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# Selenium Concentrations and Loads in the Yampa River Basin, Northwestern Colorado, 1997–98

## Selenium Concentrations are Elevated in the Western United States

Irrigation in the arid to semiarid Western United States is known to locally cause enrichment of selenium concentrations in return flows. Between 1986 and 1993, the National Irrigation Water-Quality Program (NIWQP) investigated 26 areas in 14 Western States for irrigation-induced contamination of selenium (Seiler, 1998). Fourteen of the 26 areas were considered to be seleniferous because 25 percent or more of surface-water samples had selenium concentrations exceeding 3 micrograms per liter. Seiler (1998) concluded that 12 of these seleniferous NIWQP sites were associated with Upper Cretaceous and Tertiary marine sediments and high rates of evaporation. Studies for NIWQP concluded that the middle Green River area in Utah contributes substantial sources of selenium to the Green River (Stephens and others, 1992) and that the Uncompahgre and Grand Valleys in Colorado contribute substantial quantities of selenium to the Gunnison and Colorado Rivers (Butler and others, 1996). Selenium enrichment in these valleys was associated with irrigation in areas underlain by the marine Mancos Shale of Cretaceous age.

The Yampa and Green Rivers are designated as critical habitat for recovery of several endangered fish species (U.S. Fish and Wildlife Service, 1994). The Yampa River discharges into the Green River upstream from critical razorback sucker spawning areas near Jensen, Utah (fig. 1). The NIWQP and the Recovery Implementation Program for endangered fish (Wydoski and Hamill, 1991) require more information about the Yampa River with respect to concentrations and loads of selenium, the distribution of selenium concentrations throughout the year, and the effect of the Yampa River on selenium concentrations and loads in the Green River.

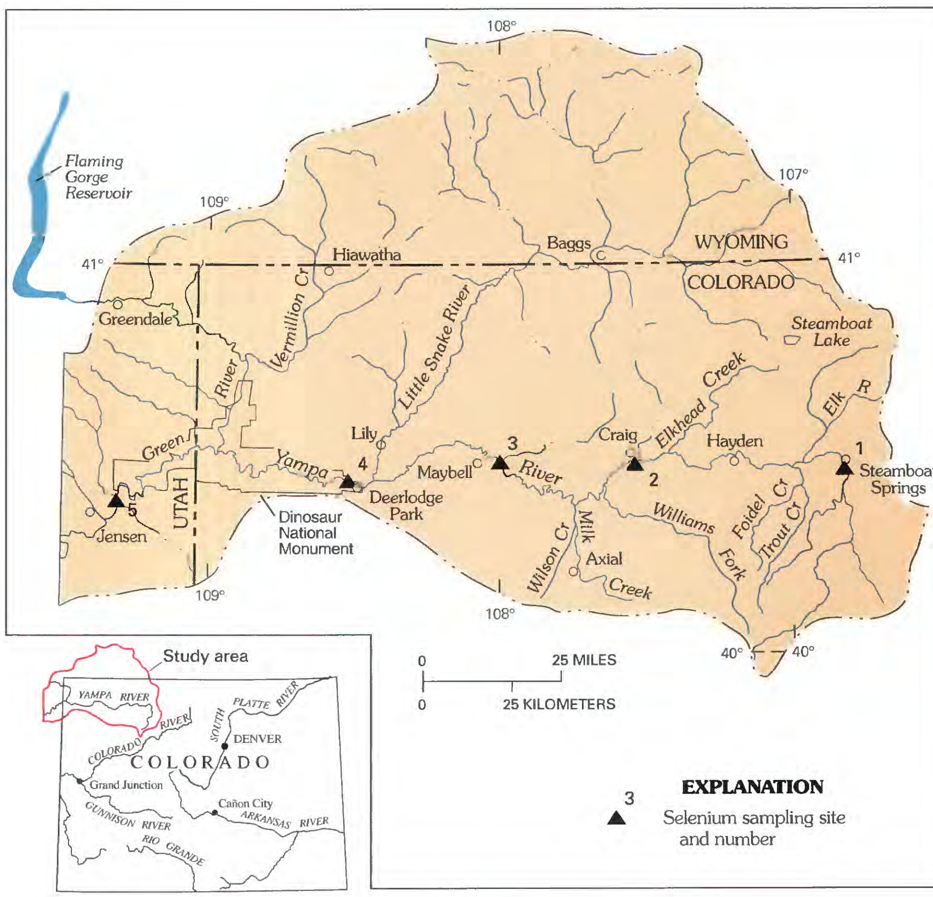


**Figure 1.** Location of study area and sampling sites on the Yampa and Green Rivers.

This fact sheet describes results of selenium sampling during 1997–98 in the Yampa River Basin and on the Green River near Jensen, Utah. Selenium loads are presented and comparisons among sites are done to delineate source areas during snowmelt runoff in 1998. The effects of selenium loads from the Yampa River on selenium concentrations in the Green River are discussed. Interpretation of data collected for this study is supplemented by historical data from the U.S. Geological Survey National Water Information System (NWIS).

## Selenium Samples were Collected during 1997–98

Between November 1997 and October 1998, samples were collected for dissolved- and total-recoverable selenium concentrations at five sites. These sites (as numbered in fig. 1) were: (1) Yampa River at Steamboat Springs, Colorado, U.S. Geological Survey station number 09239500; (2) Yampa River below Craig, Colorado, station number 09247600; (3) Yampa River near Maybell, Colorado, station number 09251000; (4) Yampa River at Deerlodge Park, Colorado, station number 09260050; and (5) Green River near Jensen, Utah, station number 09261000. During this period, each site was sampled three to four times during low flow from October through February, four to five times during early runoff from March through April, once during peak runoff in May, and one to three times during the summer after peak runoff. Data resulting from sampling the four sites on the Yampa River are reported in Crowfoot and others (1998 and 1999). Data resulting from sampling the Green River near Jensen are reported in Herbert and others (1998 and 1999).

## The Largest Dissolved-Selenium Concentrations and Loads in the Yampa and Green Rivers Occurred in March

Dissolved-selenium concentrations in samples collected for this study (fig. 2) had the following ranges and means (concentrations reported as less than 1 microgram per liter were set equal to 0.5 microgram per liter for computation of means): Yampa River at Steamboat Springs, all less than 1 microgram per liter; Yampa River below Craig, less than 1 to 4.8 (mean 2.3) micrograms per liter; Yampa River near Maybell, less than 1 to 4.9 (mean 2.4) micrograms per liter; Yampa River at Deerlodge Park, less than 1 to 3.6 (mean 1.8) micrograms per liter; and Green River near Jensen, Utah, less than 1 to 2.0 (mean 1.0) micrograms per liter.

The confluence of the Yampa River and the Green River at Echo Park in Dinosaur National Monument. (Photograph courtesy of John Elliott, U.S. Geological Survey)

The average ratios of total-selenium concentration to dissolved-selenium concentration for samples collected for this study were as follows (based on samples collected for both forms on the same day and assuming that concentrations less than 1 microgram per liter were equal to 0.5 microgram per liter): Yampa River at Steamboat Springs, 1.00 (dissolved and total concentrations all less than 1 microgram per liter); Yampa River below Craig, 0.96; Yampa River near Maybell, 1.04; Yampa River at Deerlodge Park, 1.35; and Green River near Jensen, 1.14. These ratios indicate that most selenium was transported in dissolved form at all sites. However, the ratio for the Yampa River at Deerlodge Park indicates that about one-fourth of the total-selenium concentration at this site was in particulate form.

The distribution of dissolved-selenium concentrations over time (fig. 2) shows that concentrations exceeded the reporting limit of 1 microgram per liter during January–April 1998 at all sites except the Yampa River at Steamboat Springs (which had no detectable concentrations) and possibly at the Green River near Jensen site (which was not sampled in January 1998). Maximum concentrations at all sites (except possibly the Yampa River at Steamboat Springs) were in March. Concentrations were less than the reporting limit during May through October 1998 at all sites. During November–December 1997, dissolved-selenium concentrations were 1.8 micrograms per liter at Yampa River below Craig and 1.9 micrograms per liter at Yampa River at Deerlodge Park.

A plot of dissolved-selenium loads for samples collected for this study (fig. 2) shows relatively small loads at all sites during the sampling period except during March through early April 1998. The sharp peak in the loads during late March 1998 resulted from a rapid rise in streamflow during near-peak concentrations. Loads were not calculated for May–October 1998 because all concentrations were less than 1 microgram per liter.

Historical data for the Little Snake River near Lily (USGS station 09260000, about 10 miles upstream from the mouth of the river) (fig. 1) for 1975–86 indicate that 41 of 45 samples contained less than or 1 microgram per liter dissolved selenium and that the other four samples contained 2 micrograms per liter. During the same period, dissolved-selenium concentrations at the Yampa River near Maybell site were less than or 1 microgram per liter in only 31 of 45 samples and were as large as 11 micrograms per liter in the other 14 samples. Therefore, dissolved-selenium concentrations at the Yampa River at Deerlodge Park generally are diluted

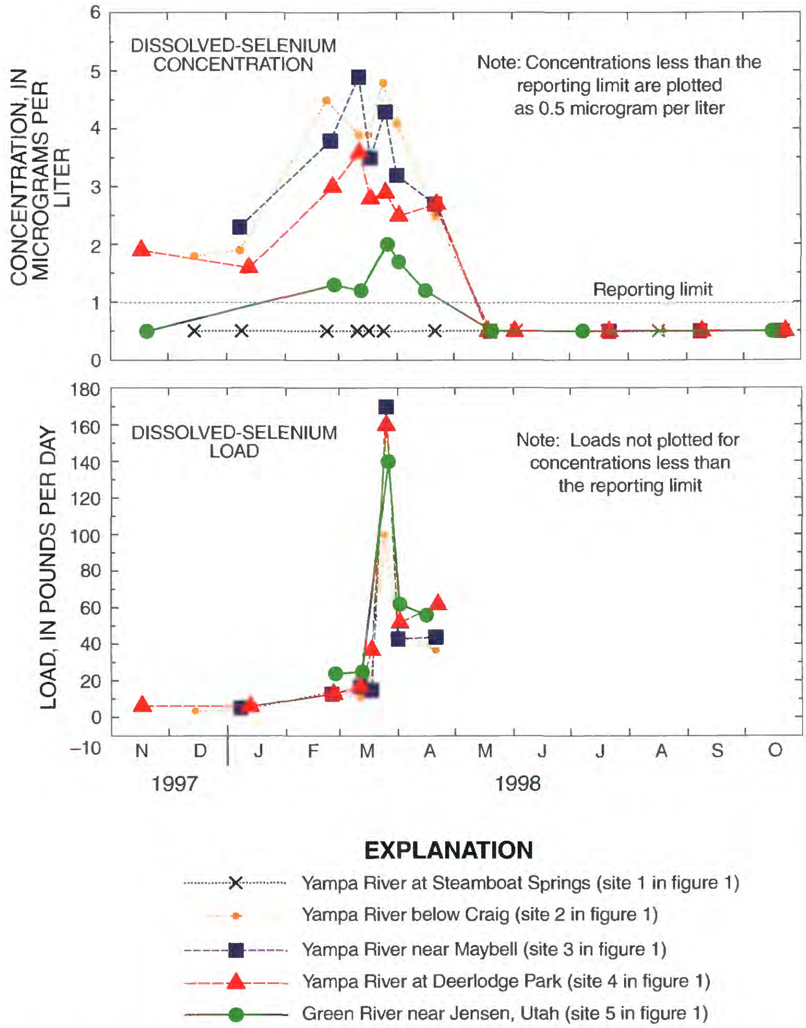


**Figure 2.** Dissolved-selenium concentrations and loads in the Yampa River and in the Green River near Jensen, Utah, during 1997–98.

by the Little Snake River, which is the only substantial tributary between the Yampa River near Maybell and the Yampa River at Deerlodge Park.

## Most of the Selenium in the Green River near Jensen, Utah, is from the Yampa River

Hydrographs for the Yampa River at Deerlodge Park (which is about 45 miles upstream from the mouth of the Yampa River), the Green River at Jensen (which is about 35 miles downstream of the mouth of the Yampa River), and the Green River near Greendale (which about about 75 miles upstream from the mouth of the Yampa River and 0.5 mile downstream from Flaming Gorge Reservoir)(fig. 1) during November 1997 through October 1998 (fig. 3) show relative contributions of streamflow from the Yampa and Green Rivers at their confluence to the Green River near Jensen. Streamflow in the Green River upstream from the mouth of the Yampa River is controlled largely by release of water from the Flaming Gorge Reservoir (as is indicated by the hydrograph for the Green River near Greendale). Releases during summer are regulated to keep the lake relatively full for recreation yet provide enough water for downstream rafting. During fall and winter, releases exceed inflow to lower the lake level for the following spring runoff. In contrast, the Yampa River is largely free-flowing, with only one small main-stem reservoir upstream from Steamboat Springs. During spring runoff when Green River water is being impounded in the reservoir, the Yampa River (as is indicated by the hydrograph for the Yampa River at Deerlodge Park) contributes most of the streamflow in the Green River near Jensen. During summer, the relative streamflow from the Yampa River steadily decreases to a minor fraction. During winter, the Yampa River typically contributes one-fourth to one-third of the streamflow at the Jensen site.

Dissolved-selenium data for the 1997–98 sampling (fig. 2) show that concentrations in the Green River near Jensen were elevated slightly above the reporting limit of 1 microgram per liter only during late February through April 1998. During this period, concentrations in the Yampa River were increased by early melting of snow and ice at lower elevations but were not substantially diluted at the confluence with the Green River because of impounding of Green River water in Flaming Gorge Reservoir.

Historical dissolved- and total-selenium concentrations in the Green River near Jensen generally have been smaller than concentrations at Yampa River sites downstream from Steamboat Springs, indicating dilution by Green River water at its confluence with the Yampa River. Dilution also is indicated by historical NWIS data for the Green River near Greendale: nearly all concentrations have been less than or 1 microgram per liter. Stephens and Waddell (1998) also concluded that the Yampa River is the first substantial contributor of selenium to the Green River.

Dissolved-selenium loads for samples collected for this study during 1997–98 (fig. 2) indicate that most of the load in the Green River near Jensen originated from the Yampa River. No major tributaries or diversions are on the Yampa and Green Rivers between Deerlodge Park and the site near Jensen. Therefore, 1997–98 data from these two sites are acceptable for estimating dissolved-selenium loads con-

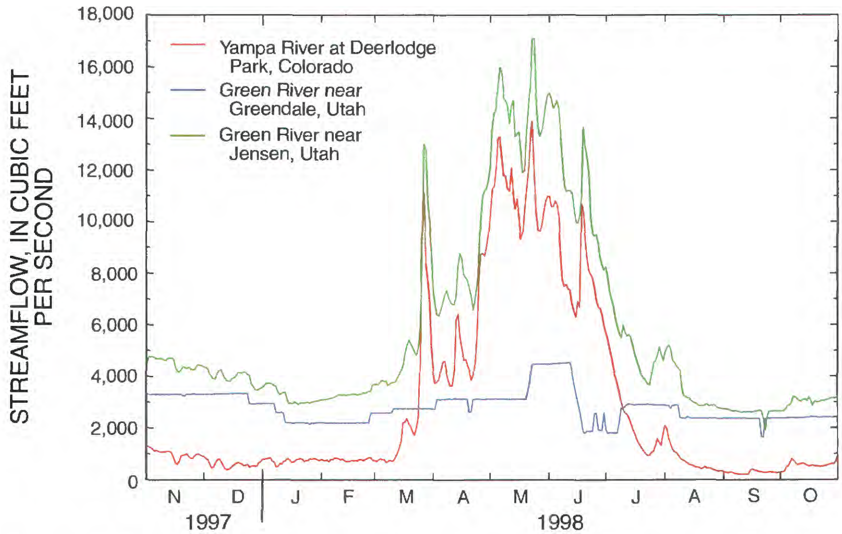


**Figure 3.** Streamflow hydrographs for the Yampa River at Deerlodge Park, Colorado, the Green River near Jensen, Utah, and the Green River near Greendale, Utah, November 1997–October 1998.

tributed by the Yampa River to the Green River. However, these estimates of load contributions are approximate because sampling at the Jensen site was not timed to sample the exact same parcels of water that were sampled at Deerlodge Park.

Ratios of streamflow and dissolved-selenium loads at the Deerlodge Park and Jensen sites were calculated for five sample pairs collected within 3 days of each other between November 17, 1997, and April 2, 1998. During November 17–20, 1997, February 26–27, 1998, and March 12–13, 1998, the Yampa River at Deerlodge Park had less than or one-fourth of the streamflow at the Green River near Jensen but had about one-half to two-thirds of the dissolved-selenium load that was measured at the Jensen site. During March 26–27, 1998, streamflow had increased substantially at both sites (over tenfold at Deerlodge) in response to rain on melting snow and ice at lower elevations; Deerlodge then had about three-fourths of the streamflow and nearly all of the dissolved-selenium load at Jensen. By April 2, 1998, streamflow had decreased substantially at both sites; Deerlodge had slightly more than one-half of the streamflow but more than three-fourths of the dissolved-selenium load at Jensen.

## Potential Sources of Selenium in the Yampa River are the Natural Leaching of Rocks and Soils, Irrigation, and Coal Mining

Natural leaching of rocks and soils in the basin probably has provided a small but steady source of selenium to the Yampa River. Marine and continental shales, mostly of Cretaceous age, are exposed over a large part of the basin, beginning a few miles downstream from Steamboat Springs (Tweto, 1976).

Irrigated agriculture is a minor land use in the Yampa River Basin. Only about 86,800 acres (136 square miles) (Crowfoot and others, 1999), less than 2 percent of the drainage basin upstream from Deerlodge Park, is irrigated. Most of the irrigated land drains to the Yampa River between Steamboat Springs and Craig. Substantial dry-land (nonirrigated) wheat farming is done at elevations above the Yampa River flood plain, largely between Hayden and Craig. Tillage of land for this farming potentially enhances infiltration of precipitation and leaching of selenium to the ground water, especially during late winter and early spring melting of snow and ice. Most historical dissolved-selenium concentrations in the Yampa River near Maybell (fig. 4) that were larger than the reporting limit occurred between late February and mid-April, not during summer months. Therefore, to the extent that irrigation affects selenium concentrations in the Yampa River, it is largely caused by flushing of infiltrated irrigation water and residual salts during late winter and early spring melting of snow and ice rather than by runoff of precipitation and return flow of irrigation-affected water during summer.

Selenium is associated with sulfides, primarily pyrite (Hem, 1985), in coal and in shale interlayered with coal deposits and in organic complexes in coal (Naftz and Rice, 1989). Naftz and Rice (1989) detected selenium concentrations as large as 340 micrograms per liter in shallow ground water affected by coal mining in the Powder

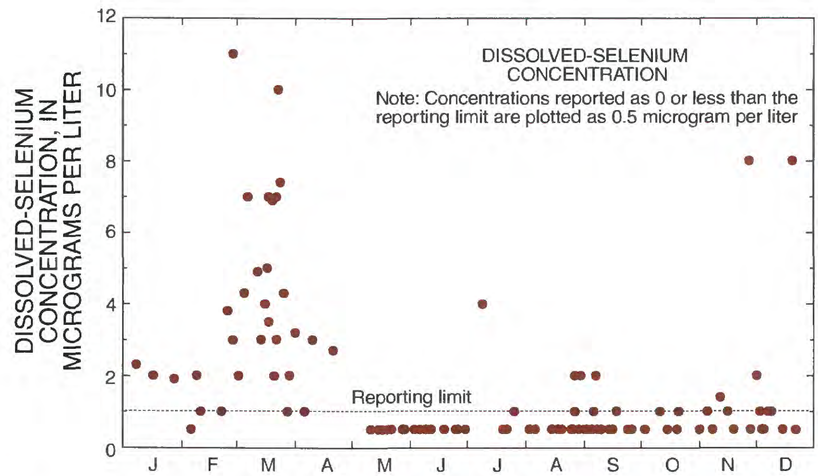


**Figure 4.** Historical dissolved-selenium concentrations in the Yampa River near Maybell by month, 1974–99.

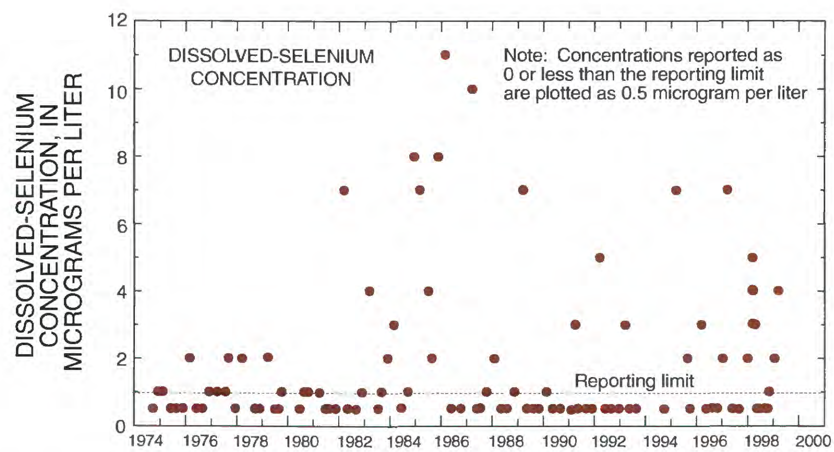


**Figure 5.** Historical dissolved-selenium concentrations in the Yampa River near Maybell, 1974–99.

River Basin of Wyoming. Therefore, coal mining possibly has contributed selenium to the Yampa River. Extensive coal-mining development in the Yampa River Basin, which largely has been located in areas south of the river between Steamboat Springs and Craig, grew rapidly in the early 1980's and peaked in the mid-1980's. Historical data for the Yampa River near Maybell (fig. 5) show that maximum dissolved-selenium concentrations increased from 2 micrograms per liter in the late 1970's, peaked at 11 micrograms per liter during the mid-1980's, and decreased to 7 micrograms per liter in the early 1990's.

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The Yampa River near Hayden, Colorado. (Photograph courtesy of John Elliott, U.S. Geological Survey)

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