

IMPACT OF REMOVING THE GRANBY DAM ON WATER LEVELS IN THE CONGAREE RIVER

**SOUTH CAROLINA
DEPARTMENT OF NATURAL RESOURCES
LAND, WATER AND CONSERVATION DIVISION**



WATER RESOURCES REPORT 27

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by
Andrew Wachob

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SUMMARY OF FINDINGS

The Granby Dam and Lock structure was constructed at the beginning of the 20th Century to provide at least a 4-foot navigation depth in the Congaree River up to the city of Columbia. Unused for many years, the structure remains in place as a short dam and an open-lock passage that is used by boaters to bypass the dam when river levels are low. A recent proposal to remove the Granby Dam has raised concerns that removing the dam might decrease water levels within the lock, making navigation through that area difficult, especially during periods of low river flow. This study examines how removing the dam would affect water levels and depths within the lock passage and in the river's main channel.

Removing the Granby Dam from the Congaree River could cause water depths within the lock passage to decrease by as much as 4 feet. This decrease in water depth would result from a combination of lower water-surface elevation and increased sedimentation within the lock area. Removing the dam would impact water depths most significantly during periods of low flow, but even during higher flows the water depth within the lock would be less because of sedimentation.

During low flows, most of the river water is diverted through the lock, and at high flows, when most of the river water spills over the dam, a significant amount of water still passes through the lock. Because there is always considerable flow in the narrow lock, water velocities stay high (greater than 4 feet per second), which keeps the lock free of deposited sediment. Without the dam, flow through the lock would be substantially reduced, and water velocities within the lock would seldom exceed 3 feet per second. As a result, the lock would begin to fill with sediment, effectively decreasing the water depth in this channel by as much as 2 feet.

Removing the dam would also decrease water depths within the lock by lowering the elevation of the water surface. At the upstream end of the lock passage, water-surface elevations would be reduced 1 to 2 feet during low flows; at the downstream end of the lock, the reduction would be 1 foot or less. During higher flows, the decrease in water-surface elevation would be 0.5 foot or less.

The impact of removing the dam was evaluated by comparing conditions in the river (water depths, water velocities, and flow distribution) as they are now, with conditions as they would be if the dam were removed. These conditions were determined by using a combination of surveyed water-surface and riverbed elevation data, flow rate data for the Congaree River, and computer model simulations.

PHYSICAL SETTING

Granby Dam and Lock

The Granby Dam is situated in a relatively narrow part of the Congaree River, approximately 9,200 feet downstream of the Gervais Street bridge and 4,000 feet upstream of the Barney Jordan boat landing located near the end of Rosewood Drive in Richland County (Fig. 1). The steel-and-concrete dam, which has a roughly southwest-northeast orientation, is about 3½ feet high and extends for 375 feet from the eastern (Richland County) bank of the river to the upstream end of the concrete “island” that defines the lock passage (Fig. 2). The lock, bounded on its sides by two large concrete structures, has a uniform width of 55 feet and is located along the western (Lexington County) bank of the river. The concrete “island” that separates the lock from the dam is about 20 feet high, 15 feet wide, and 235 feet long. At the upstream end of this island is a wedge-shaped structure of timber and riprap that extends 110 feet upstream from the concrete island. It is at the tip of this extension that the river flow splits into two sections—the lock channel and the dam area—giving the lock channel an effective length of 345 feet.

Congaree River

The Congaree River is formed by the confluence of the Saluda and Broad Rivers 3 miles upstream of the Granby Dam, and in this study area the river has a natural slope of about 1 foot per 2,500 feet, or 0.0004 feet per foot. Average annual flow in the river near Columbia is 9,100 cfs (cubic feet per second), and the flow should exceed 3,000 cfs about 90 percent of the time. The lowest daily average flow recorded was 662 cfs in October 1954, during the drought of the 1950’s, and the highest peak flow has been estimated at 364,000 cfs during the flood of August 1908. Daily flows in the river can be highly variable, as they are heavily influenced by releases from the Lake Murray Dam on the Saluda River. Flows tend to be highest during the winter and early spring, and lowest during the summer and early fall (Fig. 3).

During low flows, the Granby Dam has a significant effect on the Congaree River, but during high flows, the dam’s presence is almost negligible. Because the impact the dam has on the river—and, hence, the impact that removing the dam would have—is most significant during low flows, it is helpful to know how often low flows are likely to occur. Figure 4 illustrates the likelihood of various low flows occurring in the Congaree River during any given month.

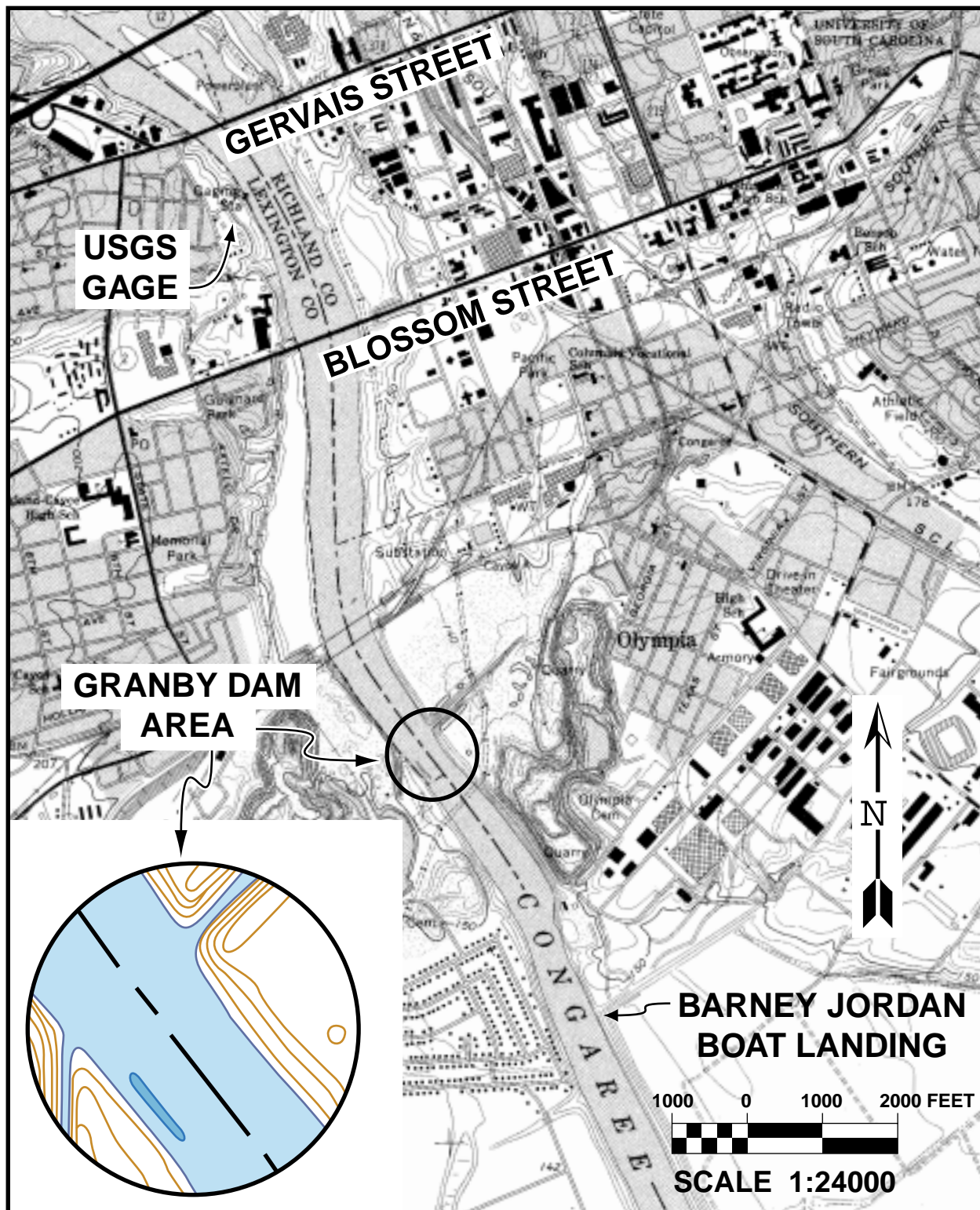


Figure 1. Map showing the location of the Granby Dam in the Congaree River. The narrow island shown in the enlarged inset is the concrete island that defines the lock. Base map is the USGS 7½ -minute *Southwest Columbia, S. C.*, topographic map (1982).

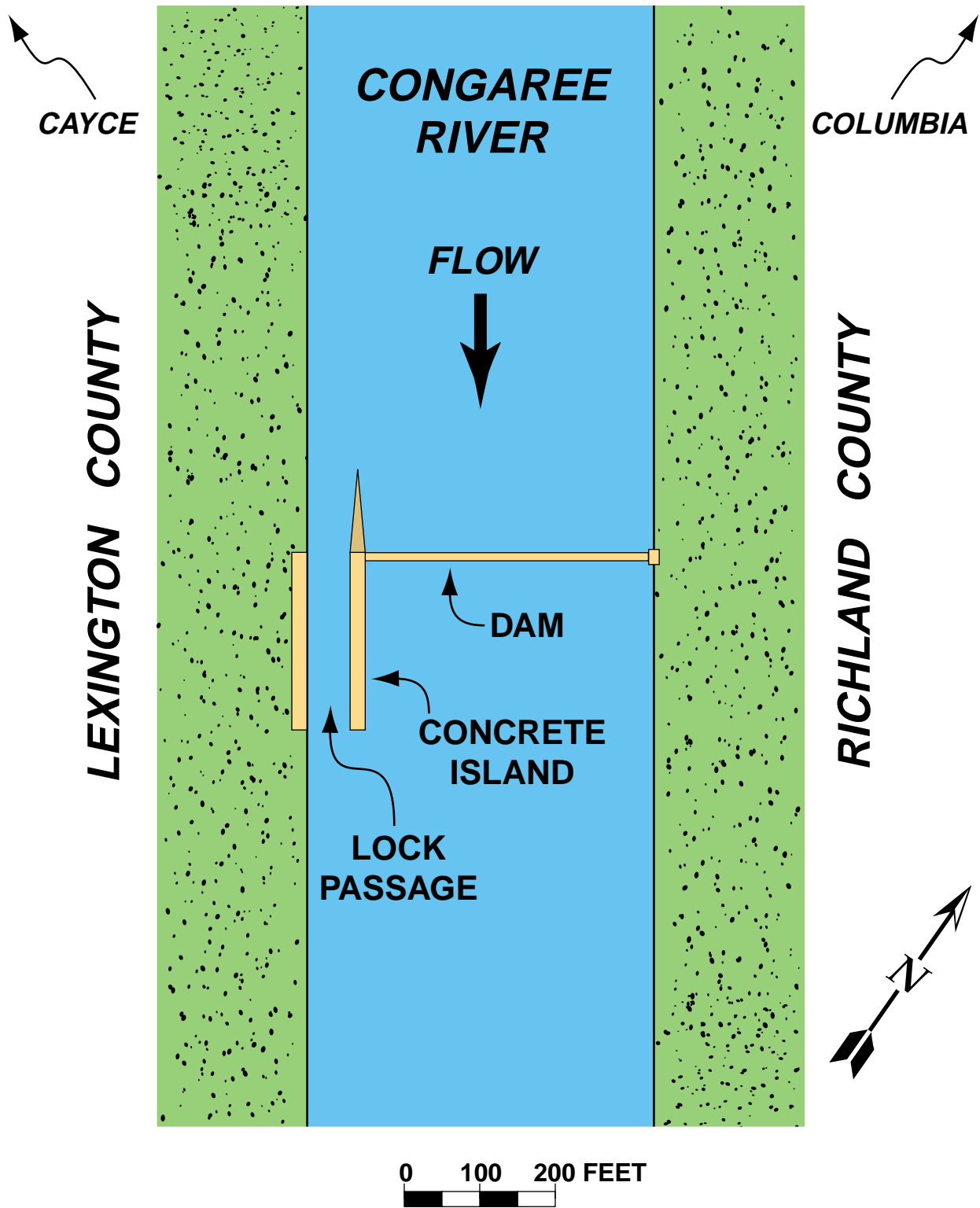


Figure 2. Illustration showing the features of the Granby Dam and Lock.

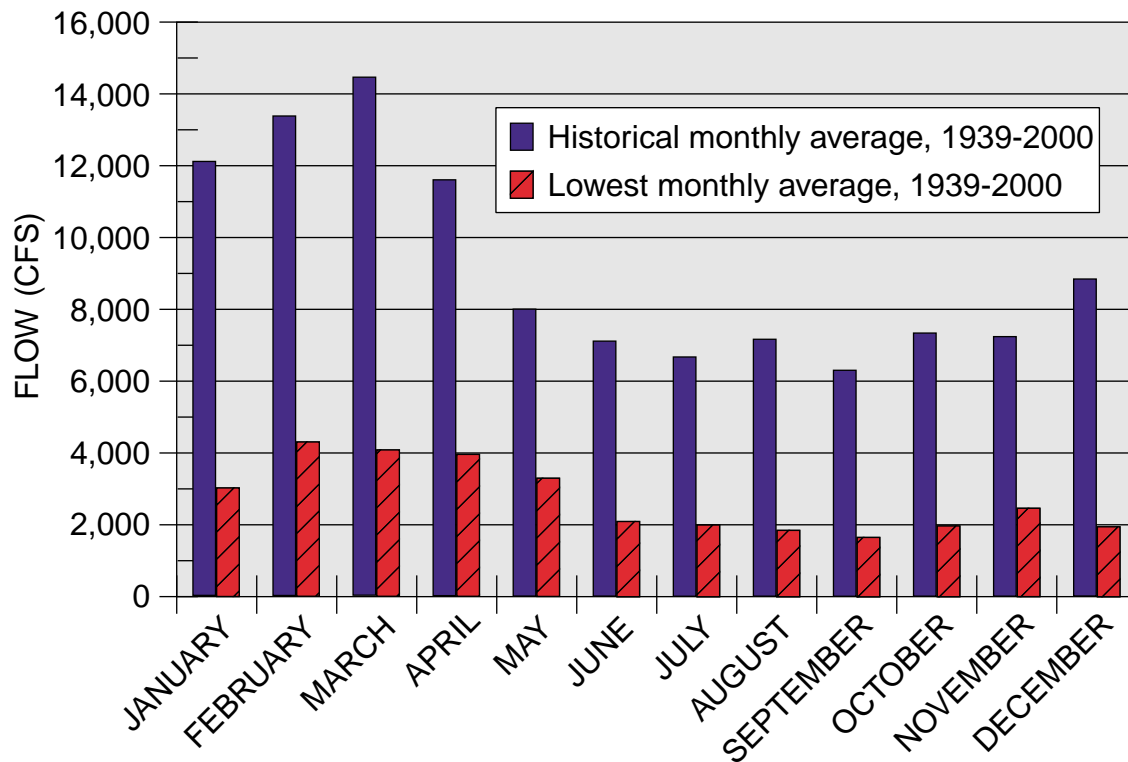


Figure 3. Historical monthly average and lowest monthly average flows in the Congaree River near Columbia, S.C., for the years 1939 through 2000.

FIELD MEASUREMENTS AND ANALYTICAL TECHNIQUES

Field Surveys

Most of the information presented in this report was derived from data collected during field surveys made by personnel of the South Carolina Department of Natural Resources. Measurements were made of the dimensions of the lock-and-dam structures, water-surface elevations during different river flow rates, variations in the shape of the riverbed, the “natural” gradient of the water surface, and the height of water spilling over the dam during various river flows.

Measurement of Water Depth in the Lock

Attempts to measure the depth of water within the lock were marginally successful. Initial attempts involved measuring the water depth by lowering a rigid staff or a weighted rope to the bottom of the lock from a boat while holding the boat in a fixed position, but because of the high velocity of the water, these techniques proved unworkable, and only a few soundings were successful.

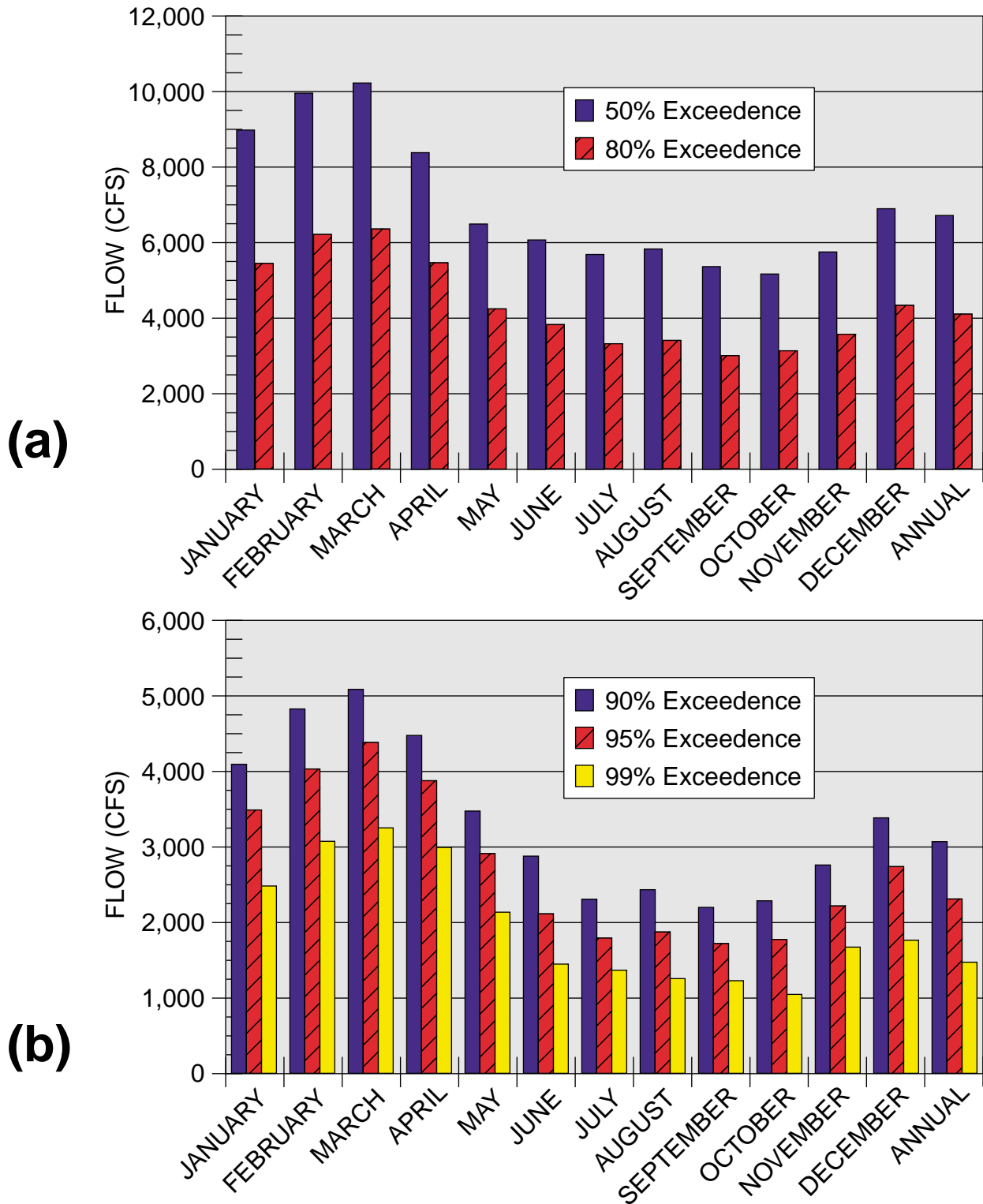


Figure 4. Exceedence graphs for the Congaree River near Columbia, showing the degree of likelihood that a certain flow will be exceeded. For example, in March, the flow can be expected to exceed 10,200 cfs 50 percent of the time; the flow can be expected to exceed 6,330 cfs 80 percent of the time; and the flow can be expected to exceed 3,240 cfs 99 percent of the time. In other words, on any given day in March, there is a 1-percent chance of the flow being less than 3,240 cfs.

A different technique—using a boat-mounted depth sensor to measure water depths as the boat moved through the lock—produced more results, but with less accuracy. Although the depth sensor provided depths with a precision of 0.1 foot, the results were not nearly that accurate. There were two main problems with this technique: (1) Choppy water within the lock caused the boat to move up and down a foot or more as it passed through the lock; and (2) the inability to accurately relate an instantaneous depth reading to the boat’s precise location within the lock. The great variety of depth readings taken during the trial of this technique—values ranged from 3.3 to 9.0 feet—combined with the imprecise position information limited the analytical usefulness of the depth data. In general, however, the water at the upstream end of the lock appeared to be about 2 feet deeper than at the downstream end.

Computer Model

In addition to using data from field surveys, a computer model was developed to help analyze such things as how the river’s flow is distributed between the lock and the dam, water velocities within the main river channel and within the lock, the height of water spilling over the dam at various flow rates, and the upstream extent of impoundment for different flow rates. Use of a computer model is also very helpful because, after calibrating the model to the existing river conditions, it is fairly easy to remove the dam from modeled river and see how the system changes.

This one-dimensional, steady-flow model was developed from the U.S. Army Corps of Engineers HEC-RAS (Hydraulic Engineering Center – River Analysis System) software, and was calibrated with data from the field surveys and river flow data from the USGS gage located near the Gervais Street bridge. The HEC-RAS model represents a simplistic version of the Congaree River near the Granby Dam, rather than an exact recreation of the system. The amount of topographic surveying, in-stream flow measurements, and water-surface elevation measurements required to very accurately calibrate and fine-tune a model of this section of the river is beyond the scope of this project and might be appropriate only if using a more sophisticated two- or three-dimensional model. Simplified as it is, however, the HEC-RAS model is still a useful tool for evaluating the impact that the dam has on local water levels.

USGS Gage Data for the Congaree River

The United States Geological Survey operates a water-stage recorder 8,200 feet upstream of the Granby Dam, or about 1,000 feet downstream of the Gervais Street bridge (see Fig. 1). This gage (Station 02169500) has been used to measure flows in the Congaree River since October 1939. Between this gage and the Granby Dam, there are no significant tributaries or other sources

of inflow into the Congaree, so the flow rates at the dam should be only slightly greater than at the gage. For the purposes of this study, the flow at the dam is assumed to be the same as the flow at the gage, and as such, the flow statistics determined for the Congaree at the gage site are assumed to apply to the Congaree River in the vicinity of the Granby Dam.

Note on Water Depths

While it would be convenient to relate the effects of the dam to the depth of water in the river, this is not practical because the highly irregular shape of the riverbed results in a wide range of depths for a given flow rate or water-surface elevation. For example, a steady flow with a uniform water-surface elevation that leaves some in-stream boulders and bedrock exposed several feet above the water can result in water depths ranging from 0 to 6 feet within a short horizontal distance because of variations in sediment thickness, the shape of the underlying bedrock, and localized flow patterns. *Changes* in water depths can be inferred, however, from changes in water-surface elevation.

IMPOUNDMENT AND FLOW DIVERSION CAUSED BY THE DAM

While the Granby Dam is no longer used to aid navigation up to Columbia, the structure, spanning 85 percent of the river's width, still acts as a barrier to flow. The dam has two significant effects on the hydraulics of the Congaree River: (1) The impoundment of water, resulting in deeper, slower water upstream of the dam; and (2) the diversion of the river's flow into the relatively narrow but unobstructed lock. Because of the low height of the dam and the open-lock channel, the increase in water depth due to impoundment is limited but not insignificant during low flows when the river is very shallow in places.

Increased Water Levels Behind the Dam and in the Lock

To understand how the dam affects the river's water levels, it is helpful to view a section of the river along its length (Fig. 5). The "impacted zone" is the section of the river that is affected by the presence of the dam. Outside the impacted zone, on both the upstream and downstream sides, the river is in its "natural" condition, unaffected by the dam. At low flows, when the dam's effect is greatest, this impacted zone may extend for several thousand feet upstream from the dam, and several hundred feet downstream from the dam.

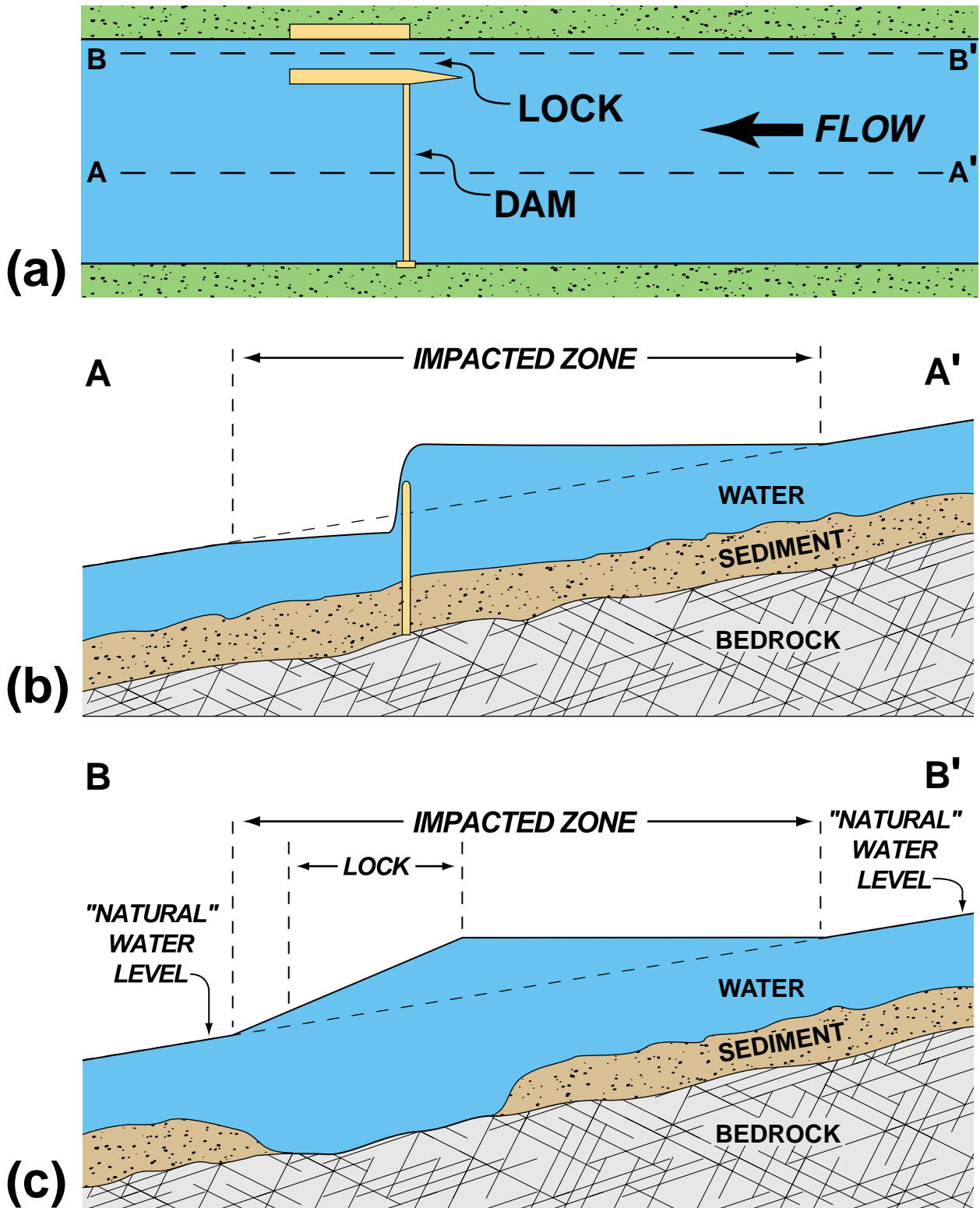


Figure 5. Schematic illustration showing how the Granby Dam influences water levels along sections across the dam (b) and through the lock (c). In both sections, the length of the “impacted zone” is identical, and both have the same water-surface elevations upstream of the lock/dam split.

Dam area.—The dam blocks the river’s flow, causing water to pool up behind the dam and diverting much of the flow into the lock. By obstructing the flow, the dam, in effect, adds a wedge of water onto the “natural” water level upstream of the dam (Fig. 5b). The extra depth is greatest just upstream of the dam, and tapers off toward the upstream end of the impacted zone. The increase in water depth and the length of the impacted zone are functions of the river’s flow rate. While the flow is usually great enough that some water spills over the dam, a considerable amount of water is always diverted into the lock. Only during very low flows (less than about 1,200 cfs) will the water not overtop the dam; in these cases, all the river’s flow is diverted through the lock. Because the dam is fairly low—about 3½ feet high—and because of the open-lock channel, the increase in water depth upstream of the dam will not exceed 2.0 feet (Fig. 6).

The impounded water’s surface does not slope as much as that of the “natural” river; there is little change in the water-surface elevation along the entire impacted zone upstream of the dam. Downstream of the dam, the water-surface elevation also has a very small slope until the divided flows recombine below the lock. Along this profile (Fig. 5b), almost all of the change in water-surface elevation occurs as the water spills over the dam.

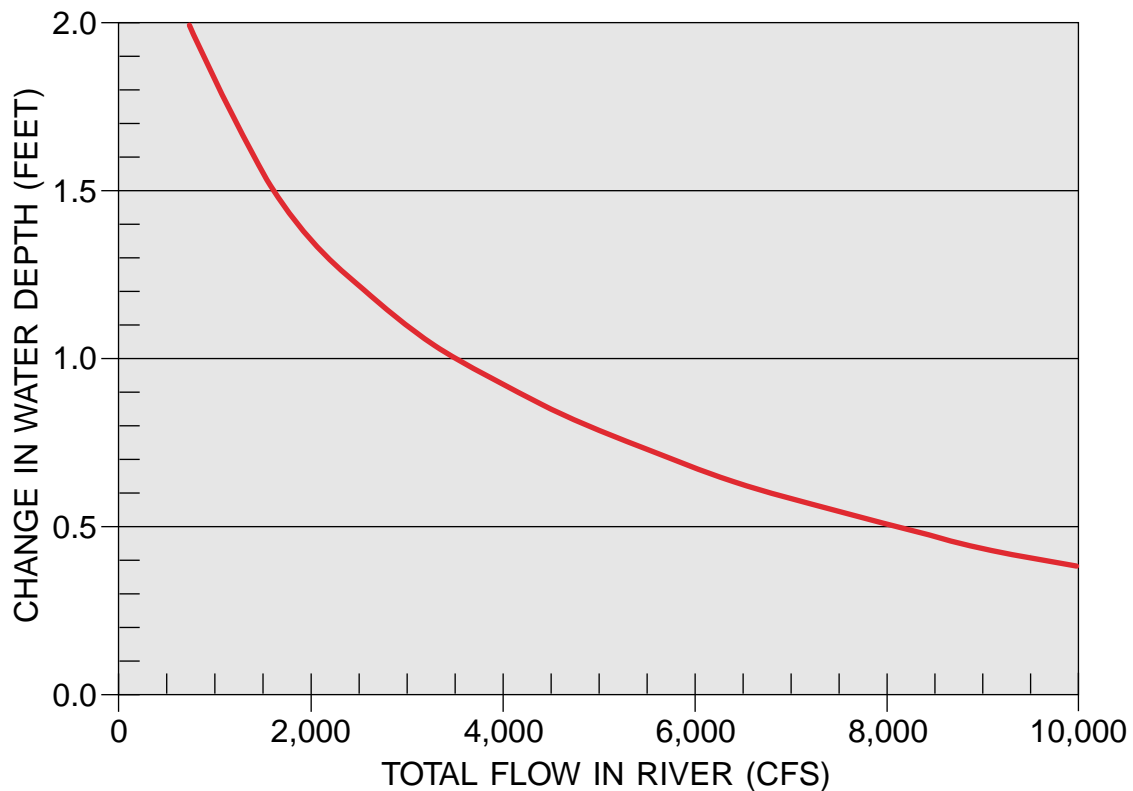


Figure 6. Graph showing how much the impoundment of water increases water depth just upstream of the Granby Dam.

Lock area.—Water enters the lock passage with the same elevation at which it enters the dam area; upstream of the lock/dam split, both profiles have identical water-surface elevations. Inside the lock, the water’s surface elevation decreases rapidly and uniformly over the length of the lock (Fig. 5c). As a result, the water in the lock is deepest at the upstream end of the lock. At the downstream end of the lock, the water-surface elevation is still slightly higher than “natural.” Downstream of the lock, freed from the confines of the cement walls, the water spreads out, rejoins the main channel, and quickly returns to its “natural” level.

Diversion of Water Keeps Lock Free of Sediment

Water flowing down the Congaree River passes the Granby Dam in one of two ways: it either spills over the dam or it flows through the unobstructed lock. Without the dam to impede the river, only about 10 percent of the river’s flow would pass through the lock. With the dam impeding flow through the main channel, however, a significant amount of water is always diverted into the lock (Figs. 7 and 8). During very low flows (less than about 1,200 cfs), the water level behind the

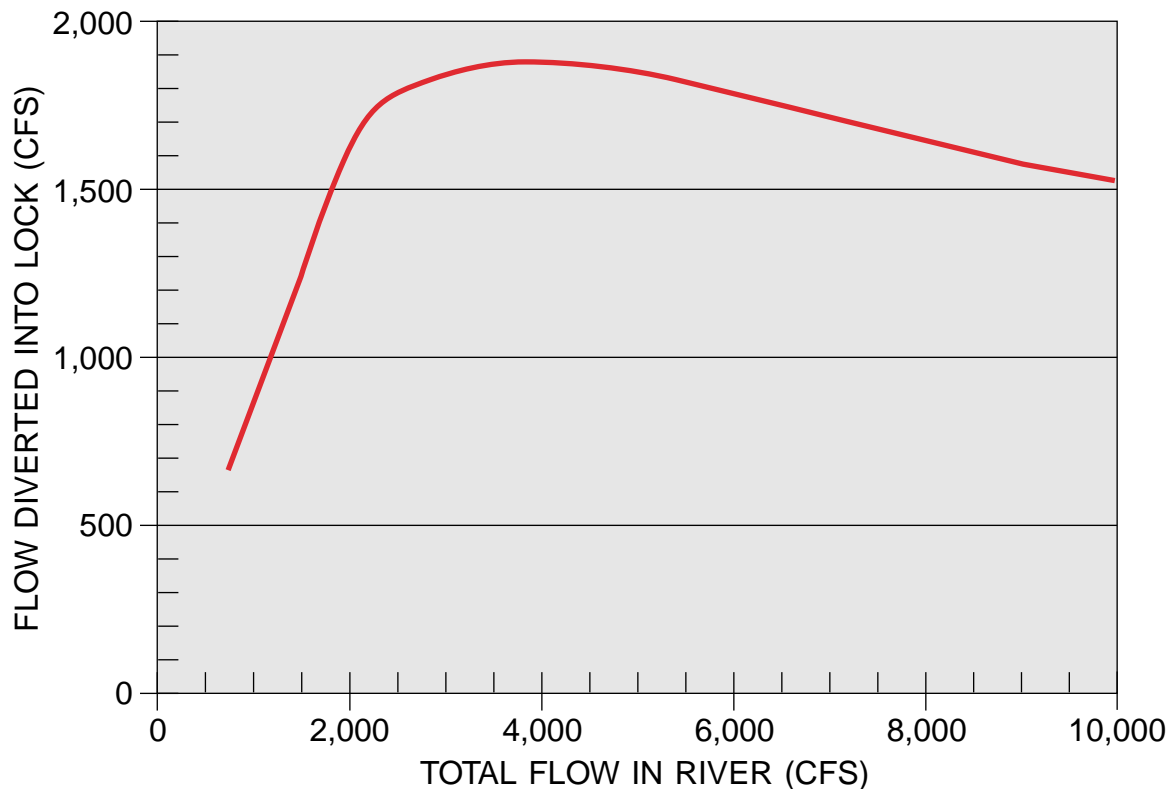


Figure 7. Amount of flow diverted into the lock because of the Granby Dam.

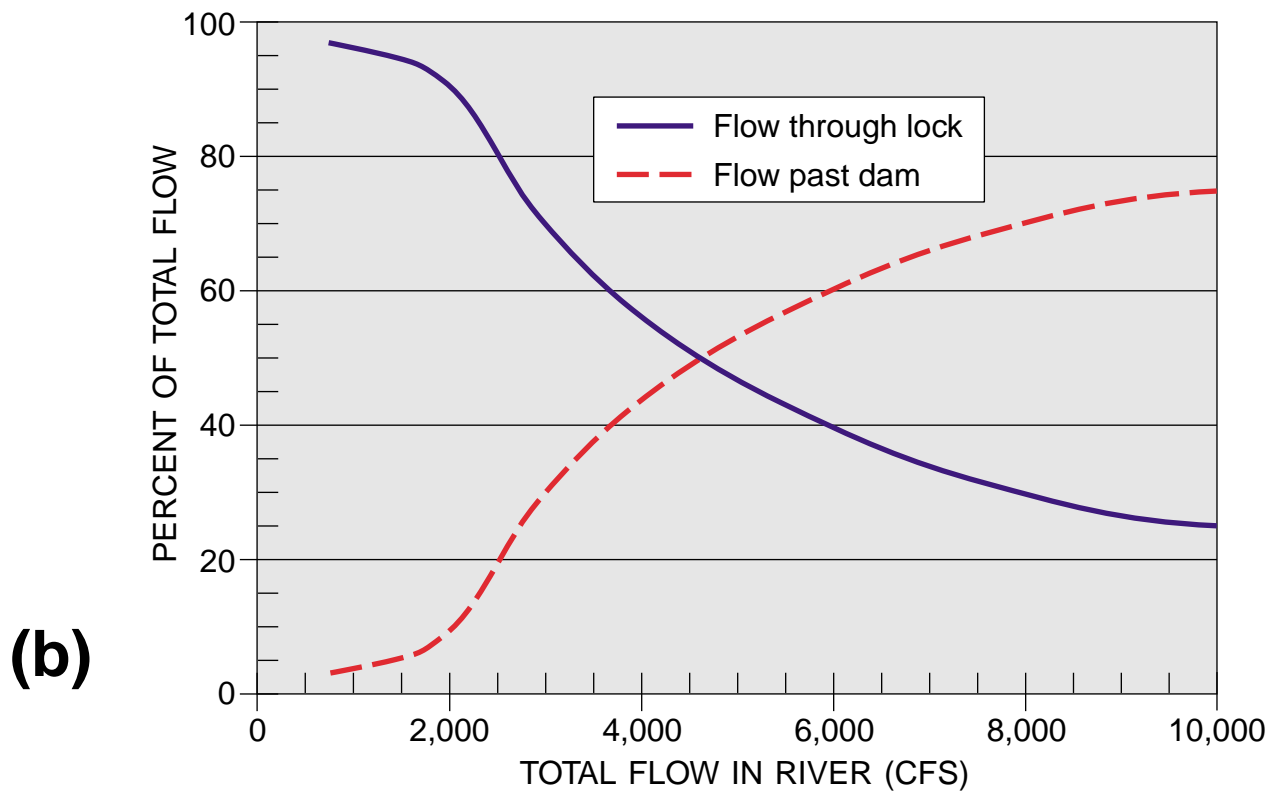
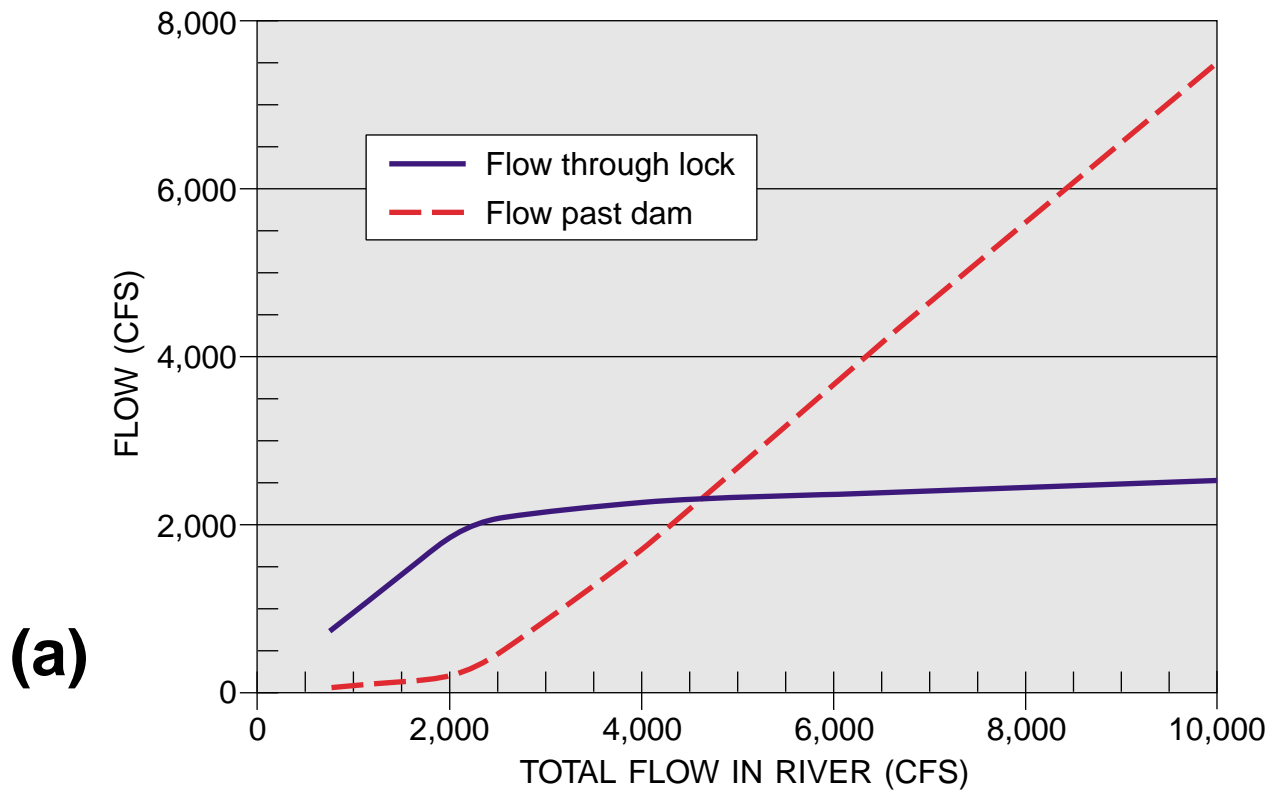


Figure 8. Distribution of total river flow between the lock and the dam, expressed in terms of (a) cubic feet per second, and (b) percentage of the total river flow.

dam remains below the top of the dam, so essentially all of the river's water moves through the lock. At moderately low flows (1,200 to 4,600 cfs), some water spills over the dam, but most of the water still passes through the lock. Above 4,600 cfs, more water spills over the dam than passes through the lock. During high flows, when most of the water passes over the dam, 20 percent or more of the total flow still moves through the lock.

The significance of this diversion is not so much the increased volume of the water moving through the lock but it is the increased velocity; the water flowing through the lock always maintains a relatively high velocity compared to the main channel (Fig. 9). Even during low flows, when the average velocity in the main river channel might be as low as 1 foot per second, the water velocity within the lock will exceed 4 feet per second. This fast-moving water has enough energy to keep the lock clean of the sediment that accumulates on the riverbed everywhere outside the lock, and since the flow in the lock is always faster than in the main channel, any sediment that is carried into the lock will be transported out of it. Because the lock channel remains sediment-free, water within the lock tends to be deeper than elsewhere in the river (see Fig. 5c). How much deeper is difficult to quantify, because of the irregular riverbed shape and the variable nature of the sediment thickness, but field measurements suggest that the extra depth is on the order of 2 feet.

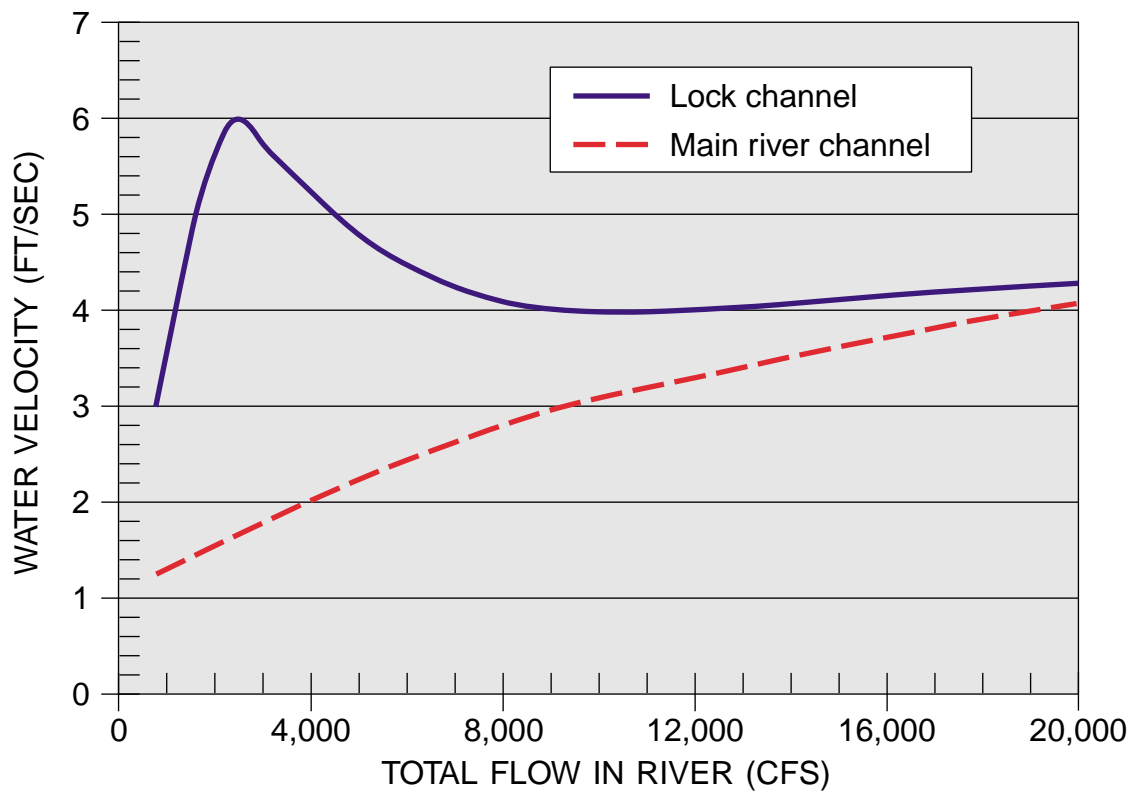


Figure 9. Comparison of typical water velocities in the lock and in the main river channel (away from the dam).

The Dam's Impact Above and Below the Lock and Dam Area

The Granby Dam influences water levels in the river far upstream of the dam and lock area. The dam's impact is greatest during low flows, both in terms of increased water depth and how far upstream the impoundment extends. For example, during a very low flow of 1,000 cfs, in which the water depth at the dam/lock split would be increased by about 2 feet, some deepening would be noticed as far as 6,000 feet upstream (up to the Blossom Street bridge). For a moderately low flow of 3,000 cfs, the water would be as much as 1 foot deeper behind the dam, and the impoundment would extend upstream for about 4,000 feet. At high flows, such as 10,000 cfs or more, most of the water passes over the dam, and the dam has little practical impact on water levels, depths, and velocities upstream of the dam and lock area.

Between the dam and the downstream end of the lock, the flow in the main river channel is reduced by as much as 1,800 cfs because of the diversion through the lock (Fig. 7). Accordingly, this 200-foot section of the river tends to have slower, shallower water than elsewhere in the river. At the downstream end of the lock, the divided flows recombine, and the river quickly returns to its "natural" condition. At very low flows, the dam's impact becomes unnoticeable beyond about 500 feet from the end of the lock; at higher flows, the dam's impact extends less than that.

IMPACT OF REMOVING THE GRANBY DAM

The Granby Dam impacts the Congaree River in two significant ways: It impounds water upstream, and it diverts water from the main river channel into the lock passage. If the dam were removed, both of these impacts would be removed, and the river would return to more natural conditions. Within the lock passage the water would become much slower and shallower, and upstream from the dam the depth of the water would decrease slightly. Downstream of the lock and dam the conditions in the river will be almost unchanged, since the effects of the dam are not noticed much beyond the lock and dam structure.

Reduced Water Volume and Velocity in the Lock

The lock passage occupies the western edge of the river, covering about $\frac{1}{7}$ of the river's surface width at the point where the flow splits (see Fig. 2). Because water along the edge of the river flows more slowly than in midchannel, and because the river tends to be deeper in midchannel, only about 10 percent of the total river flow would pass through the lock if the dam were removed. With the dam, the lock carries no less than 20 percent of the total river flow. Figure 10 illustrates how removing the dam would decrease flow rates within the lock channel.

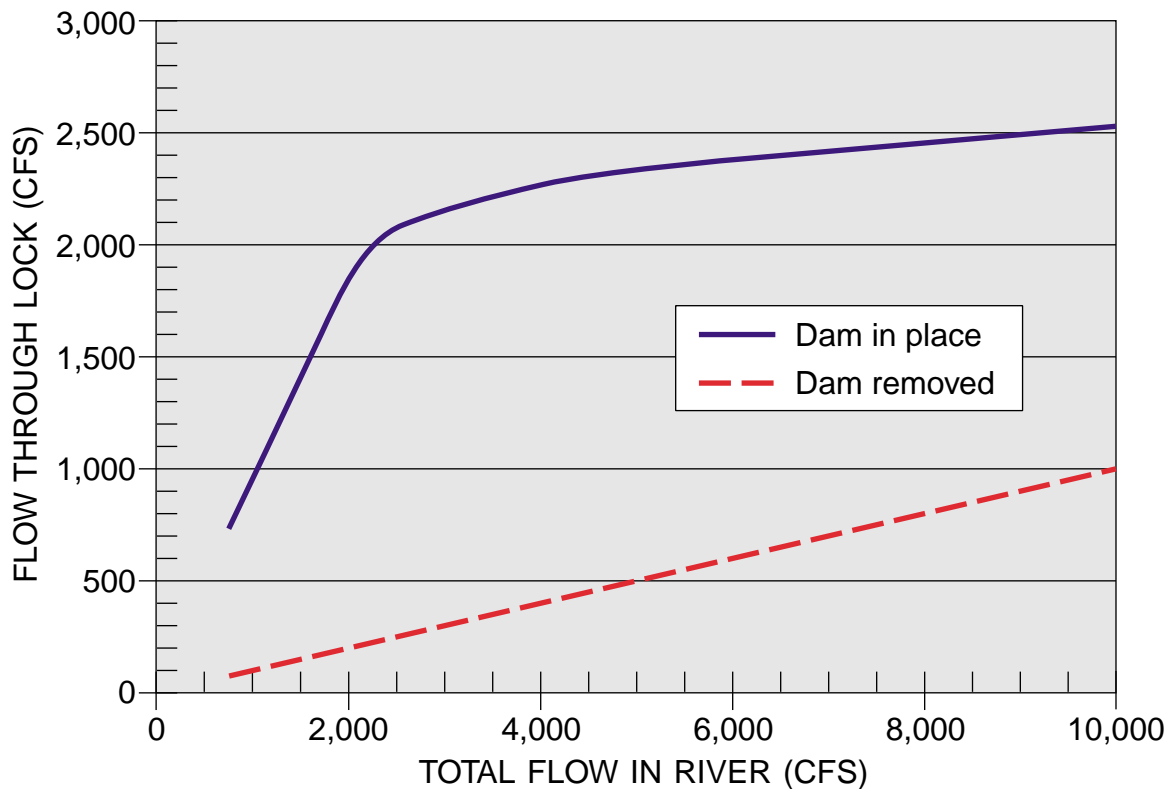


Figure 10. Predicted flow through the lock with the dam removed, compared to flow through the lock with the dam in place.

Not only would the volume of water passing through the lock decrease if the dam was removed, but the velocity of that water would decrease also. Computer modeling suggests that, without the dam, the water entering into the lock passage would have a velocity approximately half that of the midstream flow. With the dam, lock-channel velocities range from 4 to 6 feet per second; without the dam, lock-channel velocities would rarely exceed 3 feet per second (Fig.11).

Increased Sedimentation in the Lock

With the dam in place, even during low flows, the water velocity within the lock is high enough to transport sand and pebbles, preventing sediment from accumulating within the lock passage. Elsewhere in the river, sediment covers the riverbed because the water does not usually move with enough energy to carry it. The lack of sediment keeps the water depths within the lock about two feet deeper than elsewhere in the river. Removing the dam would slow the water passing through the lock, allowing for sediment to accumulate within the lock.

The extent to which sediment would accumulate within the lock if the dam were removed is difficult to quantify precisely. Surveys made of the riverbed elevation both above and below the

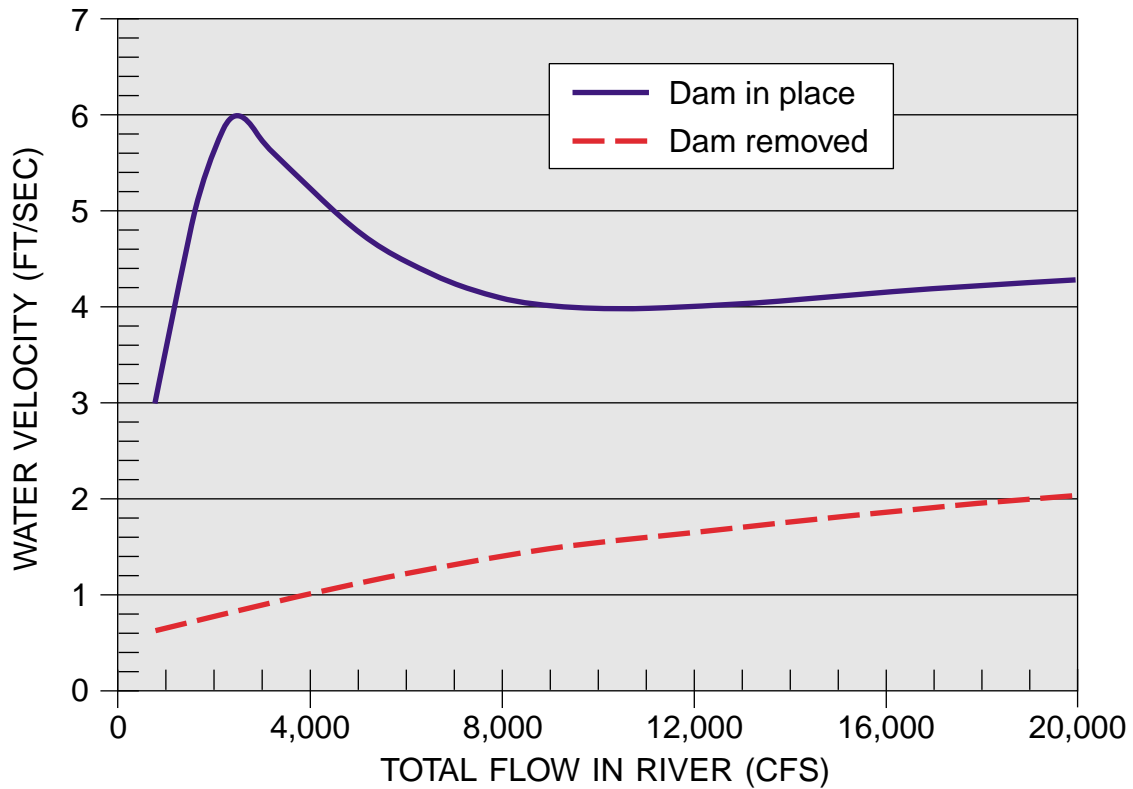


Figure 11. Velocity of water flowing through the lock, both with the dam in place and the dam removed.

dam indicate localized depth variations of several feet owing to variations in sediment thickness, and downstream of the dam, sandbars can be found that decrease the water depth by 2 or 3 feet. Considering the surveyed riverbed elevation data, the measured lock depths, and the observed sandbars, it is reasonable to conclude that sediment accumulation of as much as 2 feet is likely. The sediment thickness will vary with both time and location within the lock, but the general result will be a decrease in water depth on the order of 2 feet.

Only during periods of high flow (greater than about 20,000 cfs) would the water move through the lock with sufficient energy to clean out sand-and-gravel deposits. These high flows are infrequent, however, and as soon as the flow decreases and the water slows down, sediment would begin to accumulate again.

Lower Water-Surface Elevations in the Lock

As described earlier, the water-surface elevation upstream of the dam is higher than “natural” owing to impoundment. Without the dam, water would not be impounded, so the water-surface elevation would once again be “natural” (Fig. 12). The resulting decrease in water-surface elevation

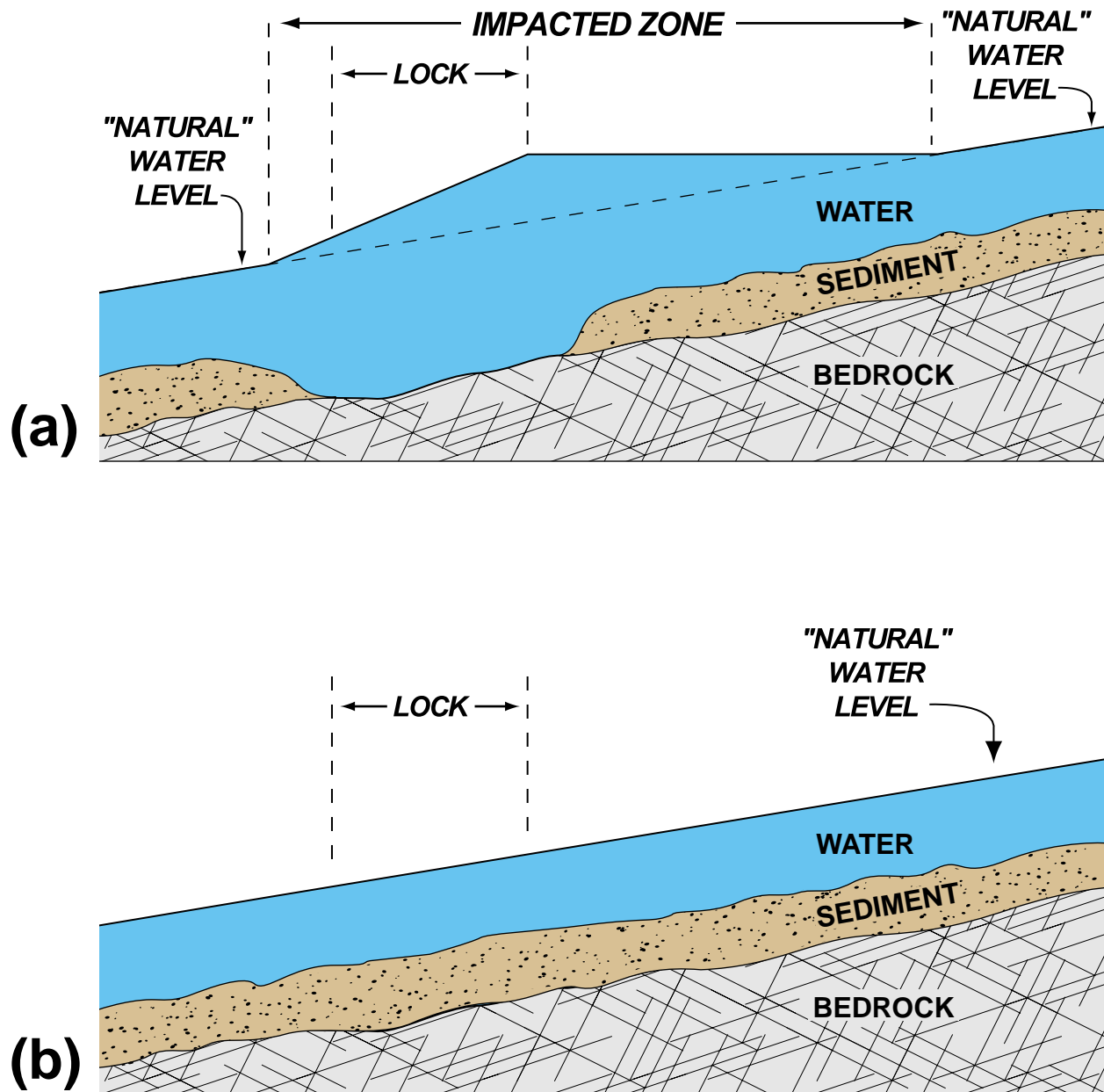


Figure 12. Schematic comparison of water levels and depths along a profile through the lock, with (a) the dam in place, and (b) the dam removed. (Figure 12a is identical to Figure 5c.) Note that the depth of water within the lock is reduced because of both the lowering of the water surface and increased sedimentation within the lock.

would be greatest at the upstream end of the lock (as much as 2 feet lower) and least at the downstream end of the lock (less than 1 foot) (Fig. 13). With sediment deposition in the lock, the net effect of removing the dam would be to decrease water depths by 2.5 to 4.0 feet at the upstream end of the lock and by as much as 2.5 feet at the downstream end of the lock.

Effect on the River Above and Below the Lock and Dam Area

Without the dam, the water-surface elevation of the river upstream of the dam/lock area would return to “natural” levels. This means that, during very low flows, water depths would be lower by as much as 2 feet near the dam and lock and as much as 1 foot near the railroad bridges located 2,000 feet upstream of the dam. In this upstream section of the river, there are many boulders and rock outcrops already exposed during low flows; decreasing the water level by 1 foot would result in more rocks being exposed or coming very close to the water surface. Navigation through this section of the river may become more difficult or hazardous when the river is at a very low stage.

Removing the dam would have very little impact on the water depths and velocities downstream of the lock channel, because the dam itself does not have much of an effect on that part of the river. Field measurements suggest that the effects of impoundment and diversion through the lock do not extend more than 500 feet downstream from the lock channel, even at very low flows. Since the dam has little effect on this segment of the river, removing the dam would result in little change.

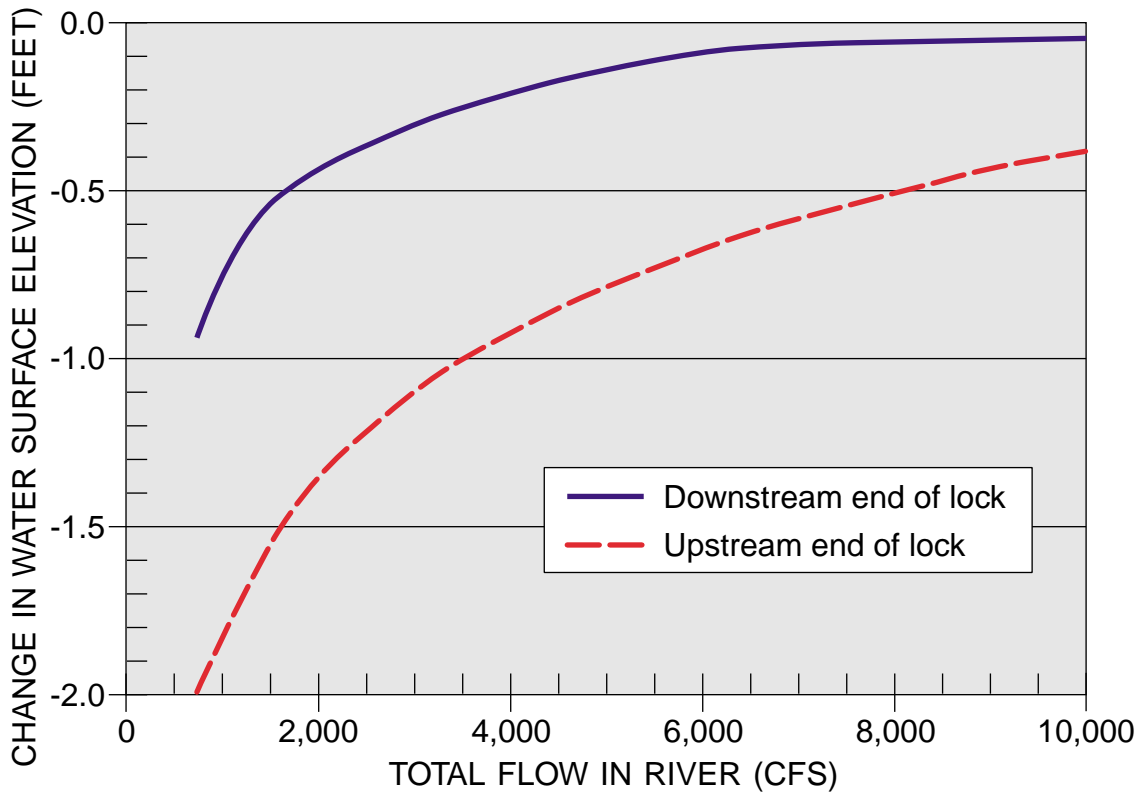


Figure 13. Graph showing the decrease in water surface elevation at both ends of the lock that would result from removing the Granby Dam.