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Bathymetric and Sediment Facies Maps for China Bend and Marcus Flats, Franklin D. Roosevelt Lake, Washington, 2008 and 2009

By Rhonda J. Weakland, Ryan L.Fosness, Marshall L. Williams, and Gary J. Barton

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Introduction

In support of an interdisciplinary study of white sturgeon (*Acipenser transmontanus*) and their habitat areas within Franklin D. Roosevelt Lake, Washington (hereinafter referred to as Lake Roosevelt), the U.S. Geological Survey (USGS) created bathymetric and sediment facies maps for portions of two reaches of Lake Roosevelt. The mapping effort focused on utilizing noninvasive study techniques to characterize the elevation, texture, and grain size of the lakebed surface in areas used by Lake Roosevelt white sturgeon fry. Surface relief was characterized by using a multibeam echo sounder to generate bathymetric data. The purpose of this research is to aid future physical sampling efforts focusing on areas that have the greatest potential to find smelter slag contamination, while reducing the effect on the environment or culturally sensitve areas through random sampling. Past research has indicated that smelter slag often looks like black sand particles. Videography sampling in the survey area allows for characterizing sediment facies by grain size, areas of sand deposition, and in some cases, depending upon light availability, color. This survey has identified areas containing black-colored particulate matter that may be elements and minerals, organic material, or slag.

The white sturgeon population in Lake Roosevelt is threatened by the failure of natural recruitment, resulting in a native population that consists primarily of aging fish that is gradually declining as fish die and are not replaced by nonhatchery reared juvenile fish. Many newly hatched native sturgeon fry have been observed in previous years in the upper riverine reaches of Lake Roosevelt; however, recent assessments of sturgeon population structure indicate that native juvenile sturgeon do not survive to sexual maturity. These fish spawn and rear in the riverine and upper reservoir reaches where smelter slag is present in the sediment of the river and lake bed (Howell and McLellan, 2005; U.S. Environmental Protection Agency, 2006).

Tons of granulated (sand-sized) slag has been discharged into the Columbia River and subsequently transported downstream by river currents as part of the sediment load where slag may have been deposited in river bars and quiescent regions of Lake Roosevelt (Cominco, 1991; G3 Consulting Ltd., 2001; Northwest Hydraulic Consultants, 2007). During periods of low reservoir stage, slag has been observed among the interstitial sediments of exposed gravel bars that are believed to be used as habitat by newly hatched sturgeon fry during their hiding phase. Some large deposits of slag, such as the one at Black Sand Beach, are well documented, but the location of much of the deposited slag material is not well documented or known. A conceptual site model for sediments in Lake Roosevelt based on grain-size distribution and analysis of channel cross-sectional area hypothesize that most of the slag has been deposited in the pre-reservoir river channel area near Marcus Flats (U.S. Environmental Protection Agency, 2006). However, other large deposits of slag may occur as much of the bed sediments in the riverine reach were not sampled due to the difficulty of sampling interstitial sediments present in the gravelly boulder substrate of the swiftly flowing reaches. Granulated slag particles have distinctive morphological features that have been described by Cominco Ltd. (1991) and Cox and others (2005). Slag grains typically are black sand-size particles with a smooth, glassy surface often containing vugs and a combination of smooth, rounded and angular surfaces often with needle-like projections and an appearance similar to that of eggshells. The surface appearance is often lustrous in relatively unweathered grains. When examined with a petrographic microscope, slag grains are opaque under polarized light.

Effects of slag on the white sturgeon population in Lake Roosevelt are largely unknown, but recent studies indicate that slag may harm white sturgeon and (or) their young. Recent studies demonstrated that copper and other metals can be mobilized from slag containing sediments (Paulson and Cox, 2007). In the riverine reach of Lake Roosevelt, concentrations of copper and zinc in bed sediments can reach levels of 10,000 and 30,000 mg/kg due to the presence of smelter slag (U.S. Environmental Protection Agency, 2006). In a separate study, copper was found to be highly toxic to 30-day-old white sturgeon with 96–h LC50 (96–h, 96–hour exposure; LC50, median lethal concentration which kills 50 percent of the population) concentrations ranging from 3 to 5 µg copper per liter (Edward E. Little, U.S. Geological Survey, Columbia, Mo., written commun., 2009). Older juvenile and adult sturgeons commonly ingest substantial amounts of sediment while foraging. Thus, fish foraging in slag-contaminated sediments likely have slag particles in their guts. The physical properties of slag particles may contribute to environmental stress that has detrimental effects on the gut tissue as they pass through the spiral intestine (Parsley and others, 2010). These studies suggest that slag may have adverse effects on white sturgeon fry and juvenile age groups. Resource managers for the Lake Roosevelt ecosystem need additional information about the factors and processes that may affect the abundance of the white sturgeon. Identifying areas of where slag could potentially accumulate within the white sturgeon habitat areas of Lake Roosevelt is important in evaluating potential effects of the slag. Past coarse-scale telemetry studies have shown that white sturgeons seasonally occupy the Marcus Flats reach. It has been noted that considerable quantities of slag are present in the old river channel in the vicinity of Marcus Flats (U.S. Environmental Protection Agency, 2006).

Purpose and Scope

In October 2008, scientists from the USGS used a boat-mounted multibeam echo sounder (MBES) to collect bathymetric data at China Bend and Marcus Flats. In March 2009, an underwater video camera was used to collect sediment facies data from the same areas. These data were used to construct bathymetric and sediment facies maps for China Bend and Marcus Flats. This report presents bathymetric and sediment facies maps of China Bend and Marcus Flats for Lake Roosevelt, between Northport and Kettle Falls, Washington. These maps can be used to help identify areas that may contain slag within the riverbed deposits. This study was conducted by the USGS as part of a broader study examining white sturgeon habitat and the occurrence and effects of smelter slag on white sturgeon populations in the upper Columbia River. Together this information may be useful in efforts to locate areas of potential smelter-slag accumulation.

Description of the Study Area

Lake Roosevelt is a reservoir in Washington on the Columbia River impounded by Grand Coulee Dam. The reservoir extends northward for about 151 miles to the United States–Canada border (fig. 1). The Columbia contributes about 70 percent of the inflow into Lake Roosevelt. Sediment transported and deposited into Lake Roosevelt is primarily derived from the inflowing Columbia River, tributary streams and rivers, landslides, and erosion of unconsolidated sediment along the margins of the reservoir (Cox and others, 2005). Inflow of suspended sediment to Lake Roosevelt is depleted as a result of sediment trapping by numerous upstream dams such as Waneta and Sevenmile Dams on the Pend Oreille River and Long Lake Dam on the Spokane River.

China Bend is located at river mile (RM) 725, approximately 10 miles southwest of Northport, Wash., and Marcus Flats is located at RM 705, less than 5 miles northwest of Kettle Falls, Wash. (fig. 1). The Washington Department of Fish and Wildlife have used acoustic telemetry to track sturgeon movement in the Upper Columbia River and verified white sturgeon live, spawn, and stage as juveniles in these study areas (Howell and McLellan, 2005). Granulated slag was discharged into the Columbia River until 1995 from lead-zinc smelters upstream from Lake Roosevelt (G3 Consulting Ltd., 2001). The slag was transported downstream and can now be found within the reservoir sands and gravels and along the shoreline (Northwest Hydraulic Consultants, 2007; Majewski and others, 2003).

Methods and Techniques

The MBES was used in October 2008 to map the bed elevation of Lake Roosevelt at China Bend, river miles (RM) 725.2 to 724.0, and Marcus Flats, RM 707.3 to 704.9. The referenced bed elevation is based on North American Vertical Datum 1988 (NAVD88). The MBES uses a 240–kilohertz (kHz) pulse over a 120-degree-wide swath to profile the bathymetry of the lake bottom. The MBES data were collected using Hypack® hydrographic survey software (available at *http://www.hypack.com/new*), and were processed through Hysweep® collection and editing software to produce a digital elevation model (DEM, a regularly spaced grid of elevation points) on a 10-ft grid. The grid spacing provided a high-resolution surface that displayed sand dune formations, rock outcroppings, and other unique features that aid in the development of the sediment facies maps. The DEMs were imported into geographical information system (GIS) software to create bathymetric maps at China Bend and Marcus Flats (figs. 2*A* and 2*B*).

Sediment facies were determined in March 2009 by using a tethered high-resolution, color video camera. The predominant particle size of sediment at the riverbed surface was determined using two parallel lasers with 4-inch separation mounted on the camera housing. Video images were captured at discrete points along numerous cross sections through the study areas, allowing for sufficient detail to map distinct changes in sediment facies. Sediment facies classifications: gravel, sand, and silt, were characterized according to sediments observed in the video images (figs. 3*A* and 3*B*). Each cross section contained video points spaced apart by about 100 ft. The total number of video points per cross section varied with the width of the cross section. Cross sections were drawn at major deviations in channel bathymetry to capture changes in sediment facies and possible presence of black-colored particles (fig. 4*A* and 4*B*). Sediment facies categories used in construction of the facies map were based on the grain size distribution of Wentworth (1922) which included the following ranges: bedrock, gravel (greater than 0.08 to 2.5 inches), sand (0.002 inch to less than 0.08 inch), and silt (fines) (less than 0.002 inch).

Results

Results of the digital elevation model for the China Bend reach, based on the 10-ft-grid spacing of the MBES survey, show deeper water (dark blue colored areas with depths ranging from 85 ft to 90 ft, from water surface) and corresponding riverbed elevations of 1,194 ft to 1,203 ft. (fig. 2*A*). The areas of greater depth were found on the outside of the river meander where higher streamflow velocities and bed scour are expected. Conversely, shallower regions were observed on the inside of the meander were depositional areas would be expected. The narrow stream channel at China Bend allows for higher streamflow velocity, resulting primarily in clean gravel along the channel bottom and gravel with sand along the channel margins. Clean gravel and gravel with sand were the predominant sediment facies in this reach (fig. 3*A*). Deposits that were predominantly sand and silt were evident in isolated areas along the inside channel margins and toward the downstream end of the reach. However, sand and fine grained sediments were apparent in some of the interstitial spaces between gravel and cobble material. Most areas of sediment accumulation were along the inside of the point bar and toward the downstream end of the bar where sand facies were more often observed. Areas of scour occur all along the outer perimeter of the river bend. Black-colored particles identified in China Bend are depicted in figure 4*A*. Sediment that contains these particles was found both in depositional and erosional environments of the study areas.

The digital elevation model of Marcus Flats based on the MBES survey is shown in fig. 2B. The dark blue color represents a hole about 165 ft deep from the water surface; riverbed elevation ranged from 1,118 ft to 1,138 ft, coinciding with an area of exposed basalt where sediment has been scoured from the river bottom. The DEM shows what appear to be sand dunes; dune height on the order of 2–3 feet is present in the downstream portion of Marcus Flats. The sediment facies map in figure 3*B* indicates a predominance of sand with silt, interspersed with areas of gravel embedded in the sand and silt. Silt deposits were observed along the western edge of Marcus Flats. Black-colored particles that were identified in areas of Marcus Flats are depicted in figure 4*B*. Sand deposits that contained these particles were found both in depositional and erosional environments of the study areas.

Future study efforts in Lake Roosevelt could include sampling of bottom material to confirm the presence or absence of possible slag material. In addition, follow-up acoustic work to determine stream velocities at varying discharges, in conjunction with sediment mapping, would be helpful to more accurately identify areas of scour and areas of sediment deposition where slag deposits may accumulate within the Marcus Flats and China Bend reaches. MBES mapping could also be used to determine changes in bed elevation and sedimentation in the study reaches and could help evaluate annual deposition and provide estimates on fine-sediment thickness.

Acknowledgments

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Middle of Lake Roosevelt. Photograph by L. Snook, National Park Service. Available at *http://www.nps.gov/laro/parkmgmt/businesswithpark.htm.*

Measuring a white sturgeon (*Acipenser transmontanus*). Photograph by USGS staff; record number 10469; date published, Sept. 27, 2008; image originally taken in May 1999. Published by National Biological Information Infrastructure, available at *http://life.nbii.gov/dml/home.do.*

Figure 1. Site map and location of Marcus flats and China Bend study reaches. Shaded relief from U.S. Geological Survey Landsat Tri-decadal State satellite Mosaic Washington, 2001, available from the USGS Store at *http://usgs.store.gov/*. Lake Roosevelt National Recreation Area boundary accessed on Dec. 16, 2010 at *http://www.nps.gov/carto/PDF/LAROmap1.pdf.* Colville National Forest boundary from the U.S. Dept. of Agriculture National Forest Service accessed on Dec. 16, 2010 at *http://www.fs.fed.us/r6/data-library/gis/colville/index.shtml*, Okanogan National Forest Service boundary at *http://www.fs.fed.us/r6/data-library/gis/okanogan/index.shtml,* Little Pend Oreille National Wildlife Refuge boundary from *http://www.fws.gov/littlependoreille/pdf/PublicUseRefugeMap.pdf.* Spokane Indian Reservation boundary accessed on Dec. 16, 2010 at *http://www.spokanetribe.com/reservation.* Colville Indian Reservation Boundary from *http://www.colvilletribes.com/map%20of%20non%20tribe%20camp.html.* River miles from National Oceanic and Atmospheric Administration (NOAA), Office of Coast Survey at *http://www.nauticalcharts.noaa.gov/.* All boundaries are generalized and approximately located and for display purposes only. Inholdings have not been shown.

China Bend

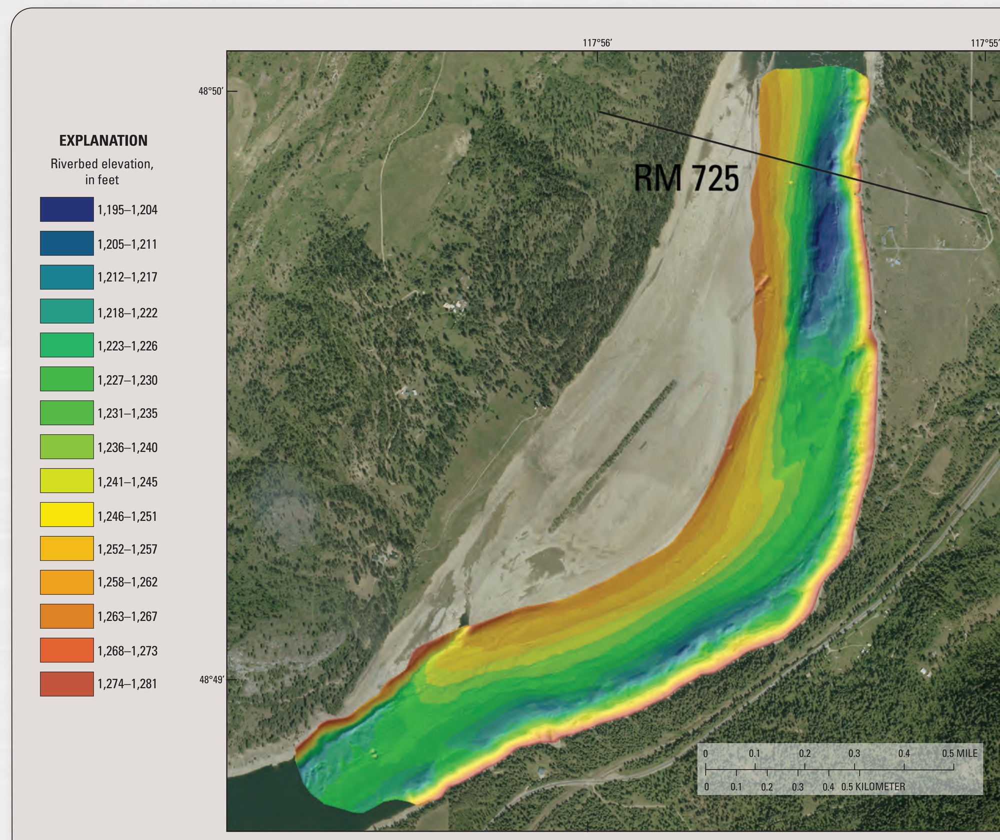


Figure 2*A*. Elevation of the Lake Roosevelt bed at China Bend as mapped with a multibeam echo sounder during October 2008. RM, river mile.

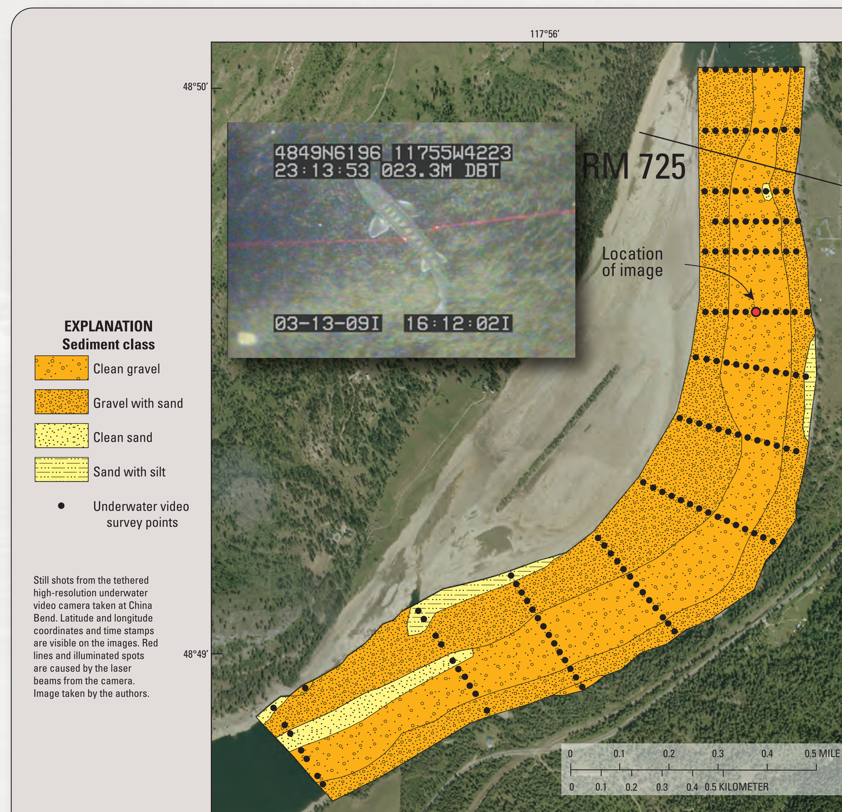


Figure 3*A*. China Bend sediment facies as mapped with underwater video, March 2008. RM, river mile.

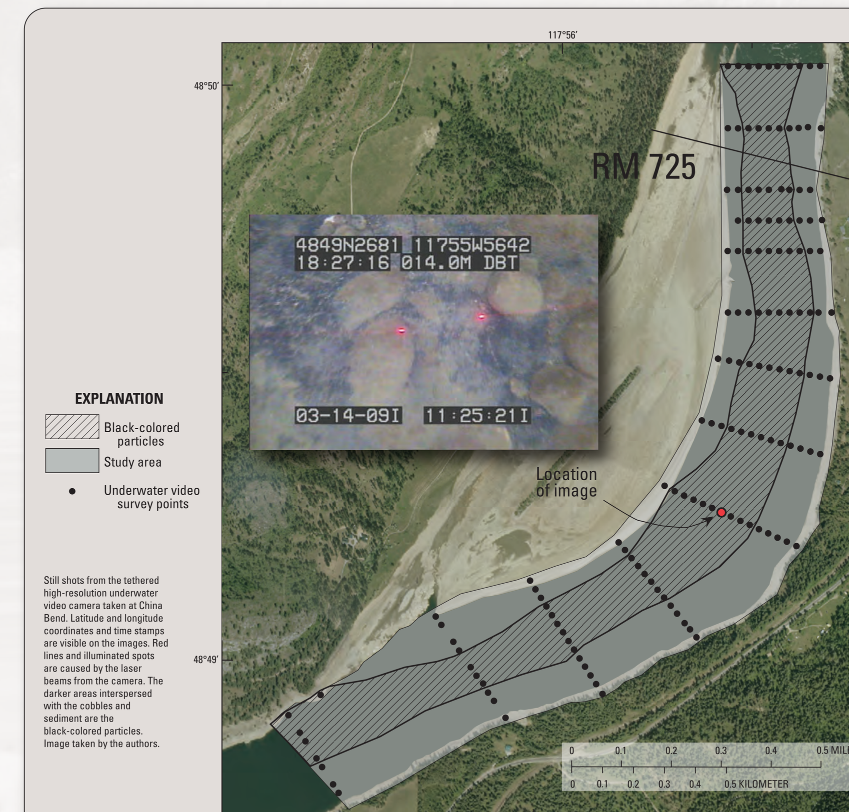
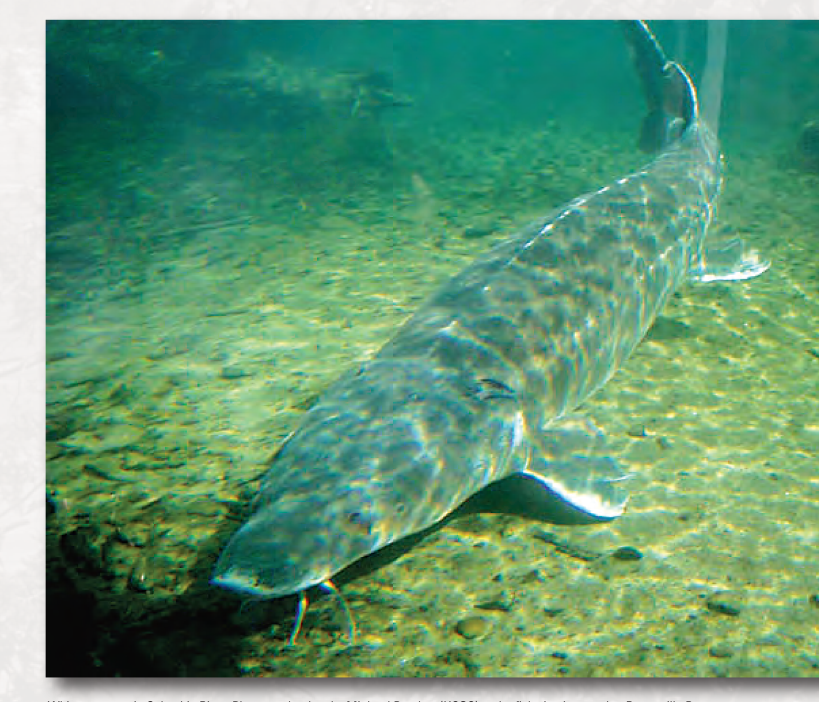


Figure 4*A*. China Bend. Location of black-colored particles as mapped with underwater video during March 2009 Wash. RM, river mile.



White sturgeon in Columbia River. Photograph taken by Michael Parsley (USGS) at the fish viewing pond at Bonneville Dam.

Marcus Flats

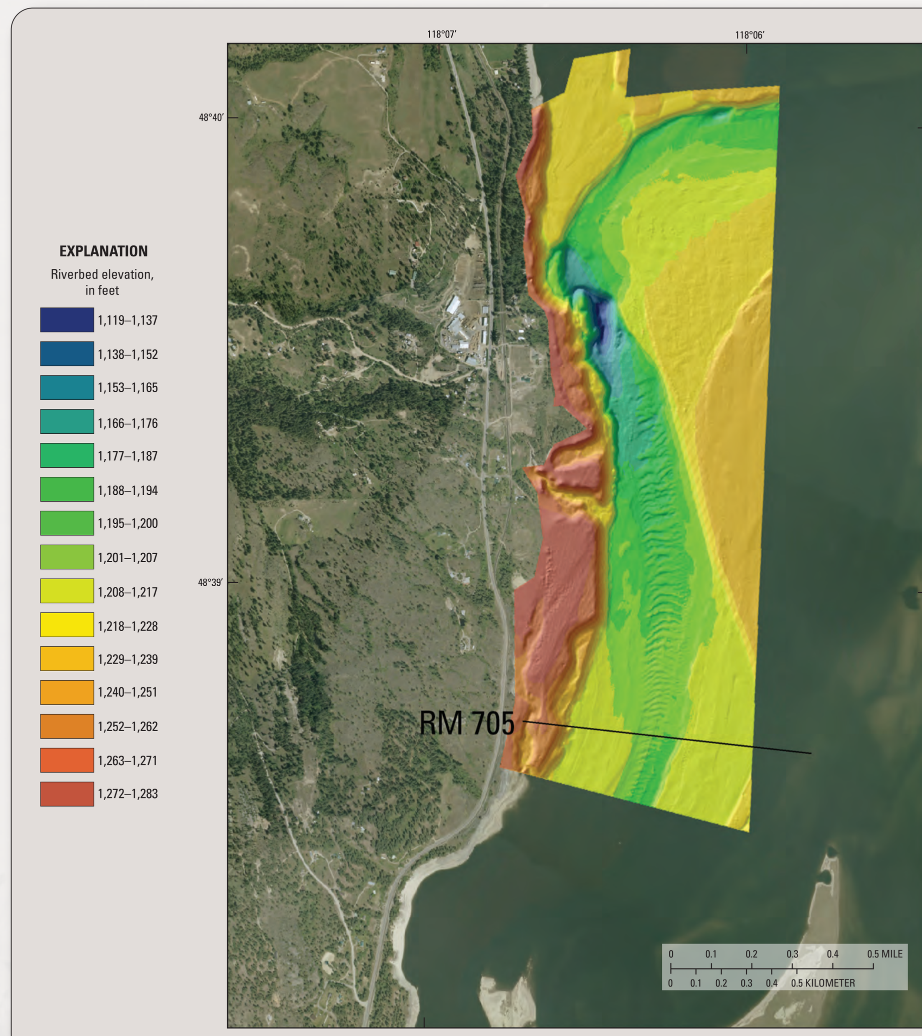


Figure 2*B*. Elevation of the Lake Roosevelt bed at Marcus Flats as mapped with a multibeam echo sounder during October 2008. RM, river mile.

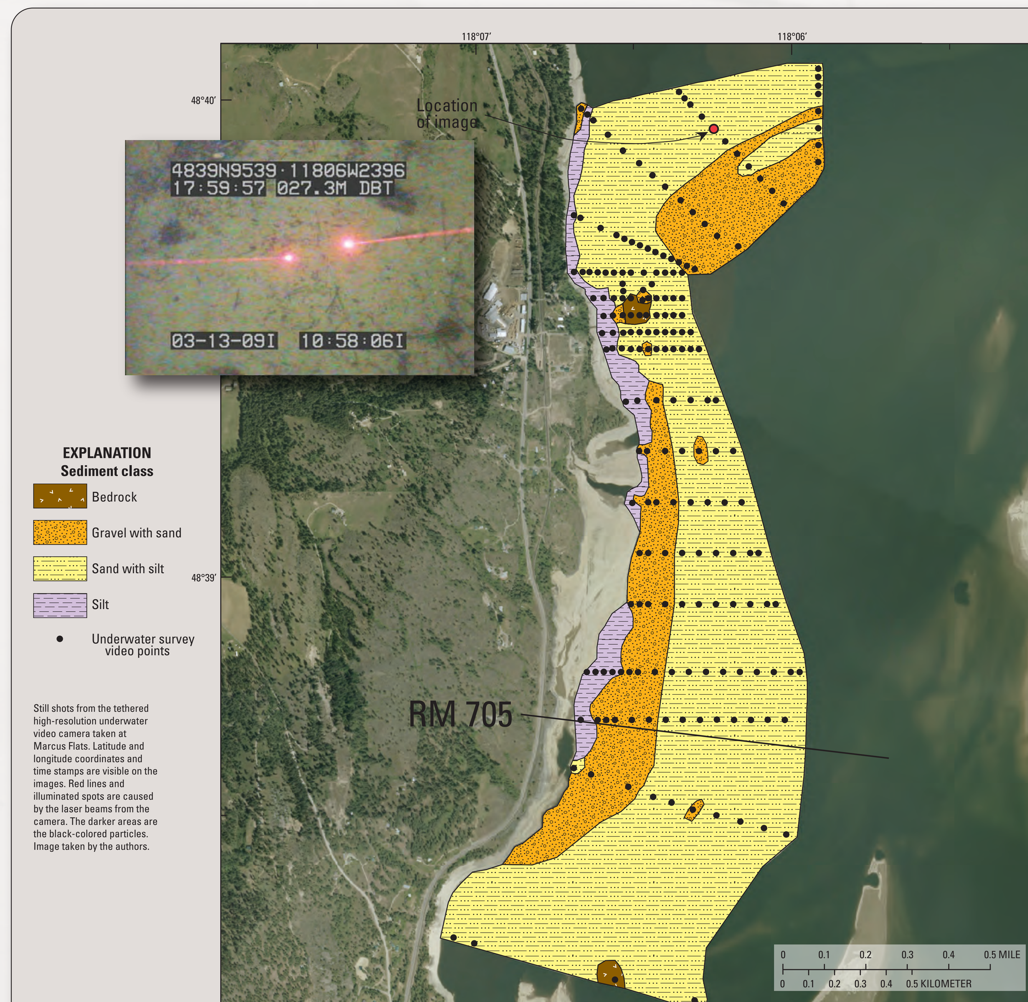
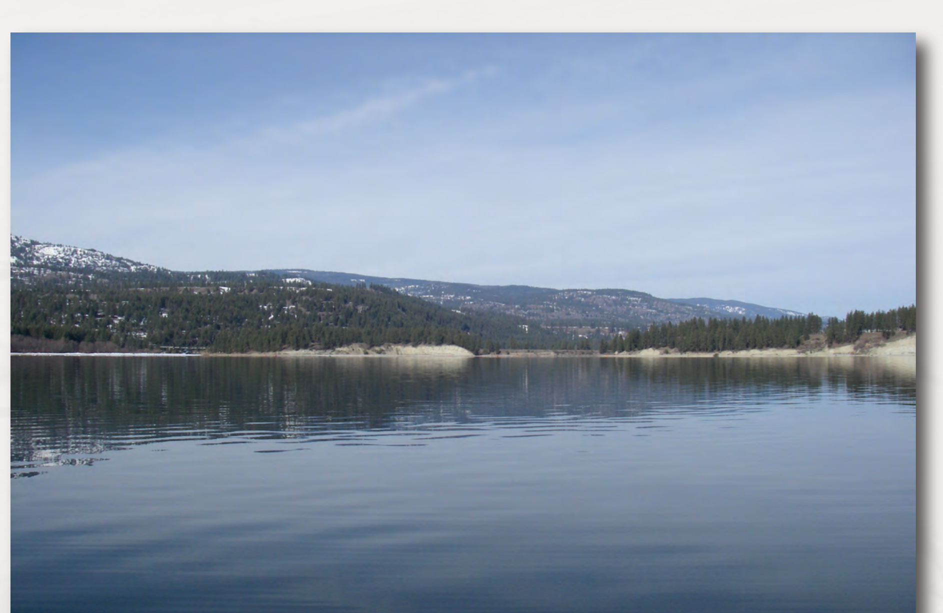


Figure 3*B*. Marcus Flats sediment facies as mapped with underwater video during March 2009. RM, river mile.

Figure 4*B*. Marcus Flats. Black-colored particles as mapped with underwater video during March 2009 near Kettle Falls, Wash. RM, river mile.



Marcus Flats, Washington, at the northern end of the study boundary. The photo is looking northwest near the confluence of the Kettle and Columbia Rivers. Photograph by Rhonda J. Weakland, Dec. 2009.

CONVERSION FACTORS

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inches (in)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)

SI to Inch/Pound

Multiply	By	To obtain
	Volume	
liter (L)	0.2642	gallon (gal)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound, avoirdupois (lb)

Elevation, as used in this report, refers to distance above the vertical datum.

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Concentrations of chemical constituents in water are given in (µg/L).

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Basemap images (dated 2004) for figures 2A–4A and 2B–4B from U.S. Department of Agriculture, Farm Service Agency, Aerial Photography Field Office, National Agriculture Imagery Program (NAIP) available at: *http://www.apfo.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai-or*

Drawing of sturgeon done by Nonindigenous Aquatic Species (NAS, http://nas.er.usgs.gov/).

Background image: About four miles below Boundary Post Office. Terrace on west side of Columbia River, direction northwest. Stevens County, Wash., August 1901. Image from USGS Photographic Library, ID Ransome, F.F., 087, rfl00087.

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