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# What happens to nutrients in offstream reservoirs in the lower South Platte River Basin?

**NATIONAL WATER–QUALITY ASSESSMENT PROGRAM**

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The practice of storing South Platte River water in offstream reservoirs reduces nutrient concentrations but also contributes to the growth of algae, which may adversely affect the recreational use of the reservoirs. Results of a study of five offstream reservoirs in the lower South Platte River Basin during the 1995 irrigation season showed that the reservoirs trapped 20 to 88 percent of incoming nitrogen and phosphorus, except for phosphorus in one reservoir. Total nitrogen concentrations in the reservoirs were highest in March and decreased through September, largely as a result of uptake by algae and other aquatic life for growth. Total phosphorus concentrations in the reservoirs were more variable because of the recycling of phosphorus by aquatic life. Chlorophyll-*a* concentrations indicated that the amount of algae in all reservoirs increased during the summer and that all reservoirs were eutrophic. This study was done by the U.S. Geological Survey as part of the National Water-Quality Assessment (NAWQA) Program.

## Why can nutrients be a problem in reservoirs?

Nutrients such as nitrogen and phosphorus are essential for all plant and animal life. In excess amounts, however, nutrients can accelerate the growth of aquatic plants and cause algal blooms that deprive deeper water of the sunlight needed by other aquatic plants and animals. This process is known as eutrophication. The subsequent decay of algae and other aquatic plants consumes dissolved oxygen, which can lead to fishkills. Algal blooms and excess aquatic plant growth also can make a water body unsuitable for recreation. Sources of nutrients in the South Platte River are both natural and human derived and include precipitation, discharges from wastewater-treatment plants, and fertilizers and manure used on croplands in agricultural areas and on lawns in urban areas.

In 1995, as part of the National Water-Quality Assessment (NAWQA) South Platte River Basin Study, the U.S. Geological Survey did a study to determine how the practice of storing South Platte River water in offstream reservoirs affects the concentration of nutrients in the stored water during the irrigation season from March through September. These reservoirs serve as critical sources of irrigation water for agricultural areas in the basin. Several also are used for fishing, boating, and swimming and are habitats for birds, including bald eagles, white pelicans, and a variety of ducks and geese.

**Jackson Reservoir during summer. Offstream reservoirs in the lower South Platte River Basin provide habitat for a variety of birds.**

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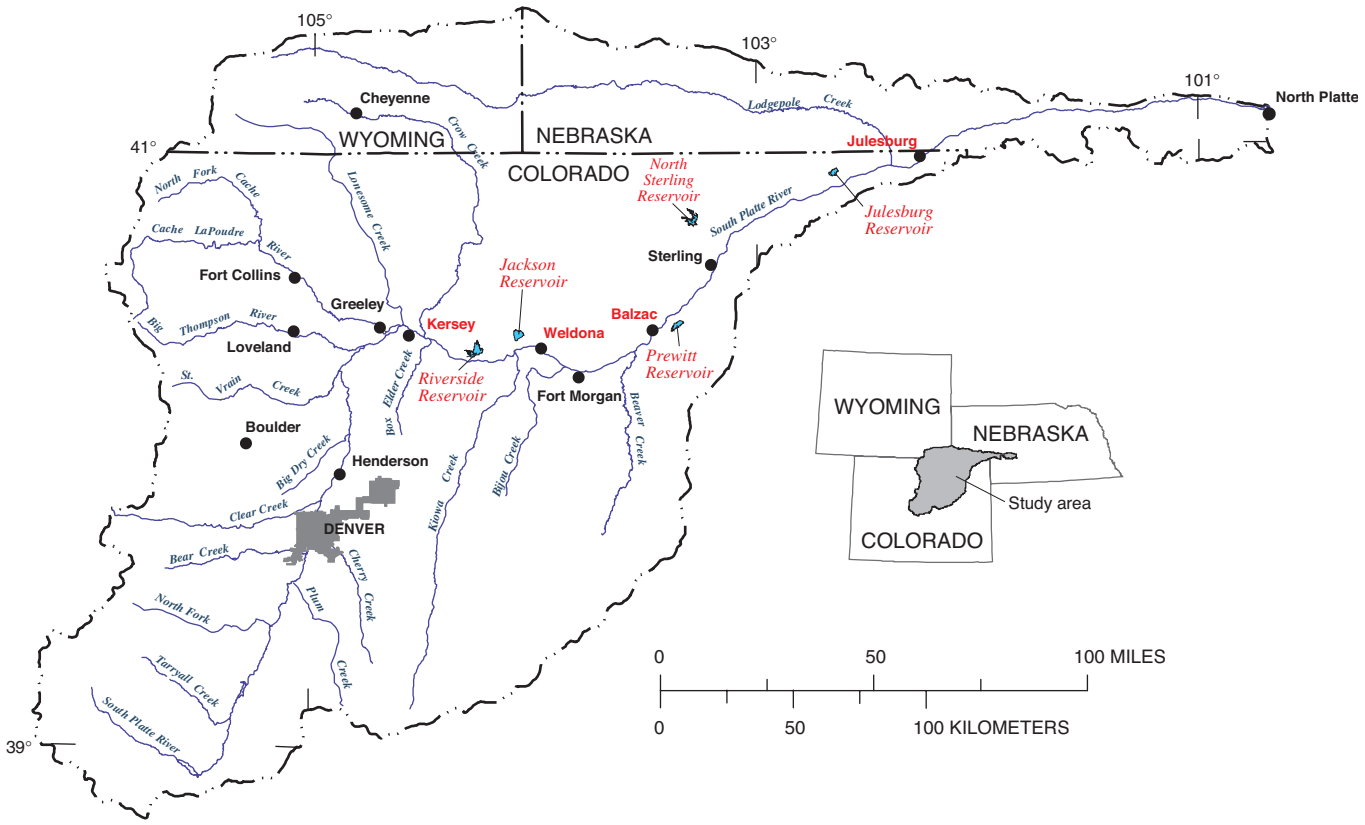


Base from U.S. Geological Survey and U.S. Census Bureau digital data, 1974 to 1993

**Figure 1.** Offstream reservoirs and river sites sampled in the South Platte River Basin in 1995. These reservoirs are valuable for irrigation water, recreation, and wildlife habitat.

High nutrient concentrations have been measured in the South Platte River, the source of water to the reservoirs. Nutrient concentrations in the South Platte River just downstream from Denver, Colo., were among the highest measured from 1992 through 1995 in the 20 river basins sampled throughout the United States by the NAWQA Program (Dennehy and others, 1998). Concentrations in the South Platte River from Kersey to Julesburg commonly exceeded 0.15 mg/L (milligrams per liter) of total nitrogen and 0.01 mg/L of total phosphorus, the generally accepted inflow limits for the control of algal blooms in reservoirs (U.S. Environmental Protection Agency, 2000).

The reservoirs are filled by diversions from the South Platte River, and the amount of water diverted from the river in any given year can be substantial. The combined storage capacity of the five reservoirs—about 235,000 acre-feet—equals nearly one-fourth of the annual streamflow in the South Platte River at Kersey, Colo. Water from the reservoirs is released through irrigation canals and delivered to agricultural fields, where some of the water infiltrates down into ground water and ultimately returns to the river.

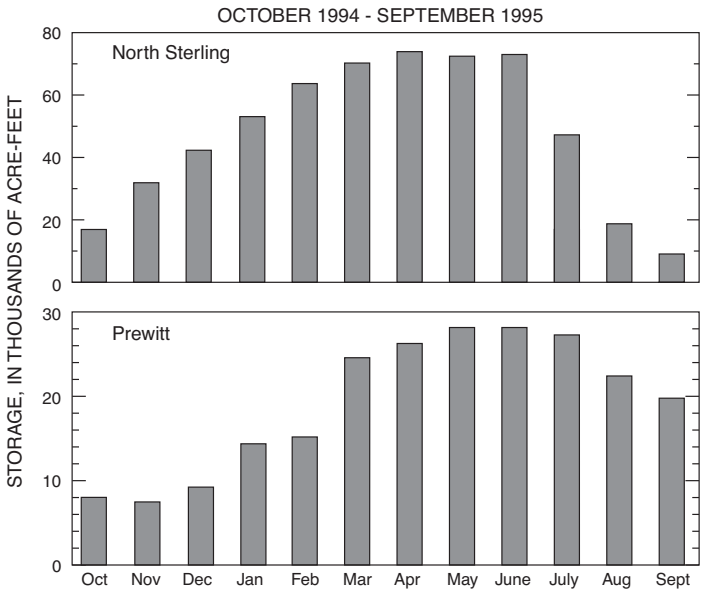


**Figure 2.** Seasonal variation in storage in North Sterling and Prewitt Reservoirs was substantial. Storage patterns for the other three reservoirs showed similar increases through the spring and decreases through the summer as water was released for irrigation.

The five reservoirs sampled during this study and their maximum storage capacities are, in downstream order, Riverside (65,000 acre-feet), Jackson (35,629 acre-feet), Prewitt (28,840 acre-feet), North Sterling (74,010 acre-feet), and Julesburg (31,800 acre-feet) (fig. 1). Most of the reservoirs are near the flood plain of the South Platte River on fairly flat land. As a result, the reservoirs are shallow, with mean depths around 20 feet. An exception is North Sterling Reservoir, which has a mean depth of about 30 feet and a maximum depth of about 55 feet. The reservoirs typically begin to fill in October and reach maximum storage from March through May. The volume of water in the reservoirs decreases over the summer as water is released for irrigation. An example of the seasonal variation in storage for two of the five reservoirs is shown in figure 2.

## How did nutrient concentrations in the reservoirs change during the irrigation season?

Nutrient concentrations in the South Platte River decrease downstream from Denver because of dilution of discharge from the basin's largest wastewater-treatment plants and replacement of diverted river water with more dilute ground-water inflow (Litke, 1996). As in the South Platte River, reservoir nutrient concentrations generally decreased in the downstream direction during March 1995. Nutrient concentrations measured in the reservoirs were similar to concentrations at nearby locations on the South Platte River, an indication that the river was the predominant source not only of water to the reservoirs but also of nitrogen and phosphorus (fig. 3).

Concentrations of total nitrogen, computed as the sum of ammonia, nitrate, nitrite, and organic nitrogen, generally were highest in the reservoirs in March and decreased through September (fig. 4). In March, most of the nitrogen was in the form of nitrate. By late summer, concentrations of nitrate, nitrite, and ammonia—the forms of nitrogen most readily used by algae for growth—generally were below detectable levels in all reservoirs, and only organic nitrogen was left in measurable quantities. Early decreases in nitrogen concentrations resulted from the inflow of more dilute river water and the uptake of nitrogen, particularly nitrate, by algae for growth. Once inflows from the river were cut off, continued algae growth led to further decreases in nitrate concentrations. In eutrophic lakes and reservoirs, low concentrations of nitrate resulting from summer algal uptake are not unusual (Horne and Goldman, 1994).

Concentrations of total phosphorus, computed as the sum of dissolved orthophosphorus and total organic phosphorus, did not decrease in the same way as nitrogen throughout the summer (fig. 4). This difference likely was due to the recycling of phosphorus within the reservoir by processes such as excretion from fish and zooplankton, decomposition of dead plants and animals, and the release of phosphorus from reservoir bottom sediment during periods of anoxia (the absence

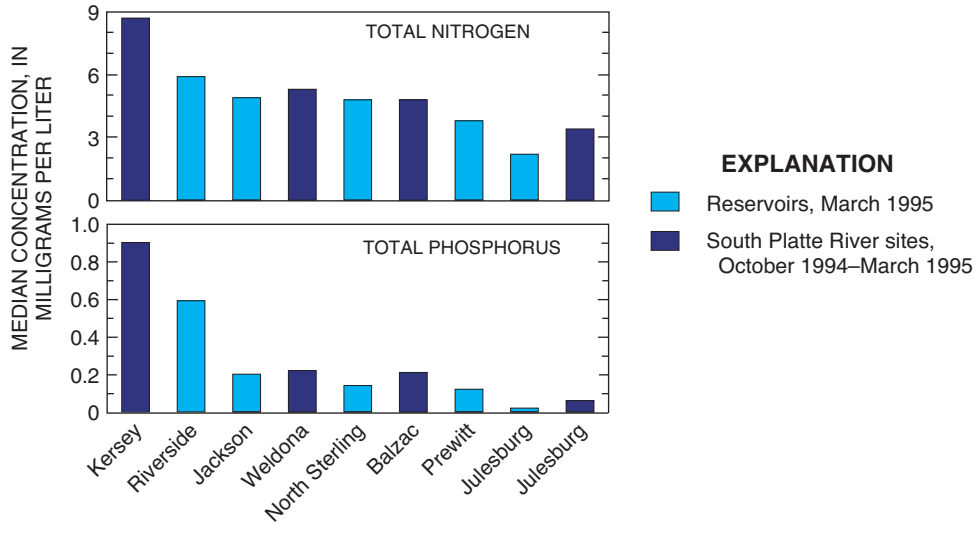


**Figure 3.** Concentrations of nitrogen and phosphorus in the South Platte River closely corresponded to concentrations in nearby reservoirs, indicating that the river was the predominant source of nutrients to the reservoirs.

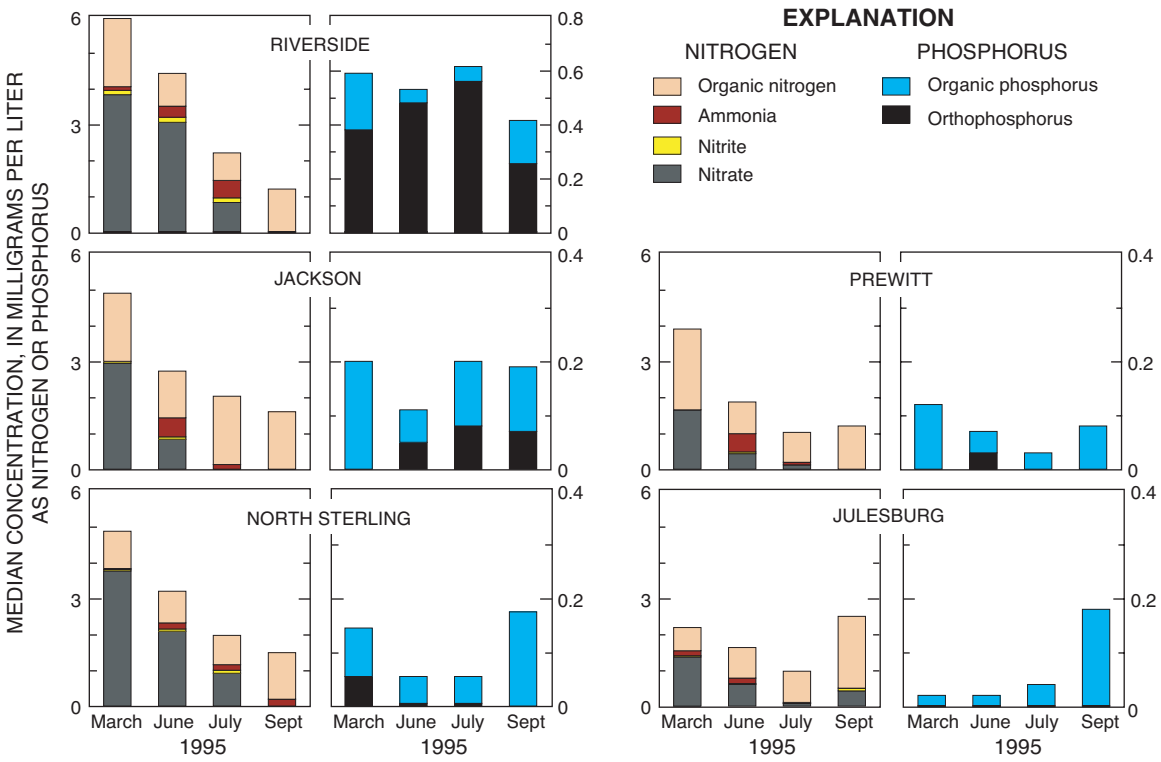


**Figure 4.** Nitrogen concentrations generally decreased from March through September, largely as a result of uptake by algae for growth. Phosphorus concentrations were more variable because of the recycling of phosphorus within the reservoir.

of oxygen) (Horne and Goldman, 1994). Concentrations of orthophosphorus—the form of phosphorus most readily used by algae for growth—fluctuated during the summer, evidence that phosphorus was recycled back into the water after biological uptake.

Unlike nutrient concentrations in the other four reservoirs, concentrations of both nitrogen and phosphorus in Julesburg Reservoir increased substantially in September. Julesburg Reservoir was the only one of the five reservoirs that received late summer inflow from the South Platte River.

## Did the reservoirs remove nutrients from the stored water before it was released for irrigation?

With the exception of phosphorus in Jackson Reservoir, the mass of nutrients leaving the reservoirs in irrigation water was less than the mass that came into the reservoir during the study period. The percentage of the total nutrient mass trapped in the reservoir through processes such as biological uptake and sedimentation of nutrients bound to sinking particles ranged from

**Table 1.** The percentage of nutrient mass trapped in the reservoir from March through September 1995. Reservoirs with long water residence times generally trapped a higher percentage of nutrients through processes like biological uptake and sedimentation

| Measurements | Riverside | Jackson | Prewitt | North Sterling | Julesburg |
|---|---|---|---|---|---|
| Nitrogen, percent trapped | 68 | 63 | 88 | 59 | 49 |
| Phosphorus, percent trapped | 25 | 0 | 86 | 42 | 20 |
| Residence time (days) | 149 | 469 | 57 | 32 | 82 |

49 to 88 percent for nitrogen and from 0 to 86 percent for phosphorus (table 1). Generally, reservoirs with shorter water residence times—the time necessary for the volume of water in a reservoir to be removed by outflowing water—trapped a smaller percentage in the reservoir because some of the nutrient mass was flushed out before it could be used by algae.

There were several exceptions to this general conclusion. Jackson Reservoir gained nearly as much phosphorus as it trapped within the reservoir during the irrigation season, resulting in no net loss. Outflow from the reservoir was minimal until August; therefore, the long period of storage allowed phosphorus to be regenerated in the reservoir without being removed in the outflow. In North Sterling Reservoir, large outflows from July through September flushed out a large part of the recycled phosphorus before it could be trapped within the reservoir again.

**Table 2.** Concentrations of chlorophyll-*a* indicated that the amount of algae increased during the summer in all reservoirs (µg/L, micrograms per liter)

| Date | Riverside (µg/L) | Jackson (µg/L) | Prewitt (µg/L) | North Sterling (µg/L) | Julesburg (µg/L) |
|---|---|---|---|---|---|
| May/June | 1.8 | 2.5 | 1.6 | 26 | 1.0 |
| July | 7.0 | 150 | 23 | 14 | 14 |
| September | 33 | 72 | 37 | 65 | 150 |
| **Average** | **14** | **75** | **21** | **35** | **55** |

**High nutrient concentrations can contribute to excessive algal growth, as seen here in Julesburg Reservoir.**

## How were the changes in nutrient concentrations related to the growth of algae in the reservoirs?

The amount of algae (indicated by the concentration of chlorophyll-*a*, a green pigment in algae) increased during the summer in all reservoirs (table 2). Because algae used nitrogen for growth, the increase in the amount of algae generally corresponded to the decrease in nitrogen concentrations during the summer. In Jackson Reservoir, excessive algal growth near the water surface during July may have blocked the light necessary to sustain growth from reaching underlying water, leading to a drop in chlorophyll-*a* concentrations by September.

Chlorophyll-*a* concentrations also provided an indication of the trophic state of each reservoir, a relative classification that reflects the nutrient enrichment in a water body. Higher average concentrations of chlorophyll-*a* in the range from 2.7 to 150 µg/L are characteristic of eutrophic reservoirs with high nutrient concentrations, low light penetration, high amounts of algae, and frequent algal blooms (Organization for Economic Cooperation and Development, 1982). Average concentrations of chlorophyll-*a* measured during the summer of 1995 indicate that all five reservoirs were eutrophic (table 2). Eutrophication may result in deterioration of water quality and aquatic life in a reservoir.

## SUMMARY

The results of this study indicate that the practice of storing South Platte River water in offstream reservoirs substantially decreases nitrogen concentrations during the irrigation season. Nitrogen concentrations in the reservoirs were highest in March and decreased through September, largely as a result of nitrate uptake by algae. Phosphorus concentrations in the reservoirs did not show the same consistent decrease from March through September, likely because phosphorus was continuously recycled back to algae through processes such as excretion from fish, decay of aquatic plants and animals, and release of orthophosphorus from bottom sediment during periods of low oxygen. Overall, with the exception of phosphorus in Jackson Reservoir, the reservoirs acted as a trap for both nitrogen and phosphorus. Associated with the loss of nitrogen and phosphorus, however, was an increase in the amount of algae, which may have adversely affected the recreational use of the reservoirs.

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## FOR MORE INFORMATION

This fact sheet is based on the following report:
Sprague, Lori A., 2002, Nutrient dynamics in five offstream reservoirs in the Lower South Platte River Basin, March - September 1995: U.S. Geological Survey Water-Resources Investigations Report 02–4142, 72 pages.

**For more information on the South Platte NAWQA study, please contact:**


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