for the Lower Basin of the Coeur d'Alene River. More than a century of mining, milling, and smelting practices in the Coeur d'Alene Basin has elevated concentrations of metals that are potentially hazardous to humans, plants, and animals in substantial portions of the Lower Basin. The ECSM is being developed to help guide effective decision-making regarding remedial actions for the Lower Basin.

The ECSM is an effort to better define and quantify the sources, mobility, and deposition of sediment in the Coeur d'Alene Basin and thereby support strategies and remediation plans that effectively reduce risks to people and the environment. The ECSM builds upon previously completed work, including the role and influence of Upper Basin conditions and processes on the Lower Basin system. The ECSM includes the following components:

- Compilation of existing data and knowledge
- Identification of data gaps and recommendations to address them
- Identification of key parameters and associated levels of uncertainty
- Numerical modeling to evaluate and prioritize remedial actions.

The ECSM will aid decision makers with the selection and implementation of remedial actions to address human health and ecological risks with a high level of certainty and success.

Background

History

The historic mining and processing of metal-rich ores within North Idaho's Coeur d'Alene Basin began more than 100 years ago. The basin has been one of the leading silver-, lead-, and zinc-producing areas in the world, and its history of extraction activity has produced widespread metal contamination of soil, sediment, water, and biota within the basin. The U.S. Bureau of Land Management (BLM) has identified hundreds of mining or milling-related features in the region surrounding the South Fork of the Coeur d'Alene River.

Mining-related activities generated tailings, waste rock, concentrates, and smelter emissions. In addition, the water that drains from many abandoned adits contains elevated levels of metals. Mining, milling, and smelting practices resulted in substantial portions of the basin containing elevated concentrations of metals that are potentially hazardous to humans and plants and animals. The primary metals of concern include lead and arsenic for human health, and cadmium, lead, and zinc for ecological receptors.

The Upper Basin is characterized by relatively steep tributaries that route water and sediment to the North and South Forks. In contrast, the Lower Basin is characterized by a flat gradient (especially downstream of Cataldo) with a meandering channel in a floodplain valley up to several miles wide. River stage through much of the lower reach is controlled by water levels in Coeur d'Alene Lake, which is in turn partially controlled by Post Falls Dam, located near the natural outlet of the lake. Seasonal flooding within the Coeur d'Alene Basin continues to mobilize metals-contaminated sediment to, within, and through the Lower Basin.

Large amounts of mine tailings have been transported downstream in the Coeur d'Alene River, primarily during high flows, and have been deposited as "lenses" of tailings or as tailings/sediment mixtures in the beds, banks, floodplains, and lateral lakes of the Upper Basin, Lower Basin, and Coeur d'Alene Lake. Some fine-grained material has washed through Coeur d'Alene Lake and been deposited as sediment within the Spokane River. The estimated total mass and extent of the contaminated materials (primarily sediments) exceeds 100 million tons dispersed over thousands of acres.

Operable Units and Interim ROD

The US Environmental Protection Agency (EPA) identified three operable units (OUs) within the Bunker Hill Mining and Metallurgical Complex Superfund Site: populated areas inside the Bunker Hill Box (OU1), non-populated areas inside the Box (OU2), and mining-related contamination in the broader Coeur d'Alene Basin (OU3). The broader OU3 Basin has been divided into the Upper Basin and the Lower Basin to facilitate management of on-going cleanup activities.

The OU3 Interim Record of Decision (ROD) (EPA, 2002) specifically defines the Upper Basin to generally include mining contaminated source areas within the South Fork of the Coeur d'Alene River and associated riparian areas and its tributaries east of Cataldo. The Lower Basin includes the Coeur d'Alene River from the confluence of the North and South Forks of the Coeur d'Alene River downstream to Harrison, where it enters Lake Coeur d'Alene. The Lower Basin also includes the associated lateral lakes and floodplain wetlands in the Coeur d'Alene River valley where contamination is located.

The OU3 Interim ROD identified the primary source areas of contamination and defined the initial actions to address the risks (EPA, 2002). The ROD proposed initial remedies, recognizing that the scope and scale of remediation would require many years and significant costs, and that additional refinement of the strategies and approaches of the remedies would be necessary to achieve ultimate cleanup goals and compliance with regulatory requirements. The initial remedies proposed in the OU3 Interim ROD for the Lower Basin include the following:

- Pilot-scale removal of contaminated sediment from the river bed and banks and placement in repositories
- Evaluation of splay areas to trap contaminated sediment
- Restoration of shallow portions of lateral lakes to provide less-contaminated waterfowl habitat
- Evaluation of hydraulic controls to reduce the potential recontamination of restored lakes and marshes (envisioned as dikes or levees by the ROD, more recent concepts involve intentional flooding of protected areas with clean water to reduce recontamination risks).

Specific details regarding Lower Basin remedies were largely deferred to later stages of the OU3 effort. This was necessary given the need to proceed with critical source control measures in the Upper Basin. This also allowed more time to further refine the understanding of the Lower Basin system and evaluate the complex remedial actions proposed.

Conceptual Site Model

A conceptual site model (CSM) was developed to describe the complex interaction of contaminant sources, pathways, and receptors. The CSM identified sources of contamination and physical and geochemical mechanisms of contaminant fate and transport for the entire Coeur d'Alene River Basin, including the downstream waters of Lake Coeur d'Alene and the Spokane River (CH2M HILL 2000). Key elements of the CSM include the following and are reflected in the OU3 Interim ROD (EPA, 2002):

- Mining wastes in the Upper Basin, especially in South Fork tributaries such as Canyon and Ninemile Creeks, continue to act as sources of both particulate and dissolved-phase metals that create risks to ecosystems and humans in the Lower Basin
- Significant volumes of mining wastes from the Upper Basin have been deposited in the Lower Basin and are present in the river bed, banks, and floodplain soil and in sediments in lateral lakes and marshes
- Deposited wastes in the Upper and Lower Basins may be exposed, mobilized, transported, and redeposited downstream during flood events
- The North Fork of the Coeur d'Alene River contributes a volume of clean water and sediment several times greater than the South Fork, thereby increasing the total volume of water and sediment in the Lower Basin and diluting contaminant concentrations.
- Early mining practices were less efficient in recovering metals from ore, resulting in older (and deeper) sediment deposits with generally higher contaminant concentrations than more recent deposits
- Contaminants such as lead, zinc, cadmium, and arsenic have different geochemical characteristics and, therefore, different fate and transport characteristics; lead is primarily present in sediments, but zinc and cadmium are present in both aqueous and solid phases

- Lead, zinc and arsenic are considered the metals of principal concern for the protection of human health, and lead, cadmium, and zinc are of concern for protection of ecological receptors
- Particulate lead in the Lower Basin is a primary source of risk to both human and waterfowl receptors
- Lead and other metals may be present in colloidal forms that resist settling and remain suspended in the water column for extended periods
- Lake Coeur d'Alene rises during high flows, causing the Coeur d'Alene River to back up into the Lower Basin as far as Cataldo, allowing contamination borne by floodwaters to spread across the floodplains and deposit in lateral lakes and marshes
- Concentrations of metals are generally higher near the river and in the lateral lakes more directly connected to the river by surface flow

NAS Recommendations

EPA requested that the National Academy of Sciences (NAS) review the OU3 Interim ROD. Key comments from the NAS review (NRC, 2005) include the following:

- A quantitative model that uses a systems approach should be employed to address basin-wide sediment dynamics, deposition, and geochemistry, as well as to guide decisions regarding priority areas and remedy design
- Sediment transport from upper reaches should be addressed before significant cleanup efforts commence in the Lower Basin to ensure long-term effectiveness of the remedy
- Sediment transport modeling should be used to evaluate the long-term effectiveness of the selected remedies
- Riverbed sediments downstream of Cataldo represent a significant source of particulate lead that, if mobilized, may spread contamination further or recontaminate downstream areas; controlling mobilization of contaminated sediment in this area during flood stages should be a high priority
- The role of riverbanks in erosional and depositional dynamics of lead in sediment is not well understood
- Repositories for large volumes of contaminated sediment and soil need to be identified
- Levee enhancements and other flood control actions may cause hydraulic flow alterations and should be evaluated
- Restoration of wetlands on agricultural land is encouraged, as is enhancement of existing wetland areas that have a low probability of recontamination.

EPA is pursuing incorporation of NAS recommendations in its implementation of the OU3 Interim ROD, and the ECSM helps outline its overall approach.

Enhanced Conceptual Site Model

Overview

The ECSM will support decision making and planning, remedial option evaluation and selection, and the design and implementation of both short- and long-term remedial actions. Development of the ECSM is guided by remedial action goals, objectives and benchmarks established by the interim ROD, and the intent of Alternative 3 of the Feasibility Study and the NAS Recommendations. The ECSM will use numerical models to test source area removal scenarios, sediment mobility and deposition, recontamination potential, remedial option effectiveness, and other factors such as splay area design.

Benchmarks, or measures of progress, specific to the ECSM will be developed to assess the effectiveness of remedial strategies. These remediation benchmarks will be integrated with ecological benchmarks currently identified in the ROD; the topic of integrated benchmarks is addressed in Technical Memorandum B.

The numerical model will quantify hydraulics and sediment transport at the basin scale and address the associated spatial and temporal variability and uncertainty. Once calibrated, the numerical model can be used as a predictive tool to facilitate decision making related to recontamination risk, location, size, and cost-effectiveness of potential remedial actions such as sediment traps, splays, dredging, bank stabilization, and hydraulic controls. The numerical model will encompass primary source areas in the Upper Basin, transport reaches, and depositional areas including the lateral lakes, marshes, and floodplains in the Lower Basin.

A numerical model that is suited to addressing the spatial and temporal variability of the key parameters at the appropriate level of detail for the needs and uses of the project will be selected. Input from a variety of experts will be sought and considered by EPA in the selection process to help ensure that the modeling tool will be versatile, cost-effective, and reliable.

The accuracy of the numerical model will be strongly influenced by the quality of the input parameters and calibration and validation data, including topography and bathymetry; hydrology; hydraulics; sediment characteristics and rates of transport (suspended and bedload); and bed, bank, and floodplain roughness.

In addition to the numerical model, the ECSM will incorporate field sampling and monitoring results and the potential use of pilot studies. Products from the ECSM process will be documented in a series of technical memorandums addressing components such hydrology; hydraulics; geomorphology; geochemistry; contaminant sources, transport, and deposition; hydraulic and sediment transport modeling; and related elements. As summarized below, the technical memorandums will document past work, identify data gaps, and propose the next steps for each component.

The ECSM is focused in the Lower Basin, but encompasses Upper Basin elements where necessary. The ECSM is also envisioned as an adaptive management approach that will be routinely updated based on results of additional data collection, monitoring, understanding of system dynamics, and the responses to on-going remediation.

Components

The ECSM incorporates the following components known to influence contaminant fate and transport, remedial design, and ecological risk in the Lower Basin:

Hydrology – Hydrology incorporates the magnitude and duration of flows and associated probabilities that affect contaminant mobility and deposition. The basin is relatively well gaged, although some reaches have much shorter periods of record and fewer gages are present in the Upper Basin. Hydrologic data is a necessary input parameter for a hydraulic model.

Hydraulics – Hydraulics describes physical characteristics of flow in the channel and on the floodplains, including depth, velocity, and shear stress. Hydraulic data is primarily limited to that which can be pulled from manual discharge measurement records at USGS gages. Hydraulic data is a necessary calibration and validation parameter for a hydraulic model.

Geomorphology – Geomorphology describes the process by which water and sediment are mobilized, transported, and deposited. Understanding how this process operates in the Upper and Lower Basins and how it interfaces with sources of contaminants is central to the ECSM.

Geochemistry – An understanding of the aquatic chemistry of contaminants relative to sources, transport, and deposition is required to assess fate and transport mechanisms. The groundwater/surface water interaction is very complex component of Lower Basin contaminant transport. The mobility of contaminants is dependent on the chemistry and geochemistry of groundwater, sediment, and surface water. Groundwater elements will likely be indirectly incorporated in a numerical model, given the different temporal scales of groundwater and surface water systems.

Contaminant sources – Extensive data have been collected to describe lead and zinc concentrations in river beds, banks, riparian zones, wetlands, lakes, and upland fields. However, these data have not yet been fully evaluated for physical, temporal, and spatial comparability. This is a necessary step prior to using these data as inputs to (and calibration and validation parameters for) sediment transport models.

Hydraulic and sediment transport modeling – A numerical model will provide a tool to predict sediment transport and recontamination potential during defined flood events, to evaluate river system responses to proposed remedial actions, and to refine future design efforts. Ideally, the surface water modeling package used for the ECSM should spatially link the source, transport, and deposition areas (including floodplains and lakes) and include three elements: hydraulics, sediment transport, and morphology. The hydraulic model is the foundation for both the sediment transport and morphology models.

Related elements – The ECSM is built around a "weight of evidence" approach so that multiple lines of evidence and logic, in addition to the numerical model, can be used to assess factors affecting implementation of remedies in the Lower Basin. This may include observational, political, land use, biological, and other factors that complement the numerical model and expand the ECSM beyond a simple source-pathway-receptor model to include a range of options for remedial actions, repositories, and other consideration. The Coeur d'Alene Basin Environmental Monitoring Plan (BEMP) guides data collection for assessing the biological health, and will be incorporated into the ECSM through the use of remedy-specific benchmarks to link planned actions with desired ecological outcomes.

Attachments

Table 1 "Potential Remedies and Areas of Focus - Lower Basin of the Coeur d'Alene River" identifies the significant remedial actions identified for OU3 and the key issues that will need to be systematically evaluated. This table will link with data objectives, benchmarks and data sources in subsequent technical memorandums, and will be updated periodically to provide context for coordination of the multiple tasks necessary to achieve remedial goals in the Lower Basin.

Table 2 "ECSM Technical Memorandums" lists the ECSM components that will be prepared as separate deliverables.

References

CH2M HILL 2000. Draft Final Conceptual Site Model Summary and Update, Technical Memorandum to US EPA Region 10, August 31, 2000.

NRC 2005. National Research Council of The National Academies, Superfund and Mining Megasites, Lessons from the Coeur d'Alene River Basin, 2005.

US EPA 1991. The Bunker Hill Mining and Metallurgical Complex, Operable Unit 1 Record of Decision, August 1991.

US EPA 1992. The Bunker Hill Mining and Metallurgical Complex, Operable Unit 2 Record of Decision, September 2002.

US EPA 2001. Coeur D'Alene Basin Remedial Investigation/Feasibility Study, 2001.

US EPA 2002. The Bunker Hill Mining and Metallurgical Complex, Operable Unit 3 Record of Decision, September 2002.

Table A-1 - Potential Remedies and Areas of Focus
Lower Basin of the Coeur D'Alene River

Drivers	Potential Control Technologies [(a)]	Potential Remediation Actions for Evaluation	Evaluation Focus
Record of Decision	Monitored Natural Recovery (MNR)	In-Channel Sediment Traps	EF1. Contaminant and sediment mass loading from North and South Forks of Coeur d'Alene River. EF2. Contaminant characteristics and distribution in Lower Basin EF3. Contaminant mobility into and within Lower Basin. EF4. Contaminant characteristics and distribution in Lower Basin at T+10, T+20 and T+30 years based on projected flood events EF5. Effect of sediment trap(s) upstream of the main stem of the CdA River EF6. Effect of sediment trap on CdA River at Mission Flats. EF7. Effect of sediment trap at Dudley Reach. EF8. Effect of pilot dredging at Dudley Reach.
		Splay Areas	EF9. Effect of splay areas of XX acres in upper reaches of Lower Basin. EF10. Size of splay areas with YY% removal effectiveness to achieve ZZ% sediment load removal in upper reaches of Lower Basin.
	Capping	Wetland Sediment and Soil Capping	EF11. Effectiveness and feasibility of inverting soil in floodplain with contaminant concentrations above XX mg/kg. EF12. Effectiveness of supplemental vegetation program to stabilize areas of highest floodplain contaminant concentrations in soil.
	Dredging/ Disposal	Lateral Lake Dredging	EF13. Feasibility of hydraulic diking to protect lateral lakes and marshes from recontamination. EF14. Effects on sediment transport and floodwater elevations in Lower Basin from potential use of hydraulic diking.
		Riverbed and Delta Sediments Dredging with Bank Stabilization/ Vegetative Growth In-Channel Sediment Traps Wetlands Lateral Lakes Floodplain areas	EF15. Effectiveness of dredging on sediment transport and redeposition under various dredging scenarios. EF16. Effectiveness of bank stabilization on sediment transport and redeposition. EF17.Sediment removal with disposal at regional repository and revegetation with native plants and soil amendments. EF18. Sediment removal and disposal in an on-site regional repository. EF19. Sediment removal and disposal in a local repository.

Drivers	Potential Control Technologies [a]	Potential Remediation Actions for Evaluation	Evaluation Focus
Alternative 3. Additional RAs from RI/FS	Excavation/ Disposal	Contaminated Bank Wedge Removal	EF20. Effectiveness of bank wedge removal that can be subject to erosion or leaching.
	Dike/Levee	Dike/Levee Construction and Enhancement	EF21. Effectiveness of a levee system to protect back-levee areas from flooding.
	Capping	Floodplain/Wetland Capping	EF22. Effectiveness of capping impacted floodplain/wetland areas with material from a local borrow pit.
	Dredging/ Disposal	Sub-aqueous Disposal in Lateral Lake and Coeur D'Alene Lake	EF23. Feasibility of constructing a disposal facility in the central portion of a lateral lake.
		Local Repository	EF24. Feasibility of constructing a local repository for dredge spoils adjacent to a lateral lake.
		Regional Repository	EF25. Feasibility of constructing a regional repository.
	Hydraulic Isolation	Hydraulic Control Structure	EF26. Feasibility of controlling flow of water and sediments between the river and adjacent lakes and wetland areas.
	Soil Restoration	Soil Amendments	EF27. Effectiveness of applying soil amendments to restore soil fertility and encourage growth of desirable plant species.

Notes: (a) EPA Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (2005). Remedies applicable to sediment are consistent with EPA guidance. Upland and other remedies are consistent with those identified in the Feasibility Study.

TABLE A-2 - ECSM TECHNICAL MEMORANDUMS
Coeur d'Alene River Lower Basin OU3

Memo Topic	Memo Code	Description	Estimated Date Available to EPA Reviewers
Overview	A	Provides background, purpose and approach to ECSM.	October 15, 2008
Goals, objectives and performance criteria	B	Identifies goals and objectives for Lower Basin portion of OU3, and identifies measures of performance and how they can be used to assess task sequencing, interim milestones and project success.	November 30, 2008
Hydrology	C	Input to probability, characteristics and effects of flood and non-flood events for ECSM and modeling.	January 30, 2009
Hydraulics	D	Modeling provides data on flow, inundation and velocity in various reaches, and key input to sediment recruitment deposition at given cross sections.	January 30, 2009
Geomorphology & aerial photography	E	Addresses effects of hydraulics on erosion and deposition on river bed, banks, floodplain and lateral lakes.	February 28, 2009
Geochemistry	F	Assesses effects of groundwater/surface water interactions and other factors related to contaminant mobility, solubility, precipitation and contaminant loading.	January 30, 2009
Contaminant sources & characteristics	G	Identifies locations and characteristics of significant sources of contaminant loading, including river bed and banks in Lower Basin. Assesses temporal comparability and usability of existing sediment data.	March 31, 2009
Modeling selection criteria & process	H	Assesses existing models for Upper and Lower Basins of the Coeur d'Alene River, their strengths and limitations, and their relative ability to meet long-term project objectives.	March 31, 2009
GIS and mapping/ vegetation data	I	Documents data needs and uses to allow a coordinated approach to accessing, coordinating and utilizing data within a GIS framework.	February 28, 2009
Data requirements & data gaps	J	Outlines the data needed for the ECSM as identified by the ECSM technical memorandums, and assesses these needs relative to existing and planned data collection. Identifies data gaps, data needs and schedules.	March 31, 2009
Related Elements	K	Describes factors in addition to the predictive model that can be combined in a "weight of evidence" approach to evaluating sources, potential remedial designs, remedy effectiveness and other factors.	March 31, 2009