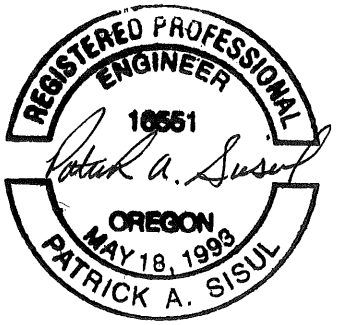
STORM DRAINAGE REPORT FOR

Sandy Woods 2 Land Use Application

Silver V Construction

J.O. SGL 19-042

June 2021



EXPIRATION DATE: 6/30/2022
6/1/2021

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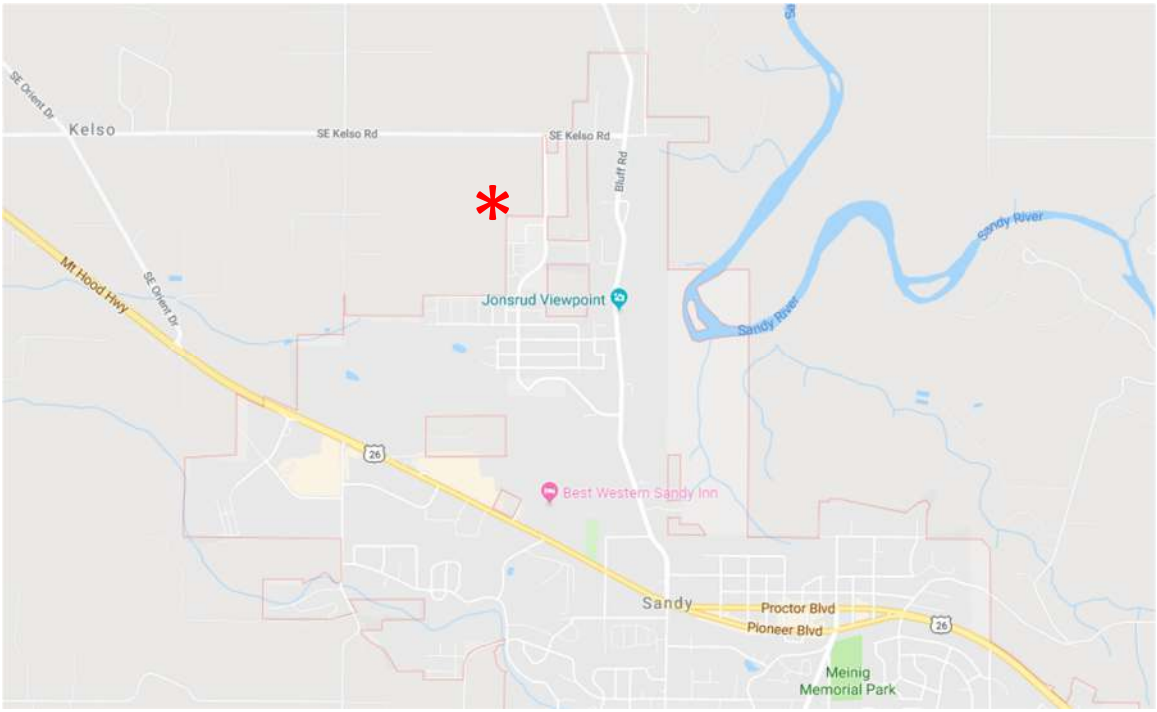
Objective:

The goal of this stormwater calculation is to demonstrate that the residential subdivision development is meeting City of Sandy's stormwater requirements for the Sandy Woods 2 subdivision on SE Kelso Road, Sandy, OR.

Site Location & Vicinity Map:

The site has no address, although it had an address of 37090 SE Kelso Road until the existing home was removed from the property and the land was re-platted with the first phase of the subdivision. The site is in the City of Sandy, Clackamas County, Oregon and is west of Jewelberry Avenue and south of Kelso Road. Tax lots include 2202, 2203 & 2204 of Sec. 11, T2S, R4E, W.M.



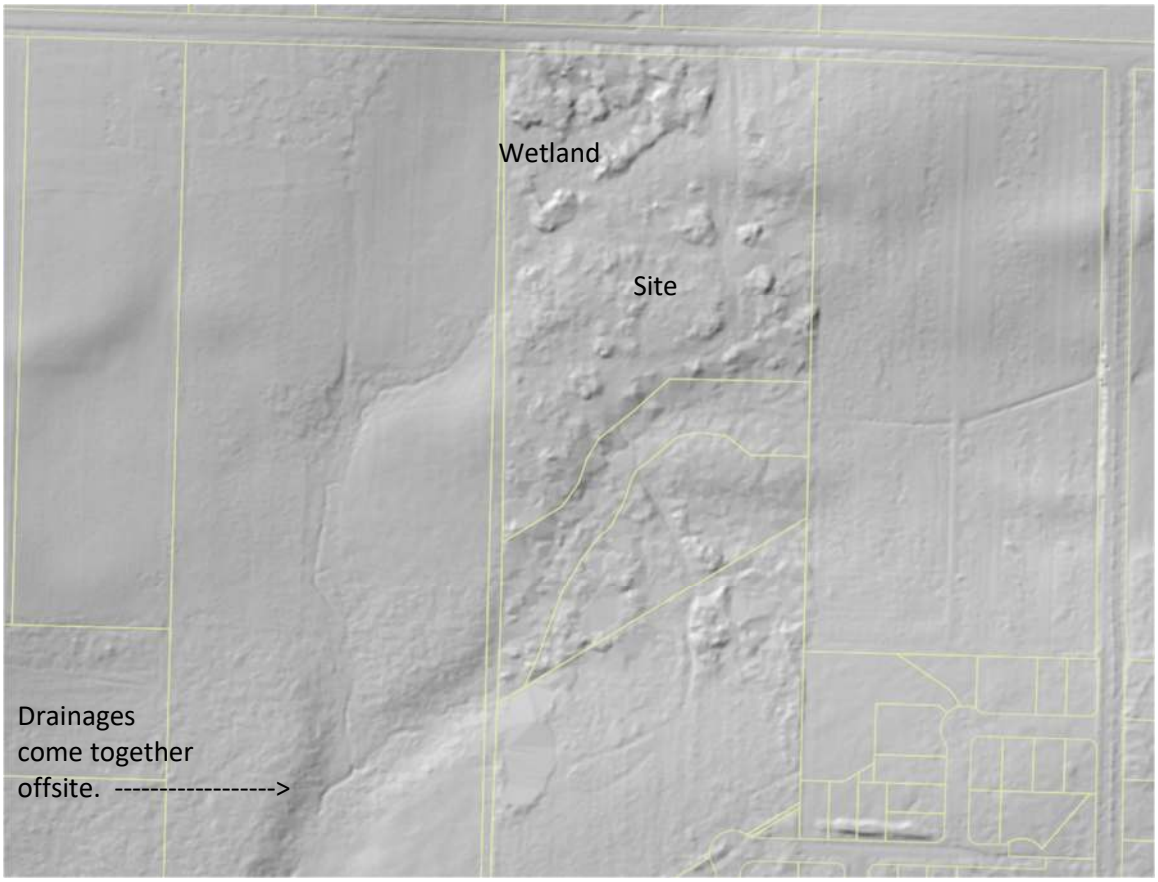
The site area is 769,848 sq. ft. which equals 17.67 acres. The center of the site is located at Latitude: 45°25'00"N, Longitude 122°16'55"W.

Local Vicinity Map:

Site Terrain & Drainageways:

Generally, the site falls from east to west. A seasonal drainageway runs from east to west across the site, leaving the site at the low point along the western property line. Much of the site drains northerly or southerly toward that seasonal drainageway. Along SE Kelso Road there are roadside ditches on the north and south sides of the roadway. The roadside ditch on the north side of Kelso Road collects runoff from the northern half of the roadway and from the agricultural properties north of the roadway. In front of this site, two culverts move the ditch runoff underneath Kelso Road and into the northwestern corner of this site. The flow spreads out into a wide wetland and flows southwesterly toward Tax Lot 2300 west of this site. The northern portion of this site also drains to that wetland in an east to west direction.

The two drainageways on this site come together on Tax Lot 2300 to the west of this site. The drainages are tributaries to Tickle Creek. The LIDAR map below shows how the two drainageways cross the site and come together on Tax Lot 2300 to the west of the site.



Rainfall Intensity:
Sandy has higher rainfall values than the rest of the Portland urban area. Below is a comparison of rainfall intensities between Portland and Sandy.

24-hour Rainfall Depth		
Reoccurrence Interval	24-hour rainfall Portland (inches)	24-hour rainfall Sandy (inches)
2	2.4	3.5
5	2.9	4.5
10	3.4	4.8
25	3.9	5.5

* Sandy rainfall depth based upon NOAA Isopluvial values listed in the Storm Drainage Master Plan Appendix A

The 10-year event in Portland is approximately equal to the 2-year event in Sandy, while the 100-year event in Portland is approximately equal to the 5-year event in Sandy. The PAC calculator does not have a storm event large enough to approximate a 10-year storm event in Sandy, nor does the WES BMP tool.

We must use HydroCAD to calculate storm drain runoff, as none of the continuous storm modeling programs can simulate Sandy's higher rainfall rates.

Pollutants of Concern:
The contributing impervious area consists of streets, sidewalks, roofs and driveways. Per the 2016 City of Portland Stormwater Management Manual the pollutants of concern are:

- Suspended Solids (sediment)
- Heavy Metals (such as lead, copper, zinc & cadmium)
- Nutrients (such as nitrogen and phosphorus)
- Bacteria & Viruses
- Organics (oil, grease, hydrocarbons, etc.)
- Floatable trash & debris

Stormwater Treatment BMP's:
Stormwater will be treated with vegetated planters, vegetated basins & swales.

According to the City of Portland 2016 Stormwater Management Manual:

Vegetation may be one of the most cost-effective and ecologically efficient means available to improve water quality. Vegetation shades water courses, which lowers water temperature; captures and absorbs water in leaves and roots, which reduces peak

flows; and stabilizes soil by providing cover for disturbed soils. Vegetation also provides wildlife habitat and scenic and aesthetic benefits.

As stormwater enters a vegetated facility, the vegetation slows the water down, allowing sediments to be trapped on the surface of the facility. Typically, the surface area of the facility is designed to allow stormwater to pond and evaporate while sediments settle into a layer of mulch and then soil. The mulch prevents soil erosion and retains moisture for plant roots. It also provides a medium for biological growth and the decomposition or decay of organic matter. The soil stores water and nutrients to support plant life. Bacteria, nematodes, and other soil organisms degrade organic pollutants such as petroleum-based compounds. They also help mix organic material, increase aeration, and improve water infiltration and water-holding capacity. Bacteria and other beneficial soil microbes process most pollutants.

As described above, vegetated facilities can treat all of the pollutants of concern above through infiltration through the soil and treatment by the vegetation. Also, per the Oregon DEQ BMP table, vegetated planters (bioretention facilities) are capable of removing all of the pollutants listed above.

Existing site soils:

Onsite soils are a combination of Cazadero silty clay loam and Cottrell silty clay loam. According to the Web Soil Survey, 59.3% of the site is 15B, Cazadero silty clay loam and 40.7% of the site is Cottrell silty clay loam. Both soils are identified as being Hydrologic Soil Group C.

Infiltration rate:

Onsite soil testing was performed in June 2020 by Mia Mahedy, PE, GE of Rapid Soil Solutions, Inc. Onsite testing determined an infiltration rate of 6 inches per hour in the vicinity of future Lots 54 – 64 that back up to the wetland in the NW corner of the property, and a rate of 20 inches per hour in the vicinity of the surface water facility located south the east-west drainageway. A copy of the geotechnical testing from Rapid Soil Solutions, Inc. is contained in the Appendices.

Using Factor of Safety of 2, the design infiltration rate for the facilities located on the rear of Lots 54 - 64 will be 3 inches/hour, while the rate used for the public facility in the southern portion of the site will be 10 inches/hour:

City of Sandy Stormwater Requirements:

Water Quality Treatment:
All developments shall treat 80 percent of the average annual volume of storm water runoff for the site. This standard can be met by installing storm water quality treatment facilities to satisfy the following design criteria:

A. Detention based storm water quality control: The required design volume for detention-based control is equal to the entire runoff volume that would occur from a site with a 1.2–inch, 12-hour storm. The draw-down time for the entire volume must be greater than or equal to 48 hours. For the lower half of the detention volume, the drawdown time must be greater than 36 hours. Additional design criteria for inlet and outlet spacing and design, as well as guidelines for calculating volumes, are contained in the Public Works Department Standards.

B. Flow-through based storm water quality control: the required design flow rate for treatment is the runoff that would be produced from a rainfall intensity of 0.2 inches/hour for on-line facilities, and 0.11 inches/hour for off-line facilities. This rate must be maintainable for a minimum of three hours. Additional design criteria for flow calculation, as well as specific treatment criteria for various types of storm water facilities (e.g., infiltration and storm water filters), are contained in the Public Works Standards.

C. Combination detention based on flow-through based storm water quality control: Detention facilities may be combined with flow-through facilities. The applicant must demonstrate that the combined system could sufficiently treat storm water runoff for the runoff produced by the flow-through treatment rates of 0.2 inches/hour (on-line facilities), occurring for a three-hour period.

Detention: Detain the 2-, 5-, 10-, and 25-year, 24-hour storm events to pre-development peak release levels.

The calculations will be performed using Santa Barbra Urban Hydrograph methodology.

Pre-Development Site Conditions:

The pre-development site condition is primarily Himalayan blackberries mixed with some grass. The site also includes forest with light underbrush, wetlands, pasture, gravel/dirt driveway/roadway, and structures. The home, barn and shed were recently removed from the property. The highest point of the site is located along the eastern property line approximately 200 feet south of Kelso Road at elevation 820. The lowest point onsite is at elevation 767 along the western property line approximately 35 feet north of the SW corner.

An aerial view of the site is below:

Pre-development site areas and curve numbers are noted below. All soils are Hydrologic Soil Group C:

	Pre-Development Area	(CN)
Woods, protected from grazing 50 – 75% ground cover	235,225 sf	70
Brush-weed-grass mixture with brush as the major element	516,708 sf	70
Gravel / Dirt roadway	15,695 sf	89
Buildings – Home, Barn & Shed	2,220 sf	98
Area along Kelso Road Frontage assumed to be pervious	12,778 sf	74

Post-Developed Condition:

The developed site condition is planned as 43 Lots and multiple tracts for stormwater detention, water quality treatment, and water quality protection. 11.26 acres will be developed, and 6.41 acres will remain undeveloped.

The developed portion of the site will consist of new low-density residential lots of 7,500 square feet or larger with new residential homes. New lots are assumed to have

2,640 square feet of impervious area, with the remaining area landscaping in good condition. Stormwater runoff from new lots will be conveyed via piping and grading into a public storm drain in the proposed roads.

Drainage Facilities for this development site:

The Sandy Woods 2 subdivision will widen Kelso Road on the northern end of the site and will construct a subdivision south of Kelso Road. The developed site will drain to the wetland in the north and the seasonal drainageway in the central portion of the site in order to follow existing drainage patterns.

Basin 1 (green) – Basin 1 includes the area of Kelso Road that is widened as well as the curb and sidewalks adjacent to the widening immediately due west of the proposed catch basin near station 17+50. That portion of the Kelso Road improvements will be conveyed to the proposed detention pond to the northwestern corner of the site. The outflow from this facility will release to the existing wetland in the northwestern corner of the site.

Basin 2 (blue) – Basin 2 includes the area of Kelso Road that is widened as well as the curb and sidewalks adjacent to the widening immediately due east of the proposed catch basin near station 17+50. It also includes the on-site improvements consisting of roads, curbs, sidewalks, driveways, and the lot areas of the development. The runoff from the improvements will be conveyed via piping and grading to a detention pond to the south side of the site.

Basin 3 (yellow) -- The undisturbed areas around the drainageways will go directly to the drainageways undetained, yet will still be included in the calculations.

Basin Map

Developed Site Impervious & Pervious Area Breakdown:

Post-development site areas and curve numbers are noted below. All soils are Hydrologic Soil Group C.

New homes on new Lots are estimated to create an impervious area of 2,640 sf per lot, 0.061 acres. The remainder of the lot will be a combination of Landscaping with >75% grass and/or Woods, protected from grazing:

Basin 1:	Kelso Road Improvements (Off-site)		
	Impervious Area	6,172 sf	CN = 98
	Planter Strip	1,146 sf	CN = 74
Basin 2:	On-site Improvements		
	Impervious Area	201,631 sf	CN = 98
	Pervious Area	303,524 sf	CN = 74
Basin 3:	Undetained Areas	255,689 sf	CN = 74
Total Post Development Area:		768,162 sf = 17.63 Ac.	

Pre-Development Combined CN Values & Time of Concentration:

Combined CN for Pervious: Both pervious CN values have a CN of 70, CN = 70

Combined CN for Impervious: $\frac{(15{,}695 \text{ sf})(89) + (2{,}220 \text{ sf})(98)}{(15{,}695 \text{ sf} + 2{,}220 \text{ sf})} = 90.1$, CN = 90.1

TIME OF CONCENTRATION: (see supporting pages)
Time of concentration for the pre-development condition will be calculated from the hydraulically most distant point in the property.

Time of Concentration:

Sheet Flow (dense grass): $T_{t1} = \frac{0.42(0.24*150')^{0.8}}{(3.50)^{0.5} * (0.0167)^{0.4}} =$ ***20.3 min*** L = 150' S = 0.0167 $n_s = 0.24$

Shallow Concentrated Flow: $T_{t2} = \frac{215'}{60* 9 * (0.0256)^{0.5}} =$ ***2.5 min*** L = 215' S = 0.0256 $k_s = 9$

T_{cu} = 20.3 min + 2.5 min = 22.8 min

Post-Development Combined CN Values & Time of Concentration:

BASIN 1:

TIME OF CONCENTRATION:
Due to the nature of this basin and the short distance of flow, it shall be assumed that the time of concentration for this basin is 5 minutes for the post-developed condition.

T_c = 5.0 min

BASIN 2:

TIME OF CONCENTRATION:
Time is based on the time of concentration from the hydraulically most distant point in the basin. Based on the layout of the site, lot 67's front yard will drain toward the street via sheet flow and then transition to gutter flow until it reaches the first catch basin downstream where it will become pipe flow until the release into the detention pond for this basin.

Time of Concentration:

Sheet Flow (lawn): $T_{t1} = \frac{0.42(0.15*15.27')^{0.8}}{(3.50)^{0.5} * (0.072)^{0.4}}$ = ***1.25 min*** — L = 15.27', S = 0.072, n_s = 0.15

Sheet Flow (sidewalk): $T_{t1} = \frac{0.42(0.011*10.0')^{0.8}}{(3.50)^{0.5} * (0.015)^{0.4}}$ = ***0.21 min*** — L = 10.0', S = 0.015, n_s = 0.011

Gutter Flow: $T_{t2} = \frac{72.61'}{60* 27 * (0.014)^{0.5}}$ = ***0.38 min*** — L = 72.61', S = 0.014, k_s = 27

Pipe Flow: $T_{t3} = \frac{1495'}{60* 42 * (0.005)^{0.5}}$ = ***8.39 min*** — L = 1495', S = 0.005, k_s = 42

**NOTE: For the purposes of the time of concentration calculations, the pipe segments will have an assumed slope of 0.0050 (0.50%).*

T_{cu} = 1.25 min + 0.21min + 0.38 min + 8.39 min = 10.23 min

Pre-Development Hydrographs:

Summary for Subcatchment 7S: Pre-Developed Conditions - Whole Site

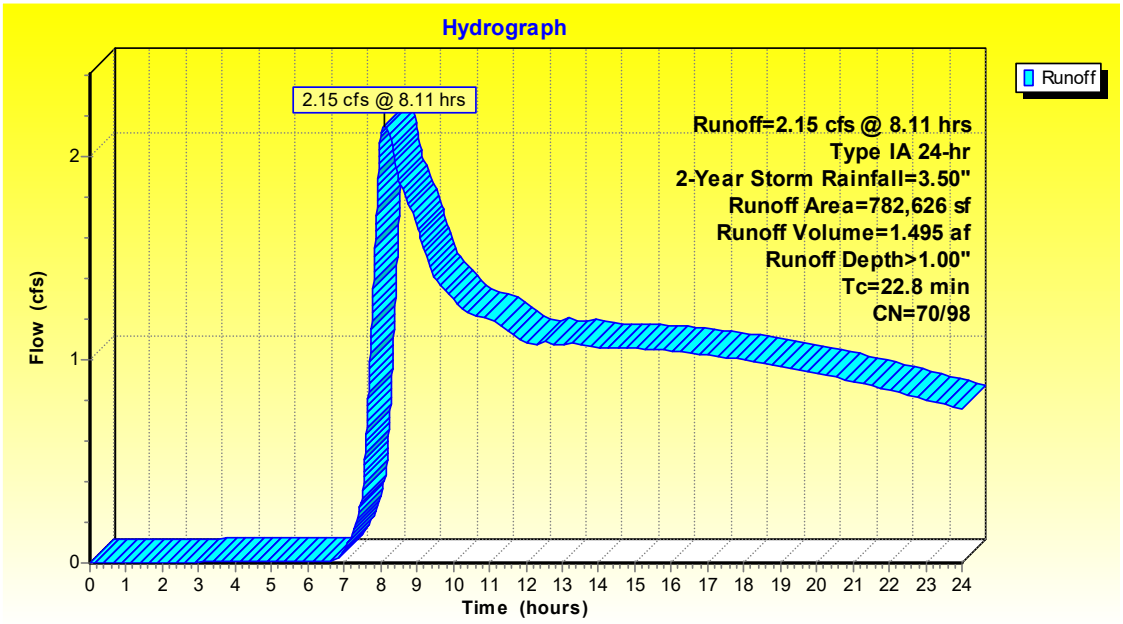
Runoff = 2.15 cfs @ 8.11 hrs, Volume= 1.495 af, Depth> 1.00"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type IA 24-hr 2-Year Storm Rainfall=3.50"

	Area (sf)	CN	Description
*	235,225	70	Woods, protected from grazing (50-75% ground cover)
*	516,708	70	Brush-weed-grass mixture with brush as the major element
*	15,695	89	Gravel/dirt roadway
*	2,220	98	Buildings - Home, barn, and shed
*	12,778	74	Pervious area near Kelso Road
	782,626	71	Weighted Average
	780,406	70	99.72% Pervious Area
	2,220	98	0.28% Impervious Area

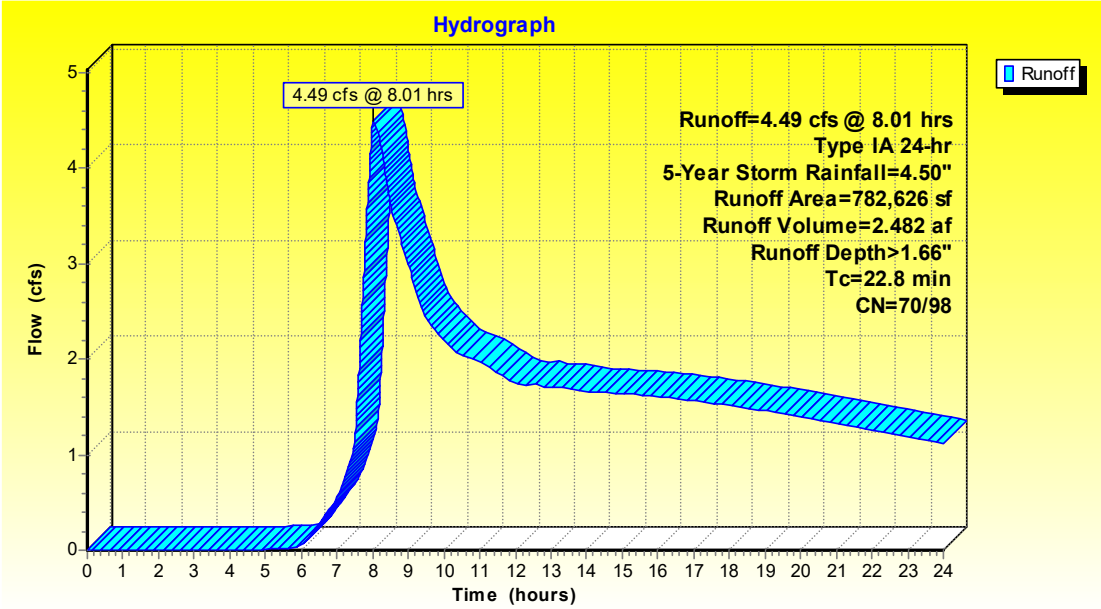
Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
22.8					Direct Entry, Direct Entry

2-YEAR STORM



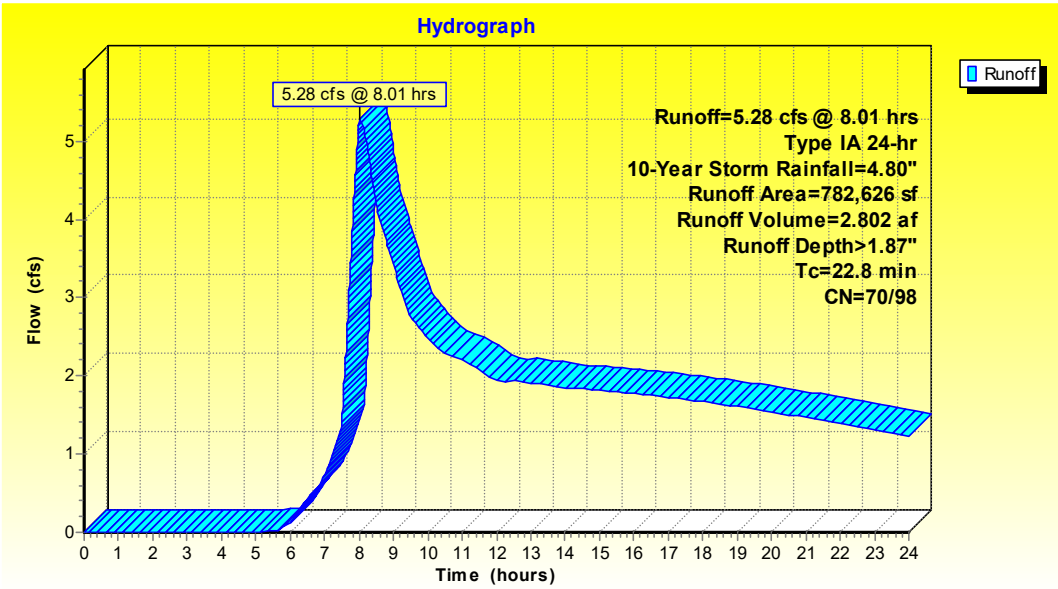
Per the above hydrograph, the runoff generated by the pre-developed conditions of the site is 2.15 cfs.

5-YEAR STORM



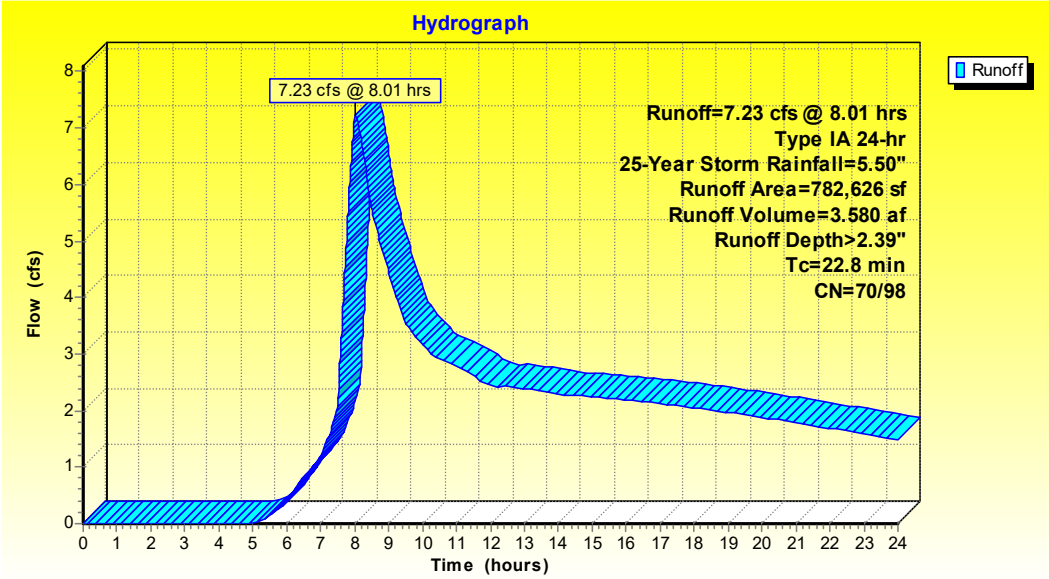
Per the above hydrograph, the runoff generated by the pre-developed conditions of the site is 4.49 cfs.

10-YEAR STORM



Per the above hydrograph, the runoff generated by the pre-developed conditions of the site is 5.28 cfs.

25-YEAR STORM



Per the above hydrograph, the runoff generated by the pre-developed conditions of the site is 7.23 cfs.

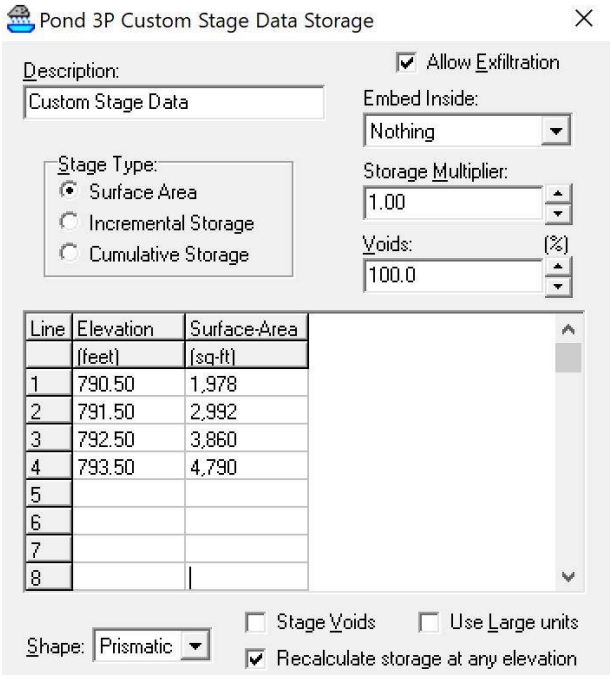
SUMMARY OF PRE-DEVELOPMENT PEAK FLOWS:

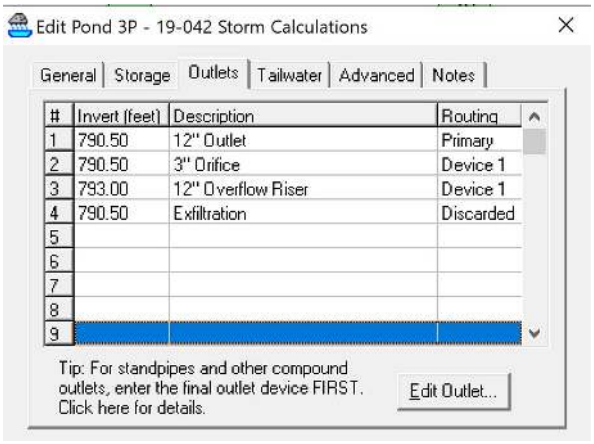
2-YEAR STORM	**Q = 2.15 cfs**
5-YEAR STORM	**Q = 4.49 cfs**
10-YEAR STORM	**Q = 5.28 cfs**
25-YEAR STORM	**Q = 7.23 cfs**

Post-Development Hydrographs:

Basin 1: The area of Kelso Road that is widened as well as the curb and sidewalks adjacent to the widening. That portion of the Kelso Road improvements will be conveyed to the proposed detention pond to the northwestern corner of the site. The outflow from this facility will release to the existing wetland in the northwestern corner of the site. Below is a design of the detention pond as modeled in HydroCAD.

Basin 1 Detention Pond Design:





2-YEAR STORM

Summary for Pond 3P: Basin 1 Detention Pond

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=738)

Inflow Area = 0.175 ac, 81.02% Impervious, Inflow Depth > 2.88" for 2-Year Storm event
Inflow = 0.12 cfs @ 7.89 hrs, Volume= 0.042 af
Outflow = 0.08 cfs @ 8.18 hrs, Volume= 0.042 af, Atten= 39%, Lag= 17.3 min
Discarded = 0.07 cfs @ 8.18 hrs, Volume= 0.042 af
Primary = 0.01 cfs @ 8.18 hrs, Volume= 0.000 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Peak Elev= 790.54' @ 8.18 hrs Surf.Area= 2,019 sf Storage= 81 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 2.5 min (679.3 - 676.8)

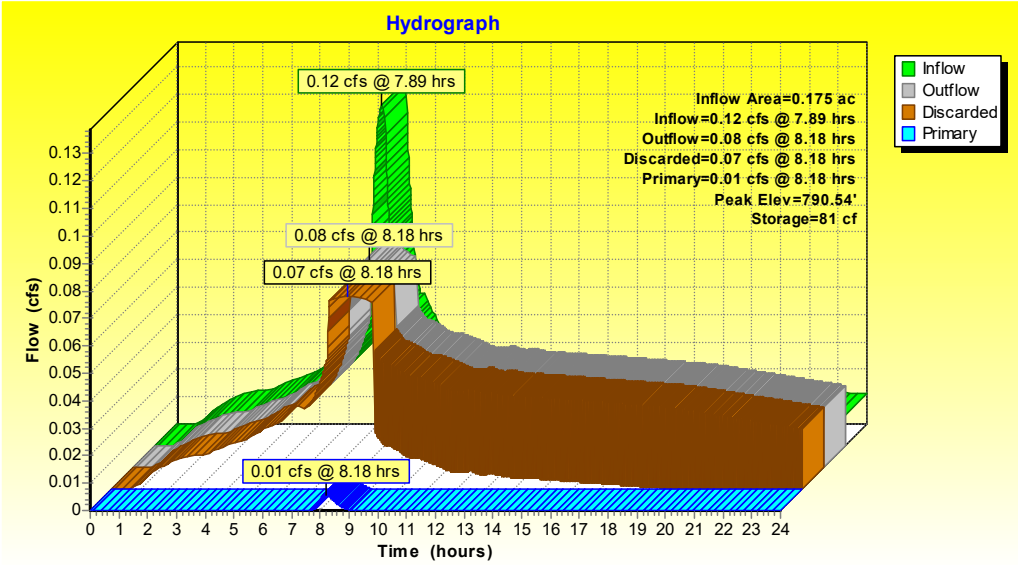
Volume	Invert	Avail.Storage	Storage Description
#1	790.50'	10,236 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
790.50	1,978	0	0
791.50	2,992	2,485	2,485
792.50	3,860	3,426	5,911
793.50	4,790	4,325	10,236

Device	Routing	Invert	Outlet Devices
#1	Primary	790.50'	**12.0" Round 12" Outlet** L= 50.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 790.50' / 790.00' S= 0.0100 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#2	Device 1	790.50'	**3.0" Horiz. 3" Orifice** C= 0.600 Limited to weir flow at low heads
#3	Device 1	793.00'	**3.1' long 12" Overflow Riser** 2 End Contraction(s)
#4	Discarded	790.50'	**1.500 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.07 cfs @ 8.18 hrs HW=790.54' (Free Discharge)
└**4=Exfiltration** (Exfiltration Controls 0.07 cfs)

Primary OutFlow Max=0.01 cfs @ 8.18 hrs HW=790.54' (Free Discharge)
└**1=12" Outlet** (Barrel Controls 0.01 cfs @ 0.84 fps)
  └**2=3" Orifice** (Passes 0.01 cfs of 0.02 cfs potential flow)
  └**3=12" Overflow Riser** (Controls 0.00 cfs)



Per the above hydrograph, the total runoff generated by the post-developed conditions of the site is 0.08 cfs. Since the brown hydrograph represents the discarded infiltration outflow which will not be released, this value will be excluded from the total release rate for the 2-year, 24-hour storm of the post-developed conditions. Therefore, the primary outflow from the structure (blue hydrograph) shall be the value for the release rate of this storm. The primary release rate is 0.01 cfs.

5-YEAR STORM

Summary for Pond 3P: Basin 1 Detention Pond

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=702)

Inflow Area = 0.175 ac, 81.02% Impervious, Inflow Depth > 3.82" for 5-Year Storm event
Inflow = 0.16 cfs @ 7.89 hrs, Volume= 0.056 af
Outflow = 0.09 cfs @ 8.23 hrs, Volume= 0.056 af, Atten= 44%, Lag= 20.3 min
Discarded = 0.07 cfs @ 8.23 hrs, Volume= 0.054 af
Primary = 0.02 cfs @ 8.23 hrs, Volume= 0.002 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Peak Elev= 790.57' @ 8.23 hrs Surf.Area= 2,052 sf Storage= 148 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 4.7 min (676.3 - 671.5)

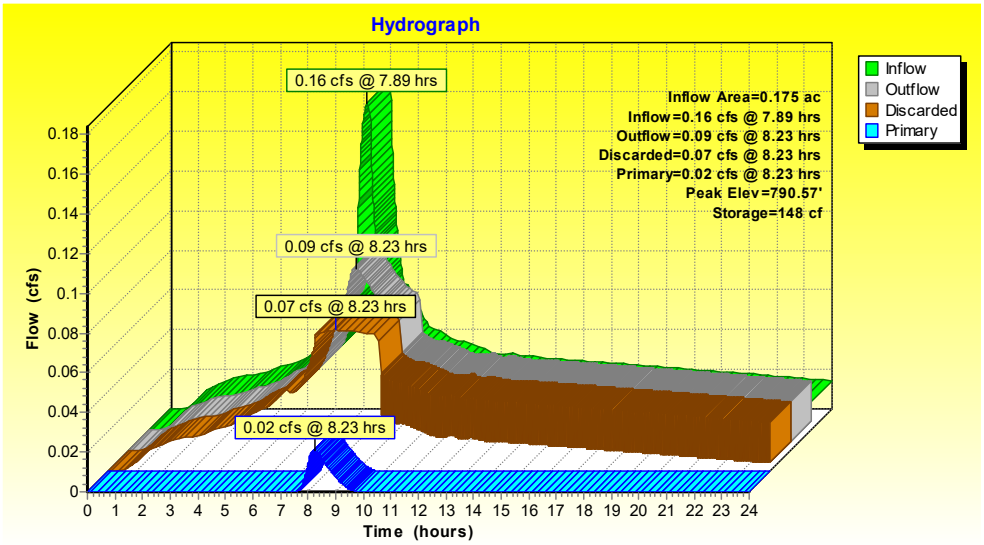
Volume	Invert	Avail.Storage	Storage Description
#1	790.50'	10,236 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
790.50	1,978	0	0
791.50	2,992	2,485	2,485
792.50	3,860	3,426	5,911
793.50	4,790	4,325	10,236

Device	Routing	Invert	Outlet Devices
#1	Primary	790.50'	**12.0" Round 12" Outlet** L= 50.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 790.50' / 790.00' S= 0.0100 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#2	Device 1	790.50'	**3.0" Horiz. 3" Orifice** C= 0.600 Limited to weir flow at low heads
#3	Device 1	793.00'	**3.1' long 12" Overflow Riser** 2 End Contraction(s)
#4	Discarded	790.50'	**1.500 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.07 cfs @ 8.23 hrs HW=790.57' (Free Discharge)
└**4=Exfiltration** (Exfiltration Controls 0.07 cfs)

Primary OutFlow Max=0.02 cfs @ 8.23 hrs HW=790.57' (Free Discharge)
└**1=12" Outlet** (Barrel Controls 0.02 cfs @ 1.23 fps)
  └**2=3" Orifice** (Passes 0.02 cfs of 0.05 cfs potential flow)
  └**3=12" Overflow Riser** (Controls 0.00 cfs)



Per the above hydrograph, the total runoff generated by the post-developed conditions of the site is 0.09 cfs. Since the brown hydrograph represents the discarded infiltration outflow which will not be released, this value will be excluded from the total release rate for the 5-year, 24-hour storm of the post-developed conditions. Therefore, the primary outflow from the structure (blue hydrograph) shall be the value for the release rate of this storm. The primary release rate is 0.02 cfs.

10-YEAR STORM

Summary for Pond 3P: Basin 1 Detention Pond

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=691)

Inflow Area = 0.175 ac, 81.02% Impervious, Inflow Depth > 4.11" for 10-Year Storm event
Inflow = 0.18 cfs @ 7.89 hrs, Volume= 0.060 af
Outflow = 0.10 cfs @ 8.23 hrs, Volume= 0.060 af, Atten= 44%, Lag= 20.5 min
Discarded = 0.07 cfs @ 8.23 hrs, Volume= 0.058 af
Primary = 0.03 cfs @ 8.23 hrs, Volume= 0.002 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Peak Elev= 790.58' @ 8.23 hrs Surf.Area= 2,062 sf Storage= 167 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 5.5 min (675.8 - 670.3)

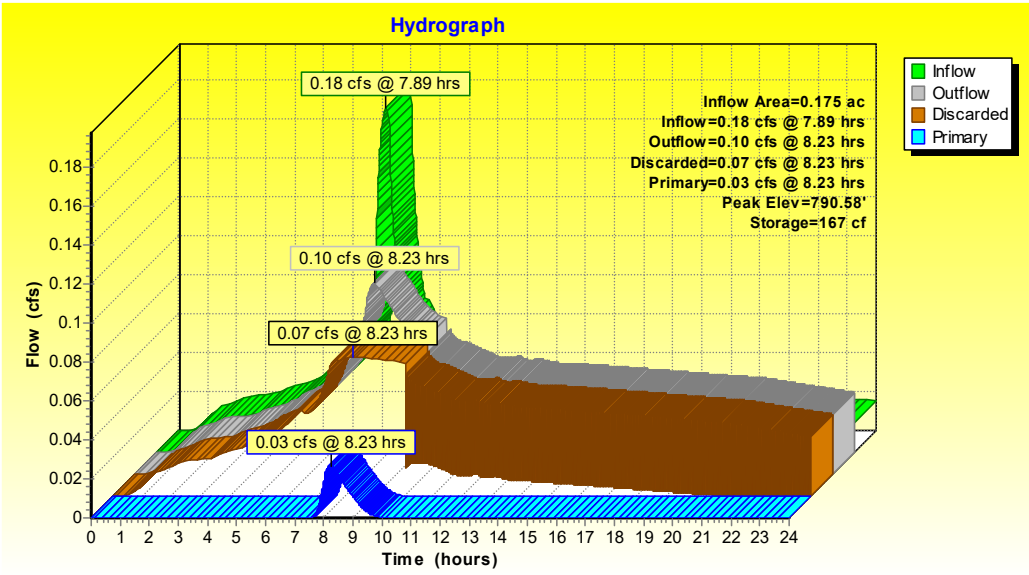
Volume	Invert	Avail.Storage	Storage Description
#1	790.50'	10,236 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
790.50	1,978	0	0
791.50	2,992	2,485	2,485
792.50	3,860	3,426	5,911
793.50	4,790	4,325	10,236

Device	Routing	Invert	Outlet Devices
#1	Primary	790.50'	**12.0" Round 12" Outlet** L= 50.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 790.50' / 790.00' S= 0.0100 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#2	Device 1	790.50'	**3.0" Horiz. 3" Orifice** C= 0.600 Limited to weir flow at low heads
#3	Device 1	793.00'	**3.1' long 12" Overflow Riser** 2 End Contraction(s)
#4	Discarded	790.50'	**1.500 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.07 cfs @ 8.23 hrs HW=790.58' (Free Discharge)
└**4=Exfiltration** (Exfiltration Controls 0.07 cfs)

Primary OutFlow Max=0.03 cfs @ 8.23 hrs HW=790.58' (Free Discharge)
└**1=12" Outlet** (Barrel Controls 0.03 cfs @ 1.32 fps)
  ├**2=3" Orifice** (Passes 0.03 cfs of 0.06 cfs potential flow)
  └**3=12" Overflow Riser** (Controls 0.00 cfs)



Per the above hydrograph, the total runoff generated by the post-developed conditions of the site is 0.10 cfs. Since the brown hydrograph represents the discarded infiltration outflow which will not be released, this value will be excluded from the total release rate for the 10-year, 24-hour storm of the post-developed conditions. Therefore, the primary outflow from the structure (blue hydrograph) shall be the value for the release rate of this storm. The primary release rate is 0.03 cfs.

25-YEAR STORM

Summary for Pond 3P: Basin 1 Detention Pond

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=668)

Inflow Area = 0.175 ac, 81.02% Impervious, Inflow Depth > 4.78" for 25-Year Storm event
Inflow = 0.21 cfs @ 7.89 hrs, Volume= 0.070 af
Outflow = 0.12 cfs @ 8.22 hrs, Volume= 0.070 af, Atten= 44%, Lag= 20.2 min
Discarded = 0.07 cfs @ 8.22 hrs, Volume= 0.066 af
Primary = 0.04 cfs @ 8.22 hrs, Volume= 0.004 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Peak Elev= 790.60' @ 8.22 hrs Surf.Area= 2,084 sf Storage= 211 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 6.8 min (674.4 - 667.6)

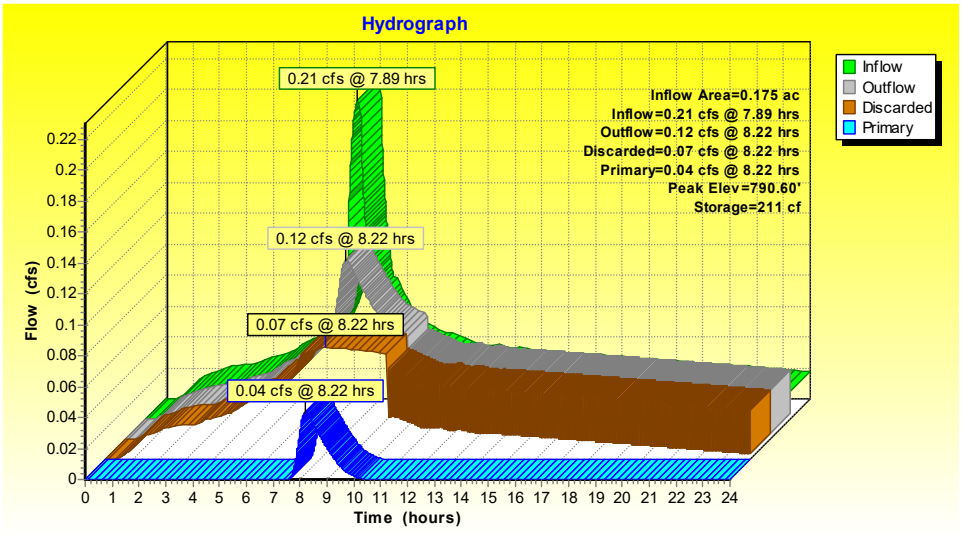
Volume	Invert	Avail.Storage	Storage Description
#1	790.50'	10,236 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
790.50	1,978	0	0
791.50	2,992	2,485	2,485
792.50	3,860	3,426	5,911
793.50	4,790	4,325	10,236

Device	Routing	Invert	Outlet Devices
#1	Primary	790.50'	**12.0" Round 12" Outlet** L= 50.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 790.50' / 790.00' S= 0.0100 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#2	Device 1	790.50'	**3.0" Horiz. 3" Orifice** C= 0.600 Limited to weir flow at low heads
#3	Device 1	793.00'	**3.1' long 12" Overflow Riser** 2 End Contraction(s)
#4	Discarded	790.50'	**1.500 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=0.07 cfs @ 8.22 hrs HW=790.60' (Free Discharge)
└**4=Exfiltration** (Exfiltration Controls 0.07 cfs)

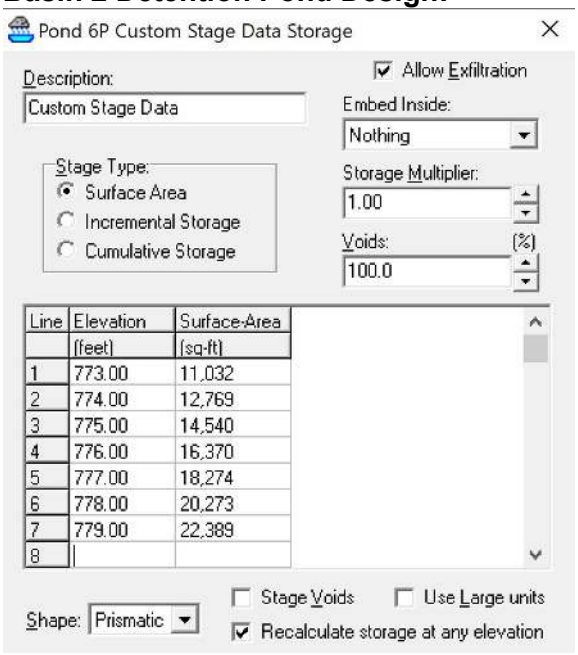
Primary OutFlow Max=0.04 cfs @ 8.22 hrs HW=790.60' (Free Discharge)
└**1=12" Outlet** (Barrel Controls 0.04 cfs @ 1.52 fps)
  ├**2=3" Orifice** (Passes 0.04 cfs of 0.08 cfs potential flow)
  └**3=12" Overflow Riser** (Controls 0.00 cfs)

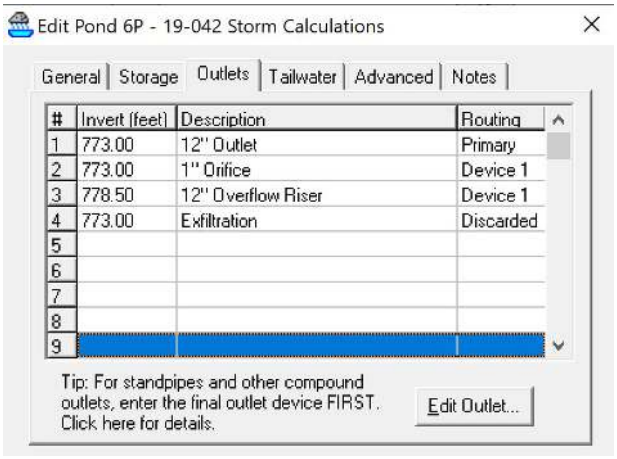


Per the above hydrograph, the total runoff generated by the post-developed conditions of the site is 0.12 cfs. Since the brown hydrograph represents the discarded infiltration outflow which will not be released, this value will be excluded from the total release rate for the 25-year, 24-hour storm of the post-developed conditions. Therefore, the primary outflow from the structure (blue hydrograph) shall be the value for the release rate of this storm. The primary release rate is 0.04 cfs.

Basin 2: This includes the on-site improvements consisting of roads, curbs, sidewalks, driveways, and the lot areas of the development. The runoff from the improvements will be conveyed via piping and grading to a detention pond to the south side of the site. Below is a design of the detention pond as modeled in HydroCAD.

Basin 2 Detention Pond Design:





2-YEAR STORM

Summary for Pond 6P: Basin 2 Detention Pond

[87] Warning: Oscillations may require smaller dt or Finer Routing (severity=253)

Inflow Area = 11.597 ac, 39.91% Impervious, Inflow Depth > 2.04" for 2-Year Storm event
Inflow = 5.17 cfs @ 8.00 hrs, Volume= 1.971 af
Outflow = 1.49 cfs @ 9.89 hrs, Volume= 1.971 af, Atten= 71%, Lag= 113.9 min
Discarded = 1.47 cfs @ 9.89 hrs, Volume= 1.953 af
Primary = 0.03 cfs @ 9.89 hrs, Volume= 0.018 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Peak Elev= 773.94' @ 9.89 hrs Surf.Area= 12,666 sf Storage= 11,147 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 53.3 min (786.5 - 733.3)

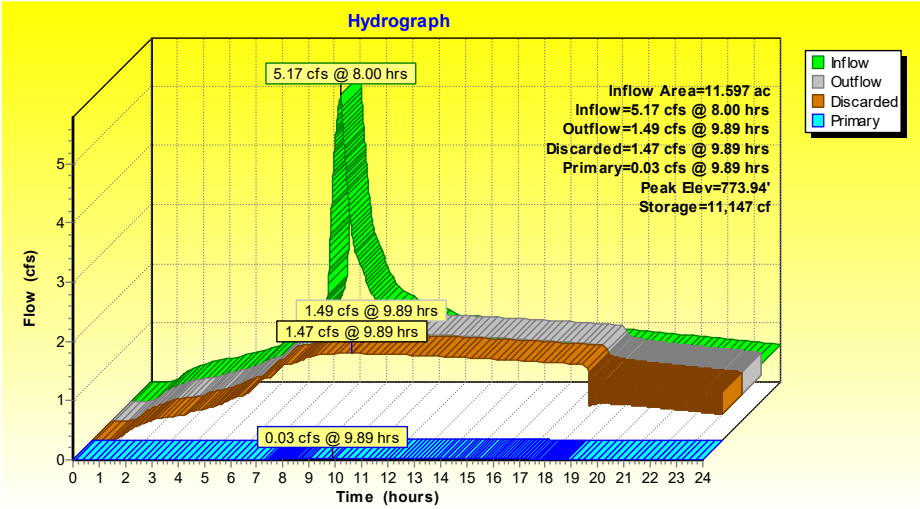
Volume	Invert	Avail.Storage	Storage Description
#1	773.00'	98,937 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
773.00	11,032	0	0
774.00	12,769	11,901	11,901
775.00	14,540	13,655	25,555
776.00	16,370	15,455	41,010
777.00	18,274	17,322	58,332
778.00	20,273	19,274	77,606
779.00	22,389	21,331	98,937

Device	Routing	Invert	Outlet Devices
#1	Primary	773.00'	**12.0" Round 12" Outlet** L= 50.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 773.00' / 772.50' S= 0.0100 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#2	Device 1	773.00'	**1.0" Horiz. 1" Orifice** C= 0.600 Limited to weir flow at low heads
#3	Device 1	778.50'	**3.1' long 12" Overflow Riser** 2 End Contraction(s)
#4	Discarded	773.00'	**5.000 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=1.47 cfs @ 9.89 hrs HW=773.94' (Free Discharge)
└**4=Exfiltration** (Exfiltration Controls 1.47 cfs)

Primary OutFlow Max=0.03 cfs @ 9.89 hrs HW=773.94' (Free Discharge)
└**1=12" Outlet** (Passes 0.03 cfs of 2.60 cfs potential flow)
  ├**2=1" Orifice** (Orifice Controls 0.03 cfs @ 4.67 fps)
  └**3=12" Overflow Riser** (Controls 0.00 cfs)



Per the above hydrograph, the total runoff generated by the post-developed conditions of the site is 1.49 cfs. Since the brown hydrograph represents the discarded infiltration outflow which will not be released, this value will be excluded from the total release rate for the 2-year, 24-hour storm of the post-developed conditions. Therefore, the primary outflow from the structure (blue hydrograph) shall be the value for the release rate of this storm. The primary release rate is 0.03 cfs.

5-YEAR STORM

Summary for Pond 6P: Basin 2 Detention Pond

Inflow Area = 11.597 ac, 39.91% Impervious, Inflow Depth > 2.87" for 5-Year Storm event
Inflow = 7.49 cfs @ 8.00 hrs, Volume= 2.778 af
Outflow = 1.69 cfs @ 11.45 hrs, Volume= 2.605 af, Atten= 77%, Lag= 207.4 min
Discarded = 1.65 cfs @ 11.45 hrs, Volume= 2.562 af
Primary = 0.04 cfs @ 11.45 hrs, Volume= 0.043 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Peak Elev= 774.85' @ 11.45 hrs Surf.Area= 14,270 sf Storage= 23,358 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 106.5 min (832.7 - 726.2)

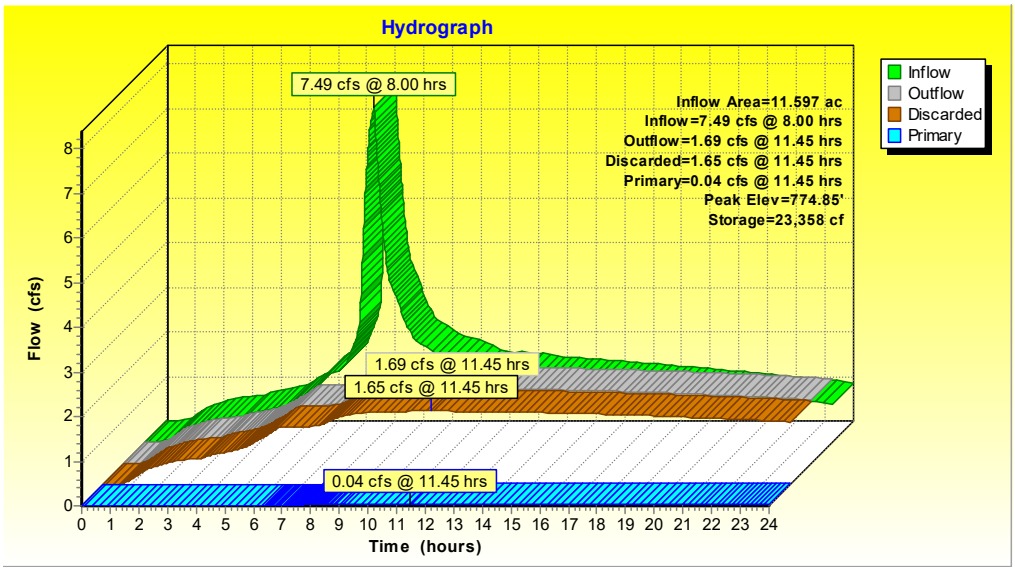
Volume	Invert	Avail.Storage	Storage Description
#1	773.00'	98,937 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
773.00	11,032	0	0
774.00	12,769	11,901	11,901
775.00	14,540	13,655	25,555
776.00	16,370	15,455	41,010
777.00	18,274	17,322	58,332
778.00	20,273	19,274	77,606
779.00	22,389	21,331	98,937

Device	Routing	Invert	Outlet Devices
#1	Primary	773.00'	**12.0" Round 12" Outlet** L= 50.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 773.00' / 772.50' S= 0.0100 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#2	Device 1	773.00'	**1.0" Horiz. 1" Orifice** C= 0.600 Limited to weir flow at low heads
#3	Device 1	778.50'	**3.1' long 12" Overflow Riser** 2 End Contraction(s)
#4	Discarded	773.00'	**5.000 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=1.65 cfs @ 11.45 hrs HW=774.85' (Free Discharge)
└**4=Exfiltration** (Exfiltration Controls 1.65 cfs)

Primary OutFlow Max=0.04 cfs @ 11.45 hrs HW=774.85' (Free Discharge)
└**1=12" Outlet** (Passes 0.04 cfs of 4.40 cfs potential flow)
  ├**2=1" Orifice** (Orifice Controls 0.04 cfs @ 6.54 fps)
  └**3=12" Overflow Riser** (Controls 0.00 cfs)



Per the above hydrograph, the total runoff generated by the post-developed conditions of the site is 1.69 cfs. Since the brown hydrograph represents the discarded infiltration outflow which will not be released, this value will be excluded from the total release rate for the 5-year, 24-hour storm of the post-developed conditions. Therefore, the primary outflow from the structure (blue hydrograph) shall be the value for the release rate of this storm. The primary release rate is 0.04 cfs.

10-YEAR STORM

Summary for Pond 6P: Basin 2 Detention Pond

Inflow Area = 11.597 ac, 39.91% Impervious, Inflow Depth > 3.13" for 10-Year Storm event
Inflow = 8.21 cfs @ 8.00 hrs, Volume= 3.028 af
Outflow = 1.75 cfs @ 11.66 hrs, Volume= 2.732 af, Atten= 79%, Lag= 219.8 min
Discarded = 1.71 cfs @ 11.66 hrs, Volume= 2.684 af
Primary = 0.04 cfs @ 11.66 hrs, Volume= 0.048 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Peak Elev= 775.15' @ 11.66 hrs Surf.Area= 14,813 sf Storage= 27,747 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 109.2 min (833.4 - 724.2)

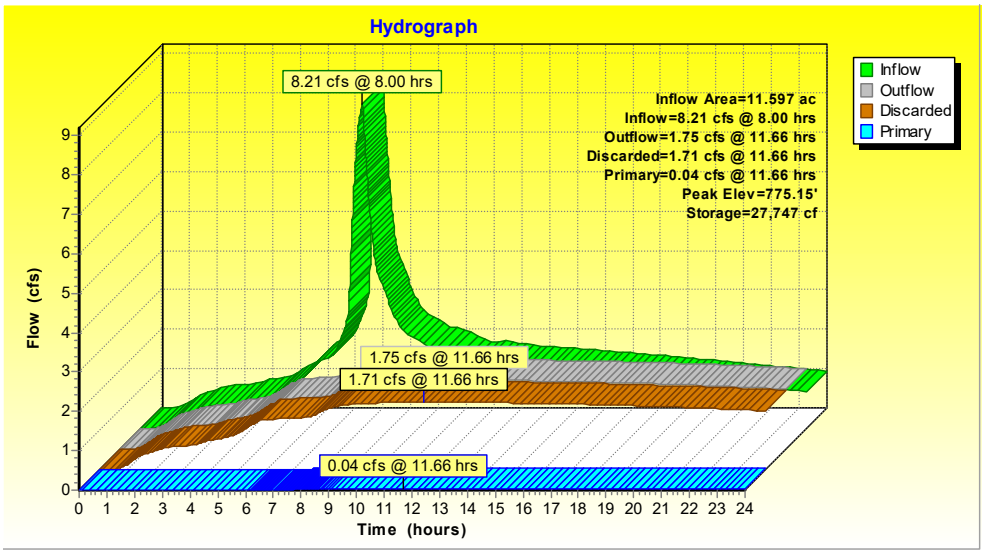
Volume	Invert	Avail.Storage	Storage Description
#1	773.00'	98,937 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
773.00	11,032	0	0
774.00	12,769	11,901	11,901
775.00	14,540	13,655	25,555
776.00	16,370	15,455	41,010
777.00	18,274	17,322	58,332
778.00	20,273	19,274	77,606
779.00	22,389	21,331	98,937

Device	Routing	Invert	Outlet Devices
#1	Primary	773.00'	**12.0" Round 12" Outlet** L= 50.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 773.00' / 772.50' S= 0.0100 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#2	Device 1	773.00'	**1.0" Horiz. 1" Orifice** C= 0.600 Limited to weir flow at low heads
#3	Device 1	778.50'	**3.1' long 12" Overflow Riser** 2 End Contraction(s)
#4	Discarded	773.00'	**5.000 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=1.71 cfs @ 11.66 hrs HW=775.15' (Free Discharge)
└**4=Exfiltration** (Exfiltration Controls 1.71 cfs)

Primary OutFlow Max=0.04 cfs @ 11.66 hrs HW=775.15' (Free Discharge)
└**1=12" Outlet** (Passes 0.04 cfs of 4.86 cfs potential flow)
  ├**2=1" Orifice** (Orifice Controls 0.04 cfs @ 7.06 fps)
  └**3=12" Overflow Riser** (Controls 0.00 cfs)



Per the above hydrograph, the total runoff generated by the post-developed conditions of the site is 1.75 cfs. Since the brown hydrograph represents the discarded infiltration outflow which will not be released, this value will be excluded from the total release rate for the 10-year, 24-hour storm of the post-developed conditions. Therefore, the primary outflow from the structure (blue hydrograph) shall be the value for the release rate of this storm. The primary release rate is 0.04 cfs.

25-YEAR STORM

Summary for Pond 6P: Basin 2 Detention Pond

Inflow Area = 11.597 ac, 39.91% Impervious, Inflow Depth > 3.75" for 25-Year Storm event
Inflow = 9.94 cfs @ 8.00 hrs, Volume= 3.623 af
Outflow = 1.91 cfs @ 13.44 hrs, Volume= 3.023 af, Atten= 81%, Lag= 326.7 min
Discarded = 1.87 cfs @ 13.44 hrs, Volume= 2.965 af
Primary = 0.04 cfs @ 13.44 hrs, Volume= 0.059 af

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Peak Elev= 775.88' @ 13.44 hrs Surf.Area= 16,157 sf Storage= 39,115 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 115.2 min (835.1 - 719.8)

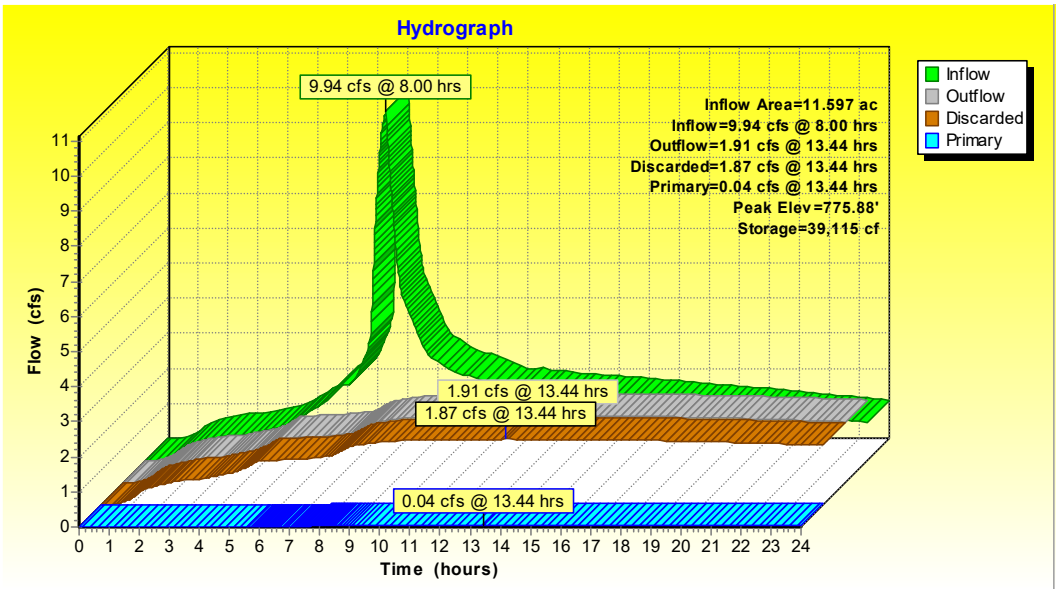
Volume	Invert	Avail.Storage	Storage Description
#1	773.00'	98,937 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
773.00	11,032	0	0
774.00	12,769	11,901	11,901
775.00	14,540	13,655	25,555
776.00	16,370	15,455	41,010
777.00	18,274	17,322	58,332
778.00	20,273	19,274	77,606
779.00	22,389	21,331	98,937

Device	Routing	Invert	Outlet Devices
#1	Primary	773.00'	**12.0" Round 12" Outlet** L= 50.0' RCP, groove end projecting, Ke= 0.200 Inlet / Outlet Invert= 773.00' / 772.50' S= 0.0100 '/' Cc= 0.900 n= 0.013, Flow Area= 0.79 sf
#2	Device 1	773.00'	**1.0" Horiz. 1" Orifice** C= 0.600 Limited to weir flow at low heads
#3	Device 1	778.50'	**3.1' long 12" Overflow Riser** 2 End Contraction(s)
#4	Discarded	773.00'	**5.000 in/hr Exfiltration over Surface area**

Discarded OutFlow Max=1.87 cfs @ 13.44 hrs HW=775.88' (Free Discharge)
└**4=Exfiltration** (Exfiltration Controls 1.87 cfs)

Primary OutFlow Max=0.04 cfs @ 13.44 hrs HW=775.88' (Free Discharge)
└**1=12" Outlet** (Passes 0.04 cfs of 5.85 cfs potential flow)
  ├**2=1" Orifice** (Orifice Controls 0.04 cfs @ 8.18 fps)
  └**3=12" Overflow Riser** (Controls 0.00 cfs)



Per the above hydrograph, the total runoff generated by the post-developed conditions of the site is 1.91 cfs. Since the brown hydrograph represents the discarded infiltration outflow which will not be released, this value will be excluded from the total release rate for the 25-year, 24-hour storm of the post-developed conditions. Therefore, the primary outflow from the structure (blue hydrograph) shall be the value for the release rate of this storm. The primary release rate is 0.04 cfs.

Basin 3: The undisturbed areas around the drainageways will go directly to the drainageways undetained, yet will still be included in the calculations.

2-YEAR STORM

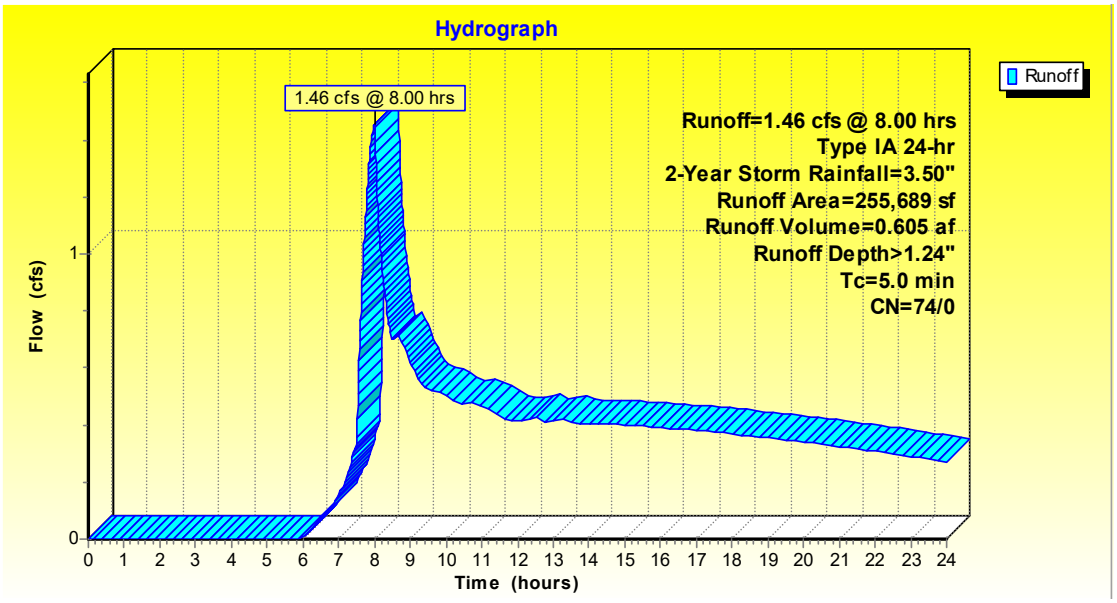
Summary for Subcatchment 5S: Post-Developed Conditions - Basin 3 (Undetained Existing Areas)

Runoff = 1.46 cfs @ 8.00 hrs, Volume= 0.605 af, Depth> 1.24"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type IA 24-hr 2-Year Storm Rainfall=3.50"

	Area (sf)	CN	Description
*	131,301	74	Undetained existing area draining to northwest drainageway
*	124,388	74	Undetained existing area draining to southerly drainageway
	255,689	74	Weighted Average
	255,689	74	100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct Entry**



Per the above hydrograph, the total runoff generated by the pre/post-developed conditions of the undisturbed and undetained area is 1.46 cfs.

5-YEAR STORM

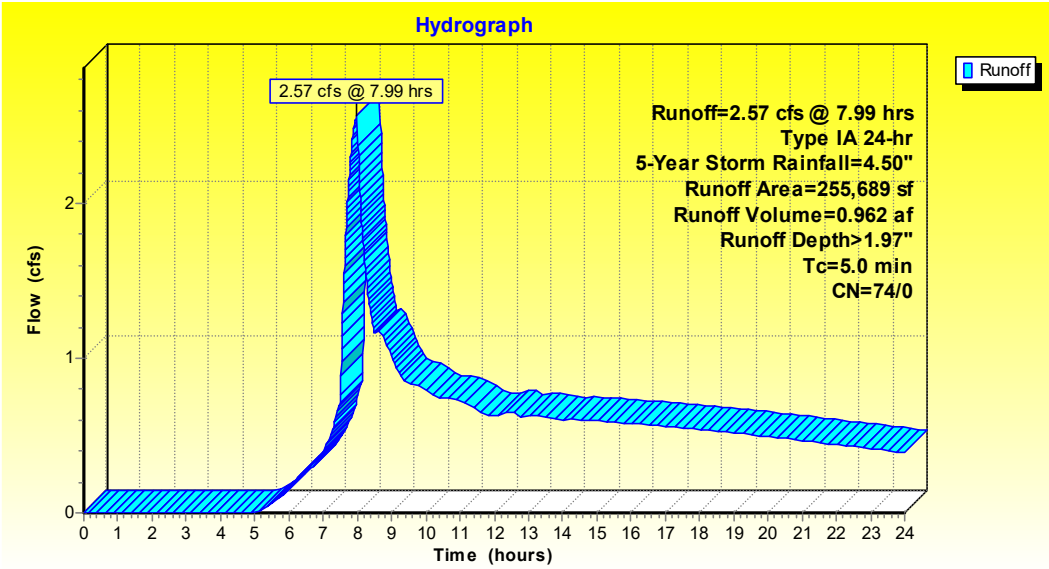
Summary for Subcatchment 5S: Post-Developed Conditions - Basin 3 (Undetained Existing Areas)

Runoff = 2.57 cfs @ 7.99 hrs, Volume= 0.962 af, Depth> 1.97"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type IA 24-hr 5-Year Storm Rainfall=4.50"

	Area (sf)	CN	Description
*	131,301	74	Undetained existing area draining to northwest drainageway
*	124,388	74	Undetained existing area draining to southerly drainageway
	255,689	74	Weighted Average
	255,689	74	100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct Entry**



Per the above hydrograph, the total runoff generated by the pre/post-developed conditions of the undisturbed and undetained area is 2.57 cfs.

10-YEAR STORM

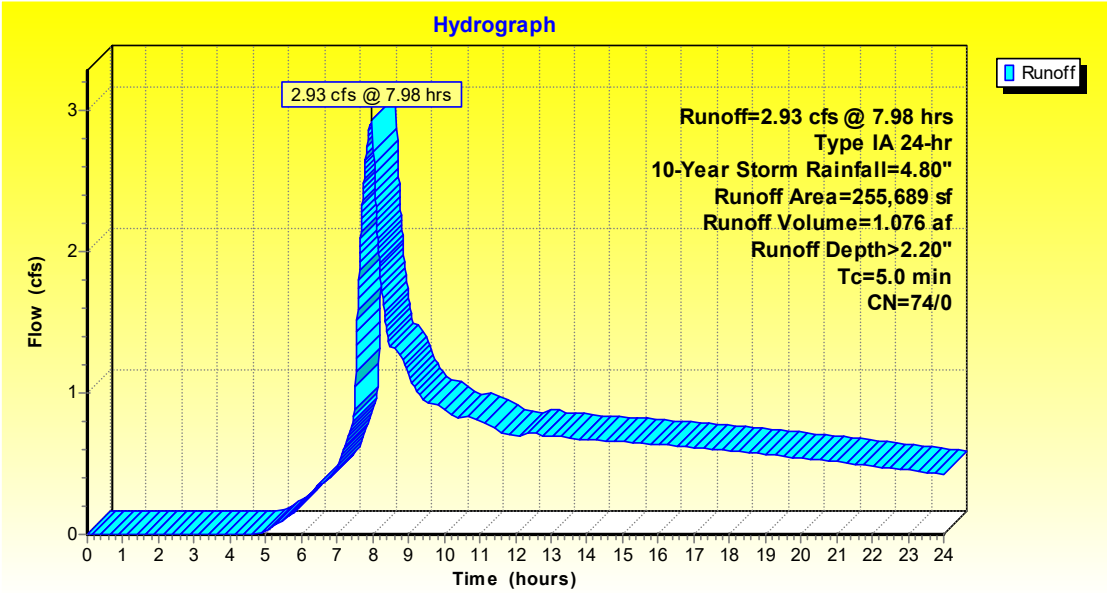
Summary for Subcatchment 5S: Post-Developed Conditions - Basin 3 (Undetained Existing Areas)

Runoff = 2.93 cfs @ 7.98 hrs, Volume= 1.076 af, Depth> 2.20"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type IA 24-hr 10-Year Storm Rainfall=4.80"

	Area (sf)	CN	Description
*	131,301	74	Undetained existing area draining to northwest drainageway
*	124,388	74	Undetained existing area draining to southerly drainageway
	255,689	74	Weighted Average
	255,689	74	100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct Entry**



Per the above hydrograph, the total runoff generated by the pre/post-developed conditions of the undisturbed and undetained area is 2.93 cfs.

25-YEAR STORM

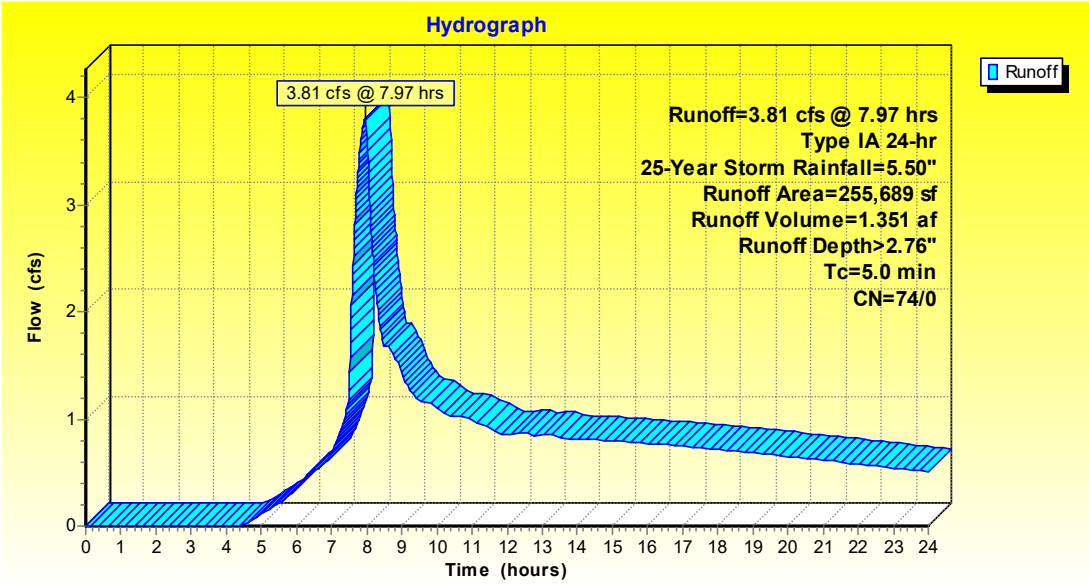
Summary for Subcatchment 5S: Post-Developed Conditions - Basin 3 (Undetained Existing Areas)

Runoff = 3.81 cfs @ 7.97 hrs, Volume= 1.351 af, Depth> 2.76"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
Type IA 24-hr 25-Year Storm Rainfall=5.50"

	Area (sf)	CN	Description
*	131,301	74	Undetained existing area draining to northwest drainageway
*	124,388	74	Undetained existing area draining to southerly drainageway
	255,689	74	Weighted Average
	255,689	74	100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.0					**Direct Entry, Direct Entry**



Per the above hydrograph, the total runoff generated by the pre/post-developed conditions of the undisturbed and undetained area is 3.81 cfs.

SUMMARY OF POST-DEVELOPMENT PEAK FLOW FOR EACH BASIN:

Basin	2-YEAR	5-YEAR	10-YEAR	25-YEAR
1	0.01	0.02	0.03	0.04
2	0.03	0.04	0.04	0.04
3	1.46	2.57	2.93	3.81

SUMMARY: PRE-DEVELOPMENT PEAK FLOW vs. POST DEVELOPMENT PEAK FLOW:

STORM	PRE-DEVELOPMENT	POST-DEVELOPMENT
2-YEAR STORM	**Q = 2.15 cfs**	**Q = 1.50 cfs**
5-YEAR STORM	**Q = 4.49 cfs**	**Q = 2.63 cfs**
10-YEAR STORM	**Q = 5.28 cfs**	**Q = 3.00 cfs**
25-YEAR STORM	**Q = 7.23 cfs**	**Q = 3.89 cfs**

All Post Development peak flows are at or below pre-development peak flow rates ✓

The detention requirements for City of Sandy have been met ✓

City of Sandy Water Quality Requirements:

As mentioned earlier in this report, City of Sandy Municipal Stormwater Standards require all developments to treat 80 percent of the average annual volume of storm water runoff for the site. This standard can be met by installing storm water quality treatment facilities to satisfy the following design criteria:

A. Detention based storm water quality control: The required design volume for detention-based control is equal to the entire runoff volume that would occur from a site with a 1.2–inch, 12-hour storm. The draw-down time for the entire volume must be greater than or equal to 48 hours. For the lower half of the detention volume, the drawdown time must be greater than 36 hours. Additional design criteria for inlet and outlet spacing and design, as well as guidelines for calculating volumes, are contained in the Public Works Department Standards.
B. Flow-through based storm water quality control: the required design flow rate for treatment is the runoff that would be produced from a rainfall intensity of 0.2 inches/hour for on-line facilities, and 0.11 inches/hour for off-line facilities. This rate must be maintainable for a minimum of three hours. Additional design criteria for flow calculation, as well as specific treatment criteria for various types of storm water facilities (e.g., infiltration and storm water filters), are contained in the Public Works Standards.
C. Combination detention based on flow-through based storm water quality control: Detention facilities may be combined with flow-through facilities. The applicant must demonstrate that the combined system could sufficiently treat storm water runoff for the runoff produced by the flow-through treatment rates of 0.2 inches/hour (on-line facilities), occurring for a three-hour period.

Per City of Sandy Municipal Code standards, the following flow-through based storm water quality control design rates are to be used: The required design flow rate for treatment is the runoff that would be produced from a rainfall intensity of 0.2 inches/hour for on-line facilities, and 0.11 inches/hour for off-line facilities. This rate must be maintainable for a minimum of three hours. Additional design criteria for flow calculation, as well as specific treatment criteria for various types of storm water facilities (e.g., infiltration and storm water filters), are contained in the Public Works Standards.

Basin 1:

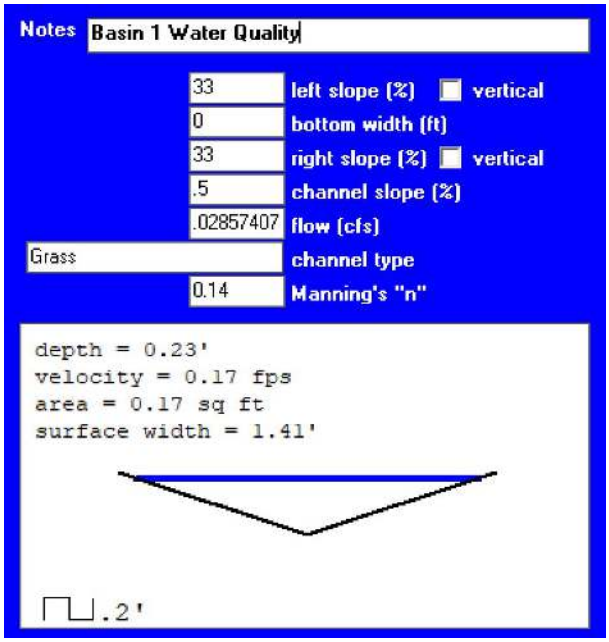
Basin 1 will utilize a water quality swale within the detention pond to the northwest corner of the site to meet the water quality requirements. The water quality swale will be a 6-foot wide x 144-foot long swale, at 0.5% slope, having 3:1 side slopes. Per ODOT hydraulics manual the Manning's n for a depth of flow up to 0.70 feet and a fair stand of grass in a maintained channel is 0.14 maximum.

The required design flow rate for treatment is the runoff that would be produced from a rainfall intensity of 0.20 inches/hour for 3 hours.

$$\text{Water Quality Flow (cfs)} = \frac{0.60 \text{ (in.)} \times \text{Area (sq.ft.)}}{12\text{(in/ft)}(3 \text{ hr})(60 \text{ min/hr})(60 \text{ sec/min})}$$

$$\text{Water Quality Flow (cfs)} = \frac{0.60 \text{ (in)} \times (0.1417 \text{ Acres})(43{,}560 \text{ sf/Ac})}{12\text{(in/ft)}(3 \text{ hr})(60 \text{ min/hr})(60 \text{ sec/min})}$$

Water Quality Flow (cfs) = 0.03 cfs



Velocity is 0.17 feet per second. Therefore, the residence time in a 144-foot-long swale would be:

$$\frac{144 \text{ feet}}{0.17 \text{ feet/sec}} = 847 \text{ seconds} = \mathbf{14.12 \text{ minutes}}$$

Since the City of Sandy references the City of Portland BES manual, a 9 minute residence time is the threshold for achieving water quality through a grassy swale. Therefore, the facility meets City of Sandy requirements for flow-through based storm water quality control. ✓

Basin 2:

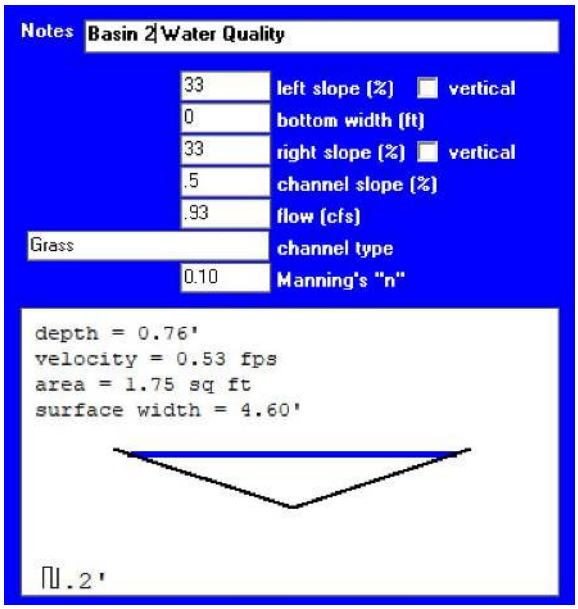
Basin 2 will utilize a water quality swale within the detention pond to the southwest corner of the site to meet the water quality requirements. The water quality swale will consist of three 10-foot wide x 135-foot long swales, at 0.5% slope, having 3:1 side slopes. Per ODOT hydraulics manual the Manning's n for a depth of flow up between 0.70 feet and 1.50 feet and a fair stand of grass in a maintained channel is 0.10 maximum.

The required design flow rate for treatment is the runoff that would be produced from a rainfall intensity of 0.20 inches/hour for 3 hours.

$$\text{Water Quality Flow (cfs)} = \frac{0.60 \text{ (in.)} \times \text{Area (sq.ft.)}}{12\text{(in/ft)}(3 \text{ hr})(60 \text{ min/hr})(60 \text{ sec/min})}$$

$$\text{Water Quality Flow (cfs)} = \frac{0.60 \text{ (in)} \times (4.63 \text{ Acres})(43{,}560 \text{ sf/Ac})}{12\text{(in/ft)}(3 \text{ hr})(60 \text{ min/hr})(60 \text{ sec/min})}$$

Water Quality Flow (cfs) = 0.93 cfs



Velocity is 0.53 feet per second. Therefore, the residence time in a 135-foot-long swale would be:

$$\frac{135 \text{ feet}}{0.53 \text{ feet/sec}} = 255 \text{ seconds} = 4.25 \text{ minutes}$$

Since there are three, parallel swales of roughly the same dimensions, the residence time can be multiplied by three to yield a total residence time of **12.75 minutes.**

Since the City of Sandy references the City of Portland BES manual, a 9 minute residence time is the threshold for achieving water quality through a grassy swale. Therefore, the facility meets City of Sandy requirements for flow-through based storm water quality control. ✓

Conclusion/Summary:

This report demonstrates compliance with the storm water requirements of the City of Sandy.

Detention:
City of Sandy has detention requirements for storm events ranging from the 2-year storm through the 25-year storm.

This report has used the HydroCAD to demonstrate that all storms between the 2-year storm event and the 25-year storm event will release at or below pre-development release levels.

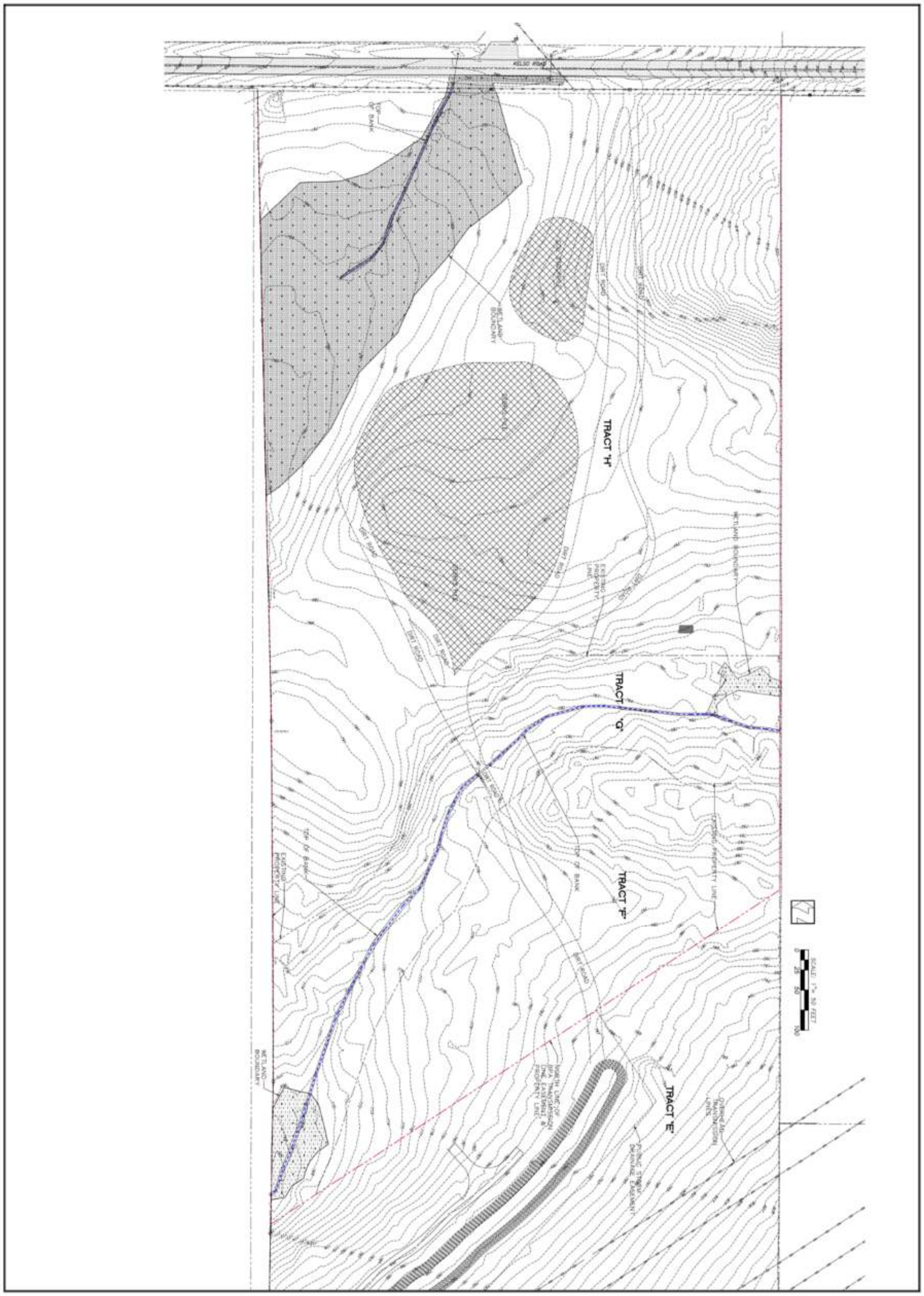
HydroCAD was used because the rainfall rates for Sandy cannot be modeled using City of Portland's PAC calculator or the Western Washington Model.

Water Quality Treatment:
The City of Sandy has detention requirements to treat 80% of total annual runoff through either a) detention based water quality treatment, b) flow through based water quality treatment, or c) a combination of detention based and flow through based water quality treatment.

This report has demonstrated that using a water quality swale in the bottom of each detention pond, the water quality treatment will meet City of Sandy's for water quality treatment.

Appendix A:

Pre-Development Site Drainage Map



SISUL ENGINEERING
375 PORTLAND AVENUE
GLADSTONE, OREGON 97027
(503) 657-0188

SHEET 3

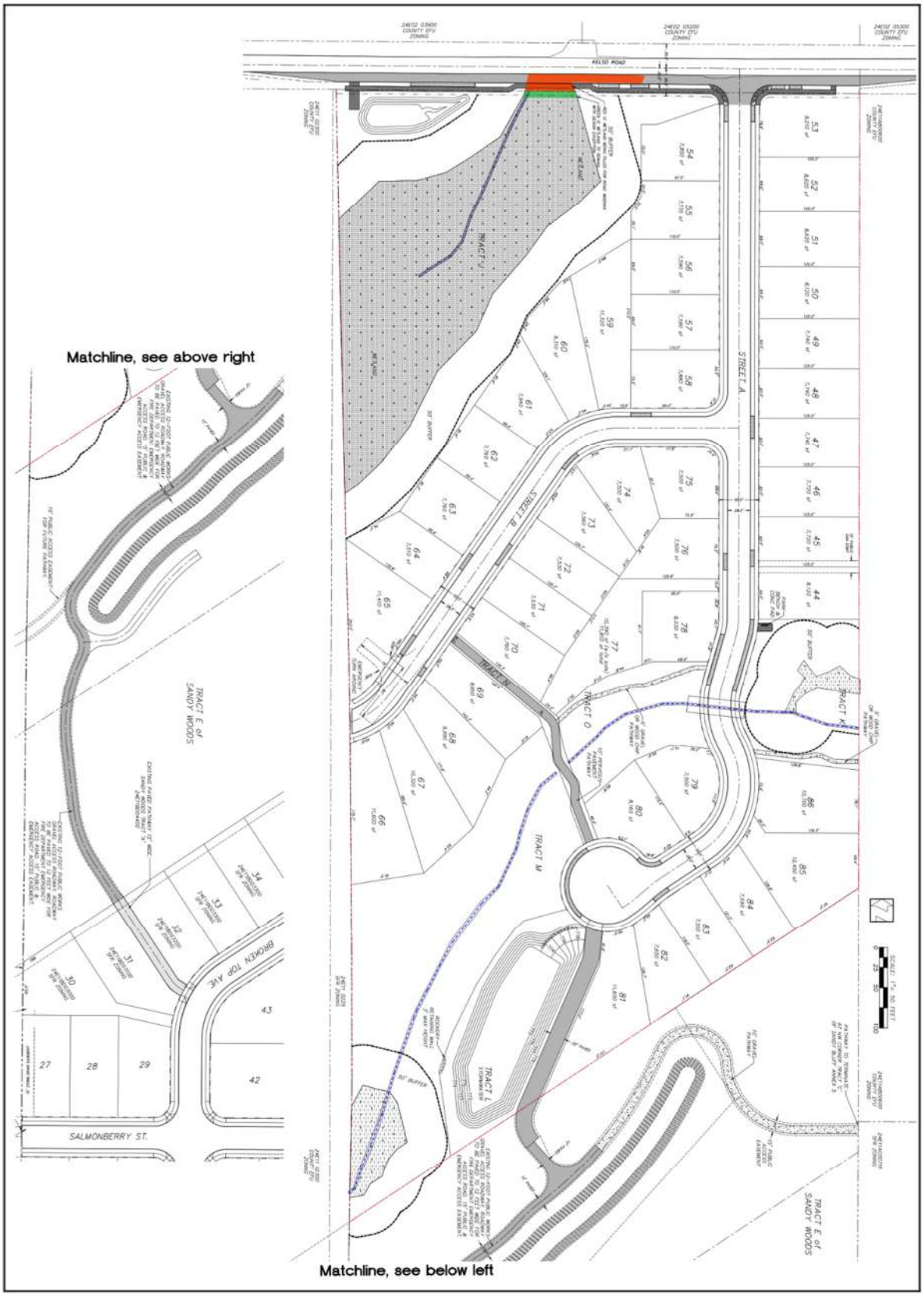
Existing Conditions

Sandy Woods 2
Rosemont Development

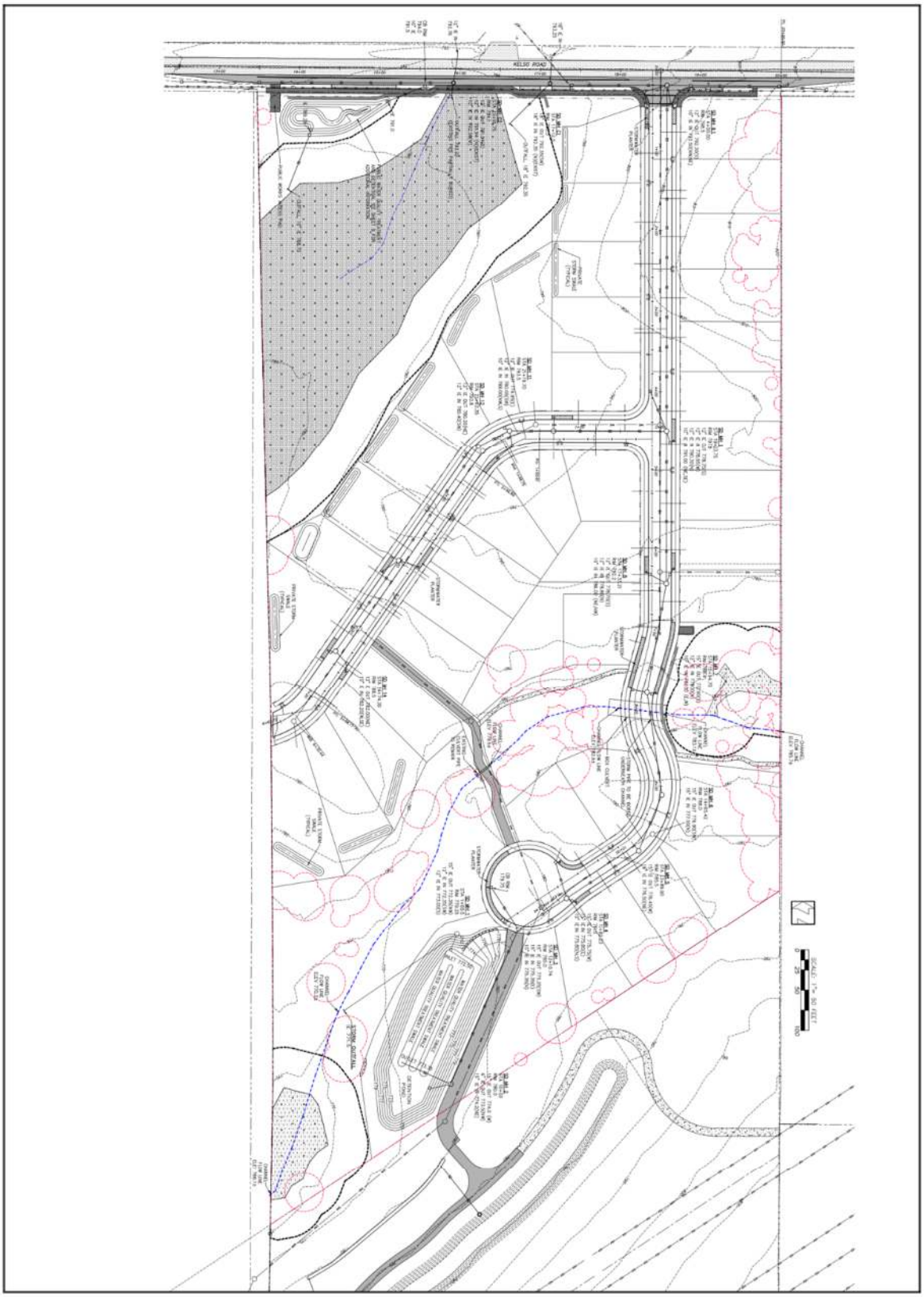
REVISIONS | BY

Appendix B:

Development Plans



SISUL ENGINEERING 375 PORTLAND AVENUE GLADSTONE, OREGON 97027 (503) 657-0188 DRAWING Sandy Woods 2 subdivision DR current.dwg	Site Plan	Sandy Woods 2 Rosemont Development	REVISIONS	BY
SHEET 1 OF 15 SHEETS JOB 5301-142 DRAWN RS SCALE 1" = 50' DATE MAY, 2021				



SISUL ENGINEERING
375 PORTLAND AVENUE
GLADSTONE, OREGON 97027
(503) 657-0188
(DRAWING Sandy Woods 2 subdivision SR current.dwg

Storm Drain Plan

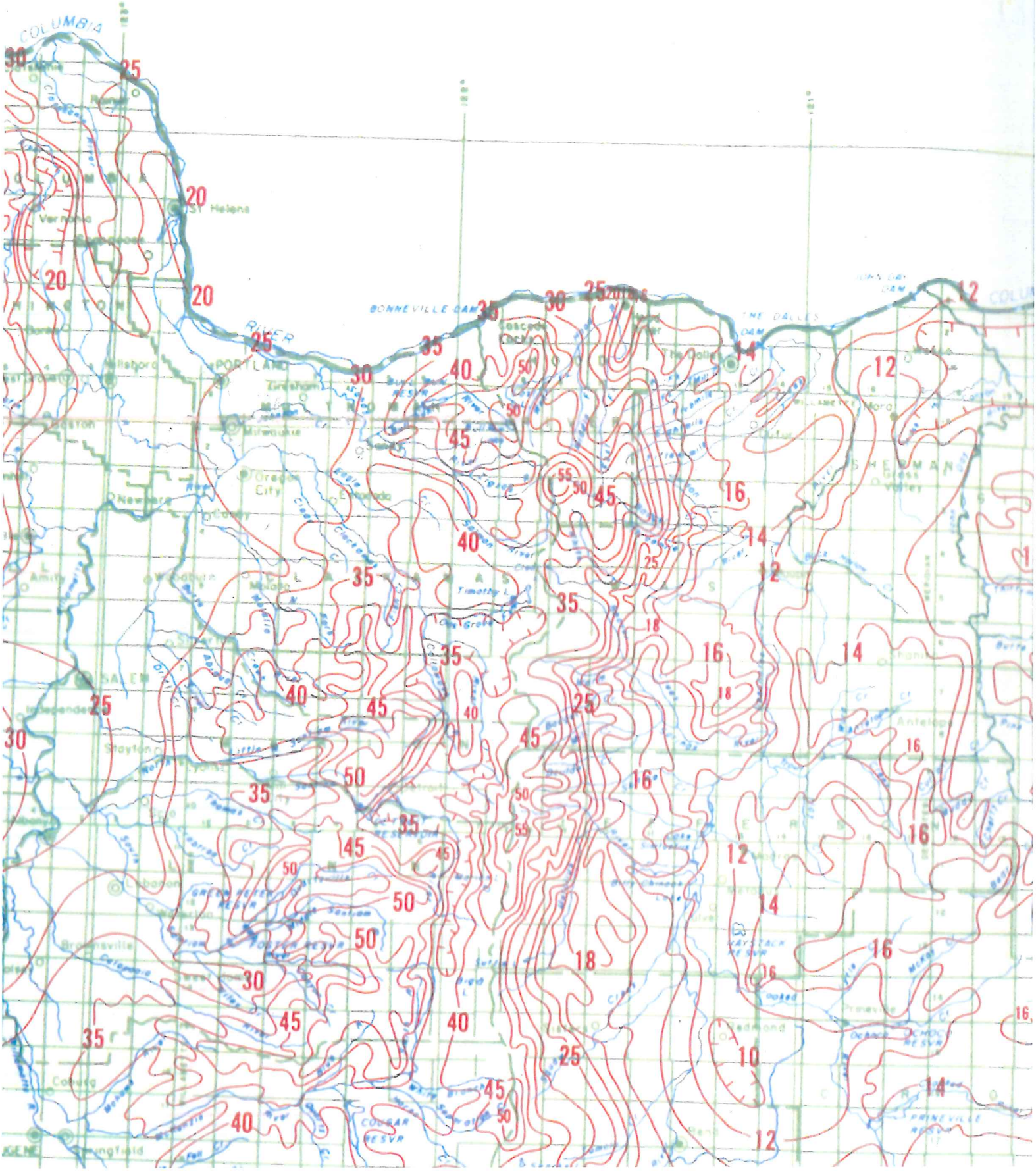
Sandy Woods 2
Rosemont Development

SHEET 8 OF 13 SHEETS
JOB 5031-042
DRAWN PS
SCALE 1" = 50'
DATE JUNE, 2021

Appendix C:

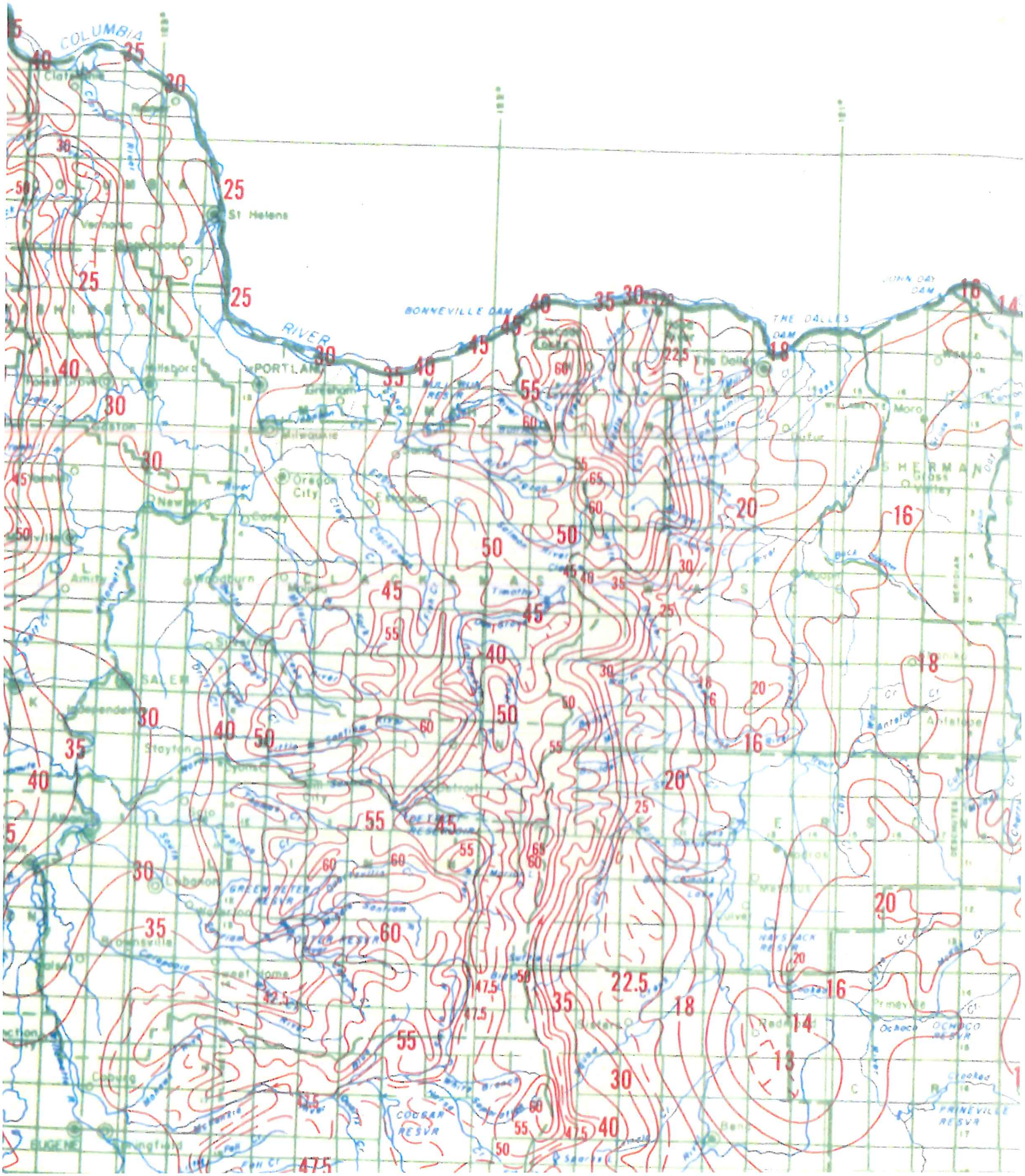
Isopluvials for 24-HR Precipitation

2 YEAR

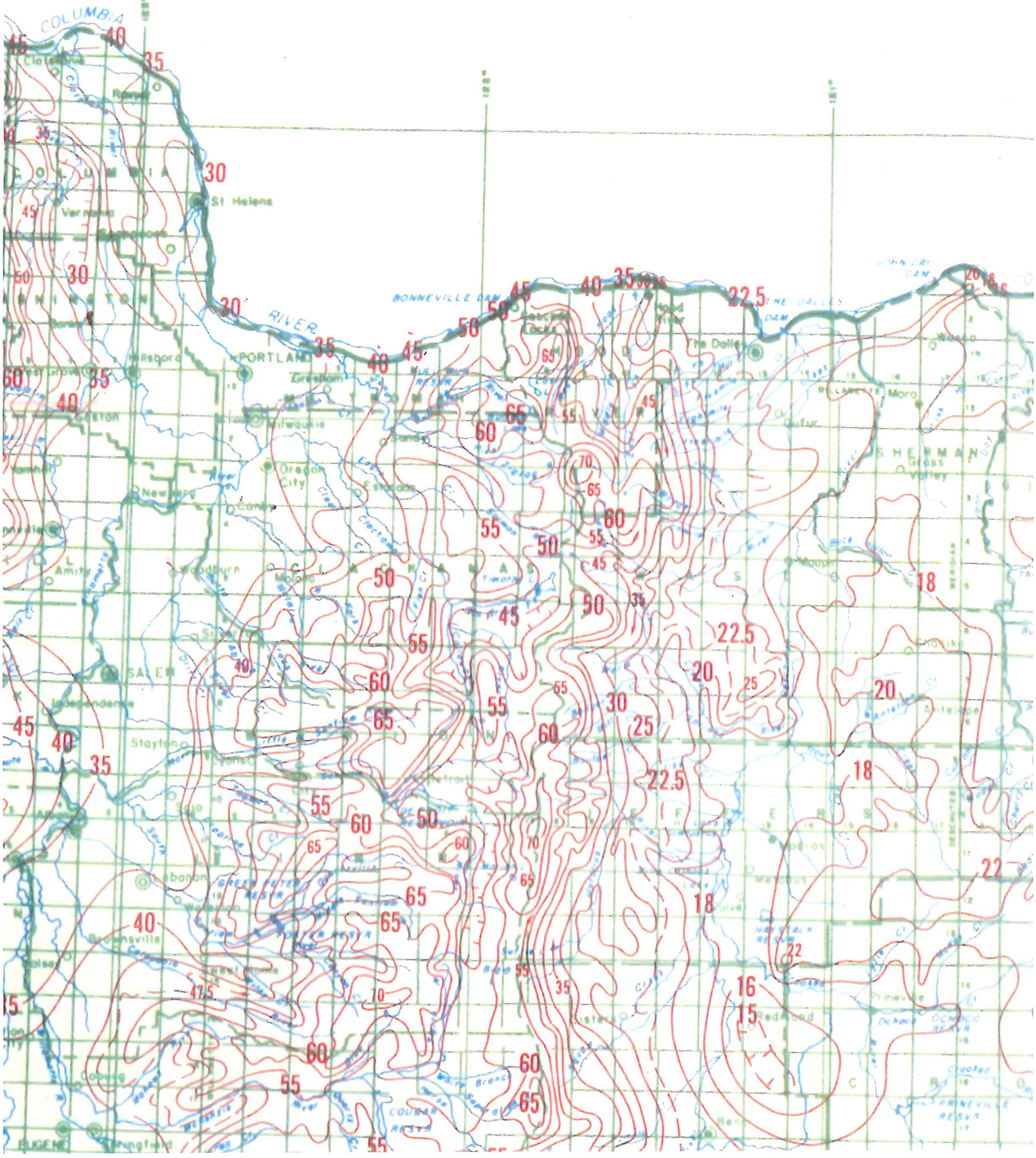

COLUMBIA
RIVER
PORTLAND
BONNEVILLE DAM
THE DALLES DAM
SALEM
EUGENE
30
25
20
35
40
45
50
55
16
14
12
18
10

5 YEAR

IRE

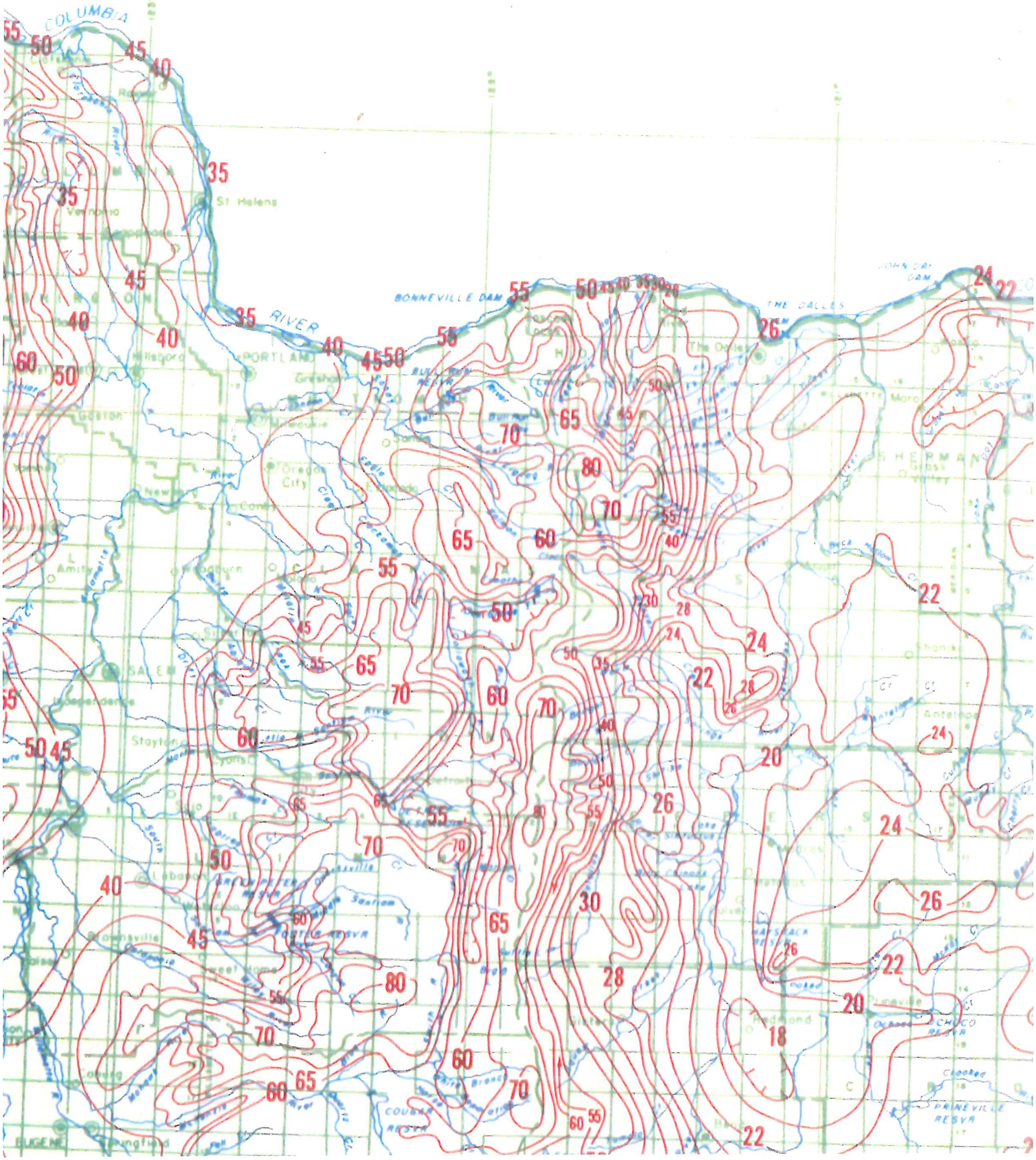

COLUMBIA
RIVER
St Helens
PORTLAND
Gresham
Milwaukie
Oregon City
Estacada
Newberg
Woodburn
Molalla
SALEM
Independence
Stayton
Lebanon
Brownsville
Sweet Home
Coburg
EUGENE
Springfield
BONNEVILLE DAM
THE DALLES DAM
JOHN DAY DAM
The Dalles
Moro
Dufur
SHERMAN
Grass Valley
Maupin
Antelope
Madras
Culver
Redmond
Prineville
Sisters
Bend
GREEN PETER RESVR
FOSTER RESVR
DETROIT RESVR
HAYSTACK RESVR
OCHOCO RESVR
PRINEVILLE RESVR
COUGAR RESVR
CLACKAMAS
S H E R M A N

10 YEAR


COLUMBIA
RIVER
St Helens
PORTLAND
Gresham
BONNEVILLE DAM
THE DALLES DAM
The Dalles
Moro
Grass Valley
Oregon City
Estacada
Woodburn
Molalla
SALEM
Independence
Stayton
Lyons
Lebanon
Brownsville
Coburg
Springfield
EUGENE
Antelope
Madras
Redmond
Prineville
OCHOCO RESVR
PRINEVILLE RESVR
COUGAR RESVR
DETROIT RESVR
GREEN PETER RESVR
FOSTER RESVR
HAYSTACK RESVR
SHERMAN
CLACKAMAS
JEFFERSON
CROOK
Amity
Newberg
Milwaukie
Hillsboro
Vernonia
Sandy
Culver
Sisters
Dufur
Wasco
Hood River
Cascade Locks
Timothy L
Amity
Canby
Maupin
Shaniko
Albany
Halsey

25 YEAR

RE



COLUMBIA
RIVER
St Helens
BONNEVILLE DAM
THE DALLES
JOHN DAY DAM
PORTLAND
Gresham
Hillsboro
Oregon City
Woodburn
SALEM
Independence
Stayton
Lyons
Lebanon
Brownsville
Sweet Home
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FOSTER RESVR
COUGAR RESVR
EUGENE
Springfield
Coburg
Amity
The Dalles
Moro
SHERMAN
Grass Valley
Shaniko
Antelope
HAYSTACK RESVR
Redmond
Prineville
OCHOCO RESVR
PRINEVILLE RESVR
Sisters

Appendix D:

Soil Testing

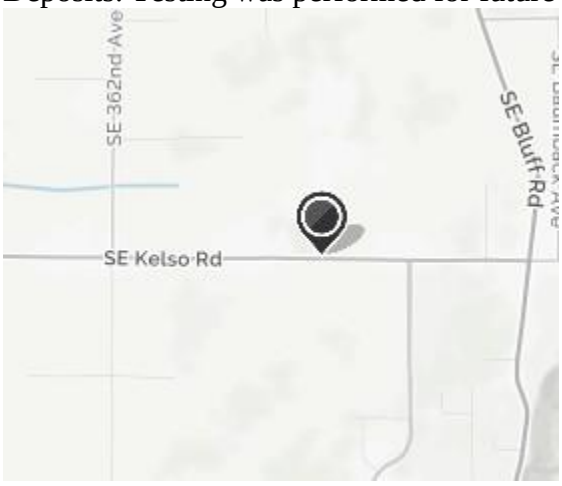
Patrick Sisul, PE
Sisul Engineering
503-657-0188
patsisul@sisulengineering.com

1 July 2020

Re: Infiltration testing at 37090 Se Kelso, Boring, OR

Dear Mr. Sisul,

Field Investigation:
Rapid Soil Solutions (RSS) has performed eight (8) infiltration tests at the above-mentioned site. Soils found on site match those in below soils map by the USGS as fine grained Missoula Flood Deposits. Testing was performed for future storm water design.



Infiltration Testing:
Infiltration testing was performed as per the Clackamas County Storm water standards. Testing took place in sleeved hand augur holes and open test pits due to the shallow depth of testing requested. The test was run a total of three times. See table below that summarizes depths and rates. See attached infiltration sheet that shows pre-soak amounts and test durations.

Hole #	Depth (ft)	Rate (in/hr)
1	0.5	3
2	1	6
3	1.5	5.5
4	0.5	3
5	1	5.5
6	1.5	6
7	3	20
8	4	20

Depth to Ground Water
Ground water not encountered. Using the USGS maps, for depth of ground water in the Portland Metro area then depth is estimated to 20ft below grade depending on the location on the site.

Recommendations
RSS does recommend an infiltration at various depths across the site.

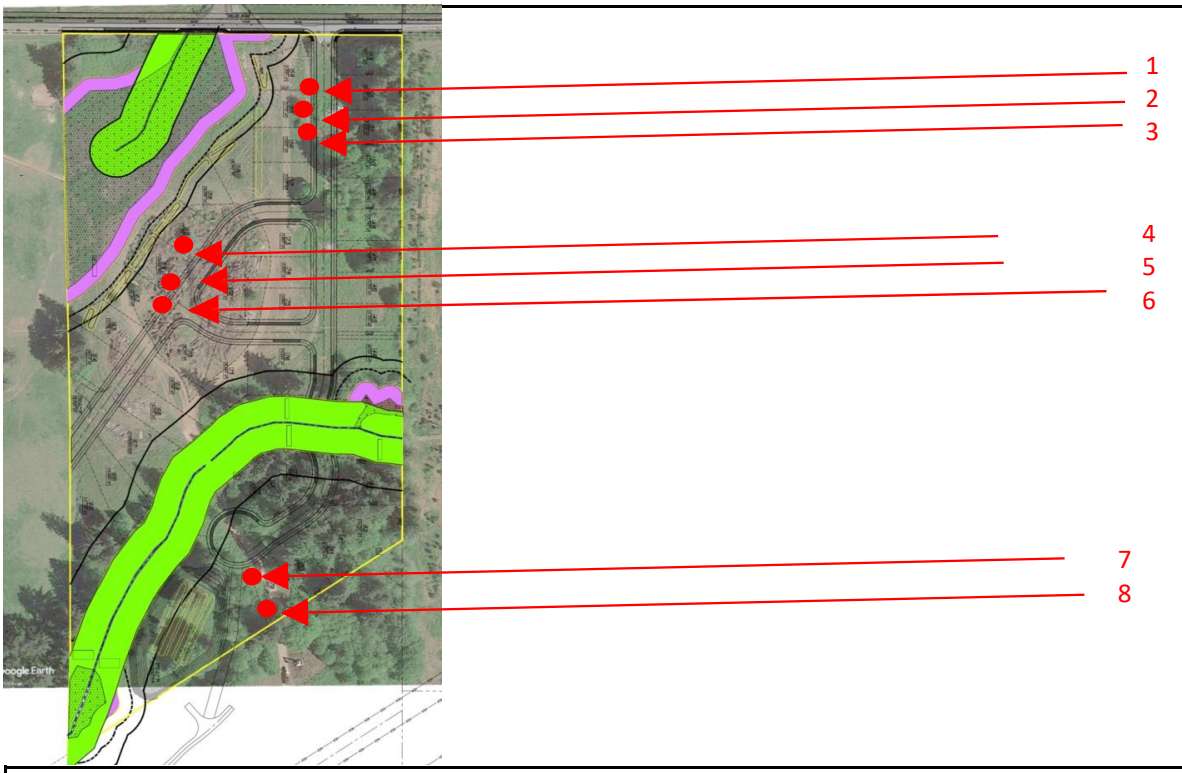
The analysis, conclusions and recommendations contained in this report are based on site conditions as they existed at the time of explorations. Any questions regarding this report please contact me at the below number or email.

Sincerely,

REGISTERED PROFESSIONAL ENGINEER
19244PE
OREGON
JULY 15, 1997
MIA C. MAHEDY
EXPIRES: 12-31-2020

Mia Mahedy, PE GE.

Rapid Soil Solutions Infiltration Test Results



Preliminary Information		
Location:	37090 SE Kelso Road, Boring	**Tester's Name** : Wilton A. Roberts, PE, retired, supervised by Mia Mahedy, PE, GE **Tester's Company**: Rapid Soil Solutions

HA #1

Soil Profile Detail

Depth (ft)	Description
0-0.3ft	Topsoil
0.3-0.5ft	Dry to damp, dark reddish brown, medium grained, clayey SILT
No water found	

Presaturatlon Start Time : 6/30/20 9:30 6". Empty @11:34. Refilled to 6". 3"@12:48. Refilled to 6".
Presaturatlon End Time: 6/30/20 13:30, 2.5".

Date & Time:	6/30/2020 9:30	**Instrument Used:**	4" hand auger
Weather:	Cloudy, 62 deg.	**Depth:**	6"
Time	**Measurement (inches)**	**Level Refilled To (inches)**	**Rate (inches/hour)**
13:30	2.5		
14:00	1.0	6.00	3.0
14:30	4.5		3.0
15:00	3.0		3.0
15:30	1.5	6.00	3.0
16:00	4.5		3.0
16:30	3.0		3.0
Infiltration rate at this test site			3.0

HA #2			
Soil Profile Detail			
Depth (ft)	**Description**		
0-0.3ft	Topsoil		
0.3-1.2ft	Dry to damp, dark reddish brown, medium grained, clayey SILT		
No water found			
Presaturatlon Start Time : 6/30/20 9:30 12". Empty @ 11:34. Refilled to 12". 3.5"@12:48. Refilled to 12". Presaturatlon End Time: 6/30/20 13:30, 5.25".			
Date & Time:	6/30/2020 9:30	**Instrument Used:**	4" hand auger
Weather:	Cloudy, 62 deg.	**Depth:**	12"
Time	**Measurement (inches)**	**Level Refilled To (inches)**	**Rate (inches/hour)**
13:30	5.3		
14:00	1.8	12.00	7.0
14:30	9.0		6.0
15:00	5.5		7.0
15:30	2.0	12.00	7.0
16:00	8.5		7.0
16:30	5.0		7.0
Infiltration rate at this test site			6.0

HA #3			
Soil Profile Detail			
Depth (ft)	**Description**		
0-0.3ft	Topsoil		
0.3-1.5ft	Dry to damp, dark reddish brown, medium grained, clayey SILT		
No water found			
Presaturatlon Start Time : 6/30/20 9:30 12". Empty @11:34. Refilled to 18". 6"@12:48. Refilled to18". Presaturatlon End Time: 6/30/20 13:30, 8".			
Date & Time:	6/30/2020 9:30	**Instrument Used:**	4" hand auger
Weather:	Cloudy, 62 deg.	**Depth:**	18"
Time	**Measurement (inches)**	**Level Refilled To (inches)**	**Rate (inches/hour)**
13:30	8.0		
14:00	5.3	18.00	5.5
14:30	15.0		6.0
15:00	12.0		6.0
15:30	9.0		6.0
16:00	6.0	18.00	6.0
16:30	14.8		6.5
Infiltration rate at this test site			5.5

HA #4			
Soil Profile Detail			
Depth (ft)	**Description**		
0-0.3ft	Topsoil		
0.3-0.5ft	Dry to damp, dark reddish brown, medium grained, clayey SILT		
No water found			
Presaturatlon Start Time : 6/30/20 9:30 6". Empty @11:34. Refilled to 6". 1"@12:42. Refilled to 6". Presaturatlon End Time: 6/30/20 13:30 3".			
Date & Time:	6/30/2020 9:30	**Instrument Used:**	4" hand auger
Weather:	Cloudy, 62 deg.	**Depth:**	6"
Time	**Measurement (inches)**	**Level Refilled To (inches)**	**Rate (inches/hour)**
13:30	3.0		
14:00	1.3	6.00	3.5
14:30	4.5		3.0
15:00	3.0		3.0
15:30	1.5	6.00	3.0
16:00	4.5		3.0
16:30	3.0		3.0
Infiltration rate at this test site			3.0

HA #5			
Soil Profile Detail			
Depth (ft)	**Description**		
0-0.3ft	Topsoil		
0.3-1.2ft	Dry to damp, dark reddish brown, medium grained, clayey SILT		
No water found			
Presaturatlon Start Time : 6/30/20 9:30 12". Empty @ 11:34. Refilled to 12". Presaturatlon End Time: 6/30/20 13:30, 4.75".			
Date & Time:	6/30/2020 9:30	**Instrument Used:**	4" hand auger
Weather:	Cloudy, 62 deg.	**Depth:**	12"
Time	**Measurement (inches)**	**Level Refilled To (inches)**	**Rate (inches/hour)**
13:30	4.8		
14:00	2.0	12.00	5.5
14:30	8.8		6.5
15:00	6.0		5.5
15:30	3.0	12.00	6.0
16:00	8.8		6.5
16:30	5.5		6.5
Infiltration rate at this test site			5.5

Rapid Soil Solutions Infiltration Test Results

HA #6			
Soil Profile Detail			
Depth (ft)	**Description**		
0-0.3ft	Topsoil		
0.3-1.5ft	Dry to damp, dark reddish brown, medium grained, clayey SILT		
No water found			
Presaturatlon Start Time : 6/30/20 9:30 12". Empty @11:34. Refilled to 18". Presaturatlon End Time: 6/30/20 13:30, 7.75".			
Date & Time:	6/30/2020 9:30	**Instrument Used:**	4" hand auger
Weather:	Cloudy, 62 deg.	**Depth:**	18"
Time	**Measurement (inches)**	**Level Refilled To (inches)**	**Rate (inches/hour)**
13:30	7.8		
14:00	4.8	18.00	6.0
14:30	14.8		6.5
15:00	11.5		6.5
15:30	8.5	18.00	6.0
16:00	14.8		6.5
16:30	11.5		6.5
Infiltration rate at this test site			6.0

HA #7			
Soil Profile Detail			
Depth (ft)	**Description**		
0-0.3ft	Topsoil		
0.3-3.0ft	Dry to damp, dark reddish brown, medium grained, clayey SILT		
No water found			
Presaturatlon Start Time : 6/30/20 9:30 12". Empty @ 11:15. Refilled to 12". Empty @11:35. Refilled to 12". Empty at 12:55. Presaturatlon End Time: 6/30/20 12:55 Use 20"/hr. For design.			
Date & Time:	6/30/2020 9:30	**Instrument Used:**	4" hand auger
Weather:	Cloudy, 62 deg.	**Depth:**	4'
Time	**Measurement (inches)**	**Level Refilled To (inches)**	**Rate (inches/hour)**
Infiltration rate at this test site			20.0

HA #8			
Soil Profile Detail			
Depth (ft)	**Description**		
0-0.3ft	Topsoil		
0.3-4ft	Dry to damp, dark reddish brown, medium grained, clayey SILT		
No water found			
Presaturatlon Start Time : 6/30/20 9:30 12". Empty @ 11:15. Refilled to 12". Empty @11:35. Refilled to 12". Empty at 12:55. Presaturatlon End Time: 6/30/20 12:55 Use 20"/hr. For design.			
Date & Time:	6/30/2020 9:30	**Instrument Used:**	4" hand auger
Weather:	Cloudy, 62 deg.	**Depth:**	3'
Time	**Measurement (inches)**	**Level Refilled To (inches)**	**Rate (inches/hour)**
Infiltration rate at this test site			20.0

Appendix E:

Curve Number Tables

Table 4B-2 Runoff curve numbers for selected agricultural, suburban, and rural areas (western Washington).

Cover Type and Hydrologic Condition	CNs for hydrologic soil group 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% to 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
Porous Pavers and Permeable Interlocking Concrete (assumed as 85% impervious and 15% lawn):				
Fair lawn condition (weighted average CNs)	95	96	97	97
Good lawn condition (weighted average CNs)	94	95	96	97
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
1.5 DU/GA		20	must be selected for
2.0 DU/GA		25	pervious & impervious
2.5 DU/GA		30	portions of the site or
3.0 DU/GA		34	basin
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 must 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 Two (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 Chapter 3, 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 remaining pervious area (lawn) is considered to be in good condition for these curve numbers.

Table 4B-5 "n" and "k" values used in time calculations for hydrographs.

"n" Sheet Flow Equation Manning's Values (for the initial 300 ft. of travel)	
Manning's Values for sheet flow only; from Overton and Meadows 1976 (see TR-55, 1986)	**n_s**
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 ≤20%	0.06
Cultivated soil with residue cover >20%	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
(210-VI-TR-55, Second Ed., June 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, uniform flow (n = 0.024)	21
7. Concrete pipe, uniform flow (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, manmade channels, and pipe	0.807/n

Table 4B-6 Values of the roughness coefficient, "n."

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

*Note: These "n" values are "normal" values for use in analysis of channels. For conservative design for channel capacity, the maximum values listed in other references should be considered. For channel bank stability, the minimum values should be considered.