LAKE WASHINGTON SHIP CANAL
SEATTLE, WASHINGTON

WATER CONTROL MANUAL

US Army Corps
of Engineers
Seattle District

August 2017

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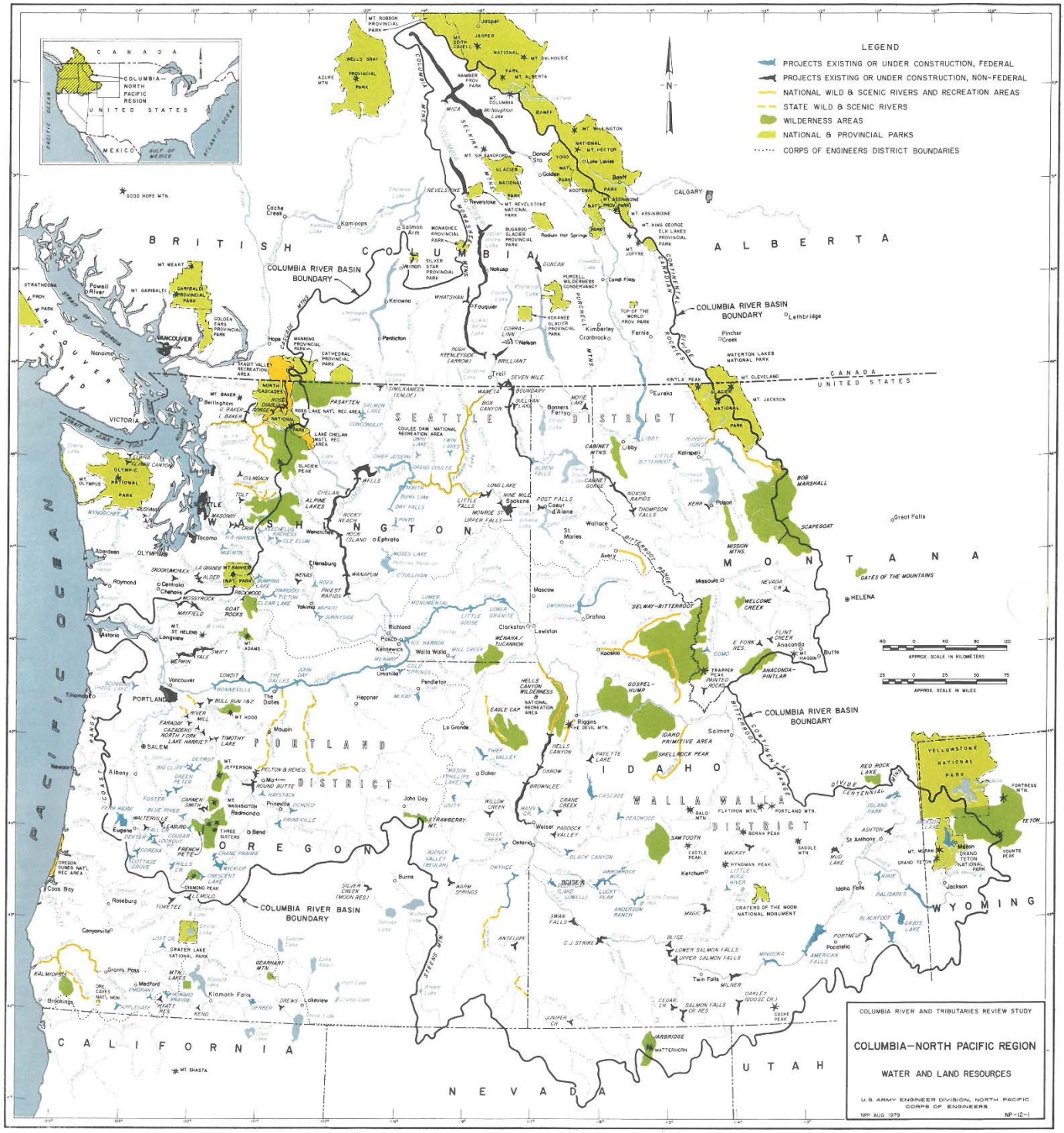
AERIAL VIEW OF THE HIRAM M. CHITTENDEN LOCK AND DAM FACILITY, 1995


LEGEND
PROJECTS EXISTING OR UNDER CONSTRUCTION, FEDERAL
PROJECTS EXISTING OR UNDER CONSTRUCTION, NON-FEDERAL
NATIONAL WILD & SCENIC RIVERS AND RECREATION AREAS
STATE WILD & SCENIC RIVERS
WILDERNESS AREAS
NATIONAL & PROVINCIAL PARKS
CORPS OF ENGINEERS DISTRICT BOUNDARIES
COLUMBIA RIVER BASIN BOUNDARY
CANADA
UNITED STATES
BRITISH COLUMBIA
ALBERTA
WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
CALIFORNIA
NEVADA
UTAH
SEATTLE DISTRICT
PORTLAND DISTRICT
WALLA WALLA DISTRICT
COLUMBIA RIVER AND TRIBUTARIES REVIEW STUDY
COLUMBIA–NORTH PACIFIC REGION
WATER AND LAND RESOURCES
U.S. ARMY ENGINEER DIVISION, NORTH PACIFIC CORPS OF ENGINEERS
NPR AUG 1979
NP-12-1

NOTICE TO USERS OF THIS MANUAL

Regulations specify that this water control manual be published in loose-leaf form and only those portions requiring changes will be revised and distributed. This copy should be preserved in good condition so that inserts can be made to keep the manual current.

REVISIONS TO THIS MANUAL

As a continuing program, portions of this manual may occasionally be revised and updated. Pertinent information will be revised when changes become evident; likewise, changes in the plan of operation or in the project development will be reported. Whenever revisions are made, new pages containing the revised material will be issued to holders of the manual.

WATER CONTROL ASSISTANCE PERSONNEL

The following telephone numbers are provided for contact during normal business and flood control operations.

U.S. Army Corps of Engineers, Seattle District, Hydraulics and Hydrology Branch (H&H), Reservoir Control Center (NWS-RCC), Seattle, Washington, at:

Telephone..... (206) 764-6702

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ACRONYMS AND ABBRIEVIATIONS

ASES	Adult Salmon Exclusion Structure	IFC	Instream Flow Oversight Commission
CBT	Columbia Basin Telecommunications	LWSC	Lake Washington Ship Canal
CCC	Critical Content Curve	M&I	Municipal and Industrial
CENWS	Seattle District, U.S. Army Corps of Engineers	MLLW	Mean Lower Low Water
cfs	cubic feet per second	NAVD	North American Vertical Datum
CHPS	Community Hydrologic Prediction System	NGVD	National Geodetic Vertical Datum
City	City of Seattle	NMFS	National Marine Fisheries Service
COE	U.S. Army Corps of Engineers	NOAA	National Oceanic and Atmospheric Administration
COOP	Continuity of Operations	NRCS	Natural Resource Conservation Service
Corps	U.S. Army Corps of Engineers	NWRFC	Northwest River Forecast Center
CWMS	Corps Water Management System	NWS	National Weather Service
DA	Data Acquisition	NWW	Walla Wall District, U.S. Army Corps of Engineers
DCP	Data Collection Platform	O&M	Operation and Maintenance
DD	Data Dissemination	PIT	Passive Integrated Transponder
DOMSAT	Domestic Communications Satellite	PMF	Probable Maximum Flood
EAP	Emergency Action Plan	PMP	Probable Maximum Precipitation
ECS	Emergency Closure System	QPF	Quantitative Precipitation Forecast
ESA	Endangered Species Act	RCC	Reservoir Control Center
ESP	Extended Streamflow Prediction	RWCDS	Regional Water Control Data System
GOES	Geostationary Operational Environmental Satellite	SDF	Spillway Design Flood
HCP	Habitat Conservation Plan	SFTP	Secure File Transfer Protocol
HMR	Hydrometeorological Report	SNOTEL	Snow Telemetry
hydromet	hydrometeorological	SPU	Seattle Public Utilities
IFA	Instream Flow Agreement	USACE-NWD	Northwestern Division, U.S. Army Corps of Engineers

USACE-NWP	Portland District, U.S. Army Corps of Engineers	WCDS	Water Control Data System
USACE-NWS	Seattle District, U.S. Army Corps of Engineers	WCM	Water Control Manual
USACE-NWW	Wall Walla District, U.S. Army Corps of Engineers	WCP	Water Control Plan
USFWS	United States Fish and Wildlife Service	WDFW	Washington State Department of Fish and Wildlife
USGS	United States Geological Survey	WDOE	Washington State Department of Ecology
WAC	Washington Administrative Code	WMS	Water Management Section

LAKE WASHINGTON SHIP CANAL
HIRAM M. CHITTENDEN LOCKS

PERTINENT DATA[1]

LOCATION OF PROJECT

County.....King
State.....Washington
River Basin.....Lake Washington
River Miles at Mouth of Lake Washington Ship Canal Outlet.....0
River Miles at Upstream Limit of Lake Washington Ship Canal.....8.6

HYDROLOGIC DATA

Drainage Area..... 607 square miles
Discharge, Mean Annual (1941-1989).....1,261 cfs
Spillway Design Flood Peak Inflow.....89,900 cfs
Spillway Design Flood Peak Outflow[2].....64,250 cfs
Spill Capacity at Normal High Lake.....3,054 cfs per bay
Spill Capacity at Normal Low Lake.....1,948 cfs per bay
Maximum Mean Daily Spill (10 Feb 1996).....13,000 cfs

RESERVOIR (PROJECT FOREBAY)

ELEVATION

Maximum Surcharge Elevation[3,4]..... 22.19 feet (25.44 ft. COE)
Normal High Lake Elevation..... 18.75 feet (22 ft. COE)
Normal Low Lake Elevation..... 16.75 feet (20 ft. COE)
Minimum Observed Lake Elevation..... 15.15 feet (18.4 ft. COE)

STORAGE CAPACITY

Maximum Surcharge Elevation[4].....249,377 acre-feet
Normal High Lake Elevation.....159,390 acre-feet
Normal Low Lake Elevation.....112,966 acre-feet
Minimum Observed Lake Elevation.....76,347 acre-feet

SURFACE AREA

Maximum Surcharge Elevation[4]..... 24,516 acres
Normal High Lake Elevation..... 23,464 acres
Normal Low Lake Elevation..... 23,018 acres
Minimum Observed Lake Elevation..... 22,755 acres

[1] All Elevations in NAVD88 unless otherwise noted
[2] Value based on the assumption that the large lock is used as an auxiliary spillway – see section 8.02
[3] Value based on the assumption that the large lock is NOT used as an auxiliary spillway – see section 8.02
[4] Surcharge elevation values are from the 2013 analysis – see section 8.02

LENGTH OF RESERVOIR

Normal Full Lake (Mouth of Cedar River South End Following Channel East of Mercer Island to Mouth of Sammamish River North End) ..... 20.7 miles

WIDTH OF RESERVOIR

Maximum (North End Mercer Island) ..... 3.8 miles

TAILWATER

Highest Tide (27 January 1983) ..... 12.14 feet
Mean Higher High Water ..... 9.02 feet
Mean High Water ..... 8.15 feet
Mean Low Water ..... 0.49 feet
Mean Lower Low Water ..... -2.34 feet
Lowest Tide (4 January 1916) ..... -7.38 feet

SPILLWAY DAM

Type ..... Concrete, ogee crest, with tainter gates
Crest Elevation ..... 10.5 feet (13.75 ft. COE)
Top of Gate Elevation (Closed) ..... 19.04 feet (22.29 ft. COE)
Number of Gates 6
Width of Each Gate ..... 32 feet
Height of Each Gate ..... 8.54 feet
Spillway Bridge Elevation ..... 22.75 feet (26 ft. COE)
Spillway Hoist Deck Elevation ..... 30.75 feet (34 ft. COE)

LARGE LOCK

Type ..... Concrete
Length of Chamber - Overall ..... 825 feet
Length of East Chamber - Overall ..... 450 feet
Length of West Chamber - Overall ..... 375 feet
Width ..... 80 feet
Elevation of Operating Deck ..... 22.75 feet (26 ft. COE)
Elevation of Upper Miter Sill ..... -19.25 feet (-16 ft. COE)
Elevation of Lower Miter Sill ..... -32.25 feet (-29 ft. COE)
Top of Saltwater Barrier - Lowered ..... -13.5 feet
Top of Saltwater Barrier - Raised ..... 4 feet
Number of Gates ..... 5 sets
Type of Gates ..... Double sheathed, miter
Upper Guard Gate (Gate No. 1) ..... 42.54 x 46.33 feet
Upper Operating Gate (Gate No. 2) ..... 42.54 x 46.33 feet
Intermediate Operating Gate (Gate No.3) ..... 55.54 x 46.33 feet
Lower Operating Gate (Gate No. 4) ..... 55.54 x 46.33 feet
Lower Guard Gate (Gate No. 5) ..... 45.54 x 46.33 feet
Elevation of Top of Gates ..... 19.95 feet (23.2 ft. COE)
Culverts ..... 2 @ 14 x 8.5 feet
Laterals ..... 44 @ 2 x 4 feet
8 @ 6 x 2 feet

Number of Valves 6
Type of Valves ..... Stoney gate
Size of Opening ..... 14 x 8.5 feet

SMALL LOCK

Type ..... Concrete
Length of Chamber-Overall ..... 150 feet
Width ..... 30 feet
Elevation of Upper Miter Sill ..... 0.75 ft (4 COE)
Elevation of Lower Miter Sill ..... -19.25 ft (-16 COE)
Number of Gates ..... 4 sets
Type of Gates ..... Single sheathed, miter
Top of Gates ..... 23.2 feet
Upper Guard Gate ..... 22.78 x 18.17 feet
Upper Operating Gate ..... 22.78 x 18.17 feet
Lower Operating Gate ..... 42.78 x 18.17 feet
Lower Guard Gate ..... 32.78 x 18.17 feet
Culverts ..... 2 @ 6 x 4.25 feet
Laterals ..... 12 @ 2 x 3 feet
2 @ 5 x 2 feet
Number of Valves 4
Type of Valves ..... Cylindrical
Sizing of Opening, Diameter ..... 5.6 feet

FISH LADDER

Width ..... 8 feet
General Slope ..... 1 vertical to 8 horizontal
Weir Height ..... 8 feet
Distance Between Weirs ..... 8 feet
Number of Fixed Weirs 18
Number of Adjustable Weirs 3
Ladder Flow ..... 18.6 to 23 cfs
Fishway Entrance
Downstream Opening ..... Gate controlled
Width ..... 3.8 feet maximum
0.94 feet minimum
Height ..... 22 feet
Side Opening ..... Uncontrolled
Width ..... 1.0 feet
Height ..... 22 feet
Fishway Exit ..... 5.5 x 10 feet
Attraction Water ..... Discharge from saltwater drain
Size of Conduit ..... 6 feet in diameter x 210 feet long
Flow Control ..... 6-foot diameter butterfly valve
Number of Diffusers 6
Design Diffuser Flow ..... 160 cfs
Minimum Diffuser Flow ..... 85 cfs

SALTWATER DRAIN

Length ..... 700 feet (approx.)
Size (Dimensions vary) ..... 30 square feet cross sectional area
Intake ..... Concrete trashrack structure at bottom elevation -33.25 feet (-30 ft. COE)
Flow Control ..... 5x7 sluice gate downstream end at bottom elevation of 6.75 feet (10 ft. COE)
Maximum Discharge ..... 225 cfs

LAKE WASHINGTON SHIP CANAL

Length ..... 8 miles
Depth of Channel Below Locks ..... 34 feet at MLLW of Puget Sound
Width of Channel Below Locks ..... 150 to 300 feet
Depth of Channel Above Locks .. …….. 30 feet at elevation of 17.75 feet (21.0 ft. COE) in upper pool
Width of Channel Above Locks ..... 100 to 300 feet

PLATE A. ELEVATIONS AND DATUM CONVERSION
Vicinity of Lake Washington

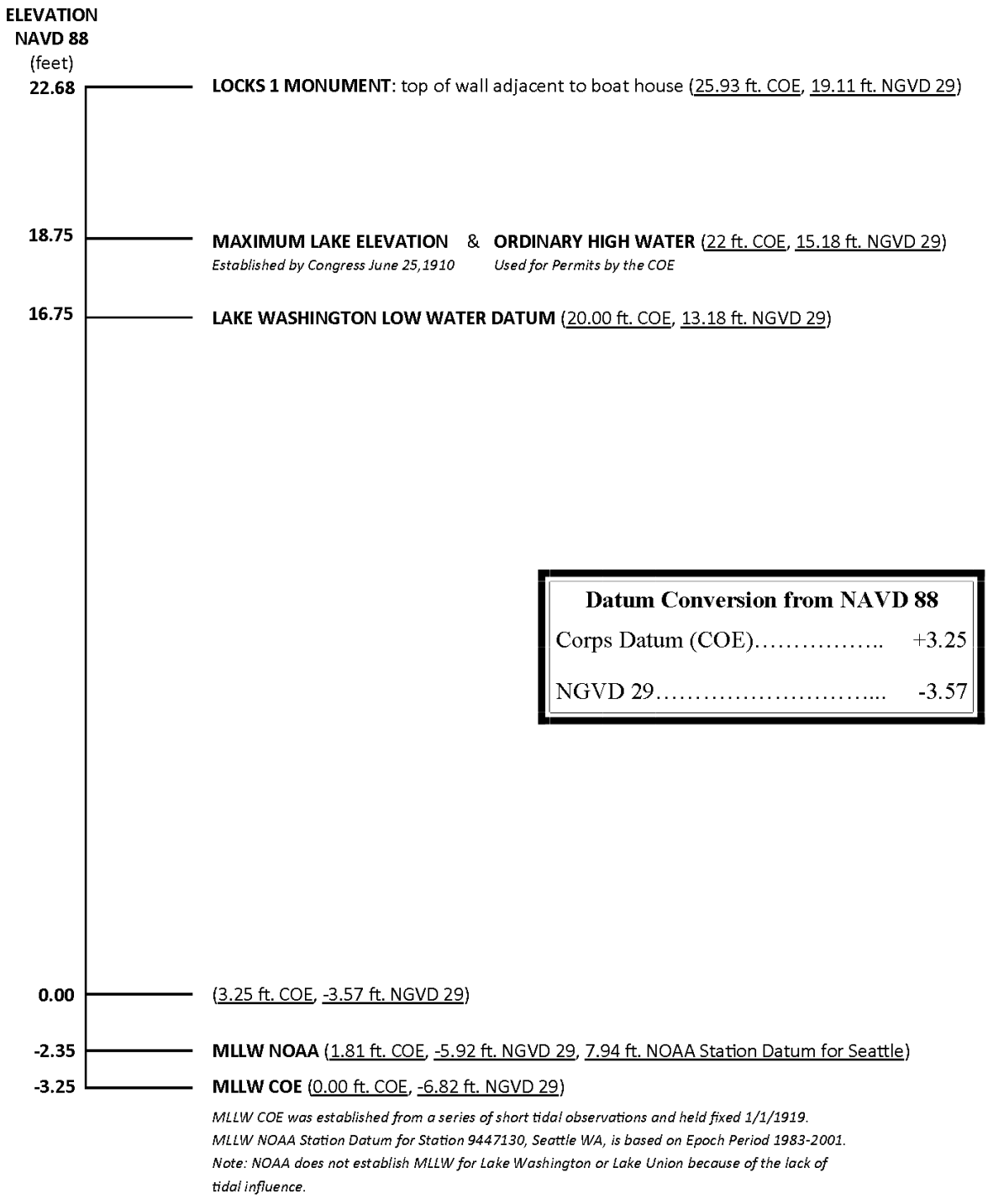

PLATE A

SECTION 1. INTRODUCTION

1.01 Authorization This manual is prepared in accordance with the following regulations and guidance:

- **ER 1110-2-240, Water Control Management, paragraph 7**, dated 8 October 1982, which assigns to District Engineers the responsibility for development of plans and manuals for operation of reservoirs.
- **EM 1110-2-3600, Management of Water Control Systems**, dated 30 November 1987, which provides technical guidance on management and operation of water control systems and general guidance on content of Water Control Manuals (WCM).
- **ER 1110-2-8156, Preparation of Water Control Manuals**, dated 31 August 1995, which provides specifications on WCM content and format.
- **NWDR 1110-2-6, Deviation Requests for Approved Water Control Manuals**, dated 9 November 2005, provides guidelines concerning deviations from approved WCMs and delegates deviation authority to the chief, Columbia Basin Water Management Division (CENWD-PDW).

Seattle District is delegated primary responsibility for regulation of the Lake Washington Ship Canal Project by NWDR 1165-2-2, "Water Resources Policies and Authorities, Water Management Responsibilities", date 23 January 2014, see Exhibit 1-1.

1.02 Purpose and Scope This manual serves as a reference source for higher authority and as a guidance manual for U.S. Army Corps of Engineers (Corps) staff involved in real-time project operation and regulation. This manual describes the Lake Washington Ship Canal (LWSC),

including the Hiram M. Chittenden Locks, the Lake Washington Basin, project features, data collection facilities, forecasting procedures, the water control plan, and the effects of regulation.

1.03 Related Manuals and Reports A list of the published design memoranda for the project and pertinent reports is provided in Table 1-1 (found in Supplemental Tables).

1.04 Project Owner The owner is the U.S. Army Corps of Engineers, an agency of the U.S. Government.

1.05 Operating Agency The Seattle District of the Corps (CENWS) operates the Lake Washington Ship Canal Project under the general supervision of the Corps Northwestern Division (NWD) office. Prior to 1997, NWD and CENWS were known as North Pacific Division (NPD) and Seattle District (NPS). The project is staffed on a continuous basis at all times. Under specific abnormal or emergency conditions as defined in the O&M Manual and in paragraph 7.04 of this manual, the project will be attended as conditions dictate and/or as directed by the appropriate authority. The project office is located on-site. The main telephone number for the project office is 206-789-2622.

1.06 Regulating Agency As owner and operator of the project, the Corps is responsible for its regulation. The CENWS Water Management Section (WMS) of the Hydraulics and Hydrology Branch, Engineering Division, provides direction regarding specified project outflows and/or target forebay elevations. WMS is located in the CENWS office, 4735 East Marginal Way South, Seattle, Washington (telephone 206-764-6702). Direct correspondence may be addressed to:

Department of the Army, Seattle District
ATTN: Water Management Section
Post Office Box 3755
Seattle, WA 98124-3755

SECTION 2. DESCRIPTION OF PROJECT

2.01 Location The LWSC lies entirely within the City of Seattle and extends from deep water in Puget Sound through Shilshole Bay, the locks, Salmon Bay, Lake Union, Portage Bay and Union Bay to deep water in Lake Washington. The Hiram M. Chittenden Locks are located at the southern end of the Ballard neighborhood of Seattle, approximately 1 mile southeast of Shilshole Bay. The location of the LWSC is shown on Plate 2-1.

2.02 Purpose The LWSC is a navigation project constructed to take advantage of the extensive bodies of fresh water lying in and adjacent to Seattle. The project also provides a means for the regulation of the lake level and passage of anadromous fish to and from upstream spawning grounds. In addition to the missions of navigation and environmental stewardship, LWSC is authorized for recreation, receiving approximately 1.3 million pedestrian visitors each year.

2.03 Physical Components

a Reservoir The locks and spillway dam regulate the elevation of the water surface of Salmon Bay, Lake Union, Lake Washington and the LWSC. Total storage between the normal operating levels of 16.75 and 18.75 feet (20.0 to 22.0 ft. COE) is 46,424 acre-feet, with a total water surface area of 23,464 acres and shoreline of about 80 miles at elevation 18.75 feet (22 ft. COE). The level of Lake Washington was lowered about 8 feet by the construction of the LWSC, but it is still the second largest natural lake in the state. An area-capacity table for 0.01-foot increments is shown as Table 2-1.

b Dam The 235-foot-long concrete gravity spillway dam is located between the small lock and the fish ladder on the south shore. The spillway consists of six 32-foot-wide bays, each

controlled by a 12.5-foot-radius tainter gate equipped with an individual electric motor-driven, cable drum-type gate hoist. The tainter gates and trunnions were replaced in 2014 due to corrosion of the original gates. The crest shape approximates that of a standard shaped ogee, having a design head of 7.4 feet, a crest elevation of 10.50 feet (13.75 ft. COE), and a weir height-to-design head ratio of approximately 1.0. Guide slots are located in the piers for installation of bulkheads for maintenance closure of the spillway bays. The spillway is capable of discharging up to 18,200 cubic feet per second (cfs) at the maximum regulated forebay elevation of 18.75 feet (22 ft. COE). The spillway empties into a flat concrete stilling basin with no end sill. The spillway dam is shown on Plates 2-2 and 2-3.

c Stilling Basin The stilling basin is approximately 235 feet wide by 115 feet long with a floor elevation of -17.25 feet (-14 ft. COE). An 8-foot-deep cutoff wall is located at the downstream end of the basin. The existing basin, with a tailwater depth range of approximately 10.25 feet to 22.75 feet, provides adequate energy dissipation for discharges up to 18,200 cfs (maximum spillway discharge at normal full pool).

d Salt Water Return System The salt water return system consists of the old salt water drain and fish attraction diffusion pipe. The fish attraction diffusion pipe was added to the saltwater drain in the mid-1970's. The saltwater drain segment that is downstream of the diffusion pipe became known as the old saltwater drain. The inlet for the salt water return system is a 30 square foot grated opening at the bottom of the ship canal at the east end of the large lock south wall. A trashrack was originally placed at the entrance of the drain to minimize debris and prevent fish from entering the drain and fish ladder system, but since has been removed because of continual clogging problems. In 2008, a temporary screen was re-installed to prevent fish from entering the system. The temporary screen is known as the Adult Salmon Exclusion Structure (ASES)

and can be opened from September to May to prevent clogging during winter storms. After entering the inlet, salt water return flow is conveyed westward back toward Puget Sound through a five foot by six foot closed conduit to a point just east of the dam structure. Here a "Y" joint splits the conduit with one fork proceeding west through the old salt water drain and exiting via a gated spillway between the south wall of the small lock and spillway gate number 1. The total length of the drain between the inlet and the gated spillway is 660 feet. The other fork can carry salt water return flow southward through the fish attraction diffuser pipe (a 400 foot long, six foot diameter conduit) along the bottom of the Ship Canal to the diffusion well at the foot of the fish ladder facility. Here the water is distributed among the lower ladder steps and empties out to Shilshole Bay. The saltwater drain and fish attraction diffusion culvert may be operated either concurrently or separately. The design operating capacity of the saltwater return system is about 330 cfs (this assumes discharge through both forks downstream of the “Y” joint). The diffusion pipe has a slide gate which is used to stop flow through the pipe for annual maintenance of the fish ladder facility or if required for other purposes such as water conservation. The original design of the diffusion pipe contained a butterfly valve which would work in concert with tide and lake elevation sensors to provide a constant fish attraction flow of approximately 160 cfs. In August 1990, the diffusion pipe flow control mechanism was rehabilitated to provide design flows; but rating curves are not available. See Plate 2-4 for a plan view of the lock and dam facility that highlights the salt water return system and the fish ladder.

e Fish Ladder The present fish ladder, located on the south side of the spillway, was completed in 1976 and is designed to operate within fish passage criteria at Lake Washington elevations of 15.25 feet to 18.75 feet (18.5 to 22.0 ft. COE), and Puget Sound tidal elevations of -3.75 feet to 8.75 feet (-0.5 to 12 feet COE). The fish ladder is 8 feet wide, with three adjustable

weirs at the fish exit, 18 fixed weirs with submerged orifices, one adjustable and one fixed slot in the entrance, and six bottom diffusers to provide transportation and attraction water. The ladder is designed to operate with about 23 cfs ladder flow and a maximum of 160 cfs attraction water supplied from the saltwater drain. A plan and a profile of the fish ladder are shown on Plate 2-5.

f Smolt Flumes Since 2000, the Corps has installed a total of four smolt passage flumes in spill bays 4 and 5 for the juvenile salmonid seasonal emigration period. The flumes installed since 2000 have been metal structures that are supported on the spillway ogee, the dam structure, and the walkway across the dam. The purpose of the smolt flumes is to provide surface passage past the dam during the entire emigration period while also conserving water. The water conserved by operating the flumes, as opposed to the spillway, allows for a much longer period of surface bypass. In general, the Corps attempts to operate at least one flume from mid-April until July 31 consistent with RPM 1 of the 2008 NMFS and 2007 FWS Biological Opinions. Operation of the smolt flumes is dependent on water availability within the constraint of the requirement to maintain the forebay elevation above elevation 16.75 feet (20.0 ft. COE) at a 70% reliability, and the other needs for water at the project (i.e., locks and fish ladder). The flumes are operated throughout the spring and early summer as long as sufficient water is available. The flumes are typically removed during the late summer or fall in order to allow operation of all the spill bays to discharge winter flows. The collective discharge capacity of the four flumes installed since the year 2000 was 400 cfs at the normal maximum forebay elevation of 18.75 feet (22.0 ft. COE).

Over the past several years the Corps has been working on a new smolt flume design, and a prototype was installed for testing in the spring of 2017. A schematic of the new smolt flume design is shown in Plate 2-11. If successful, a total of up to three of the redesigned flumes would

be constructed to replace the ones that have been used since 2000. The new flumes would also be installed in spill bays 4 and 5 and would have a collective discharge capacity in the range of 260 to 350 cfs (dependent on the number of flumes installed) at the normal maximum forebay elevation of 18.75 feet (22.0 ft. COE). The general seasonality of usage of the redesigned flumes is expected to be similar to recent smolt flume usage (i.e., mid-April through July).

g Large Lock The large lock is 825 feet long between the upper and lower service gates, 80 feet wide, and divided into two chambers by an intermediate gate; the downstream and upstream chambers are 375 feet and 450 feet long, respectively. Vessels with up to 30-foot drafts can be accommodated through the large lock. Machinery pits for operating the miter gates and valves for the culverts are located within the lock walls. A plan and sections of the lock are shown on Plates 2-2 and 2-3, respectively.

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(2) Grounds The Carl S. English, Jr. Ornamental Gardens, seven acres of lawn, trees, shrubs, and flowers, evolved from a few plantings in 1916 to a renowned collection of more than 1,000 species from around the world. The gardens are named for the man who, as head of the garden staff from 1940 to his retirement in 1974, devoted his career to enhancing and expanding the gardens' exotic and native plantings.

k Drift Control Small quantities of driftwood, deadheads and miscellaneous flotsam accumulate at the east approach of the locks, fish ladder, and spillway due to the current through the canal. Some of it passes through as a result of project operation. The remainder is collected and stored on barges moored along the north side of the upstream guide pier of the large lock. In addition, the Puget, a Corps' multipurpose craft, collects large pieces of drift, waterlogged pilings, and logs considered hazardous to navigation in Puget Sound. Periodically, the barges are moved to the LWSC maintenance wharf where a debris disposal contractor offloads it into trucks for disposal or recycling.

l Ship Canal The LWSC, approximately 8 miles long, is entirely within the City of Seattle, Washington. Downstream of the locks is a channel 34 feet deep at mean lower low water and 300 feet wide from Puget Sound to the Burlington-Northern Santa Fe Railway Bridge, with a passing basin 34 feet deep and 150 to 200 feet wide from the bridge to the locks. Upstream of the locks the channels are 30 feet deep at low water, with bottom widths of 100 feet from the

locks to Lake Union through Fremont Cut, 200 feet wide through Portage Bay, 100 feet wide through Montlake Cut, and 200 feet wide through Union Bay to Lake Washington. The banks of the Fremont and Montlake cuts are protected by revetments. A plan of the canal is shown on Plate 2-1.

2.04 Related Control Facilities Upstream control facilities located in the Cedar River sub-basin influence the discharge from the Cedar River that enters Lake Washington at Renton. The City of Seattle's Cedar Falls Project is located on the Cedar River 40 miles southeast of Seattle at River Mile 35.6. The project consists of a roller compacted concrete dam (overflow dike), a concrete gravity dam (Masonry Dam), a power tunnel and penstocks, and powerhouse. The overflow dike is submerged on the upstream side of Masonry Dam, and its main purpose is to divide Chester Morse reservoir from the Masonry Pool and allow the Masonry Pool to be drawn down to minimize seepage losses from the upstream Chester Morse Reservoir. The Cedar Falls Project provides municipal and industrial water storage and supply and hydroelectric power for the City of Seattle. The project is also operated to provide instream flows for fish and some ancillary flood control for the Cedar River. Storage and release of stored water at the Cedar Falls Project influence downstream Cedar River flows that enter Lake Washington at Renton. The City also diverts water from the Cedar River to Lake Youngs Reservoir for municipal and industrial water supply at a gated diversion dam located at Landsburg (river mile 21.6), 14 miles downstream of the dam. These diversions represent a consumptive loss of water from the river and therefore reduce Cedar River flows by an amount equivalent to the diversion rate.

2.05 Real Estate Acquisition Real estate for the LWSC project includes lands in the immediate vicinity of the locks, two acres in tide lands, and lands for the Fremont and Montlake cuts. Lands administered by the Corps include 12.57 acres in tide lands, 17.18 acres at the locks

site, 38.51 acres at the Fremont Cut, and 20.3 acres at the Montlake Cut. Of the total, 68.09 acres are held in fee.

2.06 Public Facilities

a Locks The locks have been used by the public primarily as a sightseeing adventure, as there are no facilities for picnicking or active pursuits. Visitation has risen from about 600,000 visitors per year when the updated fish ladder and its attendant underwater viewing facility were opened in the 1970's to about 1.3 million in 2015.

b Fremont Cut A walkway on the north side of Fremont Cut was dedicated in 1981. Construction costs were shared by the Corps and the City of Seattle Parks and Recreation Department. The walkway features works of art by local artists and an overlook which provides visitors with a view of the ship canal.

c Montlake Cut Montlake Cut Waterside Trail, a 1200-foot-long scenic promenade along the south bank of Montlake Cut on the east end of the canal, connects the University of Washington's Arboretum Waterfront Trail with the City's West Montlake Park on Portage Bay. The crushed stone footpath includes a rustic footbridge and is bordered by plantings and a fishing pier/observation deck accessible by wheelchair. Designed by Corps' landscape architects and engineers, the trail was built in 1970 and was designated a National Recreation Trail a year later.

SECTION 3. HISTORY OF PROJECT

3.01 Authorization The LWSC project was authorized by Public Law 61-264, River and Harbor Act of 25 June 1910, 60th Congress, First Session, in accordance with a plan set forth in House Document 953, 60th Congress, First Session. The locks included in the LWSC project were officially designated the Hiram M. Chittenden Locks by Public Law 84-779, dated 24 July 1956.

3.02 Planning and Design The first official mention of a canal to connect Lake Washington with Puget Sound was by Thomas Mercer at a picnic on the shore of Lake Union on July 4, 1854. The first earth was turned in 1869 when a local citizen, Harvey Pike, began a shallow hand-shoveled canal between Lakes Washington and Union. In 1880, the Lake Washington Canal Association was formed and undertook to finish the canal to a sufficient depth to float logs. In the early 1900's, the channel between Lake Union and Salmon Bay was deepened so that its bottom was below high tide and a dam was constructed in the channel at the lake outlet to control flows. All of these facilities were for transporting logs and did not provide sufficient depth for vessels.

On the federal level, the idea of a canal project was reviewed in 1867 by a board of engineers, chaired by General Barton S. Alexander, which was touring the region. First Lt. T.H. Handbury of the Engineer Corps reported in favor of such a canal in 1871 on a reconnaissance of military engineering problems in the region. He included preliminary surveys of possible alternate routes in his report. This report was sent to the Senate in response to a resolution dated 27 March 1888 requesting copies of all reports of Boards of Engineers and officers of the Army relative to fortifications on Puget Sound. The River and Harbor Act of 19 September 1890 directed the

Secretary of War "to appoint a board of three officers of the Corps of Engineers of the United States Army, whose duty it shall be to select and survey the most feasible location, and estimate the expense of construction of a ship-canal to connect the waters of Lakes Union, Washington, and Sammamish with Puget Sound,...." The Board was appointed and submitted a report dated 15 December 1891 which addressed routes as follows:

> "There are five possible routes for a canal connecting Lakes Union and Washington with Puget Sound."
>
> "First. By way of Duwamish Bay and the valley of the Duwamish and Black rivers to Lake Washington and across the Portage from Lake Washington to Lake Union."
>
> "Second and third. By way of depressions between the southern part of Lake Union and Duwamish Bay. (These routes were considered 20 years ago by Gen. Barton S. Alexander, and are known in his report as the "Mercer farm route" and the "Tramway route.") Thence from Lake Union to Lake Washington by a canal through the Portage."
>
> "Fourth. By way of Shilshole Bay, Salmon Bay, the valley of the outlet of Lake Union to Lake Union, and thence between Lakes Union and Washington, by a canal through the Portage."
>
> "Fifth. By way of Smiths Cove to the upper end of Salmon Bay; thence as in the preceding route."
>
> "The first route, by the valley of the Duwamish, was soon eliminated from serious consideration by its great cost and other disadvantages."
>
> "The second and third routes were practicable twenty years ago, when Seattle was a straggling village, but the land traversed by these routes is now built up with business blocks and residences and the cost of the right of way is prohibitory."
>
> "The fourth and fifth routes are entirely feasible."

The two feasible routes coincided in alignment from Lake Washington to Salmon Bay and both provided that Salmon Bay should be raised to the level of Lake Union and a lock would be provided in the channel between Lakes Union and Washington. In each of the projects, by Shilshole Bay or by Smiths Cove, vessels would pass from Puget Sound to Salmon Bay through a lock located close to the sound. In the case of the Smiths Cove route, a dam would be required

at the narrows of Salmon Bay to raise its level to the required height. The Board preferred the Smiths Cove route and did not consider a canal and lock between Lakes Washington and Sammamish to have much interest.

A Board appointed in 1898 considered the Shilshole Bay route to be preferable and the 1902 Board concurred. However, the 1902 Board considered the costs and benefits and was of the opinion "that the construction of the proposed canal at the present time is not advisable." In 1905, the Board of Engineers for Rivers and Harbors reevaluated the situation and concluded again that the project was not justified and neither was a modified plan which would eliminate the connection with Lake Washington.

In a report dated 2 December 1907, Major H.M. Chittenden, Seattle District Engineer, submitted a report which recommended two locks, one large and one small side-by-side, at the entrance to Salmon Bay, and an unbroken channelway through Salmon Bay and Lake Union to Lake Washington, the difference in the level of the two lakes to be overcome by lowering the level of the latter to that of the former. Such a project was authorized by Public Law 61-264 dated 25 June 1910.

REDACTED CONTENT

3.03 Construction Construction of the canal was started by the Corps in September 1911, with the small lock opened to traffic on 30 July 1916 and the large lock on 03 August 1916. The Fremont Cut Channel between Salmon Bay and Lake Union was opened October 1916. The Montlake Cut Channel between Lakes Union and Washington was completed 08 May 1917. Official dedication of the project was held 04 July 1917. A resume of construction activities is provided in Table 3-1.

TABLE 3-1
RESUME OF CONSTRUCTION ACTIVITIES

Activity	Date
Construction of canal begins	September 1911
Small lock opened to traffic	July 1916
Large lock opened to traffic	August 1916
Fremont Cut Channel opened	October 1916
Montlake Cut Channel opened	May 1917
Emergency closure systems for both locks designed	1920-22
Saltwater barrier designed and constructed	1966
New fish ladder constructed	1976
New closure system for large lock designed	1982
New closure system for large lock completed	1988
Four smolt flumes added	2000

3.04 Related Projects On the Cedar River, there are three structures upstream of the LWSC; the Crib Dam and Overflow Dike between Chester Morse Lake and the Masonry Pool at river

mile 37, Masonry Dam at rive mile 35.6, and the Landsburg Diversion Dam at river mile 21.6. All three of these structures are owned by the City of Seattle (City) and are related to the City's use of the Cedar River as a significant source of municipal and industrial water (M&I) for the City and its municipal customers. Storage is managed in Chester Morse Reservoir and to a lesser extent in the Masonry Pool for M&I water supply and to augment flows for fisheries purposes. Water is diverted at the Landsburg Diversion Dam for storage in Lake Youngs and ultimately for distribution to the City's water supply infrastructure. Operations for these projects collectively impact Cedar River flows as briefly summarized in Section 2.04.

3.05 Modification to Regulations Operation of many features of the LWSC project have been remarkably constant over the 100 year life of the project, including the "rule curve" used to dictate target forebay elevations within a 2-foot operational band. Operation of key project features such as the small and large lock chambers and spillway have been relatively consistent, although a saltwater barrier was added to the large lock in 1966 to help arrest the movement of the saltwater wedge that enters the large lock when the downstream miter gates are opened. Some of the most significant changes have been related to operations specific to both upstream and downstream fish passage. Although the project was originally built with a fish ladder for upstream fish passage, the fish ladder was upgraded in 1976. Changes to the fish ladder included a change in the layout of the fish ladder and the routing of one leg of the saltwater drain flow to the diffuser well located near the downstream end of the ladder to provide enhanced attraction flow for fish. Four smolt flumes were added to the project in 2000 to provide downstream fish passage for juvenile salmonids. The flumes are installed in spillway bays 4 and 5 in the spring each year and typically operated from mid to late April through July to provide downstream fish passage. The flumes are removed in September to provide access to all six spillbays during the

late fall/winter flood season. The flumes were added to the project to provide surface passage during the spring and early summer when the spillway gates are often closed for water conservation purposes. The flumes discharge smaller volumes of water than an open spillway gate which allows them to run longer into the spring and early summer. Current plans are to design and build new smolt flumes to replace the current ones. A prototype of the new flume was installed in April 2017 and based on planned testing and performance all flumes may be replaced by the new version by 2018.

3.06 Principal Regulation Problems

a Saltwater Intrusion When raising vessels from the level of Shilshole Bay to the fresh water system of Salmon Bay, a strong current of sea water flows from the bottom of the locks into the saltwater basin as the gates are opened. There is an equal counter current of fresh water at the surface. During the summer period of heavy use at the locks, the saltwater drain as normally operated (i.e., with only the fork discharging to the diffuser well active) may not remove as much sea water entering the fresh water system relative to other times of the year, resulting in some saltwater intrusion into Lake Union and towards the Montlake Cut. The Washington State Department of Ecology (WDOE) has imposed a special condition that salinity shall not exceed one part per 1,000 at any point or depth along a line that transects the canal at the University Bridge. Judicious operation at the locks, especially during low runoff years, is necessary to meet this water quality criterion while still maintaining the proper elevations in the fresh water system.

b Inflow Inflow into Lake Washington is provided by the Cedar and Sammamish rivers, minor tributaries, and direct precipitation. The Cedar River provides about 50 percent of the average annual inflow. The City uses the Cedar River as one of two major sources for M&I

water and claims water rights to the entire river flow. The Corps also maintains its superior claim (based on navigational Servitude) to all natural flow in the Cedar River. The City disputes this claim. Their requirement for water diverted for M&I use as well as their management of the river for instream flows have a seasonal impact on the amount of water available to the Corps' operation of the LWSC project; which includes maintaining the level of Lake Washington, continuing uninterrupted operation of the locks including mandated fish passage, and managing the intrusion of saltwater. In recent years, the impact of the City's operation has been most notable during years with very low spring runoff. During these years, the combined effects of storing water in Chester Morse Reservoir as well as downstream diversions at Landsburg for M&I purposes have resulted in Cedar River flows that are below natural levels and insufficient to maintain the level of Lake Washington and allow full operations at the locks (i.e., uninterrupted operation of the locks, management of saltwater intrusion, and fish passage via the fish ladder and smolt flumes). During the late fall and winter months, adequate water supply is available so that the LWSC, including Lake Union, is mostly flushed of residual saltwater. Regardless of any legal disagreements, the City and the Corps do maintain dialogue regarding their respective operations and do look for ways to coordinate to meet the interests of both entities. The Corps also participates in the Cedar River Instream Flow Commission, as discussed in Section 9, which meets monthly and provides a scheduled opportunity for Corps and City officials to exchange information and to discuss their respective operations.

SECTION 4. WATERSHED CHARACTERISTICS

4.01 General Characteristics The Lake Washington hydrologic system (shown on Plate 4-1) lies on the west slope of the Cascade Mountain Range approximately 100 miles east of the Pacific Ocean. The crescent shaped system drains 607 square miles and is comprised of three major sub-basins: the Cedar sub-basin (186 square miles) which empties into Lake Washington just below Renton; the Sammamish sub-basin (240 square miles), including Lake Sammamish, which empties into Lake Washington 10.8 river miles below the Woodinville gage; and the Lake Washington sub-basin (181 square miles), which includes all tributaries flowing into the lake and the LWSC. The Lake Washington system discharges into Puget Sound through the Hiram M. Chittenden Lock and Dam. Stream gages are listed by index numbers, drainage area, and period of record on Table 4-1 in the Tables section. The Cedar River, which lies completely within the boundaries of King County, begins a 55.8-mile west-northwest course at the peak of the Cascade Mountains. The Cedar River flows through timbered terrain into Chester Morse Lake at river mile 42.1 and exits past the Masonry Dam at river mile 35.6. The Seattle Public Utilities' M&I withdrawal point (Landsburg Diversion Dam) is at mile 21.6, and the river proceeds from there through a narrow valley, containing mostly suburban residences, to Lake Washington. The Sammamish River system originates as Issaquah Creek, contiguous to the northern boundary of the lower one-third of the Cedar River, and runs 43.5 miles northward. The outlet of Issaquah Creek is at the head of Lake Sammamish at river mile 22.9. The lake outlet is at river mile 15.3 where it is controlled by a weir. The Lake Washington sub-basin is oriented in a north-south direction and shares its eastern border with the western border of the Sammamish basin. Lake

Washington itself is situated in the south-central portion of the sub-basin. Most of the streams draining into Lake Washington are contained in heavily urbanized areas.

4.02 Topography The Lake Washington system begins as the Cedar River, beginning at Yakima Pass of the Cascade Range at an elevation of 5,500 feet and winding downstream through rugged mountainous terrain into Chester Morse Lake. Downstream from there the river progresses through a mildly steep to flattening valley at the mouth near Renton at an elevation of 18.8 feet (22.0 feet COE). See Plate A, "Elevations and Datum Conversion" (p. xix), for an explanation of the relationship between LWSC project datum (COE), NGVD29, and NAVD88. The Sammamish sub-basin is divided naturally into three parts: a mountainous southern section extending to an elevation of 2,800 feet; the central, or Lake Sammamish section; and the gently rolling northern section which discharges into northern Lake Washington at an elevation near 18.6 feet (21.8 ft. COE). The Lake Washington sub-basin has a maximum elevation of 1,400 feet, but the sub-basin is predominantly flat with elevations of less than a few hundred feet and is highly urbanized.

4.03 Geology and Soils The portion of the basin upstream from Cedar Falls is largely underlain by volcanic and granitic rocks, the steep bedrock valley sides being generally mantled by stony colluvium, talus, and coarse, gravelly deposits of valley glaciation. The principal exception to this is adjacent to the Masonry Dam and Chester Morse Lake where a long, flat-topped ridge projects across the valley from the north. This ridge is known as the Cedar Embankment. It is a product of the last maximum Pleistocene ice advance up valley from the Puget Lowland and is composed of both fine and coarse-grained unconsolidated sediments. Chester Morse Lake is the remaining vestige of a larger lake impounded behind the embankment during the closing stages of ice withdrawal. Proper geologic analysis of the Cedar Embankment

and adjacent areas bears heavily on the feasibility of any project related to the Masonry Dam or Chester Morse Lake. Below Cedar Falls, the basin is underlain by volcanic and sedimentary rocks generally thickly mantled by glacial drift and other semi-consolidated or unconsolidated Pleistocene deposits varying from boulders to clay. The valley floor throughout this reach is largely sand and gravel from the Pleistocene deposits which have been reworked by the Cedar River. The geologic history of the Sammamish and Lake Washington sub-basins is one of repeated glacial erosions and depositions. Glaciers advanced and retreated over the area at least four times, creating the major landforms around Seattle and producing the north-south running basins of Lake Sammamish and Lake Washington and the many north-south trending hills of the city. Throughout the area there are often several hundred feet of stratified and unstratified glacial deposits, including glacial outwash material deposited by meltwater streams.

4.04 Sediment Bathymetry information is available from the lock and dam to the University Bridge. The latest survey is shown on Plate 4-9. Sediment influx to the LWSC is low given the absence of significant streams discharging to the LWSC and Lake Union. As such, sedimentation issues are not of concern to the operation of the lock and dam nor to the general maintenance of the Montlake and Fremont Cuts.

4.05 Climate

a General The Lake Washington basin's climate is typical of a mid-latitude, west coast, marine-type region, with cool, relatively dry summers, and mild, wet, and cloudy winters. The location and intensity of the semi-permanent high- and low-pressure areas over the eastern North Pacific have an influence on the climate. During spring and summer, circulation about the high pressure system centered near 36° N and 153° W brings a prevailing northwesterly flow of warm

dry air over the basin. In the fall and winter, the low-pressure system near the Aleutian Islands intensifies while the high-pressure system weakens and moves southward. The result is a prevailing southwesterly flow of warm, moist air over the basin. Orographic precipitation in the upper Cedar River basin is common. Climatologic stations in the Cedar, Sammamish, and Lake Washington sub-basins are shown on Table 4-2 in the Tables section. Summaries of climatologic data for selected stations in or near the Lake Washington basin that typify the spatial variability of the climate are given on Table 4-3.

b Temperature Mean annual temperatures in degrees Fahrenheit recorded at climatologic stations vary from 51.9 degrees at Seattle-Tacoma International Airport (Sea-Tac) to 47.6 degrees at Cedar Lake. Cooler temperatures can be expected at elevations above Cedar Lake. Recorded temperature extremes are 102.9 degrees and 0.0 degrees at Sea-Tac and 100.9 degrees and -11.0 degrees at Cedar Lake. Temperature data for Sea-Tac probably best indicate mean temperature conditions at the LWSC. A summary of temperature data is found in Table 4-4.

c Rainfall Because of the broad range of elevations in the Lake Washington basin, average annual precipitation varies considerably. Observed mean annual precipitation at Sea-Tac is 38.5 inches and 100.5 inches at Cedar Lake. In general, November is the wettest month with an average of 6.1 inches of precipitation at Sea-Tac and 13.6 inches at Cedar Lake. July is the driest month with 0.7 and 2.2 inches of precipitation at the same two stations, respectively. Precipitation extremes for a 24-hour period range from a maximum of 5.02 inches at Sea-Tac on October 20, 2003, and 7.3 inches at Cedar Lake on November 7, 2006. July and August combined generally have less than 5 percent of the annual precipitation. On a more local level, the direct precipitation on Lake Washington is rarely uniform during the summer months. Pronounced variations can occur in the rainfall over the Lake Washington sub-basin associated

with the Puget Sound convergence zone. Therefore, using one precipitation gage as representative of the whole Lake Washington sub-basin can be very misleading. A summary of precipitation data is presented in Table 4-5. Seattle Public Utilities and the University of Washington Department of Atmospheric Sciences have collaborated on a project called Seattle RainWatch, which is a real-time weather system that provides rainfall estimates derived from radar data that are calibrated with local rain gage networks. Seattle RainWatch data are available online at http://www.atmos.washington.edu/SPU/.

d Evaporation The surface area of LWSC plus Lake Washington is approximately 23,183 acres at an elevation of 17.75 feet (21 ft. COE). The lake is relatively open and accessible to wind which provides an environment conducive to evaporation from the lake surface. Monthly estimates of evaporation from Lake Washington and the LWSC were determined from evaporation pan data from Puyallup, WA and are provided in Table 4-6. The maximum average monthly evaporation is estimated at about 4 inches and occurs in July. On some summer days in many years, the net effect of inflow to Lake Washington from all sources minus evaporation is negative. In other words, evaporative losses from water surfaces exceeds combined inflow from streamflow and direct precipitation. Evaporative losses are near zero during the winter months.

e Snow Snow measurements are recorded at SNOTEL stations and snow courses shown on Plate 4-1 and tabulated by name, elevation, and period-of-record on Table 4-7 in the Tables section. Snowfall varies more widely than rainfall throughout the basin due to temperature variations often tied to differences in elevation. The recorded mean annual snowfall varies from 3.3 inches at Seattle Sand Point to 62.7 inches at Cedar Lake. The maximum annual snowfall

recorded at Cedar Lake was 161.1 inches in 1948. In the Lake Washington and Sammamish sub-basins, snow is infrequent and usually melts within a few days to a week.

f Wind The prevailing wind direction is northerly from July through September and shifts to south-south westerly during the fall, winter, and spring. Winds are generally light during the summer and can gust up to 70 miles per hour during winter storms. The wind is a major contributing factor to evaporation from Lake Washington and Lake Sammamish, and wind movement over those lakes is marginally represented by readings taken at Seattle-Tacoma Airport. More representative wind data are available at the Renton Airport (available online from the National Weather Service at www.weather.gov) and the SR 520 Floating Bridge (the best) on Lake Washington (available online from the Washington Department of Transportation at www.wsdot.com/traffic/bridges/sr520).

4.06 Storms and Floods Nearly all major floods in the basin are produced by severe storms which occur mainly during the fall and winter months. The Lake Washington basin on the western slopes and foothills of the Cascade range lies directly in the path of cyclonic disturbances rising inland from the Pacific Ocean from October through March. Storm precipitation varies over the basin, with greatest amounts generally falling at the highest elevations in the upper Cedar sub-basin where precipitation is typically orographic in nature. The most common pattern of winter precipitation is alternating patterns of steady precipitation and more intermittent showery precipitation. These storms often occur as a series of waves passing at intervals of 24 to 36 hours. Virtually every winter, high winds and heavy precipitation occur throughout the basin. Storms, though intermittent, are frequent and may continue for several days. It is not uncommon for two or more storms to move through the area in rapid succession, sometimes less than 24 hours apart. The freezing level may rise above the upper

elevations of the Cedar River basin during some of these storms. The heavy rainfall and accompanying snowmelt from higher altitudes result in a high rate of runoff.

Flood inflows of significant magnitude to Lake Washington are caused by concentrated 2- to 5-day rainstorms or series of storms. Flood runoff to Lake Sammamish (upper Sammamish sub-basin) and Chester Morse Lake is characterized by sharply rising hydrographs with peak discharges maintained for only a few hours, often followed by rapid recessions. Flood flows immediately below Lake Sammamish and the Masonry Dam on the Cedar River are dependent upon elevations of the lakes. Incidental storage in these upstream areas significantly dampens flood runoff to the downstream reaches. Flood runoff from the moderately sloped topography in the lower-lying sub-basins is characterized by relatively slower rises, flatter peaks and longer duration recessions. The current minor, moderate, and major flood stages in the Cedar River at Renton are 13.0, 14.5, and 16 feet (local gage datum), respectively. The river has crested above minor flood stage ten times since 1975 and has crested above major flood stage four times since 1990. Channel aggradation from sediment deposition has decreased the channel carrying capacity which impacts the occurrence of higher stages only in the more recent years. The maximum peak stage of record occurred on November 25, 1990 at 17.13 feet with an accompanying peak discharge of 10,200 cfs. Lake Washington has never been above its authorized maximum elevation of 18.75 feet (22.0 ft. COE). The maximum 1-day discharge from the project was approximately 13,400 cfs on February 10, 1996.

TABLE 4-3
SUMMARY OF CLIMATOLOGICAL DATA

			Annual Precipitation (inches)			Annual Snowfall (inches)	Annual Temperature (° F)		
Station	**Elev (ft)**	**Period of Record** [a]	**Mean**	**Greatest**	**Least**	**Mean**	**Mean**	**Highest**	**Lowest**
Cedar Lake	1560	1898 - Act.	100.48	137.31	62.36	62.7	47.6	100.9	-11.0
Everett	60	1894 - Act.	35.88	53.18	22.57	5.5	50.7	98.1	0.0
Seattle Jackson Park	370	1961 - 1986	38.61	49.53	27.4	5.2	51.3	99.0	1.9
Seattle Sand Point WSFO	60	1986 - Act.	36.21	46.91	17.97	3.3	53.2	105.1	10.0
Sea-Tac WSCMO AP	370	1944 - Act.	38.51	55.14	23.78	10.8	51.9	102.9	0.0

a. Act. = Active gaging station

TABLE 4-4
MEAN MONTHLY TEMPERATURE (° F)

Station	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Cedar Lake	35.2	37.6	40.4	44.9	51.1	55.9	61.0	61.3	56.6	49.4	41.2	36.3	47.6
Everett	39.1	41.6	44.9	49.4	54.5	59.4	63.0	62.9	58.2	50.8	44.3	40.1	50.7
Jackson Park	39.4	43.0	45.2	48.8	54.9	60.1	64.0	64.3	59.7	52.1	44.4	40.1	51.3
Sand Point	42.1	43.8	46.8	50.8	56.5	61.3	66.2	66.7	62.1	53.9	46.4	41.6	53.2
SeaTac	40.2	42.9	45.3	49.4	55.4	60.6	65.2	65.2	60.6	52.5	45.1	40.7	51.9

TABLE 4-5
MEAN MONTHLY PRECIPITATION (INCHES)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cedar Lake	13.4	9.8	10.7	8.3	6.3	5.1	2.2	2.7	5.3	9.4	13.6	13.5	100.5
Everett	4.5	3.3	3.6	2.7	2.3	2.1	1.0	1.2	2.0	3.4	4.7	5.0	35.9
Jackson Park	5.0	4.1	3.7	2.6	1.9	1.7	1.0	1.3	2.3	3.3	5.5	6.2	38.6
Sand Point	4.9	3.0	4.0	2.8	2.1	1.5	0.8	1.1	1.6	3.4	5.7	5.2	36.2
SeaTac	5.6	4.0	3.9	2.7	1.8	1.5	0.7	1.1	1.8	3.7	6.1	5.7	38.5

TABLE 4-6
ESTIMATED MEAN MONTHLY LAKE EVAPORATION

Puyallup Evaporation Pan Values (inches): 1961-1995 [a]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	0.71	1.58	2.46	3.96	4.63	5.62	4.96	2.94	1.28	0.61	0	28.75

Estimated Mean Monthly Lake Washington Evaporation (inches) [b]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0	0.50	1.12	1.75	2.81	3.29	3.99	3.52	2.09	0.91	0.43	0	20.41

a. Puyallup pan data obtained from the Western Regional Climate Center
b. Estimated Lake Washington evaporation values based on raw Puyallup pan data multiplied by an assumed pan correction factor of 0.7

4.07 Runoff Characteristics Approximately 50 percent of the average annual Lake Washington inflow is contributed by the Cedar River above Renton, 26 percent by the Sammamish River above Woodinville, and the remaining 24 percent primarily by eight small streams surrounding Lake Washington and by direct precipitation on the lake. Stream flows typically follow the general rainfall pattern in the area, with the highest runoff occurring in the fall and winter months. Winter flows are characterized by frequent sharp rises resulting from concentrated storms; however, not all rises reach flood proportions. Runoff gradually decreases as the mountain snowpack is depleted and rainfall diminishes in the spring and summer dry months. Lowest flows typically occur in July, August and September. On rare occasions above-

normal spring precipitation from a heavy storm in March or April will produce periods of high runoff and cause the annual peak to occur during one of these months. The seasonal rise in temperatures during spring and early summer months frequently produces a period of high snowmelt runoff from the upper Cedar sub-basin which is used to fill Chester Morse Lake. Snowmelt runoff during this period is not as noticeable in the other lower sub-basins where snowpack is generally light and does not last long into the spring months. The Cedar River between the Masonry Dam and Landsburg maintains a somewhat higher base flow especially during late summer and early fall than other nearby streams because of flow augmentation from Chester Morse Lake seepage return. The yearly streamflow pattern for the Cedar sub-basin is presented in the summary hydrograph for Cedar River at Renton (United States Geologic Survey (USGS) gage ID No. 12119000) in Plate 4-2. Summary hydrographs for the Cedar River near Cedar Falls (USGS gage ID No. 12115000) and Issaquah Creek near Mouth near Issaquah (USGS gage ID No. 12121600) are presented in Plates 4-3 and 4-4, respectively. Daily discharge hydrographs for Cedar River at Renton, near Cedar Falls, and Issaquah Creek near Mouth near Issaquah are presented in Plates 4-5, 4-6, and 4-7, respectively. Plate 4-8 is a plot of the daily LWSC pool elevation. The normal and critical minimum Renton flow regimes are stated in the WAC 173-508-060 (2003). These flows are met as much as possible from natural runoff, but augmentation directly from Chester Morse Lake (SPU's Cedar River headwater storage project) and seepage return from a large moraine aquifer (fed by Chester Morse Lake seepage) between the Masonry Dam and the Landsburg gage is usually necessary in the late summer and early fall. Normal year flows must be maintained at all times unless a critical condition is declared. Critical year flows are expected to be met unless natural Cedar River flows fall below the one in fifty year Cedar River flow frequency. The normal and critical year

flows are shown in Table 4-8. Runoff from the Sammamish sub-basin during the winter months is somewhat moderated by Lake Sammamish and its outlet weir.

TABLE 4-8
NORMAL YEAR AND CRITICAL YEAR
CEDAR RIVER INSTREAM FLOWS [a]

Normal Year Flow	
Dates	**Flow**
January 1 to June 20	370 cfs
June 20 to July 15	Linear decrease from 370 cfs on June 20 to 130 cfs on July 15
July 15 to September 10	130 cfs
September 10 to September 20	Linear increase from 130 cfs on September 10 to 200 cfs on September 20
September 20 to October 1	200 cfs
October 1 to October 10	Linear increase from 200 cfs on October 1 to 370 cfs on October 10
October 10 to January 1	370 cfs
Critical Year Flow	
Dates	**Flow**
January 1 to June 15	250 cfs
June 15 to July 1	Linear decrease from 250 cfs on June 15 to 110 cfs on July 1
July 1 to October 1	110 cfs
October 1 to November 1	Linear increase from 110 cfs on October 1 to 250 cfs on November 1
November 1 to January 1	250 cfs

a. Normal and critical year instream flows for the Cedar River are established in WAC 173-508-060.

4.08 Water Quality The most significant water quality threat to Lake Washington associated with lock operation is saltwater intrusion. Each time an eastbound lockage is made, denser saltwater (which enters the lock chamber when the west gates are opened to Puget Sound) migrates into the ship canal. The large lock allows approximately 30 times as much salt per lockage to enter the ship canal than does the small lock. A saltwater drain south of the south wing wall at the east end of the large lock is effective at returning much of the saltwater to Puget Sound. The saltwater return system has two outlet conduits downstream of the "Y" joint, the outlet to the diffusion well at the downstream end of the fish ladder is normally open and

supplies about 160 cfs to the diffusion well. The other outlet conduit discharges to the old saltwater drain and is typically only opened during periods when the conduit to the diffusion well is closed during periods when the fish ladder is closed for annual maintenance. There is also a saltwater barrier attached to the bottom of the large lock at the east end of the lock to reduce saltwater intrusion. During the refill and summer months, the location and concentration of the saltwater "wedge" is monitored to assist WMS in trying to prevent exceedance of the State water quality criteria at the University Bridge site (see Plate 5-2).

4.09 Channel and Floodway Characteristics The Cedar sub-basin and the Sammamish sub-basin are the two major contributors of flow to Lake Washington. The Cedar River empties into Lake Washington just above Renton. Issaquah Creek enters Lake Sammamish on its southern end. The Sammamish River begins at the outlet of Lake Sammamish at its northern end. The Sammamish River enters Lake Washington at its northern end in Kenmore. Bathymetry is taken from the LWSC Project to the University Bridge. The latest survey is shown on Plate 4-9.

4.10 Upstream Structures On the Cedar River, there are three upstream structures, the Crib Dam and Overflow Dike between Chester Morse Lake and the Masonry Pool at river mile 37, Masonry Dam at river mile 35.6, and the Landsburg Diversion Dam at river mile 21.6.

4.11 Downstream Structures Puget Sound is immediately downstream of the project. Therefore, downstream flooding concerns are not an issue. There are no regulating stations downstream of the project.

4.12 Economic Data

a Population Most of the Lake Washington basin lies within King County, Washington, with a small portion of the northern most part of the basin residing in Snohomish County. King County's population in 2015 was estimated at about 2.1 million, an increase of 9.6 percent since 2010. The most significant population center of the Cedar River sub-basin is Renton, with an estimated 2015 population of about 100,000. The Cedar River watershed is closed above river mile 21 to protect the City of Seattle's water supply associated with the Cedar Falls Project (Chester Morse Reservoir). The Lake Washington and Sammamish sub-basins' major population centers and estimated 2015 populations are Seattle (684,000), Bellevue (140,000), Kirkland (87,000), Redmond (60,000), and Issaquah (36,000). Their combined population in 2015 was about 11.8 percent higher than their combined population in 2010.

b Agriculture Land in agriculture is largely confined to the Cedar sub-basin between river miles 10 and 21 and to portions of the Sammamish River valley. Small cattle, fruit crop, and hay operations are the primary activities. The vast majority of the farms are less than 50 acres.

c Industry Principal economic activities in the rural portions of the Cedar River valley are sand and gravel quarrying and some limited timber harvesting. The Burlington Northern Santa Fe Railroad passes through the valley. The Boeing Corporation Aircraft Plant and Pacific Car and Foundry Company (PACCAR) are located in Renton at the mouth of the Cedar River. The Lake Washington sub-basin with its large metropolitan contingent, contains all of the associated industries such as banking, light manufacturing, and wholesale and retail sales. In addition, the container cargo industry has seen a dramatic rise at the Port of Seattle. A booming software and

high technology industry has blossomed throughout in the region with Microsoft and Amazon basing corporate headquarters in the area.

d Navigation The 8-mile-long LWSC is the only waterborne link from the Puget Sound into the inland waters of the Seattle area. When first constructed, the main use of the LWSC was for commercial and military navigation, but currently about 80 percent of the typical 40,000 vessels passing through the locks each year are pleasure craft. Based on recent years, an average of about 1 to 1.5 million tons of cargo passes through the locks each year.

SECTION 5. DATA COLLECTION AND COMMUNICATION NETWORKS

5.01 Hydrometeorological Stations

a Facilities There are 38 active hydrometeorological stations in or near the Cedar River/Lake Washington basin. These include 11 climate gages managed by the National Oceanic and Atmospheric Administration (NOAA): two in the Cedar River sub-basin, one in Lake Washington, and eight in the area surrounding the Lake Washington Watershed; 17 stream and lake gages managed by the United States Geological Survey (USGS): 12 in the Cedar River sub-basin, four in the Sammamish sub-basin, and one in the Lake Washington sub-basin; two lake level sensors maintained by the Corps and located in the project forebay (LWSC) and the north end of Lake Washington at Kenmore (KELW); and 10 snow courses managed by the Natural Resources Conservation Service (NRCS), all in or near the headwaters of the Cedar River. Seven of the snow courses are SNOTEL stations and three are aerial markers. All pertinent reporting observation stations are shown on Plate 4-1. The plate also shows the locations of 46 discontinued climate and stream gages which recorded valuable data while they were in operation. Records for the discontinued stream gages are maintained by the USGS Washington Water Science Center.

Some stream gaging stations are equipped with automated rain gages or water temperature sensors. Table 4-1 indicates which data types are available at which gaging stations. Precipitation data are also available through Seattle RainWatch, a collaborative project between Seattle Public Utilities and the University of Washington Department of Atmospheric Sciences that provides rainfall estimates derived from radar data that are calibrated with local rain gage networks. Seattle RainWatch data are available online at www.atmos.washington.edu/SPU.

b Reporting Data for the two Corps operated lake level gages are reported hourly; data from these gages are stored in the Corps RWCDS database at this time-step and are reported at this time-step on the District's public access water management website. Data from the non-Corps sensors are reported at different time-steps depending on the type of data and operating agency, although in general reporting time-steps are hourly or more frequent. Data collected at these lake level sensors are reported to the closest hundredth of a foot. The reading at the LWSC sensor is checked daily using a manual observation since this is the official sensor used to maintain the desired water surface elevation for project operations.

c Maintenance Maintenance at the two Corps operated lake level gages is performed on an as-needed basis, but generally is required infrequently as these types of sensors use relatively simple technology and are inherently low maintenance.

5.02 Water Quality Stations

a Facilities Saltwater intrusion into the LWSC is the highest water quality concern for the project. Current Washington Administrative Code (WAC 173-201A-602) requires that "Salinity shall not exceed one part per thousand (1.0 ppt) at any point or depth along a line that transects the ship canal at the University Bridge (river mile 6.1)." There are water quality stations at five locations in the Lake Washington Ship Canal: at the Locks, the Ballard Bridge, the Fremont Bridge, across from Gas Works Park, and at the University Bridge. Each station is equipped with a Hydrolab MiniSonde 4a/5a. Table 5-1 details the data collection parameters for each of the stations, and Plate 5-2 shows the station locations.

TABLE 5-1
WATER QUALITY STATIONS

Station Location	Station Code	Station Depths (feet below surface) [a]	Station Depths (feet above bottom)	Parameters Measured
Large Locks	LLLW-43	43	1	DO, Salinity, Temp
	LLLW-36	36	8	Salinity, Temp
	LLLW-28	28	16	Salinity, Temp
	LLLW-18	18	26	Salinity, Temp
Ballard Bridge	BBLW-32	32	1	Salinity, Temp
	BBLW-21	21	12	Salinity, Temp
	BBLW-11	11	22	Salinity, Temp
Fremont Bridge	FBLW-40	40	1	Salinity, Temp
	FBLW-31	31	10	Salinity, Temp
	FBLW-18	18	23	Salinity, Temp
Gas Works Park	GWLW-44	44	1	DO, Salinity, Temp
	GWLW-29	29	16	Salinity, Temp
	GWLW-14	14	31	Salinity, Temp
	GWLW-5	5	40	Salinity, Temp
University Bridge	UBLW-35	35	1	DO, Salinity, Temp
	UBLW-21	21	15	Salinity, Temp
	UBLW-8	8	28	Salinity, Temp

a. Station depths referenced to a water surface elevation of 18.75 feet (22.0 COE)

b Reporting Data at these locations are collected seasonally, generally from April through early November, which is the period when a salinity concern in the LWSC is most likely to occur. Data are collected hourly and are transmitted to the RWCDS database for archiving. These data are also posted to the District's public access water management website.

c Maintenance Station maintenance is generally performed monthly, and typically consists of cleaning the probes of algal growth and checking instrument calibration.

5.03 Sedimentation Stations There are no sedimentation stations associated with the Lake Washington Ship Canal project.

5.04 Recording Hydrologic Data Hydrologic information is recorded as it is received by the Water Management Section as follows:

a Regional Water Control Data System (RWCDS) The Corps' hydromet data management policies and procedures for regulation of the Lake Washington Ship Canal Project are based on the Corps' Regional Water Control Data System (RWCDS), a regional water resource data management program. The RWCDS is a system that collects, acquires, stores and computes data for real-time modeling and decision support for water control in the Northwestern Division. Northwestern RWCDS consists of three geographic nodes, and is operated regionally by the following four water management offices: Northwestern Division (NWD), Portland District (NWP), Seattle District (USACE-NWS) and Walla Walla District (NWW).

USACE Seattle District (USACE-NWS) uses RWCDS for management of hydromet data associated with reservoir regulation and water resource projects within their jurisdiction. It should be noted that prior to about 2010, the RWCDS was known as the WCDS, Water Control Data System.

The Corps' Hydrologic Engineering Center report, Water Control Data System (WCDS), Past, Present, and Future, RD #39, dated September 1995, describes the WCDS as follows. "The WCDS is an automated information system that supports the Corps of Engineer water control mission including the hardware, software, manpower, and other resources required to acquire, develop, maintain, and operate the system. The WCDS includes the collection, acquisition, retrieval, verification, storage, display, transmission, interpretation, and archiving of information needed to carry out the Corps' water control mission. The WCDS is a nationwide integrated system of hardware and software that allows users access to virtually any data and information in

the system. A suite of software gives users the ability to display, manipulate, disseminate, interpret, and transmit information throughout the Corps and to any other interested user."

b Data Processing and Storage Plate 5-1 shows the flowchart of the RWCDS/CWMS system of Seattle District Water Management. Currently in Seattle District, data processing and storage occurs with the RWCDS/CWMS system. The Corps Water Management System (CWMS) is a decision support system that can expand and enhance the information readily available to USACE regulators who must make decisions about operation of Federal water management facilities or who must monitor and approve such decisions made by operation partners.

In the RWCDS/CWMS system, data is collected via various means (i.e., SFTP, GOES satellite, CBT web messenger) into the regional data collection servers (RWCDS1 in Portland District, and RWCDS2 in Walla Walla District). The Data Acquisition (DA) system collects data and transfers these data into the RWCDS database (an Oracle database), at which point data are corrected and computations are made. Data are distributed via the Data Dissemination (DD) system, which is used to generate and publish reports.

The NWD RWCDS system consists of three mostly identical nodes (NWP, USACE-NWS, and NWW) that are synchronized for COOP (Continuity of Operations) purposes. The file systems on each node are kept mostly identical to the others by synchronizing the file system on a schedule and installing the same versions and configurations of each software package. The databases are kept consistent by using a 3-way bi-directional streaming scheme.

Available streamflow and elevation data for the Lake Washington Watershed can be viewed by NWS-RCC staff in graphical or tabular formats on personal computers located throughout the section. Data posted to the Corps public website can be viewed in graphical or tabular format for

up to 7 days. Data for longer periods can be obtained by Corps staff from the RWCDS Oracle database. In addition to the Corps database, the U.S. Geological Survey maintains a permanent record of data collected at all stations they operate and maintain. Their Internet web page provides access to nearly all data, except for some special cases that require special handling.

5.05 Communication Network The following methods are used by Seattle District to receive data from the hydromet stations associated with the LWSC project.

a Telephone data Data from the water level sensor located in Lake Washington in Kenmore (KELW) are transmitted via telephone line to the District's data collection system on an hourly interval. Telephone lines also provide a secondary (backup) means of transmitting data from several other field sensors to the data collection system.

b Radio data Radio transmission is the primary means for transmitting data from most of the field sensors associated with the LWSC project. Radio transmission is used to transmit data hourly from the following sites: LWSC forebay water level sensor (LWSC), and water quality data from sensors located at University Bridge (UBLW), Lake Union near Gas Works Park (GWLW), Fremont (FBLW), Ballard Bridge (BBLW), and upstream of the Large Lock (LLLW). Data are also transmitted from a field DCP (data collection platform) located near the fish ladder, with multiple sensors connected that record data for fish counts, tide level, and temperature and conductivity within the fish ladder.

Data transmitted from field sensors via radio are transmitted either directly to a data collection box at the LWSC or via the Cougar Mountain repeater to a data collection box in the NWS RCC.

Data collected at both sites are sent to the XConnect box in the NWS RCC and then saved to the RWCDS database.

5.06 Communication with Project Reservoir regulation instructions are transmitted from the NWS RCC to LWSC operations personnel by commercial telephone. Backup communication is available via radio as needed. Reservoir regulation instructions are typically provided regarding which project features to operate (i.e., locks, smolt flumes, fish ladder) and/or what the objective LWSC forebay target elevations are. In addition to communicating regulation instructions by phone, NWS RCC staff prepare structured regulation instructions that are forwarded by email to project staff to provide an electronic record.

5.07 Project Reporting Instructions The LWSC operators report the 8:00 am manual project forebay elevation reading to the NWS RCC on a daily basis. Additionally, project staff manually record project operations data, including the number of large and small lockages, smolt flume usage, fish ladder status, and spill gate openings. These data are then submitted electronically to the Corps RWCDS database. Additional project reporting requirements for emergency situations (i.e., post-earthquake inspection reporting) are outlined in the Emergency Action and Notification Subplan (EAP). Copies of the EAP are located at the project, NWD, and the NWS RCC.

5.08 Warnings The EAP provides notification protocol for special operations and emergencies. The Seattle District has multiple copies including one located in the Reservoir Control Center.

SECTION 6. HYDROLOGIC FORECASTS

6.01 General Current forecast products used for making operational decisions at the LWSC project are limited to the Cedar River basin, which represents about 50 percent of the average annual inflow to Lake Washington. The two basic types of forecasts that can provide information useful for making water management decisions at the LWSC project are short-term streamflow forecasts for real-time and near real-time operations as generated by the National Weather Service's (NWS) Northwest River Forecast Center (NWRFC) for the Cedar River basin and longer term products as generated by the NWS and the Natural Resources Conservation Service (NRCS).

For general forecasting needs, several products from the NWS are particularly useful. The NWS produces a short-term, Quantitative Precipitation Forecast (QPF) that covers a three-day forecast period with forecast precipitation in six-hour increments. The current product includes several locations within the Puget Sound region. The sites most applicable to the Lake Washington basin include Mud Mountain Dam near Enumclaw, Sea-Tac airport, Skykomish, and Stampede Pass. These forecasts are mostly useful as a tool to advise Seattle District staff of possible short-term significant increases in precipitation that could drive similar significant inflow increases. NWS also provides a similar ten-day forecast product that provides graphical representations of daily forecast precipitation, maximum and minimum forecast air temperature, and forecast freezing level. These forecast products are used by the NWS to produce ten-day hydrologic forecast runs, the most relevant being the forecasts produced for the Cedar River basin forecast group. Forecast points within this group include inflow to Chester Morse Reservoir, forecast flow in the Cedar River below the Landsburg diversion dam, and forecast flow in the Cedar

River at Renton. These products provide forecasts at a six-hour time step covering the ten-day forecast window. River forecasts from this product provided for locations downstream of the City of Seattle's Cedar Falls Project (Landsburg, Renton) often don't fully capture the City's intended project operations, which adds an additional layer of uncertainty at these specific forecast locations. Regardless, this forecast product provides a relevant and useful tool for estimating expected short-term future inflow to Lake Washington from the largest source of inflow.

6.02 Flood Condition Forecasts

a Requirements A forecast product for total inflow to Lake Washington does not exist, but this is not problematic as flood forecasts are generally not a critical requirement for operation of the LWSC. Lake Washington is normally held at the minimum pool elevation of 16.75 feet (20 ft. COE) during flood season, and it is generally straightforward to adjust project spill as needed in real-time to maintain the desired pool elevation without specific forecast guidance. The NWRFC does produce daily forecast runs for the Cedar River basin as noted under Section 6.01 with additional details provided in Section 6.02b. The NWRFC Cedar River basin forecasts are generated daily throughout the year but serve as flood forecasts for the Cedar River during periods when the hydrologic modeling guidance suggests that Cedar River flows will exceed flood stage within the 10-day forecast window.

b Methods The NWRFC uses the National Weather Service Community Hydrologic Prediction System (CHPS) computer model to forecast flows within the Cedar River Basin including Cedar River flows at Renton. These 240-hour forecasts are produced on a daily basis year-round and more frequently as needed during flood events. The forecasts are in 6-hour

increments and are based on quantitative precipitation and temperature forecasts. These forecasts are not considered critical to project operations, especially since they forecast runoff from an area that on average produces only roughly fifty percent of the inflow to Lake Washington. However, these forecasts can be helpful for providing a general indication regarding expected inflow to Lake Washington over the short-term.

6.03 Conservation Purpose Forecasts The use of longer-term forecasts to help guide refill and water allocation during the summer and fall drawdown period is described in Section 6.04.

6.04 Long Range Forecasts

a Requirements Similar to the short-term forecast guidance, there is no long-range forecast guidance applicable to the entire drainage area to Lake Washington, Lake Union, and the LWSC. However, long-range forecasts are available for the Cedar River basin which can be useful for assisting with determining the Lake Washington refill schedule (February through May) and help in the planning and scheduling of water conservation activities (usually June through October) whenever necessary.

b Methods There are currently two long-range forecast products that are available specific to the Cedar River basin. The National Weather Service produces an Extended Streamflow Prediction (ESP) forecast that combines information about the current basin state with observed meteorology from historical years. This product produces streamflow estimates at a daily time-step for an 18-month forecast period. Current ESP runs are using observed precipitation and temperature data from the past 68 years (water years 1949-2016), thereby resulting in 68 traces of forecast streamflow for the 18-month forecast period. ESP runs for the Cedar River basin are produced for the following forecast locations: Cedar River at Renton, Cedar River near

Landsburg, and Cedar River at Chester Morse Lake. The ESP product generally has the most value during the spring when basin state is typically heavily influenced by snowpack and the ESP traces are useful for providing a range of spring and early summer runoff scenarios utilizing a wide variety of observed meteorological conditions.

The Natural Resources Conservation Service (NRCS) produces volumetric runoff forecasts for two forecast periods, April through July, and April through September, on a monthly basis from January through June each year. These forecasts are generated for two locations in the Cedar River basin; Cedar River near Cedar Falls and Rex River near Cedar Falls. Measurement of snow water equivalent at selected automated SNOTEL sites along with precipitation, antecedent streamflow, and the El Niño Southern Oscillation indices are used in computerized statistical and simulation models to produce these forecasts. These volumetric forecasts provide an indication of expected spring runoff in the upper Cedar River basin, which can be helpful for planning refill of Lake Washington as well as planning operations once involuntary drawdown of the lake begins. Although these forecasts are of inflow to Chester Morse Reservoir and do not provide a direct representation of forecast inflow to Lake Washington from the lower Cedar River, the forecasts assist the City of Seattle in their project operation which has a direct effect on the operation of the LWSC.

In addition to the long-range streamflow forecasts, the City of Seattle is obligated to meet minimum instream flows in the Cedar River below Landsburg mandated by their Habitat Conservation Plan (HCP). Additionally, a firm block of additional supplemental water (2,500 acre-feet) is delivered in what are considered normal years, and an additional non-firm block of supplemental water (3,500 acre-feet) can be delivered during years when the City feels there is adequate available water to offer this additional block. The supplemental blocks are provided in

the summer and fall and were specifically designed to provide additional water to protect incubating and emerging steelhead and trout from the adverse effects of dewatering. The City of Seattle makes the decision regarding whether or not to offer the non-firm supplemental block based on various hydrologic indicators in the basin. The Cedar River Instream Flow Commission (IFC), comprised of various resource agencies and summarized in more detail in Section 9, is the entity that decides whether or not to accept use of the non-firm supplemental block when offered by the City. The Seattle District Corps participates in the monthly IFC meetings but is a non-voting member. However, because decisions regarding planned use of the supplemental blocks are communicated at the IFC meetings and in associated correspondence, Seattle District Water Management staff are able to receive these plans and plan accordingly for expected minimum flows in the Cedar River entering Lake Washington. For instance, if the City anticipates some flow reductions from normal at Renton, then conservation operations at the Locks may be necessary depending on the hydrologic status of the Lake Washington and Sammamish River sub-basins.

The City of Seattle's minimum instream flows mandated per the HCP are provided in Table 6-1. The normal minimum flow requirements are reflected by the values in the column labeled as the "normal instream flow requirement." These are the minimum values that will be provided by the City except when all of the conditions and procedures are met to allow the City to provide lower instream flows as dictated by the critical minimum flows shown in Table 6-1. Criteria for allowing the City to switch to the lower critical minimum flows include low water levels and low average inflows to Chester Morse Lake, implementation of demand reduction measures, and following a consultation process that includes convening the IFC to discuss options or alternatives to adopting the critical minimum flows.

The firm (2,500 acre-feet) and non-firm (3,500 acre-feet) blocks of supplemental water are in addition to the normal flow requirements shown in Table 6-1. Between June 17 and August 4, in addition to the normal minimum flows listed in Table 6-1, the City shall provide supplemental flows as the IFC may direct up to a volume of 2,500 acre-feet (firm block) to supplement normal flows for steelhead incubation. During this same period and in addition to the firm block, the City will expect to further supplement normal minimum flows by 3,500 acre-feet of non-firm water in 63 percent of all years. Because supplying this additional water increases the risk of shortage in meeting both water supply and minimum instream flow requirements later in the year, the City has a decision making process that includes the IFC that balances the risk of providing the non-firm block with the benefits. The decision making process is discussed in detail in the City's Instream Flow Agreement for the Cedar River, which is an agreement between the City of Seattle, the State of Washington, U.S. Fish and Wildlife Service, and NOAA Fisheries Service.

6.05 Drought Forecasts Forecasts that can be useful to help plan operations and mitigate the impacts of drought are described in Section 6.04. Knowledge of the City of Seattle's mandated minimum flows in the Cedar River are particularly useful for estimating inflows to Lake Washington during the typical dry season (i.e., July through October), which is the period when droughts would most likely be expected to impact project operations.

SECTION 7. WATER CONTROL PLAN

7.01 General Objectives The LWSC is operated primarily as a navigation facility connecting Puget Sound and Lakes Union and Washington. Project authorization documents state that under normal operation the LWSC should be maintained near the pre-project level of Lake Union with an allowance of one foot above or below that level for seasonal and lock usage variations. This translates to a two foot range between 16.75 and 18.75 feet (20.0 to 22.0 ft. COE datum), respectively. The minimum elevation is maintained during the winter months to allow for annual maintenance on docks, walls, etc. by businesses and lakeside residents, to minimize wave and erosion damage during winter storms, and to provide storage space for high inflow. The storage between 16.75 and 18.75 feet (20.0 to 22.0 ft. COE) is used to augment LWSC inflows for use in operating the locks, the salt water return system, the smolt flumes, and the fish ladder facility during the summer/fall drawdown period (see section 7.03 for a definition of that period). Historically (1941-1990), the minimum annual LWSC elevation has fallen below 16.75 feet (20.0 ft. COE) on the average of three of every ten years. The water conservation plan (see Paragraph 7.12) is designed to keep the LWSC at or above 16.75 feet (20.0 ft. COE) with roughly a 70 percent annual chance while minimizing to the extent possible a drop below 16.25 feet (19.5 ft. COE); however, in some years this is not possible because of abnormally low inflow to Lake Washington or higher than usual salt water intrusion which forces more of the LWSC storage to be used. The lowest recorded lake elevation was 15.09 feet (18.34 ft. COE) in 1958.

7.02 Constraints The Hiram M. Chittenden Lock and Dam is unusual because there is no control point or damage center downstream of the project, and there are no tailwater restrictions.

In addition, there is no flood control pool although the space between 16.75 and 18.75 feet (20.0 and 22.0 ft. COE) is available if needed to store very high inflows. A summary of applicable normal operating constraints is in Table 7-1.

TABLE 7-1
NORMAL OPERATING CONSTRAINTS

1.	Reservoir Limits (NAVD 1988 DATUM):
	Maximum Pool 18.75 feet (22.0 ft. COE) Minimum Pool 16.75 feet (20.0 ft. COE)
2.	Maximum Change in Reservoir: No limit
3.	Maximum or Minimum Tailwater Change: No limit
4.	Minimum Discharge: Sufficient to provide saltwater wedge control, fish passage, and normal lockages as needed for navigation. Minimum discharge to meet these criteria typically varies seasonally (minimum rate is higher when smolt flumes are operated for downstream fish passage).
5.	Maximum Discharge: 1,950 cfs per spillway bay at elevation 16.75 feet (20.0 ft. COE) 3,000 cfs per spillway bay at elevation 18.75 feet (22.0 ft. COE)

7.03 Overall Plan for Water Control The LWSC has four named periods of seasonal operation: Winter Holding Period, Spring Refill Period, Early Summer Conservation Holding Period, and the Summer/Fall Drawdown Period. See Plate 7-1 for a graphical presentation of the annual operating cycle of the LWSC. The Spring Refill Period begins on 15 February and continues until typically sometime in May or June when the lake should reach the upper limit of the authorized project operating range 18.75 feet (22.0 ft. COE). The timing for reaching the maximum elevation is generally tied to expected inflows to Lake Washington during the late

spring period and the related potential to achieve full refill while minimizing the probability that unexpected sharp rises in inflow could make it difficult to prevent the upstream water surface from exceeding the upper authorized elevation. As such, an earlier refill target date would generally be expected in years with reduced spring runoff potential while a later date would be generally expected in years with higher spring runoff potential. Once refill is complete, operation enters the Early Summer Conservation Holding Period during which time the lake is maintained at its maximum elevation for as long as possible. As the summer progresses, normal water demands at the locks will typically exceed the inflows to the LWSC and the lake will begin involuntary drawdown (usually in late June or early July). At this point, the Summer/Fall Drawdown Period commences. The rate of drawdown is monitored and regulated under the Water Conservation Plan (paragraph 7.12). The drawdown period lasts until 1 Dec at which time the Winter Holding Period commences, and the lake is held at 16.75 feet (20.0 ft. COE) through the winter. The inherent wide variability of runoff patterns may cause the exact starting and ending dates of any or all of these periods to shift.

Project operations for authorized purposes including navigation and fish passage are discussed in subsequent sub-sections. The project is equipped with a spillway with six spill bays for the purpose of discharging water in excess of the quantity required for project operations, such as navigation (small and large lock usage), fish passage, and salinity control. The spillway is typically used during the winter holding period to maintain the forebay at elevation 16.75 feet (20.0 ft. COE), during the spring refill period to manage the forebay rise per the desired refill plan, during the early summer conservation holding period to maintain the forebay no higher than elevation 18.75 feet (22.0 feet COE), and as needed during the summer/fall drawdown

period to achieve the desired drawdown of the forebay to the winter holding elevation of 16.75 feet (20.0 ft. COE) by December 1.

Each of the six spillway bays has a radial gate with discharge under the gate a function of upstream head (i.e., forebay elevation) and spill gate opening. Table 7-2 provides a rating table for a single spill gate as a function of forebay elevation and gate opening. Maximum discharge for a single spill bay ranges from about 2,000 cfs for a forebay elevation of 16.75 feet (20.0 ft. COE) to about 3,000 cfs for a forebay elevation of 18.75 feet (22.0 ft. COE). Hatched areas shown on Table 7-2 indicate areas of unstable flow for specific gate openings and forebay elevations that should be avoided. Given that the discharge capacity of each spill bay is identical, the resulting cumulative discharge capacity for the entire spillway ranges from about 12,000 cfs for a forebay elevation of 16.75 feet (20.0 ft. COE) to about 18,000 cfs for a forebay elevation of 18.75 feet (22.0 ft. COE).

Guidance for operating the spillway is provided in Tables 7-3 through 7-5. Tables 7-3 and 7-4 provide guidance during periods when all six spill gates are available for use, which is generally from early fall through early spring. Table 7-3 is intended for spill when the forebay elevation exceeds 17.45 feet (20.7 ft. COE). Table 7-4 is intended for spill when the forebay elevation is less than 17.45 feet (20.7 ft. COE). The only difference in these tables is that Table 7-4 instructs a gate to be pulled clear from the water for desired individual gate openings greater than 4 feet when the forebay elevation is less than 17.45 feet (20.7 ft. COE), which is intended to minimize vibration on the gates.

Table 7-5 provides guidance when the smolt flumes are installed and spill gates in bays 4 and 5 are unavailable for use, which is generally from early spring through early fall. Each of these

tables provide guidance regarding the preferred set of gate openings for a given desired cumulative spill gate opening. The spill pattern guidance is intended to spread spillway discharge somewhat evenly over the spillway to minimize scouring of the downstream apron while minimizing use of spill bay #6 to minimize spill immediately adjacent to the fish ladder, thereby helping to provide better fish attraction toward the fish ladder during spill periods (keeping spill gate #6 closed minimizes "false attraction" flow adjacent to the fish ladder outlet). The minimum incremental gate opening is generally one half foot, although a desired minimum initial opening of one foot is specified to help minimize impacts to fish that might pass downstream under an open gate.

REDACTED CONTENT

REDACTED CONTENT

REDACTED CONTENT

7.06 Recreation Recreation is an authorized purpose of the project, as in visitor facilities and recreation trails and project lands. Recreational navigation is incidental to the authorized purpose of commercial navigation. Recreational boats are almost always present in Lakes Union and Washington, with a strong seasonal increase in usage in the warmer and drier late spring through early fall period. Recreational boats also comprise roughly 80 percent of the vessels passing through the locks annually, as vessels traverse between recreational destinations in the inland waters of Lakes Union and Washington and saltwater destinations. Other types of recreation upstream of the project including swimming and paddle-boarding are popular.

7.07 Water Quality Intrusion of salt water from Puget Sound into the LWSC is the principal water quality consideration. Every effort must be made to insure that the salt water does not advance through the canal into Lake Washington thereby causing potential ecological damage to Lake Washington. The State of Washington Department of Ecology has established that the concentration of salt in the LWSC at the University Bridge shall be maintained at or below 1 part per thousand. See section 9.02e for coordination requirements with WDOE.

With every eastbound (upstream) lockage, salt water (more dense than fresh water) enters the lock along the bottom of the lock chamber, and when the lock's east miter gate opens, the salt water enters the ship canal. Some of this denser salt water immediately enters the salt water return system and flows as described in section 2.03d. The remaining salt water becomes diluted and can migrate upstream into Lake Union and beyond. On average, the large lock allows 30 times the volume of salt to enter the LWSC system than does the small lock. In the late fall and winter months, there is usually enough fresh water inflow into the LWSC to keep the salt water from advancing into the Ship Canal. However, during the summer conservation period, or when the small lock is out of service, or when an abnormally high amount of vessel traffic is expected (requiring more frequent use of the large lock), there may be times when running the salt water return system is not adequate to mitigate undesirable increases in upstream salinity.

7.08 Fish and Wildlife A 22 step fish ladder is in place on the south end of the dam structure. The fish ladder allows upstream and downstream migration of a variety of species of anadromous fish. By far the largest run is sockeye salmon which ranges above 300,000 fish. When the ladder is operational, twenty three (23) cubic feet per second should continuously pass from Salmon Bay into the fish ladder, and another approximately 160 cfs is typically discharged into the diffuser well from the salt water return system. Flow into the fish ladder should be checked routinely by project personnel and adjustments made appropriately in accordance with the Fish Ladder Rehabilitation Design Memorandum No. 3, dated August 1972. Of particular concern is the potential for the sensor that regulates flow to the diffuser well to occasionally malfunction due to debris build-up and completely shut-off flow to the diffuser well. This results in a loss of a significant portion of the attraction flow to the fish ladder but perhaps more

important shuts off the return flow from the saltwater drain to Puget Sound, which can result in a rapid increase in salinity in the LWSC if left unchecked.

Routine annual maintenance of the fish ladder is usually performed in May. Annual maintenance involves dewatering and cleaning the facility and performing any needed maintenance work. The timing of the annual maintenance work is coordinated and communicated with key agencies and tribes.

7.09 Water Supply The LWSC project is not operated for water supply.

7.10 Hydroelectric Power The LWSC project is not operated for hydroelectric power**.**

7.11 Navigation The LWSC's authorized and primary project purpose is to provide a navigation channel between Puget Sound and the inland waters of Lakes Union and Washington. The LWSC supports two lock chambers (large and small) which raise and lower vessels to and from the LWSC, respectively. During normal operation, both locks are operated without delays whenever vessels need to pass. It is very desirable to maintain the LWSC at or above 16.75 feet (20.0 ft. COE) to accommodate deep draft vessels throughout the canal. Impacts to navigation when Lake Washington falls below 16.75 feet are discussed in Section 8.

7.12 Drought Contingency Plans The impacts of drought on project operations have occurred most frequently during the summer/fall drawdown period, when inflows to the project are typically low and required water usage at the project exceeds inflows. While it is typical for required water usage to exceed net inflow during the summer and early fall, drought conditions occur when either net inflows are abnormally low, the duration of low inflows extends longer than typical (i.e., well into the fall season), or both conditions. Drought impacts have also

occurred in some recent years in the spring, mainly in situations in which inflows are abnormally low throughout the spring runoff season to the extent that they are insufficient to allow full refill of the lake to the target forebay elevation of 18.75 feet (22.0 ft. COE) and to provide water for required project operations. Water shortage situations in the spring are partly an artifact of higher project demand, as providing downstream fish passage via the smolt flumes can essentially double the required water usage at the project.

In certain circumstances the effects of drought are significantly strong to warrant the implementation of water conservation at the project. In these situations, Water Management staff must consider the potential impacts to project operations such as impacts to navigation, upstream water quality (i.e., excessive salt water intrusion), lake level, and fish migration when making decisions as to when, to what degree, and what type of conservation measures should be instituted. Various sources of information should be considered when determining appropriate conservation measures, including weather and hydrologic forecast information, the City of Seattle's Cedar River management plans, critical fisheries information (i.e., fish migration seasonality and counts), and the concentration and spatial distribution of salinity in the LWSC and Lake Union as depicted by the Corps water quality monitoring network. Additionally, lake level forecasts as described in the following section can be very useful for determining both the need for conservation activities as well as the effectiveness of such measures.

a Normal Operation The procedure which most directly helps to assess the need for water conservation measures is the Critical Content Curve (CCC). This curve is designed to provide end-of-month elevations from typically May 1 through September 30, which, if equaled or exceeded, will help to ensure that at the end of September the Lake Washington elevation will be no less than 16.75 feet (20.0 ft. COE) in seven of every ten years (commonly referred to the

historic reliability, or 70% reliability of Lake Washington). The purpose of the CCC is to define the lake elevations which define the 70 percent reliability (70% exceedance) of the lake to remain above the 16.75 foot (20.0 ft. COE) minimum operating elevation throughout the period of involuntary drawdown. As such, when the observed forebay elevation coincides with the CCC, there is an estimated 30 percent chance that the forebay could fall below the 16.75 foot elevation (20.0 ft. COE) at some point during the current year's period of involuntary drawdown. The daily observed Lake Washington elevation compared to the CCC helps to indicate whether or not any water conservation might be necessary. Exhibit 7-2 provides guidance regarding how to develop the CCC. The current tool for calculating the CCC is an Excel-based water budget model that requires two sets of input information; 1) planned outflow operations at the LWSC project over the period of involuntary drawdown; and, 2) a set of net inflow scenarios that are intended to represent possible inflow scenarios for the given year. Net inflow scenarios can be based on historical data, modeling, or other methods. If historical data are used the user should be mindful that Seattle's management of the Cedar River has changed over the years. For example, the Habitat Conservation Plan implemented in 2000 has resulted in higher Cedar River flows during the summer/fall low-flow period relative to previous years. Planned outflow operations would include discharge required to perform expected lockages (without restriction), fish ladder operation, planned smolt flume operation, and any additional water usage via the old salt water drain for purposes such as salinity control. Inflow scenarios could be from a set of Extended Streamflow Prediction traces or similar set of probabilistic inflow traces if available, or a set of historical inflow traces considered representative of current year conditions. Because the current tool does not directly consider evaporation losses from the upstream lakes and LWSC, inflow traces used in the model need to represent net inflow, which would be inflow from runoff

and direct precipitation less any evaporative losses. Accounting for evaporative losses is important, especially during the warmer months of involuntary drawdown when evaporative losses can equal or sometimes exceed inflow and result in periods of negative net inflow to the Lake Washington system. One advantage of a tool such as the current spreadsheet-based water budget model is that it can be used at the beginning of the period of involuntary drawdown to establish the CCC and then run at subsequent times throughout the drawdown period as the season progresses as a planning and management tool allowing alternative project operating scenarios to be evaluated. If the forecast shows a greater than 30 percent chance of end-of-period elevations falling below 16.75 feet (20 ft. COE), then the observed forebay elevation relative to the CCC should be closely monitored and conservation measures can be implemented as appropriate (initial and/or additional if previously enacted). The following sections summarize typical water use at the project and discuss available conservation measures for the various stages of drought as well as potential water savings of each.

Under normal operation Lake Washington is filled to a target forebay elevation of 18.75 feet (22.0 ft. COE) sometime in the spring (usually late May or early June) and maintained at that elevation for as long as possible. Involuntary drawdown begins once typical water demand at the project exceeds net inflow, which generally occurs in June or July. If the daily Lake Washington elevation stays at or above the CCC throughout involuntary drawdown, then no conservation measures beyond the Stage I measures are typically needed. The following guidance is provided for operation of the LWSC under normal conditions:

Normal Project Operations (no conservation measures enacted):

- Unrestricted operation of both lock chambers
- Spillway used as needed to manage lake level
- Old saltwater drain outlet operated as needed to manage salinity
- Fish attraction water in fish ladder at normal settings
- Smolt flumes operated as needed to provide adequate downstream fish passage

Table 7-6 presents the mean monthly water usage at the project over the most recent ten year period. While these values mostly reflect water demand over this period, actual demand for the smolt flumes is probably slightly higher than the values shown because some water conservation measures were enacted in several years during this period in response to spring/early summer drought conditions.

b Conservation Operation The lake level is held near the target full pool for as long as possible; then every reasonable effort is made to avoid drafting the lake below the Critical Content Curve. Four stages of water conservation, summarized on Table 7-7 and discussed in the following paragraphs, may be implemented, as indicated by the forebay elevation relative to the CCC, to limit the probability of the forebay falling below the CCC and markedly below the typical minimum of 16.75 feet (20.0 ft. COE). Before instituting any water conservation measures, the impacts of such measures must be weighed against the impacts of allowing the forebay to draft below 16.75 feet (20.0 ft. COE). For reference, the storage in one-tenth of a foot in the operating range of Lake Washington is approximately equal to 38 cfs-months. The four stages of conservation measures should be applied depending on the severity of the drought, with Stage I representing the lowest level of severity and Stage IV representing the highest level of

severity. Stage I measures represent best practices that should be applied every year regardless of the water supply situation, while Stage IV measures are intended for the most severe water shortage situation and would be expected to be applied infrequently (i.e., in less than 10 percent of all years).

TABLE 7-6
MEAN MONTHLY WATER DEMAND FOR
LAKE WASHINGTON SHIP CANAL PROJECT (2007-2016) [a]

Month	Lockages [b]	Fish Ladder [c]	Smolt Flumes	Total
JAN	33	183	0	216
FEB	33	183	0	216
MAR	51	183	0	234
APR	58	183	91	332
MAY	69	92	334	495
JUN	70	183	303	556
JUL	67	183	204	454
AUG	71	183	81	335
SEP	70	183	15	268
OCT	48	183	0	231
NOV	26	183	0	209
DEC	32	183	0	215

a. All flows are cfs continuous for the month.
Values are based on data recorded by project personnel on the daily water sheets and reflect actual, but not necessarily desired, water demand.
b. Lockage data are based on 2009-2016.
c. Fish ladder values are comprised of 23 cfs entering the upstream end of the fish ladder and 160 cfs provided by the salt water return system to the diffuser well. Lower values in May reflect annual 2-week shut-down of the ladder for maintenance.

(1) Stage I Stage I items are not specific to a drought situation but are instead items that should be implemented every year as part of the routine management of the project. These items reflect best practices that serve as a type of preventative maintenance that help to reduce the chances that more severe and/or restrictive conservation measures are required at a later time. Stage I items include filling the lake up to the maximum target elevation of 18.75 feet (22.0 ft. COE) every year and efficient use of both the small and large lock chambers. Filling the lake to the maximum elevation maximizes the amount of stored water available that can be used to meet project water demand, which is especially important during the period of involuntary drawdown when project demand exceeds net inflow. As such, it is important to have the lake at the maximum elevation at the time when involuntary drawdown commences. Efficient use of the lock chambers generally means showing a preference for using the small lock chamber whenever possible since this uses much less water relative to use of the large lock chamber.

(2) Stage II If all of Stage I measures have been implemented and the forebay elevation drops below the CCC and continues on a trajectory of continuing to fall further below the CCC for at least five to seven consecutive days, then Stage II conservation actions should be considered. The intended purpose of these measures is to slow the drop of the forebay elevation relative to the CCC and if possible bring the forebay elevation up to the CCC. Stage II measures include the following actions and potential water savings:

Close and/or minimize use of the old saltwater drain – This should be considered during a Stage II drought only if water quality data suggest minimal concern with elevated salinity in the LWSC and Lake Union. Water savings depend on how much the old drain is being used, but could result in up to about 160 cfs savings if it is fully open on a 24/7 basis prior to closure.

Decrease smolt flume usage – This should be considered only after consultation with Corps fisheries staff. Closing a smolt flume(s) or limiting operations to certain hours can potentially provide a significant water savings.

(3) Stage III Stage III water conservation measures should be implemented in a Phase III drought situation, defined as the forebay staying below the CCC for a period of greater than one week and with forecast models showing a high probability of the forebay dropping below elevation 16.75 feet (20.0 ft. COE). If the forebay elevation continues to fall further below the CCC, Stage III conservation actions should be implemented as necessary to mitigate further drafting below the CCC and to mitigate the potential for a significant drop in the forebay elevation below 16.75 feet (20.0 ft. COE) at a later time. Stage III measures are summarized in Table 7-7 and include the following actions and potential water savings:

Request a salinity waiver from the Washington Department of Ecology – This step involves requesting a waiver from the current standard of 1 ppt at the University Bridge. Possible waivers include requesting a change in the 1 ppt standard from a point measurement to a depth-averaged measurement or requesting a higher threshold. It is noted that a waiver was granted in 2014 to allow a depth-averaged standard of 1 ppt to be applied during water quality "false locking" experiments designed to intentionally allow cooler, saline water from Puget Sound to enter the LWSC to benefit the fishery. The amount of water saved from requesting a water quality variance from the WDOE will vary depending on multiple factors including the time of year and the spatial extent of salinity and potential to exceed the existing threshold, since these factors will help determine how much water could be saved by meeting a relaxed salinity standard.

Reduce flow to the fish ladder – This step would best be enacted in coordination with an approved salinity waiver from the WDOE and in consultation with Corps fisheries staff. The primary means of reducing water usage to the fish ladder is by reducing the amount of water discharged via the saltwater drain to the diffuser well, which is a primary source of fish attraction water. For example, closing the discharge to the diffuser well for 12 hours each day would save the equivalent of about 80 cfs, which over one month represents a volume of water equivalent to about a 0.2 foot elevation difference in the forebay level. Experience has shown that operating only the discharge to the diffuser well on a 12-hour cycle can result in a rapid increase in salinity concentrations in the LWSC and Lake Union, so water quality data should be monitored carefully if this measure is adopted.

Fully closing the smolt flumes – This should be considered only after consultation with Corps fisheries staff. In general, the potential impacts to fish will be lessened the later the date at which the flumes are fully closed (i.e., fully closing them in mid-July or later might not be much of an impact if juvenile downstream migration is low at that time). Real time monitoring of fish passage (i.e., PIT tags) can assist decision making. The amount of water saved will depend on the specific situation.

Minimize usage of the large locks and impose wait times for recreational boats – Continue to favor usage of the small lock to the extent possible when performing lockages. No mandatory lockage restrictions for commercial vessels, but impose wait times of up to one hour for recreational vessels in situations when the lock chamber is partially full and there is room for additional vessels. Water savings associated with imposing a wait time of up to one hour for recreational vessels will depend on the number of reduced lockages as a result of this action. A

reduction of one full large lockage per day saves the equivalent of about 10 cfs, a reduction of five small lockages per day saves the equivalent of about 3.5 cfs.

(4) Stage IV Stage IV water conservation should be considered only under the most extreme water shortage conditions, which is defined by conditions when the forebay has fallen below elevation 16.75 feet (20.0 ft. COE) and is expected to drop below elevation 16.25 feet (19.50 ft. COE). Early and continuous coordination with all affected agencies is imperative. Stage IV conservation actions should be implemented as necessary to mitigate the potential for the forebay to drop below elevation 16.25 feet (19.5 ft. COE). Stage IV measures are summarized in Table 7-7 and include the following actions and potential water savings:

Maximize usage of the small locks and impose wait times for all vessels except emergency vessels – Continue to favor usage of the small lock to the extent possible when performing lockages. Impose mandatory lockage restrictions for all vessels with the exception of emergency vessels. Water savings associated with imposing lockage restrictions will depend on the number of reduced lockages as a result of this action.

Confer with Seattle Public Utilities regarding increasing flows in the Cedar River – In a Stage IV drought Corps Water Management staff should be engaged with the appropriate Seattle Public Utilities (SPU) staff to keep them apprised of Lake Washington water level forecasts and associated concerns. Corps staff should also confer with SPU staff about changes in their operations that could increase Cedar River flows. It is the opinion of the Corps that the City of Seattle is obligated to provide Cedar River flows at least equivalent to the natural (unregulated) flow in the river. The Corps' opinion on this matter is based on the Commerce clause in the U.S. Constitution, specifically Article 1, Section 8, Clause 3. Although the present withdrawal of

water from the Cedar River is upstream of the point it has been determined to be navigable, if impairment thereby results to navigation in Lake Washington and its interconnection with Puget Sound, it is considered that such withdrawal is subject to federal control.

Further reduce or shut-off flow to the fish ladder – This step would best be enacted in coordination with an approved salinity waiver from the WDOE and in consultation with Corps fisheries staff. Completely shutting off flow to the fish ladder would save a total of 183 cfs compared with full discharge to the fish ladder. However, the benefits of such savings should be carefully balanced with potential impacts such as the reduction in upstream fish passage and the elimination of saltwater drain flow and related water quality (i.e., salinity) impacts. Complete shut-down of the fish ladder would be expected to have a significant impact on salinity concentrations in the LWSC and Lake Union, so water quality data should be monitored carefully if this measure is adopted.

Implement administrative procedures – These mostly would consist of issuing news releases, press releases, and notifications to key stakeholder groups advising of impacts related to a Stage IV drought such as significant delays in boating traffic, reduction in fish attraction flow, and potential for lake elevations below the normal minimum operating range. Implementing administrative procedures does not result in any conservation of water but serves to inform the public and stakeholders of the consequences associated with these actions.

7.13 Flood Emergency Action Plans In the event of a controllable or uncontrollable emergency which could present a significant hazard to life and/or property, the procedures outlined in the Project's emergency action plan, "Emergency Action Plan" (EAP) are to be followed. The EAP was prepared by the District's Dam Safety Section under the authority of

ER-1110-2-1156; Dam Safety – Policy and Procedures, and describes, "procedures and means for initiating emergency operations and repairs and notifying pertinent parties concerning an existing or potential emergency at the project." A copy of the EAP is maintained in the Reservoir Control Center. Specifically, the EAP is to be implemented in the following situations:

a Uncontrollable Emergency An uncontrollable emergency condition is one in which the occurrence of a significant hazard to life and/or property is certain to occur, and no time is available to repair and/or modify operational procedures to prevent dam failure.

b Controllable Emergency A controllable emergency condition is one not normally encountered in the routine operation of the dam, but one in which the occurrence of a significant hazard to life and/or property is possible unless timely repairs and/or modifications to operational procedures are conducted. Time must be available to eliminate the condition in order for the condition to be declared controllable.

c Post-Earthquake Condition If an earthquake is felt at the dam, a post-earthquake condition exists and a project inspection is required.

d Security Alert A security alert relates to incidents at a project which could threaten the safety of the project.

The EAP describes procedures and means of initiating operation, repairs, and notifying pertinent parties of the hazard. The procedures have been coordinated with Corps elements and relevant non-Corps authorities and are updated periodically. Their prompt use is essential for minimizing hazards to affected life and property.

7.14 Other There are no other features of the water control plan.

7.15 Deviation from Normal Regulation Some deviation from normal operation and regulation can be expected during construction or maintenance periods. These deviations are typically not expected to alter operations related to the desired lake level, but instead are expected to represent deviations in terms of specific project operations, such as lockage restrictions or outages, deviation in fish passage operations, or changes in spill pattern or timing to facilitate maintenance or construction work. Any such deviations will be considered on a case by case basis. With the exception of minor deviations or deviations in an emergency situation, requested deviations from the Water Control Manual must be approved in advance by NWD per the protocol outlined in NWDR 1110-2-6.

7.16 Rate of Release Change There are no formal rate of release limits for the project, which applies to situations in which project discharge is being increased or decreased. Because the project tailwater elevation is controlled by the tidal cycle, changes in project discharge generally have an insignificant effect on the tailwater elevation. Notwithstanding the lack of formal release rate limits, discharge changes at the project should be made in a manner that is consistent with operating rules and regulations required for the purpose of protecting the dam and critical project features from damage.

SECTION 8. EFFECTS OF WATER CONTROL PLAN

8.01 General The LWSC provides a navigable waterway between Puget Sound and the inland waters of Seattle, Washington, supports an important anadromous fishery, and provides an element of flood protection to the upstream water bodies in terms of buffering lake level rises during storm events. The effect of the LWSC on these uses, based on procedures described in the Water Control Plan in Section 7, is discussed in the following paragraphs.

8.02 Flood Control Some observed and hypothetical events are discussed in this section.

a Spillway Design Flood (SDF) The SDF was not derived prior to construction of the LWSC. In 1983, H&H Branch derived a preliminary and unapproved SDF. Preliminary results from the 1983 SDF indicated that the maximum peak discharge of the SDF inflow to the LWSC (assuming a coincident failure of the Masonry Dam on the upper Cedar Basin) was 143,000 cfs, generated from a surface runoff of 23.1 inches over a 10 day period (subsequent completed dam safety work provided an emergency spillway on the Masonry Dam to pass the SDF). It appears likely that the probable maximum precipitation for this SDF was developed utilizing Hydrometeorological Report 43 (HMR 43).

An effort was completed in 2013 to update the Probable Maximum Flood (PMF) for the project utilizing guidance in Hydrometeorological Report 57 (HMR 57). The cumulative inflow hydrograph to Lake Washington resulted in a PMF with a peak flow of about 89,900 cfs with a volume equivalent to about 19.8 inches of runoff. This is a reduction of about 14 percent of the volume presented in the 1983 study, which is comparable to the expected reduction of 20 percent in the PMP precipitation due to the use of the updated HMR 57.

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(20.06 ft. COE) to a maximum of 17.34 feet (20.59 ft. COE) during the event. The six spill gates were opened to about 5 feet each during the maximum inflow.

(2) November 1990 The November 1990 event is another well-known flood event. This is when the old Interstate 90 floating bridge sank during refurbishing. The annual probability of occurrence was previously estimated from gages on the Cedar River at about 2 percent. The water surface elevation at the forebay went from 16.86 feet (20.11 ft. COE) on November 24th to a maximum of 17.03 feet (20.28 ft. COE) on November 26th. On November 24th, the spill gates were opened to nearly their maximum position which exceeded the water surface.

(3) February 1996 The February 1996 event was the result of a major atmospheric river event that impacted much of Western Washington. Heavy rainfall associated with the event occurred from February 6-9, resulting in a rise in the forebay from 16.96 feet (20.21 ft. COE) on February 6 to 17.31 feet (20.56 ft. COE) on February 9. Maximum outflow from the project reached 13,400 cfs, which appears to be the highest outflow of record from the project.

8.03 Recreation The main impact to recreational boaters on the LWSC is during water conservation periods, when space is more carefully utilized during use of the large lock (vessels are consolidated) and there is a preference for using the small lock. Delays to recreational boaters are primarily an inconvenience under Stage III restrictions and become more severe under Stage IV restrictions, with additional impacts to moorage patterns in situations when the forebay falls below the typical minimum operating elevation of 16.75 feet (20.0 ft. COE).

Residential and commercial properties may be subject to some degree of distress when the LWSC is at or very nearly at full pool (18.75 feet) or when drafted below 16.75 feet (20.0 ft. COE). When the lake is high, wind alone or in conjunction with low barometric pressure may

cause wave damage to waterfront property. Conversely, many homes and businesses have been constructed to assume a minimum lake (forebay) elevation of 16.75 feet (20.0 ft. COE), such that a drop below that elevation could cause impacts such as houseboats or floating homes grounding, moorage slips becoming inaccessible, and commercial facilities having too shallow a draft clearance for normal barge operation.

8.04 Water Quality The primary water quality concern, from an operational standpoint, is salt water intrusion into the LWSC and Lake Union and potentially Lake Washington, which mostly is a concern during the summer/fall drawdown period. The primary operational technique for mitigating elevated salinity upstream of the project is use of the salt water drain, mostly by providing flow to the diffuser well in the fish ladder but alternatively as discharge via the old salt water drain. Experience suggests that in most years, maintaining a constant discharge to the diffuser well via the salt water drain is sufficient to adequately manage salt water intrusion upstream of the project and maintain water quality at the University Bridge within the WDOE water quality standard. Operating the salt water barrier to the extent possible during the primary period of concern (summer/fall drawdown period) also helps to manage salinity intrusion. From experience, if significant water savings are desired while providing some salinity management, the most effective technique available is to close the old salt water drain (if it is being used) and reduce flow via the salt water drain to the diffuser well. Flow reduction to the diffuser well can be achieved by either reducing the continuous flow to the diffuser well or shutting off flow completely based on a daily schedule (i.e., shutting off flow every night for 12 hours). However, in this scenario, upstream water quality should be monitored very carefully to track upstream salinity changes, which can occur relatively rapidly (i.e., time frame of as little as several days). Generally, during periods of low inflow and low

outflow, salt water will advance into the ship canal and towards Lake Washington. Therefore, precautions should be taken early enough to keep the main salt water wedge as close as possible to the locks for as long as possible.

8.05 Fish and Wildlife The Water Control Plan maintains fresh water flow (23 cfs) through the fish ladder year-round. Additionally, given the priority for operating the fish ladder to provide fish passage, fresh water flow should be maintained to the fish ladder even during water conservation to the extent possible, with the one possible exception being a Stage IV drought. The only routine time when flow is shut-off to the fish ladder is during routine annual maintenance when the fish ladder is dewatered, which generally occurs during the latter part of May. Any modifications to fish ladder operation should be coordinated through the Environmental and Cultural Resources Branch of the Seattle District. Recent revisions to the spill regime (see Section 7.03) are thought to improve attraction of fish to the fish ladder, but such improvement has not yet been documented. Under severe water shortage conditions, flow through the fish attraction diffusion pipe may be regulated but is accomplished to minimize impacts to migratory fish, i.e., flow reductions are effected at night when fish movement is greatly reduced or suspended. There are no known significant impacts of the Water Control Plan to wildlife.

8.06 Water Supply This section does not apply to the LWSC.

8.07 Hydroelectric Power This section does not apply to the LWSC.

8.08 Navigation Under normal operation, the Water Control Plan (WCP) provides for unrestricted use of the large and small locks 24 hours a day every day of the year. If water conservation activities are indicated per the WCP (Section 7) and/or Lake Washington falls

below elevation 16.75 feet (20 ft. COE), then varying and increasing degrees of impact to navigation and commerce will be realized. The only real impact to navigation and waterborne commerce while Lake Washington is above the normal minimum forebay elevation of 16.75 feet (20 ft. COE) is that a modest delay (up to one hour) would occur as a result of lockage consolidations (large lock) starting with Stage III conservation measures. This type of delay would not have a major economic impact. Considerable economic damages are expected to occur when the forebay falls below elevation 16.75 feet (20 ft. ft. COE) concurrent with potentially stringent lockage restrictions as a water conservation activity. In 1987, staff in the now defunct Seattle District Economics Section conducted a damage survey in response to a Lake Washington (forebay) minimum elevation of 16.19 feet (19.44 ft. COE) that year. Even though the magnitude of the cost of damages listed in this report are significantly dated, the report is included as Exhibit 8-1 as it contains a still relevant description of the type of damages that would occur as the forebay drops below the normal minimum operating limit.

8.09 Drought Contingency Plans This section contains a general description of actual operation of the LWSC during significant water shortages in 1987 and 2015, and a relatively normal year, 2011. The application of the WCP to each year's operation is summarized below, and the effects of that operation are evaluated. It is noted that application of the four stages of conservation has evolved over the years. For instance, in 1987 Stage I conservation measures were only applied once drought conditions started, whereas current practice is to apply the Stage I measures in all years regardless of drought status. Lowest annual forebay elevations from involuntary drawdown are given in Table 8-1.

a 1987 Conservation Season The summer and fall of 1987 brought one of the worst regional droughts on record including the lowest one-day flow at the Cedar River near Cedar Falls gaging

station. LWSC refill proceeded normally, however the May-September water supply outlook from the SCS indicated a below average snowpack and forecasted below average streamflows in the upper Cedar basin. There was no indication that Lake Washington inflows from sources outside of the Cedar River basin (i.e., Sammamish River, local tributaries) were abnormally low. On 30 May, the Seattle Water Department sent a letter to the Seattle District expressing concern about early snowpack depletion and the potential for water supply problems later. The City of Seattle requested that the Corps fill LWSC to elevation 18.75 feet (22.0 ft. COE), which was effected on 30 May based on corroborating forecasts by the Corps. This action placed the operation of the LWSC in Stage I conservation. In 1987, the spillway gates were sealed to minimize leakage between the bottom of the spill gates and the spillway crest. This conservation action started on 1 July, 1987, finished on 30 November, and saved an estimated 0.40 feet on the level of Lake Washington. Stage I conservation succeeded in decelerating the drawdown rate of the LWSC to less than the slope of the CCC. Permanent spill gate seals were subsequently installed in response to the 1987 drought. On 27 July, a conference call occurred among all interested agencies regarding water status on the Cedar River. After much debate, the City of Seattle lowered flows at the Cedar River at Renton to the WDOE Critical Minimum of 110 cfs on 5 August and instituted further conservation. This reduction of Renton flows for the foreseeable future prompted the initiation of Stage II conservation on 1 August by consolidating lockages and saving 10% of normal lockage water. Use of the end-of-month LWSC elevation forecast spreadsheet (discussed in Section 7.12) indicated that the LWSC would fall below the normal minimum elevation of 16.75 feet (20.0 ft. COE). This was supported by looking at the hydrologic status of the Upper Cedar which indicated switching to critical level within two weeks. On 5 August the old salt water drain was closed and remained closed through 15

September saving 0.45 feet on the level of Lake Washington. Mini-flushing was started on 4 September and continued through 16 October. This used an additional 0.20 feet of Lake Washington storage but retarded the salt wedge advance enough to allow Stage III conservation to begin later. In addition, the salt water wedge had advanced to the University Bridge and a water quality violation had occurred. On 21 September, the WDOE was notified, and they requested continued monitoring particularly in the entrance of the Montlake Cut. On 26 September, the elevation of LWSC fell below 16.75 feet (20 ft. COE). Seattle District staff felt that the conservation measures had been adequate up to that point and that some continued drafting could be expected even with additional conservation measures. The City of Seattle agreed to begin increasing the Cedar River flows at Renton from 110 cfs to 135 cfs on 1 October to encourage sockeye to move upstream. The City agreed on 8 October to continue to increase Renton flows gradually to 200 cfs by 31 October. By 16 October, concerns about upstream salinity had lessened dramatically. The old salt water drain was closed on 17 October through 04 November. This completed Stage II conservation.

TABLE 8-2
SUMMARY OF CONSERVATION ACTIVITIES FOR 1987

Activity	Dates	Savings [a]	Conservation Stage
Seal Spill Gates	1 Jul-30 Nov	0.40 feet	I
Fill to 18.75 Feet (22.0 COE)	1-Jun	0.15 feet	I
10% Lockage Reduction	1 Aug-30 Nov	0.10 feet	II
Close Old Salt Water Drain	5 Aug-15 Sep	0.45 feet	II
Close Old Salt Water Drain	17 Oct-4 Nov	0.18 feet	II
Mini-Flush	4 Sep-16 Oct	-.20 feet	II
Cycle Fish Attraction Diffusion Flow	5 Nov-30 Nov	0.20 feet	III
Total	1 Jun-30 Nov	1.28 feet	

a. Savings expressed as the equivalent impact to LWSC water level. A negative value indicates action resulted in a drop in water level of the reported amount.

Typically, after the end of September, the CCC is no longer used; however if continued drafting is experienced, as in 1987, then more conservation is usually required unless the drought is so severe that increased conservation activities, specifically further lockage restrictions, have more of an economic impact than increased drafting does. Yet, by 05 November, expected fall precipitation had not come and was not forecasted to arrive, and the October Inflow IV (defined as net inflow from all sources except from the Cedar River) was the second lowest of record. In addition, the upper Cedar index stream depicted extremely low conditions, and the City of Seattle began to decrease flows from 200 cfs to 170 cfs. The LWSC had seemed to stop drafting at 16.20 feet (19.45 ft. COE) temporarily. Because the salt situation had improved, Seattle District staff believed that stabilization of the LWSC could be achieved by closing the fish attraction diffusion flow for 12 hours at night. This plan was coordinated with WDOE, implemented from 05 November through 30 November, and carried a 100 cfs/month savings. This, along with a press release advising boaters of potential lockage delays, began Stage III conservation. After entering Stage III, the City of Seattle further reduced flows at Renton to 140 cfs for two weeks, however the conservation at the locks countered the Renton reduction enough to allow the LWSC to begin slowly filling. As the LWSC elevation continued to rise towards 16.75 feet (20 ft. COE), normal operation and releases were gradually restored.

Overall, the combined effect of the water conservation plan as applied in 1987 prevented the LWSC from drafting an additional 1.3 feet lower than the minimum of 16.19 feet (19.44 ft. COE) for that year. See Table 8-2 for a summary of conservation activities and their effect.

b 2011 Refill and Conservation Season 2011 was a relatively typical year for operations at the LWSC project from a water management standpoint. Snow pack in the Cedar River basin was close to average and spring inflows to Lake Washington from the Cedar River basin and other

inflow sources were within the normal range. A maximum forebay elevation of 18.72 feet (21.97 ft. COE) was reached in late June before involuntary drawdown of the lake commenced. Smolt flume usage commenced in mid-April with all flumes running continuously into mid-July before smolt flume usage was curtailed to conserve water per normal operations. The lake reached the mid-point of the normal operating range in mid-August, which is within the typical range of occurrence for this elevation. The lake reached a minimum elevation of 17.18 feet (20.43 ft. COE) in late September before intentional drawdown of the lake to the normal winter level occurred later in the fall. A normal lockage schedule and normal usage of the fish ladder persisted throughout the year with no need for restrictions to either for water conservation purposes. Upstream salinity did not pose an elevated concern, with maximum recorded salinity at the University Bridge well below the 1 ppt WDOE standard.

c 2015 Refill and Conservation Season 2015 presented multiple water management challenges, starting with inflows during the refill season at or near historic lows due to sparse mountain snow pack and an abnormally dry spring. Refill was intentionally more aggressive than typical during the spring, with the forebay getting to within 0.2 feet of target full pool by about April 20 and reaching a maximum elevation of 18.68 feet (21.93 ft. COE) on May 6. However, subsequent inflows were so low that involuntary drawdown began by mid-May, roughly one month earlier than normal. The lake reached the mid-point of the normal operating range at the end of June, roughly four to six weeks earlier than normal. Plate 8-1 shows a comparison of the CCC and the observed forebay elevations during 2015. The forebay elevation fell below the CCC by mid-May and stayed well under the CCC throughout the summer, with projections showing a very high probability of the forebay dropping below the normal minimum elevation in August and reaching a minimum in the range of 15.25 to 16.25 feet (18.5 to 19.5 ft.

COE), well below the typical range. Based on these projections, there was a high expectation that the lake would drop to its lowest level since 1987.

Conditions starting in mid to late May met the Stage III drought conditions, prompting adoption of several conservation measures, most notably significantly reduced usage of the smolt flumes, a preference for using the small lock while minimizing large lock usage, and wait times of up to one hour for passage of recreational vessels through the locks. It is estimated that reduced smolt flume usage saved a volume of water equivalent to 0.9 feet of lake level, while lockage restrictions saved a volume equivalent to about 0.1 feet of lake level. Even with these conservation measures enacted the lake dropped below the normal minimum elevation on August 24 and fell to elevation 16.69 feet (19.94 ft. COE) several days later before jumping above the normal minimum in late August in response to a significant summer rain event. Subsequent rain events in September were adequate to help to keep the forebay elevation hovering above the normal minimum elevation throughout September and into October. The enactment of water conservation measures in 2015 was therefore significant, with water savings limiting the drop in forebay to only 0.06 feet below the normal minimum elevation instead of a likely one foot drop below the minimum without conservation.

8.10 Flood Emergency Action Plans Following the procedures outlined in the EAP could reduce the threat to the project's structural integrity or reduce hazards to human life or property in the event of high flows (see Section 7.13). Copies of the project's emergency action plan, EMERGENCY ACTION PLAN, HIRAM M. CHITTENDEN LOCKS, LAKE WASHINGTON SHIP CANAL, are located at the LWSC project office and in the Northwest Division and Seattle District Reservoir Control Centers.

8.11 Frequencies A frequency analysis of annual peak daily discharge at the project was performed using outflow data for the period 1941-2007. HEC-SSP was used to perform the analysis using Bulletin 17B procedures. The analysis was intended to be illustrative rather than rigorous as the Bulletin 17B procedure is intended for unregulated flows and project outflows are regulated, although much of the time the project is regulated as a run-of-river system in which outflows are set approximately equivalent to inflows, especially during the period when peak annual inflows typically occur. Plate 8-2 shows the results of the frequency analysis. Additionally, Table 8-3 shows calculated peak mean daily outflow at the project for selected recurrence intervals.

TABLE 8-3
PEAK ANNUAL MEAN DAILY OUTFLOW AT THE LWSC PROJECT
(BASED ON HEC-SSP ANALYSIS)

Annual Probability of Occurrence	2 percent	1 percent	0.5 percent	0.2 percent
Calculated Peak Mean Daily Discharge (cfs)	13,382	14,684	15,987	17,723

8.12 Other Studies No other relevant studies are listed in this section.

SECTION 9. WATER CONTROL MANAGEMENT

9.01 Responsibilities and Organizations The Corps of Engineers is the owner and operator of the LWSC project, which is operated primarily to provide a navigable waterway between Puget Sound and Lakes Union and Washington. Congressional authorizations include responsibility for the Corps to operate projects under its jurisdiction for all authorized purposes. The Corps is responsible for regulation and for all continuing studies which will ensure the maximum sustained public benefit from project operation. Agency headquarters approved a Reservoir Control Center for the NWD in May 1968 and delegated responsibility for reservoir regulation activities in the NWD area to the Division Engineer. General guidelines for water management of the LWSC project are outlined in the NWDR 1165-2-2, Jan 2014 (Water Resource Policies and Authorities, Water Management Responsibilities). Additional details of the Corps' water management history and organization are provided in the report *Reservoir Control Center Guidance Memorandum,* U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon, January 1972. Reservoir regulation is a function of the Engineering Division, in accordance with EM 1110-2-3600, which has direct responsibility on all matters concerning regulation of water with regard to timing, quantity, and quality and is assigned to WMS. Project operation and maintenance activities are assigned to the Operations Division. The physical operation of project facilities to effect the regulation directed by WMS and the performance of maintenance are the responsibility of the Operations Project Manager. A CENWS organization chart is shown as Exhibit 9-1.

9.02 Interagency Coordination There are a number of agencies that collect data and/or provide information that is invaluable to the efficient and effective regulation of the LWSC

Project. Coordination of operation of the LWSC routinely occurs with agencies who provide information used in project regulation. Coordination for operation of the LWSC is required for water quality, lake level control during high runoff, refill, and summer low-flow periods (low lake level). Various combinations of agencies participate in a supporting role in coordination of LWSC operation. Those agencies and their function(s) are described below.

a City of Seattle The City built, owns, and operates the Masonry Dam in the upper Cedar River basin as part of the Cedar Falls project. The reservoir behind the Masonry Dam is called Chester Morse Reservoir and is used primarily for water supply (a small secondary pool called the Masonry Pool is formed when the reservoir is low). Power is generated somewhat continuously during the winter but less so during low flow periods when releases need to be made for downstream purposes. During a normal hydrologic year, the Corps relies on the Cedar River at Renton flow for a significant portion of the water needed to run the locks and associated facilities at normal use levels (i.e., without any conservation measures in place). Therefore, any changes in Cedar River operations that impact flows at Renton may have a direct effect on the operation of the LWSC. The City is responsible for appropriate quantity and timeliness of releases of water from Chester Morse Reservoir to meet downstream municipal and industrial water demands, to provide water necessary (whenever possible) for a variety of species of anadromous fish, and for water supply to Lake Washington.

b National Weather Service (NWS) The NWS collects and publishes data from a variety of stations within and near the Lake Washington basin (see Plate 4-1) which provide information which can be used in planning and scheduling water management decisions at the LWSC project. The NWS also produces a variety of weather and hydrologic forecast products that can be useful for planning water management decisions. Weather forecast information includes general

regional weather forecasts including text and map products and ten-day forecast products showing forecast daily maximum and minimum air temperature and forecast daily precipitation. The Seattle forecast office also issues quantitative precipitation forecasts (QPF's) once daily for selected sites within their forecast domain which provide forecast cumulative precipitation in six-hour increments for the upcoming 72-hour (3-day) period. Although these QPF's are of necessity generalized and not necessarily specific enough for direct application to the Lake Washington Basin, they are useful as a forecast tool especially related to the potential for very high rainfall and associated high inflows that could necessitate the need for increased spillway discharge from the project. Given the relatively coarse distribution of the QPF locations, QPF forecasts are used as indicators because of the potential for wide variations in precipitation distribution based upon storm track, topographic influences, storm type, etc.

c U.S. Geological Survey (USGS) The USGS has a water resources division which collects and processes water quality and quantity records for 17 stations in the Lake Washington basin. One of these stations (Cedar River at Renton) is supported by the Corps through the Cooperative Stream-gaging Program. Plate 4-1 displays the locations of the active and inactive USGS gages located within the basin. Data from the active stations are in most cases transmitted from the individual stations via GOES satellite telemetry on an hourly basis. Seattle District staff can access these data in near real-time either via the USGS real-time website or from the Corps' RWCDS database in situations where data from specific stations are collected via the District's DOMSAT system and routed to the RWCDS database. In addition to their regular periodic streamflow measurements to maintain stage discharge relationships, the USGS will, upon request from stakeholders including the Seattle District, make special measurements if a shift in the rating table is suspected. The USGS operates a State of Washington Water Science Center

which publishes streamflow, storage, and water quality data obtained from the data collection system. Administrative and maintenance services are provided by the State office in Tacoma, Washington (telephone 253-552-1600).

d Natural Resources Conservation Service (NRCS) The NRCS operates and maintains several automated SNOTEL sites within the Cedar River basin, which are used to track observations of snow depth, snow water equivalent, precipitation, and air temperature. These data are useful to track basin state within the Cedar River basin and are also used by the NRCS to generate volumetric forecasts of runoff for two locations within the Cedar River basin. These forecasts are generated on a monthly basis from January through June and provide volumetric runoff estimates for April through July and April through September. These forecasts assist the City in their project operation which may therefore influence inflows to Lake Washington and the District's operation of the LWSC.

e Washington State Department of Ecology (WDOE) The WDOE has established the water quality special criterion for the LWSC that the salt concentration of the water under the University Bridge (see Plate 5-2) cannot exceed one part per thousand (1 ppt). This criterion is set forth is WAC 173-201A-602. The Corps is obligated to meet this water quality standard and monitors the salt concentrations at various points along the LWSC to track the movement of the salt water wedge. If the concentration remains below 1 ppt at the University Bridge, no coordination with WDOE is required. If the salt concentration approaches or begins to exceed the 1 ppt limit, coordination with the WDOE is required to inform that agency of the situation, to propose a plan of action, and in some cases to request a variance of the water quality criterion. Coordination continues with the WDOE until the problem is resolved. It is noted that in 2014 a waiver of this salinity requirement was requested by the Seattle District to facilitate a series of

water quality experiments performed by the District as directed by the 2007 USFWS Biological Opinion. The objective of these experiments was to determine whether cooler water temperatures could be maintained upstream of the Locks to improve habitat conditions for salmonids. The experiments focused on operational changes at the Locks that resulted in introducing and retaining cooler, saline Puget Sound water in the LWSC. The waiver allowed a depth-averaged method (rather than a maximum instantaneous reading) to calculate the 1 ppt salinity limit at the University Bridge. During the 2014 experiments the maximum instantaneous recorded point concentration at the University Bridge station was 2.4 ppt salinity and the maximum depth averaged value was 0.79 ppt, which was less than the 1 ppt criterion in the waiver.

f Washington State Department of Fish and Wildlife (WDFW) The WDFW is a co-manager of fish and wildlife resources in the Lake Washington basin. This agency collects data and conducts studies to evaluate the effects of the LWSC project, exchanges information with the Corps, and makes recommendations on potentially beneficial changes in project regulation.

g NOAA's National Marine Fisheries Service (NOAA Fisheries) The NOAA Fisheries Service is part of the National Oceanic and Atmospheric Administration (NOAA). NOAA Fisheries administers NOAA's programs that support domestic and international conservation and management of living marine resources. It provides services and products to support domestic and international fisheries management operations, fisheries development, trade and industry assistance activities, enforcement, protected species and habitat conservation operations, and the scientific and technical aspects of NOAA's marine fisheries. NOAA Fisheries' Northwest Region is responsible for marine and anadromous fishes under the Endangered Species Act. Two species under NOAA's jurisdiction, the Chinook salmon and steelhead, are

found in the Lake Washington basin and are listed as threatened species. NOAA Fisheries completed a biological opinion (Opinion) in 2008 that addresses effects of the LWSC project operations on Chinook salmon and steelhead in accordance with Section 7 of the Endangered Species Act. The Opinion expired in 2013. The Corps continues to operate consistent with the Opinion, to the extent possible, until a new Opinion is completed.

h U.S. Fish and Wildlife Service (USFWS) The USFWS is the Federal agency primarily responsible for ensuring, at the Federal level, the conservation and management of the nation's wild birds, mammals, and fishes, both for their recreational and their economic values. The regional office is located in Portland, Oregon. Included in the major program areas of the USFWS are: technical assistance to federal, state, and private organizations in the development and administration of fish and wildlife management programs; administration and operation of a national system of fish hatcheries engaged in the propagation and distribution of sport fish; and cooperation with other federal and non-federal agencies engaged in water resource development projects to determine the effects of such projects on fish and wildlife resources and recommending measures for the protection and improvement of these resources. It manages one ESA listed species found in the Lake Washington basin, the bull trout. The USFWS completed a biological opinion (Opinion) in 2007 that addresses effects of the LWSC project operations on bull trout in accordance with Section 7 of the Endangered Species Act. The Opinion expired in 2012. The Corps continues to operate consistent with the Opinion, to the extent possible, until a new Opinion is completed.

i Muckleshoot Indian Tribe The Muckleshoot Indian Tribe has treaty fishing rights in the Lake Washington basin. The tribe, along with WDFW and the Suquamish Tribe, are co-managers for fish and wildlife resources in the Lake Washington basin. The tribe conducts

monitoring and fisheries related activities in and around the Locks facility. Fisheries activity occurs upstream of the dam. Executive Order 13175 and policy directives issued by the Corps and the Department of Defense, requires preservation and protection of trust resources, and coordination and consultation with the tribe regarding possible impacts to treaty rights.

j Suquamish Indian Tribe The Suquamish Indian Tribe has treaty fishing rights in the Lake Washington basin. The tribe, along with WDFW and the Muckleshoot Tribe, are co-managers for fish and wildlife resources in the Lake Washington basin. The tribe conducts monitoring and fisheries related activities in and around the Locks facility. Fisheries activity occurs downstream of the dam. Executive Order 13175 and policy directives issued by the Corps and the Department of Defense, requires preservation and protection of trust resources, and coordination and consultation with the tribe regarding possible impacts to treaty rights.

9.03 Interagency Agreements Presently, there are no interagency agreements related to the operation of the LWSC project.

9.04 Commissions, River Authorities, Compacts, and Committees There are no commissions, river authorities, or compacts that directly apply to the LWSC project; however, information on the Cedar River Instream Flow Oversight Commission is provided here.

The City of Seattle is involved in the Cedar River Instream Flow Agreement (IFA), one of several agreements that establish the provisions of the Cedar River Watershed Habitat Conservation Plan. The IFA establishes an interagency body, the Cedar River Instream Flow Oversight Commission (IFC), to assist the City in carrying out its river management responsibilities. The IFC was first convened in 2000, and meets on average once per month to help manage the water resources in the Cedar River basin. The IFC is chaired by the City of

Seattle (Seattle Public Utilities) and in addition to the City consists of the following voting organizations: NOAA Fisheries Service, U.S. Fish and Wildlife Service, Washington State Department of Fish and Wildlife, Washington State Department of Ecology, and the Muckleshoot Indian Tribe. The Seattle District Corps participates in the IFC but is a non-voting member given that the Corps does not have a role in providing regulatory oversight of the Cedar River basin fishery. The focus of the IFC is to manage the Cedar River downstream of the Cedar Falls project for the benefit of fish. The IFC tracks fish activity in the river via spawning and related surveys, makes recommendations related to flow management decisions including the release of stored water in Chester Morse Reservoir to provide blocks of supplemental water for fish, and helps to guide the development and implementation of supplemental biological studies and other technical analyses that are intended to inform their management recommendations.

9.05 Non-Federal Hydropower This section does not apply to the LWSC project as there is no installed hydropower at the project.

9.06 Reports LWSC project staff prepare a daily report which summarizes water management related activities at the project and focuses on operations which result in the discharge of water from the project. This report is prepared daily year-round including weekends and holidays. The report summarizes operations for a 24-hour period ending at midnight and includes information regarding the timing of each lockage performed for both the small and large lock chamber, the status of the salt water drain and fish ladder, and the status of project spill gates including specifics regarding gate openings and the timing of any changes to gate openings. This information was historically recorded on a paper form and faxed to Water Management staff for archiving. However, starting in 2014, an online application was implemented by District staff to allow LWSC project staff to enter the data online and archive

the data to the District's RWCDS database. Once the data are entered to the database, automated calculations are performed to calculate a variety of time-series including total project outflow as well as total inflow to the entire upstream water body (Lakes Washington, Union, and the LWSC).

LAKE WASHINGTON SHIP CANAL

SEATTLE, WA

WATER CONTROL MANUAL

SUPPLEMENTAL TABLES

TABLE 1-1
PERTINENT REPORTS AND DESIGN MEMORANDA

Title	Date Submitted	Date Approved
Design Memorandum No. 1, Lock Control Modernization, Centralized Control	31 Jan 1966	13 Jul 1966
Design Memorandum No. 2, Lock Control Modernization, Downstream Waiting Pier	31 Jan 1966	14 Jul 1966
Design Memorandum No. 3, Fish Ladder Rehabilitation	31 Aug 1972	04 Oct 1972
Design Memorandum No. 4, Electrical Distribution Rehabilitation	02 Oct 1973	07 Feb 1974
Design Memorandum No. 5, Large Lock Downstream Miter Gate Rehabilitation	15 Sep 1977	17 Oct 1977
Design Memorandum No. 6, Entryway Development	20 Sep 1979	14 Jan 1980
General Design Memorandum No. 7, Emergency Closure System - Major Rehabilitation Program Supplement 1	16 Dec 1981 20 May 1982	20 Jan 1982 30 Jun 1982
Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, Washington, 1969 Periodic Inspection and Continuing Evaluation Report	Jan 1970	
Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, Washington, Periodic Inspection Report No. 2	Apr 1975	
Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, Washington, Periodic Inspection Report No. 3	29 Jul 1980	14 Aug 1980
Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, Washington, Periodic Inspection Report No. 4, 28 February 1985	Sep 1985	
Lake Washington Ship Canal and Hiram M. Chittenden Locks - Operation and Maintenance Manual	Issued Jul 1972 Revised Sep 1976	
Lake Washington Ship Canal, Master Plan (Design Memo 5)	Apr 1977	
General Report, Flood Emergency Plan, Hiram M. Chittenden Locks and Dam, Lake Washington Ship Canal	Jul 1984	
Emergency Action and Notification Subplan, Flood Emergency Plan, Hiram M. Chittenden Locks and Dam, Lake Washington Ship Canal	Jun 1987	
Lake Washington Basin Runoff Model, Northwest Hydraulic Consultants, Work Order No.3, Contract DACW67-87-D-0030	Jul 1987	

Title	Date Submitted	Date Approved
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Physical Security and National Emergency Preparedness Manual for Lake Washington Ship Canal	Mar 1988	
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Lake Washington Ship Canal, Master Plan (Design Memo 9)	Feb 1994	
Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, Washington, Periodic Inspection Report No. 7	Mar 1994	
Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, Washington, Periodic Inspection Report No. 8	Sep 1997	
Lake Washington Ship Canal Smolt Passage Section 1135 Restoration Project	May 1999	
Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, Washington, Periodic Inspection Report No. 9	2002	
Documentation for Re-Screening for Dam WA000301 – Chittenden Locks and Dam, Seattle, WA	Issued Jul 2005 Revised 2010	
Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, Washington, Periodic Inspection Report No. 10	Nov 2007	
Emergency Action and Notification Subplan, Flood Emergency Plan, Hiram M. Chittenden Locks and Dam, Lake Washington Ship Canal	Mar 2009	
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Title	Date Submitted	Date Approved
Lake Washington Ship Canal, Hiram M. Chittenden Locks, Seattle, Washington, Periodic Inspection Report No. 11	Nov 2012	
Dam Safety Analysis of Spillway Capacity Under Conditions of Probable Maximum Flood, Lake Washington Ship Canal and Hiram M. Chittenden Locks, WEST Consultants, Contract W9128F-09-D-0002	Sep 2013	

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
11.75	**15.0**	0	221	442	664	885	1107	1329	1550	1772	1993
		22150	22151	22153	22155	22157	22158	22160	22162	22164	22166
11.85	**15.1**	2215	2437	2658	2880	3102	3324	3545	3767	3989	4211
		22167	22169	22171	22173	22175	22176	22178	22180	22182	22184
11.95	**15.2**	4433	4655	4876	5098	5320	5542	5764	5986	6208	6430
		22185	22187	22189	22191	22192	22194	22196	22198	22200	22201
12.05	**15.3**	6652	6874	7096	7318	7540	7763	7985	8207	8429	8651
		22203	22205	22207	22209	22210	22212	22214	22216	22218	22219
12.15	**15.4**	8874	9096	9318	9540	9762	9985	10207	10429	10652	10874
		22221	22223	22225	22226	22228	22230	22232	22234	22235	22237
12.25	**15.5**	11097	11319	11541	11764	11986	12209	12431	12654	12876	13099
		22239	22241	22243	22244	22246	22248	22250	22252	22253	22255
12.35	**15.6**	13321	13544	13767	13989	14212	14435	14657	14880	15103	15325
		22257	22259	22261	22262	22264	22266	22268	22270	22271	22273
12.45	**15.7**	15548	15771	15994	16216	16439	16662	16885	17108	17331	17554
		22275	22277	22279	22280	22282	22284	22286	22287	22289	22291
12.55	**15.8**	17777	17999	18222	18445	18668	18891	19114	19337	19560	19784
		22293	22295	22296	22298	22300	22302	22304	22305	22307	22309
12.65	**15.9**	20007	20230	20453	20676	20899	21123	21346	21569	21792	22015
		22311	22313	22314	22316	22318	22320	22322	22323	22325	22327
12.75	**16.0**	22239	22462	22685	22909	23132	23355	23579	23802	24026	24249
		22329	22331	22332	22334	22336	22338	22340	22341	22343	22345
12.85	**16.1**	24473	24696	24920	25143	25367	25590	25814	26037	26261	26485
		22347	22349	22350	22352	22354	22356	22358	22359	22361	22363

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet)									
		Area (Acres)									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
12.95	**16.2**	26708	26932	27156	27379	27603	27827	28050	28274	28498	28722
		22365	22367	22368	22370	22372	22374	22376	22377	22379	22381
13.05	**16.3**	28946	29169	29393	29617	29841	30065	30289	30513	30737	30961
		22383	22384	22386	22388	22390	22392	22393	22395	22397	22399
13.15	**16.4**	31185	31409	31633	31857	32081	32305	32529	32753	32978	33202
		22401	22402	22404	22406	22408	22410	22411	22413	22415	22417
13.25	**16.5**	33426	33650	33874	34099	34323	34547	34771	34996	35220	35444
		22419	22420	22422	22424	22426	22428	22429	22431	22433	22435
13.35	**16.6**	35669	35893	36118	36342	36566	36791	37015	37240	37464	37689
		22437	22438	22440	22442	22444	22446	22447	22449	22451	22453
13.45	**16.7**	37913	38138	38363	38587	38812	39036	39261	39486	39710	39935
		22455	22457	22458	22460	22462	22464	22466	22467	22469	22471
13.55	**16.8**	40160	40385	40609	40834	41059	41284	41509	41733	41958	42183
		22473	22475	22476	22478	22480	22482	22484	22485	22487	22489
13.65	**16.9**	42408	42633	42858	43083	43308	43533	43758	43983	44208	44433
		22491	22493	22494	22496	22498	22500	22502	22503	22505	22507
13.75	**17.0**	44658	44883	45108	45334	45559	45784	46009	46234	46459	46685
		22509	22511	22512	22514	22516	22518	22520	22521	22523	22525
13.85	**17.1**	46910	47135	47360	47586	47811	48037	48262	48487	48713	48938
		22527	22529	22530	22532	22534	22536	22538	22539	22541	22543
13.95	**17.2**	49164	49389	49615	49840	50066	50291	50517	50742	50968	51193
		22545	22547	22548	22550	22552	22554	22556	22558	22559	22561
14.05	**17.3**	51419	51645	51870	52096	52322	52547	52773	52999	53225	53450
		22563	22565	22567	22568	22570	22572	22574	22576	22577	22579
14.15	**17.4**	53676	53902	54128	54354	54580	54806	55031	55257	55483	55709
		22581	22583	22585	22586	22588	22590	22592	22594	22595	22597

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet)									
		Area (Acres)									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
14.25	**17.5**	55935	56161	56387	56613	56840	57065	57292	57518	57744	57970
		22599	22601	22603	22604	22606	22608	22610	22612	22614	22615
14.35	**17.6**	58196	58422	58649	58875	59101	59327	59554	59780	60006	60233
		22617	22619	22621	22623	22624	22626	22628	22630	22632	22633
14.45	**17.7**	60459	60685	60912	61138	61364	61591	61817	62044	62270	62497
		22635	22637	22639	22641	22642	22644	22646	22648	22650	22651
14.55	**17.8**	62723	62950	63176	63403	63630	63856	64083	64310	64536	64763
		22653	22655	22657	22659	22661	22662	22664	22666	22668	22670
14.65	**17.9**	64990	65216	65443	65670	65897	66124	66350	66577	66804	67031
		22671	22673	22675	22677	22679	22680	22682	22684	22686	22688
14.75	**18.0**	67258	67485	67712	67939	68166	68393	68620	68847	69074	69301
		22690	22691	22693	22694	22696	22698	22699	22701	22703	22704
14.85	**18.1**	69528	69755	69982	70209	70436	70663	70890	71117	71345	71572
		22706	22707	22709	22711	22712	22714	22716	22717	22719	22721
14.95	**18.2**	71799	72026	72253	72481	72708	72935	73163	73390	73617	73845
		22722	22724	22725	22727	22729	22730	22732	22734	22735	22737
15.05	**18.3**	74072	74299	74527	74754	74982	75209	75437	75664	75892	76119
		22739	22740	22742	22743	22745	22747	22748	22750	22752	22753
15.15	**18.4**	76347	76574	76802	77030	77257	77485	77713	77940	78168	78396
		22755	22757	22758	22760	22761	22763	22765	22766	22768	22770
15.25	**18.5**	78623	78851	79079	79306	79534	79762	79990	80218	80446	80673
		22771	22773	22775	22776	22778	22779	22781	22783	22784	22786
15.35	**18.6**	80901	81129	81357	81585	81813	82041	82269	82497	82725	82953
		22788	22789	22791	22793	22794	22796	22798	22799	22801	22802
15.45	**18.7**	83181	83409	83637	83865	84093	84321	84549	84778	85006	85234
		22804	22806	22807	22809	22811	22812	22814	22816	22817	22819

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
15.55	**18.8**	85462	85690	85919	86147	86375	86603	86832	87060	87288	87517
		22820	22822	22824	22825	22827	22829	22830	22832	22834	22835
15.65	**18.9**	87745	87974	88202	88430	88659	88887	89116	89344	89573	89801
		22837	22838	22840	22842	22843	22845	22847	22848	22850	22852
15.75	**19.0**	90030	90258	90487	90715	90944	91173	91401	91630	91859	92087
		22853	22855	22857	22858	22860	22861	22863	22865	22866	22868
15.85	**19.1**	92316	92545	92773	93002	93231	93460	93688	93917	94146	94375
		22870	22871	22873	22875	22876	22878	22880	22881	22883	22884
15.95	**19.2**	94604	94833	95061	95290	95519	95748	95977	96206	96435	96664
		22886	22888	22889	22891	22893	22894	22896	22898	22899	22901
16.05	**19.3**	96893	97122	97351	97580	97809	98039	98268	98497	98726	98955
		22902	22904	22906	22907	22909	22911	22912	22914	22916	22917
16.15	**19.4**	99184	99414	99643	99872	100101	100331	100560	100789	101018	101248
		22919	22921	22922	22924	22925	22927	22929	22930	22932	22934
16.25	**19.5**	101477	101707	101936	102165	102395	102624	102854	103083	103312	103542
		22935	22937	22939	22940	22942	22944	22945	22947	22948	22950
16.35	**19.6**	103772	104001	104231	104460	104690	104919	105149	105379	105608	105838
		22952	22953	22955	22957	22958	22960	22962	22963	22965	22967
16.45	**19.7**	106068	106297	106527	106757	106986	107216	107446	107676	107906	108135
		22968	22970	22972	22973	22975	22976	22978	22980	22981	22983
16.55	**19.8**	108365	108595	108825	109055	109285	109515	109745	109975	110205	110435
		22985	22986	22988	22990	22991	22993	22995	22996	22998	22999
16.65	**19.9**	110665	110895	111125	111355	111585	111815	112045	112275	112505	112736
		23001	23003	23004	23006	23008	23009	23011	23013	23014	23016
16.75	**20.0**	112966	113196	113426	113656	113886	114117	114347	114577	114808	115038
		23018	23019	23021	23023	23024	23026	23027	23029	23031	23032

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		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
16.85	**20.1**	115268	115499	115729	115959	116190	116420	116651	116881	117112	117342
		23034	23036	23037	23039	23041	23042	23044	23046	23047	23049
16.95	**20.2**	117572	117803	118034	118264	118495	118725	118956	119187	119417	119648
		23051	23052	23054	23055	23057	23059	23060	23062	23064	23065
17.05	**20.3**	119878	120109	120340	120571	120801	121032	121263	121494	121724	121955
		23067	23069	23070	23072	23074	23075	23077	23079	23080	23082
17.15	**20.4**	122186	122417	122648	122879	123110	123340	123571	123802	124033	124264
		23083	23085	23087	23088	23090	23092	23093	23095	23097	23098
17.25	**20.5**	124495	124726	124957	125188	125419	125650	125882	126113	126344	126575
		23100	23102	23103	23105	23107	23108	23110	23112	23113	23115
17.35	**20.6**	126806	127037	127269	127500	127731	127962	128193	128425	128656	128887
		23116	23118	23120	23121	23123	23125	23126	23128	23130	23131
17.45	**20.7**	129119	129350	129581	129813	130044	130275	130507	130738	130970	131201
		23133	23135	23136	23138	23140	23141	23143	23145	23146	23148
17.55	**20.8**	131433	131664	131896	132128	132359	132591	132822	133054	133285	133517
		23149	23151	23153	23154	23156	23158	23159	23161	23163	23164
17.65	**20.9**	133749	133980	134212	134444	134676	134907	135139	135371	135603	135834
		23166	23168	23169	23171	23173	23174	23176	23178	23179	23181
17.75	**21.0**	136066	136298	136530	136762	136994	137226	137458	137690	137922	138154
		23183	23185	23188	23191	23194	23197	23199	23202	23205	23208
17.85	**21.1**	138386	138618	138850	139082	139315	139547	139779	140011	140244	140476
		23211	23213	23216	23219	23222	23225	23227	23230	23233	23236
17.95	**21.2**	140708	140941	141173	141406	141638	141871	142103	142336	142568	142801
		23239	23242	23244	23247	23250	23253	23256	23258	23261	23264
18.05	**21.3**	143034	143266	143499	143732	143965	144198	144430	144663	144896	145129
		23267	23270	23272	23275	23278	23281	23284	23287	23289	23292

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		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
18.15	**21.4**	145362	145595	145828	146061	146294	146527	146760	146993	147226	147460
		23295	23298	23301	23303	23306	23309	23312	23315	23318	23320
18.25	**21.5**	147693	147926	148159	148393	148626	148859	149093	149326	149560	149793
		23323	23326	23329	23332	23334	23337	23340	23343	23346	23349
18.35	**21.6**	150027	150260	150494	150727	150961	151195	151428	151662	151896	152130
		23351	23354	23357	23360	23363	23365	23368	23371	23374	23377
18.45	**21.7**	152363	152597	152831	153065	153299	153533	153767	154001	154235	154469
		23380	23382	23385	23388	23391	23394	23396	23399	23402	23405
18.55	**21.8**	154703	154937	155171	155405	155639	155873	156108	156342	156576	156811
		23408	23411	23413	23416	23419	23422	23425	23427	23430	23433
18.65	**21.9**	157045	157279	157514	157748	157983	158217	158452	158686	158921	159155
		23436	23439	23442	23444	23447	23450	23453	23456	23459	23461
18.75	**22.0**	159390	159625	159859	160094	160329	160564	160798	161033	161268	161503
		23464	23467	23470	23473	23476	23478	23481	23484	23487	23490
18.85	**22.1**	161738	161973	162208	162443	162678	162913	163148	163383	163618	163853
		23492	23495	23498	23501	23504	23507	23509	23512	23515	23518
18.95	**22.2**	164089	164324	164559	164794	165030	165265	165500	165736	165971	166207
		23521	23524	23526	23529	23532	23535	23538	23541	23543	23546
19.05	**22.3**	166442	166678	166913	167149	167384	167620	167856	168091	168327	168563
		23549	23552	23555	23558	23560	23563	23566	23569	23572	23575
19.15	**22.4**	168799	169034	169270	169506	169742	169978	170214	170450	170686	170922
		23577	23580	23583	23586	23589	23592	23594	23597	23600	23603
19.25	**22.5**	171158	171394	171630	171866	172102	172338	172575	172811	173047	173284
		23606	23609	23611	23614	23617	23620	23623	23626	23628	23631
19.35	**22.6**	173520	173756	173993	174229	174465	174702	174938	175175	175411	175648
		23634	23637	23640	23643	23645	23648	23651	23654	23657	23660

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ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
19.45	**22.7**	175885	176121	176358	176595	176831	177068	177305	177542	177779	178016
		23662	23665	23668	23671	23674	23677	23679	23682	23685	23688
19.55	**22.8**	178252	178489	178726	178963	179200	179437	179674	179911	180149	180386
		23691	23694	23696	23699	23702	23705	23708	23711	23714	23716
19.65	**22.9**	180623	180860	181097	181335	181572	181809	182047	182284	182521	182759
		23719	23722	23725	23728	23731	23733	23736	23739	23742	23745
19.75	**23.0**	182996	183234	183471	183709	183947	184184	184422	184659	184897	185135
		23748	23750	23753	23756	23759	23762	23765	23768	23770	23773
19.85	**23.1**	185373	185610	185848	186086	186324	186562	186800	187038	187276	187514
		23776	23779	23782	23785	23787	23790	23793	23796	23799	23802
19.95	**23.2**	187752	187990	188228	188466	188704	188942	189180	189419	189657	189895
		23804	23807	23810	23813	23816	23819	23822	23824	23827	23830
20.05	**23.3**	190134	190372	190610	190849	191087	191326	191564	191803	192041	192280
		23833	23836	23839	23842	23844	23847	23850	23853	23856	23859
20.15	**23.4**	192518	192757	192996	193234	193473	193712	193951	194189	194428	194667
		23861	23864	23867	23870	23873	23876	23879	23881	23884	23887
20.25	**23.5**	194906	195145	195384	195623	195862	196101	196340	196579	196818	197057
		23890	23893	23896	23898	23901	23904	23907	23910	23913	23916
20.35	**23.6**	197296	197536	197775	198014	198253	198493	198732	198971	199211	199450
		23918	23921	23924	23927	23930	23933	23936	23938	23941	23944
20.45	**23.7**	199690	199929	200169	200408	200648	200888	201127	201367	201607	201846
		23947	23950	23953	23956	23958	23961	23964	23967	23970	23973
20.55	**23.8**	202086	202326	202566	202805	203045	203285	203525	203765	204005	204245
		23976	23978	23981	23984	23987	23990	23993	23996	23998	24001
20.65	**23.9**	204485	204725	204965	205205	205446	205686	205926	206166	206406	206647
		24004	24007	24010	24013	24016	24018	24021	24024	24027	24030

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
20.75	**24.0**	206887	207127	207368	207608	207849	208089	208329	208570	208811	209051
		24033	24036	24038	24041	24044	24047	24050	24053	24056	24058
20.85	**24.1**	209292	209532	209773	210014	210254	210495	210736	210977	211218	211458
		24061	24064	24067	24070	24073	24076	24078	24081	24084	24087
20.95	**24.2**	211699	211940	212181	212422	212663	212904	213145	213386	213628	213869
		24090	24093	24096	24099	24101	24104	24107	24110	24113	24116
21.05	**24.3**	214110	214351	214592	214834	215075	215316	215558	215799	216040	216282
		24119	24121	24124	24127	24130	24133	24136	24139	24141	24144
21.15	**24.4**	216523	216765	217006	217248	217489	217731	217973	218214	218456	218698
		24147	24150	24153	24156	24159	24162	24164	24167	24170	24173
21.25	**24.5**	218939	219181	219423	219665	219907	220149	220390	220632	220874	221116
		24176	24179	24182	24185	24187	24190	24193	24196	24199	24202
21.35	**24.6**	221359	221601	221843	222085	222327	222569	222811	223054	223296	223538
		24205	24207	24210	24213	24216	24219	24222	24225	24228	24230
21.45	**24.7**	223780	224023	224265	224508	224750	224992	225235	225478	225720	225963
		24233	24236	24239	24242	24245	24248	24251	24253	24256	24259
21.55	**24.8**	226205	226448	226691	226933	227176	227419	227662	227904	228147	228390
		24262	24265	24268	24271	24274	24276	24279	24282	24285	24288
21.65	**24.9**	228633	228876	229119	229362	229605	229848	230091	230334	230577	230820
		24291	24294	24297	24299	24302	24305	24308	24311	24314	24317
21.75	**25.0**	231064	231307	231550	231793	232037	232280	232523	232767	233010	233253
		24320	24322	24325	24327	24330	24333	24335	24338	24340	24343
21.85	**25.1**	233497	233740	233984	234227	234471	234714	234958	235202	235445	235689
		24346	24348	24351	24353	24356	24359	24361	24364	24367	24369
21.95	**25.2**	235933	236176	236420	236664	236908	237152	237396	237639	237883	238127
		24372	24374	24377	24380	24382	24385	24387	24390	24393	24395

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet)									
		Area (Acres)									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
22.05	**25.3**	238371	238615	238859	239103	239347	239592	239836	240080	240324	240568
		24398	24401	24403	24406	24408	24411	24414	24416	24419	24421
22.15	**25.4**	240812	241057	241301	241545	241790	242034	242278	242523	242767	243012
		24424	24427	24429	24432	24435	24437	24440	24442	24445	24448
22.25	**25.5**	243256	243501	243745	243990	244235	244479	244724	244968	245213	245458
		24450	24453	24455	24458	24461	24463	24466	24469	24471	24474
22.35	**25.6**	245703	245947	246192	246437	246682	246927	247172	247417	247662	247907
		24476	24479	24482	24484	24487	24490	24492	24495	24497	24500
22.45	**25.7**	248152	248397	248642	248887	249132	249377	249622	249868	250113	250358
		24503	24505	24508	24511	24513	24516	24518	24521	24524	24526
22.55	**25.8**	250603	250849	251094	251339	251585	251830	252076	252321	252566	252812
		24529	24531	24534	24537	24539	24542	24545	24547	24550	24552
22.65	**25.9**	253058	253303	253549	253794	254040	254286	254531	254777	255023	255269
		24555	24558	24560	24563	24566	24568	24571	24573	24576	24579
22.75	**26.0**	255514	255760	256006	256252	256498	256744	256990	257236	257482	257728
		24581	24584	24587	24589	24592	24594	24597	24600	24602	24605
22.85	**26.1**	257974	258220	258466	258712	258959	259205	259451	259697	259943	260190
		24608	24610	24613	24615	24618	24621	24623	24626	24629	24631
22.95	**26.2**	260436	260682	260929	261175	261422	261668	261915	262161	262408	262654
		24634	24636	24639	24642	24644	24647	24650	24652	24655	24658
23.05	**26.3**	262901	263147	263394	263641	263887	264134	264381	264628	264875	265121
		24660	24663	24665	24668	24671	24673	24676	24679	24681	24684
23.15	**26.4**	265368	265615	265862	266109	266356	266603	266850	267097	267344	267591
		24686	24689	24692	24694	24697	24700	24702	24705	24707	24710
23.25	**26.5**	267838	268085	268333	268580	268827	269074	269321	269569	269816	270064
		24713	24715	24718	24721	24723	24726	24729	24731	24734	24736

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
23.35	**26.6**	270311	270558	270806	271053	271301	271548	271796	272043	272291	272539
		24739	24742	24744	24747	24750	24752	24755	24758	24760	24763
23.45	**26.7**	272786	273034	273282	273529	273777	274025	274273	274520	274768	275016
		24765	24768	24771	24773	24776	24779	24781	24784	24787	24789
23.55	**26.8**	275264	275512	275760	276008	276256	276504	276752	277000	277248	277496
		24792	24794	24797	24800	24802	24805	24808	24810	24813	24816
23.65	**26.9**	277745	277993	278241	278489	278738	278986	279234	279483	279731	279979
		24818	24821	24823	24826	24829	24831	24834	24837	24839	24842
23.75	**27.0**	280228	280476	280725	280973	281222	281470	281719	281968	282216	282465
		24845	24847	24850	24852	24855	24858	24860	24863	24866	24868
23.85	**27.1**	282714	282962	283211	283460	283709	283958	284206	284455	284704	284953
		24871	24874	24876	24879	24882	24884	24887	24889	24892	24895
23.95	**27.2**	285202	285451	285700	285949	286198	286447	286696	286946	287195	287444
		24897	24900	24903	24905	24908	24911	24913	24916	24919	24921
24.05	**27.3**	287693	287943	288192	288441	288691	288940	289189	289439	289688	289938
		24924	24926	24929	24932	24934	24937	24940	24942	24945	24948
24.15	**27.4**	290187	290437	290686	290936	291185	291435	291685	291934	292184	292434
		24950	24953	24956	24958	24961	24963	24966	24969	24971	24974
24.25	**27.5**	292683	292933	293183	293433	293683	293933	294183	294432	294682	294932
		24977	24979	24982	24985	24987	24990	24993	24995	24998	25001
24.35	**27.6**	295182	295433	295683	295933	296183	296433	296683	296933	297184	297434
		25003	25006	25008	25011	25014	25016	25019	25022	25024	25027
24.45	**27.7**	297684	297934	298185	298435	298686	298936	299186	299437	299688	299938
		25030	25032	25035	25038	25040	25043	25046	25048	25051	25053
24.55	**27.8**	300188	300439	300690	300940	301191	301442	301692	301943	302194	302445
		25056	25059	25061	25064	25067	25069	25072	25075	25077	25080

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet)									
		Area (Acres)									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
24.65	**27.9**	302696	302946	303197	303448	303699	303950	304201	304452	304703	304954
		25083	25085	25088	25091	25093	25096	25099	25101	25104	25107
24.75	**28.0**	305205	305456	305707	305959	306210	306461	306712	306964	307215	307466
		25109	25112	25114	25117	25120	25122	25125	25128	25130	25133
24.85	**28.1**	307717	307969	308220	308472	308723	308975	309226	309478	309729	309981
		25136	25138	25141	25144	25146	25149	25152	25154	25157	25160
24.95	**28.2**	310232	310484	310736	310988	311239	311491	311743	311994	312246	312498
		25162	25165	25168	25170	25173	25176	25178	25181	25184	25186
25.05	**28.3**	312750	313002	313254	313506	313758	314010	314262	314514	314766	315018
		25189	25191	25194	25197	25199	25202	25205	25207	25210	25213
25.15	**28.4**	315270	315523	315775	316027	316279	316531	316784	317036	317289	317541
		25215	25218	25221	25223	25226	25229	25231	25234	25237	25239
25.25	**28.5**	317793	318046	318298	318551	318803	319056	319308	319561	319814	320066
		25242	25245	25247	25250	25253	25255	25258	25261	25263	25266
25.35	**28.6**	320319	320572	320824	321077	321330	321583	321835	322088	322341	322594
		25269	25271	25274	25277	25279	25282	25285	25287	25290	25293
25.45	**28.7**	322847	323100	323353	323606	323859	324112	324365	324618	324872	325125
		25295	25298	25301	25303	25306	25309	25311	25314	25317	25319
25.55	**28.8**	325378	325631	325885	326138	326391	326644	326898	327151	327405	327658
		25322	25325	25327	25330	25333	25335	25338	25341	25343	25346
25.65	**28.9**	327912	328165	328419	328672	328926	329179	329433	329687	329940	330194
		25349	25351	25354	25357	25359	25362	25365	25367	25370	25373
25.75	**29.0**	330448	330702	330955	331209	331463	331717	331971	332225	332479	332733
		25375	25378	25381	25383	25386	25389	25391	25394	25397	25399
25.85	**29.1**	332987	333241	333495	333749	334003	334257	334511	334766	335020	335274
		25402	25405	25407	25410	25413	25415	25418	25421	25423	25426

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet)									
		Area (Acres)									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
25.95	**29.2**	335528	335783	336037	336291	336546	336800	337055	337309	337564	337818
		25429	25431	25434	25437	25439	25442	25445	25447	25450	25453
26.05	**29.3**	338073	338327	338582	338836	339091	339346	339600	339855	340110	340365
		25455	25458	25461	25463	25466	25469	25471	25474	25477	25479
26.15	**29.4**	340620	340874	341129	341384	341639	341894	342149	342404	342659	342914
		25482	25485	25487	25490	25493	25495	25498	25501	25503	25506
26.25	**29.5**	343169	343424	343679	343935	344190	344445	344700	344955	345211	345466
		25509	25511	25514	25517	25519	25522	25525	25527	25530	25533
26.35	**29.6**	345721	345977	346232	346488	346743	346999	347254	347509	347765	348021
		25535	25538	25541	25544	25546	25549	25552	25554	25557	25560
26.45	**29.7**	348276	348532	348788	349043	349299	349555	349811	350066	350322	350578
		25562	25565	25568	25570	25573	25576	25578	25581	25584	25586
26.55	**29.8**	350834	351090	351346	351602	351858	352114	352370	352626	352882	353138
		25589	25592	25594	25597	25600	25602	25605	25608	25610	25613
26.65	**29.9**	353394	353650	353907	354163	354419	354675	354932	355188	355444	355701
		25616	25618	25621	25624	25627	25629	25632	25635	25637	25640
26.75	**30.0**	355957	356214	356470	356727	356983	357240	357496	357753	358010	358266
		25643	25645	25648	25651	25653	25656	25659	25661	25664	25667
26.85	**30.1**	358523	358780	359036	359293	359550	359807	360064	360320	360577	360834
		25669	25672	25675	25677	25680	25683	25686	25688	25691	25694
26.95	**30.2**	361091	361348	361605	361862	362119	362376	362633	362891	363148	363405
		25696	25699	25702	25704	25707	25710	25712	25715	25718	25720
27.05	**30.3**	363662	363920	364177	364434	364691	364949	365206	365464	365721	365978
		25723	25726	25728	25731	25734	25737	25739	25742	25745	25747
27.15	**30.4**	366236	366494	366751	367009	367266	367524	367781	368039	368297	368555
		25750	25753	25755	25758	25761	25763	25766	25769	25771	25774

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
27.25	**30.5**	368812	369070	369328	369586	369844	370102	370360	370618	370875	371133
		25777	25780	25782	25785	25788	25790	25793	25796	25798	25801
27.35	**30.6**	371392	371650	371908	372166	372424	372682	372940	373198	373457	373715
		25804	25806	25809	25812	25815	25817	25820	25823	25825	25828
27.45	**30.7**	373973	374232	374490	374748	375007	375265	375524	375782	376041	376299
		25831	25833	25836	25839	25841	25844	25847	25849	25852	25855
27.55	**30.8**	376558	376816	377075	377334	377592	377851	378110	378368	378627	378886
		25858	25860	25863	25866	25868	25871	25874	25876	25879	25882
27.65	**30.9**	379145	379404	379663	379922	380181	380439	380698	380958	381217	381476
		25885	25887	25890	25893	25895	25898	25901	25903	25906	25909
27.75	**31.0**	381735	381994	382253	382512	382771	383031	383290	383549	383809	384068
		25911	25914	25917	25920	25922	25925	25928	25930	25933	25936
27.85	**31.1**	384327	384587	384846	385106	385365	385625	385884	386144	386403	386663
		25938	25941	25944	25946	25949	25952	25955	25957	25960	25963
27.95	**31.2**	386923	387182	387442	387702	387961	388221	388481	388741	389001	389261
		25965	25968	25971	25973	25976	25979	25982	25984	25987	25990
28.05	**31.3**	389520	389780	390040	390300	390560	390820	391080	391341	391601	391861
		25992	25995	25998	26000	26003	26006	26009	26011	26014	26017
28.15	**31.4**	392121	392381	392642	392902	393162	393422	393683	393943	394204	394464
		26019	26022	26025	26027	26030	26033	26036	26038	26041	26044
28.25	**31.5**	394725	394985	395246	395506	395767	396027	396288	396548	396809	397070
		26046	26049	26052	26054	26057	26060	26063	26065	26068	26071
28.35	**31.6**	397331	397591	397852	398113	398374	398635	398895	399156	399417	399678
		26073	26076	26079	26082	26084	26087	26090	26092	26095	26098
28.45	**31.7**	399939	400200	400461	400722	400984	401245	401506	401767	402028	402289
		26100	26103	26106	26109	26111	26114	26117	26119	26122	26125

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
28.55	**31.8**	402551	402812	403073	403335	403596	403857	404119	404380	404642	404903
		26128	26130	26132	26135	26137	26139	26142	26144	26146	26149
28.65	**31.9**	405165	405426	405688	405949	406211	406473	406734	406996	407258	407519
		26151	26153	26156	26158	26160	26163	26165	26167	26170	26172
28.75	**32.0**	407781	408043	408305	408566	408828	409090	409352	409614	409876	410138
		26174	26177	26179	26181	26184	26186	26188	26191	26193	26195
28.85	**32.1**	410400	410662	410924	411186	411448	411710	411972	412234	412496	412758
		26198	26200	26202	26205	26207	26209	26212	26214	26216	26219
28.95	**32.2**	413021	413283	413545	413807	414070	414332	414594	414857	415119	415381
		26221	26223	26226	26228	26230	26233	26235	26237	26240	26242
29.05	**32.3**	415644	415906	416169	416431	416694	416956	417219	417482	417744	418007
		26244	26247	26249	26251	26254	26256	26258	26261	26263	26265
29.15	**32.4**	418269	418532	418795	419058	419320	419583	419846	420109	420372	420635
		26268	26270	26272	26275	26277	26279	26282	26284	26286	26289
29.25	**32.5**	420897	421160	421423	421686	421949	422212	422475	422738	423001	423265
		26291	26293	26296	26298	26300	26303	26305	26307	26310	26312
29.35	**32.6**	423528	423791	424054	424317	424581	424844	425107	425370	425634	425897
		26315	26317	26319	26322	26324	26326	26329	26331	26333	26336
29.45	**32.7**	426160	426424	426687	426951	427214	427477	427741	428005	428268	428532
		26338	26340	26343	26345	26347	26350	26352	26354	26357	26359
29.55	**32.8**	428795	429059	429323	429586	429850	430114	430378	430641	430905	431169
		26361	26364	26366	26368	26371	26373	26375	26378	26380	26382
29.65	**32.9**	431433	431696	431960	432224	432488	432752	433016	433280	433544	433808
		26385	26387	26389	26392	26394	26397	26399	26401	26404	26406
29.75	**33.0**	434072	434336	434600	434865	435129	435393	435657	435922	436186	436450
		26408	26411	26413	26415	26418	26420	26422	26425	26427	26429

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet)									
		Area (Acres)									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
29.85	**33.1**	436714	436979	437243	437507	437772	438036	438301	438565	438830	439094
		26432	26434	26436	26439	26441	26443	26446	26448	26451	26453
29.95	**33.2**	439359	439623	439888	440152	440417	440682	440946	441211	441476	441741
		26455	26458	26460	26462	26465	26467	26469	26472	26474	26476
30.05	**33.3**	442005	442270	442535	442800	443065	443330	443594	443859	444125	444390
		26479	26481	26483	26486	26488	26490	26493	26495	26497	26500
30.15	**33.4**	444654	444919	445185	445450	445715	445980	446245	446510	446775	447041
		26502	26505	26507	26509	26512	26514	26516	26519	26521	26523
30.25	**33.5**	447306	447571	447836	448102	448367	448632	448898	449163	449429	449694
		26526	26528	26530	26533	26535	26537	26540	26542	26544	26547
30.35	**33.6**	449960	450225	450491	450756	451022	451287	451553	451819	452084	452350
		26549	26552	26554	26556	26559	26561	26563	26566	26568	26570
30.45	**33.7**	452616	452881	453147	453413	453679	453945	454211	454476	454742	455008
		26573	26575	26577	26580	26582	26584	26587	26589	26592	26594
30.55	**33.8**	455274	455540	455806	456072	456338	456604	456870	457136	457403	457669
		26596	26599	26601	26603	26606	26608	26610	26613	26615	26617
30.65	**33.9**	457935	458201	458467	458734	459000	459266	459533	459799	460065	460332
		26620	26622	26625	26627	26629	26632	26634	26636	26639	26641
30.75	**34.0**	460598	460865	461131	461398	461664	461931	462197	462464	462730	462997
		26643	26646	26648	26650	26653	26655	26658	26660	26662	26665
30.85	**34.1**	463264	463530	463797	464064	464331	464597	464864	465131	465398	465665
		26667	26669	26672	26674	26676	26679	26681	26683	26686	26688
30.95	**34.2**	465932	466198	466465	466732	466999	467266	467533	467800	468068	468335
		26691	26693	26695	26698	26700	26702	26705	26707	26709	26712
31.05	**34.3**	468602	468869	469136	469403	469670	469938	470205	470472	470740	471007
		26714	26716	26719	26721	26724	26726	26728	26731	26733	26735

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
31.15	**34.4**	471274	471542	471809	472077	472344	472612	472879	473147	473414	473682
		26738	26740	26742	26745	26747	26749	26752	26754	26757	26759
31.25	**34.5**	473949	474217	474485	474752	475020	475288	475556	475823	476091	476359
		26761	26764	26766	26768	26771	26773	26775	26778	26780	26783
31.35	**34.6**	476627	476894	477162	477430	477698	477966	478234	478502	478770	479038
		26785	26787	26790	26792	26794	26797	26799	26801	26804	26806
31.45	**34.7**	479306	479574	479843	480111	480379	480647	480915	481184	481452	481720
		26809	26811	26813	26816	26818	26820	26823	26825	26827	26830
31.55	**34.8**	481988	482257	482525	482793	483062	483330	483599	483867	484136	484404
		26832	26835	26837	26839	26842	26844	26846	26849	26851	26853
31.65	**34.9**	484673	484941	485210	485479	485747	486016	486285	486553	486822	487091
		26856	26858	26861	26863	26865	26868	26870	26872	26875	26877
31.75	**35.0**	487359	487628	487897	488166	488435	488704	488973	489242	489511	489780
		26880	26882	26884	26886	26889	26891	26893	26896	26898	26900
31.85	**35.1**	490049	490318	490587	490856	491125	491394	491663	491932	492202	492471
		26902	26905	26907	26909	26912	26914	26916	26919	26921	26923
31.95	**35.2**	492740	493009	493279	493548	493817	494087	494356	494625	494895	495164
		26925	26928	26930	26932	26935	26937	26939	26942	26944	26946
32.05	**35.3**	495434	495703	495973	496242	496512	496782	497051	497321	497590	497860
		26948	26951	26953	26955	26958	26960	26962	26965	26967	26969
32.15	**35.4**	498130	498399	498669	498939	499209	499479	499748	500018	500288	500558
		26971	26974	26976	26978	26981	26983	26985	26988	26990	26992
32.25	**35.5**	500828	501098	501368	501638	501908	502178	502448	502718	502988	503259
		26994	26997	26999	27001	27004	27006	27008	27011	27013	27015
32.35	**35.6**	503529	503799	504069	504339	504610	504880	505150	505420	505691	505961
		27017	27020	27022	27024	27027	27029	27031	27034	27036	27038

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
32.45	**35.7**	506232	506502	506772	507043	507313	507584	507854	508125	508396	508666
		27040	27043	27045	27047	27050	27052	27054	27057	27059	27061
32.55	**35.8**	508937	509207	509478	509749	510020	510290	510561	510832	511103	511373
		27063	27066	27068	27070	27073	27075	27077	27080	27082	27084
32.65	**35.9**	511644	511915	512186	512457	512728	512999	513270	513541	513812	514083
		27086	27089	27091	27093	27096	27098	27100	27103	27105	27107
32.75	**36.0**	514354	514625	514896	515167	515439	515710	515981	516252	516524	516795
		27110	27112	27114	27116	27119	27121	27123	27126	27128	27130
32.85	**36.1**	517066	517337	517609	517880	518152	518423	518695	518966	519238	519509
		27133	27135	27137	27140	27142	27144	27146	27149	27151	27153
32.95	**36.2**	519781	520052	520324	520595	520867	521139	521410	521682	521954	522226
		27156	27158	27160	27163	27165	27167	27170	27172	27174	27176
33.05	**36.3**	522497	522769	523041	523313	523585	523857	524129	524400	524673	524944
		27179	27181	27183	27186	27188	27190	27193	27195	27197	27200
33.15	**36.4**	525216	525488	525761	526033	526305	526577	526849	527121	527393	527666
		27202	27204	27206	27209	27211	27213	27216	27218	27220	27223
33.25	**36.5**	527938	528210	528482	528755	529027	529299	529572	529844	530117	530389
		27225	27227	27230	27232	27234	27236	27239	27241	27243	27246
33.35	**36.6**	530661	530934	531206	531479	531752	532024	532297	532569	532842	533115
		27248	27250	27253	27255	27257	27260	27262	27264	27267	27269
33.45	**36.7**	533387	533660	533933	534206	534478	534751	535024	535297	535570	535843
		27271	27273	27276	27278	27280	27283	27285	27287	27290	27292
33.55	**36.8**	536116	536389	536662	536935	537208	537481	537754	538027	538300	538573
		27294	27297	27299	27301	27304	27306	27308	27310	27313	27315
33.65	**36.9**	538846	539119	539393	539666	539939	540212	540486	540759	541032	541306
		27317	27320	27322	27324	27327	27329	27331	27334	27336	27338

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet)									
		Area (Acres)									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
33.75	**37.0**	541579	541852	542126	542399	542673	542946	543220	543494	543767	544041
		27341	27343	27345	27348	27350	27352	27354	27357	27359	27361
33.85	**37.1**	544314	544588	544862	545135	545409	545683	545957	546230	546504	546778
		27364	27366	27368	27371	27373	27375	27378	27380	27382	27385
33.95	**37.2**	547052	547326	547600	547874	548148	548422	548696	548970	549244	549518
		27387	27389	27392	27394	27396	27398	27401	27403	27405	27408
34.05	**37.3**	549792	550066	550340	550614	550888	551163	551437	551711	551985	552260
		27410	27412	27415	27417	27419	27422	27424	27426	27429	27431
34.15	**37.4**	552534	552808	553083	553357	553632	553906	554180	554455	554729	555004
		27433	27436	27438	27440	27443	27445	27447	27449	27452	27454
34.25	**37.5**	555278	555553	555828	556102	556377	556651	556926	557201	557476	557750
		27456	27459	27461	27463	27466	27468	27470	27473	27475	27477
34.35	**37.6**	558025	558300	558575	558850	559125	559399	559674	559949	560224	560499
		27480	27482	27484	27487	27489	27491	27494	27496	27498	27501
34.45	**37.7**	560774	561049	561325	561600	561875	562150	562425	562700	562975	563251
		27503	27505	27507	27510	27512	27514	27517	27519	27521	27524
34.55	**37.8**	563526	563801	564076	564352	564627	564902	565178	565453	565729	566004
		27526	27528	27531	27533	27535	27538	27540	27542	27545	27547
34.65	**37.9**	566280	566555	566831	567106	567382	567657	567933	568209	568484	568760
		27549	27552	27554	27556	27559	27561	27563	27566	27568	27570
34.75	**38.0**	569036	569311	569587	569863	570139	570415	570690	570966	571242	571518
		27573	27575	27577	27580	27582	27584	27587	27589	27591	27593
34.85	**38.1**	571794	572070	572346	572622	572898	573174	573450	573726	574003	574279
		27596	27598	27600	27603	27605	27607	27610	27612	27614	27617
34.95	**38.2**	574555	574831	575107	575384	575660	575936	576212	576489	576765	577042
		27619	27621	27624	27626	27628	27631	27633	27635	27638	27640

TABLE 2-1
ELEVATION – AREA – CAPACITY DATA

		Capacity (Acre-Feet) **Area (Acres)**									
Elev (ft) NAVD88	**Elev (ft) Corps Datum**	**0.00**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**	**0.07**	**0.08**	**0.09**
35.05	**38.3**	577318	577594	577871	578147	578424	578700	578977	579253	579530	579807
		27642	27645	27647	27649	27652	27654	27656	27659	27661	27663
35.15	**38.4**	580083	580360	580637	580913	581190	581467	581744	582020	582297	582574
		27666	27668	27670	27673	27675	27677	27680	27682	27684	27687
35.25	**38.5**	582851	583128	583405	583682	583959	584236	584513	584790	585067	585344
		27689	27691	27694	27696	27698	27701	27703	27705	27708	27710
35.35	**38.6**	585621	585898	586175	586453	586730	587007	587284	587562	587839	588116
		27712	27715	27717	27719	27722	27724	27726	27729	27731	27733
35.45	**38.7**	588393	588671	588948	589226	589503	589781	590058	590336	590613	590891
		27736	27738	27740	27743	27745	27747	27750	27752	27754	27757
35.55	**38.8**	591168	591446	591723	592001	592279	592557	592834	593112	593390	593668
		27759	27761	27764	27766	27768	27771	27773	27775	27778	27780
35.65	**38.9**	593945	594223	594501	594779	595057	595335	595613	595891	596169	596447
		27782	27785	27787	27789	27792	27794	27796	27799	27801	27803

TABLE 2-2
LARGE LOCK RATING TABLE, KCFS FOR 1 CULVERT

$$Q = CA\sqrt{2gH}$$

C= 0.47, A=108.5 ft^2 per culvert, H=(POOL ELEVATION TIDE)

POOL ELEVATION (FEET)

TIDE (FEET NAVD 88)	Corps Datum:	22.00	21.95	21.90	21.85	21.80	21.75	21.70	21.65	21.60	21.55	21.50	21.45	21.40	21.35	21.30	21.25	21.20	21.15	21.10	21.05	21.00	
	NAVD 88:	**18.75**	**18.70**	**18.65**	**18.60**	**18.55**	**18.50**	**18.45**	**18.40**	**18.35**	**18.30**	**18.25**	**18.20**	**18.15**	**18.10**	**18.05**	**18.00**	**17.95**	**17.90**	**17.85**	**17.80**	**17.75**	
-9.25		2.165	2.164	2.162	2.160	2.158	2.156	2.154	2.152	2.150	2.148	2.146	2.144	2.142	2.140	2.138	2.136	2.134	2.132	2.130	2.128	2.126	**-9.25**
-8.75		2.146	2.144	2.142	2.140	2.138	2.136	2.134	2.132	2.130	2.128	2.126	2.124	2.122	2.121	2.119	2.117	2.115	2.113	2.111	2.109	2.107	**-8.75**
-8.25		2.126	2.124	2.122	2.121	2.119	2.117	2.115	2.113	2.111	2.109	2.107	2.105	2.103	2.101	2.099	2.097	2.095	2.093	2.091	2.089	2.087	**-8.25**
-7.75		2.107	2.105	2.103	2.101	2.099	2.097	2.095	2.093	2.091	2.089	2.087	2.085	2.083	2.081	2.079	2.077	2.075	2.073	2.071	2.069	2.067	**-7.75**
-7.25		2.087	2.085	2.083	2.081	2.079	2.077	2.075	2.073	2.071	2.069	2.067	2.064	2.062	2.060	2.058	2.056	2.054	2.052	2.050	2.048	2.046	**-7.25**
-6.75		2.067	2.064	2.062	2.060	2.058	2.056	2.054	2.052	2.050	2.048	2.046	2.044	2.042	2.040	2.038	2.036	2.034	2.032	2.030	2.028	2.026	**-6.75**
-6.25		2.046	2.044	2.042	2.040	2.038	2.036	2.034	2.032	2.030	2.028	2.026	2.024	2.021	2.019	2.017	2.015	2.013	2.011	2.009	2.007	2.005	**-6.25**
-5.75		2.026	2.024	2.021	2.019	2.017	2.015	2.013	2.011	2.009	2.007	2.005	2.003	2.001	1.999	1.996	1.994	1.992	1.990	1.988	1.986	1.984	**-5.75**
-5.25		2.005	2.003	2.001	1.999	1.996	1.994	1.992	1.990	1.988	1.986	1.984	1.982	1.980	1.977	1.975	1.973	1.971	1.969	1.967	1.965	1.963	**-5.25**
-4.75		1.984	1.982	1.980	1.977	1.975	1.973	1.971	1.969	1.967	1.965	1.963	1.960	1.958	1.956	1.954	1.952	1.950	1.948	1.945	1.943	1.941	**-4.75**
-4.25		1.963	1.960	1.958	1.956	1.954	1.952	1.950	1.948	1.945	1.943	1.941	1.939	1.937	1.935	1.933	1.930	1.928	1.926	1.924	1.922	1.919	**-4.25**
-3.75		1.941	1.939	1.937	1.935	1.933	1.930	1.928	1.926	1.924	1.922	1.919	1.917	1.915	1.913	1.911	1.909	1.906	1.904	1.902	1.900	1.898	**-3.75**
-3.25		1.919	1.917	1.915	1.913	1.911	1.909	1.906	1.904	1.902	1.900	1.898	1.895	1.893	1.891	1.889	1.886	1.884	1.882	1.880	1.878	1.875	**-3.25**
-2.75		1.898	1.895	1.893	1.891	1.889	1.886	1.884	1.882	1.880	1.878	1.875	1.873	1.871	1.869	1.866	1.864	1.862	1.860	1.857	1.855	1.853	**-2.75**
-2.25		1.875	1.873	1.871	1.869	1.866	1.864	1.862	1.860	1.857	1.855	1.853	1.851	1.848	1.846	1.844	1.842	1.839	1.837	1.835	1.832	1.830	**-2.25**
-1.75		1.853	1.851	1.848	1.846	1.844	1.842	1.839	1.837	1.835	1.832	1.830	1.828	1.826	1.823	1.821	1.819	1.816	1.814	1.812	1.809	1.807	**-1.75**
-1.25		1.830	1.828	1.826	1.823	1.821	1.819	1.816	1.814	1.812	1.809	1.807	1.805	1.802	1.800	1.798	1.796	1.793	1.791	1.788	1.786	1.784	**-1.25**
-0.75		1.807	1.805	1.802	1.800	1.798	1.796	1.793	1.791	1.788	1.786	1.784	1.781	1.779	1.777	1.774	1.772	1.770	1.767	1.765	1.763	1.760	**-0.75**
-0.25		1.784	1.781	1.779	1.777	1.774	1.772	1.770	1.767	1.765	1.763	1.760	1.758	1.755	1.753	1.751	1.748	1.746	1.743	1.741	1.739	1.736	**-0.25**
0.25		1.760	1.758	1.755	1.753	1.751	1.748	1.746	1.743	1.741	1.739	1.736	1.734	1.731	1.729	1.727	1.724	1.722	1.719	1.717	1.714	1.712	**0.25**
0.75		1.736	1.734	1.731	1.729	1.727	1.724	1.722	1.719	1.717	1.714	1.712	1.709	1.707	1.705	1.702	1.700	1.697	1.695	1.692	1.690	1.687	**0.75**
1.25		1.712	1.709	1.707	1.705	1.702	1.700	1.697	1.695	1.692	1.690	1.687	1.685	1.682	1.680	1.677	1.675	1.672	1.670	1.667	1.665	1.662	**1.25**
1.75		1.687	1.685	1.682	1.680	1.677	1.675	1.672	1.670	1.667	1.665	1.662	1.660	1.657	1.655	1.652	1.650	1.647	1.645	1.642	1.639	1.637	**1.75**
2.25		1.662	1.660	1.657	1.655	1.652	1.650	1.647	1.645	1.642	1.639	1.637	1.634	1.632	1.629	1.627	1.624	1.622	1.619	1.616	1.614	1.611	**2.25**
2.75		1.637	1.634	1.632	1.629	1.627	1.624	1.622	1.619	1.616	1.614	1.611	1.609	1.606	1.603	1.601	1.598	1.595	1.593	1.590	1.588	1.585	**2.75**
3.25		1.611	1.609	1.606	1.603	1.601	1.598	1.595	1.593	1.590	1.588	1.585	1.582	1.580	1.577	1.574	1.572	1.569	1.566	1.564	1.561	1.558	**3.25**
3.75		1.585	1.582	1.580	1.577	1.574	1.572	1.569	1.566	1.564	1.561	1.558	1.556	1.553	1.550	1.548	1.545	1.542	1.539	1.537	1.534	1.531	**3.75**
4.25		1.558	1.556	1.553	1.550	1.548	1.545	1.542	1.539	1.537	1.534	1.531	1.528	1.526	1.523	1.520	1.517	1.515	1.512	1.509	1.506	1.504	**4.25**
4.75		1.531	1.528	1.526	1.523	1.520	1.517	1.515	1.512	1.509	1.506	1.504	1.501	1.498	1.495	1.492	1.490	1.487	1.484	1.481	1.478	1.476	**4.75**
5.25		1.504	1.501	1.498	1.495	1.492	1.490	1.487	1.484	1.481	1.478	1.476	1.473	1.470	1.467	1.464	1.461	1.458	1.456	1.453	1.450	1.447	**5.25**
5.75		1.476	1.473	1.470	1.467	1.464	1.461	1.458	1.456	1.453	1.450	1.447	1.444	1.441	1.438	1.435	1.432	1.429	1.426	1.424	1.421	1.418	**5.75**
6.25		1.447	1.444	1.441	1.438	1.435	1.432	1.429	1.426	1.424	1.421	1.418	1.415	1.412	1.409	1.406	1.403	1.400	1.397	1.394	1.391	1.388	**6.25**
6.75		1.418	1.415	1.412	1.409	1.406	1.403	1.400	1.397	1.394	1.391	1.388	1.385	1.382	1.379	1.376	1.373	1.370	1.366	1.363	1.360	1.357	**6.75**
7.25		1.388	1.385	1.382	1.379	1.376	1.373	1.370	1.366	1.363	1.360	1.357	1.354	1.351	1.348	1.345	1.342	1.339	1.336	1.332	1.329	1.326	**7.25**
7.75		1.357	1.354	1.351	1.348	1.345	1.342	1.339	1.336	1.332	1.329	1.326	1.323	1.320	1.317	1.313	1.310	1.307	1.304	1.301	1.297	1.294	**7.75**
8.25		1.326	1.323	1.320	1.317	1.313	1.310	1.307	1.304	1.301	1.297	1.294	1.291	1.288	1.284	1.281	1.278	1.275	1.271	1.268	1.265	1.261	**8.25**
8.75		1.294	1.291	1.288	1.284	1.281	1.278	1.275	1.271	1.268	1.265	1.261	1.258	1.255	1.251	1.248	1.245	1.241	1.238	1.235	1.231	1.228	**8.75**
9.25		1.261	1.258	1.255	1.251	1.248	1.245	1.241	1.238	1.235	1.231	1.228	1.224	1.221	1.217	1.214	1.211	1.207	1.204	1.200	1.197	1.193	**9.25**
9.75		1.228	1.224	1.221	1.217	1.214	1.211	1.207	1.204	1.200	1.197	1.193	1.190	1.186	1.183	1.179	1.175	1.172	1.168	1.165	1.161	1.157	**9.75**
10.25		1.193	1.190	1.186	1.183	1.179	1.175	1.172	1.168	1.165	1.161	1.157	1.154	1.150	1.147	1.143	1.139	1.136	1.132	1.128	1.124	1.121	**10.25**
10.75		1.157	1.154	1.150	1.147	1.143	1.139	1.136	1.132	1.128	1.124	1.121	1.117	1.113	1.109	1.106	1.102	1.098	1.094	1.090	1.087	1.083	**10.75**
11.25		1.121	1.117	1.113	1.109	1.106	1.102	1.098	1.094	1.090	1.087	1.083	1.079	1.075	1.071	1.067	1.063	1.059	1.055	1.051	1.047	1.043	**11.25**
11.75		1.083	1.079	1.075	1.071	1.067	1.063	1.059	1.055	1.051	1.047	1.043	1.039	1.035	1.031	1.027	1.023	1.019	1.015	1.011	1.007	1.002	**11.75**

TABLE 2-2
LARGE LOCK RATING TABLE, KCFS FOR 1 CULVERT

TIDE (FEET NAVD 88)	POOL ELEVATION (FEET)																				
Corps Datum:	21.00	20.95	20.90	20.85	20.80	20.75	20.70	20.65	20.60	20.55	20.50	20.45	20.40	20.35	20.30	20.25	20.20	20.15	20.10	20.05	20.00
NAVD 88:	**17.75**	**17.70**	**17.65**	**17.60**	**17.55**	**17.50**	**17.45**	**17.40**	**17.35**	**17.30**	**17.25**	**17.20**	**17.15**	**17.10**	**17.05**	**17.00**	**16.95**	**16.90**	**16.85**	**16.80**	**16.75**
-9.25	2.126	2.124	2.122	2.121	2.119	2.117	2.115	2.113	2.111	2.109	2.107	2.105	2.103	2.101	2.099	2.097	2.095	2.093	2.091	2.089	2.087
-8.75	2.107	2.105	2.103	2.101	2.099	2.097	2.095	2.093	2.091	2.089	2.087	2.085	2.083	2.081	2.079	2.077	2.075	2.073	2.071	2.069	2.067
-8.25	2.087	2.085	2.083	2.081	2.079	2.077	2.075	2.073	2.071	2.069	2.067	2.064	2.062	2.060	2.058	2.056	2.054	2.052	2.050	2.048	2.046
-7.75	2.067	2.064	2.062	2.060	2.058	2.056	2.054	2.052	2.050	2.048	2.046	2.044	2.042	2.040	2.038	2.036	2.034	2.032	2.030	2.028	2.026
-7.25	2.046	2.044	2.042	2.040	2.038	2.036	2.034	2.032	2.030	2.028	2.026	2.024	2.021	2.019	2.017	2.015	2.013	2.011	2.009	2.007	2.005
-6.75	2.026	2.024	2.021	2.019	2.017	2.015	2.013	2.011	2.009	2.007	2.005	2.003	2.001	1.999	1.996	1.994	1.992	1.990	1.988	1.986	1.984
-6.25	2.005	2.003	2.001	1.999	1.996	1.994	1.992	1.990	1.988	1.986	1.984	1.982	1.980	1.977	1.975	1.973	1.971	1.969	1.967	1.965	1.963
-5.75	1.984	1.982	1.980	1.977	1.975	1.973	1.971	1.969	1.967	1.965	1.963	1.960	1.958	1.956	1.954	1.952	1.950	1.948	1.945	1.943	1.941
-5.25	1.963	1.960	1.958	1.956	1.954	1.952	1.950	1.948	1.945	1.943	1.941	1.939	1.937	1.935	1.933	1.930	1.928	1.926	1.924	1.922	1.919
-4.75	1.941	1.939	1.937	1.935	1.933	1.930	1.928	1.926	1.924	1.922	1.919	1.917	1.915	1.913	1.911	1.909	1.906	1.904	1.902	1.900	1.898
-4.25	1.919	1.917	1.915	1.913	1.911	1.909	1.906	1.904	1.902	1.900	1.898	1.895	1.893	1.891	1.889	1.886	1.884	1.882	1.880	1.878	1.875
-3.75	1.898	1.895	1.893	1.891	1.889	1.886	1.884	1.882	1.880	1.878	1.875	1.873	1.871	1.869	1.866	1.864	1.862	1.860	1.857	1.855	1.853
-3.25	1.875	1.873	1.871	1.869	1.866	1.864	1.862	1.860	1.857	1.855	1.853	1.851	1.848	1.846	1.844	1.842	1.839	1.837	1.835	1.832	1.830
-2.75	1.853	1.851	1.848	1.846	1.844	1.842	1.839	1.837	1.835	1.832	1.830	1.828	1.826	1.823	1.821	1.819	1.816	1.814	1.812	1.809	1.807
-2.25	1.830	1.828	1.826	1.823	1.821	1.819	1.816	1.814	1.812	1.809	1.807	1.805	1.802	1.800	1.798	1.796	1.793	1.791	1.788	1.786	1.784
-1.75	1.807	1.805	1.802	1.800	1.798	1.796	1.793	1.791	1.788	1.786	1.784	1.781	1.779	1.777	1.774	1.772	1.770	1.767	1.765	1.763	1.760
-1.25	1.784	1.781	1.779	1.777	1.774	1.772	1.770	1.767	1.765	1.763	1.760	1.758	1.755	1.753	1.751	1.748	1.746	1.743	1.741	1.739	1.736
-0.75	1.760	1.758	1.755	1.753	1.751	1.748	1.746	1.743	1.741	1.739	1.736	1.734	1.731	1.729	1.727	1.724	1.722	1.719	1.717	1.714	1.712
-0.25	1.736	1.734	1.731	1.729	1.727	1.724	1.722	1.719	1.717	1.714	1.712	1.709	1.707	1.705	1.702	1.700	1.697	1.695	1.692	1.690	1.687
0.25	1.712	1.709	1.707	1.705	1.702	1.700	1.697	1.695	1.692	1.690	1.687	1.685	1.682	1.680	1.677	1.675	1.672	1.670	1.667	1.665	1.662
0.75	1.687	1.685	1.682	1.680	1.677	1.675	1.672	1.670	1.667	1.665	1.662	1.660	1.657	1.655	1.652	1.650	1.647	1.645	1.642	1.639	1.637
1.25	1.662	1.660	1.657	1.655	1.652	1.650	1.647	1.645	1.642	1.639	1.637	1.634	1.632	1.629	1.627	1.624	1.622	1.619	1.616	1.614	1.611
1.75	1.637	1.634	1.632	1.629	1.627	1.624	1.622	1.619	1.616	1.614	1.611	1.609	1.606	1.603	1.601	1.598	1.595	1.593	1.590	1.588	1.585
2.25	1.611	1.609	1.606	1.603	1.601	1.598	1.595	1.593	1.590	1.588	1.585	1.582	1.580	1.577	1.574	1.572	1.569	1.566	1.564	1.561	1.558
2.75	1.585	1.582	1.580	1.577	1.574	1.572	1.569	1.566	1.564	1.561	1.558	1.556	1.553	1.550	1.548	1.545	1.542	1.539	1.537	1.534	1.531
3.25	1.558	1.556	1.553	1.550	1.548	1.545	1.542	1.539	1.537	1.534	1.531	1.528	1.526	1.523	1.520	1.517	1.515	1.512	1.509	1.506	1.504
3.75	1.531	1.528	1.526	1.523	1.520	1.517	1.515	1.512	1.509	1.506	1.504	1.501	1.498	1.495	1.492	1.490	1.487	1.484	1.481	1.478	1.476
4.25	1.504	1.501	1.498	1.495	1.492	1.490	1.487	1.484	1.481	1.478	1.476	1.473	1.470	1.467	1.464	1.461	1.458	1.456	1.453	1.450	1.447
4.75	1.476	1.473	1.470	1.467	1.464	1.461	1.458	1.456	1.453	1.450	1.447	1.444	1.441	1.438	1.435	1.432	1.429	1.426	1.424	1.421	1.418
5.25	1.447	1.444	1.441	1.438	1.435	1.432	1.429	1.426	1.424	1.421	1.418	1.415	1.412	1.409	1.406	1.403	1.400	1.397	1.394	1.391	1.388
5.75	1.418	1.415	1.412	1.409	1.406	1.403	1.400	1.397	1.394	1.391	1.388	1.385	1.382	1.379	1.376	1.373	1.370	1.366	1.363	1.360	1.357
6.25	1.388	1.385	1.382	1.379	1.376	1.373	1.370	1.366	1.363	1.360	1.357	1.354	1.351	1.348	1.345	1.342	1.339	1.336	1.332	1.329	1.326
6.75	1.357	1.354	1.351	1.348	1.345	1.342	1.339	1.336	1.332	1.329	1.326	1.323	1.320	1.317	1.313	1.310	1.307	1.304	1.301	1.297	1.294
7.25	1.326	1.323	1.320	1.317	1.313	1.310	1.307	1.304	1.301	1.297	1.294	1.291	1.288	1.284	1.281	1.278	1.275	1.271	1.268	1.265	1.261
7.75	1.294	1.291	1.288	1.284	1.281	1.278	1.275	1.271	1.268	1.265	1.261	1.258	1.255	1.251	1.248	1.245	1.241	1.238	1.235	1.231	1.228
8.25	1.261	1.258	1.255	1.251	1.248	1.245	1.241	1.238	1.235	1.231	1.228	1.224	1.221	1.217	1.214	1.211	1.207	1.204	1.200	1.197	1.193
8.75	1.228	1.224	1.221	1.217	1.214	1.211	1.207	1.204	1.200	1.197	1.193	1.190	1.186	1.183	1.179	1.175	1.172	1.168	1.165	1.161	1.157
9.25	1.193	1.190	1.186	1.183	1.179	1.175	1.172	1.168	1.165	1.161	1.157	1.154	1.150	1.147	1.143	1.139	1.136	1.132	1.128	1.124	1.121
9.75	1.157	1.154	1.150	1.147	1.143	1.139	1.136	1.132	1.128	1.124	1.121	1.117	1.113	1.109	1.106	1.102	1.098	1.094	1.090	1.087	1.083
10.25	1.121	1.117	1.113	1.109	1.106	1.102	1.098	1.094	1.090	1.087	1.083	1.079	1.075	1.071	1.067	1.063	1.059	1.055	1.051	1.047	1.043
10.75	1.083	1.079	1.075	1.071	1.067	1.063	1.059	1.055	1.051	1.047	1.043	1.039	1.035	1.031	1.027	1.023	1.019	1.015	1.011	1.007	1.002
11.25	1.043	1.039	1.035	1.031	1.027	1.023	1.019	1.015	1.011	1.007	1.002	0.998	0.994	0.990	0.986	0.981	0.977	0.973	0.968	0.964	0.960
11.75	1.002	0.998	0.994	0.990	0.986	0.981	0.977	0.973	0.968	0.964	0.960	0.955	0.951	0.947	0.942	0.938	0.933	0.929	0.924	0.920	0.915

TABLE 2-2
LARGE LOCK RATING TABLE, KCFS FOR 1 CULVERT

POOL ELEVATION (FEET)

TIDE (FEET NAVD 88)	Corps Datum:	20.00	19.95	19.90	19.85	19.80	19.75	19.70	19.65	19.60	19.55	19.50	19.45	19.40	19.35	19.30	19.25	19.20	19.15	19.10	19.05	19.00	
	NAVD 88:	**16.75**	**16.70**	**16.65**	**16.60**	**16.55**	**16.50**	**16.45**	**16.40**	**16.35**	**16.30**	**16.25**	**16.20**	**16.15**	**16.10**	**16.05**	**16.00**	**15.95**	**15.90**	**15.85**	**15.80**	**15.75**	
-9.25		2.087	2.085	2.083	2.081	2.079	2.077	2.075	2.073	2.071	2.069	2.067	2.064	2.062	2.060	2.058	2.056	2.054	2.052	2.050	2.048	2.046	**-9.25**
-8.75		2.067	2.064	2.062	2.060	2.058	2.056	2.054	2.052	2.050	2.048	2.046	2.044	2.042	2.040	2.038	2.036	2.034	2.032	2.030	2.028	2.026	**-8.75**
-8.25		2.046	2.044	2.042	2.040	2.038	2.036	2.034	2.032	2.030	2.028	2.026	2.024	2.021	2.019	2.017	2.015	2.013	2.011	2.009	2.007	2.005	**-8.25**
-7.75		2.026	2.024	2.021	2.019	2.017	2.015	2.013	2.011	2.009	2.007	2.005	2.003	2.001	1.999	1.996	1.994	1.992	1.990	1.988	1.986	1.984	**-7.75**
-7.25		2.005	2.003	2.001	1.999	1.996	1.994	1.992	1.990	1.988	1.986	1.984	1.982	1.980	1.977	1.975	1.973	1.971	1.969	1.967	1.965	1.963	**-7.25**
-6.75		1.984	1.982	1.980	1.977	1.975	1.973	1.971	1.969	1.967	1.965	1.963	1.960	1.958	1.956	1.954	1.952	1.950	1.948	1.945	1.943	1.941	**-6.75**
-6.25		1.963	1.960	1.958	1.956	1.954	1.952	1.950	1.948	1.945	1.943	1.941	1.939	1.937	1.935	1.933	1.930	1.928	1.926	1.924	1.922	1.919	**-6.25**
-5.75		1.941	1.939	1.937	1.935	1.933	1.930	1.928	1.926	1.924	1.922	1.919	1.917	1.915	1.913	1.911	1.909	1.906	1.904	1.902	1.900	1.898	**-5.75**
-5.25		1.919	1.917	1.915	1.913	1.911	1.909	1.906	1.904	1.902	1.900	1.898	1.895	1.893	1.891	1.889	1.886	1.884	1.882	1.880	1.878	1.875	**-5.25**
-4.75		1.898	1.895	1.893	1.891	1.889	1.886	1.884	1.882	1.880	1.878	1.875	1.873	1.871	1.869	1.866	1.864	1.862	1.860	1.857	1.855	1.853	**-4.75**
-4.25		1.875	1.873	1.871	1.869	1.866	1.864	1.862	1.860	1.857	1.855	1.853	1.851	1.848	1.846	1.844	1.842	1.839	1.837	1.835	1.832	1.830	**-4.25**
-3.75		1.853	1.851	1.848	1.846	1.844	1.842	1.839	1.837	1.835	1.832	1.830	1.828	1.826	1.823	1.821	1.819	1.816	1.814	1.812	1.809	1.807	**-3.75**
-3.25		1.830	1.828	1.826	1.823	1.821	1.819	1.816	1.814	1.812	1.809	1.807	1.805	1.802	1.800	1.798	1.796	1.793	1.791	1.788	1.786	1.784	**-3.25**
-2.75		1.807	1.805	1.802	1.800	1.798	1.796	1.793	1.791	1.788	1.786	1.784	1.781	1.779	1.777	1.774	1.772	1.770	1.767	1.765	1.763	1.760	**-2.75**
-2.25		1.784	1.781	1.779	1.777	1.774	1.772	1.770	1.767	1.765	1.763	1.760	1.758	1.755	1.753	1.751	1.748	1.746	1.743	1.741	1.739	1.736	**-2.25**
-1.75		1.760	1.758	1.755	1.753	1.751	1.748	1.746	1.743	1.741	1.739	1.736	1.734	1.731	1.729	1.727	1.724	1.722	1.719	1.717	1.714	1.712	**-1.75**
-1.25		1.736	1.734	1.731	1.729	1.727	1.724	1.722	1.719	1.717	1.714	1.712	1.709	1.707	1.705	1.702	1.700	1.697	1.695	1.692	1.690	1.687	**-1.25**
-0.75		1.712	1.709	1.707	1.705	1.702	1.700	1.697	1.695	1.692	1.690	1.687	1.685	1.682	1.680	1.677	1.675	1.672	1.670	1.667	1.665	1.662	**-0.75**
-0.25		1.687	1.685	1.682	1.680	1.677	1.675	1.672	1.670	1.667	1.665	1.662	1.660	1.657	1.655	1.652	1.650	1.647	1.645	1.642	1.639	1.637	**-0.25**
0.25		1.662	1.660	1.657	1.655	1.652	1.650	1.647	1.645	1.642	1.639	1.637	1.634	1.632	1.629	1.627	1.624	1.622	1.619	1.616	1.614	1.611	**0.25**
0.75		1.637	1.634	1.632	1.629	1.627	1.624	1.622	1.619	1.616	1.614	1.611	1.609	1.606	1.603	1.601	1.598	1.595	1.593	1.590	1.588	1.585	**0.75**
1.25		1.611	1.609	1.606	1.603	1.601	1.598	1.595	1.593	1.590	1.588	1.585	1.582	1.580	1.577	1.574	1.572	1.569	1.566	1.564	1.561	1.558	**1.25**
1.75		1.585	1.582	1.580	1.577	1.574	1.572	1.569	1.566	1.564	1.561	1.558	1.556	1.553	1.550	1.548	1.545	1.542	1.539	1.537	1.534	1.531	**1.75**
2.25		1.558	1.556	1.553	1.550	1.548	1.545	1.542	1.539	1.537	1.534	1.531	1.528	1.526	1.523	1.520	1.517	1.515	1.512	1.509	1.506	1.504	**2.25**
2.75		1.531	1.528	1.526	1.523	1.520	1.517	1.515	1.512	1.509	1.506	1.504	1.501	1.498	1.495	1.492	1.490	1.487	1.484	1.481	1.478	1.476	**2.75**
3.25		1.504	1.501	1.498	1.495	1.492	1.490	1.487	1.484	1.481	1.478	1.476	1.473	1.470	1.467	1.464	1.461	1.458	1.456	1.453	1.450	1.447	**3.25**
3.75		1.476	1.473	1.470	1.467	1.464	1.461	1.458	1.456	1.453	1.450	1.447	1.444	1.441	1.438	1.435	1.432	1.429	1.426	1.424	1.421	1.418	**3.75**
4.25		1.447	1.444	1.441	1.438	1.435	1.432	1.429	1.426	1.424	1.421	1.418	1.415	1.412	1.409	1.406	1.403	1.400	1.397	1.394	1.391	1.388	**4.25**
4.75		1.418	1.415	1.412	1.409	1.406	1.403	1.400	1.397	1.394	1.391	1.388	1.385	1.382	1.379	1.376	1.373	1.370	1.366	1.363	1.360	1.357	**4.75**
5.25		1.388	1.385	1.382	1.379	1.376	1.373	1.370	1.366	1.363	1.360	1.357	1.354	1.351	1.348	1.345	1.342	1.339	1.336	1.332	1.329	1.326	**5.25**
5.75		1.357	1.354	1.351	1.348	1.345	1.342	1.339	1.336	1.332	1.329	1.326	1.323	1.320	1.317	1.313	1.310	1.307	1.304	1.301	1.297	1.294	**5.75**
6.25		1.326	1.323	1.320	1.317	1.313	1.310	1.307	1.304	1.301	1.297	1.294	1.291	1.288	1.284	1.281	1.278	1.275	1.271	1.268	1.265	1.261	**6.25**
6.75		1.294	1.291	1.288	1.284	1.281	1.278	1.275	1.271	1.268	1.265	1.261	1.258	1.255	1.251	1.248	1.245	1.241	1.238	1.235	1.231	1.228	**6.75**
7.25		1.261	1.258	1.255	1.251	1.248	1.245	1.241	1.238	1.235	1.231	1.228	1.224	1.221	1.217	1.214	1.211	1.207	1.204	1.200	1.197	1.193	**7.25**
7.75		1.228	1.224	1.221	1.217	1.214	1.211	1.207	1.204	1.200	1.197	1.193	1.190	1.186	1.183	1.179	1.175	1.172	1.168	1.165	1.161	1.157	**7.75**
8.25		1.193	1.190	1.186	1.183	1.179	1.175	1.172	1.168	1.165	1.161	1.157	1.154	1.150	1.147	1.143	1.139	1.136	1.132	1.128	1.124	1.121	**8.25**
8.75		1.157	1.154	1.150	1.147	1.143	1.139	1.136	1.132	1.128	1.124	1.121	1.117	1.113	1.109	1.106	1.102	1.098	1.094	1.090	1.087	1.083	**8.75**
9.25		1.121	1.117	1.113	1.109	1.106	1.102	1.098	1.094	1.090	1.087	1.083	1.079	1.075	1.071	1.067	1.063	1.059	1.055	1.051	1.047	1.043	**9.25**
9.75		1.083	1.079	1.075	1.071	1.067	1.063	1.059	1.055	1.051	1.047	1.043	1.039	1.035	1.031	1.027	1.023	1.019	1.015	1.011	1.007	1.002	**9.75**
10.25		1.043	1.039	1.035	1.031	1.027	1.023	1.019	1.015	1.011	1.007	1.002	0.998	0.994	0.990	0.986	0.981	0.977	0.973	0.968	0.964	0.960	**10.25**
10.75		1.002	0.998	0.994	0.990	0.986	0.981	0.977	0.973	0.968	0.964	0.960	0.955	0.951	0.947	0.942	0.938	0.933	0.929	0.924	0.920	0.915	**10.75**
11.25		0.960	0.955	0.951	0.947	0.942	0.938	0.933	0.929	0.924	0.920	0.915	0.910	0.906	0.901	0.897	0.892	0.887	0.882	0.878	0.873	0.868	**11.25**
11.75		0.915	0.910	0.906	0.901	0.897	0.892	0.887	0.882	0.878	0.873	0.868	0.863	0.858	0.854	0.849	0.844	0.839	0.834	0.829	0.824	0.818	**11.75**

TABLE 2-3
LARGE LOCK RATING TABLE, KCFS FOR 2 CULVERTS

$$Q = CA\sqrt{2gH}$$

C= 0.47, A=108.5 ft^2 per culvert, H=(POOL ELEVATION TIDE)

POOL ELEVATION (FEET)

TIDE (FEET NAVD 88)	Corps Datum:	22.00	21.95	21.90	21.85	21.80	21.75	21.70	21.65	21.60	21.55	21.50	21.45	21.40	21.35	21.30	21.25	21.20	21.15	21.10	21.05	21.00	
	NAVD 88:	**18.75**	**18.70**	**18.65**	**18.60**	**18.55**	**18.50**	**18.45**	**18.40**	**18.35**	**18.30**	**18.25**	**18.20**	**18.15**	**18.10**	**18.05**	**18.00**	**17.95**	**17.90**	**17.85**	**17.80**	**17.75**	
-9.25		4.331	4.327	4.323	4.319	4.315	4.312	4.308	4.304	4.300	4.296	4.292	4.288	4.284	4.280	4.276	4.273	4.269	4.265	4.261	4.257	4.253	**-9.25**
-8.75		4.292	4.288	4.284	4.280	4.276	4.273	4.269	4.265	4.261	4.257	4.253	4.249	4.245	4.241	4.237	4.233	4.229	4.225	4.221	4.217	4.213	**-8.75**
-8.25		4.253	4.249	4.245	4.241	4.237	4.233	4.229	4.225	4.221	4.217	4.213	4.209	4.205	4.201	4.197	4.193	4.189	4.185	4.181	4.177	4.173	**-8.25**
-7.75		4.213	4.209	4.205	4.201	4.197	4.193	4.189	4.185	4.181	4.177	4.173	4.169	4.165	4.161	4.157	4.153	4.149	4.145	4.141	4.137	4.133	**-7.75**
-7.25		4.173	4.169	4.165	4.161	4.157	4.153	4.149	4.145	4.141	4.137	4.133	4.129	4.125	4.121	4.117	4.113	4.109	4.105	4.101	4.096	4.092	**-7.25**
-6.75		4.133	4.129	4.125	4.121	4.117	4.113	4.109	4.105	4.101	4.096	4.092	4.088	4.084	4.080	4.076	4.072	4.068	4.064	4.059	4.055	4.051	**-6.75**
-6.25		4.092	4.088	4.084	4.080	4.076	4.072	4.068	4.064	4.059	4.055	4.051	4.047	4.043	4.039	4.035	4.030	4.026	4.022	4.018	4.014	4.010	**-6.25**
-5.75		4.051	4.047	4.043	4.039	4.035	4.030	4.026	4.022	4.018	4.014	4.010	4.005	4.001	3.997	3.993	3.989	3.985	3.980	3.976	3.972	3.968	**-5.75**
-5.25		4.010	4.005	4.001	3.997	3.993	3.989	3.985	3.980	3.976	3.972	3.968	3.963	3.959	3.955	3.951	3.946	3.942	3.938	3.934	3.929	3.925	**-5.25**
-4.75		3.968	3.963	3.959	3.955	3.951	3.946	3.942	3.938	3.934	3.929	3.925	3.921	3.917	3.912	3.908	3.904	3.900	3.895	3.891	3.887	3.882	**-4.75**
-4.25		3.925	3.921	3.917	3.912	3.908	3.904	3.900	3.895	3.891	3.887	3.882	3.878	3.874	3.869	3.865	3.861	3.856	3.852	3.848	3.843	3.839	**-4.25**
-3.75		3.882	3.878	3.874	3.869	3.865	3.861	3.856	3.852	3.848	3.843	3.839	3.835	3.830	3.826	3.821	3.817	3.813	3.808	3.804	3.799	3.795	**-3.75**
-3.25		3.839	3.835	3.830	3.826	3.821	3.817	3.813	3.808	3.804	3.799	3.795	3.791	3.786	3.782	3.777	3.773	3.768	3.764	3.760	3.755	3.751	**-3.25**
-2.75		3.795	3.791	3.786	3.782	3.777	3.773	3.768	3.764	3.760	3.755	3.751	3.746	3.742	3.737	3.733	3.728	3.724	3.719	3.715	3.710	3.706	**-2.75**
-2.25		3.751	3.746	3.742	3.737	3.733	3.728	3.724	3.719	3.715	3.710	3.706	3.701	3.697	3.692	3.688	3.683	3.679	3.674	3.669	3.665	3.660	**-2.25**
-1.75		3.706	3.701	3.697	3.692	3.688	3.683	3.679	3.674	3.669	3.665	3.660	3.656	3.651	3.647	3.642	3.637	3.633	3.628	3.624	3.619	3.614	**-1.75**
-1.25		3.660	3.656	3.651	3.647	3.642	3.637	3.633	3.628	3.624	3.619	3.614	3.610	3.605	3.600	3.596	3.591	3.586	3.582	3.577	3.572	3.568	**-1.25**
-0.75		3.614	3.610	3.605	3.600	3.596	3.591	3.586	3.582	3.577	3.572	3.568	3.563	3.558	3.553	3.549	3.544	3.539	3.535	3.530	3.525	3.520	**-0.75**
-0.25		3.568	3.563	3.558	3.553	3.549	3.544	3.539	3.535	3.530	3.525	3.520	3.516	3.511	3.506	3.501	3.496	3.492	3.487	3.482	3.477	3.472	**-0.25**
0.25		3.520	3.516	3.511	3.506	3.501	3.496	3.492	3.487	3.482	3.477	3.472	3.468	3.463	3.458	3.453	3.448	3.443	3.439	3.434	3.429	3.424	**0.25**
0.75		3.472	3.468	3.463	3.458	3.453	3.448	3.443	3.439	3.434	3.429	3.424	3.419	3.414	3.409	3.404	3.399	3.394	3.389	3.385	3.380	3.375	**0.75**
1.25		3.424	3.419	3.414	3.409	3.404	3.399	3.394	3.389	3.385	3.380	3.375	3.370	3.365	3.360	3.355	3.350	3.345	3.340	3.335	3.330	3.325	**1.25**
1.75		3.375	3.370	3.365	3.360	3.355	3.350	3.345	3.340	3.335	3.330	3.325	3.320	3.315	3.309	3.304	3.299	3.294	3.289	3.284	3.279	3.274	**1.75**
2.25		3.325	3.320	3.315	3.309	3.304	3.299	3.294	3.289	3.284	3.279	3.274	3.269	3.264	3.258	3.253	3.248	3.243	3.238	3.233	3.227	3.222	**2.25**
2.75		3.274	3.269	3.264	3.258	3.253	3.248	3.243	3.238	3.233	3.227	3.222	3.217	3.212	3.207	3.201	3.196	3.191	3.186	3.180	3.175	3.170	**2.75**
3.25		3.222	3.217	3.212	3.207	3.201	3.196	3.191	3.186	3.180	3.175	3.170	3.165	3.159	3.154	3.149	3.143	3.138	3.133	3.127	3.122	3.117	**3.25**
3.75		3.170	3.165	3.159	3.154	3.149	3.143	3.138	3.133	3.127	3.122	3.117	3.111	3.106	3.100	3.095	3.090	3.084	3.079	3.073	3.068	3.062	**3.75**
4.25		3.117	3.111	3.106	3.100	3.095	3.090	3.084	3.079	3.073	3.068	3.062	3.057	3.051	3.046	3.040	3.035	3.029	3.024	3.018	3.013	3.007	**4.25**
4.75		3.062	3.057	3.051	3.046	3.040	3.035	3.029	3.024	3.018	3.013	3.007	3.002	2.996	2.990	2.985	2.979	2.974	2.968	2.962	2.957	2.951	**4.75**
5.25		3.007	3.002	2.996	2.990	2.985	2.979	2.974	2.968	2.962	2.957	2.951	2.945	2.940	2.934	2.928	2.923	2.917	2.911	2.905	2.899	2.894	**5.25**
5.75		2.951	2.945	2.940	2.934	2.928	2.923	2.917	2.911	2.905	2.899	2.894	2.888	2.882	2.876	2.870	2.865	2.859	2.853	2.847	2.841	2.835	**5.75**
6.25		2.894	2.888	2.882	2.876	2.870	2.865	2.859	2.853	2.847	2.841	2.835	2.829	2.823	2.817	2.812	2.806	2.800	2.794	2.788	2.782	2.776	**6.25**
6.75		2.835	2.829	2.823	2.817	2.812	2.806	2.800	2.794	2.788	2.782	2.776	2.770	2.763	2.757	2.751	2.745	2.739	2.733	2.727	2.721	2.715	**6.75**
7.25		2.776	2.770	2.763	2.757	2.751	2.745	2.739	2.733	2.727	2.721	2.715	2.708	2.702	2.696	2.690	2.684	2.677	2.671	2.665	2.658	2.652	**7.25**
7.75		2.715	2.708	2.702	2.696	2.690	2.684	2.677	2.671	2.665	2.658	2.652	2.646	2.639	2.633	2.627	2.620	2.614	2.608	2.601	2.595	2.588	**7.75**
8.25		2.652	2.646	2.639	2.633	2.627	2.620	2.614	2.608	2.601	2.595	2.588	2.582	2.575	2.569	2.562	2.556	2.549	2.543	2.536	2.529	2.523	**8.25**
8.75		2.588	2.582	2.575	2.569	2.562	2.556	2.549	2.543	2.536	2.529	2.523	2.516	2.509	2.503	2.496	2.489	2.483	2.476	2.469	2.462	2.455	**8.75**
9.25		2.523	2.516	2.509	2.503	2.496	2.489	2.483	2.476	2.469	2.462	2.455	2.449	2.442	2.435	2.428	2.421	2.414	2.407	2.400	2.393	2.386	**9.25**
9.75		2.455	2.449	2.442	2.435	2.428	2.421	2.414	2.407	2.400	2.393	2.386	2.379	2.372	2.365	2.358	2.351	2.344	2.337	2.329	2.322	2.315	**9.75**
10.25		2.386	2.379	2.372	2.365	2.358	2.351	2.344	2.337	2.329	2.322	2.315	2.308	2.300	2.293	2.286	2.279	2.271	2.264	2.256	2.249	2.241	**10.25**
10.75		2.315	2.308	2.300	2.293	2.286	2.279	2.271	2.264	2.256	2.249	2.241	2.234	2.226	2.219	2.211	2.204	2.196	2.189	2.181	2.173	2.165	**10.75**
11.25		2.241	2.234	2.226	2.219	2.211	2.204	2.196	2.189	2.181	2.173	2.165	2.158	2.150	2.142	2.134	2.126	2.119	2.111	2.103	2.095	2.087	**11.25**
11.75		2.165	2.158	2.150	2.142	2.134	2.126	2.119	2.111	2.103	2.095	2.087	2.079	2.071	2.062	2.054	2.046	2.038	2.030	2.021	2.013	2.005	**11.75**

TABLE 2-3
LARGE LOCK RATING TABLE, KCFS FOR 2 CULVERTS

POOL ELEVATION (FEET)

TIDE (FEET NAVD 88)	Corps Datum:	21.00	20.95	20.90	20.85	20.80	20.75	20.70	20.65	20.60	20.55	20.50	20.45	20.40	20.35	20.30	20.25	20.20	20.15	20.10	20.05	20.00	
	NAVD 88:	**17.75**	**17.70**	**17.65**	**17.60**	**17.55**	**17.50**	**17.45**	**17.40**	**17.35**	**17.30**	**17.25**	**17.20**	**17.15**	**17.10**	**17.05**	**17.00**	**16.95**	**16.90**	**16.85**	**16.80**	**16.75**	
-9.25		4.253	4.249	4.245	4.241	4.237	4.233	4.229	4.225	4.221	4.217	4.213	4.209	4.205	4.201	4.197	4.193	4.189	4.185	4.181	4.177	4.173	**-9.25**
-8.75		4.213	4.209	4.205	4.201	4.197	4.193	4.189	4.185	4.181	4.177	4.173	4.169	4.165	4.161	4.157	4.153	4.149	4.145	4.141	4.137	4.133	**-8.75**
-8.25		4.173	4.169	4.165	4.161	4.157	4.153	4.149	4.145	4.141	4.137	4.133	4.129	4.125	4.121	4.117	4.113	4.109	4.105	4.101	4.096	4.092	**-8.25**
-7.75		4.133	4.129	4.125	4.121	4.117	4.113	4.109	4.105	4.101	4.096	4.092	4.088	4.084	4.080	4.076	4.072	4.068	4.064	4.059	4.055	4.051	**-7.75**
-7.25		4.092	4.088	4.084	4.080	4.076	4.072	4.068	4.064	4.059	4.055	4.051	4.047	4.043	4.039	4.035	4.030	4.026	4.022	4.018	4.014	4.010	**-7.25**
-6.75		4.051	4.047	4.043	4.039	4.035	4.030	4.026	4.022	4.018	4.014	4.010	4.005	4.001	3.997	3.993	3.989	3.985	3.980	3.976	3.972	3.968	**-6.75**
-6.25		4.010	4.005	4.001	3.997	3.993	3.989	3.985	3.980	3.976	3.972	3.968	3.963	3.959	3.955	3.951	3.946	3.942	3.938	3.934	3.929	3.925	**-6.25**
-5.75		3.968	3.963	3.959	3.955	3.951	3.946	3.942	3.938	3.934	3.929	3.925	3.921	3.917	3.912	3.908	3.904	3.900	3.895	3.891	3.887	3.882	**-5.75**
-5.25		3.925	3.921	3.917	3.912	3.908	3.904	3.900	3.895	3.891	3.887	3.882	3.878	3.874	3.869	3.865	3.861	3.856	3.852	3.848	3.843	3.839	**-5.25**
-4.75		3.882	3.878	3.874	3.869	3.865	3.861	3.856	3.852	3.848	3.843	3.839	3.835	3.830	3.826	3.821	3.817	3.813	3.808	3.804	3.799	3.795	**-4.75**
-4.25		3.839	3.835	3.830	3.826	3.821	3.817	3.813	3.808	3.804	3.799	3.795	3.791	3.786	3.782	3.777	3.773	3.768	3.764	3.760	3.755	3.751	**-4.25**
-3.75		3.795	3.791	3.786	3.782	3.777	3.773	3.768	3.764	3.760	3.755	3.751	3.746	3.742	3.737	3.733	3.728	3.724	3.719	3.715	3.710	3.706	**-3.75**
-3.25		3.751	3.746	3.742	3.737	3.733	3.728	3.724	3.719	3.715	3.710	3.706	3.701	3.697	3.692	3.688	3.683	3.679	3.674	3.669	3.665	3.660	**-3.25**
-2.75		3.706	3.701	3.697	3.692	3.688	3.683	3.679	3.674	3.669	3.665	3.660	3.656	3.651	3.647	3.642	3.637	3.633	3.628	3.624	3.619	3.614	**-2.75**
-2.25		3.660	3.656	3.651	3.647	3.642	3.637	3.633	3.628	3.624	3.619	3.614	3.610	3.605	3.600	3.596	3.591	3.586	3.582	3.577	3.572	3.568	**-2.25**
-1.75		3.614	3.610	3.605	3.600	3.596	3.591	3.586	3.582	3.577	3.572	3.568	3.563	3.558	3.553	3.549	3.544	3.539	3.535	3.530	3.525	3.520	**-1.75**
-1.25		3.568	3.563	3.558	3.553	3.549	3.544	3.539	3.535	3.530	3.525	3.520	3.516	3.511	3.506	3.501	3.496	3.492	3.487	3.482	3.477	3.472	**-1.25**
-0.75		3.520	3.516	3.511	3.506	3.501	3.496	3.492	3.487	3.482	3.477	3.472	3.468	3.463	3.458	3.453	3.448	3.443	3.439	3.434	3.429	3.424	**-0.75**
-0.25		3.472	3.468	3.463	3.458	3.453	3.448	3.443	3.439	3.434	3.429	3.424	3.419	3.414	3.409	3.404	3.399	3.394	3.389	3.385	3.380	3.375	**-0.25**
0.25		3.424	3.419	3.414	3.409	3.404	3.399	3.394	3.389	3.385	3.380	3.375	3.370	3.365	3.360	3.355	3.350	3.345	3.340	3.335	3.330	3.325	**0.25**
0.75		3.375	3.370	3.365	3.360	3.355	3.350	3.345	3.340	3.335	3.330	3.325	3.320	3.315	3.309	3.304	3.299	3.294	3.289	3.284	3.279	3.274	**0.75**
1.25		3.325	3.320	3.315	3.309	3.304	3.299	3.294	3.289	3.284	3.279	3.274	3.269	3.264	3.258	3.253	3.248	3.243	3.238	3.233	3.227	3.222	**1.25**
1.75		3.274	3.269	3.264	3.258	3.253	3.248	3.243	3.238	3.233	3.227	3.222	3.217	3.212	3.207	3.201	3.196	3.191	3.186	3.180	3.175	3.170	**1.75**
2.25		3.222	3.217	3.212	3.207	3.201	3.196	3.191	3.186	3.180	3.175	3.170	3.165	3.159	3.154	3.149	3.143	3.138	3.133	3.127	3.122	3.117	**2.25**
2.75		3.170	3.165	3.159	3.154	3.149	3.143	3.138	3.133	3.127	3.122	3.117	3.111	3.106	3.100	3.095	3.090	3.084	3.079	3.073	3.068	3.062	**2.75**
3.25		3.117	3.111	3.106	3.100	3.095	3.090	3.084	3.079	3.073	3.068	3.062	3.057	3.051	3.046	3.040	3.035	3.029	3.024	3.018	3.013	3.007	**3.25**
3.75		3.062	3.057	3.051	3.046	3.040	3.035	3.029	3.024	3.018	3.013	3.007	3.002	2.996	2.990	2.985	2.979	2.974	2.968	2.962	2.957	2.951	**3.75**
4.25		3.007	3.002	2.996	2.990	2.985	2.979	2.974	2.968	2.962	2.957	2.951	2.945	2.940	2.934	2.928	2.923	2.917	2.911	2.905	2.899	2.894	**4.25**
4.75		2.951	2.945	2.940	2.934	2.928	2.923	2.917	2.911	2.905	2.899	2.894	2.888	2.882	2.876	2.870	2.865	2.859	2.853	2.847	2.841	2.835	**4.75**
5.25		2.894	2.888	2.882	2.876	2.870	2.865	2.859	2.853	2.847	2.841	2.835	2.829	2.823	2.817	2.812	2.806	2.800	2.794	2.788	2.782	2.776	**5.25**
5.75		2.835	2.829	2.823	2.817	2.812	2.806	2.800	2.794	2.788	2.782	2.776	2.770	2.763	2.757	2.751	2.745	2.739	2.733	2.727	2.721	2.715	**5.75**
6.25		2.776	2.770	2.763	2.757	2.751	2.745	2.739	2.733	2.727	2.721	2.715	2.708	2.702	2.696	2.690	2.684	2.677	2.671	2.665	2.658	2.652	**6.25**
6.75		2.715	2.708	2.702	2.696	2.690	2.684	2.677	2.671	2.665	2.658	2.652	2.646	2.639	2.633	2.627	2.620	2.614	2.608	2.601	2.595	2.588	**6.75**
7.25		2.652	2.646	2.639	2.633	2.627	2.620	2.614	2.608	2.601	2.595	2.588	2.582	2.575	2.569	2.562	2.556	2.549	2.543	2.536	2.529	2.523	**7.25**
7.75		2.588	2.582	2.575	2.569	2.562	2.556	2.549	2.543	2.536	2.529	2.523	2.516	2.509	2.503	2.496	2.489	2.483	2.476	2.469	2.462	2.455	**7.75**
8.25		2.523	2.516	2.509	2.503	2.496	2.489	2.483	2.476	2.469	2.462	2.455	2.449	2.442	2.435	2.428	2.421	2.414	2.407	2.400	2.393	2.386	**8.25**
8.75		2.455	2.449	2.442	2.435	2.428	2.421	2.414	2.407	2.400	2.393	2.386	2.379	2.372	2.365	2.358	2.351	2.344	2.337	2.329	2.322	2.315	**8.75**
9.25		2.386	2.379	2.372	2.365	2.358	2.351	2.344	2.337	2.329	2.322	2.315	2.308	2.300	2.293	2.286	2.279	2.271	2.264	2.256	2.249	2.241	**9.25**
9.75		2.315	2.308	2.300	2.293	2.286	2.279	2.271	2.264	2.256	2.249	2.241	2.234	2.226	2.219	2.211	2.204	2.196	2.189	2.181	2.173	2.165	**9.75**
10.25		2.241	2.234	2.226	2.219	2.211	2.204	2.196	2.189	2.181	2.173	2.165	2.158	2.150	2.142	2.134	2.126	2.119	2.111	2.103	2.095	2.087	**10.25**
10.75		2.165	2.158	2.150	2.142	2.134	2.126	2.119	2.111	2.103	2.095	2.087	2.079	2.071	2.062	2.054	2.046	2.038	2.030	2.021	2.013	2.005	**10.75**
11.25		2.087	2.079	2.071	2.062	2.054	2.046	2.038	2.030	2.021	2.013	2.005	1.996	1.988	1.980	1.971	1.963	1.954	1.945	1.937	1.928	1.919	**11.25**
11.75		2.005	1.996	1.988	1.980	1.971	1.963	1.954	1.945	1.937	1.928	1.919	1.911	1.902	1.893	1.884	1.875	1.866	1.857	1.848	1.839	1.830	**11.75**

TABLE 2-3
LARGE LOCK RATING TABLE, KCFS FOR 2 CULVERTS

POOL ELEVATION (FEET)

TIDE (FEET NAVD 88)	Corps Datum: 20.00	19.95	19.90	19.85	19.80	19.75	19.70	19.65	19.60	19.55	19.50	19.45	19.40	19.35	19.30	19.25	19.20	19.15	19.10	19.05	19.00	
	NAVD 88: 16.75	**16.70**	**16.65**	**16.60**	**16.55**	**16.50**	**16.45**	**16.40**	**16.35**	**16.30**	**16.25**	**16.20**	**16.15**	**16.10**	**16.05**	**16.00**	**15.95**	**15.90**	**15.85**	**15.80**	**15.75**	
-9.25	4.173	4.169	4.165	4.161	4.157	4.153	4.149	4.145	4.141	4.137	4.133	4.129	4.125	4.121	4.117	4.113	4.109	4.105	4.101	4.096	4.092	**-9.25**
-8.75	4.133	4.129	4.125	4.121	4.117	4.113	4.109	4.105	4.101	4.096	4.092	4.088	4.084	4.080	4.076	4.072	4.068	4.064	4.059	4.055	4.051	**-8.75**
-8.25	4.092	4.088	4.084	4.080	4.076	4.072	4.068	4.064	4.059	4.055	4.051	4.047	4.043	4.039	4.035	4.030	4.026	4.022	4.018	4.014	4.010	**-8.25**
-7.75	4.051	4.047	4.043	4.039	4.035	4.030	4.026	4.022	4.018	4.014	4.010	4.005	4.001	3.997	3.993	3.989	3.985	3.980	3.976	3.972	3.968	**-7.75**
-7.25	4.010	4.005	4.001	3.997	3.993	3.989	3.985	3.980	3.976	3.972	3.968	3.963	3.959	3.955	3.951	3.946	3.942	3.938	3.934	3.929	3.925	**-7.25**
-6.75	3.968	3.963	3.959	3.955	3.951	3.946	3.942	3.938	3.934	3.929	3.925	3.921	3.917	3.912	3.908	3.904	3.900	3.895	3.891	3.887	3.882	**-6.75**
-6.25	3.925	3.921	3.917	3.912	3.908	3.904	3.900	3.895	3.891	3.887	3.882	3.878	3.874	3.869	3.865	3.861	3.856	3.852	3.848	3.843	3.839	**-6.25**
-5.75	3.882	3.878	3.874	3.869	3.865	3.861	3.856	3.852	3.848	3.843	3.839	3.835	3.830	3.826	3.821	3.817	3.813	3.808	3.804	3.799	3.795	**-5.75**
-5.25	3.839	3.835	3.830	3.826	3.821	3.817	3.813	3.808	3.804	3.799	3.795	3.791	3.786	3.782	3.777	3.773	3.768	3.764	3.760	3.755	3.751	**-5.25**
-4.75	3.795	3.791	3.786	3.782	3.777	3.773	3.768	3.764	3.760	3.755	3.751	3.746	3.742	3.737	3.733	3.728	3.724	3.719	3.715	3.710	3.706	**-4.75**
-4.25	3.751	3.746	3.742	3.737	3.733	3.728	3.724	3.719	3.715	3.710	3.706	3.701	3.697	3.692	3.688	3.683	3.679	3.674	3.669	3.665	3.660	**-4.25**
-3.75	3.706	3.701	3.697	3.692	3.688	3.683	3.679	3.674	3.669	3.665	3.660	3.656	3.651	3.647	3.642	3.637	3.633	3.628	3.624	3.619	3.614	**-3.75**
-3.25	3.660	3.656	3.651	3.647	3.642	3.637	3.633	3.628	3.624	3.619	3.614	3.610	3.605	3.600	3.596	3.591	3.586	3.582	3.577	3.572	3.568	**-3.25**
-2.75	3.614	3.610	3.605	3.600	3.596	3.591	3.586	3.582	3.577	3.572	3.568	3.563	3.558	3.553	3.549	3.544	3.539	3.535	3.530	3.525	3.520	**-2.75**
-2.25	3.568	3.563	3.558	3.553	3.549	3.544	3.539	3.535	3.530	3.525	3.520	3.516	3.511	3.506	3.501	3.496	3.492	3.487	3.482	3.477	3.472	**-2.25**
-1.75	3.520	3.516	3.511	3.506	3.501	3.496	3.492	3.487	3.482	3.477	3.472	3.468	3.463	3.458	3.453	3.448	3.443	3.439	3.434	3.429	3.424	**-1.75**
-1.25	3.472	3.468	3.463	3.458	3.453	3.448	3.443	3.439	3.434	3.429	3.424	3.419	3.414	3.409	3.404	3.399	3.394	3.389	3.385	3.380	3.375	**-1.25**
-0.75	3.424	3.419	3.414	3.409	3.404	3.399	3.394	3.389	3.385	3.380	3.375	3.370	3.365	3.360	3.355	3.350	3.345	3.340	3.335	3.330	3.325	**-0.75**
-0.25	3.375	3.370	3.365	3.360	3.355	3.350	3.345	3.340	3.335	3.330	3.325	3.320	3.315	3.309	3.304	3.299	3.294	3.289	3.284	3.279	3.274	**-0.25**
0.25	3.325	3.320	3.315	3.309	3.304	3.299	3.294	3.289	3.284	3.279	3.274	3.269	3.264	3.258	3.253	3.248	3.243	3.238	3.233	3.227	3.222	**0.25**
0.75	3.274	3.269	3.264	3.258	3.253	3.248	3.243	3.238	3.233	3.227	3.222	3.217	3.212	3.207	3.201	3.196	3.191	3.186	3.180	3.175	3.170	**0.75**
1.25	3.222	3.217	3.212	3.207	3.201	3.196	3.191	3.186	3.180	3.175	3.170	3.165	3.159	3.154	3.149	3.143	3.138	3.133	3.127	3.122	3.117	**1.25**
1.75	3.170	3.165	3.159	3.154	3.149	3.143	3.138	3.133	3.127	3.122	3.117	3.111	3.106	3.100	3.095	3.090	3.084	3.079	3.073	3.068	3.062	**1.75**
2.25	3.117	3.111	3.106	3.100	3.095	3.090	3.084	3.079	3.073	3.068	3.062	3.057	3.051	3.046	3.040	3.035	3.029	3.024	3.018	3.013	3.007	**2.25**
2.75	3.062	3.057	3.051	3.046	3.040	3.035	3.029	3.024	3.018	3.013	3.007	3.002	2.996	2.990	2.985	2.979	2.974	2.968	2.962	2.957	2.951	**2.75**
3.25	3.007	3.002	2.996	2.990	2.985	2.979	2.974	2.968	2.962	2.957	2.951	2.945	2.940	2.934	2.928	2.923	2.917	2.911	2.905	2.899	2.894	**3.25**
3.75	2.951	2.945	2.940	2.934	2.928	2.923	2.917	2.911	2.905	2.899	2.894	2.888	2.882	2.876	2.870	2.865	2.859	2.853	2.847	2.841	2.835	**3.75**
4.25	2.894	2.888	2.882	2.876	2.870	2.865	2.859	2.853	2.847	2.841	2.835	2.829	2.823	2.817	2.812	2.806	2.800	2.794	2.788	2.782	2.776	**4.25**
4.75	2.835	2.829	2.823	2.817	2.812	2.806	2.800	2.794	2.788	2.782	2.776	2.770	2.763	2.757	2.751	2.745	2.739	2.733	2.727	2.721	2.715	**4.75**
5.25	2.776	2.770	2.763	2.757	2.751	2.745	2.739	2.733	2.727	2.721	2.715	2.708	2.702	2.696	2.690	2.684	2.677	2.671	2.665	2.658	2.652	**5.25**
5.75	2.715	2.708	2.702	2.696	2.690	2.684	2.677	2.671	2.665	2.658	2.652	2.646	2.639	2.633	2.627	2.620	2.614	2.608	2.601	2.595	2.588	**5.75**
6.25	2.652	2.646	2.639	2.633	2.627	2.620	2.614	2.608	2.601	2.595	2.588	2.582	2.575	2.569	2.562	2.556	2.549	2.543	2.536	2.529	2.523	**6.25**
6.75	2.588	2.582	2.575	2.569	2.562	2.556	2.549	2.543	2.536	2.529	2.523	2.516	2.509	2.503	2.496	2.489	2.483	2.476	2.469	2.462	2.455	**6.75**
7.25	2.523	2.516	2.509	2.503	2.496	2.489	2.483	2.476	2.469	2.462	2.455	2.449	2.442	2.435	2.428	2.421	2.414	2.407	2.400	2.393	2.386	**7.25**
7.75	2.455	2.449	2.442	2.435	2.428	2.421	2.414	2.407	2.400	2.393	2.386	2.379	2.372	2.365	2.358	2.351	2.344	2.337	2.329	2.322	2.315	**7.75**
8.25	2.386	2.379	2.372	2.365	2.358	2.351	2.344	2.337	2.329	2.322	2.315	2.308	2.300	2.293	2.286	2.279	2.271	2.264	2.256	2.249	2.241	**8.25**
8.75	2.315	2.308	2.300	2.293	2.286	2.279	2.271	2.264	2.256	2.249	2.241	2.234	2.226	2.219	2.211	2.204	2.196	2.189	2.181	2.173	2.165	**8.75**
9.25	2.241	2.234	2.226	2.219	2.211	2.204	2.196	2.189	2.181	2.173	2.165	2.158	2.150	2.142	2.134	2.126	2.119	2.111	2.103	2.095	2.087	**9.25**
9.75	2.165	2.158	2.150	2.142	2.134	2.126	2.119	2.111	2.103	2.095	2.087	2.079	2.071	2.062	2.054	2.046	2.038	2.030	2.021	2.013	2.005	**9.75**
10.25	2.087	2.079	2.071	2.062	2.054	2.046	2.038	2.030	2.021	2.013	2.005	1.996	1.988	1.980	1.971	1.963	1.954	1.945	1.937	1.928	1.919	**10.25**
10.75	2.005	1.996	1.988	1.980	1.971	1.963	1.954	1.945	1.937	1.928	1.919	1.911	1.902	1.893	1.884	1.875	1.866	1.857	1.848	1.839	1.830	**10.75**
11.25	1.919	1.911	1.902	1.893	1.884	1.875	1.866	1.857	1.848	1.839	1.830	1.821	1.812	1.802	1.793	1.784	1.774	1.765	1.755	1.746	1.736	**11.25**
11.75	1.830	1.821	1.812	1.802	1.793	1.784	1.774	1.765	1.755	1.746	1.736	1.727	1.717	1.707	1.697	1.687	1.677	1.667	1.657	1.647	1.637	**11.75**

TABLE 4-1
HYDROLOGIC GAGING STATIONS

Index No. [b]	Station Name	USGS Gage ID	Drainage Area (sq. mi)	Available Data [c]	Period of Record [a]
1	North Fork Cedar River near Lester	12113500	9.3	D	Oct 1944 - Dec 1963
2	South Fork Cedar River near Lester	12114000	6	D	Oct 1944 - Nov 1983
3	Cedar River below Bear Creek near Cedar Falls	12114500	25.4	D, GH	Oct 1945 - Act.
4	Cedar River near Cedar Falls	12115000	40.7	D, GH, WT	Oct 1945 - Act.
5	Green Point Creek near Cedar Falls	12115300	0.9	PS	Dec 1956 - Dec 1987
6	Rex River near Cedar Falls	12115500	13.4	D, GH	Oct 1945 - Act.
7	Boulder Creek near Cedar Falls	12115700	4.64	D, GH	Mar 1983 - Act.
8	Rack Creek near Cedar Falls	12115800	2.14	D	Mar 1983 - Sep 1993
9	Chester Morse Lake at Cedar Falls	12115900	78.4	LE	Oct 1978 - Act.
10	Cedar Lake (Masonry Pool) near Cedar Falls	12116060	78.4	LE	Feb 1999 - Act.
11	Canyon Creek near Cedar Falls	12116100	0.2	D, GH	Jun 1945 - Act.
12	Cedar River at Powerplant at Cedar Falls	12116400	83.9	D, GH	Oct 2005 - Act.
13	Cedar River at Cedar Falls	12116500	84.2	D, GH, WT	Apr 1914 - Act.
14	Middle Fork Taylor Creek near Selleck	12116700	5.2	D	Aug 1956 - Dec 1963
15	North Fork Taylor Creek near Selleck	12116800	3.8	D	Jul 1956 - Dec 1963
16	Taylor Creek near Selleck	12117000	17.2	D, GH	Jul 1945 - Act.
17	Cedar River near Landsburg	12117500	121	D, GH	Aug 1895 - Act.
18	Cedar River below Diversion near Landsburg	12117600	124	D, GH, WT	Dec 1991 - Act.
19	Rock Creek above Walsh Lake Ditch near Landsburg	12117700	4.9	D	Oct 1985 - Sep 1990
20	Walsh Lake Ditch near Landsburg	12117820	9.4	D	Oct 1985 - Sep 1990
21	Rock Creek at Highway 516 near Ravensdale	12118400	11.2	D, GH, P	Jul 1956 - Act.
22	Rock Creek near Maple Valley	12118500	12.6	D, GH	Jul 1945 - Act.
23	Cedar River at Renton	12119000	184	D, GH, WT	Nov 1906 - Act.
24	May Creek near Renton	12119500	12.5	D	Jul 1945 - Sep 1950, Jul 1955 - Sep 1958, Oct 1963 - Sep 1964

TABLE 4-1
HYDROLOGIC GAGING STATIONS

Index No. [b]	Station Name	USGS Gage ID	Drainage Area (sq. mi)	Available Data [c]	Period of Record [a]
25	May Creek at Mouth near Renton	12119600	12.7	D	Dec 1945 - May 1979
26	Coal Creek near Bellevue	12119700	6.8	D	Jan 1964 - Feb 1979
27	Valley (no Branch Mercer) Creek near Bellevue	12119800	3.1	PS	Feb 1949 - Mar 1977
28	Mercer Creek near Bellevue	12120000	12	D, GH	Jul 1945 - Act.
29	Juanita Creek near Kirkland	12120500	6.7	D	Jul 1945 - Jun 1990
30	Issaquah Creek near Hobart	12120600	17.6	D, GH	Dec 1985 - Act.
31	Issaquah Creek near Issaquah	12121000	27	D	Jul 1945 - Sep 1964
32	Issaquah Creek near Mouth near Issaquah	12121600	56.6	D, GH	Jul 1945 - Act.
33	Tibbets Creek near Issaquah	12121700	3.9	D	Sep 1945 - Dec 1976
34	Sammamish Lake near Redmond	12122000	99.6	GH, LE	Jan 1939 - Act.
35	Sammamish River above Bear Creek near Redmond	12122010	102	D	Sep 1975 - Oct 1978
36	Bear Creek near Redmond	12122500	13.9	D	Jun 1945 - Oct 1949, May 1979 - Sep 1996
37	Cottage Lake Creek near Redmond	12123000	10.7	D	Jul 1955 - Sep 1965
38	Evans Creek Tributary near Redmond	12123300	2.5		Jan 1949 - Dec 1968
39	Evans Creek (above Mouth) near Redmond	12124000	13	D	Jul 1955 - Dec 1976, Oct 1984 - Mar 1987
40	Bear Creek at Redmond	12124500	48.2	D	Jun 1945 - Sep 1950, Jul 1955 - Sep 1958, Sep 1984 - Mar 1987
41	Sammamish River near Redmond	12125000	150	D	Feb 1939 - Apr 1957
42	Sammamish River near Woodinville	12125200	159	D, GH	Feb 1965 - Jun 2006
43	North Creek near Bothell	12126000	24.6	D	Jul 1945 - Jul 1973
44	Sammamish River at Bothell	12126500	212	D	Oct 1939 - Sep 1963, Oct 1982 - Oct 1986
45	Swamp Creek at Kenmore	12127100	23.1	D	Oct 1963 - May 1990

TABLE 4-1
HYDROLOGIC GAGING STATIONS

Index No. [b]	Station Name	USGS Gage ID	Drainage Area (sq. mi)	Available Data [c]	Period of Record [a]
46	Lyon Creek at Lake Forest Park	12127300	3.7	D	Sep 1963 - Jan 1975
47	Lake Ballinger near Edmonds	12127400	5.1	ND	1966-1978
48	McAleer Creek at Lake Forest Park	12127600	7.8	D	Sep 1963 - Jan 1974
49	Thornton Creek near Seattle	12128000	12.1	D	Jun 1945 - Sep 1946, Jun 1961 - Sep 1968, Mar 1996 - Sep 2013

a. Act. = Active gaging station
b. Gage locations are shown on Plate 4-1
c. Codes for data available online at the USGS National Water Information System:
D = Discharge (cfs)
GH = Gage Height (feet)
WT = Water Temperature (degrees Celsius)
LE = Lake Elevation (above NGVD 1929, feet)
P = Precipitation (total inches)
PS = Peak Streamflow only
ND = No Data available online

TABLE 4-2
CLIMATOLOGIC GAGING STATIONS

Index No. [b]	Station Name	Elevation (Feet NGVD)	Period of Record [a]
1	Carnation 1NW	60	1946 - Act.
2	Carnation 4NW	50	1940-2004
3	Cedar Falls 4SE	1700	1961 - 1976
4	Cedar Falls 5SE	3000	1961 - 1976
5	Cedar Falls 7SE	1800	1947 - 1976
6	Cedar Falls 7SSE	2400	1953 - 1976
7	Cedar Falls 8 SE	1700	1953 - 1976
8	Cedar Falls 10SE	2400	1953 - 1976
9	Cedar Lake	1560	1898 - Act.
10	Duvall 3NE	801	1931-1954
11	Everett	60	1894 - Act.
12	Kent	30	1912 - Act.
13	Landsburg	535	1903 - Act.
14	North Fork Taylor Creek	2200	1956 - 1976
15	Palmer 3ESE	920	1924 - Act.
16	Seattle Jackson Park	370	1961 - 1986
17	Seattle Maple Leaf Reservoir	423	1941 - 1960
18	Seattle Naval Air Station	49	1929 - 1970
19	Seattle Sand Point WSFO	60	1986 - Act.
20	Seattle-Tacoma WSCMO AP	370	1944 - Act.
21	Seattle University of Washington	95	1909 - 1983
22	Seattle WB Airport	10	1948 - 1965
23	Seattle WB City	10	1893 - 1972
24	Snoqualmie Falls	440	1898 - Act.
25	Snoqualmie Pass	3020	1909 - Act.
26	Snoqualmie Pass 4W	2200	1948 - 1952
27	Stampede Pass WSCMO	3850	1944 - Act.

a. Act. = Active gaging station
b. Gage locations are shown on Plate 4-1

TABLE 4-7
SNOW GAGING STATIONS

Index No. [b]	Station Name [c]	Station type	Station number	Elevation (feet NGVD)	Period of Record [a]
1	City Cabin	Snow Course/Aerial Marker	21B03	2390	1948 - Act.
2	Cougar Mountain	SNOTEL	21B42S	3200	1980 - Act.
3	Meadows Pass	SNOTEL	21B59S	3230	1994 - Act.
4	Mt. Gardner	Snow Course/Aerial Marker	21B21	3300	1959 - Act.
5	Mount Gardner	SNOTEL	21B21S	2920	1994 - Act.
6	Olallie Meadows	SNOTEL	21B55S	4030	1980 - Act.
7	Rex River	SNOTEL	21B17S	3810	1995 - Act.
8	Stampede Pass	SNOTEL	21B10S	3850	1980 - Act.
9	Tinkham Creek	SNOTEL	21B20S	2990	1993 - Act.
10	West Smay Creek	Snow Course/Aerial Marker	21B44	3600	2007 - Act.

a. Act. = Active gaging station
b. Gage locations are shown on plate 4-1
c. Stations with data available as of 2016 online at http://www.wcc.nrcs.usda.gov/

TABLE 6-1
CEDAR RIVER MINIMUM INSTREAM FLOWS [a]
MANDATED FOR THE CITY OF SEATTLE
(COMPLIANCE LOCATION: CEDAR RIVER BELOW DIVERSION NEAR LANDSBURG (12117600))

Water Week Starting	Critical Instream Flow Requirement (cfs)	Normal Instream Flow Requirement (cfs)	Normal Supplemental Instream Flow Requirement (cfs) [b]
1-Oct	103	214	214
8-Oct	133	279	334
15-Oct	163	279	334
22-Oct	183	279	334
29-Oct	203	279	334
5-Nov	203	279	334
12-Nov	203	284	339
19-Nov	203	284	339
26-Nov	206	292	347
3-Dec	206	292	347
10-Dec	206	292	347
17-Dec	206	292	347
24-Dec	206	290	345
31-Dec	188	275	275
7-Jan	188	275	275
14-Jan	188	275	275
21-Jan	188	275	275
29-Jan	188	275	275
4-Feb	188	275	275
11-Feb	188	273	378
18-Feb	188	273	378
25-Feb	188	273	378
4-Mar	188	273	378
11-Mar	188	273	378
18-Mar	188	273	378
25-Mar	188	273	378
1-Apr	188	273	378
8-Apr	186	273	378
15-Apr	186	273	273
22-Apr	196	268	268
29-Apr	196	268	268
6-May	200	268	268
13-May	205	268	268
20-May	215	258	258
27-May	215	258	258
3-Jun	205	256	256

TABLE 6-1
CEDAR RIVER MINIMUM INSTREAM FLOWS [a]
MANDATED FOR THE CITY OF SEATTLE
(COMPLIANCE LOCATION: CEDAR RIVER BELOW DIVERSION NEAR LANDSBURG (12117600))

Water Week Starting	Critical Instream Flow Requirement (cfs)	Normal Instream Flow Requirement (cfs)	Normal Supplemental Instream Flow Requirement (cfs) [b]
10-Jun	205	231	231
17-Jun	164	231	246
24-Jun	104	231	246
1-Jul	84	174	240
8-Jul	84	109	209
15-Jul	84	84	200
22-Jul	83	84	168
29-Jul	73	83	119
5-Aug	73	83	83
12-Aug	73	83	83
19-Aug	73	83	83
26-Aug	73	83	83
2-Sep	73	83	83
9-Sep	72	83	83
16-Sep	82	98	136
23-Sep	82	98	213

a. Values are in cfs
b. From June 17 through August 4, actual annual supplemental flow values will vary according to daily allocation established by the Cedar River Instream Flow Commission

TABLE 7-2
SPILLWAY DISCHARGE RATING FOR A SINGLE GATE (CFS)

Pool Elevation		Gate Opening (Feet)															
NAVD 88	Corps Datum	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8
16.75	20.0	204	400	596	798	1007	1188	1364	1512	#	#	#	1948	1948	1948	1948	1948
16.85	20.1	206	404	601	806	1017	1200	1379	1530	1688	#	#	2000	2000	2000	2000	2000
16.95	20.2	208	407	607	813	1027	1213	1394	1547	1708	#	#	2053	2053	2053	2053	2053
17.05	20.3	209	411	612	820	1037	1225	1408	1564	1728	#	#	2106	2106	2106	2106	2106
17.15	20.4	211	414	617	828	1046	1237	1423	1581	1748	#	#	2159	2159	2159	2159	2159
17.25	20.5	213	417	622	835	1056	1249	1437	1598	1768	#	#	2214	2214	2214	2214	2214
17.35	20.6	214	421	628	842	1065	1261	1451	1615	1787	#	#	#	2281	2281	2281	2281
17.45	20.7	216	424	633	850	1075	1272	1465	1632	1806	#	#	#	2318	2318	2318	2318
17.55	20.8	218	427	638	857	1084	1284	1479	1648	1825	1994	#	#	2371	2371	2371	2371
17.65	20.9	219	430	643	864	1093	1295	1493	1664	1843	2016	#	#	2427	2427	2427	2427
17.75	21.0	221	434	648	871	1103	1307	1506	1680	1862	2037	#	#	#	2482	2482	2482
17.85	21.1	222	437	653	878	1112	1318	1520	1696	1880	1308	#	#	#	2539	2539	2539
17.95	21.2	224	440	658	884	1121	1329	1533	1712	1898	2079	#	#	#	2594	2594	2594
18.05	21.3	226	443	663	891	1130	1340	1547	1728	1916	2100	2230	#	#	2650	2650	2650
18.15	21.4	227	446	667	898	1139	1352	1560	1743	1934	2120	2253	#	#	2705	2705	2705
18.25	21.5	229	449	672	905	1148	1362	1573	1759	1952	2140	2275	#	#	2765	2765	2765
18.35	21.6	230	453	677	911	1156	1373	1586	1774	1969	2161	2298	#	#	2822	2822	2822
18.45	21.7	232	456	682	911	1165	1384	1599	1789	1987	2180	2320	#	#	#	2879	2879
18.55	21.8	233	459	687	931	1174	1395	1611	1804	2004	2200	2342	#	#	#	2937	2937
18.65	21.9	235	462	691	931	1182	1405	1624	1819	2021	2220	2363	#	#	#	2995	2995
18.75	22.0	236	465	696	938	1191	1416	1637	1833	2038	2239	2385	#	#	#	#	3054

- Indicates unstable flow conditions, avoid operating in this range of gate openings and pool elevations. For example, for a pool of elev. 17.75 feet NAVD 1988, any gate opening should be less than or equal to 5 feet or greater than or equal to 7 feet.

TABLE 7-3
SPILLWAY GATE OPENING PATTERN [1]
For use when forebay elevation is GREATER than 17.45 feet (20.7 ft. COE)

Check Pool Elevation	Individual Gate Openings [b]					
Total Spillgate Opening	#1	#2	#3	#4	#5	#6 [c]
0	0	0	0	0	0	0
1	0	0	0	0	1	0
1.5	0	0	0	0	1.5	0
2	0	0	1	0	1	0
2.5	0	0	1.5	0	1	0
3	0	0	1	1	1	0
3.5	0	0	1.5	1	1	0
4	0	1	1	1	1	0
4.5	0	1	1.5	1	1	0
5	1	1	1	1	1	0
5.5	1	1	1.5	1	1	0
6	1	1	1.5	1.5	1	0
6.5	1	1.5	1.5	1.5	1	0
7	1	1.5	1.5	1.5	1.5	0
7.5	1.5	1.5	1.5	1.5	1.5	0
8	1.5	1.5	2	1.5	1.5	0
8.5	1.5	1.5	2	2	1.5	0
9	1.5	2	2	2	1.5	0
9.5	1.5	2	2	2	2	0
10	2	2	2	2	2	0
11	2	2	3	2	2	0
12	2	2	3	3	2	0
13	2	3	3	3	2	0
14	2	3	3	3	3	0
15	3	3	3	3	3	0
16	3	3	4	3	3	0
17	3	3	4	4	3	0
18	3	4	4	4	3	0
19	3	4	4	4	4	0
20	4	4	4	4	4	0
21	4	4	5	4	4	0
22	4	4	5	5	4	0
23	4	5	5	5	4	0
24	4	5	5	5	5	0
25	5	5	5	5	5	0
26	5	5	5	5	5	1
27	5	5	5	5	5	2
28	5	5	5	5	5	3
29	5	5	5	5	5	4
30	5	5	5	5	5	5
31	5	5	6	5	5	5
32	5	5	6	6	5	5
33	5	6	6	6	5	5
34	5	6	6	6	6	5
35	6	6	6	6	6	5
36	6	6	6	6	6	6

a. Do not operate in the range of gate opening and pool elevation indicated by the shaded area in Table 7-2
b. Flow pattern is based on having flow uniformly distributed across the channel and a minimum 1.0 foot gate opening to facilitate downstream fish passage
c. Spillway 6 is not opened until necessary for higher flows to optimize fish passage

TABLE 7-4

SPILLWAY GATE OPENING PATTERN [a]

For use when forebay elevation is LESS than 17.45 feet (20.7 ft. COE)

Check Pool Elevation	Individual Gate Openings [b]					
Total Spillgate Opening	#1	#2	#3	#4	#5	#6 [c]
0	0	0	0	0	0	0
1	0	0	0	0	1	0
1.5	0	0	0	0	1.5	0
2	0	0	1	0	1	0
2.5	0	0	1.5	0	1	0
3	0	0	1	1	1	0
3.5	0	0	1.5	1	1	0
4	0	1	1	1	1	0
4.5	0	1	1.5	1	1	0
5	1	1	1	1	1	0
5.5	1	1	1.5	1	1	0
6	1	1	1.5	1.5	1	0
6.5	1	1.5	1.5	1.5	1	0
7	1	1.5	1.5	1.5	1.5	0
7.5	1.5	1.5	1.5	1.5	1.5	0
8	1.5	1.5	2	1.5	1.5	0
8.5	1.5	1.5	2	2	1.5	0
9	1.5	2	2	2	1.5	0
9.5	1.5	2	2	2	2	0
10	2	2	2	2	2	0
11	2	2	3	2	2	0
12	2	2	3	3	2	0
13	2	3	3	3	2	0
14	2	3	3	3	3	0
15	3	3	3	3	3	0
16	3	3	4	3	3	0
17	3	3	4	4	3	0
18	3	4	4	4	3	0
19	3	4	4	4	4	0
20	4	4	4	4	4	0
21	4	4	CLEAR	4	4	0
22	4	4	CLEAR	CLEAR	4	0
23	4	CLEAR	CLEAR	CLEAR	4	0
24	4	CLEAR	CLEAR	CLEAR	CLEAR	0
25	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	0
26	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	1
27	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	2
28	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	3
29	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	4
30	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR
31	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR
32	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR
33	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR
34	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR
35	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR
36	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR	CLEAR

a. Do not operate in the range of gate opening and pool elevation indicated by the shaded area in Table 7-2

b. Flow pattern is based on having flow uniformly distributed across the channel and a minimum 1.0 foot gate opening to facilitate downstream fish passage

c. Spillway 6 is not opened until necessary for higher flows to optimize fish passage

TABLE 7-5

SPILLWAY GATE OPENING PATTERN WITH FLUMES [a]

All Flumes Should Be Turned On Before Opening Spillgates

Check Pool Elevation	Individual Gate Openings [b]					
Total Spillgate Opening	#1	#2	#3	#4 FLUMES	#5 FLUMES	#6 [c]
1	0	0	0	OPEN	OPEN	0
2	0	0	1	OPEN	OPEN	0
2.5	0	0	1.5	OPEN	OPEN	0
3	0	1	1	OPEN	OPEN	0
3.5	0	1	1.5	OPEN	OPEN	0
4	1	1	1	OPEN	OPEN	0
4.5	1	1	1.5	OPEN	OPEN	0
5	1	1.5	1.5	OPEN	OPEN	0
5.5	1.5	1.5	1.5	OPEN	OPEN	0
6	1.5	1.5	2	OPEN	OPEN	0
6.5	1.5	2	2	OPEN	OPEN	0
7	2	2	2	OPEN	OPEN	0
7.5	2	2	2.5	OPEN	OPEN	0
8	2	2.5	2.5	OPEN	OPEN	0
8.5	2.5	2.5	2.5	OPEN	OPEN	0
9	2.5	2.5	3	OPEN	OPEN	0
9.5	2.5	3	3	OPEN	OPEN	0
10	3	3	3	OPEN	OPEN	0
10.5	3	3	3.5	OPEN	OPEN	0
11	3	3.5	3.5	OPEN	OPEN	0
12	3.5	3.5	4	OPEN	OPEN	0
13	4	4	4	OPEN	OPEN	0
14	4	4	5	OPEN	OPEN	0
15	4	5	5	OPEN	OPEN	0
16	5	5	5	OPEN	OPEN	0
17	5	5	5	OPEN	OPEN	1
18	5	5	5	OPEN	OPEN	2
19	5	5	5	OPEN	OPEN	3
20	5	5	5	OPEN	OPEN	4
21	5	5	5	OPEN	OPEN	5
22	5	5	6	OPEN	OPEN	5
23	5	6	6	OPEN	OPEN	5
24	6	6	6	OPEN	OPEN	5
25	6	6	6	OPEN	OPEN	6

a. Do not operate in the range of gate opening and pool elevation indicated by the shaded area in Table 7-2

b. Flow pattern is based on having flow uniformly distributed across the channel and a minimum 1.0 foot gate opening to facilitate downstream fish passage

c. Spillway 6 is not opened until necessary for higher flows to optimize fish passage

TABLE 7-7
LWSC WATER CONSERVATION MEASURES

STAGE	TRIGGER	ACTION	POTENTIAL SAVINGS
I	These items should be done every year as a way to maximize available water	Minimize use of the large locks; maximized usage of the small locks. Fill lake to 18.75 feet (22.0 COE) during spring refill, maintain lake at this elevation until involuntary drawdown commences	Minimizing use of the large lock reduces water usage and reserves more stored water for use later during the drawdown period. Filling lake to 18.75 feet (22.0 ft. COE) maximizes amount of storage available for subsequent usage.
II	Pool falls below Critical Conservation Curve (CCC) for 5-7 consecutive days and with forecast trend to continue below this curve. Anticipated inflows are such that the pool is expected to continue to fall below the CCC unless project outflows are reduced.	Close old saltwater drain if open (as long as saltwater intrusion poses no problem), minimize use to extent possible Decrease smolt flume operation as feasible in coordination with Corps fisheries staff to optimize choice of flumes and hours of operation. No lockage restrictions for commercial vessels; continue to minimize usage of the large locks; maximize usage of the small locks. Initiate administrative procedures (notifications, press releases, etc.) as appropriate as outlined in Chapter 7 of the Water Control Manual.	Closure of the old saltwater drain can save a significant amount of water if it is being used (up to about 160 cfs if it is fully open 24/7). Closing a smolt flume or limiting operation to only part of the day can provide significant water savings.
III	Pool continues to stay below the CCC and the pool is expected to drop below an elevation of 16.75 feet (20.0 COE) with a high probability.	Request salinity waiver from Washington Department of Ecology regarding University bridge salinity standard. Keep saltwater return closed as salinity levels permit. Consider fully closing smolt flumes. If no DOE waiver and if salinity approaching U Bridge salinity standard, further reduce lockages as necessary by extending waiting times up to 1 hour for recreational vessels. Reduce flows to fish attraction diffuser well at the fish ladder when there is minimal impact on fish movement (this may be contingent on getting a DOE salinity waiver at University Bridge. No lockage restrictions for commercial vessels; continue to minimize usage of the large locks; maximize use of the small locks; limit waiting time for recreational vessels up to 1 hour. Implement administrative procedures (variances, notifications, press releases, etc.) as outlined in Chapter 7 of the Water Control Manual.	Savings dependent on whether salinity waiver allows a reduction in outflow from the project Savings dependent on prior usage. Savings dependent on smolt flume usage prior to closure. Up to 80 cfsd savings if fish ladder attraction water to diffuser well is shut 12 hours per day. Imposing a wait time of up to one hour for recreational vessels reduces the number of lockages to save on the order of 10 cfsd.

STAGE	TRIGGER	ACTION	POTENTIAL SAVINGS
IV	Pool falls below 16.75 feet (20.0 COE) and is forecast to drop below 16.25 feet (19.50 COE).	Maximize use of the small locks. Make further reductions in large lock usage, impose wait times for all vessels except emergency vessels. Consider further reductions to fish attraction flow, either via reduced flow to the diffuser well or full shut-down of the fish ladder. Implement administrative procedures (variances, notifications, press releases, etc.) as outlined in Chapter 7 of the Water Control Manual. Confer with Seattle Public Utilities about increasing flows in the Cedar River. Issue news releases advising of significant delays in all boating traffic at the Locks, and other potential impacts (i.e., reduction in fish attraction water to the fish ladder).	10 cfsd savings per large lockage reduction. Potential savings depends on flow reduction to the fish ladder. Completely shutting down the ladder is a savings of 183 cfs. Potential inflow increases to Lake Washington from increased Cedar River flows dependent on magnitude of Seattle's operational changes.

TABLE 8-1
LOWEST ANNUAL LAKE ELEVATIONS FROM INVOLUNTARY DRAWDOWN

Year	Elev. [a]	Date		Year	Elev.[a]	Date
1940	17.05	-		1979	17.17	1-Sep
1941	17.55	-		1980	17.64	31-Aug
1942	17.35	-		1981	18.07	31-Aug
1943	17.95	-		1982	16.98	22-Sep
1944	17.05	-		1983	18.08	26-Aug
1945	17.45	-		1984	17.10	8-Oct
1946	17.65	-		1985	16.72	11-Oct
1947	17.05	-		1986	16.84	22-Sep
1948	18.25	-		1987	16.19	30-Oct
1949	18.25	-		1988	17.03	24-Sep
1950	17.75	-		1989	17.00	10-Oct
1951	17.25	-		1990	17.09	1-Oct
1952	16.75	-		1991	17.05	20-Oct
1953	17.00	-		1992	16.97	22-Sep
1954	17.95	-		1993	17.70	4-Oct
1955	17.75	-		1994	16.98	8-Oct
1956	17.15	-		1995	17.72	25-Sep
1957	16.15	-		1996	17.77	14-Sep
1958	15.10	-		1997	17.89	14-Sep
1959	17.05	-		1998	17.13	25-Sep
1960	17.10	-		1999	17.47	5-Oct
1961	16.05	-		2000	17.65	8-Sep
1962	16.25	-		2001	17.97	19-Aug
1963	16.15	-		2002	16.95	27-Sep
1964	18.40	-		2003	16.91	4-Oct
1965	16.35	-		2004	17.36	10-Sep
1966	16.55	-		2005	17.07	25-Sep
1967	16.20	-		2006	16.94	12-Sep
1968	18.10	-		2007	17.22	24-Sep
1969	17.45	-		2008	17.37	1-Oct
1970	16.73	17-Sep		2009	17.07	12-Oct
1971	17.90	1-Sep		2010	17.45	15-Sep
1972	17.78	20-Sep		2011	17.18	20-Sep
1973	17.04	19-Sep		2012	16.97	10-Oct
1974	17.66	13-Oct		2013	17.43	25-Aug
1975	18.20	31-Jul		2014	17.66	20-Sep
1976	18.26	4-Sep		2015	16.69	28-Aug
1977	17.30	22-Aug		2016	16.94	25-Sep
1978	17.43	31-Aug				

a. Elevations in feet (NAVD 1988), measured at the project forebay

LAKE WASHINGTON SHIP CANAL
SEATTLE, WA

WATER CONTROL MANUAL

PLATES

PUGET SOUND

Hiram M. Chittenden Lock and Dam

Salmon Bay

Fremont Cut

Green Lake

LAKE WASHINGTON SHIP CANAL

0 0.5 1 2 Miles

N

Lake Washington Watershed Boundary

Portage Bay

Montlake Cut

Union Bay

Lake Union

Lake Washington

Elliott Bay

SEATTLE

99

5

520

NOTE: PLATE SIZE IS 11"x17"

U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

Plate 2-1
Location and Vicinity Map
Lake Washington Ship Canal

Completed by: WEST	Sep 2016

PLATE 2-1

Vicinity Map

Cities

Everett
Seattle
Bellevue
Renton
Tacoma
Puget Sound
LAKE WASHINGTON SHIP CANAL
LAKE WASHINGTON
SAMMAMISH RIVER
LAKE SAMMAMISH
CEDAR RIVER
CHESTER MORSE LAKE
LAKE WASHINGTON WATERSHED
Snohomish County
King County
Kittitas County
Pierce County
5
520
405
90

0 12.5 25 50 Miles

N

REDACTED CONTENT

PLATE 2-2

REDACTED CONTENT

PLATE 2-3

REDACTED CONTENT

PLATE 2-4

REDACTED CONTENT

PLATE 2-5

REDACTED CONTENT

REDACTED CONTENT

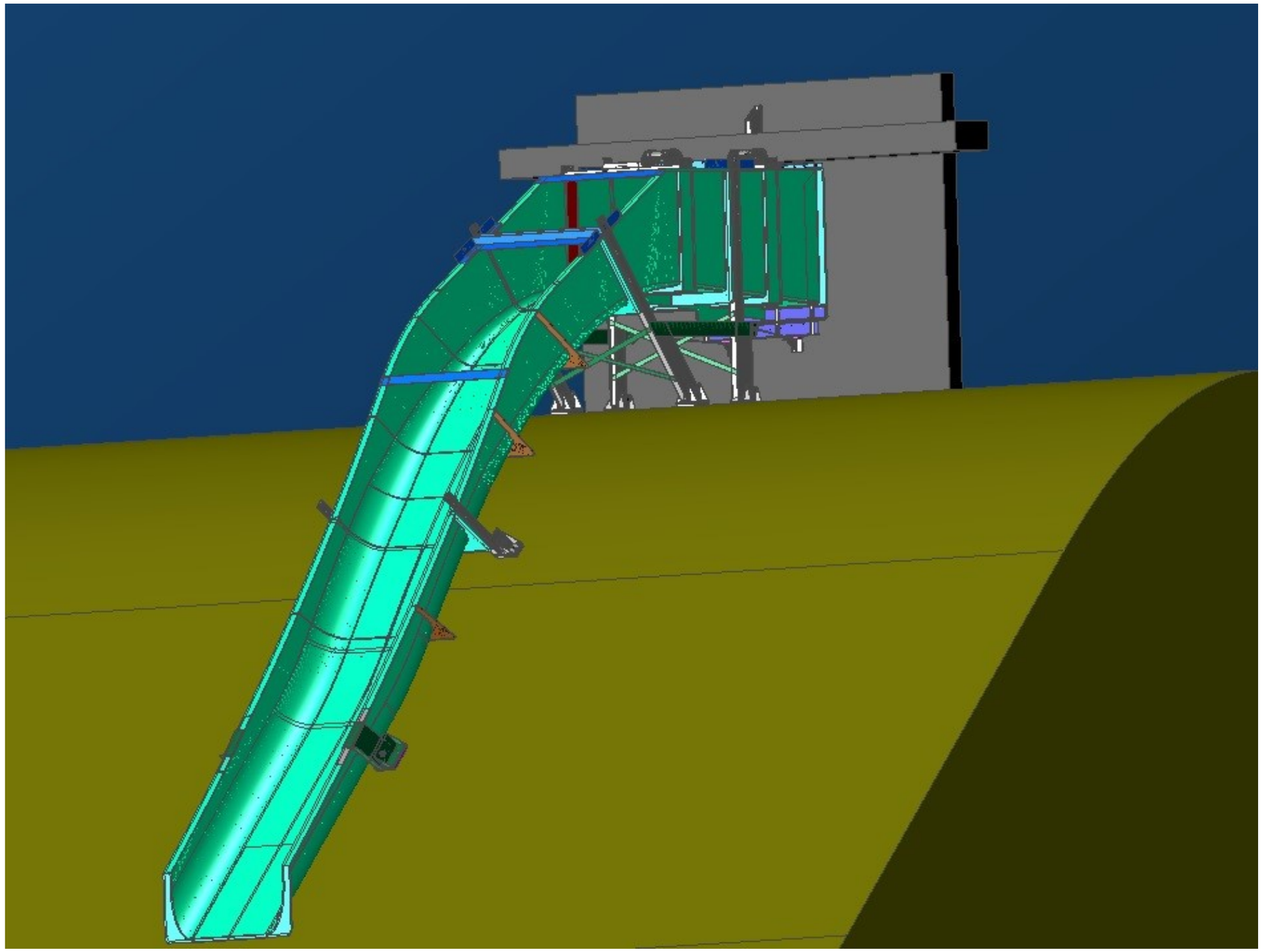
PLATE 2-7

REDACTED CONTENT

REDACTED CONTENT

REDACTED CONTENT

PLATE 2-10



U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

Plate 2-11

Smolt Flume Schematic
schematic of new flume installed and tested in 2017

May 2017

REDACTED CONTENT

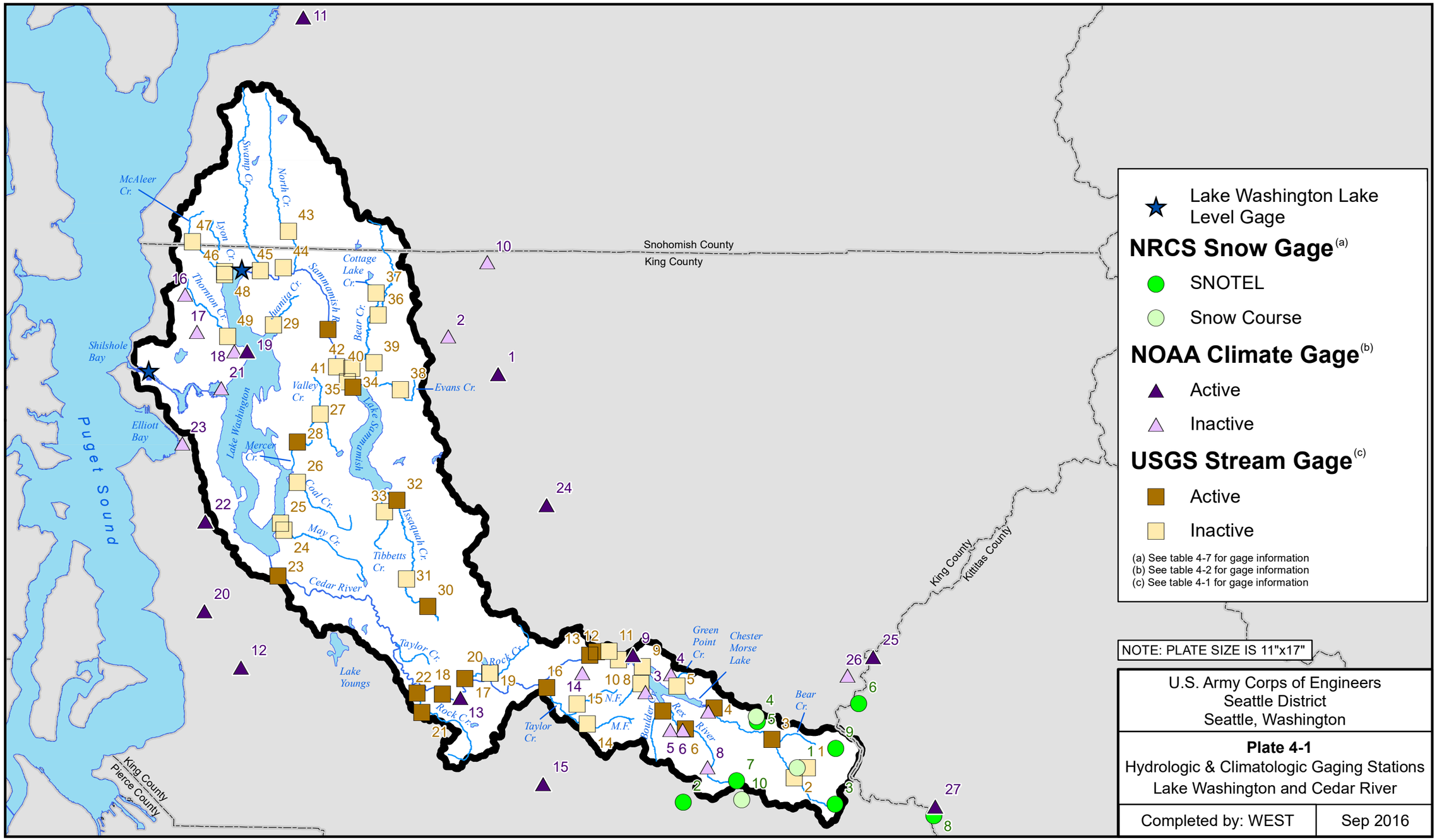
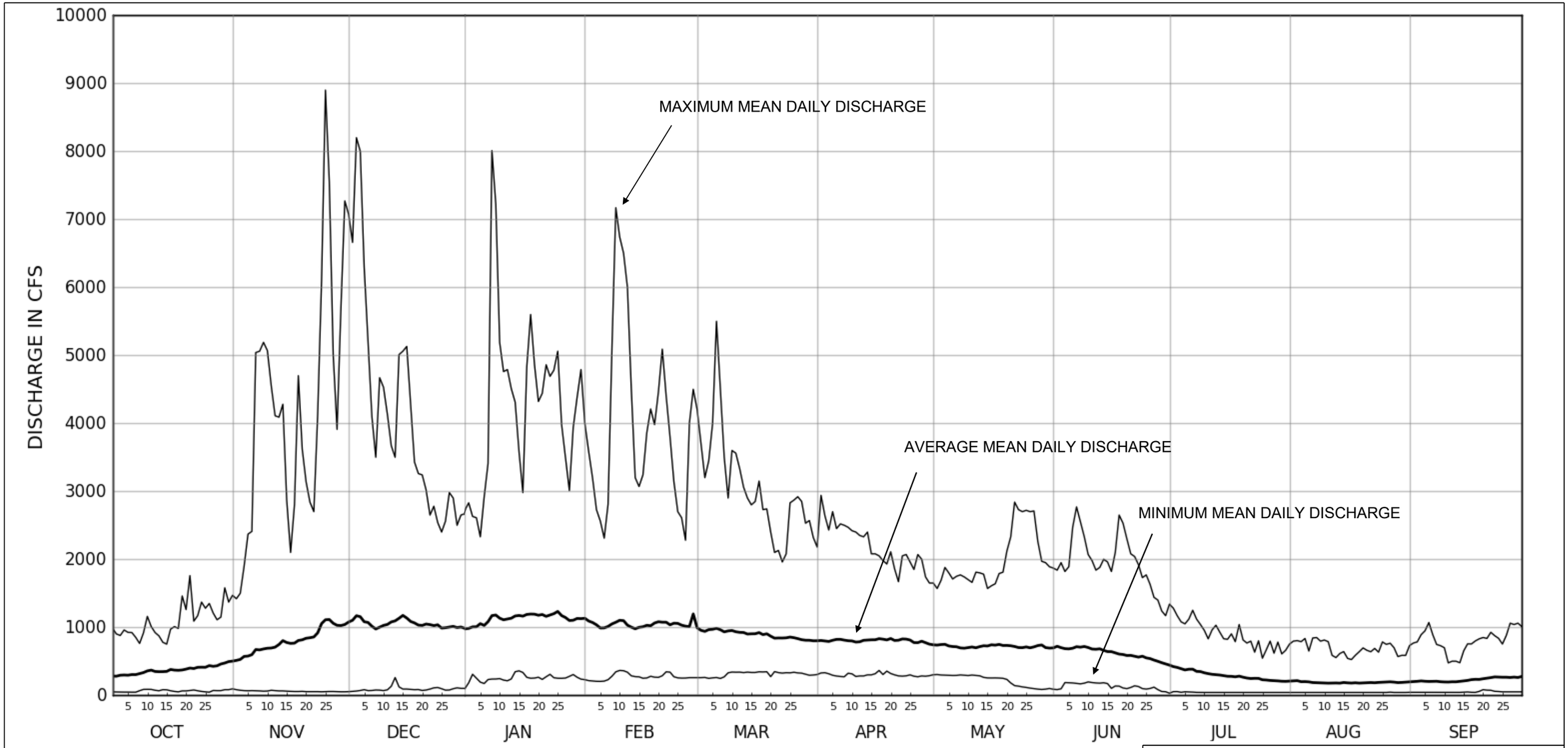

McAleer Cr.
Swamp Cr.
North Cr.
Lyon Cr.
Thornton Cr.
Issaquah Cr.
Sammamish R.
Cottage Lake Cr.
Bear Cr.
Shilshole Bay
Elliott Bay
Puget Sound
Lake Washington
Lake Sammamish
Valley Cr.
Evans Cr.
Mercer Cr.
Coal Cr.
May Cr.
Tibbetts Cr.
Issaquah Cr.
Cedar River
Taylor Cr.
Rock Cr.
Lake Youngs
Green Point Cr.
Chester Morse Lake
N.F. Rec. River
M.F. Boulder River
Bear Cr.
Snohomish County
King County
King County
Kittitas County
King County
Pierce County
Lake Washington Lake Level Gage
NRCS Snow Gage(a)
SNOTEL
Snow Course
NOAA Climate Gage(b)
Active
Inactive
USGS Stream Gage(c)
Active
Inactive
(a) See table 4-7 for gage information
(b) See table 4-2 for gage information
(c) See table 4-1 for gage information
NOTE: PLATE SIZE IS 11"x17"
U.S. Army Corps of Engineers
Seattle District
Seattle, Washington
Plate 4-1
Hydrologic & Climatologic Gaging Stations
Lake Washington and Cedar River
Completed by: WEST
Sep 2016

PLATE 4-1

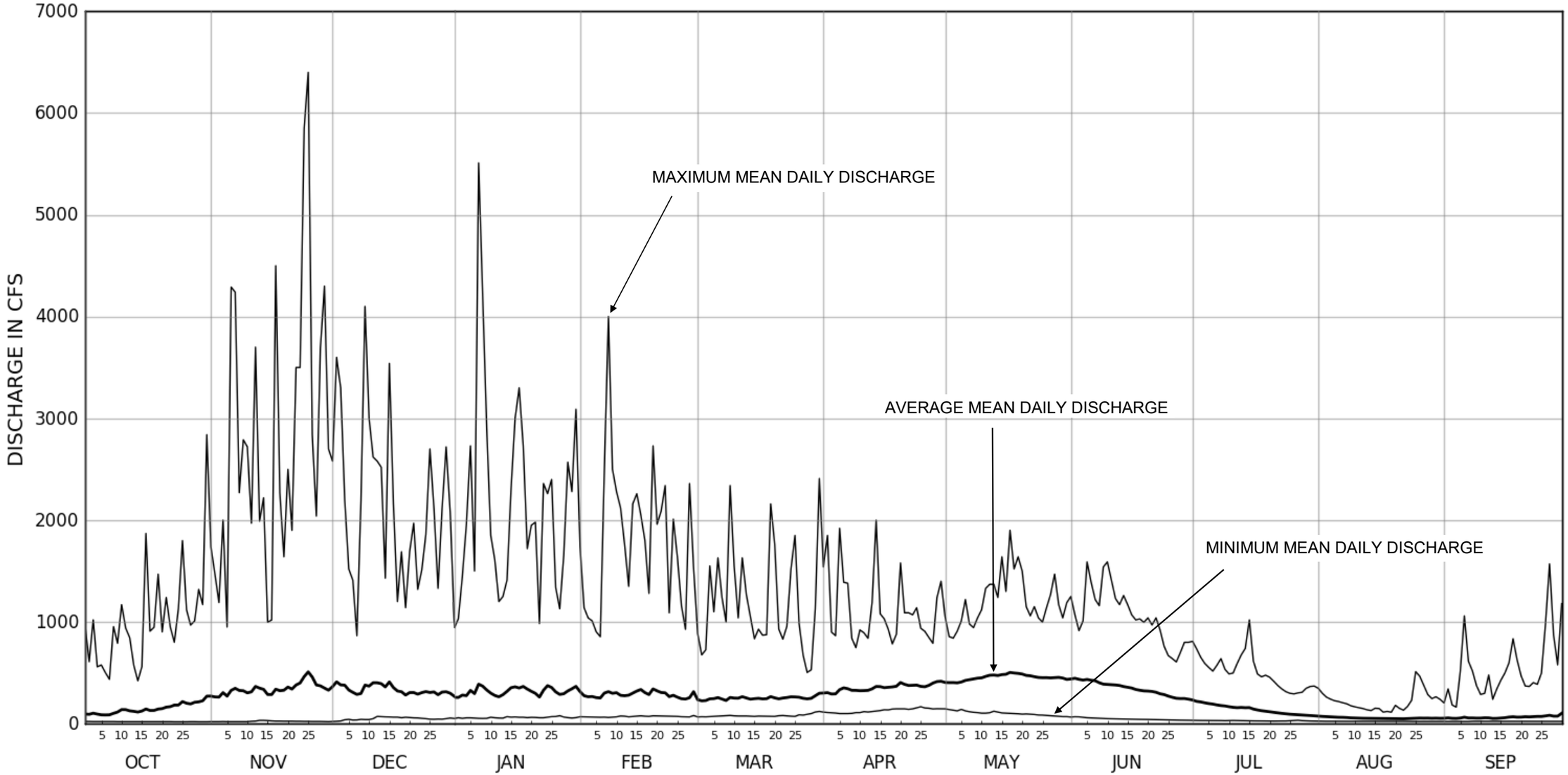


U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

Plate 4-2
Summary Hydrograph
Cedar River at Renton
USGS Gage 12119000
1945 - 2016

Completed by: WEST	Nov 2016

PLATE 4-2

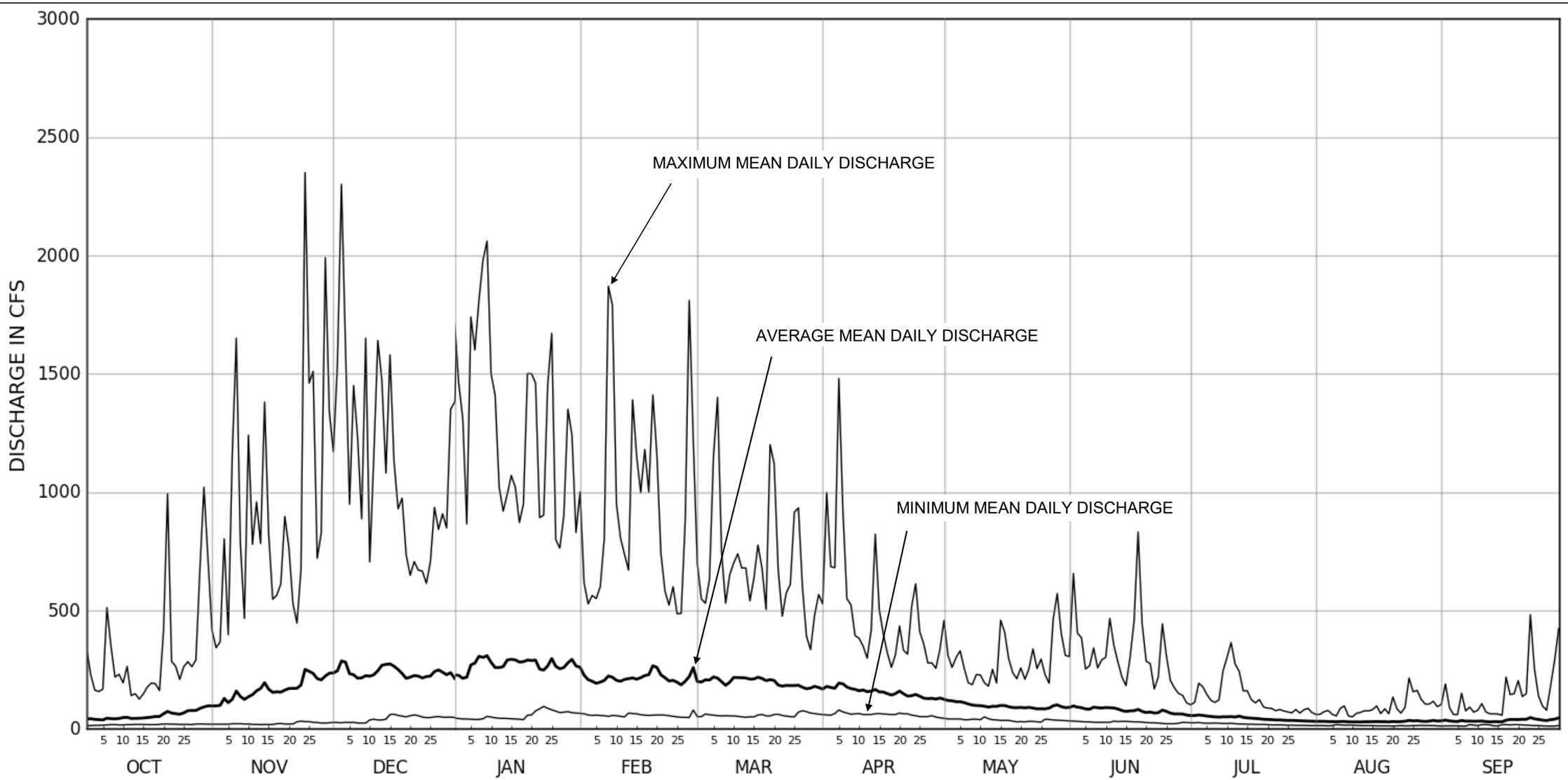


U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

Plate 4-3
Summary Hydrograph
Cedar River near Cedar Falls
USGS Gage 12115000
1945 - 2016

Completed by: WEST	Nov 2016

PLATE 4-3

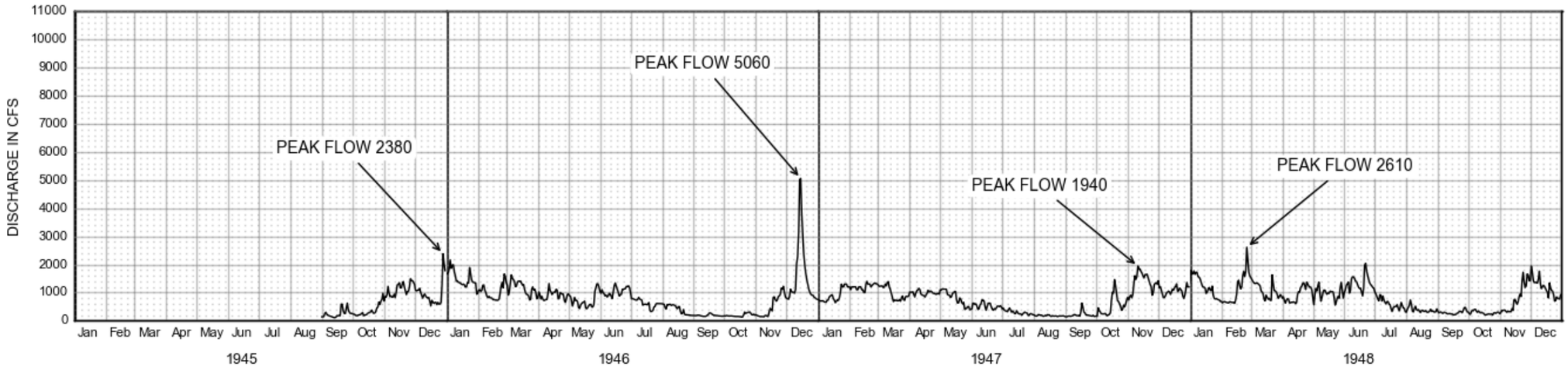


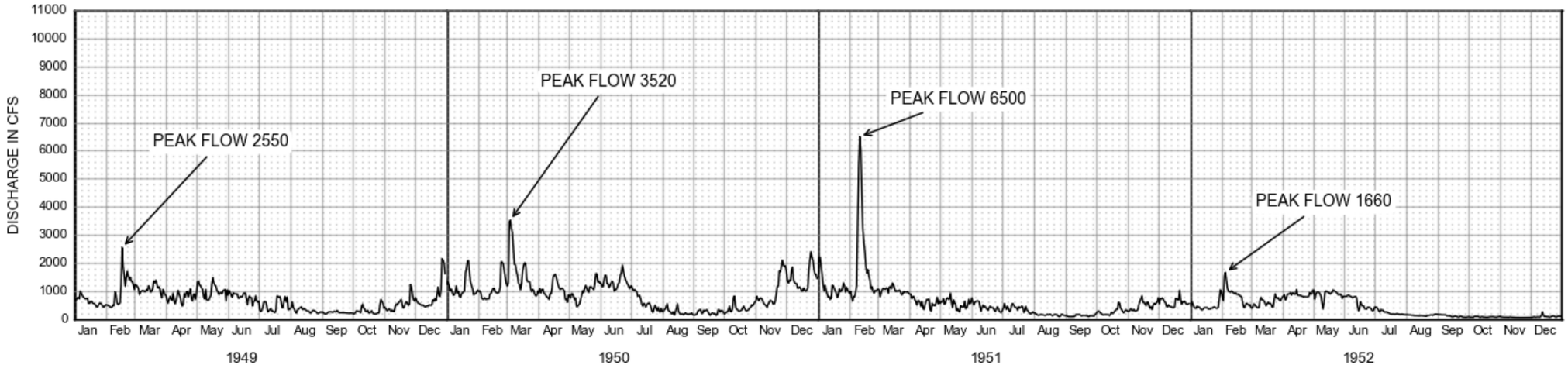
U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

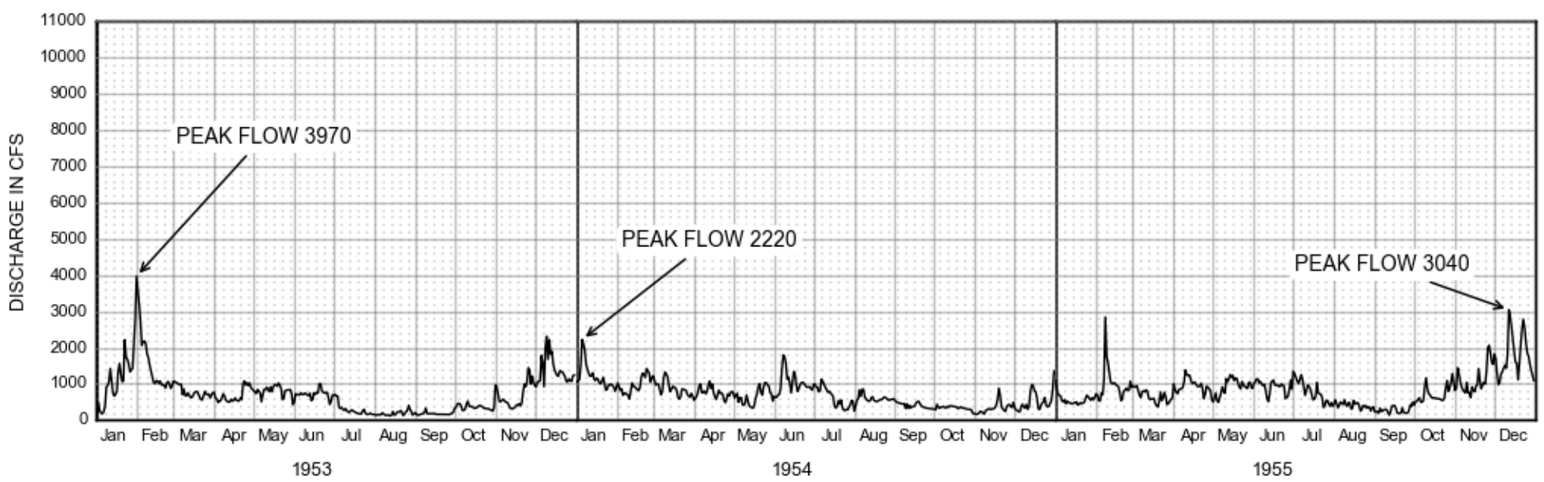
Plate 4-4
Summary Hydrograph
Issaquah Creek near Mouth near Issaquah
USGS Gage 12121600
1963 - 2016

Completed by: WEST	Nov 2016

PLATE 4-4







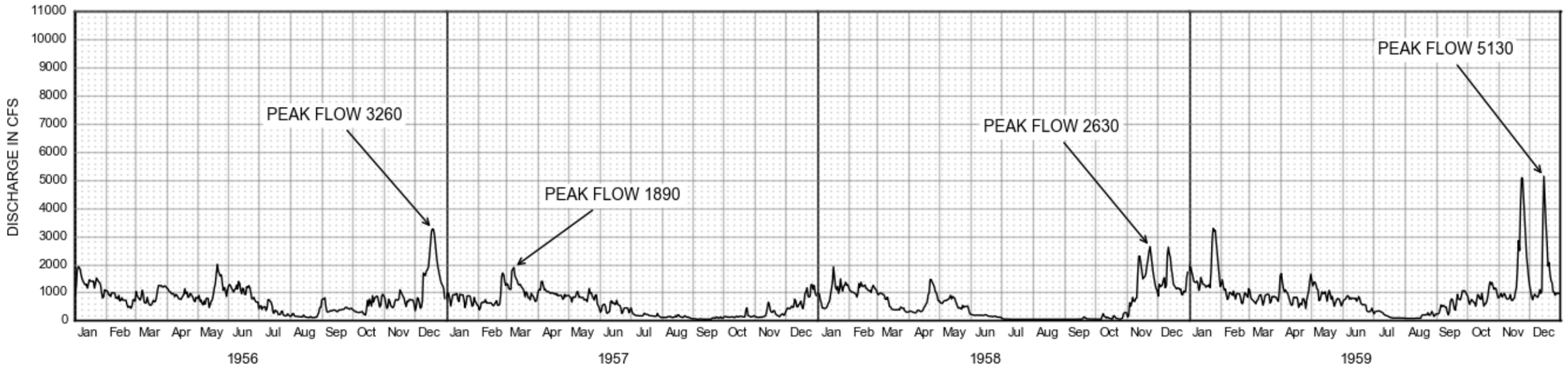
Note: Plate size is 11" x 17"

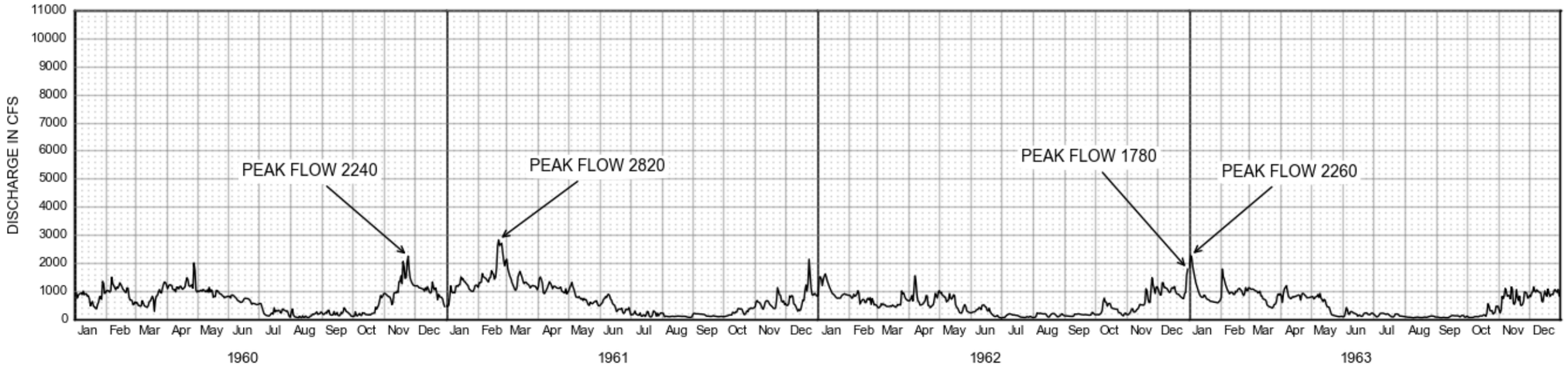
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

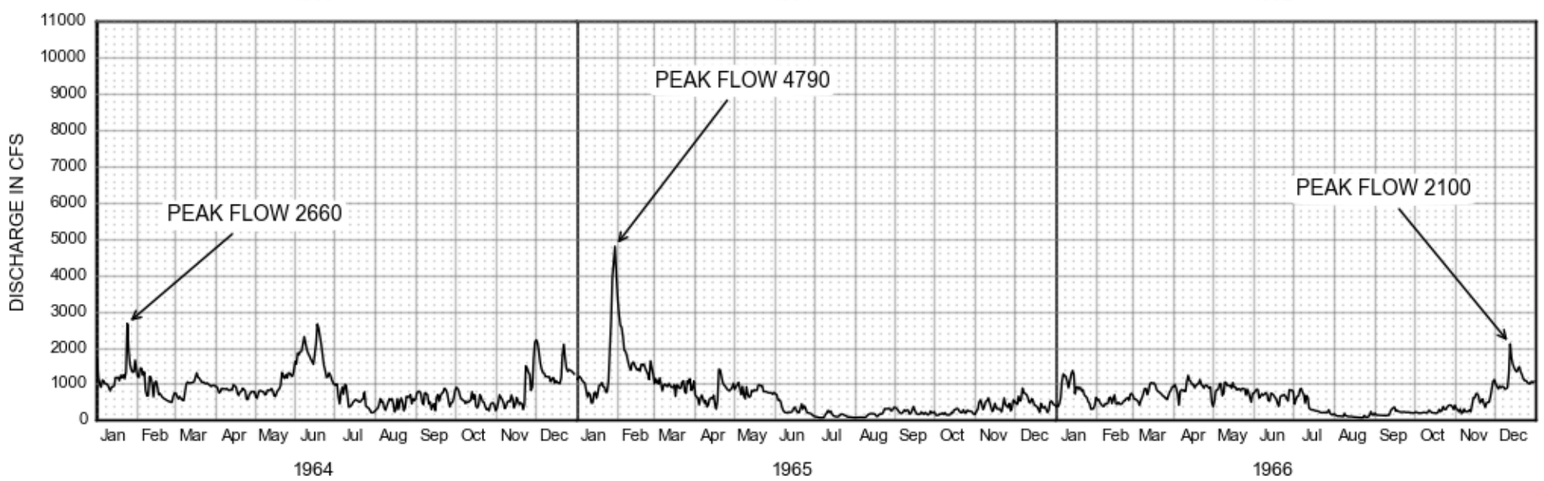
Plate 4-5
Daily Discharge Hydrographs
Cedar River at Renton, USGS Gage 12119000
1945-2016
Sheet 1 of 7

Completed by: WEST	Nov 2016

PLATE 4-5







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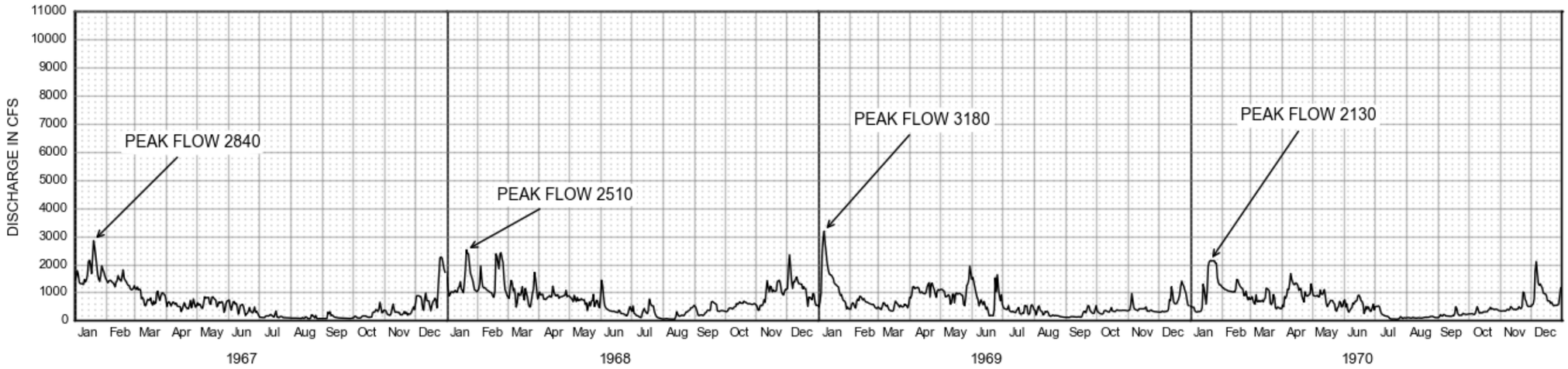
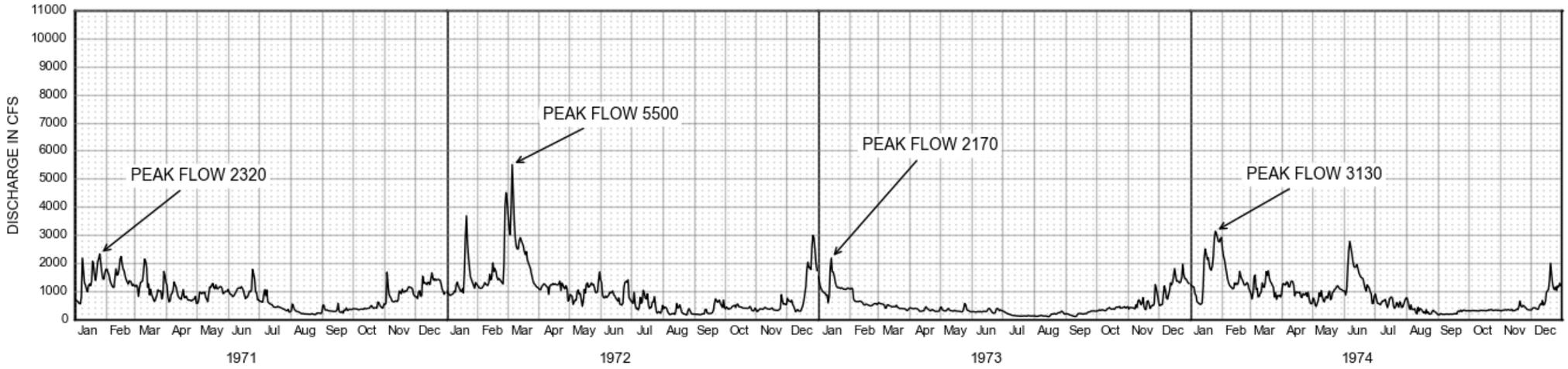
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

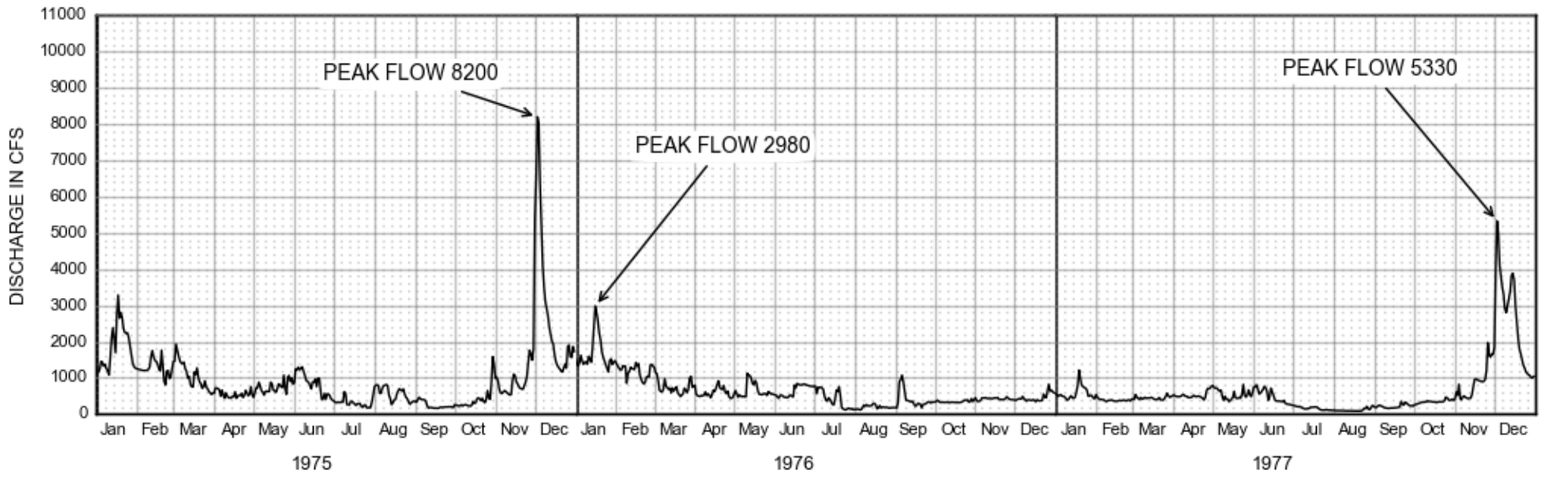
Plate 4-5
Daily Discharge Hydrographs
Cedar River at Renton, USGS Gage 12119000
1945-2016
Sheet 2 of 7

Completed by: WEST	Nov 2016

PLATE 4-5







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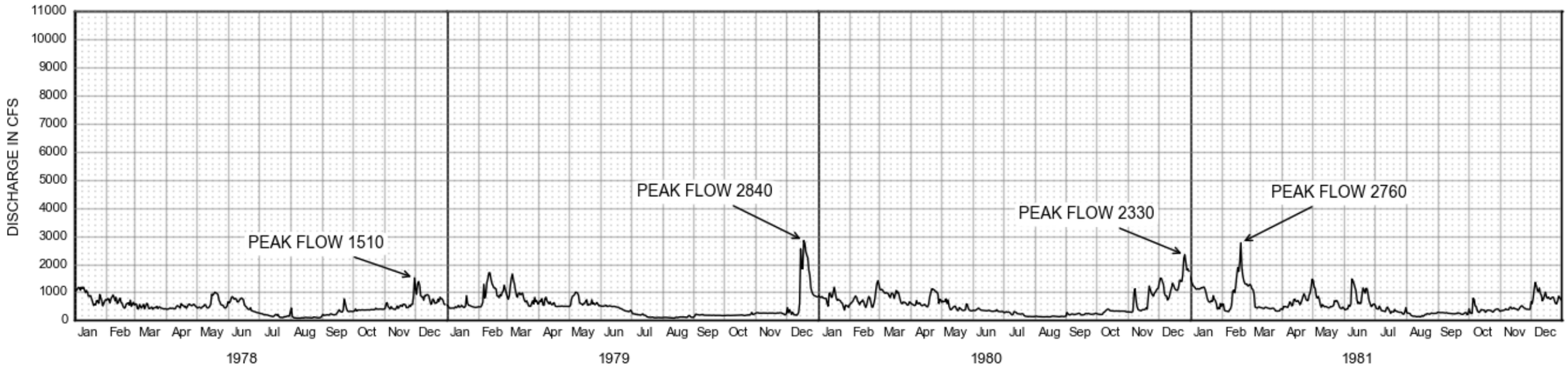
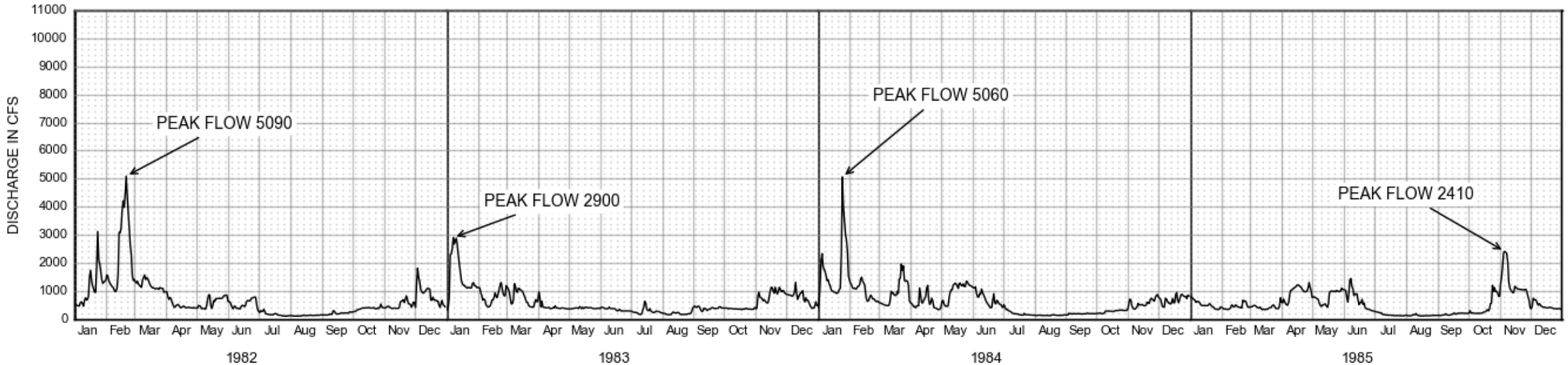
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

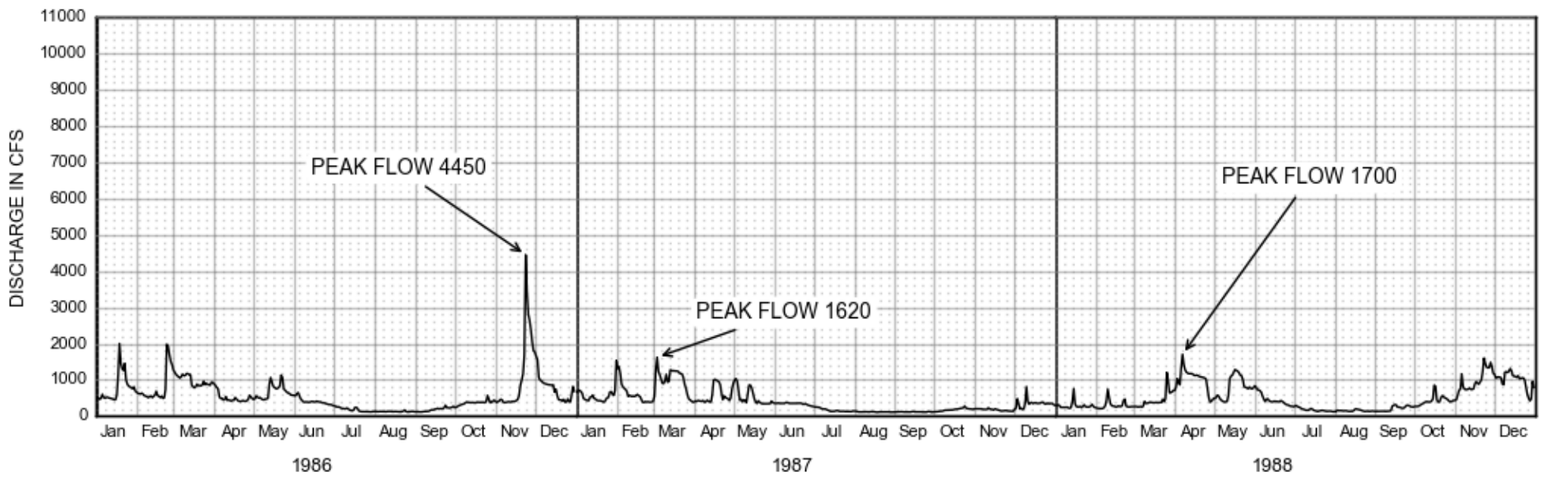
Plate 4-5
Daily Discharge Hydrographs
Cedar River at Renton, USGS Gage 12119000
1945-2016
Sheet 3 of 7

Completed by: WEST	Nov 2016

PLATE 4-5







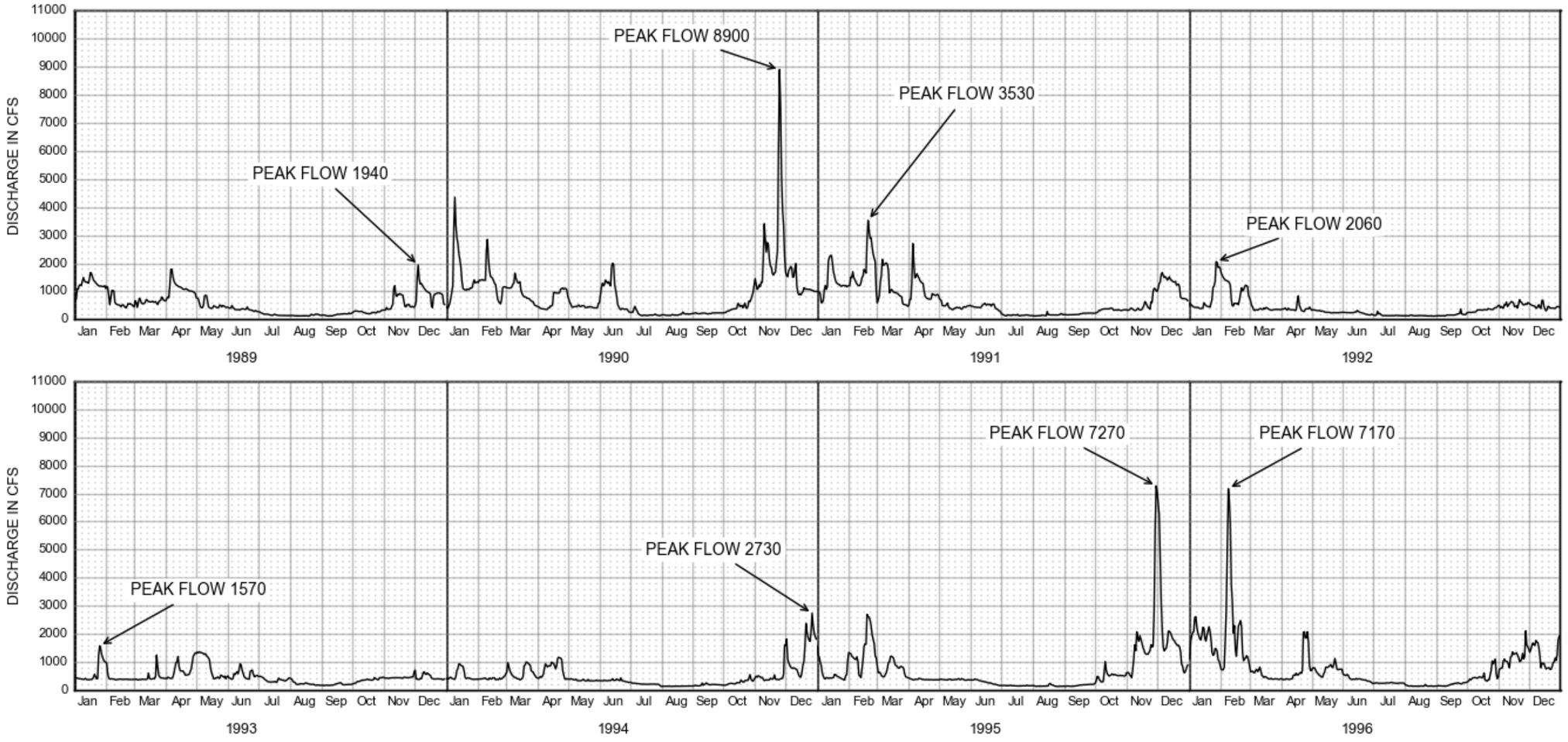
Note: Plate size is 11" x 17"

U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-5
Daily Discharge Hydrographs
Cedar River at Renton, USGS Gage 12119000
1945-2016
Sheet 4 of 7

Completed by: WEST	Nov 2016

PLATE 4-5



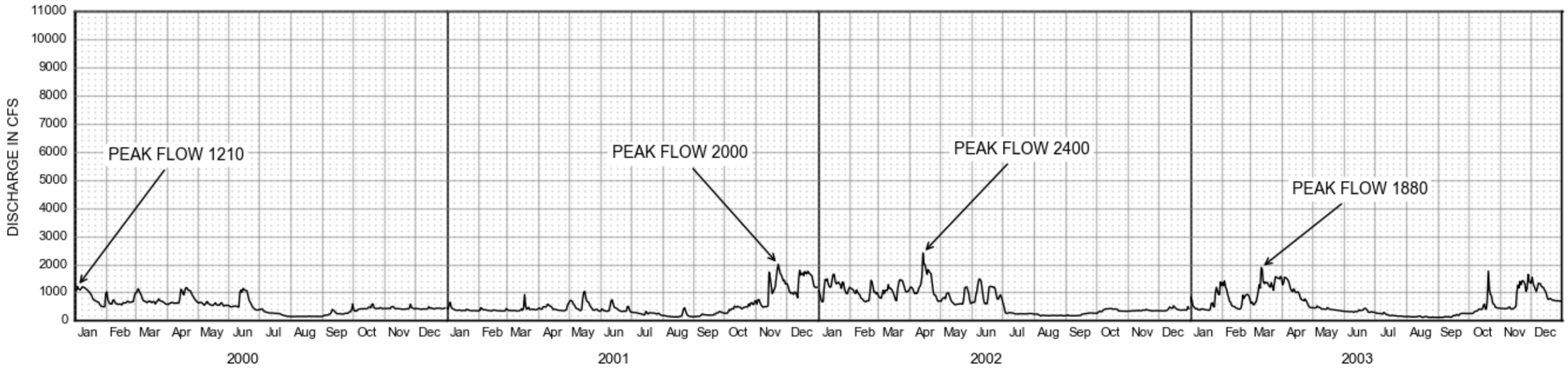
Note: Plate size is 11" x 17"

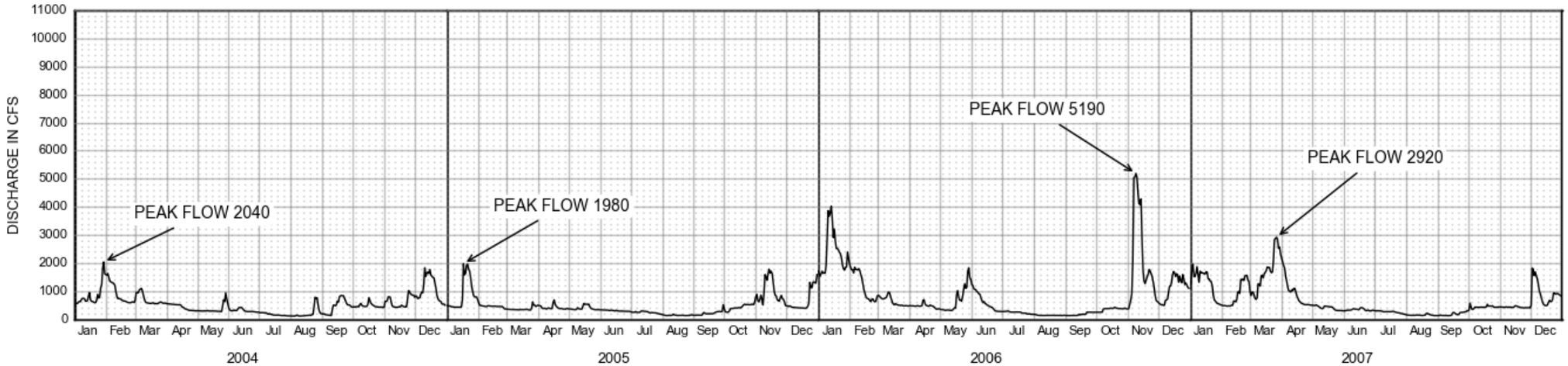
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

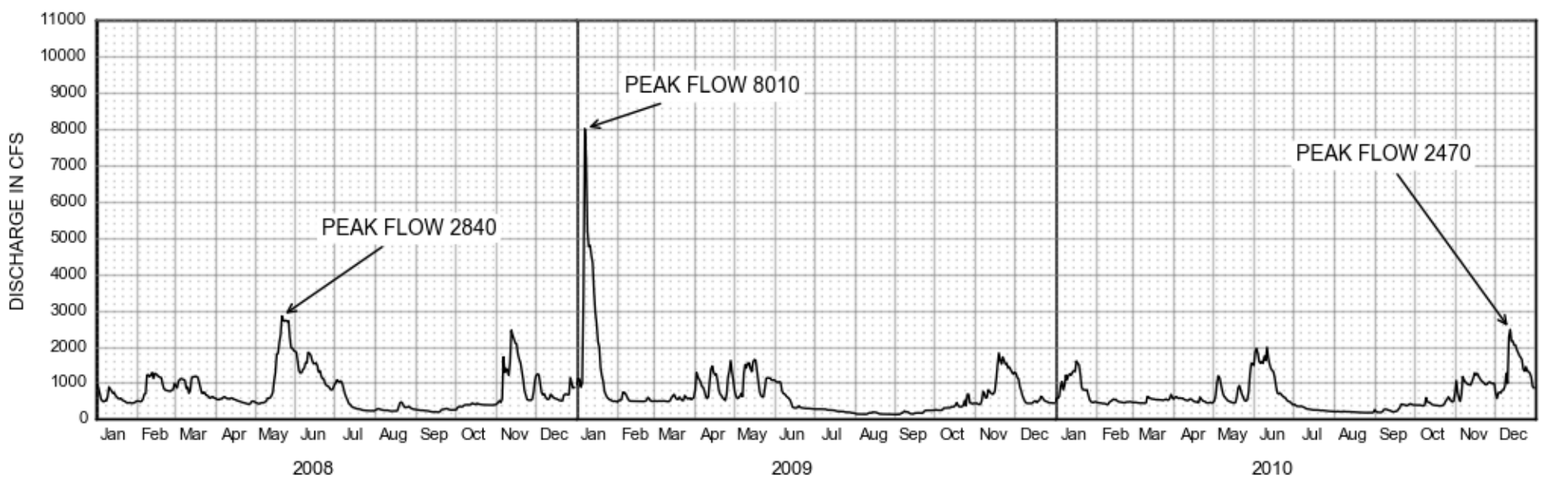
Plate 4-5
Daily Discharge Hydrographs
Cedar River at Renton, USGS Gage 12119000
1945-2016
Sheet 5 of 7

Completed by: WEST	Nov 2016

PLATE 4-5







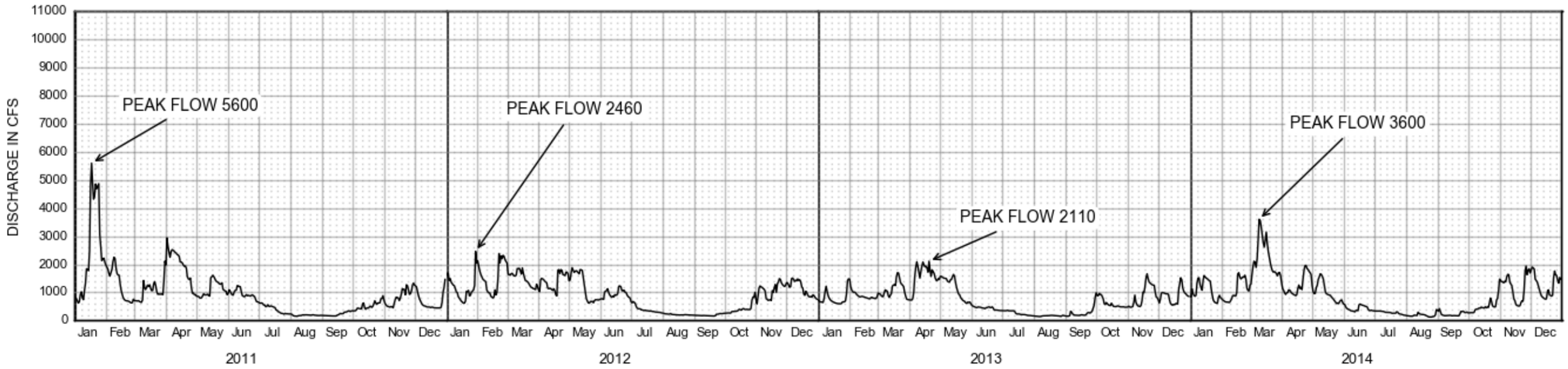
Note: Plate size is 11" x 17"

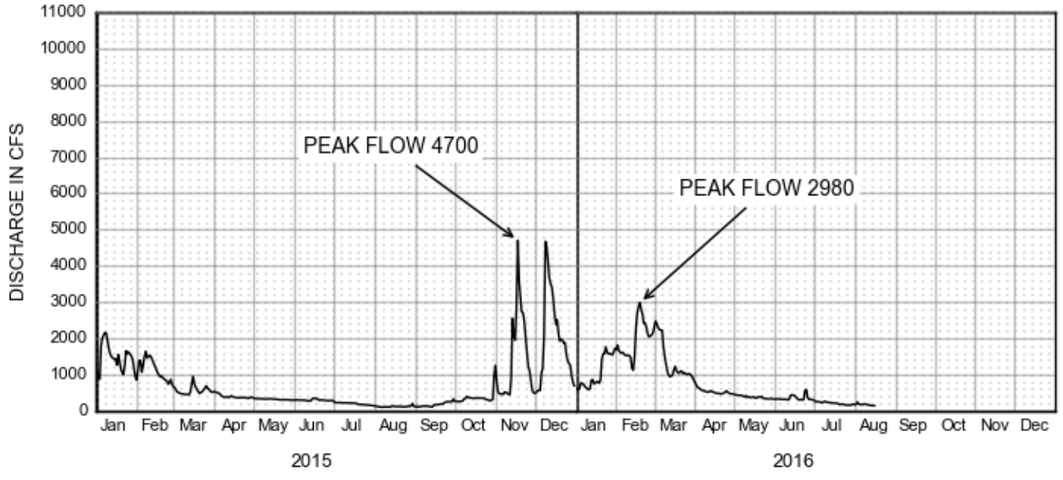
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-5
Daily Discharge Hydrographs
Cedar River at Renton, USGS Gage 12119000
1945-2016
Sheet 6 of 7

Completed by: WEST	Nov 2016

PLATE 4-5





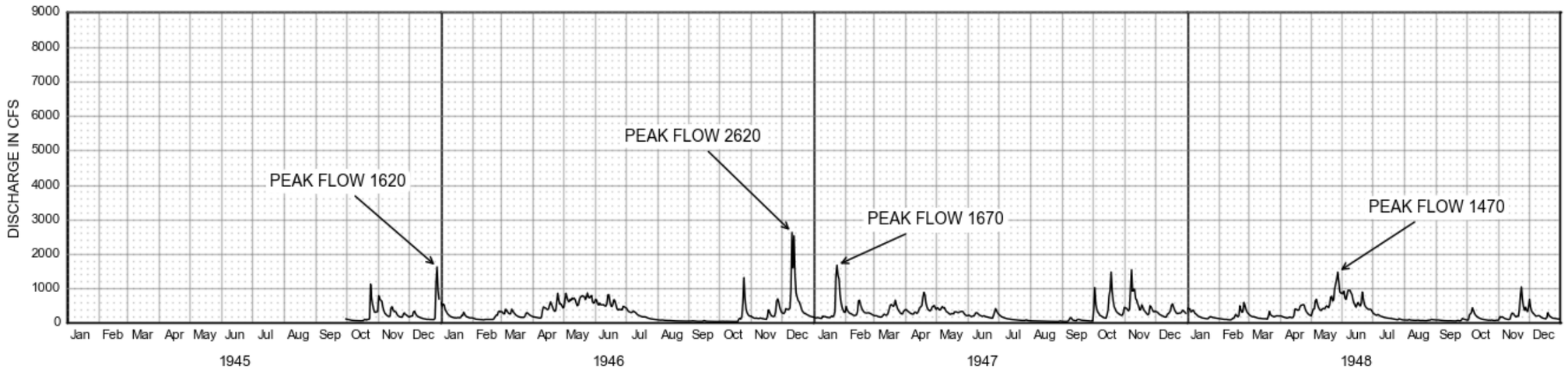
Note: Plate size is 11" x 17"

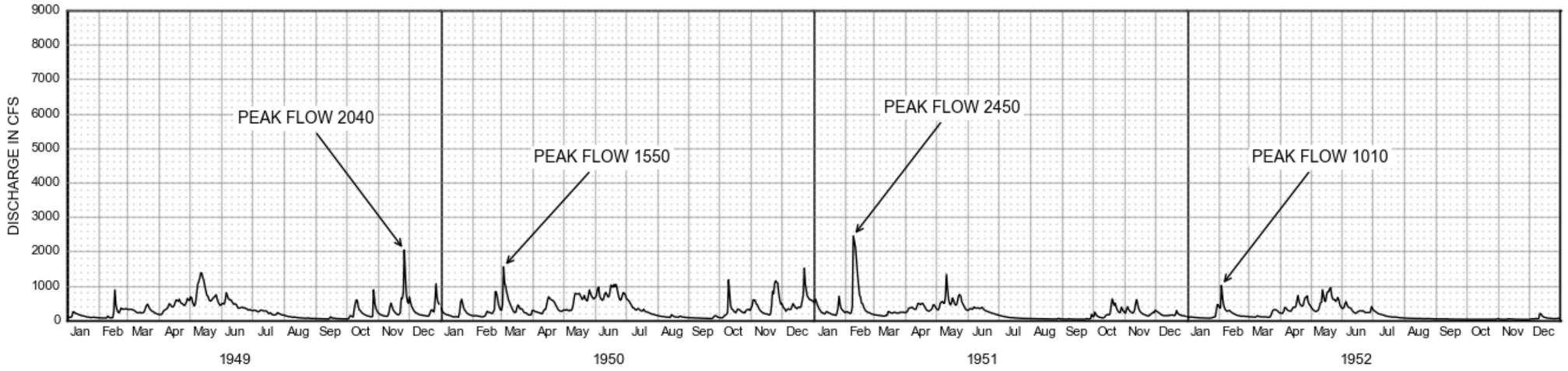
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

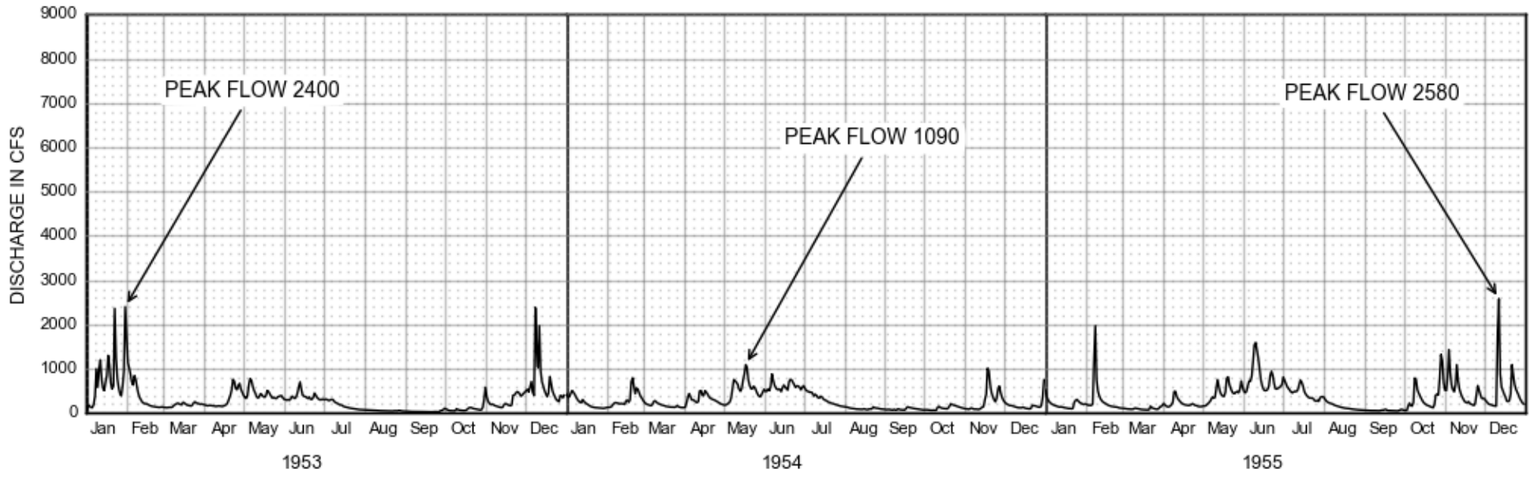
Plate 4-5
Daily Discharge Hydrographs
Cedar River at Renton, USGS Gage 12119000
1945-2016
Sheet 7 of 7

Completed by: WEST	Nov 2016

PLATE 4-5







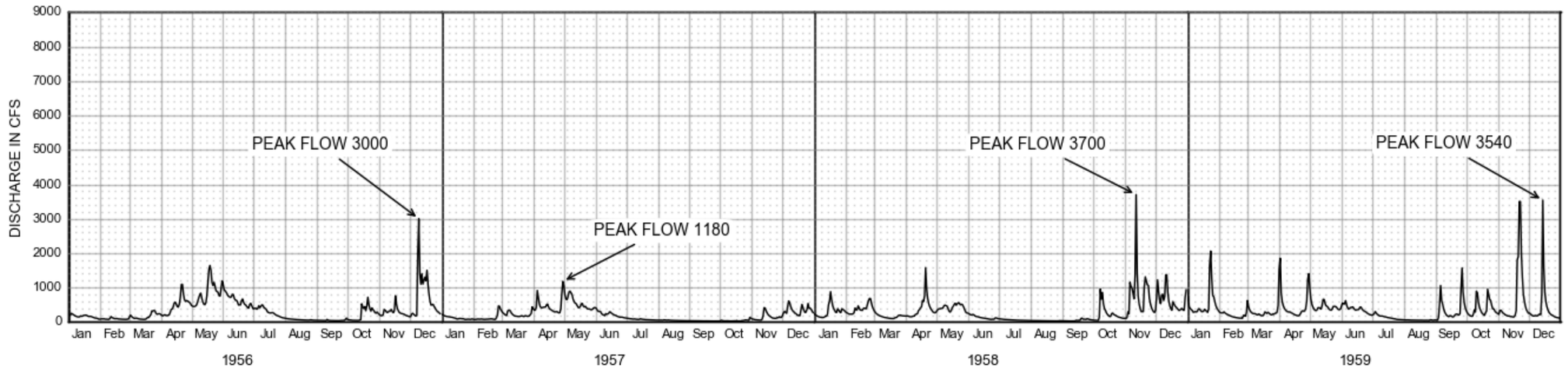
Note: Plate size is 11" x 17"

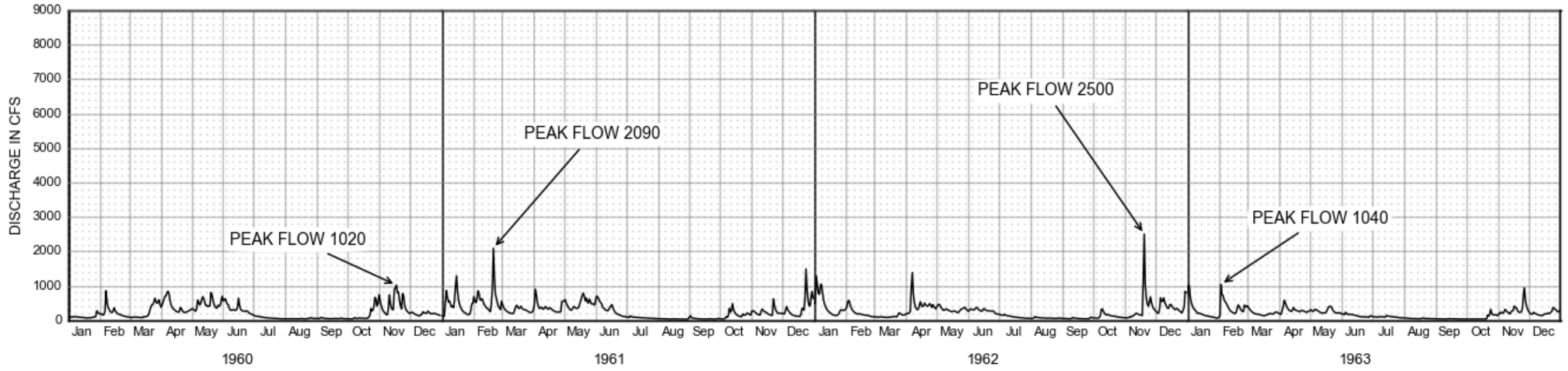
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

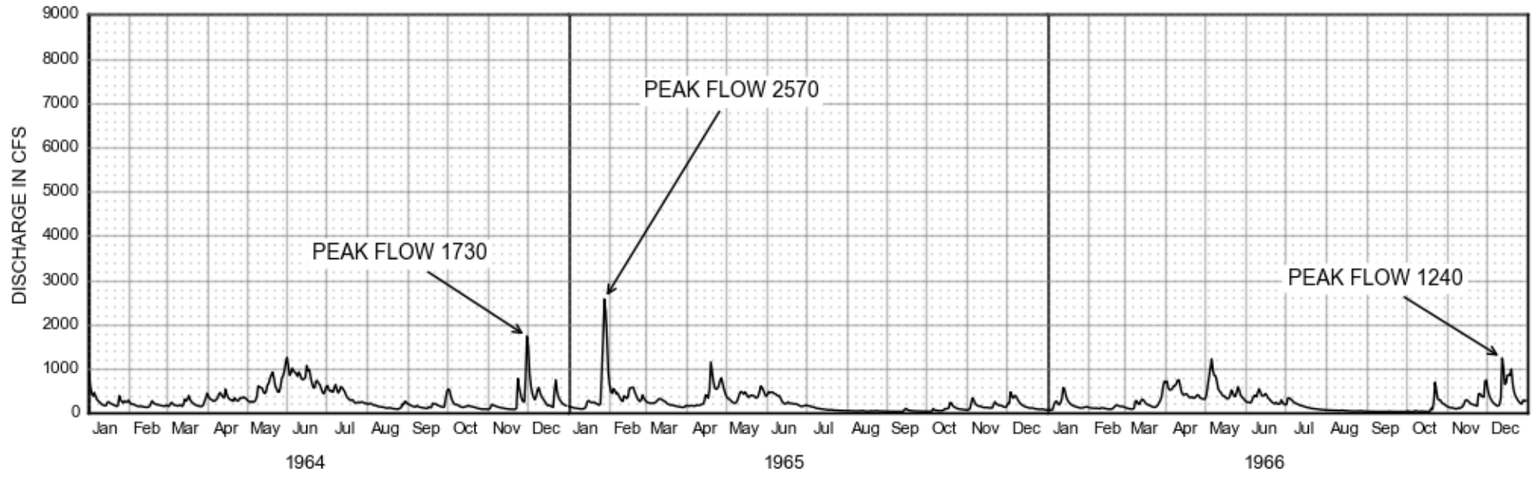
Plate 4-6
Daily Discharge Hydrographs
Cedar River near Cedar Falls, USGS Gage 1211500
1945-2016
Sheet 1 of 7

Completed by: WEST	Nov 2016

PLATE 4-6







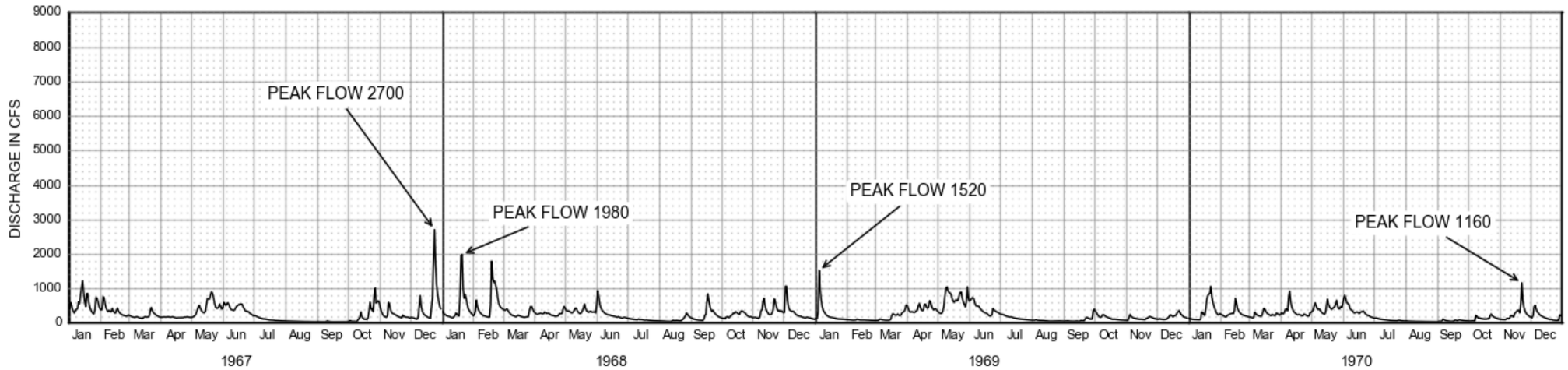
Note: Plate size is 11" x 17"

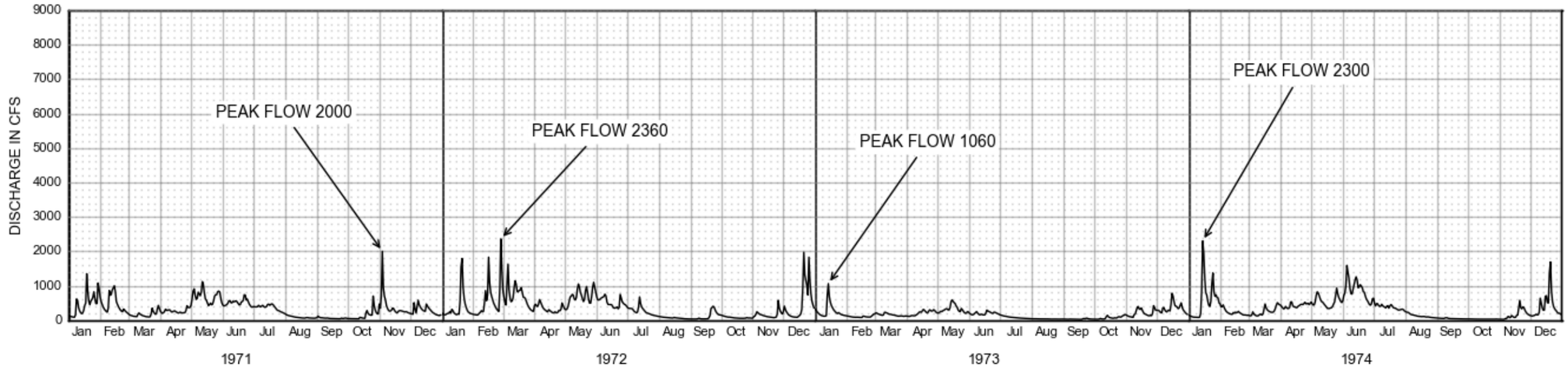
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

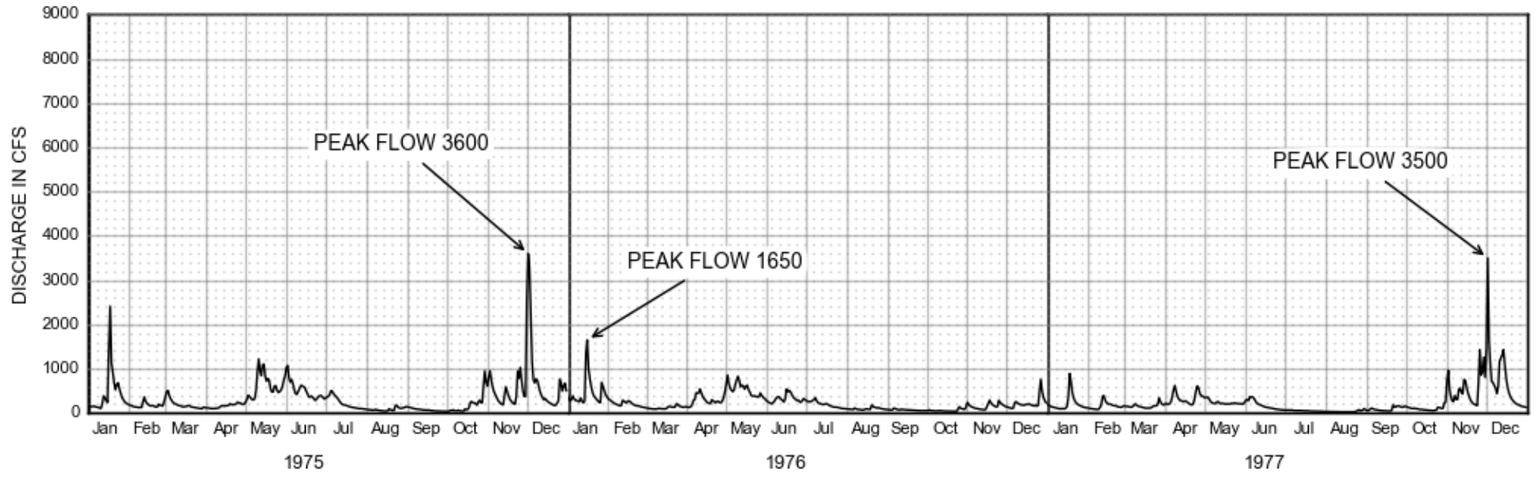
Plate 4-6
Daily Discharge Hydrographs
Cedar River near Cedar Falls, USGS Gage 1211500
1945-2016
Sheet 2 of 7

Completed by: WEST	Nov 2016

PLATE 4-6







Note: Plate size is 11" x 17"

U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-6
Daily Discharge Hydrographs
Cedar River near Cedar Falls, USGS Gage 1211500
1945-2016
Sheet 3 of 7

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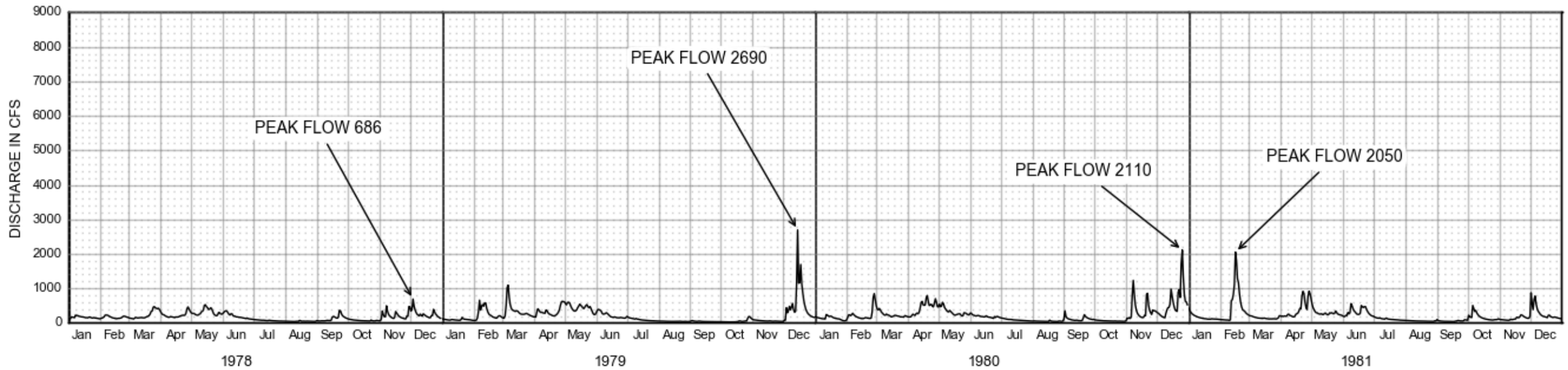
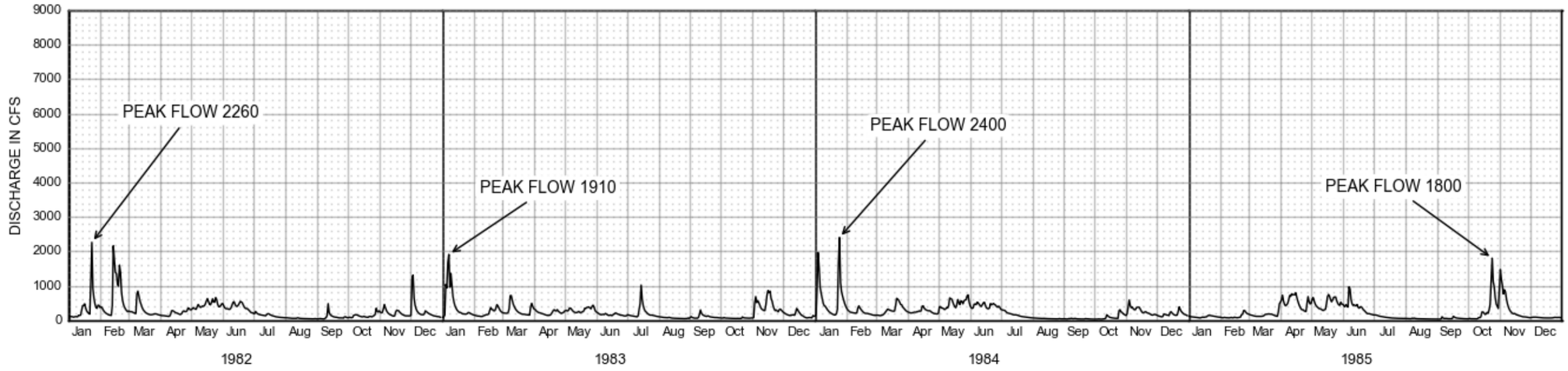
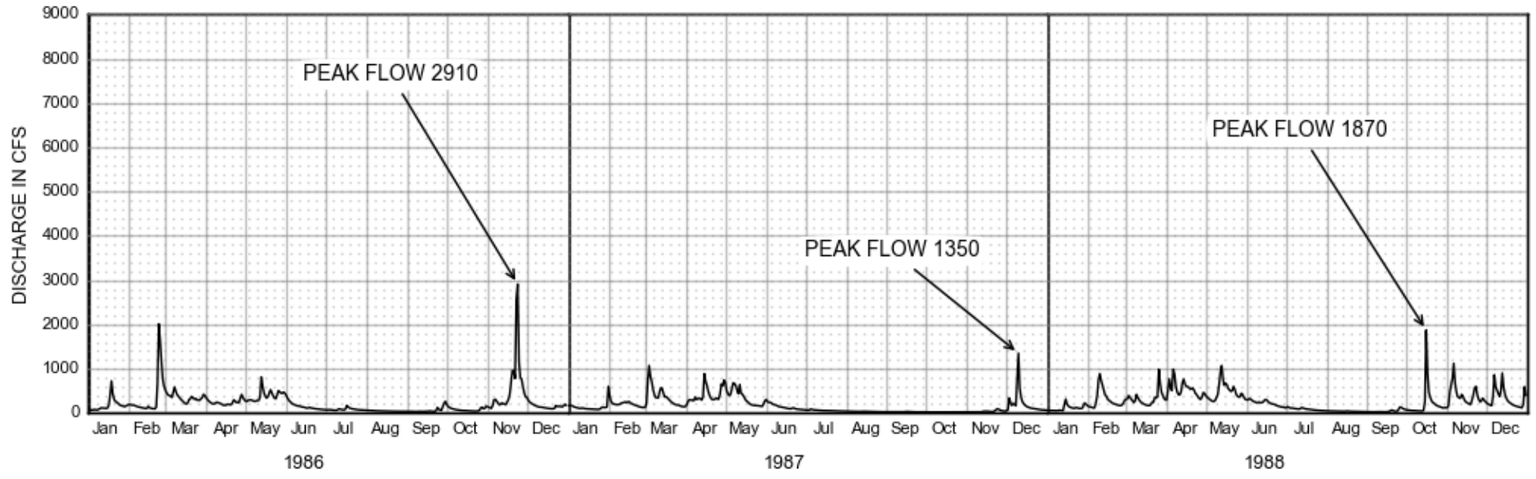
PLATE 4-6







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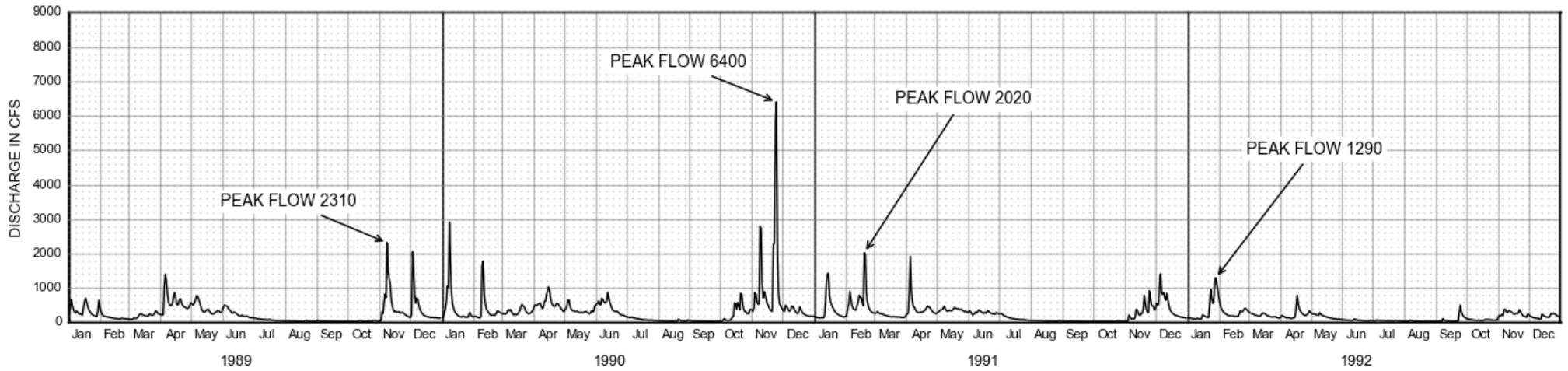
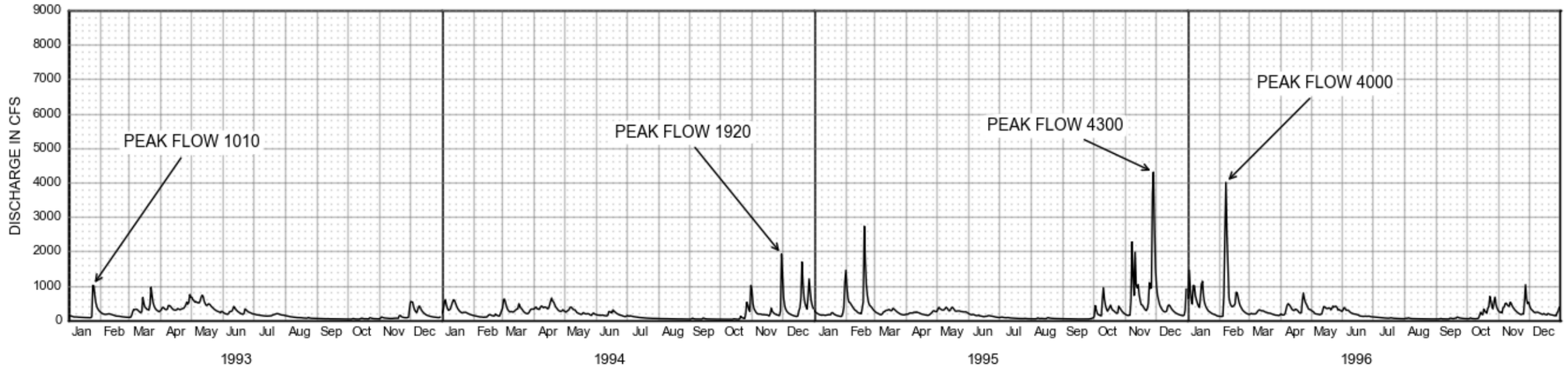
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

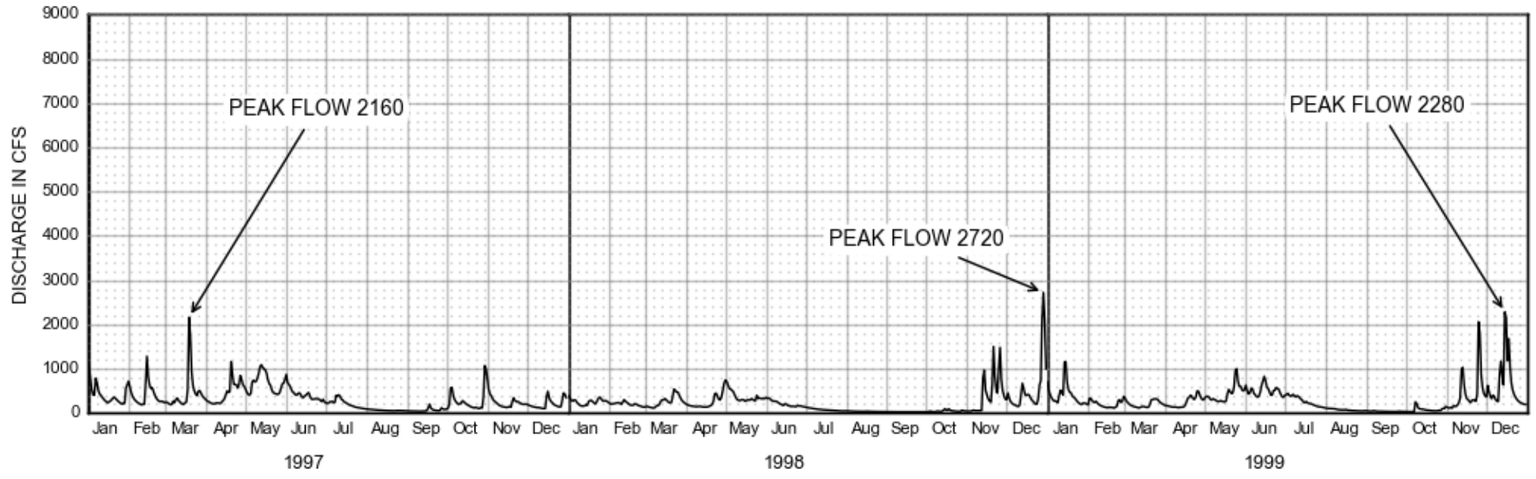
Plate 4-6
Daily Discharge Hydrographs
Cedar River near Cedar Falls, USGS Gage 1211500
1945-2016
Sheet 4 of 7

Completed by: WEST	Nov 2016

PLATE 4-6







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U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-6
Daily Discharge Hydrographs
Cedar River near Cedar Falls, USGS Gage 1211500
1945-2016
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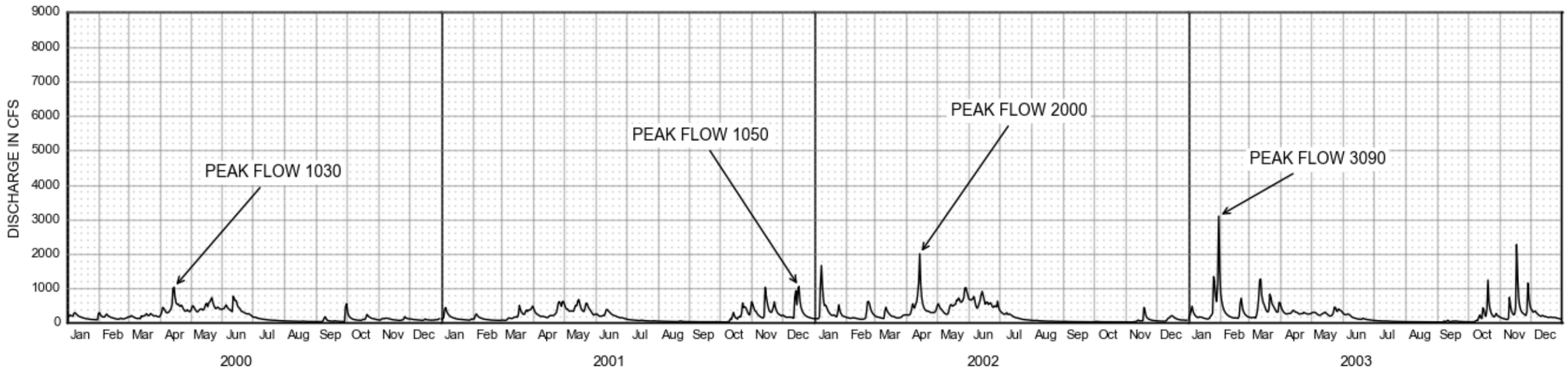
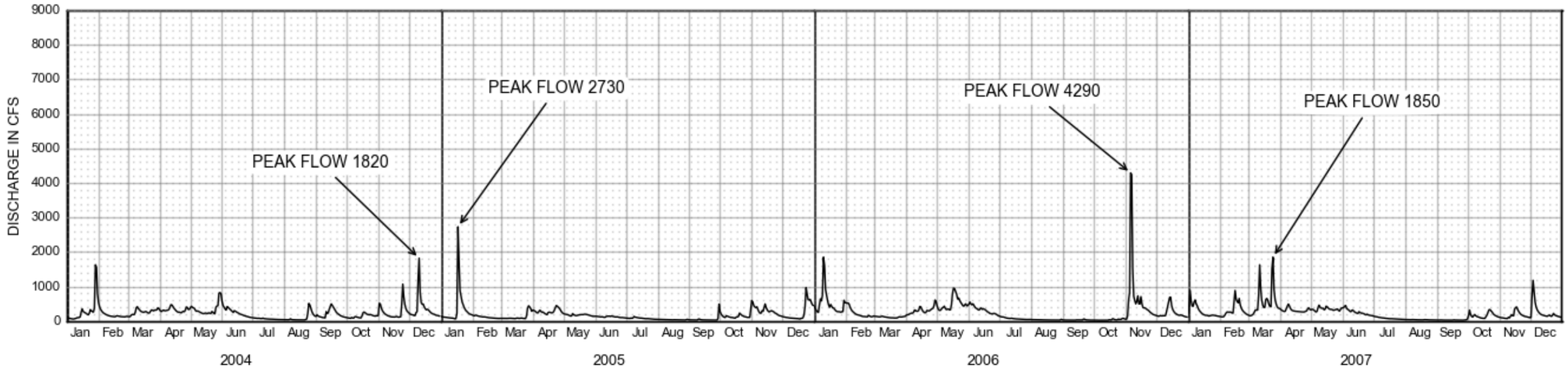
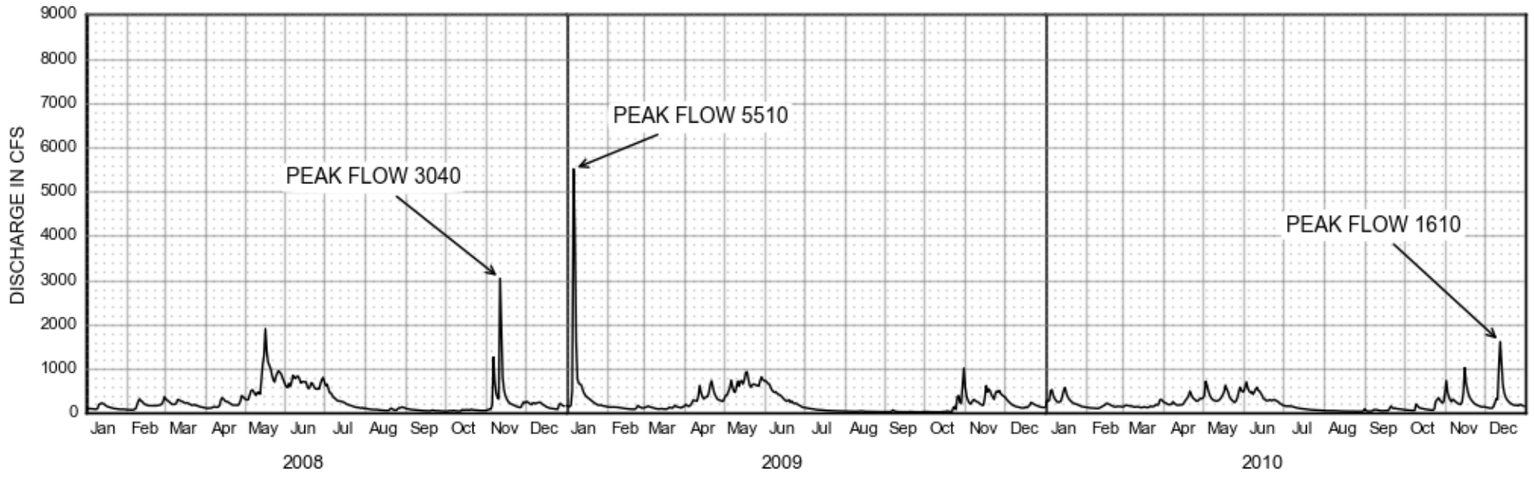
PLATE 4-6







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U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-6
Daily Discharge Hydrographs
Cedar River near Cedar Falls, USGS Gage 1211500
1945-2016
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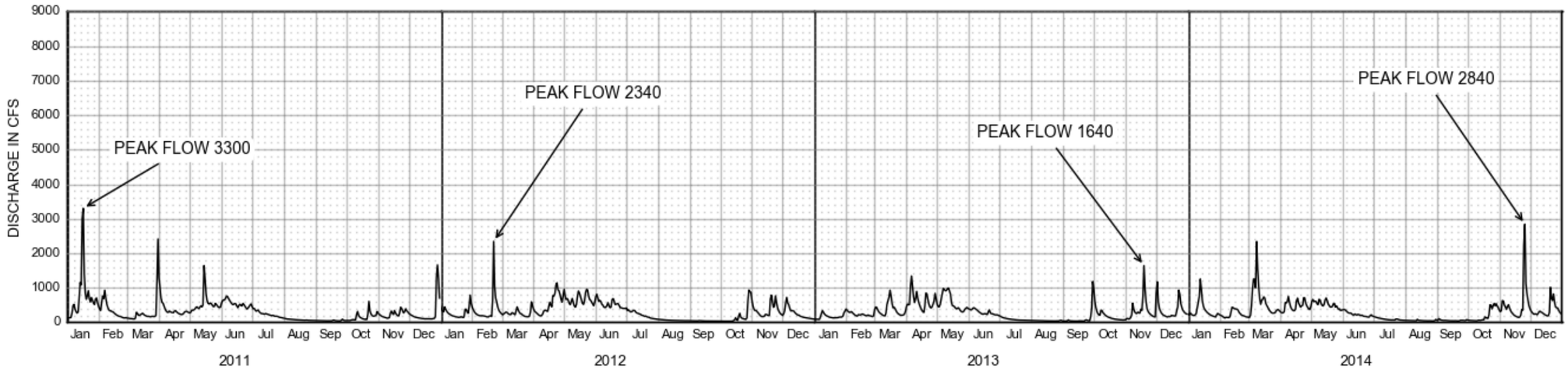
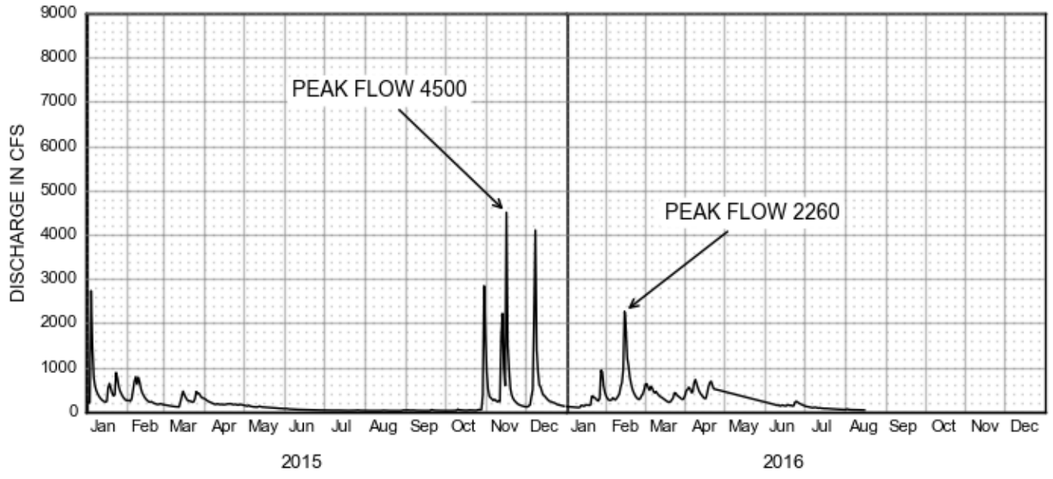
PLATE 4-6





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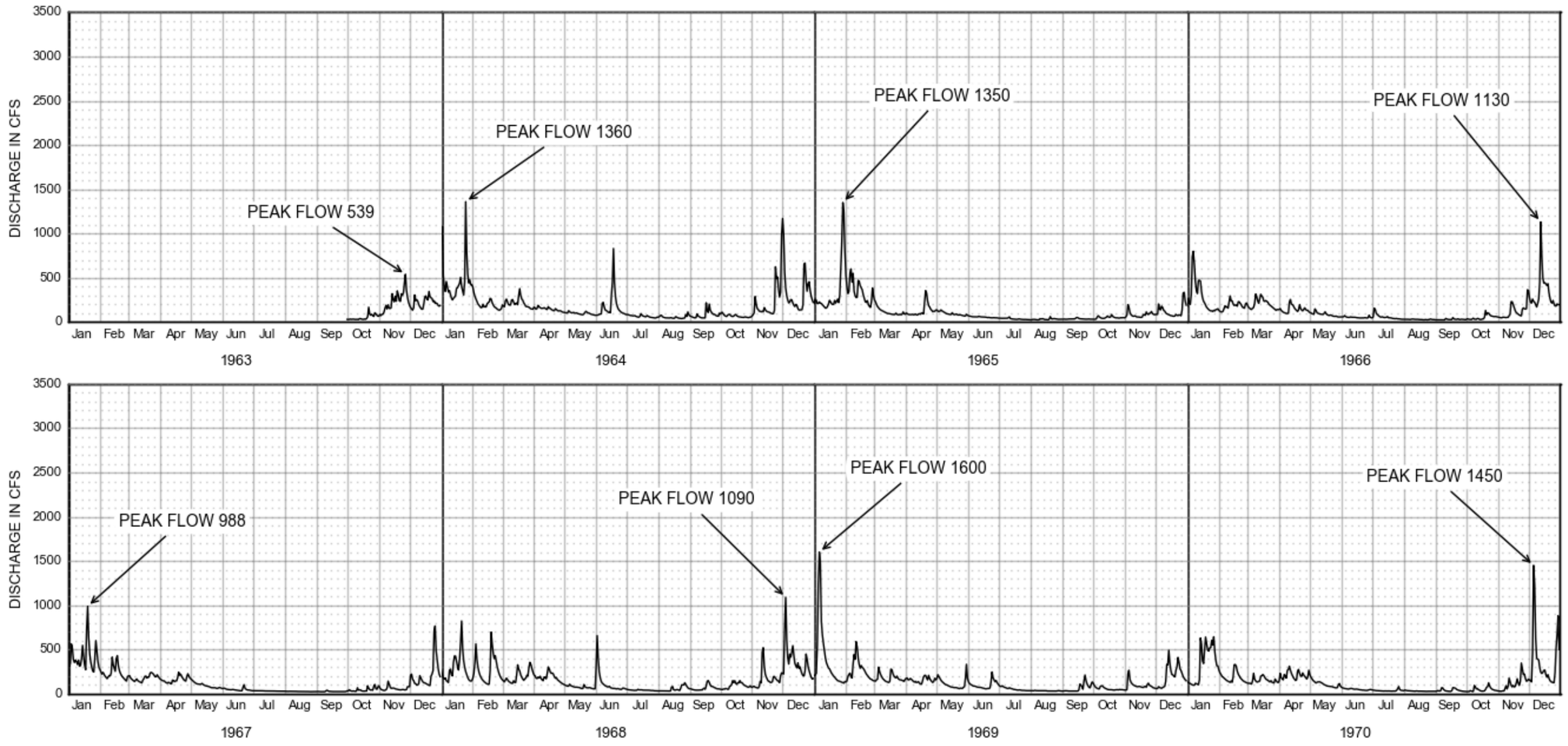
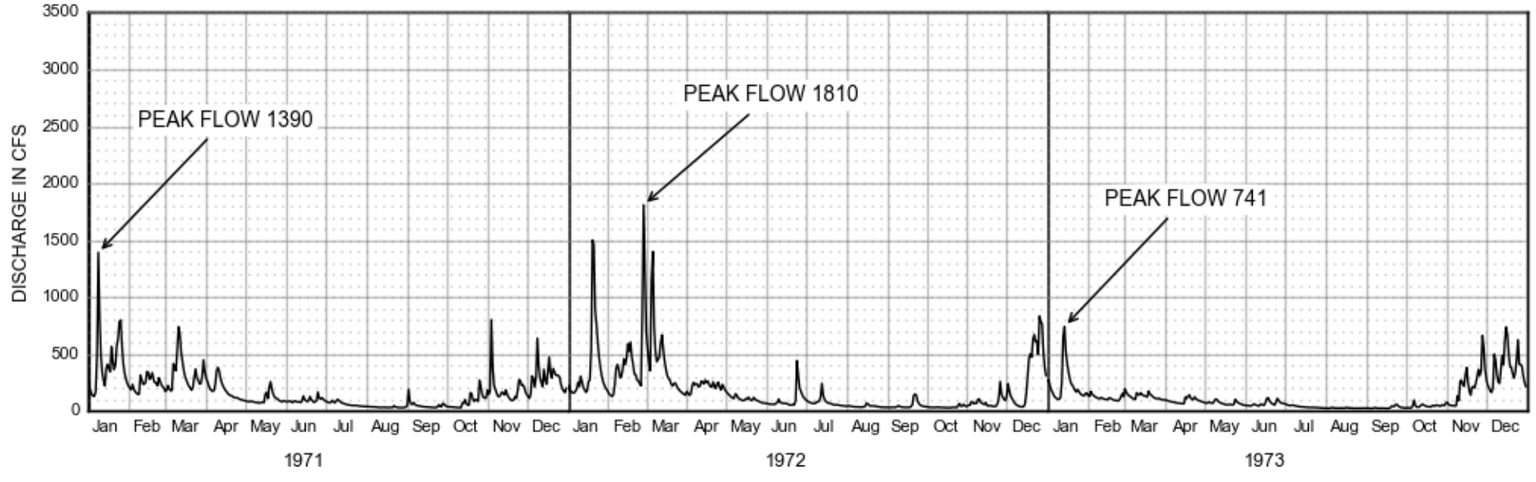
U.S. Army Corps of Engineers Seattle District Seattle Washington
Plate 4-6 Daily Discharge Hydrographs Cedar River near Cedar Falls, USGS Gage 1211500 1945-2016 Sheet 7 of 7
Completed by: WEST | Nov 2016

PLATE 4-6





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U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-7
Daily Discharge Hydrographs
Issaquah Creek near Mouth, USGS Gage 12121600
1963-2016
Sheet 1 of 5

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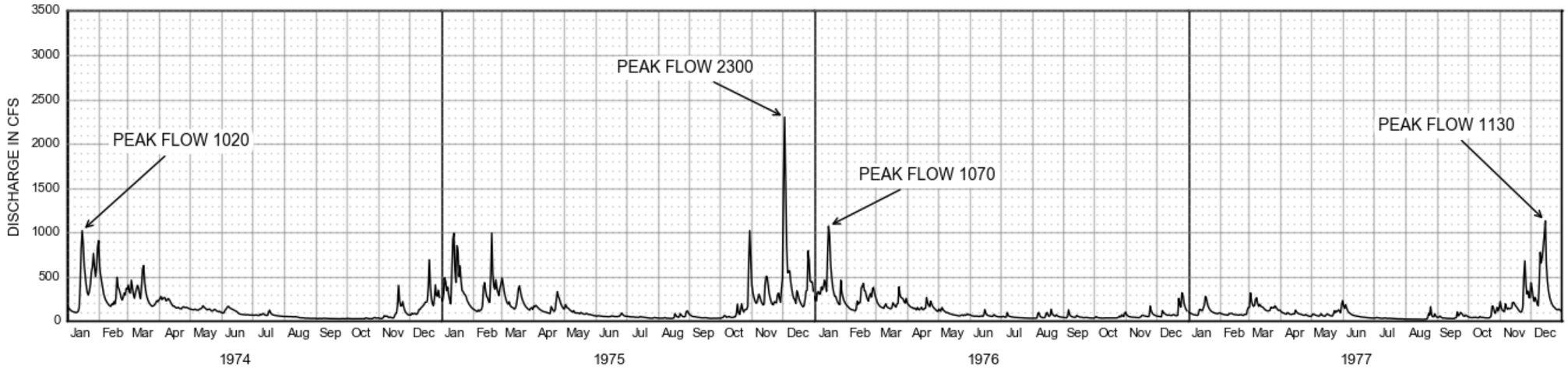
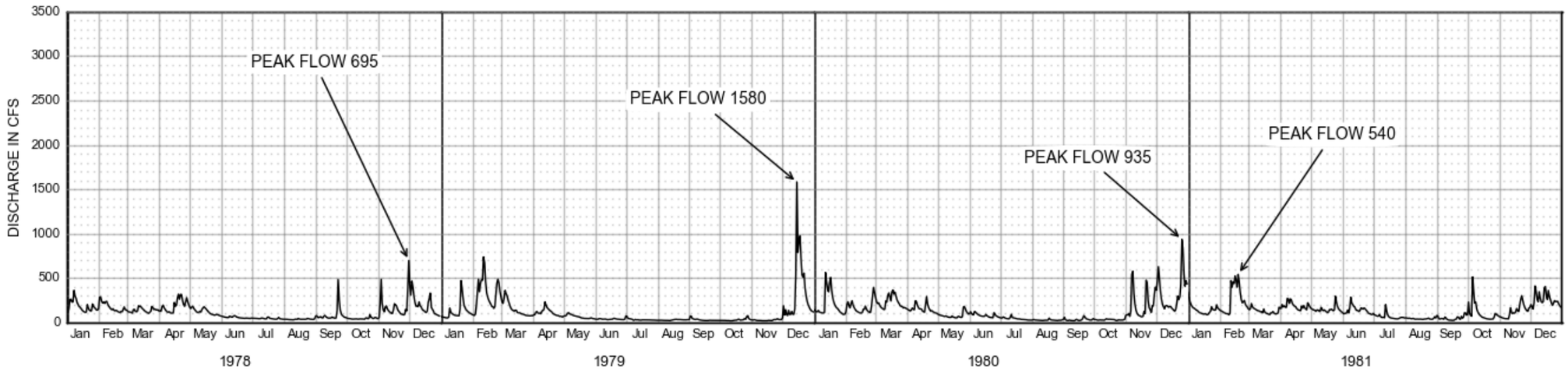
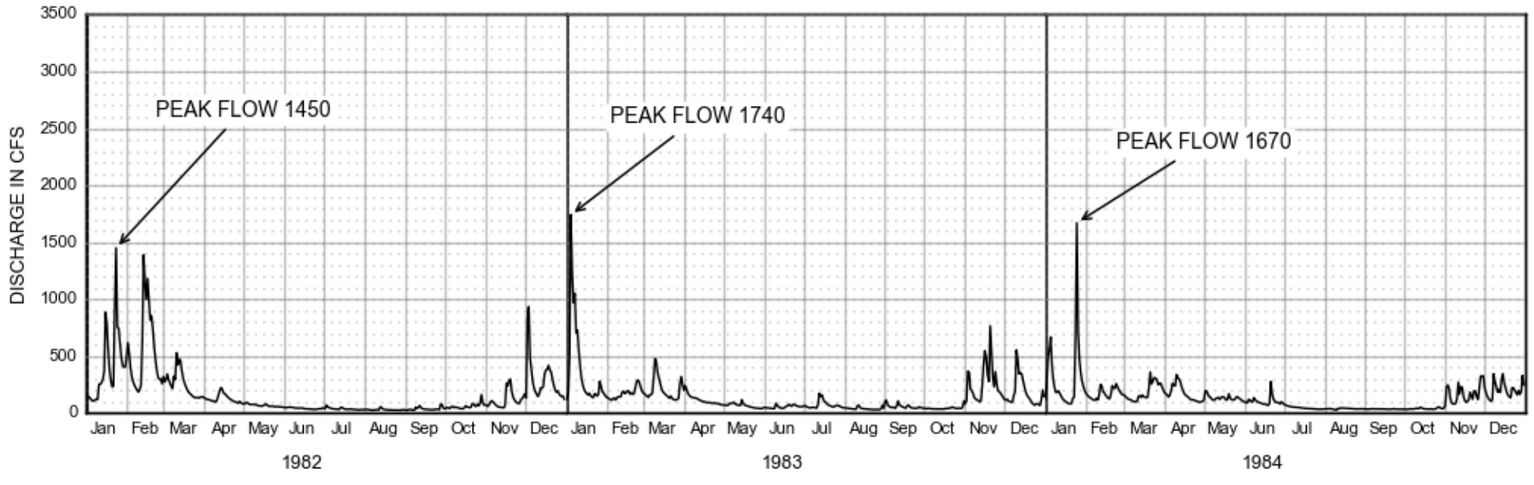
PLATE 4-7







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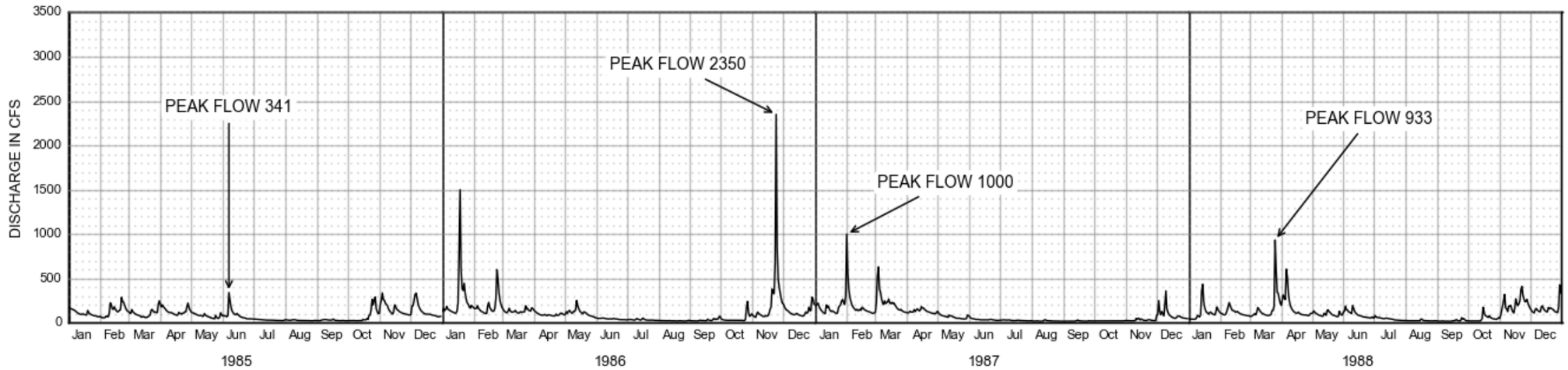
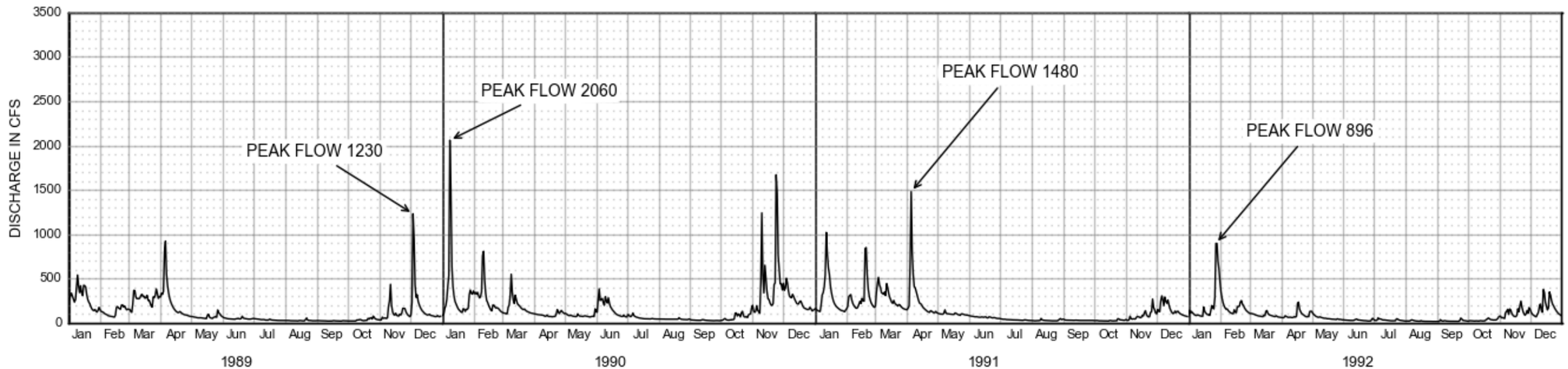
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

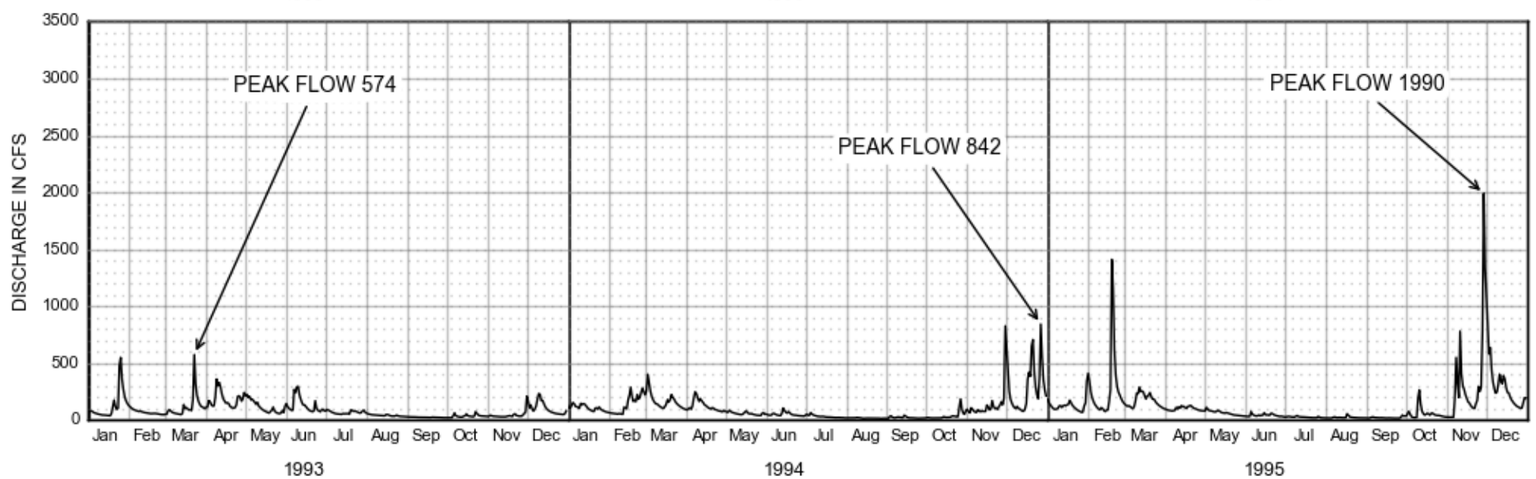
Plate 4-7
Daily Discharge Hydrographs
Issaquah Creek near Mouth, USGS Gage 12121600
1963-2016
Sheet 2 of 5

Completed by: WEST	Nov 2016

PLATE 4-7







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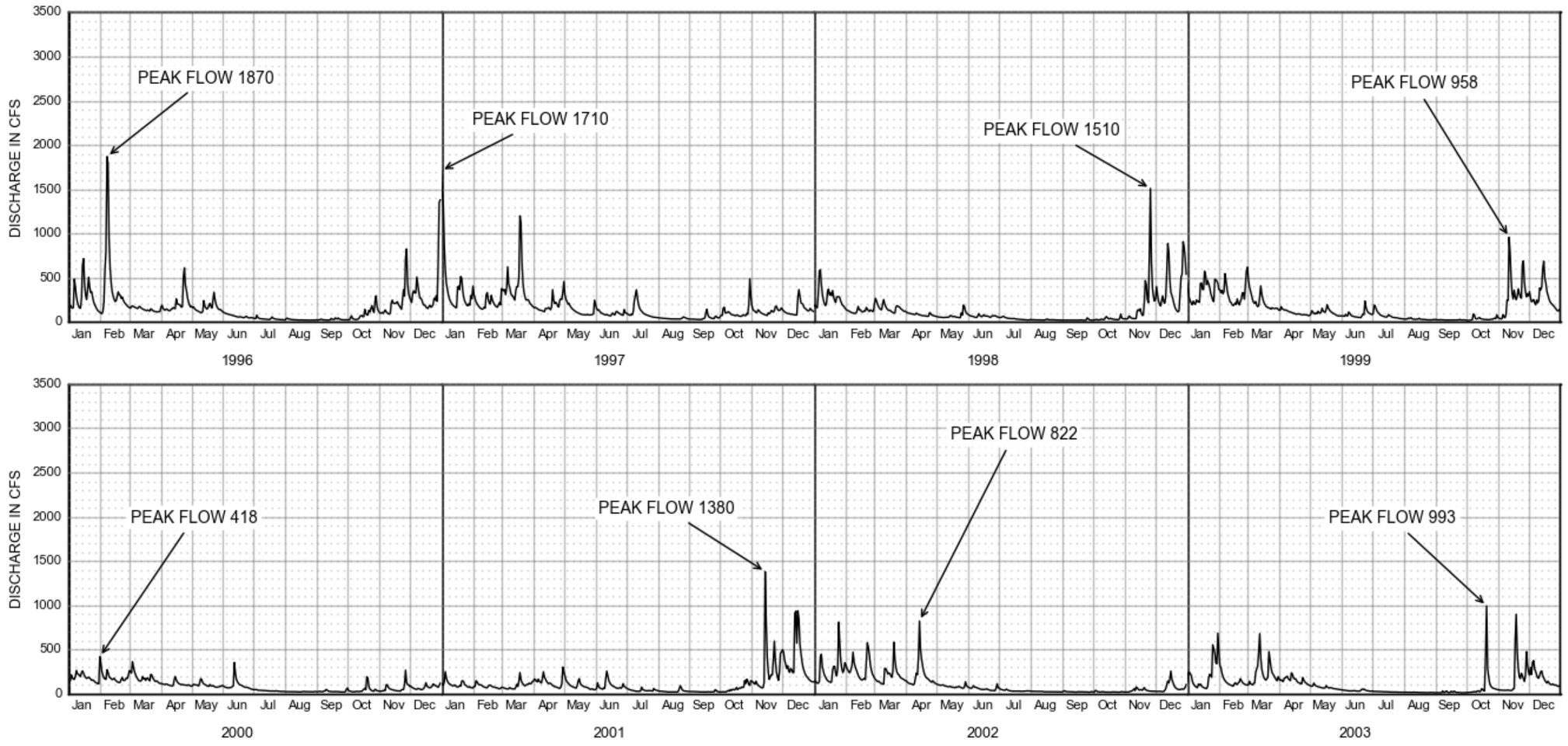
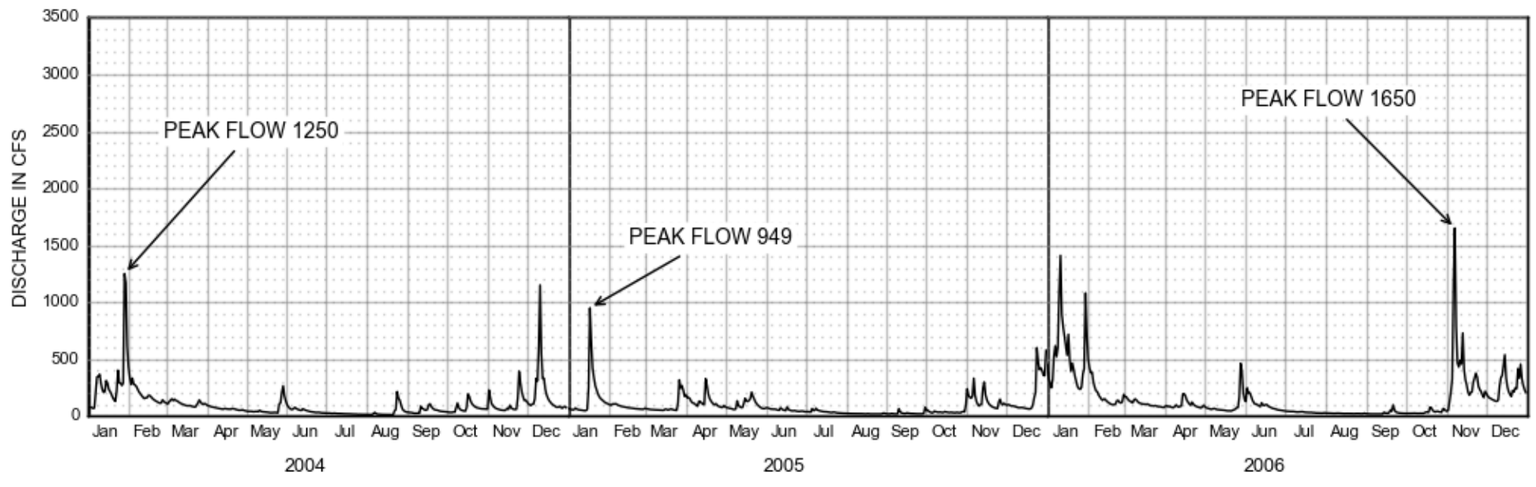
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-7
Daily Discharge Hydrographs
Issaquah Creek near Mouth, USGS Gage 12121600
1963-2016
Sheet 3 of 5

Completed by: WEST	Nov 2016

PLATE 4-7





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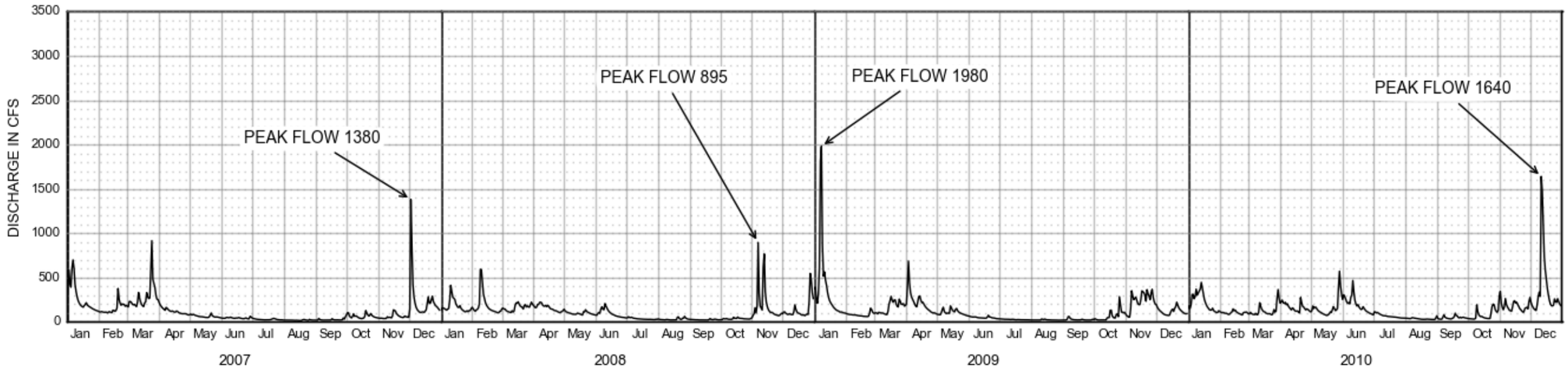
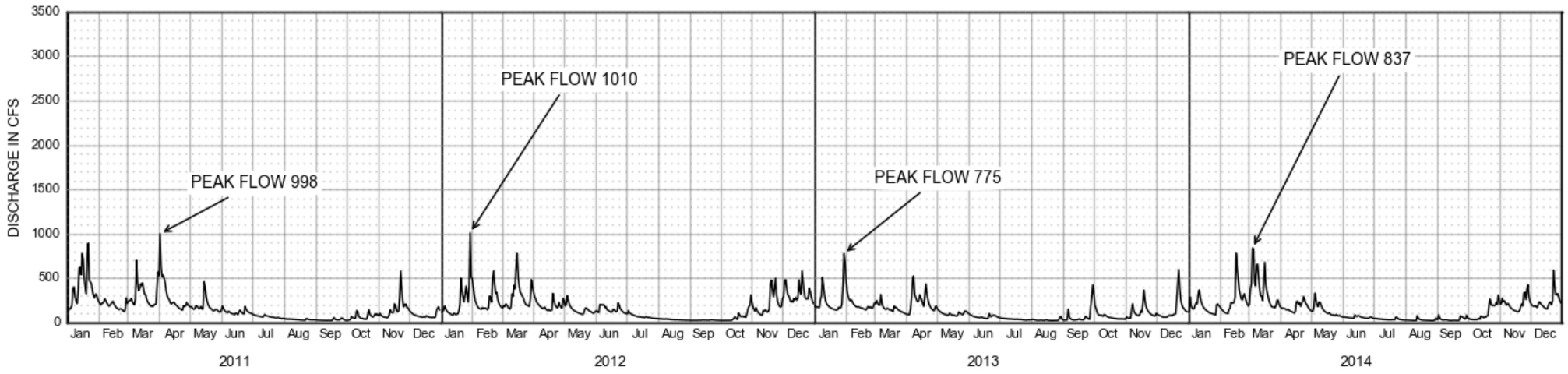
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

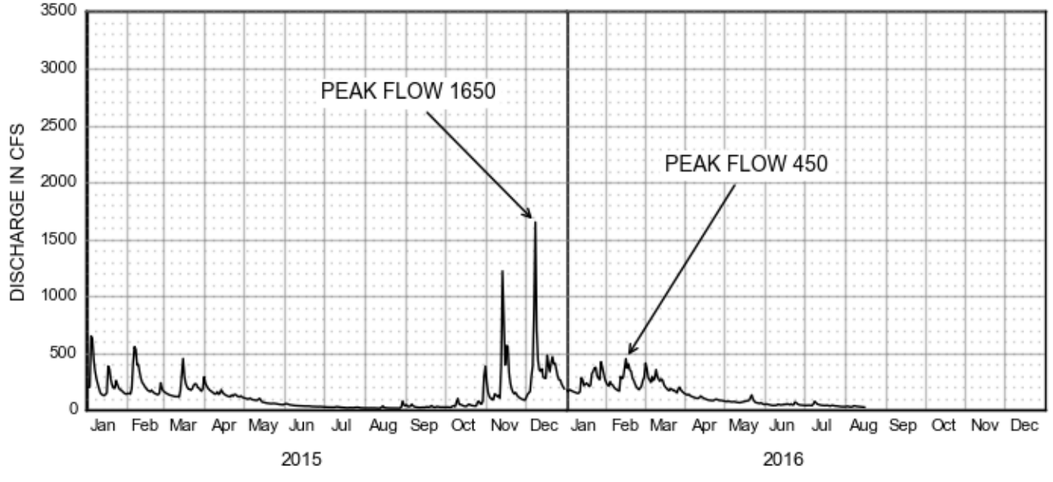
Plate 4-7
Daily Discharge Hydrographs
Issaquah Creek near Mouth, USGS Gage 12121600
1963-2016
Sheet 4 of 5

Completed by: WEST	Nov 2016

PLATE 4-7







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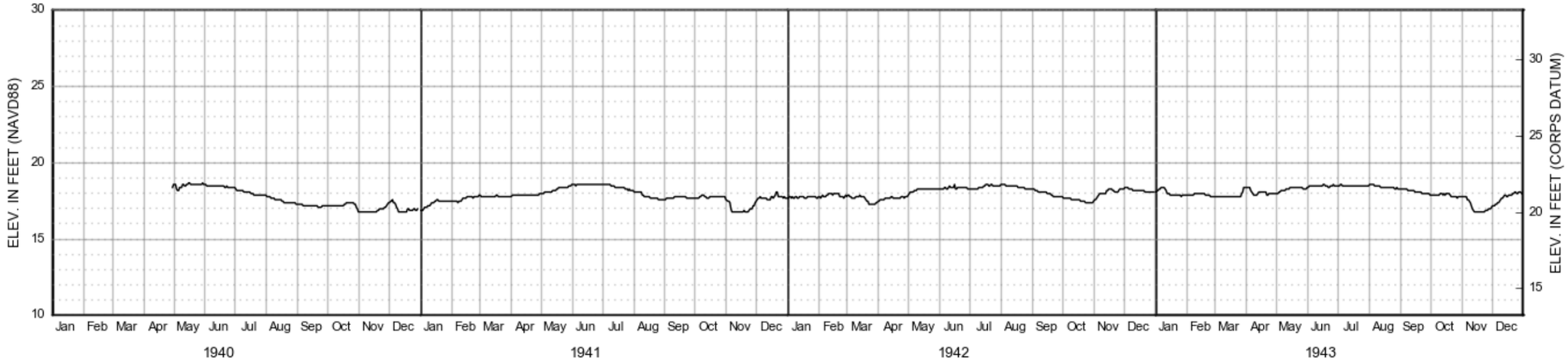
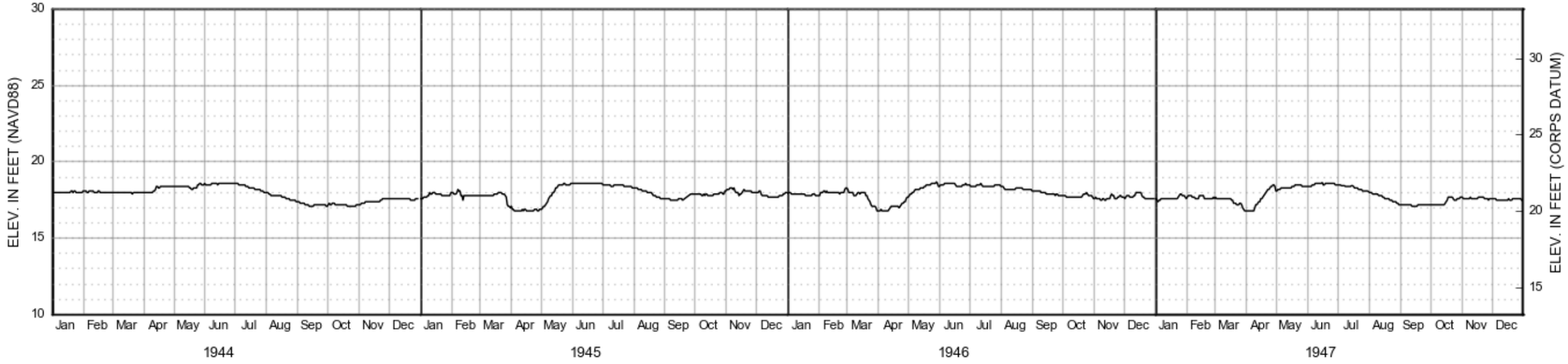
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

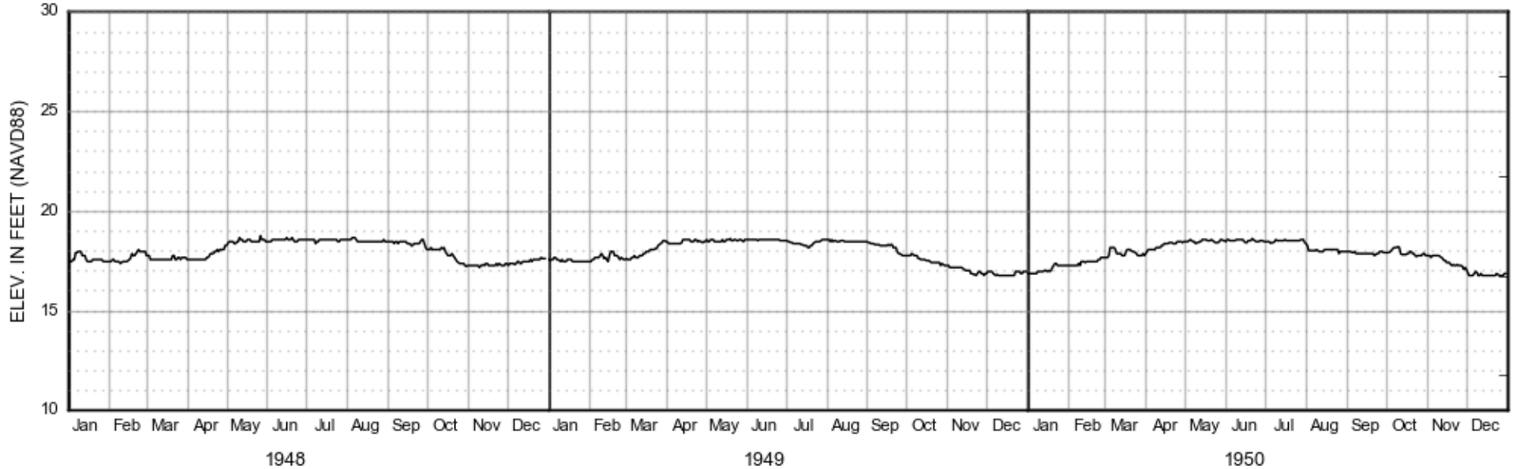
Plate 4-7
Daily Discharge Hydrographs
Issaquah Creek near Mouth, USGS Gage 12121600
1963-2016
Sheet 5 of 5

Completed by: WEST	Nov 2016

PLATE 4-7







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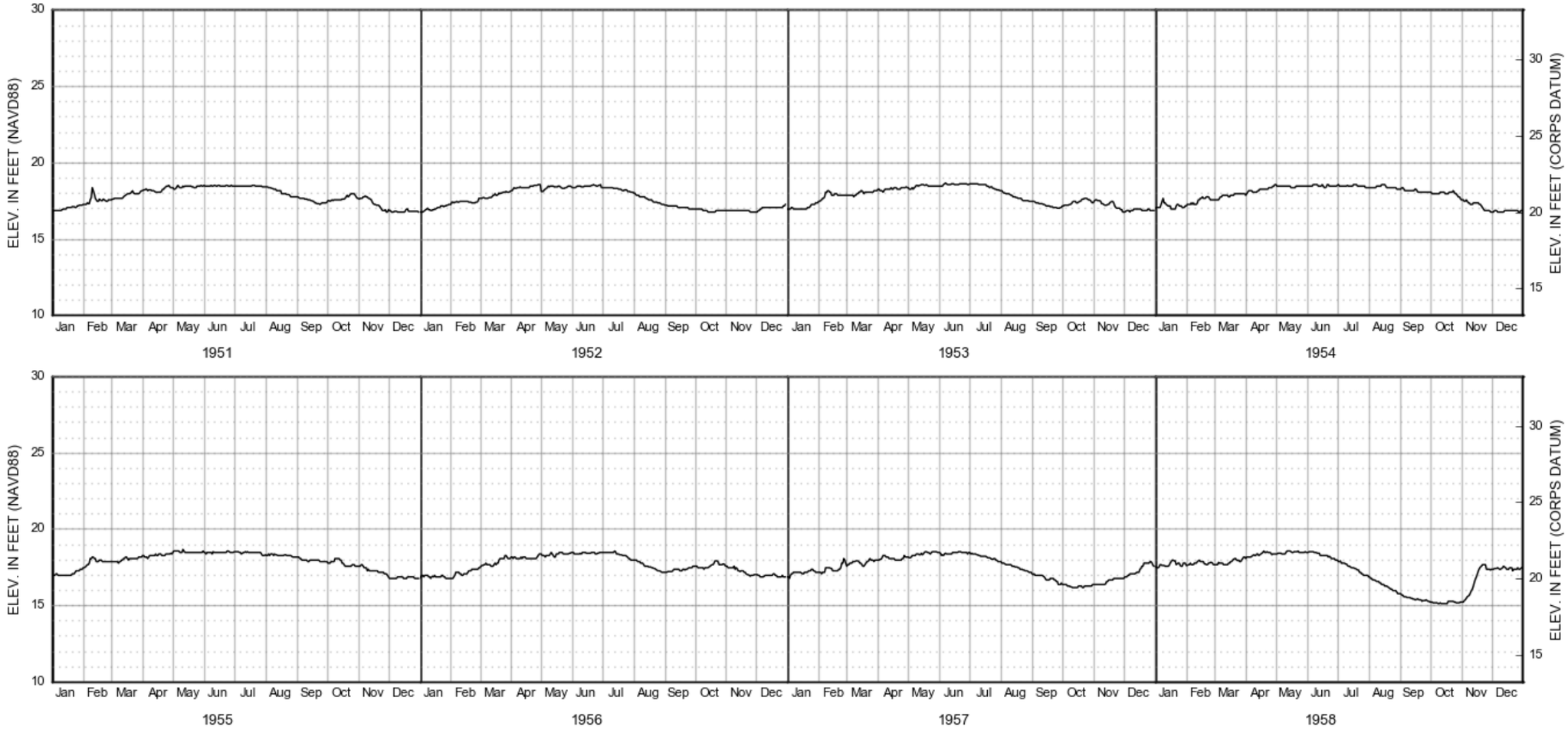
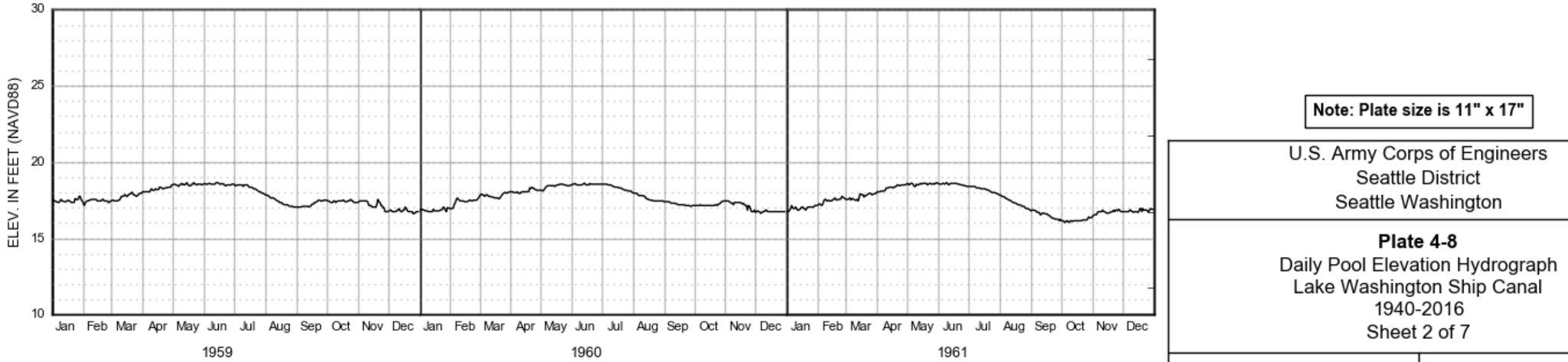
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-8
Daily Pool Elevation Hydrograph
Lake Washington Ship Canal
1940-2016
Sheet 1 of 7

Completed by: WEST	Nov 2016

PLATE 4-8





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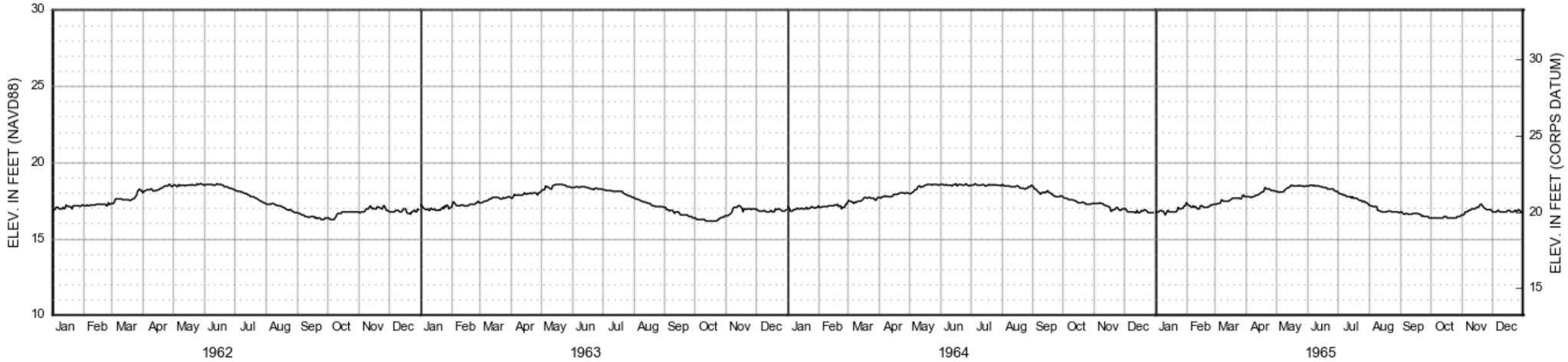
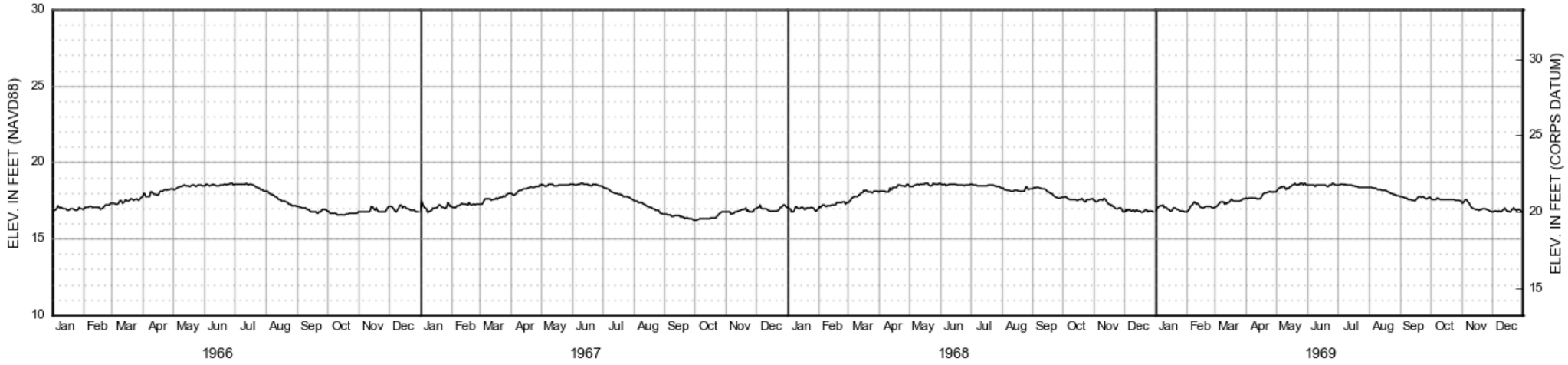
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

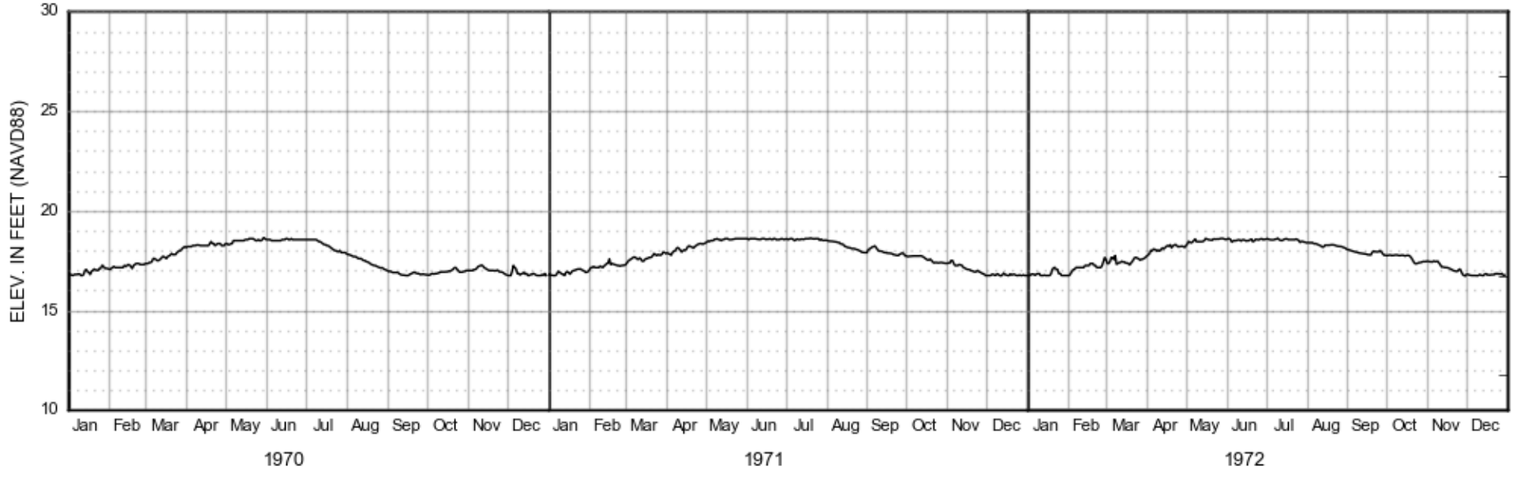
Plate 4-8
Daily Pool Elevation Hydrograph
Lake Washington Ship Canal
1940-2016
Sheet 2 of 7

Completed by: WEST	Nov 2016

PLATE 4-8







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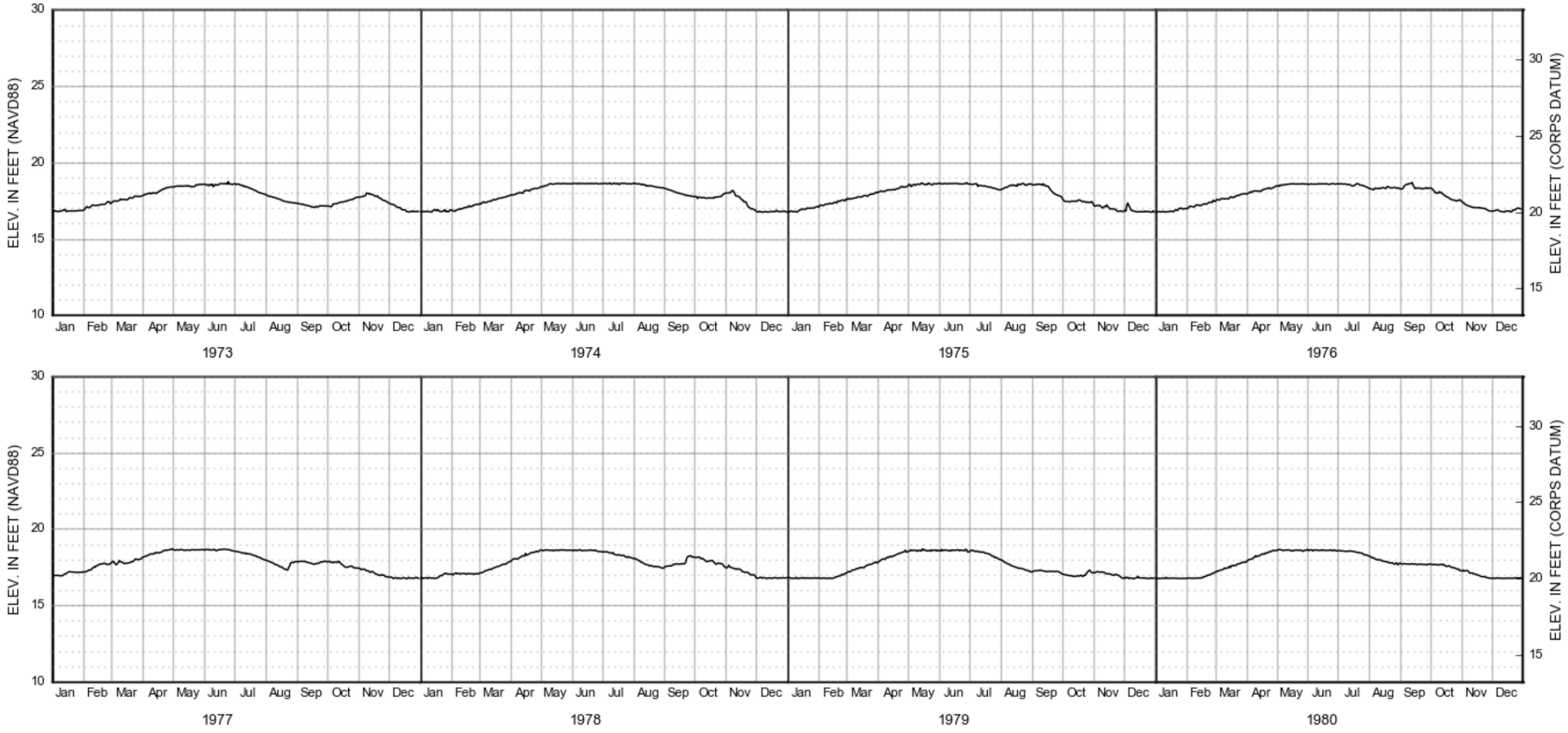
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-8
Daily Pool Elevation Hydrograph
Lake Washington Ship Canal
1940-2016
Sheet 3 of 7

Completed by: WEST	Nov 2016

PLATE 4-8



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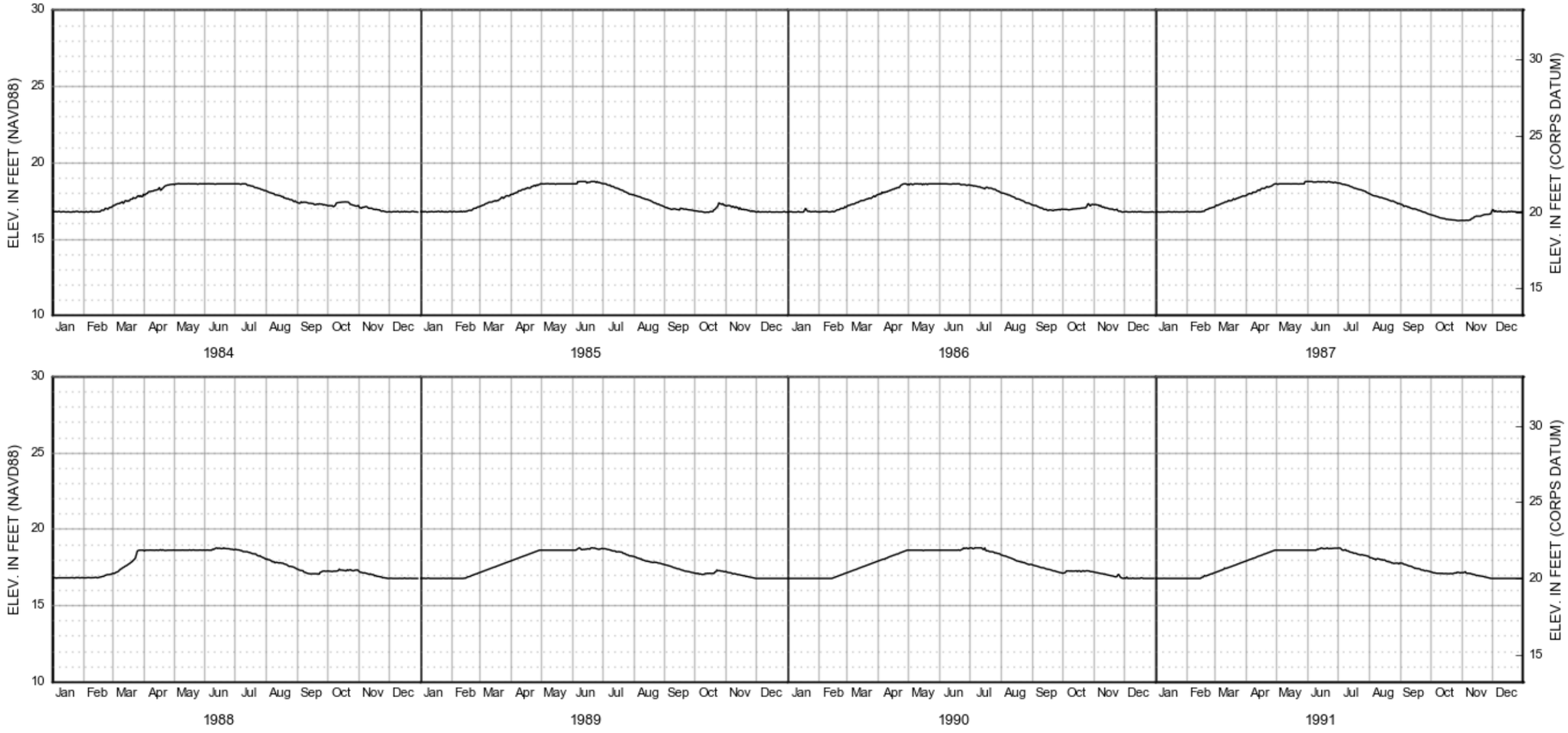
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-8
Daily Pool Elevation Hydrograph
Lake Washington Ship Canal
1940-2016
Sheet 4 of 7

Completed by: WEST	Nov 2016

PLATE 4-8



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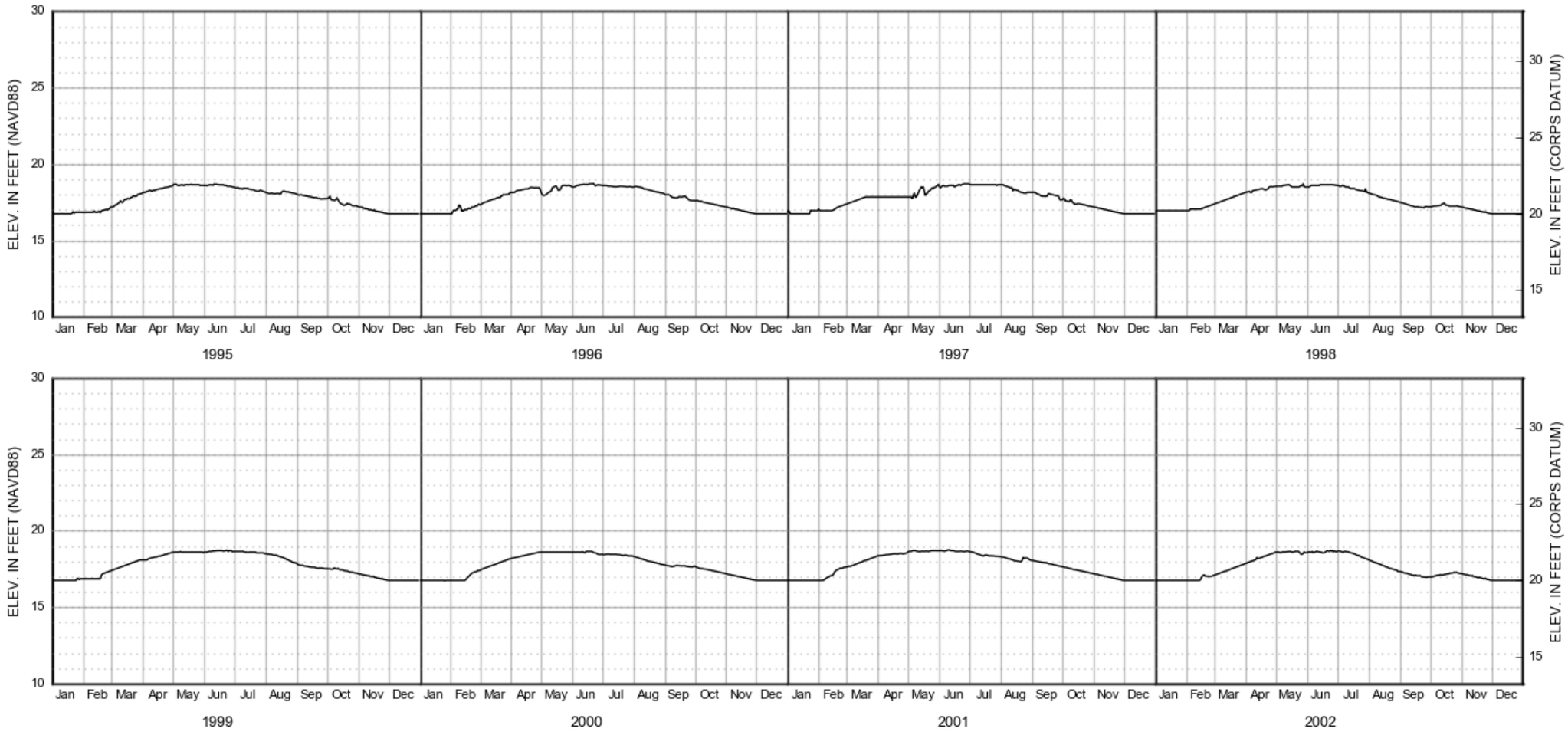
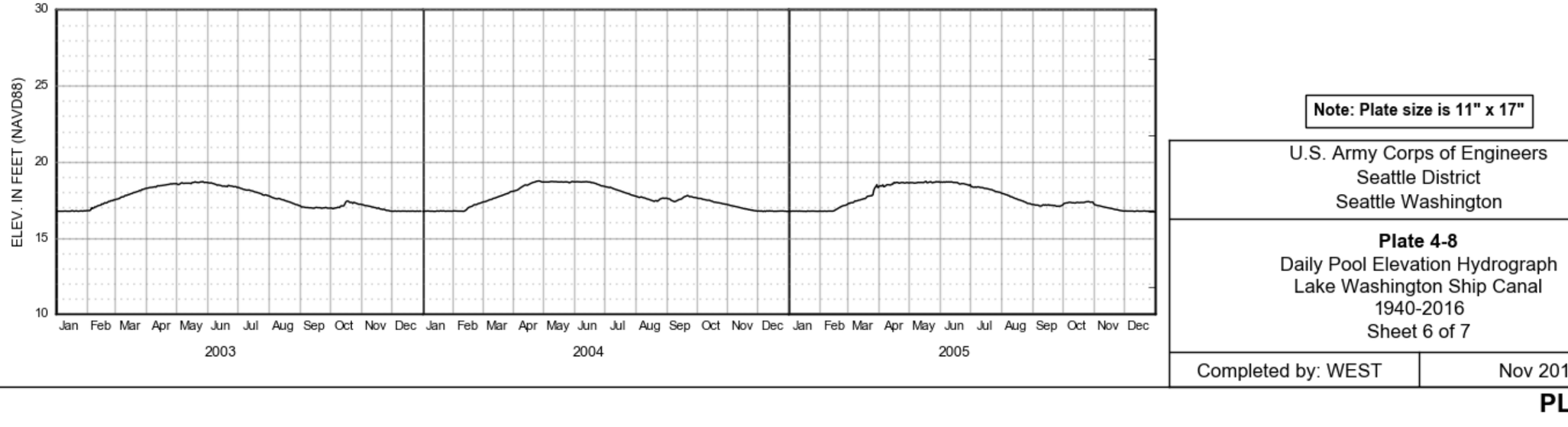
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-8
Daily Pool Elevation Hydrograph
Lake Washington Ship Canal
1940-2016
Sheet 5 of 7

Completed by: WEST	Nov 2016

PLATE 4-8





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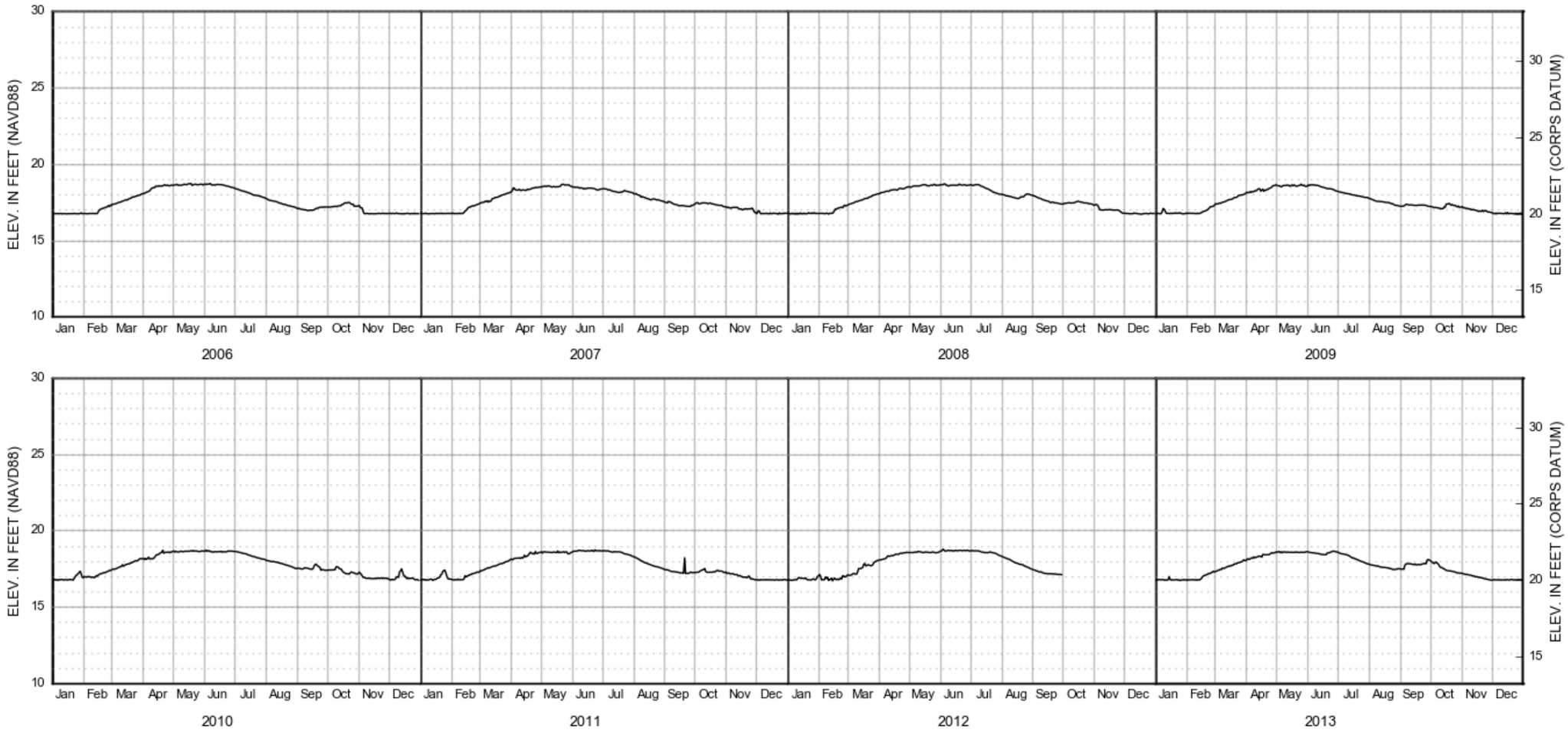
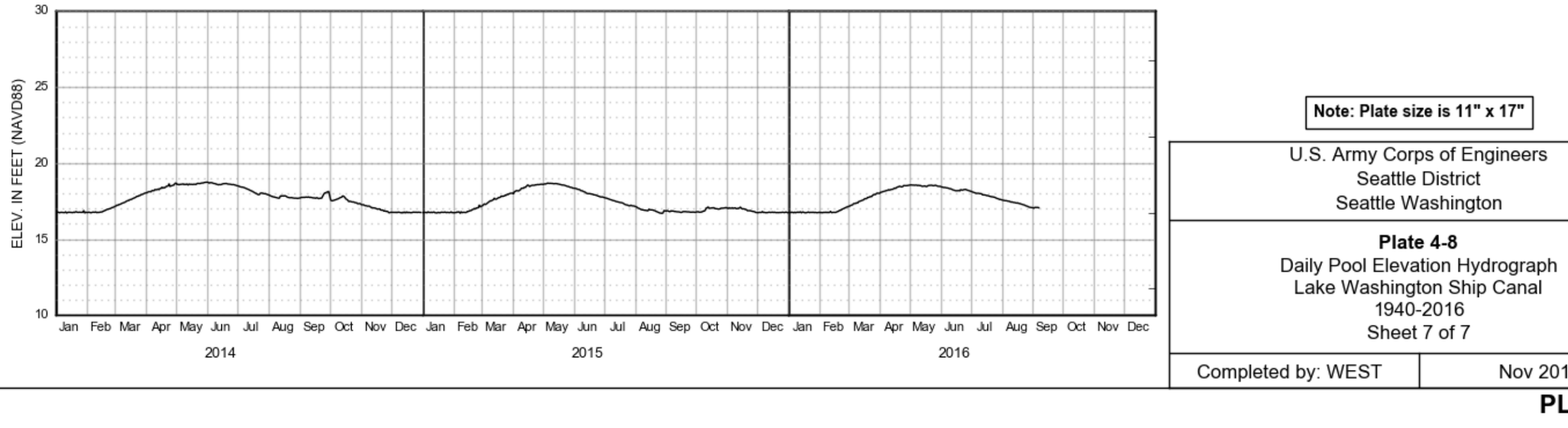
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-8
Daily Pool Elevation Hydrograph
Lake Washington Ship Canal
1940-2016
Sheet 6 of 7

Completed by: WEST	Nov 2016

PLATE 4-8





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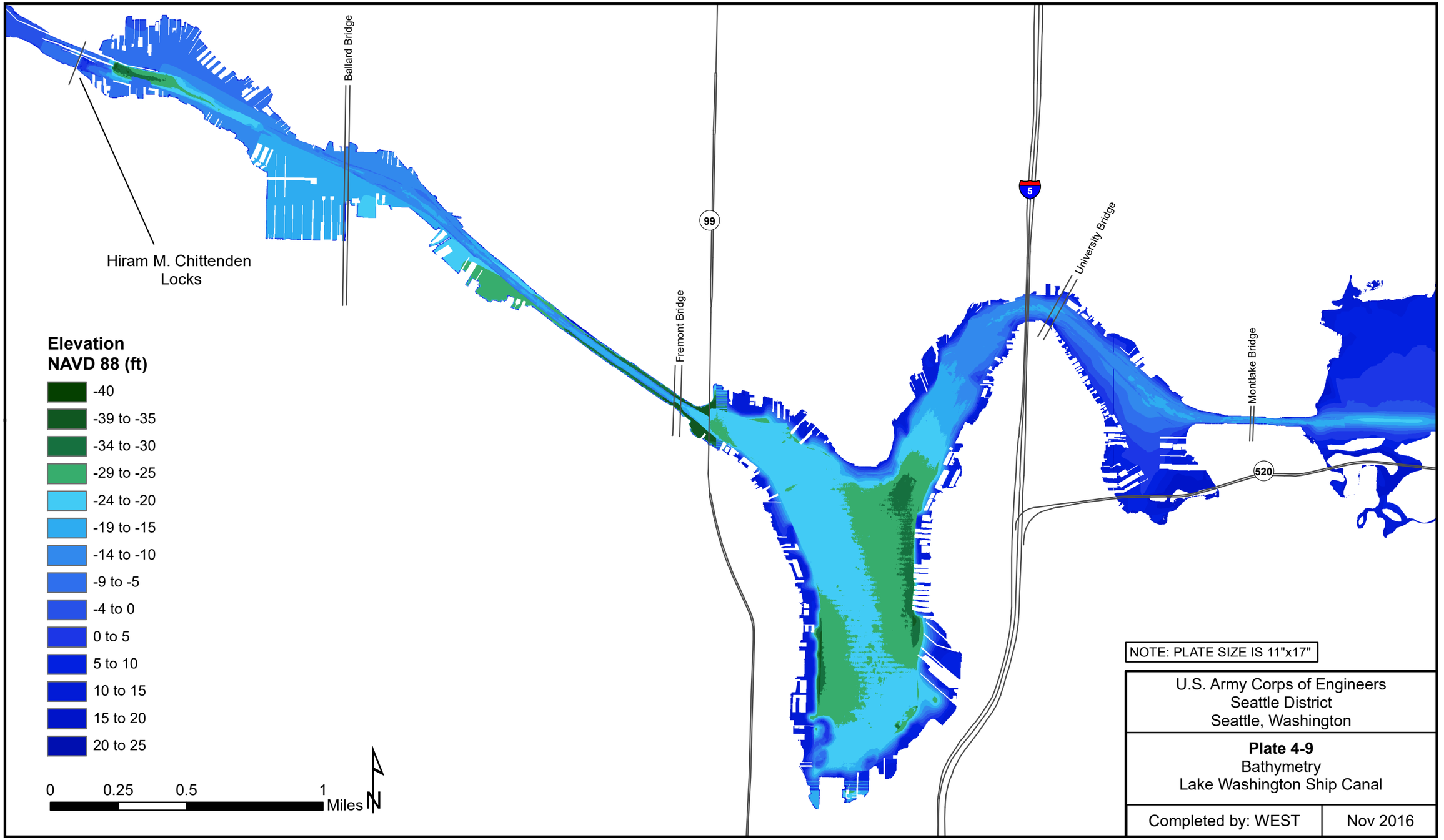
U.S. Army Corps of Engineers
Seattle District
Seattle Washington

Plate 4-8
Daily Pool Elevation Hydrograph
Lake Washington Ship Canal
1940-2016
Sheet 7 of 7

Completed by: WEST	Nov 2016

PLATE 4-8



NOTE: PLATE SIZE IS 11"x17"

U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

Plate 4-9
Bathymetry
Lake Washington Ship Canal

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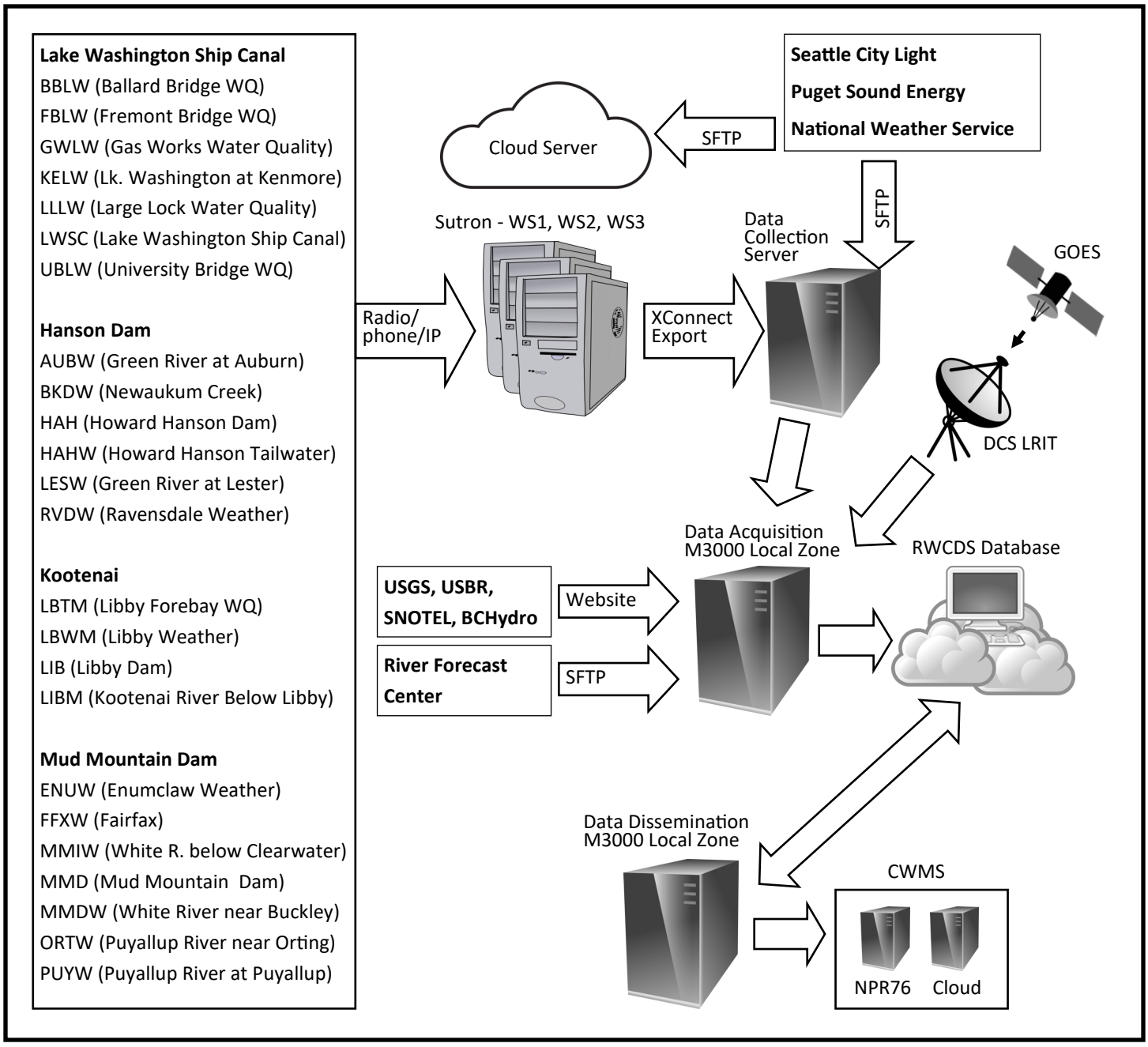
PLATE 4-9

PLATE 5-1 WATER CONTROL DATA SYSTEM SCHEMATIC

NWS Regional Water Control Data System — Data Collection



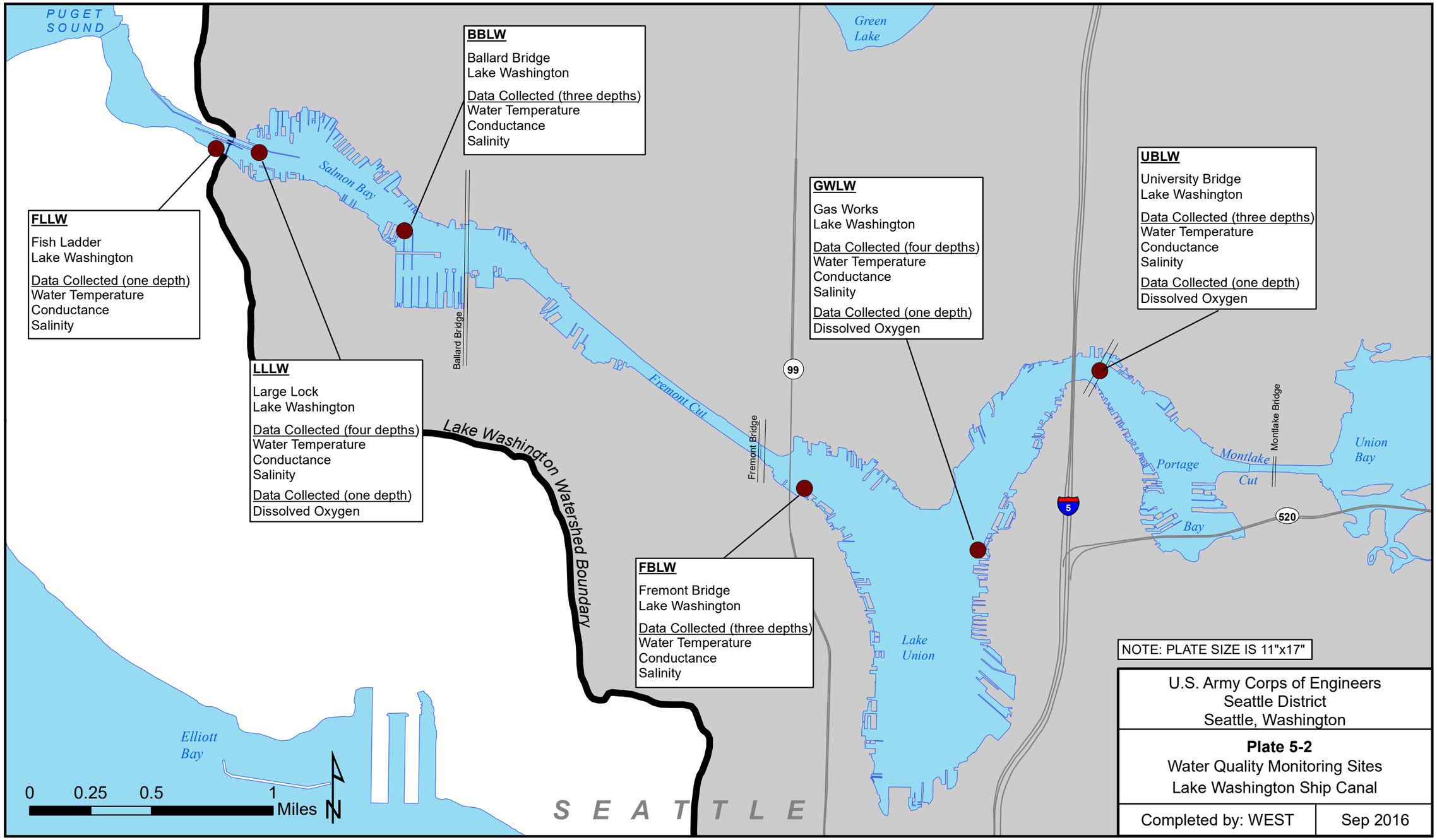
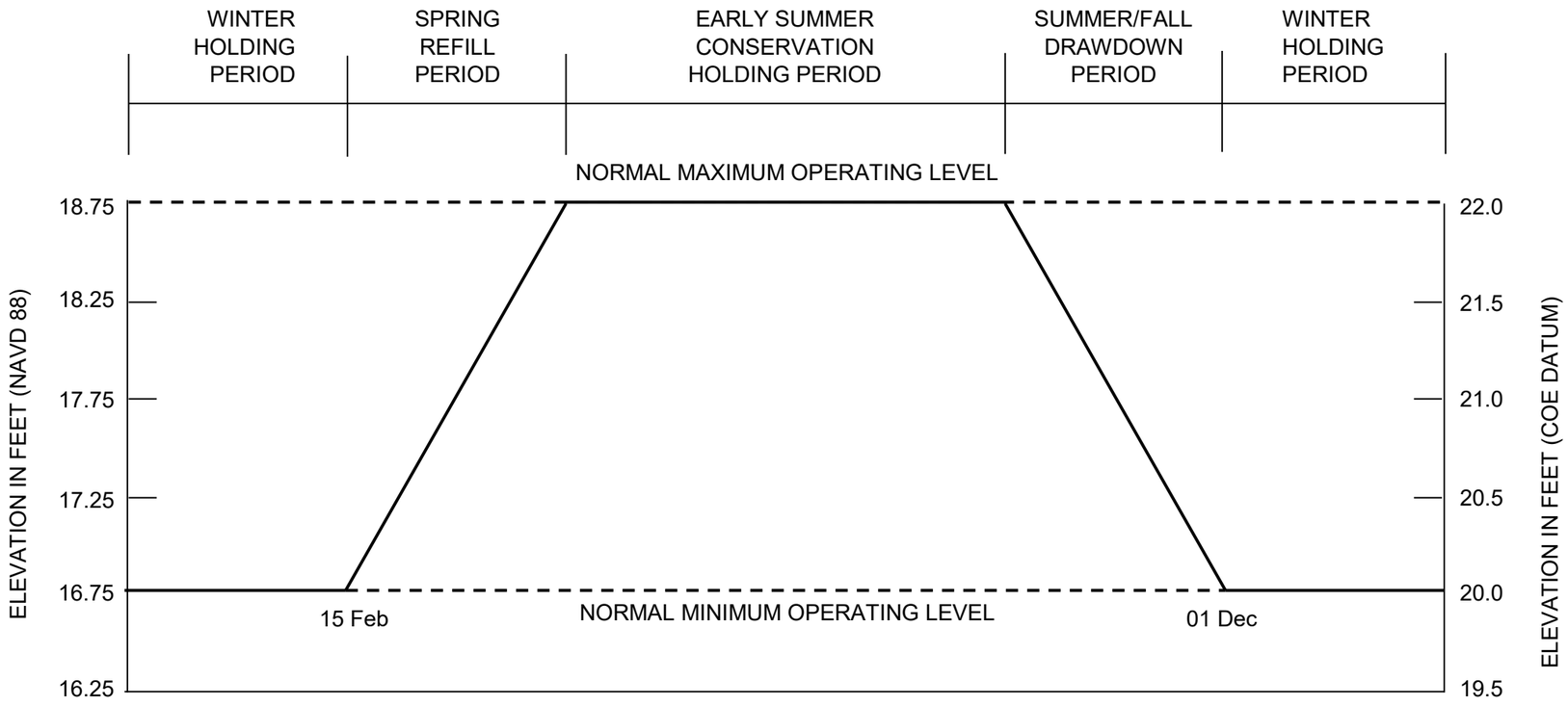

PUGET SOUND
Green Lake
Salmon Bay
Ballard Bridge
Fremont Cut
Fremont Bridge
Lake Washington Watershed Boundary
Lake Union
Portage Bay
Montlake Cut
Montlake Bridge
Union Bay
Elliott Bay
SEATTLE
99
5
520
BBLW
Ballard Bridge
Lake Washington
Data Collected (three depths)
Water Temperature
Conductance
Salinity
FLLW
Fish Ladder
Lake Washington
Data Collected (one depth)
Water Temperature
Conductance
Salinity
LLLW
Large Lock
Lake Washington
Data Collected (four depths)
Water Temperature
Conductance
Salinity
Data Collected (one depth)
Dissolved Oxygen
GWLW
Gas Works
Lake Washington
Data Collected (four depths)
Water Temperature
Conductance
Salinity
Data Collected (one depth)
Dissolved Oxygen
UBLW
University Bridge
Lake Washington
Data Collected (three depths)
Water Temperature
Conductance
Salinity
Data Collected (one depth)
Dissolved Oxygen
FBLW
Fremont Bridge
Lake Washington
Data Collected (three depths)
Water Temperature
Conductance
Salinity
0 0.25 0.5 1 Miles
N
NOTE: PLATE SIZE IS 11"x17"
U.S. Army Corps of Engineers
Seattle District
Seattle, Washington
Plate 5-2
Water Quality Monitoring Sites
Lake Washington Ship Canal
Completed by: WEST
Sep 2016

PLATE 5-2

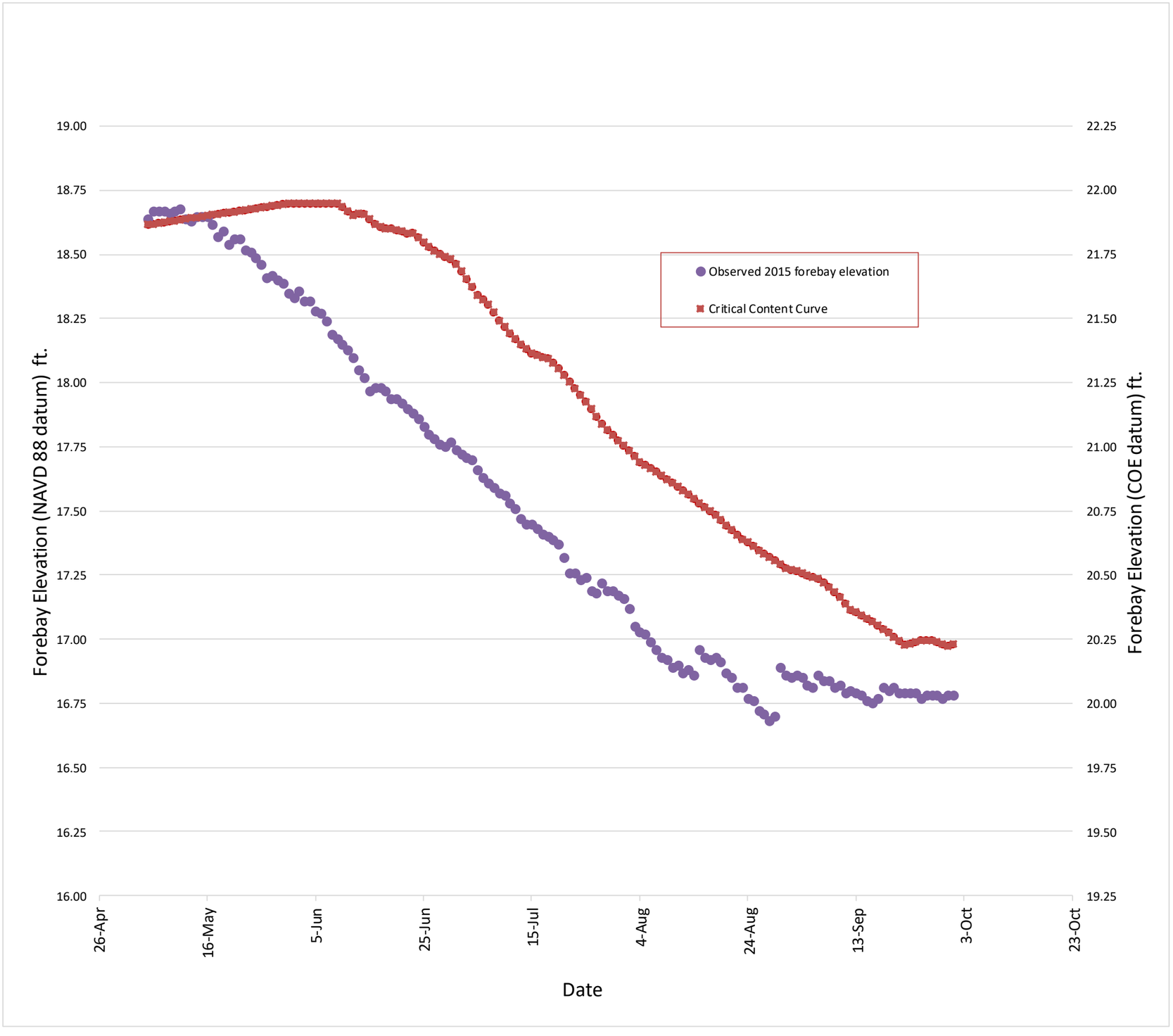


U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

Plate 7-1
Lake Washington
Normal Operating Constraints

Completed by: WEST	Oct 2016

PLATE 7-1



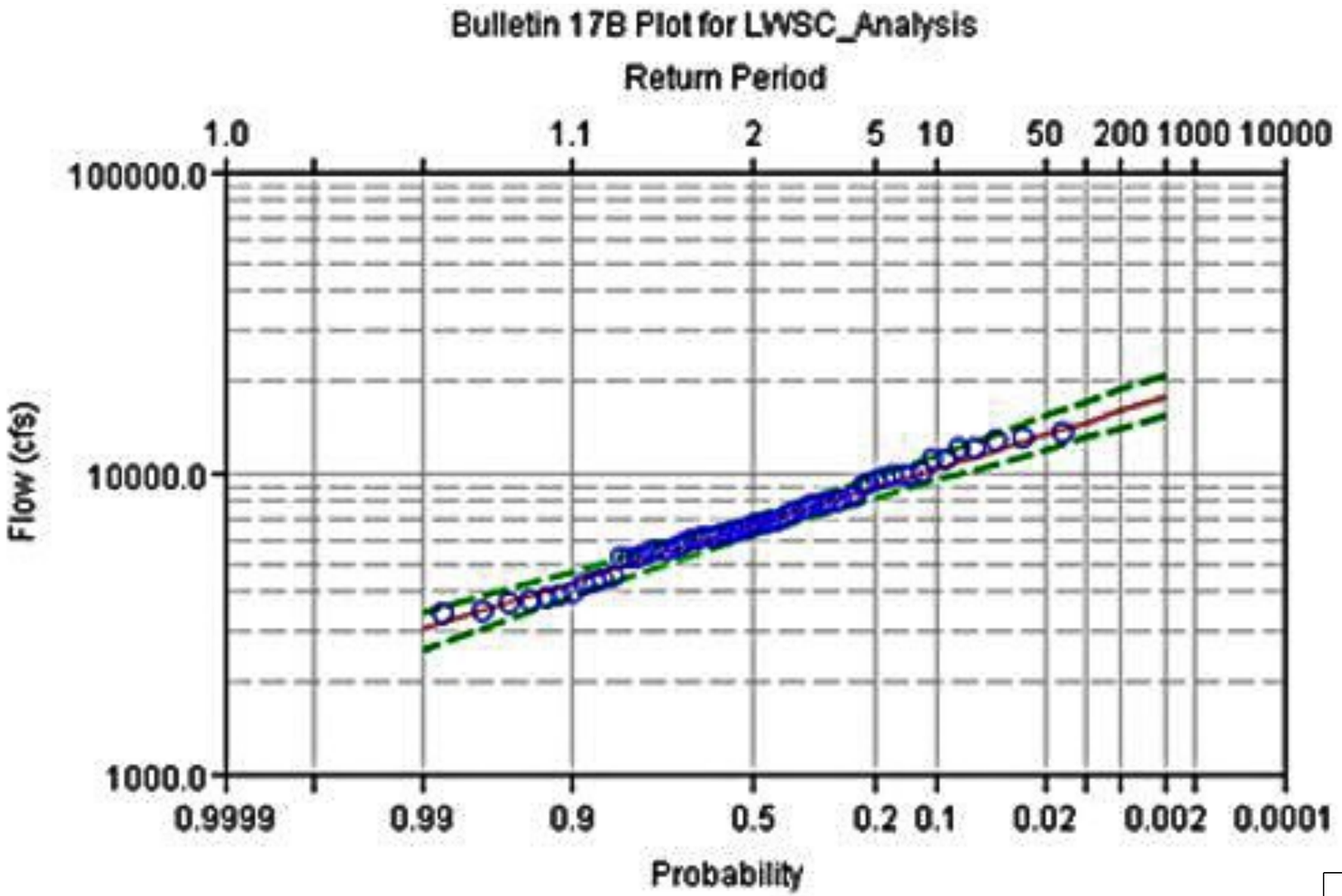
U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

Plate 8-1
Critical Content Curve, 2015 Conservation Season

This plate provided by Seattle District COE

May 2017

PLATE 8-1



U.S. Army Corps of Engineers
Seattle District
Seattle, Washington

Plate 8-2
LWSC Outflow Frequency Curve
Based on frequency analysis of historical peak annual project outflows, 1947-1987

This plate provided by the Seattle District	April 2017

LAKE WASHINGTON SHIP CANAL
SEATTLE, WA

WATER CONTROL MANUAL

EXHIBITS

EXHIBIT 1-1

NWDR 1165-2-2

DEPARTMENT OF THE ARMY
Corps of Engineers, Northwestern Division
P.O. Box 2870
Portland, Oregon, 97208-2870

CENWD-PDW
Regulation
No. 1165-2-2

23 January 2014

Water Resource Policies and Authorities
WATER MANAGEMENT RESPONSIBILITIES

History. This issue is a revision of the former NPDR 1165-2-2 as a result of an organizational restructure.

Summary. This regulation addresses the management of the reservoir projects and reservoir systems in the Pacific Northwest region for which the Corps is responsible, including the Columbia River Basin and coastal tributaries within the physical boundaries of the Northwestern Division (NWD) of the U.S. Army Corps of Engineers.

1. PURPOSE. To provide policy and guidance regarding the operation of the NWD Corps dams and the Corps' implementation of its authority to regulate projects owned or operated by other entities and agencies pursuant to these authorities for flood risk management and navigation (see 33 USC§ 701 and 33 CFR § 208.11). This regulation describes the organizational structure and defines specific responsibilities for the division, districts, and project offices engaged in this activity. It also defines the Water Management Board along with the associated procedures for division-district interface on water management activities.

2. APPLICABILITY. This regulation is applicable to the Columbia Basin Water Management Division (CBWM) within Headquarters, Northwestern Division (HQNWD), and the offices with water management responsibilities in the Portland, Seattle, and Walla Walla Districts. A separate guidance memorandum covers the management of the reservoirs and reservoir systems in the Missouri River Basin of NWD.

3. REQUIRED PUBLICATIONS.

a. ER 1110-2-240, Water Control Management, cited in paragraph 5a, 6c(6)(a), 6c(6)(c), 11b(5), 12a, 12b, and 13a.

b. ER 1110-2-241, Use of Storage Allocated for Flood Control and Navigation at Non-Corps Projects, cited in paragraph 5a.

c. ER 1110-2-249, Management of Water Control Data Systems, cited in paragraph 12a.

d. ER 1110-2-1400, Reservoir/Water Control Centers, cited in paragraph 4e.

e. EM 1110-2-3600, Management of Water Control Systems, cited in paragraph 5a.

*Supersedes NPDR 1165-2-2, January 1990

f. Columbia River Basin Master Water Control Manual, cited in paragraph 5c, 6c(6)(b), and 11a.

g. CENWD Master Plan for Water Control Data Systems, cited in paragraphs 6c(5)(c), 6c(5)(d), 6c(6)(a), 7c(5)(c), 7c(5)(d), 12a, and 12b.

h. NWDR 1110-2-6, Deviation Requests for Approved Water Control Manuals, cited in paragraphs 6c(2)(e) and 6c(7)(e), and 7c(2)(c).

4. BACKGROUND AND DEFINITIONS.

a. Water Management activities in the Pacific Northwest Region of the Northwestern Division are characterized by a regionally dispersed, interdependent, collaborative effort utilizing the staff and coordinated resources of the Portland District (NWP), Seattle District (NWS), Walla Walla District (NWW) and Division Columbia Basin Water Management (CBWM) offices. District and division technical water management expertise will be shared and focused as needed to shape an interdependent water management team for the Columbia Basin.

b. CBWM is responsible for executive direction and oversight responsibility of all Water Management functions throughout the Columbia River Basin and the coastal watersheds. These executive direction and oversight responsibilities are further detailed in paragraph 6(b), and generally include: (1) establishing and implementing policies and guidance; and (2) directing and managing overall execution and performance of all Corps Water Management offices in the Pacific Northwest Region. CBWM also has responsibilities regarding the regulation of projects, which are further detailed in paragraph 6(b)(2) – (b)(8); and (c)(2).

c. District offices are responsible for regulation and operation of the Columbia River tributary projects and any coastal projects in their respective areas of responsibility.

d. Division/district responsibilities for each major project are shown in Appendix A.

e. The duties and responsibilities of district and division water management offices, collectively and individually referred to as Reservoir Control Centers, are broadly defined by ER 1110-2-1400. Paragraph 8b of ER 1110-2-1400 calls for the development of a guidance memorandum to be used as the basic guide for management of water control activities in each MSC. This regulation, NWDR 1165-2-2, serves that purpose by providing specific direction and describing roles and responsibilities for the Reservoir Control Centers at NWP, NWS, NWW, and CBWM.

f. Certain key terms used in this regulation are defined in Appendix B, and contain specific or explicit definitions that apply to parties subject to this regulation.

5. WATER MANAGEMENT POLICIES AND GUIDANCE.

a. General Policies and Guidance. Corps projects will be regulated to conform to basic provisions in authorizing documents, applicable Federal statutes and regulations, and water management policies and criteria. Corps policies regarding water management are contained in

ER 1110-2-240 and ER 1110-2-241. Technical guidance in carrying out reservoir regulation is contained in EM 1110-2-3600.

b. Project Regulation Guidance. Project water control plans have been developed to define and describe regulation procedures for each Corps and non-Corps project for which the Corps has regulation responsibility. These are usually contained in the project water control manuals.

c. Policies and Guidance for System Management. The Columbia River Basin Master Water Control Manual contains policy and guidance for regulating the dams and reservoirs in the Columbia basin (excluding the system of reservoirs in the Willamette Basin) to fulfill integrated system objectives. Since the projects in the Columbia system are interrelated, regulation for individual projects and local objectives must be coordinated with objectives for the system as a whole. Project obligations to meet system objectives are described in the Columbia River Basin Master Water Control Manual. Should perceived discrepancies arise between the guidance contained in a project's Water Control Manual, the Columbia River Basin Master Water Control Manual, and/or system operating guidance, the Chief of CBWM will be contacted for clarification and resolution.

6. DIVISION OFFICE ORGANIZATION AND RESPONSIBILITIES.

a. Organization. Water management responsibilities within NWD are geographically divided into activities west and east of the Continental Divide. These responsibilities are assigned to the Columbia River Basin Water Management Division (CBWM) and the Missouri River Basin Water Management Division offices, respectively, which operate within the Programs Directorate of NWD. The CBWM is organized into two branches which carry out the various responsibilities relating to the water management mission described below. The organizational chart for those elements in CBWM associated with water management is provided in Appendix C. Also listed are the other agencies with which coordination is required.

b. General CBWM Responsibilities.

(1) CBWM has executive direction and oversight responsibilities for all Water Management functions throughout the Columbia River Basin and the coastal watersheds that includes:

(a) Establishing and implementing policies and guidance; and

(b) directing and managing overall execution and performance of all Corps Water Management offices in the Pacific Northwest Region.

(2) CBWM has responsibility for regulating the mainstem Columbia River and Lower Snake River projects for authorized purposes. CBWM is also responsible for regional reservoir regulation support as conditions warrant during system flood events or other situations as determined by the CBWM Chief.

(3) CBWM coordinates tributary operations with the districts in order to meet system objectives.

(4) CBWM establishes system flood control requirements and coordinates system power operations for implementation by CBWM and the districts.

(5) CBWM has responsibility for the planning and implementation of the Columbia River Treaty and PNCA.

(6) CBWM has technical capability commensurate with all of their regional responsibilities (on-call technical support will be available from the districts).

(7) CBWM serves as the point of contact for regional stakeholders for all projects as necessary to implement system water management requirements.

(8) CBWM coordinates and provides oversight function for navigation safety.

c. Specific CBWM Responsibilities

(1) System Power Coordination and Columbia River Treaty.

(a) Prepare annual operating plans for the Columbia River system in accordance with the PNCA and the Columbia River Treaty, including performing system regulation studies and coordination.

(b) Implement the Columbia River Treaty in accordance with the Treaty and related implementation documents, through the Treaty Operating Committee and Treaty Hydro meteorological Committee, including performing required studies for Treaty coordination.

(c) Represent the Corps on the Northwest Power Pool Coordinating Group and participate in other PNCA activities as needed.

(2) Reservoir Regulation.

(a) Provide primary regulation of the mainstem Columbia, Lower Snake River projects, and others as specified in Appendix A. This includes issuing regulation instructions to projects and coordinating with Bonneville Power Administration (BPA), US Bureau of Reclamation (USBR), district offices, fishery agencies, Tribes, electrical utilities, and other stakeholders.

(b) Provide backup regulation for projects specified in Appendix A when requested.

(c) Model flow and reservoir conditions for short and intermediate term reservoir system operation planning (excluding the Willamette system). Work with the National Weather Service Northwest River Forecast Center (NWRFC), NWS, and NWW. During flood or other emergencies work with NWP.

(d) Coordinate and lead the execution of long term seasonal planning models with districts.

(e) Submit a formal deviation request to the Chief of CBWM for any Columbia mainstem or Lower Snake project operation that varies from the project's Water Control Manual, in accordance with NWDR 1110-2-6.

(f) Provide requirements to district water managers regarding:

-reservoir storage space to meet Columbia River system flood control requirements during the evacuation and refill season, and

-Columbia River system flood control flow requirements during a system flood event (including the Willamette projects if needed), during evacuation and the spring refill period, and

-Columbia River system objectives for coordinated operations for power needs and various levels of power emergencies.

-Columbia River system power emergencies.

(3) Environmental Support.

(a) Act as the regional lead and coordinate with the districts on the development, planning, and implementation of the Fish Passage Plan, Water Quality Plan, Water Management Plan, and other related plans on the Columbia and Snake rivers.

(b) Act as chair for Technical Management Team (TMT). Coordinate with districts on applicable project operations before TMT meetings. Coordinate with districts to fulfill requests for any products requested of them by TMT.

(c) Review and provide timely responses to TMT System Operations Requests. Coordinate with districts as needed.

(d) Participate in or conduct regional and interagency meetings that provide information in the form of technical input, comments, or recommendations to the Corps on project operations.

(e) Act as lead Water Management POC for litigation for the FCRPS and prepare documents as necessary to support litigation effort and requirements.

(f) Perform water quality modeling as required to meet regulatory requirements.

(4) Forecasting, Studies, and Reports.

(a) Perform system flood control, power, water quality, conservation storage, and other system studies to improve regulation procedures or analyze problem areas in system operations.

(b) Provide technical coordination with district offices, BC Hydro, NWRFC, NRCS, and Treaty Hydrometeorlogical and Operating Committees on water supply forecasting techniques.

(c) Reviews and approves district water supply forecasts and forecasting procedures for projects that provide system flood control.

(5) Regional Water Control Data System (RWCDS).

(a) Operate and maintain the Regional WCDS with district offices. Maintain RWCDS consistent with the standard regional configuration.

(b) Coordinate and implement timely, efficient regional exchange of data.

(c) Perform Quality Assurance/Quality Control (QA/QC) on data, as designated in the RWCDS Master Plan.

(d) Coordinate regionally on RWCDS Master Plan updates.

(6) Plans and Manuals.

(a) Detailed plans for subsystems and networks of approved RWCDS Master Plan are approved by the Division Commander as required by ER 1110-2-240.

(b) Prepare and maintain Columbia River Master Manual.

(c) Review updates to Master Manuals as well as District Water Control Manuals. Water control plans and manuals are approved by the Division Commander as required by ER 1110-2-240.

(d) Coordinate with districts to prepare/review portions of water control plans and manuals for projects as designated in Appendix A.

(e) Prepare the Columbia River Treaty, PNCA, and other system-related reports.

(f) Prepare annual Total Dissolved Gas (TDG) Monitoring Plan.

(g) Prepare annual water quality reports describing TDG and temperature information related to project operations such as annual TDG Report.

(h) Lead development, planning, and implementation of the Fish Passage Plan, Water Quality Plan, Water Management Plan, and other related plans on the Columbia and Snake Rivers.

(7) Other.

(a) Issue public information statements as necessary.

(b) Hold and participate in public meetings for all projects as needed to present information or to solicit public comment on proposed system operations or changes to system operations.

(c) Assume necessary dam safety responsibilities relating to reservoir regulation and flood warning and notification, including coordinating the development of system dam break models, conducting and participating in emergency action plan exercises, and other related activities.

(d) Plan, implement and regularly exercise COOP procedures.

(e) Review and provide timely response to deviation requests in accordance with NWDR 1110-2-6.

(f) Prepare Water Management Budget for CBWM. Coordinate the preparation of the regional Water Management Budget.

7. DISTRICT OFFICE ORGANIZATION AND RESPONSIBILITIES.

a. Organization. Organizational charts for the district organizations associated with water management are provided in Appendix C.

b. General District Responsibilities.

(1) Each district has responsibility for the regulation of Corps coastal and Columbia River tributary projects within their area of responsibility (see Appendix A) for authorized project purposes. Districts are also responsible for regional reservoir regulation support as conditions warrant during system flood events or other situations as determined by the CBWM Chief.

(2) Each district has responsibility for oversight, and when necessary, flood control regulation, of non-Corps projects pursuant to applicable requirements (e.g. FERC licenses and Section 7 of the 1944 Flood Control Act projects, see Appendix A).

(3) Each district will follow Water Control Manuals, Water Management Plans and other applicable guidance to meet system requirements provided by CBWM.

(4) Each district will serve as the point of contact for local and regional stakeholders as necessary to implement district water management requirements.

(5) The districts maintain full technical capabilities and will provide on-call technical support for CBWM when requested.

c. Specific Responsibilities Common to all Districts.

(1) System Power Coordination and Columbia River Treaty.

(a) Review applicable annual operating plan and other related submittals for the PNCA and the Columbia River Treaty, as requested by CBWM.

(b) Provide technical support for Columbia River Treaty studies and investigations, as requested by CBWM.

(c) Implement requirements established by CBWM for system flood events and power emergencies.

(d) Provide data to CBWM for Actual Energy Regulation (AER) for projects where the district has primary responsibility and participate in AER coordination calls.

(2) Reservoir Regulation.

(a) Provide primary regulation of projects as specified in Appendix A. This includes issuing regulation instructions to projects and coordinating with stakeholders.

(b) Provide backup regulation for projects specified in Appendix A when requested.

(c) Submit a formal deviation request to Chief CBWM for any project operation that varies from the project's Water Control Manual, in accordance with NWDR 1110-2-6.

(3) Environmental Support.

(a) Review applicable TMT System Operations Requests and provide timely input to CBWM. Prepare products to support TMT activities as requested, and participate in TMT meetings as needed.

(b) Install and maintain real-time Fixed Monitoring System stations at projects in district area of responsibility to monitor water quality conditions.

(c) Conduct water quality studies and activities for tributary and coastal streams as needed.

(d) Perform water quality modeling as required to meet regulatory requirements.

(e) Prepare TDG QA/QC documents that are incorporated as appendices to the annual TDG report prepared by CBWM.

(f) Provide technical support to CBWM when requested, respond to memos from CBWM and other agencies, and review regional water quality related documents.

(4) Forecasting, Studies, and Reports.

(a) Perform flood control, conservation storage, and other water management studies for projects specified in Appendix A to improve regulation procedures. Analyze and anticipate potential problems or concerns for projects for which water control plan responsibility exists.

(b) Develop and after CBWM review and approval , implement water supply and streamflow forecasting procedures or utilize external agency forecasts for projects that provide system flood control.

(c) Coordinate water supply forecasts with NWRFC, BPA and other agencies; oversee forecast integrity and prepare forecasting procedures for projects listed in Appendix A.

(5) Regional Water Control Data System (RWCDS).

(a) Operate and maintain the Regional WCDS with CBWM and all district offices. Maintain RWCDS consistent with the standard regional configuration.

(b) Coordinate and implement timely, efficient regional exchange of data.

(c) Perform Quality Assurance/Quality Control (QA/QC) on data, as designated in the RWCDS Master Plan.

(d) Coordinate regionally on RWCDS Master Plan updates.

(6) Plans and Manuals.

(a) Support CBWM in the development, planning, and implementation of the Fish Passage Plan, Water Quality Plan, Water Management Plan, and other related plans on the Columbia and Snake Rivers.

(b) Maintain and update as necessary water control plans and/or water control manuals for projects as specified in Appendix A. Perform studies and coordinate with agencies and other stakeholders as appropriate.

(7) Other.

(a) Issue public information statements as necessary.

(b) Hold and participate in public meetings to present information or to solicit public comment on proposed operations or operational changes.

(c) Assume necessary dam safety responsibilities relating to reservoir regulation and flood warning and notification, including conducting and participating in emergency action plan exercises, and preparing and maintaining individual and system dam break models.

(d) Plan, implement, and regularly exercise COOP procedures.

(e) Provide technical assistance to NWD for water management, water quality, and biological studies or evaluations as needed.

(f) Prepare Water Management Budget for district.

d. Specific Responsibilities Assigned to Individual Districts.

(1) NWP prepares and maintains the Master Water Control Manual for the Willamette Basin.

(2) NWP prepares the seasonal and annual operating plans for the Willamette Valley Project dams, Rogue River Project dams, and Willow Creek Dam.

(3) NWS prepares the Libby water supply forecast. NWS oversees forecast integrity and coordinates with NWRFC, BPA, and other agencies.

(4) NWW prepares the Dworshak water supply forecast. NWW oversees forecast integrity and coordinates with NWRFC, BPA, and other agencies.

(5) NWW provides temperature modeling output to CBWM for varying Dworshak Project operations as needed for TMT.

(6) NWW is responsible for ensuring safe navigation conditions in the Snake River (Lime Point).

8. PROJECT OFFICE ORGANIZATION AND RESPONSIBILITIES.

a. Organization and Coordination. Project offices are within the purview of NWD Program Support Division and the Chief of Operations Division at each District provides oversight to the Operations Project Managers. Interface with water management personnel in division or district

offices occurs in the project regulation process. In routine regulation situations, this is normally accomplished by direct contact between division or district reservoir regulation personnel and project personnel.

b. Responsibilities. Project offices will be responsible for the following actions, with regard to water management.

(1) Coordination and implementation of division and district water control instructions.

(2) Reporting project status and hydromet data as required.

(3) Reporting and coordinating O&M activities that will affect project operability for water management purposes.

(4) Conducting water management operations during situations when division/district water control managers are unavailable, such as during a COOP.

9. WATER MANAGEMENT BOARD. The NWD Water Management Board (WMB) is established to ensure that water management activities in NWD are pursued within the regional business center (RBC) framework. The WMB will act as the working group that provides data and recommendations to the Regional Management Board (RMB), and the Regional Command Council. The goal is to provide a structured forum for corporate oversight, strategic planning, issue resolution, and assurance of the most effective program execution through the use of best business practices.

a. Membership. The WMB will be co-chaired by the Chief, Columbia River Basin Water Management Division (NWD); the Chief, Missouri River Basin Water Management Division (NWD); and the Chief, Program Support Division (NWD). The Board will also include one member from Business Resource Division, and two members from each NWD district consisting of one from the Hydraulics and Hydrology Branch and one from the Operations Division.

b. Program Development. The WMB will review and recommend a budget and work plan for division and district water management activities. This information will be reviewed annually in the March-April timeframe to determine if changes are necessary to the existing budget and work plan, and to add information as needed for future years. Upon review and concurrence by the Director of Programs Directorate, the Division water management budget and work plan will be presented to the RMB for review and approval. Upon concurrence of the RMB, the Director of Programs Directorate will make the information available as required to the Regional Command Council for information. The Division budget and work plan will then be used to develop the activity letters to the districts that initiate funding for Division water management for the next fiscal year. It will also be used as input to the overall Operations and Management budget for NWD, and for long-range strategic planning.

c. Best Business Practices. The WMB will review and evaluate the NWD Water Management Program as a whole, including current and future operations, trends, processes, practices and resource allocations, to determine if best business practices are in use. This review and evaluation will consist of both division and district Water Management activities, including sedimentation and water quality elements. Recommended changes to business practices will be reported to the Director of Programs Directorate, the RMB, and the Regional Command Council.

d. Issue Resolution. District and division representatives will be responsible for coordinating the proposed Water Management budget and any other issues with the district leadership, gathering and presenting comments to the WMB. Responses on comments from the board will be reported to district leadership through the district WMB representatives. The WMB will strive to resolve issues by ensuring that all pertinent data surrounding the issue at question is available to each WMB member, and through open dialog within the Board. If issues cannot be resolved by the WMB, the Director of Programs Directorate will mediate the disagreement in an attempt to reach consensus. If that fails, the issues will be elevated to the RMB and ultimate resolution by the Regional Command Council.

10. PUBLIC INFORMATION. In most cases, the districts have the lead responsibility for public information, including gathering input from the public, disseminating information, and organizing public meetings. The districts will work with CBWM to ensure that dissemination of public information is consistent with system objectives. CBWM has the lead responsibility for public information for issues pertaining to the Lower Snake projects and the mainstem Columbia projects as well as system operations.

11. WATER CONTROL PLANS AND MANUALS.

a. Responsibilities. District and Division responsibilities for preparing and maintaining water control plans and manuals are listed by project in Appendix A. In the case of several projects on the mainstem Columbia River which involve extensive system-wide coordination, CBWM will be involved in preparing/reviewing portions of those manuals. CBWM is responsible for preparing and maintaining the Columbia Basin Master Water Control Manual. Review and approval of water control manuals is a HQNWD responsibility. This approval responsibility applies to water control manuals for individual projects as well as master manuals.

b. Requirements. The following requirements and procedures apply to project water control manuals, with the objective of maintaining the most important parts of the manuals (including the water control plan) in an accurate and up-to-date status while utilizing a minimum of personnel resources.

(1) The water control plan for the project is to be current and accurate.

(2) The water control manual will be considered functional if it contains at a minimum an up-to-date water control plan. Preferably, it would also contain other chapters that are of a technical nature. It need not contain other chapters with general information to be a functional manual.

(3) Water control manuals will be updated such that the more important parts are given a higher priority, such as the water control plan.

(4) The manual will be contained in a loose-leaf binder with cover sheets at the front that indicate status of the chapters in the manual.

(5) District offices will prepare their annual status report to CBWM in accordance with ER 1110-2-240. A division-wide report will be submitted to HQUSACE.

12. WATER CONTROL DATA SYSTEMS.

a. Responsibilities. General responsibilities as defined in ER 1110-2-240 and ER 1110-2-249 are for district and division offices to develop and maintain Water Control Data Systems (WCDS). CBWM maintains approval authority for systems and networks through the submittal of the RWCDS Master Plan and its annual updates. Specific office responsibilities related to the RWCDS for the Columbia River Basin and coastal tributaries will be documented in the RWCDS Master Plan.

b. Requirements and Procedures. ER 1110-2-240 gives specific requirements for submittal and updating of division and district WCDS Master Plans.

13. AFTER-ACTION REPORTING.

a. Routine Reports. ER 1110-2-240 requires that a Division report on water management activities be submitted to HQUSACE annually. Another routine water management report prepared by HQNWD is the Columbia River Treaty Annual Report. Input from districts may be requested at the end of each water year for inclusion in these reports.

b. Special after-action reports. After the occurrence of large floods and other unusual events such as natural disasters, Corps Emergency Management offices may be required to prepare an after action report. Division and/or district water management personnel are typically requested to provide input to post-flood after action reports.

FOR THE COMMANDER:

Pamela D. Hertzberg

PAMELA D. HERTZBERG
Executive Officer

3 Appendices
App A – Division and District Water Management Responsibilities
App B – Definitions and Acronyms
App C – Division and District Organizations for Water Management

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NWDR 1165-2-2
APPENDIX A
DIVISION AND DISTRICT WATER MANAGEMENT RESPONSIBILITIES

PROJECT	OWNER	AUTHORITY	PRIMARY REGU-LATION	BACKUP REGU-LATION	WATER CONTROL PLAN	WATER SUPPLY FORECAST	STREAM-FLOW FORECAST	WATER CONTROL MANUAL
UPPER COLUMBIA								
Mica	BCH	Treaty	Owner/NWD	------	NWD	NWRFC*	NWRFC	------
Revelstoke	BCH	Power Coord	Owner	------	------	NWRFC*	NWRFC	------
Hugh Keenleyside	BCH	Treaty	Owner/NWD	------	NWD	NWRFC*	NWRFC	------
LIBBY	CE	Congress.	NWS	NWD	NWS/NWD	NWS	NWRFC	NWS
Duncan	BCH	Treaty	Owner/NWD	------	NWD	NWRFC*	NWRFC	------
Corra Linn	FORTISBC	Power Coord	Owner	------	------	NWRFC*	NWRFC	------
Kootenay Projects	FORTISBC	Power Coord	Owner	------	------	NWRFC*	NWRFC	
Hungry Horse	USBR	FCA 1944, sec 7	Owner/NWD	NWS	NWD	NWRFC*	NWRFC	NWS/NWD*
Kerr	PPL MONTANA	FERC Lic.	Owner/NWD	NWS	NWD	NWRFC	NWRFC	------
Thompson Falls	PPL MONTANA	Power Coord	Owner	------	------	NWRFC	NWRFC	------
Noxon Rapids	AVISTA	Power Coord	Owner	------	------	NWRFC	NWRFC	------
Cabinet Gorge	AVISTA	Power Coord	Owner	------	------	NWRFC	NWRFC	------
ALBENI FALLS	CE	Congress.	NWS	NWD	NWS/NWD	NWRFC	NWRFC	NWS
Box Canyon	PEND PUD	Power Coord	Owner	------	------	NWRFC	NWRFC	------
Boundary	SEATTLE CITY LIGHT	Power Coord	Owner	------	------	NWRFC	NWRFC	------
Seven Mile	BCH	Power Coord	Owner	------	------	NWRFC	NWRFC	------
Waneta	TECK COMINCO	Power Coord	Owner	------	------	NWRFC	NWRFC	------
Spokane Projects	AVISTA	Power Coord	Owner	------	------	NWRFC	NWRFC	------
Grand Coulee	USBR	FCA 1944, sec 7	Owner/NWD	------	NWD	NWRFC	NWRFC	NWD*/NWS
MID-COLUMBIA								
CHIEF JOSEPH	CE	Congress.	NWD	NWS	NWD/NWS	NWRFC	NWRFC	NWS
Wells	DOUGLAS PUD	FERC Lic.	Owner/NWD	------	NWD	NWRFC	NWRFC	NWS/NWD*
Rocky Reach	CHELAN PUD	FERC Lic.	Owner/NWD	------	NWD	NWRFC	NWRFC	NWS/NWD*
Rock Island	CHELAN PUD	FERC Lic.	Owner/NWD	------	NWD	NWRFC	NWRFC	------
Wanapum	GRANT PUD	FERC Lic.	Owner/NWD	------	NWD	NWRFC	NWRFC	NWS/NWD*
Priest Rapids	GRANT PUD	FERC Lic.	Owner/NWD	------	NWD	NWRFC	NWRFC	NWS/NWD*
Yakima Projects	USBR	------	Owner/NWD	------	NWD	NWRFC	NWRFC	------
LOWER COLUMBIA								

PROJECT	OWNER	AUTHORITY	PRIMARY REGU-LATION	BACKUP REGU-LATION	WATER CONTROL PLAN	WATER SUPPLY FORECAST	STREAM-FLOW FORECAST	WATER CONTROL MANUAL
MILL CREEK	CE	Congress.	NWW	------	NWW	------	NWW	NWW
MCNARY	CE	Congress.	NWD	NWW	NWD/NWW	NWRFC	NWRFC	NWW
WILLOW CREEK	CE	Congress.	NWP	------	NWP	NWP*	NWP	NWP
JOHN DAY	CE	Congress.	NWD	NWP	NWD / NWP	NWRFC*	NWRFC	NWP
Prineville	USBR	FCA 1944, sec 7	Owner	NWP	Owner	NWRFC*	Owner	NWP*
Ochoco	USBR	FCA 1944, sec 7	Owner	NWP	Owner	NWRFC*	Owner	NWP*
THE DALLES	CE	Congress.	NWD	NWP	NWD / NWP	NWRFC*	NWRFC	NWP
BONNEVILLE	CE	Congress.	NWD	NWP	NWD / NWP	NWRFC*	NWRFC	NWP
Swift #1	PACIFICORP	FERC Lic.	Owner	NWP	Owner/NWP	------	NWRFC	NWP*
Swift #2	PACIFICORP	FERC Lic.	Owner	NWP	Owner/NWP	------	------	------
Yale V	PACIFICORP	FERC Lic.	Owner	NWP	Owner/NWP	------	NWRFC	NWP*
Merwin	PACIFICORP	FERC Lic.	Owner	NWP	Owner/NWP	------	------	NWP*
Mossyrock/ Mayfield	TACOMA CL	FERC Lic.	Owner	NWP	Owner	------	NWRFC	NWP*
WILLAMETTE								
HILLS CREEK	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
LOOKOUT POINT	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
DEXTER	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
FALL CREEK	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
COTTAGE GROVE	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
DORENA	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
COUGAR	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
BLUE RIVER	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
FERN RIDGE	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
GREEN PETER	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
FOSTER	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
DETROIT	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
BIG CLIFF	CE	Congress.	NWP	NWD	NWP	NWP*	NWRFC / NWP	NWP
Scoggins	USBR	Section 7	Owner	NWP	Owner	Owner	Owner	NWP*
UPPER SNAKE								
Jackson Lake	USBR	Congress.	Owner /NWW	Owner	Owner/NWW	Owner/NWW*	NWRFC	NWW*
Palisades	USBR	Congress.	Owner/NWW	Owner	Owner/NWW	Owner/NWW*	NWRFC	NWW*
Ririe	USBR	Congress.	Owner/NWW	Owner	Owner/NWW	Owner/NWW*	NWRFC	NWW*
American Falls	USBR	------	Owner	------	Owner/NWW	------	NWRFC	------
Little Wood	USBR	Section 7	Owner/NWW	Owner	Owner/NWW	Owner/NWW	NWRFC	NWW

PROJECT	OWNER	AUTHORITY	PRIMARY REGU-LATION	BACKUP REGU-LATION	WATER CONTROL PLAN	WATER SUPPLY FORECAST	STREAM-FLOW FORECAST	WATER CONTROL MANUAL
Owyhee	USBR	------	Owner		Owner	NWRFC*	NWRFC	------
Anderson Ranch	USBR	Section 7**	Owner/NWW	NWW	Owner/NWW	Owner/NWW*	NWRFC	NWW
Arrowrock	USBR	Section 7**	Owner/NWW	NWW	Owner/NWW	Owner/NWW*	NWRFC	NWW
LUCKY PEAK	CE	Congress.	NWW	USBR	NWW/USBR	NWW/USBR*	NWRFC	NWW
Warm Springs	USBR	Section 7	Owner	NWW	Owner/NWW	NWW/Owner*	NWRFC	NWW*
Agency Valley	USBR	Section 7	Owner	NWW	Owner/NWW	NWW/Owner*	NWRFC	NWW*
Bully Creek	USBR	Section 7	Owner	NWW	Owner/NWW	NWW/Owner*	NWRFC	NWW*
Cascade	USBR	------	Owner	-----	Owner	Owner	NWRFC	------
Deadwood	USBR	------	Owner	-----	Owner	Owner	NWRFC	------
Mason	USBR	Section 7	Owner	NWW	Owner/NWW	Owner/NWW*	NWRFC	NWW
MID/LOWER SNAKE								
Brownlee	IDAHO POWER CO.	FERC Lic.	Owner/NWD	NWW/	NWD/NWW	NWRFC	NWRFC	NWW/NWD*
Oxbow	IDAHO POWER CO.	FERC Lic.	Owner		NWD/NWW	NWRFC	NWRFC	NWW/NWD*
Hells Canyon	IDAHO POWER CO.	FERC Lic.	Owner		NWD/NWW	NWRFC	NWRFC	NWW/NWD*
DWORSHAK	CE	Congress.	NWW	NWD	NWW/NWD	NWW	NWRFC	NWW
LOWER GRANITE	CE	Congress.	NWD	NWW	NWD/NWW	NWRFC	NWRFC	NWW
LITTLE GOOSE	CE	Congress.	NWD	NWW	NWD/NWW	NWRFC	NWRFC	NWW
LOWER MONUMENTAL	CE	Congress.	NWD	NWW	NWD/NWW	NWRFC	NWRFC	NWW
ICE HARBOR	CE	Congress.	NWD	NWW	NWD/NWW	NWRFC	NWRFC	NWW
PUGET SOUND								
Ross	SEATTLE CITY LGT	FERC Lic.	Owner/NWS	------	NWS	NRCS	NWRFC	NWS*
Upper Baker	PUGET SOUND ENERGY	FERC Lic.	Owner/NWS	------	NWS	NRCS	NWRFC	NWS*
LAKE WASHINGTON	CE	Congress.	NWS	------	NWS	------	NWRFC	NWS
HOWARD A HANSON	CE	Congress.	NWS	------	NWS	NRCS	NWRFC	NWS
MUD MOUNTAIN	CE	Congress.	NWS	------	NWS	NRCS	NWRFC	NWS
WYNOOCHEE	City of Aberdeen	Congress.	Owner/NWS	------	NWS	------	NWRFC	NWS*
UMPQUA/ROGUE								
Galesville	DOUGLAS COUNTY	Section 7	Owner	NWP	Owner	Owner	Owner	NWP*
LOST CREEK	CE	Congress.	NWP	------	NWP	NWP*	NWRFC / NWP	NWP
ELK CREEK ***	CE	Congress.	NWP	------	NWP	NWP*	NWRFC / NWP	NWP
Emigrant	USBR	Congress.	Owner	NWP	Owner	Owner	Owner	NWP*

PROJECT	OWNER	AUTHORITY	PRIMARY REGU-LATION	BACKUP REGU-LATION	WATER CONTROL PLAN	WATER SUPPLY FORECAST	STREAM-FLOW FORECAST	WATER CONTROL MANUAL
APPLEGATE	CE	Congress.	NWP	------	NWP	NWP*	NWRFC / NWP	NWP
MASTER MANUALS								
Columbia	------	------	------	------	------	------	------	NWD
Willamette	------	------	------	------	------	------	------	NWP

NOTES

1. Corps of Engineers projects are listed in capital letters
2. When joint responsibilities are shown, the office with lead responsibility is shown first.
3. Definitions of Headings:
    - "Primary Regulation" - For the purposes of this regulation the term "primary regulation" is meant to indicate the office having the lead responsibility for a regulation of a project. This involves frequent monitoring of the project, the issuing of operating instructions, and personal contact with project
    - "Backup Regulation" - Temporary assumption by another office of the roles and responsibilities of Primary Regulation (a) when requested to do so by the activity that normally provides this function, (b) in a COOP situation or COOP exercise, or (c) at the specific request of the CBWM Chief.
    - "Water Control Plan" - Development and updating of the project's Water Control Plan. This may be for either the project's Water Control Manual or an annual system operation.
    - "Water Supply Forecast" - Development and updating of water supply forecast procedure for the project.
    - "Streamflow Forecast" - Development, updating and implementation of streamflow forecasting procedure(s).
    - "Water Control Manual" - A manual used as reference for regulating a reservoir project or system of projects. It contains a Water Control Plan, a specific plan of regulation for that project.
4. A single asterisk (*) indicates that coordination with another agency is required in carrying out the responsibility. This notation was not used for the regulation function, since interagency coordination is assumed to be inherent in the process.
5. ** Arrowrock and Anderson Ranch are no longer managed as Section 7 Projects. Flood Control Space in the Boise System is managed jointly per the current Water Control Plan and Water Control Manual.
6. *** ELK CREEK DAM has been decommissioned, although it remains an authorized multipurpose storage project. It currently passes inflow through a constructed breach. No active storage is available.
7. CBWM determines system flood control requirements and coordinates power operations during power emergencies

APPENDIX B
NWDR 1165-2-2
DEFINITIONS AND ACRONYMS

Regulation/Operation The term "regulation" means the activity of monitoring the information and data on reservoir and streamflow status, analyzing information, and making reservoir regulation decisions based on current conditions and weather and streamflow forecasts, coordinating with affected parties/agencies, and issuing instructions to dam operators. In this NWDR the term "regulation" is kept distinct from "operation", the latter which refers to the actions by field personnel of maintaining and physically operating equipment at projects.

> "Backup Regulation" - Temporary assumption by another office of the roles and responsibilities of Primary Regulation (a) when requested to do so by the activity that normally provides this function, (b) in a COOP situation or COOP exercise, or (c) at the specific request of the CBWM Chief.

> "Primary Regulation" - For the purposes of this regulation the term "primary regulation" is meant to indicate the office having the lead responsibility for a regulation of a project. This involves frequent monitoring of the project, the issuing of operating instructions, and personal contact with project

BCH British Columbia Hydro and Power Authority

BPA Bonneville Power Administration

CBWM The Columbia Basin Water Management Division, one of two water management organizations within HQNWD (the other being the Missouri River Water Management Division)

COOP Continuity of Operations

Executive Direction and Oversight Responsibility for: (1) establishing and implementing policies and guidance; and (2) directing and managing overall execution and performance of all Corps Water Management offices in the Pacific Northwest Region.

FCRPS Federal Columbia River Power System

HQNWD Headquaters, Northwestern Division, in Portland, Oregon

Main Stem Main stem refers to the following projects on the main stem of the Columbia and lower Snake Rivers (Chief Joseph, McNary, John Day, The Dalles, Bonneville, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor)

NRCS Natural Resources Conservation Service

NWRFC Northwest River Forecast Center, National Weather Service

POC Point of Contact
PNCA Pacific Northwest Coordination Agreement

RCC Reservoir Control Center

RWCDS (Regional Water Control Data Systems) A system of gages, telemetry, and computer processors that collects hydrometeorological data from remote sites and sends it to computer controllers for processing, storage, and use by modelers and water control managers. The system is managed regionally and data and model output may be incorporated into products made available to water control staff, managers, and stakeholders.

TDG Total Dissolved Gas

TMT Technical Management Team

Treaty Columbia River Treaty

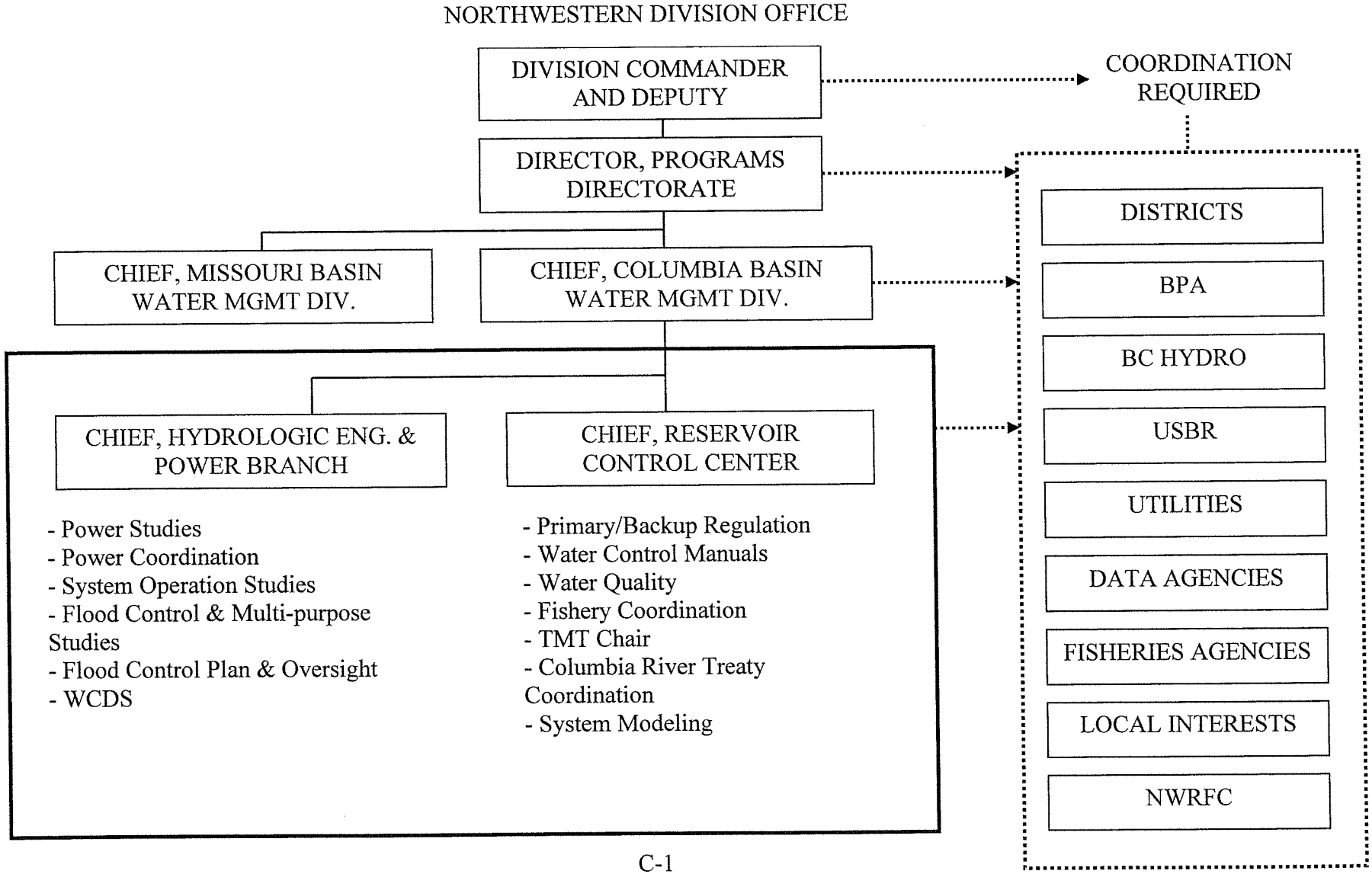
USBR U.S. Bureau of Reclamation

WMB Water Management Board

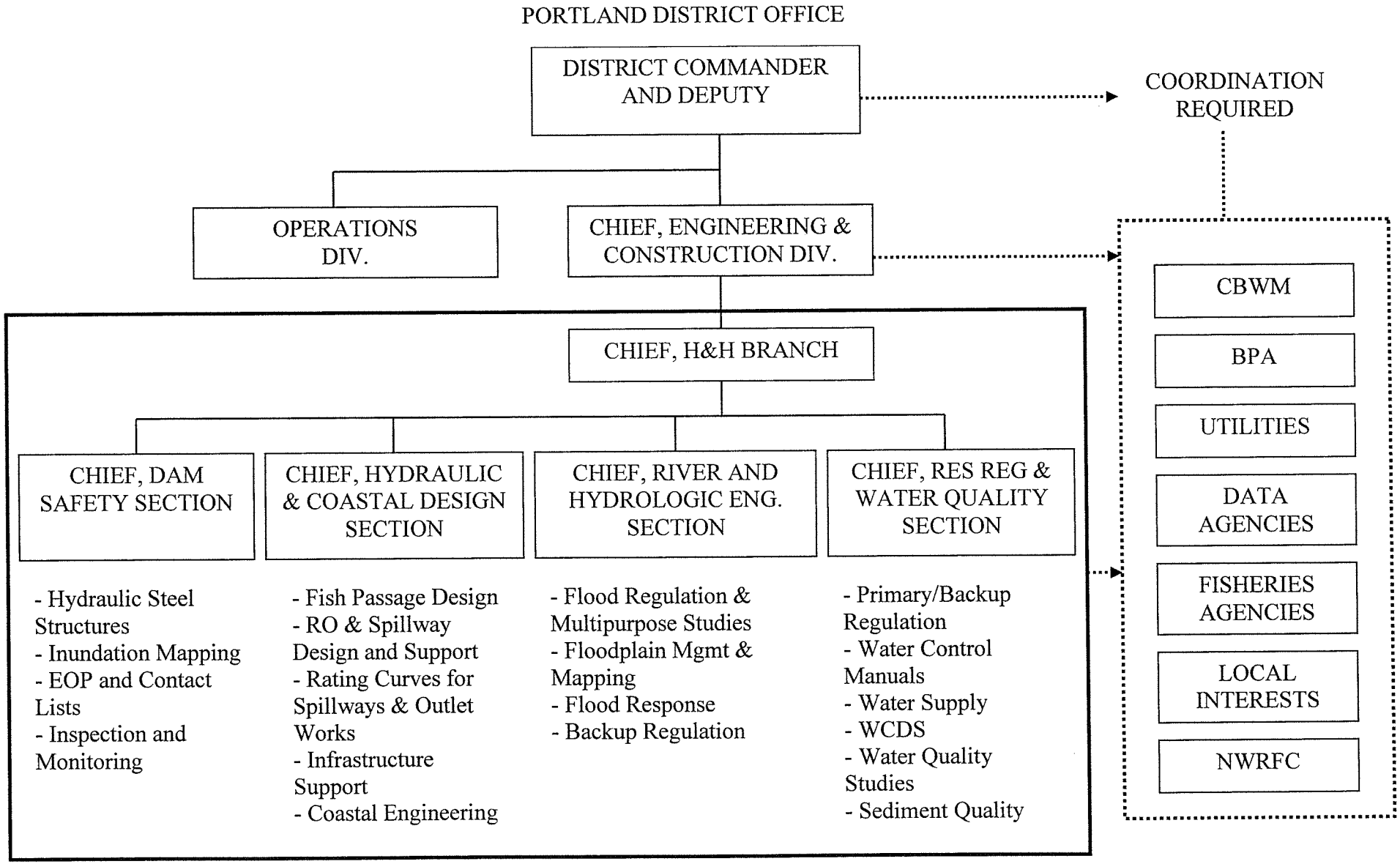
FCA 1944, Section 7 Section 7 of the Flood Control Act of 1944

Congress Congressional Authority

APPENDIX C
NWDR 1165-2-2
DIVISION AND DISTRICT ORGANIZATION FOR WATER MANAGEMENT

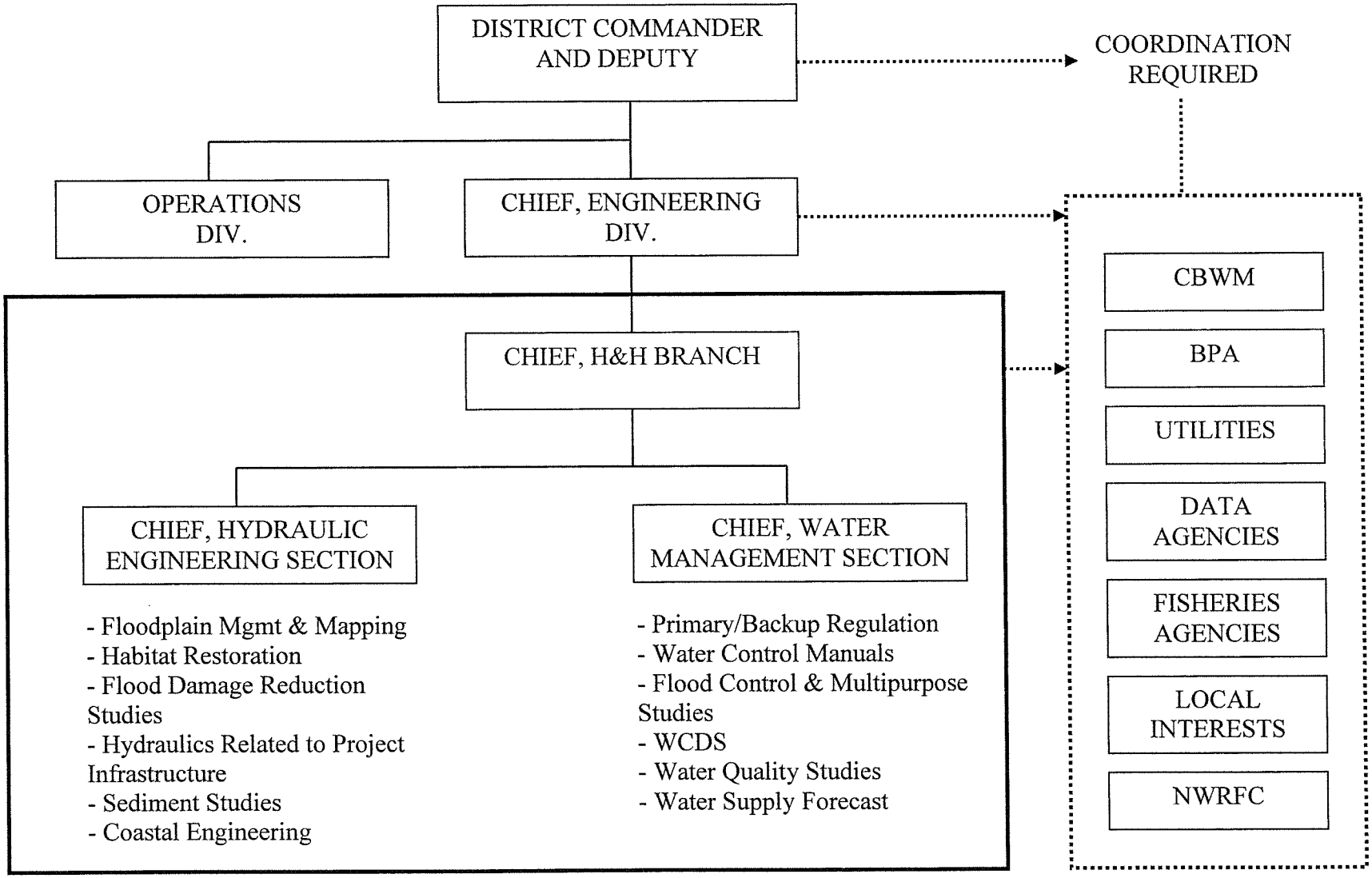


APPENDIX C
NWDR 1165-2-2
DIVISION AND DISTRICT ORGANIZATION FOR WATER MANAGEMENT



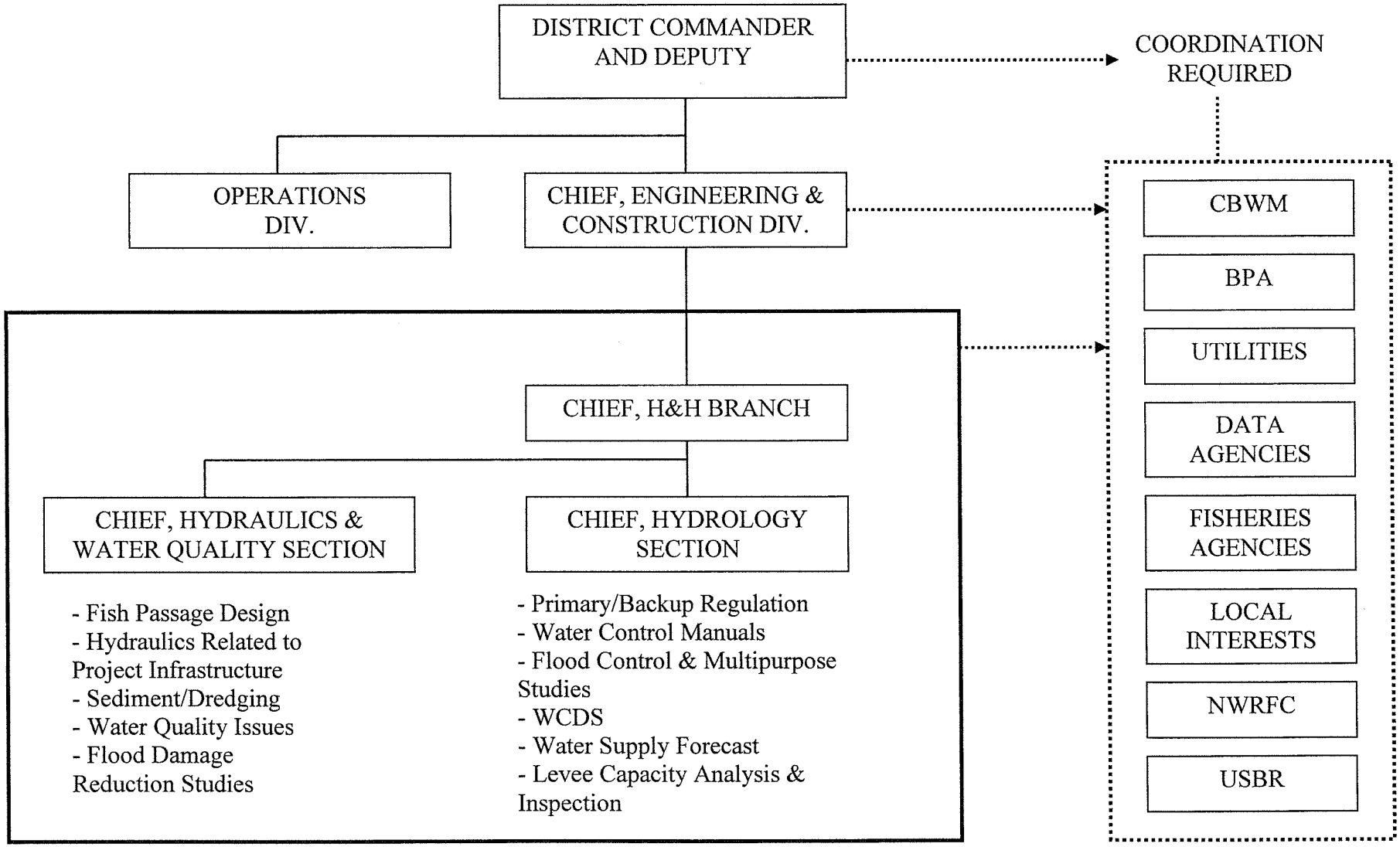
APPENDIX C
NWDR 1165-2-2
DIVISION AND DISTRICT ORGANIZATION FOR WATER MANAGEMENT

SEATTLE DISTRICT OFFICE



APPENDIX C
NWDR 1165-2-2
DIVISION AND DISTRICT ORGANIZATION FOR WATER MANAGEMENT

WALLA WALLA DISTRICT OFFICE



REDACTED CONTENT

REDACTED CONTENT

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EXHIBIT 7-2

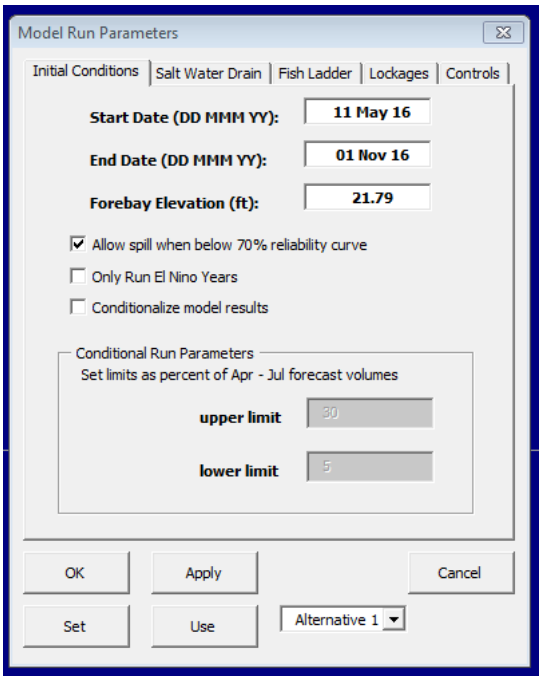
CRITICAL CONTENT CURVE DEVELOPMENT

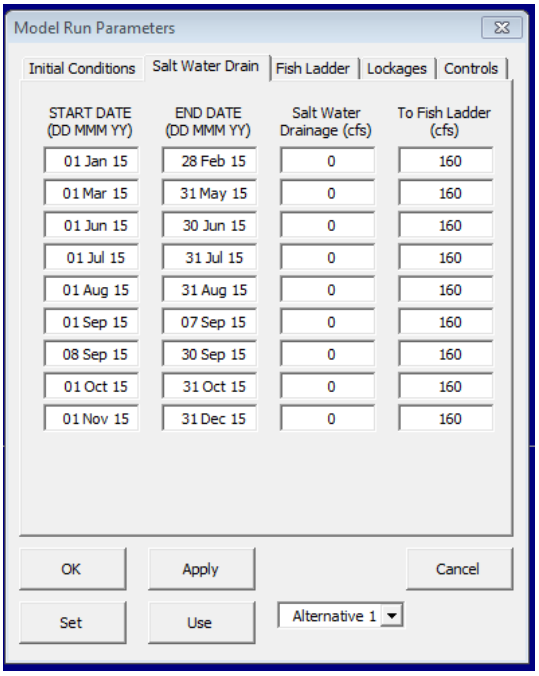
Note: All elevations are referenced to the local project vertical datum.

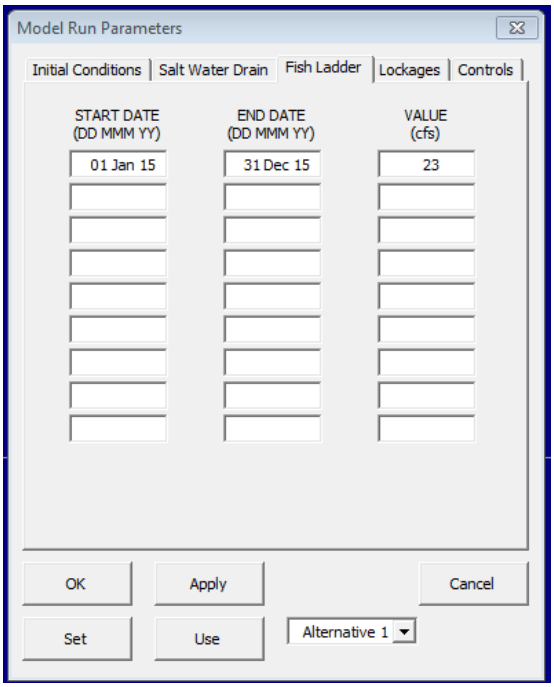
1. INTRODUCTION AND BACKGROUND. The LWSC Critical Content Curve (CCC) was first developed in 1985 as a means of evaluating the lake elevation status through the Conservation Holding Period and the Fall Drawdown Period. The CCC is designed to provide daily forebay elevations during the typical period of involuntary drawdown, which is the period during which it is common for required project water usage (lockages, fish passage) plus evaporative losses to exceed inflows to the lake. The period of involuntary drawdown typically extends from June through September, but may cover a period as wide as April through October. The purpose of the CCC is to define the lake elevations which represent the 70 percent reliability (70% exceedance) of the lake to remain above the 20 foot minimum operating elevation throughout the period of involuntary drawdown. As such, when the actual lake (forebay) level coincides with the CCC, there is an estimated 30% chance that the lake level could fall below the 20 foot minimum forebay elevation at some point during the current year's period of involuntary drawdown. The CCC is normally generated at the beginning of the involuntary drawdown period (May-June timeframe) and then only updated as needed if planned operations (water usage) at the LWSC project are modified from the original plan. The procedure for generating the CCC is described in the following section.

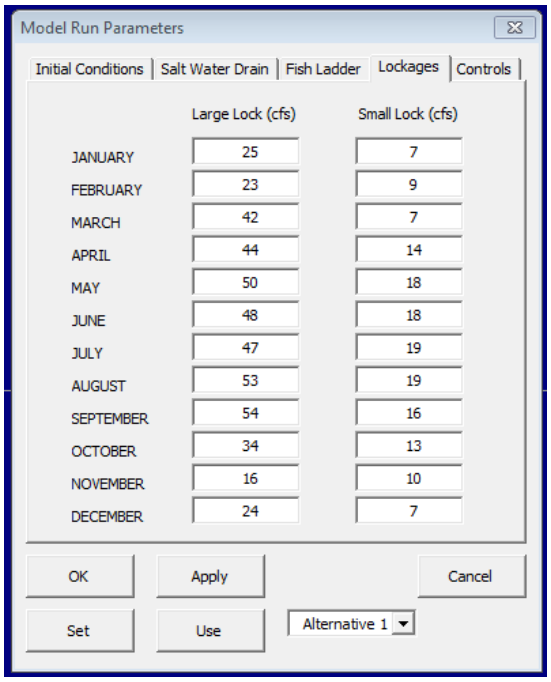
2. PROCEDURE. Calculation of the CCC requires two sets of input information; 1) planned outflow operations at the LWSC project over the duration of the involuntary drawdown period; and, 2) a set of net inflow scenarios that are intended to represent possible inflow scenarios for the given year. For item number 2, a dataset of historical net inflows has generally been used. A convenience of the historical dataset is that it includes the effects of evaporative losses and therefore reflects net inflows to the Lake Washington system (i.e., the data represent inputs from streamflow and incident precipitation over the lakes less evaporative losses). Accounting for evaporative losses is important, especially during the warmer months when evaporative losses can exceed inflow and result in periods of negative net inflow to the Lake Washington system. It is noted that one of the potential challenges of using the dataset of historical net inflows is that the City of Seattle's operation of the Cedar Falls Project and Landsburg diversion has changed over the years. For instance, minimum instream flows that the City currently adheres to on the Cedar River downstream of the Landsburg gage were set in the Habitat Conservation Plan adopted in 2000. Another option, if available, would be to use a set of "ESP" or Extended Streamflow Prediction traces that represent possible inflow scenarios for the current year. If this product is available, the traces would need to be adjusted to include the effects of evaporative losses if not already accounted for.

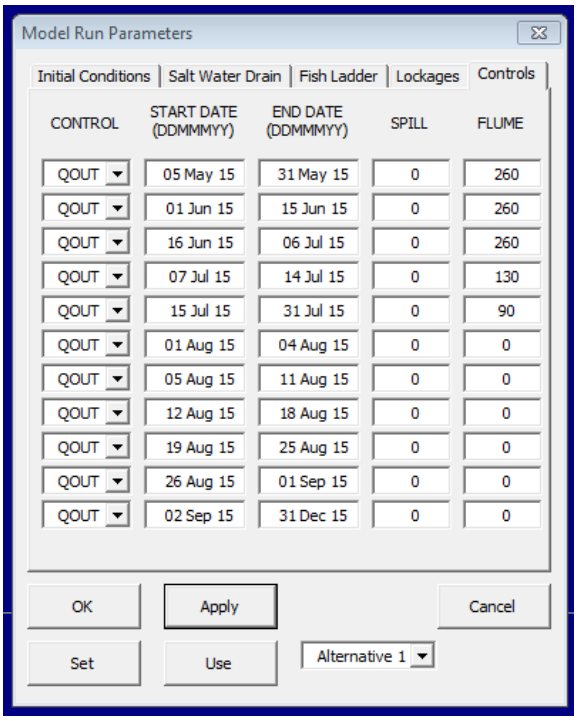
   Once planned project operations, which define project outflow, and the inflow scenarios have been defined, a water budget model is used to determine the lake elevation time-series for each inflow scenario. As of 2016, Seattle District was using an Excel-based water budget model to produce the lake elevation time-series. The following images show the input screens from the current model that are used to define planned project water usage.


Model Run Parameters
Initial Conditions
Salt Water Drain
Fish Ladder
Lockages
Controls
Start Date (DD MMM YY):
11 May 16
End Date (DD MMM YY):
01 Nov 16
Forebay Elevation (ft):
21.79
Allow spill when below 70% reliability curve
Only Run El Nino Years
Conditionalize model results
Conditional Run Parameters
Set limits as percent of Apr - Jul forecast volumes
upper limit
30
lower limit
5
OK
Apply
Cancel
Set
Use
Alternative 1


Model Run Parameters
Initial Conditions
Salt Water Drain
Fish Ladder
Lockages
Controls
START DATE (DD MMM YY)
END DATE (DD MMM YY)
Salt Water Drainage (cfs)
To Fish Ladder (cfs)
01 Jan 15 | 28 Feb 15 | 0 | 160
01 Mar 15 | 31 May 15 | 0 | 160
01 Jun 15 | 30 Jun 15 | 0 | 160
01 Jul 15 | 31 Jul 15 | 0 | 160
01 Aug 15 | 31 Aug 15 | 0 | 160
01 Sep 15 | 07 Sep 15 | 0 | 160
08 Sep 15 | 30 Sep 15 | 0 | 160
01 Oct 15 | 31 Oct 15 | 0 | 160
01 Nov 15 | 31 Dec 15 | 0 | 160
OK
Apply
Cancel
Set
Use
Alternative 1


Model Run Parameters
Initial Conditions
Salt Water Drain
Fish Ladder
Lockages
Controls
START DATE (DD MMM YY)
END DATE (DD MMM YY)
VALUE (cfs)
01 Jan 15 | 31 Dec 15 | 23
OK
Apply
Cancel
Set
Use
Alternative 1


Model Run Parameters
Initial Conditions
Salt Water Drain
Fish Ladder
Lockages
Controls
Large Lock (cfs)
Small Lock (cfs)
JANUARY 25 7
FEBRUARY 23 9
MARCH 42 7
APRIL 44 14
MAY 50 18
JUNE 48 18
JULY 47 19
AUGUST 53 19
SEPTEMBER 54 16
OCTOBER 34 13
NOVEMBER 16 10
DECEMBER 24 7
OK
Apply
Cancel
Set
Use
Alternative 1


Model Run Parameters
Initial Conditions
Salt Water Drain
Fish Ladder
Lockages
Controls
CONTROL
START DATE (DDMMMYY)
END DATE (DDMMMYY)
SPILL
FLUME
QOUT 05 May 15 31 May 15 0 260
QOUT 01 Jun 15 15 Jun 15 0 260
QOUT 16 Jun 15 06 Jul 15 0 260
QOUT 07 Jul 15 14 Jul 15 0 130
QOUT 15 Jul 15 31 Jul 15 0 90
QOUT 01 Aug 15 04 Aug 15 0 0
QOUT 05 Aug 15 11 Aug 15 0 0
QOUT 12 Aug 15 18 Aug 15 0 0
QOUT 19 Aug 15 25 Aug 15 0 0
QOUT 26 Aug 15 01 Sep 15 0 0
QOUT 02 Sep 15 31 Dec 15 0 0
OK
Apply
Cancel
Set
Use
Alternative 1

Running the water budget model should result in a set of time-series of daily lake elevations, with the number of time-series matching the number of inflow time-series. For example, if planned project operations were simulated using a set of 50 historical inflow time-series, then model output would consist of a set of 50 lake level time-series. Each time-series starts at the same initial date and lake level but yields a unique lake elevation time-series based on the specific inflow time-series. The below screen shot provides an example of the output from the current water budget model.

Return to Main Page

LWSC SIMULATED LAKE ELEVATION (Feet above Corps Datum)

CURRENT RUN RELIABILITY: 56% CURRENT REFILL RELIABILITY: 15%

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
02 May		21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.85	21.86	21.86	21.86
03 May		21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86
04 May		21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86	21.86
05 May	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87
06 May	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87
07 May	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.87
08 May	21.87	21.88	21.88	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.88	21.88	21.87	21.87	21.87	21.87	21.87	21.87
09 May	21.87	21.88	21.88	21.87	21.87	21.87	21.87	21.87	21.87	21.87	21.88	21.88	21.87	21.87	21.87	21.87	21.87	21.87
10 May	21.88	21.88	21.88	21.86	21.86	21.86	21.86	21.86	21.86	21.88	21.88	21.88	21.86	21.86	21.86	21.86	21.86	21.86
11 May	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79	21.79
12 May	21.79	21.79	21.79	21.79	21.79	21.78	21.78	21.78	21.78	21.79	21.79	21.79	21.79	21.79	21.78	21.78	21.78	21.78
13 May	21.79	21.79	21.79	21.79	21.79	21.78	21.78	21.78	21.78	21.79	21.79	21.79	21.79	21.79	21.78	21.78	21.78	21.78
14 May	21.79	21.79	21.79	21.79	21.79	21.78	21.78	21.78	21.78	21.79	21.79	21.79	21.79	21.79	21.78	21.78	21.78	21.78
15 May	21.79	21.79	21.79	21.79	21.79	21.77	21.78	21.78	21.77	21.78	21.79	21.78	21.79	21.79	21.77	21.78	21.78	21.77
16 May	21.79	21.79	21.79	21.79	21.79	21.77	21.78	21.78	21.77	21.78	21.80	21.78	21.79	21.79	21.77	21.78	21.78	21.77
17 May	21.79	21.79	21.79	21.79	21.79	21.76	21.78	21.78	21.76	21.77	21.80	21.77	21.79	21.79	21.76	21.78	21.78	21.76
18 May	21.79	21.79	21.79	21.79	21.79	21.76	21.79	21.78	21.76	21.76	21.80	21.76	21.79	21.79	21.76	21.79	21.78	21.76
19 May	21.80	21.80	21.80	21.80	21.80	21.75	21.79	21.78	21.75	21.75	21.80	21.75	21.80	21.80	21.75	21.79	21.78	21.75
20 May	21.80	21.80	21.80	21.80	21.80	21.75	21.79	21.79	21.75	21.74	21.80	21.74	21.80	21.80	21.75	21.79	21.79	21.75
21 May	21.81	21.80	21.79	21.81	21.81	21.74	21.79	21.79	21.74	21.73	21.80	21.73	21.81	21.81	21.74	21.79	21.79	21.74
22 May	21.84	21.81	21.78	21.77	21.77	21.73	21.79	21.79	21.73	21.72	21.79	21.72	21.77	21.77	21.73	21.79	21.79	21.73
23 May	21.86	21.81	21.77	21.78	21.78	21.73	21.80	21.79	21.73	21.71	21.78	21.71	21.78	21.78	21.73	21.80	21.79	21.73
24 May	21.89	21.81	21.76	21.75	21.75	21.72	21.80	21.79	21.72	21.71	21.77	21.71	21.75	21.75	21.72	21.80	21.79	21.72
25 May	21.91	21.82	21.75	21.73	21.73	21.72	21.80	21.79	21.72	21.70	21.76	21.70	21.73	21.73	21.72	21.80	21.79	21.72
26 May	21.93	21.83	21.74	21.70	21.70	21.71	21.81	21.79	21.71	21.69	21.75	21.69	21.70	21.70	21.71	21.81	21.79	21.71
27 May	21.94	21.84	21.73	21.68	21.68	21.70	21.81	21.79	21.70	21.68	21.74	21.68	21.68	21.68	21.70	21.81	21.79	21.70
28 May	21.94	21.87	21.72	21.66	21.66	21.70	21.81	21.79	21.70	21.67	21.73	21.67	21.66	21.66	21.70	21.81	21.79	21.70
29 May	21.94	21.90	21.71	21.61	21.61	21.69	21.82	21.79	21.69	21.66	21.72	21.66	21.61	21.61	21.69	21.82	21.79	21.69
30 May	21.94	21.93	21.70	21.62	21.62	21.68	21.82	21.79	21.68	21.65	21.70	21.65	21.62	21.62	21.68	21.82	21.79	21.68
31 May	21.93	21.95	21.69	21.58	21.58	21.68	21.82	21.79	21.68	21.64	21.69	21.64	21.58	21.58	21.68	21.82	21.79	21.68
01 Jun	21.92	21.95	21.68	21.56	21.56	21.67	21.83	21.79	21.67	21.62	21.68	21.63	21.56	21.56	21.67	21.83	21.79	21.67
02 Jun	21.91	21.95	21.67	21.56	21.56	21.65	21.83	21.78	21.65	21.61	21.67	21.62	21.56	21.56	21.65	21.83	21.78	21.65
03 Jun	21.90	21.95	21.66	21.52	21.52	21.64	21.83	21.78	21.64	21.59	21.65	21.60	21.52	21.52	21.64	21.83	21.78	21.64
04 Jun	21.90	21.95	21.65	21.50	21.50	21.63	21.84	21.78	21.63	21.58	21.64	21.59	21.50	21.50	21.63	21.84	21.78	21.63
05 Jun	21.89	21.94	21.63	21.50	21.50	21.61	21.84	21.78	21.61	21.56	21.62	21.58	21.50	21.50	21.61	21.84	21.78	21.61
06 Jun	21.88	21.94	21.61	21.48	21.48	21.60	21.84	21.78	21.60	21.54	21.61	21.56	21.48	21.48	21.60	21.84	21.78	21.60
07 Jun	21.86	21.93	21.60	21.45	21.45	21.59	21.85	21.78	21.59	21.53	21.59	21.55	21.45	21.45	21.59	21.85	21.78	21.59
08 Jun	21.84	21.92	21.58	21.44	21.44	21.57	21.85	21.78	21.57	21.51	21.58	21.54	21.44	21.44	21.57	21.85	21.78	21.57
09 Jun	21.82	21.91	21.56	21.39	21.39	21.56	21.86	21.78	21.56	21.49	21.56	21.52	21.39	21.39	21.56	21.86	21.78	21.56
10 Jun	21.80	21.90	21.54	21.37	21.37	21.55	21.86	21.78	21.55	21.47	21.55	21.51	21.37	21.37	21.55	21.86	21.78	21.55
11 Jun	21.77	21.89	21.53	21.33	21.33	21.53	21.86	21.77	21.53	21.45	21.53	21.49	21.33	21.33	21.53	21.86	21.77	21.53
12 Jun	21.74	21.88	21.51	21.33	21.33	21.52	21.86	21.77	21.52	21.44	21.52	21.48	21.33	21.33	21.52	21.86	21.77	21.52
13 Jun	21.71	21.86	21.49	21.24	21.24	21.50	21.86	21.77	21.50	21.42	21.50	21.46	21.24	21.24	21.50	21.86	21.77	21.50
14 Jun	21.69	21.85	21.48	21.21	21.21	21.49	21.86	21.76	21.49	21.40	21.48	21.44	21.21	21.21	21.49	21.86	21.76	21.49
15 Jun	21.66	21.84	21.46	21.18	21.18	21.47	21.86	21.76	21.47	21.38	21.46	21.43	21.18	21.18	21.47	21.86	21.76	21.47
16 Jun	21.65	21.84	21.46	21.17	21.17	21.47	21.88	21.77	21.47	21.37	21.46	21.42	21.17	21.17	21.47	21.88	21.77	21.47
17 Jun	21.64	21.84	21.46	21.16	21.16	21.46	21.89	21.78	21.46	21.37	21.45	21.42	21.16	21.16	21.46	21.89	21.78	21.46
18 Jun	21.63	21.83	21.45	21.13	21.13	21.46	21.90	21.79	21.46	21.36	21.44	21.41	21.13	21.13	21.46	21.90	21.79	21.46
19 Jun	21.62	21.83	21.45	21.10	21.10	21.46	21.92	21.80	21.46	21.35	21.43	21.40	21.10	21.10	21.46	21.92	21.80	21.46
20 Jun	21.61	21.82	21.44	21.10	21.10	21.45	21.93	21.81	21.45	21.34	21.43	21.40	21.10	21.10	21.45	21.93	21.81	21.45
21 Jun	21.60	21.82	21.43	21.09	21.09	21.45	21.94	21.81	21.45	21.34	21.42	21.39	21.09	21.09	21.45	21.94	21.81	21.45
22 Jun	21.58	21.81	21.42	21.03	21.03	21.45	21.95	21.82	21.45	21.33	21.41	21.39	21.03	21.03	21.45	21.95	21.82	21.45
23 Jun	21.57	21.81	21.40	21.03	21.03	21.44	21.95	21.83	21.44	21.32	21.40	21.38	21.03	21.03	21.44	21.95	21.83	21.44
24 Jun	21.56	21.81	21.39	21.01	21.01	21.44	21.95	21.84	21.44	21.32	21.39	21.37	21.01	21.01	21.44	21.95	21.84	21.44
25 Jun	21.54	21.80	21.38	20.98	20.98	21.44	21.95	21.85	21.44	21.31	21.38	21.37	20.98	20.98	21.44	21.95	21.85	21.44
26 Jun	21.53	21.80	21.37	20.95	20.95	21.43	21.95	21.86	21.43	21.30	21.37	21.36	20.95	20.95	21.43	21.95	21.86	21.43
27 Jun	21.51	21.79	21.37	20.96	20.96	21.43	21.95	21.87	21.43	21.29	21.36	21.36	20.96	20.96	21.43	21.95	21.87	21.43
28 Jun	21.49	21.78	21.36	20.91	20.91	21.42	21.95	21.87	21.42	21.29	21.35	21.35	20.91	20.91	21.42	21.95	21.87	21.42
29 Jun	21.47	21.77	21.36	20.89	20.89	21.42	21.95	21.88	21.42	21.28	21.33	21.34	20.89	20.89	21.42	21.95	21.88	21.42
30 Jun	21.45	21.77	21.36	20.88	20.88	21.42	21.95	21.89	21.42	21.27	21.32	21.33	20.88	20.88	21.42	21.95	21.89	21.42

The output traces are then used to determine the 70% exceedance trace, this is done by determining the 70th percentile exceedance value for each time-step (day) for all output traces. The resulting trace (time-series) provides the 70th percentile exceedance value at a daily time-step, this resulting trace may or may not at some point drop below elevation 20 feet. If it doesn't drop below elevation 20 feet at any point, then the assumed outflow plan has less than a 30% chance of resulting in a drop of the lake below the 20-foot minimum lake elevation. In this case, planned outflow can be increased and the water balance model re-run until the resulting 70% exceedance trace yields a minimum elevation of 20 feet. Once this is achieved, then the resulting time-series (70th percentile exceedance curve) defines the Critical Content Curve. In summary, the Critical Content Curve is intended to represent the 70% reliability curve for maintaining a minimum 20-foot lake elevation based on an assumed inflow regime. As such, the CCC can be used for several purposes. One, it provides somewhat of a "guide curve" for operations that are intended to specifically target a 30% chance in any given year of an operation that results in the lake dropping below elevation 20 feet during the period of involuntary drawdown. Two, it can be used as a basis for actions such as conservation. For example, if actual lake elevations begin to consistently track below the CCC, indicating a greater than 30% chance of the lake dropping below elevation 20 feet, then water conservation measures can be implemented to attempt to return the current year lake elevation to following the CCC.

EXHIBIT 8-1

ECONOMIC CONSIDERATIONS OF HIRAM M. CHITTENDEN
LOCK OPERATIONS DURING LOW FLOW PERIODS, 1987

1.01 Purpose and Scope. Lake Washington and adjacent waters[1] water surface elevation is regulated by the Corps of Engineers at the Hiram M. Chittenden Locks. Normally, the lake is regulated between elevations 20.0 and 22.0 feet Corps of Engineers datum (COE). During dry years the level can be expected to fall below 20 feet (COE). During 1987 the Lake Washington watershed experienced severe low runoff with Lake Washington elevation dropping to as low as 19.44 feet (COE) on 29 October 1987. During low flow periods, Hiram M. Chittenden locks are operated to minimize the outflow from Lake Washington. This is done by eliminating leakage, reductions in saltwater return flows, and reductions in lockages. The reduction in lockages is accomplished by delaying vessels. The purpose of this study was to (1) identify the economic cost due to low water elevation to homes and businesses on Lake Washington, (2) identify the cost of delaying commercial vessels, and (3) examine the economic trade-offs between reduced outflow and lake elevations.

1.02 Economic Study Area. The study area includes all residential houseboats and commercial operations within and along Lake Washington, Union Bay, Portage Bay, Lake Union, Lake Washington Ship Canal, and Salmon Bay.

LOW WATER DAMAGE SURVEY - LAKE WASHINGTON AND ADJACENT WATERS

2.01 Problem Statement. Many water side structures, homes and businesses are constructed and operate assuming a minimum lake elevation of 20.0 feet MLLW. Low runoff conditions have dropped the lake elevation below 20.0 feet MLLW causing houseboats to ground, moorage slips to be inaccessible, and commercial facilities to have too shallow draft clearance for normal barge operation. Paragraph 2.02 details the types of damages caused by the low water elevations.

2.02 Types of Damage Evaluated. Losses or damages attributed to the low water levels are designated by income lost and physical category of damage. The following tangible damages were considered: (1) physical damages to houseboats caused by grounding; (2) cost incurred in drought damage prevention; (3) income to business or other financial losses resulting from decreased productivity, loss of wages, and increased cost of normal operations. Tangible damages were estimated for the following categories of losses:

[1]For the purpose of this study "Lake Washington" includes the adjacent waters of Lake Washington Ship Canal, Lake Union, Portage Bay, Salmon Bay, and Union Bay.

a. Houseboats. As the lake level drops, the foundation floats on which the houseboats are built settle on the lake bottom. Prior to settling, when the foundation is just off the lake bottom, wave action raises and lowers the houseboat, pounding it on the bottom. In most cases the lake bottom under the floating foundation is not flat and settling of the structure occurs in an uneven manner. Both the wave action and settling cause the houseboat to twist, bending the frame. Observable damages include cracked drywall and siding; stairways, countertops and cabinets pulled away from the wall, as well as bowed walls and ceilings. Houseboat land connections such as mooring arms to docks and gang planks needed to be modified. Damage to water and sewerage land connections can be expected if elevation is below 19.0 feet. Unobservable but probable damage includes diminished structural integrity.

b. Marine Ways and Lifts. Ways and lifts are used to raise vessels out of water, to complete maintenance or repairs. There are basically three types:

(1) Track or Railway. A track or railway runs into the water. A boat is placed on the rail, and pulled out of the water where maintenance is performed. With the low water levels, the tracks do not extend far enough into the water to provide the necessary clearance for the ship to reach the track.

(2) Sling. Slings are lowered underneath the vessel and then cranes or hydraulic lifts raise the vessel out of the water. With the low water levels some boats cannot reach the docks and slings.

(3) Dry Dock. Dry dock is a concave wood or metal enclosure in which a ship is supported out of water on blocks so that maintenance and repairs can be completed. Usually a ship is floated into a water filled basin and the entrance gate is closed, then the water is removed. With the low water levels ships are not able to enter the dry docks. When ships cannot enter the marine ways and lifts, due to low water, no work can be completed. In other cases there is reduced clearance under the ships. This means that work must be done by hand rather than using more efficient tools and machines.

c. Marinas. Marina damages include loss in income to marina operators and physical damage to boats and docks. The low lake elevation rendered many moorage slips inaccessible by boat and also restricted dock access by transient boaters, causing a loss of moorage income to the marina. Boats which were left unattended as the lake level receded had mooring line and cleat damages.

d. Other Commercial Establishments. Other commercial establishments which were affected by the low lake elevation include sand, gravel and road construction materials movements, cement, metal fabricators, ship building, and marine transportation. All are affected by loss of use of normal dock areas. Some commercial vessels cannot reach fuel docks, others must light load barges, and all expect delays at the locks. These conditions have resulted in increased operating cost for business, loss of business, and layoffs of employees.

e. Impact on State and Local Governments. The Governor of the State of Washington developed a task force composed of various agencies to monitor the water shortage. The Department of Ecology was appointed to chair the committee with other agencies such as USGS, the Weather Service, Department of Fisheries and Soil Conservation Service also acting as members of the task force. The position of the task force was to allow local government and agencies to develop the necessary measures to meet their own individual needs. In King County, the Water Surface Management quadrupled its normal efforts during the water shortage period and added five additional employees. The agency made arrangements to procure water from other purveyors (the City of Renton). This effort required additional time for planning and engineering the transfer of water. The implementation of these plans resulted in additional costs for pipes, valves, and other equipment. One of the greatest costs to the City of Seattle was the design, construction and operation of floating pumps on Chester Morse Lake to pump 120 million gallons of water per day. In addition the City of Seattle spent time and money for information dissemination of conservation measures and on enforcement of water conservation. The State has been coordinating the efforts of local agencies and convening the task force once a month. The task force has hired two temporary persons and reassigned state employees to study the water shortage problem. The task force also bought additional monitoring equipment (stream flow gages etc.) to aid their study. These damages were not quantified for this report.

2.03 Results of Damage Survey. Damages were surveyed while the lake elevation was 19.5 feet MLLW. Damage estimates were made on a per month basis for recurring damages, such as loss of wages, and income, and on a one-time occurrence basis for physical damage to houseboats, commercial and recreational marine facilities and equipment. Estimates were also made for an assumed lake elevation of 19.0 feet MLLW. Table 2-1 shows damage estimates by category for 19.0 and 19.5 feet MLLW. Plate 1 interpolates between the data points and converts the recurring damages to daily estimates.

TABLE 2-1
SUMMARY OF DAMAGES

		Water Elevation, COE Datum	
Category[1]	Observ.	19.5 Feet	19.0 Feet
Loss of Income (per month)			
Marinas	20	$13,000	$62,000
Marine Ways and Lifts	12	33,000	400,000
Commercial	30	190,000	1,004,000
Total Recurring Damages		236,000	1,466,000
Damages			
Houseboats	25	21,000	75,000
Other[1]		700	3,000
Total Non-recurring Damages		21,700	78,000

1 Includes commercial and recreational marine facilities and equipment.

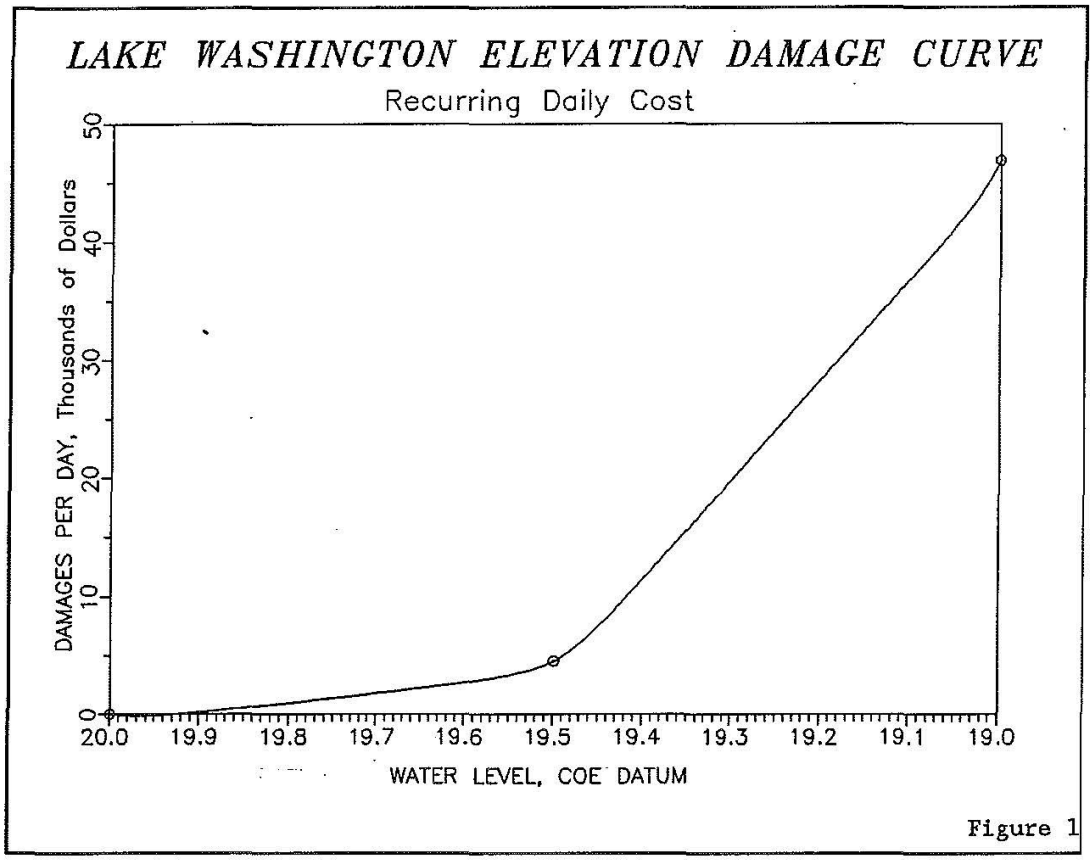


Figure 1

DELAYS TO COMMERCIAL VESSELS

3.01 Problem Statement. During periods of low flow, conservation operation procedures are used at Hiram M. Chittenden locks to help maintain Lake Washington water surface elevation. This includes possible delays of commercial vessels. This section analyzes the cost to commercial vessel operators of increased delay times at the locks.

3.02 Delay Cost to Commercial Users. Delaying commercial vessels increases operating cost. This includes cost for fuel, labor, and lower capital utilization. A list of commercial users was provided by lock personnel. A survey of these users was conducted between 13 and 20 November 1987. The survey asked each user to estimate the increased cost to their operation from a 1-hour, 3-hour, and 6-hour delay at the locks. They were also asked to estimate their average daily usage of the locks. This data was used to develop a cost-per-day to commercial users from the three delay scenarios. The results of this survey are shown in table 3-1 and plate 2.

TABLE 3-1

DELAY COST TO COMMERCIAL USERS - NOVEMBER 1987
PER MONTH

Delay Time	Total Delay Cost
1 Hour	$203,000
3 Hours	$710,000
6 Hours	$1,400,000

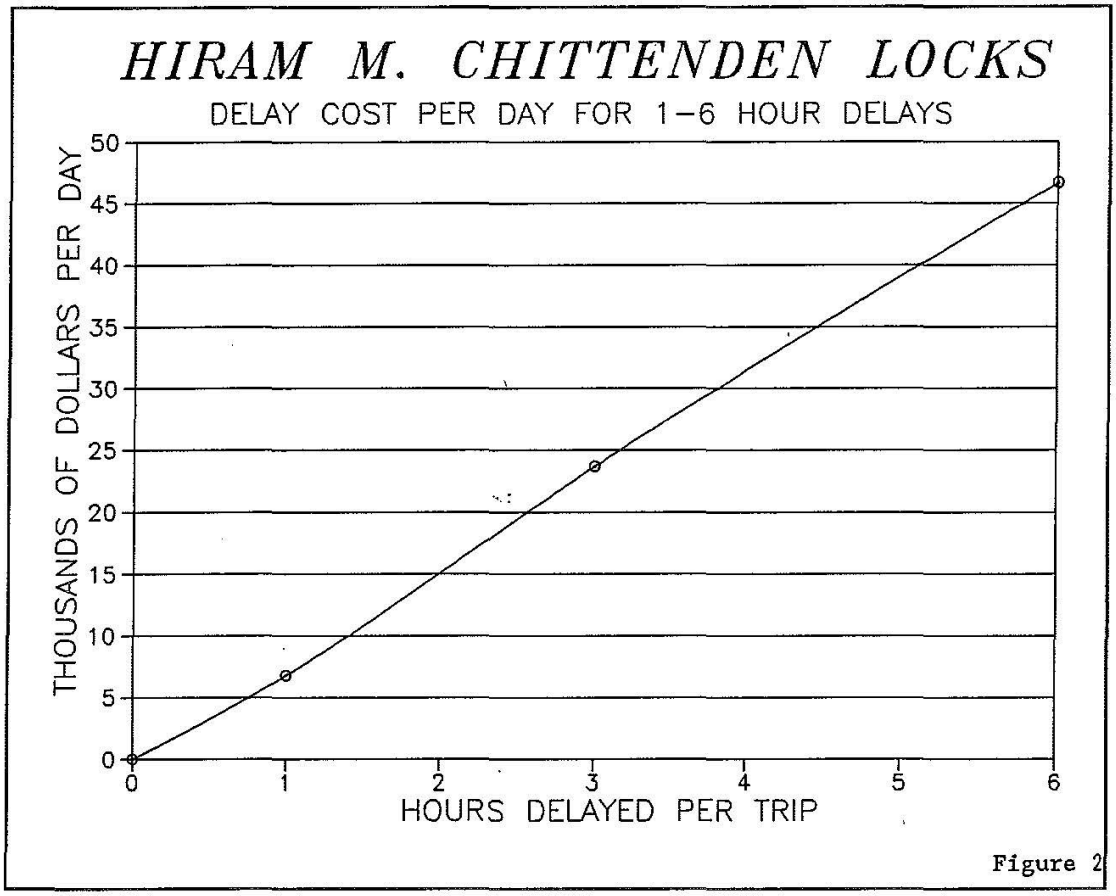


Figure 2

3.03 Conservation Operations. The initial stage of conservation consists of eliminating water leakages at the spillway sites. This is done by sealing the spillway gates. During the second stage of conservation, the saltwater return drain is closed and use of the small locks is maximized by minor delays to recreation boaters. The saltwater wedge is allowed to advance towards Lake Washington. Stage three includes longer delays of recreation vessels and reductions in fish attraction water. The saltwater wedge is allowed to advance and a water quality variance is requested. It is in stage four that commercial vessels may be delayed. This has two effects; first, the consolidation of vessels in the locks reduces the number of lockages per day, reducing the outflow for lockages and second, it reduces saltwater intrusion, allowing further reductions to the fish attraction water.[1] The reduction in outflow resulting from a reduction in daily lockages is equal to 10.7 cubic feet per second (c.f.s.) per lockage. The reduction in fish attraction water depends on the condition of the saltwater wedge. With good conditions the saltwater drain and fish attraction flows can be eliminated. Water quality guidelines allow for a maximum saltwater concentration of 1 part per 1,000 at the University Bridge. A water quality variance is required to exceed this limit. When the saltwater wedge has advanced to this limit, reductions in lockages may not allow for a reduction in saltwater return flows. Moreover, lockage delays may be instituted to reduce saltwater intrusion, regardless of lake elevation.

3.04 Lockages per Day. The minimum acceptable number of lockages per day has been defined as that number needed to pass all commercial vessels each day. Lock personnel estimated that on average it would take a minimum of six lockages per day to pass all commercial vessels each day. It was estimated that a 4-hour delay regime would be required to consolidate the commercial traffic into six daily lockages. During the 1987 low flow period the lock master was operating with vessels incurring a 1-hour delay. Under this operation there was an average of nine daily lockages. Under normal operating procedures (based on November 1986) there was an average of 13 daily lockages. These three points were used to develop the delays associated with the number of daily lockages and extended from zero delay at 13 daily lockages to 4 hour delay with 6 daily lockages. This curve is presented in Figure 3.

[1]When the saltwater wedge advances, the fish attraction flows also act as saltwater return flows.

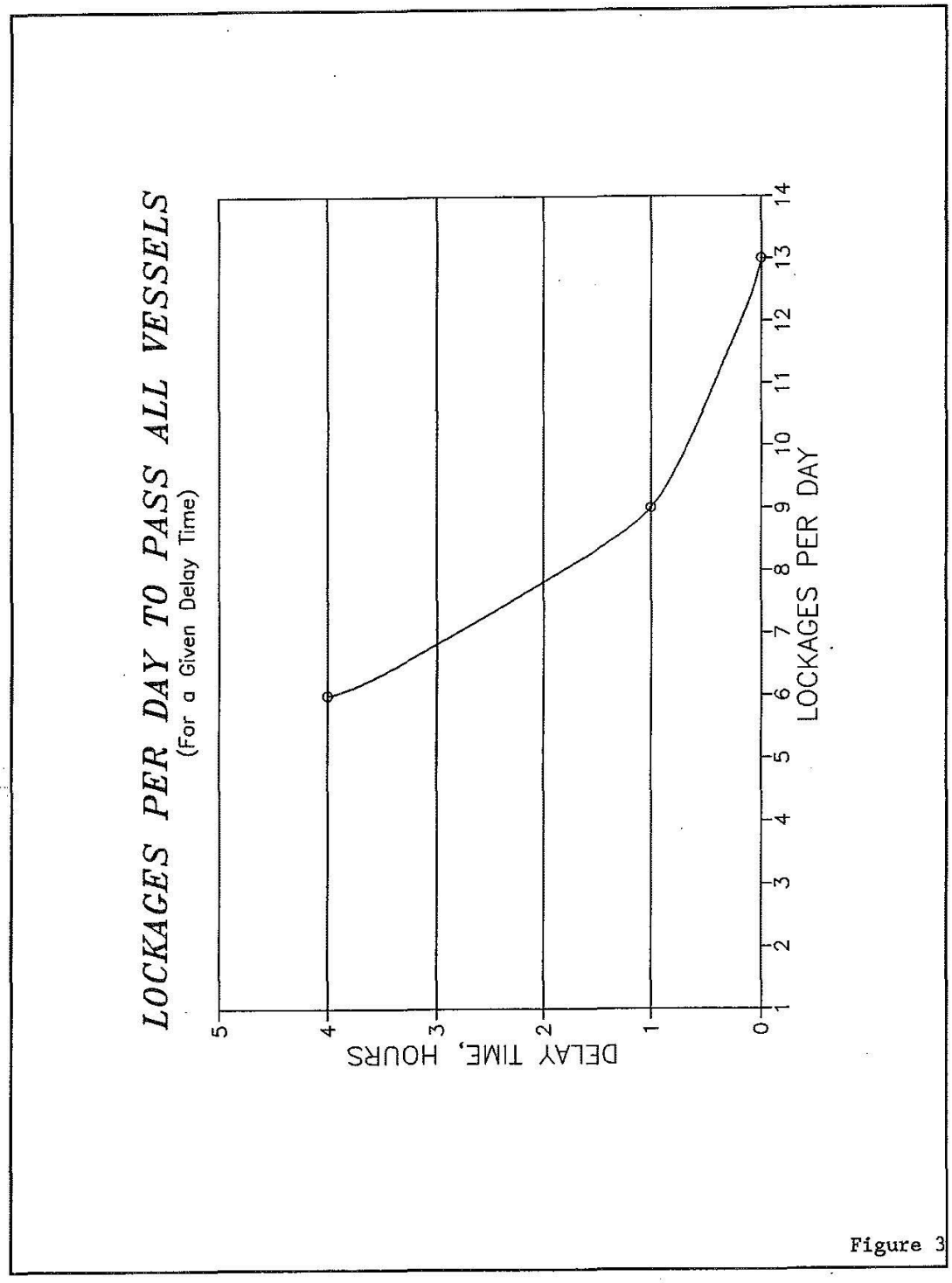

LOCKAGES PER DAY TO PASS ALL VESSELS
(For a Given Delay Time)
DELAY TIME, HOURS
0
1
2
3
4
5
LOCKAGES PER DAY
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Figure 3

COST BENEFIT ANALYSIS

4.01 Economic Benefits of Lockage Reduction. When the Lake Washington water level is below 20.0 feet COE, shoreline establishments begin to incur economic losses as discussed in section 2. By reducing the number of lockages and hence the water outflow from Lake Washington, the extent and duration the lake elevation stays below 20.0 feet (COE) is reduced. Lake Washington water surface elevation dropped below 20.0 feet COE from 25 September to 1 October. During this time the lock master was operating under a 1-hour delay regime. As shown in plate 3, a 1-hour delay reduces the average daily lockages by four, approximately a 43 c.f.s. reduction in outflow[1]. Had he not been delaying commercial vessels, the lake elevation would have been lower and stayed below 20.0 feet COE longer. Plate 4 shows the comparison of Lake Washington's daily water surface profile for the 25 September through 2 December period, both actual (with delays) and normal operating conditions (without delays). The without delay elevations were calculated accounting for reductions in lockage flows only. No reductions in the saltwater drain or fish attraction water was assumed.

4.02 Calculation of Economic Benefits. By integrating the with and without delay water surface elevation curves with the elevation damage curve we can compare with and without delay shoreline damages. The net difference was defined as benefits of the delay regime. Plate 5 shows the daily with and without delay shoreline damages. The average net daily difference (benefits) for the period were $4,800. From plate 2 the daily cost to commercial vessels for a 1-hour delay regime was $6,800. Indicating the benefits of delay were exceeded by the cost. As stated in paragraph 2.04, the reduction in outflow attributed to lockage delays was 10.7 c.f.s. per reduced lockage. Plate 6 shows the with and without delay lake elevations attributing an additional 75 c.f.s. of reduced saltwater return flows to the delayed lockages. Plate 7 shows the with and without delay shoreline damages for this scenario. Integrating the curves, the average daily benefits from this scenario was $20,500. Therefore, if lockage reductions allow reductions in saltwater return flows, the delays may be economically justified.

4.03 Prospective Analysis. The preceeding analysis was retrospective. The benefits of lockage delays were easily calculated because all other variables were known. However, the real time decision to delay commercial vessels must be made without full knowledge of future inflows and outlfows. Precipitation, evaporation, Cedar River flows, and local runoff all must be estimated. The benefits of delay also depend on the lake elevation at the beginning of the analysis period. The unpredictability of these variables substantialy increases the uncertainty of any economic analysis. A "what if" analysis based on assumed variable values give understanding to the relationships between variables, i.e., the magnitude of change over time correlated to value, but offer the decisionmaker little service beyond that. During scenarios where lockage delays may be economically justified, economic

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[1]A flow of 38 cfs for 1 month is equal to 1/10 of an foot on Lake Washington.

considerations would probably be superseded by environmental and legal considerations. During a low flow period the most likely future scenario is for normal precipitation to return (and thus lake elevations) prior to reaching the duration and low lake levels required to economically justify lockage delays. Because of this, the general conclusion from this study is that lockage delays cannot be economically justified from a prospective analysis.

4.04 Review of the Conservation Operating Plan. This study revealed some needed changes in the conservation operating plan, from a procedural prospective. Communications between lock personnel and the district office concerning operating procedures should have written confirmation. During the low flow period, verbal district direction to delay recreational vessels resulted in the delay of both recreational and commercial vessels. Several weeks passed before this miscommunication was revealed. The Corps of Engineers used press releases to encourage recreational boaters to limit their use of the locks. The Corps of Engineers was criticized for not using more aggressive promotions to discourage recreational lock use. Given the low water use of the small lock, this is more of a public relations concern than a significant source of water savings.

4.05 Limitations of This Study. The primary limitation of this study is the lake elevation stage/damage relationship. The low flow period experienced in 1987 resulted in a lake elevation of 19.44 feet COE. This low flow period did not qualify as a drought. During a severe drought the lake elevation may drop below 19.0 feet COE. The economic impact of the lake dropping below 19.0 feet COE was not identified by this report. This report should not be used as guidance if the lake level falls below 19.0 feet COE. Should the lake drop below 19.0 feet (COE) a survey should be conducted to determine the economic impacts.

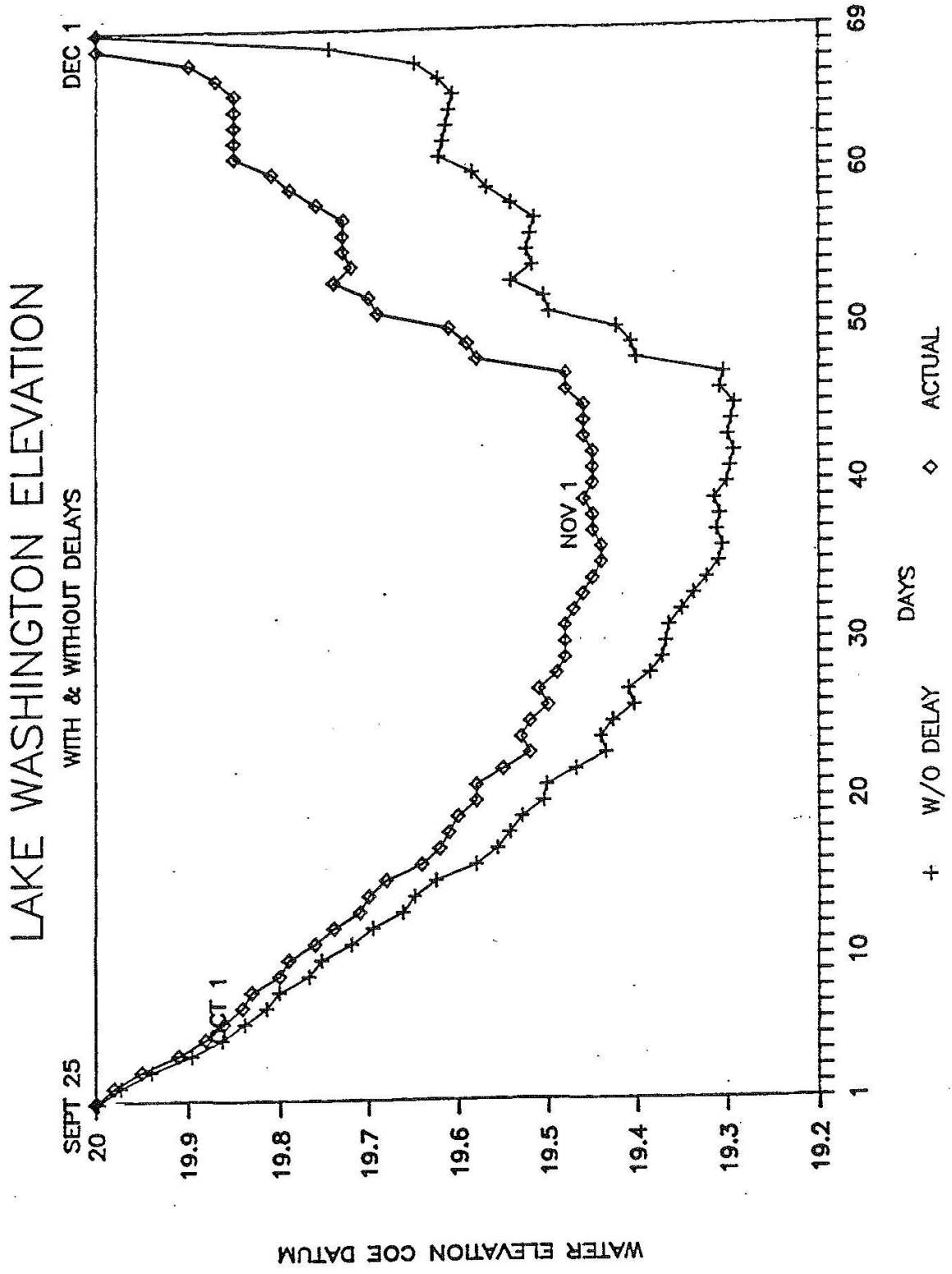

PLATE 4
of Exhibit 8-1

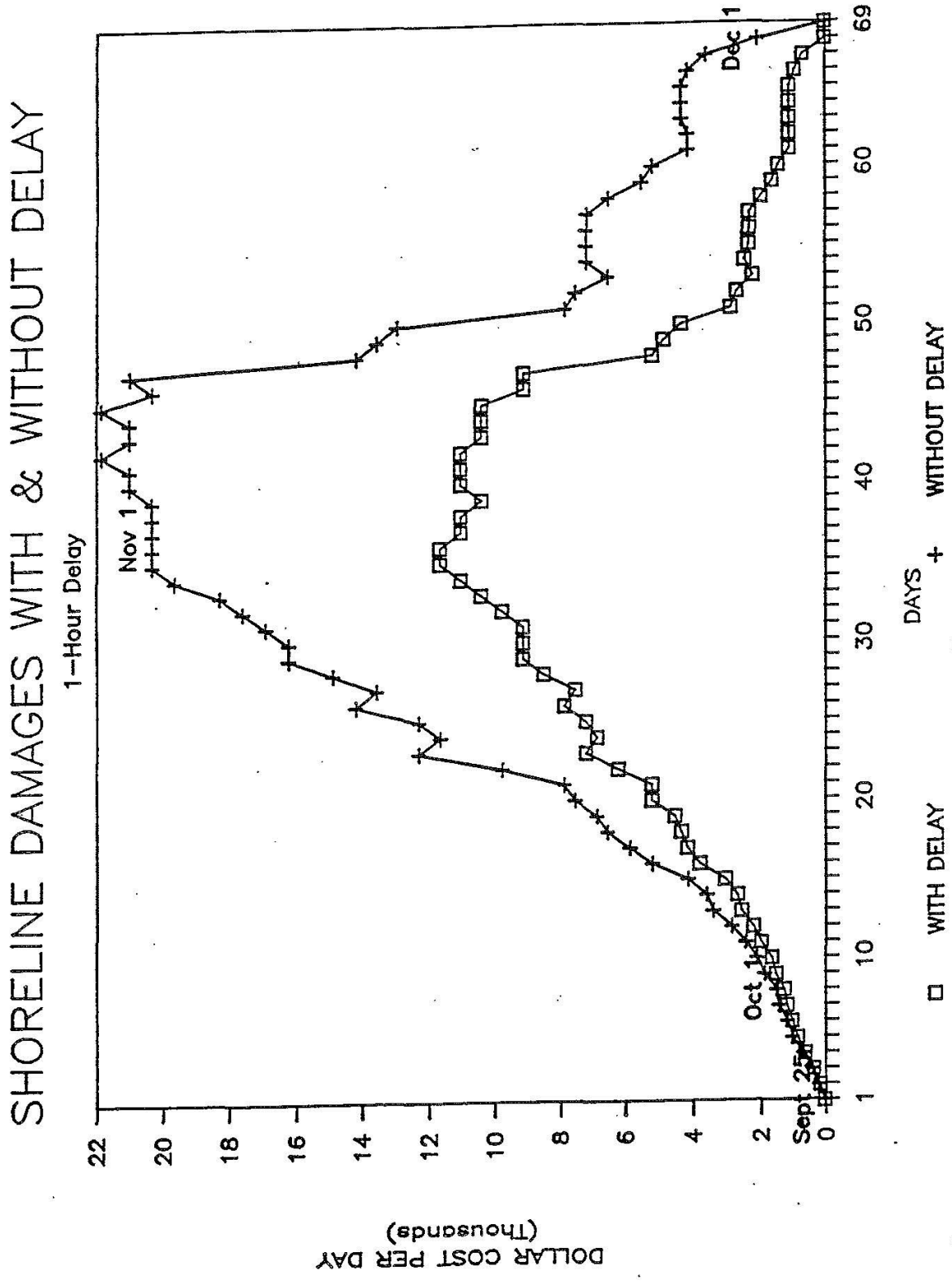

PLATE 5
of Exhibit 8-1

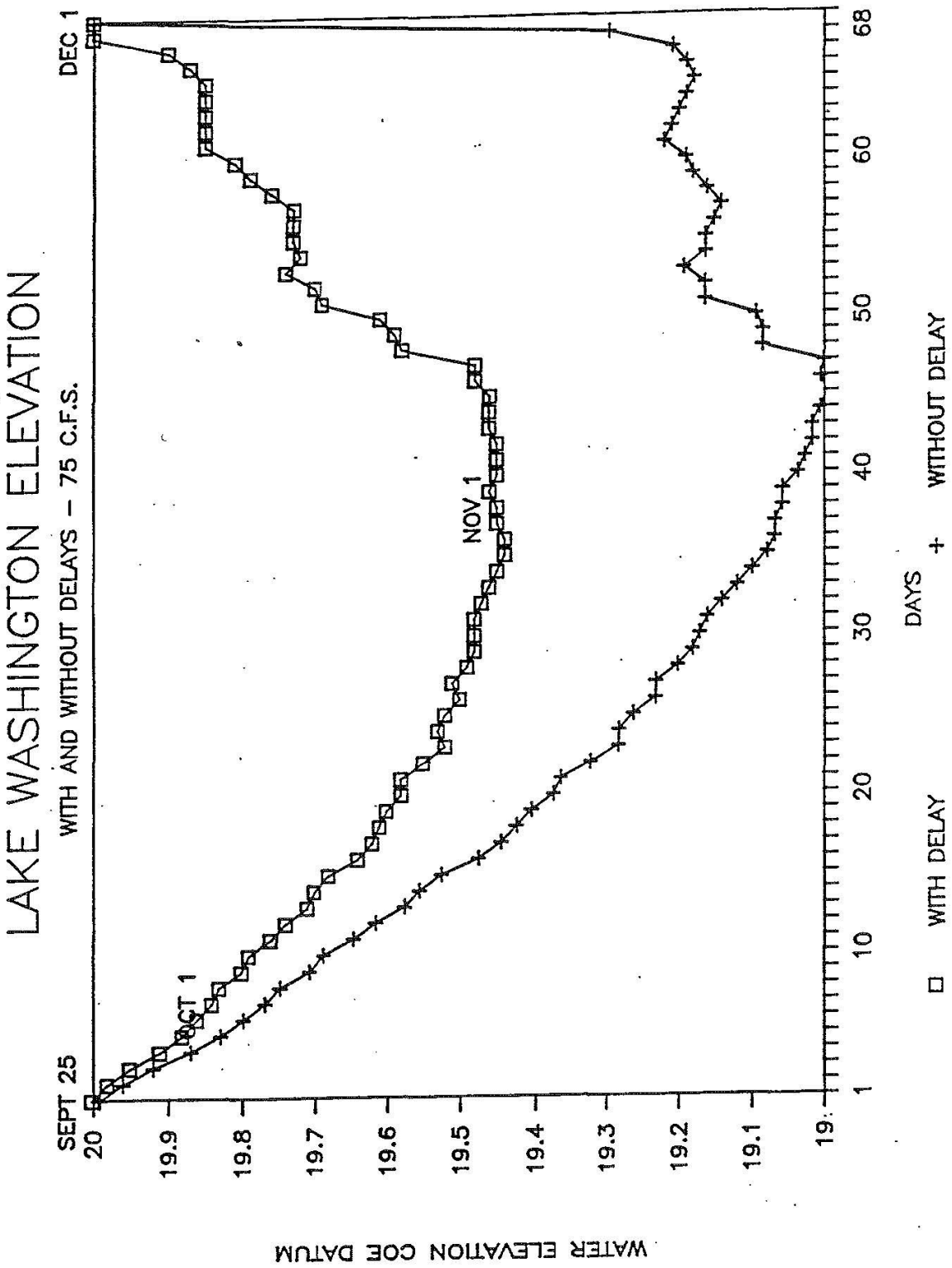

PLATE 6
of Exhibit 8-1

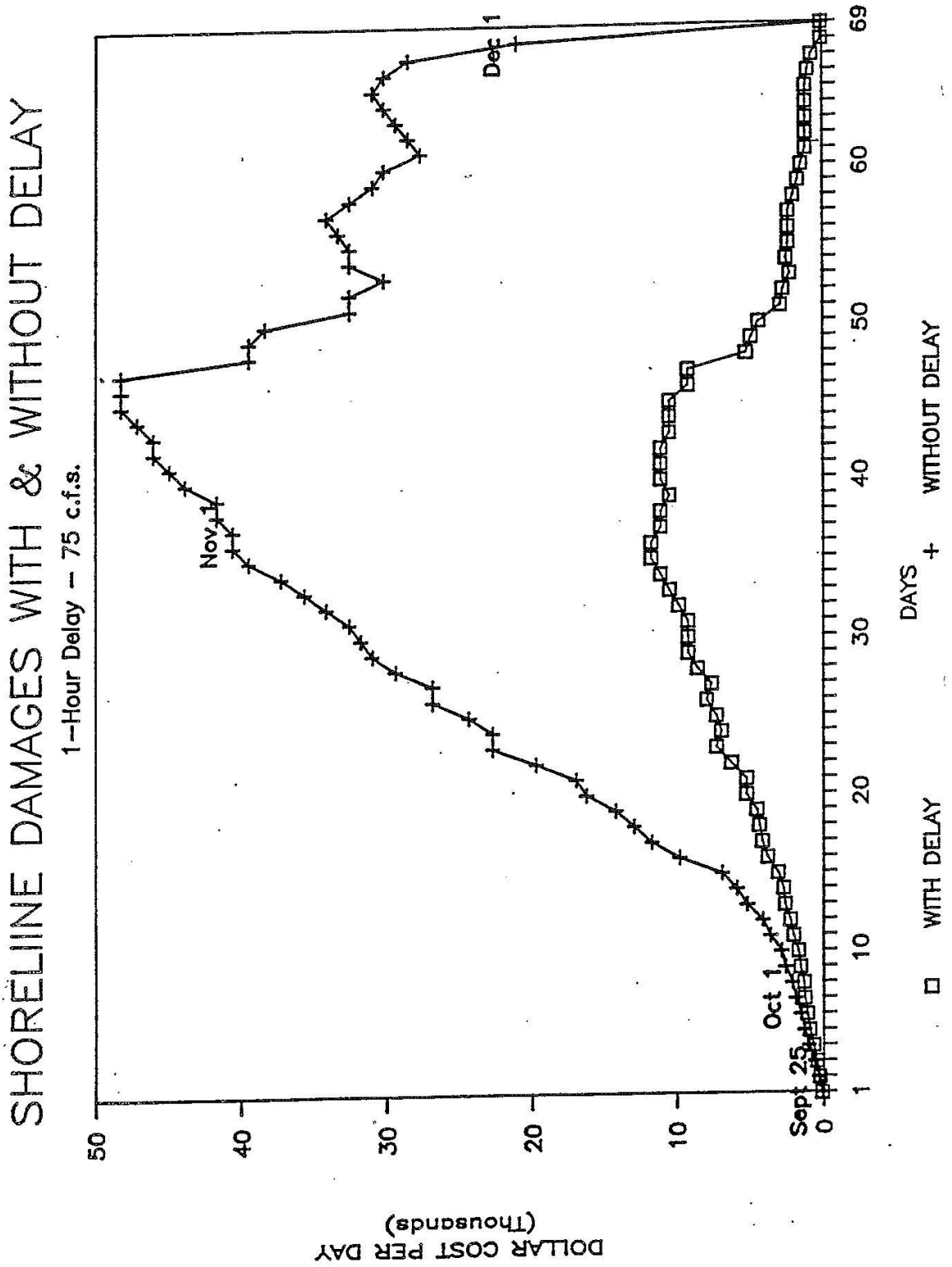

PLATE 7

of Exhibit 8-1

REDACTED CONTENT

US Army Corps of Engineers®
Seattle District

EXECUTIVE OFFICE
Seattle District
CENWS-Command

District Commander	COL
Deputy District Commander	LTC
Deputy District Engr-Project Mgmt	GS15
Supervisory Executive Specialist	GS13

CENWS-XO

Secretary (Stenography)	GS08
Office Support Assistant	GS07
District OPS Officer	CPT

District Counsel
CENWS-OC

Supv Attorney	GS15
Attorney	GS14
(11) Attorney (2V)	GS13
Paralegal	GS11
Legal Tech	GS07

Security & Law Enforcement
CENWS-SL

Supervisory Security Specialist	GS12
Security Specialist (V)	GS11
Security Technician	GS09

Resource Management Office
CENWS-RM

Financial Manager	GS14
Budget Officer	GS13
(4) Financial Mgmt Analyst (1V)	GS12
Budget Analyst (V)	GS11
Budget Analyst	GS09
Accounting Officer	GS13
System Accountant	GS12
(4) Accountant (1V)	GS12
Accountant	GS11
Civilian Payroll Tech	GS08

Internal Review Office
CENWS-IR

Auditor (V)	GS12

Mission Support Office
CENWS-MS

Mission Support Officer	GS12
Training & Organizational Dev Spec	GS12
Mission Support Specialist	GS11
Mission Support Specialist	GS09/11
Mission Support Specialist	GS09
Librarian	GS09
Office Support Assistant (OA)	GS07
Office Support Assistant (OA)	GS06/07
File Assistant	GS06
Engineering Tech (V)	GS07

Small Business Specialist
CENWS-SB

Contracting Specialist (V)	GS12

Public Affairs Office
CENWS-PA

Supervisory Public Affairs Specialist	GS13
Public Affairs Specialist	GS12
(2) Public Affairs Specialist	GS11
Editorial Assistant	GS07

Safety & Occupational Health
CENWS-SO

Safety & Occupational Health Specialist	GS12
Safety & Occupational Health Specialist	GS11

Equal Employment Opportunity Office
CENWS-EE

Equal Employment Spec	GS12
Equal Employment Spec	GS11

Executive Office/Support
April 2016

US Army Corps of Engineers®
Seattle District

EXECUTIVE OFFICE
Seattle District

Planning, Programs & Project Management Division
CENWS-PM

Supv Program Manager (1)	GS15
Organizational Development Ofcr (V)	GS13
Administrative Officer	GS07/11

Project Support Branch
CENWS-PM-PS

Supv Program Manager	GS14
Supv Program Manager (V)	GS13
Native American Coordinator (V)	GS13
General Engineer (V)	GS13
(2) Management Analyst (2V)	GS12
Program Analyst (V)	GS11/12
Budget Analyst	GS12
Office Automation Asst	GS05/06
Office Automation Asst (1V)	GS05/06

Data ManagementSection

Lead Project Mgmt AIS Admin	GS12
(4) Project Scheduler (1V)	GS11
Project Scheduler	GS09
(2) Project Assistant	GS07

Financial Services Section

Supv Budget Analyst	GS12
(15) Budget Analyst (4V)	GS11
(2) Budget Tech (2V)	GS07

Military, Environmental & IIS Branch
CENWS-PM-MEI

Supv Program Manager	GS14
Project Engineer (V)	GS13
Environmental Engineer	GS13
Project Support Spc (V)	GS09
Program Assistant (V)	GS07
Office Automation Asst	GS05/06

Military Programs

Supv Program Manager	GS13
Project Engineer	GS13
Community Planner	GS13
(2) General Engineer (1V)	GS13
(2) Physical Scientist (1V)	GS12
(2) Environmental Protection Spc	GS12
Landscape Architect	GS12
Interdisciplinary (V)	GS12
Architect (V)	GS12
(3) Civil Engineer	GS12
Community Planner	GS12

Interagency and International Support

Supv Program Manager	GS13
(4) Environmental Engineer (1V)	GS13
(2) Civil Engineer	GS13
Envir Protection Spec	GS13
(2) Envir Protection Spec	GS12
Civil Engineer (V)	GS12
(4) Environmental Engineer	GS12
Civil Engineer (V)	GS11

Planning Branch
CENWS-PM-PL

Supv Biologist	GS14
Supv Community Planner	GS13
(2) Economist	GS13
Interdisciplinary (V)	GS13
Landscape Architect (V)	GS12
(2) Community Planner	GS12
(2) Economist (1V)	GS12
Regional Economist	GS12
(2) Biologist (1V)	GS12
Sociologist	GS07/11
Office Support Asst (V)	GS06

Environmental & Cultural Resources Branch
CENWS-PM-ER

Supv Biologist	GS14
Secretary (OA)	GS06
Biologist	GS13
Archaeologist	GS13
Historian	GS13
Supv Biologist	GS13
Biologist (V)	GS12
Fish Biologist	GS12
Aquatic Biologist	GS11
(2) Sdt Trn Bilogy(T)	GS04
Aquatic Biologist (V)	GS07/11
(3) Archaeologist	GS12
(4) Aquatic Biologist (1V)	GS12
(2) Supv Biologist (2V)	GS13
Biologist	GS13
(4) Biologist	GS12
Social Scientist	GS12
Ecologist	GS12
Historian	GS12
Ecologist	GS11/12
Archaeologist (V)	GS11/12
Sdt Trn Arch Tech	GS11
Sdt Trn Arch Tech (V)	GS05

Civil Works Branch
CENWS-PM-CP

Supv Program Manager	GS14
Office Support Asst (V)	GS05/06
(2) Community Planner (1V)	GS13
(2) Physical Scientist (1V)	GS13
Community Planner (T)(V)	GS13
Supv Program Manager	GS13
(2) General Engineer (1V)	GS13
General Engineer	GS12
Community Planner	GS12
(2) Project Mgmt Engineer (2V)	GS12
Civil Engineer	GS12
Biologist	GS12
Physical Scientist	GS11/12
Project Mgmt Engineer	GS11/12
Supv Program Analyst	GS13
(2) Program Analyst	GS12
Program Analyst (V)	GS11/12
Project Manager	GS11/12
Project Support Spec (V)	GS09

(1) Dual assignment as Deputy District Engineer for Project Management

Planning, Programs & Project Management Division
April 2016

US Army Corps of Engineers®
Seattle District

EXECUTIVE OFFICE
Seattle District

Contracting Division
CENWS-CT

Supervisory Contract Specialist	GS14
Procurement Analyst	GS13

Military/Environmental/IIS Branch
CECT-NWS-A

Supervisory Contract Specialist	GS13
Contract Specialist	GS13
(7) Contract Specialist (2V)	GS12
Contract Specialist (V)	GS7/12

Business Operations Branch
CECT-NWS-B

Supervisory Procurement Analyst	GS13
Procurement Analyst	GS13
(4) Procurement Analyst (4V)	GS12
Procurement Analyst (V)	GS11
Contract Specialist	GS12
Technical Acquisition Spc	GS11
Acquisition Business Spc	GS09
(2) Admin Supt Clerk (2V)	GS04
Admin Supt Clerk (V)	GS-05/06
Procurement Technician (Lead)	GS08
Procurement Technician	GS07

Operations & Civil Branch
CECT-NWS-C

Supervisory Contract Specialist	GS13
(2) Contract Specialist	GS13
(6) Contract Specialist (1V)	GS12
Contract Specialist (V)	GS11/12
(3) Purchasing Agent(1V)	GS09
Student Trainee	GS4/7

Special Projects Branch (JBLM)
CECT-NWS-D

Supervisory Contract Specialist	GS13
(2) Contract Specialist (1V)	GS13
(6) Contract Specialist	GS12
Contract Specialist	GS11/12
Procurement Program Specialist	GS11
Admin Support Clerk	GS04

Contracting Division
April 2016

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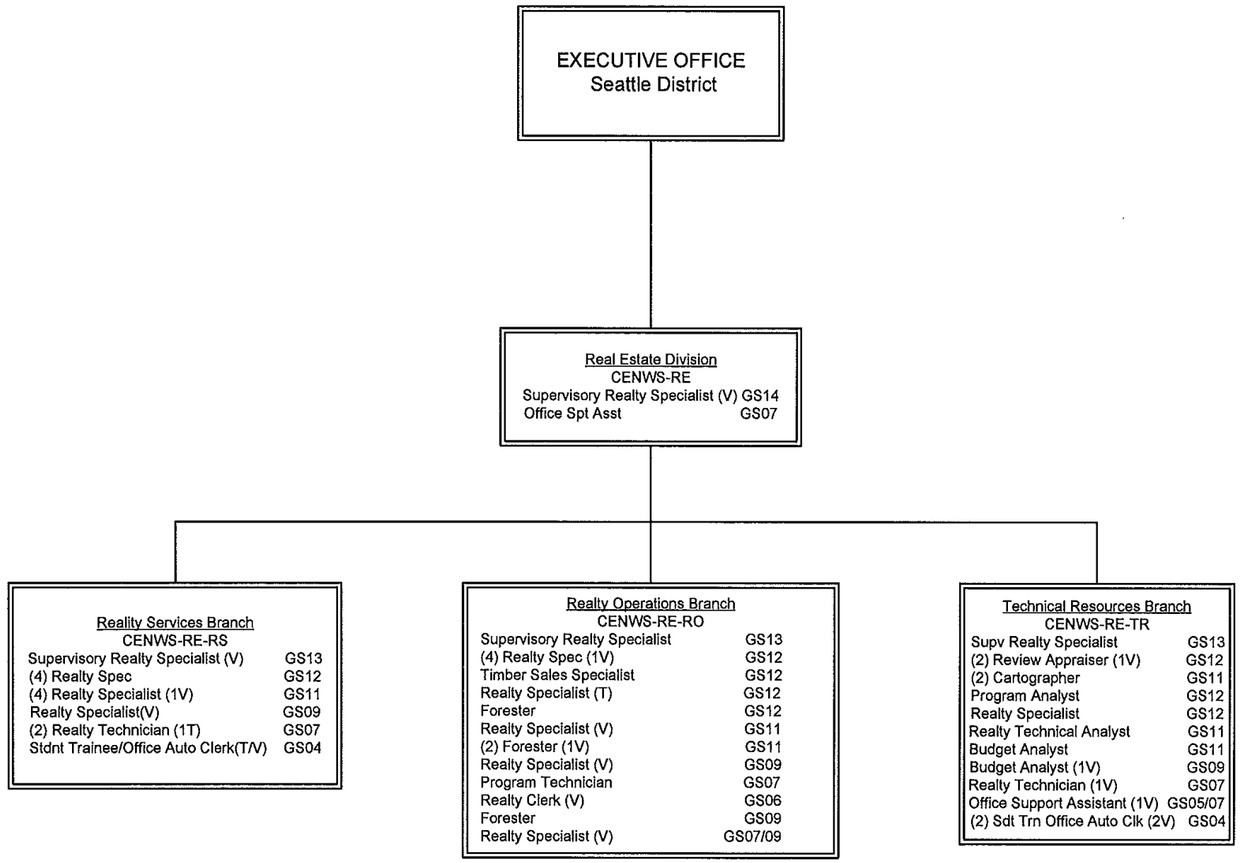
Seattle District



Real Estate Division
April 2016

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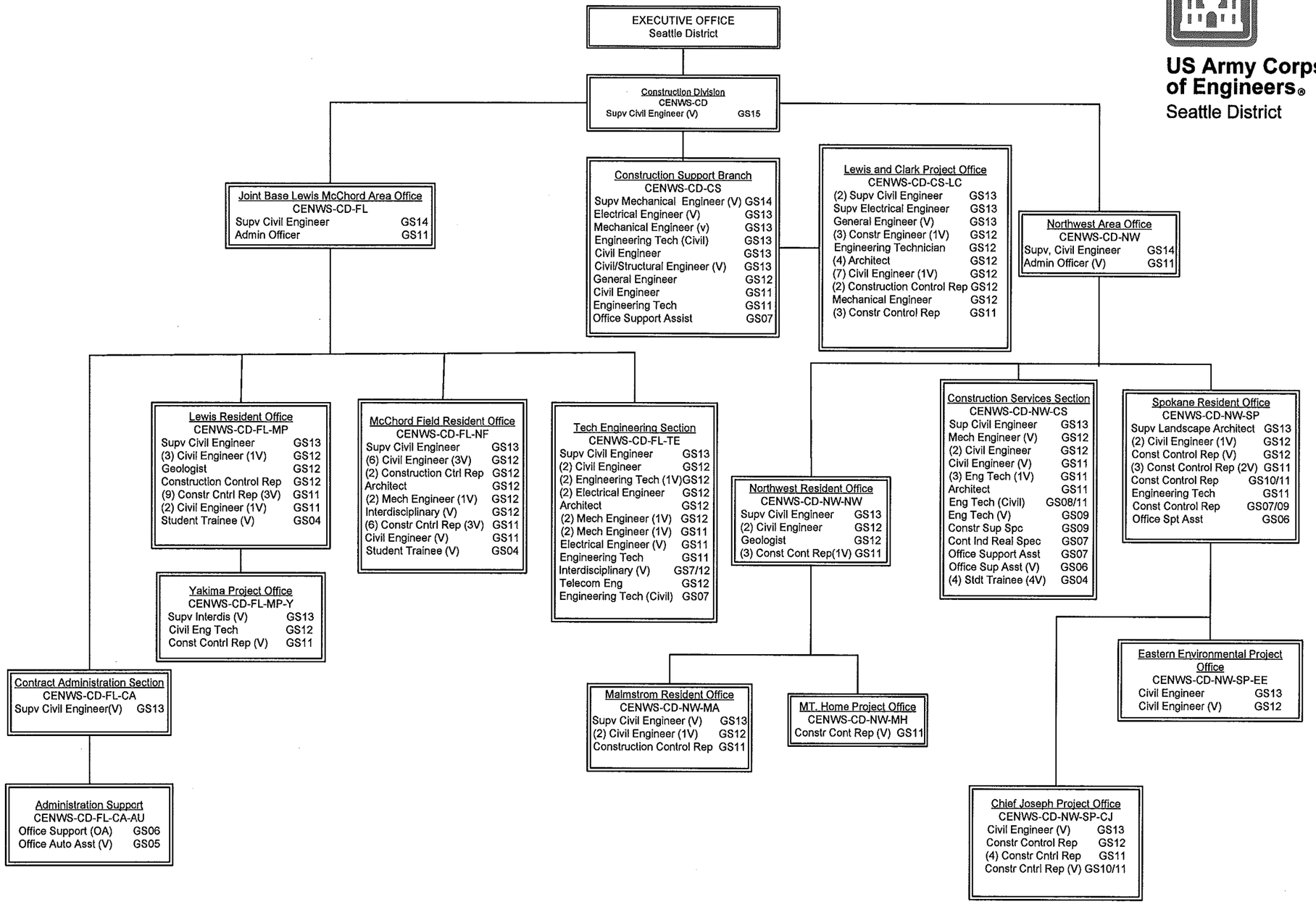

Construction Division
April 2016

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Seattle District

EXECUTIVE OFFICE
Seattle District

Engineering Division
CENWS-EN

Supv Civil Engineer	GS15
Civil Engineer	GS12
Geologist	GS13
Geologist	GS12
Administrative Officer (V)	GS09/11
Ofc Support Assistant (OA)	GS07

Design Branch
CENWS-EN-DB

Supervisory Civil Engineer	GS14
Architect	GS13
Office Spt Clerk	GS06

Civil Section
CENWS-EN-DB-CS

Supervisory Civil Engineer	GS13
(3) Civil Engineer	GS13
(7) Civil Engineer (3V)	GS12
Civil Engineer (V)	GS11/12
(2) Engineering Tech (Civil)	GS11
Sdt Trn Eng Tech (T/V)	GS04/05

Specifications & Technical Review Section
CENWS-EN-DB-SP

Supervisory Electrical Engineer	GS13
(2) Civil Engineer (1V)	GS12
Mechanical Engineer	GS13
Electrical Engineer	GS12
Architect	GS12
Writer-Editor	GS11
Engineering Tech	GS09
Office Automation Assistant	GS05
Engineering Tech(T/V)	GS04

Electrical / Mechanical Section
CENWS-EN-DB-EM

Supv Mechanical Engineer	GS13
Fire Protection Engineer (V)	GS13
(7) Mechanical Engineer (1V)	GS12
Mechanical Engineer	GS11
(2) Mechanical Engineer (2V)	GS11/12
Sdt Trn Eng Tech (T) (V	GS/04/05

Electrical Unit
CENWS-EN-DB-EM-EU

(2) Electrical Engineer (1V)	GS13
(4) Electrical Engineer (1V)	GS12
(3) Electrical Engineer	GS11/12
Engineering Tech (Elect)	GS09
Sdt Trn Eng Tech (T/V)	GS04/05

Architect / Structure Section
CENWS-EN-DB-AS

Supv Interior Design Spec	GS13
Architect	GS13
(2) Architect (V)	GS12
(4) Architect(2V)	GS11/12
Student Trainee (V)	GS04/05

Structures Unit
CENWS-EN-DB-AS-SU

(2) Structural Engineer	GS13
(6) Structural Engineer (3V)	GS12
Structural Engineer	GS11
Sdt Trn Eng Tech(T/V)	GS04/05

Soils Section
CENWS-EN-DB-SS

Supv Civil Engineer (1V)	GS13
(2) Civil Engineer	GS13
Civil Engineer (V)	GS12
(7) Civil Eng (Geotech) (3V)	GS12
(2) Civil Engineer (Geo)(1V)	GS11/12
Civil Engineer (Geotech)	GS11
(2) Sdt Trn Eng Tech (T/V)	GS04/05

Hydraulics and Hydrology Branch
CENWS-EN-HH

Supv Hydraulic Engineer	GS14
Civil Engineer (Hrydologic)	GS13
Office Support Clerk	GS06

Hydraulic Engineering Section
CENWS-EN-HH-HE

Supv Civi Engr (Hydraulic)	GS13
(2) Hydraulic Engineer	GS13
(6) Hydraulic Engineer	GS12
Physical Scientist	GS12
Hydraulic Engineer	GS09/12
Hydraulic Engineer (V)	GS11
Engineering Tech (Civil)	GS09
Sdt Trn Eng Tech (T/V)	GS04

Costal Engineering Unit
CENWS-EN-HH-HE-CU

Hydraulic Engineer	GS13
Civil Engineer (Hydraulic)	GS12

Water Management Section
CENWS-EN-HH-WM

Supv Civi Engineer (Hydraulic)	GS13
(4) Hydraulic Engineer	GS13
Physical Scientist	GS12
(6) Hydraulic Engineer (2V)	GS12
Meteorologist	GS12
Hydraulic Engineer	GS11/12
Hydraulic Engineer	GS09/12
Meteorological Technician	GS11
(2) Hydrologic Technician	GS09
(2) Sdt Trn Eng Tech (T/V)	GS04/05

Geospatial Section
CENWS-EN-TS-GS

Supervisory General Engineer	GS13
Architect	GS13
(2) Engineering Tech (1V)	GS12
Cartographer	GS12
Architect	GS11/12
(2) Geographer	GS11
Engineering Tech	GS11
Engineering Tech (V)	GS09/12
Engineering Tech	GS09/11
Engineering Tech (V)	GS07/11
Engineering Tech	GS09
Student Trainee (V)	GS05

DA INTERNS-GS11

(4) Electrical Engineer(1V)
Environmental Engineer
Geologist
(3) Civil Engineer
Aquatic Biologist
Biologist
Sociologist

Technical Services Branch
CENWS-EN-TS

Supervisory Civil Engineer	GS14
Office Automation Asst	GS06

Environmental Engineering & Technical Section
CENWS-EN-TS-ET

Supervisory Physical Scientist	GS13
Biologist (V)	GS13
Environmental Engineer (V)	GS13
Remediation Biologist	GS12
Envr Health Scientist	GS12
Chemical Engineer	GS12
(2) Chemist (1V)	GS12
(4) Environmental Engineer	GS12
(2) Physical Scientist	GS12
Environmental Engineer	GS11/12
Physical Scientist	GS11/12
Chemist	GS05/11
Remediation Biologist	GS11
Environmental Eng	GS11
(2)Student Trainee (T/V)	GS04

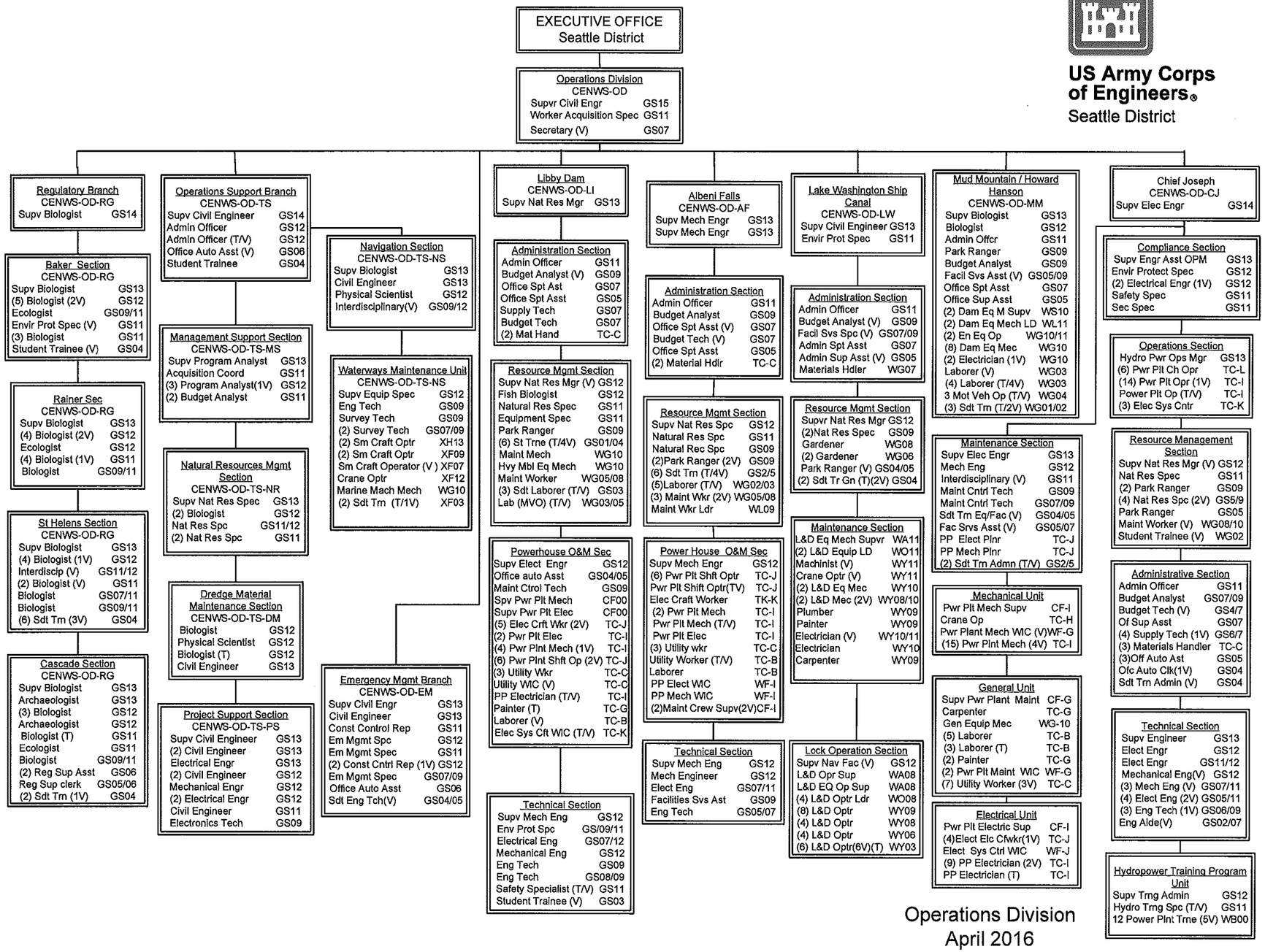
Geology & Instrumentation Section
CENWS-EN-GB-GE

Supervisory Geologist	GS13
Environmental Protection Spec	GS12
(9) Geologist(3V)	GS12
Geologist (V)	GS11/12
Geologist	GS11
Engineering Tech (Civil)	GS11
Sdt Trn Eng Tech (T)	GS04/07

Cost Engineering Section
CENWS-EN-ES-CE

Supervisory Civil Engineer	GS13
Engineering Tech	GS12
(4) Civil Engineer (1V)	GS12
Electrical Engineer (V)	GS11/12
Civil Engineer	GS09/12
(2) Mechanical Engineer (V)	GS07/12
(2) Sdt Trn Eng Tech (T/V)	GS04

Engineering Division
April 2016


US Army Corps of Engineers®
Seattle District
EXECUTIVE OFFICE
Seattle District
Operations Division
CENWS-OD
Supvr Civil Engr GS15
Worker Acquisition Spec GS11
Secretary (V) GS07
Regulatory Branch
CENWS-OD-RG
Supv Biologist GS14
Baker Section
CENWS-OD-RG
Supv Biologist GS13
(5) Biologist (2V) GS12
Ecologist GS09/11
Envir Prot Spec (V) GS11
(3) Biologist GS11
Student Trainee (V) GS04
Rainer Sec
CENWS-OD-RG
Supv Biologist GS13
(4) Biologist (2V) GS12
Ecologist GS12
(4) Biologist (1V) GS11
Biologist GS09/11
St Helens Section
CENWS-OD-RG
Supv Biologist GS13
(4) Biologist (1V) GS12
Interdiscip (V) GS11/12
(2) Biologist (V) GS11
Biologist GS07/11
Biologist GS09/11
(6) Sdt Trn (3V) GS04
Cascade Section
CENWS-OD-RG
Supv Biologist GS13
Archaeologist GS13
(3) Biologist GS12
Archaeologist GS12
Biologist (T) GS11
Ecologist GS11
Biologist GS09/11
(2) Reg Sup Asst GS06
Reg Sup clerk GS05/06
(2) Sdt Trn (1V) GS04
Operations Support Branch
CENWS-OD-TS
Supv Civil Engineer GS14
Admin Officer GS12
Admin Officer (T/V) GS12
Office Auto Asst (V) GS06
Student Trainee GS04
Management Support Section
CENWS-OD-TS-MS
Supv Program Analyst GS13
Acquisition Coord GS11
(3) Program Analyst(1V) GS12
(2) Budget Analyst GS11
Natural Resources Mgmt Section
CENWS-OD-TS-NR
Supv Nat Res Spec GS13
(2) Biologist GS12
Nat Res Spc GS11/12
(2) Nat Res Spc GS11
Dredge Material Maintenance Section
CENWS-OD-TS-DM
Biologist GS12
Physical Scientist GS12
Biologist (T) GS12
Civil Engineer GS13
Project Support Section
CENWS-OD-TS-PS
Supv Civil Engineer GS13
(2) Civil Engineer GS13
Electrical Engr GS13
(2) Civil Engineer GS12
Mechanical Engr GS12
(2) Electrical Engr GS12
Civil Engineer GS11
Electronics Tech GS09
Navigation Section
CENWS-OD-TS-NS
Supv Biologist GS13
Civil Engineer GS13
Physical Scientist GS12
Interdisciplinary(V) GS09/12
Waterways Maintenance Unit
CENWS-OD-TS-NS
Supv Equip Spec GS12
Eng Tech GS09
Survey Tech GS09
(2) Survey Tech GS07/09
(2) Sm Craft Optr XH13
(2) Sm Craft Optr XF09
Sm Craft Operator (V) XF07
Crane Optr XF12
Marine Mach Mech WG10
(2) Sdt Trn (T/1V) XF03
Emergency Mgmt Branch
CENWS-OD-EM
Supv Civil Engr GS13
Civil Engineer GS13
Const Control Rep GS11
Em Mgmt Spc GS12
Em Mgmt Spec GS11
(2) Const Cntrl Rep (1V) GS12
Em Mgmt Spec GS07/09
Office Auto Asst GS06
Sdt Eng Tch(V) GS04/05
Libby Dam
CENWS-OD-LI
Supv Nat Res Mgr GS13
Administration Section
Admin Officer GS11
Budget Analyst (V) GS09
Office Spt Ast GS07
Office Spt Asst GS05
Supply Tech GS07
Budget Tech GS07
(2) Mat Hand TC-C
Resource Mgmt Section
Supv Nat Res Mgr (V) GS12
Fish Biologist GS12
Natural Res Spec GS11
Equipment Spec GS11
Park Ranger GS09
(6) St Trne (T/4V) GS01/04
Maint Mech WG10
Hvy Mbl Eq Mech WG10
Maint Worker WG05/08
(3) Sdt Laborer (T/V) GS03
Lab (MVO) (T/V) WG03/05
Powerhouse O&M Sec
Supv Elect Engr GS12
Office auto Asst GS04/05
Maint Ctrol Tech GS09
Spv Pwr Plt Mech CF00
Supv Pwr Plt Elec CF00
(5) Elec Crft Wkr (2V) TC-J
(2) Pwr Plt Elec TC-I
(4) Pwr Plnt Mech (1V) TC-I
(6) Pwr Plnt Shft Op (2V) TC-J
(3) Utility Wkr TC-C
Utility WIC (V) TC-C
PP Electrician (T/V) TC-I
Painter (T) TC-G
Laborer (V) TC-B
Elec Sys Cft WIC (T/V) TC-K
Technical Section
Supv Mech Eng GS12
Env Prot Spc GS/09/11
Electrical Eng GS07/12
Mechanical Eng GS12
Eng Tech GS09
Eng Tech GS08/09
Safety Specialist (T/V) GS11
Student Trainee (V) GS03
Albeni Falls
CENWS-OD-AF
Supv Mech Engr GS13
Supv Mech Engr GS13
Administration Section
Admin Officer GS11
Budget Analyst GS09
Office Spt Asst (V) GS07
Budget Tech (V) GS07
Office Spt Asst GS05
(2) Material Hdlr TC-C
Resource Mgmt Section
Supv Nat Res Spc GS12
Natural Res Spc GS11
Natural Rec Spc GS09
(2)Park Ranger (2V) GS09
(6) Sdt Trn (T/4V) GS2/5
(5)Laborer (T/V) WG02/03
(3) Maint Wkr (2V) WG05/08
Maint Wkr Ldr WL09
Power House O&M Sec
Supv Mech Engr GS12
(6) Pwr Plt Shft Optr TC-J
Pwr Plt Shift Optr(TV) TC-J
Elec Craft Worker TK-K
(2) Pwr Plt Mech TC-I
Pwr Plt Mech (T/V) TC-I
Pwr Plt Elec TC-I
(3) Utility wkr TC-C
Utility Worker (T/V) TC-B
Laborer TC-B
PP Elect WIC WF-I
PP Mech WIC WF-I
(2)Maint Crew Supv(2V)CF-I
Technical Section
Supv Mech Eng GS12
Mech Engineer GS12
Elect Eng GS07/11
Facilities Svs Ast GS09
Eng Tech GS05/07
Lake Washington Ship Canal
CENWS-OD-LW
Supv Civil Engineer GS13
Envir Prot Spec GS11
Administration Section
Admin Officer GS11
Budget Analyst (V) GS09
Facil Svs Spc (V) GS07/09
Admin Spt Asst GS07
Admin Sup Asst (V) GS05
Materials Hdler WG07
Resource Mgmt Section
Supvr Nat Res Mgr GS12
(2)Nat Res Spec GS09
Gardener WG08
(2) Gardener WG06
Park Ranger (V) GS04/05
(2) Sdt Tr Gn (T)(2V) GS04
Maintenance Section
L&D Eq Mech Supvr WA11
(2) L&D Equip LD WO11
Machinist (V) WY11
Crane Optr (V) WY11
(2) L&D Eq Mec WY10
(2) L&D Mec (2V) WY08/10
Plumber WY09
Painter WY09
Electrician (V) WY10/11
Electrician WY10
Carpenter WY09
Lock Operation Section
Supv Nav Fac (V) GS12
L&D Opr Sup WA08
L&D EQ Op Sup WA08
(4) L&D Optr Ldr WO08
(8) L&D Optr WY09
(4) L&D Optr WY08
(4) L&D Optr WY06
(6) L&D Optr(6V)(T) WY03
Mud Mountain / Howard Hanson
CENWS-OD-MM
Supv Biologist GS13
Biologist GS12
Admin Offcr GS11
Park Ranger GS09
Budget Analyst GS09
Facil Svs Asst (V) GS05/09
Office Spt Asst GS07
Office Sup Asst GS05
(2) Dam Eq M Supv WS10
(2) Dam Eq Mech LD WL11
(2) En Eq Op WG10/11
(8) Dam Eq Mec WG10
(2) Electrician (1V) WG10
Laborer (V) WG03
(4) Laborer (T/4V) WG03
3 Mot Veh Op (T/V) WG04
(3) Sdt Trn (T/2V) WG01/02
Maintenance Section
Supv Elec Engr GS13
Mech Eng GS12
Interdisciplinary (V) GS11
Maint Cntrl Tech GS09
Maint Cntrl Tech GS07/09
Sdt Trn Eq/Fac (V) GS04/05
Fac Srvs Asst (V) GS05/07
PP Elect Plnr TC-J
PP Mech Plnr TC-J
(2) Sdt Trn Admn (T/V) GS2/5
Mechanical Unit
Pwr Plt Mech Supv CF-I
Crane Op TC-H
Pwr Plant Mech WIC (V)WF-G
(15) Pwr Plnt Mech (4V) TC-I
General Unit
Supv Pwr Plant Maint CF-G
Carpenter TC-G
Gen Equip Mec WG-10
(5) Laborer TC-B
(3) Laborer (T) TC-B
(2) Painter TC-G
(2) Pwr Plt Maint WIC WF-G
(7) Utility Worker (3V) TC-C
Electrical Unit
Pwr Plt Electric Sup CF-I
(4)Elect Elc Cfwkr(1V) TC-J
Elect Sys Ctrl WIC WF-J
(9) PP Electrician (2V) TC-I
PP Electrician (T) TC-I
Chief Joseph
CENWS-OD-CJ
Supv Elec Engr GS14
Compliance Section
Supv Engr Asst OPM GS13
Envir Protect Spec GS12
(2) Electrical Engr (1V) GS12
Safety Spec GS11
Sec Spec GS11
Operations Section
Hydro Pwr Ops Mgr GS13
(6) Pwr Plt Ch Opr TC-L
(14) Pwr Plt Opr (1V) TC-I
Power Plt Op (T/V) TC-I
(3) Elec Sys Cntr TC-K
Resource Management Section
Supv Nat Res Mgr (V) GS12
Nat Res Spec GS11
(2) Park Ranger GS09
(4) Nat Res Spc (2V) GS5/9
Park Ranger GS05
Maint Worker (V) WG08/10
Student Trainee (V) WG02
Administrative Section
Admin Officer GS11
Budget Analyst GS07/09
Budget Tech (V) GS4/7
Of Sup Asst GS07
(4) Supply Tech (1V) GS6/7
(3) Materials Handler TC-C
(3)Off Auto Ast GS05
Ofc Auto Clk(1V) GS04
Sdt Trn Admin (V) GS04
Technical Section
Supv Engineer GS13
Elect Engr GS12
Elect Engr GS11/12
Mechanical Eng(V) GS12
(3) Mech Eng (V) GS07/11
(4) Elect Eng (2V) GS05/11
(3) Eng Tech (1V) GS06/09
Eng Aide(V) GS02/07
Hydropower Training Program Unit
Supv Trng Admin GS12
Hydro Trng Spc (T/V) GS11
12 Power Plnt Trne (5V) WB00
Operations Division
April 2016