A SunCam online continuing education course

Design of Drywells

by

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Introduction:
This course is an overview of all of the features that go into properly designing a drywell for stormwater management.

When you complete this course you should be familiar with all of the design criteria and be able to design a drywell or series of drywells. As explained in this course, drywells are generally used to control the runoff from the rooftop of a single dwelling, but drywells can be used in other residential or commercial situations as well.

For this course the primary reference is the "New Jersey Stormwater Best Management Practices Manual", Chapter 9.3 entitled "Standard for Drywells". Information is also contained in the "New York State Stormwater Management Design Manual", Section 6.3: Stormwater Infiltration. However, there is no standard "cook book" of drywell design and the design engineer must make a number of decisions to ensure that the drywell will function properly.

What is a Drywell & When Should it be Used?
A Drywell is an underground stormwater detention facility, which utilizes percolation into the ground as at least part of its outlet. A drywell has numerous environmental benefits. Not only does it reduce the peak rate of runoff leaving a site, but it can also recharge water back into the ground. In addition, a drywell is often more desirable than a conventional above-ground detention system, simply because it is underground and it does not occupy land that can be used for other purposes. Simple drywells are often used to control the runoff from the roof of a single family dwelling. Larger and more complex drywells are useful for stormwater detention on a variety of commercial or residential projects.

A drywell can be constructed of concrete chambers, concrete or plastic seepage pits, perforated pipes, stone, or some combination of these materials. We will show in this course that the chose of materials to be used is one of the main design decisions to be made and it will hinge on a variety of considerations.

It must also be pointed out that there are limitations to the use of drywells. We will see that drywells cannot be used in areas with shallow bedrock, high water table, or with insufficient permeability. Likewise, drywells cannot be used if they will be expected to negatively interact with existing or proposed wells, septic systems, or other features on the property or on downstream properties. Therefore, evaluating the site and properly locating the drywell are both significant factors in the design. In addition, drywells are generally considered viable options only for relatively small contributing drainage areas (i.e. one acre or less). Finally, drywells should not be used if the runoff is expected to be contaminated as, for instance, in the following cases:

1. In areas where solvents, petroleum products, or pesticides are loaded or unloaded, applied, or stored.
2. In areas where hazardous materials are known or expected to be present.
3. In areas with a high risk of spills of toxic materials (e.g. gas stations).
4. In areas where industrial stormwater runoff is exposed to “source material”. Source material is defined as any material or machinery, located at an industrial facility, that is directly or indirectly related to process, manufacturing, or other industrial activities that could be a source of pollutants in any industrial stormwater discharge to groundwater.

If any of these conditions exist on the property then drywells should not be used and the design engineer should look into alternative means of providing stormwater management (e.g. by the use of a standard above-ground detention basin).

Sizing the Drywell:

When sizing the drywell a number of considerations have to be considered. These include the following:

1. Reviewing agency regulations.
2. Required design storm.
3. Soils.
4. Materials to be used.

Different reviewing agencies have different requirements for sizing drywells. Many municipalities in New Jersey require that the drywell for a single family home be sized to store a volume equivalent to 3” of rainfall over the roof area. The town of Southhold, NY requires that a drywell be designed for a 10 year storm or a 2” rainfall over 24 hours. Still other municipalities require that the storage in the volume is equal to 3” of rainfall over all of the proposed impervious surfaces on the property.

Still other reviewing agencies require that the drywell be designed to store the increase in runoff from a 100 year, 24 hour storm. Because percolation into the ground is a key component of a properly-function drywell, the underlying soils have a great deal to do with the overall drywell design. The configuration of the drywell will be greatly affected by the soil characteristics.

Shallow depth to groundwater, for example, will require a shallow profile for the drywell. Generally the drywell will have one of the following basic configurations:

1. One or more concrete or plastic seepage pits placed within a stone mass. This type of drywell generally has the deepest profile.
2. One or more rows of perforated pipe placed within a stone mass. This will generally have a shallower profile.
3. One or more plastic seepage chambers (such as the infiltrator units discussed below) placed within a stone mass. This type of drywell functions very much like the drywell described above with perforated pipe.
4. Very small drywells are sometimes constructed only of stone.

In the following examples, the design decisions will be based the requirements of the reviewing agencies, the soil characteristics, and the design storm to be stored.

Example 1: A new single family home with a roof area of 3000 SF is to be constructed. The municipal ordinance requires that drywell be designed to store 3" of runoff over the roof area. Soil investigations have shown that the soil is permeable and groundwater was not encountered in test hole more than 10 feet deep.

Solution: Required volume: $= 3000 SF X\, 3'' / 12 in / ft = 750 CF$.

The design will utilize three concrete recharge tanks in a stone bed. The design will be based on the actual tank dimensions (to the invert of the outlet pipe), which are: 6' inside diameter X 58" high. One of the tanks will be equipped with a 4" PVC overflow pipe and a light duty inlet for maintenance.

Volume in the tank: $= 3(58/12)\Pi(3)^2 = 410 CF$

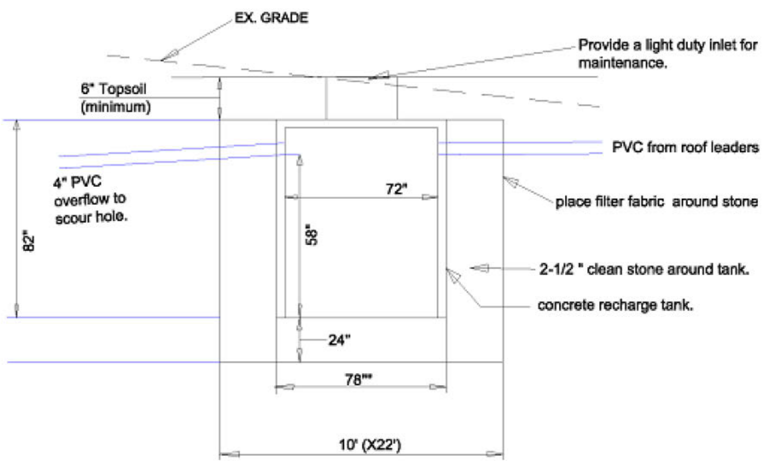
Required volume in the stone surrounding the tank: $750 - 410 = 340 CF$.

Depending on the size of the stone, the void ratio may range from 33% to more than 40%. Generally, assuming 40% voids in the stone will fairly accurate. The designer may want to change this assumption if smaller stone is used or if the reviewing agency requires a different void ratio be used. In this case the void ratio of the stone is assumed to be 40%.

Volume in Stone: $(0.40)((10 X\, 22 X\, 82/12) - 3(58/12)\Pi(3.25)^2) = 409 CF$

Total Volume Provided: $410 CF + 409 CF = 819 CF$

A schematic cross section of this drywell is shown in the figure below. Photographs of the installation of this drywell are included under the "Installation" section of this course below.



Drywell Cross Section
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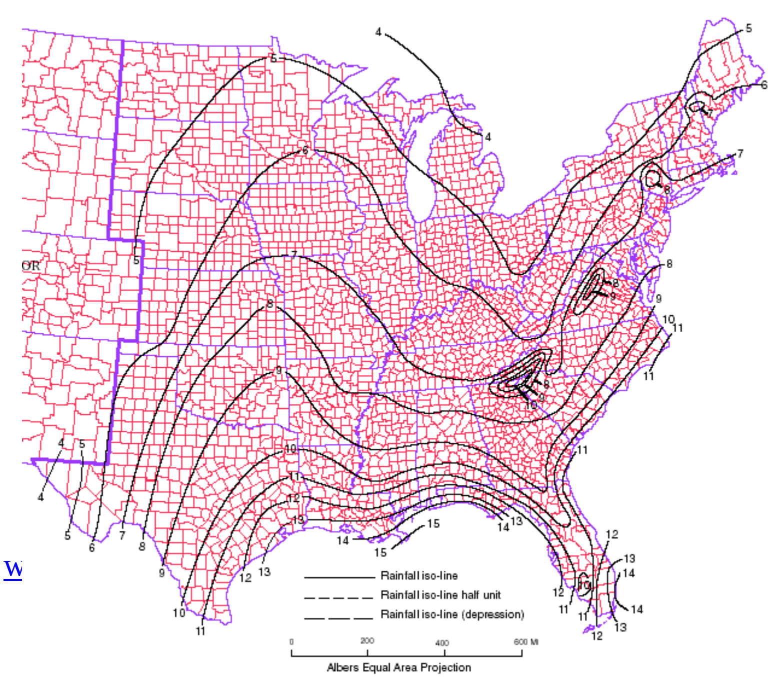
Example 2: An apartment building and parking lot will be built on the site of an existing meadow in central New Jersey. The site area is 20,000 square feet and a total of 12,500 square feet will be covered by impervious surfaces. The reviewing agency is requiring that the entire increase from a 100 year storm is stored in the drywell. It is assumed that the entire impervious area will be directed into the drywell. Soils investigations have shown that the soil is permeable but that groundwater is encountered at a depth of approximately eight feet. Therefore, the drywell cross section utilized in Example 1 would be too deep. Instead, we will utilize 30" perforated pipe laid flat in a shallow stone bed. The rainfall map shown below will be used to determine the 100 year, 24 hour, storm.



Note: This map is reprinted from the University of Texas at Dallas website. For more western states the 100 year, 24 hour rainfall amounts can be obtained through the Natural Resource Conservation Service.

Solution: The Modified Rational Method will be employed to determine the increase in runoff from a 100 year storm. Runoff coefficients ("C" values) are taken from the chart below.

Ground Cover	C	
	Low	High
Lawns	0.05	0.35
Forest	0.05	0.25
Cultivated land	0.08	0.41
Meadow	0.10	0.50
Parks, cemeteries	0.10	0.25
Unimproved areas	0.10	0.30
Pasture	0.12	0.62
Residential areas	0.30	0.75
Business areas	0.50	0.95
Industrial areas	0.50	0.90
Streets		
bricks	0.70	0.85
asphalt	0.70	0.95
concrete	0.70	0.95
Roofs	0.75	0.95

Existing meadow "c" value = 0.30 (based on the average of the values in the chart above).
Proposed impervious "c" value = 0.95.
In order to determine the increase in runoff volume, the change in runoff over the proposed impervious surfaces will be multiplied by the area of these surfaces.
The 100 year, 24 hour rainfall (Based on the map above) = 7.5 inches.
Increase in runoff volume:

$$v = 12{,}500 X (0.95 - 0.30) X 7.5 / 12 = 5078 CF$$

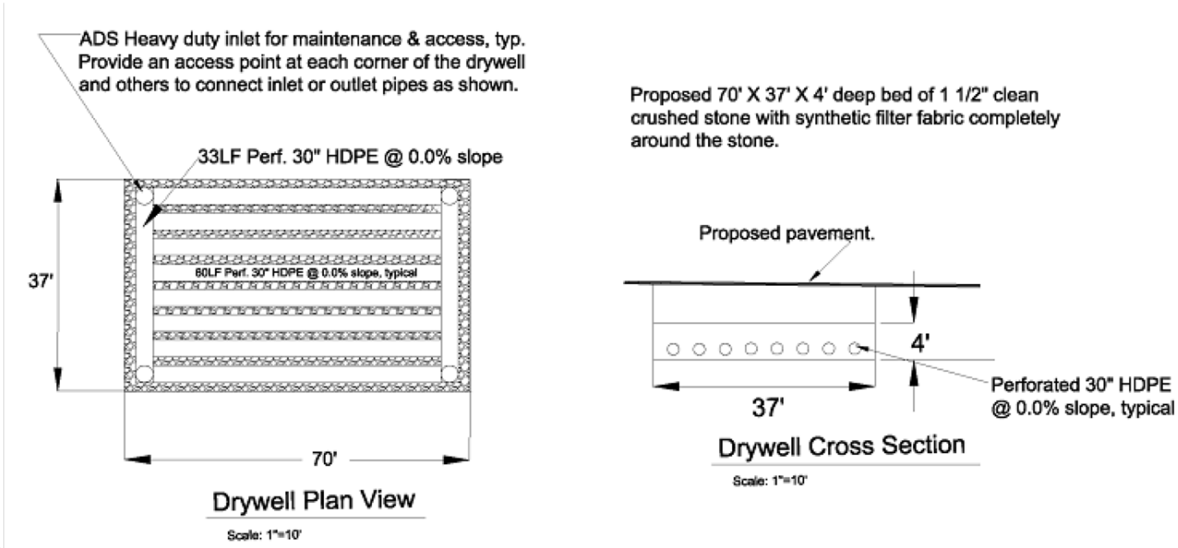
The design will incorporate a 70' X 37' X 4' deep stone mass. 30" diameter plastic pipe will be placed within the stone bed in eight 60 foot long rows with two 33 foot long manifolds as shown schematically below. Therefore, the total length of the 30" pipes in the drywell is 546 feet. In the calculations below it is assumed that the outside diameter of the 30" pipe is 36".

Volume in pipes: $= 546 X \Pi (1.25)^2 = 2680 CF$

Volume in stone: $= (0.40)((70 X 37 X 4) - 546 \Pi (1.5)^2) = 2600 CF$

Total volume in drywell = 5280 CF

A plan view and cross section of this drywell is shown below. There are photographs of drywells utilizing perforated pipe included in the "Installation" portion of this course, below.

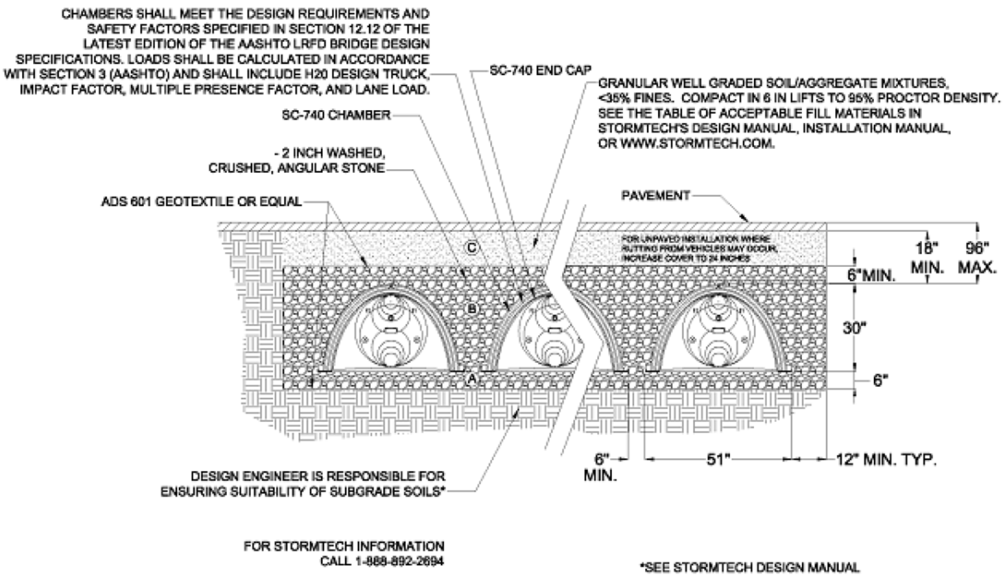


Example 3: This is the exact same as Example 2 but the decision is made to use Infiltrator chambers (Model SC-740, which have nominal dimensions of 30" high X 51" wide X 90" long) instead of perforated pipe. These units are very light and easy t9o install.

Solution: The required volume is 5078 CF. The design brochure for the infiltrator chambers indicates that each of the chambers (with the required stone) has a minimum storage of 74.9 CF. Therefore, the required number of chambers is calculated as:
5078 CF/74.9 CF per chamber = 68 chambers.

Complete information on the design and installation of the stormtech units can be found at www.stormtech.com. If the drywell is going to be under a parking area then it is strongly recommended that concrete seepage pits and/or perforated piping is used instead of the infiltrator units.

The typical cross section shown below was taken from the Stormtech Design Manual. Photographs of the infiltrator units are included in the "Installation" portion of this course, below.



In all of these examples the drywell is designed solely on the volume of runoff generated. However, a design storm can be routed through the drywell as well. In this case, the drywell is treated as a detention basin and the routing can be accomplished by a standard computer - generated routing technique. When inputting the outlet configuration of the drywell into the computer it is important to add the percolation out of the bottom of the system in the calculations. A technique for approximating the percolation through the bottom of the drywell is included later in this course.

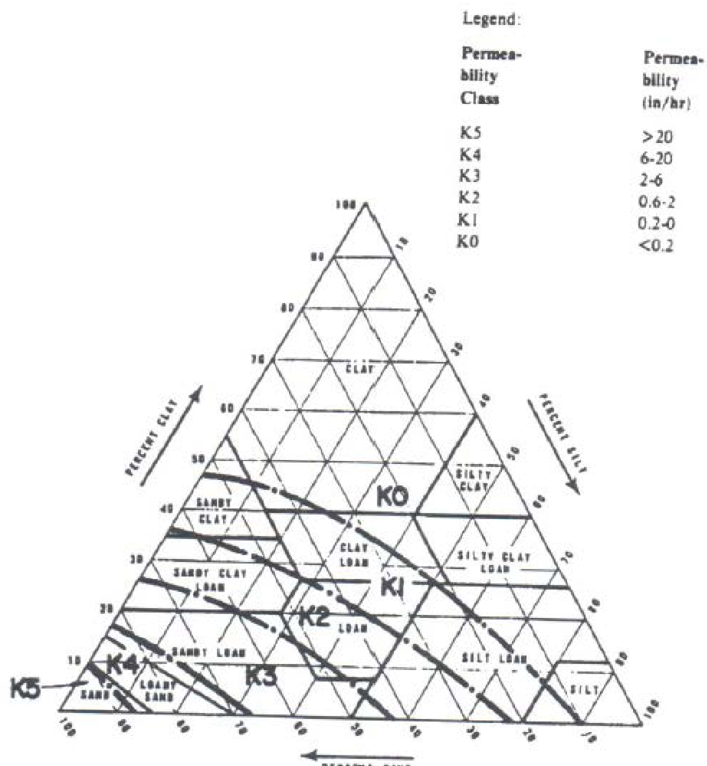
Soil Testing:

Because drywells are intended to recharge the stormwater back into the ground it is imperative that the design engineer has an understanding of the soil characteristics of the drywell location. Of course, as stated above, certain soil conditions would make it impossible for the drywell to function properly. These include a high water table, shallow bedrock, and clayey soils that have poor permeability. Published sources, including the National Resource Conservation Service web soil survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm), are a good place to start obtaining soils data. However, the best soils information is always obtained by on-site investigations. In digging a soil log to determine suitability for a drywell there are several things to keep in mind:

1. The soil log should be dug in the actual location of proposed drywell if possible.

2. The log should extend at least two feet below the anticipated bottom of the drywell to determine the minimum required separation form the drywell and the groundwater.
3. It is important that some form of soil testing be done to determine the permeability of the soil. This may be a direct measurement of the permeability (e.g. via a perc test or basin flood test), or an indirect measurement by determining the properties of the soil (e.g. a soil class rating analysis or sieve analysis).

The chart below (taken from the Standards for Subsurface Sewage Disposal Systems in New Jersey') shows permeability rates for various types of soil.



As a rule drywells should not be used in clayey soils and in no case should they be used if the permeability has a value of K0. Drywells in these situations will not function properly because they will not drain. Conversely, if the permeability is strongly K5, the design engineer should be careful not to site the drywell on a steep slope where the water may break out of the hillside and negatively affect downstream properties.

It is often important to determine the amount of time it takes a drywell to drain. To accomplish this, the permeability can be converted to an outlet value from the drywell. For example, assume the drywell has a square 20' X 20' bottom and is located in sandy loam with a permeability value of K3 and that the total inflow to the drywell during the design storm has been calculated as 1000 CF. In this case the following calculation will approximate the draining time of the drywell:

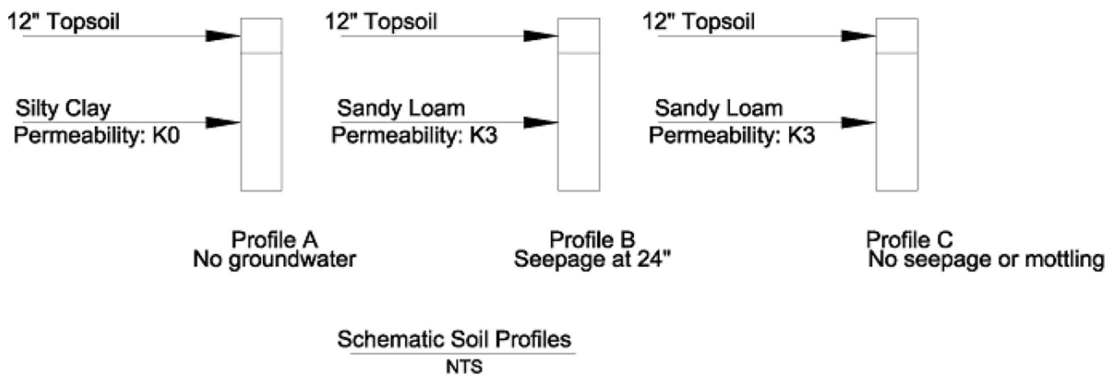
1. Determining the outflow rate from the drywell.
    a. K3 translates to a permeability of between 2 and 6 inches per hour. Using the midpoint of this range = 4 inches per hour.
    b. Apply a factor of safety of 2 to account for potential siltation of the bottom of the drywell over time. Therefore, the actual design value to be employed is 2 inches per hour.
    c. Convert inches per hour to CFS per square foot of drywell bottom. $2in/hrX1hr/3600\sec X1ft/12in = 0.000046296CFS/SF$.
    d. The total outlet from the bottom of the drywell is then calculated as $0.000046296CFS/SFX400SF = 0.0185CFS$.
2. The draining time of the drywell is calculated as: $1000CF/0.0185CFS = 54{,}054\sec onds = 15hours.$

Most reviewing agencies set a time of 72 hours by which the drywell must drain. If this standard cannot be met by the methodology explained above, it may be necessary to increase the bottom area of the drywell or to relocate the drywell to an area with a higher permeability.

The same type of calculation can be done to calculate the outflow from the drywell for routing purposes as described above.

As indicated above, one of the most important observations to make in soil testing for the drywell is the high water table. Generally, the bottom of the drywell should be at least two feet above the level of the water table. The two main observations of groundwater are seepage and soil mottling. If neither seepage nor mottling is present, the design engineer should note the depth of the root system in the hole. If all of the roots are shallow, this might be an indication that there is water present not far from the surface at some times during the growing season. However, other factors in the soil may prevent the roots from penetrating deeper and this cannot be used as the sole indicator of high groundwater.

Three schematic soil profiles are shown below. It is assumed that each profile extends to a depth of 10 feet.
Profile A would not be suitable for a drywell because the material s not permeable.
Profile B has appropriate permeability but would not be suitable for a drywell due to the presence of a high water table.
Profile C represents a suitable site for a drywell.



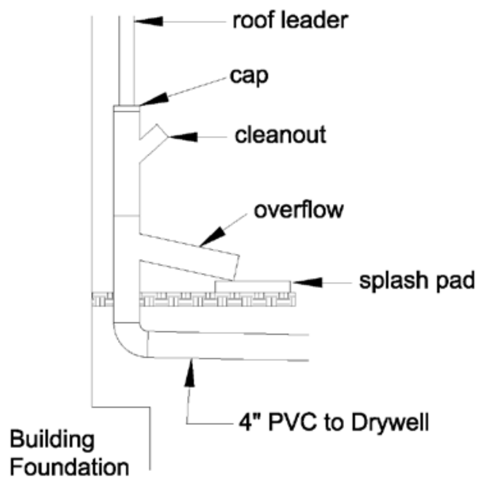
Additional Design Considerations:
Although a drywell can have many different configurations and can be installed with or without seepage pits and or perforated pipes there are several design elements that are key to the proper functioning of the system. These include the following:

1. Stone used in the drywell should be clean and should have a minimum size of 1½". Using smaller stone or stone that has grit in it will cause the drywell to silt in more quickly and will thus reduce the effective lifespan of the drywell.
2. The stone mass should always be wrapped in filter fabric. This will help prevent fines from entering the stone and silting it in.
3. If the drywell is to collect water from inlets, they should not be directed into the drywell during the construction phase of the project. They should be connected to the drywell only after the contributing drainage area is stabilized to prevent silt from reaching the drywell.
4. The drywell should always be equipped with a positive outlet. This can be directed to a watercourse, inlet, curb, or other stable area. It may be necessary to provide a scour hole or other conduit outlet protection to avoid eroding the area below the outlet.
5. There should always be some provision built into the drywell to allow for inspection and maintenance. A 4" PVC riser will allow for an observation of the

water level in the system but will not allow for maintenance. A manhole cover is preferable. If a PVC riser is used and, depending on the location of the drywell, there may be a need to provide the riser with a locking cap for security reasons.

6. If it is anticipated that traffic will be passing over the drywell it is imperative that all structural elements (pipes, seepage pits, etc.) are designed to be traffic bearing.
7. If the building is equipped with a sump pump and/or a foundation drain, these features should not be drained into the drywell. Because the drywell is designed to fill up with water and drain slowly it would almost certainly cause the sump pump outlet and the foundation drains to back up and could cause flooding problems in the basement.

It is also important that the roof leaders that drain into the drywell have an overflow pipe. This not only allows the water to escape if the drywell is overtaxed, but also allows for maintenance of the inflow pipe. This overflow should empty onto a splash pad as shown schematically, below.



Roof Leader Detail

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In addition, it is sometimes advisable to provide a pre-treatment unit upstream of the drywell. This can take the form of a septic tank, manufactured pre-treatment unit, sand filter, or other feature that will reduce the sediment load reaching the drywell. The pre-treatment unit will often greatly increase the useful lifespan of the drywell.

Locating the Drywell:
Properly locating the drywell on the property is one of the most important features of the design. When locating the drywell, the following parameters must be considered:

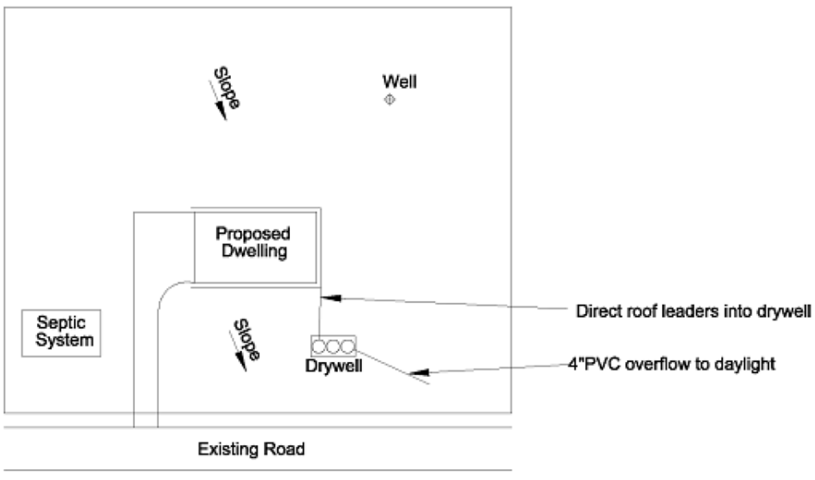
1. Topography.
2. Soil characteristics.
3. Location of wells, septic systems, and other underground utilities.
4. Potential interaction with the basement.
5. Proximity to the driveway.

Because the drywell is meant to store water for a time and allow it to seep back into the ground there is the potential for adverse interactions between the drywell and other features on the property. The drywell should always be positioned downhill of the dwelling. Pumping drainage up to the drywell is not considered a viable option because failure of the pumps could have disastrous results. If possible, the level of the top of the drywell should be below the level of the basement. If this is not possible, the drywell should be separated horizontally from the dwelling far enough to avoid water seeping from the drywell into the basement. A minimum distance of 50 feet is advisable but this distance can be adjusted based on the characteristics of the intervening soil. If there is any question of the drywell seeping into the basement, a synthetic, impermeable liner should be used to avoid this situation.

As indicated above, the drywell should not be placed in areas of high groundwatwer, shallow bedrock or areas that have questionable permeability. It may be necessary to move other site improvements to allow the drywell to be placed in an area with proper soil characteristics. Reviewing agencies generally have minimum distances that the drywell can be from the well or septic system. The New Jersey Department of Environmental Protection requires that the drywell be at least 50 feet from a well or septic system. Some other agencies increase these distances to 100 feet. Generally, these values should be considered minimums and should be increased if the soil in the area is exceptionally permeable.

Finally, it should be determined that the drywell will not interact negatively with any other features on the property. For instance, if the drywell is close to the driveway and there is the potential for vehicles to travel over the drywell then it is imperative that the seepage pits, pipes, or other structural elements in the drywell be load-bearing or that a fence or other permanent barrier is established to keep vehicles away from the drywell.

The plan below shows schematically how a drywell can fit into a residential lot development plan. Remember to keep the minimum required distances between the drywell and the other site improvements.



Schematic Typical Lot Layout with Drywell

NOT TO SCALE

Installation:

It is a good idea for the design engineer to be present, if possible, during installation of the drywell. This is to ensure that the assumptions made during the design of the drywell translate to its actual installation. The most important observation for the design engineer to make is the drywell hole. It should be determined, beyond any doubt, that the drywell bottom is (a) not intercepting the water table and (b) in material that has acceptable permeability. This is especially important if on-site soils investigations were not conducted during the design phase of the project. While on site the designer should also be sure that the stone used in the drywell is clean and that filter fabric is placed around the stone mass.

In New York City, the Department of Buildings has a "Drywell Installation Report" that must be filled out when a drywell is installed. An inspector from the Department of Buildings is present to inspect the installation.

The photographs below show the installation of the drywell that is the subject of Example #1, discussed earlier in this course.

Recharge tanks awaiting placement.

Recharge tank being installed. (Note filter fabric around stone).


Recharge tanks placed within drywell.


Recharge tanks installed with stone.

The photographs below show the installation of a larger drywell with perforated plastic pipe in a stone bed. This drywell is similar to the drywell analyzed in Example 2, above.

The photographs below show a variety of drywells with infiltrator units being used in lieu of perforated pipe and/or concrete recharge tanks. The inspection ports are visible in the photo on the right.

Infiltrator plastic recharge unit.

Infiltrator units placed in drywell.

The photograph at the left above shows that the stotmtech infiltrator units are so light that several can be carried in the back of a standard pickup truck. The photograph at the right above shows a drywell consisting of a single stomtech infiltrator unit in a stone bed. The roof leaders from the house will be directed to this drywell.

Maintenance:

On-going maintenance is essential to the proper long-term operation of a drywell. If routine maintenance is not performed, the drywell stone can easily silt it which can lead to:

1. More frequent overflowing of the drywell.
2. Negative impacts at the outlet and on downstream properties.
3. Allowing the water to back up the inlet pipe system which could then affect the basement, septic system, or other improvements.
4. Much more costly remedial action to replace part or all of the stone in the drywell.

Maintenance is generally the responsibility of the property owner and the design engineer should spell out what maintenance activities are required. Generally these can be divided into the following categories:

1. Maintenance of the roof leaders or other inlets that drain into the drywell.
2. Maintenance of the drywell itself.

Maintenance of the roof leaders and inlets is absolutely essential to prevent debris from entering the drywell. Leaves, grass clippings, and other organic debris can clog up the drywell and can silt over the bottom of the drywell reducing the effective permeability out of the facility. All roof leaders and contributing inlets must be cleaned regularly to ensure that this debris does not enter the drywell.

Maintenance of the drywell itself is generally required less often than maintenance of the inlets. However, this maintenance can sometimes be more involved. To maintain the drywell, the responsible party may need to open the manhole lid and enter the chamber. (Note that entering into the drywell chamber may constitute entering a confined space and is regulated by OSHA). Depending on the size and configuration of the drywell maintenance of the drywell itself can include some or all of the following:

1. Removing sediment, grit, or debris from the interior of the drywell.
2. Replacing stone if necessary.
3. Replacing or repairing pipes and or seepage rings as necessary.

If the drywell system incorporates a pre-treatment unit, this feature must also be maintained in order to remain useful.

Concluding Remarks:

It can be seen that drywells can be effective features in stormwater management and that they can be used in a variety of situations.

Failure to properly account for any of the criteria discussed in this course may result in a drywell that does not function properly. However, if each of these criteria is carefully considered the drywell should function properly and have a long life-span.

Drywells are flexible in that they can be used alone, in series or in parallel. In addition, on large projects they can be used as one part of an overall stormwater management system. A picture of a number of drywells operating in series is shown below.

This photo also shows one other advantage of drywells. Once they are installed, the areas above them can be integrated into the lawn and/or driveway of the property. Above-ground detention facilities would not allow these areas to be used for residential purposes.