Madsen Creek

West Basin Water Quality Improvement Engineering Design Report

November 2002

KING COUNTY

Department of Natural Resources and Parks
Water and Land Resources Division
Capital Projects and Open Space Acquisitions Section
201 South Jackson Street, Suite 600
Seattle, Washington 98104-3855

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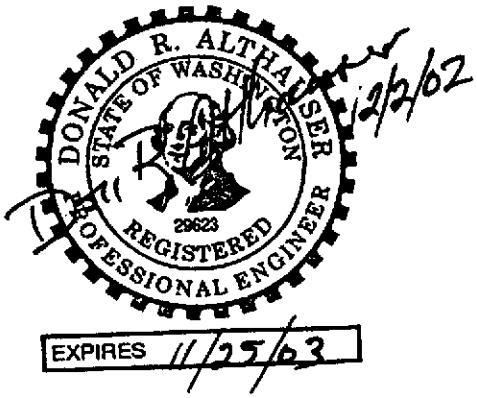
Prepared for:

Washington State Department of Ecology
Water Resources Program
Dam Safety Office



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Section 1: Project Overview

1.1 Project Background

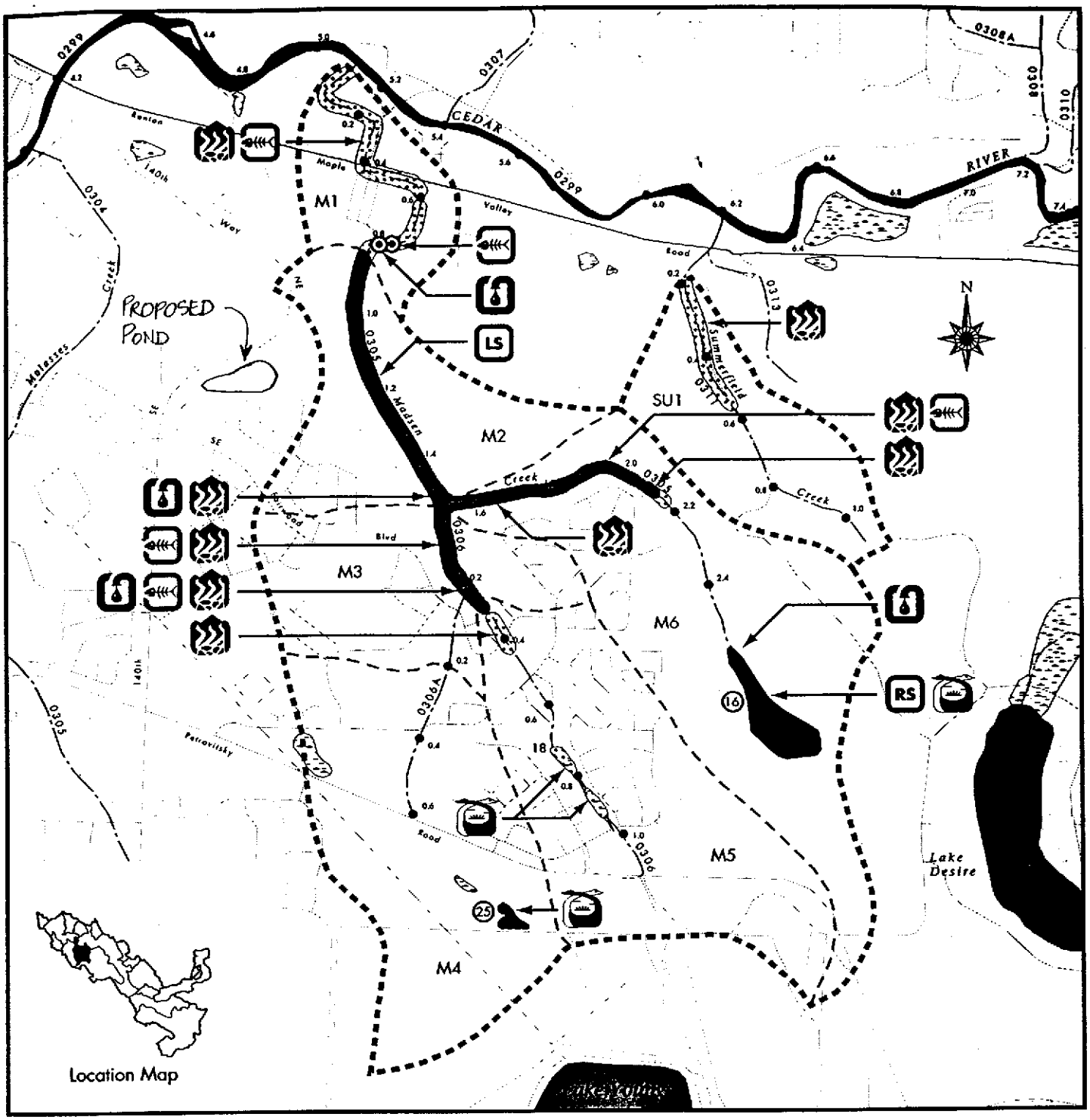
The Madsen Creek Subbasin, shown in Figure 1.1.1, has experienced significant urban development over the last 40 years. This development has taken its toll on both habitat and the natural drainage systems, resulting in flooding and erosion on a regular basis throughout the basin. In April 1986, the King County Council adopted Resolution 6018, forming the Basin Reconnaissance Program. This program called for the reconnaissance and evaluation of drainage basins within King County to identify and assess drainage problem areas. The *Cedar River Basin Current & Future Conditions Report* was completed by the County in April 1993. The report provided a comprehensive assessment of the condition of Cedar River Basin. Degradation of conditions of Madsen Creek, a tributary of the Cedar River, is brought on mainly by large areas of impervious surfaces that generate high flows, resulting in severe erosion and sedimentation of the natural drainage system. Habitat within Madsen Creek has also been damaged, or destroyed, due to degradation of water quality, loss of vegetation, and the filling of wetlands.

A King County study team outlined measures in the *Cedar River Draft Basin and Nonpoint Pollution Action Plan* to mitigate current and future flooding and habitat problems. One of the key elements of their report identified measures to mitigate present damage by establishing a number of regional detention and water quality facilities within the basin to filter pollutants and sediments, stabilize large organic debris and streambed loads, and reduce peak flow conditions within the stream systems. One of the regional detention facility projects proposed for the Lower Cedar River Basin is the Bonneville Power Administration (BPA) Madsen Creek Pond facility.

1.2 Project Description

The King County Department of Natural Resources and Parks proposes to construct a 28-acre-foot detention and water quality facility. The construction will consist of two cells, a control outlet structure and conduit system, an emergency overflow structure, a drain valve, a 25-foot-wide emergency spillway, and a 9.5-foot-high berm along the north perimeter of the pond. The pond will provide 2.5 feet of dead storage for water quality and incorporate vegetation for habitat. Construction of the pond will also include installing 100 feet of a high-density solid wall polyethylene (SWPE) pipe near the outlet in preparation of possible future construction. Possible future construction would encompass tying into the SWPE line with additional SWPE pipe and structures to direct the flows overland if further degradation of Northwest ravine continues.

The pond will provide detention and water quality treatment for a drainage area of 67.5 acres. The pond will be located east of 140th Way Southeast and north of Southeast 162nd Place, on property owned by King County but within a 650-foot-wide BPA right-of-way. The project site is located in Section 27, Township 23, and Range 5 East, as shown in Figure 1.2.1.

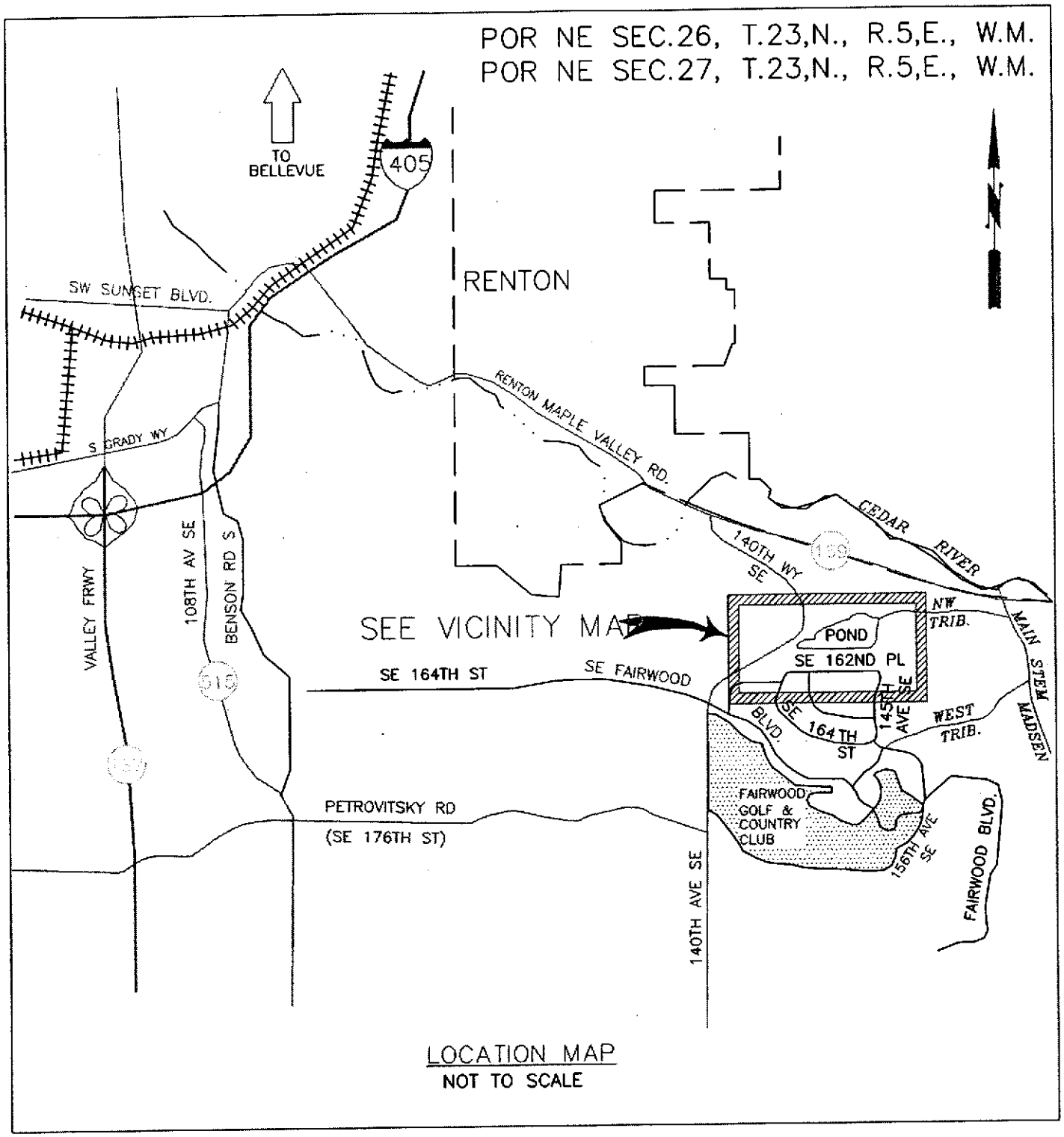


Madsen Creek & Summerfield Subbasin Conditions *Map*

Cedar River Basin Planning Area

- 0299 Stream & Stream Number
- Lake/River
- 3.6 Stream Mile
- 5 Wetland & Wetland Number
- (5) Class I Wetland & Number
- Subbasin Boundary
- Catchment Boundary
- M1 Catchment Number
- Problem Location/Area
- Areawide Nonpoint Water Quality Problem
- Wetland Habitat Problem
- Stream Habitat Problem
- LS Locally Significant Resource Area
- RS Regionally Significant Resource Area
- Erosion/Sedimentation
- Flooding

0 ¼ ½ Mile



MADSEN CREEK
WEST BASIN WATER QUALITY IMPROVEMENT

FIGURE 1.2.1

1.3 Facility Design Standards

County design criterion for the development of regional detention facilities provides for optimizing peak flow reduction and duration and habitat enhancement through stormwater detention. The pond design closely follows the guidelines set forth in the 1998 *King County Surface Water Design Manual.*

At the crest of spillway, the total impoundment volume of Madsen Creek Pond is approximately 28 acre-feet. This includes 2.13 feet of freeboard above the water surface elevation of the 100-year storm event. The Dam Safety Regulations are applicable to dams that can impound a volume of 10 acre-feet or more of water above natural ground as measured at the dam crest elevation. This project proposal falls under the jurisdictional threshold and is therefore subject to the requirements of the Washington State Department of Ecology (WSDOE) *Dam Safety Guidelines.*

1.4 Facility Classification

The height of the impounding barrier is 9.3 feet. Based on Table 1: Dam Size Classification of the *Dam Safety Guidelines* (Appendix A), the height of the embankment is less than the 15-foot threshold. Thus, the dam size classification is small.

The purposes of the pond are to detain flow and provide water quality treatment for runoff generated from 67.5 acres of a high-density residential area. Based on Table 2: Reservoir Operation Classification of the *Dam Safety Guidelines* (Appendix A), the reservoir operation classification of the pond is a permanent pool. The determining factor is a permanent dead storage pool of 2.5 feet for water quality.

1.5 Permits

The purposes of the pond are to detain flow and provide water quality treatment. A State Environmental Policy Act process was initiated in February 2001. A King County grading permit was issued for Phase I of the pond construction. Phase I work includes building a refueling road, preparing the site (mowing), and installing a gate at the access road. These activities were completed in 2001. Issuance of a grading permit for construction of the pond berm is contingent on receiving a dam safety permit.

Section 2: Hydrologic and Hydraulic Analysis

In February 2000, a King County study team outlined several measures in the *Madsen Creek Tributaries Stabilization and Enhancement Proposal.* The proposal presented design concepts to reduce erosion, improve water quality, and enhance fish and stream habitat. One concept includes constructing a pond for detention and water quality at a location, as shown in previous Figure 1.2.1.

The project proposes to detain and treat runoff from a contributing area of 67.5 acres. The proposed pond will decrease flow rates below those that existed in pre-development, forested conditions. The 67.5 acres is comprised of two subbasins, 19 and 15, as identified in Appendix F. Flows from the subbasins are inadequately detained, with no water quality facilities before joining with Madsen Creek. Runoff from subbasin 19 flows into the northwest tributary of Madsen Creek. Runoff from subbasin 15 currently flows into the west tributary of Madsen Creek.

The west tributary has suffered damaging effects of inadequately controlled runoff. The proposal is to redirect flows of subbasin 15 through a new bypass line northwesterly to the proposed new combination water quality and detention pond. From there, the flows will be directed to Madsen Creek from the northwest tributary basin area. Table 2.1 below lists the pre-developed and existing land use and acreage attributed to each subbasin.

Table 2.1 LAND USE HYDROLOGIC DATA

Basin	Sub-basin	Description	Pre-Developed (Ac)	Developed (Existing) (Ac)		
			Pervious Till Forest	Pervious Till Grass	Impervious	Total
Northwest Tributary	19	High-Density, Single-Family Residential	43.12	31.53	11.59	43.12
West Tributary	15	High-Density, Single-Family Residential	24.40	14.15	10.25	24.40
Total			67.52	45.68	21.84	67.52

The values listed above were used to determine the runoff events and the volume generated by the existing conditions such that the pre-developed conditions could be matched.

The analysis was determined using the King County Runoff Time Series (KCRTS) hydrological modeling program. The KCRTS program was developed as a hydrologic modeling tool for western King County. The program uses a set of files containing unit-area continuous runoff records ("runoff files"). The runoff files have been pre-simulated for a range of landcover conditions and soil types for different regions of King County using the U.S. Environmental Protection Agency's Hydrological Simulation Program-Fortran (HSPF)-10 model. The calibration of the HSPF-10 model was performed using regionalized parameters developed by the U.S. Geological Survey and King County Basin Planning. The KCRTS program allows the user to simulate the project hydrology through scaling, summing, lagging, and level-pool routing of the runoff files.

The pond is designed to a Level 3 standard, in accordance with the requirements set forth in the 1998 *King County Surface Water Design Manual*. This level requires maintaining the durations of high flows at their pre-development level for all flows greater than 50 percent of the 2-year flow up to the 50-year flow and holding the 100-year peak flow rate at its pre-development level. This standard also maintains the pre-development peak flow rates for the 2-year and 10-year runoff events. In doing so, it provides additional storage and increases the detention time to minimize downstream impacts.

The pond was designed to maintain storm durations and match pre-developed peak flows for combined Basins 15 and 19 in pre-developed conditions. Table 2.2 below lists the amount of flow for the 2-year, 10-year, and 100-year event for existing and pre-developed conditions and the discharge flow from the proposed pond.

Table 2.2 FLOW RATES (cfs)

	Condition	2-yr	10-yr	25-yr	100-yr	Volume (ac-ft)	
						Req'd	Available
Basin 19 & 15 (combined)	Developed (Existing)	7.82	9.85	11.47	19.97		
	Pre-Developed	1.87	3.27	4.26	5.45		
	Pond Discharge	1.00	2.91	3.51	5.45	14.5	15.5

Discharge flows from the pond are released at or lower than the pre-developed flows obtained from the KCRTS model. Data output from the modeling program listed in Appendix F shows that the flow durations are also maintained.

Designing a pond to accommodate flows from Basin 15 and 19 in developed conditions yet maintaining durations and matching peaks for Basin 19 in pre-developed conditions as the pond function would require a pond approximately 30 acre-feet. Pond size and depth was limited to site constraints and safety. The proposed pond will hold approximately 28 acre-feet. This includes 2.2 acre-feet for water quality, 15.5 acre-feet for detention, and 10.1 acre-feet to adequately address the Intermediate 6-hour precipitation, 1,000,000-year storm event, and freeboard requirements.

Section 3: Geological Analysis-Summary

In August 2002, a Shannon & Wilson, Inc. Geotechnical Report, *Madsen Creek Detention Pond King County, Washington* was submitted. The report described the geological and subsurface conditions of the project site and provided analysis of the proposed pond design. The report also provided recommendations for its construction.

The project proposes to excavate native material and use this material to construct a north perimeter embankment for the pond. The embankment will also serve as an access road. The embankment will be approximately 775 feet in length and 20 feet in width. It will have side slope inclination of 6H:1V inside from elevation 436 feet to 441 feet and a slope inclination of 4H:1V from elevation 441 feet to the dam road top, 444 feet. The downface slope will be 3H:1V. Construction of the pond will include lining the pond with a geosynthetic clay liner to provide a more impervious quality of the berm. The drainage system of the pond will consist of flow control and overflow structures and appurtenances and a spillway.

The soil conditions of the proposed pond location have been determined to be deposits of Recessional Outwash (Qvro) at the ground surface in several places and near the ground surface. Vashon Ablation Till (Qvat) underlies a surficial layer of recessional outwash. Ablation Till was found at shallow depths in the western half of the site. To the east, it was found in sporadic locations at greater depths. Underlying the Ablation Till and Recessional Outwash deposits are additional deposits of very dense sand, most likely to be Advance Outwash (Qva). It is the opinion of the report that the native material is acceptable for the embankment, provided the criteria outlined in the report by Shannon & Wilson is met.

The geotechnical report is submitted with this document to provide the Dam Safety Office an overall engineering assessment of the pond design.

Section 4: Dam Safety Analysis

A dam safety analysis was completed in accordance with the WSDOE *Dam Safety Guidelines*. The dam safety analysis was divided into four steps:

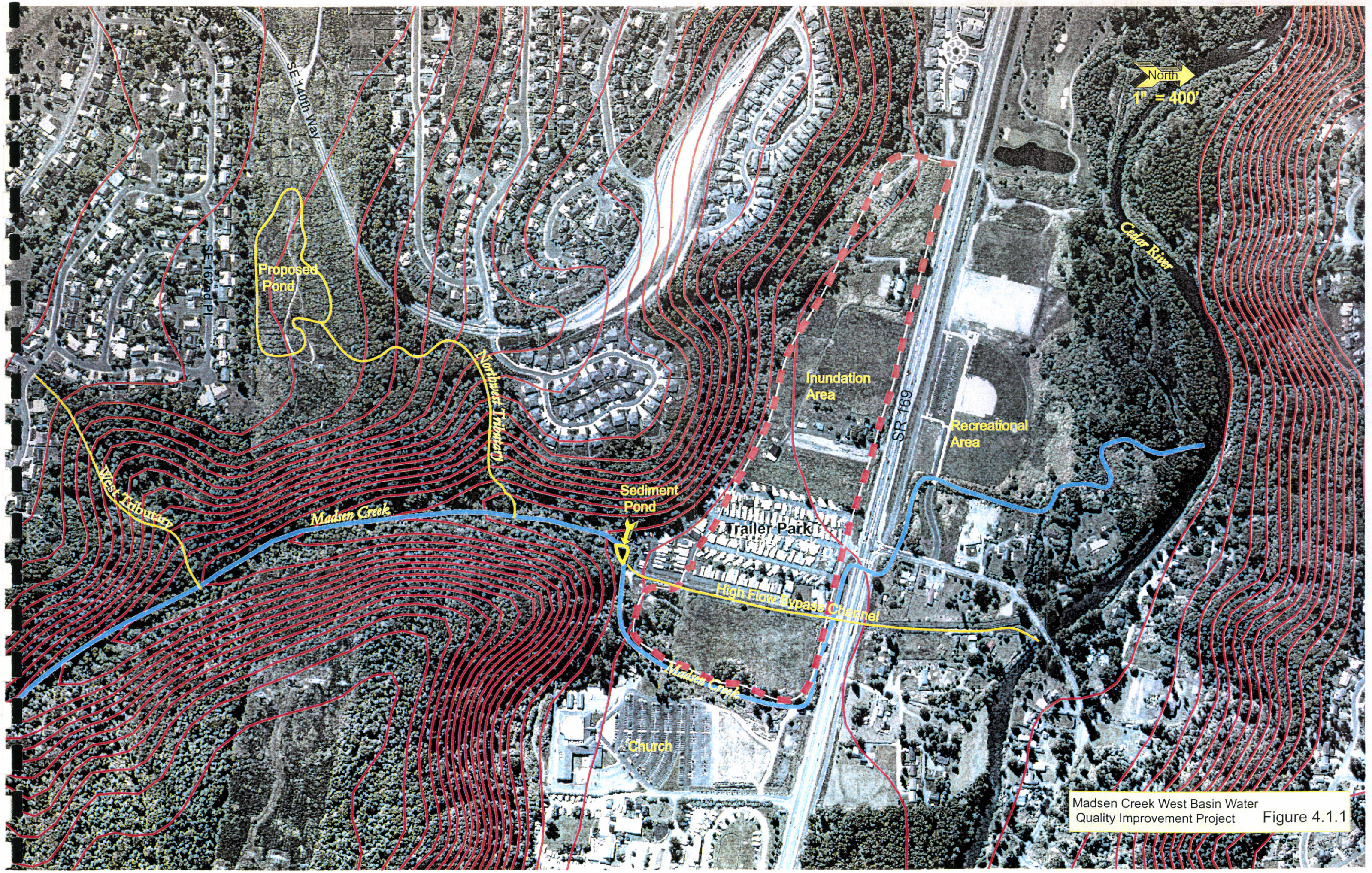
- Downstream Hazard Classification
- Design Level Determination
- Dam Break Inundation Analysis and Flood Routing
- Engineering Calculations

4.1 Downstream Hazard Classification

The first phase of the Dam Safety analysis is classifying the potential downstream impacts in accordance with Table 3: Downstream Hazard Classification of the *Dam Safety Guidelines* (Appendix A).

The project proposes to construct the detention and water quality pond, east of 140th Way Southeast and north of residential homes of Southeast 162nd Street, on property owned by King County but within a 650-foot-wide Bonneville Power Administration right-of-way (Figure 4.1.1). The outlet will be located at the northeast area of the pond and will discharge its flows easterly onto a 100-foot-constructed, rock-lined streambed channel. It will then turn and flow in a northerly direction into an existing channel known as the Northwest Tributary. The Northwest Tributary flows 700 feet north before making a bend to the east. It then flows 800 feet in an easterly direction and converges with the main channel of Madsen Creek. Madsen Creek then continues approximately 500 feet in a northerly direction down the ravine. At the base of the ravine is a 1.15-acre-foot sedimentation pond with a high flow by-pass channel. Madsen Creek flows 500 feet east from the sedimentation pond before turning north toward State Highway 169, approximately 1,000 feet away. The creek then turns west, parallel with State Highway 169 approximately 700 feet before flowing north through a box culvert 130 feet long, 6 feet wide, and 3 feet high. Madsen Creek turns west and is conveyed under Jones Road, 200 feet away. It continues 300 feet west and turns north toward the Cedar River approximately 1,500 feet farther at River Mile 5.0.

A residential development is located 600 feet northwest of the project site; 140th Way Southeast separates the project site from the residential development area. It is unlikely that the area would encounter any flooding from a dam failure because the road is elevated and acts as a berm. There are no residences from the pond outlet to the bend of the Northwest Tributary and from its convergence with Madsen Creek. Three hundred feet north of the Northwest Tributary and 450 feet west of Madsen Creek is a residential area. It is situated high above the Northwest Tributary and Madsen Creek ravines. This area would not encounter any flooding from a dam failure, though it could possibly suffer some encroachment of erosion at its southernmost boundary from the Northwest Tributary and its easternmost boundary from Madsen Creek.



Madsen Creek West Basin Water Quality Improvement Project Figure 4.1.1

From the convergence with Madsen Creek to the sedimentation pond, there are no residences. However, a sewer line is located in the vicinity of the Madsen Creek Ravine. The sewer line runs parallel with Madsen Creek and has suffered damage from previous storms. There is a proposal to abandon the line. Just north of the sedimentation pond is a 9-acre mobile home trailer park with more than 100 homes. This area has suffered sedimentation damage due to overflows caused by inadequate channel capacity of Madsen Creek. As a result, a 0.9-acre-foot sedimentation pond with a high flow by-pass was constructed in 1974. In 1995, the embankment between the pond and the mobile home trailer park was raised to provide additional protection, thus increasing the pond size to 1.15 acre-feet.

A church is located 1,000 feet east of the sedimentation pond. It is unlikely it would sustain severe damage from a possible dam break because it is situated at a higher elevation than the creek.

A recreational field is located west of Madsen Creek as the flows continue north toward the Cedar River. There is approximately a 5-acre area to which flows from Madsen Creek could be spread as it makes its way through the highly vegetated corridor to converge with the Cedar River. This is not likely, given that the high-flow by-pass system at the sedimentation pond will convey most of the flows from a possible pond failure.

It is anticipated the high flows from a dam failure would be conveyed 2,000 feet north to the Cedar River from the sedimentation pond via the high flow by-pass system. High flows at the sedimentation pond enter the by-pass open channel through a box culvert 40 feet long, 12 feet wide, and 3 feet high. The capacity of the box culvert is estimated at 250 cubic feet per second. The by-pass open channel system is approximately 5 feet wide at the bottom, 15 feet wide at the top, 6 feet deep, and approximately 1,000 feet in length. The flows from the channel are then conveyed through another box culvert 8 feet wide by 6 feet high under State Highway 169. The capacity of the culvert is estimated at 415 cubic feet per second. North of State Highway 169, the size of the high flow by-pass open channel system increases to approximately 14 feet wide at the bottom, 35 feet wide at the top, and 9 feet deep. The high flow by-pass system would reduce the extent of damage to the church and its parking lot. North of the highway, there are several homes on both sides of the high flow by-pass, but the homes are situated at a higher elevation than the by-pass system and are protected by a levee. These homes are more likely to sustain flooding from the Cedar River than from a dam failure.

The area most likely to be affected would be the trailer park and the surrounding fields south of State Highway 169. This computes to approximately 38 acres. Inundation from a possible dam break failure would be approximately 8 inches throughout this area. State Highway 169 would not sustain overtopping of its roadway because it is at least 2 feet higher than the trailer park and the fields.

A preliminary assessment downstream of the project site reveals that the Downstream Hazard Classification is 1A. Factors based on this assessment include more than 100 inhabited structures, at least 300 people at risk, and the severity of water quality degradation.

4.2 Design Level Determination

The second phase of the Dam Safety analysis consisted of an assessment of the consequences associated with dam failure. The design level was determined using the DOE Dam Safety Section's Worksheet (Appendix A) for estimating the minimum design level. The worksheet is divided into three categories: Capital Value of Project, Population at Risk, and Downstream Property at Risk. Each category has several sections that receive numerical weightings for assessing the consequences of dam failure.

The Capital Value of Project is based on two parts: the Dam Height Index and the Value of Reservoir Contents. The height of the dam is 9.3 feet from the pond's base (elevation of 434 feet) to the spillway crest (elevation of 443.3 feet). This includes 2.13 feet of freeboard above the 100-year storm elevation. The assignment of rating points for items listed in the Value of Reservoir Contents is at the discretion of the owner. None of the items listed adequately described the contents of the pond. An adequate description of the pond's contents is detention and water quality while incorporating habitat. King County places great value on the construction of the pond for reducing the erosion of Madsen Creek generated from years of increased flows due to development. Therefore, an assignment of large values to the consequence rating points was made.

The second and third category, Population at Risk and Downstream Property at Risk, respectively, includes consideration of dam failure flow and the actual population and property that may be affected by a dam failure. A conservative approach for the BPA Madsen Creek detention facility was taken. The flow associated with a possible dam failure was estimated using the storage associated at the dam crest level. This is 2.13 feet above the 100-year water surface elevation, an additional 10.1 acre-feet of the volume stored above the 100-year water surface elevation. The calculation of the Population at Risk value also assumed the volume of water stored (approximately 27.8 acre-feet) is a result of the control structure and emergency overflow systems not functioning properly, or that the tops of the control structure and emergency overflow catch basins are blocked by impenetrable debris. This would allow the water to rise to the dam crest elevation of 443.3 feet. This is highly unlikely, given the fact the catch basins will each have a birdcage set on their top to allow water to be conveyed through the conduit system. However, if a dam failure occurred under the stated circumstance, approximately 27.8 acre-feet of water would be released in a 40-minute period, resulting in an average flow of 535 cubic feet per second (cfs).

There are many residences downstream from the pond site, as shown in Figure 4.1.1. The population at risk from failure of a facility outlet structure is approximately 300 to 600. The property downstream of the facility that may be at risk from an outlet structure failure includes residences, a church, and roads. As shown in Figure 4.1.1, a mobile trailer park with over 100 trailer homes would sustain some damage due to dam failure. Another property at risk is a church located a few hundred feet east of the trailer park. The only major road at risk from a dam failure is Highway 169, approximately one mile downstream of the project site. The possibility of the roadway being washed out is highly unlikely. There is considerable environmental degradation that would occur if the dam failed. However, the primary reason for construction of the pond is to reduce the substantial degradation of the

creek that has occurred from years of increased flows due to development of which the trailer park has suffered its effects.

A summary of the worksheet that shows the relationship between the rating point system and the design level is located in Appendix B. The dam safety rating point total for the dam safety rating for the BPA Madsen Creek Pond has been estimated to be 715, resulting in the maximum design level of a 1,000,000-year return interval.

4.3 Dam Break Inundation Analysis and Flood Routing

A dam break inundation analysis was performed using seven spreadsheets developed by the Dam Safety Office. This is an estimation of the magnitude of the dam break flood resulting from hypothetical dam failures occurring with the reservoir at normal storage elevation and maximum storage elevation. Normal storage elevation is 436.5 feet, but for the purposes of the analysis, the 100-year water surface elevation of 441.17 feet was used. The elevation crest of the berm, 443.3 feet, was designated as the maximum storage elevation.

The project proposes to construct the embankment with native till material, placed as outlined in the geotechnical report, and overlaid with Bentonite blankets. This use of materials is similar to a combination of cohesionless materials and resistant materials. The values listed in the spreadsheets were provided only for use of either cohesionless material or resistant material. A conservative approach was taken, and it was assumed the material used to construct the embankment would be cohesionless and that the estimated side slope of a breach would be 1.

The first spreadsheet, Break–1, developed hydrographs for pipe failure and overtopping when a breach is constrained. The spreadsheet uses the Breach Formation Factor equation. A conservative approach was taken by assuming that the control outlet structure, the emergency overflow structure and the drain valve were not functioning to release the water over time as designed, thus allowing the surface water elevation rise. The table below summarizes the maximum discharge, Q-peak, and times.

Table 4.3.1 BREAK–1 ANALYSIS

	Pipe Failure	Overtopping
Q-peak (cfs)	434	1067
T-peak (hr)	0.18	0.21
T-base (hr)	1.05	0.63

Break–2, the second spreadsheet, developed a hydrograph for a failure due to overtopping when a breach is constrained by other physical factors. This had produced similar estimates and a hydrograph to the values and hydrograph in Break–1.

Break–3 was used to revise the estimates for peak discharge and time of peak discharge by using a time-step computation. The estimates produced were lower than the values obtained

from Break–1 and Break–2. The table below compares the estimates obtained from all three break analyses.

Table 4.3.2 FAILURE DUE TO OVERTOPPING

	Break–1	Break–2	Break–3	Break–4	Break–5
Q-peak (cfs)	1067	1063	985	1070	1070
T-peak (hr)	0.21	0.21	0.21	0.21	0.21
T-base (hr)	0.63	0.63	0.68	0.63	*

* The T-base (hr) for Break-5 is exponential; therefore, no value was inserted.

Break–4 developed a triangular hydrograph of a dam breach due to overtopping. It was developed by setting the hydrograph volume equivalent to the reservoir volume at the time of a breach. A conservative approach was taken. The reservoir volume was set at 27.8 acre-feet. This is assuming that the control outlet structure, the emergency overflow structure, and the drain valve are not functioning, and thus allowing the normal surface water elevation of 437 feet to rise above the 100-year surface water elevation 441.17 feet to the dam emergency spillway elevation of 443.3 feet.

Break–5 had a similar approach to Break–4, but developed an exponential hydrograph of a dam breach due to overtopping. The hydrographs of all these break analyses are found in Appendix B.

The Q-peaks estimated are based on a conservative approach by assuming the embankment to be constructed is of cohesionless material. Q-peaks estimated from assuming resistant material would be considerably lower and may be more reflective of the characteristics of a possible failure of the BPA pond. The estimations were also compared with Table 4A and 4B of the *Dam Safety Guidelines—Technical Note 1*. These tables and spreadsheets can be found in Appendix B.

Two flood analyses were performed using spreadsheets developed by the Dam Safety Office. The estimated peak discharge assigned for the Flood analysis used values obtained from Break–4 and Break–5. Flood–1 is an analysis of the flood peak attenuation and flood wave travel time. Flood–2 is similar to Flood–1 and includes inundation depths. Both produced the hydraulic profile from the pond outlet to the convergence of Madsen Creek and the Cedar River. The point of interest is at the location of the sedimentation pond. The spreadsheets can be found in Appendix C.

4.4 Engineering Calculations

The Dam Safety Worksheet (Appendix B) calculated a total of 715 points. Design Step 8 is applicable to our project. Design 8 requires calculation of the Inflow Design Flow for a 1,000,000-year return interval to allow an analysis of the response of the reservoir and spillway to various flood characteristics.

The project lies in Region 3 (Appendix D). The pond is designed to detain and treat runoff from a contributing area of 0.11 square miles. No areal adjustments were needed to account for the storm spatial distribution based on Table 1 of *Technical Note 3*. Four candidate design storms were generated to describe the range of storm characteristics that affect flood peak discharge, runoff volume, and hydrograph shape. Table 4.4.1 below summarizes the Design Precipitation (Pd), calculated for the duration of 2, 6, and 24 hours. The spreadsheets, developed by the Dam Safety Office, can be found in Appendix D.

Table 4.4.1 DESIGN STEP 8 (Pd)

	Design Step 8			
	2–hour	6–hour	24–hour	
			Intensity	Volume
Design Precipitation, Pd (in)	3.90	4.40	9.62	9.62
Total Precipitation for Storm (in)	4.60	6.09	11.54	12.68

These values were then used in the King County HYD program in conjunction with the Region 3 spreadsheets for precipitation developed by the Dam Safety Office to create a storm data file. The files created were used to generate runoff hydrographs using the Santa Barbara Urban Hydrograph method. Table 4.4.2 below summarizes the values obtained for the 1,000,000-year storm event.

Table 4.4.2 DURATION PEAKS AND VOLUMES

Duration (hr)		Q-Peak (cfs)	T-Peak (hrs)	Total Volume	
				(cf)	(ac-ft)
2		189.81	1.50	1,020,113	23.42
6		87.49	13.67	1,305,927	29.98
24	Intensity	58.36	39.00	2,560,392	58.78
	Volume	51.97	39.00	2,851,883	65.47

Each of these storm events was then routed through the pond and its appurtenances to determine the peak outflow and peak elevation. The routine depicts how the pond attenuates flow from a hydrograph file.

Discharge from the pond below the 100-year storm event will be routed through the conduit system via the flow control structure. The conduit system includes 128 feet of 36-inch pipe and an energy dissipator.

Discharge from the pond above the 100-year storm will be routed through the same conduit system via the primary overflow structure. The elevation of the overflow structure is 441.17 feet. Table 4.4.3 summarizes the analysis. The design storm calculations and routing analysis are located in Appendix E.

Table 4.4.3 INFLOW/OUTFLOW						
Duration (hr)		Inflow (cfs)	Outflow (cfs)	T-Peak (hrs)	V-Peak (ac-ft)	Elevation (ft)
2		189.81	46.22	2.92	16.77	441.71
6		87.49	57.41	14.42	17.23	441.83
24	Intensity	58.36	55.19	39.00	17.14	441.81
	Volume	51.97	49.43	39.00	16.91	441.75

The controlling water level from the inflow design flood is based on the intermediate 6-hour precipitation storm. The water level is 441.83 feet. The dam crest elevation of the pond is 443.3 feet. This is a difference of 1.47 feet. The *Dam Safety Guidelines* requires 0.5 feet of Minimum Freeboard for small dams.

Normal Freeboard requires 2 feet of freeboard for small dams. The 100-year, normal water level is 441.17 feet. The difference is 2.13 feet from the dam crest level and the normal water level. The pond design meets the minimum requirements.

Further analysis is required to determine if additional freeboard is necessary to accommodate wind/wave action. A spreadsheet developed by the Dam Safety Office was used to calculate the freeboard. The calculations also made allowances for embankment settlement, design/ operation uncertainties, and geological hazards. Calculations determined that the total Normal Freeboard required is 0.66 foot and the Minimum Freeboard is 0.35 foot. These values are below the minimum requirements set by the Dam Safety Office. Below is a table summarizing the freeboard required and available for the pond.

Table 4.4.4 FREEBOARD SUMMARY					
	Dam Crest	Calculated Freeboard	Minimum Freeboard Req'd	Actual Freeboard	Difference
Normal WL = 441.17 ft	443.30 ft	0.66 ft	2.0 ft	2.13 ft	0.13 ft
Peak Stage WL = 441.83 ft	443.30 ft	0.35 ft	0.5 ft	1.47 ft	0.97 ft

The pond design has adequate freeboard with consideration of wind/wave action. Analysis can be found in Appendix D.

References

Adolfson Associates, Inc. *Madsen Creek Tributary Erosion Stabilization Projects Biological Assessment.* January 2001.

King County Department of Public Works. Surface Water Management Division. *Cedar River Basin Current & Future Conditions Report.* November 1993.

King County Department of Public Works. Surface Water Management Division. *Cedar River Draft Basin and Nonpoint Pollution Action Plan.* February 1995.

King County Department of Natural Resources. Water and Land Resources Division. *King County Surface Water Design Manual.* 1998.

King County Department of Natural Resources. Wastewater Treatment Division. *Madsen Creek Tributaries Stabilization and Enhancement Proposal.* February 2000.

Shannon & Wilson, Inc. *Geotechnical Report Madsen Creek Detention Pond.* July 2002.

Washington State Department of Ecology. Water Resources Program. *Dam Safety Guidelines.* July 1992.

Appendix A

Dam Safety Worksheet for Selection of Design/Performance Goals

Appendix A

Dam Safety Worksheet for Selection of Design/Performance Goals

WORKSHEET
DAM SAFETY GUIDELINES

SELECTION OF DESIGN/PERFORMANCE GOALS FOR CRITICAL PROJECT ELEMENTS

PROJECT NAME: Madsen Creek West Basin Water Quality & Detention Pond

DAM NAME: —

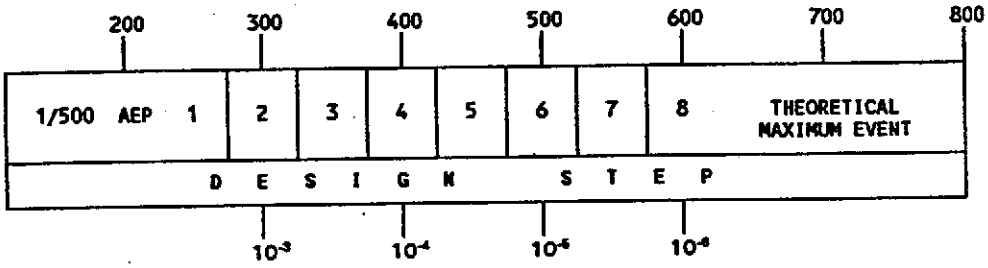
CONSEQUENCES EVALUATED FOR FAILURE OF North Perimeter Embankment (Access Rd)

AT RESERVOIR LEVEL OF 443.3 feet (dam crest level)

SUMMARY SHEET

		CONSEQUENCE RATING POINTS
I.	CAPITAL VALUE OF PROJECT	95
II.	POPULATION AT RISK	360
III.	DOWNSTREAM PROPERTY AT RISK	210
	BASE POINTS	150
	CUMULATIVE CONSEQUENCE RATING POINTS . . .	715

CUMULATIVE CONSEQUENCE RATING POINTS



DESIGN/PERFORMANCE GOAL - ANNUAL EXCEEDANCE PROBABILITY

DESIGN STEP NUMBER 8

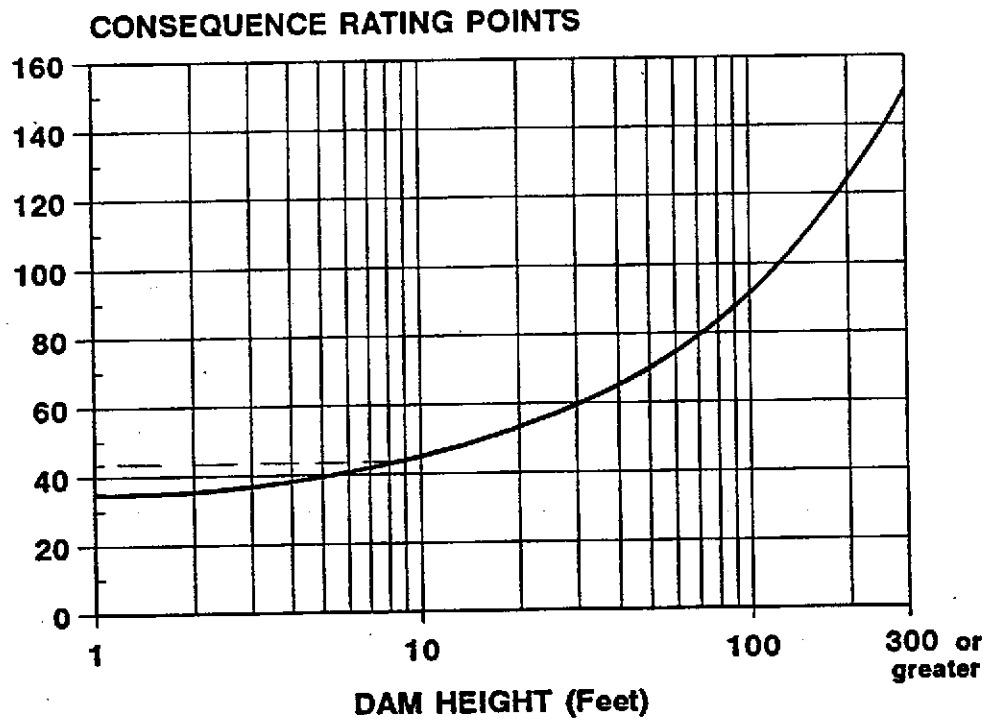
PROJECT ENGINEER Don Althauser DATE 11/26/02

I. CAPITAL VALUE OF PROJECT

A. DAM HEIGHT INDEX

	Dam Height (feet)	Consequence Rating Points
Maximum Dam Height	9.3	45

from pond bottom to crest



B. VALUE OF RESERVOIR CONTENTS/PROJECT BENEFITS

Mandatory Consideration for Some Projects	Points Per Item	Consequence Rating Points
1. Public Water Supply Storage	25 - 75	0
Discretionary Considerations		
2. Irrigation Water Supply Storage	10 - 75	0
3. Industrial Water Supply Storage	10 - 75	0
4. Hydropower Generation Facilities	10 - 75	0
5. Mining or Manufacturing Process Water	10 - 75	0
6. Aesthetics, Recreation or Wildlife Habitat	10 - 25	25
7. Other Detention + Water Quality Facility		25

Describe: Pond facility is approximately 28 ac-ft. 2 ac-ft is dead storage for water quality

Assignment of consequence rating points to dams which provide a community with a limited resource, such as a public water supply, is mandatory.

Assignment of consequence rating points to dams which provide benefits primarily to the owner, is at the discretion of the owner and/or project engineer.

A wide range of consequence rating points are possible for the various project benefits. Selection of an appropriate value should be based on the size and importance of the project benefit under consideration relative to the broad range of projects of that type. In addition, a larger or smaller value may be selected depending on the owner's and/or project engineer's perceived need for conservatism in protecting project benefits.

SUBSECTION I - SUBTOTAL OF CONSEQUENCE RATING POINTS 95

II. POPULATION AT RISK

A. CATASTROPHIC POTENTIAL INDEX

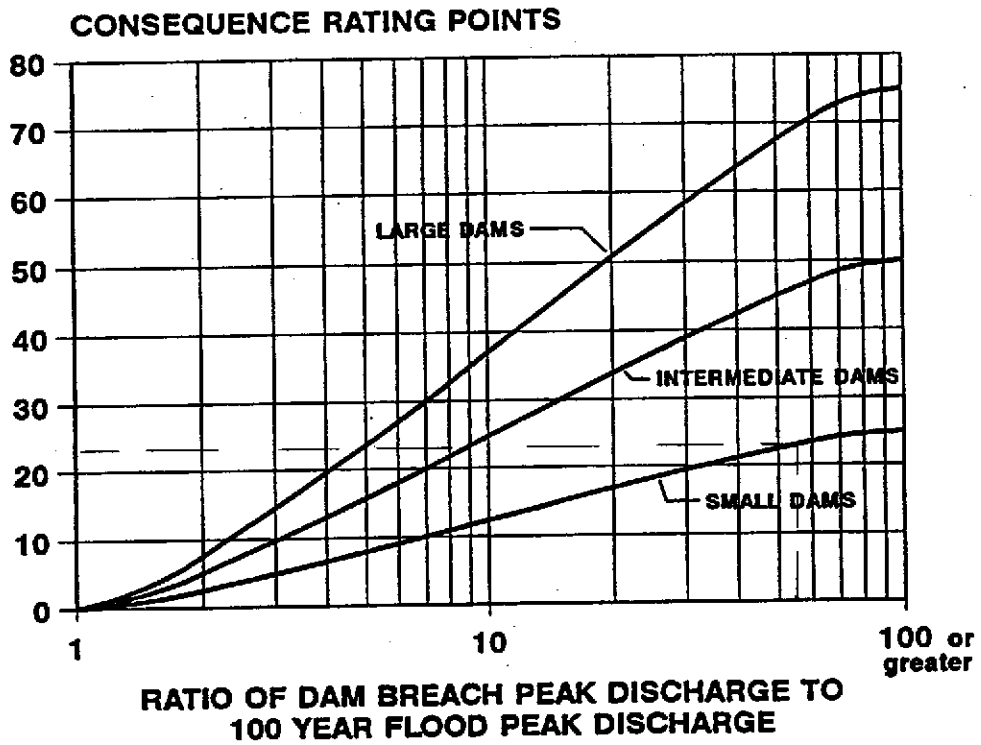
1. Estimated Dam Breach Peak Discharge at Dam Site due to Failure of Critical Project Element _____1069_____ cfs

2. Estimated 100 year Flood Peak Discharge _____20_____ cfs

Taken on a Natural Watercourse at First Location Downstream of the Dam Where There is a Potential for Loss of Life or

If There is No Downstream Development, It is Taken on the Natural Watercourse at a Point 1 Mile Downstream of Dam

	Index	Consequence Rating Points
3. Ratio of Dam Breach Peak Discharge to 100 Year Flood Peak Discharge	$\frac{1069}{20}$ = 53.5	25

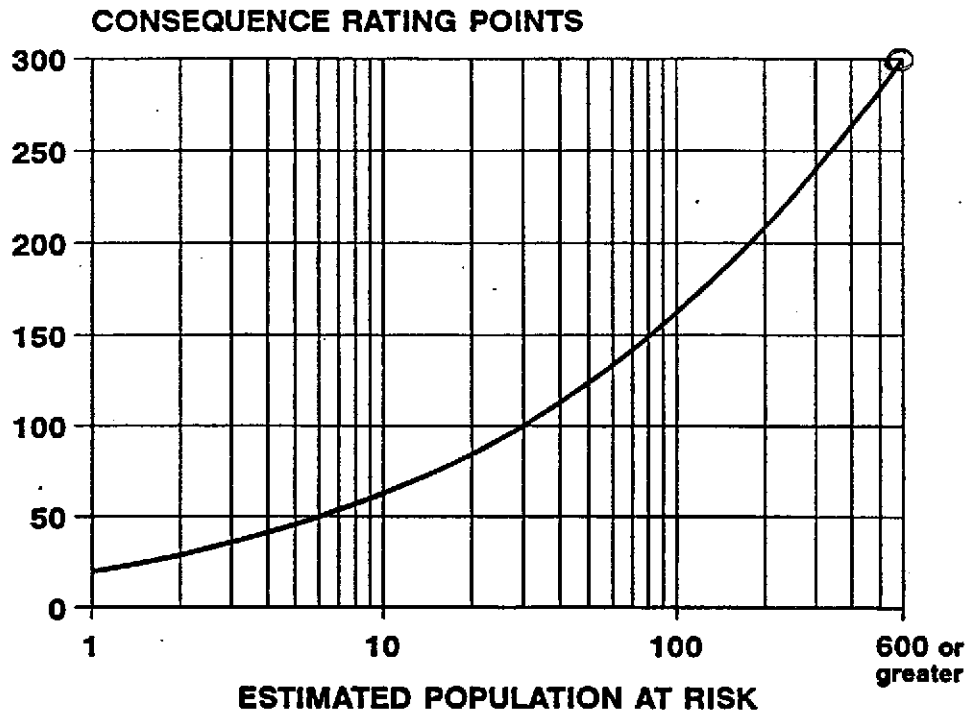


II. POPULATION AT RISK - Continued

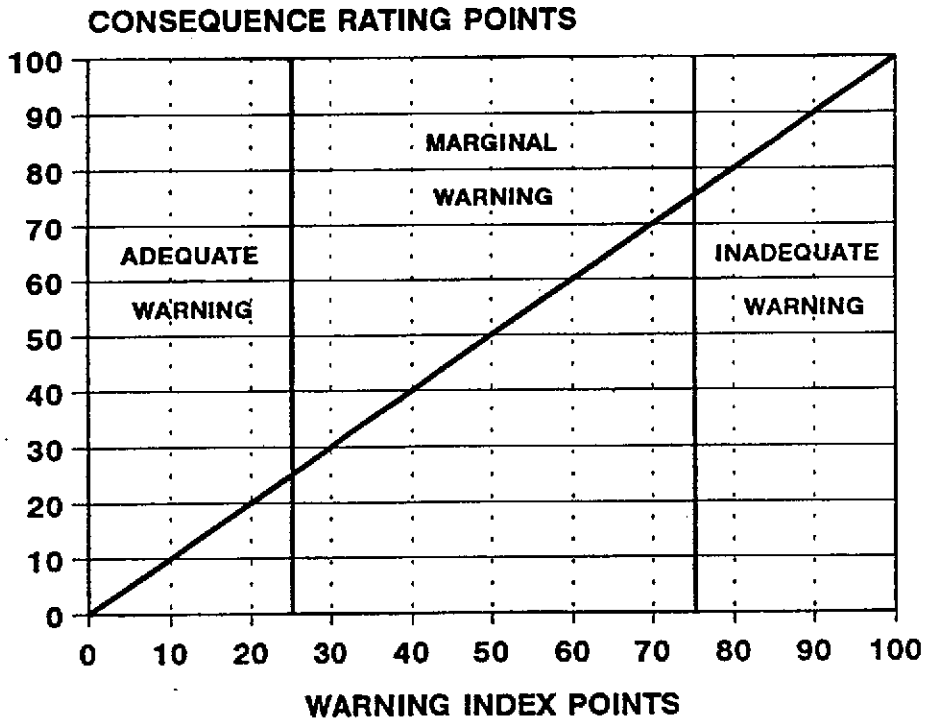
B. POPULATION AT RISK INDEX

		No. of Persons	Consequence Rating Points
1.	Estimated Current Population at Risk (PAR)	31 - 300	
2.	Increase in Population Due to Development	+ 300	
3.	TOTAL - Future Population at Risk	+ 600	300

Describe:
5400' downstream of proposed project : Trailer park w/ approximately 100 homes.



II. POPULATION AT RISK - Continued



Describe: King County shops & offices are near by and the pond will be visible to the general public who travel SE 140th Way

SUBSECTION II - SUBTOTAL OF CONSEQUENCE RATING POINTS 360

II. POPULATION AT RISK - Continued

C. ADEQUACY OF WARNING

To be used when there is Population at Risk

FACTOR	ADEQUATE WARNING	MARGINAL WARNING	INADEQUATE WARNING
ADVANCED WARNING TIME	More than 30 minutes *0 Warning Index Points*	More Than 10 Minutes but Less Than 30 Minutes *25 Warning Index Points*	Less Than 10 Minutes *50 Warning Index Points*
LIKELIHOOD OF DANGEROUS SITUATION TO BE OBSERVED AND NOTIFICATION GIVEN TO GENERAL PUBLIC	Dam Owner Resides near Dam Site, or Designated Responsible Party Has Reasonably Short Access Time to Dam Site and has Duty of Initiating Warning *0 Warning Index Points*	Designated Responsible Party not Located near Dam Site, but Dam Site is Visible to General Public. There is Reasonably Good Vehicular Access near Dam Site and Intermittent Vehicular Traffic. *15 Warning Index Points*	No Designated Responsible Party near Dam Site. Dam in Remote Location. Poor Vehicular Access to Dam Site. *30 Warning Index Points*
DOWNSTREAM VALLEY SETTING AND EASE OF EVACUATION	Valleys with Good Access to High Ground and Good Roadway Systems for Escape Routes *0 Warning Index Points*	Valleys with Limited Access to High Ground and Limited Roadway Systems *10 Warning Index Points*	Narrow Confining Valley with Roadways near the Stream Bank or Along Valley Floor and Poor Access to High Ground *20 Warning Index Points*

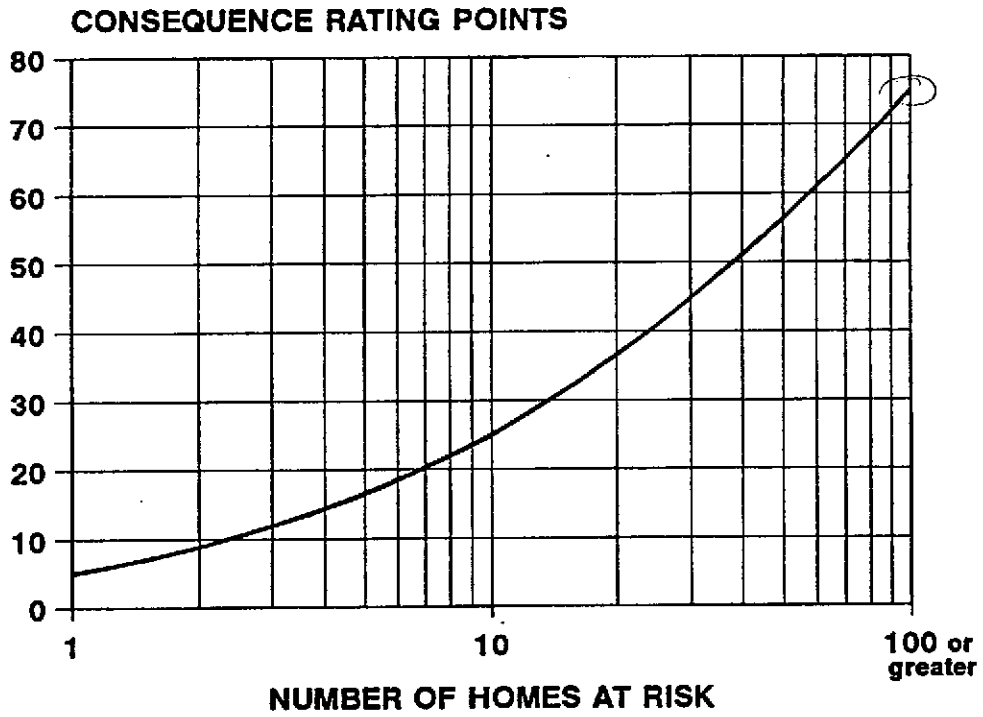
	Item	Warning Index Points	Consequence Rating Points
1.	Advanced Warning Time	25	
2.	Likelihood of Dangerous Situations to be Observed and Notification Give to Public	10	
3.	Downstream Valley Setting and Ease of Evacuation	0	
	TOTAL WARNING INDEX POINTS	35	

WARNING RATED AS Marginal 35

III. DOWNSTREAM PROPERTY AT RISK

A. RESIDENTIAL UNITS

	No. of Items	Consequence Rating Points
1. Equivalent Single Family Dwelling Units	100	75



B. LIFELINE FACILITIES

	Points Per Item	No. of Items	Consequence Rating Points
1. Transportation Links - Bridges and Stream Crossings			
a. Freeways/interstate highways Railway main lines	25	0	0
b. State highways	10	1	0
c. Other public roads Railway spur lines	2 - 5	1	5

III. DOWNSTREAM PROPERTY AT RISK - Continued

		Points Per Item	No. of Items	Consequence Rating Points
2.	Water Supply Systems			
	a. Storage Reservoirs (Downstream)	10 - 75	0	0
	b. Treatment Facilities	10 - 25	0	0
	c. Delivery Systems	5 - 25	0	0
3.	Domestic Waste Treatment Systems			
	a. Treatment Facilities /Sewer [illegible] Ex sewer [illegible] scheduled to be removed	5 - 25	1	25
4.	Electric Power Facilities			
	a. Electric power plant or Appurtenant works	5 - 75	1	25
5.	Emergency Response Facilities			
	a. Hospitals, Police, Fire, Paramedical Units	10 - 75	0	0

C. OTHER IMPORTANT FACILITIES

1.	Public Buildings, Schools, Libraries	10 - 75	0	0
2.	Fish Hatcheries	5 - 25	0	0
3.	Industrial, Commercial and Agricultural Developments	5 - 75	1	10 church
4.	Other Facilities or Considerations		1	25 Cedar River

A wide range of consequence rating points are possible for the damages that could occur to property and lifeline facilities. Selection of an appropriate value should be based on the size and importance of the features under consideration relative to the broad range of features of that type. In addition, a larger or smaller value may be selected depending on the owner's and/or project engineer's perceived need for the protection against property damages.

III. DOWNSTREAM PROPERTY AT RISK - Continued

		Points Per Item	No. of Items	Consequence Rating Points
D.	**ENVIRONMENTAL DEGRADATION**			
1.	Deleterious contents in proposed reservoir			
a.	Release of reservoir contents will result in long term environmental degradation	10 - 75	1	15
b.	Release of reservoir contents will result in temporary, minor environmental degradation	5 - 20	1	20
2.	Damage to downstream facilities could result in release of deleterious materials stored on-site			
a.	Release of deleterious materials will result in long term environmental degradation	10 - 75	0	0
b.	Release of deleterious materials will result in temporary, minor environmental degradation	5 - 20	0	0

Description of damages to property, lifeline facilities, and environmental degradation: Sedimentation + flooding to homes in Trailer Park
Possible interrupted power: pond will be in BPA easement
Sewer line breakage - causing environmental degradation but line is scheduled to be removed

SUBSECTION III - SUBTOTAL OF CONSEQUENCE RATING POINTS 210

TABLE 1. DAM SIZE CLASSIFICATION

SIZE CLASSIFICATION	DAM HEIGHT
Small Dam	Less than 15 feet
Intermediate Dam	15 feet or greater but less than 50 feet
Large Dam	50 feet or greater

TABLE 2. RESERVOIR OPERATION CLASSIFICATION

RESERVOIR OPERATION CLASSIFICATION	DETERMINING FACTOR
Permanent Pool or Seasonal Pool Operation	Steady state seepage or saturated flow conditions occur in impounding barrier and foundation at or near normal pool conditions.
Intermittent Operation	Duration of normal high pool condition is insufficient for steady state seepage or saturated flow conditions to develop in impounding barrier and foundation.

TABLE 3. DOWNSTREAM HAZARD CLASSIFICATION

DOWNSTREAM HAZARD POTENTIAL	DOWNSTREAM HAZARD CLASSIFICATION	COLUMN 3A POPULATION AT RISK	COLUMN 3B ECONOMIC LOSS GENERIC DESCRIPTIONS	COLUMN 3C ENVIRONMENTAL DAMAGES
Low	3	0	Minimal. No inhabited structures. Limited agriculture development.	No deleterious materials in reservoir contents
Significant	2	1 to 6	Appreciable. 1 or 2 inhabited structures. Notable agriculture or work sites. Secondary highway and/or rail lines.	Limited water quality degradation from reservoir contents and only short term consequences.
High	1C	7 to 30	Major. 3 to 10 inhabited structures. Low density suburban area with some industry and work sites. Primary highways and rail lines.	Severe water quality degradation potential from reservoir contents and long term effects on aquatic and human life.
High	1B	31-300	Extreme. 11 to 100 inhabited structures. Medium density suburban or urban area with associated industry, property and transportation features.	
High	1A	More than 300	Extreme. More than 100 inhabited structures. Highly developed, densely populated suburban or urban area with associated industry, property, transportation and community life line features.	

Appendix B

Break Analysis Spreadsheets

Appendix B

Break Analysis Spreadsheets

Madsen Creek BPA Pond (King County DNR&P); Dam Safety file no. ___ **Break-1**

Estimation of Dam Breach Characteristics for earthfill dams

Reference: Technical Note 1, pages 3 to 11

RJB, 07/08/02 page 1 of 4

Key equations:

Breach Formation Factor	$BFF = V_w * H_w$
Volume of material eroded	
Cohesionless/erodible materials	$V_m = 3.75\ BFF^{0.77}$
Erosion resistant materials	$V_m = 2.50\ BFF^{0.77}$
Breach geometry	
Base width	$W_b = [27\ V_m - K_2] / [K_1]$
(of breach and flow)	$K_1 = H_b\ [C + (H_b\ Z_3 / 2)]$
	$K_2 = (H_b^2)\ [(C\ Z_b) + (H_b\ Z_b\ Z_3 / 3)]$
Average width of flow	$W_{avg} = W_b + Z_b\ H_w$
Top width of flow	$W_{top} = W_b + 2\ Z_b\ H_w$
Time for breach development	
Cohesionless/erodible materials	$t = 0.028\ V_m^{0.36}$
Erosion resistant materials	$t = 0.042\ V_m^{0.36}$
Dam breach peak discharge	$Q_p = 3.1\ W_{avg}\ H_w^{1.5}\ [K_3^3]$
	$K_3 = [A / (A + (t * H_w^{0.5}))]$
	$A = 23.4\ S_a / W_{avg}$

Project-specific data :

		Reference : (report title & page; drawing no.)
Elevations :		
Dam crest elevation (ft.) =	443.3	Drawing C9, Sheet 11
Base elevation of breach (ft.) =	434	Drawing C2, Sheet 4
Height (depth) of breach, H_b =	9.3	
At **100-year storm** :		
Water surface elevation (ft.) =	441.17	Drawing C3, Sheet 5; KCRTS, Appendix F
Height over breach elev, H_w =	7.17	
Volume of water, V_w (ac-ft) =	18.76	Appendix B
Surface area, S_a (acres) =	4.25	Appendix B
Inflow during breach (cfs) =	19.97	KCRTS, Appendix F
At maximum pool (dam crest) :		
Water surface elevation (ft.) =	443.3	Drawing C9, Sheet 11
Height over breach elev, H_w =	9.3	
Volume of water, V_w (ac-ft) =	27.84	Appendix B
Surface area, S_a (acres) =	4.76	Appendix B
Inflow during breach (cfs) =	19.97	KCRTS, Appendix F

Erosion resistance of dam materials:		Typical range : cohesionless	resistant
factor for volume (V_m) =	3.75	3.75	2.50
factor for breach time (t) =	0.028	0.028	0.042

Madsen Creek BPA Pond (King County DNR&P); Dam Safety file no. ___

Estimation of Dam Breach Characteristics for earthfill dams

Reference: Technical Note 1, pages 3 to 11

RJB, 07/08/02

Project-specific data (cont.) :

Reference : (report title & page; drawing no.)

Geometry :

Crest width, C (ft.) =	20	Drawing C3, Sheet 5	
Crest length (ft.) =	775	Drawing C2, Sheet 4	
Slope of upstream face, Z_1 =	5	Slope average; Drawing C2, Sheet 4	
Slope of downstream face, Z_2 =	3	Drawing C3, Sheet 5	
$Z_1 + Z_2 = Z_3$ =	8		
Est. sideslope of breach, Z_b :		cohesionless	resistant
normal pool, Z_b =	1.0	1.0	0.5
max. pool, Z_b =	1.0	1.0	0.5

Failure due to **piping** (WL at **100-year storm**) :

Breach Formation Factor, BFF (--) =		134.5
Volume of material eroded, V_m (cu.yds.) =		163.4
Breach geometry: K_1 =	531.96	
K_2 =	3874.752	
Base width, W_b (ft.) =		1.0
Average width, W_{avg} (ft.) =		8.2
Top width (flow), W_{top} (ft.) =		15.3
Top width (crest), W_{cr} (ft.) =		19.6
Breach % of crest length =		3 %
Time for breach development, t (hrs.) =		0.18
t (min.) =		10.5
Dam breach peak discharge		
A =	12.16067	
K_3 =	0.962825	
Peak discharge, Q_p (cfs) =		434
Inflow during breach (cfs) =		19.97
Combined peak discharge =		454

Comparisons:	This project	Typical range
Breach width/height	0.88	0.5 to 3.0
Failure time (hrs.)	0.18	0.2 to 4.0
Peak discharge (cfs)	434	470 from Table 4A (cohesionless)
		320 from Table 4B (resistant)

Madsen Creek BPA Pond (King County DNR&P); Dam Safety file no. ___

Estimation of Dam Breach Characteristics for earthfill dams

Reference: Technical Note 1, pages 3 to 11

RJB, 07/08/02

Failure due to **overtopping** (WL at dam crest / maximum pool) :

Breach Formation Factor, BFF (--) =		258.9
Volume of material eroded, V_m (cu.yds.) =		270.5
Breach geometry:	K_1 =	531.96
	K_2 =	3874.752
Base width, W_b (ft.) =		6.4
Average width, W_{avg} (ft.) =		15.7
Top width (flow), W_{top} (ft) =		25.0
Top width (crest), W_{cr} (ft.) =		25.0
Breach % of crest length =		3 %
Time for breach development, t (hrs.) =		0.21
t (min.) =		12.6
Dam breach peak discharge		
	A =	7.074147
	K_3 =	0.916896
Breach discharge, Q_p (cfs) =		1067
Inflow during breach (cfs) =		19.97
Combined peak discharge =		1087

Comparisons:	This project	Typical range
Breach width/height	1.69	0.5 to 3.0
Failure time (hrs.)	0.21	0.2 to 4.0
Breach discharge	1067	1240 from Table 4A (cohesionless)
		850 from Table 4B (resistant)

Estimate triangular hydrograph with T.Peak and Q.Peak as calculated per Tech Note 1 methodology:

Dam breach hydrograph volume = reservoir volume at time of breach

Time base for dam breach hydrograph:

Vol. = (1/2) * Q.Peak * T.Base

T.Base = (2 * Vol.) / Q.Peak

(cont. on next page)

Madsen Creek BPA Pond (King County DNR&P); Dam Safety file no. ___

Estimation of Dam Breach Characteristics for earthfill dams

Reference: Technical Note 1, pages 3 to 11

RJB, 07/08/02

Dam breach hydrographs :

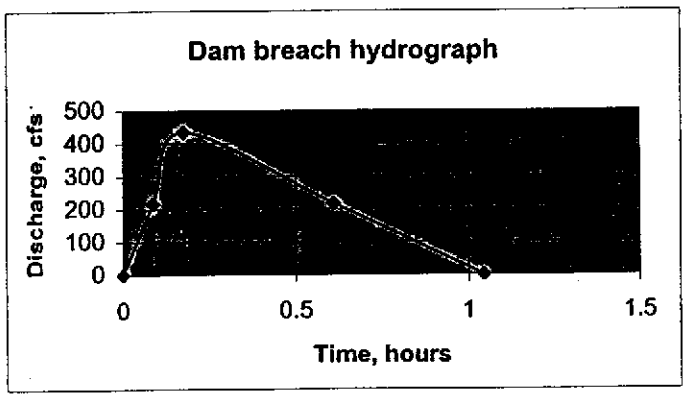
Scenario: **Piping** failure, WL at normal pool / 100 yr storm

Reservoir volume = 18.76 Ac-ft Surface area = 4.25 Ac.

Q.Peak = 434 cfs = 1563985 cu.ft./hr = 35.904 Ac-ft / hour (equivalent)

T.Base = 1.05 hours

T.Peak = 0.18 hr.



Hydrograph coordinates :	time, hr.	Q, cfs
	0	0
	0.09	217
	0.18	434
	0.61	217
	1.05	0

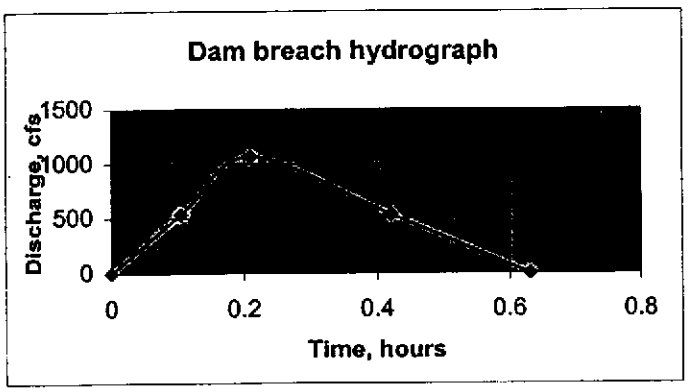
Scenario: **Overtopping**, WL at dam crest / maximum pool

Reservoir volume = 27.84 Ac-ft Surface area = 4.76 Ac.

Q.Peak = 1067 cfs = 3841470 cu.ft./hr = 88.188 Ac-ft / hour (equivalent)

T.Base = 0.63 hours

T.Peak = 0.21 hr.



Hydrograph coordinates :	time, hr.	Q, cfs
	0	0
	0.11	534
	0.21	1067
	0.42	534
	0.63	0

Madsen Creek BPA Pond (King County DNR&P); Dam Safety file no. ___ **Break-2**

Estimation of Dam Breach Characteristics for earthfill dams

Reference: Technical Note 1, pages 3 to 11

RJB, 05/08/02

Key equations:

Breach Formation Factor	$BFF = V_w * H_w$
Volume of material eroded	
Cohesionless/erodible materials	$V_m < 3.75\ BFF^{0.77}$
Erosion resistant materials	$V_m < 2.50\ BFF^{0.77}$
Breach geometry	
Volume of material eroded vs. base width	$27\ V_m = (W_b * K_1) + K_2$
	$K_1 = H_b\ [C + (H_b Z_3 / 2)]$
	$K_2 = (H_b^2)\ [(C Z_b) + (H_b Z_b Z_3 / 3)]$
Average width of flow	$W_{avg} = W_b + Z_b H_w$
Top width of flow	$W_{top} = W_b + 2 Z_b H_w$
Top width at dam crest	$W_{cr} = W_b + 2 Z_b H_b$
Time for breach development	
Cohesionless/erodible materials	$t = 0.028\ V_m^{0.36}$
Erosion resistant materials	$t = 0.042\ V_m^{0.36}$
Dam breach peak discharge	$Q_p = 3.1\ W_{avg}\ H_w^{1.5}\ [K_3^3]$
	$K_3 = [A / (A + (t * H_w^{0.5}))]$
	$A = 23.4\ S_a / W_{avg}$

Project-specific data:

		Reference : (report title & page; drawing no.)
Elevations:		
Dam crest elevation (ft.) =	443.3	Drawing C9, Sheet 11
Base elevation of breach (ft.) =	434	Drawing C2, Sheet 4
Height (depth) of breach, H_b =	9.3	
At max pool (Dam crest):		
Water surface elevation (ft.) =	443.3	Drawing C3, Sheet 5
Height over breach elev, H_w =	9.3	
Volume of water, V_w (ac-ft) =	27.84	Appendix B
Surface area, S_a (acres) =	4.76	Appendix B
Inflow during breach (cfs) =	19.97	KCRTS, Appendix F
Geometry:		
Crest width, C (ft.) =	20	Drawing C3, Sheet 5
Crest length (ft.) =	775	Drawing C2, Sheet 4
Slope of upstream face, Z_1 =	5	Slope average; Drawing C2, Sheet 4
Slope of downstream face, Z_2 =	3	Drawing C3, Sheet 5
$Z_1 + Z_2 = Z_3$ =	8	
Sideslope of breach: Z_L =	1	
Z_R =	1	
Z_b =	1	

Madsen Creek BPA Pond (King County DNR&P); Dam Safety file no. ___

Estimation of Dam Breach Characteristics for earthfill dams

Reference: Technical Note 1, pages 3 to 11

RJB, 05/08/02

		Typical range : cohesionless	resistant
Erosion resistance of dam materials:			
factor for volume (V_m) =	3.75	3.75	2.50
factor for breach time (t) =	0.028	0.028	0.042

Upper limit for volume of material eroded :

Breach Formation Factor, BFF (--) =	258.9
Volume of material eroded, V_m (cu.yds.) <	270.5

Breach geometry : K_1 = 531.96

K_2 = 3874.752

Scenario: Failure due to overtopping.

Dam breach constrained by physical setting / by ratio of breach width to dam height :

Breach geometry :

Estimate base width, W_b (ft.) =	6.4		
Volume eroded, V_m (cu.yds.) =	269.6	less than	270.5 cu.yds.
Average width, W_{avg} (ft.) =	15.7		
Top width (flow), W_{top} (ft.) =	25.0		
Top width (crest), W_{cr} (ft.) =	25.0		
Breach % of crest length =	3 %		
Time for breach development, t (hrs.) =	0.21		
t (min.) =	12.6		

Dam breach peak discharge

A = 7.094522

K_3 = 0.917205

Peak discharge, Q_p (cfs) =	1065
Inflow during breach (cfs) =	19.97
Combined peak discharge =	1085

Comparisons:	This project	Typical range
Breach width/height	1.7	0.5 to 3.0
Failure time (hrs.)	0.2	0.2 to 4.0
Peak discharge (cfs)	1065	1240 from Table 4A (cohesionless)
		850 from Table 4B (resistant)

Madsen Creek BPA Pond (King County DNR&P); Dam Safety file no. ___

Estimation of Dam Breach Characteristics for earthfill dams

Reference: Technical Note 1, pages 3 to 11

RJB, 05/08/02

Estimate triangular hydrograph with T.Peak and Q.Peak as calculated per Tech Note 1 methodology:

Dam breach hydrograph volume = reservoir volume at time of breach

Time base for dam breach hydrograph:

Vol. = (1/2) * Q.Peak * T.Base

T.Base = (2 * Vol.) / Q.Peak

Dam breach hydrograph :

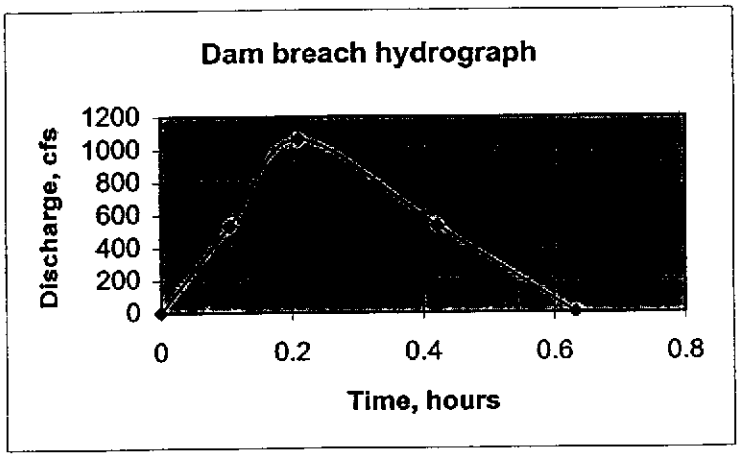
Scenario: Overtopping failure, WL max pool (dam crest)

Reservoir volume = 27.84 Ac-ft Surface area = 4.76 Ac.

Q.Peak = 1065 cfs = 3834313 cu.ft./hr = 88.024 Ac-ft / hour (equivalent)

T.Base = 0.63 hours

T.Peak = 0.21 hr.



Hydrograph coordinates : time, hr.	Q, cfs
0	0
0.10	533
0.21	1065
0.42	533
0.63	0

Madsen Creek Pond (King County DNR&P), Dam Safety file no. ___ **Break-3**

Estimate peak discharge and time to peak for Dam Break hydrograph

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Approach: Calculate crest portion of dam breach hydrograph following the methodology of HEC-1 using $T_{.Fail}$ and W_b from dam breach characteristics (see Tech Note 1)

Key equations :

Dam breach development:

Failure length L_b^* = breach depth D_b + breach base width W_b

where: D_b = dam crest elevation - breach base elevation BL

W_b = W_b calculated from Tech Note 1 methodology (separate spreadsheet)

Failure rate $dL_b^*/dt = L_b^*/T_{.Fail}$ = constant during breach development

where: $T_{.Fail}$ = time for breach development calculated from Tech Note 1 methodology (separate spreadsheet)

Flow: Discharge Q (in cfs) = $Q_{tri} + Q_{rect}$

where: Q_{tri} = 2.45 * Z_b * H^2.5

Q_{rect} = 3.1 * W_b * H^1.5

Z_b = side slope of breach, Z_bH:1V

H = WL - BL = hydraulic head measured from breach elevation BL

Q (Ac-ft / min) = Q (cfs) * (60 / 43,560)

Water level:

Change in reservoir volume dVol = (Q_{out} - Q_{in}) (Ac-ft/min) * dt (min)

Change in reservoir water level dWL = dVol (Ac-ft) / S_a (acres)

where: dt = time increment, usually 3 min (=0.05 hr) or 6 min (=0.1 hr)

S_a = reservoir surface area at WL = initial WL for this increment

estimate S_a from stage-storage relationship for the reservoir (see below)

Time base for dam breach hydrograph (i.e., time for reservoir to empty out)

Volume under outflow hydrograph = volume of reservoir, approx. = (1/2) * $Q_{.Peak}$ * $T_{.Base}$

$T_{.Base}$ = (2 * Vol.) / $Q_{.Peak}$

where: Vol. = volume of reservoir at time of failure, in Ac-ft

Q.Peak = peak discharge estimated by Tech Note 1 methodology, in Ac-ft / minute

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___
Estimate peak discharge and time to peak for Dam Break hydrograph
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Key equations (cont.) :

Stage--storage--surface area relationship for the reservoir

Estimate $S_a = A_o + m\,k\,y^{(m-1)}$, and $V = A_o\,y + k\,y^m$. Typically, $2 < m < 3$.

To "calibrate" for known or estimated values of **y**, S_a and V :

$k = (y\,S_a - V) / [(m-1)\,y^m]$

$A_o = (V / y)\,[m / (m-1)] - S_a\,\{[m / (m-1)] - 1\}$

$m > (y\,S_a / V) > 2$

y = (water level, WL) - (reservoir base elevation)

Project-specific data :

Dam crest elevation (feet) =	443.3		Scenario :	Overtopping	
Initial water level (feet) =	443.3		Estimated Q.Peak (cfs) =		1070
Reservoir volume (Ac-ft) =	27.89		Q.Peak (Ac-ft / min) =		1.474

At full breach development:

Breach base elevation, BL (ft.) =	434	Failure length, L_b* (feet) =		15.8
Depth of breach, D_b (feet) =	9.3	Breach time, T_{Fail} (minutes) =		12.6
Breach base width, W_b (feet) =	6.5	Breach rate (feet/minute) =		1.253968
Breach side slope, Z_b (--) =	1	t = time at start of interval		

Inflow to reservoir during breach, Q_{in} = 0 cfs

Representative values for reservoir: y = 9.3 feet, S_a = 4.78 Ac, V = 27.89 Ac-ft.

A_o = 1.217849 Ac, k = 0.191513 m > 1.593905

Reservoir base elevation = 434 feet use m = 2 > 2

Est. time base for hydrograph, T.Base = 37.84699 minutes = 0.630783 hours

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___

Estimate peak discharge and time to peak for Dam Break hydrograph

RJB, 05/08/02

Compute breach development as function of time. Time interval 6 minutes = 0.1 hours.

t (min.)	Lb* (ft.)	Db (ft.)	Wb (ft.)	B.L. (ft.)
0	0	0	0	443.3
6	7.52	7.52	0	435.8
12	15.05	9.30	5.75	434.0
18	15.80	9.3	6.50	434
24	15.80	9.3	6.50	434
30	15.80	9.3	6.50	434
36	15.80	9.3	6.50	434
42	15.80	9.3	6.50	434
48	15.80	9.3	6.50	434
54	15.80	9.3	6.50	434
60	15.80	9.3	6.50	434
66	15.80	9.3	6.50	434
72	15.80	9.3	6.50	434
78	15.80	9.3	6.50	434
84	15.80	9.3	6.50	434
90	15.80	9.3	6.50	434
96	15.80	9.3	6.50	434
102	15.80	9.3	6.50	434
108	15.80	9.3	6.50	434
114	15.80	9.3	6.50	434
120	15.80	9.3	6.50	434

t (min.)	Lb* (ft.)	Db (ft.)	Wb (ft.)	B.L. (ft.)
126	15.80	9.3	6.50	434
132	15.80	9.3	6.50	434
138	15.80	9.3	6.50	434
144	15.80	9.3	6.50	434
150	15.80	9.3	6.50	434
156	15.80	9.3	6.50	434
162	15.80	9.3	6.50	434
168	15.80	9.3	6.50	434
174	15.80	9.3	6.50	434
180	15.80	9.3	6.50	434
186	15.80	9.3	6.50	434
192	15.80	9.3	6.50	434
198	15.80	9.3	6.50	434
204	15.80	9.3	6.50	434
210	15.80	9.3	6.50	434
216	15.80	9.3	6.50	434
222	15.80	9.3	6.50	434
228	15.80	9.3	6.50	434
234	15.80	9.3	6.50	434
240	15.80	9.3	6.50	434
246	15.80	9.3	6.50	434
252	15.80	9.3	6.50	434
258	15.80	9.3	6.50	434
264	15.80	9.3	6.50	434
270	15.80	9.3	6.50	434

276	15.80	9.3	6.50	434
282	15.80	9.3	6.50	434
288	15.80	9.3	6.50	434
294	15.80	9.3	6.50	434
300	15.80	9.3	6.50	434
306	15.80	9.3	6.50	434
312	15.80	9.3	6.50	434
318	15.80	9.3	6.50	434
324	15.80	9.3	6.50	434
330	15.80	9.3	6.50	434
336	15.80	9.3	6.50	434
342	15.80	9.3	6.50	434
348	15.80	9.3	6.50	434
354	15.80	9.3	6.50	434
360	15.80	9.3	6.50	434
366	15.80	9.3	6.50	434
372	15.80	9.3	6.50	434
378	15.80	9.3	6.50	434
384	15.80	9.3	6.50	434
390	15.80	9.3	6.50	434

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___
Estimate peak discharge and time to peak for Dam Break hydrograph
RJB, 05/08/02

Compute dam breach hydrograph. Time interval = 6 minutes = 0.1 hours

t (hr.)	B.L. (ft.)	Wb (ft.)	W.L. (ft.)	Sa (Ac.)	H (ft.)	Qtri	Qrect	Qout (cfs)	Qout - Qin (Ac-ft/min)	dVol. (Ac-ft)	dWL (ft.)
0	443.30	0.00	443.30	4.78	0.00	0.0	0.0	0.0	0.0	0.0	0.00
0.10	435.78	0.00	443.30	4.78	7.5	380.4	0.0	380.4	0.5	3.1	0.66
0.20	434.00	5.75	442.64	4.53	8.6	537.9	452.7	**990.6**	1.4	8.2	1.81
0.30	434	6.50	440.83	3.84	6.8	299.2	360.0	659.2	0.9	5.4	1.42
0.40	434	6.50	439.41	3.29	5.4	167.1	253.8	420.9	0.6	3.5	1.06
0.50	434	6.50	438.36	2.89	4.4	97.1	183.3	280.3	0.4	2.3	0.80
0.60	434	6.50	437.55	2.58	3.6	58.4	135.0	193.4	0.3	1.6	0.62
0.70	434	6.50	436.93	2.34	2.9	36.2	101.3	137.5	0.2	1.1	0.49
0.80	434	6.50	436.45	2.16	2.4	23.0	77.3	100.3	0.1	0.8	0.38
0.90	434	6.50	436.07	2.01	2.1	15.0	59.8	74.8	0.1	0.6	0.31
1.00	434	6.50	435.76	1.89	1.8	10.0	47.0	57.0	0.1	0.5	0.25
1.10	434	6.50	435.51	1.80	1.5	6.8	37.3	44.2	0.1	0.4	0.20
1.20	434	6.50	435.31	1.72	1.3	4.8	30.0	34.8	0.0	0.3	0.17
1.30	434	6.50	435.14	1.65	1.1	3.4	24.5	27.8	0.0	0.2	0.14
1.40	434	6.50	435.00	1.60	1.0	2.4	20.1	22.5	0.0	0.2	0.12
1.50	434	6.50	434.88	1.56	0.9	1.8	16.7	18.5	0.0	0.2	0.10
1.60	434	6.50	434.78	1.52	0.8	1.3	14.0	15.3	0.0	0.1	0.08
1.70	434	6.50	434.70	1.49	0.7	1.0	11.8	12.8	0.0	0.1	0.07
1.80	434	6.50	434.63	1.46	0.6	0.8	10.1	10.8	0.0	0.1	0.06
1.90	434	6.50	434.57	1.44	0.6	0.6	8.6	9.2	0.0	0.1	0.05
2.00	434	6.50	434.51	1.42	0.5	0.5	7.4	7.9	0.0	0.1	0.05
2.10	434	6.50	434.47	1.40	0.5	0.4	6.5	6.8	0.0	0.1	0.04
2.20	434	6.50	434.43	1.38	0.4	0.3	5.6	5.9	0.0	0.0	0.04
2.30	434	6.50	434.39	1.37	0.4	0.2	5.0	5.2	0.0	0.0	0.03
2.40	434	6.50	434.36	1.36	0.4	0.2	4.4	4.6	0.0	0.0	0.03
2.50	434	6.50	434.33	1.35	0.3	0.2	3.9	4.0	0.0	0.0	0.02

Peak Q (cfs) = 990.6225 Cum.Vol= 29.13169 Ac-ft.

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___
Estimate peak discharge and time to peak for Dam Break hydrograph
RJB, 05/08/02

Compute dam breach hydrograph. Time interval = 6 minutes = 0.1 hours

t (hr.)	B.L. (ft.)	Wb (ft.)	W.L. (ft.)	Sa (Ac.)	H (ft.)	Qtri	Qrect	Qout (cfs)	Qout - Qin (Ac-ft/min)	dVol. (Ac-ft)	dWL (ft.)
								990.6225		29.13169	
2.60	434	6.50	434.31	1.34	0.3	0.1	3.5	3.6	0.0	0.0	0.0
2.70	434	6.50	434.29	1.33	0.3	0.1	3.1	3.2	0.0	0.0	0.0
2.80	434	6.50	434.27	1.32	0.3	0.1	2.8	2.9	0.0	0.0	0.0
2.90	434	6.50	434.25	1.31	0.2	0.1	2.5	2.6	0.0	0.0	0.0
3.00	434	6.50	434.23	1.31	0.2	0.1	2.3	2.3	0.0	0.0	0.0
3.10	434	6.50	434.22	1.30	0.2	0.1	2.0	2.1	0.0	0.0	0.0
3.20	434	6.50	434.20	1.30	0.2	0.0	1.9	1.9	0.0	0.0	0.0
3.30	434	6.50	434.19	1.29	0.2	0.0	1.7	1.7	0.0	0.0	0.0
3.40	434	6.50	434.18	1.29	0.2	0.0	1.6	1.6	0.0	0.0	0.0
3.50	434	6.50	434.17	1.28	0.2	0.0	1.4	1.5	0.0	0.0	0.0
3.60	434	6.50	434.16	1.28	0.2	0.0	1.3	1.3	0.0	0.0	0.0
3.70	434	6.50	434.15	1.28	0.2	0.0	1.2	1.2	0.0	0.0	0.0
3.80	434	6.50	434.15	1.27	0.1	0.0	1.1	1.1	0.0	0.0	0.0
3.90	434	6.50	434.14	1.27	0.1	0.0	1.0	1.0	0.0	0.0	0.0
4.00	434	6.50	434.13	1.27	0.1	0.0	1.0	1.0	0.0	0.0	0.0
4.10	434	6.50	434.12	1.27	0.1	0.0	0.9	0.9	0.0	0.0	0.0
4.20	434	6.50	434.12	1.26	0.1	0.0	0.8	0.8	0.0	0.0	0.0
4.30	434	6.50	434.11	1.26	0.1	0.0	0.8	0.8	0.0	0.0	0.0
4.40	434	6.50	434.11	1.26	0.1	0.0	0.7	0.7	0.0	0.0	0.0
4.50	434	6.50	434.10	1.26	0.1	0.0	0.7	0.7	0.0	0.0	0.0
4.60	434	6.50	434.10	1.26	0.1	0.0	0.6	0.6	0.0	0.0	0.0
4.70	434	6.50	434.09	1.25	0.1	0.0	0.6	0.6	0.0	0.0	0.0
4.80	434	6.50	434.09	1.25	0.1	0.0	0.6	0.6	0.0	0.0	0.0
4.90	434	6.50	434.09	1.25	0.1	0.0	0.5	0.5	0.0	0.0	0.0
5.00	434	6.50	434.08	1.25	0.1	0.0	0.5	0.5	0.0	0.0	0.0
5.10	434	6.50	434.08	1.25	0.1	0.0	0.5	0.5	0.0	0.0	0.0
5.20	434	6.50	434.08	1.25	0.1	0.0	0.4	0.4	0.0	0.0	0.0

5.30	434	6.50	434.07	1.25	0.1	0.0	0.4	0.4	0.0	0.0	0.0
5.40	434	6.50	434.07	1.25	0.1	0.0	0.4	0.4	0.0	0.0	0.0
5.50	434	6.50	434.07	1.24	0.1	0.0	0.4	0.4	0.0	0.0	0.0
5.60	434	6.50	434.07	1.24	0.1	0.0	0.3	0.3	0.0	0.0	0.0
5.70	434	6.50	434.06	1.24	0.1	0.0	0.3	0.3	0.0	0.0	0.0
5.80	434	6.50	434.06	1.24	0.1	0.0	0.3	0.3	0.0	0.0	0.0
5.90	434	6.50	434.06	1.24	0.1	0.0	0.3	0.3	0.0	0.0	0.0
6.00	434	6.50	434.06	1.24	0.1	0.0	0.3	0.3	0.0	0.0	0.0
6.10	434	6.50	434.06	1.24	0.1	0.0	0.3	0.3	0.0	0.0	0.0
6.20	434	6.50	434.05	1.24	0.1	0.0	0.3	0.3	0.0	0.0	0.0
6.30	434	6.50	434.05	1.24	0.1	0.0	0.2	0.2	0.0	0.0	0.0
6.40	434	6.50	434.05	1.24	0.1	0.0	0.2	0.2	0.0	0.0	0.0
6.50	434	6.50	434.05	1.24	0.0	0.0	0.2	0.2	0.0	0.0	0.0

Peak Q (cfs) = 990.6225 Cum.Vol= 29.37171 Ac-ft.
Compare to reservoir volume = 27.89 Ac-ft.
Difference = 1.481715 Ac-ft.
% difference = 5.31271 %

Peak discharge = **990.6** cfs

Time to peak = 0.21 hr. = **12.6** min.

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___
Estimate peak discharge and time to peak for Dam Break hydrograph
RJB, 05/08/02

Estimate triangular hydrograph with T.Peak and Q.Peak as calculated above:

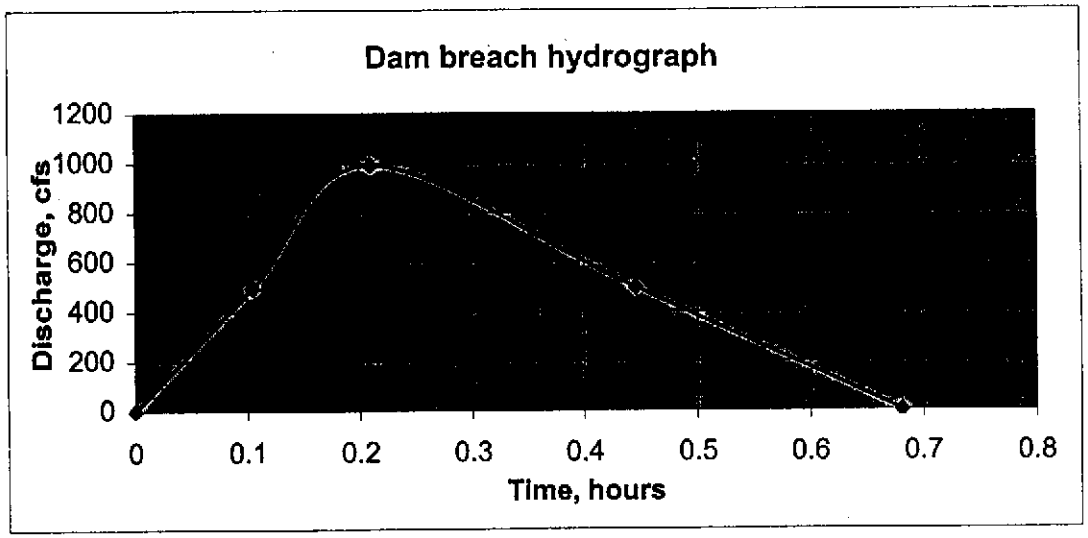
Dam breach hydrograph volume = reservoir volume at time of breach

Time base for dam breach hydrograph:
Vol. = (1/2) * Q.Peak * T.Base
T.Base = (2 * Vol.) / Q.Peak

Dam breach hydrograph :

Scenario: **Overtopping**

Reservoir volume =	27.89	Ac-ft			Surface area =	4.78	Ac.
Q.Peak =	991	cfs	=	3566241 cu.ft./hr =		81.870	Ac-ft / hour (equivalent)
T.Base =	0.68	hours					
T.Peak =	0.21	hr.					



Hydrograph coordinates :

time, hr.	Q, cfs
0	0
0.11	495
0.21	991
0.45	495
0.68	0

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___ **Break 4**

Estimate Dam Breach hydrograph for use computer program

RJB, 05/08/02 page 1 of 1

Approach: Calculate dam breach hydrograph equivalent to reservoir volume, estimate T.Peak and Q.Peak from dam breach characteristics (see Tech Note 1)

Key equations:

Dam breach hydrograph volume = reservoir volume at time of breach

Estimate triangular hydrograph with T.Peak and Q.Peak as calculated per Tech Note 1 methodology:

Time base for dam breach hydrograph:

Vol. = (1/2) * Q.Peak * T.Base

T.Base = (2 * Vol.) / Q.Peak

Rising limb of hydrograph:

Q(t) = Q.Peak * (t / T.Peak)

Receding limb of hydrograph:

Q(t) = Q.Peak * { 1 - [(t - T.Peak) / (T.Base - T.Peak)]}

Dam breach hydrograph :

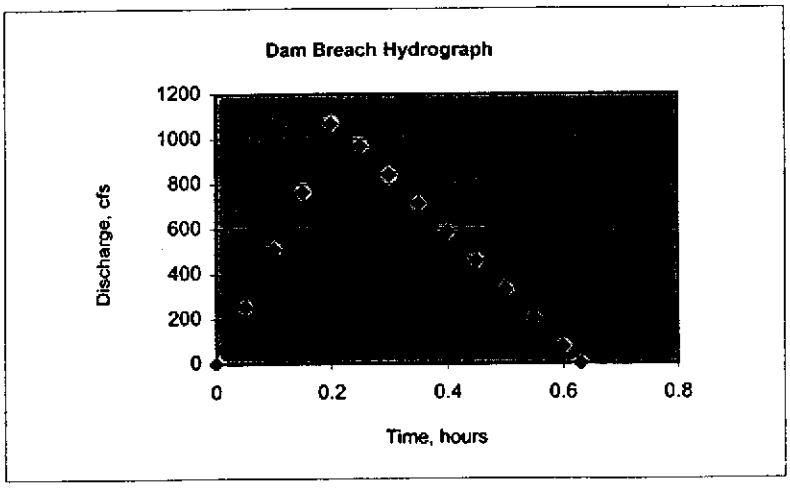
Scenario: **Overtopping failure, WL max. pool**

Reservoir volume = 27.89 Ac-ft Surface area = 4.78 Ac.

Q.Peak = 1070 cfs = 3852000 cu.ft./hr = 88.430 Ac-ft / hour (equivalent)

T.Base = 0.6307832 hours

T.Peak = 0.21 hr. time increment = 3 min. = 0.05 hr.



Hydrograph coordinates :	time, hr.	Q, cfs
	0	0
	0.05	254.8
	0.10	509.5
	0.15	764.3
	0.20	**1070.0**
	0.25	968.3
	0.30	841.1
	0.35	714.0
	0.40	586.9
	0.45	459.7
	0.50	332.6
	0.55	205.4
	0.60	78.3
	0.63	0

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___ **Break-5**

Estimate Dam Breach hydrograph for use in computer program

RJB, 05/08/02 page 1 of 2

Approach : Calculate dam breach hydrograph equivalent to reservoir volume, estimate T.Peak and Q.Peak from dam breach characteristics (see Tech Note 1)

Reference : Barfield, Warner and Haan. Applied Hydrology and Sedimentology for Disturbed Areas. Oklahoma Technical Press, 1981. pp. 104 - 108

Key equations:

Dam breach hydrograph volume = reservoir volume at time of breach = sum (Qi x dt)

Estimate hydrograph with T.peak and Q.peak as calculated per Tech Note 1 methodology :

Dimensionless hydrograph :

Q(t) / Q.peak = [t/T.peak * exp(1 - t/T.peak)] ^ K

Initial estimate for K :

K = 6.566 [(Q.peak * T.peak) / (Vol.)] ^ 1.9

Revise K as needed to make hydrograph volume = reservoir volume

Typical values: 1.5 < K < 5.0

Dam breach hydrograph :

Scenario: **Overtopping** failure, WL at max. pool

Reservoir volume = 27.89 Ac-ft Surface area = 4.78 Ac.

Q.Peak = 1070 cfs = 3852000 cu.ft./hr = 88.430 Ac-ft / hour (equivalent)

T.Peak = 0.21 hr. Initial K = 3.032

time increment = 3 min. = 0.05 hr.

Time, hr.	t/T.peak	exp[...]	[...]^K	equiv Q, Ac-ft/hr.	incr. Vol. Ac-ft.	Q, cfs
0	0	1	0	0	0	0
0.05	0.238	2.142	0.137	12.156	0.608	147
0.10	0.476	1.688	0.526	46.488	2.324	563
0.15	0.714	1.331	0.861	76.141	3.807	921
0.20	0.952	1.049	0.997	88.125	4.406	**1066**
0.25	1.190	0.827	0.954	84.325	4.216	1020
0.30	1.429	0.651	0.809	71.541	3.577	866
0.35	1.667	0.513	0.632	55.858	2.793	676
0.40	1.905	0.405	0.464	41.041	2.052	497
0.45	2.143	0.319	0.326	28.787	1.439	348
0.50	2.381	0.251	0.220	19.465	0.973	236
0.55	2.619	0.198	0.145	12.778	0.639	155
0.60	2.857	0.156	0.093	8.185	0.409	99
0.65	3.095	0.123	0.058	5.137	0.257	62
0.70	3.333	0.097	0.036	3.168	0.158	38
0.75	3.571	0.076	0.022	1.924	0.096	23
0.80	3.810	0.060	0.013	1.154	0.058	14
0.85	4.048	0.047	0.008	0.684	0.034	8
0.90	4.286	0.037	0.005	0.401	0.020	4.9
0.95	4.524	0.029	0.003	0.233	0.012	2.8
1.00	4.762	0.023	0.002	0.134	0.007	1.6
1.05	5.000	0.018	0.001	0.077	0.004	0.9

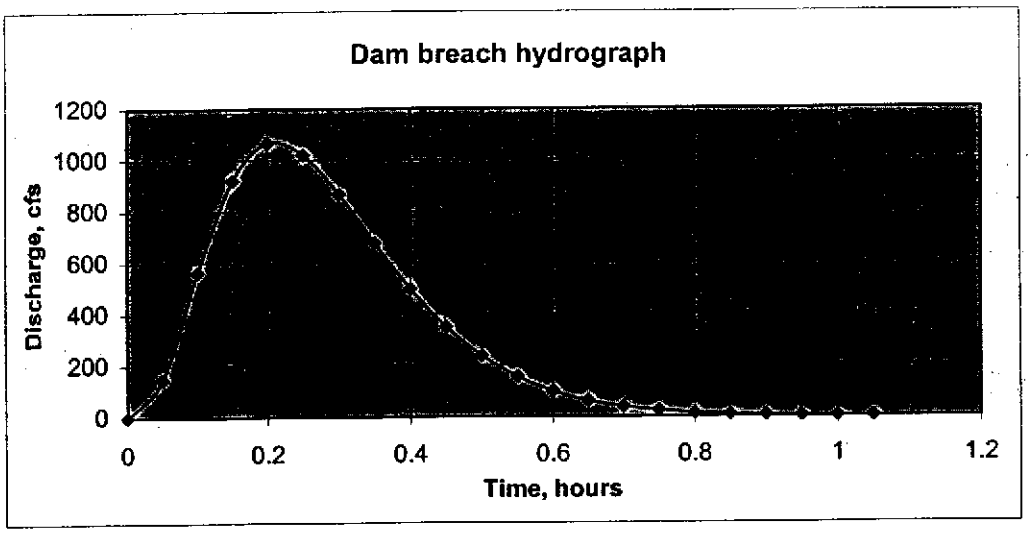
initial K = 3.032 Vol. = 27.890 Diff. = 0.000 Ac-ft.

% adjust. = 97.23 % Ac-ft. % diff. = 0.001 %

revised K = 2.948

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___
Estimate Dam Breach hydrograph for use in computer program
RJB, 05/08/02

Hydrograph coordinates :	time, hr.	Q, cfs
	0	0
	0.05	147
	0.10	563
	0.15	921
	0.20	**1066**
	0.25	1020
	0.30	866
	0.35	676
	0.40	497
	0.45	348
	0.50	236
	0.55	155
	0.60	99
	0.65	62
	0.70	38
	0.75	23
	0.80	14
	0.85	8
	0.90	4.9
	0.95	2.8
	1.00	1.6
	1.05	0.9



As discussed previously, the most analytically sophisticated methodology currently available for estimating the breach outflow hydrograph is the computer program BREACH[6] developed by Fread. This program incorporates principles of sediment transport, soil mechanics and unsteady flow hydraulics to compute both breach dimensions and the outflow hydrograph.

TABLE 4A - DAM BREACH PEAK DISCHARGE ESTIMATES FOR DAMS CONSTRUCTED OF COHESIONLESS MATERIALS

DAM HEIGHT (FEET)	DAM BREACH PEAK DISCHARGE (CFS)									
	RESERVOIR SURFACE AREA (ACRES)									
	2	4	7	10	15	20	30	40	60	100
4	170	300	460	610	830	1010	1090	1110	1130	1140
6	280	470	730	960	1300	1620	2220	2760	2920	3020
8	380	640	990	1300	1770	2200	3010	3750	5100	5840
10	480	810	1240	1630	2220	2770	3780	4700	6400	9420
12	570	970	1490	1960	2660	3320	4520	5630	7660	11280
14	670	1130	1730	2280	3100	3860	5250	6530	8880	13070
18	850	1440	2200	2890	3930	4880	6640	8250	11210	16500
22	1020	1730	2650	3470	4700	5850	7950	9880	13420	19720
26	1190	2010	3070	4020	5450	6770	9200	11430	15510	22770
30	1350	2280	3470	4550	6170	7650	10390	12900	17490	25660
35	1540	2600	3950	5170	7000	8700	11800	14640	19830	29080
40	1720	2900	4400	5760	7800	9680	13120	16280	22040	32290
45	1890	3190	4840	6330	8560	10620	14380	17830	24130	35330
50	2060	3460	5250	6860	9270	11500	15580	19310	26110	38200

from Dam Safety Guidelines

TABLE 4B - DAM BREACH PEAK DISCHARGE ESTIMATES FOR DAMS CONSTRUCTED OF EROSION RESISTANT MATERIALS

DAM HEIGHT (FEET)	DAM BREACH PEAK DISCHARGE (CFS)									
	RESERVOIR SURFACE AREA (ACRES)									
	2	4	7	10	15	20	30	40	60	100
4	120	200	300	410	560	700	950	1090	1110	1130
6	190	320	500	650	880	1100	1510	1880	2560	2950
8	260	440	670	880	1200	1500	2050	2560	3480	5150
10	320	550	850	1120	1520	1900	2590	3220	4390	6480
12	390	670	1020	1340	1830	2280	3110	3870	5270	7770
14	460	780	1190	1570	2130	2650	3620	4500	6130	9040
18	590	1000	1520	2000	2710	3380	4600	5730	7790	11470
22	710	1200	1840	2410	3280	4080	5550	6900	9370	13790
26	830	1400	2140	2810	3810	4740	6450	8010	10880	16000
30	940	1600	2430	3190	4330	5380	7310	9080	12330	18110
35	1080	1830	2780	3650	4950	6140	8340	10360	14050	20620
40	1210	2050	3110	4080	5530	6870	9320	11570	15690	23010
45	1340	2260	3430	4500	6090	7560	10260	12730	17250	25290
50	1460	2460	3740	4900	6630	8230	11160	13840	18740	27450

from Dam Safety Guidelines

MAY 23 2002

Slice Volume Results
Original Surface Model: Storage
Final Surface Model: Constant Elevation: 444.00
Cut Compaction Factor: 0.000000
Fill Compaction Factor: 0.000000

dead storage 434 - 436.5

Elevation Interval	Cut Area (ft^2)	Cut Volume (CY)		Fill Area (ft^2)	Fill Volume (CY)	Cumulative Cut (CY)		Cumulative Fill (CY)
433.00 - 433.50	0.00	0.00		1241.07	22.98	0.00		22.98
433.50 - 434.00	0.00	0.00		3357.77	62.18	0.00		85.16
434.00 - 434.50	0.00	0.00		4757.73	88.11	0.00		173.27
434.50 - 435.00	0.00	0.00		8704.94	161.20	0.00		334.47
435.00 - 435.50	0.00	0.00		33300.60	616.68	0.00		951.15
435.50 - 436.00	0.00	0.00		60112.33	1113.19	0.00		2064.34
436.00 - 436.50	0.00	0.00	436.5	77955.67 1.79 ac	1443.62	0.00	436.5	3507.97 = 2.17 acft
436.50 - 437.00	0.00	0.00		100442.73	1860.05	0.00		5368.02
437.00 - 437.50	0.00	0.00		115095.99	2131.41	0.00		7499.42
437.50 - 438.00	0.00	0.00		127268.44	2356.82	0.00		9856.25
438.00 - 438.50	0.00	0.00		136029.36	2519.06	0.00		12375.31
438.50 - 439.00	0.00	0.00		145813.35	2700.25	0.00		15075.56
439.00 - 439.50	0.00	0.00		150954.32	2795.45	0.00		17871.01
439.50 - 440.00	0.00	0.00		159740.92	2958.17	0.00		20829.17
440.00 - 440.50	0.00	0.00		164210.92	3040.94	0.00		23870.11
440.50 - 441.00	0.00	0.00		173323.53	3209.69	0.00		27079.81 16.79 acft
100yr-441.2 441.00 - 441.50	0.00	0.00	441.5	180763.23 4.15ac	3347.47	0.00		30427.28 18.76 acft
441.50 - 442.00	0.00	0.00		187475.75 4.30ac	3471.77	0.00		33899.05
442.00 - 442.50	0.00	0.00		191840.55	3552.60	0.00		37451.65
442.50 - 443.00	0.00	0.00		198104.69	3668.61	0.00		41120.26
443.00 - 443.50	0.00	0.00	crest	204615.91 4.70ac	3789.18	0.00	crest=	44909.44 = 27.84 acft
443.50 - 444.00	0.00	0.00	rd top	211552.49 4.86 ac	3917.64	0.00	rd	48827.08 = 30.26 acft
444.00 - 444.50	5559.96	102.96		0.00	0.00	102.96		48827.08
444.50 - 445.00	4157.16	76.98		0.00	0.00	179.95		48827.08

Avail det: 16.785 acft - 2.17 acft = 14.61 acft
Req det = 14.57 acft < 14.61 acft so ok

Appendix C

Flood Inundation Worksheets

Appendix C

Flood Inundation Worksheets

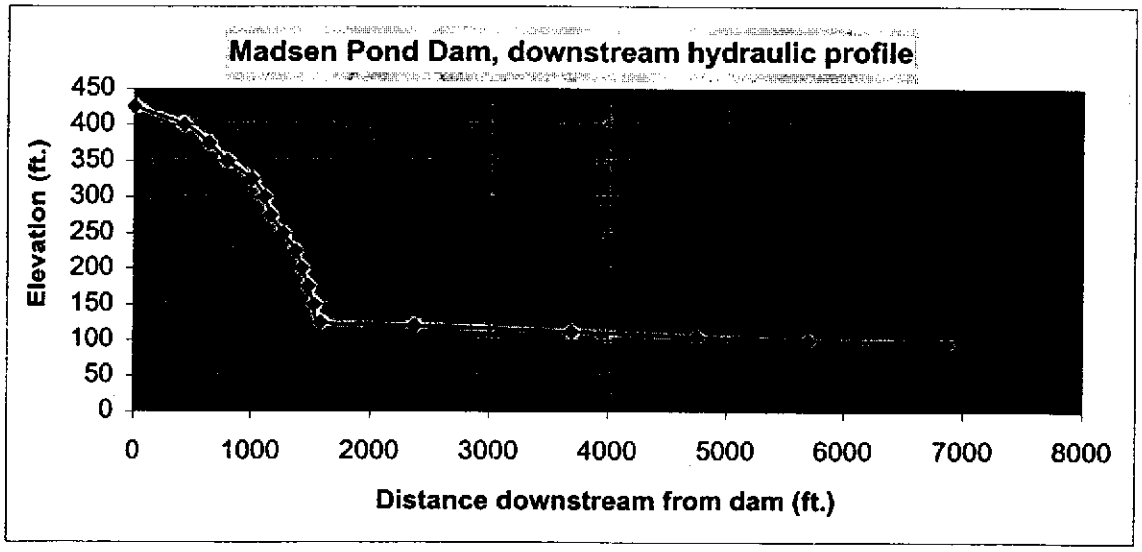
Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___ **Flood-1**

Hydraulic Profile of drainage basin; Dam Break flood attenuation and flood wave travel time

RJB, 05/08/02 page 1 of 3

Map reference :
USGS topo map, **Renton** quad

River Mile	Dist. from dam (ft)	Elevation (ft)	Description
1.30	0	425	Pond outlet
1.22	425	400	
1.18	634	375	
1.15	792	350	
1.11	1003	325	
1.09	1109	300	
1.08	1162	275	
1.06	1267	250	
1.04	1373	225	
1.03	1426	200	
1.02	1478	175	
1.01	1531	150	
1.00	1584	125	confluence with Madsen Creek mainstem
0.85	2376	120	sedimentation pond near trailer park
0.6	3696	112	
0.4	4752	105	crossing under SR 169
0.22	5702	100	vicinity of recreational field (soccer/baseball)
0	6864	95	confluence with major river (Cedar River)



Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___

Hydraulic Profile of drainage basin; Dam Break flood attenuation and flood wave travel time

RJB, 05/08/02 page 2 of 3

Failure scenario : **Overtopping**

Initial reservoir volume = 27.89 Ac-ft (use attenuation curve for 10 ac-ft)

Estimated peak discharge Qp = 1070 cfs (estimated from Tech Note 1 / time-step computation)

Estimate Type 2 channel from dam to R.Mile 1.15, Type 3 channel downstream from R.Mile 1.15 to R.Mile 0.85
Type 1 channel downstream From R.Mile 0.85 to R.Mile 0.0 (Cedar River)
(Reference: Tech Note 1, Table 7 on page 15)

River Mile	Dist. from dam (ft)	Elevation (ft)	Channel gradient (ft/ft)	(ft/mile)	Flow vel. (ft/sec)	Downstream distance (miles)	Qx/Qp	Dam break Qx (cfs)	
1.30	0	425				0	1.0	1070	Type 2
1.22	425	400	0.059	311	12	0.08	1.00	1070	
1.18	634	375	0.120	632	12	0.12	0.95	1016.5	
1.15	792	350	0.158	835	12	0.15	0.95	1016.5	Type 3
1.11	1003	325	0.118	626	12	0.19	0.90	963	
1.09	1109	300	0.236	1245	12	0.21	0.90	963	
1.08	1162	275	0.472	2491	12	0.22	0.90	963	
1.06	1267	250	0.238	1257	12	0.24	0.90	963	
1.04	1373	225	0.236	1245	12	0.26	0.85	909.5	
1.03	1426	200	0.472	2491	12	0.27	0.85	909.5	
1.02	1478	175	0.481	2538	12	0.28	0.85	909.5	
1.01	1531	150	0.472	2491	12	0.29	0.85	909.5	
1.00	1584	125	0.472	2491	12	0.30	0.85	909.5	
0.85	**2376**	**120**	**0.006**	**33**	**5.8**	**0.45**	**0.75**	**802.5**	Type 1
0.60	3696	112	0.006	32	5.8	0.70	0.65	695.5	
0.40	4752	105	0.007	35	5.8	0.90	0.60	642	
0.22	5702	100	0.006	32	5.8	1.08	0.55	588.5	
0	6864	95	0.004	23	4.8	1.30	0.45	481.5	

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___

Hydraulic Profile of drainage basin; Dam Break flood attenuation and flood wave travel time

RJB, 05/08/02

Calculate "window" for travel time of dam breach flood wave :

Flood wave velocity (V_w) relative to water velocity (V) = V_w/V = 1 + (A/dA)(dV/V). (Refs: Henderson, Open Channel Flow, pp. 365 - 369; Chow, Open Channel Hydraulics, pp. 528 - 531.)

Minimum flood velocity > water velocity. Estimate maximum flood velocity < 1.5 x water velocity. Travel time for dam breach flood wave = travel distance / flood velocity. Maximum flood velocity => minimum travel time, and conversely, minimum flood velocity => maximum travel time.

River Mile	Dist. from dam (ft)	Channel gradient (ft/mile)	Flow vel. (ft/sec)	Downstream distance (miles)	Flood travel time (minutes) Minimum (incr.)	Minimum (cum.)	Maximum (incr.)	Maximum (cum.)
1.30	0			0	0	0	0	0
1.22	425	310.59	12	0.08	0.4	0.4	0.6	0.6
1.18	634	631.58	12	0.12	0.2	0.6	0.3	0.9
1.15	792	835.44	12	0.15	0.1	0.7	0.2	1.1
1.11	1003	625.59	12	0.19	0.2	0.9	0.3	1.4
1.09	1109	1245.28	12	0.21	0.1	1.0	0.1	1.5
1.08	1162	2490.57	12	0.22	0.0	1.1	0.1	1.6
1.06	1267	1257.14	12	0.24	0.1	1.2	0.1	1.8
1.04	1373	1245.28	12	0.26	0.1	1.3	0.1	1.9
1.03	1426	2490.57	12	0.27	0.0	1.3	0.1	2.0
1.02	1478	2538.46	12	0.28	0.0	1.4	0.1	2.1
1.01	1531	2490.57	12	0.29	0.0	1.4	0.1	2.1
1.00	1584	2490.57	12	0.30	0.0	1.5	0.1	2.2
0.85	**2376**	**33.33**	**5.8**	**0.45**	**1.5**	**3.0**	**2.3**	**4.5**
0.60	3696	32.00	5.8	0.70	2.5	5.5	3.8	8.3
0.40	4752	35.00	5.8	0.90	2.0	7.5	3.0	11.3
0.22	5702	31.75	5.8	1.08	6.4	9.4	9.6	14.0
0	6864	22.72	4.8	1.30	2.7	12.0	4.0	18.1

(end)

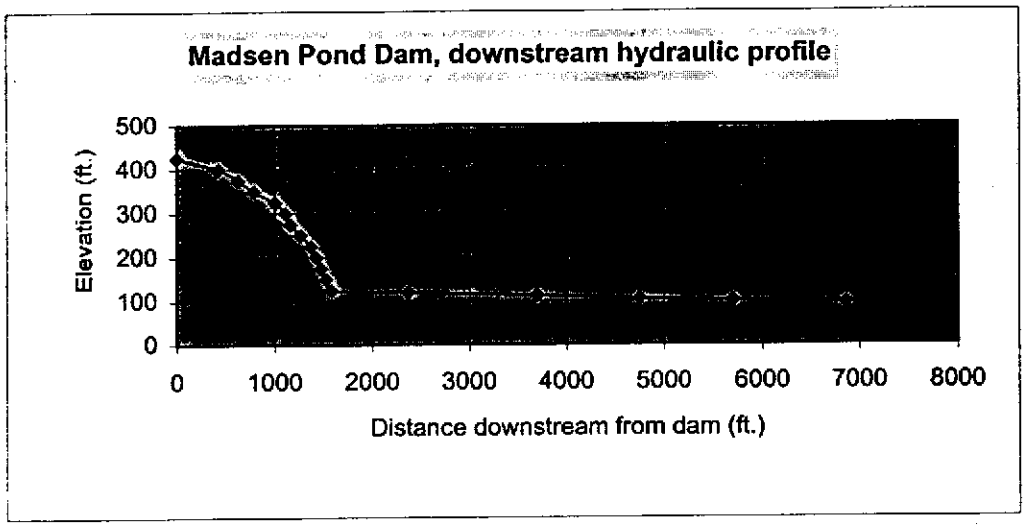
Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___ **Flood-2**

Hydraulic Profile of drainage basin; Dam Break flood attenuation,
flood wave travel time, and preliminary estimate of inundation depths

RJB, 05/08/02 page 1 of 4

Map reference :
USGS topo map, Renton quad

River Mile	Dist. from dam (ft)	Elevation (ft)	Distance to contour line Left (ft)	Distance to contour line Right (ft)	Description
1.30	0	425	750	500	Pond outlet
1.22	425	400	800	175	
1.18	634	375	850	200	
1.15	792	350	175	125	
1.11	1003	325	75	75	
1.09	1109	300	75	50	
1.08	1162	275	50	50	
1.06	1267	250	75	75	
1.04	1373	225	75	100	
1.03	1426	200	100	100	
1.02	1478	175	75	225	
1.01	1531	150	200	225	
1.00	1584	125	50	100	confluence with Madsen Creek mainstem
0.85	**2376**	**120**	**125**	**125**	sedimentation pond near trailer park
0.60	3696	112	Flat	Flat	
0.40	4752	105	Flat	Flat	crossing under SR 169
0.22	5702	100	Flat	Flat	vicinity of recreational field (soccer/baseball)
0.00	6864	95	Flat	Flat	confluence with major river or lake



Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___

Hydraulic Profile of drainage basin; Dam Break flood attenuation,
flood wave travel time, and preliminary estimate of inundation depths

RJB, 05/08/02 page 2 of 4

Failure scenario : **Overtopping**

Initial reservoir volume = 27.89 Ac-ft (use attenuation curve for 10 ac-ft)

Estimated peak discharge Q_p = 1070 cfs (estimated from Tech Note 1 / time-step computation)

Estimate Type 2 channel from dam to R.Mile 1.15, Type 3 channel downstream from R.Mile 1.15 to R.Mile 0.85,
Type 1 channel downstream from R.Mile 0.85 to R.Mile 0.0 (Cedar River)
(Reference: Tech Note 1, Table 7 on page 15)

River Mile	Dist. from dam (ft)	Elevation (ft)	Channel gradient (ft/ft)	Channel gradient (ft/mile)	Flow vel. (ft/sec)	Downstream distance (miles)	Q_x/Q_p	Dam break Q_x (cfs)	
1.30	0	425				0	1.0	1070	Type 2
1.22	425	400	0.0588	311	12	0.08	1.00	1070	
1.18	634	375	0.1196	632	12	0.12	0.95	1016.5	
1.15	792	350	0.1582	835	12	0.15	0.95	1016.5	Type 3
1.11	1003	325	0.1185	626	12	0.19	0.90	963	
1.09	1109	300	0.2358	1245	12	0.21	0.90	963	
1.08	1162	275	0.4717	2491	12	0.22	0.90	963	
1.06	1267	250	0.2381	1257	12	0.24	0.90	963	
1.04	1373	225	0.2358	1245	12	0.26	0.85	909.5	
1.03	1426	200	0.4717	2491	12	0.27	0.85	909.5	
1.02	1478	175	0.4808	2538	12	0.28	0.85	909.5	
1.01	1531	150	0.4717	2491	12	0.29	0.85	909.5	
1.00	1584	125	0.4717	2491	12	0.30	0.85	909.5	
0.85	**2376**	**120**	**0.0063**	**33**	**5.8**	**0.45**	**0.75**	**802.5**	Type 1
0.6	3696	112	0.0061	32	5.8	0.70	0.75	802.5	
0.4	4752	105	0.0066	35	5.8	0.90	0.60	642	
0.22	5702	100	0.0060	32	5.8	1.08	0.55	588.5	
0	6864	95	0.0043	23	4.8	1.30	0.45	481.5	

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___

Hydraulic Profile of drainage basin; Dam Break flood attenuation,
flood wave travel time, and preliminary estimate of inundation depths

RJB, 05/08/02

Calculate "window" for travel time of dam breach flood wave :

Flood wave velocity (V_w) relative to water velocity (V) = V_w/V = 1 + (A/dA)(dV/V). (Refs: Henderson, Open Channel Flow, pp. 365 - 369; Chow, Open Channel Hydraulics, pp. 528 - 531.)

Minimum flood velocity > water velocity. Estimate maximum flood velocity < 1.5 x water velocity. Travel time for dam breach flood wave = travel distance / flood velocity. Maximum flood velocity => minimum travel time, and conversely, minimum flood velocity => maximum travel time.

River Mile	Dist. from dam (ft)	Channel gradient (ft/mile)	Flow vel. (ft/sec)	Downstream distance (miles)	Flood travel time (minutes) Minimum (incr.)	Minimum (cum.)	Maximum (incr.)	Maximum (cum.)
1.30	0			0	0	0	0	0
1.22	425	310.5882	12	0.08	0.4	0.4	0.6	0.6
1.18	634	631.5789	12	0.12	0.2	0.6	0.3	0.9
1.15	792	835.4430	12	0.15	0.1	0.7	0.2	1.1
1.11	1003	625.5924	12	0.19	0.2	0.9	0.3	1.4
1.09	1109	1245.2830	12	0.21	0.1	1.0	0.1	1.5
1.08	1162	2490.5660	12	0.22	0.0	1.1	0.1	1.6
1.06	1267	1257.1429	12	0.24	0.1	1.2	0.1	1.8
1.04	1373	1245.2830	12	0.26	0.1	1.3	0.1	1.9
1.03	1426	2490.5660	12	0.27	0.0	1.3	0.1	2.0
1.02	1478	2538.4615	12	0.28	0.0	1.4	0.1	2.1
1.01	1531	2490.5660	12	0.29	0.0	1.4	0.1	2.1
1.00	1584	2490.5660	12	0.30	0.0	1.5	0.1	2.2
0.85	2376	33.3333	5.8	0.45	1.5	3.0	2.3	4.5
0.6	3696	32.0000	5.8	0.70	2.5	5.5	3.8	8.3
0.4	4752	35.0000	5.8	0.90	2.0	7.5	3.0	11.3
0.22	5702	31.7498	5.8	1.08	6.4	9.4	9.6	14.0
0	6864	22.7194	4.8	1.30	2.7	12.0	4.0	18.1

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___

Hydraulic Profile of drainage basin; Dam Break flood attenuation,
flood wave travel time, and preliminary estimate of inundation depths

RJB, 05/08/02

Preliminary estimate of inundation depths at key locations :

Key equations and approximations :

In the absence of other information on downstream channel and flood plain geometry, cross-section area of flow can be estimated by linear interpolation between contour lines from USGS or other topographic maps. Estimated channel is approximately triangular-shaped, with geometry as follows:

Side slopes Z_L and Z_R (ZH:1V) = distance to countour line / countour interval

$$\text{X-Area} = 1/2\, Z_L\, y^2 + 1/2\, Z_R\, y^2 = 1/2\, (Z_L + Z_R)\, y^2$$
$$y^2 = 2\, (\text{X-Area}) / (Z_L + Z_R)$$
$$y = [\, 2\, (\text{X-Area}) / (Z_L + Z_R)\,]^{0.5}$$

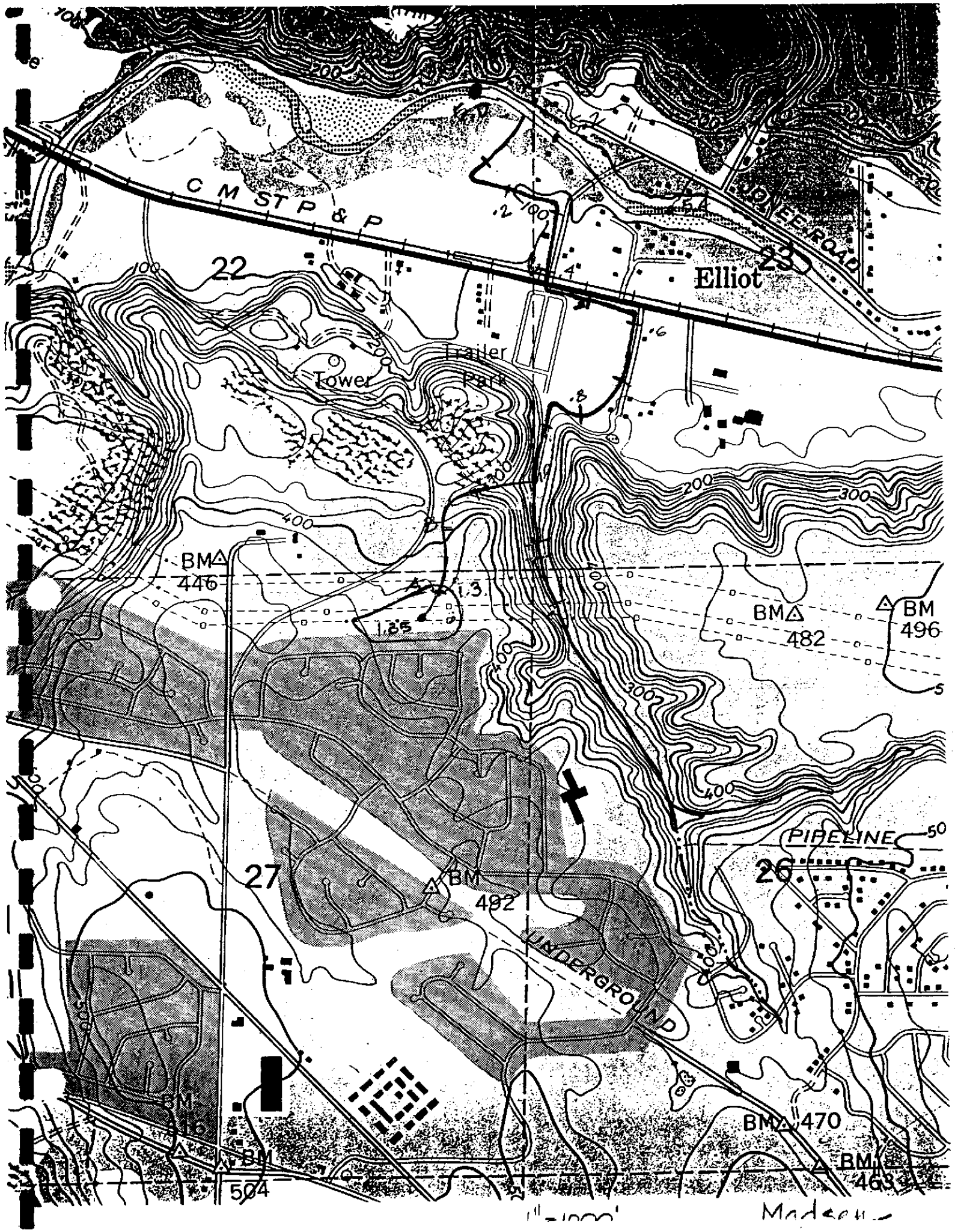
Required X-Area = discharge / velocity = Q / v, then solve for y

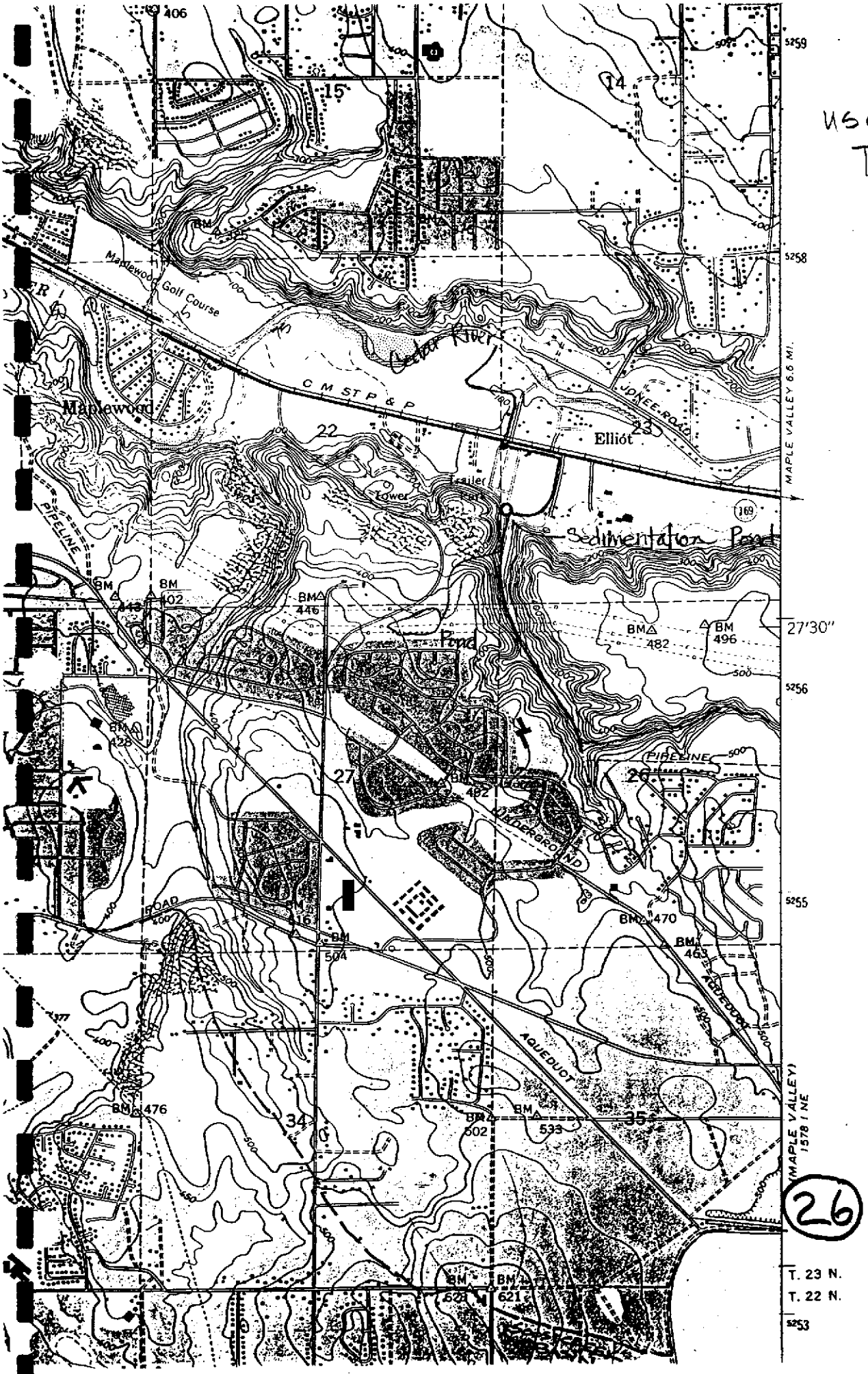
Water surface elev. = channel elev. + water depth y

Inundation area, distance from channel center line = Z_i * y (each side)

Map contour interval = 25 feet

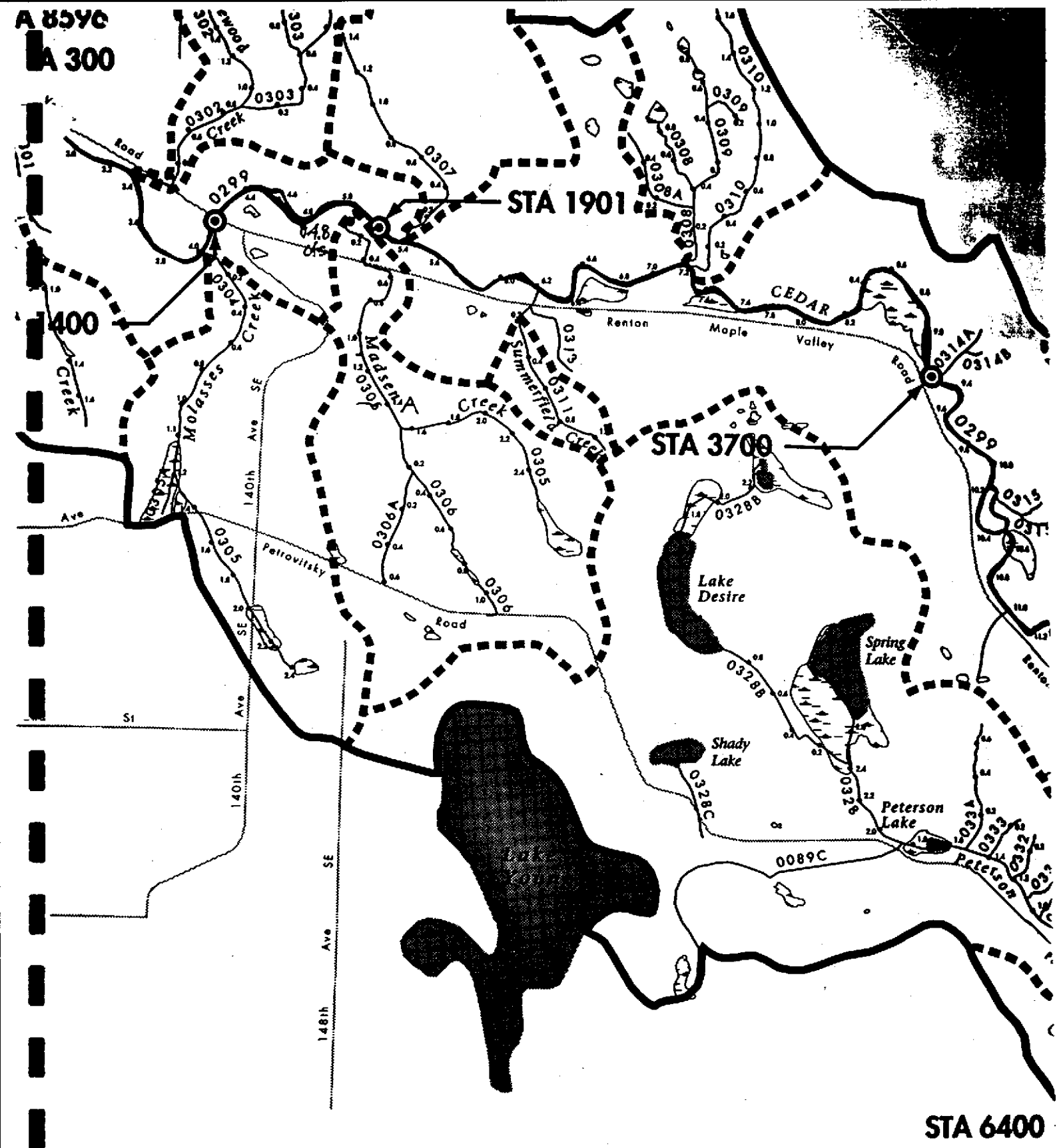
Station	Channel Elevation	Z_L	Z_R	X-section Area	Water Depth	W.S. Elevation	Inundation distance Left	Right
0	425	30	20	89.2	1.9	426.9	56.7	37.8
425	400	32	7	89.2	2.1	402.1	68.4	15.0
634	375	34	8	84.7	2.0	377.0	68.3	16.1
792	350	7	5	84.7	3.8	353.8	26.3	18.8
1003	325	3	3	80.3	5.2	330.2	15.5	15.5
1109	300	3	2	80.3	5.7	305.7	17.0	11.3
1162	275	2	2	80.3	6.3	281.3	12.7	12.7
1267	250	3	3	80.3	5.2	255.2	15.5	15.5
1373	225	3	4	75.8	4.7	229.7	14.0	18.6
1426	200	4	4	75.8	4.4	204.4	17.4	17.4
1478	175	3	9	75.8	3.6	178.6	10.7	32.0
1531	150	8	9	75.8	3.0	153.0	23.9	26.9
1584	125	2	4	75.8	5.0	130.0	10.1	20.1
2376	120	5	5	138.4	5.3	125.3	26.3	26.3
3696	112	Flat	Flat	138.4	4.5	116.5	26.3	26.3
4752	105	Flat	Flat	110.7	4.0	109.0	26.3	26.3
5702	100	Flat	Flat	101.5	3.5	103.5	26.3	26.3
6864	95	Flat	Flat	100.3	1.5	96.5	26.3	26.3


C M ST P & P
22
23
Elliot
Trailer
Park
Tower
BM
446
1.3
1.25
BM
482
BM
496
PIPELINE
26
27
BM
482
UNDERGROUND
BM
516
BM
504
BM
470
BM
463



USGS
Topo Map
1: 2000

26



A 8596
A 300
STA 1901
STA 3700
STA 6400
CEDAR
Renton
Maple
Valley
Road
Creek
Molasses
Creek
Madsen
Creek
Summerfield
Creek
Petrovitsky
Road
140th Ave SE
148th Ave SE
Lake Desire
Spring Lake
Shady Lake
Peterson Lake
Peterson
0299
0303
0302
0307
0308
0308A
0309
0310
0313
0311
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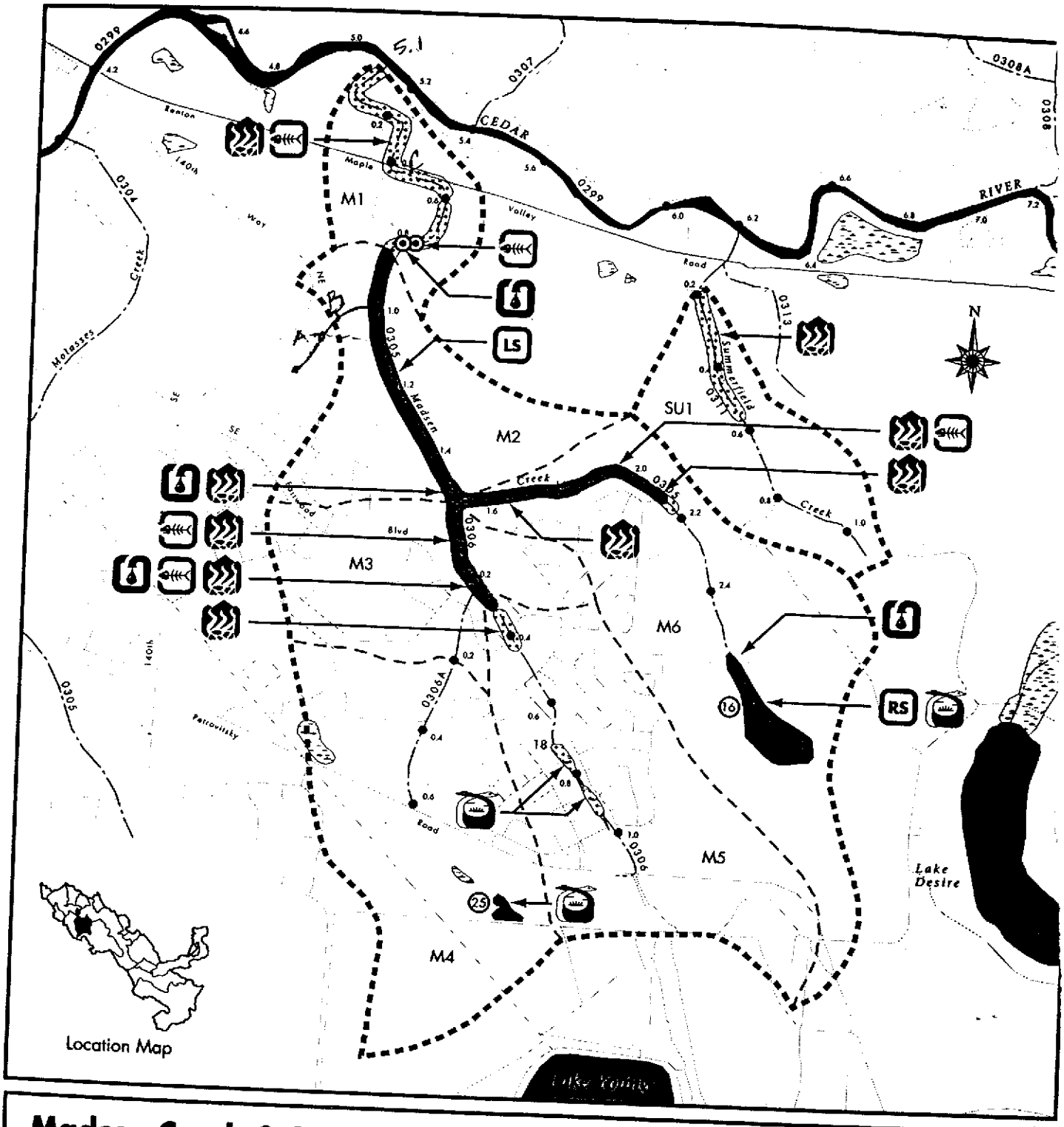
0315
0334
0333
0332



Madsen Creek & Summerfield Subbasin Conditions

Cedar River Basin Planning Area

Map 22

- 0299 Stream & Stream Number
- Lake/River
- 3.6 Stream Mile
- 5 Wetland & Wetland Number
- (5) Class I Wetland & Number
- Subbasin Boundary
- Catchment Boundary
- M1 Catchment Number
- Problem Location/Area
- Areawide Nonpoint Water Quality Problem
- Wetland Habitat Problem
- Stream Habitat Problem
- LS Locally Significant Resource Area
- RS Regionally Significant Resource Area
- Erosion/Sedimentation
- Flooding

0 ½ ½ Mile

4. INUNDATION MAPPING

The inundation map provides a description of the areal extent of flooding which would be produced by the dam break flood. It should also identify zones of high velocity flow and depict inundation for representative cross-sections of the channel. This information is standard output from many computer flood routing models and inundation maps may be developed utilizing cross-section and flood height data in conjunction with U.S. Geological Survey topographic maps.

For many planning purposes, a reasonable approximation of the inundation at a given location can be made using flood peak discharge information from Tables 4a or 4b, the attenuation curves in Figure 5, site specific channel cross-section data and representative flow velocities from Table 7.

TABLE 7 - REPRESENTATIVE VELOCITIES FOR USE IN ESTIMATING INUNDATION FROM DAM BREAK FLOODS

RM 0.3 to RM 0.0 Dam to RM 1.15 RM 1.15 to RM 0.85

TYPE 1 MAIN CHANNEL - GRAVEL OVERBANKS - GRASS, PASTURE		TYPE 2 MAIN CHANNEL - GRAVEL, COBBLES OVERBANKS - IRREGULAR, BRUSH, SCATTERED SHRUBS		TYPE 3 MAIN CHANNEL GRAVEL COBBLES, BOULDERS OVERBANKS WOODED	
BEDSLOPE (ft/mi)	VELOCITY (ft/sec)	BEDSLOPE (ft/mi)	VELOCITY (ft/sec)	BEDSLOPE (ft/mi)	VELOCITY (ft/sec)
5	2.4	5	1.7	5	1.4
10	3.4	10	2.4	10	1.9
15	4.1	15	3.0	15	2.4
20	4.8	20	3.5	20	2.7
30	5.8	30	4.2	30	3.3
40	6.7	40	4.9	40	3.8
60	8.2	60	6.0	60	4.7
80	9.5	80	6.9	80	5.4
100	10.6	100	7.7	100	6.1
200	12.0	200	10.9	200	8.6
300	12.0	300	12.0	300	10.5
400 or greater	12.0	400 or greater	12.0	400 or greater	12.0

The cross-sectional area of flow required to pass the flood would be

$$A = Q_x/V \tag{10}$$

where:

A = Cross-sectional area of channel and overbank (ft^2) needed to pass the flood
Q_x = Flood peak discharge (cfs) at location x
V = Representative, average velocity (ft/sec)

Whether using the results of the simplified method above, or data from computer modeling, one should consider the potential effects of debris buildup and sediment transport. The inundation map should represent a conservative estimate of the consequences of a dam failure.

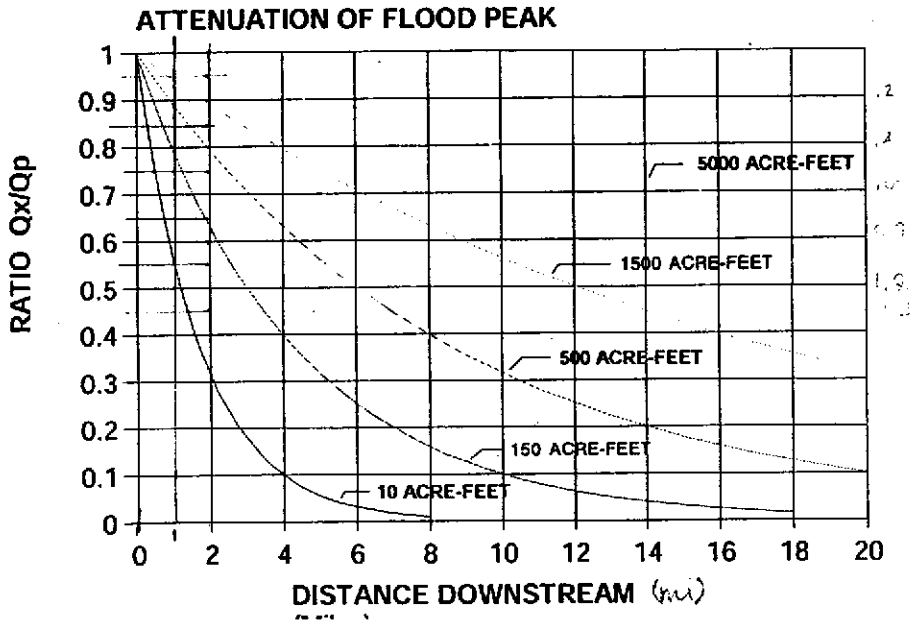


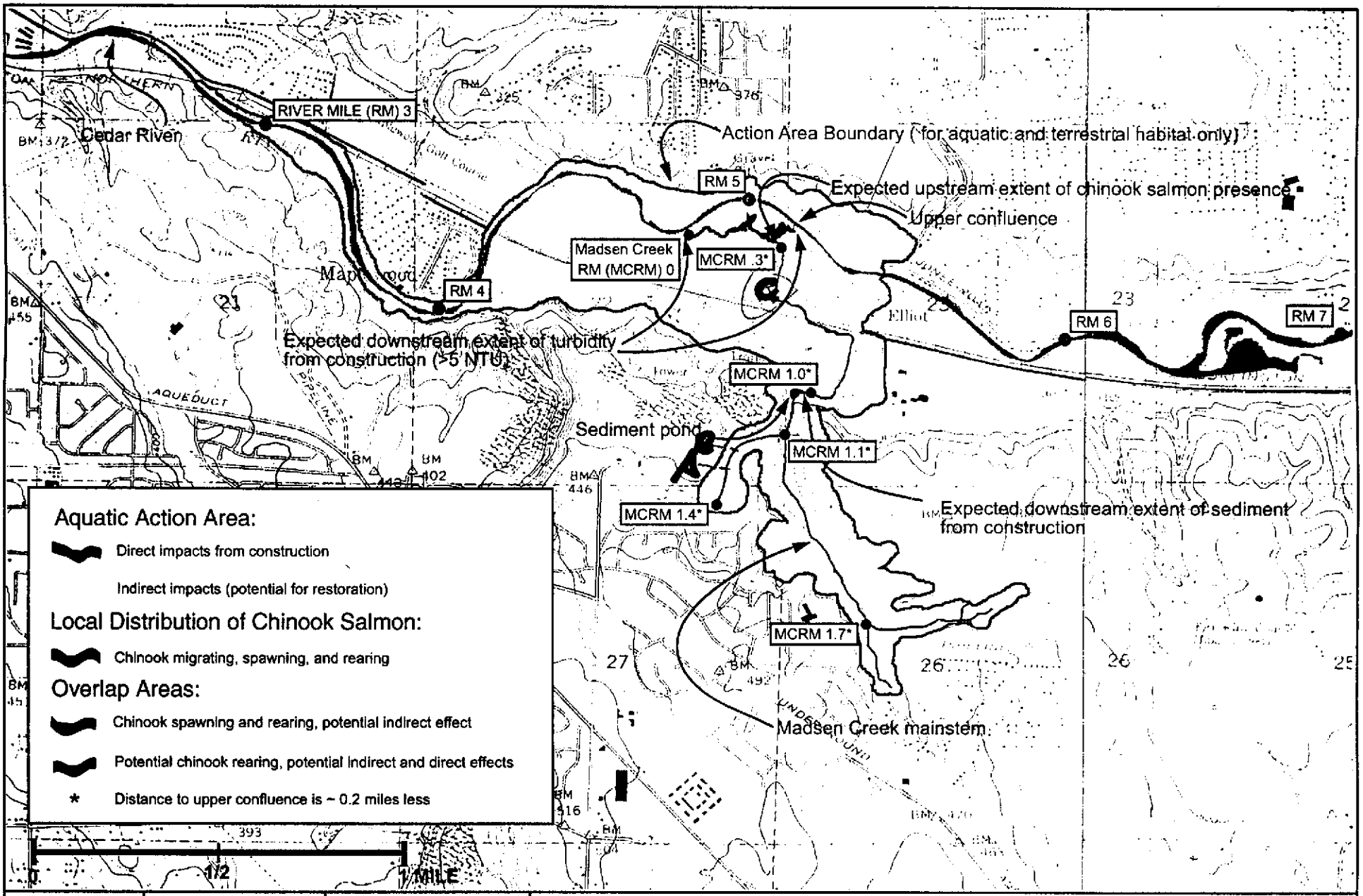
FIGURE 5 - GENERALIZED FLOOD ATTENUATION CURVES

The family of attenuation curves contained in Figure 5 are arranged according to reservoir storage volume (acre-feet). The attenuation is described in terms of the dam break peak discharge (Q_p) at the dam site and the peak discharge (Q_x) at some distance downstream.

More sophisticated routing methods, in increasing order of sophistication, include: hydrologic; diffusion; and hydraulic routing. Examples of these methods are listed in Table 6.

Flood routing should be continued to a point downstream where the dam break flood no longer poses a risk to life and there is limited potential for further property damage. Flood routing is usually terminated when the dam break flood enters a large body of water which could accommodate the floodwaters without a significant increase in water level or when the flood has attenuated to a level which is within the 100-year floodplain for the receiving stream. In the latter case, flood plain inundation maps may be available (through the Federal Emergency Management Agency (FEMA)) for use in inundation mapping in these areas.

When routing dam break floods in steep channels, care should be exercised to realistically account for the large magnitude energy losses produced by abrupt changes in channel geometry and alignment. Investigations by Jarrett[14,15,16] have shown that supercritical flow is uncommon in steep natural channels, particularly mountain streams. The irregularity of the channel geometry, presence of boulders and frequent changes in channel alignment cause large energy losses which generally restrict flow to the subcritical range. Artificially large Manning's n values are often needed to account for the increased roughness and energy losses posed by the above conditions.



NORTH
Approx. 1/2"=1000'

File name: 99138.chinook.ai
Original Graphic by: ACT
Edits by: ACT 1/30/01
Date: 10/30/00

Source: USGS; Renton and Maple Valley, Washington quadrangles; 1949.

FIGURE 3b.
ACTION AREA FOR CHINOOK SALMON
MADSEN CREEK TRIBUTARY STABILIZATION PROJECT
KING COUNTY, WASHINGTON

Appendix D

Precipitation Magnitude–Frequency Curve Spreadsheets

Appendix D

Precipitation Magnitude–Frequency Curve Spreadsheets

2 hr

BPA Madsen Creek Pond (King County DNR & P); Dam Safety file no. ___]

Worksheet for Computation of 2-hour Precipitation Magnitude-Frequency Curve
Reference: Technical Note 3, page 11 and worksheet from page B-10

RJB, 2/27/02 page 1 of 2

Project data:

Location:	T 23N, R 5E, Section 26 & 27; 4 miles N/S/E/W of Renton		
Lat/Long:	47.5 deg. N	122.1 deg. W	in Western Washington
Basin elevation :	434	feet	
Climatic Region:	3		(Figure 4 on page 12)
Mean Annual Precip:	45	inches	(Isopluvial maps, App. A)
Duration of interest:	2	hours	
Design Step:	8		(Worksheet from Tech Note 2)
Drainage area:	0.1	sq.miles.	(Compare to small watershed < 1 sq.mile.)

Parameters for Computation of At-Site Mean:

6-hour, 2-year Partial Duration Value, X_6 (in.) =	0.95	(Isopluvial maps, App. A)
24-hour, 2-year Partial Duration Value, X_{24} (in.) =	1.75	(Isopluvial maps, App. A)
Regional value of Coefficient of Variation, C_v =	0.295	(Figure 5 on page 13)
Regional value of L-Skewness, T_3 =	0.220	(Figure 6 on page 14)
Frequency factor for 2-year event, K_2 =	-0.197	(Table B1, App. B)

Latitude Index, L_1 =	7.5
Longitude Index L_2 =	22.1
Elevation Index, Z =	4.34
Estimated 2-hour, 2-year Partial Duration Value =	0.55 (Isopluvial maps, App. A)

Key equations :

2-hour, 2-year Partial Duration Value, X_2 :

$X_2 = A + B*X_6 + C*X_{24} + D*(X_6^2/X_{24}) + E*Z - F*L_1*L_2$

where values for A, B, C, D, E and F vary by climatic region as follows:

Region	A	B	C	D	E	F
1	0.014	0.250	0	0.533	0.0008	0
2	0.056	0.278	0.245	0	0	0.0003
3	0.119	0.240	0	0.390	0	0
4	0.122	0.240	0	0.395	0	0
5	0.119	0.240	0	0.390	0	0

At-Site Mean, $X_M = (0.88 * X_{2p}) / [(1 + (K_2 * C_v)]$

where: X_{2p} = 2-year Partial Duration Value (= X_2 from above calculation)

Quantile estimates: $X_i = X_M * [1 + (K_i * C_v)]$

where: X_i = estimated 2-hour precipitation for selected frequency, inches
K_i = frequency factor for selected frequency (Table B1 or B2, App.B)

Design precipitation, $P_d = DF * X_{ds}$ Use design factor = 1.15

where: X_{ds} = quantile estimate X_i for selected design step, inches
DF = design factor; DF = 1.15 for new dams

BPA Madsen Creek Pond (King County DNR & P); Dam Safety file no. ___]

Worksheet for Computation of 2-hour Precipitation Magnitude-Frequency Curve
Reference: Technical Note 3, page 11 and worksheet from page B-10

RJB, 2/27/02 page 2 of 2

Key equations (cont.) :

Total storm precip = (design precip for 2-hr storm) x (multiplier from mass curve for 6-hr storm)

multiplier for 6-hr design storm = 1.1794

2-hour, 2-year Partial Duration Value, X_2 (in.) :

Region	A	B	C	D	E	F
3	0.119	0.240	0	0.390	0	0

X_2 (inches) = 0.55 compares with 0.55 inches estimated from isopluvial map

At-Site Mean, X_M (inches) = 0.51

Frequency / design step :	2 yr	10 yr	25 yr	100 yr	Step 1	Step 2
Frequency factor, K_i (--) :	-0.179	1.23	2.05	3.41	5.22	6.10
Quantile estimate, X_i (inches) :	0.49	0.70	0.82	1.03	1.30	1.43
Design precipitation, P_d (in.) :	0.56	0.80	0.95	1.18	1.50	1.65
Total precip for design storm :	0.66	0.95	1.11	1.39	1.76	1.94

Frequency / design step :	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Frequency factor, K_i (--) :	7.69	9.47	11.47	13.71	16.22	19.04
Quantile estimate, X_i (inches) :	1.67	1.94	2.24	2.58	2.96	3.39
Design precipitation, P_d (in.) :	1.92	2.23	2.58	2.97	3.41	3.90
Total precip for design storm :	2.27	2.64	3.04	3.50	4.02	4.60

Comparison to PMP for local storm (thunderstorm). Ref: HMR-57, Fig. 11.19 and 11.12, Table 11.4.

Local storm, 1-hour PMP = in.

2-hour PMP = 110% x 1-hr = #VALUE! in.

Frequency / design step :	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Design precipitation, P_d (in.) :	1.92	2.23	2.58	2.97	3.41	3.90
Percentage of 2-hr PMP (%) :	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!

6 hr

BPA Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___]

Worksheet for Computation of 6-hour Precipitation Magnitude-Frequency Curve
Reference: Technical Note 3, worksheet from page B-10
RJB, 2/27/02 page 1 of 2

Project data:

Location:	T 23N, R 5E, Section 26 &27; 4 miles SE of Renton	
Lat/Long:	47.5 deg. N 122.1 deg. W	in Western Washington
Climatic Region:	3	(Figure 4 on page 12)
Mean Annual Precip:	45 inches	(Isopluvial maps, App. A)
Duration of interest:	6 hours	
Design Step:	8	(Worksheet from Tech Note 2)
Drainage area:	0.1 sq.miles.	(Compare to small watershed < 10 sq.miles.)

Parameters for Computation of At-Site Mean:

6-hour, 2-year Partial Duration Value, X_6 (in.)	=	0.95	(Isopluvial maps, App. A)
Regional value of Coefficient of Variation, C_v	=	0.260	(Figure 5 on page 13)
Regional value of L-Skewness, T_3	=	0.180	(Figure 6 on page 14)
Frequency factor for 2-year event, K_2	=	-0.169	(Table B1, App. B)

Key equations:

At-Site Mean, $X_M = (0.88 * X_{2p}) / [(1 + (K_2 * C_v)]$
where: X_{2p} = 2-year Partial Duration Value (= X_6 from above)

Quantile estimates: $X_i = X_M * [1 + (K_i * C_v)]$
where: X_i = estimated 6-hour precipitation for selected frequency, inches
K_i = frequency factor for selected frequency (Table B1 or B2, App.B)

Design precipitation, $P_d = DF * X_{ds}$ Use design factor = 1.15
where: X_{ds} = quantile estimate X_i for selected design step, inches
DF = design factor; DF = 1.15 for new dams

Total storm precip = (design precip for 6-hr storm) x (multiplier from mass curve for 18-hr storm)
multiplier for 18-hr design storm = 1.385

At-Site Mean, X_M (inches) = 0.87

Frequency / design step :	2 yr	10 yr	25 yr	100 yr	Step 1	Step 2
Frequency factor, K_i (--) :	-0.169	1.28	2.04	3.22	4.67	5.32
Quantile estimate, X_i (inches) :	0.84	1.17	1.34	1.61	1.94	2.08
Design precipitation, P_d (in.) :	0.96	1.34	1.54	1.85	2.23	2.40
Total precip for design storm :	1.33	1.86	2.13	2.56	3.08	3.32

Frequency / design step :	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Frequency factor, K_i (--) :	6.45	7.63	8.87	10.17	11.54	12.97
Quantile estimate, X_i (inches) :	2.34	2.61	2.89	3.19	3.50	3.82
Design precipitation, P_d (in.) :	2.69	3.00	3.32	3.66	4.02	4.40
Total precip for design storm :	3.73	4.16	4.60	5.08	5.57	6.09

BPA Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___]

Worksheet for Computation of 6-hour Precipitation Magnitude-Frequency Curve
Reference: Technical Note 3, worksheet from page B-10

RJB, 2/27/02 page 2 of 2

Comparison to PMP for general storm. Ref: HMR-57, Map 1 - NW, Table 10.10.

PMP for a 6-hour period is estimated as a percentage of the 24-hour PMP. The percentage factor varies by climatic region as follows :

	Eastern Washington		Western Washington		
	Mountains	Central Basin	Puget Sound	Mountains	Coast
Region :	1	2	3	4	5
Factor :	0.52	0.59	0.44	0.40	0.43

This project :

General storm, 24-hour PMP = in.

For region: 3
6-hr PMP= 0.44 x 24-hr = #VALUE! in.

Frequency / design step :	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Design precipitation, P_d (in.) :	2.69	3.00	3.32	3.66	4.02	4.40
Percentage of 6-hr PMP (%) :	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!

Comparison to PMP for local storm (thunderstorm). Ref: HMR-57, Fig. 11.19 and 11.12, Table 11.4.

Local storm, 1-hour PMP = in.
6-hour PMP = 115% x 1-hr = #VALUE! in.

Frequency / design step :	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Design precipitation, P_d (in.) :	2.69	3.00	3.32	3.66	4.02	4.40
Percentage of 6-hr PMP (%) :	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!

24 hr

BPA Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___]

Worksheet for Computation of 24-hour Precipitation Magnitude-Frequency Curve
Reference: Technical Note 3, worksheet from page B-10
RJB,2/27/02 page 1 of 2

Project data:

Location:	T 23N, R 5E, Section 26 & 27; 4 miles SE of Renton	
Lat/Long:	47.5 deg. N 122.1 deg. W	in Western Washington
Climatic Region:	3	(Figure 4 on page 12)
Mean Annual Precip:	45 inches	(Isopluvial maps, App. A)
Duration of interest:	24 hours	
Design Step:	8	(Worksheet from Tech Note 2)
Drainage area:	0.1 sq.miles.	(Compare to small watershed < 10 sq.miles.)

Parameters for Computation of At-Site Mean:

24-hour, 2-year Partial Duration Value, X_{24} (in.)	=	1.75	(Isopluvial maps, App. A)
Regional value of Coefficient of Variation, C_v	=	0.305	(Figure 5 on page 13)
Regional value of L-Skewness, T_3	=	0.185	(Figure 6 on page 14)
Frequency factor for 2-year event, K_2	=	-0.173	(Table B1, App. B)

Key equations:

At-Site Mean, $X_M = (0.88 * X_{2p}) / [(1 + (K_2 * C_v)]$
where: X_{2p} = 2-year Partial Duration Value (= X_{24} from above)

Quantile estimates: $X_i = X_M * [1 + (K_i * C_v)]$
where: X_i = estimated 24-hour precipitation for selected frequency, inches
K_i = frequency factor for selected frequency (Table B1 or B2, App.B)

Design precipitation, $P_d = DF * X_{ds}$ Use design factor = 1.15
where: X_{ds} = quantile estimate X_i for selected design step, inches
DF = design factor; DF = 1.15 for new dams

Total storm precip = (design precip for 24-hr storm) x (multiplier from mass curve for 72-hr storm)
multiplier for 72-hr high intensity storm = 1.1994
multiplier for 72-hr high volume storm = 1.3183

At-Site Mean, X_M (inches) = 1.63

Frequency / design step :	2 yr	10 yr	25 yr	100 yr	Step 1	Step 2
Frequency factor, K_i (--) :	-0.173	1.27	2.04	3.25	4.74	5.42
Quantile estimate, X_i (inches) :	1.54	2.26	2.64	3.24	3.98	4.31
Design precipitation, P_d (in.) :	1.77	2.59	3.03	3.72	4.57	4.96
Total precip for intensity storm :	2.12	3.11	3.64	4.47	5.48	5.95
Total precip for volume storm :	2.33	3.42	4.00	4.91	6.03	6.54

Frequency / design step :	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Frequency factor, K_i (--) :	6.60	7.84	9.16	10.56	12.03	13.59
Quantile estimate, X_i (inches) :	4.90	5.51	6.17	6.86	7.59	8.36
Design precipitation, P_d (in.) :	5.63	6.34	7.09	7.89	8.73	9.62
Total precip for intensity storm :	6.76	7.60	8.51	9.46	10.47	11.54
Total precip for volume storm :	7.43	8.36	9.35	10.40	11.51	12.68

BPA Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___]

Worksheet for Computation of 24-hour Precipitation Magnitude-Frequency Curve
Reference: Technical Note 3, worksheet from page B-10

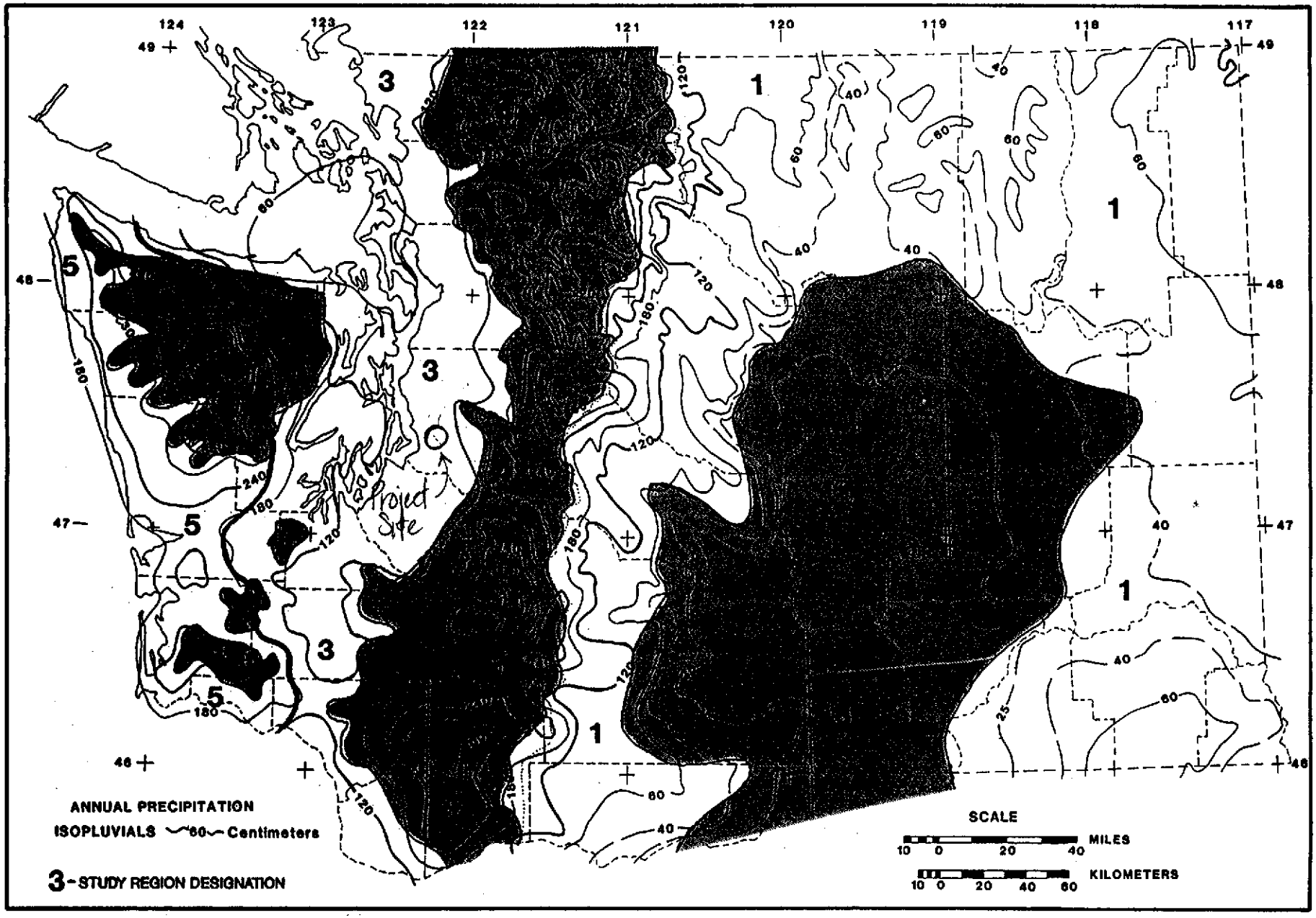
RJB,2/27/02 page 2 of 2

Comparison to PMP for general storm. Ref: HMR-57, Map 1 - NW.

General storm, 24-hour PMP = in.

Frequency / design step :	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Design precipitation, P_d (in.) :	5.63	6.34	7.09	7.89	8.73	9.62
Percentage of 24-hr PMP (%):	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!

[end]



Region 3

FIGURE 4. CLIMATIC REGIONS IN WASHINGTON

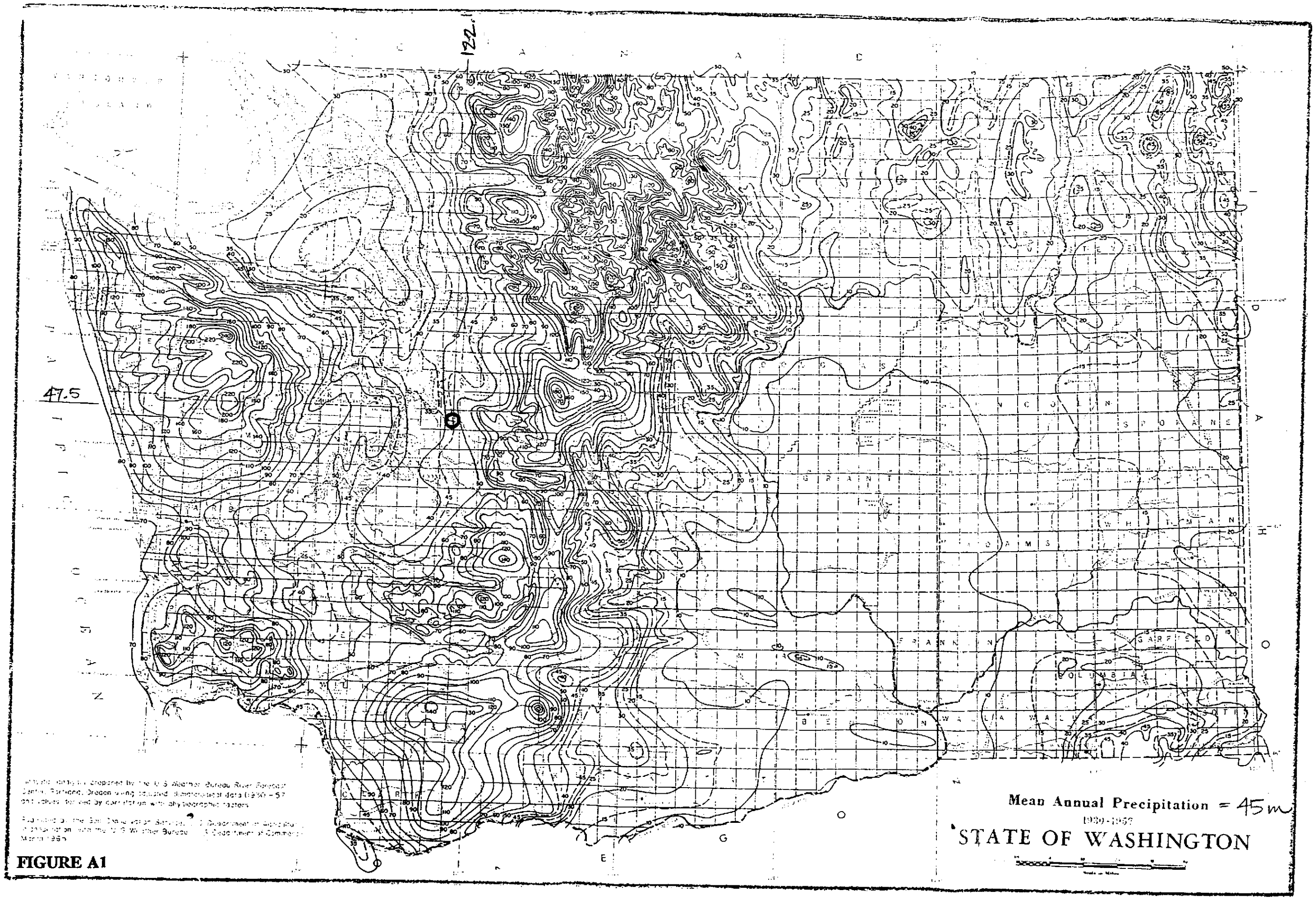

122.
47.5
Mean Annual Precipitation = 45m
1930-1957
STATE OF WASHINGTON

FIGURE A1

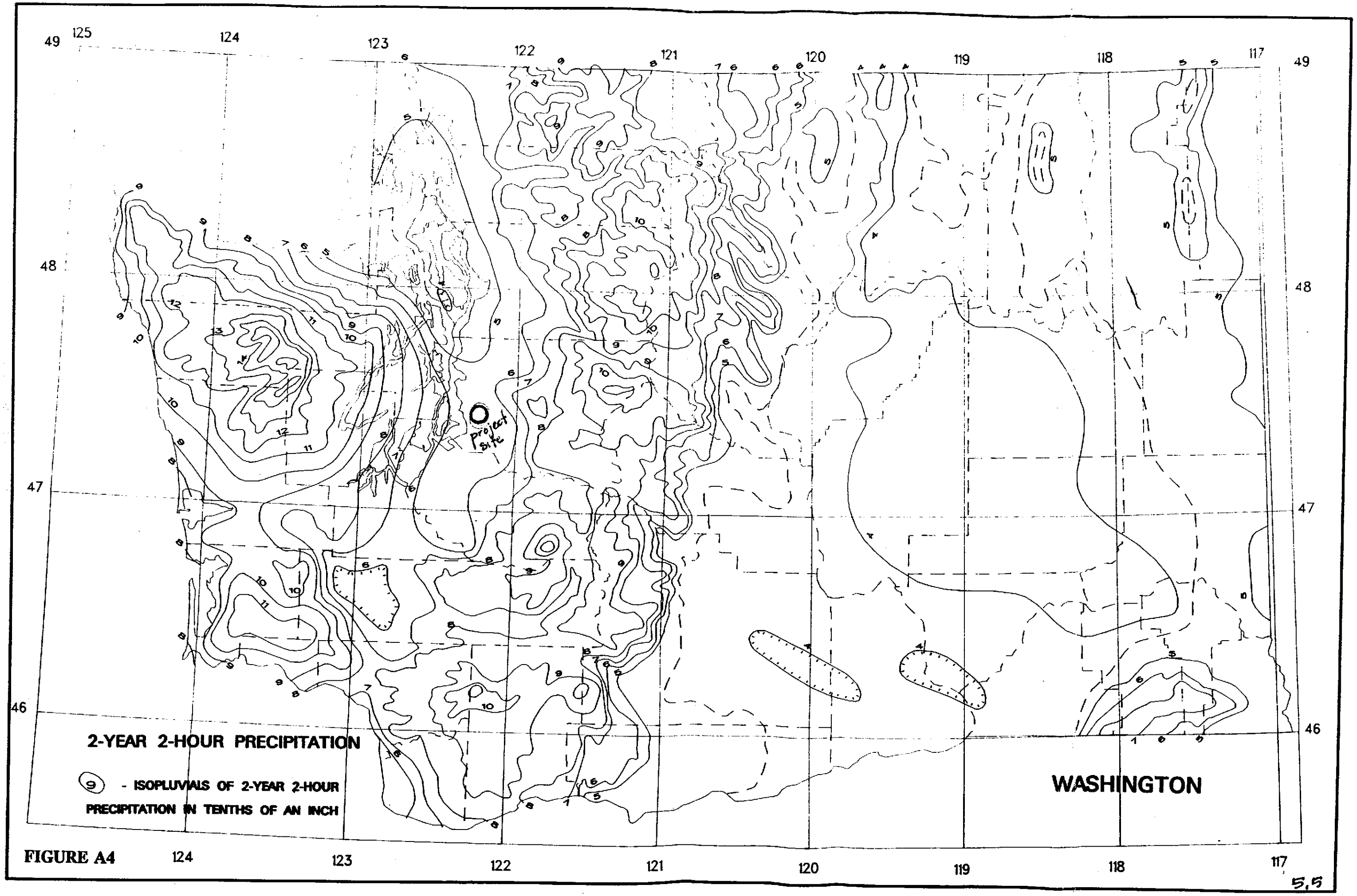
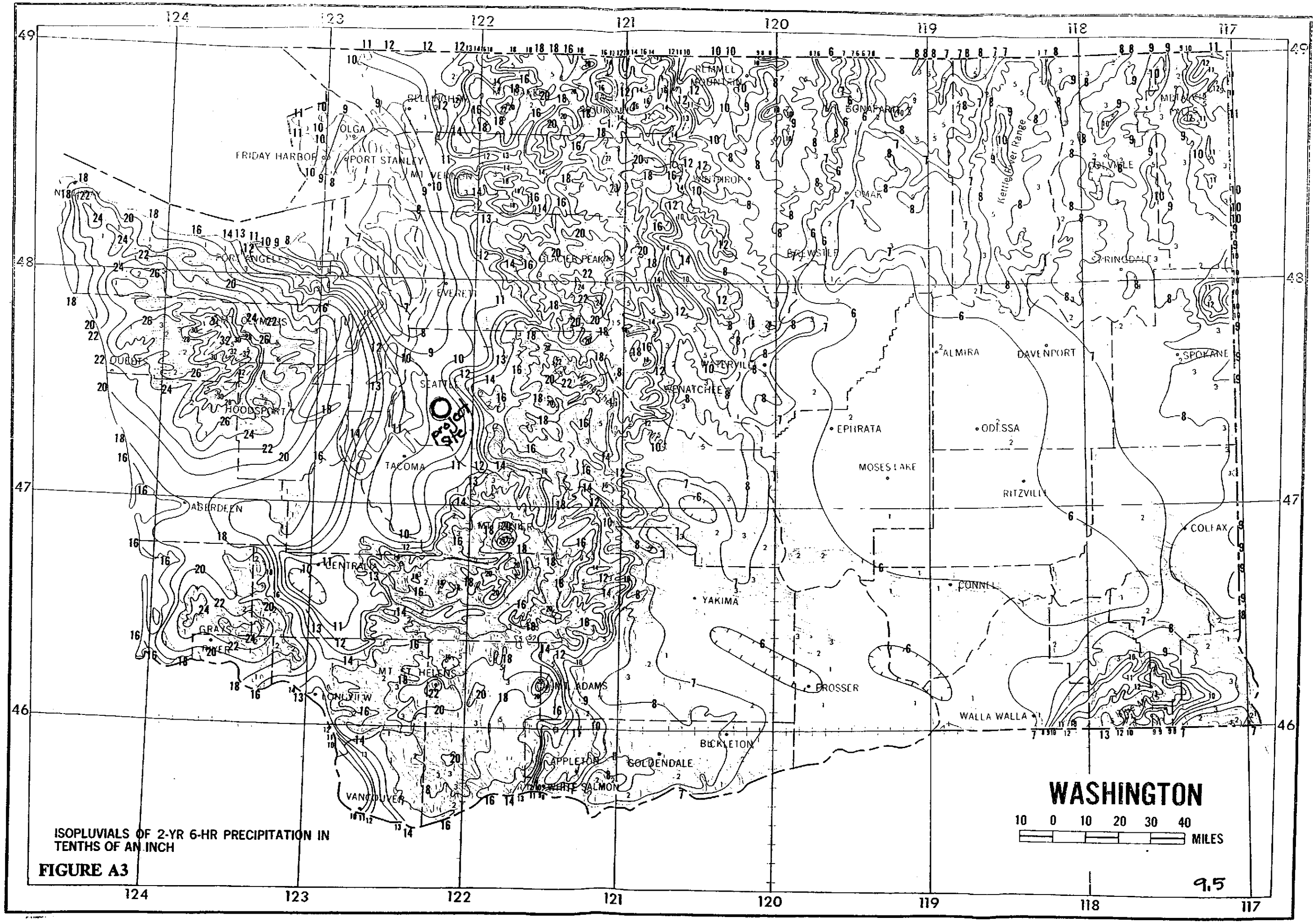

2-YEAR 2-HOUR PRECIPITATION
9 - ISOPLUVIALS OF 2-YEAR 2-HOUR PRECIPITATION IN TENTHS OF AN INCH
WASHINGTON
Project site
125
124
123
122
121
120
119
118
117
49
48
47
46

FIGURE A4



ISOPLUVIALS OF 2-YR 6-HR PRECIPITATION IN TENTHS OF AN INCH

FIGURE A3

9.5

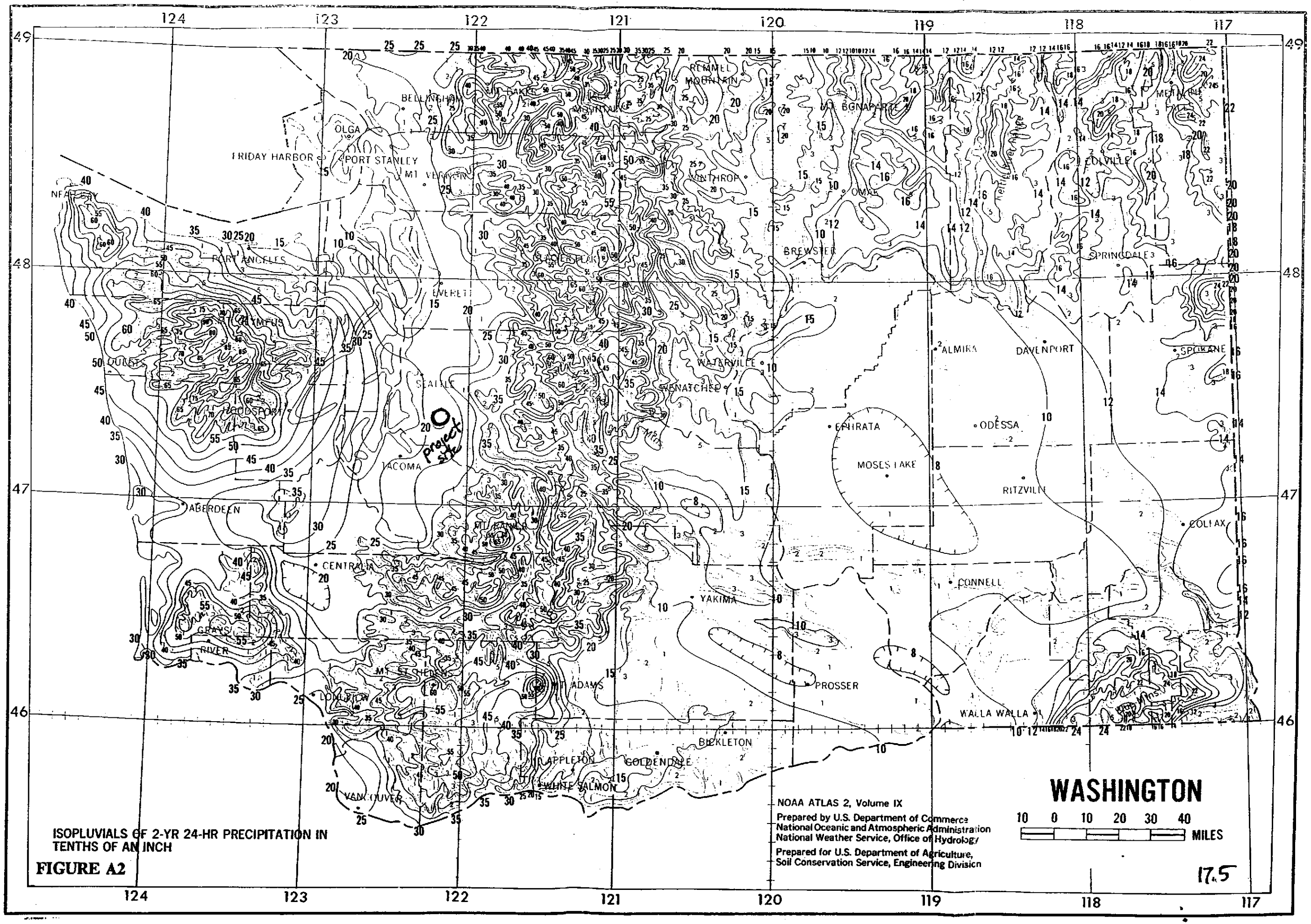
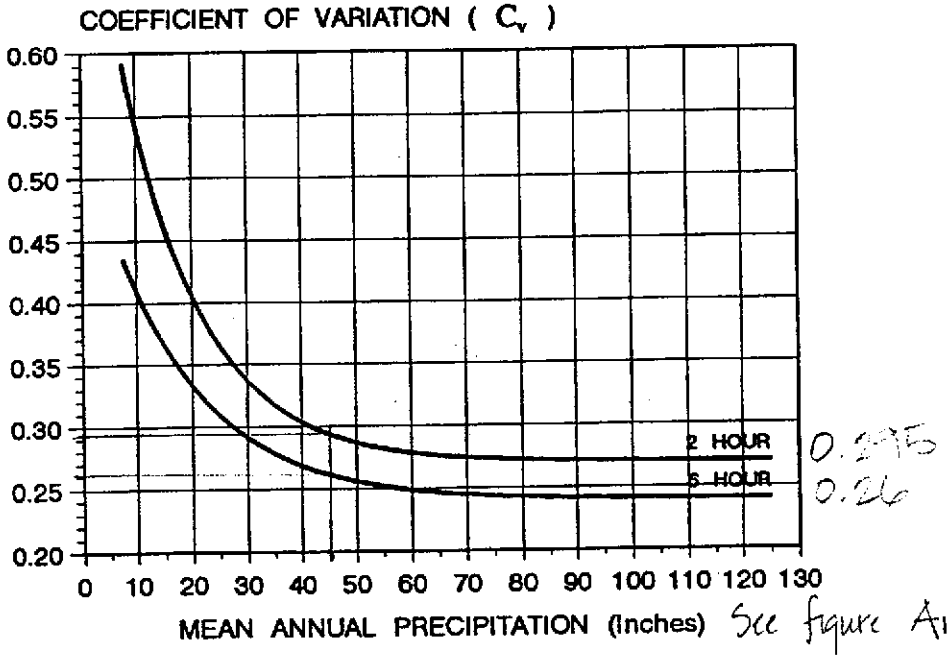
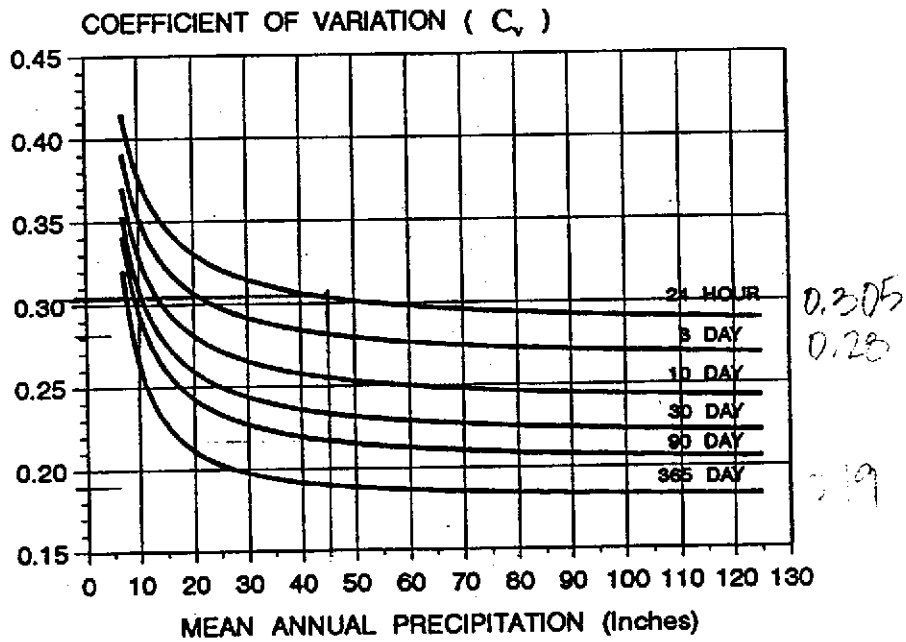


FIGURE A2

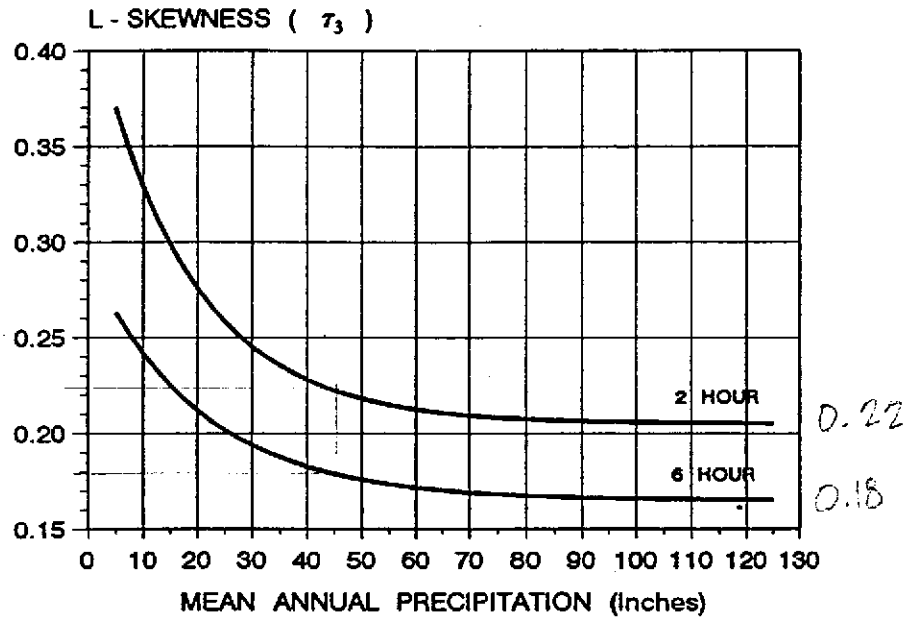
17.5

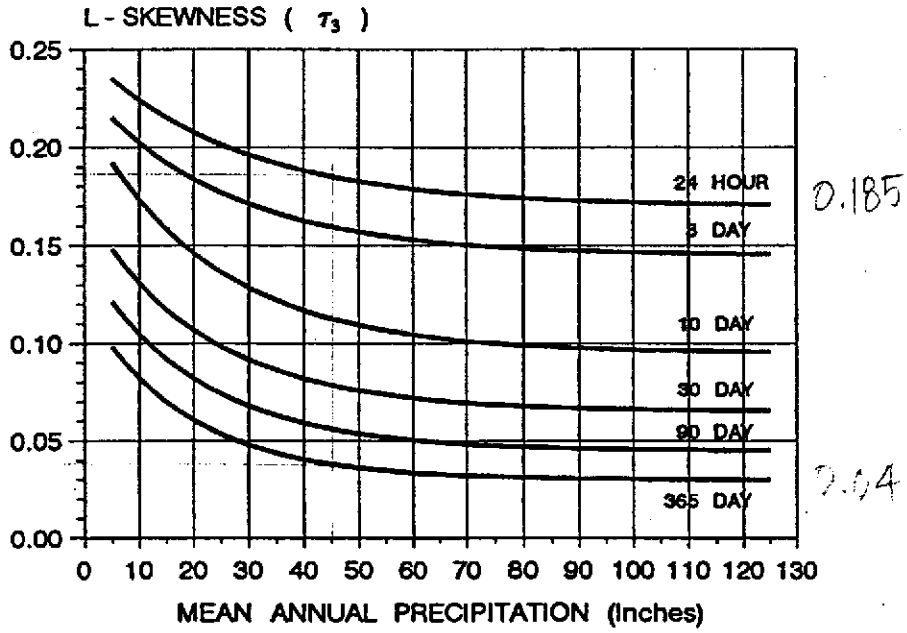
The regional parameters C_v and τ_3 are displayed in Figures 5a,5b and 6a,6b respectively, and values from the graphs may be used directly in computational procedures once a value of the MAP (Appendix A) for the geographic location of interest has been obtained.





FIGURES 5a, 5b RELATIONSHIP OF REGIONAL COEFFICIENT OF VARIATION WITH MEAN ANNUAL PRECIPITATION AND DURATION





FIGURES 6a, 6b RELATIONSHIP OF REGIONAL L-SKEWNESS WITH MEAN ANNUAL PRECIPITATION AND DURATION

TABLE B1. FREQUENCY FACTORS FOR WESTERN WASHINGTON

KAPPA DISTRIBUTION h= -0.10

τ3	2 YR	10 YR	25 YR	100 YR	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8
.200	-.184	1.26	2.05	3.32	4.94	5.70	7.05	8.50	10.08	11.80	13.66	15.67
.205	-.187	1.25	2.05	3.34	5.01	5.80	7.20	8.73	10.41	12.25	14.25	16.45
.210	-.190	1.25	2.05	3.37	5.08	5.90	7.36	8.97	10.75	12.71	14.88	17.26
.215	-.194	1.24	2.05	3.39	5.15	6.00	7.52	9.22	11.11	13.20	15.54	18.13
2hr — .220	-.197	1.23	2.05	3.41	5.22	6.10	7.69	9.47	11.47	13.71	16.22	19.04 —
.225	-.200	1.23	2.05	3.43	5.29	6.20	7.86	9.73	11.85	14.24	16.95	20.01
.230	-.203	1.22	2.05	3.45	5.36	6.30	8.03	9.99	12.23	14.79	17.70	21.02
.235	-.206	1.21	2.05	3.47	5.43	6.40	8.20	10.27	12.64	15.36	18.49	22.09
.240	-.209	1.20	2.05	3.49	5.50	6.51	8.38	10.54	13.05	15.96	19.33	23.23
.245	-.211	1.20	2.04	3.51	5.58	6.61	8.56	10.83	13.49	16.58	20.20	24.43
.250	-.214	1.19	2.04	3.53	5.65	6.72	8.74	11.12	13.93	17.23	21.12	25.69
.255	-.217	1.18	2.04	3.55	5.72	6.82	8.93	11.42	14.39	17.90	22.08	27.03
.260	-.219	1.17	2.03	3.56	5.79	6.93	9.11	11.73	14.86	18.60	23.08	28.43
.265	-.221	1.16	2.03	3.58	5.85	7.03	9.31	12.05	15.35	19.33	24.13	29.92
.270	-.224	1.15	2.02	3.59	5.92	7.14	9.50	12.37	15.85	20.08	25.23	31.48
.275	-.226	1.14	2.02	3.61	5.99	7.25	9.69	12.69	16.37	20.87	26.38	33.13
.280	-.228	1.14	2.01	3.62	6.06	7.35	9.89	13.03	16.90	21.68	27.58	34.87
.285	-.230	1.13	2.01	3.63	6.13	7.46	10.09	13.37	17.45	22.52	28.84	36.70
.290	-.232	1.12	2.00	3.64	6.19	7.56	10.29	13.72	18.01	23.40	30.15	38.62
.295	-.233	1.10	1.99	3.66	6.26	7.67	10.50	14.07	18.59	24.30	31.52	40.64
.300	-.235	1.09	1.98	3.66	6.32	7.77	10.70	14.43	19.19	25.24	32.95	42.77

TABLE B1. FREQUENCY FACTORS FOR WESTERN WASHINGTON

KAPPA DISTRIBUTION h= -0.10

τ3	2 YR	10 YR	25 YR	100 YR	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8
.100	-.102	1.32	1.95	2.80	3.67	4.01	4.54	5.02	5.46	5.86	6.22	6.56
.105	-.107	1.32	1.96	2.83	3.73	4.08	4.64	5.15	5.62	6.05	6.45	6.82
.110	-.111	1.32	1.97	2.86	3.79	4.16	4.74	5.28	5.78	6.25	6.69	7.09
.115	-.116	1.32	1.97	2.88	3.84	4.23	4.84	5.42	5.96	6.46	6.93	7.38
.120	-.120	1.32	1.98	2.91	3.90	4.31	4.95	5.56	6.13	6.68	7.19	7.68
.125	-.125	1.31	1.99	2.94	3.96	4.39	5.06	5.70	6.32	6.91	7.47	8.00
.130	-.129	1.31	1.99	2.96	4.03	4.47	5.17	5.85	6.51	7.14	7.75	8.34
.135	-.133	1.31	2.00	2.99	4.09	4.55	5.29	6.01	6.71	7.39	8.05	8.70
.140	-.137	1.31	2.01	3.02	4.15	4.63	5.41	6.17	6.92	7.65	8.37	9.07
.145	-.142	1.30	2.01	3.04	4.21	4.71	5.53	6.33	7.13	7.92	8.70	9.47
.150	-.146	1.30	2.02	3.07	4.28	4.79	5.65	6.50	7.36	8.20	9.05	9.89
.155	-.150	1.30	2.02	3.10	4.34	4.88	5.78	6.68	7.59	8.50	9.42	10.34
.160	-.154	1.29	2.03	3.12	4.41	4.97	5.91	6.86	7.83	8.81	9.80	10.81
.165	-.158	1.29	2.03	3.15	4.47	5.05	6.04	7.04	8.07	9.13	10.20	11.31
.170	-.162	1.29	2.03	3.17	4.54	5.14	6.17	7.23	8.33	9.46	10.63	11.83
.175	-.165	1.28	2.04	3.20	4.60	5.23	6.31	7.43	8.60	9.81	11.07	12.39
6hr — .180	-.169	1.28	2.04	3.22	4.67	5.32	6.45	7.63	8.87	10.17	11.54	12.97
24 — .185	-.173	1.27	2.04	3.25	4.74	5.42	6.60	7.84	9.16	10.56	12.03	13.59
.190	-.177	1.27	2.05	3.27	4.81	5.51	6.74	8.06	9.46	10.95	12.55	14.25
.195	-.180	1.26	2.05	3.30	4.88	5.61	6.89	8.28	9.76	11.37	13.09	14.94
.200	-.184	1.26	2.05	3.32	4.94	5.70	7.05	8.50	10.08	11.80	13.66	15.67

M02-33.R03
Region 3, Design Hyetograph
Short Duration Storm; 33% exceedance

TIME	PI	PC	PI adj	PC adj
0		0		0
0.083	0.0064	0.0064	0.025	0.02
0.167	0.0069	0.0133	0.027	0.05
0.250	0.0078	0.0211	0.030	0.08
0.333	0.0092	0.0304	0.036	0.12
0.417	0.0111	0.0415	0.043	0.16
0.500	0.0135	0.0550	0.053	0.21
0.583	0.0161	0.0711	0.063	0.28
0.667	0.0180	0.0891	0.070	0.35
0.750	0.0189	0.1080	0.074	0.42
0.833	0.0204	0.1284	0.080	0.50
0.917	0.0283	0.1567	0.110	0.61
1.000	0.0633	0.2200	0.247	0.86
1.083	0.1380	0.3580	0.538	1.40
1.167	0.1550	0.5130	0.605	2.00
1.250	0.1490	0.6620	0.581	2.58
1.333	0.1091	0.7711	0.425	3.01
1.417	0.0716	0.8428	0.279	3.29
1.500	0.0482	0.8910	0.188	3.47
1.583	0.0366	0.9276	0.143	3.62
1.667	0.0278	0.9555	0.108	3.73
1.750	0.0195	0.9750	0.076	3.80
1.833	0.0090	0.9840	0.035	3.84
1.917	0.0085	0.9925	0.033	3.87
2.000	0.0077	1.0002	0.030	3.90
2.083	0.0073	1.0075	0.028	3.93
2.167	0.0068	1.0143	0.027	3.96
2.250	0.0066	1.0209	0.026	3.98
2.333	0.0064	1.0273	0.025	4.01
2.417	0.0063	1.0336	0.025	4.03
2.500	0.0062	1.0398	0.024	4.06
2.583	0.0061	1.0459	0.024	4.08
2.667	0.0059	1.0518	0.023	4.10
2.750	0.0053	1.0571	0.021	4.12
2.833	0.0048	1.0619	0.019	4.14
2.917	0.0044	1.0663	0.017	4.16
3.000	0.0041	1.0704	0.016	4.17
3.083	0.0038	1.0742	0.015	4.19
3.167	0.0036	1.0778	0.014	4.20
3.250	0.0034	1.0812	0.013	4.22
3.333	0.0032	1.0845	0.012	4.23
3.417	0.0031	1.0875	0.012	4.24
3.500	0.0030	1.0905	0.012	4.25

3.583	0.0029	1.0934	0.011	4.26
3.667	0.0028	1.0962	0.011	4.28
3.750	0.0028	1.0990	0.011	4.29
3.833	0.0028	1.1018	0.011	4.30
3.917	0.0028	1.1046	0.011	4.31
4.000	0.0028	1.1074	0.011	4.32
4.083	0.0029	1.1103	0.011	4.33
4.167	0.0030	1.1133	0.012	4.34
4.250	0.0030	1.1163	0.012	4.35
4.333	0.0031	1.1194	0.012	4.37
4.417	0.0031	1.1225	0.012	4.38
4.500	0.0031	1.1256	0.012	4.39
4.583	0.0031	1.1288	0.012	4.40
4.667	0.0032	1.1319	0.012	4.41
4.750	0.0032	1.1351	0.012	4.43
4.833	0.0031	1.1382	0.012	4.44
4.917	0.0031	1.1413	0.012	4.45
5.000	0.0031	1.1444	0.012	4.46
5.083	0.0031	1.1475	0.012	4.48
5.167	0.0030	1.1505	0.012	4.49
5.250	0.0030	1.1535	0.012	4.50
5.333	0.0030	1.1564	0.012	4.51
5.417	0.0029	1.1594	0.011	4.52
5.500	0.0029	1.1623	0.011	4.53
5.583	0.0029	1.1651	0.011	4.54
5.667	0.0029	1.1680	0.011	4.56
5.750	0.0029	1.1709	0.011	4.57
5.833	0.0028	1.1737	0.011	4.58
5.917	0.0028	1.1766	0.011	4.59
6.000	0.0028	1.1794	0.011	4.60

c hr

M06-20.R03
Region 3, Design Hyetograph
Intermediate Duration Storm; 20% exceedance

TIME	PI	PC	PI adj	PC adj
0		0		0
0.25	0.0031	0.0031	0.014	0.014
0.50	0.0031	0.0062	0.014	0.027
0.75	0.0032	0.0094	0.014	0.041
1.00	0.0032	0.0126	0.014	0.055
1.25	0.0032	0.0158	0.014	0.070
1.50	0.0033	0.0191	0.015	0.084
1.75	0.0034	0.0225	0.015	0.099
2.00	0.0035	0.0260	0.015	0.114
2.25	0.0036	0.0295	0.016	0.130
2.50	0.0037	0.0332	0.016	0.146
2.75	0.0038	0.0370	0.017	0.163
3.00	0.0040	0.0410	0.018	0.180
3.25	0.0041	0.0451	0.018	0.198
3.50	0.0043	0.0494	0.019	0.217
3.75	0.0046	0.0540	0.020	0.238
4.00	0.0048	0.0588	0.021	0.259
4.25	0.0052	0.0640	0.023	0.28
4.50	0.0055	0.0695	0.024	0.31
4.75	0.0060	0.0755	0.026	0.33
5.00	0.0064	0.0819	0.028	0.36
5.25	0.0069	0.0888	0.030	0.39
5.50	0.0075	0.0963	0.033	0.42
5.75	0.0081	0.1043	0.036	0.46
6.00	0.0087	0.1130	0.038	0.50
6.25	0.0094	0.1224	0.041	0.54
6.50	0.0101	0.1325	0.044	0.58
6.75	0.0109	0.1433	0.048	0.63
7.00	0.0117	0.1550	0.051	0.68
7.25	0.0126	0.1676	0.055	0.74
7.50	0.0135	0.1810	0.059	0.80
7.75	0.0145	0.1955	0.064	0.86
8.00	0.0155	0.2110	0.068	0.93
8.25	0.0165	0.2275	0.073	1.00
8.50	0.0177	0.2452	0.078	1.08
8.75	0.0188	0.2640	0.083	1.16
9.00	0.0200	0.2840	0.088	1.25
9.25	0.0213	0.3053	0.094	1.34
9.50	0.0225	0.3278	0.099	1.44
9.75	0.0238	0.3516	0.105	1.55
10.00	0.0250	0.3766	0.110	1.66
10.25	0.0262	0.4028	0.115	1.77
10.50	0.0275	0.4303	0.121	1.89
10.75	0.0287	0.4590	0.126	2.02

11.00	0.0299	0.4888	0.132	2.15
11.25	0.0310	0.5199	0.136	2.29
11.50	0.0322	0.5521	0.142	2.43
11.75	0.0334	0.5855	0.147	2.58
12.00	0.0345	0.6200	0.152	2.73
12.25	0.0357	0.6557	0.157	2.89
12.50	0.0368	0.6925	0.162	3.05
12.75	0.0378	0.7302	0.166	3.21
13.00	0.0388	0.7690	0.171	3.38
13.25	0.0630	0.8320	0.277	3.66
13.50	0.1390	0.9710	0.612	4.27
13.75	0.0815	1.0525	0.359	4.63
14.00	0.0315	1.0840	0.139	4.77
14.25	0.0305	1.1145	0.134	4.90
14.50	0.0295	1.1440	0.130	5.03
14.75	0.0285	1.1725	0.125	5.16
15.00	0.0275	1.2000	0.121	5.28
15.25	0.0264	1.2264	0.116	5.40
15.50	0.0234	1.2499	0.103	5.50
15.75	0.0208	1.2707	0.092	5.59
16.00	0.0184	1.2891	0.081	5.67
16.25	0.0164	1.3055	0.072	5.74
16.50	0.0146	1.3200	0.064	5.81
16.75	0.0131	1.3331	0.058	5.87
17.00	0.0119	1.3450	0.052	5.92
17.25	0.0109	1.3559	0.048	5.97
17.50	0.0101	1.3660	0.044	6.01
17.75	0.0096	1.3757	0.042	6.05
18.00	0.0094	1.3850	0.041	6.09

24 hr
intensity

M24-20i.R03
Region 3, Design Hyetograph
Long Duration Storm (high intensity); 20% exceedance

TIME	PI	PC	PI adj	PC adj
0		0		
0.5	0.0001	0.0001	0.001	0.00
1.0	0.0001	0.0003	0.001	0.00
1.5	0.0001	0.0004	0.001	0.00
2.0	0.0001	0.0005	0.001	0.00
2.5	0.0002	0.0007	0.002	0.01
3.0	0.0002	0.0009	0.002	0.01
3.5	0.0002	0.0011	0.002	0.01
4.0	0.0002	0.0013	0.002	0.01
4.5	0.0002	0.0015	0.002	0.01
5.0	0.0003	0.0018	0.003	0.02
5.5	0.0003	0.0021	0.003	0.02
6.0	0.0003	0.0024	0.003	0.02
6.5	0.0004	0.0028	0.004	0.03
7.0	0.0004	0.0032	0.004	0.03
7.5	0.0004	0.0036	0.004	0.03
8.0	0.0005	0.0041	0.005	0.04
8.5	0.0005	0.0046	0.005	0.04
9.0	0.0006	0.0052	0.006	0.05
9.5	0.0006	0.0059	0.006	0.06
10.0	0.0007	0.0066	0.007	0.06
10.5	0.0008	0.0073	0.008	0.07
11.0	0.0008	0.0081	0.008	0.08
11.5	0.0009	0.0090	0.009	0.09
12.0	0.0010	0.0100	0.010	0.10
12.5	0.0010	0.0110	0.010	0.11
13.0	0.0011	0.0122	0.011	0.12
13.5	0.0012	0.0134	0.012	0.13
14.0	0.0014	0.0147	0.013	0.14
14.5	0.0015	0.0162	0.014	0.16
15.0	0.0016	0.0179	0.015	0.17
15.5	0.0018	0.0197	0.017	0.19
16.0	0.0020	0.0217	0.019	0.21
16.5	0.0022	0.0239	0.021	0.23
17.0	0.0024	0.0263	0.023	0.25
17.5	0.0026	0.0289	0.025	0.28
18.0	0.0029	0.0318	0.028	0.31
18.5	0.0032	0.0350	0.031	0.34
19.0	0.0034	0.0384	0.033	0.37
19.5	0.0037	0.0422	0.036	0.41
20.0	0.0041	0.0463	0.039	0.45
20.5	0.0044	0.0506	0.042	0.49
21.0	0.0047	0.0554	0.045	0.53

21.5	0.0051	0.0605	0.049	0.58
22.0	0.0055	0.0660	0.053	0.63
22.5	0.0059	0.0718	0.057	0.69
23.0	0.0063	0.0781	0.061	0.75
23.5	0.0067	0.0848	0.064	0.82
24.0	0.0072	0.0920	0.069	0.89
24.5	0.0076	0.0996	0.073	0.96
25.0	0.0081	0.1077	0.078	1.04
25.5	0.0085	0.1162	0.082	1.12
26.0	0.0090	0.1252	0.087	1.20
26.5	0.0094	0.1346	0.090	1.29
27.0	0.0098	0.1444	0.094	1.39
27.5	0.0103	0.1547	0.099	1.49
28.0	0.0107	0.1654	0.103	1.59
28.5	0.0111	0.1765	0.107	1.70
29.0	0.0115	0.1881	0.111	1.81
29.5	0.0120	0.2000	0.115	1.92
30.0	0.0124	0.2124	0.119	2.04
30.5	0.0128	0.2252	0.123	2.17
31.0	0.0135	0.2387	0.130	2.30
31.5	0.0144	0.2530	0.139	2.43
32.0	0.0155	0.2686	0.149	2.58
32.5	0.0169	0.2855	0.163	2.75
33.0	0.0185	0.3040	0.178	2.92
33.5	0.0204	0.3244	0.196	3.12
34.0	0.0222	0.3465	0.214	3.33
34.5	0.0238	0.3704	0.229	3.56
35.0	0.0254	0.3958	0.244	3.81
35.5	0.0269	0.4227	0.259	4.07
36.0	0.0280	0.4507	0.269	4.34
36.5	0.0290	0.4797	0.279	4.61
37.0	0.0300	0.5097	0.289	4.90
37.5	0.0310	0.5407	0.298	5.20
38.0	0.0320	0.5727	0.308	5.51
38.5	0.0710	0.6437	0.683	6.19
39.0	0.0430	0.6867	0.414	6.61
39.5	0.0386	0.7253	0.371	6.98
40.0	0.0351	0.7604	0.338	7.32
40.5	0.0320	0.7924	0.308	7.62
41.0	0.0295	0.8219	0.284	7.91
41.5	0.0276	0.8495	0.266	8.17
42.0	0.0259	0.8754	0.249	8.42
42.5	0.0249	0.9003	0.240	8.66
43.0	0.0238	0.9241	0.229	8.89
43.5	0.0227	0.9468	0.218	9.11
44.0	0.0214	0.9682	0.206	9.31
44.5	0.0199	0.9881	0.191	9.51
45.0	0.0183	1.0064	0.176	9.68
45.5	0.0167	1.0231	0.161	9.84
46.0	0.0151	1.0383	0.145	9.99
46.5	0.0137	1.0520	0.132	10.12

47.0	0.0125	1.0645	0.120	10.24
47.5	0.0114	1.0759	0.110	10.35
48.0	0.0105	1.0864	0.101	10.45
48.5	0.0097	1.0961	0.093	10.54
49.0	0.0090	1.1051	0.087	10.63
49.5	0.0083	1.1134	0.080	10.71
50.0	0.0076	1.1209	0.073	10.78
50.5	0.0069	1.1279	0.066	10.85
51.0	0.0063	1.1342	0.061	10.91
51.5	0.0057	1.1399	0.055	10.97
52.0	0.0052	1.1451	0.050	11.02
52.5	0.0047	1.1498	0.045	11.06
53.0	0.0042	1.1540	0.040	11.10
53.5	0.0038	1.1578	0.037	11.14
54.0	0.0033	1.1611	0.032	11.17
54.5	0.0030	1.1641	0.029	11.20
55.0	0.0026	1.1667	0.025	11.22
55.5	0.0023	1.1690	0.022	11.25
56.0	0.0020	1.1710	0.019	11.27
56.5	0.0017	1.1727	0.016	11.28
57.0	0.0015	1.1742	0.014	11.30
57.5	0.0013	1.1756	0.013	11.31
58.0	0.0012	1.1767	0.012	11.32
58.5	0.0010	1.1778	0.010	11.33
59.0	0.0009	1.1787	0.009	11.34
59.5	0.0009	1.1796	0.009	11.35
60.0	0.0009	1.1804	0.009	11.36
60.5	0.0008	1.1813	0.008	11.36
61.0	0.0008	1.1821	0.008	11.37
61.5	0.0008	1.1830	0.008	11.38
62.0	0.0008	1.1838	0.008	11.39
62.5	0.0008	1.1847	0.008	11.40
63.0	0.0008	1.1855	0.008	11.40
63.5	0.0008	1.1863	0.008	11.41
64.0	0.0008	1.1872	0.008	11.42
64.5	0.0008	1.1880	0.008	11.43
65.0	0.0008	1.1888	0.008	11.44
65.5	0.0008	1.1896	0.008	11.44
66.0	0.0008	1.1904	0.008	11.45
66.5	0.0008	1.1912	0.008	11.46
67.0	0.0008	1.1920	0.008	11.47
67.5	0.0008	1.1928	0.008	11.47
68.0	0.0008	1.1935	0.008	11.48
68.5	0.0008	1.1943	0.008	11.49
69.0	0.0007	1.1950	0.007	11.50
69.5	0.0007	1.1958	0.007	11.50
70.0	0.0007	1.1965	0.007	11.51
70.5	0.0007	1.1972	0.007	11.52
71.0	0.0007	1.1980	0.007	11.52
71.5	0.0007	1.1987	0.007	11.53
72.0	0.0007	1.1994	0.007	11.54

24 hr
volume

M24-20v.R03
Region 3, Design Hyetograph
Long Duration Storm (high volume); 20% exceedance

TIME	PI	PC	PI adj	PC adj
0		0		
0.5	0.0017	0.0017	0.016	0.02
1.0	0.0017	0.0035	0.016	0.03
1.5	0.0017	0.0052	0.016	0.05
2.0	0.0017	0.0070	0.016	0.07
2.5	0.0017	0.0087	0.016	0.08
3.0	0.0017	0.0105	0.016	0.10
3.5	0.0018	0.0122	0.017	0.12
4.0	0.0018	0.0140	0.017	0.13
4.5	0.0018	0.0157	0.017	0.15
5.0	0.0018	0.0175	0.017	0.17
5.5	0.0018	0.0193	0.017	0.19
6.0	0.0018	0.0210	0.017	0.20
6.5	0.0018	0.0228	0.017	0.22
7.0	0.0018	0.0246	0.017	0.24
7.5	0.0018	0.0264	0.017	0.25
8.0	0.0018	0.0282	0.017	0.27
8.5	0.0018	0.0300	0.017	0.29
9.0	0.0018	0.0318	0.017	0.31
9.5	0.0018	0.0337	0.017	0.32
10.0	0.0018	0.0355	0.017	0.34
10.5	0.0019	0.0374	0.018	0.36
11.0	0.0019	0.0392	0.018	0.38
11.5	0.0019	0.0411	0.018	0.40
12.0	0.0019	0.0430	0.018	0.41
12.5	0.0019	0.0449	0.018	0.43
13.0	0.0019	0.0468	0.018	0.45
13.5	0.0020	0.0488	0.019	0.47
14.0	0.0020	0.0509	0.019	0.49
14.5	0.0021	0.0530	0.020	0.51
15.0	0.0022	0.0552	0.021	0.53
15.5	0.0023	0.0575	0.022	0.55
16.0	0.0025	0.0600	0.024	0.58
16.5	0.0026	0.0626	0.025	0.60
17.0	0.0028	0.0653	0.027	0.63
17.5	0.0029	0.0682	0.028	0.66
18.0	0.0031	0.0714	0.030	0.69
18.5	0.0033	0.0747	0.032	0.72
19.0	0.0035	0.0782	0.034	0.75
19.5	0.0038	0.0820	0.037	0.79
20.0	0.0040	0.0861	0.038	0.83
20.5	0.0043	0.0904	0.041	0.87

21.0	0.0046	0.0950	0.044	0.91
21.5	0.0049	0.0999	0.047	0.96
22.0	0.0052	0.1052	0.050	1.01
22.5	0.0056	0.1108	0.054	1.07
23.0	0.0060	0.1168	0.058	1.12
23.5	0.0064	0.1232	0.062	1.19
24.0	0.0068	0.1300	0.065	1.25
24.5	0.0073	0.1373	0.070	1.32
25.0	0.0079	0.1452	0.076	1.40
25.5	0.0086	0.1538	0.083	1.48
26.0	0.0094	0.1633	0.090	1.57
26.5	0.0103	0.1736	0.099	1.67
27.0	0.0114	0.1850	0.110	1.78
27.5	0.0125	0.1975	0.120	1.90
28.0	0.0135	0.2110	0.130	2.03
28.5	0.0144	0.2255	0.139	2.17
29.0	0.0152	0.2407	0.146	2.32
29.5	0.0159	0.2566	0.153	2.47
30.0	0.0164	0.2730	0.158	2.63
30.5	0.0169	0.2899	0.163	2.79
31.0	0.0173	0.3072	0.166	2.96
31.5	0.0178	0.3250	0.171	3.13
32.0	0.0183	0.3433	0.176	3.30
32.5	0.0187	0.3621	0.180	3.48
33.0	0.0192	0.3813	0.185	3.67
33.5	0.0197	0.4010	0.190	3.86
34.0	0.0202	0.4212	0.194	4.05
34.5	0.0208	0.4420	0.200	4.25
35.0	0.0214	0.4634	0.206	4.46
35.5	0.0223	0.4857	0.215	4.67
36.0	0.0234	0.5091	0.225	4.90
36.5	0.0247	0.5338	0.238	5.14
37.0	0.0262	0.5600	0.252	5.39
37.5	0.0284	0.5884	0.273	5.66
38.0	0.0320	0.6204	0.308	5.97
38.5	0.0600	0.6804	0.577	6.55
39.0	0.0390	0.7194	0.375	6.92
39.5	0.0335	0.7529	0.322	7.24
40.0	0.0322	0.7851	0.310	7.55
40.5	0.0309	0.8160	0.297	7.85
41.0	0.0296	0.8456	0.285	8.13
41.5	0.0283	0.8739	0.272	8.41
42.0	0.0270	0.9009	0.260	8.67
42.5	0.0257	0.9266	0.247	8.91
43.0	0.0244	0.9510	0.235	9.15
43.5	0.0231	0.9741	0.222	9.37
44.0	0.0220	0.9961	0.212	9.58
44.5	0.0209	1.0170	0.201	9.78
45.0	0.0200	1.0370	0.192	9.98

45.5	0.0190	1.0560	0.183	10.16
46.0	0.0180	1.0740	0.173	10.33
46.5	0.0164	1.0904	0.158	10.49
47.0	0.0147	1.1051	0.141	10.63
47.5	0.0130	1.1181	0.125	10.76
48.0	0.0112	1.1293	0.108	10.86
48.5	0.0094	1.1388	0.090	10.96
49.0	0.0079	1.1467	0.076	11.03
49.5	0.0067	1.1534	0.064	11.10
50.0	0.0058	1.1592	0.056	11.15
50.5	0.0052	1.1644	0.050	11.20
51.0	0.0049	1.1693	0.047	11.25
51.5	0.0049	1.1742	0.047	11.30
52.0	0.0049	1.1791	0.047	11.34
52.5	0.0049	1.1839	0.047	11.39
53.0	0.0049	1.1888	0.047	11.44
53.5	0.0048	1.1936	0.046	11.48
54.0	0.0048	1.1985	0.046	11.53
54.5	0.0048	1.2032	0.046	11.57
55.0	0.0047	1.2080	0.045	11.62
55.5	0.0047	1.2127	0.045	11.67
56.0	0.0046	1.2173	0.044	11.71
56.5	0.0046	1.2219	0.044	11.75
57.0	0.0045	1.2264	0.043	11.80
57.5	0.0044	1.2308	0.042	11.84
58.0	0.0043	1.2351	0.041	11.88
58.5	0.0042	1.2393	0.040	11.92
59.0	0.0041	1.2434	0.039	11.96
59.5	0.0040	1.2474	0.038	12.00
60.0	0.0039	1.2513	0.038	12.04
60.5	0.0038	1.2551	0.037	12.07
61.0	0.0036	1.2587	0.035	12.11
61.5	0.0035	1.2622	0.034	12.14
62.0	0.0034	1.2656	0.033	12.18
62.5	0.0033	1.2689	0.032	12.21
63.0	0.0032	1.2721	0.031	12.24
63.5	0.0031	1.2752	0.030	12.27
64.0	0.0030	1.2782	0.029	12.30
64.5	0.0029	1.2811	0.028	12.32
65.0	0.0028	1.2840	0.027	12.35
65.5	0.0028	1.2868	0.027	12.38
66.0	0.0027	1.2895	0.026	12.40
66.5	0.0026	1.2921	0.025	12.43
67.0	0.0026	1.2947	0.025	12.46
67.5	0.0025	1.2972	0.024	12.48
68.0	0.0025	1.2996	0.024	12.50
68.5	0.0024	1.3021	0.023	12.53
69.0	0.0024	1.3045	0.023	12.55
69.5	0.0024	1.3068	0.023	12.57

70.0	0.0023	1.3092	0.022	12.59
70.5	0.0023	1.3115	0.022	12.62
71.0	0.0023	1.3138	0.022	12.64
71.5	0.0023	1.3160	0.022	12.66
72.0	0.0023	1.3183	0.022	12.68

Cumulative precipitation multipliers for design hyetographs

MDW, 7/31/01

Eastern Washington	Mountains	Central Basin
Region :	**1**	**2**
Short duration storm	1.0752	1.0752
Intermediate storm	1.3680	1.2570
Long, high-intensity storm	1.3136	1.1553
Long, high-volume storm	1.5070	1.2796

Western Washington	Puget Sound	Mountains	Coast
Region :	**3**	**4**	**5**
Short duration storm	1.1794	1.1794	1.1794
Intermediate storm	1.3850	1.5792	1.4810
Long, high-intensity storm	1.1994	1.4195	1.3205
Long, high-volume storm	1.3183	1.6977	1.5350

Appendix E

Design Storm Calculations and Routing Analysis

Appendix E

Design Storm Calculations and Routing Analysis

	Storm Yr		ELEV ft	Stage ft	Q (cfs) KCRTS 30" Riser 441.17	KCRTS 72" Overflow 441.17	Riser+OF	BW TW=OutletCrown 36" Conduit	BW TW=OutletCrown 30" to Conduit	Effective Outflow (cfs)	VOL (cu-ft)
Orifice Control			437	0	0					0.00	0
			437.28	0.28	0.30					0.30	37347
			437.52	0.52	0.40					0.40	69940
	1.1		438.04	1.04	0.57					0.57	142502
	1.3		439.16	2.16	0.82					0.82	307288
	2		439.73	2.73	1.00					1.00	395857
	3		440.03	3.03	1.58					1.58	479372
	5		440.25	3.25	2.64					2.64	577513
	10		440.44	3.44	2.91					2.91	443092
	25		440.84	3.84	4.23					4.23	510660
	50		440.98	3.98	5.05					5.05	601986
	100	Riser & OF Rim Elev	441.17	4.17	5.45	5.45	10.90	106.45	35.00	10.90	634699
			441.27	4.27	6.42	7.50	13.92	107.00		13.92	652067
			441.37	4.37	8.02	11.07	19.09	107.60		19.09	669541
		100 yr Undetained = 19.97cfs	~ 441.39								
			441.47	4.47	10.02	15.62	25.64	108.20	45.00	25.64	687120
			441.57	4.57	12.36	20.98	33.34	108.75		33.34	704804
		CS Rim Elev	441.67	4.67	14.98	27.03	42.01	109.35		42.01	722594
		WS Elev 2hr = 441.71 WS Elev 24v = 441.75	441.77	4.77	17.85	33.70	51.55	109.90		51.55	740489
		WS Elev 24i = 441.80 **WS Elev 6hr = 441.83**	441.87	4.87	20.96	40.92	61.88	110.50		61.88	758491
			441.97	4.97	24.28	48.67	72.95	111.05		72.95	776600
			442.07	5.07	27.80	56.90	84.70	111.60		84.70	794815
			442.17	5.17	30.80	65.60	96.40	112.20		96.40	813137
			442.27	5.27	32.10	74.72	106.82	112.75	50.00	106.82	831567
		H/R = 0.4	442.37	5.37	33.34	84.26	117.60	113.25		113.25	850105
			442.47	5.47	34.55	94.20	128.75	113.60		113.60	868750
			442.57	5.57	35.70	104.53	140.23	113.90		113.90	887504
		H/R = 0.5	442.67	5.67	36.81	115.22	152.03	114.20		114.20	906366
			442.77	5.77	37.90	126.26	164.16	114.50		114.50	925338
			442.87	5.87	38.95	137.65	176.60	114.80		114.80	944418
			442.97	5.97	39.97	149.37	189.34	115.00		115.00	963608
			443.07	6.07	40.96	161.42	202.38	115.42		115.42	982907
			443.17	6.17	41.94	173.78	215.72	115.72	55.25	115.72	1002317
		Berm Elev	443.30	6.30							

KING COUNTY DEPARTMENT OF PUBLIC WORKS
Surface Water Management Division

HYDROGRAPH PROGRAMS
Version 4.21B

1 - INFO ON THIS PROGRAM
2 - SBUHYD
3 - MODIFIED SBUHYD
4 - ROUTE
5 - ROUTE2
6 - ADDHYD
7 - BASEFLOW
8 - PLOTHYD
9 - DATA
10 - RDFAC
11 - RETURN TO DOS

ENTER OPTION:
4

RESERVOIR ROUTING INFLOW/OUTFLOW ROUTINE

SPECIFY [d:][path]filename[.ext] OF ROUTING DATA
f:\berryer\hyd\madsen**r1p17**
DISPLAY ROUTING DATA (Y or N)?
Y

ROUTING DATA:

STAGE(FT)	DISCHARGE(CFS)	STORAGE(CU-FT)	PERM-AREA(SQ-FT)
.00	.00	.0	.0
.28	.30	37347.0	.0
.52	.40	69940.0	.0
1.04	.57	142502.0	.0
2.16	.82	307288.0	.0
2.73	1.00	395857.0	.0
3.02	1.58	443092.0	.0
3.25	2.64	479372.0	.0
3.44	2.91	510660.0	.0
3.84	4.23	577513.0	.0
3.98	5.05	601986.0	.0
4.17	10.90	634756.0	.0
4.27	13.92	652067.0	.0
4.37	19.09	669541.0	.0
4.47	25.64	687120.0	.0
4.57	33.34	704804.0	.0
4.67	42.01	722594.0	.0
4.77	51.55	740489.0	.0
4.87	61.88	758491.0	.0
4.97	72.95	776600.0	.0
5.07	84.70	794815.0	.0
5.17	96.40	813137.0	.0
5.27	106.82	831567.0	.0
5.37	113.25	850180.0	.0
5.47	113.60	868750.0	.0
5.57	113.90	887504.0	.0
5.67	114.20	906366.0	.0
5.77	114.50	925338.0	.0

5.87	114.80	944418.0	.0
5.97	115.00	963608.0	.0
6.07	115.42	982907.0	.0
6.17	115.72	1002317.0	.0

AVERAGE PERM-RATE: .0 MINUTES/INCH

ENTER [d:][path]filename[.ext] OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\2hr\2hbq

INFLOW/OUTFLOW ANALYSIS:

PEAK-INFLOW(CFS)	PEAK-OUTFLOW(CFS)	OUTFLOW-VOL(CU-FT)
189.81	46.22	655384
INITIAL-STAGE(FT)	**TIME-OF-PEAK(HRS)**	**PEAK-STAGE-ELEV(FT)**
437.00	2.92	**441.71**

PEAK STORAGE: 730480 CU-FT

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\2hr**2r1p17**

SPECIFY: C - CONTINUE, N - NEWJOB, P - PRINT, S - STOP, R - REVISE
s

KING COUNTY DEPARTMENT OF PUBLIC WORKS
Surface Water Management Division

HYDROGRAPH PROGRAMS
Version 4.21B

1 - INFO ON THIS PROGRAM
2 - SBUHYD
3 - MODIFIED SBUHYD
4 - ROUTE
5 - ROUTE2
6 - ADDHYD
7 - BASEFLOW
8 - PLOTHYD
9 - DATA
10 - RDFAC
11 - RETURN TO DOS

ENTER OPTION:
4

RESERVOIR ROUTING INFLOW/OUTFLOW ROUTINE

SPECIFY [d:][path]filename[.ext] OF ROUTING DATA
f:\berryer\hyd\madsen**r1p17**

DISPLAY ROUTING DATA (Y or N)?
y

ROUTING DATA:

STAGE(FT)	DISCHARGE(CFS)	STORAGE(CU-FT)	PERM-AREA(SQ-FT)
.00	.00	.0	.0
.28	.30	37347.0	.0
.52	.40	69940.0	.0
1.04	.57	142502.0	.0
2.16	.82	307288.0	.0
2.73	1.00	395857.0	.0
3.02	1.58	443092.0	.0
3.25	2.64	479372.0	.0
3.44	2.91	510660.0	.0
3.84	4.23	577513.0	.0
3.98	5.05	601986.0	.0
4.17	10.90	634756.0	.0
4.27	13.92	652067.0	.0
4.37	19.09	669541.0	.0
4.47	25.64	687120.0	.0
4.57	33.34	704804.0	.0
4.67	42.01	722594.0	.0
4.77	51.55	740489.0	.0
4.87	61.88	758491.0	.0
4.97	72.95	776600.0	.0
5.07	84.70	794815.0	.0
5.17	96.40	813137.0	.0
5.27	106.82	831567.0	.0
5.37	113.25	850180.0	.0
5.47	113.60	868750.0	.0
5.57	113.90	887504.0	.0
5.67	114.20	906366.0	.0

5.77	114.50	925338.0	.0
5.87	114.80	944418.0	.0
5.97	115.00	963608.0	.0
6.07	115.42	982907.0	.0
6.17	115.72	1002317.0	.0

AVERAGE PERM-RATE: .0 MINUTES/INCH

ENTER [d:][path]filename[.ext] OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\6hr\6hbq

INFLOW/OUTFLOW ANALYSIS:

PEAK-INFLOW(CFS)	PEAK-OUTFLOW(CFS)	OUTFLOW-VOL(CU-FT)
87.49	57.41	896003
INITIAL-STAGE(FT)	**TIME-OF-PEAK(HRS)**	**PEAK-STAGE-ELEV(FT)**
437.00	14.42	**441.83**

PEAK STORAGE: 750695 CU-FT

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\6hr**6r1p17**

SPECIFY: C - CONTINUE, N - NEWJOB, P - PRINT, S - STOP, R - REVISE
s

KING COUNTY DEPARTMENT OF PUBLIC WORKS
Surface Water Management Division

HYDROGRAPH PROGRAMS
Version 4.21B

1 - INFO ON THIS PROGRAM
2 - SBUHYD
3 - MODIFIED SBUHYD
4 - ROUTE
5 - ROUTE2
6 - ADDHYD
7 - BASEFLOW
8 - PLOTHYD
9 - DATA
10 - RDFAC
11 - RETURN TO DOS

ENTER OPTION:
4

RESERVOIR ROUTING INFLOW/OUTFLOW ROUTINE

SPECIFY [d:][path]filename[.ext] OF ROUTING DATA
f:\berryer\hyd\madsen**r1p17**

DISPLAY ROUTING DATA (Y or N)?
y

ROUTING DATA:

STAGE(FT)	DISCHARGE(CFS)	STORAGE(CU-FT)	PERM-AREA(SQ-FT)
.00	.00	.0	.0
.28	.30	37347.0	.0
.52	.40	69940.0	.0
1.04	.57	142502.0	.0
2.16	.82	307288.0	.0
2.73	1.00	395857.0	.0
3.02	1.58	443092.0	.0
3.25	2.64	479372.0	.0
3.44	2.91	510660.0	.0
3.84	4.23	577513.0	.0
3.98	5.05	601986.0	.0
4.17	10.90	634756.0	.0
4.27	13.92	652067.0	.0
4.37	19.09	669541.0	.0
4.47	25.64	687120.0	.0
4.57	33.34	704804.0	.0
4.67	42.01	722594.0	.0
4.77	51.55	740489.0	.0
4.87	61.88	758491.0	.0
4.97	72.95	776600.0	.0
5.07	84.70	794815.0	.0
5.17	96.40	813137.0	.0
5.27	106.82	831567.0	.0
5.37	113.25	850180.0	.0
5.47	113.60	868750.0	.0
5.57	113.90	887504.0	.0
5.67	114.20	906366.0	.0

5.77	114.50	925338.0	.0
5.87	114.80	944418.0	.0
5.97	115.00	963608.0	.0
6.07	115.42	982907.0	.0
6.17	115.72	1002317.0	.0

AVERAGE PERM-RATE: .0 MINUTES/INCH

ENTER [d:][path]filename[.ext] OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\i4hr\i4hbq

INFLOW/OUTFLOW ANALYSIS:

PEAK-INFLOW(CFS)	PEAK-OUTFLOW(CFS)	OUTFLOW-VOL(CU-FT)
58.36	55.19	2559724
INITIAL-STAGE(FT)	**TIME-OF-PEAK(HRS)**	**PEAK-STAGE-ELEV(FT)**
437.00	39.00	**441.81**

PEAK STORAGE: 746820 CU-FT

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\i4hr**i4rp17**

SPECIFY: C - CONTINUE, N - NEWJOB, P - PRINT, S - STOP, R - REVISE
s

KING COUNTY DEPARTMENT OF PUBLIC WORKS
Surface Water Management Division

HYDROGRAPH PROGRAMS
Version 4.21B

1 - INFO ON THIS PROGRAM
2 - SBUHYD
3 - MODIFIED SBUHYD
4 - ROUTE
5 - ROUTE2
6 - ADDHYD
7 - BASEFLOW
8 - PLOTHYD
9 - DATA
10 - RDFAC
11 - RETURN TO DOS

ENTER OPTION:
4

RESERVOIR ROUTING INFLOW/OUTFLOW ROUTINE

SPECIFY [d:][path]filename[.ext] OF ROUTING DATA
f:\berryer\hyd\madsen**r1p17**

DISPLAY ROUTING DATA (Y or N)?
y

ROUTING DATA:

STAGE(FT)	DISCHARGE(CFS)	STORAGE(CU-FT)	PERM-AREA(SQ-FT)
.00	.00	.0	.0
.28	.30	37347.0	.0
.52	.40	69940.0	.0
1.04	.57	142502.0	.0
2.16	.82	307288.0	.0
2.73	1.00	395857.0	.0
3.02	1.58	443092.0	.0
3.25	2.64	479372.0	.0
3.44	2.91	510660.0	.0
3.84	4.23	577513.0	.0
3.98	5.05	601986.0	.0
4.17	10.90	634756.0	.0
4.27	13.92	652067.0	.0
4.37	19.09	669541.0	.0
4.47	25.64	687120.0	.0
4.57	33.34	704804.0	.0
4.67	42.01	722594.0	.0
4.77	51.55	740489.0	.0
4.87	61.88	758491.0	.0
4.97	72.95	776600.0	.0
5.07	84.70	794815.0	.0
5.17	96.40	813137.0	.0
5.27	106.82	831567.0	.0
5.37	113.25	850180.0	.0
5.47	113.60	868750.0	.0
5.57	113.90	887504.0	.0
5.67	114.20	906366.0	.0

5.77	114.50	925338.0	.0
5.87	114.80	944418.0	.0
5.97	115.00	963608.0	.0
6.07	115.42	982907.0	.0
6.17	115.72	1002317.0	.0

AVERAGE PERM-RATE: .0 MINUTES/INCH

ENTER [d:][path]filename[.ext] OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\v4hr\v4hbq

INFLOW/OUTFLOW ANALYSIS:

PEAK-INFLOW(CFS)	PEAK-OUTFLOW(CFS)	OUTFLOW-VOL(CU-FT)
51.97	49.43	2851285
INITIAL-STAGE(FT)	**TIME-OF-PEAK(HRS)**	**PEAK-STAGE-ELEV(FT)**
437.00	39.00	**441.75**

PEAK STORAGE: 736500 CU-FT

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\v4hr**v4rp17**

SPECIFY: C - CONTINUE, N - NEWJOB, P - PRINT, S - STOP, R - REVISE
s

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                    KING COUNTY DEPARTMENT OF PUBLIC WORKS
                      Surface Water Management Division

                            HYDROGRAPH PROGRAMS
                                Version 4.21B

                          1 - INFO ON THIS PROGRAM
                          2 - SBUHYD
                          3 - MODIFIED SBUHYD
                          4 - ROUTE
                          5 - ROUTE2
                          6 - ADDHYD
                          7 - BASEFLOW
                          8 - PLOTHYD
                          9 - DATA
                         10 - RDFAC
                         11 - RETURN TO DOS

ENTER OPTION:
2

SBUH/SCS METHOD FOR COMPUTING RUNOFF HYDROGRAPH

STORM OPTIONS:

1 - S.C.S. TYPE-1A
2 - 7-DAY DESIGN STORM
3 - STORM DATA FILE

SPECIFY STORM OPTION:
3

ENTER [d:][path]filename[.ext] OF STORM DATA-FILE
f:\berryer\hyd\madsen\2hr\hr2
----------------------------------------------------------------------
************ STORM DATA FILE "f:\berryer\hyd\madsen\2hr\hr2   " ******
******** STORM DURATION:   6 HOURS  **** TOTAL PRECIP:  4.57" ********

----------------------------------------------------------------------
ENTER: A(PERV), CN(PERV), A(IMPERV), CN(IMPERV), TC FOR BASIN NO.  1
14.15 90 10.25 98 36

DATA PRINT-OUT:

  AREA(ACRES)     PERVIOUS     IMPERVIOUS   TC(MINUTES)
                  A     CN     A     CN
      24.4       14.1  95.3   10.3  99.2        36.0

  PEAK-Q(CFS)    T-PEAK(HRS)     VOL(CU-FT)
     75.54          1.33          368131

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\2hr\B15Q

SPECIFY: C - CONTINUE, N - NEWSTORM, P - PRINT, S - STOP
C
```

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-----------------------------------------------------------------------
ENTER: A(PERV), CN(PERV), A(IMPERV), CN(IMPERV), TC FOR BASIN NO.  2
22.5 90 20.62 98 43.1

DATA PRINT-OUT:

  AREA(ACRES)     PERVIOUS     IMPERVIOUS   TC(MINUTES)
                   A     CN      A     CN
      43.1        22.5  95.3   20.6  99.2        43.1

  PEAK-Q(CFS)   T-PEAK(HRS)     VOL(CU-FT)
    119.70          1.42          651986


ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\2hr\B19Q

SPECIFY: C - CONTINUE, N - NEWSTORM, P - PRINT, S - STOP
S
PEAK-Q(CFS)   T-PEAK(HRS)     VOL(CU-FT)
    119.70          1.42          651986

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\2hr\B9

SPECIFY: C - CONTINUE, N - NEWSTORM, P - PRINT, S - STOP
s
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                    KING COUNTY DEPARTMENT OF PUBLIC WORKS
                      Surface Water Management Division

                            HYDROGRAPH PROGRAMS
                                Version 4.21B

                          1 - INFO ON THIS PROGRAM
                          2 - SBUHYD
                          3 - MODIFIED SBUHYD
                          4 - ROUTE
                          5 - ROUTE2
                          6 - ADDHYD
                          7 - BASEFLOW
                          8 - PLOTHYD
                          9 - DATA
                         10 - RDFAC
                         11 - RETURN TO DOS

ENTER OPTION:
6

ROUTINE FOR ADDING HYDROGRAPHS

ENTER: [d:][path]filename[.ext] OF HYDROGRAPH 1
f:\berryer\hyd\madsen\2hr\b15q

ENTER: TRAVEL TIME (MINUTES) OF HYDROGRAPH 1
12

ENTER: [d:][path]filename[.ext] OF HYDROGRAPH 2
f:\berryer\hyd\madsen\2hr\b19q

ENTER: TRAVEL TIME (MINUTES) OF HYDROGRAPH 2
0

DATA PRINT-OUT:

  HYDROGRAPH 1: PEAK-Q=  75.00 CFS   T-PEAK=  1.58 HRS   TT= 12 MINUTES
  HYDROGRAPH 2: PEAK-Q= 119.70 CFS   T-PEAK=  1.42 HRS   TT=  0 MINUTES

HYDROGRAPH SUM: PEAK-Q= 189.81 CFS   T-PEAK=  1.50 HRS

  TOTAL VOLUME:  1020113CU-FT

SPECIFY: C - CONTINUE, N - NEWJOB, F - FILE, P - PRINT, S - STOP
f

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\2hr\2HBQ

SPECIFY: C - CONTINUE, N - NEWJOB, F - FILE, P - PRINT, S - STOP
s
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                    KING COUNTY DEPARTMENT OF PUBLIC WORKS
                      Surface Water Management Division

                            HYDROGRAPH PROGRAMS
                                Version 4.21B

                          1 - INFO ON THIS PROGRAM
                          2 - SBUHYD
                          3 - MODIFIED SBUHYD
                          4 - ROUTE
                          5 - ROUTE2
                          6 - ADDHYD
                          7 - BASEFLOW
                          8 - PLOTHYD
                          9 - DATA
                         10 - RDFAC
                         11 - RETURN TO DOS

ENTER OPTION:
2

SBUH/SCS METHOD FOR COMPUTING RUNOFF HYDROGRAPH

STORM OPTIONS:

1 - S.C.S. TYPE-1A
2 - 7-DAY DESIGN STORM
3 - STORM DATA FILE

SPECIFY STORM OPTION:
3

ENTER [d:][path]filename[.ext] OF STORM DATA-FILE
f:\berryer\hyd\madsen\6hr\hr6
-----------------------------------------------------------------------
************ STORM DATA FILE "f:\berryer\hyd\madsen\6hr\hr6   " ******
******** STORM DURATION:  18 HOURS  **** TOTAL PRECIP:  6.06" ********

-----------------------------------------------------------------------
ENTER: A(PERV), CN(PERV), A(IMPERV), CN(IMPERV), TC FOR BASIN NO.  1
14.15 90 10.25 98 36

DATA PRINT-OUT:

  AREA(ACRES)     PERVIOUS     IMPERVIOUS   TC(MINUTES)
                  A     CN     A     CN
      24.4       14.1  91.1   10.3  98.2        36.0

  PEAK-Q(CFS)    T-PEAK(HRS)    VOL(CU-FT)
     33.21          13.67         469538

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\6hr\B15Q


SPECIFY: C - CONTINUE, N - NEWSTORM, P - PRINT, S - STOP
c
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---------------------------------------------------------------------
ENTER: A(PERV), CN(PERV), A(IMPERV), CN(IMPERV), TC FOR BASIN NO.  2
22.5 90 20.62 98 43.1

DATA PRINT-OUT:

  AREA(ACRES)     PERVIOUS     IMPERVIOUS    TC(MINUTES)
                   A     CN      A     CN
      43.1       22.5  91.1    20.6  98.2        43.1

  PEAK-Q(CFS)    T-PEAK(HRS)     VOL(CU-FT)
     55.58          13.67          836389

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\6hr\B19Q

SPECIFY: C - CONTINUE, N - NEWSTORM, P - PRINT, S - STOP
s
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                    KING COUNTY DEPARTMENT OF PUBLIC WORKS
                      Surface Water Management Division

                            HYDROGRAPH PROGRAMS
                                Version 4.21B

                         1 - INFO ON THIS PROGRAM
                         2 - SBUHYD
                         3 - MODIFIED SBUHYD
                         4 - ROUTE
                         5 - ROUTE2
                         6 - ADDHYD
                         7 - BASEFLOW
                         8 - PLOTHYD
                         9 - DATA
                        10 - RDFAC
                        11 - RETURN TO DOS

ENTER OPTION:
6

ROUTINE FOR ADDING HYDROGRAPHS

ENTER: [d:][path]filename[.ext] OF HYDROGRAPH 1
f:\berryer\hyd\madsen\6hr\b15q

ENTER: TRAVEL TIME (MINUTES) OF HYDROGRAPH 1
12

ENTER: [d:][path]filename[.ext] OF HYDROGRAPH 2
f:\berryer\hyd\madsen\6hr\b19q

ENTER: TRAVEL TIME (MINUTES) OF HYDROGRAPH 2
0

DATA PRINT-OUT:

  HYDROGRAPH 1: PEAK-Q=  33.12 CFS   T-PEAK= 13.83 HRS   TT= 12 MINUTES
  HYDROGRAPH 2: PEAK-Q=  55.58 CFS   T-PEAK= 13.67 HRS   TT=  0 MINUTES

HYDROGRAPH SUM: PEAK-Q=  87.49 CFS   T-PEAK= 13.67 HRS

  TOTAL VOLUME:  1305927CU-FT

SPECIFY: C - CONTINUE, N - NEWJOB, F - FILE, P - PRINT, S - STOP
f

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\6hr\6HBQ

SPECIFY: C - CONTINUE, N - NEWJOB, F - FILE, P - PRINT, S - STOP
s
```

```
                    KING COUNTY DEPARTMENT OF PUBLIC WORKS
                      Surface Water Management Division

                           HYDROGRAPH PROGRAMS
                               Version 4.21B

                          1 - INFO ON THIS PROGRAM
                          2 - SBUHYD
                          3 - MODIFIED SBUHYD
                          4 - ROUTE
                          5 - ROUTE2
                          6 - ADDHYD
                          7 - BASEFLOW
                          8 - PLOTHYD
                          9 - DATA
                         10 - RDFAC
                         11 - RETURN TO DOS

ENTER OPTION:
2

SBUH/SCS METHOD FOR COMPUTING RUNOFF HYDROGRAPH

STORM OPTIONS:

1 - S.C.S. TYPE-1A
2 - 7-DAY DESIGN STORM
3 - STORM DATA FILE

SPECIFY STORM OPTION:
3

ENTER [d:][path]filename[.ext] OF STORM DATA-FILE
F:\BERRYER\HYD\MADSEN\I4HR\I4HR
-----------------------------------------------------------------------
************ STORM DATA FILE "F:\BERRYER\HYD\MADSEN\I4HR\I4HR " ******
******** STORM DURATION:  72 HOURS  **** TOTAL PRECIP: 11.57" ********

-----------------------------------------------------------------------
ENTER: A(PERV), CN(PERV), A(IMPERV), CN(IMPERV), TC FOR BASIN NO.  1
14.15 90 10.25 98 36

DATA PRINT-OUT:

  AREA(ACRES)     PERVIOUS     IMPERVIOUS    TC(MINUTES)
                  A     CN     A     CN
      24.4       14.1  85.8   10.3  97.1        36.0

  PEAK-Q(CFS)    T-PEAK(HRS)     VOL(CU-FT)
     21.35          39.00          920621

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\i4hr\b15q

SPECIFY: C - CONTINUE, N - NEWSTORM, P - PRINT, S - STOP
C
```

```
-----------------------------------------------------------------------
ENTER: A(PERV), CN(PERV), A(IMPERV), CN(IMPERV), TC FOR BASIN NO.  2
22.5 90 20.62 98 43.1

DATA PRINT-OUT:

  AREA(ACRES)     PERVIOUS     IMPERVIOUS    TC(MINUTES)
                   A     CN      A     CN
      43.1        22.5  85.8    20.6  97.1        43.1

  PEAK-Q(CFS)    T-PEAK(HRS)     VOL(CU-FT)
     37.35          39.00         1639747

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\i4hr\b19q

SPECIFY: C - CONTINUE, N - NEWSTORM, P - PRINT, S - STOP
S
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                    KING COUNTY DEPARTMENT OF PUBLIC WORKS
                       Surface Water Management Division

                             HYDROGRAPH PROGRAMS
                                Version 4.21B

                           1 - INFO ON THIS PROGRAM
                           2 - SBUHYD
                           3 - MODIFIED SBUHYD
                           4 - ROUTE
                           5 - ROUTE2
                           6 - ADDHYD
                           7 - BASEFLOW
                           8 - PLOTHYD
                           9 - DATA
                          10 - RDFAC
                          11 - RETURN TO DOS

ENTER OPTION:
6

ROUTINE FOR ADDING HYDROGRAPHS

ENTER: [d:][path]filename[.ext] OF HYDROGRAPH 1
f:\berryer\hyd\madsen\i4hr\b15q

ENTER: TRAVEL TIME (MINUTES) OF HYDROGRAPH 1
12

ENTER: [d:][path]filename[.ext] OF HYDROGRAPH 2
f:\berryer\hyd\madsen\i4hr\b19q

ENTER: TRAVEL TIME (MINUTES) OF HYDROGRAPH 2
0

DATA PRINT-OUT:

  HYDROGRAPH 1: PEAK-Q=  21.01 CFS   T-PEAK= 39.00 HRS   TT= 12 MINUTES
  HYDROGRAPH 2: PEAK-Q=  37.35 CFS   T-PEAK= 39.00 HRS   TT=  0 MINUTES

HYDROGRAPH SUM: PEAK-Q=  58.36 CFS   T-PEAK= 39.00 HRS

  TOTAL VOLUME:  2560392CU-FT

SPECIFY: C - CONTINUE, N - NEWJOB, F - FILE, P - PRINT, S - STOP
f

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\i4hr\I4HBq

SPECIFY: C - CONTINUE, N - NEWJOB, F - FILE, P - PRINT, S - STOP
s
```

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                    KING COUNTY DEPARTMENT OF PUBLIC WORKS
                      Surface Water Management Division

                            HYDROGRAPH PROGRAMS
                               Version 4.21B

                          1 - INFO ON THIS PROGRAM
                          2 - SBUHYD
                          3 - MODIFIED SBUHYD
                          4 - ROUTE
                          5 - ROUTE2
                          6 - ADDHYD
                          7 - BASEFLOW
                          8 - PLOTHYD
                          9 - DATA
                         10 - RDFAC
                         11 - RETURN TO DOS

ENTER OPTION:
2

SBUH/SCS METHOD FOR COMPUTING RUNOFF HYDROGRAPH

STORM OPTIONS:

1 - S.C.S. TYPE-1A
2 - 7-DAY DESIGN STORM
3 - STORM DATA FILE

SPECIFY STORM OPTION:
3

ENTER [d:][path]filename[.ext] OF STORM DATA-FILE
f:\berryer\hyd\madsen\v4hr\v4hr
-----------------------------------------------------------------------
************ STORM DATA FILE "f:\berryer\hyd\madsen\v4hr\v4hr " ******
******** STORM DURATION:  72 HOURS  **** TOTAL PRECIP: 12.77" ********

-----------------------------------------------------------------------
ENTER: A(PERV), CN(PERV), A(IMPERV), CN(IMPERV), TC FOR BASIN NO.  1
14.15 90 10.25 98 36

DATA PRINT-OUT:

  AREA(ACRES)     PERVIOUS     IMPERVIOUS   TC(MINUTES)
                  A     CN     A     CN
      24.4       14.1  85.8   10.3  97.1        36.0

  PEAK-Q(CFS)    T-PEAK(HRS)    VOL(CU-FT)
     18.96          39.00        1025947

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\v4hr\b15q

SPECIFY: C - CONTINUE, N - NEWSTORM, P - PRINT, S - STOP
c
-----------------------------------------------------------------------
```

```
ENTER: A(PERV), CN(PERV), A(IMPERV), CN(IMPERV), TC FOR BASIN NO.  2
22.5 90 20.62 98 43.1

DATA PRINT-OUT:

  AREA(ACRES)     PERVIOUS     IMPERVIOUS    TC(MINUTES)
                   A     CN      A     CN
      43.1        22.5  85.8   20.6  97.1        43.1

  PEAK-Q(CFS)    T-PEAK(HRS)     VOL(CU-FT)
     33.23          39.00         1825981

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\v4hr\b19q

SPECIFY: C - CONTINUE, N - NEWSTORM, P - PRINT, S - STOP
s
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                    KING COUNTY DEPARTMENT OF PUBLIC WORKS
                      Surface Water Management Division

                          HYDROGRAPH PROGRAMS
                              Version 4.21B

                         1 - INFO ON THIS PROGRAM
                         2 - SBUHYD
                         3 - MODIFIED SBUHYD
                         4 - ROUTE
                         5 - ROUTE2
                         6 - ADDHYD
                         7 - BASEFLOW
                         8 - PLOTHYD
                         9 - DATA
                        10 - RDFAC
                        11 - RETURN TO DOS


ENTER OPTION:
6

ROUTINE FOR ADDING HYDROGRAPHS

ENTER: [d:][path]filename[.ext] OF HYDROGRAPH 1
f:\berryer\hyd\madsen\v4hr\b15q

ENTER: TRAVEL TIME (MINUTES) OF HYDROGRAPH 1
12

ENTER: [d:][path]filename[.ext] OF HYDROGRAPH 2
f:\berryer\hyd\madsen\v4hr\b19q

ENTER: TRAVEL TIME (MINUTES) OF HYDROGRAPH 2
0

DATA PRINT-OUT:

  HYDROGRAPH 1: PEAK-Q=  18.74 CFS   T-PEAK= 39.00 HRS   TT= 12 MINUTES
  HYDROGRAPH 2: PEAK-Q=  33.23 CFS   T-PEAK= 39.00 HRS   TT=  0 MINUTES

HYDROGRAPH SUM: PEAK-Q=  51.97 CFS   T-PEAK= 39.00 HRS

  TOTAL VOLUME:  2851883CU-FT

SPECIFY: C - CONTINUE, N - NEWJOB, F - FILE, P - PRINT, S - STOP
f

ENTER [d:][path]filename[.ext] FOR STORAGE OF COMPUTED HYDROGRAPH:
f:\berryer\hyd\madsen\v4hr\v4HBQ

SPECIFY: C - CONTINUE, N - NEWJOB, F - FILE, P - PRINT, S - STOP
s
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King County Surface Water Management *Everyone lives downstream* Engineering & Environmental Services	Madsen Comp Berryessa Chk _____ Rev _____ Date 2/28/02 Date _____ Date _____	Project 86295 Page 1 of ____ Pages

Per T Pham's KCRTS analysis:

Area 19 & 15 = 67.5 ac

Area 15 = 24.4 ac

14.15 ac pervious CN = 70

10.25 ac impervious " = 5

Time of concentration, Tc

• L_1 = 300' n_s = 0.15 P_2 = 2 in

$$S = \frac{487 - 481}{300} = 0.02$$

$$T_{c_1} = \frac{0.42(0.15 \times 300)^{0.8}}{(2)^{1/2}(0.02)^{0.4}} = 29.85 \text{ min}$$

• L_2 = 700' K = 11

$$S = \frac{481 - 460}{700} = 0.03$$

$$T_{c_2} = \frac{700}{60(11)(0.03)^{1/2}} = 6.12 \text{ min}$$

T_c = 36.0 min

Travel Time, T_t

L = 1000' K = 11

$$S = \frac{460 - 443}{1000} = 0.017$$

$$T_t = \frac{1000}{60(11)(0.017)^{1/2}} = 11.6 \text{ min}$$

T_t = 12.0 min

King County Surface Water Management
Everyone lives downstream
Engineering & Environmental Services

Comp Berryessa Chk _____ Rev _____
Date _____ Date _____ Date _____

Project _____

Page 2 of 2 Pages

Area 19 = 43.12 ac

22.50 ac [illegible] CN = 90

20.62 ac [illegible] CN = 98

Time of concentration, Tc

- L_1 = 300' H_2 = [illegible] K_2 = 20

$$S = \frac{495 - 490}{300} = 0.0167$$

$$T_{c_1} = \frac{0.42\,(0.5 \times 300)^{.8}}{(2)^{1/2}\,(0.02)^{0.4}} = 32.1 \text{ min}$$

- L_2 = 1350' K = 11

$$S = \frac{490 - 443}{1350} = 0.035$$

$$T_{c_2} = \frac{1350}{60(11)(0.035)^{1/2}} = 11.0$$

Tc = 43 min

$P_2 = 2.0$ ← max

FIGURE 3.5.1C 2-YEAR 24-HOUR ISOPLUVIALS DDE · P_2 1.75

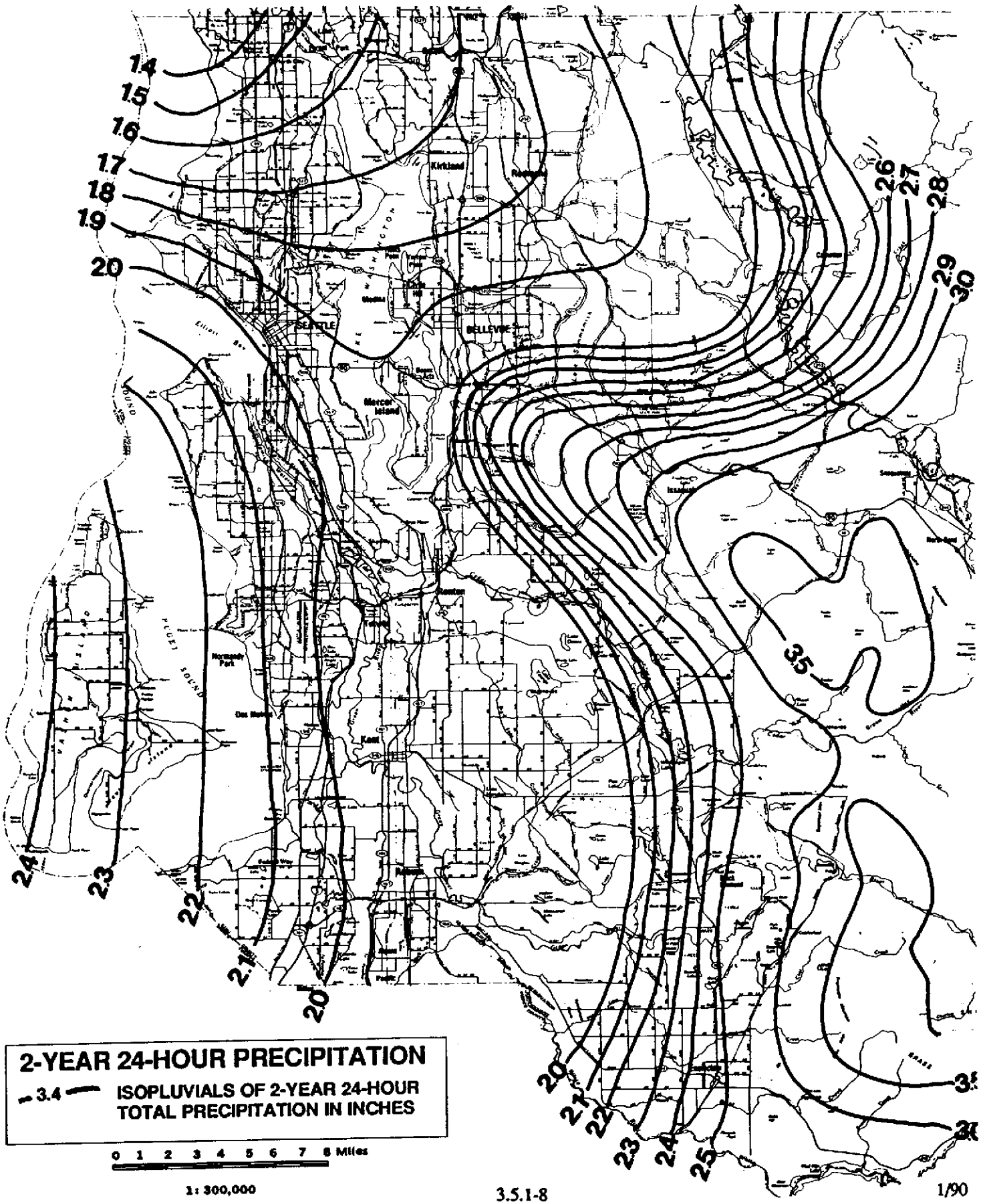


TABLE 3.5.2B SCS WESTERN WASHINGTON RUNOFF CURVE NUMBERS

SCS WESTERN WASHINGTON RUNOFF CURVE NUMBERS (Published by SCS in 1982)

Runoff curve numbers for selected agricultural, suburban and urban land use for Type 1A rainfall distribution, 24-hour storm duration.

LAND USE DESCRIPTION		CURVE NUMBERS BY HYDROLOGIC SOIL GROUP A	B	C	D
Cultivated land(1):	winter condition	86	91	94	95
Mountain open areas:	low growing brush and grasslands	74	82	89	92
Meadow or pasture:		65	78	85	89
Wood or forest land:	undisturbed	42	64	76	81
Wood or forest land:	young second growth or brush	55	72	81	86
Orchard:	with cover crop	81	88	92	94
Open spaces, lawns, parks, golf courses, cemeteries, landscaping.					
good condition:	grass cover on 75% or more of the area	68	80	86	90
fair condition:	grass cover on 50% to 75% of the area	77	85	90	92
Gravel roads and parking lots		76	85	89	91
Dirt roads and parking lots		72	82	87	89
Impervious surfaces, pavement, roofs, etc.		98	98	98	98
Open water bodies:	lakes, wetlands, ponds, etc.	100	100	100	100
Single Family Residential (2)					
Dwelling Unit/Gross Acre	% Impervious (3)	Separate curve number shall be selected for pervious and impervious portion of the site or basin			
1.0 DU/GA	15				
1.5 DU/GA	20				
2.0 DU/GA	25				
2.5 DU/GA	30				
3.0 DU/GA	34				
3.5 DU/GA	38				
4.0 DU/GA	42				
4.5 DU/GA	46				
5.0 DU/GA	48				
5.5 DU/GA	50				
6.0 DU/GA	52				
6.5 DU/GA	54				
7.0 DU/GA	56				
Planned unit developments, condominiums, apartments, commercial business and industrial areas.	% impervious must be computed				

(1) For a more detailed description of agricultural land use curve numbers refer to National Engineering Handbook, Section 4, Hydrology, Chapter 9, August 1972.
(2) Assumes roof and driveway runoff is directed into street/storm system.
(3) The remaining pervious areas (lawn) are considered to be in good condition for these curve numbers.

TABLE 3.5.2C "n" AND "k" VALUES USED IN TIME CALCULATIONS FOR HYDROGRAPHS

"n_s" Sheet Flow Equation Manning's Values (For the initial 300 ft of travel)	n_s*
Smooth surfaces (concrete, asphalt, gravel, or bare hard packed soil)	0.011
Fallow fields or loose soil surface (no residue)	0.05
Cultivated soil with residue cover (s < = 0.20 ft/ft)	0.06
Cultivated soil with residue cover (S > 0.20 ft/ft)	0.17
Short prairie grass and lawns	0.15
Dense grasses	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods or forest with light underbrush	0.40
Woods or forest with dense underbrush	0.80

*Manning values for sheet flow only, from Overton and Meadows 1976 (See TR-55, 1986)

"k" Values Used in Travel Time/Time of Concentration Calculations

Shallow Concentrated Flow (After the initial 300 ft. of sheet flow, R = 0.1)		k_s
1.	Forest with heavy ground litter and meadows (n=0.10)	3
2.	Brushy ground with some trees (n = 0.060)	5
3.	Fallow or minimum tillage cultivation (n =0.040)	8
4.	High grass (n = 0.035)	9
5.	Short grass, pasture and lawns (n=0.030)	11
6.	Nearly bare ground (n=0.025)	13
7.	Paved and gravel areas (n=0.012)	27

Channel Flow (Intermittent) (At the beginning of visible channels: R=0.2)		k_c
1.	Forested swale with heavy ground litter (n = 0.10)	5
2.	Forested drainage course/ravine with defined channel bed (n=0.050)	10
3.	Rock-lined waterway (n=0.035)	15
4.	Grassed waterway (n=0.030)	17
5.	Earth-lined waterway (n=0.025)	20
6.	CMP pipe (n=0.024)	21
7.	Concrete pipe (0.012)	42
8.	Other waterways and pipes	0.508/n

Channel Flow (Continuous stream, R = 0.4)		k_c
9.	Meandering stream with some pools (n = 0.040)	20
10.	Rock-lined stream (n=0.035)	23
11.	Grass-lined stream (n=0.030)	27
12.	Other streams, man-made channels and pipe	0.807/n**

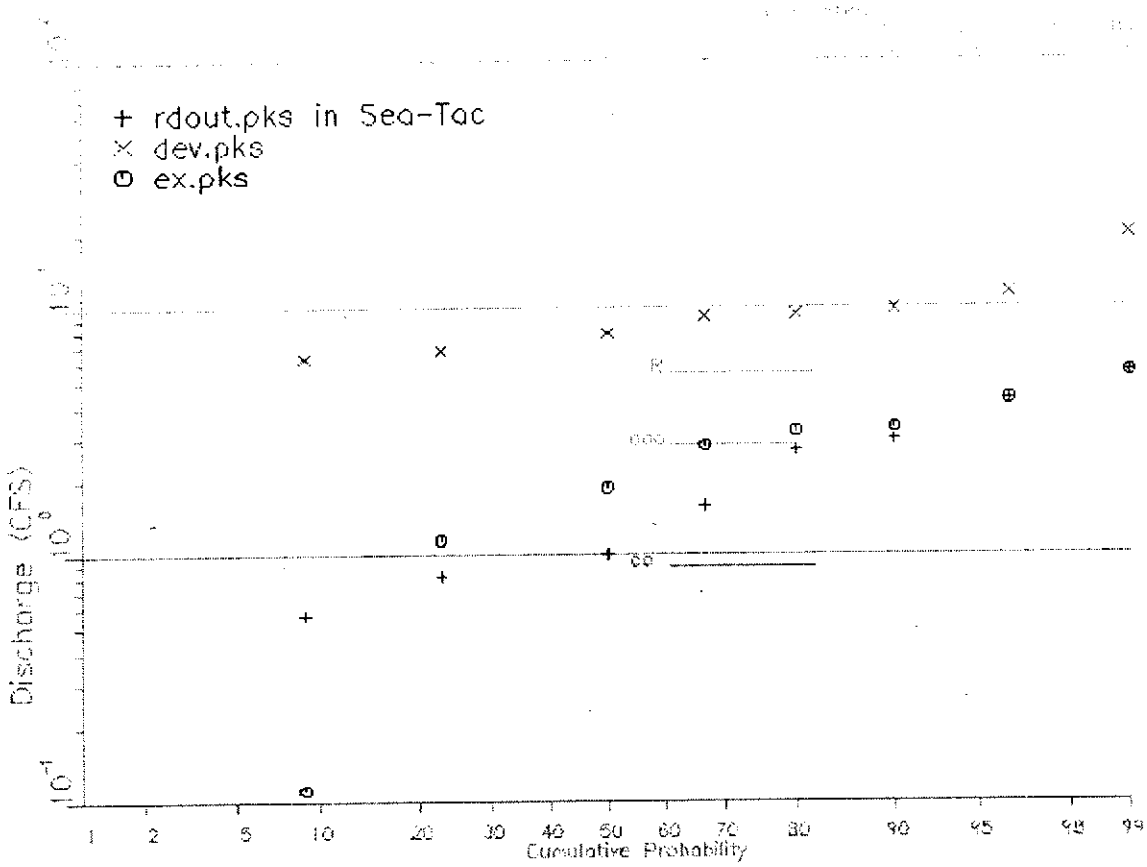
**See Chapter 5, Table 5.3.6C for additional Mannings "n" values for open channels

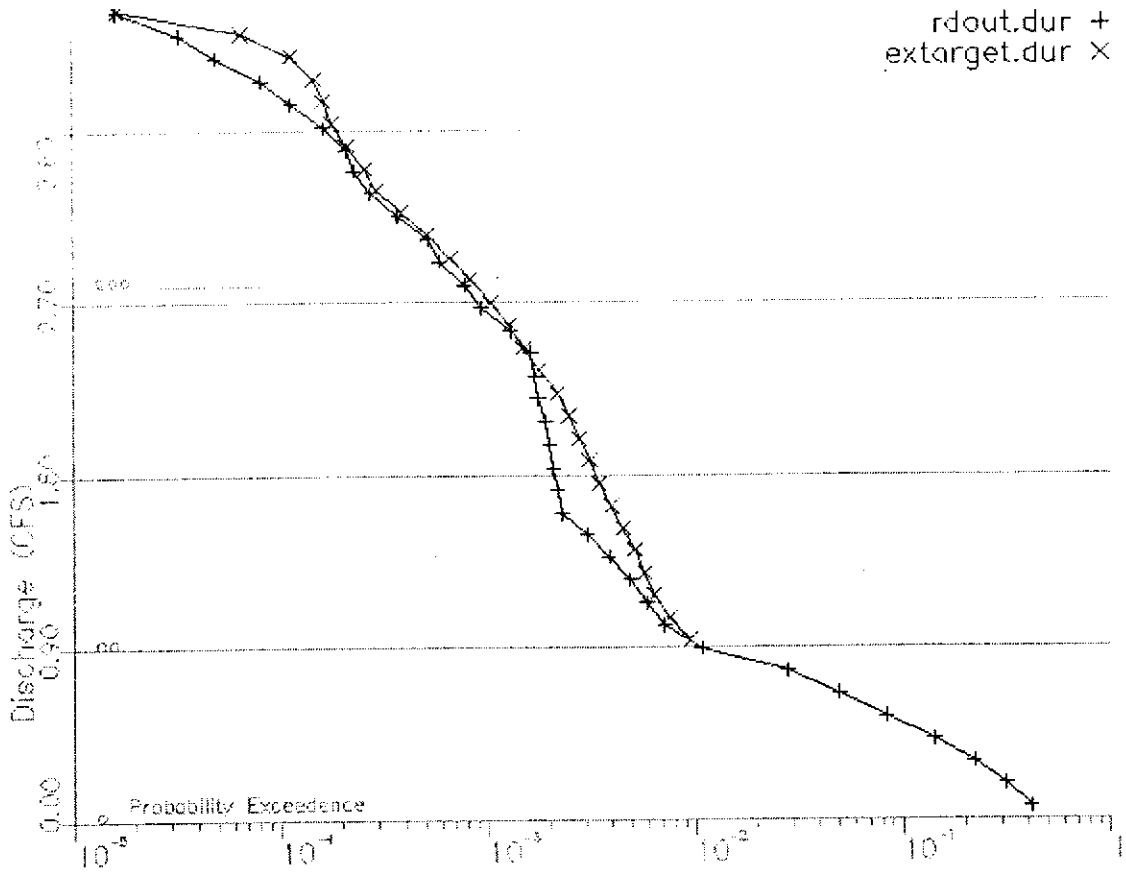
Appendix F

King County Runoff Time Series and Backwater Analysis

Appendix F

King County Runoff Time Series and Backwater Analysis


+ rdout.pks in Sea-Tac
× dev.pks
⊖ ex.pks
Discharge (CFS)
Cumulative Probability



Retention/Detention Facility

Type of Facility:	Detention Pond	
Side Slope:	6.00	H:1V
Pond Bottom Length:	513.97	ft
Pond Bottom Width:	256.98	ft
Pond Bottom Area:	132082.	sq. ft
Top Area at 1 ft. FB:	183761.	sq. ft
	4.219	acres
Effective Storage Depth:	4.17	ft
Stage 0 Elevation:	437.00	ft
Storage Volume:	634699.	cu. ft
	14.571	ac-ft
Riser Head:	4.17	ft
Riser Diameter:	30.00	inches
Number of orifices:	3	

Orifice #	Height (ft)	Diameter (in)	Full Head Discharge (CFS)	Pipe Diameter (in)
1	0.00	4.53	1.136	
2	2.58	8.60	2.528	12.0
3	3.36	8.55	1.785	12.0

Top Notch Weir: None
Outflow Rating Curve: None

Stage (ft)	Elevation (ft)	Storage (cu. ft)	Storage (ac-ft)	Discharge (cfs)	Percolation (cfs)	Surf Area (sq. ft)
0.00	437.00	0.	0.000	0.000	0.00	132082.
0.05	437.05	6616.	0.152	0.121	0.00	132545.
0.09	437.09	11925.	0.274	0.171	0.00	132916.
0.14	437.14	18582.	0.427	0.209	0.00	133380.
0.19	437.19	25263.	0.580	0.242	0.00	133845.
0.24	437.24	31967.	0.734	0.270	0.00	134311.
0.28	437.28	37347.	0.857	0.296	0.00	134684.
0.33	437.33	44093.	1.012	0.320	0.00	135151.
0.38	437.38	50862.	1.168	0.342	0.00	135618.
0.42	437.42	56294.	1.292	0.362	0.00	135993.
0.52	437.52	69940.	1.606	0.403	0.00	136932.
0.62	437.62	83680.	1.921	0.440	0.00	137873.
0.72	437.72	97515.	2.239	0.474	0.00	138818.
0.82	437.82	111444.	2.558	0.505	0.00	139765.
0.92	437.92	125468.	2.880	0.535	0.00	140715.
1.02	438.02	139587.	3.204	0.563	0.00	141668.
1.12	438.12	153802.	3.531	0.590	0.00	142624.
1.22	438.22	168112.	3.859	0.616	0.00	143583.
1.32	438.32	182519.	4.190	0.640	0.00	144545.
1.42	438.42	197021.	4.523	0.664	0.00	145509.
1.52	438.52	211620.	4.858	0.687	0.00	146477.
1.62	438.62	226317.	5.196	0.709	0.00	147447.
1.72	438.72	241110.	5.535	0.731	0.00	148420.
1.82	438.82	256001.	5.877	0.751	0.00	149397.
1.92	438.92	270989.	6.221	0.772	0.00	150376.
2.02	439.02	286076.	6.567	0.792	0.00	151357.
2.12	439.12	301261.	6.916	0.811	0.00	152342.
2.22	439.22	316545.	7.267	0.830	0.00	153330.
2.32	439.32	331927.	7.620	0.848	0.00	154320.
2.42	439.42	347409.	7.975	0.866	0.00	155314.
2.52	439.52	362990.	8.333	0.884	0.00	156310.
2.58	439.58	372387.	8.549	0.894	0.00	156909.
2.67	439.67	386549.	8.874	0.936	0.00	157810.
2.76	439.76	400792.	9.201	1.030	0.00	158713.
2.85	439.85	415117.	9.530	1.170	0.00	159618.
2.94	439.94	429524.	9.861	1.360	0.00	160526.
3.03	440.03	444012.	10.193	1.590	0.00	161436.
3.12	440.12	458582.	10.528	2.450	0.00	162348.
3.21	440.21	473235.	10.864	2.580	0.00	163263.
3.30	440.30	487970.	11.202	2.710	0.00	164180.
3.36	440.36	497839.	11.429	2.790	0.00	164793.
3.45	440.45	512712.	11.770	2.930	0.00	165713.
3.54	440.54	527667.	12.114	3.120	0.00	166637.
3.63	440.63	542706.	12.459	3.340	0.00	167562.
3.72	440.72	557829.	12.806	3.610	0.00	168490.
3.81	440.81	573035.	13.155	3.920	0.00	169420.
3.89	440.89	586621.	13.467	4.850	0.00	170249.
3.98	440.98	601986.	13.820	5.050	0.00	171184.
4.07	441.07	617435.	14.174	5.250	0.00	172121.
4.16	441.16	632968.	14.531	5.430	0.00	173060.
4.17	441.17	634699.	14.571	5.450	0.00	173165.

4.27	441.27	652067.	14.969	6.420	0.00	174211.
4.37	441.37	669541.	15.371	8.020	0.00	175261.
4.47	441.47	687120.	15.774	10.020	0.00	176313.
4.57	441.57	704804.	16.180	12.360	0.00	177369.
4.67	441.67	722594.	16.588	14.980	0.00	178427.
4.77	441.77	740489.	16.999	17.850	0.00	179488.
4.87	441.87	758491.	17.413	20.960	0.00	180552.
4.97	441.97	776600.	17.828	24.280	0.00	181619.
5.07	442.07	794815.	18.246	27.800	0.00	182688.
5.17	442.17	813137.	18.667	30.800	0.00	183761.
5.27	442.27	831567.	19.090	32.100	0.00	184836.
5.37	442.37	850105.	19.516	33.340	0.00	185915.
5.47	442.47	868750.	19.944	34.540	0.00	186996.
5.57	442.57	887504.	20.374	35.700	0.00	188080.
5.67	442.67	906366.	20.807	36.810	0.00	189167.
5.77	442.77	925338.	21.243	37.900	0.00	190257.
5.87	442.87	944418.	21.681	38.950	0.00	191350.
5.97	442.97	963608.	22.121	39.970	0.00	192445.
6.07	443.07	982907.	22.564	40.960	0.00	193544.
6.17	443.17	1002317.	23.010	41.940	0.00	194645.

Hyd	Inflow	Outflow		Peak		Storage	
		Target	Calc	Stage	Elev	(Cu-Ft)	(Ac-Ft)
1	19.97	5.45	5.45	4.17	441.17	634424.	14.564
2	11.47	*******	2.91	3.44	440.44	510660.	11.723
3	9.85	*******	1.58	3.02	440.02	443092.	10.172
4	9.37	*******	4.23	3.84	440.84	577513.	13.258
5	9.19	*******	2.63	3.25	440.25	479372.	11.005
6	7.82	*******	1.00	2.73	439.73	395857.	9.088
7	6.75	*******	0.82	2.16	439.16	307288.	7.054
8	6.29	*******	0.57	1.04	438.04	142502.	3.271

Route Time Series through Facility
Inflow Time Series File:dev.tsf
Outflow Time Series File:rdout.tsf

Inflow/Outflow Analysis

Peak Inflow Discharge:	19.98	CFS at	6:00 on Jan 9 in Year 8
Peak Outflow Discharge:	5.45	CFS at	11:00 on Jan 9 in Year 8
Peak Reservoir Stage:	4.17	Ft	
Peak Reservoir Elev:	441.17	Ft	
Peak Reservoir Storage:	634424.	Cu-Ft	
:	14.564	Ac-Ft	

Flow Frequency Analysis
Time Series File:rdout.tsf
Project Location:Sea-Tac

---Annual Peak Flow Rates---			-----Flow Frequency Analysis-------				
Flow Rate (CFS)	Rank	Time of Peak	- - Peaks - - (CFS)	(ft)	Rank	Return Period	Prob
4.23	2	2/09/01 20:00	5.45	4.17	1	100.00	0.990
0.818	7	12/29/01 12:00	4.23	3.84	2	25.00	0.960
2.91	3	3/06/03 22:00	2.91	3.44	3	10.00	0.900
0.569	8	8/26/04 8:00	2.64	3.25	4	5.00	0.800
0.997	6	1/08/05 5:00	1.58	3.03	5	3.00	0.667

1.58	5	1/19/06 16:00	0.997	2.73	6	2.00	0.500
2.64	4	11/24/06 11:00	0.818	2.16	7	1.30	0.231
5.45	1	1/09/08 11:00	0.569	1.04	8	1.10	0.091
Computed Peaks			5.04	3.98		50.00	0.980

Flow Duration from Time Series File:rdout.tsf

Cutoff CFS	Count	Frequency %	CDF %	Exceedence_Probability %	
0.060	36040	58.774	58.774	41.226	0.412E+00
0.179	5928	9.667	68.441	31.559	0.316E+00
0.298	5852	9.543	77.984	22.016	0.220E+00
0.417	4784	7.802	85.786	14.214	0.142E+00
0.535	3595	5.863	91.649	8.351	0.835E-01
0.654	2049	3.341	94.990	5.010	0.501E-01
0.773	1341	2.187	97.177	2.823	0.282E-01
0.892	1068	1.742	98.919	1.081	0.108E-01
1.01	224	0.365	99.284	0.716	0.716E-02
1.13	76	0.124	99.408	0.592	0.592E-02
1.25	64	0.104	99.512	0.488	0.488E-02
1.37	63	0.103	99.615	0.385	0.385E-02
1.49	50	0.082	99.697	0.303	0.303E-02
1.60	45	0.073	99.770	0.230	0.230E-02
1.72	7	0.011	99.781	0.219	0.219E-02
1.84	6	0.010	99.791	0.209	0.209E-02
1.96	5	0.008	99.799	0.201	0.201E-02
2.08	6	0.010	99.809	0.191	0.191E-02
2.20	9	0.015	99.824	0.176	0.176E-02
2.32	3	0.005	99.829	0.171	0.171E-02
2.44	5	0.008	99.837	0.163	0.163E-02
2.55	20	0.033	99.870	0.130	0.130E-02
2.67	22	0.036	99.905	0.095	0.946E-03
2.79	10	0.016	99.922	0.078	0.783E-03
2.91	12	0.020	99.941	0.059	0.587E-03
3.03	4	0.007	99.948	0.052	0.522E-03
3.15	9	0.015	99.962	0.038	0.375E-03
3.27	6	0.010	99.972	0.028	0.277E-03
3.39	3	0.005	99.977	0.023	0.228E-03
3.50	1	0.002	99.979	0.021	0.212E-03
3.62	3	0.005	99.984	0.016	0.163E-03
3.74	3	0.005	99.989	0.011	0.114E-03
3.86	2	0.003	99.992	0.008	0.815E-04
3.98	2	0.003	99.995	0.005	0.489E-04
4.10	1	0.002	99.997	0.003	0.326E-04
4.22	1	0.002	99.998	0.002	0.163E-04

Duration Comparison Anaylsis
Base File: ex.tsf
New File: rdout.tsf
Cutoff Units: Discharge in CFS

	-----Fraction of Time-----			---------Check of Tolerance-------			
Cutoff	Base	New	%Change	Probability	Base	New	%Change
0.915	0.98E-02	0.96E-02	-2.3	0.98E-02	0.915	0.908	-0.8
1.17	0.64E-02	0.55E-02	-14.8	0.64E-02	1.17	1.08	-7.7
1.43	0.50E-02	0.34E-02	-31.0	0.50E-02	1.43	1.23	-13.8
1.69	0.38E-02	0.23E-02	-40.5	0.38E-02	1.69	1.38	-18.2
1.94	0.29E-02	0.20E-02	-30.3	0.29E-02	1.94	1.50	-22.5
2.20	0.22E-02	0.18E-02	-20.6	0.22E-02	2.20	1.70	-22.6
2.46	0.15E-02	0.16E-02	6.5	0.15E-02	2.46	2.49	1.3
2.71	0.10E-02	0.90E-03	-12.7	0.10E-02	2.71	2.63	-3.0
2.97	0.62E-03	0.54E-03	-13.2	0.62E-03	2.97	2.90	-2.4
3.23	0.34E-03	0.29E-03	-14.3	0.34E-03	3.23	3.20	-0.7
3.48	0.23E-03	0.21E-03	-7.1	0.23E-03	3.48	3.44	-1.2
3.74	0.16E-03	0.11E-03	-30.0	0.16E-03	3.74	3.64	-2.6
4.00	0.11E-03	0.49E-04	-57.1	0.11E-03	4.00	3.79	-5.2
4.25	0.16E-04	0.00E+00	-100.0	0.16E-04	4.25	4.22	-0.8

Maximum positive excursion = 0.064 cfs (1.6%)
occurring at 4.13 cfs on the Base Data:ex.tsf
and at 4.19 cfs on the New Data:rdout.tsf

Maximum negative excursion = 0.586 cfs (-27.0%)
occurring at 2.17 cfs on the Base Data:ex.tsf
and at 1.58 cfs on the New Data:rdout.tsf

Flow Frequency Analysis
Time Series File:ex.tsf (Pre developed forested conditions)
Project Location:Sea-Tac

---Annual Peak Flow Rates---			-----Flow Frequency Analysis-------			
Flow Rate (CFS)	Rank	Time of Peak	- - Peaks - - (CFS)	Rank	Return Period	Prob
4.26	2	2/09/01 18:00	5.45	1	100.00	0.990
1.15	7	1/06/02 3:00	4.26	2	25.00	0.960
3.16	4	2/28/03 3:00	3.27	3	10.00	0.900
0.112	8	3/24/04 20:00	3.16	4	5.00	0.800
1.87	6	1/05/05 8:00	2.76	5	3.00	0.667
3.27	3	1/18/06 21:00	1.87	6	2.00	0.500
2.76	5	11/24/06 4:00	1.15	7	1.30	0.231
5.45	1	1/09/08 9:00	0.112	8	1.10	0.091
Computed Peaks			5.05		50.00	0.980

Basin 15 & 19

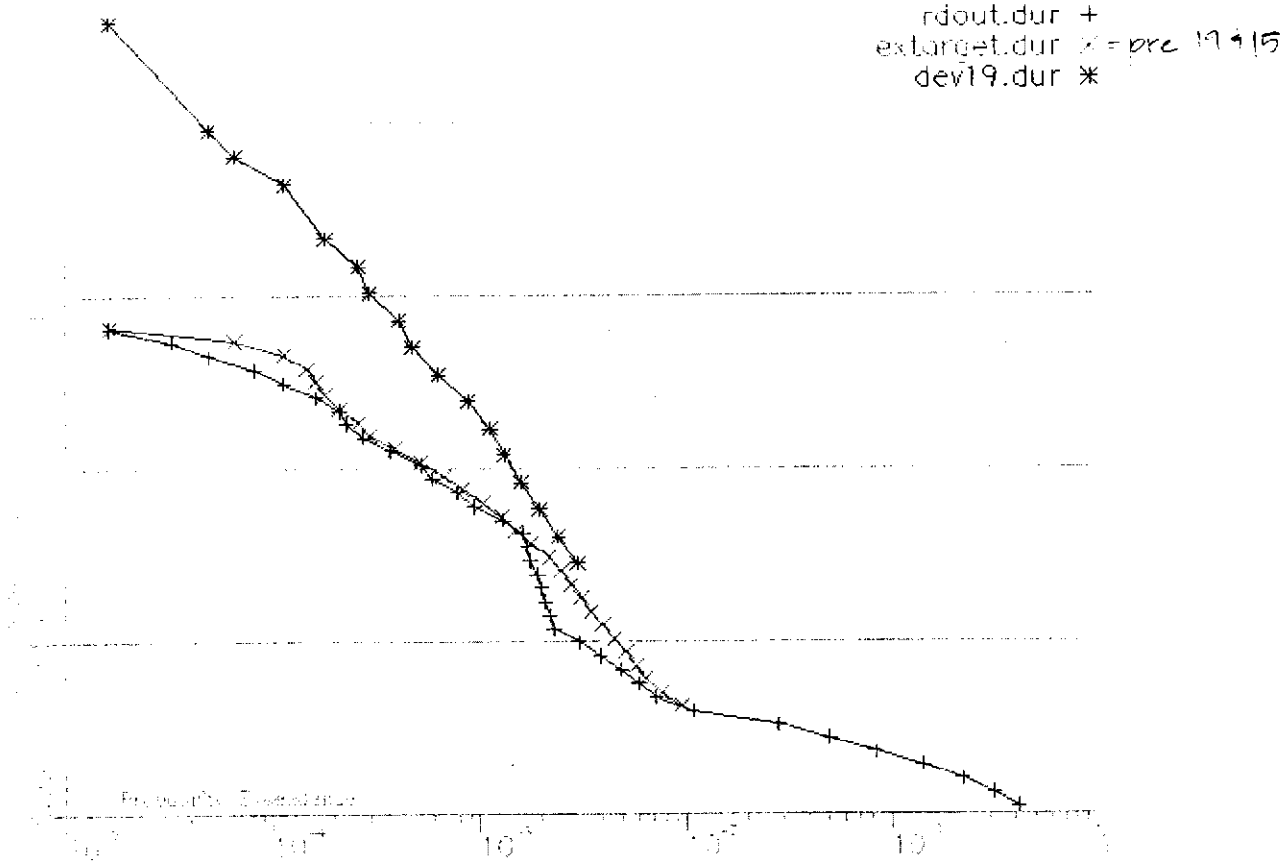
Flow Frequency Analysis
Time Series File:dev.tsf (Existing residential conditions)
Project Location:Sea-Tac

---Annual Peak Flow Rates---			-----Flow Frequency Analysis-------			
Flow Rate (CFS)	Rank	Time of Peak	- - Peaks - - (CFS)	Rank	Return Period	Prob
9.37	4	2/09/01 2:00	19.97	1	100.00	0.990
6.75	7	1/05/02 16:00	11.47	2	25.00	0.960
11.47	2	2/27/03 7:00	9.85	3	10.00	0.900
6.29	8	8/26/04 2:00	9.37	4	5.00	0.800
7.82	6	10/28/04 16:00	9.19	5	3.00	0.667
9.85	3	1/18/06 16:00	7.82	6	2.00	0.500
9.19	5	11/24/06 3:00	6.75	7	1.30	0.231
19.97	1	1/09/08 6:00	6.29	8	1.10	0.091
Computed Peaks			17.13		50.00	0.980

Basin 15+19

Flow Frequency Analysis
Time Series File:rdout.tsf (Pond output, does not include overflow)
Project Location:Sea-Tac

---Annual Peak Flow Rates---			-----Flow Frequency Analysis-------				
Flow Rate (CFS)	Rank	Time of Peak	- - Peaks - - (CFS)	(ft)	Rank	Return Period	Prob
4.25	2	2/09/01 20:00	5.45	4.17	1	100.00	0.990
0.818	7	12/29/01 12:00	4.25	3.84	2	25.00	0.960
2.91	3	3/06/03 22:00	2.91	3.44	3	10.00	0.900
0.567	8	8/26/04 8:00	2.64	3.25	4	5.00	0.800
0.998	6	1/08/05 5:00	1.58	3.03	5	3.00	0.667
1.58	5	1/19/06 15:00	0.998	2.73	6	2.00	0.500
2.64	4	11/24/06 10:00	0.818	2.16	7	1.30	0.231
5.45	1	1/09/08 11:00	0.567	1.04	8	1.10	0.091
Computed Peaks			5.05	3.98		50.00	0.980



Duration Comparison Anaylsis
Base File: dev19.tsf
New File: rdout.tsf
Cutoff Units: Discharge in CFS

	-----Fraction of Time-----			---------Check of Tolerance-------			
Cutoff	Base	New	%Change	Probability	Base	New	%Change
2.17	0.30E-02	0.18E-02	-39.7	0.30E-02	2.17	1.49	-31.3
2.54	0.22E-02	0.13E-02	-40.4	0.22E-02	2.54	1.69	-33.2
2.90	0.16E-02	0.60E-03	-61.9	0.16E-02	2.90	2.47	-14.9
3.26	0.12E-02	0.28E-03	-76.7	0.12E-02	3.26	2.59	-20.7
3.63	0.80E-03	0.16E-03	-79.6	0.80E-03	3.63	2.78	-23.5
3.99	0.51E-03	0.49E-04	-90.3	0.51E-03	3.99	3.04	-23.9
4.36	0.36E-03	0.00E+00	-100.0	0.36E-03	4.36	3.18	-26.9
4.72	0.28E-03	0.00E+00	-100.0	0.28E-03	4.72	3.31	-29.9
5.08	0.15E-03	0.00E+00	-100.0	0.15E-03	5.08	3.69	-27.5
5.45	0.11E-03	0.00E+00	-100.0	0.11E-03	5.45	3.79	-30.5
5.81	0.65E-04	0.00E+00	-100.0	0.65E-04	5.81	3.92	-32.6
6.18	0.16E-04	0.00E+00	-100.0	0.16E-04	6.18	4.22	-31.7
6.54	0.16E-04	0.00E+00	-100.0	0.16E-04	6.54	4.22	-35.5
6.90	0.16E-04	0.00E+00	-100.0	0.16E-04	6.90	4.22	-38.9

There is no positive excursion

Maximum negative excursion = 2.68 cfs (-38.9%)
occurring at 6.90 cfs on the Base Data:dev19.tsf
and at 4.22 cfs on the New Data:rdout.tsf

Madsen Pond
KCRTS program used to assist in determining effective Q of 72" Overflow riser

Retention/Detention Facility

Type of Facility:	Detention Pond	
Side Slope:	6.00	H:1V
Pond Bottom Length:	513.97	ft
Pond Bottom Width:	256.98	ft
Pond Bottom Area:	132082.	sq. ft
Top Area at 1 ft. FB:	183761.	sq. ft
	4.219	acres
Effective Storage Depth:	4.17	ft
Stage 0 Elevation:	437.00	ft
Storage Volume:	634699.	cu. ft
	14.571	ac-ft
Riser Head:	4.17	ft
Riser Diameter:	72.00	inches
Number of orifices:	3	

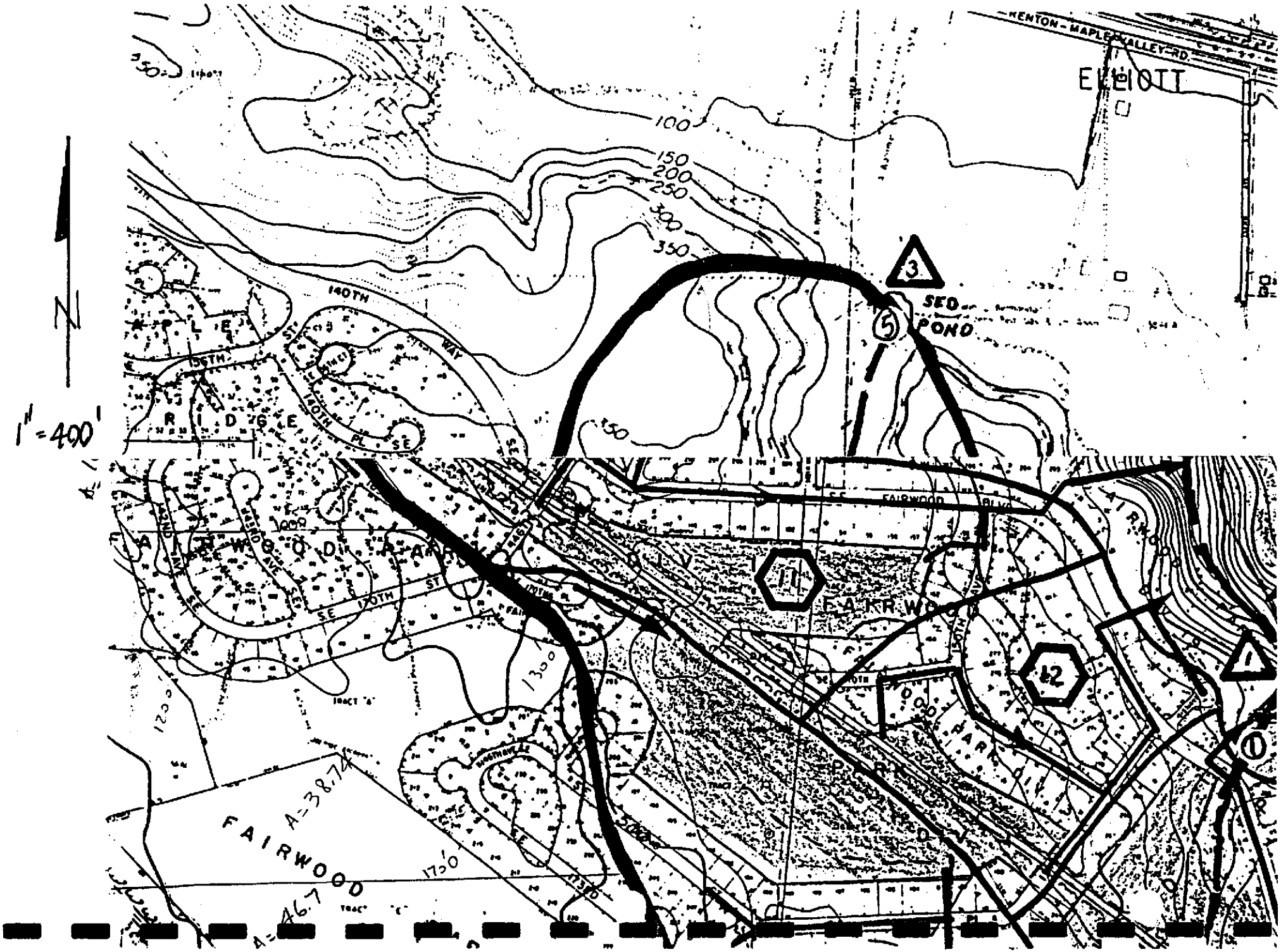
Orifice #	Height (ft)	Diameter (in)	Full Head Discharge (CFS)	Pipe Diameter (in)
1	0.00	4.53	1.136	
2	2.58	8.60	2.528	12.0
3	3.36	8.55	1.785	12.0

Top Notch Weir: None
Outflow Rating Curve: None

Stage (ft)	Elevation (ft)	Storage (cu. ft)	Storage (ac-ft)	Discharge (cfs)	Percolation (cfs)	Surf Area (sq. ft)
0.00	437.00	0.	0.000	0.000	0.00	132082.
0.05	437.05	6616.	0.152	0.121	0.00	132545.
0.09	437.09	11925.	0.274	0.171	0.00	132916.
0.14	437.14	18582.	0.427	0.209	0.00	133380.
0.19	437.19	25263.	0.580	0.242	0.00	133845.
0.24	437.24	31967.	0.734	0.270	0.00	134311.
0.28	437.28	37347.	0.857	0.296	0.00	134684.
0.33	437.33	44093.	1.012	0.320	0.00	135151.
0.38	437.38	50862.	1.168	0.342	0.00	135618.
0.42	437.42	56294.	1.292	0.362	0.00	135993.
0.52	437.52	69940.	1.606	0.403	0.00	136932.
0.62	437.62	83680.	1.921	0.440	0.00	137873.
0.72	437.72	97515.	2.239	0.474	0.00	138818.
0.82	437.82	111444.	2.558	0.505	0.00	139765.
0.92	437.92	125468.	2.880	0.535	0.00	140715.
1.02	438.02	139587.	3.204	0.563	0.00	141668.
1.12	438.12	153802.	3.531	0.590	0.00	142624.
1.22	438.22	168112.	3.859	0.616	0.00	143583.
1.32	438.32	182519.	4.190	0.640	0.00	144545.
1.42	438.42	197021.	4.523	0.664	0.00	145509.
1.52	438.52	211620.	4.858	0.687	0.00	146477.
1.62	438.62	226317.	5.196	0.709	0.00	147447.
1.72	438.72	241110.	5.535	0.731	0.00	148420.
1.82	438.82	256001.	5.877	0.751	0.00	149397.
1.92	438.92	270989.	6.221	0.772	0.00	150376.
2.02	439.02	286076.	6.567	0.792	0.00	151357.
2.12	439.12	301261.	6.916	0.811	0.00	152342.

2.22	439.22	316545.	7.267	0.830	0.00	153330.
2.32	439.32	331927.	7.620	0.848	0.00	154320.
2.42	439.42	347409.	7.975	0.866	0.00	155314.
2.52	439.52	362990.	8.333	0.884	0.00	156310.
2.58	439.58	372387.	8.549	0.894	0.00	156909.
2.67	439.67	386549.	8.874	0.936	0.00	157810.
2.76	439.76	400792.	9.201	1.030	0.00	158713.
2.85	439.85	415117.	9.530	1.170	0.00	159618.
2.94	439.94	429524.	9.861	1.360	0.00	160526.
3.03	440.03	444012.	10.193	1.590	0.00	161436.
3.12	440.12	458582.	10.528	2.450	0.00	162348.
3.21	440.21	473235.	10.864	2.580	0.00	163263.
3.30	440.30	487970.	11.202	2.710	0.00	164180.
3.36	440.36	497839.	11.429	2.790	0.00	164793.
3.45	440.45	512712.	11.770	2.930	0.00	165713.
3.54	440.54	527667.	12.114	3.120	0.00	166637.
3.63	440.63	542706.	12.459	3.340	0.00	167562.
3.72	440.72	557829.	12.806	3.610	0.00	168490.
3.81	440.81	573035.	13.155	3.920	0.00	169420.
3.89	440.89	586621.	13.467	4.850	0.00	170249.
3.98	440.98	601986.	13.820	5.050	0.00	171184.
4.07	441.07	617435.	14.174	5.250	0.00	172121.
4.16	441.16	632968.	14.531	5.430	0.00	173060.
4.17	441.17	634699.	14.571	5.450	0.00	173165.
4.27	441.27	652067.	14.969	7.500	0.00	174211.
4.37	441.37	669541.	15.371	11.070	0.00	175261.
4.47	441.47	687120.	15.774	15.620	0.00	176313.
4.57	441.57	704804.	16.180	20.980	0.00	177369.
4.67	441.67	722594.	16.588	27.030	0.00	178427.
4.77	441.77	740489.	16.999	33.700	0.00	179488.
4.87	441.87	758491.	17.413	40.920	0.00	180552.
4.97	441.97	776600.	17.828	48.670	0.00	181619.
5.07	442.07	794815.	18.246	56.900	0.00	182688.
5.17	442.17	813137.	18.667	65.600	0.00	183761.
5.27	442.27	831567.	19.090	74.720	0.00	184836.
5.37	442.37	850105.	19.516	84.260	0.00	185915.
5.47	442.47	868750.	19.944	94.200	0.00	186996.
5.57	442.57	887504.	20.374	104.530	0.00	188080.
5.67	442.67	906366.	20.807	115.210	0.00	189167.
5.77	442.77	925338.	21.243	126.260	0.00	190257.
5.87	442.87	944418.	21.681	137.650	0.00	191350.
5.97	442.97	963608.	22.121	149.370	0.00	192445.
6.07	443.07	982907.	22.564	161.420	0.00	193544.
6.17	443.17	1002317.	23.010	173.780	0.00	194645.

Hyd	Inflow	Outflow		Peak		Storage	
		Target	Calc	Stage	Elev	(Cu-Ft)	(Ac-Ft)
1	19.97	5.45	5.45	4.17	441.17	634424.	14.564
2	11.47	*******	2.91	3.44	440.44	510660.	11.723
3	9.85	*******	1.58	3.02	440.02	443092.	10.172
4	9.37	*******	4.23	3.84	440.84	577513.	13.258
5	9.19	*******	2.63	3.25	440.25	479372.	11.005
6	7.82	*******	1.00	2.73	439.73	395857.	9.088
7	6.75	*******	0.82	2.16	439.16	307288.	7.054
8	6.29	*******	0.57	1.04	438.04	142502.	3.271



RENTON-MAPLE VALLEY RD
ELLIOTT
100
150
200
250
300
350
3
SED POND
5
140TH WAY
140TH PL SE
RIDGE
FAIRWOOD BLVD
FAIRWOOD
11
12
1
1300
1200
1700
A=38.74
A=46.7
FAIRWOOD
1" = 400'
N

PROJECT: PAGE ___ OF ___

PIPE DATA FILE NAME _____ .BWP

#	LENGTH(ft)	DIA(in)	PIPE-TYPE	OUTLET-IE	INLET-IE	INLET-TYPE
1	36	36	1	422	422.08	5

KE = ___ K = ___ M = ___ C = ___ Y = ___ BW program assigns values

OVERFLOW-ELEV	BEND-ANGLE(deg)	STRUCT.DIA/WIDTH(ft)	Q-RATIO
436.58	55	6	0

#	LENGTH(ft)	DIA(in)	PIPE-TYPE	OUTLET-IE	INLET-IE	INLET-TYPE
2	86	36	1	429.50	430.15	5

KE = ___ K = ___ M = ___ C = ___ Y = ___

OVERFLOW-ELEV	BEND-ANGLE(deg)	STRUCT.DIA/WIDTH(ft)	Q-RATIO
441.17	75	6	0

#	LENGTH(ft)	DIA(in)	PIPE-TYPE	OUTLET-IE	INLET-IE	INLET-TYPE
3	40	30	1	435	436.50	5

KE = ___ K = ___ M = ___ C = ___ Y = ___

OVERFLOW-ELEV	BEND-ANGLE(deg)	STRUCT.DIA/WIDTH(ft)	Q-RATIO
441.67		8	0

#	LENGTH(ft)	DIA(in)	PIPE-TYPE	OUTLET-IE	INLET-IE	INLET-TYPE

KE = ___ K = ___ M = ___ C = ___ Y = ___

OVERFLOW-ELEV	BEND-ANGLE(deg)	STRUCT.DIA/WIDTH(ft)	Q-RATIO

#	LENGTH(ft)	DIA(in)	PIPE-TYPE	OUTLET-IE	INLET-IE	INLET-TYPE

KE = ___ K = ___ M = ___ C = ___ Y = ___

OVERFLOW-ELEV	BEND-ANGLE(deg)	STRUCT.DIA/WIDTH(ft)	Q-RATIO

BACKWATER COMPUTER PROGRAM FOR PIPES
Pipe data from file:PipeS.bwp

Surcharge condition at intermediate junctions
Tailwater Elevation:425. feet crown of outlet
Discharge Range:2.5 to 125. Step of 2.5 [cfs]
Overflow Elevation:443.3 feet
Weir:NONE
Upstream Velocity:0. feet/sec

PIPE NO. 1: 42 LF - 36"CP @ 0.19% OUTLET: 422.00 INLET: 422.08 INTYP: 5
JUNC NO. 1: OVERFLOW-EL: 436.50 BEND: 55 DEG DIA/WIDTH: 6.0 Q-RATIO: 0.00

Q(CFS)	HW(FT)	HW ELEV.	* N-FAC	DC	DN	TW	DO	DE	HWO	HWI
2.50	2.93	425.01	* 0.012	0.50	0.58	3.00	3.00	2.93	2.93	0.66
5.00	2.94	425.02	* 0.012	0.71	0.81	3.00	3.00	2.93	2.94	0.95
7.50	2.95	425.03	* 0.012	0.87	1.00	3.00	3.00	2.93	2.95	1.17
10.00	2.96	425.04	* 0.012	1.01	1.17	3.00	3.00	2.93	2.96	1.37
12.50	2.99	425.07	* 0.012	1.13	1.32	3.00	3.00	2.94	2.99	1.55
15.00	3.01	425.09	* 0.012	1.24	1.46	3.00	3.00	2.94	3.01	1.71
17.50	3.05	425.13	* 0.012	1.34	1.60	3.00	3.00	2.95	3.05	1.86
20.00	3.08	425.16	* 0.012	1.44	1.74	3.00	3.00	2.95	3.08	2.01
22.50	3.13	425.21	* 0.012	1.53	1.88	3.00	3.00	2.96	3.13	2.15
25.00	3.17	425.25	* 0.012	1.62	2.02	3.00	3.00	2.97	3.17	2.29
27.50	3.23	425.31	* 0.012	1.70	2.17	3.00	3.00	2.98	3.23	2.43
30.00	3.29	425.37	* 0.012	1.78	2.34	3.00	3.00	3.00	3.29	2.56
32.50	3.35	425.43	* 0.012	1.86	2.56	3.00	3.00	3.00	3.35	2.69
35.00	3.42	425.50	* 0.012	1.93	3.00	3.00	3.00	3.02	3.42	2.82
37.50	3.49	425.57	* 0.012	2.00	3.00	3.00	3.00	3.03	3.49	2.95
40.00	3.57	425.65	* 0.012	2.06	3.00	3.00	3.00	3.05	3.57	3.07
42.50	3.65	425.73	* 0.012	2.13	3.00	3.00	3.00	3.07	3.65	3.20
45.00	3.74	425.82	* 0.012	2.19	3.00	3.00	3.00	3.08	3.74	3.33
47.50	3.84	425.92	* 0.012	2.25	3.00	3.00	3.00	3.10	3.84	3.47
50.00	3.93	426.01	* 0.012	2.31	3.00	3.00	3.00	3.12	3.93	3.64
52.50	4.04	426.12	* 0.012	2.36	3.00	3.00	3.00	3.14	4.04	3.81
55.00	4.15	426.23	* 0.012	2.41	3.00	3.00	3.00	3.16	4.15	3.99
57.50	4.26	426.34	* 0.012	2.46	3.00	3.00	3.00	3.19	4.26	4.17
60.00	4.38	426.46	* 0.012	2.51	3.00	3.00	3.00	3.21	4.38	4.37
62.50	4.57	426.65	* 0.012	2.55	3.00	3.00	3.00	3.23	4.50	4.57
65.00	4.77	426.85	* 0.012	2.59	3.00	3.00	3.00	3.26	4.63	4.77
67.50	4.99	427.07	* 0.012	2.63	3.00	3.00	3.00	3.29	4.77	4.99
70.00	5.87	427.95	* 0.012	2.66	3.00	3.00	3.00	3.31	5.56	5.87
72.50	6.15	428.23	* 0.012	2.70	3.00	3.00	3.00	3.34	5.75	6.15
75.00	6.45	428.53	* 0.012	2.72	3.00	3.00	3.00	3.37	5.96	6.45
77.50	6.75	428.83	* 0.012	2.75	3.00	3.00	3.00	3.40	6.16	6.75
80.00	7.06	429.14	* 0.012	2.78	3.00	3.00	3.00	3.43	6.38	7.06
82.50	7.39	429.47	* 0.012	2.80	3.00	3.00	3.00	3.47	6.60	7.39
85.00	7.72	429.80	* 0.012	2.82	3.00	3.00	3.00	3.50	6.83	7.72
87.50	8.06	430.14	* 0.012	2.84	3.00	3.00	3.00	3.54	7.07	8.06
90.00	8.42	430.50	* 0.012	2.85	3.00	3.00	3.00	3.57	7.31	8.42
92.50	8.78	430.86	* 0.012	2.87	3.00	3.00	3.00	3.61	7.56	8.78
95.00	9.15	431.23	* 0.012	2.88	3.00	3.00	3.00	3.65	7.82	9.15
97.50	9.54	431.62	* 0.012	2.89	3.00	3.00	3.00	3.68	8.08	9.54
100.00	9.93	432.01	* 0.012	2.90	3.00	3.00	3.00	3.72	8.35	9.93

→ 102.50	10.33	432.41	* 0.012	2.91	3.00	3.00	3.00	3.77	8.63	10.33
105.00	10.75	432.83	* 0.012	2.92	3.00	3.00	3.00	3.81	8.91	10.75
107.50	11.17	433.25	* 0.012	2.93	3.00	3.00	3.00	3.85	9.20	11.17
110.00	11.60	433.68	* 0.012	2.93	3.00	3.00	3.00	3.89	9.50	11.60
112.50	12.05	434.13	* 0.012	2.94	3.00	3.00	3.00	3.94	9.81	12.05
115.00	12.50	434.58	* 0.012	2.94	3.00	3.00	3.00	3.98	10.12	12.50
117.50	12.97	435.05	* 0.012	2.95	3.00	3.00	3.00	4.03	10.44	12.97
120.00	13.44	435.52	* 0.012	2.95	3.00	3.00	3.00	4.08	10.76	13.44
122.50	13.92	436.00	* 0.012	2.96	3.00	3.00	3.00	4.13	11.09	13.92
125.00	14.42	436.50	* 0.012	2.96	3.00	3.00	3.00	4.18	11.43	14.42

PIPE NO. 2: 86 LF - 36"CP @ 0.76% OUTLET: 429.50 INLET: 430.15 INTYP: 5
JUNC NO. 2: OVERFLOW-EL: 441.17 BEND: 75 DEG DIA/WIDTH: 6.0 Q-RATIO: 0.00

Q(CFS)	HW(FT)	HW ELEV.	* N-FAC	DC	DN	TW	DO	DE	HWO	HWI
2.50	0.65	430.80	* 0.012	0.50	0.41	0.00	0.41	0.50	*****	0.65
5.00	0.94	431.09	* 0.012	0.71	0.58	0.00	0.58	0.71	*****	0.94
7.50	1.17	431.32	* 0.012	0.87	0.70	0.00	0.70	0.87	*****	1.17
10.00	1.37	431.52	* 0.012	1.01	0.81	0.00	0.81	1.01	*****	1.37
12.50	1.55	431.70	* 0.012	1.13	0.91	0.00	0.91	1.13	*****	1.55
15.00	1.73	431.88	* 0.012	1.24	1.00	0.00	1.00	1.24	*****	1.73
17.50	1.89	432.04	* 0.012	1.34	1.09	0.00	1.09	1.34	*****	1.89
20.00	2.05	432.20	* 0.012	1.44	1.17	0.00	1.17	1.44	*****	2.05
22.50	2.20	432.35	* 0.012	1.53	1.25	0.00	1.25	1.53	*****	2.20
→ 25.00	2.35	432.50	* 0.012	1.62	1.32	0.00	1.32	1.62	*****	2.35
27.50	2.50	432.65	* 0.012	1.70	1.39	0.00	1.39	1.70	*****	2.50
30.00	2.65	432.80	* 0.012	1.78	1.47	0.00	1.47	1.78	*****	2.65
32.50	2.80	432.95	* 0.012	1.86	1.54	0.00	1.54	1.86	*****	2.80
35.00	2.95	433.10	* 0.012	1.93	1.61	0.00	1.61	1.93	*****	2.95
37.50	3.10	433.25	* 0.012	2.00	1.67	0.00	1.67	2.00	*****	3.10
40.00	3.25	433.40	* 0.012	2.06	1.74	0.00	1.74	2.06	*****	3.25
42.50	3.40	433.55	* 0.012	2.13	1.81	0.00	1.81	2.13	*****	3.40
45.00	3.55	433.70	* 0.012	2.19	1.88	0.00	1.88	2.19	*****	3.55
47.50	3.72	433.87	* 0.012	2.25	1.95	0.00	1.95	2.25	*****	3.72
50.00	3.92	434.07	* 0.012	2.31	2.03	0.00	2.03	2.31	*****	3.92
52.50	4.11	434.26	* 0.012	2.36	2.10	0.00	2.10	2.36	*****	4.11
55.00	4.32	434.47	* 0.012	2.41	2.18	0.00	2.18	2.41	*****	4.32
57.50	4.54	434.69	* 0.012	2.46	2.26	0.00	2.26	2.46	*****	4.54
60.00	4.76	434.91	* 0.012	2.51	2.35	0.00	2.35	2.51	*****	4.76
62.50	5.00	435.15	* 0.012	2.55	2.45	0.00	2.45	2.55	*****	5.00
65.00	5.24	435.39	* 0.012	2.59	2.57	0.00	2.57	2.59	*****	5.24
67.50	5.62	435.77	* 0.012	2.63	2.78	0.00	2.63	2.74	5.05	5.62
70.00	5.90	436.05	* 0.012	2.66	3.00	0.00	2.66	2.90	5.23	5.90
72.50	6.18	436.33	* 0.012	2.70	3.00	0.00	2.70	3.05	5.50	6.18
75.00	6.47	436.62	* 0.012	2.72	3.00	0.00	2.72	3.12	5.74	6.47
77.50	6.78	436.93	* 0.012	2.75	3.00	0.00	2.75	3.19	5.99	6.78
80.00	7.09	437.24	* 0.012	2.78	3.00	0.00	2.78	3.26	6.24	7.09
82.50	7.42	437.57	* 0.012	2.80	3.00	0.00	2.80	3.33	6.50	7.42
85.00	7.75	437.90	* 0.012	2.82	3.00	0.30	2.82	3.40	6.77	7.75
87.50	8.09	438.24	* 0.012	2.84	3.00	0.64	2.84	3.47	7.04	8.09
90.00	8.45	438.60	* 0.012	2.85	3.00	1.00	2.85	3.55	7.33	8.45
92.50	8.81	438.96	* 0.012	2.87	3.00	1.36	2.87	3.62	7.61	8.81
95.00	9.18	439.33	* 0.012	2.88	3.00	1.73	2.88	3.70	7.91	9.18
97.50	9.57	439.72	* 0.012	2.89	3.00	2.12	2.89	3.78	8.21	9.57
100.00	9.96	440.11	* 0.012	2.90	3.00	2.51	2.90	3.87	8.53	9.96

102.50	10.36	440.51	*	0.012	2.91	3.00	2.91	2.91	3.95	8.85	10.36
105.00	10.78	440.93	*	0.012	2.92	3.00	3.33	3.33	4.49	9.64	10.78

********** OVERFLOW ENCOUNTERED AT 107.50 CFS DISCHARGE **********

******** OVERFLOW CONDITIONS CALCULATED ASSUMING SURCHARGE CONDITIONS *********

107.50	11.20	441.35	*	0.012	2.93	3.00	3.75	3.75	5.01	10.40	11.20
110.00	11.63	441.78	*	0.012	2.93	3.00	4.18	4.18	5.53	11.17	11.63
112.50	12.08	442.23	*	0.012	2.94	3.00	4.63	4.63	6.06	11.97	12.08
115.00	12.78	442.93	*	0.012	2.94	3.00	5.08	5.08	6.61	12.78	12.53
117.50	13.61	443.76	*	0.012	2.95	3.00	5.55	5.55	7.17	13.61	12.99
120.00	14.46	444.61	*	0.012	2.95	3.00	6.02	6.02	7.74	14.46	13.47
122.50	15.33	445.48	*	0.012	2.96	3.00	6.50	6.50	8.32	15.33	13.95
125.00	16.21	446.36	*	0.012	2.96	3.00	7.00	7.00	8.92	16.21	14.44

PIPE NO. 3: 40 LF - 30"CP @ 3.75% OUTLET: 435.00 INLET: 436.50 INTYP: 5

Q(CFS)	HW(FT)	HW ELEV.	*	N-FAC	DC	DN	TW	DO	DE	HWO	HWI
2.50	0.65	437.15	*	0.012	0.52	0.30	0.00	0.30	0.52	*****	0.65
5.00	0.97	437.47	*	0.012	0.74	0.41	0.00	0.41	0.74	*****	0.97
7.50	1.22	437.72	*	0.012	0.91	0.50	0.00	0.50	0.91	*****	1.22
10.00	1.45	437.95	*	0.012	1.06	0.58	0.00	0.58	1.06	*****	1.45
12.50	1.66	438.16	*	0.012	1.19	0.65	0.00	0.65	1.19	*****	1.66
15.00	1.87	438.37	*	0.012	1.31	0.71	0.00	0.71	1.31	*****	1.87
17.50	2.07	438.57	*	0.012	1.42	0.77	0.00	0.77	1.42	*****	2.07
20.00	2.27	438.77	*	0.012	1.52	0.82	0.00	0.82	1.52	*****	2.27
22.50	2.47	438.97	*	0.012	1.62	0.88	0.00	0.88	1.62	*****	2.47
25.00	2.68	439.18	*	0.012	1.71	0.93	0.00	0.93	1.71	*****	2.68
27.50	2.88	439.38	*	0.012	1.79	0.98	0.00	0.98	1.79	*****	2.88
30.00	3.10	439.60	*	0.012	1.87	1.02	0.00	1.02	1.87	*****	3.10
32.50	3.37	439.87	*	0.012	1.95	1.07	0.00	1.07	1.95	*****	3.37
35.00	3.65	440.15	*	0.012	2.01	1.12	0.00	1.12	2.01	*****	3.65
37.50	3.95	440.45	*	0.012	2.08	1.16	0.00	1.16	2.08	*****	3.95
40.00	4.27	440.77	*	0.012	2.13	1.20	0.00	1.20	2.13	*****	4.27
42.50	4.61	441.11	*	0.012	2.19	1.25	0.00	1.25	2.19	*****	4.61
45.00	4.97	441.47	*	0.012	2.23	1.29	0.00	1.29	2.23	*****	4.97
47.50	5.35	441.85	*	0.012	2.27	1.33	0.00	1.33	2.27	*****	5.35
50.00	5.76	442.26	*	0.012	2.30	1.37	0.00	1.37	2.30	*****	5.76
52.50	6.18	442.68	*	0.012	2.33	1.42	0.00	1.42	2.33	*****	6.18
55.00	6.62	443.12	*	0.012	2.36	1.46	0.00	1.46	2.36	*****	6.62

********** OVERFLOW ENCOUNTERED AT 57.50 CFS DISCHARGE **********

57.50	7.09	443.59	*	0.012	2.38	1.50	0.00	1.50	2.38	*****	7.09
60.00	7.57	444.07	*	0.012	2.40	1.54	0.00	1.54	2.40	*****	7.57
62.50	8.08	444.58	*	0.012	2.41	1.59	0.15	1.59	2.41	*****	8.08
65.00	8.61	445.11	*	0.012	2.43	1.63	0.39	1.63	2.43	*****	8.61
67.50	9.15	445.65	*	0.012	2.44	1.67	0.77	1.67	2.44	*****	9.15
70.00	9.72	446.22	*	0.012	2.45	1.72	1.05	1.72	2.45	*****	9.72
72.50	10.31	446.81	*	0.012	2.45	1.76	1.33	1.76	2.45	*****	10.31
75.00	10.92	447.42	*	0.012	2.46	1.81	1.62	1.81	2.46	*****	10.92
77.50	11.55	448.05	*	0.012	2.47	1.86	1.93	1.93	2.47	*****	11.55
80.00	12.20	448.70	*	0.012	2.47	1.91	2.24	2.24	2.47	*****	12.20
82.50	12.87	449.37	*	0.012	2.47	1.97	2.57	2.57	2.47	*****	12.87
85.00	13.56	450.06	*	0.012	2.48	2.03	2.90	2.90	2.86	9.86	13.56
87.50	14.27	450.77	*	0.012	2.48	2.09	3.24	3.24	3.29	10.70	14.27
90.00	15.01	451.51	*	0.012	2.48	2.18	3.60	3.60	3.74	11.58	15.01
92.50	15.76	452.26	*	0.012	2.49	2.33	3.96	3.96	4.19	12.47	15.76
95.00	16.54	453.04	*	0.012	2.49	2.50	4.33	4.33	4.66	13.40	16.54

97.50	17.33	453.83	*	0.012	2.49	2.50	4.72	4.72	5.14	14.34	17.33
100.00	18.15	454.65	*	0.012	2.49	2.50	5.11	5.11	5.64	15.31	18.15
102.50	18.98	455.48	*	0.012	2.49	2.50	5.51	5.51	6.14	16.31	18.98
105.00	19.84	456.34	*	0.012	2.49	2.50	5.93	5.93	6.66	17.33	19.84
107.50	20.72	457.22	*	0.012	2.49	2.50	6.35	6.35	7.19	18.38	20.72
110.00	21.61	458.11	*	0.012	2.50	2.50	6.78	6.78	7.74	19.45	21.61
112.50	22.53	459.03	*	0.012	2.50	2.50	7.23	7.23	8.29	20.54	22.53
115.00	23.47	459.97	*	0.012	2.50	2.50	7.93	7.93	9.11	21.91	23.47
117.50	24.43	460.93	*	0.012	2.50	2.50	8.76	8.76	10.06	23.42	24.43
120.00	25.41	461.91	*	0.012	2.50	2.50	9.61	9.61	11.03	24.96	25.41
122.50	26.54	463.04	*	0.012	2.50	2.50	10.48	10.48	12.02	26.54	26.41
125.00	28.15	464.65	*	0.012	2.50	2.50	11.36	11.36	13.03	28.15	27.44

Madsen Pond
Conveyance System

PIPES.DOC

BACKWATER COMPUTER PROGRAM FOR PIPES
Pipe data from file:conduit.bwp

Surcharge condition at intermediate junctions
Tailwater Elevation:425. feet
Discharge Range:106. to 119. Step of 0.25 [cfs]
Overflow Elevation:441.17 feet
Weir:NONE
Upstream Velocity:0. feet/sec

PIPE NO. 1: 42 LF - 36"CP @ 0.19% OUTLET: 422.00 INLET: 422.08 INTYP: 5
JUNC NO. 1: OVERFLOW-EL: 436.50 BEND: 55 DEG DIA/WIDTH: 6.0 Q-RATIO: 0.00

Q(CFS)	HW(FT)	HW ELEV.	*	N-FAC	DC	DN	TW	DO	DE	HWO	HWI
106.00	10.92	433.00	*	0.012	2.92	3.00	3.00	3.00	3.82	9.03	10.92
106.25	10.96	433.04	*	0.012	2.92	3.00	3.00	3.00	3.83	9.06	10.96
106.50	11.00	433.08	*	0.012	2.92	3.00	3.00	3.00	3.83	9.09	11.00
106.75	11.04	433.12	*	0.012	2.92	3.00	3.00	3.00	3.84	9.11	11.04
107.00	11.09	433.17	*	0.012	2.92	3.00	3.00	3.00	3.84	9.14	11.09
107.25	11.13	433.21	*	0.012	2.93	3.00	3.00	3.00	3.85	9.17	11.13
107.50	11.17	433.25	*	0.012	2.93	3.00	3.00	3.00	3.85	9.20	11.17
107.75	11.21	433.29	*	0.012	2.93	3.00	3.00	3.00	3.85	9.23	11.21
108.00	11.26	433.34	*	0.012	2.93	3.00	3.00	3.00	3.86	9.26	11.26
108.25	11.30	433.38	*	0.012	2.93	3.00	3.00	3.00	3.86	9.29	11.30
108.50	11.34	433.42	*	0.012	2.93	3.00	3.00	3.00	3.87	9.32	11.34
108.75	11.39	433.47	*	0.012	2.93	3.00	3.00	3.00	3.87	9.35	11.39
109.00	11.43	433.51	*	0.012	2.93	3.00	3.00	3.00	3.88	9.38	11.43
109.25	11.47	433.55	*	0.012	2.93	3.00	3.00	3.00	3.88	9.41	11.47
109.50	11.52	433.60	*	0.012	2.93	3.00	3.00	3.00	3.88	9.44	11.52
109.75	11.56	433.64	*	0.012	2.93	3.00	3.00	3.00	3.89	9.47	11.56
110.00	11.60	433.68	*	0.012	2.93	3.00	3.00	3.00	3.89	9.50	11.60
110.25	11.65	433.73	*	0.012	2.93	3.00	3.00	3.00	3.90	9.53	11.65
110.50	11.69	433.77	*	0.012	2.93	3.00	3.00	3.00	3.90	9.56	11.69
110.75	11.74	433.82	*	0.012	2.93	3.00	3.00	3.00	3.91	9.59	11.74
111.00	11.78	433.86	*	0.012	2.94	3.00	3.00	3.00	3.91	9.62	11.78
111.25	11.83	433.91	*	0.012	2.94	3.00	3.00	3.00	3.92	9.65	11.83
111.50	11.87	433.95	*	0.012	2.94	3.00	3.00	3.00	3.92	9.68	11.87
111.75	11.91	433.99	*	0.012	2.94	3.00	3.00	3.00	3.92	9.71	11.91
112.00	11.96	434.04	*	0.012	2.94	3.00	3.00	3.00	3.93	9.74	11.96
112.25	12.00	434.08	*	0.012	2.94	3.00	3.00	3.00	3.93	9.77	12.00
112.50	12.05	434.13	*	0.012	2.94	3.00	3.00	3.00	3.94	9.81	12.05
112.75	12.09	434.17	*	0.012	2.94	3.00	3.00	3.00	3.94	9.84	12.09
113.00	12.14	434.22	*	0.012	2.94	3.00	3.00	3.00	3.95	9.87	12.14
113.25	12.18	434.26	*	0.012	2.94	3.00	3.00	3.00	3.95	9.90	12.18
113.50	12.23	434.31	*	0.012	2.94	3.00	3.00	3.00	3.96	9.93	12.23
113.75	12.27	434.35	*	0.012	2.94	3.00	3.00	3.00	3.96	9.96	12.27
114.00	12.32	434.40	*	0.012	2.94	3.00	3.00	3.00	3.97	9.99	12.32
114.25	12.36	434.44	*	0.012	2.94	3.00	3.00	3.00	3.97	10.02	12.36
114.50	12.41	434.49	*	0.012	2.94	3.00	3.00	3.00	3.97	10.05	12.41
114.75	12.46	434.54	*	0.012	2.94	3.00	3.00	3.00	3.98	10.09	12.46
115.00	12.50	434.58	*	0.012	2.94	3.00	3.00	3.00	3.98	10.12	12.50
115.25	12.55	434.63	*	0.012	2.94	3.00	3.00	3.00	3.99	10.15	12.55
115.50	12.59	434.67	*	0.012	2.95	3.00	3.00	3.00	3.99	10.18	12.59
115.75	12.64	434.72	*	0.012	2.95	3.00	3.00	3.00	4.00	10.21	12.64

116.00	12.69	434.77	* 0.012	2.95	3.00	3.00	3.00	4.00	10.24	12.69
116.25	12.73	434.81	* 0.012	2.95	3.00	3.00	3.00	4.01	10.28	12.73
116.50	12.78	434.86	* 0.012	2.95	3.00	3.00	3.00	4.01	10.31	12.78
116.75	12.83	434.91	* 0.012	2.95	3.00	3.00	3.00	4.02	10.34	12.83
117.00	12.87	434.95	* 0.012	2.95	3.00	3.00	3.00	4.02	10.37	12.87
117.25	12.92	435.00	* 0.012	2.95	3.00	3.00	3.00	4.03	10.40	12.92
117.50	12.97	435.05	* 0.012	2.95	3.00	3.00	3.00	4.03	10.44	12.97
117.75	13.01	435.09	* 0.012	2.95	3.00	3.00	3.00	4.04	10.47	13.01
118.00	13.06	435.14	* 0.012	2.95	3.00	3.00	3.00	4.04	10.50	13.06
118.25	13.11	435.19	* 0.012	2.95	3.00	3.00	3.00	4.04	10.53	13.11
118.50	13.15	435.23	* 0.012	2.95	3.00	3.00	3.00	4.05	10.56	13.15
118.75	13.20	435.28	* 0.012	2.95	3.00	3.00	3.00	4.05	10.60	13.20
119.00	13.25	435.33	* 0.012	2.95	3.00	3.00	3.00	4.06	10.63	13.25

PIPE NO. 2: 86 LF - 36"CP @ 0.76% OUTLET: 429.50 INLET: 430.15 INTYP: 5
JUNC NO. 2: OVERFLOW-EL: 441.17 BEND: 75 DEG DIA/WIDTH: 6.0 Q-RATIO: 0.00

Q(CFS)	HW(FT)	HW ELEV.	* N-FAC	DC	DN	TW	DO	DE	HWO	HWI
106.00	10.95	441.10	* 0.012	2.92	3.00	3.50	3.50	4.70	9.94	10.95
106.25	10.99	441.14	* 0.012	2.92	3.00	3.54	3.54	4.75	10.01	10.99
********** OVERFLOW ENCOUNTERED AT 106.50 CFS DISCHARGE **********										
******** OVERFLOW CONDITIONS CALCULATED ASSUMING SURCHARGE CONDITIONS *********										
106.50	11.03	441.18	* 0.012	2.92	3.00	3.58	3.58	4.80	10.09	11.03
106.75	11.07	441.22	* 0.012	2.92	3.00	3.62	3.62	4.85	10.17	11.07
107.00	11.12	441.27	* 0.012	2.92	3.00	3.67	3.67	4.90	10.24	11.12
107.25	11.16	441.31	* 0.012	2.93	3.00	3.71	3.71	4.95	10.32	11.16
107.50	11.20	441.35	* 0.012	2.93	3.00	3.75	3.75	5.01	10.40	11.20
107.75	11.24	441.39	* 0.012	2.93	3.00	3.79	3.79	5.06	10.47	11.24
108.00	11.29	441.44	* 0.012	2.93	3.00	3.84	3.84	5.11	10.55	11.29
108.25	11.33	441.48	* 0.012	2.93	3.00	3.88	3.88	5.16	10.63	11.33
108.50	11.37	441.52	* 0.012	2.93	3.00	3.92	3.92	5.21	10.70	11.37
108.75	11.42	441.57	* 0.012	2.93	3.00	3.97	3.97	5.27	10.78	11.42
109.00	11.46	441.61	* 0.012	2.93	3.00	4.01	4.01	5.32	10.86	11.46
109.25	11.50	441.65	* 0.012	2.93	3.00	4.05	4.05	5.37	10.94	11.50
109.50	11.55	441.70	* 0.012	2.93	3.00	4.10	4.10	5.42	11.02	11.55
109.75	11.59	441.74	* 0.012	2.93	3.00	4.14	4.14	5.48	11.09	11.59
110.00	11.63	441.78	* 0.012	2.93	3.00	4.18	4.18	5.53	11.17	11.63
110.25	11.68	441.83	* 0.012	2.93	3.00	4.23	4.23	5.58	11.25	11.68
110.50	11.72	441.87	* 0.012	2.93	3.00	4.27	4.27	5.63	11.33	11.72
110.75	11.77	441.92	* 0.012	2.93	3.00	4.32	4.32	5.69	11.41	11.77
111.00	11.81	441.96	* 0.012	2.94	3.00	4.36	4.36	5.74	11.49	11.81
111.25	11.85	442.00	* 0.012	2.94	3.00	4.41	4.41	5.79	11.57	11.85
111.50	11.90	442.05	* 0.012	2.94	3.00	4.45	4.45	5.85	11.65	11.90
111.75	11.94	442.09	* 0.012	2.94	3.00	4.49	4.49	5.90	11.73	11.94
112.00	11.99	442.14	* 0.012	2.94	3.00	4.54	4.54	5.96	11.81	11.99
112.25	12.03	442.18	* 0.012	2.94	3.00	4.58	4.58	6.01	11.89	12.03
112.50	12.08	442.23	* 0.012	2.94	3.00	4.63	4.63	6.06	11.97	12.08
112.75	12.12	442.27	* 0.012	2.94	3.00	4.67	4.67	6.12	12.05	12.12
113.00	12.17	442.32	* 0.012	2.94	3.00	4.72	4.72	6.17	12.13	12.17
113.25	12.21	442.36	* 0.012	2.94	3.00	4.76	4.76	6.23	12.21	12.21
113.50	12.29	442.44	* 0.012	2.94	3.00	4.81	4.81	6.28	12.29	12.26
113.75	12.37	442.52	* 0.012	2.94	3.00	4.85	4.85	6.34	12.37	12.30
114.00	12.45	442.60	* 0.012	2.94	3.00	4.90	4.90	6.39	12.45	12.35
114.25	12.54	442.69	* 0.012	2.94	3.00	4.94	4.94	6.45	12.54	12.39
114.50	12.62	442.77	* 0.012	2.94	3.00	4.99	4.99	6.50	12.62	12.44

114.75	12.70	442.85	*	0.012	2.94	3.00	5.04	5.04	6.56	12.70	12.49
115.00	12.78	442.93	*	0.012	2.94	3.00	5.08	5.08	6.61	12.78	12.53
115.25	12.86	443.01	*	0.012	2.94	3.00	5.13	5.13	6.67	12.86	12.58
115.50	12.95	443.10	*	0.012	2.95	3.00	5.17	5.17	6.72	12.95	12.62
115.75	13.03	443.18	*	0.012	2.95	3.00	5.22	5.22	6.78	13.03	12.67
116.00	13.11	443.26	*	0.012	2.95	3.00	5.27	5.27	6.83	13.11	12.72
116.25	13.19	443.34	*	0.012	2.95	3.00	5.31	5.31	6.89	13.19	12.76
116.50	13.28	443.43	*	0.012	2.95	3.00	5.36	5.36	6.94	13.28	12.81
116.75	13.36	443.51	*	0.012	2.95	3.00	5.41	5.41	7.00	13.36	12.85
117.00	13.44	443.59	*	0.012	2.95	3.00	5.45	5.45	7.06	13.44	12.90
117.25	13.53	443.68	*	0.012	2.95	3.00	5.50	5.50	7.11	13.53	12.95
117.50	13.61	443.76	*	0.012	2.95	3.00	5.55	5.55	7.17	13.61	12.99
117.75	13.70	443.85	*	0.012	2.95	3.00	5.59	5.59	7.23	13.70	13.04
118.00	13.78	443.93	*	0.012	2.95	3.00	5.64	5.64	7.28	13.78	13.09
118.25	13.86	444.01	*	0.012	2.95	3.00	5.69	5.69	7.34	13.86	13.14
118.50	13.95	444.10	*	0.012	2.95	3.00	5.73	5.73	7.40	13.95	13.18
118.75	14.03	444.18	*	0.012	2.95	3.00	5.78	5.78	7.45	14.03	13.23
119.00	14.12	444.27	*	0.012	2.95	3.00	5.83	5.83	7.51	14.12	13.28

PIPE NO. 3: 40 LF - 30"CP @ 3.75% OUTLET: 435.00 INLET: 436.50 INTYP: 5

Q(CFS)	HW(FT)	HW ELEV.	*	N-FAC	DC	DN	TW	DO	DE	HWO	HWI
**********											
********** OVERFLOW ENCOUNTERED AT 106.00 CFS DISCHARGE **********											
********** ACTUAL OVERFLOW MAY OCCUR AT LESS THAN 106.00 CFS **********											
106.00	20.19	456.69	*	0.012	2.49	2.50	6.10	6.10	6.87	17.75	20.19
106.25	20.27	456.77	*	0.012	2.49	2.50	6.14	6.14	6.93	17.85	20.27
106.50	20.36	456.86	*	0.012	2.49	2.50	6.18	6.18	6.98	17.96	20.36
106.75	20.45	456.95	*	0.012	2.49	2.50	6.22	6.22	7.03	18.06	20.45
107.00	20.54	457.04	*	0.012	2.49	2.50	6.27	6.27	7.08	18.17	20.54
107.25	20.63	457.13	*	0.012	2.49	2.50	6.31	6.31	7.14	18.27	20.63
107.50	20.72	457.22	*	0.012	2.49	2.50	6.35	6.35	7.19	18.38	20.72
107.75	20.80	457.30	*	0.012	2.49	2.50	6.39	6.39	7.25	18.48	20.80
108.00	20.89	457.39	*	0.012	2.49	2.50	6.44	6.44	7.30	18.59	20.89
108.25	20.98	457.48	*	0.012	2.49	2.50	6.48	6.48	7.35	18.70	20.98
108.50	21.07	457.57	*	0.012	2.49	2.50	6.52	6.52	7.41	18.80	21.07
108.75	21.16	457.66	*	0.012	2.49	2.50	6.57	6.57	7.46	18.91	21.16
109.00	21.25	457.75	*	0.012	2.49	2.50	6.61	6.61	7.52	19.02	21.25
109.25	21.34	457.84	*	0.012	2.49	2.50	6.65	6.65	7.57	19.12	21.34
109.50	21.43	457.93	*	0.012	2.49	2.50	6.70	6.70	7.63	19.23	21.43
109.75	21.52	458.02	*	0.012	2.50	2.50	6.74	6.74	7.68	19.34	21.52
110.00	21.61	458.11	*	0.012	2.50	2.50	6.78	6.78	7.74	19.45	21.61
110.25	21.71	458.21	*	0.012	2.50	2.50	6.83	6.83	7.79	19.56	21.71
110.50	21.80	458.30	*	0.012	2.50	2.50	6.87	6.87	7.85	19.66	21.80
110.75	21.89	458.39	*	0.012	2.50	2.50	6.92	6.92	7.90	19.77	21.89
111.00	21.98	458.48	*	0.012	2.50	2.50	6.96	6.96	7.96	19.88	21.98
111.25	22.07	458.57	*	0.012	2.50	2.50	7.00	7.00	8.01	19.99	22.07
111.50	22.16	458.66	*	0.012	2.50	2.50	7.05	7.05	8.07	20.10	22.16
111.75	22.26	458.76	*	0.012	2.50	2.50	7.09	7.09	8.12	20.21	22.26
112.00	22.35	458.85	*	0.012	2.50	2.50	7.14	7.14	8.18	20.32	22.35
112.25	22.44	458.94	*	0.012	2.50	2.50	7.18	7.18	8.24	20.43	22.44
112.50	22.53	459.03	*	0.012	2.50	2.50	7.23	7.23	8.29	20.54	22.53
112.75	22.63	459.13	*	0.012	2.50	2.50	7.27	7.27	8.35	20.65	22.63
113.00	22.72	459.22	*	0.012	2.50	2.50	7.32	7.32	8.40	20.76	22.72
113.25	22.81	459.31	*	0.012	2.50	2.50	7.36	7.36	8.46	20.87	22.81
113.50	22.91	459.41	*	0.012	2.50	2.50	7.44	7.44	8.55	21.02	22.91

113.75	23.00	459.50	*	0.012	2.50	2.50	7.52	7.52	8.64	21.17	23.00
114.00	23.09	459.59	*	0.012	2.50	2.50	7.60	7.60	8.74	21.31	23.09
114.25	23.19	459.69	*	0.012	2.50	2.50	7.69	7.69	8.83	21.46	23.19
114.50	23.28	459.78	*	0.012	2.50	2.50	7.77	7.77	8.92	21.61	23.28
114.75	23.38	459.88	*	0.012	2.50	2.50	7.85	7.85	9.02	21.76	23.38
115.00	23.47	459.97	*	0.012	2.50	2.50	7.93	7.93	9.11	21.91	23.47
115.25	23.57	460.07	*	0.012	2.50	2.50	8.01	8.01	9.20	22.06	23.57
115.50	23.66	460.16	*	0.012	2.50	2.50	8.10	8.10	9.30	22.21	23.66
115.75	23.76	460.26	*	0.012	2.50	2.50	8.18	8.18	9.39	22.36	23.76
116.00	23.85	460.35	*	0.012	2.50	2.50	8.26	8.26	9.49	22.51	23.85
116.25	23.95	460.45	*	0.012	2.50	2.50	8.34	8.34	9.58	22.66	23.95
116.50	24.05	460.55	*	0.012	2.50	2.50	8.43	8.43	9.68	22.81	24.05
116.75	24.14	460.64	*	0.012	2.50	2.50	8.51	8.51	9.77	22.96	24.14
117.00	24.24	460.74	*	0.012	2.50	2.50	8.59	8.59	9.87	23.12	24.24
117.25	24.34	460.84	*	0.012	2.50	2.50	8.68	8.68	9.96	23.27	24.34
117.50	24.43	460.93	*	0.012	2.50	2.50	8.76	8.76	10.06	23.42	24.43
117.75	24.53	461.03	*	0.012	2.50	2.50	8.85	8.85	10.15	23.57	24.53
118.00	24.63	461.13	*	0.012	2.50	2.50	8.93	8.93	10.25	23.73	24.63
118.25	24.72	461.22	*	0.012	2.50	2.50	9.01	9.01	10.35	23.88	24.72
118.50	24.82	461.32	*	0.012	2.50	2.50	9.10	9.10	10.44	24.03	24.82
118.75	24.92	461.42	*	0.012	2.50	2.50	9.18	9.18	10.54	24.19	24.92
119.00	25.02	461.52	*	0.012	2.50	2.50	9.27	9.27	10.64	24.34	25.02

BACKWATER COMPUTER PROGRAM FOR PIPES
Pipe data from file:PipeS.bwp

Using a broad-crested weir at intermediate junctions
Individual CB's subject to surcharged condition
should be simulated by raising the overflow elevation
to an appropriate height above the rim elevation.
Tailwater Elevation:425. feet crown of outlet
Discharge Range:2.5 to 125. Step of 2.5 [cfs]
Overflow Elevation:441.17 feet
Sharp Crested Weir: Length:18.8 feet, Height:2.13 feet
Upstream Velocity:0. feet/sec

PIPE NO. 1: 42 LF - 36"CP @ 0.19% OUTLET: 422.00 INLET: 422.08 INTYP: 5
JUNC NO. 1: OVERFLOW-EL: 436.50 BEND: 55 DEG DIA/WIDTH: 6.0 Q-RATIO: 0.00

Q(CFS)	HW(FT)	HW ELEV.	* N-FAC	DC	DN	TW	DO	DE	HWO	HWI
2.50	2.93	425.01	* 0.012	0.50	0.58	3.00	3.00	2.93	2.93	0.66
5.00	2.94	425.02	* 0.012	0.71	0.81	3.00	3.00	2.93	2.94	0.95
7.50	2.95	425.03	* 0.012	0.87	1.00	3.00	3.00	2.93	2.95	1.17
10.00	2.96	425.04	* 0.012	1.01	1.17	3.00	3.00	2.93	2.96	1.37
12.50	2.99	425.07	* 0.012	1.13	1.32	3.00	3.00	2.94	2.99	1.55
15.00	3.01	425.09	* 0.012	1.24	1.46	3.00	3.00	2.94	3.01	1.71
17.50	3.05	425.13	* 0.012	1.34	1.60	3.00	3.00	2.95	3.05	1.86
20.00	3.08	425.16	* 0.012	1.44	1.74	3.00	3.00	2.95	3.08	2.01
22.50	3.13	425.21	* 0.012	1.53	1.88	3.00	3.00	2.96	3.13	2.15
25.00	3.17	425.25	* 0.012	1.62	2.02	3.00	3.00	2.97	3.17	2.29
27.50	3.23	425.31	* 0.012	1.70	2.17	3.00	3.00	2.98	3.23	2.43
30.00	3.29	425.37	* 0.012	1.78	2.34	3.00	3.00	3.00	3.29	2.56
32.50	3.35	425.43	* 0.012	1.86	2.56	3.00	3.00	3.00	3.35	2.69
35.00	3.42	425.50	* 0.012	1.93	3.00	3.00	3.00	3.02	3.42	2.82
37.50	3.49	425.57	* 0.012	2.00	3.00	3.00	3.00	3.03	3.49	2.95
40.00	3.57	425.65	* 0.012	2.06	3.00	3.00	3.00	3.05	3.57	3.07
42.50	3.65	425.73	* 0.012	2.13	3.00	3.00	3.00	3.07	3.65	3.20
45.00	3.74	425.82	* 0.012	2.19	3.00	3.00	3.00	3.08	3.74	3.33
47.50	3.84	425.92	* 0.012	2.25	3.00	3.00	3.00	3.10	3.84	3.47
50.00	3.93	426.01	* 0.012	2.31	3.00	3.00	3.00	3.12	3.93	3.64
52.50	4.04	426.12	* 0.012	2.36	3.00	3.00	3.00	3.14	4.04	3.81
55.00	4.15	426.23	* 0.012	2.41	3.00	3.00	3.00	3.16	4.15	3.99
57.50	4.26	426.34	* 0.012	2.46	3.00	3.00	3.00	3.19	4.26	4.17
60.00	4.38	426.46	* 0.012	2.51	3.00	3.00	3.00	3.21	4.38	4.37
62.50	4.57	426.65	* 0.012	2.55	3.00	3.00	3.00	3.23	4.50	4.57
65.00	4.77	426.85	* 0.012	2.59	3.00	3.00	3.00	3.26	4.63	4.77
67.50	4.99	427.07	* 0.012	2.63	3.00	3.00	3.00	3.29	4.77	4.99
70.00	5.87	427.95	* 0.012	2.66	3.00	3.00	3.00	3.31	5.56	5.87
72.50	6.15	428.23	* 0.012	2.70	3.00	3.00	3.00	3.34	5.75	6.15
75.00	6.45	428.53	* 0.012	2.72	3.00	3.00	3.00	3.37	5.96	6.45
77.50	6.75	428.83	* 0.012	2.75	3.00	3.00	3.00	3.40	6.16	6.75
80.00	7.06	429.14	* 0.012	2.78	3.00	3.00	3.00	3.43	6.38	7.06
82.50	7.39	429.47	* 0.012	2.80	3.00	3.00	3.00	3.47	6.60	7.39
85.00	7.72	429.80	* 0.012	2.82	3.00	3.00	3.00	3.50	6.83	7.72
87.50	8.06	430.14	* 0.012	2.84	3.00	3.00	3.00	3.54	7.07	8.06
90.00	8.42	430.50	* 0.012	2.85	3.00	3.00	3.00	3.57	7.31	8.42
92.50	8.78	430.86	* 0.012	2.87	3.00	3.00	3.00	3.61	7.56	8.78

95.00	9.15	431.23	*	0.012	2.88	3.00	3.00	3.00	3.65	7.82	9.15
97.50	9.54	431.62	*	0.012	2.89	3.00	3.00	3.00	3.68	8.08	9.54
100.00	9.93	432.01	*	0.012	2.90	3.00	3.00	3.00	3.72	8.35	9.93
102.50	10.33	432.41	*	0.012	2.91	3.00	3.00	3.00	3.77	8.63	10.33
105.00	10.75	432.83	*	0.012	2.92	3.00	3.00	3.00	3.81	8.91	10.75
107.50	11.17	433.25	*	0.012	2.93	3.00	3.00	3.00	3.85	9.20	11.17
110.00	11.60	433.68	*	0.012	2.93	3.00	3.00	3.00	3.89	9.50	11.60
112.50	12.05	434.13	*	0.012	2.94	3.00	3.00	3.00	3.94	9.81	12.05
115.00	12.50	434.58	*	0.012	2.94	3.00	3.00	3.00	3.98	10.12	12.50
117.50	12.97	435.05	*	0.012	2.95	3.00	3.00	3.00	4.03	10.44	12.97
120.00	13.44	435.52	*	0.012	2.95	3.00	3.00	3.00	4.08	10.76	13.44
122.50	13.92	436.00	*	0.012	2.96	3.00	3.00	3.00	4.13	11.09	13.92
125.00	14.42	436.50	*	0.012	2.96	3.00	3.00	3.00	4.18	11.43	14.42

PIPE NO. 2: 86 LF - 36"CP @ 0.76% OUTLET: 429.50 INLET: 430.15 INTYP: 5
JUNC NO. 2: OVERFLOW-EL: 441.17 BEND: 75 DEG DIA/WIDTH: 6.0 Q-RATIO: 0.00

Q(CFS)	HW(FT)	HW ELEV.	*	N-FAC	DC	DN	TW	DO	DE	HWO	HWI
2.50	0.65	430.80	*	0.012	0.50	0.41	0.00	0.41	0.50	*****	0.65
5.00	0.94	431.09	*	0.012	0.71	0.58	0.00	0.58	0.71	*****	0.94
7.50	1.17	431.32	*	0.012	0.87	0.70	0.00	0.70	0.87	*****	1.17
10.00	1.37	431.52	*	0.012	1.01	0.81	0.00	0.81	1.01	*****	1.37
12.50	1.55	431.70	*	0.012	1.13	0.91	0.00	0.91	1.13	*****	1.55
15.00	1.73	431.88	*	0.012	1.24	1.00	0.00	1.00	1.24	*****	1.73
17.50	1.89	432.04	*	0.012	1.34	1.09	0.00	1.09	1.34	*****	1.89
20.00	2.05	432.20	*	0.012	1.44	1.17	0.00	1.17	1.44	*****	2.05
22.50	2.20	432.35	*	0.012	1.53	1.25	0.00	1.25	1.53	*****	2.20
25.00	2.35	432.50	*	0.012	1.62	1.32	0.00	1.32	1.62	*****	2.35
27.50	2.50	432.65	*	0.012	1.70	1.39	0.00	1.39	1.70	*****	2.50
30.00	2.65	432.80	*	0.012	1.78	1.47	0.00	1.47	1.78	*****	2.65
32.50	2.80	432.95	*	0.012	1.86	1.54	0.00	1.54	1.86	*****	2.80
35.00	2.95	433.10	*	0.012	1.93	1.61	0.00	1.61	1.93	*****	2.95
37.50	3.10	433.25	*	0.012	2.00	1.67	0.00	1.67	2.00	*****	3.10
40.00	3.25	433.40	*	0.012	2.06	1.74	0.00	1.74	2.06	*****	3.25
42.50	3.40	433.55	*	0.012	2.13	1.81	0.00	1.81	2.13	*****	3.40
45.00	3.55	433.70	*	0.012	2.19	1.88	0.00	1.88	2.19	*****	3.55
47.50	3.72	433.87	*	0.012	2.25	1.95	0.00	1.95	2.25	*****	3.72
50.00	3.92	434.07	*	0.012	2.31	2.03	0.00	2.03	2.31	*****	3.92
52.50	4.11	434.26	*	0.012	2.36	2.10	0.00	2.10	2.36	*****	4.11
55.00	4.32	434.47	*	0.012	2.41	2.18	0.00	2.18	2.41	*****	4.32
57.50	4.54	434.69	*	0.012	2.46	2.26	0.00	2.26	2.46	*****	4.54
60.00	4.76	434.91	*	0.012	2.51	2.35	0.00	2.35	2.51	*****	4.76
62.50	5.00	435.15	*	0.012	2.55	2.45	0.00	2.45	2.55	*****	5.00
65.00	5.24	435.39	*	0.012	2.59	2.57	0.00	2.57	2.59	*****	5.24
67.50	5.62	435.77	*	0.012	2.63	2.78	0.00	2.63	2.74	5.05	5.62
70.00	5.90	436.05	*	0.012	2.66	3.00	0.00	2.66	2.90	5.23	5.90
72.50	6.18	436.33	*	0.012	2.70	3.00	0.00	2.70	3.05	5.50	6.18
75.00	6.47	436.62	*	0.012	2.72	3.00	0.00	2.72	3.12	5.74	6.47
77.50	6.78	436.93	*	0.012	2.75	3.00	0.00	2.75	3.19	5.99	6.78
80.00	7.09	437.24	*	0.012	2.78	3.00	0.00	2.78	3.26	6.24	7.09
82.50	7.42	437.57	*	0.012	2.80	3.00	0.00	2.80	3.33	6.50	7.42
85.00	7.75	437.90	*	0.012	2.82	3.00	0.30	2.82	3.40	6.77	7.75
87.50	8.09	438.24	*	0.012	2.84	3.00	0.64	2.84	3.47	7.04	8.09
90.00	8.45	438.60	*	0.012	2.85	3.00	1.00	2.85	3.55	7.33	8.45
92.50	8.81	438.96	*	0.012	2.87	3.00	1.36	2.87	3.62	7.61	8.81

95.00	9.18	439.33	* 0.012	2.88	3.00	1.73	2.88	3.70	7.91	9.18
97.50	9.57	439.72	* 0.012	2.89	3.00	2.12	2.89	3.78	8.21	9.57
100.00	9.96	440.11	* 0.012	2.90	3.00	2.51	2.90	3.87	8.53	9.96
102.50	10.36	440.51	* 0.012	2.91	3.00	2.91	2.91	3.95	8.85	10.36
105.00	10.78	440.93	* 0.012	2.92	3.00	3.33	3.33	4.49	9.64	10.78

********** OVERFLOW ENCOUNTERED AT 107.50 CFS DISCHARGE **********

********** OVERFLOW HEADWATERS ASSUME 6.4 FT. BROAD_WEIR **********

107.50	11.02	441.35	* 0.012	2.93	3.00	3.75	3.75	5.01	10.40	11.20

********** PIPE FLOW PLUS WEIR FLOW **********

107.50	11.02	441.17	*
110.00	11.28	441.43	*
112.50	11.43	441.58	*
115.00	11.56	441.71	*
117.50	11.67	441.82	*
120.00	11.78	441.93	*
122.50	11.88	442.03	*
125.00	11.97	442.12	*

PIPE NO. 3: 40 LF - 30"CP @ 3.75% OUTLET: 435.00 INLET: 436.50 INTYP: 5

Q(CFS)	HW(FT)	HW ELEV.	* N-FAC	DC	DN	TW	DO	DE	HWO	HWI
2.50	0.65	437.15	* 0.012	0.52	0.30	0.00	0.30	0.52	*****	0.65
5.00	0.97	437.47	* 0.012	0.74	0.41	0.00	0.41	0.74	*****	0.97
7.50	1.22	437.72	* 0.012	0.91	0.50	0.00	0.50	0.91	*****	1.22
10.00	1.45	437.95	* 0.012	1.06	0.58	0.00	0.58	1.06	*****	1.45
12.50	1.66	438.16	* 0.012	1.19	0.65	0.00	0.65	1.19	*****	1.66
15.00	1.87	438.37	* 0.012	1.31	0.71	0.00	0.71	1.31	*****	1.87
17.50	2.07	438.57	* 0.012	1.42	0.77	0.00	0.77	1.42	*****	2.07
20.00	2.27	438.77	* 0.012	1.52	0.82	0.00	0.82	1.52	*****	2.27
22.50	2.47	438.97	* 0.012	1.62	0.88	0.00	0.88	1.62	*****	2.47
25.00	2.68	439.18	* 0.012	1.71	0.93	0.00	0.93	1.71	*****	2.68
27.50	2.88	439.38	* 0.012	1.79	0.98	0.00	0.98	1.79	*****	2.88
30.00	3.10	439.60	* 0.012	1.87	1.02	0.00	1.02	1.87	*****	3.10
32.50	3.37	439.87	* 0.012	1.95	1.07	0.00	1.07	1.95	*****	3.37
35.00	3.65	440.15	* 0.012	2.01	1.12	0.00	1.12	2.01	*****	3.65
37.50	3.95	440.45	* 0.012	2.08	1.16	0.00	1.16	2.08	*****	3.95
40.00	4.27	440.77	* 0.012	2.13	1.20	0.00	1.20	2.13	*****	4.27
42.50	4.61	441.11	* 0.012	2.19	1.25	0.00	1.25	2.19	*****	4.61

********** OVERFLOW ENCOUNTERED AT 45.00 CFS DISCHARGE **********

45.00	4.97	441.47	* 0.012	2.23	1.29	0.00	1.29	2.23	*****	4.97
47.50	5.02	441.52	* 0.012	2.24	1.29	0.00	1.29	2.24	*****	5.02
50.00	5.12	441.62	* 0.012	2.25	1.31	0.00	1.31	2.25	*****	5.12
52.50	5.20	441.70	* 0.012	2.26	1.31	0.00	1.31	2.26	*****	5.20
55.00	5.27	441.77	* 0.012	2.26	1.32	0.00	1.32	2.26	*****	5.27
57.50	5.33	441.83	* 0.012	2.27	1.33	0.00	1.33	2.27	*****	5.33
60.00	5.38	441.88	* 0.012	2.27	1.33	0.00	1.33	2.27	*****	5.38
62.50	5.43	441.93	* 0.012	2.28	1.34	0.15	1.34	2.28	*****	5.43
65.00	5.47	441.97	* 0.012	2.28	1.34	0.39	1.34	2.28	*****	5.47
67.50	5.51	442.01	* 0.012	2.28	1.35	0.77	1.35	2.28	*****	5.51
70.00	5.55	442.05	* 0.012	2.29	1.35	1.05	1.35	2.29	*****	5.55
72.50	5.59	442.09	* 0.012	2.29	1.36	1.33	1.36	2.29	*****	5.59
75.00	5.62	442.12	* 0.012	2.29	1.36	1.62	1.62	2.29	*****	5.62
77.50	5.66	442.16	* 0.012	2.30	1.36	1.93	1.93	2.30	*****	5.66
80.00	5.69	442.19	* 0.012	2.30	1.37	2.24	2.24	2.30	*****	5.69
82.50	5.72	442.22	* 0.012	2.30	1.37	2.57	2.57	2.30	*****	5.72

85.00	5.75	442.25	*	0.012	2.30	1.37	2.90	2.90	2.30	*****	5.75
87.50	5.77	442.27	*	0.012	2.31	1.37	3.24	3.24	2.31	*****	5.77
90.00	5.80	442.30	*	0.012	2.31	1.38	3.60	3.60	2.61	5.05	5.80
92.50	5.83	442.33	*	0.012	2.31	1.38	3.96	3.96	2.97	5.43	5.83
95.00	5.85	442.35	*	0.012	2.31	1.38	4.33	4.33	3.35	5.83	5.85
97.50	5.90	442.40	*	0.012	2.31	1.38	4.72	4.72	3.68	5.90	5.42
100.00	5.96	442.46	*	0.012	2.31	1.38	5.11	5.11	4.02	5.96	4.94
102.50	6.01	442.51	*	0.012	2.31	1.38	5.51	5.51	4.36	6.01	4.45
105.00	6.06	442.56	*	0.012	2.31	1.38	5.93	5.93	4.71	6.06	3.94
107.50	6.10	442.60	*	0.012	2.31	1.38	6.17	6.17	4.92	6.10	3.65
110.00	6.16	442.66	*	0.012	2.31	1.38	6.43	6.43	5.14	6.16	3.36
112.50	6.21	442.71	*	0.012	2.31	1.38	6.58	6.58	5.28	6.21	3.27
115.00	6.25	442.75	*	0.012	2.31	1.38	6.71	6.71	5.39	6.25	3.17
117.50	6.29	442.79	*	0.012	2.31	1.38	6.82	6.82	5.49	6.29	3.08
120.00	6.34	442.84	*	0.012	2.31	1.38	6.93	6.93	5.59	6.34	3.01
122.50	6.38	442.88	*	0.012	2.31	1.38	7.03	7.03	5.67	6.38	3.06
125.00	6.42	442.92	*	0.012	2.31	1.38	7.12	7.12	5.76	6.42	3.01

Appendix G

Calculations:
Freeboard, Emergency Spillway,
Outfall Pad Sizing, and Discharge Velocity

Appendix G

Calculations:
Freeboard, Emergency Spillway,
Outfall Pad Sizing, and Discharge Velocity

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___]

Calculation of reservoir freeboard
Reference: Guidelines, Part IV, Section 4.6

[RJB], [3/22/02]

Project-specific data:

Project location: Western Washington
Design wind speed U, mph (Table 1, p. 4-39)
for normal pool: 60
for peak stage: 30

Fetch (feet) = 210
Fetch (miles) = 0.04
Avg. depth (ft) = 9

Wave height, feet (Table 2, p. 4-41)
for normal pool: 0.65
for peak stage: 0.35

Wave run-up coefficient (Table 3, p. 4-42)
dam face: grass / riprap
upstream slope: 5 H:1V
coefficient: 1

Dam height (range) : ≤ 15 ft.
Size classification: small
W.L. at normal pool (feet) = 441.17
W.L. at peak stage, due to inflow design flood (feet) = 441.84
Dam crest elevation per plans & specs (feet) = 443.5

Key equations:
Wind/wave freeboard $F_w = S_w + R_w$
Wind set-up $S_w = (U^2) * F / 1400 * D$
Wave run-up $R_w = C_r * H_s$

Reference :

Note: pond will be vegetative where possible
Note: this is the average slope/interpolated value

Note: this is the 100-year water elevation

Normal freeboard (WL at normal pool):

Wind set-up S_w (feet) = 0.01
Wave run-up R_w (feet) = 0.65
Wind/wave freeboard F_w (ft.) = 0.66

Allowances for:
Embankment settlement (ft.): 0.0 Note: construction will overbuild the embankment
Design/operation uncertainties: 0.0 Note: reason why WL set at 441.17
Geologic hazards (ft.): 0.0 Note: inside average slope set 5:1

Total freeboard (feet) = 0.66

Compare to min. design freeboard
2.0 ft. from Table 4, p. 4-43
for normal pool conditions

Madsen Creek Pond (King County DNR&P); Dam Safety file no. ___]

Calculation of reservoir freeboard
Reference: Guidelines, Part IV, Section 4.6

[RJB], [3/22/02]

Minimum freeboard (WL at peak stage):

Wind set-up S_w (feet) =	0.00	
Wave run-up R_w (feet) =	0.35	
Wind/wave freeboard F_w (ft.) =	0.35	

Allowances for:

Embankment settlement (ft.):	0.0	Note: construction will overbuild the embankment
Design/operation uncertainties:	0.0	Note: reason why WL set at 441.17
Geologic hazards (ft.):	0.0	Note: inside slope set 6:1
Total freeboard (feet) =	0.35	Compare to min. design freeboard 0.5 ft. from Table 4, p. 4-43 for peak stage conditions

Freeboard summary:

Normal pool :	Required	Actual	Excess
Calculated (feet) :	0.7	2.3	1.7
Min. design (ft.) :	2.0	2.3	0.3
Peak stage (IDF):			
Calculated (feet) :	0.4	1.7	1.3
Min. design (ft.) :	0.5	1.7	1.2

Required dam crest elevation:

Based on normal pool and freeboard:	443.2 ft.
Based on peak stage and min. freeboard:	442.3 ft.

Compare:

Dam crest elevation per plans & specs:	443.5 ft.

[End]

TABLE 1 - SUGGESTED DESIGN WIND SPEEDS FOR AREAS OF LIMITED DATA

GENERALIZED DESIGN WIND SPEEDS			
FREEBOARD CONDITION	WASHINGTON LOCATION		
	COASTAL AREAS	WESTERN WASHINGTON	EASTERN WASHINGTON
NORMAL FREEBOARD	70 MPH	60 MPH	50 MPH
MINIMUM FREEBOARD	50 MPH	30 MPH	30 MPH

TABLE 2. ESTIMATION OF WIND GENERATED WAVES

SIGNIFICANT WAVE HEIGHT (FEET)							
SUSTAINED WIND SPEED	EFFECTIVE FETCH (MILES)						
	.05	.10	.25	.50	1	2	5
20 MPH	0.20	0.30	0.45	0.60	0.85	1.20	1.75
30 MPH	0.35	0.45	0.65	0.90	1.30	1.75	2.70
40 MPH	0.45	0.60	0.90	1.25	1.75	2.45	3.70
50 MPH	0.55	0.75	1.15	1.60	2.20	3.00	4.70
60 MPH	0.65	0.90	1.40	1.90	2.70	3.60	5.70
70 MPH	0.75	1.15	1.60	2.25	3.20	4.30	6.70
80 MPH	0.90	1.20	1.85	2.60	3.70	5.00	7.80
90 MPH	1.00	1.35	2.10	3.00	4.20	4.70	8.90
100 MPH	1.15	1.50	2.40	3.40	4.70	6.40	10.00

TABLE 3. VALUES OF THE COEFFICIENT OF WAVE RUNUP

COEFFICIENT OF WAVE RUNUP (C_r)							
DAM FACE	SLOPE OF UPSTREAM FACE OF DAM (H:V)						
	Vertical	1.5:1	2:1	3:1	4:1	6:1	10:1
Concrete Facing	1.7	2.5	2.2	1.8	1.3	0.8	0.5
Grass Lined	—	2.3	2.0	1.6	1.2	0.8	0.5
Riprap	—	1.4	1.3	1.2	1.0	0.7	0.4

TABLE 4. DESIGN MINIMUMS IN SELECTING RESERVOIR FREEBOARD

RESERVOIR FREEBOARD (FEET)	SMALL DAM	INTERMEDIATE DAM	LARGE DAM
NORMAL FREEBOARD	2.00	3.50	5.00
MINIMUM FREEBOARD	0.50	0.75	1.00

from DSGuidelines

Emergency Overflow Spillway Capacity

The emergency overflow spillway weir section shall be designed to pass the 100-year runoff event for developed conditions assuming a broad-crested weir. The **broad-crested weir equation** for the spillway section in Figure 5.3.1.E, for example, would be:

$$Q_{100} = C\,(2g)^{1/2}\,[{}^{2}/_{3}\,LH^{3/2} + {}^{8}/_{15}\,(\text{Tan}\,\theta)\,H^{5/2}] \qquad (5\text{-}1)$$

where
- Q_{100} = peak flow for the 100-year runoff event (fps)
- C = discharge coefficient (0.6)
- g = gravity (32.2 ft/sec^2)
- L = length of weir (ft)
- H = height of water over weir (ft)
- θ = angle of side slopes

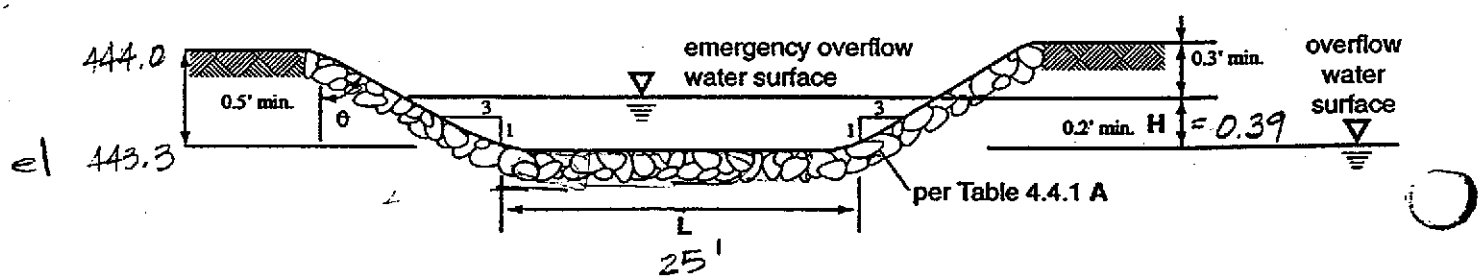
Assuming $C = 0.6$ and Tan $\theta = 3$ (for 3:1 slopes), the equation becomes:

$$Q_{100} = 3.21\,(LH^{3/2} + 2.4\,H^{5/2}) \qquad (5\text{-}2)$$

To find width L for the weir section, the equation is rearranged to use the computed Q_{100} and trial values of H (0.2 feet minimum):

$$L = [Q_{100} / (3.21\,H^{3/2})] - 2.4\,H \quad \text{or} \quad 6 \text{ feet minimum} \qquad (5\text{-}3)$$

FIGURE 5.3.1.E WEIR SECTION FOR EMERGENCY OVERFLOW SPILLWAY



Emergency Spillway Capacity

Q (cfs)	H (ft)	3.21H^1.5	2.4*H	L (ft)	
19.97	0.2	0.287	0.48	69.07	Min H
19.97	0.25	0.401	0.60	49.17	
19.97	0.26	0.426	0.62	46.30	
19.97	0.27	0.450	0.65	43.70	
19.97	0.28	0.476	0.67	41.32	
19.97	0.285	0.488	0.68	40.20	
19.97	0.286	0.491	0.69	39.99	
19.97	0.29	0.501	0.70	39.14	
19.97	0.3	0.527	0.72	37.14	
19.97	0.33	0.609	0.79	32.03	Min cut from FB
19.97	0.35	0.665	0.84	29.20	
19.97	0.36	0.693	0.86	27.94	
19.97	0.386	0.770	0.93	25.01	Optimum L
19.97	0.4	0.812	0.96	23.63	
19.97	0.44	0.937	1.06	20.26	
19.97	0.443	0.946	1.06	20.04	K's desired L
19.97	0.45	0.969	1.08	19.53	
19.97	0.5	1.135	1.20	16.40	
19.97	0.6	1.492	1.44	11.95	
19.97	0.7	1.880	1.68	8.94	
19.97	0.8	2.297	1.92	6.77	
19.97	0.844	2.489	2.03	6.00	Min L

Selecting L = 25', H = 0.39'

height of weir = 0.39' + 0.3' = 0.69'

Rd top = 444'

∴ weir elevation = 444 - 0.69 = 443.3

Normal 100 yr el = 441.17

2' freeboard req for weir el 443.17' < 443.3 so ok

King County Wastewater Treatment Division Engineering & Environmental Services	Riprap design - Velocity calc	Project
	Comp Berryessa Chk Rev Date 8/1/02 Date Date	Page of Pages

$Q_{100} = 5.45$ cfs

$= 20.0$ cfs unidformed

for 36" steel pipe $n = 0.12$ $S = 0.2\%$

$Q_{full} = 32$ cfs then $V_{full} = 4.53$ fps

$\frac{Q_{100}}{Q} = \frac{5.45}{32} = 0.17$

$\frac{d}{D} = \frac{d}{36''} = 0.28$

$d = 10.1''$

$\frac{V_{100}}{V} = \frac{V_{100}}{4.53} = 0.75$

$V_{100} = 3.4$ fps

$\frac{Q_{100}}{Q} = \frac{20}{32} = 0.625$

$\frac{d}{D} = \frac{d}{36} = 0.58$

$d = 20.9''$

$\frac{V_{100\,uniformed}}{V} = \frac{V_{100\,u}}{4.53} = 1.06$

$V_{100} = 4.8$ fps

FIGURE 4.2.1.G CIRCULAR CHANNEL RATIOS

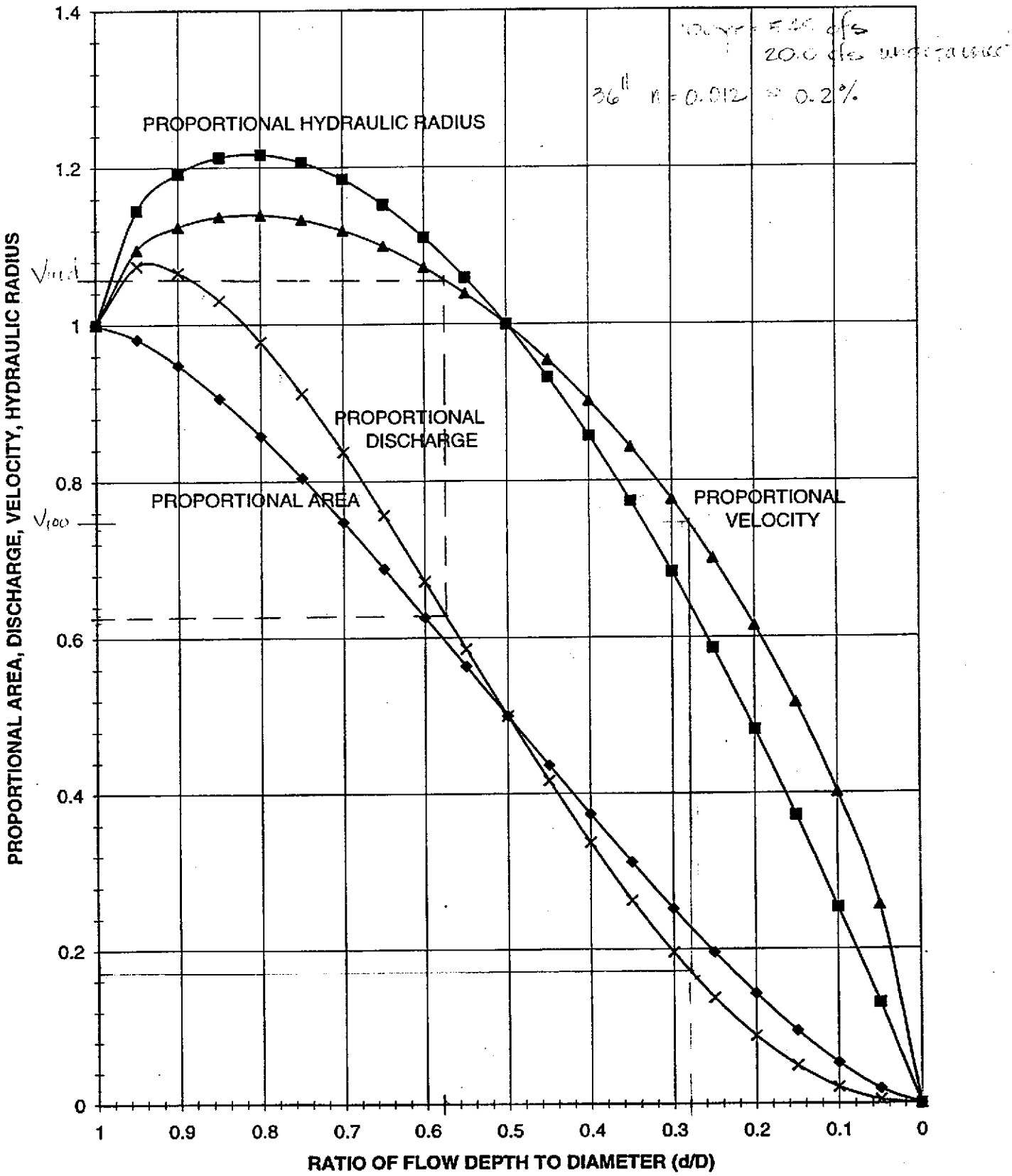
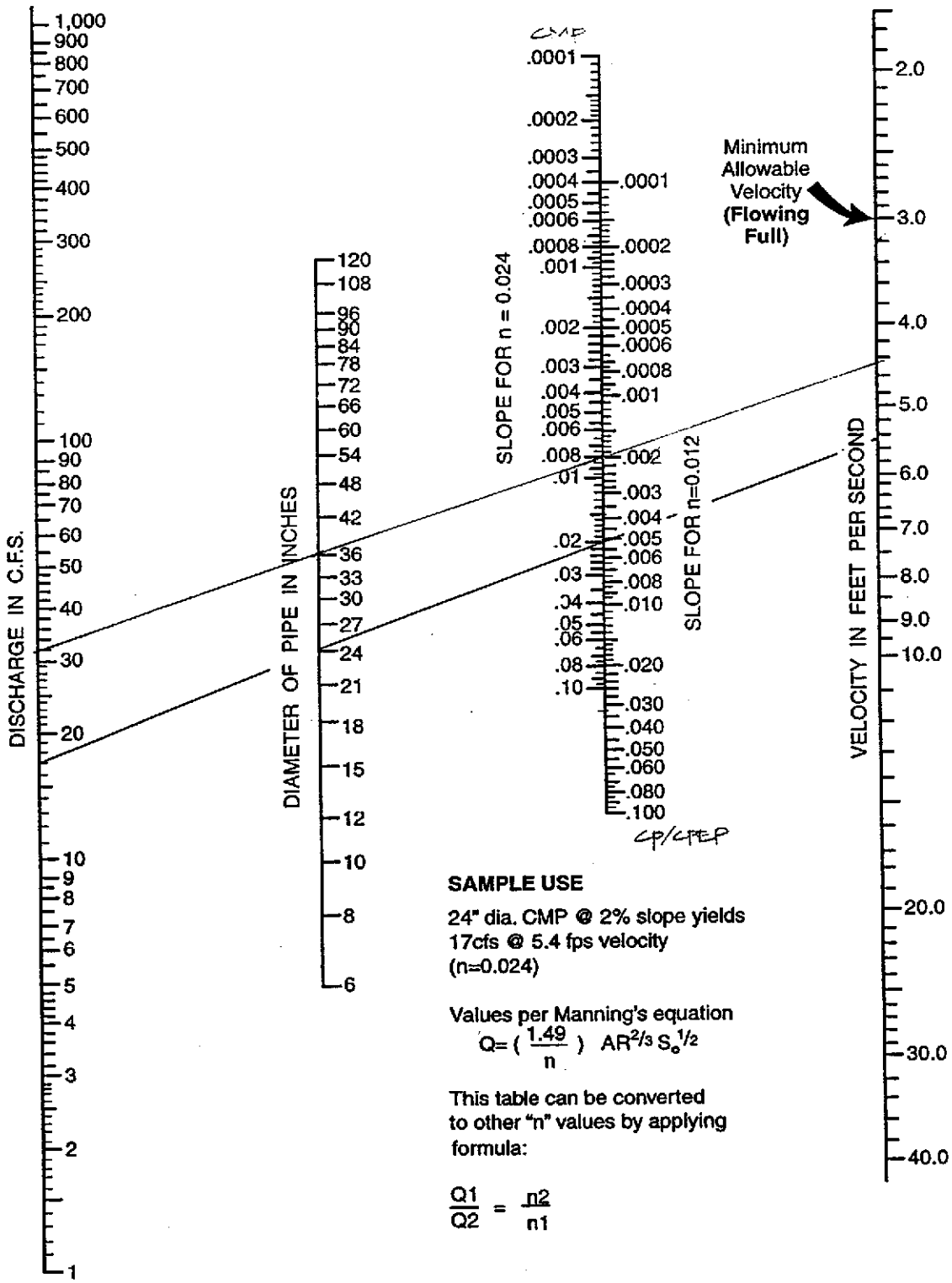


FIGURE 4.2.1.F NOMOGRAPH FOR SIZING CIRCULAR DRAINS FLOWING FULL



SAMPLE USE

24" dia. CMP @ 2% slope yields 17cfs @ 5.4 fps velocity (n=0.024)

Values per Manning's equation

$$Q = \left(\frac{1.49}{n}\right) AR^{2/3} S_o^{1/2}$$

This table can be converted to other "n" values by applying formula:

$$\frac{Q1}{Q2} = \frac{n2}{n1}$$

King County Wastewater Treatment Division Engineering & Environmental Services	Riprap design	Project
	Comp ____ Chk ____ Rev ____	
	Date 8/1/02 Date ____ Date ____	Page ____ of ____ Pages

Velocity of undetained 100 yr storm = 4.8 fps
(Q = 20 cfs)

dg = 0.45' (= 4")

stone weight 8 lbs × 400% = 24 lbs ∴ dg = 0.6'

Q allowable in backwater 120 cfs

∴ $V = \frac{Q}{A} = \frac{120}{\pi (1.5)^2} = 17.0$ fps

TABLE 4.4.1.A CHANNEL PROTECTION

Velocity at Design Flow (fps)		REQUIRED PROTECTION		
Greater than	Less than or equal to	Type of Protection	Thickness	Minimum Height Above Design Water Surface
0	5	Grass lining or bioengineered lining	N/A	
5	8	Rock lining[1] or bioengineered lining	1 foot	1 foot
8	12	Riprap[2]	2 feet	2 feet
12	20	Slope mattress gabion, etc.	Varies	2 feet

(1) Rock Lining shall be reasonably well graded as follows:

Maximum stone size: 12 inches
Median stone size: 8 inches
Minimum stone size: 2 inches

(2) Riprap shall be reasonably well graded as follows:

Maximum stone size: 24 inches
Median stone size: 16 inches
Minimum stone size: 4 inches

Note: Riprap sizing is governed by side slopes on channel, assumed to be approximately 3:1.

Riprap Design[7]

When riprap is set, stones are placed on the channel sides and bottom to protect the underlying material from being eroded. Proper riprap design requires the determination of the median size of stone, the thickness of the riprap layer, the gradation of stone sizes, and the selection of angular stones which will interlock when placed. Research by the U.S. Army Corps of Engineers has provided criteria for selecting the **median stone weight, W_{50}** (Figure 4.4.1.A, p. 4-57). If the riprap is to be used in a highly turbulent zone (such as at a culvert outfall, downstream of a stilling basin, at sharp changes in channel geometry, etc.), the median stone W_{50} should be increased from 200% to 600% depending on the severity of the locally high turbulence. The thickness of the riprap layer should generally be twice the **median stone diameter (D_{50})** or at least that of the maximum stone. The riprap should have a reasonably well graded assortment of stone sizes within the following gradation:

$$1.25 \leq D_{max}/D_{50} \leq 1.50$$

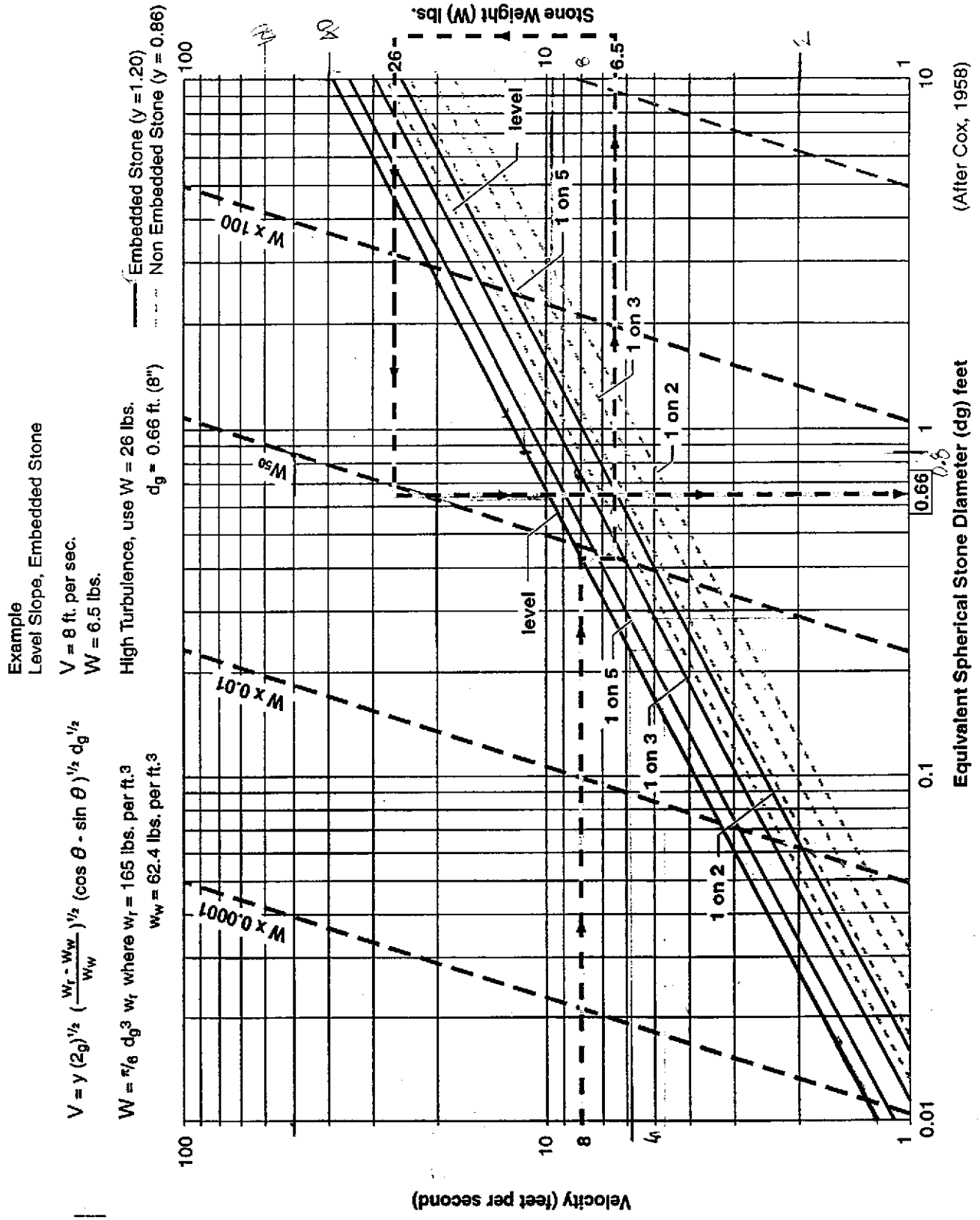
$$D_{15}/D_{50} = 0.50$$

$$D_{min}/D_{50} = 0.25$$

For a more detailed analysis and design procedure for riprap requiring water surface profiles and estimates of tractive force, refer to the paper by Maynord et al in *Journal of Hydraulic Engineering (A.S.C.E.)*, July 1989.

[7] From a paper prepared by M. Schaefer, Dam Safety Section, Washington State Department of Ecology.

FIGURE 4.4.1.A
MEAN CHANNEL VELOCITY VS. MEDIUM STONE WEIGHT (W_{50}) AND EQUIVALENT STONE DIAMETER



WATER RESOURCES PROGRAM
DAM SAFETY SECTION

APPLICATION FOR DAM CONSTRUCTION PERMIT

$500.00 initial non-refundable payment required with application
or $10.00 Fee for Dam Removal
(GRAY BOXES FOR OFFICE USE ONLY)

File No.	County Code	WRIA	Date Rec'd	Initial Fee Paid

1. OWNER INFORMATION			
Owner's Name King County Department of Natural Resources & Parks (DNRP)		Telephone Number (206) 296-8371	
Mailing Address (Street or P.O. Box) 201 South Jackson Street, Suite 600	(City) Seattle	(State) WA	(Zip) 98104-3855
2. PROJECT ENGINEER INFORMATION			
Project Engineer for Dam Design: Don Althauser		Telephone Number: (206) 296-8371	
Address (Street or P.O. Box) 201 South Jackson Street, Suite 600	(City) Seattle	(State) WA	(Zip) 98104-3855
Washington State P.E. # 29623		Expiration Date 11/25/03	
3. CONSTRUCTION ENGINEER INFORMATION			
Project Engineer for Oversight of Dam Construction: Don Althauser		Telephone Number: (206) 296-8371	
Address (Street or P.O. Box) 201 South Jackson Street, Suite 600	(City) Seattle	(State) WA	(Zip) 98104-3855
Washington State P.E. # 29623		Expiration Date 11/25/03	
4. PROJECT INFORMATION			
Project Name: Bonneville Power Administration (BPA) Madsen Creek West Basin Water Quality Improvement Design			
Dam Name(s) (Also List Names of All Impounding Structures Associated with Project) None			
Reservoir/Impoundment Name: BPA Pond			
New Construction ☒ Modification of Existing Dam ☐ Dam Removal ☐			
Name of Stream (If Offstream, Write **Offstream** and Name of Nearest Stream) Offstream – Madsen Creek			

Location of Dam (Include Map Showing Location of Project)	Section	Township N.	Range (E. or W.)	County
	27	23	5E	King
Location of Dam	**Latitude**		**Longitude**	

4. PROJECT INFORMATION (cont.)		
Purpose of Dam Reservoir (Water Supply, Recreation, Power, Fish Propagation, etc.) Retention/Detention		
Reservoir Operation Class (Permanent, Seasonal, or Intermittent Pool) Permanent		Dam Size – ☒ Small ☐ Intermediate ☐ Large
Downstream Hazard Classification (Class 1A, 1B, 1C, 2, or 3) 1A		
Is Dam Regulated by Federal Agency? No	If yes, Name of Agency	
Is Dam a Hydropower Project? No	If yes, FERC License #	
Is Dam Constructed on Federal Land? No		
Has Environmental Checklist Been Completed in Accordance with SEPA? Yes		
Has Determination Been Made if Water Right Permit and/or Reservoir Storage Permit is Needed? NA		
5. DAM INFORMATION		
Proposed Dam Height (Crest to Toe) 6.5 feet	Length Along Dam Crest 775 feet	Width of Dam Crest 20 feet
Type of Construction and Material of Which Dam is to be Built (Examples: Homogeneous Earthfill, Zoned Earthfill, Concrete Gravity) Zoned Earthfill		
Proposed Date of Construction Startup 2003	Anticipated Date Construction will Be Completed 9/03	
6. RESERVOIR INFORMATION		
Number of Acres Submerged at Normal Full Pool 4.12 acres		
Number of Acre-Feet to be Stored at Normal Full Pool 18.36 acre-feet at elevation = 441.17 (100-year storm)		
Number of Acre-Feet that can be Stored at Dam Crest Level 29.9 acre-feet		
7. PROJECT OPERATION		
Who Will Be Responsible for Project Operation & Maintenance? King County DNRP		
Who Will Be Responsible for Project Inspections & Monitoring? King County DNRP		

Dec 2, 2002
(Date)

Ken Gresset
(Name of Project Contact)

(206) 296-8314
(Telephone Number)