Appendix III-B – Design Aids: Design Storm Precipitation Values, Isopluvial Maps, SCS Curve Numbers, Roughness Coefficients, and Soil Types

Single Event Model Guidance

The only approved use of a single event model is for the sizing of conveyance systems. Approved continuous simulation runoff models will be used for the design of water quality and quantity BMPs.

SBUH or SCS Methods

The applicant shall use the western Washington SCS curve numbers, not the SCS national curve numbers. These have been included in Table B.4. Individual curve numbers for a drainage area may be averaged into a "composite" curve number for use in either the SCS or SBUH methods. The NRCS (formerly SCS) has, for many years, conducted studies of the runoff characteristics for various land types. After gathering and analyzing extensive data, NRCS has developed relationships between land use, soil type, vegetation cover, interception, infiltration, surface storage, and runoff. The relationships have been characterized by a single runoff coefficient called a "curve number." The National Engineering Handbook – Section 4: Hydrology (NEH-4, SCS, August 1972) contains a detailed description of the development and use of the curve number method.

NRCS has developed "curve number" (CN) values based on soil type and land use. They can be found in "Urban Hydrology for Small Watersheds", Technical Release 55 (TR-55), June 1986, published by the NRCS. The combination of these two factors is called the "soil-cover complex." The soil-cover complexes have been assigned to one of four hydrologic soil groups, according to their runoff characteristics. NRCS has classified over 4,000 soil types into these four soil groups. Table B.5 shows the hydrologic soil group of most soils in Pierce County and Gig Harbor and provides a brief description of the four groups. For details on other soil types refer to the NRCS publication mentioned above (TR-55, 1986).

Isopluvial Maps

National Oceanic and Atmospheric Administration (NOAA) isopluvial maps for Gig Harbor, Pierce County, and Tacoma are included below. The professional engineer shall use the best engineering judgment in selecting the runoff totals for the project site.

Time of Concentration

Time of concentration is the sum of the travel times for sheet flow, shallow concentrated flow, and channel flow. For lakes and submerged wetlands, the travel time can be determined with storage routing techniques if the stage-storage versus discharge relationship is known or it may be assumed to be "zero."

Sheet Flow

With sheet flow, the friction value (n_s) (a modified Manning's effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges and rocks; and erosion and transportation of sediment) is used. These n_s values are for very shallow flow depths of about 0.1 foot and are only used for travel lengths up to 300 feet. Table B.2 gives Manning's n_s values for sheet flow for various surface conditions.

For sheet flow of up to 300 feet, use Manning's kinematic solution to directly compute T_t.

$$T_t = \frac{0.42\,(n_s L)^{0.8}}{(P_2)^{0.527}(S_o)^{0.4}}$$

where:

T_t = travel time (min),

n_s = sheet flow Manning's effective roughness coefficient (Table B.2).

L = flow length (ft),

P_2 = 2-year, 24-hour rainfall (in), and

S_o = slope of hydraulic grade line (land slope, ft/ft)

The maximum allowable distance for sheet flow shall be 300 feet, the remaining overland flow distance shall be shallow concentrated flow until the water reaches a channel.

Shallow Concentrated Flow

After a maximum of 300 feet, sheet flow is assumed to become shallow concentrated flow. The average velocity for this flow can be calculated using the k_s values from Table B.2 in which average velocity is a function of watercourse slope and type of channel.

The average velocity of flow, once it has measurable depth, shall be computed using the following equation:

$$V = k\sqrt{s_o}$$

where:

V = velocity (ft/s)

k = time of concentration velocity factor (ft/s)

S_o = slope of flow path (ft/ft)

"k" is computed for various land covers and channel characteristics with assumptions made for hydraulic radius using the following rearrangement of Manning's equation:

$$k = (1.49(R)^{0.667})/n$$

where:

R = an assumed hydraulic radius

n = Manning's roughness coefficient for open channel flow (see Table B.3)

Open Channel Flow

Open channels are assumed to begin where surveyed cross-section information has been obtained, where channels are visible on aerial photographs, or where lines indicating streams appear (in blue) on United States Geological Survey (USGS) quadrangle sheets. The k_c values from Table B.2 used in the Velocity Equation above or water surface profile information can be used to estimate average flow velocity.

Lakes or Wetlands

This travel time is normally very small and can be assumed as zero. Where significant attenuation may occur due to storage effects, the flows should be routed using a "level pool routing" technique.

Limitations

The following limitations apply in estimating travel time (T_t).

- Manning's kinematic solution should not be used for sheet flow longer than 300 feet.
- In watersheds with storm drains, carefully identify the appropriate hydraulic flow path to estimate Tc.
- Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or non-pressure flow.
- A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. A hydrograph should be developed to this point and a level pool routing technique used to determine the outflow rating curve through the culvert or bridge.

Design Storm Hyetographs

The standard design hyetograph is the SCS Type 1A 24-hour rainfall distribution resolved into 10-minute time intervals. Various interpretations of the hyetograph are available and may differ slightly from distributions used in other unit hydrograph based computer simulations. Other distributions will be accepted with adequate justification and as long as they do not increase the allowable release rates.

For project sites with tributary drainage areas above elevation 1,000 feet MSL, an additional total precipitation must be added to the total depth of rainfall for the 25-, 50-, and 100-year design storm events to account for the potential average snowmelt which occurs during major storm events.

The MSL "factor" is computed as follows:

$$M_s \text{ (in inches)} = 0.004\ (MB_{el} - 1000)$$

where:

M_s = rainfall amount to be added to P_r

Mb_{el} = the mean tributary basin elevation above sea level (in feet)

Subbasin Delineation

Within an overall drainage basin it may be necessary to delineate separate subbasins based on similar land uses and/or runoff characteristics or when hydraulically "self-contained" areas are found to exist. When this is necessary, separate hydrographs shall be generated, routed, and recombined, after travel time is considered, into a single hydrograph to represent runoff flows into the quantity or quality control facility.

Hydrograph Phasing Analysis

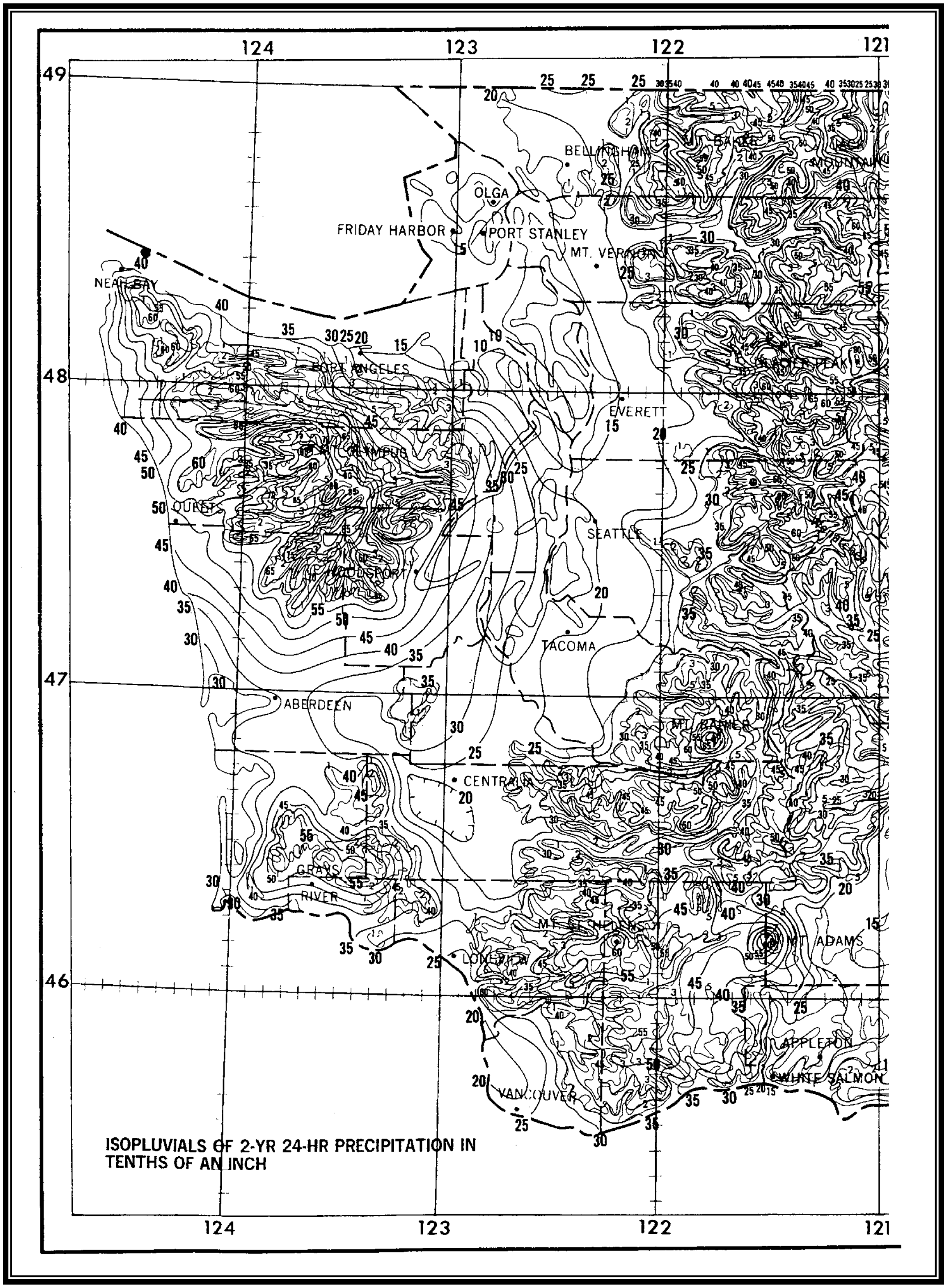
Where flows from multiple basins or subbasins having different runoff characteristics and/or travel times combine, the design engineer shall sum the hydrographs after shifting each hydrograph according to its travel time to the discharge location of interest. The resultant hydrograph shall be either routed downstream as required in the downstream analysis, or routed through the control facility.

Included in this appendix are the 2-, 10-, and 100-year, 24-hour design storm and mean annual precipitation isopluvial maps for western Washington. These have been taken from NOAA Atlas 2 "Precipitation - Frequency Atlas of the Western United States, Volume IX, Washington. The applicant has the option of using the National Oceanic and Atmospheric Administration (NOAA) isopluvials for design purposes or utilizing the design storm precipitation values listed in Table B.1 below. The listed values can be used to an elevation of 650 feet, Mean Sea Level (MSL). Above 650 feet, MSL, the applicant shall use the NOAA isopluvials for selection of the design storm precipitation.

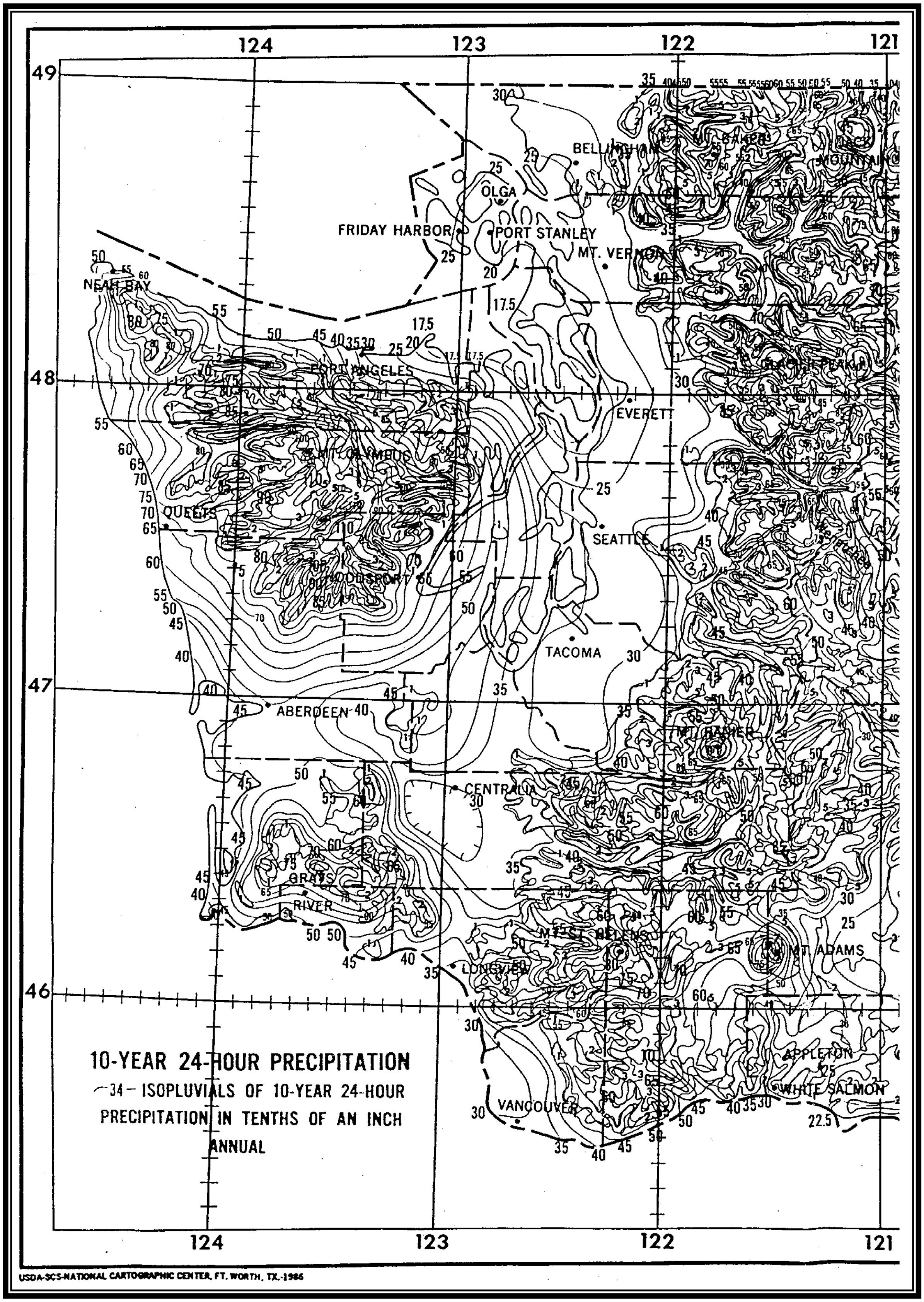
Table B.1. Design Storm Precipitation Values

Return Frequency 24-Hour Storm Event (Years)		Gig Harbor	KPN[1]
0.5		1.6	1.92
2		2.5	3.0
5		3.0	3.5
10		3.5	4.3
25		4.0	4.5-5.0
50		4.5	5.0-5.5
100		4.8	5.5-6.0

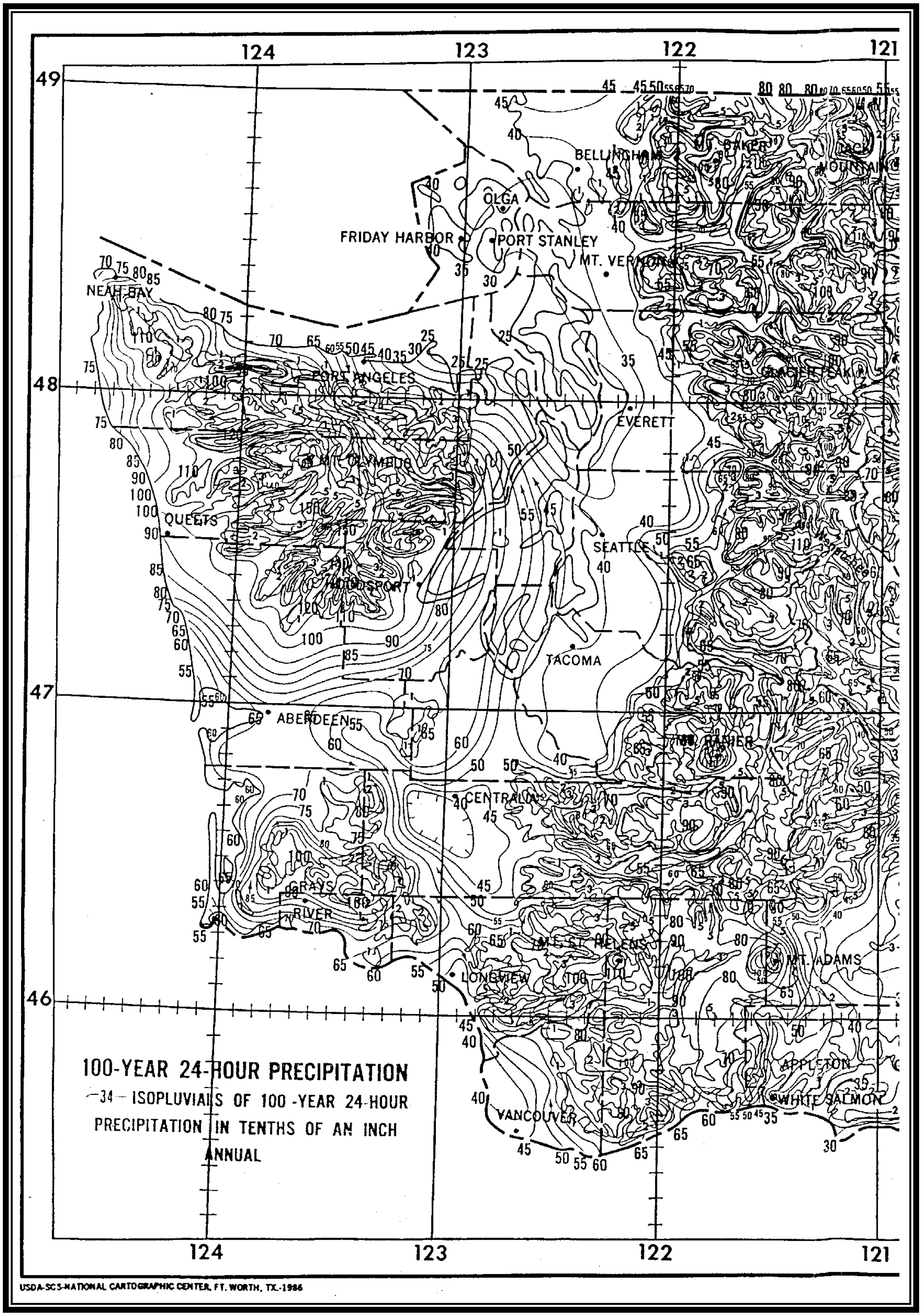
[1] KPN = Key Peninsula, North



Western Washington Isopluvial 2-year, 24-hour.



Western Washington Isopluvial 10-year, 24-hour.



Western Washington Isopluvial 100-year, 24-hour.

Table B.2. "n" and "k" Values Used in Time Calculations for Hydrographs.

"n" Sheet Flow Equation Manning's Values (for the initial 300 ft. of travel)		n_s[1]
Smooth surfaces (concrete, asphalt, gravel, or bare hand 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
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 pipe	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[2]

[1] 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
[2] Determined from Table B.3

Ref: DOE Stormwater Management Manual for the Puget Sound Basin, February 1992.

Table B.3. Values of the Roughness Coefficient “n”.

Type of Channel and Description	Manning's “n“
A. Constructed Channels	
a. Earth, straight and uniform	
1. Clean, recently completed	0.018
2. Gravel, uniform section, clean	0.025
3. With short grass, few weeds	0.027
b. Earth, winding and sluggish	0.025
1. No vegetation	0.025
2. Grass, some weeds	0.030
3. Dense weeds or aquatic plants in deep channels	0.035
4. Earth bottom and rubble sides	0.030
5. Stony bottom and weedy banks	0.035
6. Cobble bottom and clean sides	0.040
c. Rock lined	
1. Smooth and uniform	0.035
2. Jagged and irregular	0.040
d. Channels not maintained, weeds and brush uncut	
1. Dense weeds, high as flow depth	0.080
2. Clean bottom, brush on sides	0.050
3. Same as above, highest stage of flow	0.070
4. Dense brush, high stage	0.100
B. Natural Streams	
B-1 Minor streams (top width at flood stage < 100 ft.)	
a. Streams on plain	
1. Clean, straight, full stage no rifts or deep pools	0.030
2. Same as above, but more stones and weeds	0.035
3. Clean, winding, some pools and shoals	0.040
4. Same as above, but some weeds	0.040
5. Same as 4, but more stones	0.050
6. Sluggish reaches, weedy deep pools	0.070
7. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.100
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages	
1. Bottom: gravel, cobbles, and few boulders	0.040
2. Bottom: cobbles with large boulders	0.050
B-2 Flood plains	
a. Pasture, no brush	
1. Short grass	0.030
2. High grass	0.035
b. Cultivated areas	
1. No crop	0.030
2. Mature row crops	0.035
3. Mature field crops	0.040
c. Brush	
1. Scattered brush, heavy weeds	0.050
2. Light brush and trees	0.060
3. Medium to dense brush	0.070
4. Heavy, dense brush	0.100
d. Trees	
1. Dense willows, straight	0.150
2. Cleared land with tree stumps, no sprouts	0.040
3. Same as above, but with heavy growth of sprouts	0.060
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.100
5. Same as above, but with flood stage reaching branches	0.120

Ref: DOE Stormwater Management Manual for the
Puget Sound Basin, February 1992.

Table B.4. Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas.

(Sources: TR 55, 1986, and Stormwater Management Manual, 1992.)				
	CNs for hydrologic soil group			
Cover type and hydrologic condition.	A	B	C	D
Curve Numbers for Predevelopment Conditions				
Pasture, grassland, or range-continuous forage for grazing:				
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77
Curve Numbers for Postdevelopment Conditions				
Open space (lawns, parks, golf courses, cemeteries, landscaping, etc.)[1]				
Fair condition (grass cover on 50% - 75% of the area).	77	85	90	92
Good condition (grass cover on >75% of the area)	68	80	86	90
Impervious areas:				
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs[2], driveways, etc. (excluding right-of-way)	98	98	98	98
Permeable Pavement				
Landscaped area	77	85	90	92
50% landscaped area/50% impervious	87	91	94	96
100% impervious area	98	98	98	98
Paved	98	98	98	98
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, grassland, or range-continuous forage for grazing:				
Poor condition (ground cover <50% or heavily grazed with no mulch).	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed).	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Woods:				
Poor (Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning).	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil).	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil).	30	55	70	77

Single family residential[3]: Dwelling Unit/Gross Acre	Should only be used for subdivisions > 50 acres	Average Percent impervious area[3,4]	
1.0 DU/GA		15	Separate curve number shall be selected for pervious and impervious portions of the site or basin
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	
7.5 DU/GA		58	
PUDs, condos, apartments, commercial businesses, industrial areas and subdivisions < 50 acres	% impervious must be computed	Separate curve numbers shall be selected for pervious and impervious portions of the site	
For a more detailed and complete description of land use curve numbers refer to chapter 2 of the Soil Conservation Service's Technical Release No. 55 , (210-VI-TR-55, Second Ed., June 1986).			

1 Composite CNs may be computed for other combinations of open space cover type.

2 Where roof runoff and driveway runoff are infiltrated or dispersed according to the requirements in Section 3.9.3 and 3.9.4, the average percent impervious area may be adjusted in accordance with the procedure described under "Flow Credit for Roof Downspout Infiltration" and "Flow Credit for Roof Downspout Dispersion.".

3 Assumes roof and driveway runoff is directed into street/storm system.

4 All the remaining pervious area (lawn) are considered to be in good condition for these curve numbers.

Table B.5. Major Soil Groups in Gig Harbor.

Soil Number	Soil Description	Hydrologic Soil Group
04A	Bellingham silty clay loam	D
05C	Bow silt loam, 8 to 15 percent slopes	D
05D	Bow silt loam, 15 to 30 percent slopes	D
11A	Coastal beaches	A
12A	Dupont muck	D
13C	Everett gravelly sandy loam, 6 to 15 percent slopes	A
16B	Harstine gravelly sandy loam, 0 to 6 percent slopes	C
16C	Harstine gravelly sandy loam, 6 to 15 percent slopes	C
16D	Harstine gravelly sandy loam, 15 to 30 percent slopes	C
16E	Harstine gravelly sandy loam, 30 to 45 percent slopes	C
17A	Hydraquents, level	D
18B	Indianola loamy sand, 0 to 6 percent slopes	A
18C	Indianola loamy sand, 6 to 15 percent slopes	A
18E	Indianola loamy sand, 15 to 45 percent slopes	A
20B	Kitsap silt loam, 2 to 8 percent slopes	C
20C	Kitsap silt loam, 8 to 15 percent slopes	C
20D	Kitsap silt loam, 15 to 30 percent slopes	C
20F	Kitsap silt loam, 30 to 65 percent slopes	C
21F	Kitsap-Indianola complex, 45 to 70 percent slopes	C/A
24D	Neilton gravelly loamy sand, 8 to 25 percent slopes	A
26A	Norma fine sandy loam	D
47F	Xerochrepts, 45 to 70 percent slopes	D
48A	Xerothents, fill areas	D

Soils Table Notes:
Hydrologic Soil Group Classifications, as Defined by the Soil Conservation Service:

A = (Low runoff potential) Soils having low runoff potential and high infiltration rates, even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr.).

B = (Moderately low runoff potential). Soils having moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.3 in/hr.).

C = (Moderately high runoff potential). Soils having low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine textures. These soils have a low rate of water transmission (0.05-0.15 in/hr.).

D = (High runoff potential). Soils having high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr.).

[1] = From NRCS Database for Pierce and Snoqualmie surveys, SCS, TR-55, Second Edition, June 1986, Exhibit A-1. Revisions made from SCS, Soil Interpretation Record, Form No. 5, September 1988 and various county soil surveys.

Additional Note: Where field infiltration tests indicate a measured (initial) infiltration rate less than 0.30 in/hr, continuous simulation model users may model the site as a C soil if needed to meet the MR#5 LID performance standard.