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Appendix A: Runoff Volume and Sediment Reduction Methodology for Rainfall BMPs

West Hills Innovative Stormwater Demonstration

The Rainfall Approach

This approach will reduce sediment export in two ways, in two different locations. Only the upland, project site sediment export reduction can be predictably modeled within the scope of this effort; however, runoff that is prevented upstream will no longer scour stream banks in the valley, thereby preventing an additional, uncalculated amount of sediment from being conveyed into Mill Pond.

Minimize Sediment Export at the Project Site

Since many pollutants attach to sediment and sediment itself is a pollutant and these pollutants are contained in our runoff, then *reducing runoff at the source will automatically improve water quality* by keeping those pollutants where they are. In this case, our main pollutant of concern is sediment and reducing runoff will ensure that less dirt will move downhill.

Reduce Sediment Export Downstream

Scientific research has shown that, even in our clay soils, runoff from land in its natural condition (forested, prairie, etc) is only 0.5% on an average annual basis. Any runoff in excess of this will scour downstream stream banks. *While modeling the volume of sediment that is not being scoured from the stream banks is outside the scope of this modeling effort, there will be less sediment scoured from the stream banks uphill of Mill Pond resulting in an even lower dredging frequency than predicted.*

The Rainfall Modeling Process

The modeling process consists of the following steps:

1. Estimate sediment from the current condition using the Center for Watershed Protection equation below.
2. Estimate sediment from the future condition using the same equation.
3. Subtract the value of the future condition from the current condition to estimate pounds of sediment kept on-site as a result of implementing the practice that defines the future condition.

Estimating Sediment Loads from Rainfall Practices

A commonly accepted method to estimate sediment loads from various land use types is provided by the Center for Watershed Protection in their *Urban Stormwater Retrofit Practices, Appendices, 2007*. The method is described in detail in Appendix B and can be viewed online here: http://www.staunton.va.us/directory/departments-h-z/planning-inspections/images%20and%20files/Urban%20retro-fit%20apendices.pdf.

The following equation can be used to estimate sediment loading from both the current (before retrofit application or existing) and future (after retrofit application or proposed) land use condition.

From Table B.1: Pollutant Load Export Equation:

$$L = [(P)(Pj)(Rv) \div (12)](C)(A)(2.72)$$

where:
L = Average annual pollutant load (pounds)
P = Average annual rainfall depth (inches) = 37 inches in Portland
Pj = Fraction of rainfall events that produce runoff = 0.9 (common assumption from previous research)
Rv = Runoff coefficient, which expresses the fraction of rainfall converted into runoff
C = Event mean concentration of the pollutant in urban runoff (mg/l)
A = Area of the contributing drainage (acres)
12 and 2.72 are unit conversion factors

Less runoff will be generated from the future rainfall practice sites than the current condition. Runoff volume (V) for both conditions can be derived from the above equation as:

$$V = [(P)(Pj)(Rv) \div (12)](A)$$

Since P is known and Pj is assumed, how to determine Rv, A, and C is described next.

Determining Variables

Runoff Coefficient, Rv

Runoff coefficients for a hilly area vary with the land cover types as follows:

Description	Rv
Existing Lawn (soils not restored)	0.60
Compost amended (i.e. future) lawn	0.35
Meadow	0.35
Forest	0.20
Existing gravel walkway	0.85
Porous walkway	0.05
Impervious asphalt	0.90

ODOT Runoff Coefficients, Rv

A common engineering model used in runoff calculations is the “Rational Method”. While this model doesn’t estimate the runoff volume on an average annual basis, there are a number of similarities to the sediment estimate model, including most importantly, the runoff coefficient. Standard runoff coefficients are available from a variety of engineering sources.

From the Oregon Department of Transportation (ODOT) Hydraulics Manual (ftp://ftp.odot.state.or.us/techserv/Geo-Environmental/Hydraulics/Hydraulics%20Manual/Chapter_07/Chapter_07_appendix_F/CHAPTER_07_appendix_F.pdf page 7-F-3):

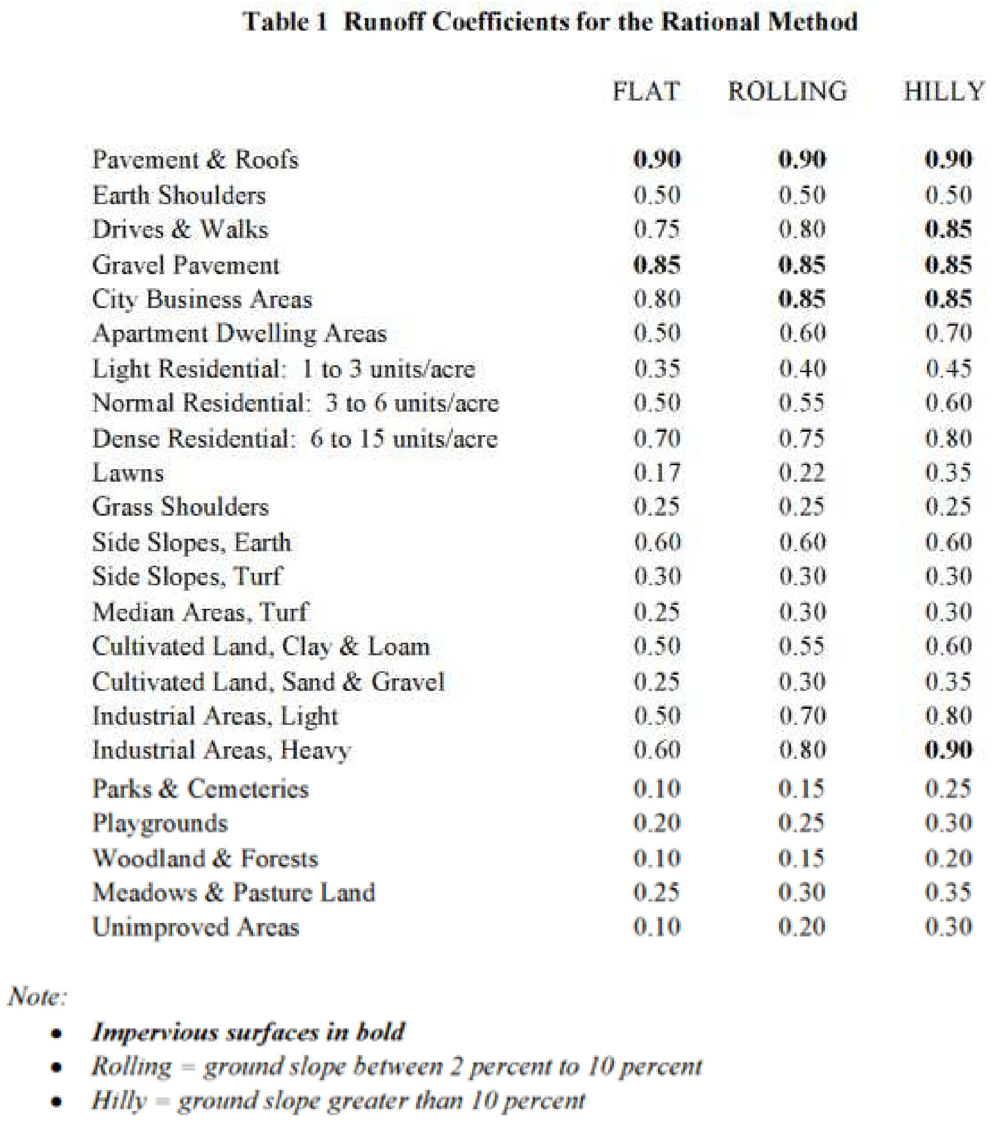


Table 1 Runoff Coefficients for the Rational Method

	FLAT	ROLLING	HILLY
Pavement & Roofs	**0.90**	**0.90**	**0.90**
Earth Shoulders	0.50	0.50	0.50
Drives & Walks	0.75	0.80	**0.85**
Gravel Pavement	**0.85**	**0.85**	**0.85**
City Business Areas	0.80	**0.85**	**0.85**
Apartment Dwelling Areas	0.50	0.60	0.70
Light Residential: 1 to 3 units/acre	0.35	0.40	0.45
Normal Residential: 3 to 6 units/acre	0.50	0.55	0.60
Dense Residential: 6 to 15 units/acre	0.70	0.75	0.80
Lawns	0.17	0.22	0.35
Grass Shoulders	0.25	0.25	0.25
Side Slopes, Earth	0.60	0.60	0.60
Side Slopes, Turf	0.30	0.30	0.30
Median Areas, Turf	0.25	0.30	0.30
Cultivated Land, Clay & Loam	0.50	0.55	0.60
Cultivated Land, Sand & Gravel	0.25	0.30	0.35
Industrial Areas, Light	0.50	0.70	0.80
Industrial Areas, Heavy	0.60	0.80	**0.90**
Parks & Cemeteries	0.10	0.15	0.25
Playgrounds	0.20	0.25	0.30
Woodland & Forests	0.10	0.15	0.20
Meadows & Pasture Land	0.25	0.30	0.35
Unimproved Areas	0.10	0.20	0.30

Note:

- ***Impervious surfaces in bold***
- *Rolling = ground slope between 2 percent to 10 percent*
- *Hilly = ground slope greater than 10 percent*

The values provided by ODOT are for common land uses, but do not necessarily define values for all the best practices proposed, so other research and professional judgment must be applied to determine appropriate values for assessing the response of the land to storm events after our retrofits have been installed. All values are based on this table, though.

Runoff Coefficient for Restored Soils. Research conducted by the College of Forestry Resources at University of Washington found that compost amended soils could significantly reduce runoff on an average annual basis regardless of whether the final landscape is lawn (achieving about a 50% reduction) or shrubs (achieving about an 80% reduction). (Source of info: Bioretention training in 2010 by David McDonald at Washington State University Puyallup Extension.)

In Western Washington’s Stormwater Management Manual, when lawns are compost amended, the runoff coefficient that may be assumed is equivalent to “Pasture” (Rv = 0.35) and when perennial gardens are the final landscape, then “Forest” (Rv = 0.20) may be assumed.

https://fortress.wa.gov/ecy/publications/publications/1210030part6.pdf (page 5-9)

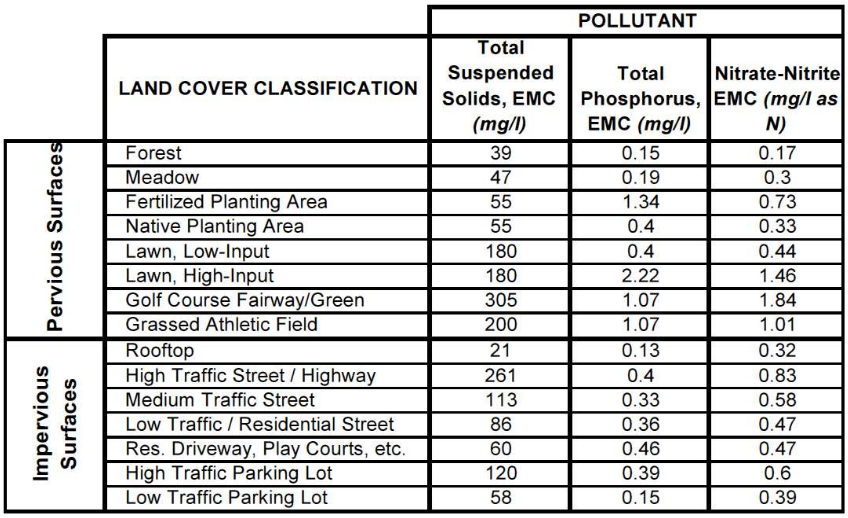
Runoff Coefficient for Porous Pavements. Modeling of porous pavement in Portland, using the method used in the City of Portland Stormwater Management Manual 2008, has shown that the rainfall from the very large, infrequent 25-year, 24-hour storm (3.9 inches/24 hours) can be infiltrated in just 6 inches of base rock, with storage room left to manage another rainfall event of 1.5 inches, even in soils that drain very slowly (0.1 inches/hour). From this, the conservative assumption used in this report is that on an average annual year, 95% of the rainfall hitting a 6” or deeper porous pavement will be infiltrated

Runoff Coefficient for Existing Lawns. In the ODOT table, lawn in a hilly area is assigned a runoff coefficient of 0.35, which also defines “Unimproved Areas” (i.e. natural areas) as having a runoff coefficient of 0.30; however, this clashes with recent research performed by the College of Forestry Resources at University of Washington described above. In addition, many other studies have found that after construction, lawns that have not been restored often have a density that is almost as high as concrete, with a similar runoff potential to concrete. In short, the runoff coefficient of existing lawn areas at the FHHOA is probably much higher than 0.30.

Taking this research into account, without actually finding a suggested updated value, a conservative estimate for an Rv for lawns would be to assume that in a rain event they respond more like “Cultivated Land, Clay & Loam” (Rv=0.60) or “Normal Residential: 3 to 6 units/acre” (Rv = 0.60).

Event Mean Concentrations, C

Event mean concentrations for total suspended solids (assumed to be the solids that are suspended and conveyed off-site) have been diligently researched and vary, not only with land use, but also by research effort. One convenient summary of event mean concentrations that defines values for a number of land uses found at the FHHOA is from the Pennsylvania Stormwater Management Best Management Practices Manual, 2006 as follows:



		POLLUTANT		
	LAND COVER CLASSIFICATION	**Total Suspended Solids, EMC *(mg/l)***	**Total Phosphorus, EMC *(mg/l)***	**Nitrate-Nitrite EMC *(mg/l as N)***
Pervious Surfaces	Forest	39	0.15	0.17
	Meadow	47	0.19	0.3
	Fertilized Planting Area	55	1.34	0.73
	Native Planting Area	55	0.4	0.33
	Lawn, Low-Input	180	0.4	0.44
	Lawn, High-Input	180	2.22	1.46
	Golf Course Fairway/Green	305	1.07	1.84
	Grassed Athletic Field	200	1.07	1.01
Impervious Surfaces	Rooftop	21	0.13	0.32
	High Traffic Street / Highway	261	0.4	0.83
	Medium Traffic Street	113	0.33	0.58
	Low Traffic / Residential Street	86	0.36	0.47
	Res. Driveway, Play Courts, etc.	60	0.46	0.47
	High Traffic Parking Lot	120	0.39	0.6
	Low Traffic Parking Lot	58	0.15	0.39

The more recent Center for Watershed Protection document (previously referenced) offers up a few refinements for relevant land uses, which were substituted in this model for the values above as follows:

Land Use Classification	C [mg/l]
Lawn	602
Rooftop	19
Low traffic/Residential Street	172
Residential Driveway	173

Taking the more recent values from the Center for Watershed Protection inserts an interesting "glitch" in the model, since the C for "Low traffic/Residential street" is higher than the PA stormwater manual's C for "Medium Traffic Street", and the Center for Watershed Protection has not provided a value for "Medium Traffic Street". In practice, we know that higher traffic streets generate higher levels of pollutants, which the final table contradicts.

Determining Area, A

Areas were determined by either pacing off the practice in the field or by importing an aerial (provided by West Multnomah and Soil Water Conservation District) and tracing an area in AutoCAD.

Runoff Volume and Sediment Reduction Methodology for Runoff BMPs

For bioretention/runoff BMPs, a similar methodology to the rainfall BMPs has been used. Since a runoff BMP captures runoff from an area much larger than itself, some modifications are needed.

The Runoff Approach

This approach will reduce sediment export in a similar fashion to the rainfall practices (through runoff reduction that keeps pollutants on-site and reduces downstream bank erosion); however, it won't be as environmentally or cost-effective as the rainfall practices proposed because the facilities must all be lined. Runoff reduction in lined facilities was monitored in a lined facility at the Oregon Zoo and found to be 23% (https://www.portlandoregon.gov/bes/article/417248, page 133).

Nonetheless, this is a very common way to manage runoff in cities throughout the country and research has shown that these facilities can be effective at capturing sediment, and there is public funding available for these practices, so 20 bioretention facilities have been included in this analysis.

NOTE: Since Bioretention Facility R manages groundwater, not runoff, it is an exception to all the practices here and is not included in the modeling. This facility was included at the request of Jennifer Callaghan who was looking for a solution to the dangerous condition caused by the seepage during icy periods.

The Modeling Process

In this modeling, the drainage area is much larger than the facility area (as opposed to the two being the same in rainfall practices). The modeling process consists of the following steps:

1. Estimate sediment export from the drainage area in the current condition (which will not change in the future) using the Center for Watershed Protection equation above.
2. Estimate sediment leaving the future/proposed bioretention facility.

3. Subtract the value of the future condition from the current condition to estimate pounds of sediment kept on-site as a result of implementing bioretention.

Estimating Sediment Loads from Runoff Practices

The current sediment load, $L_{current}$ is estimated using the question from "Estimating Sediment Loads from Rainfall Practices" above, for more information.

Determining Variables

Runoff Coefficient, Rv

The bioretention practices all receive runoff from pavement only, so based on the ODOT Runoff Coefficients, Rv = 0.90 for estimating runoff volume and sediment export from the current condition. For the future condition, an Rv of 0.77 has been used, based on research from the City of Portland at the Oregon Zoo that found that in a similar lined facility, runoff was reduced by 23% annually (0.77 = 1-0.23).

Event Mean Concentrations, C

Since the pavement area that drains to the bioretention facility isn't being modified, the event mean concentrations for total suspended solids are either 0.000943 pounds/gallon for "Medium Traffic Street" or 0.001435 pounds/gallon for "Low Traffic/Residential Street".

Determining Drainage Area, A

Drainage areas were determined by importing an aerial (provided by West Multnomah and Soil Water Conservation District) and tracing an area in AutoCAD. In the case where facilities are too small or too large, compared to the available area for the facility or draining to the facility, the appropriate simplified sizing factor was used to optimize the facility size to the site and the drainage area.

Sediment Reduction from Bioretention

Annual sediment reduction of bioretention has been defined by the Center for Watershed Protection document referenced above as ranging from 15 to 75% with a median sediment capture of 60%, meaning that 40% still leaves the site; therefore, the future sediment export, L_{future}, can be estimated as follows:

$$L_{future} = L_{current}\ x\ (1 - 0.6)$$

The final annual sediment reduction, L_{annual}, is then calculated as:

$$L_{annual} = L_{current} - L_{future}$$

Model Limitations

This effort is a large-scale planning effort, not a detailed water quality modeling project; however, even if this were a detailed modeling project, for some recommended practices, the data and best modeling methods have not been developed or if they have been developed, they have not been calibrated using a real world condition in our region. Without calibration and detailed modeling analysis, estimates of sediment export in this report should be considered preliminary.

This doesn't mean that the values are meaningless. Models are just that – models. In developing them, we often oversimplify the world to evaluate it within a given effort level and budget. *The value of models, regardless of* *their level of detail or accuracy, is in comparing outcomes across similar situations.* In this regard, the approach presented here is a sound one that will allow prioritization of projects based on their predicted relative outcome to one another.

Calibrating the Model

When the HOA is ready to build a site, more fully detailed plans should be developed. Included in the first few of these constructed practices should be detailed information and infrastructure (piping, etc) that will be needed to assess the performance of these practices. Then, a more detailed model could also be developed and calibrated.

If the expense of this is not required (many grant sources will require post-construction monitoring) or desired, then the current conclusion from the scientific literature today is that these practices will still be highly beneficial in reducing sediment in Mill Pond.