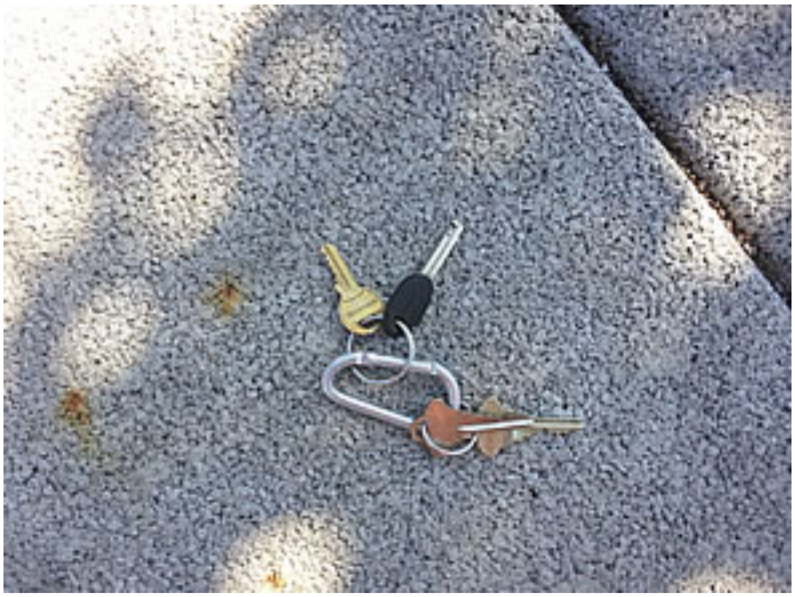
Additional Notes: Porous Pavement

Design of porous pavement requires the optimization of two main criteria:

1. **Hydrologic Design**: What depth of base rock will store enough water to infiltrate the desired design storm? Answering this question is usually the work of your civil/site engineer. Due to Oregon's rainfall patterns, even during relatively infrequent, large storms, our "poorly drained" clay soils can effectively infiltrate most of the rainfall. To protect downstream waterways from erosion, it is generally recommended to infiltrate the 2-year, 24-hour design storm at a minimum. However, stream protection requirements vary by watershed and recommended frequencies vary from the 1.5-year to 2.5-year design storms. Regardless, you will often find that the depth of rock needed to infiltrate the desired storm in clay soils is usually less than that needed to provide structural stability.
2. **Structural Design**: What are the depths of the various pavement layers (surface & base courses) needed to support the anticipated traffic load on the native soil in a wet, uncompacted condition? Answering this question is usually the work of your geotechnical engineer who must analyze the soil to determine its load bearing capacity, which varies with soil type with clay being the weakest and sand and gravel being the strongest. The thickness of the pavement section depends on the kind of pavement surface you choose. Pervious concrete is a rigid pavement while porous asphalt, permeable pavers, flexible grids and gravel are all flexible pavements. For pervious concrete in soils with high infiltration rates, it's possible that you won't need any rock because the material is such that the rigid pervious concrete will be structurally sound on the native soils. Porous asphalt, permeable pavers, flexible grids and gravel, on the other hand, all require rock for structural support, regardless of the type of native soils on which they will sit.

In the calculator for porous pavement, you will calculate the pavement thicknesses required for hydrologic and structural purposes separately. The most conservative (thickest) of the two requirements will be chosen for the design. The calculators here can determine the hydrologic design requirement for you, but you will need to determine the structural design requirement on your own. ***Consider hiring a geotechnical engineer to properly determine the structural design requirement of your porous pavement.***



Pervious concrete infiltrates rainfall at the source.

The section below includes information for ONLY the Porous Pavement RUNOFF calculator

USER INPUTS

24-Hour Rainfall Depth [in]: Enter the size of the storm that you're required or wish to infiltrate. A good minimum rule of thumb to protect streams from scouring is the 2-year 24-hour design storm, but use whatever your jurisdiction requires.

Drainage Area [sf]: This value is entered automatically from completing the top portion of the form in which the drainage area (total remaining hardscape area) is calculated.

Storage Rock Area [sf]: This equals the pavement area installed over soils that can infiltrate. In some cases, for constructability, a portion of the pavement will be installed on compacted soil (aka fill). In this case the storage rock storage area equals the infiltration area, which is the area of native soil in a wet, uncompacted condition.

Drainage Area Runoff Coefficient: This is the C in Q=CIA of the rational method. Click here to learn more about the rational method and to see typical values if you'd like to model this for all areas, not just impervious areas, draining to the pervious pavement/soakage trench (not typical). Choosing the upper end of the range for the particular land cover is safe. For instance, according to the link provided, lawns have a runoff coefficient between 0.05 and 0.35, so enter 0.35. If you are only managing impervious area (typical), then leave this at 0.9. Note that this worksheet is NOT able to model pervious pavement that drains any landscape areas (lawns, grasses, forest, etc.). Another method would be needed for this.

Design Infiltration Rate of Soil [in/hr]: Enter the infiltration rate of the native soils. This would come from running an infiltration test (see fact sheet "Infiltration Testing") in the location of the infiltration BMP at the depth where the constructed facility intersects with the native uncompacted soil. This number cannot be altered by the design. If the infiltration rate is low, then the facility will have to be bigger, incorporate a rock trench, import soils or use a lined BMP.

Depth of Storage Rock [in]: Guess a value for the depth of storage rock (equivalent to the base rock) and check the calculated values. This is an iterative process. For Type IA SBUH storms such as those found in Western Oregon, 12" is a good first guess, but you could also enter the depth of rock needed for structural stability for your traffic loads on your wet uncompacted native soils if you've gotten a geotechnical report already.

Void Porosity of Storage Rock [%]: The rock trench is made up of open graded (all almost the same size) rock. The open graded rock provides storage for the additional volume of water that must be stored in the voids between the rocks. The void ratio is ratio of solid to voids and is often 40%, but your rock supplier should be able to confirm this. Some jurisdictions require you to assume 30% void ratio to account for fines moving upwards or downwards, which will reduce storage unless you deepen the rock. In effect, this requirement becomes a safety factor, but the actual void ratio may be easily measured. Measuring your void ratio ahead of time may allow you to incorporate a smaller design and save money.

Outflow Elevation Above Bottom of Storage Rock [in]: Enter the depth of water allowed to pond by whatever overflow control structure you employ. If there is not a large storm overflow control structure (recommended), this value equals the depth of the storage rock entered above. This will be the maximum value possible for "Maximum Ponding Depth in Storage Rock During Storm" in the “Calculated Values” section below. If you are not using a large storm overflow, ensure that the base rock is deep enough to be structurally sound when completely inundated, since buoyancy could come into play for very large storms.

CALCULATED VALUES: OVERFLOW AND PONDING

Is Outflow Elevation Above Bottom of Storage Rock <= Depth of Storage Rock?: This checks that you entered numbers above that do not cause the impossible situation where the overflow elevation is higher than possible ponding depth. This should always be TRUE. Is this FALSE, increase Depth of Storage Rock or decrease Outflow Elevation Above Bottom of Storage Rock.

Maximum Ponding Depth in Storage Rock During Storm [in]: This is the maximum depth to which the design storm will rise in the Storage Rock. This number is calculated from the SBUH hydrograph and usually occurs in the middle of the storm when the most intense rainfall is modeled to occur. If structural design doesn't require a deeper rock section, you could set your Depth of Storage Rock to this value and build a pavement section with this depth of storage rock.

Depth of Water Left in Storage Trench After 30 Hours [in]: In some jurisdictions, this will be required to be zero (0). Due to the frequency of rainstorms, there is a common of thumb that all stormwater facilities should be empty in 30 hours to be ready for the next storm.

Size of Following Storm That Could be Stored in Remaining Rock [in]: This value indicates any additional storage available for the next storm when if the geotechnical report recommends a rock section based on structural design (which should be entered in Depth of Storage Rock) that's greater than the Maximum Ponding Depth in Storage Rock During Storm. If this value for storm depth is equal to or greater than the required design storm, then the facility does not necessarily have to be empty in 30 hours to be ready for the next storm.

Is the Storage Trench Empty in 30 Hours?: This checks the Depth of Water Left in Storage Trench After 30 Hours to see if there's a value in it. While the general rule of thumb and many jurisdictions require this to be TRUE this is not always the case. As described above, depending on the jurisdiction, required 24-Hour Design Storm, and the Depth of Storage Rock, this value doesn't necessarily have to be TRUE to have a pavement that functions well and is ready for the next storm.

Is the Storage Trench Empty in 72 Hours? For porous pavement, this checks the to see if the depth of water in the storage trench is 0 after 72 hours (calculated but not shown). This value should always be TRUE to avoid mosquito hatchings. 72 hours is the length of time mosquito larvae need to hatch and while it is unlikely that mosquitoes will be able to lay eyes in the pavement, mosquitoes have been found to hatch from ponded water in rip rap in bioretention facilities, so it is a safe practice to make sure the facility is empty by then.
If this is FALSE, you have a few options for different design situations:

- The infiltration rate of the native soils is just too low and unless you can overexcavate to a faster draining soil below or import faster draining soils, there's nothing you can do to increase this physical property of the soil. Deepening the storage rock will only exacerbate the problem. **You may be able to rearrange the site layout plan to place the porous pavement over soils with faster infiltration rates.**
- If you're draining runoff from other areas to the pavement and getting a FALSE, you can direct some or all of the flows elsewhere, reducing the volume of water that must be infiltrated in the area of the porous pavement.
- It may be possible to extend the storage rock beyond the pavement area, increasing the area of the facility and the effective infiltration rate of the facility. Rock may extend into landscape areas as long as the top is wrapped in geotextile fabric; however, make sure enough soil exists on top of the storage rock to grow the proposed landscape. Grasses need at least 12" rooting depth, while shrubs may need up to 24" of soil and trees need about 36".
- You can put a perforated pipe at the bottom of the facility (potentially a UIC in Oregon, see information on avoiding a UIC) connected to a flow control structure. Make sure the flow control structure holds back as much rainfall as possible since water will "prefer" to flow out of the pipe than into the soil at the bottom of

the facility negating the water quality and stream scouring protection value of porous pavements. The challenge is that when using a perforated pipe, it may be very small (under 1") and can clog.

- If your 24-Hour Design Storm is greater than 1", try modeling it with some other software that uses the TR-55 method instead of the rational method. The rational method used here overestimates runoff generated every 10 minutes over the course of the storm compared to the TR-55 approach.

CALCULATED VALUES: 25-YEAR STORM ATTENUATION

Peak Predeveloped Runoff Rate [cfs]: Calculated from the pre-developed SBUH hydrograph. For this value to calculate, you must completed the PREDEVELOPED MODEL FIRST (see Predeveloped Model-User Inputs).

Peak Outflow Rate from Control Structure [cfs]: This is the rate at which stormwater overflows the control structure and leaves the site. If there is a value in this cell, but the pavement was designed with no control structure, this means water is surcharging out of the top of the pavement during your design storm. This is dangerous and could cause structural failure if the pavement section is not designed for a buoyant condition.

Is Post-developed 25-Year Flood Storm Attenuated?: If required to manage the 25-year storm, increase "Depth of Storage Rock" and/or "Outflow Elevation Above Bottom of Storage Rock" until this says TRUE.

OTHER CALCULATED VALUES

Peak Rainfall Intensity [in/hr]: This provides the peak rainfall intensity for the storm entered, calculated from the Santa Barbara Urban Hydrograph (SBUH) for different rainfall distribution.

Peak Inflow Rate [cfs]: This is the peak rate at which water enters the porous pavement, calculated from the Santa Barbara Urban Hydrograph (SBUH) for different rainfall distribution.

Peak Outflow Rate from Infiltration [cfs]: This is the effective infiltration rate of the facility. While the infiltration rate of the native soil is fixed, the effective infiltration rate of the facility depends on the area over which a volume of water is spread. Depending on the design, this may vary. In the case of a hydraulically isolated pavement with a drainage area equal to the Storage Rock area, the infiltration rate and peak outflow rate will always be the same number, regardless of what area you enter. In the case of a facility that is receiving runoff pre-treated for sediment from elsewhere, this number will vary.

SIZING FACTOR: Ratio of BMP Footprint to Drainage Area: This is provided for agencies who would like to create a SIM form similar to that of the City of Portland. If you look on page 4 of this link to Portland's SIM Form, you'll see what's called a "Sizing Factor." This number accounts for rainfall patterns (i.e. storm type), 24-hour design storm size, the infiltration rate of the native soils, etc. For hydraulically isolated pavements where the Contribution Area is the same size as the Storage Rock Area, this number is always 1.0.

Storage Capacity of Storage Rock [cf]: This calculates the volume of storage in the voids in the rock based on the Depth of Storage Rock and Void Ratio for Rock Trench values that you entered.

PREDEVELOPED MODEL: USER INPUTS

Since detention rules often require that you detain a certain post-developed storm so that peak flows from the facility do not exceed pre-developed flows, there are two worksheets in this calculator: one to model post-developed flows--which we've already looked at in detail above--and one that models the pre-developed condition.

Pre-developed 24-Hour Rainfall Depth [in]: Enter desired pre-developed 24-hour storm that the post-developed 24-hour flood storm must be attenuated back to as required by your jurisdiction. (If you're the jurisdiction, requiring that the 25-year storm be attenuated to the peak flow from 1/2 of the 2-year storm may be stringent enough to protect streams from scouring.)

Drainage Area [sf]: This is the larger of either the post-developed Contribution Area or the Rock Storage Area. This number is entered automatically.

Drainage Area Runoff Coefficient: Enter 0.1 for woodlands or other appropriate number for your site's predeveloped land cover. Equivalent to the C in Q=CI. Click here to learn more about the rational method and to see typical values.

OTHER CALCULATED VALUES

Peak Predeveloped Runoff Rate [cfs]: Calculated from the Santa Barbara Urban Hydrograph (SBUH) for different rainfall distribution.

Peak Rainfall Intensity [in/hr]: Calculated from the pre-developed calculated from the Santa Barbara Urban Hydrograph (SBUH) for different rainfall distribution.