



Air, Water and Aquatic Environments Science Program



Rocky Mountain Research Station

Assessing Environmental Impacts of Dam Operation



Research

Technology Transfer

Science Application

Key Findings:

- River systems have been altered worldwide by dams and diversions, resulting in a broad array of environmental impacts.
- A hierarchical framework is used for quantifying successive scales of impact and for isolating the relative effects of multiple dams over a 233 km reach of the Kootenai River in western North America.
- First-order impacts describe broad changes in hydrology; second-order impacts quantify resultant changes in channel hydraulics and bed mobility; third-order impacts describe consequences for recruitment of riparian trees; and fourth-order impacts consider biological feedback.
- Results show that dam operation has significantly changed 1) the timing, magnitude, frequency, duration, and rate of change of flows, 2) the spatial and temporal patterns of daily stage fluctuation, unit stream power, shear stress, and bed mobility, and 3) the potential for cottonwood recruitment (a key structural element in western rivers).
- A process-based, hierarchical framework allows defensible evaluation of impacts and alternative management strategies.

Challenge

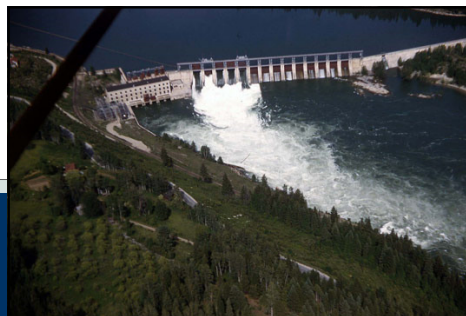
The societal benefits of the use of our rivers are profound, including irrigation, transportation, flood control, power generation and recreation. As a result of our sustained development of these resources, river systems have been altered significantly worldwide, with nearly 60% of major river basins fragmented by large dams. A broad array of operational impacts may occur depending on the purpose of the facility, the architecture of the system, and the physiographic setting, but in general facility operation causes a cascade of effects on hydrology, hydraulics, river and floodplain morphology, and riverine ecology, with potentially complex biophysical feedback loops.

Context

This study investigates the hierarchical impacts of dam operation on hydrology, channel hydraulics, bed mobility, and recruitment of riparian trees on the Kootenai River in western North America (Fig. 1). The Kootenai River basin has a total drainage area of 41,910 km² and comprises parts of British Columbia, Montana, and Idaho (70%, 23% and 7% of basin area, respectively). The study area is a 233 km reach of the river between Libby Dam and Kootenai Lake, referred to as the lower Kootenai River. In the 1930s, Corra Linn Dam was constructed at the outlet of Kootenay Lake to generate hydropower and control floods. Libby Dam was completed in 1974 and is operated to meet power generation and flood control objectives. In this study, focus was put on the recruitment of cottonwoods because they are native to the study area and because of their general importance as structural elements in riparian areas of western North America.

Actions

A process-based, hierarchical approach was used for quantifying the spatial and temporal impacts of the dams on the study reach (Fig. 2). First-order impacts describe broad changes in hydrology (timing, magnitude, frequency, duration and rate of change of streamflow as determined from gages within the study area). Second-order impacts quantify resultant changes in channel hydraulics and bed mobility (predicted from a 1D flow model). Third-order impacts describe consequences for recruitment of cottonwoods (recruitment box analysis), and fourth-order impacts consider biological feedback on physical processes. Three time periods were examined to isolate the effects of Libby Dam from other river management activities: historic (1910–1938, prior to operation of Corra Linn Dam), pre-Libby Dam (1939–1967, including operational impacts of Corra Linn Dam and other reclamation activities), and post-Libby Dam (1975–2003, including operational impacts of Libby Dam and all other river management activities).



Corra Linn Dam



Libby Dam



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Results

Results show that dam operations have caused significant alteration of the historic flow regime (first-order impact), reducing maximum flows during the time of year when snowmelt peaks historically occurred, increasing minimum flows during the winter low-flow period, and increasing irregularity of the annual hydrograph (due to hydropower generation). These results suggest that flow parameters and ecological processes that are dependent on the magnitude and timing of flow extremes and on sustained hydrograph trends (i.e., limited irregularity and moderate rates of change), are likely to be most influenced by operation of the dams. These first-order impacts on hydrology influence the spatial and temporal distribution of second-order impacts to flow parameters (channel hydraulics and bed mobility). An analysis of changes in flow parameters showed that daily stage fluctuation and mean stream power were most affected by hydropower operations, with assessed alterations in excess of 100% of pre-regulation values. Bed shear stress and bed mobility showed the next largest change, with maximum flow depth and wetted width least altered. Comparison of second-order changes over different time periods indicates that impacts from Libby Dam dominate, accounting for 91% of the total change in flow and bed mobility parameters. Third-order impacts were assessed in terms of potential changes in cottonwood recruitment due to altered stage recession patterns during the post-flood establishment period. The results suggest that the greatest potential for seedling recruitment historically occurred during low-flow years, and that dam operations have reduced the potential for cottonwood recruitment along the river. However, results also indicate that recent flow releases aimed at restoration of native fishes, in combination with tributary inputs and backwater effects of Kootenai Lake, may enhance cottonwood recruitment in the meandering and braided reaches (Fig. 1). These results hold promise for guiding riparian restoration efforts in those portions of the river.

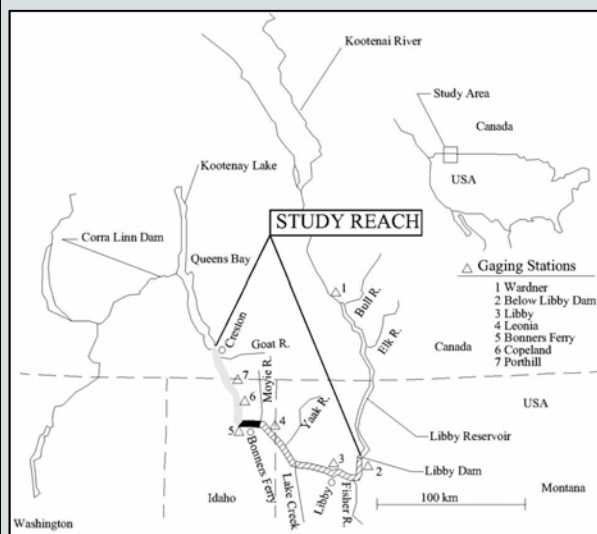


Fig. 1: Location of the study site, dams, geomorphic subreaches (canyon, hatched; braided, black; meandering, gray) and gaging stations.

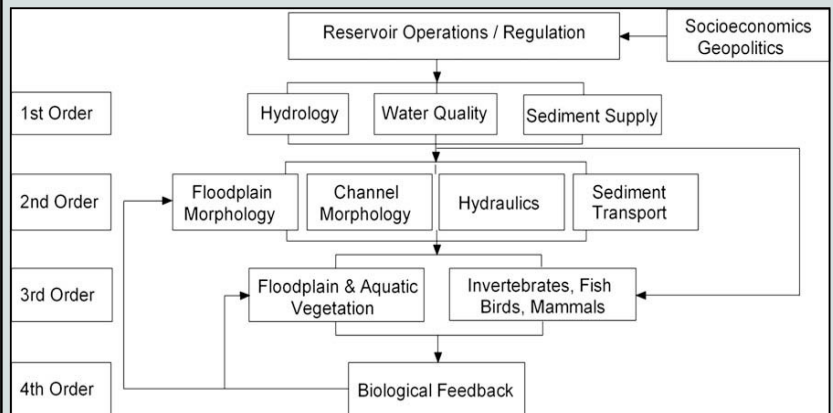


Fig. 2: Hierarchical framework of physical and biological impacts caused by dam operation.

Publications and Presentations

Burke, M., Jorde, K., and Buffington, J.M. 2009. [Application of a hierarchical framework for assessing environmental impacts of dam operation: changes in hydrology, channel hydraulics, bed mobility and recruitment of riparian trees in a western North American river.](#) *Journal of Environmental Management* 90: S224-S236.

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