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HISTORICAL CHANGES TO LAKE WASHINGTON AND ROUTE OF THE LAKE WASHINGTON SHIP CANAL, KING COUNTY, WASHINGTON

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INTRODUCTION

Lake Washington, in the midst of the greater Seattle metropolitan area of the Puget Sound region (fig. 1), is an exceptional commercial, recreational, and esthetic resource for the region. In the past 130 years, Lake Washington has been changed from a "wild" lake in a wilderness setting to a regulated lake surrounded by a growing metropolis—a transformation that provides an unusual opportunity to study changes to a lake's shoreline and hydrologic characteristics resulting from urbanization.

The desirability of lakefront residences, and the past preference for commerce and industry to locate elsewhere, resulted in about 78 percent of the Lake Washington shoreline being devoted to residential land use (U.S. Geological Survey, 1977). Thus, the shores of the lake so far have been largely spared the impacts of commercial and industrial development and the large-scale shoreline modification that typically accompany such land use. Still, the entire present-day shoreline of Lake Washington is much different from the predevelopment shore, and the lake's former hydrologic system has been permanently changed.

The Construction of the Lake Washington Ship Canal has been the most important human factor to ever affect the lake and its shorelands, inflowing and outflowing streams, and natural water bodies along the canal route. In less than a decade (1911–16), the following changes occurred. Construction of a canal linking the freshwater lakes with the marine waters of Puget Sound resulted in a lowering of the Lake Washington surface to a level common with the canal. The surface area and shoreline of Lake Washington were diminished, and several wetlands and sloughs drained or reduced in size. In conjunction with the lake lowering, a major river was diverted into the lake, and a river channel formerly draining the lake was permanently abandoned. Significant changes also were made along the canal route, including excavations, dredging, water-level change, and the transformation of a saltwater tidal inlet to a freshwater bay. With greater development and growing population, more changes came to Lake Washington, such as shoreline landfills, wetland "reclamation," dredging, modification, or loss of small streams to city sewers, and the gradual transition of land along the lake from old-growth forest to cleared agricultural land and subsequently to urban use. The former shorelines, wetlands, and streams are not readily discernible on today's landscape, yet knowledge of the former natural shoreline and hydrologic system, and of the more recent man-induced changes, is of significant value to scientists, engineers, planners, and others interested in a better understanding of Lake Washington, past and present.

The accompanying map depicts the earliest recorded information about shorelines, streams, vegetation, and land uses fringing the lake and canal route, compiled from historical surveys and maps that predate the canal project. This historical information has been overprinted on a base map comprising the most current U.S. Geological Survey 1:24,000-scale topographic maps, so as to provide a direct comparison of the former and present-day conditions. A detailed description of the data transfer from such historical maps was described by Bortleson and others (1980). Included with the map is a summary of changes to selected shoreline and drainage features subsequent to completion of the Lake Washington Ship Canal. The following text, table, and figures describe (1) the lake and canal route in its present-day setting, (2) the natural conditions preceding the canal project, and (3) a brief history of the canal project. Also discussed are several planning implications derived from the historical and present-day comparison.

The geographic limits and edition dates of the modern maps are indexed on the accompanying map. All had been updated to reflect changes shown by aerial photographs (photorevised) in 1973, except for the Seattle North and Renton quadrangles, which were photorevised in 1968. Any changes to shoreline or land use that have occurred since the times of those photorevisions are not shown on the base map.

The compiled historical map data range in date from 1875 to 1907 and consists of topographic and hydrographic surveys, river surveys, and published maps of the following Federal mapping agencies: (1) The former U.S. Coast and Geodetic Survey, now the National Ocean Survey of the National Oceanic and Atmospheric Administration (NOAA); (2) U.S. Geological Survey; and (3) U.S. Army Corps of Engineers. Included on the accompanying map is an index of the historical surveys and maps, with dates and scales. Some shoreline modification had already occurred at the time of these early surveys and maps.

This map is part of an ongoing effort by the U.S. Geological Survey to provide earth-science and related information for such purposes as land-use planning, resource development, and environmental protection in the Puget Sound region.

PRESENT-DAY LAKE WASHINGTON AND THE LAKE WASHINGTON SHIP CANAL

Lake Washington forms the east city limits of Seattle and separates the city from neighboring communities to the east (fig. 1). It is the largest lake west of the Cascade Range and the second largest natural lake in the State. Total water area of the lake is 28.0 mi^2 and the shoreline length is 71.5 mi. Centrally, in the southern

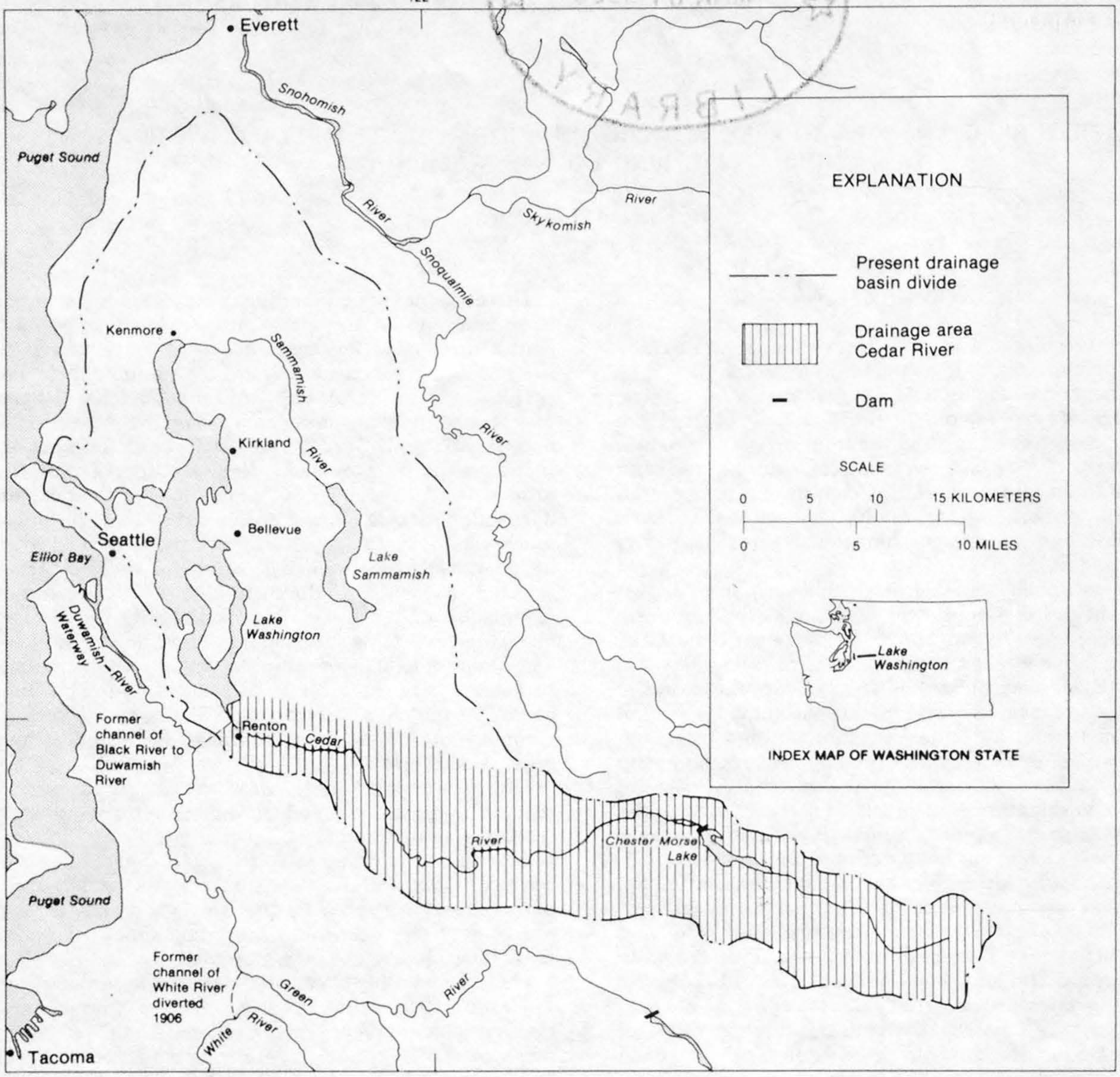

Figure 1. — Sketch map of Lake Washington vicinity showing major rivers and boundaries of the Lake Washington – Lake Washington Ship Canal drainage basin. The drainage area of the Cedar River (line pattern) was added to the Lake Washington basin as a result of the artificial diversion of the Cedar in conjunction with the Ship Canal project.

half of the lake is Mercer Island, which has an area of 6.5 mi^2 and accounts for about 19 percent of the lake's total shoreline (Wolcott, 1973, p. 166). The maximum lake depth, northwest of Mercer Island, has been measured at 214 ft. The average lake depth is about 110 ft.

The drainage basin of Lake Washington—land that contributes surface runoff to the lake—is 182 mi^2 and presently comprises a mixture of forest, agricultural, and urban land (fig. 1). The principal inflows to the lake are from the Cedar River, with headwaters near the crest of the Cascade Range, and the Sammamish River, which drains Lake Sammamish. Cedar River, which is partly regulated in its upper watershed by a dam and reservoir for impounding Seattle municipal water and for hydropower generation, enters the south end of the lake at Renton. The Cedar has an average discharge of 704 ft^3/s. Sammamish River enters the north end of the lake at Kenmore; its average discharge of 367 ft^3/s is 52 percent as much as that of the Cedar (U.S. Geological Survey, 1979, p. 194; and 1964, p. 141). Flow through Lake Washington is generally from these two ends toward the lake's present-day outflow, the Lake Washington Ship Canal, in the middle part of the lake's west shore. From inflow of the Cedar and Sammamish Rivers to outflow through the Ship Canal there is an average water-residence time in the lake of 2.3 years (Edmondson and Lehman, 1981, p. 12).

The Lake Washington Ship Canal, which provides navigable access between Lake Washington and the marine waters of Puget Sound, is about 8 mi long and has a minimum depth of 30 ft. It is a combination of dredged channel, excavated canal, and a linkage of the intervening natural basins of Lake Union and Salmon Bay (see map). Maximum depth in Lake Union is 50 ft and in Salmon Bay, 39 ft. Commercial and industrial land uses dominate the shorelines of the Ship Canal, though several communities of houseboats occupy nearshore waters of Lake Union. The Ship Canal is used mostly by a large fleet of small commercial and pleasure craft, that moor in the freshwater basin but cruise on Puget Sound. Oceangoing ships of small to medium size make less-frequent use of the waterway.

A common water level in Lake Washington and the Lake Washington Ship Canal is created and controlled by a dam and adjoining double (side-by-side) navigations locks located at the west end (or "Narrows") of Salmon Bay. This facility, the Hiram M. Chittenden Locks, is maintained by the U.S. Army Corps of Engineers, Seattle District. Lake Washington water flowing westward through the canal system discharges either over the dam spillway, during lockage operations, or through an adjoining fish ladder, and artificial "rapids" for passage of migrating anadromous fish. The mean elevation of Lake Washington and the Ship Canal is 21.0 ft above the tidal datum or mean lower low water (MLLW) of Puget Sound. This lake-water level can be adjusted 1 ft above or below the mean elevation by movable gates on the crest of the dam spillway. In winter months, the water level is drained down to the established lower limit in order to facilitate clean-up and dock repairs along the Ship Canal and the shores of Lake Washington. The maximum water level of 22.0 ft is never exceeded.

The mean tidal range on the saltwater (west) side of the locks is 11.3 ft. Saltwater that may enter the locks during their operation, being denser than the fresh lake water, tends to remain in the bottom of the system. It is partly prevented from entering the freshwater system by a hinged barrier on the floor above the large lock, lowered only for deep-draft vessels. Immediately beyond this saltwater barrier is a basin to trap any escaping saltwater, and a discharge pipe to return this denser water to Puget Sound (U.S. Army Corps of Engineers, 1976, sec. 2, p. 8).

THE HYDROLOGIC SETTING PRIOR TO CONSTRUCTION OF THE LAKE WASHINGTON SHIP CANAL

Lake Washington, like neighboring Lake Sammamish and Puget Sound itself, occupies a trough that was scoured and modified by the most recent continental glacier to invade the Puget Sound region. Lake Union and Salmon Bay are lesser basins that similarly owe their origins to glacial processes. Although few data are available from which to recreate the recent geologic history of Lake Union or Salmon Bay, the evidence for Lake Washington is somewhat clearer.

When the Lake Washington water level was artificially lowered in 1916, it apparently was being lowered from its highest recent elevation, which resulted from a long-term natural "damming" process. Higher land surrounding Lake Washington prevented a natural drainage outlet except at its southern end, and there the outlet had to cross the flood plain or "fan" of the Cedar River. During prehistoric time, a buildup of this fan as a result of fluvial deposition slowly raised the lake's spillway elevation and, thus, continually raised the lake's water level. Evidence of earlier lower water levels for Lake Washington included a wave-cut terrace that extends to 40 ft below the present lake surface (Gould and Budinger, 1958, p. 186). Rooted on this terrace (or at even greater depths) are the submerged remains of forests still in growth position (McKnight, 1923, p. 57).

During historical time, but prior to construction of the Ship Canal, Lake Washington, Lake Union, and Salmon Bay played an important role in commerce and development of the region. In their natural (pre-canal) setting, these water bodies were separated, each had different mean water levels, and each had hydrologic characteristics significantly different from those that exist today. The following is a description of the pre-canal conditions and some of the early modifications of these natural conditions that were made to improve commerce and flood control.

Historical Lake Washington

Lake Washington was named in 1854 in honor of the first U.S. president and the newly-formed Washington Territory. The Lake had earlier been called Lake Duwamish, Lake Geneva and, by the regional trade language (or Chinook jargon) name, "Hyas Chuck", meaning "Big Lake".

Before construction of the Lake Washington Ship Canal, Lake Washington had a mean seasonal water level that was 29.8 ft above MLLW of Puget Sound, or a mean water level 8.8 ft higher than at present (fig. 6) (U.S. Army Corps of Engineers, 1976, sec. 2, p. 13). The lake level fluctuated considerably; as much as 7 ft between wet and dry seasons at the time of earliest pioneer settlement, decreasing to 3–4 ft as human intervention improved the lake's flood-stage discharge (U.S. Coast and Geodetic Survey, 1902; Eastwich, 1891, p. 24). This large seasonal fluctuation was a hindrance to early farming of adjacent lowlands, and generated interest in constructing a canal to Puget Sound as a means of flood control.

The rivers of the Lake Washington hydrologic system were responsible for the water-level fluctuation and a slow lake-flushing rate. The system included the Sammamish River, the major tributary to the lake; the Black (and Duwamish) River, the lake's natural outlet and drainage way to Puget Sound; and the Cedar River, which, though not normally entering the lake, was an occasional source of water to the lake basin when the river was flooding.

Sammamish River. — Before the lowering of Lake Washington, the Sammamish River had a higher base water level, was broader, deeper, and had a slower current than it now has. The river was navigable for its entire length by shallow-draft steamers, and was a route used to transport logs and coal barges between Lakes Sammamish and Washington. The Sammamish was the largest tributary stream entering Lake Washington (see map, location 1).

Black River. — Lake Washington originally discharged at its southern end through the Black River, which flowed southward and then westward, a total distance of 3.3 mi (see map, location 11, and fig. 2). The river ranged in width from 50 to 150 ft and had an average depth of 4 ft (Eastwick, 1891, p. 4; U.S. Army Corps of Engineers, 1907). The Black River joined what was then the White River to form the Duwamish River, which meandered northward and discharged into Elliott Bay of Puget Sound. The Black River was named for the contrast of its darker, organic-rich water to the milky, glacier-fed waters of the White River. By 1906, White River was permanently diverted from the channel that joined Black River, and since that time its former major tributary, the Green River, has occupied the channel upstream from the Black-Duwamish confluence (fig. 1)

For a time, the Black and Duwamish River provided a natural navigational access between Lake Washington and Puget Sound, but it was an access limited by low river flow, tidal fluctuations in the lower Duwamish, and many shoals, snags, and a meandering channel. Nonetheless, the Black-Duwamish River route was used to transport coal barges, logs, and even for passage of shallow-draft steamers between Puget Sound and Lake Washington.

Early efforts were made to improve navigation through the Black and Duwamish Rivers by dredging out bars and removing other obstructions. This modification of the channel, as well as clearing of thick brush for farming of the flood plains, enhanced the channel capacity and decreased the backwater at the lake outlet during periods of flooding and, thereby, reduced the highest water levels of Lake Washington. The last time that "backwater flooding" occurred in the Cedar, Black, and Duwamish valleys, reaching a flood level as high as 7 ft was in December 1867 (King County, 1939, p. 163). This probably was the final time that Lake Washington reached a "natural" extreme high water level.

Cedar River. — In prehistoric time, the Cedar River may have been a major tributary to Lake Washington, as it now is; however, historical accounts indicate that, prior to 1912, the main channel of the Cedar River did not enter the lake, but instead joined the Black River 0.5 mi downstream from the lake outlet (see map, location 10). When the Cedar was at flood stage, its flow branched into several channels near its mouth, part flowing westward to the Black River, but part also northward across then extensive wetlands and into Lake Washington (Eastwick, 1891, p. 24). During these flood stages, the large outpouring of the Cedar River water commonly reversed the flow direction in the upper segment of the Black River, discharging Cedar River flood waters into Lake Washington. At those times, the Black River actually had water flowing in opposite directions at its two ends. This oddity was reflected in the Chinook jargon name for the Black River — "Mocks La Push" or, "river with two mouths" (Matson, 1974, p. 133).

Although flood stages of inflowing streams brought a large volume of water into Lake Washington, any lake-flushing benefits were shortlived and inconsistent. For most of the year, Lake Washington in its natural state was a poorly flushed lake, and water quality reportedly worsened noticeably during the dry season (July–Sept.) when the lake was relatively stagnant. Average residence time for the lake water in the natural state probably was about twice the present-day value, or nearly 5 years.

Historical Lake Union

Before construction of the Ship Canal, the mean seasonal elevation of Lake Union was about as it is now—21.0 ft above MLLW (fig.6). Seasonal variation of the lake level was about 0.5 ft (Eastwick, 1891, p. 10).

Lakes Union and Washington were naturally separated by a ridge between Portage Bay (the eastern extension of Lake Union) and Union Bay (the westernmost reach of Lake Washington). The intervening ridge had a low place where, at least one report mentions, a small stream crossed from Union Bay into Portage Bay (Waterman, 1921, p. 192). However, the substantial height of even the lowest divide makes the existence of a natural stream there unlikely. The reported "stream" may have been the flow through a small ditch shoveled across the ridge in 1860 by a local resident, Harvey L. Pike, in the unsuccessful earliest attempt to make a canal between the two lakes (Bagley, 1916, p. 371). The area of this low divide between the lakes was called "The Portage" and was long used by Indians and early settlers to carry canoes between Lakes Washington and Union. Its location corresponds to the present-day route of Highway 520 between Portage Bay and Union Bay.

No rivers entered Lake Union. The Lake's small natural inflow was limited to springs, small streams, and intermittent runoff from surrounding hills. This limited inflow undoubtedly was a factor that contributed to common dry-season stagnation and degradation of the lake during that period. The lake's outlet was at its northwest corner, through a small, nonnavigable stream, variously called "The Outlet," "Shilshole Creek," or "Ross Creek," which descended westward to Salmon Bay along a route generally corresponding to the present Fremont Cut (see map, location 27).

Historical Salmon Bay

In its natural state, Salmon Bay was a saltwater tidal inlet fringed at its eastern end with brackish-water and saltwater marsh. At its west end, beyond a restriction called "The Narrows," Salmon Bay connected to Shilshole Bay of Puget Sound. Historically, the name Shilshole Bay also was used to refer to this interior embayment, but the local name "Salmon Bay" was later accepted. Salmon Bay raised and lowered with the twice-daily tides of 11.3-ft mean range; it was navigable at high tide but practically dry at extreme low tide (fig. 6). At mean lower low water, Salmon Bay and inner Shilshole Bay were reduced to a narrow meandering channel about 3 ft deep (U.S. Army Corps of Engineers, 1939, p. 3).

THE LINKING OF LAKE WASHINGTON AND PUGET SOUND

Because of the natural alinement of water bodies between Shilshole Bay and Union Bay, the idea of a canal linking Lake Washington with Puget Sound is virtually as old as pioneer settlement in the area. In fact, Seattle pioneer Thomas Mercer first suggested such a canal in 1854, and also suggested the name "Union" for the lake and bay that were foreseen as links in this canal uniting Lake Washington with Puget Sound.

The benefits anticipated from such a canal were seen differently by the various communities, and changed through the years of discussion. Navigation was the principal objective to aid the transport of logs, coal, and farm produce. Flood control was an additional advantage. And although residential land use now dominates the lakeshore, initially there was anticipation of financial gains from the commerical and industrial development of land surrounding this excellent freshwater harbor; free of saltwater corrosion, marine-plant growth, and tidal fluctuations. The history of the

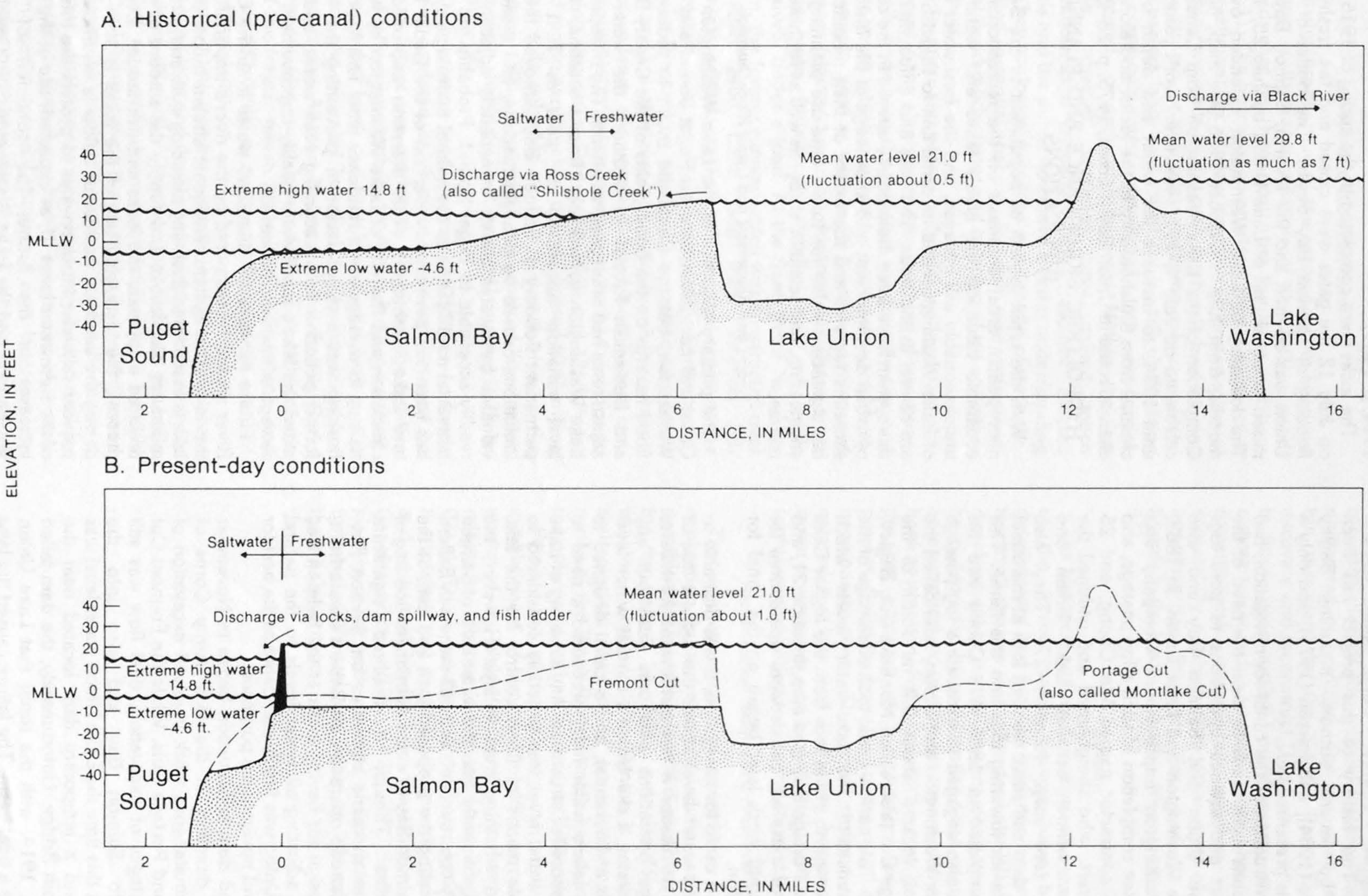

Figure 6. — Schematic sections comparing historical and present-day bottom configuration and elevations along route of the Lake Washington Ship Canal. All water elevations are in feet above or below (−) mean lower low water (MLLW)

Lake Washington Ship Canal is colorful, spanning 63 years, dealing with six possible routes, and involving private enterprise, county, State, and Federal governments. The history of this project has been documented by several authors, including Bagley (1916), Purvis (1934), and Larson (1975), and only a brief account is presented here.

Prior to construction of the canal for navigation, two small excavations were made to meet the need of the bustling timber and sawmill operations to pass logs between Lake Union and Salmon Bay and also between Lake Washington and Lake Union. In 1883, the Lake Washington Improvement Company was organized to see completion of such a log passage, and hired a local contractor named Wa Chong, and 25 Chinese laborers, who straightened and widened the existing streamchannel between Lake Union and Salmon Bay (see map, location 27). They also constructed a dam and small wooden lock at the outlet of Lake Union for lowering logs into this flume. This work was completed in 1885. Wa Chong and his laborers were also engaged to excavate a log passage between Lakes Washington and Union, later called the Protage Canal, located about 0.2 mi south of the present Protage Cut (also called Montlake Cut; Bagley, 1916, p. 375). This narrow canal took advantage of the natural difference in the lake-water levels which produced a current to chute logs from the higher Lake Washington to Portage Bay (see map, location 21, and fig. 5). Both of these log canals were operational for many years until work later began on the canal for vessel navigation.

In planning a canal for navigation, it was desirable to maintain a lake-water level above the highest tide of Puget Sound to assure a net outflow of freshwater during lockage operations and thus flush out any intruding saltwater. Lake Union's natural water level provided such a differential, and a canal designed to maintain that lake's water level prevented a need to alter existing shoreline structures. Any lowering of Lake Washington's water level was generally considered to be a favorable means of flood control for the lake perimeter and adjoining river valleys. However, the proposal to permanently alter the water level of Salmon Bay was highly controversial, and mill owners in Ballard argued for locating the proposed lock and dam at the east end of Salmon Bay to avoid permanent flooding of the tidal inlet. Though it required significant modification to shoreline structures on Salmon Bay, and a major landfill operation on Ballard's waterfront, the project design for having locks at the Salmon Bay Narrows and adjusting all water levels to the natural level of Lake Union was finally mandated as the best for engineering and navigational purposes.

The lock and dam construction began in November 1911, under direction of the U.S. Army Corps of Engineers. Simultaneous work involved excavation of the Fremont and Portage Cuts. While the Fremont Cut was in final stages of excavation, tidal flow was still permitted into Salmon Bay and also into the excavation. At this time the Lake Union water level was retained behind a temporary dam located near the present Fremont Bridge. Unfortunately, the dam failed on March 13, 1914, with the result that Lake Union briefly became a tidal basin. The failure caused the lake to lower 3–4 ft below high-tide level, allowing saltwater tidal flow into and out of Lake Union for 10 days. The dam was repaired within 6 weeks and the lake level was eventually restored (U.S. Army Corps of Engineers, 1914, p. 1439).

The locks were completed in the spring of 1916, and on July 12 the gates were closed and the freshwater flooding of Salmon Bay began. The outlet of Lake Union was opened and the level of Salmon Bay was raised to equal that of Lake Union by July 25, 1916. The lowering of Lake Washington extended over 4 months, from July to October 1916 (see map, fig. 6). Completion of the Lake Washington Ship Canal was celebrated on July 4, 1917; however, work continued until 1934, to increase the width and depth of the channel from Shilshole Bay to the locks, and along the channel route in Union Bay (Larson, 1975, p. 23–25).

HYDROLOGIC SIGNIFICANCE AND PLANNING IMPLICATIONS

With the rapid growth of population in the Seattle metropolitan area, emphasis on the recreational and economic value on the area's lakes and waterways unquestionably will increase, and the freshwater basin of Lake Washington and its canal link to Puget Sound are central to the issue. The lake and embayments in this system have been dramatically altered in the course of urban development, and knowledge of the historical shoreline features and the extent of their modification has significant value for future land-use planning, site engineering, and scientific study, as well as for historical interest.

Water-Level Adjustment and Cedar River Diversion

The primary objective of the Lake Washington Ship Canal was navigation between Puget Sound and Lake Washington, but the Canal did much to reduce the flood hazards on the flood plains of the Cedar, Black, and Duwamish Rivers. In addition, the water-level adjustments had other positive effects. The shoreland of Lake Washington gained relief from a seasonal water-level variation historically as great as 7 ft. The permanent flooding of Salmon Bay removed the use limitations caused by tidal fluctuations, and created a valuable freshwater harbor immediately adjacent and readily accessible to Puget Sound. Probably the most beneficial modification to the natural hydrologic system has been the permanent diversion of the Cedar River into Lake Washington. This diversion improved the circulation and flushing of Lake Washington by nearly halving its average water-residence time. This improved flushing was a major factor in preventing the lake's former pollution from becoming even worse, and also aided the lake's rapid water-quality improvement after sewage inflow was eliminated.

Future demand for municipal water from the Cedar River should be tempered by the river's importance to the lake-canal system. Adequate stream inflow to the lake is essential to flush any intruding saltwater, provide minimum lake levels, and supply the amount of water required to operate the locks and fish ladder. Even at present, the increasing use of the locks is such that, during dry seasons, freshwater inflow is insufficient to prevent saltwater intrusion and to protect the integrity of the freshwater lakes. If, as expected, use of the locks increases in the future, the condition of Lake Washington and the Lake Washington Ship Canal may depend on the availability of additional freshwater inflow during dry summer months. It has been suggested that additional inflow could conceivably be provided by diversion from the Snoqualmie River basin (fig. 1) (Richardson and others, 1968, p. 20).

Wetlands and Landfill Areas

One significant value of the accompanying historical mapping is its documentation of the total area of wetlands that has been lost from the lakes and bays (table 1). The historical comparison gives a perspective to the alternatives of development or preservation of remaining wetlands. In the past, the marsh land fringing a lake, stream, or tidal inlet was commonly considered to be useless land, well-suited for landfill or dredging and commonly was developed into residential, commercial, or industrial property. Within the last decade, however, wetlands have gained much recognition as a critically needed resource. Elected officials and the public now have a better understanding of the key ecological functions and benefits of wetlands, including essential habitat for fish and waterfowl, natural flood moderation, and trapping of silt and other pollutants.

The location and extent of former wetlands are also significant in the planning and engineering of structures. The soils underlying the wetlands are typically peat and organic muck which can reach considerable thickness. For example, peat as thick as 70 ft has been measured in Mercer Slough (see map, location 6). These areas provide poor foundation stability and will settle excessively under a load. At the Sand Point Naval Air Station, the former runway which was constructed over earth-filled Mud Lake (see map, location 23) continually settled, cracked, and required repair as the lake-bottom peat gradually compacted. Furthermore, the Lake Washington area is in an earthquake-prone region and, in the event of major earth movement, former wetlands and unconsolidated landfill areas may be susceptible to severe ground failure and damage to overlying structures. During the 1949 and 1965 Puget Sound region earthquakes, unconsolidated fill overlying wetland soils subsided in the industrial area of the Duwamish valley, apparently as a result of liquefaction during earth shaking (U.S. Geological Survey, 1975, p. 95–99).

As the present land use of the former wetlands becomes outdated or obsolete, consideration may be given to future use guidelines based on the relative ground-failure susceptibility of the underlying material. A present-day land use that is well matched to the resource and potential benefits of a former lakeshore wetland is the Atlantic Nursery of the Seattle Parks Department (see map, location 13). The rich organic soil of the former marsh is ideal for plant growth, and there would be little or no financial loss in the event of ground instability.

Many of the former wetlands and shoreline areas fringing the lake and canal route were used as sites for solid-waste disposal, a practice that today is generally regarded as a serious environmental misuse. Landfill over the former dumps is susceptible to instability and subsidence, but another major concern for the future is that water quality near these sites may be reduced by contaminents from the unknown assortment of organic and inorganic material buried there. Water-quality monitoring near these sites may be necessary to assess this possibility, and certain activities such as water-contact recreation may be inappropriate in the near proximity.

The historical maps of the shorelines, wetlands, and drainages may be useful for future restoration or reconstruction of the original features that have been obliterated or modified. The idea may seem unusual, but the plans by the Seattle Parks Department to excavate and reconstruct Mud Lake is an example, and in future years artificial marshes may be proposed to restore wetland acreage that has been lost. Experimental manmade marshes have been successfully established in other parts of the country, including San Francisco Bay, and on Miller Sands Islands in the lower Columbia River (Horowitz, 1978, p. 51).

Streams

The historical and modern maps also show how many of the former small streams have been lost to development and provide guidance for preservation of the small streams that still enter Lake Washington. New development or redevelopment along streams that have been degraded by previous land-use changes provides an opportunity to implement stream-channel or stream-bank restoration. Such restoration may become part of the site planning or a condition for development permits. Setbacks from the stream may be planned for new construction. The small streams that formerly entered the lake and that have become routed into storm-sewer pipes and buried might also be candidates for future restoration to a near-natural state.

Archeological Studies and Historical Interest

The accompanying map information has additional application in archeological studies and location of possible sites for archeological digs. This is true not only for the natural lakeshore, but also for the adjacent streams. A recent dig in Renton is an example of an archeological site located on a former shoreline (the banks of the Black River), which has no expression on the present-day urban landscape (Williams, 1979).

Finally, the accompanying map may aid in the establishment of historical markers or commemorative works of art giving recognition to events or effects related to construction of the Lake Washington Ship Canal. These amenities have been recommended for the existing and proposed bikeways, pedestrian trails, and parks that border Lake Washington and the Ship Canal (Larson, 1975, p. 28, 29). Such information plaques or art work could be of significant cultural and historical value and help retain an interesting aspect of the area's heritage.

Table 1. — Comparison of historical and present-day water-surface area, shoreline length, wetland area, and mean water elevations for Lake Washington, Lake Union, and Salmon Bay.

Lake or Embayment	Water-surface area (excluding islands)		Total shoreline		Wetland area		Mean water level (above mean lower low water)	
	Historical mapping (mi^2)	Present mapping (mi^2)	Historical mapping (mi)	Present mapping (mi)	Historical mapping (acres)	Present mapping (acres)	Historical (ft)	Present (ft)
Lake Washington[a]	30.1	28.0[d]	82.0	71.5[d]	1,087.2	74.1 (est.)	29.8	21.0
Lake Union[b] (including Portage Bay)	1.4	1.1[d]	9.1	8.8	[e]	7.4	21.0	21.0
Salmon Bay[c]	0.5	0.4	7.0	5.4	49.4	0	Tidal inlet Mean tide level 6.6	21.0

[a] Water areas and shorelines computed from bridge near Sammamish River mouth to Black River outlet,or Cedar River mouth to bridge over Portage Canal or Montlake Cut. Wetland areas are computed for the entire extent shown on the historical compilation.

[b] Areas and shoreline computed from bridge over Portage Canal, or Montlake Cut, to historical lake outlet or to Fremont Bridge.

[c] Areas and shoreline computed from railroad bridge at east end of Salmon Bay to the entrance from Shilshole Bay, latitude 47°40.3'N.

[d] Data from Wolcott, 1973, p. 166.

[e] Although no wetlands are shown on the historical maps of Lake Union, small wetlands were reported along part of the southwest shore of that lake (Johnson, 1975), and the south of Portage Bay (Waterman, 1922, p. 193).

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