FHHOA FINAL REPORT (DEQ 319 Grant)

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http://greengirlpdx.com/JOBS/FHHOA/FHPartners.htm

Forest Heights Homeowners Association
West Hills Innovative Stormwater Demonstration

Reducing Runoff & Sediment Export on Challenging Sites

This demonstration project was made possible through a 319 water quality **grant** from the Oregon Department of Environment Quality. The **319 program** is dedicated to preventing or eliminating pollution in Oregon's waterways by addressing nonpoint source pollution, which is any pollution that does not come directly through a pipe, such as from roads, roofs, sidewalks, and landscaped areas.

Many thanks to the project's partners & stakeholders!

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Project Objective

The objective of the stormwater demonstration is to to reduce runoff on challenging sites**in the developed uplands of the Forest Heights Homeowners Association (FHHOA) on privately, commonly, and publically-owned property**. The scope of work is to identify and prioritize a suite of best management practices (or simply "practices") and their potential locations and extents ("projects"). For the purposes of this report, a site is considered challenging because it cannot easily or safely infiltrate runoff, so other means of runoff reduction must be identified, which may include prevention, infiltration of rainfall (before it becomes runoff), evaporation of rainfall, and/or evaporation of runoff.

The Erosion & Sediment Problem

Erosion of the existing stream banks is caused by runoff conveyed quickly and in a much higher volume than historic rates as a result of development upstream from the stream itself. This erosion causes a high degree of maintenance in two ways:

1. Recent dredging to remove sediment accumulated in Mill Pond over time cost $585,000 with a projected cost in 2028 of $891,000. For this reason, this demonstration focuses on reducing runoff as a way to reduce sediment moving downstream to Mill Pond with the intent of extending the time period between dredgings. Since lawn has the highest capacity for exporting sediment and is much less permeable than most people think (**see Chapter 2**), many projects that address grassy areas are proposed.

2. **Erosion at the upland sites themselves is generating a high level of maintenance costs.** For instance, according to the landscape company contracted to perform work in common areas, one trouble spot, Valley View Park (at the intersections of NW Miller & NW Thompson Roads at the top and NW Miller Road and NW Murdock Street at the bottom) is a time consuming area for them to maintain compared to other common areas. Steep, compacted area make lawn difficult to keep established and runoff from those compacted soil areas, in addition to runoff from the highly compacted gravel walkways and a long private driveway at the top of the hill, generate a larger volume of runoff with a much faster rate of runoff than might be expected from landscape areas.

Practices and Projects

Information is provided based on "practices", which are general approaches that can be taken to reduce runoff and sediment export. Practices are prioritized in **Chapter 3** & described in detail in **Chapter 5,** including specifications and preliminary details.

Within each practice are a variety of "projects". Projects are described in detail in**Chapter 4**.

Implementing any of the proposed projects will reap multiple benefits:

- More stable slopes with less erosion and fewer landslides in both the developed uplands and the stream valleys
- Reduced sediment in our waterways
- Improved safety
- Improved water quality
- Improved air quality
- Long-term savings to residents
- If well implemented, reduced maintenance

Detailed information is provided in various sections of Chapter 5. The practices are briefly summarized as:

Revegetate/Stabilize slopes. Steep slopes generate faster and more erosive flows, so the grassy areas between and around existing trees should be planted with native trees & shrubs to intercept rainfall during our small, frequent rain events and to slow runoff by breaking up the flows during more intense storms.

Restored Soils. This is the practice of amending compacted soils by mixing compost and other helpful materials into them to restore their ability to manage rainfall instead of generate runoff. Once the area has been amended, future landscape types may include lawn (but only if it was lawn already), perennial garden, or meadow. Each has a different capacity to reduce runoff so the "Restored Soils" practice description always includes a description of the final proposed landscape, such as "Restored Soils (from Lawn to Perennial Garden)".

Depaving. The practice of removing any unnecessary areas of impervious pavement (aka hardscape) and replacing it with vegetation. Unnecessary areas most often include excess parking areas where houses are not fronting a street.

Porous Pavements. These are a stormwater facility that you can walk or drive on. This report proposes two different paving surfaces, retrofitting the gravel trails with porous gravel and permeable pavers. Mostly porous walkways and gathering spaces are proposed, but there is one roadway replacement included, should there be interest in implementing this practice on a wider scale.

Bioretention. Bioretention is the practice of infiltrating runoff through soil to reduce pollution. Some variations include rain gardens, stormwater planters, swales, or vegetated filter strips. When placed in the public right-of-way, any of these facilities are also be called “green streets”. Bioretention facilities designed for challenging sites are lined to prevent runoff from infiltrating into the ground; however, water still passes through soil placed above the liner, within the facility providing a high degree of pollutant removal.

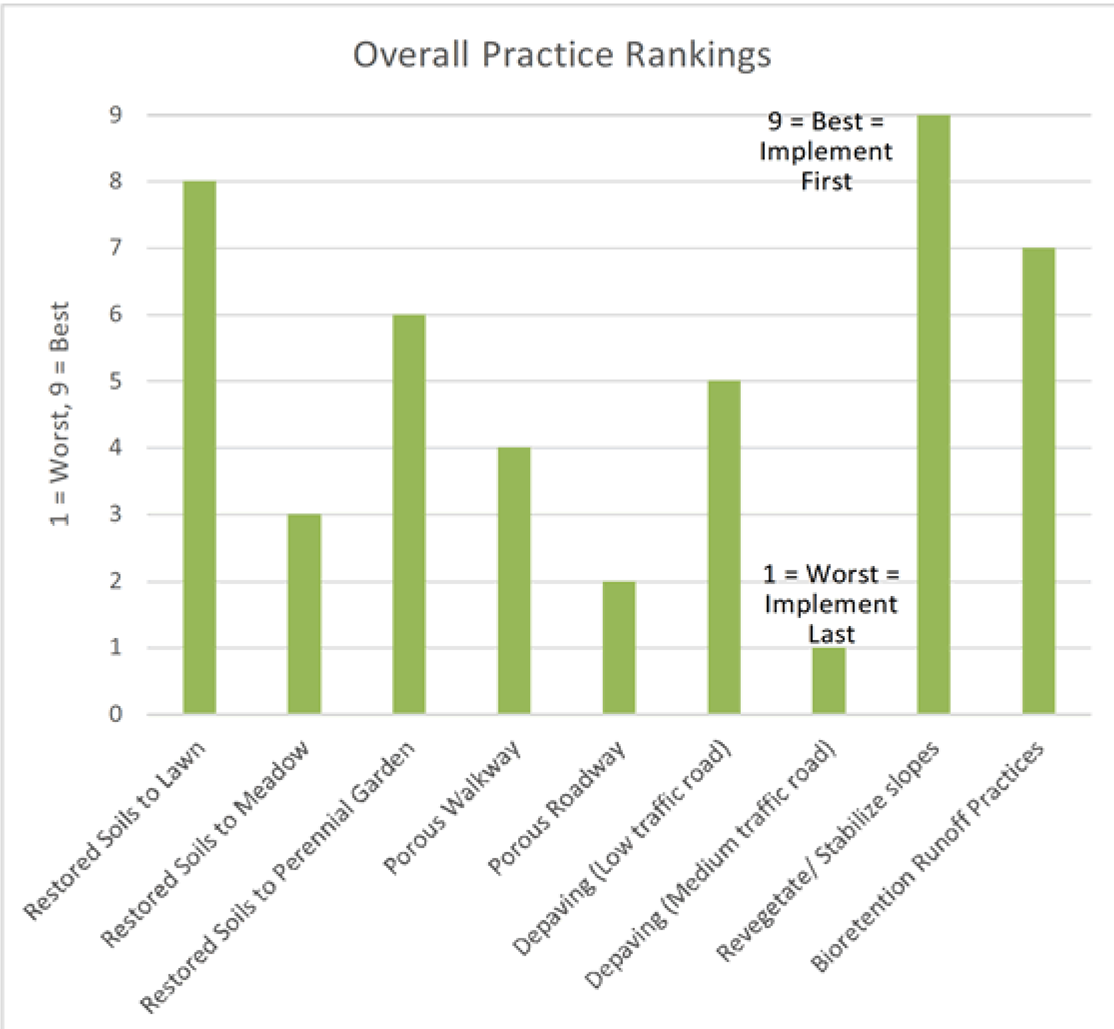
Modeling the Practices to Prioritize Projects

For modeling and analysis purposes, projects are also divided by rainfall projects and runoff projects. "Rainfall projects" reduce runoff by managing the rain that falls on them and include practices such as restoring soil and revegetating steep slopes. "Runoff projects" (also referred to as "Bioretention" in this report) reduce runoff by managing the runoff that flows into them from a much larger drainage area.

Modeling, using an **industry standard methodology** applicable to early planning efforts such as this, was performed to estimate the average annual reduction in runoff and in sediment export for each project, and this was subsequently used to help the HOA decide the order the practices should be implemented. **Unit costs for each practice**were developed with the assistance of local landscape contractors, and were subsequently used to estimate the cost of individual projects.
By **analyzing the environmental effectiveness of practices** and **the design and construction cost of the practices** and **considering stakeholder preferences**, practices were ranked as follows:

Ranking by Practice (from best to worst)
1st = Revegetate/Stabilize slopes (Ranking = 9)
2nd = Restored Soils (from Lawn to Lawn) (Ranking = 8)
3rd = Bioretention Runoff Practices (Ranking = 7)

4th = Restored Soils (from Lawn to Perrenial Garden) (Ranking = 6)
5th = Depaving (Low Traffic Road) (Ranking = 5)
6th = Porous Walkway ((Ranking = 4)
7th = Restored Soils (from Lawn to Meadow) (Ranking = 3)
8th = Porous Roadway (Ranking = 2)
9th = Depaving (Medium Traffic Road) (Ranking = 1)



Forty four rainfall projects and 20 runoff projects (aka bioretention projects) were identified and mapped, each falling into one of the above practice categories. These projects are listed with a photograph of most sites in **Chapter 4 Recommended Projects Summary, and maps of all the projects together or projects individually mapped by practice can also be found in Chapter 4**.

Fact sheets were created to give homeowners more information about a variety of practices and additional implementation information for each practice is included in**Chapter 5**.

Life Cycle Cost Analysis

Due to the cost of dredging, the area draining to Mill Pond was isolated as the target area on which to focus efforts. Modeling shows that by implementing all 64 recommended projects, sediment carried by runoff from the developed uplands to Mill Pond can be reduced by about 29,000 pounds or approximately 10 cubic yards annually. The current cost to implement all the projects, based on preliminary cost estimating (**see Appendix B**), is $1,231,600; however, if the City of Portland implements all the projects that could be considered capitol improvements (i.e. all the bioretention facilities that manage runoff from the public right-of-way), then the cost is reduced to $862,500.

Per a conversation with Jennifer Callaghan, FHHOA Manager, dredging was completed in 2012 and the quantity of sediment was known, so she estimates that about 700 cubic yards of sediment are captured in Mill Pond every year.She predicts dredging will be needed again in 16 years in 2028, costing $891,000.

In studying the life cycle costs of these practices, the 64 projects proposed here will not make a significant impact on the dredging frequency. Over a 32 year period, making some conservative assumptions, about $24,800 might be saved in two dredging events, based on the volume of sediment prevented.

So, why implement these projects? There are number of reasons:

1. Generally, **for the multiple benefits already discussed above.** A general benefit that is also a safety concern is stabilizing the slopes. Planting shrubs and trees and reducing runoff through these and other practices are powerful tools to improve public safety and serve as a kind of insurance policy that can reduce the liklihood of landslides.

2. The model estimates only the amount of sediment carried in runoff from developed areas. It does not estimate the amount of sediment scoured from stream banks as a result of that runoff being conveyed to it. If this sediment scouring could be modeled accurately, the projects would likely be found to be more effective at reducing sediment to Mill Pond, with additional cost savings.

3. Maintenance cost has not been factored in, and in a number of cases, is likely to be lower over time.

4. Significant water quality problems are present in Cedar Mill Creek, downstream of Mill Pond. Without the cooperation of partners like the FHHOA in implementing projects similar to the ones identifed, regulators are unlikely to ever meet our community's water quality goals. Runoff is estimated to be reduced about 2,299,000 gallons (307,322 cubic feet). Every gallon of runoff that is kept from draining rapidly out of the FHHOA stream network helps to improve overall water quality in Cedar Mill Creek, and ultimately the Tualatin, Willamette, and Columbia Rivers, which are the receiving waters for stream flow from the HOA.

A more detailed discussion of reasons to implement these practices can be found in Chapter 3.

Challenging Sites	The Problem	Overall Approach: Rainfall vs. Runoff	Multiple Benefits

The objective of this demonstration effort is to identify and prioritize a suite of best management practices and their potential locations and extents, to reduce runoff on challenging sites in the developed uplands of the Forest Heights Homeowners Association (FHHOA) on privately, commonly, and publically-owned property (see Figure 1-1).

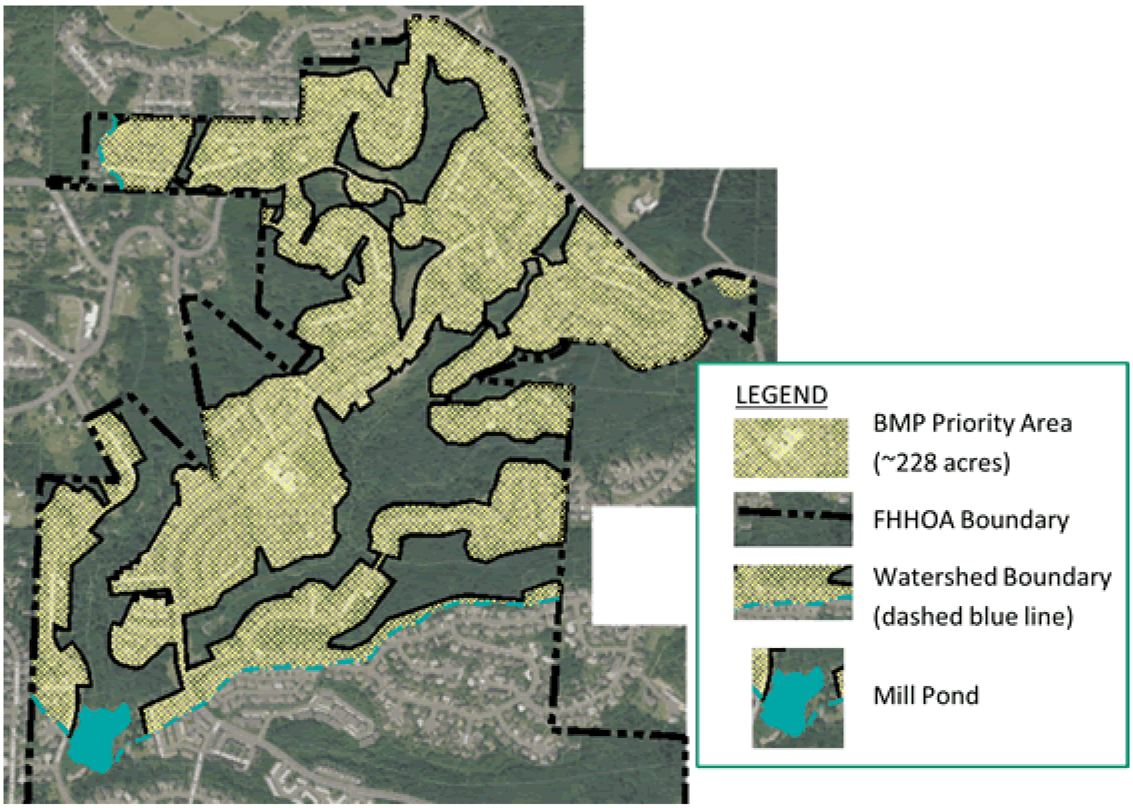


Figure 1-1, Best Management Practice (BMP) Priority Area

Challenging Sites

Back to the top

For the purposes of this report, a site is considered challenging because it cannot easily or safely infiltrate runoff, so other means of runoff reduction must be identified, which may include prevention, infiltration of rainfall (before it becomes runoff), evaporation of rainfall, or evaporation of runoff. The criteria that make a site challenging, all of which are known to be present at the FHHOA, include:

- Steep slopes
- High seasonal groundwater tables (i.e. seasonally flooded landscape areas)
- Slowly draining & compacted, clayey soils
- Tight setbacks or inadequate space between buildings

The Problem

Back to the top

Rainfall on hardscapes and on urban landscape areas tends to end up quickly in storm drains, which drain indirectly or directly to a waterway. This stormwater is called runoff and is laden with a whole host of pollutants, including soil.

While erosion is a natural process, the extent of erosion occurring at the FHHOA, caused by the past and current development pattern on its steep slopes, is unnaturally high. Oversaturated steep and compacted soils, as well as roofs, paved and gravel roads, driveways, sidewalks, and lawns are all contributing a volume of runoff that is much, much higher than the natural, pre-development conditions, to which the watershed is adapted. This additional volume of runoff not only scours soil and other pollutants from surfaces in the uplands, but also scours the stream banks in the valleys, contributing even more pollution and destabilizing slopes.

As a result, houses everywhere, both uphill and along the stream banks, are experiencing erosion on their property that one homeowner (**project 52**) believes threatens the property value of every home in the Forest Heights HOA area. Evidence of soils that have slid down the hill can be found throughout the HOA, and Mill Pond must be regularly dredged (**map**), at a recent cost of $585,000 with a projected cost in 2028 of $891,000. This cost and the associated landslide risk are spread collectively across all homeowners, and so, regardless of who is experiencing challenges, the problem is a collective one. So is the solution.

Maintenance is a costly issue as well. Excess runoff scours a variety of landscapes and sediment clogs storm systems.

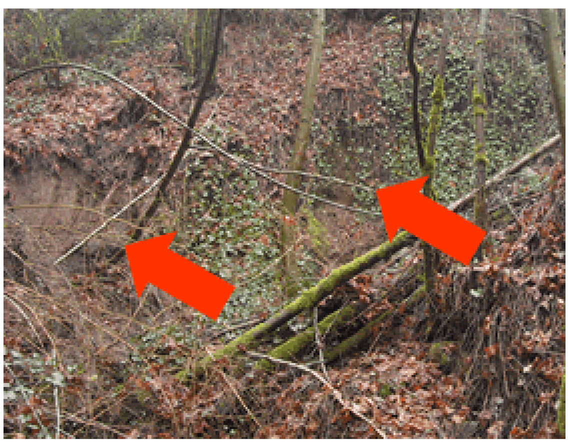


Fig 1-2: Excess runoff from developed uplands (yellow areas of Fig 1-1) contribute to stream bank erosion.

Fig 1-3: Runoff is eroding the landscape next to Skyline Drive (right red arrow) and clogging a small area drain installed and maintained by the HOA (left red arrow)

Figure 1-4: Runoff from compacted lawn area and compacted gravel walkways generate enough runoff to regularly erode the compost in the garden beds at Valley View Park causing an expensive regular maintenance issue

Figure 1-5: Future minor soil slides (like this one at the elementary school that can be seen from Miller Road) could be prevented by revegetating steep slopes with native trees & shrubs.

Overall Approach: Rainfall vs. Runoff

Back to the top

The city government has made reducing runoff one of their top priorities, with a strong emphasis on **infiltration**; however, the west hills of Portland, like so many other places in the world, have steep slopes, high groundwater tables, and clay soils, which make infiltration difficult if not, in some cases, dangerous.

To reduce landslides and flooding, there are a number of creative solutions that take a two-pronged approach to runoff (i.e. high volume flows often concentrated in downspouts and pipes from a particular area and directed to a particular area) and rainfall (i.e. low volume rain that falls on the facility itself before becoming concentrated):

- Limit the volume of runoff actively directed into the ground by lining a facility, and instead use evaporation and uptake by plants.
- In landscape areas, restore the historic hydrologic function by encouraging evaporation and/or infiltration of rainfall.

Multiple Benefits

Back to the top

By reducing runoff, we gain multiple benefits:

- More stable slopes with less erosion and fewer landslides in both the developed uplands and the stream valleys
- Reduced sediment in our waterways
- Improved safety
- Improved water quality

- Improved air quality
- Long-term savings to residents
- If well implemented, reduced maintenance

West Hills Innovative Stormwater Demonstration

Final Report, Chapter 2: Identifying the Most Problematic Land Uses

Forest Heights is already a very green place with lots of trees. A mix of good regulation and "best practices" in the past protected its stream corridors… to a point. Unfortunately, sediment (which is just another word for dirt) and other pollutants from the property continue to impact water quality.

Historically, the lion's share of this pollution has come from projects under construction, but over time, we have come to understand that **pollution comes from all of our already constructed land surfaces** in developed areas, including roofs, sidewalks, roads, driveways, and even lawns and gardens! The FHHOA hopes to implement practices in the common areas, but since sediment comes from everywhere (see chart), an ongoing, cooperative partnership with residents is needed. This will likely take years to fully implement.

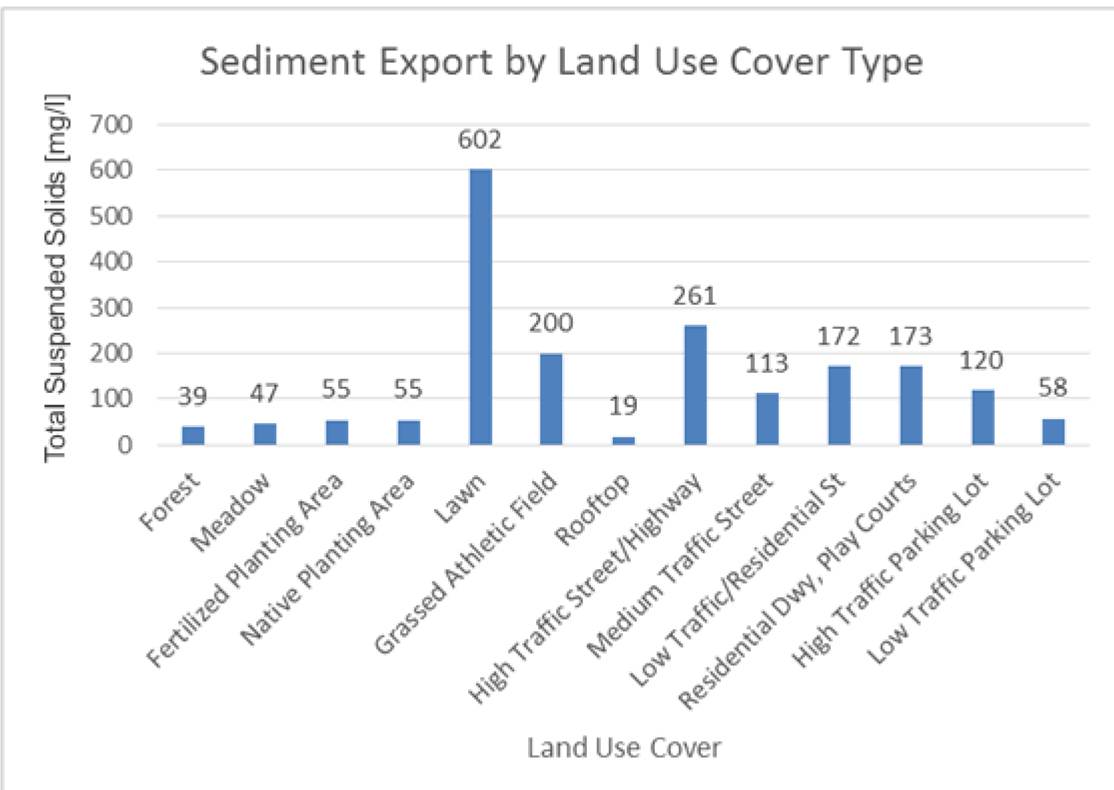


*Table 2-1: Soil exported from a variety of different land use covers, after construction is completed.Adapted from the "**Pennsylvania Stormwater Best Management Practices Manual**", Table 8.3 and more recent data for some values was incorporated from the Center for Watershed Protection "Urban Stormwater Retrofit Practices, Appendices, 2007"*

Table 2-1 summarizes the concentration of sediment that comes from typical landscapes*after being constructed and put into use.* This table is a powerful tool in helping to prioritize the kinds of areas that should be targeted for treatment. The top three sources of sediment are “Lawn”, “High Traffic Street/Highway””, “Grassed Athletic Field”. Since the FHHOA doesn’t have the second and third highest sources of sediment (the playing field at the school is artificial turf), the top three sediment sources at the FHHOA are “Lawn”, “High Traffic Parking Lot”, and “Medium Traffic Street”.

The model that was developed combines these sediment export values with surfaces that generate high levels of runoff to inform the final recommendations. **Read more about the methodology in Appendix A.**

Runoff Reduction & Sediment Prevention Capacity	Environmental Effectiveness	Design & Construction Costs	Cost Effectiveness	Why Implement More Costly Practices	Practices by the Numbers

The practices are briefly summarized as:

Revegetate/Stabilize slopes. Steep slopes generate faster and more erosive flows, so the grassy areas between and around existing trees should be planted with native trees & shrubs to intercept rainfall during our small, frequent rain events and to slow runoff by breaking up the flows during more intense storms.

Restored Soils. This is the practice of amending compacted soils by mixing compost and other helpful materials into them to restore their ability to manage rainfall instead of generate runoff. Once the area has been amended, future landscape types may include lawn (but only if it was lawn already), perennial garden, or meadow. Each has a different capacity to reduce runoff so the "Restored Soils" practice description always includes a description of the final proposed landscape, such as "Restored Soils (from Lawn to Perennial Garden)".

Depaving. The practice of removing any unnecessary areas of impervious pavement (aka hardscape) and replacing it with vegetation. Unnecessary areas most often include excess parking areas where houses are not fronting a street.

Porous Pavements. These are a stormwater facility that you can walk or drive on. This report proposes two different paving surfaces, retrofitting the gravel trails with porous gravel and permeable pavers. Mostly porous walkways and gathering spaces are proposed, but there is one roadway replacement included, should there be interest in implementing this practice on a wider scale.

Bioretention. Bioretention is the practice of passing runoff through soil to reduce pollution. Some variations include rain gardens, stormwater planters, swales, or vegetated filter strips. When placed in the public right-of-way, any of these facilities are also be called “green streets”. Bioretention facilities designed for challenging sites are lined to prevent runoff from infiltrating into the ground; however, water still passes through soil placed above the liner, within the facility, providing a high degree of pollutant removal.

Analyzing the data from the individual projects proposed in **the model**, there appears to be only one clear "winner" where immediate consensus might be acheived: revegetating and stabilizing steep slopes. Partly, this is because Clean Water Services has committed to provide the FHHOA with about

14,500 bare root, native shrubs and trees, but also**lawns have a very high rate of sediment export**, so changing a landscape from lawn to forest is highly effective for addressing runoff reduction and sediment export.

Each surface (lawn, meadow, perennial garden, forest, or pavement) has a different runoff characteristic that changes from one to another after a particular project has been implemented. Likewise, each surface has a different amount of sediment it may export, but this is further complicated by pavement, which exports more sediment with more traffic. These variables have been accounted for in **the model** but add a relatively high degree of complexity that can make decision making processes arduous.

The remainder of this page is designed to step you through the recommended decision making process. To look at just my recommendation on the order in which best practices should be implemented based on environmental and cost-effective, **click here to skip down to the bottom of the page and read the last two sections**.

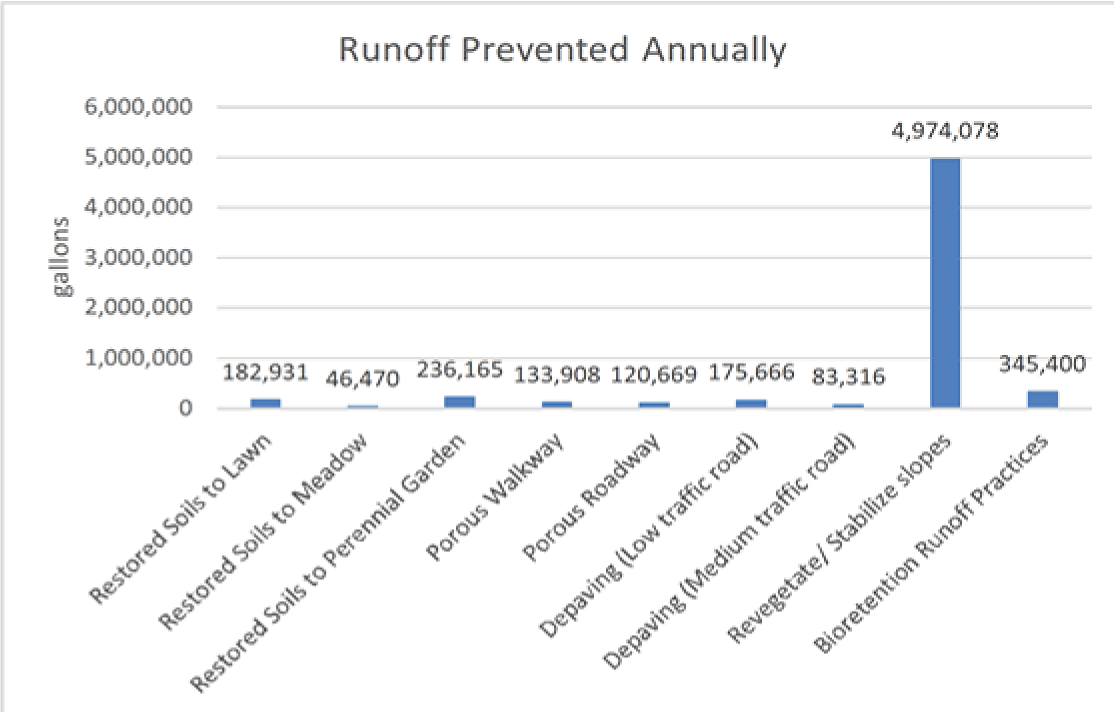
IMPORTANT! This data was specifically tailored to respond to the decision making needs of the FHHOA as well as local costs and conditions. Incorporating different best practices with a different set of stakeholders in a different part of the country is likely to yield very different conclusions!

Let's step through the logic together...

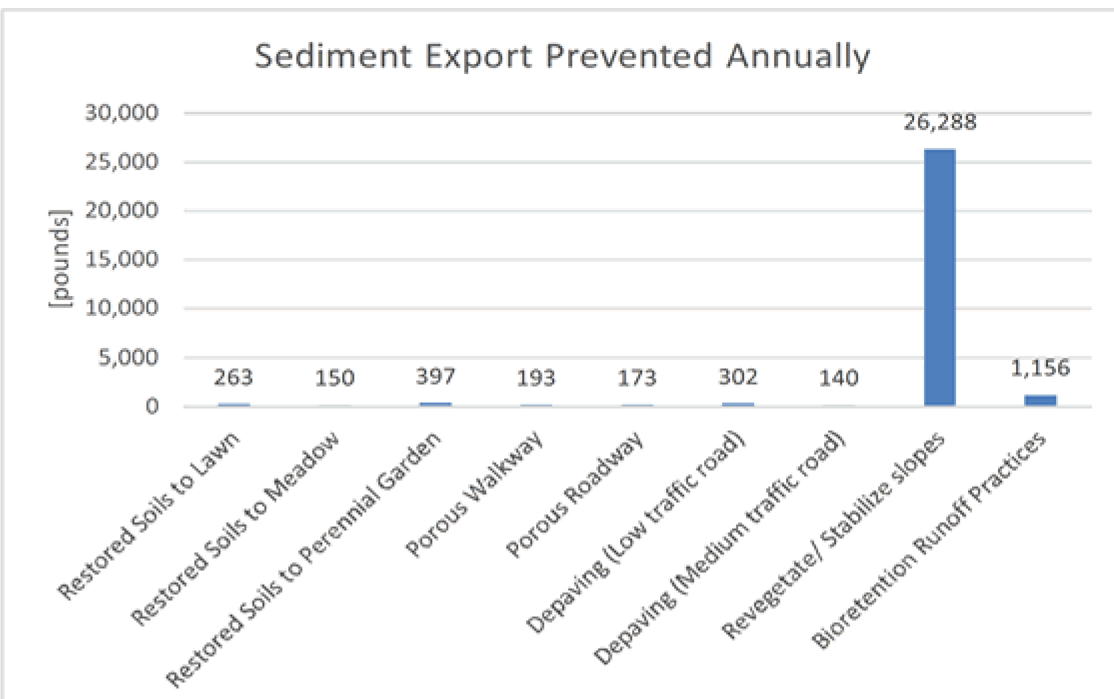
Runoff Reduction & Sediment Prevention Capacity

Back to the top

The following chart shows the volume of runoff prevented annually when the runoff reduction capacity of all the proposed projects for each practice are added up. One of the reasons that revegetating steep slopes has such a high value compared to other practices is that there were numerous opportunities and a larger physical area at the HOA to revegetate, while other practices had more limited areas. While knowing how much runoff is predicted to be prevented is useful, looking at this chart alone, we cannot make a reasonalbe decision about where to start working.



Similarly, the next chart shows the pounds of sediment prevented annually when all the proposed projects for each practice are added up.



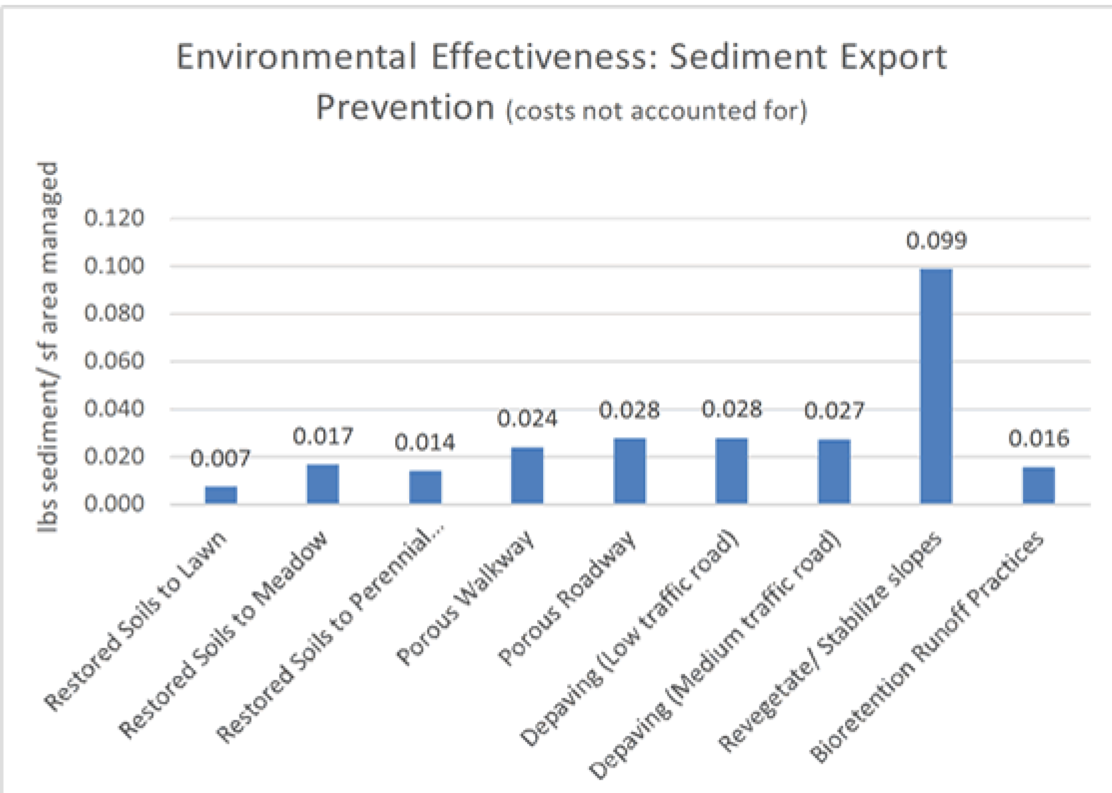
Environmental Effectiveness: Runoff Reduction & Sediment Prevention

Back to the top

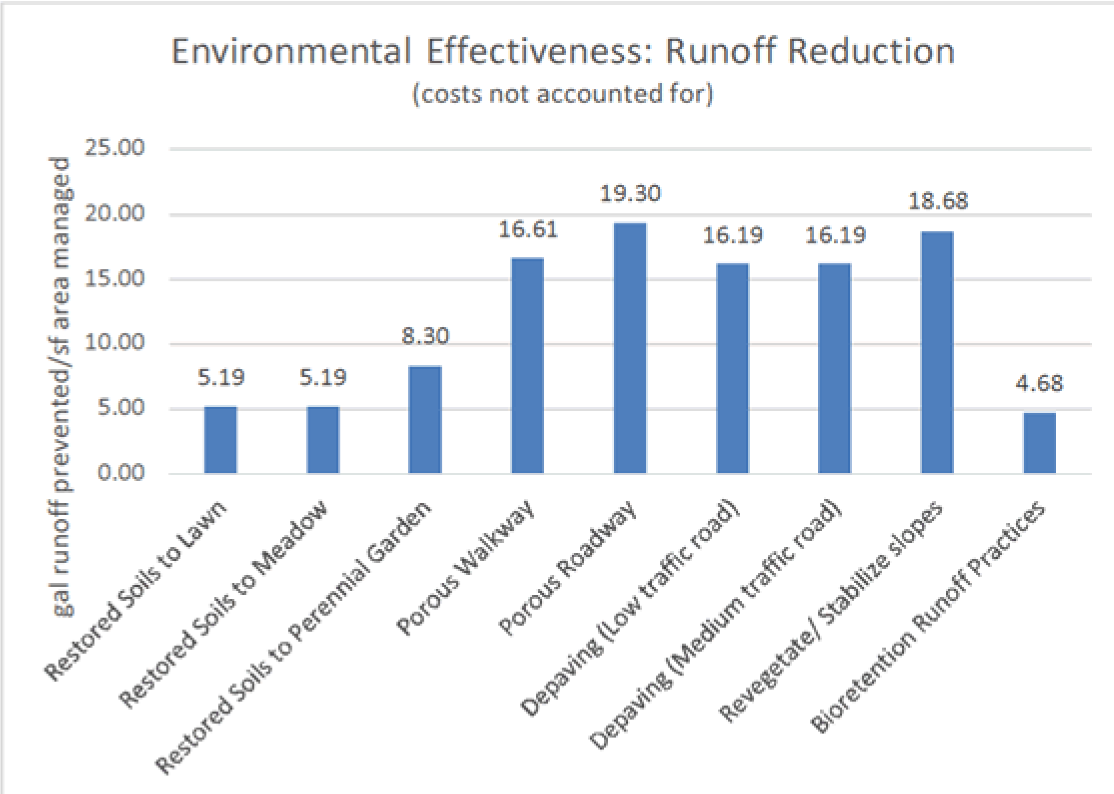
We can account for the area differences across practices by dividing the total pounds of sediment prevented or the total volume of runoff reduced for all the practices by the total area managed for all the practices, which gives us a measure of the environmental effectiveness of each practice.

In the case of the first eight rainfall practices, the area managed by the facility is the same as the area retrofitted. In the case of the bioretention practices, runoff is collected from a much larger area into a relatively small facility, so the area managed is much larger than the actual facility area. Graphing the environmental impact per square foot of area managed is the most meaningful way to compare "apples to apples".

Doing this analysis for sediment, we see that revegetating steep slopes is still the most effective practice.



Analyzing each practice for runoff reduction effectiveness below, we can see that from a purely runoff reduction perspective, removing pavement and replacing it with porous pavement generates the least amount of runoff of all the practices.



Converting existing conventional pavement to porous pavement, as you might expect, is a very expensive approach, so we obviously need to account for the design and construction costs of each practice.

Design & Construction Cost

Back to the top

The cost per square foot (aka unit cost) of design and construction costs were estimated for each practice (**see Appendix B: Preliminary Cost Estimate** for assumptions, sources of data, etc). The cost per square foot to design and construct the practice is of interest, but to the City of Portland, the cost per square foot to design and construct the practice relative to the area that's managed is more important (and is part of their **% for Green Program application**). Both unit costs are shown in the next chart.

In the case of the first eight rainfall practices, the area managed by the facility is the same as the area retrofitted, so the construction cost construction per square foot of the facility equals cost per square foot of area managed. In the case of the bioretention practices, runoff is collected from a much larger area into a relatively small facility. In this case the cost of construction per square foot is much higher than the cost per square foot managed.

	Area of practice [sf]	Area Managed [sf]	Design & construction cost/square foot of area managed	Design & construction cost/square foot
Restored Soils from Lawn to Lawn	39,655	39,655	$2.45	$2.45

Restored Soils from Lawn to Meadow	8,955	8,955	$4.46	$4.46
Restored Soils from Lawn to Perennial Garden	28,444	28,444	$4.46	$4.46
Porous Walkway	6,189	6,189	$8.17	$8.17
Porous Roadway	6,251	6,251	$9.45	$9.45
Depaving (Low traffic road)	10,850	10,850	$19.21	$19.21
Depaving (Medium traffic road)	5,146	5,146	$19.21	$19.21
Revegetate/ Stabilize slopes	263,050	263,050	$0.32	$0.32
Bioretention Runoff Practices	6,394	80,197	$6.08	$76.29
Total	**376,809**	**450,612**		

Cost Effectiveness of Practices

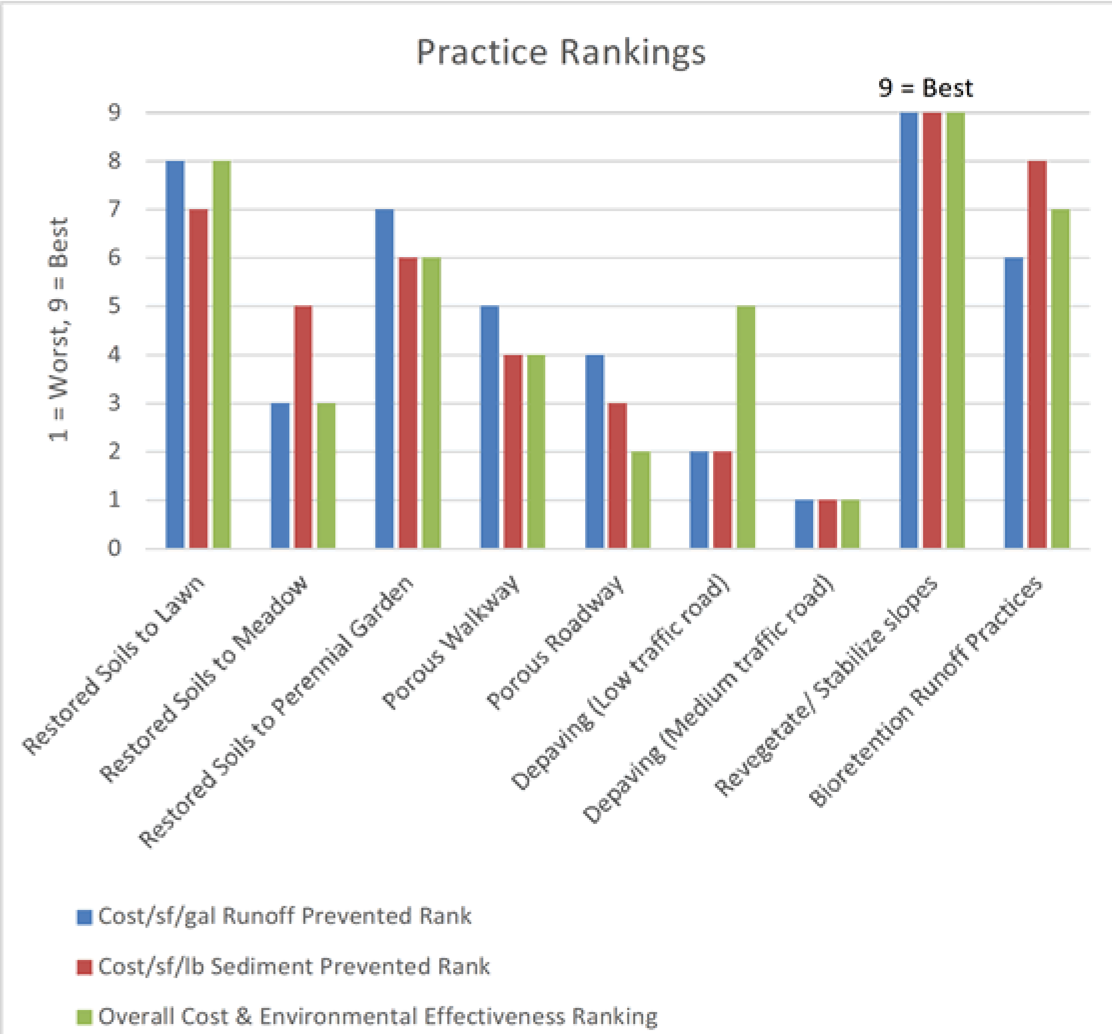
Back to the top

Using the unit cost only to decide on the best "best practice" does not account for the widely varying environmental effectiveness of each practice. **In other words, the cheapest practice per square foot may not be the smartest way to spend a limited budget if the main goals are reducing runoff and preventing sediment export.**

To analyze the true cost effectiveness of each practice, we should also account for how environmentally effective it is. The model calculates the cost per square foot per gallon of runoff prevented and the cost per square foot per pound of sediment prevented, but when the relatively small unit costs are divided by the relatively large gallon of runoff prevented or pounds of sediment prevented, the numbers are difficult to chart; therefore, a rank between 1 and 9 was assigned to each practice with the following logic:

Rankings
1 = worst = least cost effective considering the environmental benefit and should be the last practice to implement
9 = best = most cost effective considering the environmental benefit and should be the first practice to implement

The following chart shows the best practices ranked according to their cost effectiveness in reducing runoff, their cost effectiveness in preventing sediment export, and their overall cost effectiveness when the cost considerations for runoff and sediment are combined.



Simplfying this chart to only show the overall cost & environmental effectiveness ranking, we see that if we want to pick a family of practices to implement first, based on both their environmental and cost effectiveness, then we would implement them in this order:

Ranking by Practice (from best to worst)
1st = Revegetate/Stabilize slopes (Ranking = 9)
2nd = Restored Soils to Lawn (Ranking = 8)
3rd = Bioretention Runoff Practices (Ranking = 7)
4th = Restored Soils to Perrenial Garden (Ranking = 6)
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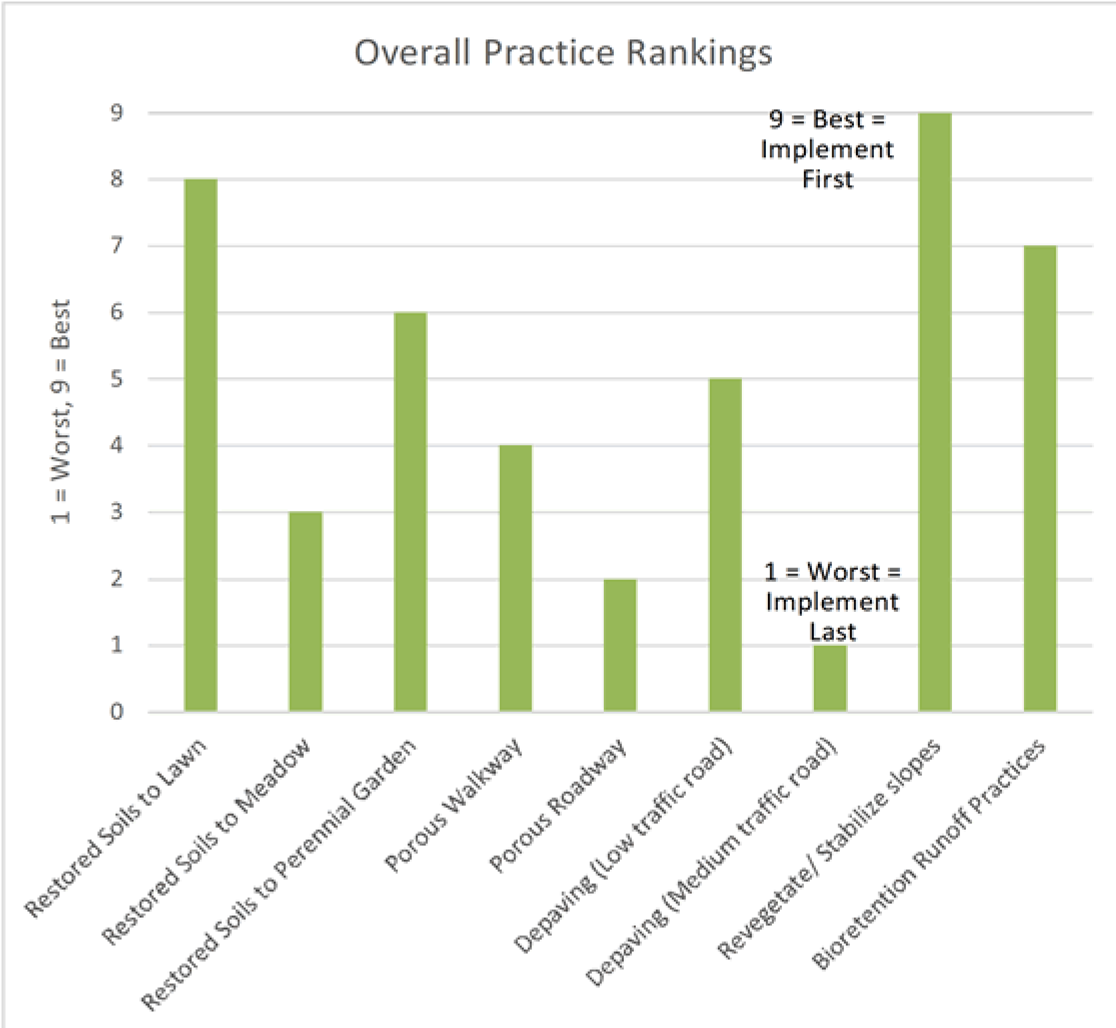

Why Implement More Costly Practices

Back to the top

While the revegetation strategy is considered to be a "no brainer" by FHHOA stakeholders at the time of this report, more expensive practices may need further justification. Following are arguments for implementing more than just the "low hanging fruit":

1. **Public safety can be improved.** By implementing these practices, this study shows that reducing runoff and sediment export is possible and that through this strategy the upland hills and lowland stream corridors can be better stabilized from sliding. Even though the **64 projects proposed in Chapter 4** will not make a significant impact on dredging frequency, **the criteria provided in Chapter 5 for each practice** will help you and future professionals who assist you in identifying many more project sites to retrofit for this very important benefit.

2. **Not all the benefits of all the practices have been quantified.** For instance, all of the rainfall practices will improve groundwater conditions and reduce flooding, while lined bioretention facilities, which exclude groundwater entirely from their system, are not as effective at this. Flooding was not one of the criteria for this demonstration effort, but throughout the effort, properties have been identified that

do have drainage issues that would be improved more effectively with rainfall practices than runoff bioretention facilities. These projects have been summarized in **Chapter 4: Recommended Projects Summary**.

3. **Not all the benefits can be accurately quantified scientifically .** The dynamics and interplay of stream bank erosion with uphill runoff is extremely complex and cannot be accurately predicted at this time; however, we do know from watershed scale studies that stream bank scouring will decrease with a decrease in runoff, so the amount of sediment prevented from these practices has likely been underestimated.

4. **Maintenance costs are likely to be reduced.** While a life cycle cost for maintenance is outside the scope of these recommendations, the maintenance of eroded landscapes is a known issue. For example, in Valley View Park (on NW Miller Road), monthly maintenance costs are $700. The recommendations for this area, reflected in 4 different projects, should significantly reduce erosion and the maintenance associated with this area.

5. **All practices are not equally applicable to all existing sites.** For example, you might ask if bioretention is so much more cost effective, why build another practice like porous walkways? The short answer is that the bioretention facilities chosen for this demonstration effort have been specifically chosen to be as cost effective as possible. Also, bioretention is suited for relatively flat areas (less than 8% slope) and the HOA has limited opportunities where drainage is concentrated in curbs or other drainages.

Let's compare installing bioretention against replacing gravel walkways with porous walkways. The porous walkways are proposed for woodland walkways where the area of the walkway and it's stormwater management would be one and the same. If we tried to used bioretention on these woodland paths, conveying runoff from the existing gravel path would be one challenge and finding an adequate place to install a bioretention facility adjacent to the path without needing to remove trees would be likely very difficult. Finally, those lined bioretention facilities would be far removed from the underground network of pipes where 77% of the annual rainfall would have to be conveyed as runoff.*In this case, bioretention would be far more expensive due to excessive piping.*

Another example might be comparing depaving against bioretention. According to Jennifer Devlin at the City of Portland, a water line beneath bioretention is a "deal killer", since it is perceived by the city's Water Bureau as a health hazard, so sometimes flatter areas that look suitable for bioretention are instead recommended to be depaved.

6. There are multiple benefits to implementing these practices, as described in Chapter 1.

Practices by the Numbers

Back to the top

The following chart summarizes all the projects by practice and was used to develop the ranking described above.

	Rainfall Practices								Runoff Practices	
	Restored Soils (Lawn to Lawn)	Restored Soils (Lawn to Meadow)	Restored Soils (Lawn to Perennial Garden)	Porous Walkway	Porous Roadway	Depaving (Low traffic road)	Depaving (Medium traffic road)	Revegetate / Stabilize slopes	Bioretention	Total for All Practices
# Proposed Projects	6	1	7	5	1	5	1	21	20	
Area Managed [sf]	39,655	8,955	28,444	6,189	6,251	10,850	5,146	263,050	79,541	449,956
Area of practice [sf]	39,655	8,955	28,444	6,189	6,251	10,850	5,146	263,050	6,394	376,809
Runoff prevented annually [gal]	205,780	46,470	236,165	133,908	120,669	175,666	83,316	4,914,116	372,100	6,288,190
Sediment prevented annually [lbs]	295	150	397	193	173	302	140	25,971	1,257	28,879
Sediment reduction effectiveness [lbs sediment prevented/sf area managed]	0.007	0.017	0.014	0.024	0.028	0.028	0.027	0.099	0.016	
Runoff reduction effectiveness [gal runoff prevented/sf area managed]	5.19	5.19	8.3	16.61	19.3	16.19	16.19	18.68	4.68	
Design & construction cost/square foot	$2.45	$4.46	$4.46	$8.17	$9.45	$19.21	$19.21	$0.32	$68.67 to $76.29	
Design & construction cost/square foot of area managed	$2.45	$4.46	$4.46	$8.17	$9.45	$19.21	$19.21	$0.32	$5.83	
Area Managed Rank by Cost	6	5	5	2	1	3	3	7	4	
Cost/sf/lb sediment prevented x 100	$0.83	$2.98	$1.12	$4.23	$5.45	$6.36	$13.67	$0.00	$0.49	
Sediment Prevented Rank by Cost	7	5	6	4	3	2	1	9	8	
Total cost to implement per practice	$97,100	$40,000	$126,900	$65,900	$59,100	$208,400	$98,800	$83,000	$467,734	$1,267,000
Sum of Two Cost Rankings above	15	8	13	9	7	4	2	18	14	
Overall Ranking (9 = best)	8	4	6	5	3	2	1	9	7	

West Hills Innovative Stormwater Demonstration
Final Report, Chapter 4: Prioritizing the Projects

Intro	Responding to Stakeholders	Ranking Method	Recommended Projects Summary

The projects included here are only a small handful of the myriad of opportunities that exist in the basin that drains to Mill Pond (See Fig 4-1 below, BMP stands for "best management practices" but in this report, they are simply referred to as "practices"). In addition to the many more sites available within the priority area, even more opportunities are available at the FHHOA outside the Mill Pond drainage area, where the HOA is generally less steep.

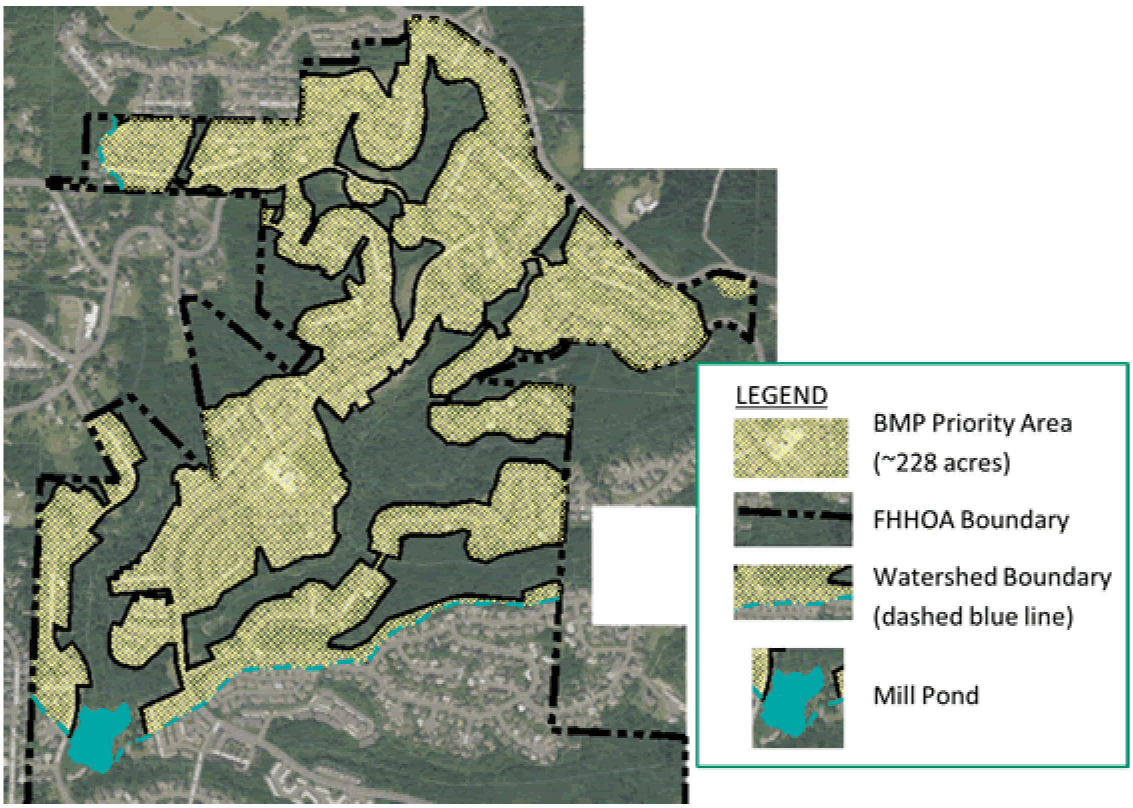

Figure 4-1: BMP ("Practice" for short) Priority Area

Responding to Stakeholders

Back to the top

A variety of messages heard at the ecocharrete workshop and numerous conversations with FHHOA stakeholders, especially Pam Morris (Board Liason), Meg Miller & Susan Weedall (G2 committee members) and Jennifer Callaghan (HOA Manager), narrowed the types and locations of the proposed project sites further. What follows is a discussion of those messages and goals, how they shaped the selection of opportunities, and the recommended projects themselves.

“Big impact”. The FHHOA Board wanted projects with big impacts, specifically projects that will reduce the volume of sediment entering Mill Pond.

Planning Response:
1. Larger site area opportunities were prioritized over smaller projects.
2. Lawns and grassy areas, which export the most sediment of any other land use area at the HOA, were prioritized over other more difficult to address areas like pavement.

Cost. Some additional implementation money for these projects is available in the future; however, discussion of raising the FHHOA monthly fees in the past, even by a small amount, is reported to have resulted in a tremendous push-back by residents.

Planning Response:
1. Early estimates from landscape contractors for a variety of proposed practices were obtained to inform decisions.
2. Projects that would appeal to a variety of grant funding sources were prioritized over projects with no grant sources. The FHHOA money that is available for implementation can be used as matching funds for future grants.
3. Projects where free materials are available now (bank stabilization with re-vegetation) were prioritized over projects with no immediate cost minimization resources.

Fig 4-2 After school, a father puts out his own warning signs for drivers on his street

Improved street safety. Many people are concerned with drivers who drive too fast on neighborhood roads.

Planning Response:
There are two street design opportunities at FHHOA that would slow traffic. The traffic calming effect of tree lined streets versus no trees has been well established in scientific studies. Also, narrowing driving lanes to 10 feet, instead of the typical 12 foot width given to drivers on highways such as I-5, slows traffic. This has been done throughout the HOA, but because there is excess parking available along many of these roads, they often seem much wider than a highway lane, encouraging drivers to speed up.

Providing two on-street parking spaces per house, a number of areas were identified as viable locations to remove excess pavement and plant additional shrubs and/or trees. See the section on “Depaving” for more information on implementation.

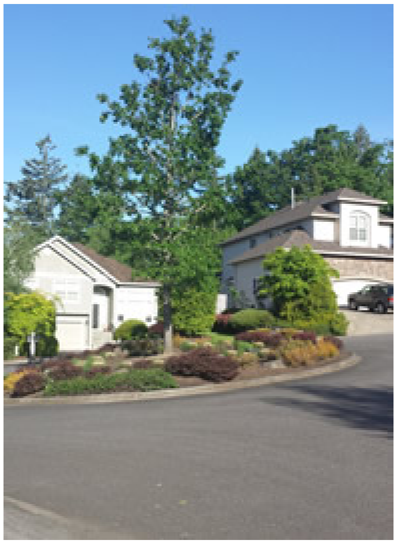

Fig 4-3 While there are numerous attractive cul-de-sacs with vegetation and amenities in the middle, this approach was ruled out due to the limited flat areas and safe areas to play.

Preserve play areas in cul-de-sacs. One approach, removing pavement and replanting the center of a cul-de-sac (aka depaving into what's called a "Pocket Park"), was promoted by stakeholders in the ecocharrette; however, this has been avoided. A few conversations later with homeowners and conversations with Meg Miller had with some of her nearby neighbors indicate that most owners would not want to lose the play area that the cul-de-sacs provide their community.

As a result, no cul-de-sac centers are proposed to be removed and replanted, although there are many great examples of these throughout the HOA and this is an encouraged practice. Some cul-de-sacs, however, are so large (90-foot diameter) and driveway alignments are located in such a way that specific portions of the cul-de-sac can be removed without impacting parking, without significantly impacting maneuverability, parking, or play areas (project 54). One other project (project 63) proposes that the existing cul-de-sac pavement be removed and replaced with permeable pavers, which will indicate to drivers that this area is designed for pedestrians (ex: kids at play) more so than for cars and has the effect (in numerous studies on what are called **woonerfs, home zones, or complete streets**) of creating a more safe condition for everyone.

Consider icy/snowy conditions. Miller Road is a busy road and while there was some discussion regarding depaving "extra" pavement down the middle and creating a tree lined roadway, the extra pavement in the middle, especially on steeper areas, isn't extra pavement at all, but needed as space for cars to drive around stranded vehicles. For this reason, depaving projects tend to be proposed on lower traffic areas and on areas that are too steep for bioretention facilities (aka green streets) but might still be considered some of the flatter areas of the FHHOA.

Address drainage & maintenance problems. A number of neighbors responded to the survey citing a variety of drainage areas including muddy yards (ex: project 61) and excessive runoff coming onto their property (ex: project 52). In addition, the HOA has a few areas known to be high maintenance, including Valley View Park (ex: projects 24, 32, 60, and 62).

Ranking Method

Back to the top

Projects are ranked:

- First on what kind of practice it is and the overall ranking that practice was found to have when cost effectiveness in reducing runoff and sediment transport was examined **(see Chapter 3)**
- Second, on the effectiveness of the individual project in reducing sediment
- After these two criteria, some projects may be moved up in the FHHOA schedule based onobservations, professional experience, and/or stakeholder input on whether the project will solve an existing drainage and/or maintenance problem. Projects with known

drainage issuess are 7, 24 (lawn area at top of Valley View Park), 25, 27, 32 (Bioretention in Valley View Park), 36, 43, 45, 51, 52, 53, 60 (Porous walkway in Valley View Park).

Recommended Projects

Back to the top

A map of recommended projects is available online through a custom Google map. CLICK HERE TO SEE ALL THE PROJECTS TOGETHER ON ONE MAP. Each place mark has a number, which reflects the recommended order in which to implement each project. Click on each place mark to see information specific to each practice, including pictures, videos, and annual volume of sediment and runoff reduced.

The projects are also listed as follows:

1st: Revegation to Stabilize Steep Slopes	2nd: Restored Soils (from Lawn to Lawn)	3rd: Bioretention	4th: Restored Soils (from Lawn to Perennial Garden)	5th: Depaving (low traffic)
6th: Porous Walkways	7th: Restored Soils (from Lawn to Meadows)	8th: Porous Roadway	9th: Depaving (medium traffic)	

1st Practice to Implement: Revegetation to Stabilize Steep Slopes

Back to the top

Click here to see only the revegetation projects on one map

Project Ranking		
1	Area of Project [sf] Area Managed [sf] Runoff reduced annually [gal] Sediment capture annually [lbs] Ownership More info Coordinates	48,514 48,514 906,300 4,790 FHHOA Project similar to video for project 7 and project 10 45.546359, -122.774009
2	Area of Project [sf] Area Managed [sf] Runoff reduced annually [gal] Sediment capture annually [lbs] Ownership More info Coordinates	34,371 34,371 642,100 3,393 Portland Public School Project similar to video for project 7 and project 10 45.542275, -122.776403
3	Area of Project [sf] Area Managed [sf] Runoff reduced annually [gal]	23,372 23,372 436,600

	Sediment capture annually [lbs] Ownership More info Coordinates	2,307 FHHOA Project similar to video for **project 7** and **project 10** **45.548829, -122.775285**
4	Area of Project [sf] Area Managed [sf] Runoff reduced annually [gal] Sediment capture annually [lbs] Ownership More info Coordinates	17,947 17,947 335,300 1,772 FHHOA Project similar to video for **project 7** and **project 10** **45.548116, -122.773865**
5	 Area of Project [sf] Area Managed [sf] Runoff reduced annually [gal] Sediment capture annually [lbs] Ownership More info Coordinates	 16,883 16,883 315,400 1,667 FHHOA Project similar to video for **project 7** and **project 10** **45.550758, -122.774956**
6	Area of Project [sf] Area Managed [sf] Runoff reduced annually [gal] Sediment capture annually [lbs] Ownership More info Coordinates	14,924 14,924 278,800 1,473 FHHOA Project similar to video for **project 7** and **project 10** **45.538615, -122.780576**

7	 Area of Project [sf] 14,134 Area Managed [sf] 14,134 Runoff reduced annually [gal] 246,000 Sediment capture annually [lbs] 1,395 Ownership FHHOA Video for **project 7.** More info Seeps from the hillside are causing sediment to end up on the road and into the catch basin inlet. This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff. Coordinates **45.551087, -122.775995**
8	Area of Project [sf] 13,616 Area Managed [sf] 13,616 Runoff reduced annually [gal] 254,400 Sediment capture annually [lbs] 1,344 Ownership FHHOA More info Project similar to video for **project 7** and **project 10** Coordinates **45.537439, -122.783405**
9	Area of Project [sf] 13,416 Area Managed [sf] 13,416 Runoff reduced annually [gal] 250,700 Sediment capture annually [lbs] 1,325 Ownership FHHOA More info Project similar to video for **project 7** and **project 10** Coordinates **45.542829, -122.778272**

10		
	Area of Project [sf]	12,520
	Area Managed [sf]	12,520
	Runoff reduced annually [gal]	233,900
	Sediment capture annually [lbs]	1,236
	Ownership	FHHOA
	More info	**Video for project 10**, area includes grassy areas on both sides of NW Chapin Drive
	Coordinates	**45.547112, -122.770154**
11	Area of Project [sf]	8,342
	Area Managed [sf]	8,342
	Runoff reduced annually [gal]	155,800
	Sediment capture annually [lbs]	824
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.538878, -122.780295**
12	Area of Project [sf]	7,354
	Area Managed [sf]	7,354
	Runoff reduced annually [gal]	137,400
	Sediment capture annually [lbs]	726
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.548641, -122.780495**
13	Area of Project [sf]	5,924
	Area Managed [sf]	5,924
	Runoff reduced annually [gal]	110,700
	Sediment capture annually [lbs]	585
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.547506, -122.773504**
14	Area of Project [sf]	5,056
	Area Managed [sf]	5,056
	Runoff reduced annually [gal]	94,500

	Sediment capture annually [lbs]	499
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.546636, -122.770357**
15	Area of Project [sf]	4,879
	Area Managed [sf]	4,879
	Runoff reduced annually [gal]	91,100
	Sediment capture annually [lbs]	482
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.548596, -122.779268**
16	Area of Project [sf]	4,126
	Area Managed [sf]	4,126
	Runoff reduced annually [gal]	77,100
	Sediment capture annually [lbs]	407
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.546764, -122.772487**
17	Area of Project [sf]	3,918
	Area Managed [sf]	3,918
	Runoff reduced annually [gal]	73,200
	Sediment capture annually [lbs]	387
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.542403, -122.778366**
18	Area of Project [sf]	3,783
	Area Managed [sf]	3,783
	Runoff reduced annually [gal]	70,700
	Sediment capture annually [lbs]	374
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.5481167, -122.7753539**
19	Area of Project [sf]	3,734
	Area Managed [sf]	3,734
	Runoff reduced annually [gal]	69,700
	Sediment capture annually [lbs]	369
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.548605, -122.780748**
20	Area of Project [sf]	3,338
	Area Managed [sf]	3,338
	Runoff reduced annually [gal]	62,300
	Sediment capture annually [lbs]	330
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.546709, -122.766290**
21	Area of Project [sf]	2,900
	Area Managed [sf]	2,900

	Runoff reduced annually [gal]	54,200
	Sediment capture annually [lbs]	286
	Ownership	FHHOA
	More info	Project similar to video for **project 7** and **project 10**
	Coordinates	**45.548622, -122.778376**

2nd Practice to Implement: Restored Soils (from Lawn to Lawn)	**Back to the top**

Click here to see only the Restored Soils projects

Project Ranking	
22	 Area of Project [sf] 22,762 Area Managed [sf] 22,762 Runoff reduced annually [gal] 118,100 Sediment capture annually [lbs] 170 Ownership Portland Public Schools More info **Video for project 22** Coordinates **45.542637, -122.777232**
23	 Area of Project [sf] 6,485 Area Managed [sf] 6,485

	Runoff reduced annually [gal] 33,700 Sediment capture annually [lbs] 48 Ownership FHHOA More info Includes grassy areas on left and right from NW Chapin to Thompson and the grassy area on the right, across Thompson Rd. The grassy area on the left is project 24 and was separated so that it could be addressed with Valley View Park improvements. Coordinates **45.5474901, -122.7726796**
24	 Area of Project [sf] 3,726 Area Managed [sf] 3,726 Runoff reduced annually [gal] 19,300 Sediment capture annually [lbs] 28 Ownership FHHOA More info **Video for project 24** in Valley View Park Valley View Park is an expensive area to maintain because runoff is regularly eroding the hillside and **moving compost out of garden beds**. This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff. Coordinates **45.5471004, -122.7729072**

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<td>25</td>
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Fig 4-4 This photo shows project 25 on Bartholemew (left) and project 26 on Miller (towards the right). These two projects were separated because this project 25 has an existing drainage problem requiring a high degree of sediment removal of the area drain inlets.

<table>
<tr><td>Area of Project [sf]</td><td>3,000</td></tr>
<tr><td>Area Managed [sf]</td><td>3,000</td></tr>
<tr><td>Runoff reduced annually [gal]</td><td>15,600</td></tr>
<tr><td>Sediment capture annually [lbs]</td><td>22</td></tr>
<tr><td>Ownership</td><td>FHHOA</td></tr>
<tr><td>More info</td><td><u>Video for project 25</u>. This project is likely to have a much higher annual sediment capture than predicted since it is actively clogging four small area drains between the sidewalk and the NW Bartholomew Drive.This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff.</td></tr>
<tr><td>Coordinates</td><td><u>45.538326, -122.780010</u></td></tr>
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<tr><td>Area of Project [sf]</td><td>2,600</td></tr>
<tr><td>Area Managed [sf]</td><td>2,600</td></tr>
<tr><td>Runoff reduced annually [gal]</td><td>13,500</td></tr>
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	Sediment capture annually [lbs]	19
	Ownership	FHHOA
	More info	Video for project 26
	Coordinates	45.5379753, -122.7799477
27		
	Area of Project [sf]	1,082
	Area Managed [sf]	1,082
	Runoff reduced annually [gal]	5,600
	Sediment capture annually [lbs]	8
	Ownership	Portland Public Schools
	More info	Video for project 27. A high degree of sediment comes down from a dusty, eroded "desire path" between the school and the track. This path is also a potential walking hazard. This project is recommended to be moved up in the ranking, at the discretion of Portland Public Schools and FHHOA staff.
	Coordinates	45.542989, -122.777523

3rd Practice to Implement: Bioretention Back to the top

Click here to see a map on only the bioretention facilities

28	 Project Type: Stormwater planter Area of Project [sf]: 300 Area Managed [sf]: 5,000 Runoff reduced annually [gal]: 24,400 Sediment capture annually [lbs]: 91 Ownership: FHHOA More info: Before & after photos similar to project 35 in Chapter 5 Coordinates: 45.544278, -122.772678
29	 *This photo shows both project 29 and 56.* Project Type: Stormwater planter Area of Project [sf]: 311 Area Managed [sf]: 5,950 Runoff reduced annually [gal]: 24,300 Sediment capture annually [lbs]: 90 Ownership: Public More info: Video for project 29 Coordinates: 45.538777, -122.784131

30

Project Type	**Stormwater planter**
Area of Project [sf]	305
Area Managed [sf]	5,083
Runoff reduced annually [gal]	23,700
Sediment capture annually [lbs]	89
Ownership	Public
More info	**Before & after photos similar to project 35**, except stormwater runoff is only coming in from one side
Coordinates	**45.538429, -122.780124**

31

Project Type	**Stormwater planter**

	Area of Project [sf]	282
	Area Managed [sf]	5,333
	Runoff reduced annually [gal]	22,000
	Sediment capture annually [lbs]	82
	Ownership	Public
	More info	**Before & after photos similar to project 35**, except stormwater runoff is only coming in from one side
	Coordinates	**45.549731, -122.777296**
32		
	Project Type	**Swale**
	Area of Project [sf]	416
	Area Managed [sf]	10,000
	Runoff reduced annually [gal]	21,600
	Sediment capture annually [lbs]	81
	Ownership	FHHOA
	More info	**Video for project 32**, Located in Valley View Park. Valley View Park is an expensive area to maintain because runoff is regularly eroding the hillside and **moving compost out of garden beds**. This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff.
	Coordinates	**45.5468088, -122.7730317**

33	 Project Type: **Stormwater planter** Area of Project [sf]: 394 Area Managed [sf]: 6,667 Runoff reduced annually [gal]: 20,500 Sediment capture annually [lbs]: 77 Ownership: Public More info: **Video for project 33** Coordinates: **45.541640, -122.783022**
34	 Project Type: **Stormwater planter** Area of Project [sf]: 238 Area Managed [sf]: 4,667 Runoff reduced annually [gal]: 18,600 Sediment capture annually [lbs]: 70 Ownership: Public More info: **Video for project 34.** **See before and after images for project 34 in Chapter 5.** In a conversation, the homeowner on this frontage expressed great interest in this project. Coordinates: **45.551537, -122.772866**

35

Project Type	Stormwater planter
Area of Project [sf]	200
Area Managed [sf]	3,333
Runoff reduced annually [gal]	18,700
Sediment capture annually [lbs]	70
Ownership	Public
More info	See before and after pictures of project 35 in Chapter 5
Coordinates	45.547673, -122.772253

36

Project Type	Stormwater planter
Area of Project [sf]	510
Area Managed [sf]	5,667
Runoff reduced annually [gal]	26,200
Sediment capture annually [lbs]	65
Ownership	FHHOA
More info	This project is uphill of project 51 and receives a high volume of runoff from Skyline Drive.This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff.
Coordinates	45.547016, -122.764229

37	Project Type	Stormwater planter
	Area of Project [sf]	200
	Area Managed [sf]	3,333
	Runoff reduced annually [gal]	17,000
	Sediment capture annually [lbs]	64
	Ownership	FHHOA
	More info	Before & after photos similar to project 35, except stormwater runoff is only coming in from one side
	Coordinates	45.543710, -122.769715

38	Project Type	Swale
	Area of Project [sf]	305
	Area Managed [sf]	3,389
	Runoff reduced annually [gal]	16,800
	Sediment capture annually [lbs]	63
	Ownership	Public
	More info	Video for project 38
	Coordinates	45.548746, -122.780379

39	
	Project Type: Vegetated filter strip

Project 39	
Project Type	Vegetated filter strip
Area of Project [sf]	325
Area Managed [sf]	325
Runoff reduced annually [gal]	4,875
Sediment capture annually [lbs]	70
Ownership	Public
More info	Video for project 39 and before and after photos in Chapter 5
Coordinates	45.547885, -122.768179

40

Project 40	
Project Type	Stormwater planter
Area of Project [sf]	260
Area Managed [sf]	2,889
Runoff reduced annually [gal]	13,400
Sediment capture annually [lbs]	50
Ownership	Public
More info	Before & after photos similar to project 35, except stormwater runoff is only coming in from one side
Coordinates	45.545754, -122.776691

41

Project Type	**Stormwater planter**
Area of Project [sf]	260
Area Managed [sf]	4,333
Runoff reduced annually [gal]	20,200
Sediment capture annually [lbs]	50
Ownership	Public
More info	**Before & after photos similar to project 35**, except stormwater runoff is only coming in from one side
Coordinates	**45.538491, -122.780306**

42

Project Type	**Stormwater planter**

	Area of Project [sf]	256
	Area Managed [sf]	2,844
	Runoff reduced annually [gal]	13,300
	Sediment capture annually [lbs]	50
	Ownership	FHHOA
	More info	**Video for project 42**
	Coordinates	**45.549096, -122.771047**

Fig 4-5 Degraded pavement, gravel road edges, and a dip in the sidewalk add up to a lot of sediment deposited on the FHHOA owned sidewalk.

Fig 4-6 The inlet located In the middle of all the rocks, cannot be seen here because it's buried beneath sediment. The pattern in Fig 4-5indicates that this area probably floods and makes foot passage difficult during intense rain events.

43	Project Type	**Vegetated filter strip**
	Area of Project [sf]	260
	Area Managed [sf]	4,125
	Runoff reduced annually [gal]	19,300
	Sediment capture annually [lbs]	47 (but there is likely to much greater volume of sediment capture than predicted by the model considering the existing drainage condition).This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff.
	Ownership	Public
	More info	**Video for project 43**
	Coordinates	**45.552154, -122.773338**

44

Project Type	**Stormwater planter**
Area of Project [sf]	243
Area Managed [sf]	5,000
Runoff reduced annually [gal]	12,600
Sediment capture annually [lbs]	47
Ownership	FHHOA
More info	**Video for project 44**
Coordinates	**45.548789, -122.782833**

45		
	Project Type	**Swale**
	Area of Project [sf]	359
	Area Managed [sf]	8,867
	Runoff reduced annually [gal]	18,700
	Sediment capture annually [lbs]	46
	Ownership	Public
		Video for project 45
	More info	This is an area of high maintenance and likely flooding due to clogged inlets, installed by the FHHOA. This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff.
	Coordinates	**45.549016, -122.770009**

46	 Project Type: **Swale** Area of Project [sf]: 225 Area Managed [sf]: 2,500 Runoff reduced annually [gal]: 11,700 Sediment capture annually [lbs]: 44 Ownership: FHHOA More info: Project similar to video for **project 42** Coordinates: **45.548594, -122.780795**
47	 Project Type: **Rain garden** Area of Project [sf]: 180 Area Managed [sf]: 2,000 Runoff reduced annually [gal]: 9,400 Sediment capture annually [lbs]: 35 Ownership: Portland Public Schools Coordinates: **45.542412, -122.776889**

4th Practice to Implement: Restored Soils (from Lawn to Perennial Garden)	**Back to the top**

Click here to see only the Restored Soils projects

48		
	Area of Project [sf]	10,654
	Area Managed [sf]	10,654
	Runoff reduced annually [gal]	88,500
	Sediment capture annually [lbs]	149
	Ownership	Public
	More info	**Video for project 48**. Area includes the entire long grassy strip on NW Chapin Drive from just south of NW Wiley to just south of the other side of NW Wiley. Area also includes grassy area in front of fountain.
	Coordinates	**45.5479992, -122.7727844**
49		
	Area of Project [sf]	7,312
	Area Managed [sf]	7,312
	Runoff reduced annually [gal]	60,700
	Sediment capture annually [lbs]	102
	Ownership	FHHOA
	More info	This project could just as easily be a revegetation project, even though it doesn't have steep slopes.
	Coordinates	**45.541711, -122.782551**

50	 Area of Project [sf] 3,733 Area Managed [sf] 3,733 Runoff reduced annually [gal] 31,000 Sediment capture annually [lbs] 52 Ownership FHHOA More info **Video for project 50** Coordinates **45.547776, -122.768047**
51	 Area of Project [sf] 2,750 Area Managed [sf] 2,750 Runoff reduced annually [gal] 22,800

	Sediment capture annually [lbs]	38
	Ownership	FHHOA
	More info	See before and after images for project 51 in Chapter 5 This project is downhill of project 36 and receives a high volume of runoff from Skyline Drive.This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff.
	Coordinates	45.546991, -122.764266
52		
	Area of Project [sf]	2,000
	Area Managed [sf]	2,000
	Runoff reduced annually [gal]	16,600
	Sediment capture annually [lbs]	28
	Ownership	Private
	More info	Video for project 52. This site is currently receiving large volumes of runoff from off-site annually. This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff.
	Coordinates	45.547017, -122.764666

5th Practice to Implement: Depaving (low traffic) to trees & groundcover	Back to the top

Click here to see a map of only depaving projects

53		
	Area of Project [sf]	5,780
	Area Managed [sf]	5,780
	Runoff reduced annually [gal]	90,600
	Sediment capture annually [lbs]	156, Could be higher if adjacent soils are restored and planted as a perennial garden.
	Ownership	Public
	More info	**Video for project 53**. A lot of dirt tumbles down the hill and into the inlets in this area. In addition, bare areas of soil in the right-of-way and up the hill on private property, if possible, should be restored and planted as a perennial garden to stabilize the soil in this area. This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff. Proposed area stretches from just south of the Herrin Ct intersection to the NW Chapin side of 8810 NW Herrin Ct.
	Coordinates	**45.546743, -122.767752**

54

Area of Project [sf]	1,517
Area Managed [sf]	1,517
Runoff reduced annually [gal]	24,600
Sediment capture annually [lbs]	42
Ownership	Public
More info	**Video for project 54**
Coordinates	**45.541308, -122.784131**

55

Area of Project [sf]	1,500
Area Managed [sf]	1,500
Runoff reduced annually [gal]	24,300
Sediment capture annually [lbs]	42
Ownership	Public
Coordinates	**45.541662, -122.782850**

56

Area of Project [sf]	1,400
Area Managed [sf]	1,400
Runoff reduced annually [gal]	22,700
Sediment capture annually [lbs]	39
Ownership	Public
More info	**Video for project 56**
Coordinates	**45.539040, -122.784261**

57

Fig 4-7 Looking downhill. Recommendations for how to address this blind curve, the fire hydrant, and more are ***in the video.***

Fig 4-8 Looking uphill. A straight road with clear sightlines offers the opportunity to safely remove the 8 foot wide parking area on the right.

Area of Project [sf]	1,028
Area Managed [sf]	1,028
Runoff reduced annually [gal]	16,600
Sediment capture annually [lbs]	29
Ownership	FHHOA
More info	**Video for project 57** **See before and after images for project 57 in Chapter 5**
Coordinates	**45.545841, -122.771643**

6th Practice to Implement: Porous Walkways	Back to the top

Click here to see a map of all porous pavement projects

58			
	Area of Project [sf]	2,800	
	Area Managed [sf]	2,800	
	Runoff reduced annually [gal]	46,500	
	Sediment capture annually [lbs]	67	
	Ownership	FHHOA	
	More info	Before and after pictures look the same	
	Coordinates	45.546174, -122.765770	
59			
	Area of Project [sf]	1,900	
	Area Managed [sf]	1,900	
	Runoff reduced annually [gal]	31,500	
	Sediment capture annually [lbs]	46	
	Ownership	Portland Public Schools	

	More info Coordinates	**Video for project 59** **45.542637, -122.777232**
60		
	Area of Project [sf]	1,300
	Area Managed [sf]	1,300
	Runoff reduced annually [gal]	21,600
	Sediment capture annually [lbs]	31
	Ownership	FHHOA
	More info	**Video for project 60** in Valley View Park Valley View Park is an expensive area to maintain because runoff is regularly eroding the hillside and **moving compost out of garden beds**. This project is recommended to be moved up in the ranking, at the discretion of FHHOA staff.
	Coordinates	**45.547049, -122.773020**
61		
	Area of Project [sf]	1,809
	Area Managed [sf]	1,809
	Runoff reduced annually [gal]	16,600
	Sediment capture annually [lbs]	27
	Ownership	Private

	More info Coordinates Multiple practices include Soil restoration to perennial garden and a porous walkway.	**Video for project 61** **45.546310, -122.765629**

7th Practice to Implement: Restored Soils (from Lawn to Meadows)	**Back to the top**

Click here to see only the Restored Soils projects

62		
	Area of Project [sf]	8,955
	Area Managed [sf]	8,955
	Runoff reduced annually [gal]	46,400
	Sediment capture annually [lbs]	150
	Ownership	FHHOA
	More info	**Video for project 62** in Valley View Park
	Coordinates	**45.546865, -122.773302**

8th Practice to Implement: Porous Roadway	**Back to the top**

Click here to see a map of all porous pavement projects

<table>
<tr><td rowspan="8">63</td><td colspan="2"></td></tr>
<tr><td>Area of Project [sf]</td><td>6,251</td></tr>
<tr><td>Area Managed [sf]</td><td>6,251</td></tr>
<tr><td>Runoff reduced annually [gal]</td><td>120,700</td></tr>
<tr><td>Sediment capture annually [lbs]</td><td>173</td></tr>
<tr><td>Ownership</td><td>Public</td></tr>
<tr><td>More info</td><td>A permeable paver roadway would replace the extent of the cul-de-sac</td></tr>
<tr><td>Coordinates</td><td>45.546131, -122.769457</td></tr>
</table>

9th Practice to Implement: Depaving (medium traffic road) to trees & groundcover	Back to the top

Click here to see a map of only depaving projects

<table>
<tr><td rowspan="7">6
4</td><td colspan="2"></td></tr>
<tr><td>Area of Project [sf]</td><td>5,146</td></tr>
<tr><td>Area Managed [sf]</td><td>5,146</td></tr>
<tr><td>Runoff reduced annually [gal]</td><td>83,300</td></tr>
<tr><td>Sediment capture annually [lbs]</td><td>140</td></tr>
<tr><td>Ownership</td><td>Public</td></tr>
</table>

	More info	See before and after images of project 64 in Chapter 5
	Coordinates	45.538198, -122.7802034

West Hills Innovative Stormwater Demonstration
Final Report, Chapter 5: Implementing Recommended Projects

Practice descriptions were provided in Chapter 3. Individual recommended projects can be found in **Chapter 4 Recommended Projects** where users can also access videos and schematic renderings with information on implementation considerations. This chapter provides implementation guidelines such as specifications, schematic designs, etc for each practice.

IMPORTANT NOTE ABOUT FINAL DESIGN: While these projects are unlikely to exacerbate existing landslide issues, if the FHHOA has any concern whatsoever, engage a geotechnical engineer to provide feedback on practices. As a result of stakeholder concern about rainfall practices, engineering costs have been incorporated into unit costs.

IMPORTANT NOTE ABOUT LAWNS: As a result of the **high sediment export of lawn**,*the only time lawn should be a future condition is when it is already lawn.* In other words, where there are gateways, where lawn is probably preferred, I've recommended lawn to put back after soil restoration. Replacing any other land use cover, such as low traffic road and converting it to lawn is likely to increase sediment export to Mill Pond. Even in cases where lawn is desired (ex: Facility 35 and 36 at the intersection of Bartholomew & Miller Roads), areas should be reduced by expanding shrub gardens and minimizing lawn in the final design.

Each practice has it's own page with implementation guidance for that particular practice. This implementation guidance and **relevant fact sheets** should be shared with contractors placing bids for the HOA:

Revegetation to Stabilize Steep Slopes

Restored Soils

Bioretention

Porous Walkways & One Porous Cul-de-sac Roadway Project

Depaving

Final Report, Chapter 5: Implementing Recommended Practices
Revegetation to Stabilize Steep Slopes

Planting Strategy	Stakeholder Considerations	Specifications & Materials Sources

Steep slopes generate faster and more erosive flows, so the grassy areas between and around existing trees should be planted with native trees & shrubs to intercept rainfall during our small, frequent rain events and to slow runoff by breaking up the flows during more intense storms. In addition, the complex and deep roots will hold the soil and pull water out of the ground, even when it’s not raining. Projects proposed for this practice are mostly in more natural, unusable, steeply sloping, open space areas.

This practice is a recommended practice for stabilizing slopes to prevent landslides. (**See "Homeowner's Guide to Landslides" by Dr. Scott Burns of Portland State University, page 10.**)

*Figure 5-1 Before planting, steep grassy slopes generate sediment laden runoff and are at a higher risk of sliding at **project 5** and many other project sites.*

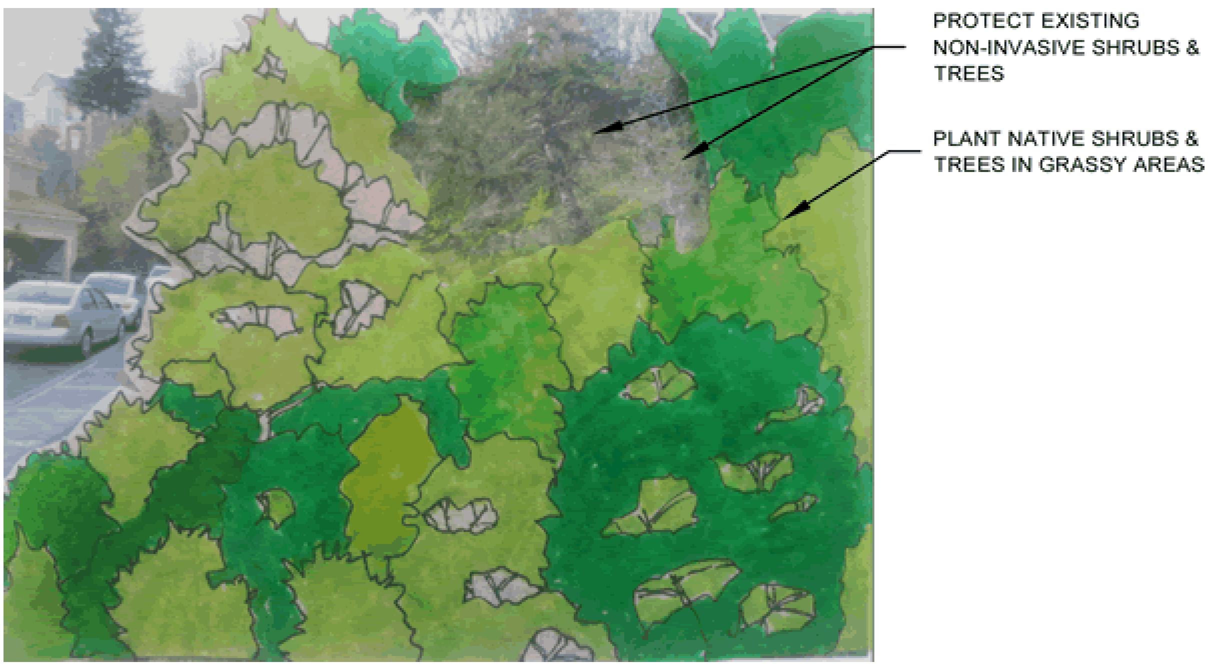


Figure 5-2 After planting steep slopes are stabilized and runoff is significantly reduced

Planting Strategy

Back to the top

Planting strategy: A formal planting plan for some areas may be desired but for these areas is not strictly needed; however, a strategy should be developed by a landscape professional experienced in habitat restoration. This professional may be a landscape contractor, designer, or architect.

This strategy should include a palette of appropriate native trees and shrubs and how they will be irrigated for two summers. If the right plant is put in the right place, sometimes irrigation will not even be needed, so this too should be considered. (See more below on plant establishment and irrigation.)

Installing the plants: Work can be done by volunteers, but these areas are quite steep. Hiring a professional landscape contractor who is experienced in planting restoration sites is recommended and this is the cost incorporated into the estimate.

Regardless of who does the actual planting, bare root or small potted trees and shrubs are recommended, which have some significant advantages over planting large (1 gallon and up) trees and shrubs.

Small pots or bare root plants:

- Adapt faster to their new conditions
- Require less water to adapt
- Have a higher rate of survival
- Cost less and are easier to plant

Stakeholder Considerations

Back to the top

Protect views: The planting strategy should ensure that no views will be impacted by the plantings. Trees topped by homeowners can be seen throughout the natural areas, and **this is a very damaging practice for a variety of reasons**. Plant shorter shrubs where views may be impacted (in most cases, this is the top of the hill) and taller trees where their mature height will not impact views (in most cases, this is the bottom of the hill).

Aesthetics: Shrubs and trees that flower at different times of the year might be carefully combined to be seen from the road.

Specifications & Materials Sources

Back to the top

Free plants from Clean Water Services: Clean Water Services is willing to provide us with thousands of small, bare root native trees and shrubs that would be ideal for these slopes, for free. Rich Hunter, the Water Resources Program Manager, at (503) 681-3600 or (503) 681-3638 and **hunterr@cleanwaterservices.org** has offered to assist the HOA with the first step in the process of getting plants.

Planting density: In restoration projects in our region, Clean Water Services recommends 1800 shrubs and 600 trees per acre as appropriate.

Restoring the soil: Soil restoration is essential to getting the plants established with minimal or no additional water. Many of the steep slopes have been compacted by equipment or covered in fabric and are likely to have a lower than optimal soil biology count or diversity.

While compost amendment **(as described in the fact sheet developed for the FHHOA**) is feasible and helpful for stabilizing slopes up to 2H:1V **(Click here and scroll down to the second photo on this website from WA Department of Transportation**), working on steep slopes with existing intermittent trees and shrubs will make this practice unreasonably expensive. Instead, as a minimum, mycorrhizae is recommended to be added to these very disturbed and highly compacted slopes. Avoid products that are manure based or commercial weed and feed products, since these will run off the steep slopes during the establishment period and degrade water quality with nutrients, excessive amounts of which can cause algae blooms and unsafe health conditions.

One such product that meets the specification and can be hydroseeded onto these steep slopes is Permamatrix, a locally sourced product from **Sunmark Environmental in Troutdale, OR.**

Time of year: Shrubs and trees should be planted in the fall when they will have the longest oppportunity to establish during the rainy season.

Irrigation for establishment period/1st year: As evidenced by the landslide on SW Terrwilliger in 2008 that destroyed a number of homes, irrigation on steep slopes must be done with great care. For this reason, conventional piped irrigation systems are NOT recommended. Instead, as is commonly done, hire a landscape company with a low pressure water truck to deeply water plants in the root zone only (generally the area between the trunk and the dripline/canopy) once in July and again in Aug after initial planting.

Although irrigation for more formal landscapes is usually recommended in our region through the first two summers after planting, the planting density accounts for some percentage of plants not expected to survive and planting in the fall will greatly reduce those losses.

This follows the guidance provided on page 10 of **"Homeowner's Guide to Landslides"**.

Invasive species: Garlic mustard is an invasive species present in the FHHOA at natural sites such as these slopes, and staff at Clean Water Services is concerned about its spread because it dominates forest floors and appears to impact habitat value. Disturbance activities could easily spread this aggressive and damaging weed. **More information on how to identify and eradicate this weed if on the Clean Water Services website and who to contact can be found on their website - click here**.

Final Report, Chapter 5: Implementing Recommended Practices Restored Soils

*Figure 5-3 Regardless of whether the area will be lawn, meadow, or perrenial garden,**following the guidance in the fact sheet** will result in a similar, high functioning soil profile.*

*Figure 5-4 Areas recommended for restored soils back to lawn are intended to look the same after the stormwater retrofit is in place, as before. In other words, in **project 23** above, the before and after pictures look the same.*

What is it? The practice of amending compacted soils by mixing compost and other helpful materials into them to restore their ability to manage rainfall instead of generate runoff.

Read important note on lawn modification at the beginning of Chapter 5.

See fact sheet on landscape types that you might like after compost amending including lawn, meadow, or a perennial garden with shrubs and/or trees. Each has a different capacity to reduce runoff so the "Restored Soils" practice description always includes a description of the final proposed landscape, such as "Restored Soils (from Lawn to Perennial Garden).

How does this reduce runoff and protect water quality? Restored soil areas temporarily aerate the soil and restore the soil biology that permanently aerate the soil, protecting watersheds with the long-term ability to infiltrate rain. Even if a lawn area is returned to lawn after amendment and receives foot traffic like mowing and playing, studies have shown that the larger soil animals (beetles, worms, etc) keep aerating the soil.

Where can it be done?

- **Disturbed or compacted soils:** Any soil that has been disturbed or compacted will benefit from compost amending, however existing landscape will be damaged and need to be replaced.
- **Avoid areas around existing landscaping:** If existing landscaping is to be preserved, areas under tree canopies and around other plants should not be tilled as this will damage roots.

What's the maintenance?

- **Reduce or eliminate irrigation, fertilizers, herbicides, & pesticides:** Maintenance practices of compost amended soils are the same as any landscape area, however improved soil health should allow reduction or elimination of irrigation, fertilizer, herbicide, and pesticide use.
- **Yearly mulch application:** Keep soil in landscaped garden areas covered with 2-4" of compost by mulching once a year. Aerate turf areas and top-dress with fine mulch.
- **Irrigation:** Using natives, irrigate during the 2-3 year establishment period. See the**supplemental fact sheet including information on establishment irrigation**.

What are some cost considerations? This practice varies with the type of landscape you choose to plant on top (lawn, meadow, shrubs, and/or trees). Long-term irrigation demand can be cut by 50% with a payback period of 3-7 years. For more info on unit costs, **see Appendix B**

More info: Please see the "**Restore Disturbed Soils**", which is very detailed fact sheet created for this project for more information on what it is and how to implement it. Also see the**Challenging Sites Supplemental fact sheet** for information on the final landscape choices (lawn, meadow, perennial gardens, and trees), establishment period irrigation, and reducing water demand.

Final Design: A landscape architect, landscape designer, and/or an arborist to choose native flowers, groundcover, shrubs, and/or trees as desired **(more info here)** and create a planting plan would be required to finalize the design of these projects. While these projects are unlikely to exacerbate existing landslide issues, if the FHHOA has any concern whatsoever, engage ageotechnical engineer to provide feedback on practices.

After amending the soils, the final landscape will be either lawn, meadow, or perennial garden. Since these landscapes have different runoff and sediment export properties, even though all the sites proposed for soil restoration are lawns now, what they will become matters in the model; therefore, the restored soils practice is actually broken up into three different practices as follows:

- Restored Soils (from Lawn to Lawn)
- Restored Soils (from Lawn to Meadow)

- Restored Soils (from Lawn to Perennial Garden)

indicating that the final condition of the project will be either lawn, meadow, or perennial garden.

Figure 5-5 ***At project 51****, bare soil can be seen to be streaking across the low point of this roadway and into the catch basin across the street. Compacted lawn and bare soils are on either side of a nicely landscaped area and are contributing this dirt.*

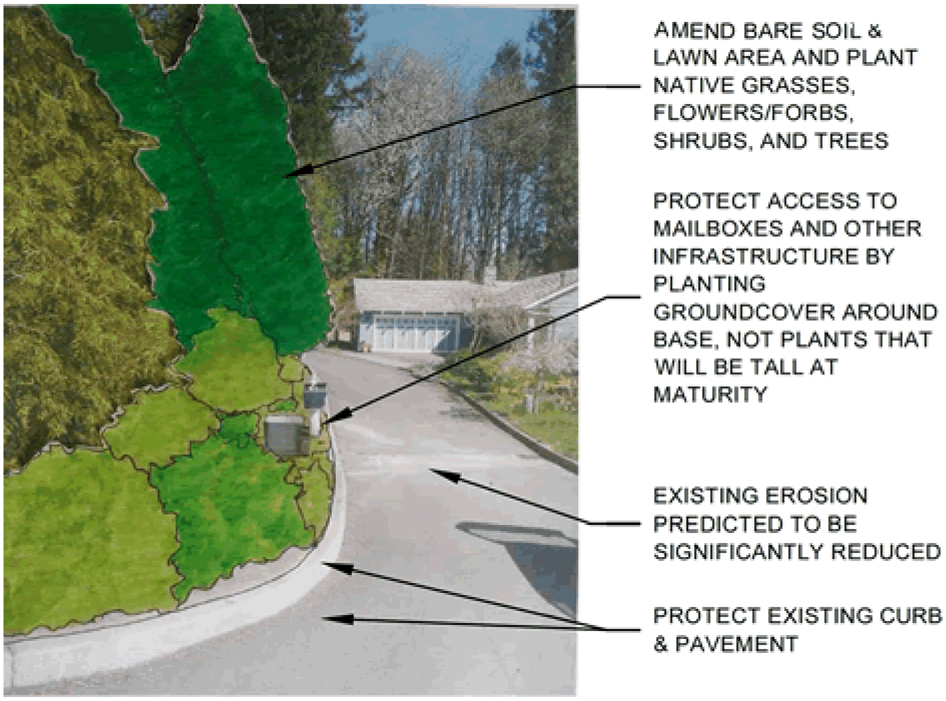


Fig 5-6 Restoring the soils and changing the lawn to perennial garden (not pictured, but just on the other side of the existing trees) and planting unplanted areas (shown) are be surprisingly effective at reducing runoff, which will reduce the amount of sediment carried to Mill Pond.

Final Report, Chapter 5: Implementing Recommended Practices, Porous Pavement

Site Investigation Criteria	Design Criteria	Construction Criteria	Schematic Details	Specifications & Other Definitions

*Fig 5-7 The highly trampled landscape of **project 59** at the school is not just unappealing, it's probably generating as much stormwater runoff as if it were conventionally paved.*

What is it? A stormwater facility that you can walk or drive on.

How does it work? When rain falls on it, the rain passes through the surface, into the base rock below, and finally into native, uncompacted soils. For a pavement to be porous, the porosity of the entire section must be carefully protected or created.

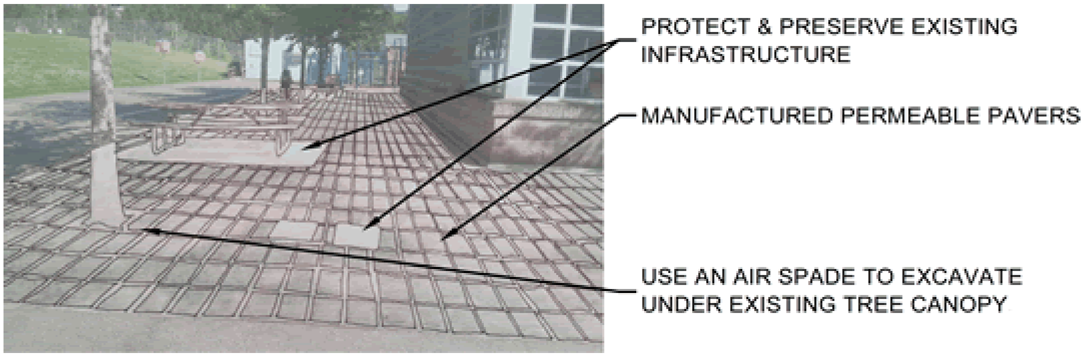


Fig 5-8 Permeable pavers could be carefully installed around existing infrastructure and would reduce runoff from this area by 90% annually.

How does this reduce runoff and protect water quality? For the area where they are installed, they reduce runoff by at least 90% annually, even in heavy clay soils.

Where can it be done?

- **Directly next to other infrastructure:** Porous pavements can be located anywhere impervious pavements might be used as long as the soils are not so compacted that they don't infiltrate (**see design criteria below**). Because the facilities manage rainfall and not runoff, basement flooding or pavement undercutting have not been found to be an issue.
- **Not on steep slopes:** Mulch and gravel paths and permeable pavers should not be placed on a slope steeper than 10%; instead, boardwalks or decks should be used.
- **Not below impervious surfaces or unstable slopes:** Mulch and gravel paths and permeable pavers should not be placed where impermeable surfaces will drain onto path, as this will transport sediment that may clog the surface. Also, any landscaping upslope from walkway must be stabilized with vegetation or stepped walls to prevent erosion of dirt onto walkway. Boardwalks and decks are not subject to these limitations.

What's the maintenance? Maintenance varies with the surface type and is much lower with proper design (**see below**). Maintenance activities consist of ensuring that the surface stays porous. Inspections for bare dirt uphill from the pavement should be performed once a year and landscapes stabilized with temporary erosion control and appropriate native plants.

Maintenance of the porous gravel project is only needed if a large portion of the surface is clogged, which, on a pedestrian path that is properly designed and annually inspected and stabilized, will likely not happen for decades. When it does happen, scrape the first inch of rock off the surface and pour water on the surface below to ensure that the pavement drains. If not, scrape off another inch and re-test until it does drain. Rock that has been scraped off can be washed off in an area where adequate sediment control practices (i.e. compost berm at the bottom of a grassy area) have been installed to capture the sediment. Washed rock should then be re-placed on the path. Close the trail until the clean rock has been installed to insure that foot traffic does not clog the exposed subsurface of the path.

Maintenance of permeable pavers should again be relatively low with adequate initial design and ongoing inspections and stabilization. When it does become clogged, the crushed rock between the pavers should be commercially vacuumed out and replaced with clean rock.

Site Investigation Criteria

Back to the top

Site suitability tool. Site suitability can be investigated using the **porous pavement siting wizard** on the Oregon State University's Stormwater Solutions website.

Infiltration testing. A geotechnical engineer should perform infiltration testing and should also inspect the downhill site to ensure that the site is suitable for infiltrating 90% of our average annual rainfall without causing slides.

Existing pavement areas. All the projects proposed will replace existing impervious pavement areas. This means that the soil below the pavement has already been compacted by heavy machinery. Excavation beyond the depth needed for hydrologic controls and structural stability may be needed to reach a soil strata that can adequately infiltrate. This cannot be predicted, only tested with infiltration testing as recommended above.

Design Criteria

Back to the top

Who can implement these? **The fact sheet discusses** porous walkways including boardwalks & decks, mulch paths, gravel paths, and permeable pavers (both manufactured and homemade), which can be implemented independently by the HOA as long as infiltration testing confirms adequate drainage. A porous roadway project should be designed by a licensed professional such as a civil engineer or landscape architect and each project should include a licensed geotechnical engineer as well.

Pavement section recommendation. During the design of a porous pavement, especially in a roadway, engage a geotechnical engineer to provide a pavement cross section, which includes the pavement and rock below it (aka base rock) for the site's soils in a wet, uncompacted condition. Traffic loading must be accounted for, both during and after construction. For instance, if heavy equipment will be used to construct the porous walkway, then a thicker pavement section will likely be needed (see construction section below for more information).

Infiltration rate. Guidance on infiltration testing is **provided in the fact sheet** or your geotechnical engineer will use a method they prefer. To infiltrate the 10-year storm in Portland, soils should drain at 0.10 inch/hour, which is a very low infiltration rate, but which works because we're managing only that rainfall that falls on the pavement surface and not concentrated runoff from other locations.

Aesthetics & cost considerations of surface types. To minimize cost, porous gravel has been proposed to replace the existing gravel pathways at the HOA. For roadway projects, while other surfaces such as pervious concrete and porous asphalt are available, permeable pavers will create a pleasing aesthetic and will be easier to unclog, should that become a problem in the future. For the small projects proposed, the cost of these three different surfaces is unlikely to be very different.

Additional general information on design criteria for roadways can be found in a **peer reviewed fact sheet** on the Oregon State University's Stormwater Solutions website.

Construction Criteria

Back to the top

Protect trees & native soil infiltration rate. Construction activity and traffic should be limited to the path or roadway areas and not be allowed under the dripline of trees outside of the path or roadway areas; however, construction equipment may not drive over exposed native soils at the bottom of the proposed porous pavement section or the infiltration rate will decrease. For the porous walkway project, where trees will surround the path, construction should occur in stages, excavating the portion of the path that can be reached with the equipment used and installing porous pavement on that section. Cover the pavement with plywood or similar rigid material to protect it from tracked-on sediment from the construction equipment. Now the porous pavement section that has been installed can be driven on and the next section can be installed.

Where trees will receive a porous pavement surface under their canopy, such as the project featured above, an **air spade, which uses compressed air,** should be used to excavate around all roots.

If the native soils at the botttom of the porous pavement must be left exposed for any period of time, especially during the rainy season, cover them temporarily with a geotextile fabric. Clayey soils are easily clogged by the action of rain drops hitting it and resorting the particles, which creates an impermeable sheen. If this is allowed to happen, it will negate the value of the porous pavement, essentially creating an impervious surface at the bottom of the pavement. If soil gets clogged during construction, experience has shown that the contractor will have to wait until the soil dries out, then rake it. (If it's the middle of the winter, this could set the project back months.)

Track, floatation tire, or small equipment. Porous pavements should be installed with equipment designed to spread the weight of their own load out over a large area or equipment that's small and not very heavy to begin with.

Clogging narrative. The contractor should be asked to write a brief narrative of how he or she will prevent clogging from occuring throughout the installation of the entire cross section of the pavement.

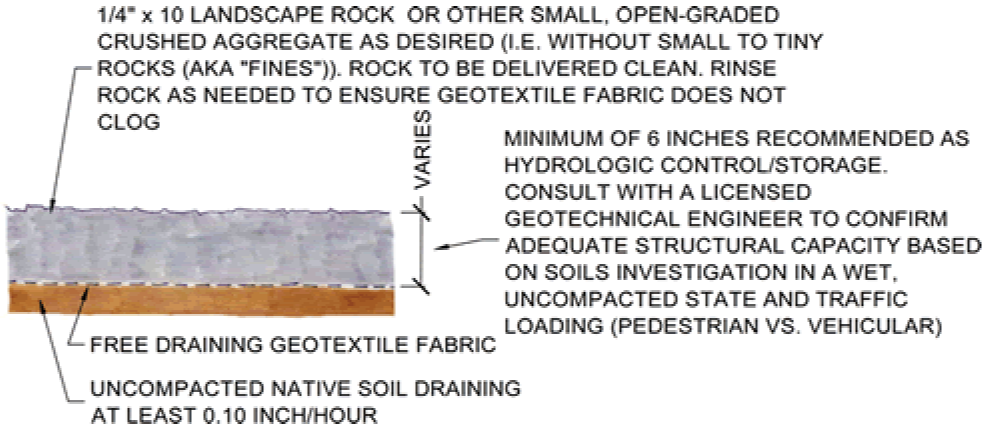
Washing the rock. Most crushed aggregate is delivered "clean" to a standard known as a 2% wash loss; however, the sediment that's left on the rock may still be enough to eventually clog the geotextile fabric. For this reason, all rock should be washed on-site. This may be done by hosing the rock off while still in the delivery truck or after stockpiling. Scoop from the top and place rock. Hose off as needed as the pile diminishes since fines will migrate to lower levels of the pile.

Schematic Details

Back to the top

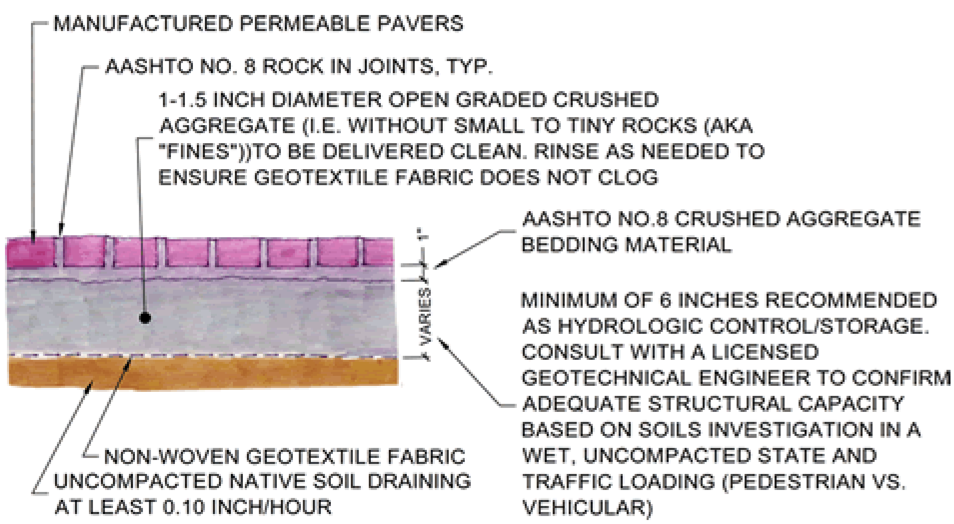
Porous Gravel Schematic Detail

This detail is proposed to replace the existing gravel paths:



Permeable Paver Schematic Detail

This detail may be used for roads or walkways:



Specifications & Other Definitions

Back to the top

Crushed aggregate. Rock quarried with a crusher is angular, not rounded. Angular rock is required to ensure structural stability and all rock used in pavements should be crushed, not rounded.

Open-graded (aka poorly graded) rock. Rock diameters are all similar in size (i.e. 1.5-1 inch rock, AASHTO No. 57, AASHTO No. 8), which creates voids between the rock where water is stored until it can infiltrate. This is the only kind of rock gradation that should be used in porous pavements. "Drain rock" may be open- (poorly graded) or well-graded rock, so take care to make sure you're ordering *open-graded rock.*

The specification for gravel walkways is provided above in the detail itself as 1/4"x10 landscape rock. For roadways, additional specifications are needed as followings:

Adapted from materials courtesy of Tom Cahill of Cahill Associates:
A. Base Course
1. All aggregates beneath the pavement shall meet the following:
a. Maximum Wash Loss of 0.5%
b. Minimum Durability Index of 35
c. Maximum Abrasion of 10% for 100 revolutions and maximum of 50% for 500 revolutions
2. Unless otherwise approved by the Engineer, coarse aggregate for the aggregate base course shall be uniformly graded with the following gradation (AASHTO No. 57)

U.S. Standard Sieve Size	Percent Passing
1 ½" (37.5 mm)	100
1" (25 mm)	95-100
½" (12.5 mm)	25-60
4 (4.75 mm)	0-10
8 (2.36 mm)	0-5

3. Unless otherwise approved by the Engineer, the bedding course shall be uniformly graded with the following gradation (AASHTO No. 8)

U.S. Standard Sieve Size	Percent Passing
½" (12.5 mm)	100
3/8" (9.5mm)	85-100
4 (4.75 mm)	10-30
8 (2.36 mm)	0-10
16 (1.18 mm)	0-5

Non-woven (free draining) geotextile fabric. Non woven geotextile (drainage filter fabric) shall conform to the following:
1. Minimum flow rate of 95 gal/min/ft2 ASTM D-4491-85
2. Grab tensile strength min 115 lb ASTM D-4632-86
3. Burst strength min 150 psi ASTM D-3786-80a
4. Puncture resistance min 45 lb ASTM D-4833-88
5. Apparent opening size 60-90 U.S. Standard Sieve

Final Report, Chapter 5: Implementing Recommended Practices Depaving

Planting Strategy	Stakeholder Considerations	Specifications	Street Width Code Considerations

What is it? The practice of removing any unnecessary areas of impervious pavement (aka hardscape) and replacing it with vegetation. (As mentioned at the beginning of this chapter, **don't replace it with lawn** or sediment export will increase.)

What pavement is considered unnecessary? At the FHHOA, depaving projects were adopted where resident parking would not be significantly impacted. *Estimates of areas always leave two to four on-street parking spaces per house available and at least a 10 foot wide driving lane.*

How does this reduce runoff and protect water quality? For every square foot of pavement removed in Portland, you can prevent, on average, 22 gallons of runoff/year. A small driveway depaving project, removing just the middle of the drive aisle can prevents about 5000 gallons of runoff/year.

Where can it be done?

- **Any unused impermeable surface.** The center of a driveway or the 2' overhang of existing parking spaces are two great opportunities for depaving. (The overhang area is where the front or back of a car hangs over the pavement, in front or behind the wheel axle. By city code, parking spaces must be a minimum of 8.5 feet wide and 16 feet long with an overhang of 2 feet. Driveways must have a minimum width of 9 feet, and roads must have a minimum width of 12 feet. Depaving should preserve these minimum areas.)
- **Steep slopes.** On slopes steeper than 8%. (For slopes less than 8%, consider**bioretention.**)
- **Improve pedestrian safety.** Locate them where pedestrians would like to be more insulated from traffic or where traffic calming/slowing is desired.

What's the maintenance?

- **Weeding:** Remove weeds twice a year, ideally in May and October (before weeds go to seed).
- **Compost application:** Annually**,** replenish compost in gardens and under tree canopies to a depth of 2-3" and lawns 1/4".
- **Irrigation:** Irrigate during the 2-3 year establishment period if using natives. (If not using natives, then permanent irrigation will be needed.) See the **supplemental fact sheet including information on establishment irrigation**.

Depaving: Example 1

Figure 5-9 On Miller Road at ***project 64,*** *pedestrians are walking on curb-tight sidewalks. Vehicles in this area have more pavement than is needed especially since parking is prohibited here.*

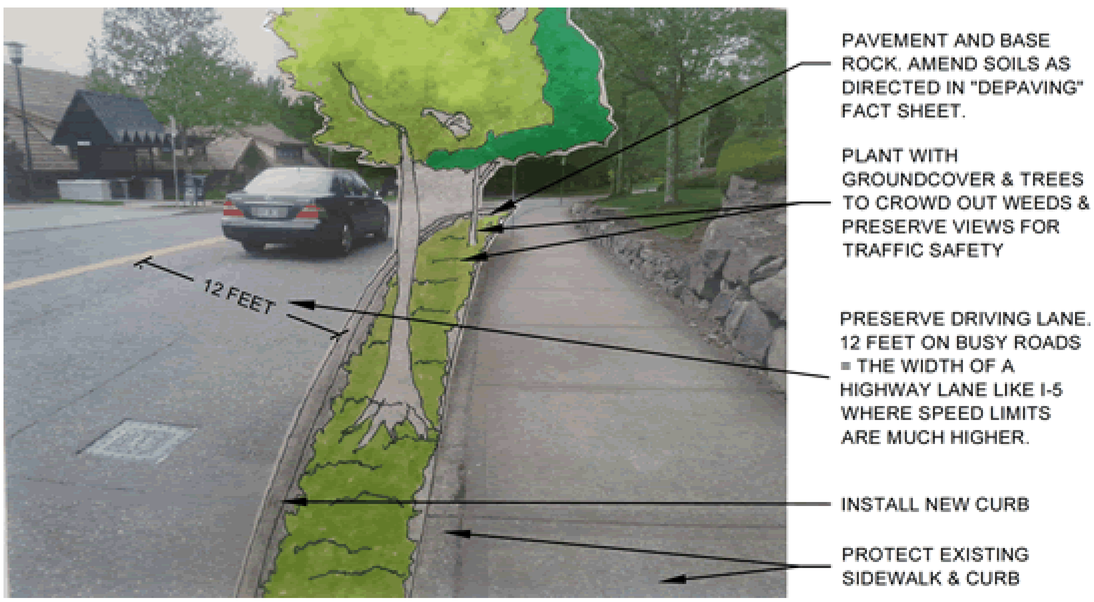


Figure 5-10 This depaving project removes pavement that far exceeds the 12 feet needed for a driving lane and where parking is not allowed anyway. (The existing "No Parking" signs here should be moved from the existing curb to the new curb.)

Depaving: Example 2

Figure 5-11 At ***project 57****, these three cars show how a typical 28-foot wide road at the FHHOA can accomodate parking (on left) and still allow 2 cars to pass. Pedestrians must walk along a curb-tight sidewalk.*

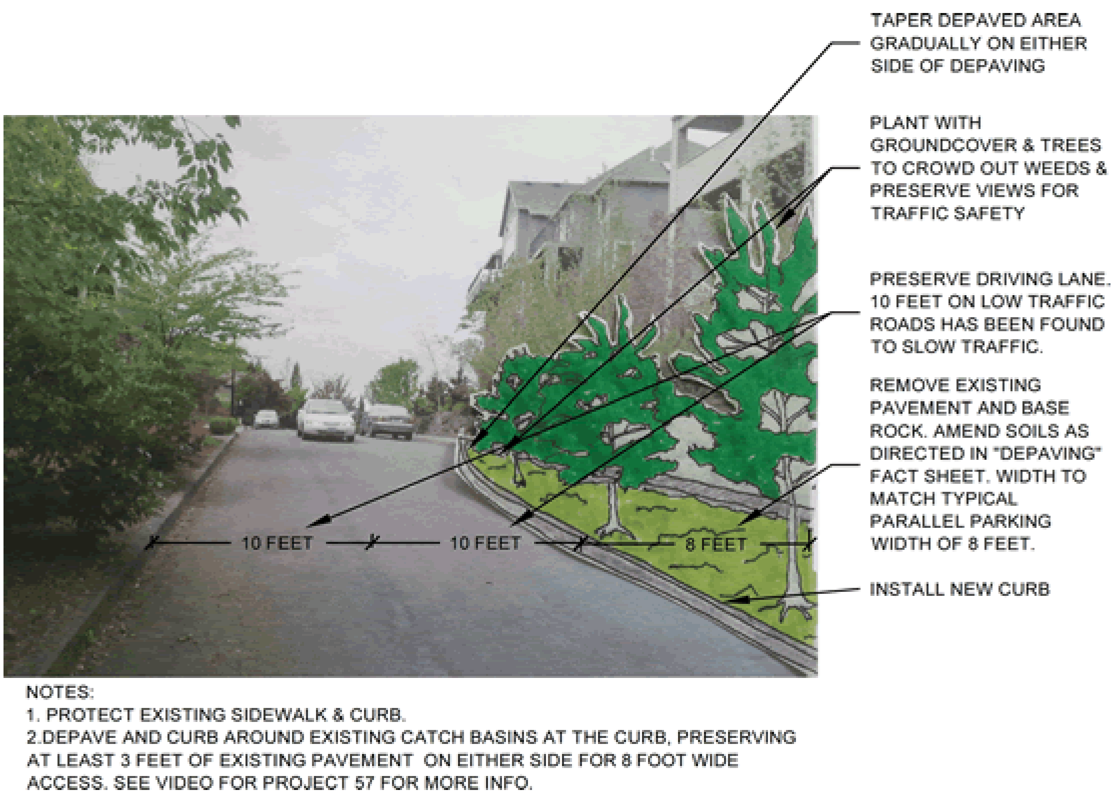


Fig 5-12 This area is adjacent to a natural area where there are no houses, so there is a generous length of road that is still 28 feet wide even though parking is not needed. This graphic shows how the road may be narrowed and still allow cars to pass. ***A video of this site explains additional site-specific information for implementing this project that might be considered at other depaving project sites.***

Planting Strategy

Back to the top

Planting strategy. Plantings will be in highly visible areas adjacent to pedestrian areas. Ecologically, many native plants will work well in these areas.

Installing the plants. Hiring a professional landscape contractor who is experienced and will guarantee the plants through a two-year establishment period is ideal.

Locating Trees. Trees should only be planted in depaved areas where adequate soil volumes is provided **(see pages 6 & 7 of this EPA document**). As a rule of thumb, trees that will be healthy, safe, and low maintenance should only be planted in areas where:

- The minimum width of the planting area is 6 feet
- The minimum planting area is 330 square feet
- The minimum depth of available soil is 3 feet

With a reasonable spacing of 25 to 30 feet, multiple trees may share the same soil.

Restoring the Soil. Restore the soil in depaved areas according to the information provided in **Chapter 5, Restored Soils**.

Stakeholder Considerations

Back to the top

Fig 5-13 NW Miller is a pleasing tree-lined street north of the commercial district. More areas of the HOA, where planters don't already exist could look similar if they were depaved.

Pedestrian safety : The traffic calming benefits of tree lined roads is well documented in numerous studies. In addition, people are more comfortable walking along a sidewalk separated by a few feet of landscape area.

Aesthetics: Shrubs and trees that flower at different times of the year might be carefully combined to be seen from the road.

Preserving Parking: Where parking is allowed, depave but leave two 20 foot long by 8 foot wide on-street parking spaces per house in the area.

Specifications

Back to the top

Restoring the soil: Soil restoration is essential to getting the plants established with minimal or no additional water. Soil underneath pavement has been highly compacted and will have a lower than optimal soil biology count or diversity. During any depaving project, **follow the guidance provided in Chapter 5 on restoring soils**.

Time of year: Shrubs and trees should be planted in the fall when they will have the longest oppportunity to establish during the rainy season.

Irrigation for 2-year establishment period: **As evidenced by the landslide on SW Terrwilliger in 2008 that destroyed a number of homes**, irrigation on steep slopes must be done with great care. For this reason, conventional piped irrigation systems are NOT recommended. Instead, as is commonly done, hire a landscape company with a low pressure water truck to deeply water plants in the root zone only (generally the area between the trunk and the dripline/canopy) **according to guidance provided in the fact sheet provided on establishment irrigation.**

Street Width Code Considerations

Back to the top

Road Widths. The road widths and parking requirements, whether public or private, are set by the city. In the recommended depaving areas, parking is likely in excess of what's required. Also, only parking areas, never road lanes, are proposed for depaving.

Fig 5-14 According to the City of Portland's standards, the typical roads widths of 28 feet and 35 feet at the HOA exceed the width needed to park cars on both sides of the and leave a driving aisle by 2 and 9 feet respectively. This road pictured here is 28 feet wide.

Per the city's website:

"City of Portland local street standards were adopted by City Council in 1991 to address many issues facing Portland. Streetscape design standards were developed to address environmental considerations, neighborhood speeding, traffic reduction, and neighborhood livability.

Local street widths range from 20 feet to 32 feet. Most local streets are 26 feet wide, which provides residents parking on both sides. In some cases, due to topography constraints, local streets will be constructed to a 20-foot width, which allows parking on one side only."

Local street widths at the HOA range from 28 feet to 35 feet wide, so they exceed the widths that the City require to pass two cars and park on both sides. (To confirm this, see the first table in **"Creating Public Streets and Pedestrian Connections through the Land Use and Building Permit Process".** The areas proposed to be depaved are in R10, which falls between the RF and R7 zoning per a conversation with city staff. Under section "A. RF-R7 Zoning", in the first table titled "Standard Through-Street OR Dead-end less than 300' in length", look for the rows labeled "Local Service Street" then "Two Lanes". Both indicate that the minimum roadway width is 26 feet.) **Per city code Title 33.266**, The standard parallel parking space width in the city is 8 feet, so this means that a only 10 foot driving lane (26 - 8 - 8 = 10) is required on a local road. What I've proposed will always leave at least 20 feet after depaving for one of two following conditions:

- Parking on the opposite side of the road to the depaving project (8' required) and one car to pass (10' required), so 18 feet total is required, or
- Two cars may safely pass each other (2 10-foot lanes), so a total of 20 feet is required.

Street Ownership. Public versus private ownership of roads was determined from a meeting with Jen Callaghan. One of the criteria is whether the road ends in a cul-de-sac (public) or a hammerhead (private).

Final Report, Chapter 5: Implementing Recommended Practices Bioretention

Facility Sketches	Planting Strategy	Materials Specifications	Facility Schematic Details

Stormwater Planter: Example 1

*Figure 5-15 **Project 35** site as it exists today.*

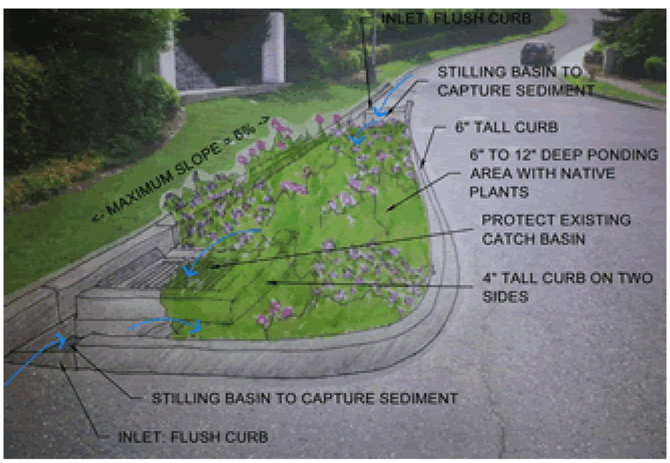


*Figure 5-16 This is the schematic design for **Project 35**, a proposed stormwater planter. Many of the stormwater planters, like this one, are situated to include an existing catch basin. Designs such as this where runoff enters very close to existing catch basin should have a strategy for diverting and ponding water in the facility that prevents water from shortcutting directly into the existing catch basin. In this case, a 4" tall curb on two sides of the catch basin is suggested.*

What is it? Bioretention is the practice of infiltrating runoff through soil to reduce pollution. Some variations include rain gardens, stormwater planters, swales, or vegetated filter strips. These facilities placed in the public right-of-way are called "green streets". Bioretention facilities designed for challenging sites are lined to prevent runoff from infiltrating into the ground; however, water still passes through soil placed above the liner, within the facility.

To teach others in future projects how a variety of facility configurations might be implemented in different places throughout the HOA, the projects include different configurations that gather and store and/or convey runoff in different ways. See the schematic details below, which include a cross section image and descriptions of a stormwater planter, rain garden, swale, and vegetated filter strip.

How does this reduce runoff and protect water quality? As stormwater passes through the soil, pollutants are reduced through physical settling of large solids, filtering of small solids, and chemical and biological activity. Since the facility must be lined, runoff is reduced through evaporation from the top of the facility.

Where can it be done?

- Since the facilities are lined to prevent infiltration into native soils, these facilities can be placed near steep slopes, but the slopes where the facilities themselves will be placed should be no greater than 8%.
- Locate them where runoff from pavement can be directed into

them. If there's a desire to locate a similar type of facility at the top of a hill, then **depaving would more appropriate**.

Where can it be done? (continued)

- Locate them where pedestrians would like to be more insulated from traffic or where traffic calming/slowing is desired.
- In Portland, avoid locating facilities where water lines run underneath.

What's the maintenance?

- **Weeding:** Remove weeds twice a year, ideally in late May and October.
- **Irrigation:** Using natives, irrigate during the 2-3 year establishment period. See the**supplemental fact sheet including information on establishment irrigation**.
- **Sediment removal:** Remove sediment once a year, preferably from an easy to access pre-treatment basin.
- Detailed maintenance information can be found in the "**Field Guide: Maintaining Rain Gardens, Swales, and Stormwater Planters**".

Facility Sketches

Back to the top

Stormwater Planter: Example 2

*Fig 5-17 **Project 34** site as it exists today.*

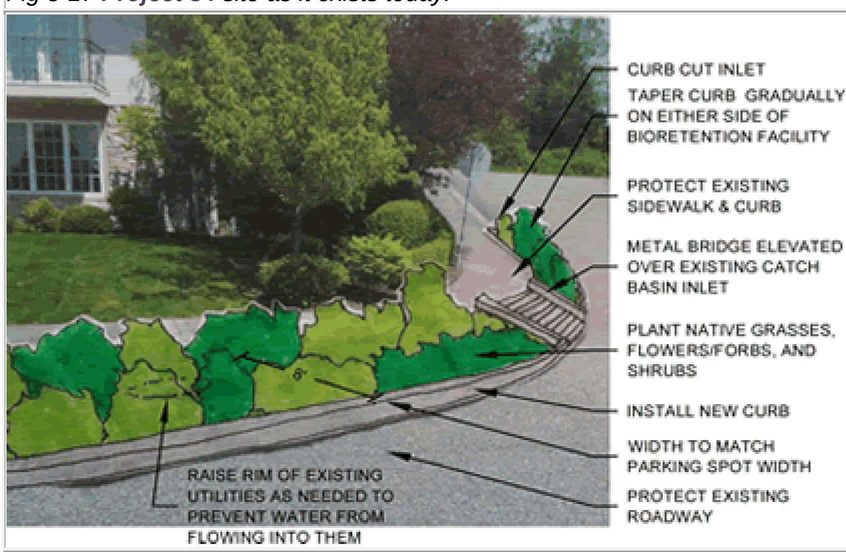


*Fig 5-18 Accompanied by the stormwater planter detail below, this is the schematic design for **Project 34**. The homeowner in the background enthusastically supports this project.*

Vegetated Filter Strip: Example 1

*Fig 5-19 **Project 43** site as it exists today.*

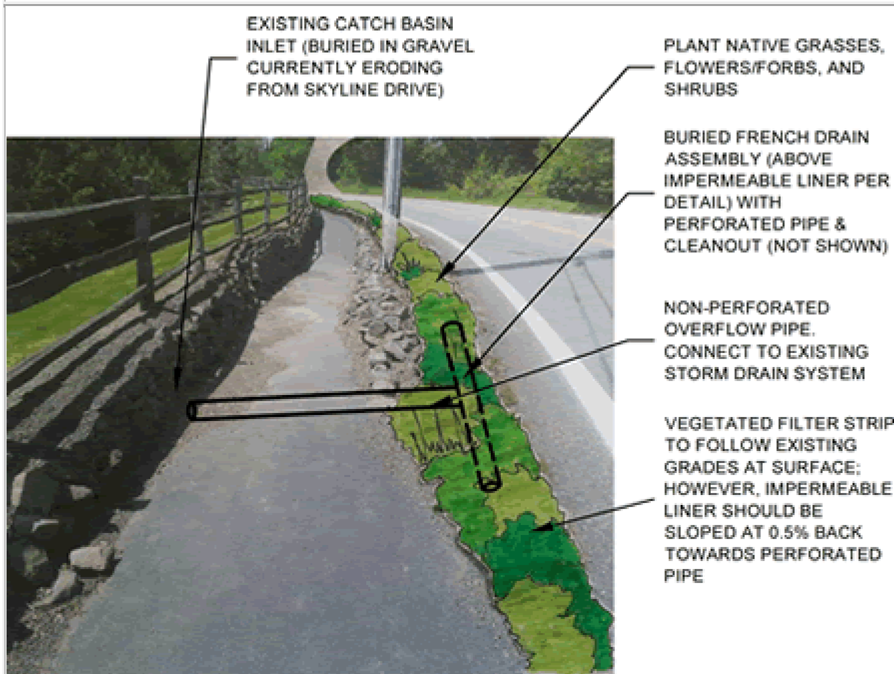


*Fig 5-20 Accompanied by the vegetated filter strip detail below, this is the schematic design for **Project 43**. This project will reduce maintenance, significantly reduce or eliminate sediment on the sidewalk and the ponding that probably occurs here during large storms when the catch basin inlet on the left is clogged (as it is in this photo).*

Vegetated Filter Strip: Example 2

*Fig 5-21 **Project 39** site as it exists today.*

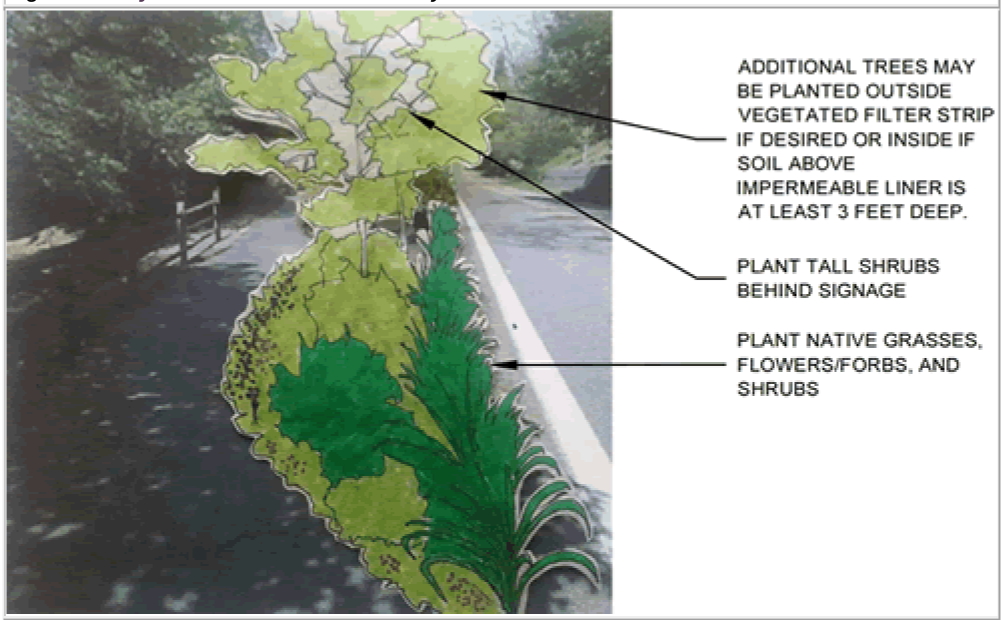


*Fig 5-22 Accompanied by the vegetated filter strip detail below, this is the schematic design for **Project 39**.*

Swale: Example 1

Fig 5-23 ***Project 45*** *site as it exists today.*

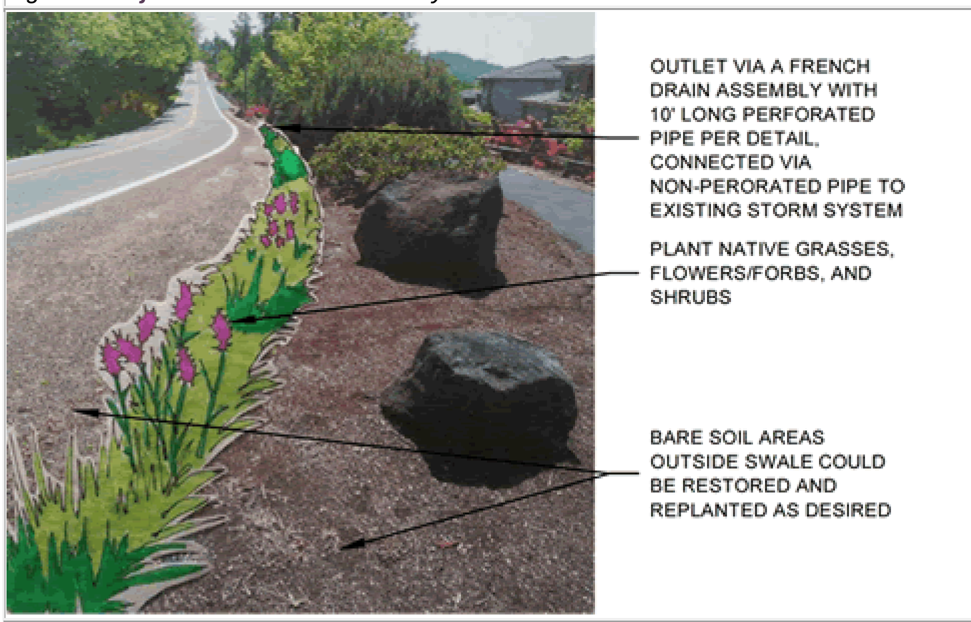


Fig 5-24 Accompanied by the swale detail below, this is the schematic design for ***Project 45****.*

Swale: Example 2 at Valley View Park

Fig 5-25 ***Project 32*** *site as it exists today.*

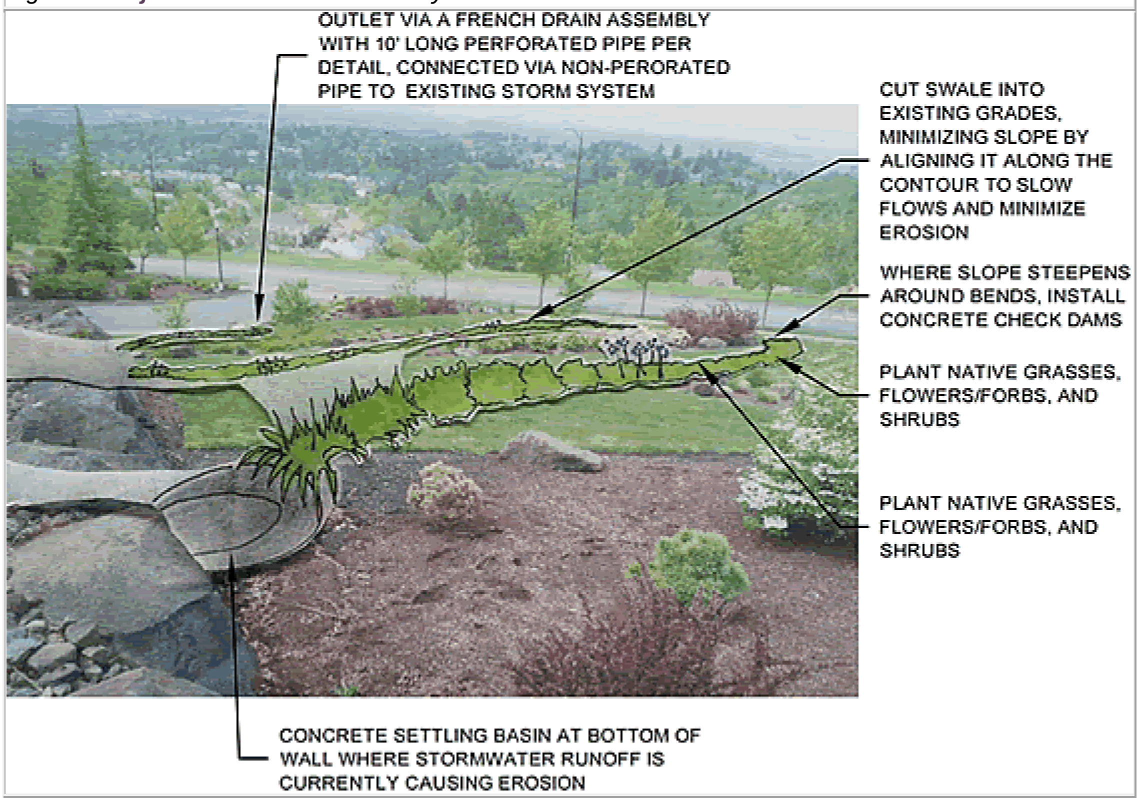


Fig 5-26 Accompanied by the swale detail below, this is the schematic design for ***Project 32****.*

Planting Strategy

Back to the top

Consider pedestrian safety: Most bioretention facilities use short shrubs and groundcovers such as grasses and flowers/forbs to ensure that pedestrians can see and be seen as they walk along the sidewalk.

Consider pedestrian comfort and aesthetics. Grasses that will grow tall and flop over should be placed in the middle of a facility, but not on the edges where vegetation could grow over the sidewalk and road. (The City of Portland receives many calls/complaints about this condition in their green streets.)

Avoid trees. A somewhat recent study by the USDA found that most trees need at least 300 square feet of soil that is at least 3 feet deep to be healthy, safe, and low maintenance. Lined bioretention facilities usually only incorporate the minimum depth of soil needed for water quality treatment, which is 18" deep. Providing an additional 18" of soil would increase costs.

Plant densely to reduce weeding. Weed seeds blow in or are carried by birds and flowing stormwater. Sunny, bare spots of dirt that are moist are the ideal place for weeds, so plant and maintain a dense cover of vegetation to shade weeds out.

Material Specifications

Back to the top

Planting soil. For public right-of-way facilities, import the City of Portland standard "3-way mix" (**click here for vendors**), per the requirements of the **City of Portland standard details for green streets**.

For privately owned and located facilities, amended native clay soils has been found in the author's experience to improve plant establishment & will likely encourage increased runoff reduction through evaporation. Recipe: 2 parts native soil to 1 part compost plus**Permamatrix** at a rate of 50 lbs/500 square feet.

All of the details below call for 18" of planting soil. This is a minimum and only applies to grasses. Shrubs will likely need 24" to 36" of planting soil.

Compost. Compost should be US Compost Council Seal of Testing Assured compost. Visit **http://compostingcouncil.org/participants** to find a participating supplier near you. The STA program is no guarantee of quality, only that the compost has been tested and those test results are available for the designer's review.

OMRI certification is also desirable, as it will certify that the product is organic.

Clackamas Compost Products (503.557.1028) has "Premium Garden Mulch", which has both certifications.

Organic compost may NOT be peat moss, which is extracted- from wetlands and negatively impacts the watershed from which the peat moss was removed.

Separation/filter rock (to keep planting soil particles from filling voids in uniformly graded rock, used in place of a geotextile fabric) and **Uniformly graded rock**. Two layers of separation/filter rock have been specified. This rock should be delivered "clean" and have the following gradations:

The coarse sand portion shall meet the following gradation:

US standard sieve size	Percent passing

3/8"	100
#4	54-82
#10	34-56
#40	9-17
#100	0-3

The 1/2"-3/8" crushed gravel portion shall meet the following gradation (ASTM C-33):

US standard sieve size	Percent passing
1/2"	100
3/8"	85-100
#4	10-30
#10	0-10
#8	0-10
#16	0-5

Uniformly graded rock shall meet the following gradation (AASHTO No. 57):

US standard sieve size	Percent passing
11/2"	100
1"	95-100
1/2"	25-60
#4	0-10
#8	0-5

Impermeable liner (to prevent concentrated stormwater runoff from infiltrating into the soil of nearby steep slopes). Impermeable liner may be:

- 45 mil EPDM (available from roofing supply stores such as Allied Building Products in NE Portland) = most environmentally sound.
- Low density polyethylene (LDPE) pond liner.
- PVC pond liner.

Check dams (used to slow water on steep slopes). These should be concrete or other non-polluted material. Avoid:

- Galvanized steel and copper, which exports zinc and copper and is harmful to fish.
- Clay, which is easily eroded and high maintenance.
- Rocks, which get moved during large storms.
- Treated wood (even the environmentally sound treated wood is infused with copper).
- Untreated wood (except for cedar), which is not very durable.

Facility Schematic Details

Back to the top

All bioretention facilites should be designed by at least a team of two, a licensed landscape architect and a licensed engineer to ensure that native plants and soils will work together and that erosion from the facility, except during very large storms, is minimized.

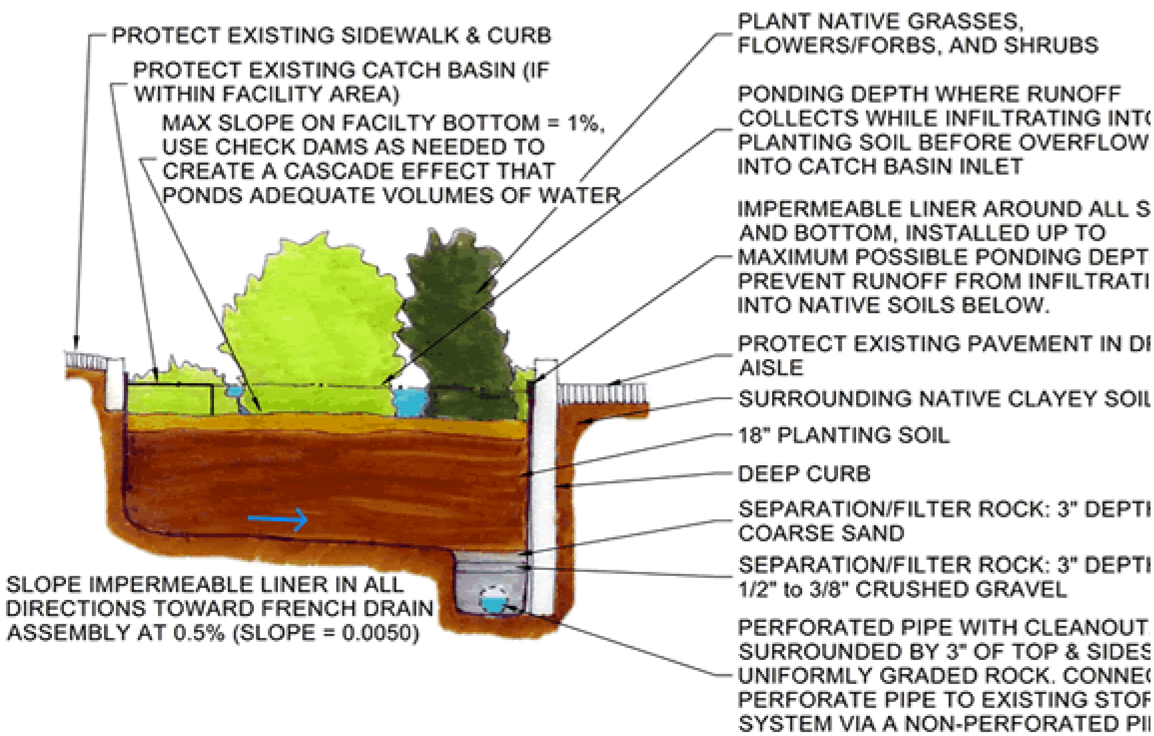
Flow splitter to reduce erosion. A flow splitter device directs fast, erosive flows from large storms around the facility. These are not typically used in Portland because the majority of our storms have historically been very small; however, this may be, at the discretion of the licensed professional team, a desirable additional element to reduce erosion and prevent sediment export from these facilities.

Facilities in the public right-of-way. Design facilities according to the **City of Portland standard details for green streets**.

Privately owned facilities. The following schematic designs are suggested:

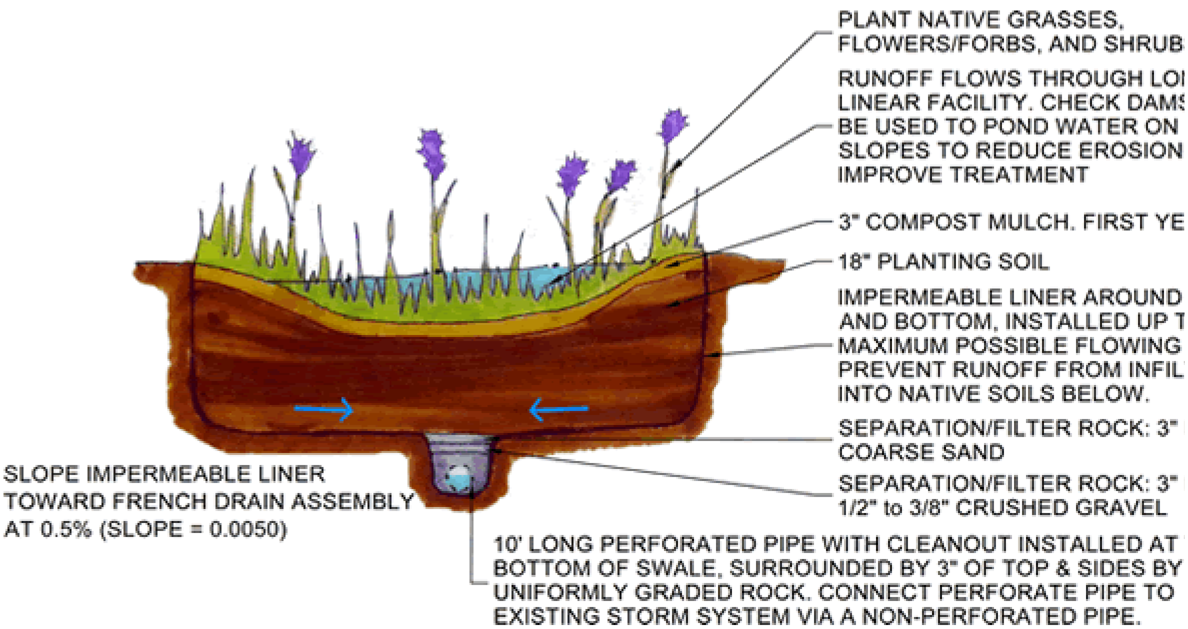
Stormwater Planter Schematic Detail

A stormwater planter is a structural container with soil and plants built to collect and slow runoff. Runoff is ponded and then treated as it passes through plants, roots, and soil. Treatment is provided through physical settling & filtration, biological breakdown or sequestering of pollutants by microbes and plants, and chemical treatment. Planters are very similar to rain gardens except they have vertical side slopes created by walls or curbs.



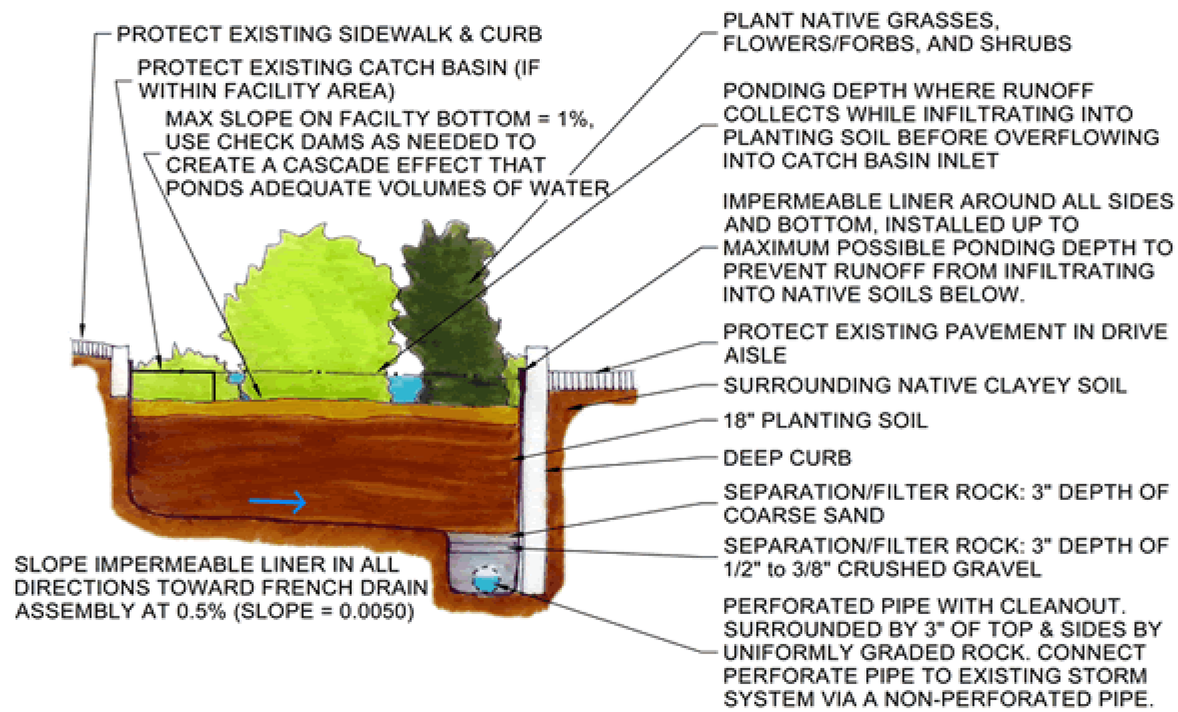
Swale Schematic Detail

A swale is long, planted, open channel that carries, slows and absorbs stormwater and filters out pollutants through settling. In most swales, infiltration into the planting or native soil is usually not the primary flow path for stormwater, but check dams, which will be needed to slow flows on steep slopes at the FHHOA, can hold water back and reduce erosion from the conveyance channel. Check dams will facilitate additional treatment in a similar fashion to stormwater planters and rain gardens, because when water ponds and passes through the soil, physical filtration, biological activity, and chemical processes will assist with pollutant treatment.



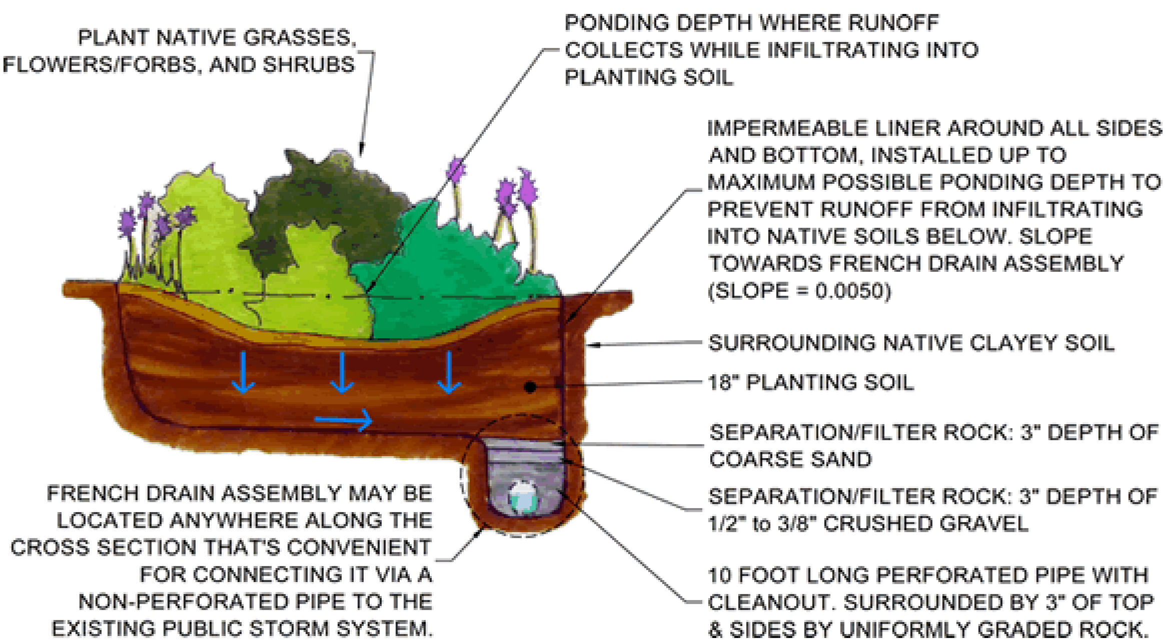
Vegetated Filter Strip Schematic Detail

A vegetated filter strip is a level facility that receives runoff in a distributed fashion along the length of one side of it and treats stormwater by settling out solids. More flat grades and dense vegetation across the top surface will encourage infiltration into the planting soil and improve treatment. A small densely vegetated berm on the surface of the left side could also be used, if desired, to pond water and improve runoff treatment.



Rain Garden Schematic Detail

A rain garden is a planted, bowl-shaped area designed to collect and absorb runoff and filter out pollutants. Runoff is ponded and then treated as it passes through plants, roots, and soil. Treatment is provided through physical settling & filtration, biological breakdown or sequestering of pollutants by microbes and plants, and chemical treatment. Rain gardens are very similar to stormwater planters except they have gentle sloping sides.



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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.

West Hills Innovative Stormwater Demonstration

Final Report, Appendix B: Preliminary Cost Estimate

Unit Cost of Practices	Preliminary Cost Estimate for Projects	Financial Funding

What's included:

- **Design & construction costs.** While some narratives suggest using volunteers to perform certain tasks, costs for all projects assume that the practice will be installed by a professional, licensed landscape contrator and designed by professionals as well, when needed.
- **Most practices based on detailed specifications and methods.** For all practices except revegetating steep slopes, implementation steps from the fact sheet were provided to Nathan Hale, a landscape architect at at **Cascadian Landscapers** (503) 647-9933.
- **Revegetation based on current planting costs.** For revegetating steep slopes, Matt Stine of of **Native Ecosystems Northwest, LLC** (971) 404-4745 provided costs based on a description of the sites and some of the information provided in**the revegetation section on Chapter 5**. His cost was increased slightly to account for traffic control at some sites such as the ones fronting Thompson Road.
- **Bioretention based on real world costs.** For bioretention, maintenance during the 2-year establishment period is included, in addition to design, permit, & construction costs. Unit costs for stormwater planters in the public right-of-way were provided by the City of Portland. Unit costs for other facilities (rain gardens, swales, and vegetated filter strips) were determined by discounting the city's unit costs by 10%, since, at the FHHOA, these facilities have more accessible overflow connections and no curbs.

What's not included:

- Except for a 2-year estabalishment period for bioretention, maintenance costs are not included in the design and construction costs.
- Permitting costs

Unit Cost of Practices

Back to the top

View or download a copy of the preliminary cost estimate for practices [pdf]

Preliminary Cost Estimate for Projects

Back to the top

Preliminary project costs are listed below. Some bioretention projects manage runoff from the public right-of-way and the team has received preliminary confirmation that these are eligible to be added to the City of Portland's capitol improvements list. Were this to happen, the City of Portland would add them to their budget and build them out over time, thus, the column that adds up project costs without those projects ("Cost without capitol improvement projects").

Project Ranking	Project description	Cost	Cost without capitol improvement projects
1	Revegetate/ Stabilize slopes	$15,305	$15,305
2	Revegetate/ Stabilize slopes	$10,843	$10,843
3	Revegetate/ Stabilize slopes	$7,373	$7,373
4	Revegetate/ Stabilize slopes	$5,662	$5,662
5	Revegetate/ Stabilize slopes	$5,326	$5,326
6	Revegetate/ Stabilize slopes	$4,708	$4,708
7	Revegetate/ Stabilize slopes	$4,459	$4,459
8	Revegetate/ Stabilize slopes	$4,295	$4,295
9	Revegetate/ Stabilize slopes	$4,232	$4,232
10	Revegetate/ Stabilize slopes	$3,950	$3,950
11	Revegetate/ Stabilize slopes	$2,632	$2,632
12	Revegetate/ Stabilize slopes	$2,320	$2,320
13	Revegetate/ Stabilize slopes	$1,869	$1,869
14	Revegetate/ Stabilize slopes	$1,595	$1,595
15	Revegetate/ Stabilize slopes	$1,539	$1,539
16	Revegetate/ Stabilize slopes	$1,302	$1,302
17	Revegetate/ Stabilize slopes	$1,236	$1,236
18	Revegetate/ Stabilize slopes	$1,193	$1,193
19	Revegetate/ Stabilize slopes	$1,178	$1,178
20	Revegetate/ Stabilize slopes	$1,053	$1,053
21	Revegetate/ Stabilize slopes	$915	$915
22	Restored Soils (from Lawn to Lawn)	$55,745	$55,745
23	Restored Soils (from Lawn to Lawn)	$15,882	$15,882
24	Restored Soils (from Lawn to Lawn)	$9,125	$9,125
25	Restored Soils (from Lawn to Lawn)	$7,347	$7,347
26	Restored Soils (from Lawn to Lawn)	$6,368	$6,368
27	Restored Soils (from Lawn to Lawn)	$2,650	$2,650
28	Bioretention: Stormwater planter	$22,888	$22,888
29	Bioretention: Stormwater planter	$23,744	
30	Bioretention: Stormwater planter	$23,270	
31	Bioretention: Stormwater planter	$21,515	
32	Bioretention: Swale	$28,551	$28,551
33	Bioretention: Stormwater planter	$30,089	
34	Bioretention: Stormwater planter	$18,128	
35	Bioretention: Stormwater planter	$15,259	
36	Bioretention: Stormwater planter	$38,910	
37	Bioretention: Stormwater planter	$15,259	$15,259
38	Bioretention: Swale	$20,943	

39	Bioretention: Swale	$22,316	
40	Bioretention: Stormwater planter	$19,837	
41	Bioretention: Stormwater planter	$19,837	
42	Bioretention: Stormwater planter	$19,531	$19,531
43	Bioretention: Vegetated filter strip	$56,649	
44	Bioretention: Stormwater planter	$18,540	
45	Bioretention: Swale	$24,658	
46	Bioretention: Swale	$15,450	
47	Bioretention: Rain garden	$12,360	$12,360
48	Restored Soils (from Lawn to Perennial Garden)	$47,549	$47,549
49	Restored Soils (from Lawn to Perennial Garden)	$32,634	$32,634
50	Restored Soils (from Lawn to Perennial Garden)	$16,661	$16,661
51	Restored Soils (from Lawn to Perennial Garden)	$12,273	$12,273
52	Restored Soils (from Lawn to Perennial Garden)	$8,926	$8,926
53	Depaving (Low Traffic)	$105,483	$105,483
54	Depaving (Low Traffic)	$29,136	$29,136
55	Depaving (Low Traffic)	$28,809	$28,809
56	Depaving (Low Traffic)	$26,889	$26,889
57	Depaving (Low Traffic)	$19,744	$19,744
58	Porous Walkway	$22,883	$22,883
59	Porous Walkway	$15,528	$15,528
60	Porous Walkway	$10,624	$10,624
61	Porous Walkway	$8,775	$8,775
62	Restored Soils (from Lawn to Meadow)	$39,967	$39,967
63	Porous Roadway	$59,053	$59,053
64	Depaving (Medium Traffic)	$98,835	$98,835
	Total for all projects	**$1,231,600**	**$862,500**

Financial Funding

Back to the top

A variety of grants are applicable to this effort from a variety of sources, linked here. Often, matching funds are needed.

- **Department of Environmental Quality 319 Water Quality Grants.** This is the source of grant funding that made this study possible.
- **City of Portland's Percent for Green Program**. Information is provided in the model that will assist in indentifying qualifying bioretention projects. (At the time of this report, talks were underway to see if these qualifying bioretention projects might be fully funded under the city's capitol improvements budget, which would cost the FHHOA nothing.)
- **Oregon Watershed Enhancement Board Grants**
- **West Multnomah Soil & Water Conservation District, Urban Programs**
- **Metro Nature in Neighborhood Grant**