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Assessment of circulation and inter-basin transport in the Salish Sea including Johnstone Strait and Discovery Islands pathways

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ABSTRACT

The Salish Sea consisting of Puget Sound and Georgia Basin in U.S and Canadian waters has been the subject of several independent data collection and modeling studies. However, these interconnected basins and their hydrodynamic interactions have not received attention as a contiguous unit. The Strait of Juan de Fuca is the primary pathway through which Pacific Ocean water enters the Salish Sea but the role played by Johnstone Strait and the complex channels northeast of Vancouver Island, connecting the Salish Sea and the Pacific Ocean, on overall Salish Sea circulation has not been characterized. In this paper we present a modeling-based assessment of the two-layer circulation and transport through the multiple interconnected sub-basins within the Salish Sea including the effect of exchange via Johnstone Strait and Discovery Islands. The Salish Sea Model previously developed using the finite volume community ocean model (FVCOM) was expanded over the continental shelf for this assessment encircling Vancouver Island, including Discovery Islands, Johnstone Strait, Broughton Archipelago and the associated waterways. A computational technique was developed to allow summation of volume fluxes across arbitrary transects through unstructured finite volume cells. Tidally averaged volume fluxes were computed at multiple transects. The results were used to validate the classic model of *Circulation in Embracing Sills* for Puget Sound and to provide quantitative estimates of the lateral distribution of tidally averaged transport through the system. Sensitivity tests with and without exchanges through Johnstone Strait demonstrate that it is a pathway for Georgia Basin runoff and Fraser River water to exit the Salish Sea and for Pacific Ocean inflow. However the relative impact of this exchange on circulation and flushing in Puget Sound Basin is small.

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1. Introduction

The inland marine waters of Washington State and British Columbia, Canada, are collectively recognized as the Salish Sea. The official designation adopted in 2009 extends from Puget Sound at the south to the mouth of the Strait of Juan de Fuca, includes waters of northern Washington and southern British Columbia and also waters surrounding San Juan Islands. The Salish Sea terminates at the north end of the Strait of Georgia and Desolation Sound (WWU, 2009) (see Fig. 1). The scientific, fishing, and tribal communities understand that these separately named bodies of water form a single estuarine ecosystem which includes numerous tide flats, marshes, and eelgrass beds that support thousands of species of fish and wildlife. Much of our present understanding of physical oceanographic behavior of the Salish Sea is based on analysis and interpretation of considerable data collected since the 1950s (e.g., Crean and Ages, 1971; Thomson and Huggett, 1980; Holbrook et al., 1980; Thomson, 1981, 1994; Collias et al., 1974; Cox et al., 1981, 1984; Cannon, 1983; Ebbesmeyer et al., 1984). Several modeling studies have been conducted since then by U.S. and Canadian researchers; however, these interconnected basins and their hydrodynamic interactions have not received attention as a contiguous unit. The Strait of Juan de Fuca is the primary pathway through which Pacific Ocean water enters the Salish Sea, but the roles played by the second pathway to the Pacific Ocean through Johnstone Strait and the complex channels northeast of Vancouver Island on overall Salish Sea circulation have not been examined and are often neglected. The validity of the inherent assumption that exchange north and transport out of the system through Johnstone Strait is relatively small is examined in this paper along with the assessment of circulation in the Salish Sea as a whole influenced by Pacific Ocean tides and freshwater loads and inter-basin exchanges.

This is a glacially carved fjordal estuarine system with many narrow long and relatively deep interconnected basins that support strong currents induced by tides 3–4 m in range. Pacific Ocean

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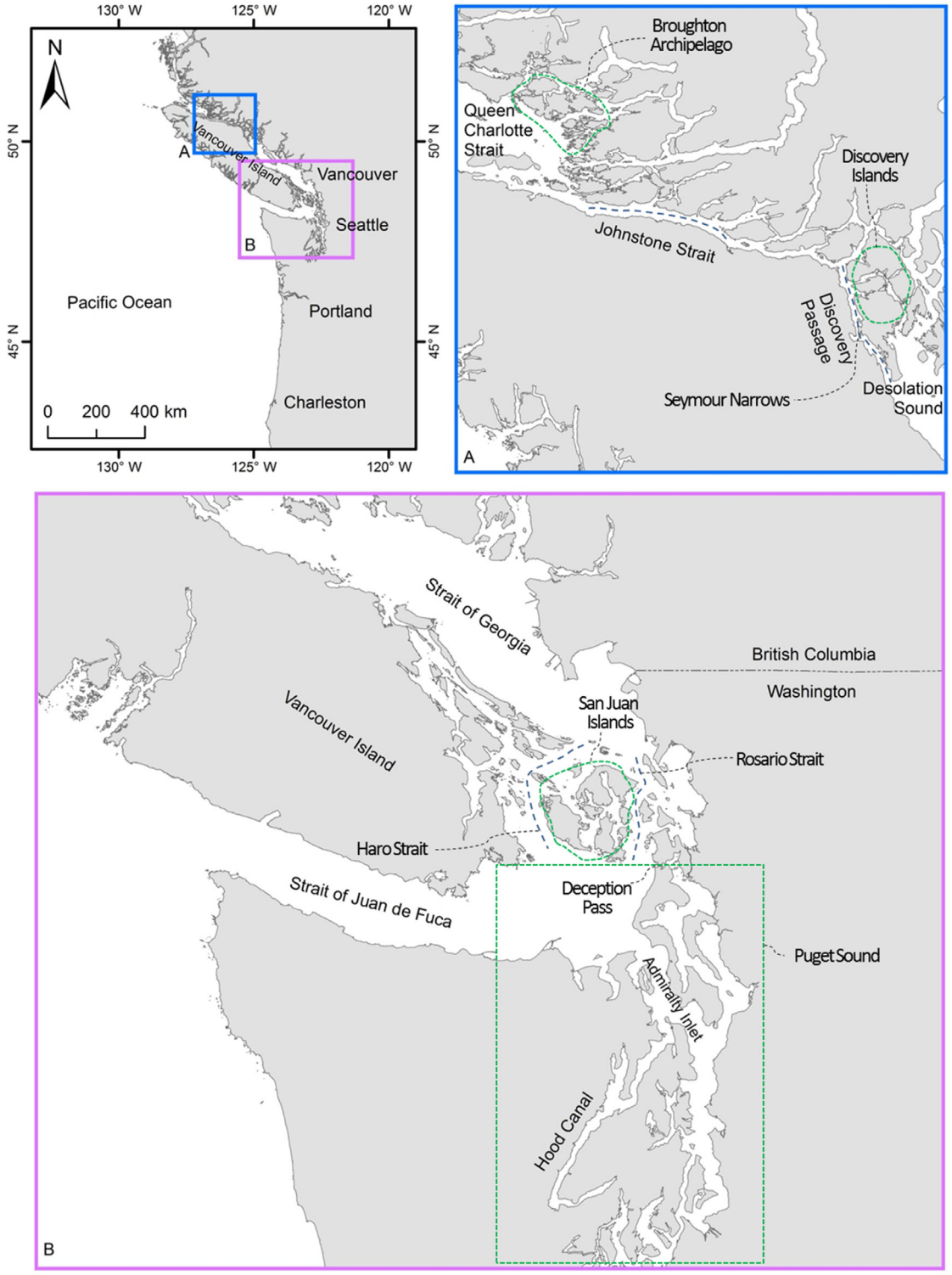

Fig. 1. Oceanographic regions of the Salish Sea (Puget Sound, the Strait of Juan de Fuca, and the Strait of Georgia) including Johnstone and Queen Charlotte Straits.

tides propagate into the system in the southeast direction from the north via Queen Charlotte Strait and eastward via the Strait of Juan de Fuca. The Salish Sea benefits from the natural presence of a strong estuarine circulation and relatively rapid water renewal and flushing. The freshwater discharged by a total of 19 major rivers and substantial regional runoff help create stratified two-layer conditions in the various large sub-basins primarily separated by the presence of sills or islands (e.g., Puget Sound, the Strait of Juan de Fuca, the Strait of Georgia, Discovery Passage, Johnstone Strait). Tidally averaged circulation in each basin consists of seaward flow of mixed brackish water in the surface layer and landward flow of saline water through the lower layers. For example, the strength of this tidally averaged inflow through the lower layer (also referred to as exchange flow) into the Puget Sound region of the Salish Sea via Admiralty Inlet ($10–20 \times 10^3$ m^3/s) is nearly 10–20 times the average freshwater river inflow to Puget Sound Basin (Sutherland et al., 2011; Khangaonkar et al., 2012). This provides sufficient dilution and flushing of pollutant loads and wastewater from