

## **Distinguishing human and climate influences on the Columbia River: changes in the disturbance processes**

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**Abstract** This paper distinguishes human and climate influences on the Columbia River streamflow disturbance regime, examines how this disturbance regime has changed over the last 150 years, and discusses downstream impacts. Flow management and withdrawal have greatly curtailed exceedence of the natural bankfull level of approx.  $20\,000\text{ m}^3\text{ s}^{-1}$ . The frequency distribution of Columbia River flow has also changed. Sediment transport is positively correlated with streamflow standard deviation, and has been greatly reduced by flow regulation. Three kinds of spring freshet styles have been identified; there are also four kinds of winter freshets. Flow regulation and regional climate warming have changed freshet styles and reduced their maximum spring intensities. Downstream effects of hydrological alterations include increased salinity intrusion length, loss of shallow water habitat area during the freshet season, increased tides throughout most of the year, and a decrease in area of the Columbia River offshore plume during spring and summer. Although climate changes and variations have played a substantial role in changing the hydrological disturbance regime, their influence is still less than that of human manipulation of the flow cycle.

**Key words** Columbia River; climate impact; human impact; freshet style; salmonid; overbank flow; disturbance frequency; flow regulation; reservoir manipulation; irrigation depletion