WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Periodic Dam Safety Inspection Report

Beacon Hill (North) Reservoir
King County, Washington

February 2007

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ECOLOGY

Periodic Dam Safety Inspection Report

Beacon Hill (North) Reservoir

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Olympia, Washington 98504-7600

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Beacon Hill (North) Reservoir
Periodic Inspection Report

Water Resources Program

The dam safety inspection of the Beacon Hill (North) Reservoir, and the engineering analyses and technical material presented in this report were prepared under the supervision and direction of the undersigned professional engineers, in accordance with RCW 43.21A.064(2).

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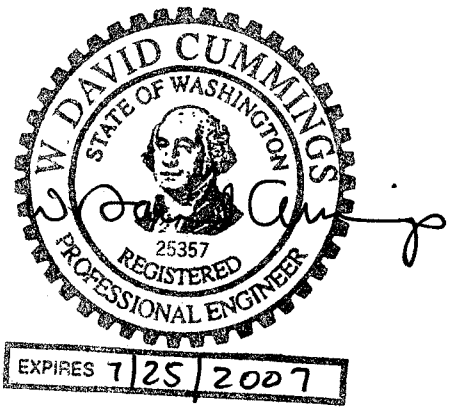

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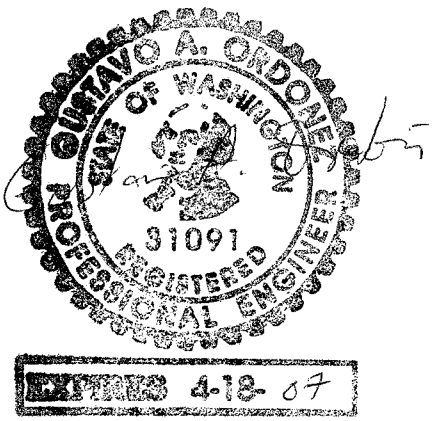

Table of Contents

Page

Summary ii
Findings and Recommendations ii
Embankment, Foundation, and Abutments ii

Introduction 1
General Background 1
Construction History 1
Reservoir Leakage 2
Past Inspections 2

Project Description and Field Inspection 4
Parapet Wall and Sidewalk 4
Embankment, Abutments, and Foundation 5
Reservoir Overflow (Service Spillway 5
Instrumentation 5
Outlet Works 6
Underdrain System 6

Evaluation and Analyses 7
Downstream Hazard Classification 7
Hydrology and Spillway Adequacy 7
Extreme Storm Analysis 7
Overflow Drain 8
Embankment Stability 8
Project Operation and Maintenance 9
Emergency Preparedness 9
Recommendations 9

Appendices

A. References
B. Figures
C. Photos
D. Owner Interview

Summary

This report summarizes the results of an inspection conducted on July 28, 2005 and a subsequent evaluation of the Beacon Hill (North) Reservoir performed by the Dam Safety Office (DSO) of the Department of Ecology. It presents the findings from the inspections, engineering evaluation and analyses of the facility, and required remedial actions to correct deficiencies.

Findings and Recommendations

In general, the Beacon Hill (North) Reservoir is well maintained and operated. The results of the field inspection and engineering analyses indicate that most elements of the facility meet current engineering standards for dam design. The recommendations and required remedial actions presented in this report are similar and complement those presented in previous inspection reports.

Embankment, Foundation, and Abutments

The embankment did not show surficial signs of slope instability. A review of previous engineering analyses[1] was conducted as part of this inspection. This review indicated that the methodology used in the analysis is still the standard procedure used by the DSO; and, that the assumptions as to the properties of the embankment and foundation soils and the loading conditions made for those analyses are still acceptable.

Static stability – The Beacon Hill (North) Reservoir embankment meets current engineering standards.

Seismic Stability – In response to the 2001 DSO report, the City of Seattle retained PanGEO, Inc. to evaluate the seismic stability of the Beacon Hill Reservoirs. The results of this evaluation indicated that the embankment is stable under the static and seismic loading conditions considered.

- The vegetation on the embankment slopes is not being properly controlled. As a result, the vegetative growth did not allow for a thorough visual inspection of the slopes. The embankment slopes need to be mowed at a more frequent interval. There were no other visible signs of distress on the embankment slopes or the crest.

- The Beacon Hill (North) Reservoir has adequate spillway capacity to accommodate the PMF and the maximum system inflow.

- Liner: Inspection of the liner during the July 28, 2005 inspection could not take place due to the reservoir being in service. However, sections of the liner were discovered at the batten connection to the reservoir wall that had been singed with a torch device very likely used for weed control (see photos 15 and 16 in Appendix C). It is possible that embrittlement caused by the singing could cause the batten connection to fail at this point.

- Outlet Works: It is not known when the interior of the inlet and outlet conduits were last inspected by the City of Seattle. According to the City of Seattle, the reservoir inlet conduit is not accessible due to its location. The Dam Safety Office recommends an inspection interval for critical conduit interiors equal to every other periodic inspection. The outlet conduit therefore should be scheduled for an inspection at the City's convenience. The resulting video should then be forwarded to the DSO. If entrance to the inlet conduit is made possible by construction or piping modifications, the City of Seattle should take this opportunity to inspect the inlet pipe. Additionally, the outlet conduit should be provided with backup, manual controls for the valve installed on the embankment crest.

    - During the July 28, 2005 inspection, vertical offsets and concrete sidewalk cracking were observed directly over the reservoir overflow conduit (service spillway). This discovery necessitated the DSO to perform an interior inspection of the overflow pipe on August 2005. When the DSO conduit camera malfunctioned, an SPU employee entered the pipe from the overflow and examined the steel pipe sections and the corresponding joints. According to the Seattle inspector's report and photographs, it was determined that the vertical offsets and concrete cracking that appeared to be settlement-related were not associated with pipe leakage or collapse as initially thought. The sidewalk cracking and offsets at the sidewalk joints could be related to vegetative growth lifting sections of sidewalk or causing them to crack.

- Project Operation and Maintenance: An Operation & Maintenance (O&M) Manual has been prepared for the Beacon Hill (North) Reservoir. A review of the O&M Manual, dated February 2000, was done as part of this inspection. The O&M plan was found to provide detailed written procedures for dam and reservoir operation, maintenance, monitoring, and inspection of the Beacon Hill (North) Reservoir.

- Emergency Preparedness: An Emergency Action Plan (EAP) for the Beacon Hill (North) Reservoir has been developed. A review of the EAP, dated November 2004, was done as part of this inspection. This document meets the minimum requirements for an EAP as recommended in the Dam Safety Guidelines.

Introduction

In accordance with RCW 43.21A.064(2), the Department of Ecology (Ecology) has responsibility and authority to inspect the construction of all dams and other works related to the use of water, and to require necessary changes in construction or maintenance to reasonably secure safety to life and property. This report has been prepared in accordance with the above mentioned statute.

The purpose of this report is to present the results of the inspection and subsequent safety evaluation of the Beacon Hill (North) Reservoir. The report provides background information and a description of the project; results of the July 28, 2005 inspection; safety evaluation and analysis of the design of the project; and, required remedial actions based on the findings.

The Beacon Hill North Reservoir is located near the top of Beacon Hill in Seattle Washington. The Beacon Hill South Reservoir is located immediately south of the North Reservoir with the two sharing a common embankment. The reservoirs are bordered by Spokane Street to the north, 15th Avenue South to the west, Beacon Avenue South to the east, and Jefferson Park Golf Course to the south. The South Reservoir has been out of service for a number of years.

General Background

A review of past inspection reports for the Beacon Hill Reservoirs indicates the facility was constructed between 1908 and 1910 as part of the Cedar River Pipeline 2 project. The reservoirs were constructed by excavating into a hillside with embankments formed by the excavated material to the north, west and south. Although available information regarding the construction was limited, fill was reportedly densified by a water filled drum pulled by a team of horses.

The Beacon Hill North Reservoir is an off-channel storage facility consisting of an earthen perimeter embankment formed by material excavated from the reservoir area. The reservoir is 27 feet deep at normal pool and was originally lined with seven inch thick concrete panels with bituminous seals. A Hypalon liner was added in late 1980 due to excessive leakage.

Construction History

The Beacon Hill North Reservoir was formed by the construction of an earthfill embankment along the boundaries of the reservoir. The maximum embankment height is about 28 feet at the northwest corner of the reservoir. The exterior slopes are approximately 1.75H:1V and the interior slopes are about 2H: 1V. The crest is about 40 feet in width.

Based on information contained in the geotechnical report, the embankment is composed of native soils. Borings indicate that the embankment is composed of silty sand classified as an SC soil type, silty sand classified as SP soil group, and fine to medium sand with pockets of clay. The embankment consistency is medium dense to dense and is primarily granular. The embankment is situated on top of stiff native blue gray clay. Borings completed for a supplemental investigation of a sinkhole feature on the north embankment crest revealed a very loose, porous fill of cinders, sand and slag which apparently had been dumped out over the

outboard slope or was used to widen the crest.

In 1976, the Beacon Hill South Reservoir was taken out of service due to excessive leakage and a slide occurring on the west embankment.

In February 1980, an eddy current was noted in the southeast corner of the North Reservoir. The water level was lowered, and it was revealed that water had been flowing through a cracked and settled portion of the concrete lining. Piping of fined grained embankment soils into the subdrains occurred resulting in the formation of a void of several cubic feet in volume beneath the concrete panels. The void was filled and the concrete panel replaced. A Hypalon liner was subsequently installed in late 1980.

The Seattle Water Department installed warning sensors in the piezometers and underdrains in 1992. These sensors send a signal to the operations center in the event of high piezometer or leakage levels.

Reservoir Leakage

Seattle Public Utilities attempts to measure reservoir leakage in their open reservoirs once per year. To accomplish this, the reservoir is taken out of service, and changes in water level, precipitation and flow due to leaking valves are measured or recorded. Losses to evaporation are taken from research performed by the U.S. Department of Agriculture in 1968. The latest leakage test was conducted between October 11th and 14th of 2005, and indicated that the daily leakage rate was approximately 0.6 gallons per minute per million gallons. This is an average that results in a total calculated leakage rate of about 37 gpm. While this is an acceptable level of leakage given the size of the reservoir and valves at this facility, inspection activities at the reservoir need to be alert to the possibility that this would be a significant leak if it occurred in one place in a buried conduit or through a plastic liner tear.

Past Inspections

February 1980 - The project was inspected by representatives of the City of Seattle Water Department, International Engineering Company, NTL Geotechnics, and Ecology as part of the National Dam Inspection Program.

> Findings – 1) Insufficient information was available to properly assess embankment stability, 2) the reservoir had adequate storage and discharge capacities to pass the Probable Maximum Flood (PMF), 3) the outlet works appeared to be adequately designed, and 4) the operation and maintenance of the facility were acceptable.
>
> Recommendations - 1) A geotechnical investigation should be performed to determine embankment stability, 2) deciduous trees and screening vegetation should be pruned or removed to allow unobstructed views of the embankment slopes, 3) rodent hole damage should be repaired, and the rodent population removed or controled, 4) protective liners in the inlet and outlet conduits should be installed, 5) and practice drills of the disaster plan should be conducted.

A sinkhole developed on the crest of the north embankment in the spring of 1980. Converse Ward Davis Dixon (CWDD) was retained by the City to investigate the cause of the subsidence. The results of the investigation indicated that the sinkhole was caused by subsidence of loose fill placed on the exterior embankment slope. This fill consisted of cinders and slag materials and was added to the north reservoir embankment sometime prior to 1980.

April 1981 - The Seattle Water Department retained Converse Ward Davis Dixon (CWDD) to perform a geotechnical study to evaluate the seismic slope stability of the reservoir, as recommended by the previous inspection report. CWDD conducted the geotechnical study, installed piezometers in the east embankment, and prepared a report summarizing the results of the investigation. The findings of this study indicated that:

> Findings – 1) The pseudostatic slope stability of the embankment was acceptable, 2) seepage was not observed on the downstream embankment slopes, 3) rodent holes were found on the embankment, and 4) vegetation on the downstream slope of the east embankment may affect embankment stability.
>
> Recommendations – 1) the new piezometers should be periodically monitored, 2) the concrete liner should be periodically inspected, 3) the rodent holes should be repaired and the rodent population controlled, and 4) some of the vegetation should be pruned to facilitate inspection of the embankments.

On January 18, 1986 a slide 30 feet wide, 2 to 4 feet deep and covering the entire height of the north embankment occurred with the slide material blocking Spokane Street. CWDD was hired to assess the slide and attributed it to the loose material that had been dumped on the north embankment slope. The slide was probably initiated by saturated soil conditions from heavy rains. Flooding and landslides occurred throughout the Seattle area on this date. The consultant stated that because the slide occurred in the loose surficial material, the structural integrity of the embankment was not compromised.

April 1992 - The DSO conducted a periodic inspection of the reservoir in 1992.

> Findings - The results of the inspection indicated that the reservoir was well maintained and that most elements of the facility met current engineering standards for dam design.
>
> Recommendations – 1) the outlet works should be visually inspected and provided with manual backups, and 2) an inundation map for the reservoir be developed, with Emergency Action and Opertation and Maintenance Plans prepared for the facility.

April 1999 - The DSO conducted a periodic inspection of the reservoir in April 7, 1999 with an additional site visit on May 11, 1999.

> Findings - The results of the inspection indicated that the reservoir was well maintained and that most elements of the facility met current engineering standards for dam design. 1) Static stability of the embankment meets current engineering standards, and shows no surficial signs of slope instability, 2) vegetation on the embankment slopes is being properly maintained, 3) a few animal burrows were noted along the southeast corner of

the reservoir, 4) the hypalon liner had a few areas with cuts and/or unglued seams, likely caused by the machine used to clean the liner during the annual cleanup operations. Recommendations – 1) The interior of the inlet and outlet conduits should be inspected to evaluate their condition, 2) the animal burrows should be backfilled, and that steps be taken to control the animal population to prevent further burrowing activity, 3) an alternative way of cleaning the reservoir's hypalon liner should be considered for future cleaning operations, 4) the EAP needs some phone numbers updated and exercises should be performed to familiarize staff with the procedures required by its implementation, 5) The City of Seattle should consider the establishment of an automatic telephone notification system to inform downstream residents in the event of an emergency at the reservoir.

Project Description and Field Inspection

The field inspection of the Beacon Hill North Reservoir was performed on July 28, 2005. The Dam Safety inspection team for the inspection consisted of the following personnel:

Name	Aspects Covered
Gustavo A. Ordonez, P.E.	Coordinator, Geotechnical
David Cummings, P.E.	Structural Features
Jennifer McCaslin	Surveying Assistance

Messrs. Carlos A. Albarracin and Daniel Huang, engineers for the Seattle Public utilities, were the owner's representatives during the inspection.

At the time of the inspection, the reservoir level was about 18 inches below the overflow spillway. As a result, an inspection of the liner could not be performed.

Parapet Wall and Sidewalk

The parapet wall and sidewalk were inspected around the entire interior rim of the reservoir. A number of cracks and vertical offsets at parapet wall joints were discovered. None of the features appeared recent by the appearance of the cracks and the presence of vegetation in most of the joints and displacements. The wall sections were sighted along their lengths and were in acceptable alignment.

Some of the vertical offsets and concrete sidewalk cracking were clustered together directly over the overflow conduit in the SW corner of the reservoir. The number of features located together led inspectors to believe that the outlet pipe below was either settling or collapsing. This led to an inspection of the pipe interior on August 2005. The inspection of the pipe joints and interior showed the pipe to be in acceptable condition however. It now appears that the cracks and displacements in this area were coincidental and not related to the conduit below.

Embankment, Abutments, and Foundation

A visual inspection of the embankment crest revealed no evidence of surface cracking, settlement, horizontal misalignment, or any other sign of distress. A survey of the embankment crest included as Figure 4 in Appendix B, indicates that there are no significant changes in crest elevation along the surveyed section.

The field inspection revealed that the visible sections of the downstream face did not show signs of slumps, scarps, erosion, or unusual movement. Vegetation on some of the slopes has not been properly maintained since our last inspection. This obscuring of some of the downstream face of the surrounding embankment made visual inspection of the downstream face incomplete. No evidence of seepage was observed during the inspection.

An examination of the visible foundation and abutment sections, and cut slopes did not reveal any signs of seepage, slides, scarps, or movement.

Reservoir Overflow (Service Spillway)

The overflow drain for the Beacon Hill North Reservoir consists of a 46 foot long concrete weir, with a crest elevation of 316.0 feet, that discharges to a 24 inch cast iron storm sewer pipe. The storm sewer discharges to the Duwamish River. The 24 inch pipe was the focus of the interior inspection on August 2005 described earlier. According to the SPU inspection of the pipe, the interior of the pipe is acceptable, with typical gasketed, fully intact joints.

Instrumentation

Data is recorded at six piezometers at the Beacon Hill North Reservoir. The water elevation is measured monthly by City staff, and the data is stored on a four to five year moving time frame. An alarm system installed in the piezometers during the summer of 1992 detects water levels at or above a warning elevation and automatically sends a signal to the operations center.

The tips of the piezometers were located below the native ground for all sites except for BN-3A, which was set into the embankment fill. The data collected at these sites for the period between February 1996 through January 2001 indicate no major increasing trends over that period, with seasonal groundwater accounting for the majority of the fluctuations in the data. Further, there does not appear to be a correlation between reservoir water surface and piezometer levels. However, there appears to be a difference of 2 feet higher in the elevation readings of BN-1 for the latest period as compared to the readings presented in our 1992 inspection report. Hence, for the period between August 1987 through August 1992, the average reading for BN-l was approximately 290 feet and for the period between February 1996 through January 2001, the range of elevation varied between 290 and 294 feet. Based on the soil explorations conducted by PanGeo[7], they concluded that *"... the rise in the water level at BN-1 resulted from unusually heavy rains during the winter of 1996-1997.*

Other instrumentation at the reservoir consists of a high water sensor installed to warn the operator in the event that the reservoir rises to unacceptably high levels.

Outlet Works

The Beacon Hill North Reservoir receives flow from Lake Youngs, which receives flow from the Cedar River. The reservoir is equipped with a 24 inch steel diffuser inlet pipe that connects to a 20 inch cast iron pipe. The 20 inch line is fitted with a remotely operated ball valve. The outlet pipe consists of a 30 inch cast iron pipe fitted with a manually operated gate valve. The plans indicate that neither the inflow or outflow lines are encased in concrete.

Underdrain System

The underdrain system for the reservoir consists of six-inch diameter sewer tiles supported on 12 inch timber planks and surrounded by gravel. There are a total of ten laterals along the floor of the reservoir that discharge to a trunk line that carries the leakage outside the reservoir area. Each drain lateral connects to the trunk line at an angle which forms a herring bone pattern across the bottom of the reservoir.

Evaluation and Analyses

Downstream Hazard Classification

The primary consequences of any dam failure are the potential for loss of life and damage to property downstream of the dam. It is common practice to use a classification system to describe the general level of development downstream from a dam and to use the classification for establishing acceptable design levels.

As part of the inspection, the downstream hazard potential in the event of a dam failure was reassessed by a visual inspection of the area downstream of the darn. Beacon Hill North Reservoir is located in a densely populated residential area in the central part of the City of Seattle. A failure of the reservoir embankment could release high velocity flows and threaten more than 100 homes and several businesses. Based on these findings the downstream hazard classification for the Green Lake Reservoir should remain Hazard Class 1A, High.

Hydrology and Spillway Adequacy

As part of the inspection, the DSO performed a hydrologic analysis to determine the response of the reservoir to extreme hydrologic and hydraulic operating conditions. For reservoirs that have parapet walls and no tributary drainage area, this entails determining the system's ability to withstand extreme precipitation events, or excessive inflow from the supply system. The results of these analyses are summarized below.

Extreme Storm Analysis

A major consideration in the assessment of spillway adequacy is the selection of an appropriate design storm for evaluating the response of the reservoir water surface elevations. It is standard engineering practice to select the magnitude of the design storm dependent upon the level and type of development downstream from the dam. As the potential for loss of life and/or property damage resulting from an upstream dam failure increases, the design criteria become increasingly more stringent.

The DSO utilizes design storm selection criteria that have an eight-step format. Design storms range from a minimum of a 500-year storm (Step 1) to Probable Maximum Precipitation (PMP, Step 8). Based on the potential for damage in the event of a storm-induced dam failure, it was determined that the Beacon Hill North Reservoir should be capable of accommodating a design storm event corresponding to Step 8 of the eight-step criteria. Step 8 corresponds to the Probable Maximum Precipitation which is an estimate of the maximum rainfall that the atmosphere could physically deliver to a given site over a period of time. The PMP used to analyze the reservoir was derived from the National Weather Service Hydrometeorological Report 574. The storm had a total duration of 72 hours with a 24-hour depth of 12.0 inches, and a total 72-hour depth of 16.2 inches.

The PMP storm was applied to the reservoir to determine if the current freeboard is sufficient.

The tributary area to the reservoir has been effectively cut off by the parapet wall that surrounds the reservoir. Thus, the volume contributed by precipitation is that which falls directly on the reservoir alone. The initial water surface elevation was set equal to the elevation of the crest of the overflow weir (elevation 316.0 feet). Water system inflows were assumed to equal outflows during the simulation and the overflow drain was, assumed to be completely blocked (a conservative assumption). The resulting increase in the reservoir water surface elevation from the IDF was 1.35 feet to elevation 317.35 feet. The elevation of the top of the curbing surrounding the reservoir perimeter is 318.2 feet and the available freeboard is, therefore, 0.85 feet. Thus, even with the overflow drain completely blocked, the reservoir has sufficient freeboard to contain the PMP.

Overflow Drain

The overflow drain consists of a 46 foot long concrete weir that discharges to a 24 inch cast iron pipe. Based on the available head between the 24 inch outlet pipe (elevation 311.4 feet) and the top of the perimeter curbing (elevation 318.2 feet), the maximum discharge from the overflow drain is approximately 40 cfs. The capacity may be less depending on backwater affects from the downstream storm drain system.

No emergency spillway exists at the facility. The maximum inlet capacity is reported by Seattle Public Utilities (SPU) Personnel to be 50 cfs. Since the maximum inflow from the supply system inlet exceeds the spillway outflow capacity, it is possible that misoperation could result in the reservoir filling and overtopping the parapet wall. However, the chances of this happening are remote, as the reservoir is equipped with a high water sensor to warn the operator in the event the reservoir rises to unacceptable levels. In addition, the Operation and Maintenance Plan for this reservoir includes procedures to prevent misoperation.

Embankment Stability

A review of the stability analysis performed for the 1992 periodic inspection[3] was conducted as part of this inspection. This review indicated that the methodology used in the analysis is still the standard procedure used by the DSO; and, that the assumptions as to the properties of the embankment and foundation soils and loading conditions made for the analysis are still acceptable. Accordingly, the static stability of the embankment meets current engineering standards.

Seismic Stability – In response to the 2001 DSO report, the City of Seattle retained PanGEO, Inc. to evaluate the seismic stability of the Beacon Hill Reservoirs. A review of the report[7] prepared by PanGEO indicates that the seismic evaluation of the reservoir considered those fault sources and seismogenic zones that may have a significant effect on the determination of the seismic loading used in the evaluation of the seismic stability. For these earthquake sources, a conservative approach of selecting the median + one standard deviation peak rock accelerations at the site was used. An “analysis” event was then selected based on the largest level of peak “rock” accelerations. For the analysis event, a target response spectrum was developed using an attenuation relation appropriate for the region. Representative time histories of ground motion from similar tectonic environments that approximately matched the target response spectrum were selected for input in the 1-D equivalent linear analysis of the structure. The results from the

ground response analyses were then used to evaluate the slope stability of the embankment and the liquefaction potential of the site under seismic loading. The results of this evaluation indicated that the soils at the site are unlikely to liquefy and that the embankment is stable under the seismic loading conditions considered.

Project Operation and Maintenance

An Operation & Maintenance (O&M) Manual has been prepared for the Beacon Hill (North) Reservoir. A review of the O&M Manual, dated February 2000, was done as part of this inspection. The O&M plan was found to provide detailed written procedures for dam and reservoir operation, maintenance, monitoring, and inspection of the Beacon Hill (North) Reservoir.

Emergency Preparedness

An Emergency Action Plan (EAP) for the Beacon Hill (North) Reservoir has been developed. A review of the EAP, dated November 2004, was done as part of this inspection. This document meets the minimum requirements for an EAP as recommended in the Dam Safety Guidelines.

Recommendations

In general, the Beacon Hill (North) Reservoir is well maintained and operated. The results of the field inspections and engineering analyses indicate that most elements of the facility meet current engineering standards for dam design.

- The hypalon liner needs to be inspected at SPU's first opportunity. The singed liner edge discussed and shown in Appendix C should be examined. If the liner section attached under the batten is affected, a new section of liner needs to be spliced and attached under the batten.

- The grass-covered slopes discussed earlier need to be mowed more frequently. These areas need to be more easily inspected for animal burrows, seepage, or slope instability.

- The Dam Safety Office recommends an inspection interval for critical conduit interiors equal to every other periodic inspection. This project feature therefore should be scheduled for an inspection at the City's convenience. The resulting video should then be forwarded to the DSO. Additionally, the outlet conduit should be provided with backup, manual controls for the valve installed on the embankment crest.

Appendix A - References

1. Converse Ward Davis Dixon, Seismic Slope Stability Evaluation for North Beacon Reservoir, Seattle, Washington; Converse Ward Davis Dixon, Geotechnical Consultants, Project No. 79-522003, Seattle, Washington, April 10, 1981.

2. International Engineering Company, Inc., Phase 1 Inspection Report, National Dam Safety Program; Lake Forest Park Reservoir, WA-210; Maple Leaf Reservoir, WA-211; Green Lake Reservoir, WA212; Bitter Lake Reservoir, WA -213; Beacon Hill South Reservoir, WA -214; Beacon Hill North Reservoir, WA-215; West Seattle Reservoir, WA-216; Lake Forest Park Reservoir, WA-217; Seattle, Washington, King County; International Engineering Company, Inc., Northwest District, Boise, Idaho, September 1980.

3. Barker, B. and Ordonez, G. (1993); Periodic Dam Safety Inspection Report, Beacon Hill North Reservoir. Report No. 92-119, Washington State Department of Ecology, Dam Safety Section, February 1993.

4. Ordonez, G. And Cummings, D. (2001); Periodic Dam Safety Inspection Report, Beacon Hill North Reservoir. Washington State Department of Ecology, Dam Safety Section, November 2001.

5. U.S. Department of Commerce, NOAA; Hydrometeorological Report No. 57: Probable Maximum Precipitation - Northwest States. Silver Spring, MD, October 1994.

6. PanGEO, Inc. (2002). *Draft Geotechnical Engineering Report – Beacon Hill Reservoir – Seismic Safety Evaluation – Seattle, Washington.* Project No. 02-003, Seattle, Washington.

Appendix B - Figures

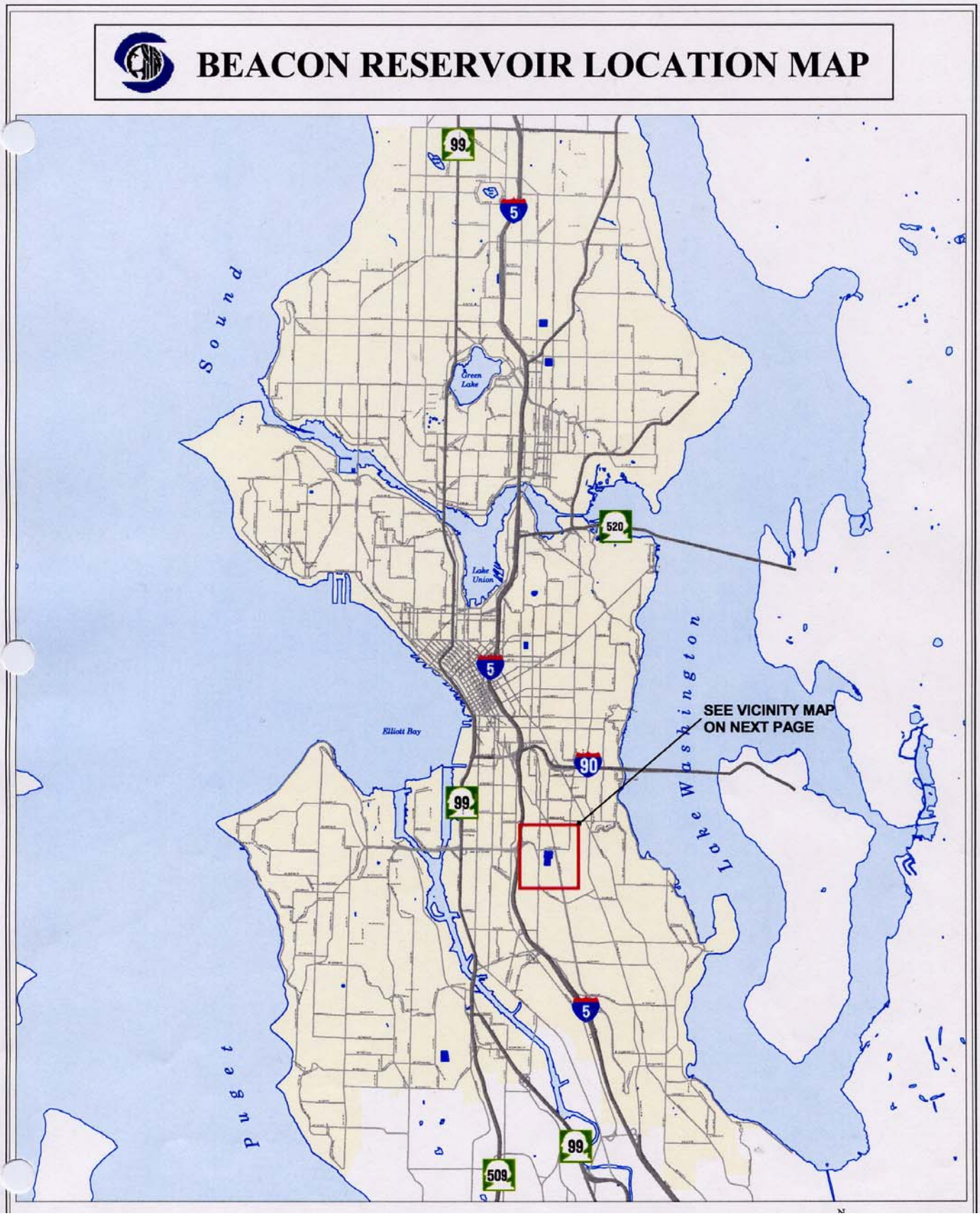

Figure 1 – Location Map

BEACON NORTH RESERVOIR

N
W E
S

200 0 200 Feet

Figure 2

Vicinity Map

Produced by the City of Seattle

March 26, 2004

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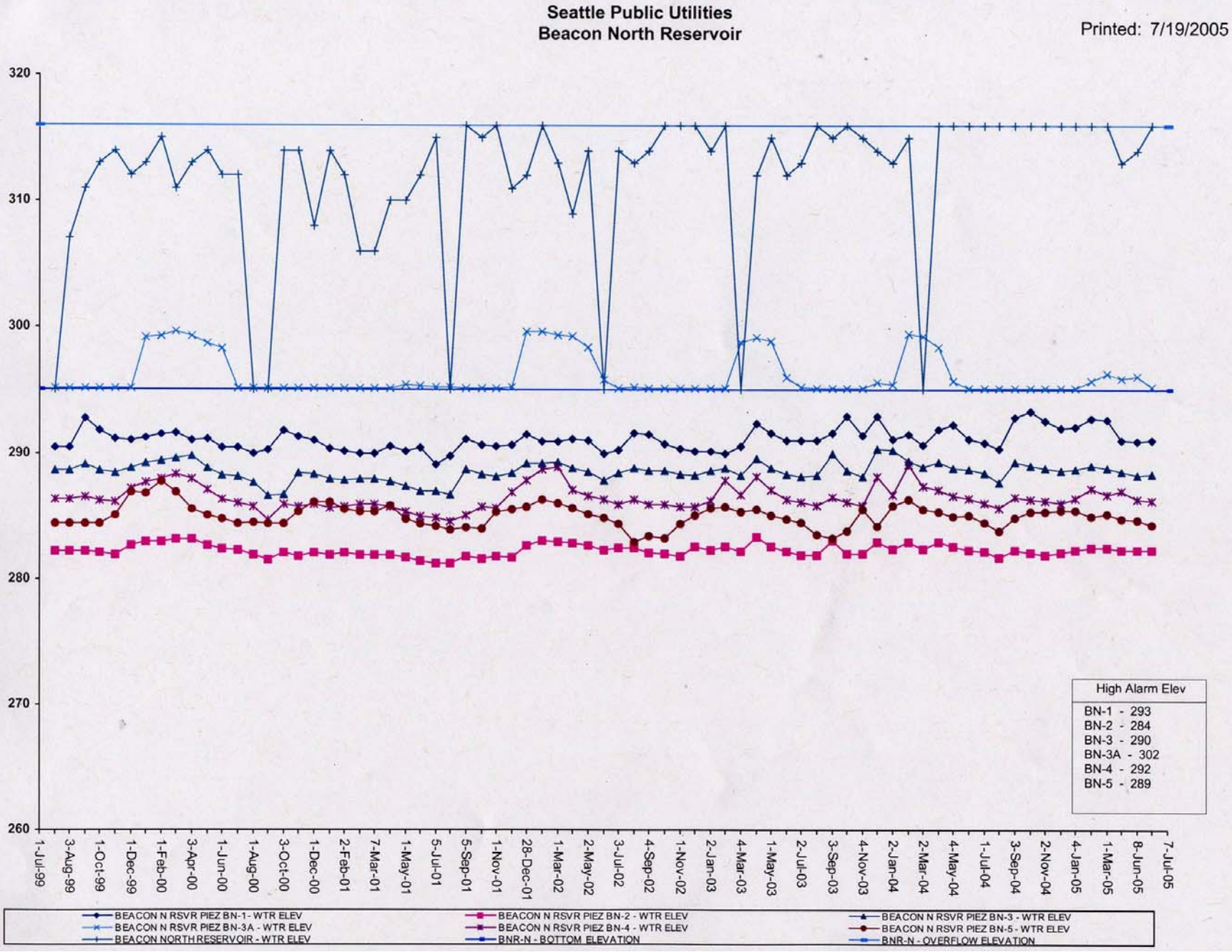

Figure 3 – Piezometer Data

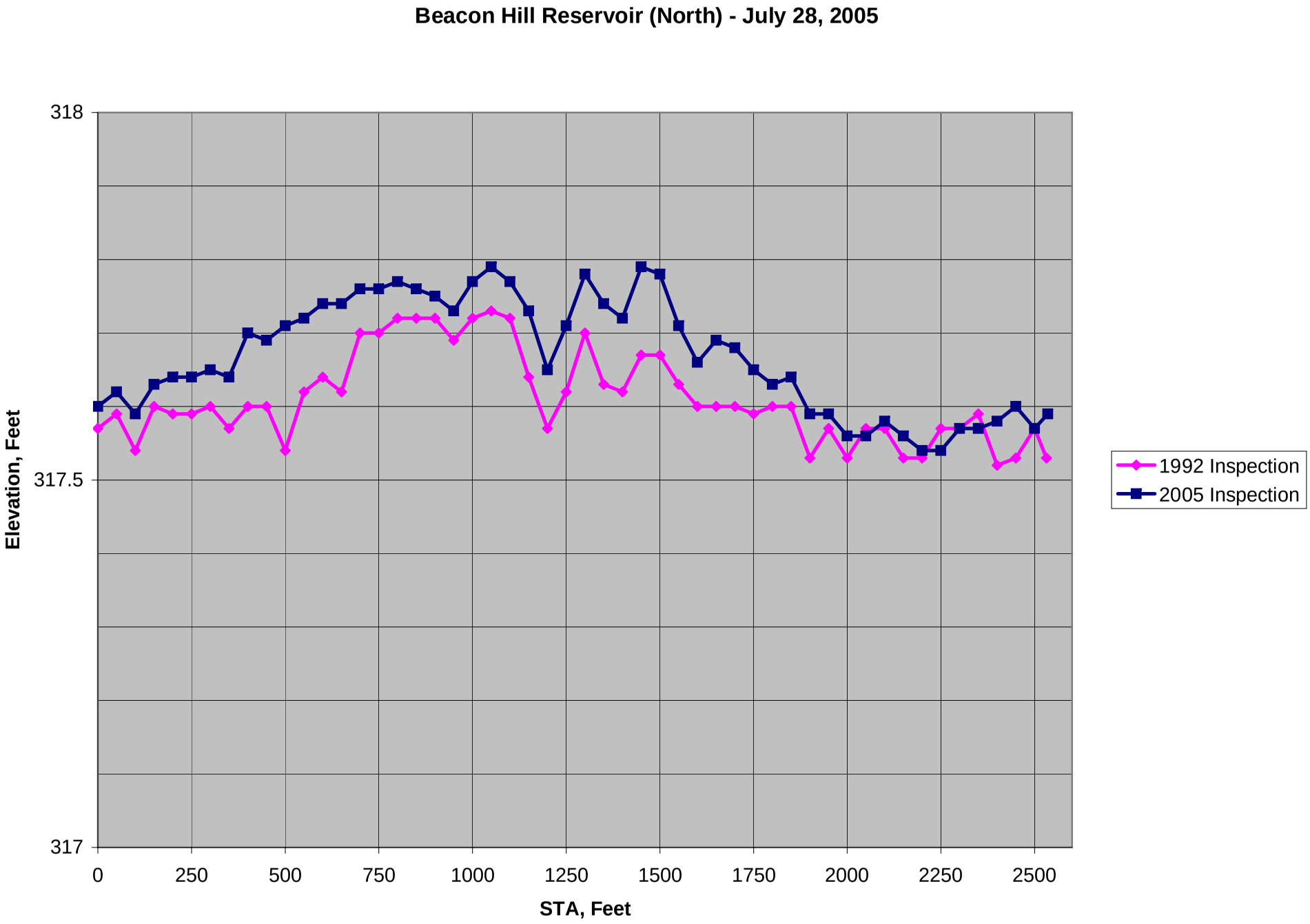

Figure 4 - Crest Elevation Survey

Appendix C - Photos

Photo 1 – West Embankment, Crest Inside Fence, Looking North

Photo 2 – West Embankment, Crest outside fence, Looking North

Photo 3 – North Embankment, Crest, Inside Fence, Looking East

Photo 4 – North Embankment, Liner At Crest, Looking East

Photo 5 – East Embankment, Crest, Outside Fence, Looking South

Photo 6 – North Embankment, Crest, Outside Fence, Looking West

Photo 7 – West Embankment, Crest, Outside Fence, Looking North

Photo 8 – West Embankment, Crest, Outside Fence, Looking South

Photo 8 – West Embankment, Toe of Slope Looking North

Photo 10 – West Embankment, Toe of Slope, Near NW Corner, Looking North

Photo 11 – North Embankment, Toe of Slope Looking West

Photo 12 – East Embankment, Toe of Slope Looking South

Photo 13 – East Embankment, Toe of Slope Looking North

Photo 14 – Reservoir Overflow (Service Spillway), Near SW Corner

Photo 15 – Singed Liner, Likely From Weed Control Using Flame Device

Photo 16 – Flame-Damaged Liner

Photo 17 – Apparent Settlement At Overflow Pipe, Cracked Sidewalk

Photo 18 – Settlement At Overflow Pipe, Cracked Sidewalk, Side View

Photo 19 – Apparent Settlement , Cracked Parapet Wall At Overflow

Photo 20 – Second Cracked Parapet Wall At Overflow

Appendix D

Owner Interview Form

Beacon Hill (North)Reservoir

STATE OF WASHINGTON
DAM SAFETY OFFICE
PERIODIC INSPECTION PROGRAM

OWNER/OPERATOR INTERVIEW

PROJECT NAME: Beacon North **DSO FILE NO.:** _____

DATE OF INTERVIEW: 08/05/05

INSPECTION TEAM MEMBERS: _____

OWNERS REPRESENTATIVES INTERVIEWED: _____

1. NORMAL OPERATING PROCEDURES

A) Operation Plan for Facility

- Is there a formal (written) plan/procedure?
- If not, what procedures are there for operating dam and reservoir

Yes

B) Seasonal Reservoir Operation

- When is reservoir normally filled?
- When is reservoir drawn down?
- What is operation of reservoir keyed to? (E.g. staff gage)

The rsvr. is normally with water all the time except during cleaning periods.

F) **Seepage observations**

- Seasonal seepage characteristics (reservoir level)
- Internal drainage outlet flow - seasonal characteristics
- Wet spots on downstream face or toe (seasonal)

No seepage or wet spots

G) **Measurements taken at dam site (if any)**

- Piezometer levels
- Reservoir pool levels
- Seepage quantities
- Survey monuments
- Reservoir inflow/outflow measurements (cfs)

Piezometers, Rsvr. pool level, reservoir inflow & outflow
The piezometer & subdrain readings are taken once a month.

H) **Maintaining Records**

- Normal recording (reservoir levels, inflow, outflow, maintenance work, etc.).
- Unusual observations recorded?

Daily reservoir levels, inflow, outflow

2. UNUSUAL CONDITIONS OBSERVED

A) **Maximum historic reservoir pool level (ft)**

- Stoplog/gate operation at time

B) Maximum inflow/outflow during floods

- Typical climatic conditions during floods (rain, rain on snow, snowmelt, thunderstorms etc.)

C) Maximum rainfall, an/ord snowpack observed

- Time period
- Duration on ground

E) Past Deficiencies Observed on Dam/abutments

- Slumping or slides, abnormal seepage or wet areas, settlement, animal burrows, cracking etc.

No deficiencies observed

F) Toe drain and other internal drainage outlets(if applicable)

- Cloudy drainage
- Unusual flowrate
- Obstructions

There is a subdrain system. Clean flow

G) Outlet conduit

- Unusual seepage
- Obstructions
- Settlement

No problems.

H) **Spillway**

- Erosion
- Performance during floods
- Debris problems during past floods

Working fine

I) **Mechanical and electrical systems (if applicable)**

J) **Reservoir rim stability problems**

Small concrete disaligment above overflow pipe.

K) **Other noteworthy problems identified by owner/operator**

3. HISTORY OF PROJECT

A) **Dates of construction**

1908/10

B) **Significant events/problems during construction**

None Kwown.

C) **Any modifications to original structure?**

Relined with Hypalon in 1980

D) **Any repairs to original structure?**

None

E) **Any recent or proposed downstream homes or other development? (for downstream hazard rating)**

None known.

4. MAINTENANCE ACTIVITIES / INSPECTION PROGRAM (BY OWNER)

A) **Are maintenance and inspection activities contained in a formal, written plan?**

Yes

B) **What elements are maintained, and how often is maintenance perfomed?**

Vegetation → anually or as required

Liner → anually or when rsvr. is empty.

Borrowing animals → as required.

Parapet wall → as required

Erosion controls → as required Piezometers/subdrain → monthly.

D) **Who is responsible for maintenance?**

The maintenance staff.

E) **Noteworthy maintenance problems**

- Recent repairs to embankment, spillway?
- Operational problems with gates, valves, etc.
- Animal Burrows?

None

F) **How often is project inspected?**

- Type of inspection
- What is inspected?
- Who performs inspection?

- Once or twice a year.
- Inspection covers: inside/outside slopes, liner, crest, values parapet wall alignment.
- Dam Safety Engineer

5. **EMERGENCY PROCEDURES**

A) **Is there a formal (written) Emergency Action Plan (EAP)?**

Yes

B) **If not, what would be your normal procedure for handling an emergency event (i.e., earthquake, flood, unusual seepage, etc.)?**

C) **Who would be responsible for action during emergency?**

Observer, Water System Operator, to initiate any action.

D) **Who would be notified in event of emergency?**

SPU Response Team.

C) **Normal maximum reservoir pool elevation**

- Datum / reference elevation
- Approximate time of year

Maximum = 316 ft. → City of Seattle Datum

D) **Normal minimum reservoir pool elevation**

- Datum / reference elevation
- Approximate time of year

Minimum = 295 ft. → City of Seattle Datum

E) **Dam Tender / Operator**

- Who is responsible for operation and control of keys, actuating mechanisms?
- When is operator on site?
- Where is residence/location of operator?

Water System Operators at Operations Control Center (OCC).
The operators are 24hrs/7 days

D) **Spillway operation**

- Stoplog placement/gate operation procedures (if applicable)
- Are gates periodically operated or "bounced" with auxiliary control mechanism?
- Seasonal frequency of spillway flows (all year, winter, summer, etc.)

When we need to improve the water quality

E) **Outlet Works Operation**

- Seasonal water releases
- How are outlet works operated?

Daily water release
Outlet value is manually operated

E) **Are emergency procedures and backup systems tested?**

No

6. OTHER PROJECT SPECIFIC QUESTIONS TO BE ASKED