

FIELD TRIALS MONITORING SAND DEPOSITION AND EROSION ON A RAZORBACK SUCKER SPAWNING BAR ON THE GREEN RIVER NEAR JENSEN, UTAH, AND OPERATIONAL DESCRIPTION OF LOAD-CELL SCOUR SENSORS

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INTRODUCTION

A liquid-filled, load-cell scour sensor is being used to monitor deposition and erosion on a sand and cobble bar on the Green River in northeastern Utah downstream from Flaming Gorge Dam and the confluence with the Yampa River (fig. 1). The bar is 3 miles downstream from the streamflow-gaging station Green River near Jensen, Utah (09261000), and is used by razorback suckers for spawning in April and May before spring runoff. The monitoring is part of a study of endangered razorback suckers being done by the U.S. Geological Survey, the National Park Service, and the U.S. Fish and Wildlife Service. The load-cell sensor weighs the sediment, water, and air above it, and an accompanying pore-pressure sensor weighs the water and air above it. The difference between the two weights is the weight of the sediment overlying the sensor pair. Combined sensitivity and repeatability are ± 0.01 foot of sediment thickness or less. A temperature sensor in the pressure-sensor housing provides useful information about the spawning-bed and sensor environment and enables calibration of the pressure sensors to ± 0.02 percent of full-scale output.

FIELD TRIALS

Seven sensor pairs were buried at depths of 0.3 to 1.5 feet in an array across the bar and the adjacent channel and provide hourly data to a datalogger (figs. 1 and 2). River stage at the spawning bar is determined from the pore pressure sensor at sensor D. The load-cell sensors have documented (1) deposition of as much as 0.7 foot of sediment on the spawning bar during the historically determined spawning period and within the historically determined spawning-temperature range (sensors A and D), (2) subsequent erosion of the deposited sediment, (3) the migration of dunes 0.2 foot in height or less in the channel (sensor F), (4) passage of a cobble, ice, or debris in the bed load with a scour hole in front of and behind the object (sensor D), and (5) ice-dam buildup with ponding of as much as 5 feet over the bar and subsequent erosion or breakup of the ice dam.

DESCRIPTION AND OPERATION

The liquid-load-cell scour sensor consists of a shallow, stamped 10-inch by 6-inch rectangular stainless-steel vessel with 0.002-inch stainless-steel foil that spans the open top and is silver soldered to the perimeter (fig. 3). A stainless-steel pipe fitting is silver soldered into a hole in the end of the vessel. The vessel is filled with degassed water, and the mating pipe fitting, which contains a pressure sensor ported inside the vessel, is attached under water. The load-cell sensor is buried, with the foil surface on top in a horizontal plane, to a depth below anticipated scour. The pressure sensor inside the water-filled vessel weighs the sediment, water, and air above it as that weight is applied to the compliant foil and, in turn, to the relatively incompressible water inside the vessel. A second pore-pressure sensor, ported to the sediment outside the vessel, weighs the water and air above it. The pressure inside the vessel minus the pore pressure outside the vessel is the weight of the overlying sediment or effective stress. A coefficient of about 0.8 times the weight of the sediment gives the sediment thickness. The coefficient is determined by field calibration and accounts for grain density and porosity.

The sensor can be buried or jetted into cohesionless sediment such as a sandbar. The sensor weighs sediment in a cone above it. The cone consists of sediment above the angle of internal friction or angle of repose, about 30 degrees above horizontal. The deeper the sensor is buried, the safer it is from being scoured and the larger the area it averages. The shallower the sensor, the greater the detail that can be determined from closely spaced sensors, but the greater the risk of removal by scour. The small change in grain packing after scour and fill is addressed by periodically resurveying the streambed above the sensor. Recalibration also can be determined in ephemeral streams when the stream goes dry. At that time, the sediment thickness above the sensor is equal to the height of the water column within the saturated sediments from the accompanying pore-pressure sensor to the bed surface. Bridging of grains across the foil, which could prevent the transfer of changes in sediment weight to the sensor, does not appear to be a problem in saturated cohesionless sediment. The sensor also works on its side, with the foil in a vertical

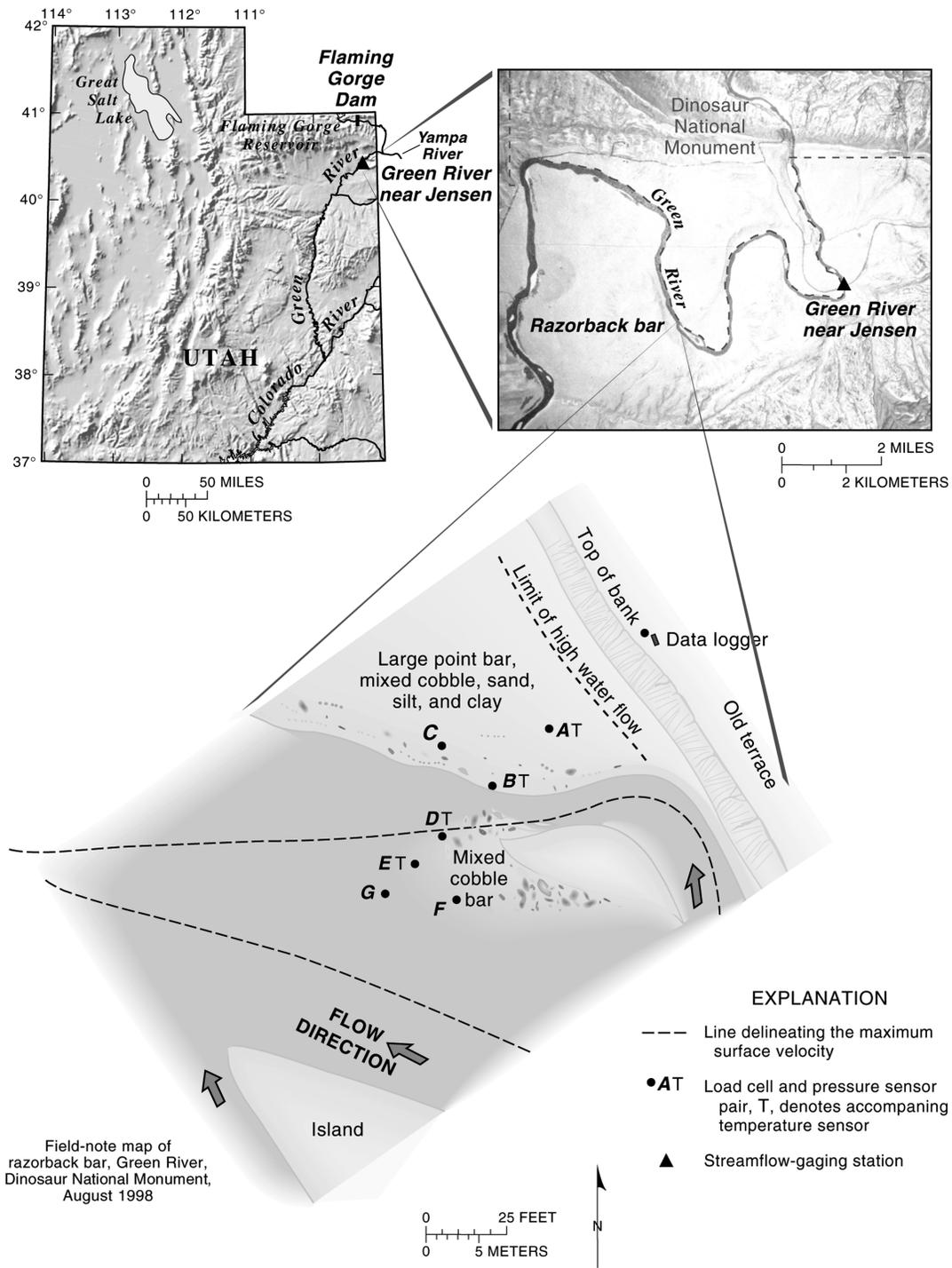


Figure 1. Location of sensors in razorback sucker spawning bar.

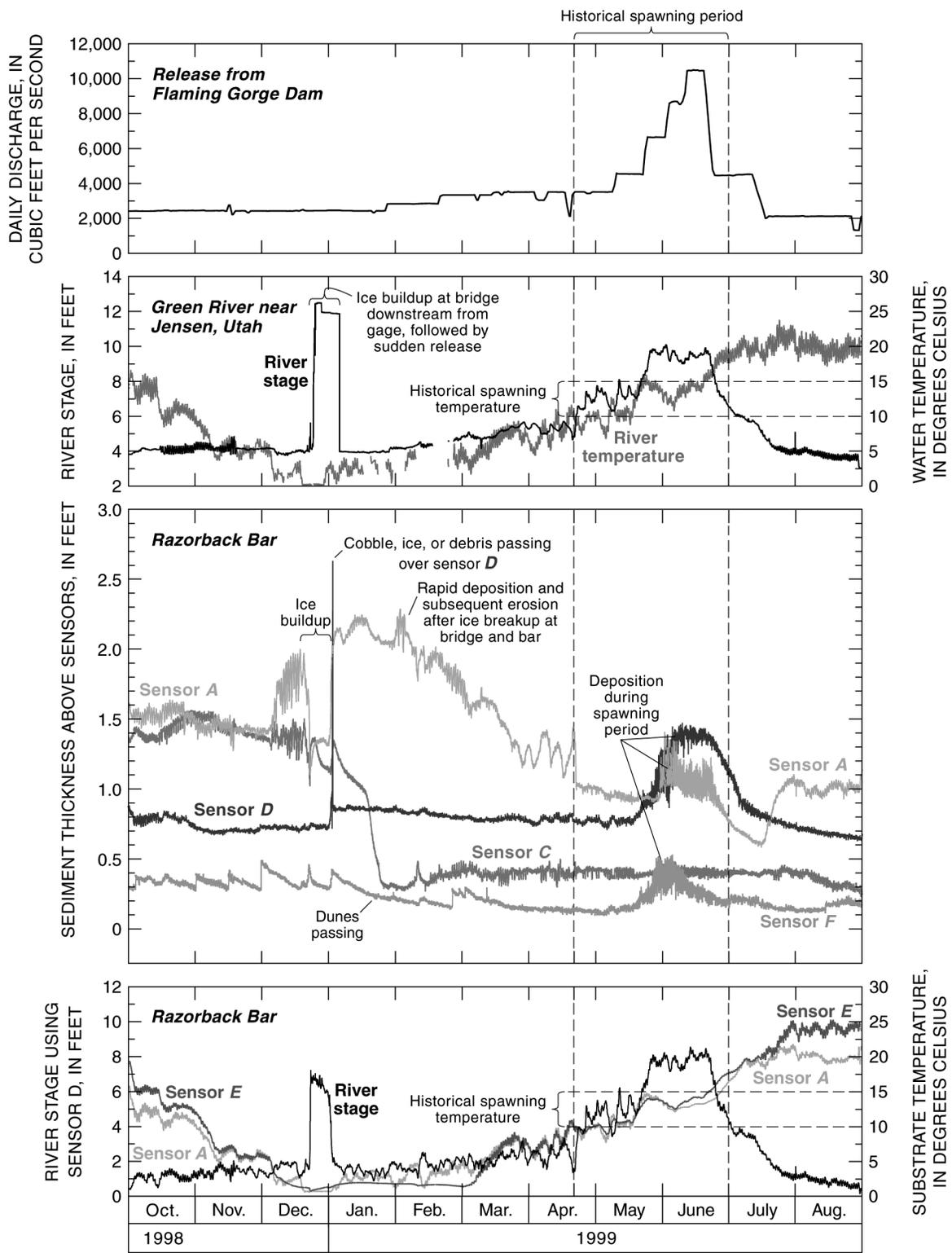


Figure 2. Streambed deposition and erosion, river stage, and substrate temperature at the razorback sucker spawning bar, release from Flaming Gorge Dam, and river stage and water temperature at the Jensen, Utah, streamflow-gaging station (09261000).

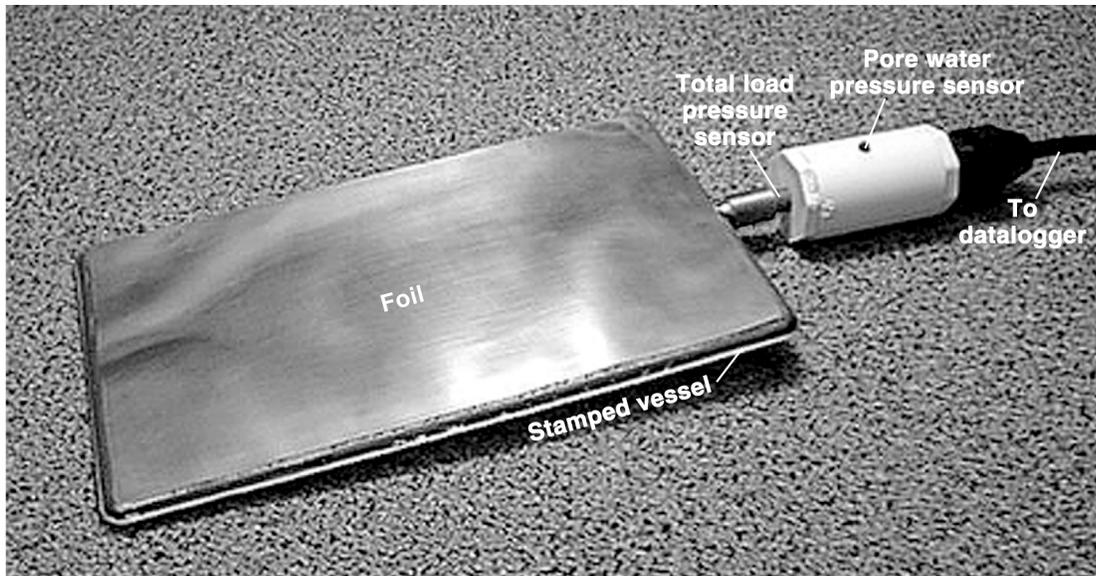


Figure 3. Load-cell scour sensor.

plane, because changes in horizontal stress (with a coefficient of about 0.3) in sediment accompany changes in vertical stress (weight per unit area) that are caused by scour and deposition.

The load-cell sensor can provide unattended measurement and documentation of scour, deposition, and sediment transport in ephemeral streams. Installation of multiple sensors in two or more closely spaced cross sections will enable automated slope-area determinations of discharge and establishment of rating curves at sites in sand channels that are inaccessible during flow. Additional uses of the sensor include scour at bridge piers and similar structures, studies of liquefaction or quicksand, and beach erosion. The load-cell measurement differs from other techniques of measuring scour, such as time-domain reflectometry and sonar, by distinguishing between actual static grain-to-grain contact and near grain-to-grain contact that occurs during liquefaction or quicksand and can occur in saltation transport of bedforms. In the case of liquefaction, both the load-cell sensor and the pore-pressure sensor measure the weight of a dense liquid, namely water with sand grains dynamically suspended in or settling through the water.

TESTING AND PRIOR USE

For the sensor to be useful, the sediment overlying the sensor must transfer a change in weight caused by deposition and erosion to the sensor in a linear, repeatable, and reversible manner. The sensor was tested by being buried at a depth of 5 feet with the water level above and below the bed. Sediment was deposited on and removed from the bed, and a load was placed on and removed from the bed. The associated accuracy and repeatability of the measurement was 0.01 feet. Seven sensor pairs were used to document erosion, deposition, and a sudden scour event on a sandbar downstream from the mouth of the Little Colorado River during the spring 1996 controlled flood experiment on the Colorado River in the Grand Canyon.

INSTALLATION AND PRACTICAL CONSIDERATIONS

Conventional installation requires trenching to a depth below anticipated scour for the electrical cable that extends from the sensor to a buried waterproof box that houses the datalogger on the river bank. In gravel and cobbles having little chance of scour, hand-shovel trenching can be done in approximately knee-deep water. In sand, hand-shovel trenching requires a dry bed. A cylindrical version of the sensor vessel and radio-frequency-modem communication, which are still under development, are intended to make installation possible or easier in flowing sand or where trenching is not possible. The sensor is robust. After the sudden erosion event in the Grand Canyon flood of 1996, the sensors were scoured out and banged against the canyon wall in the current for 2 months. Several of those sensors were subsequently used on the Green River in Utah. The sensors are tested to 30 pounds per square inch and can be buried to a depth of 20 feet with 20 feet of additional submergence. The sensor is sensitive to small changes in sediment load and can measure infilling of gravel and cobbles with fine-grained sediment. Ideal uses for the sensor include (1) shallow placement in spawning beds of fish for unattended monitoring of deposition, erosion, and substrate temperature, (2) monitoring transport of bedforms in experimental flumes, and (3) monitoring scour at bridge piers or similar structures.