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Simulating future water temperatures in the North Santiam River, Oregon

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SUMMARY

A previously calibrated two-dimensional hydrodynamic and water-quality model (CE-QUAL-W2) of Detroit Lake in western Oregon was used in conjunction with inflows derived from Precipitation-Runoff Modeling System (PRMS) hydrologic models to examine in-lake and downstream water temperature effects under future climate conditions. Current and hypothetical operations and structures at Detroit Dam were imposed on boundary conditions derived from downscaled General Circulation Models in base (1990–1999) and future (2059–2068) periods. Compared with the base period, future air temperatures were about 2 °C warmer year-round. Higher air temperature and lower precipitation under the future period resulted in a 23% reduction in mean annual PRMS-simulated discharge and a 1 °C increase in mean annual estimated stream temperatures flowing into the lake compared to the base period. Simulations incorporating current operational rules and minimum release rates at Detroit Dam to support downstream habitat, irrigation, and water supply during key times of year resulted in lower future lake levels. That scenario results in a lake level that is above the dam's spillway crest only about half as many days in the future compared to historical frequencies. Managing temperature downstream of Detroit Dam depends on the ability to blend warmer water from the lake's surface with cooler water from deep in the lake, and the spillway is an important release point near the lake's surface. Annual average in-lake and release temperatures from Detroit Lake warmed 1.1 °C and 1.5 °C from base to future periods under present-day dam operational rules and fill schedules. Simulated dam operations such as beginning refill of the lake 30 days earlier or reducing minimum release rates (to keep more water in the lake to retain the use of the spillway) mitigated future warming to 0.4 and 0.9 °C below existing operational scenarios during the critical autumn spawning period for endangered salmonids. A hypothetical floating surface withdrawal at Detroit Dam improved temperature control in summer and autumn (0.6 °C warmer in summer, 0.6 °C cooler in autumn compared to existing structures) without altering release rates or lake level management rules.

1. Introduction

Detroit Dam has altered the natural thermal regime in the North Santiam River, Oregon, since construction in 1953. Beginning in 2007, the U.S. Army Corps of Engineers (USACE) has managed releases from Detroit Dam with the intent of managing downstream temperatures for threatened/endangered Upper Willamette River Chinook salmon (*Oncorhynchus tshawytscha*) and winter steelhead (*Oncorhynchus mykiss*). USACE finished construction of Detroit Dam (141.1 m [463 ft] tall) and the smaller, re-regulating Big Cliff Dam (58.2 m [191 ft] tall) in 1953. Initial purposes for the 9-mile long impoundment of Detroit Lake were to provide flood damage reduction, navigation, irrigation/water storage (560,000,000 m^3 [455,000 acre-feet] at full pool), hydropower (100 MW), and recreation (popular swimming, boating, and fishing destination). Following the 2008 Willamette Project Biological Opinion issued by the National Marine Fisheries Service (2008), interim operations at Detroit Dam have been incorporated to improve downstream flow and temperature conditions for fish passage, spawning, incubation and rearing of ESA-listed Upper Willamette River Spring Chinook salmon and Upper Willamette River Winter Steelhead until permanent solutions can be developed and completed. Since 2007, USACE has applied specific minimum release rates year-round and has managed release temperatures during summer full-pool and autumn low-pool seasons by blending releases from multiple dam outlets (U.S. Army

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Corps of Engineers, 2014). Previous work using a two-dimensional hydrodynamic temperature model (CE-QUAL-W2) of the lake has quantified the potential improvements to downstream temperatures of hypothetical operational and structural scenarios at Detroit Dam under cool/wet, normal, and hot/dry (historically based) conditions (Buccola et al., 2012, 2015).

The primary tributaries to Detroit Lake are the North Santiam and Breitenbush Rivers (Fig. 1), which have about 78% and 46% of their headwaters located in the High Cascades hydrogeologic unit. High Cascades streams are dominated by snowmelt runoff and strong groundwater baseflow (Tague and Grant, 2004). The groundwater baseflow provides a relatively steady, cool water source throughout the late summer dry season and is projected to be relatively resilient (less year-to-year variability) to climate change than lower elevation sub-basins in the vicinity (Mateus et al., 2014). Other research has shown that similar and nearby sub-basins with headwaters in the High Cascades (i.e., McKenzie and Deschutes River basins) could have an earlier peak in spring runoff and/or large reductions in snow-water storage available as runoff in the future (Sproles et al., 2013; Waibel et al., 2013).

The goal of this study was to provide insights into potential future water temperatures (years 2059–2068) in and downstream of Detroit Lake as a result of climate change and under a range of temperature management operations at Detroit Dam. To achieve this goal, General Circulation Models (GCMs) from the Coupled Model Intercomparison Project (CMIP3) (accessible at http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php) were used as the basis for future conditions that could be compared to base conditions to assess relative changes. By focusing on changes rather than absolute predictions, the uncertainty attributed to each step in the modeling process is minimized because base and future time frames embody the same assumptions. Although this study does not include the more recent CMIP5 data, the conceptual framework described here using GCM results, rainfall–runoff models, and lake models in sequence could be applied to the newest generation of GCMs, such as CMIP5. Throughout this article, historical measurements are provided when possible; however, caution should be exercised in comparing simulated dam release temperatures with historical measurements at a downstream location, as the simulations encompass a different set of assumptions (e.g., dam operations).

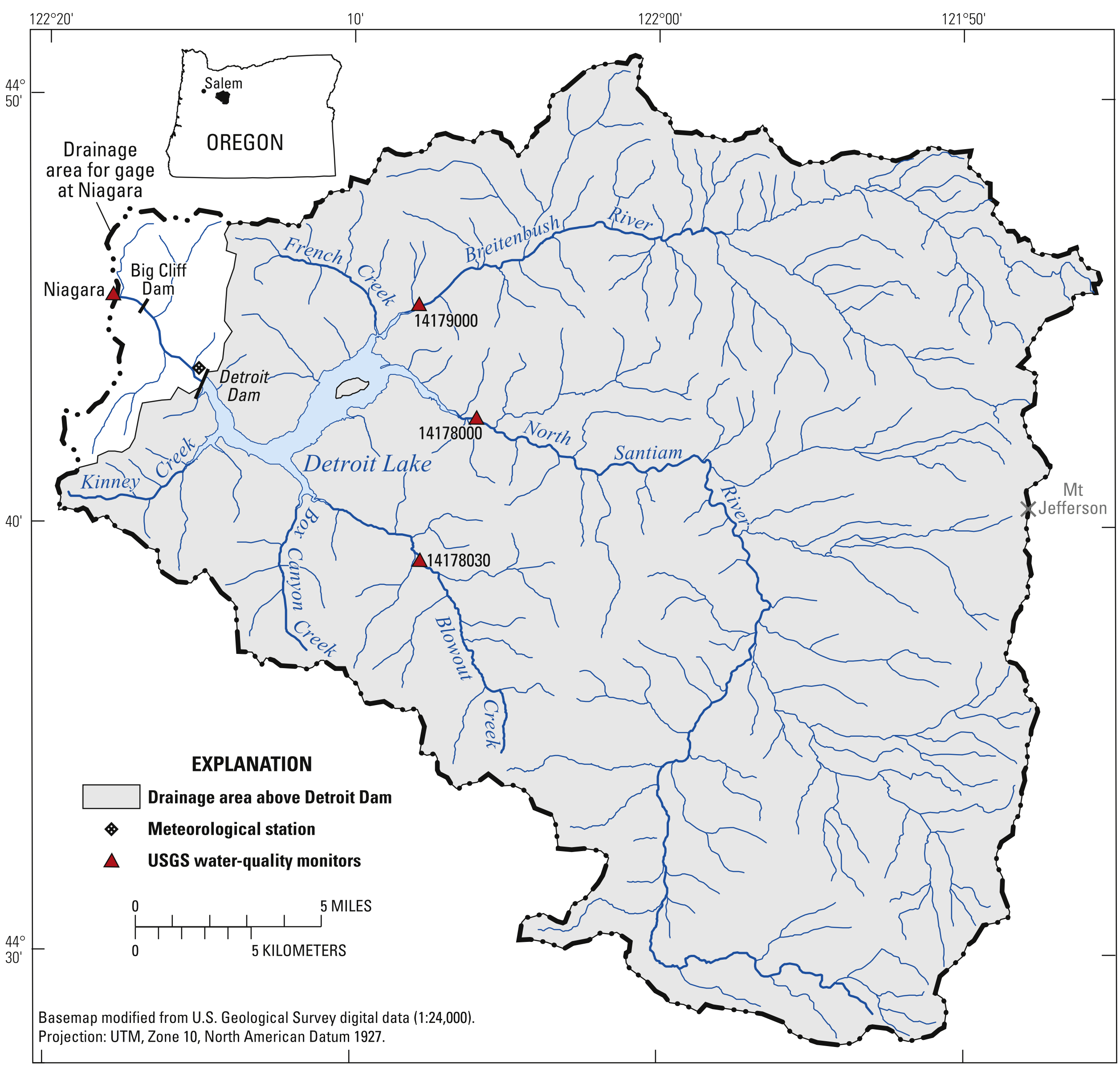

Fig. 1. Map of the upper North Santiam River Basin near Detroit Lake, Oregon.