

Chapter 6

Groundwater and Surface Water

6.1 Groundwater

Groundwater is water that exists below the ground surface in interstitial spaces in the soil or rock. In soil, groundwater most commonly exists in the pores between the soil particles, but it can also exist in fissures of less permeable soils. In rock, groundwater can exist in fissures and cavities.

Groundwater can be found almost everywhere and is commonly extracted and used for drinking water and agricultural purposes. Within the ground large stores of water can be found in aquifers and sometimes in perches. Groundwater brought to the surface through natural means via outcrops as seepage, springs, or discharge into lakes and streams. Groundwater at shallower depths can also be seasonal or intermittent or of insufficient volume and quality to be used. Site water also includes surface water which, like groundwater can be seasonal or intermittent, but is still capable of causing issues well after construction is completed.

6.1.1 Aquifers. A geologic formation that contains a large volume of groundwater is commonly referred to as an “aquifer.” Sands, gravels, and porous limestones make efficient and common aquifers. Aquifers are replenished or recharged by rainfall and melting ice and snow. This recharge can take place directly above the aquifer or at some up-gradient area. Some aquifers are recharged hundreds of miles away from the point where they are encountered. An unconfined aquifer can be recharged by water seeping from the ground surface above. A confined aquifer has an impermeable layer over it that prevents recharging by seepage from above.

Aquifers may be deep-bottomed, extending to considerable depths below the ground surface, or they can be shallow-bottomed, extending only to shallow depths below the ground surface. Wells for drinking water or agricultural purposes are commonly established within aquifers that are of sufficient volume and quality.

The top of the aquifer’s water surface is referred to as the water table. Shallow water tables are found in many parts of the country. The surface of the water table may fluctuate depending on supply and withdrawal. A number of major aquifers have been drawn down by overuse, rendering economical well production impossible. If a water table exists within a sloping terrain, it may outcrop at some point down slope, creating a seepage area or spring.

In many areas along the Gulf Coast (including Houston) and some places on the California coast, groundwater withdrawal for industrial or drinking water purposes has lowered the water table to the point that extensive regional settlement (also called subsidence) has taken place.

If a water table exists at a certain depth, the soil below this depth has an effective weight of only about one-half of what it would above the water table. This is due to the buoyancy effect of the water in the soil. For example, a typical soil weighs 120 pounds per cubic foot. Water weighs 62.4 pounds per cubic foot. If soil is below a water table, the unit weight would be 120 minus 62.4 or 57.6 pounds per cubic foot. When the water table is lowered, this buoyancy effect is removed, and the soil effectively doubles its weight and may cause consolidation of the general soil profile. Regional subsidence in Houston has been documented at over 9 feet in places. This effect depends not only on the amount of the water table reduction but also the properties of the soil.

6.1.2 Perched water. Perched water is an isolated body of groundwater separated from a regional aquifer by an impermeable layer. For example, perched water could be found in an isolated layer of gravel extending from the ground surface down 10 feet, resting on a clay or hard-pan type material.

Lowering of perched water tables will generally not cause the regional subsidence associated with draw-down of a major water table as described above, but perched water tables can be difficult for construction purposes. Because they are usually shallow and of small extent they are often seasonal. An excavation made in a dry period may not find a perched water table, but after a wet season there may be water near or exiting the ground surface.

6.1.3 Seasonal or intermittent water. Seasonal or intermittent water would include both groundwater and surface water. This is water that may appear near the surface or outcropping on the surface in the form of springs or seepage after prolonged wet periods and then disappear after the region dries out. This could be perched water described above or perhaps simply shallow soil that holds water for a period of time and then loses it during drying periods. Perched water and seasonal or intermittent water are frequently the same thing. One problem with seasonal or intermittent water is that a site may appear dry when the geotechnical borings are placed on the site but later develop water during construction or during occupancy when it is least expected. For these reasons the foundation designer should consider the possibility of seasonal water and specify waterproofing and drainage appropriate to keep water out of the below-grade habitable areas of a building.

6.2 Negative Effects of Uncontrolled Site Water

Site water, often referred to as groundwater, can be a problem during foundation construction or well after completion of construction. During construction, groundwater on a construction site that has had significant earthwork modification may outcrop in unexpected areas and lead to not only muddy seepage zones but possibly landslides that were not anticipated. Groundwater on a construction site may require temporary site-water protection and drying ranging from sheet piling and pumps to diversion ditches or even the addition of lime to dry a clay subgrade so construction can proceed. For example, drilled piers encountering water will likely have to be cased or otherwise processed to provide a relatively clean and dry hole for concrete and steel placement. Measures such as these greatly add to the expense of construction.

Well after construction has been completed, uncontrolled groundwater may appear on the surface after the conclusion of construction causing a wet seepage area to appear part of the year, which can cause foundation or pavement failure or just be irritating when it impacts people's yards or other landscaping. It is reasonable to assume that groundwater may appear for only a short time during rains at sufficient elevations to get into below-grade areas. Basements and split-level construction can be affected by groundwater requiring provisions during and after construction to keep the excavation, and later the finished spaces, dry.

6.3 Site Water Problems

Site water problems can frequently be anticipated by local experience, test borings, or simply observed during construction excavation, which is the worst time to find them because of the impact on the contractor's schedule and costs of construction. Indirect evidence includes certain types of vegetation, such as bamboo or willows, growing in particular areas where they are not normally found. This may indicate a seepage area or an area prone to holding surface water. Local experience may indicate that certain areas are prone to springs or seeps, either intermittent or continuing. Older place names such as "Spring Hill" or "Pond Road" may be clues. All these indicators should be considered when evaluating the potential for groundwater. Test borings are highly recommended because they are the best opportunity to reveal groundwater or the potential for seasonal water due to the types of soils encountered, but if the borings are drilled during the dry season, they may not be 100 percent reliable. For major projects, long-term readings of water levels in monitoring wells (also called piezometers) are frequently used to get the full picture.

6.4 Mitigation of Site Water

Because uncontrolled site water can be such a problem, whether identified prior or subsequent to completion of construction, there exist techniques and code provisions aimed at mitigating its impact.

6.4.1 Surface drainage techniques. Water that is on the surface, such as rainfall runoff, needs to be accounted for in the design and construction of all structures. If it is not controlled it can create erosion, or it can pond adjacent to buildings, softening subgrade soil or causing heave of swelling clays. In addition, if surface water is not cared for properly it may accumulate during rainstorms to the point where it penetrates into the structure causing problems for the occupants and physical damage inside the building.

Techniques for dealing with surface drainage include grading the site, providing a satisfactory protective backslope around the perimeter of structures, or providing drainage systems such as inlets and pipes. To properly design surface drainage, some estimate of the quantity of flow must be made for the various local areas, and proper drainage features must be provided.

A good rule of thumb to protect structures such as residences and commercial buildings would be to slope the surrounding soil areas away from the building at about 6 inches in 10 feet (or 5 percent). Hard surfaces, such as concrete, sidewalks, or patios may be sloped at less than 5 percent. Typically, between a 1/8-inch to 1/4-inch fall in 12 inches is adequate (between 1-percent and 2-percent) for hard surfaces. The general site should be drained away from structures with a minimum of 1 percent or 2 percent slope (1 to 2 foot fall per 100 feet) using continuously sloping swales to convey the water that may fall on the site or come off the roofs safely away to a street or other drainage facility. Overland flow of off-site storm water may also need to be considered in an overall drainage plan.

It is also a good idea to provide a proper "reveal" around foundations, typically placing the finished floor 6 to 8 inches above the adjacent ground surface. It is important to prevent the ground surface from being built up to an unacceptable level due to later additions of topsoil or landscaping features. Figure 6.1 illustrates a typical drainage and grading plan for residential construction.

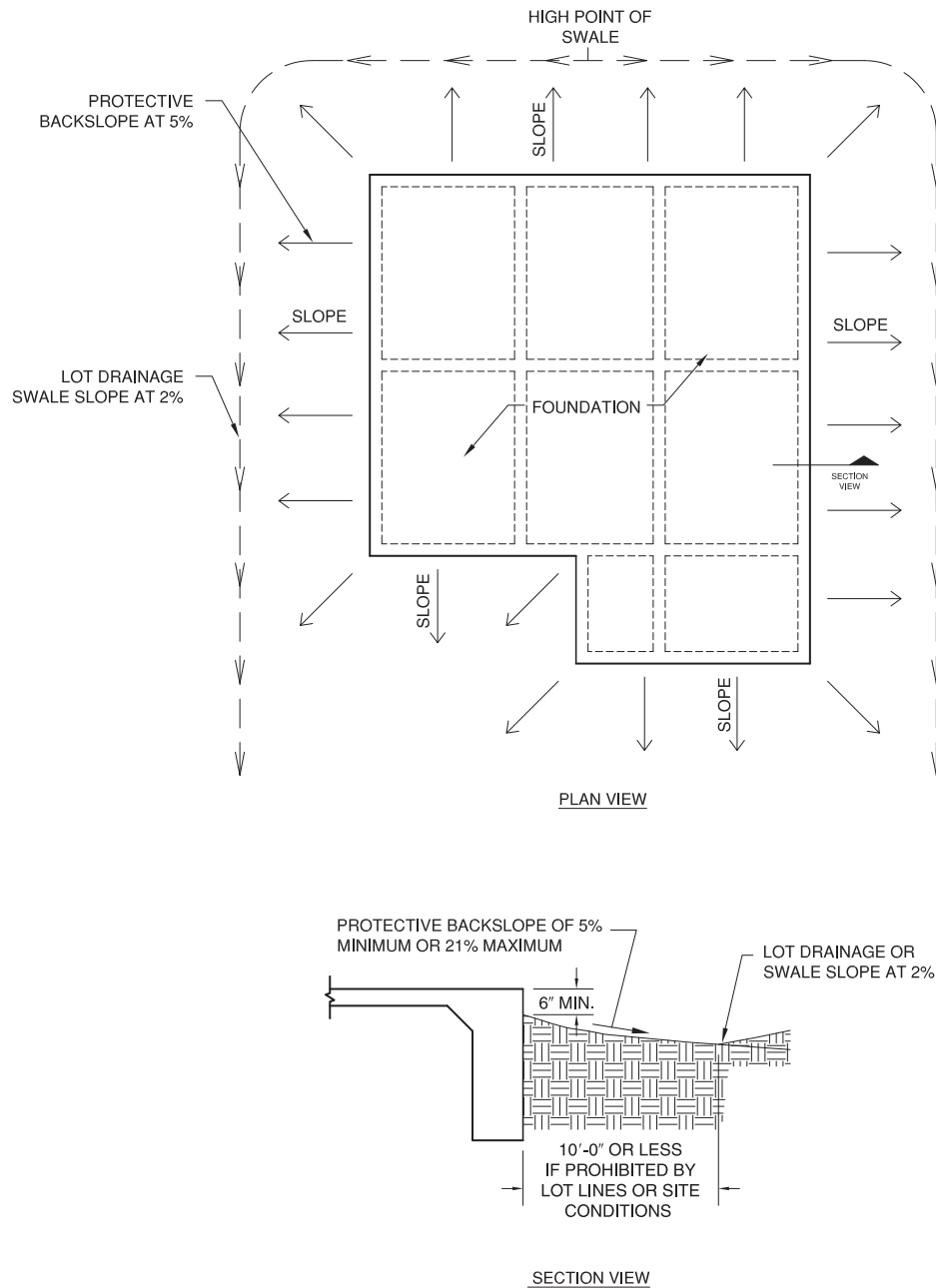


FIGURE 6.1
EXAMPLE OF TYPICAL DRAINAGE PROVISIONS FOR A RESIDENCE

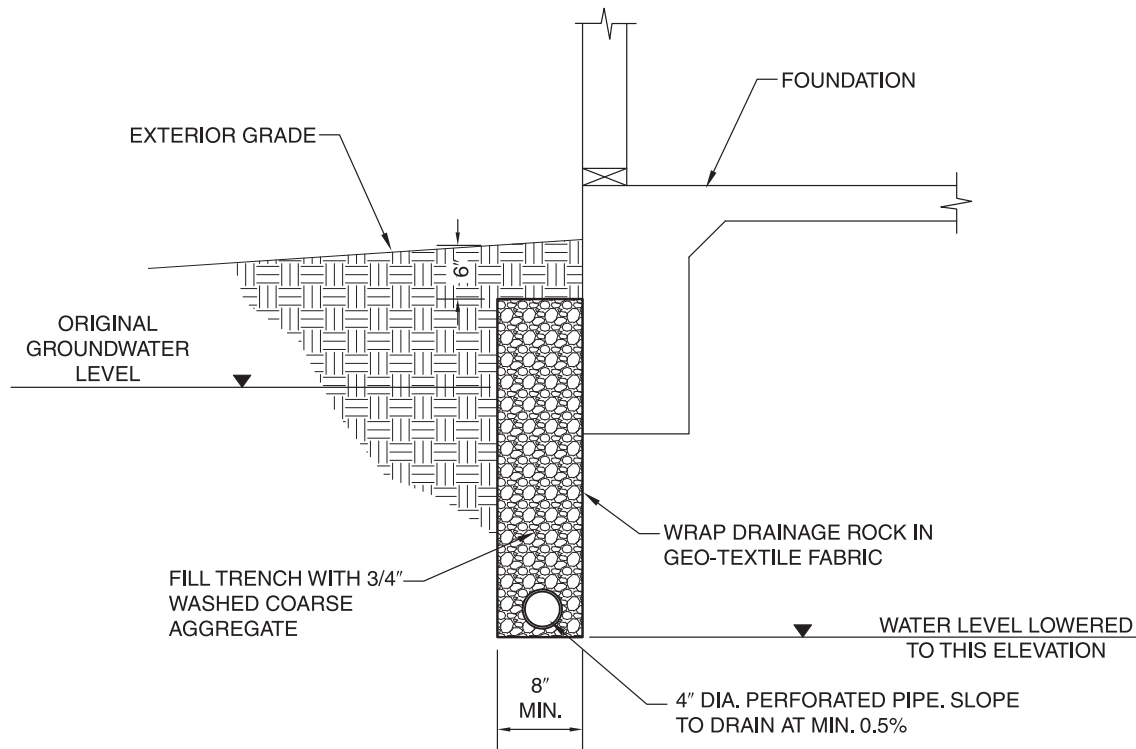
6.4.2 IBC Section 1804.4 and IRC Sections R401.3. Section 1804.4 of the 2024 *International Building Code*[®] (IBC[®]) deals with site grading and calls for the ground immediately adjacent to the foundation to be sloped away from the building at a slope of not less than 1 unit vertical in 20 units horizontal (5-percent slope) for a minimum distance of 10 feet. If site constraints prevent proving this minimum slope, an approved alternative method of diverting water away from the foundation is to be provided. This section goes on to state that if swales are to be used they are to be sloped not less than 2 percent where located within 10 feet of the building foundation. Further, impervious surfaces within 10 feet of the building’s foundation are to be sloped not less than 2 percent away from the building.

Section R401.3 of the 2024 *International Residential Code*[®] (IRC[®]) deals with site drainage and states that lots are to be graded to drain surface water away from foundation walls and the grade shall fall not fewer than 6 inches within the first 10 feet. It also states that surface waters are to be diverted to a storm sewer conveyance or other approved point of collection that does not create a hazard.

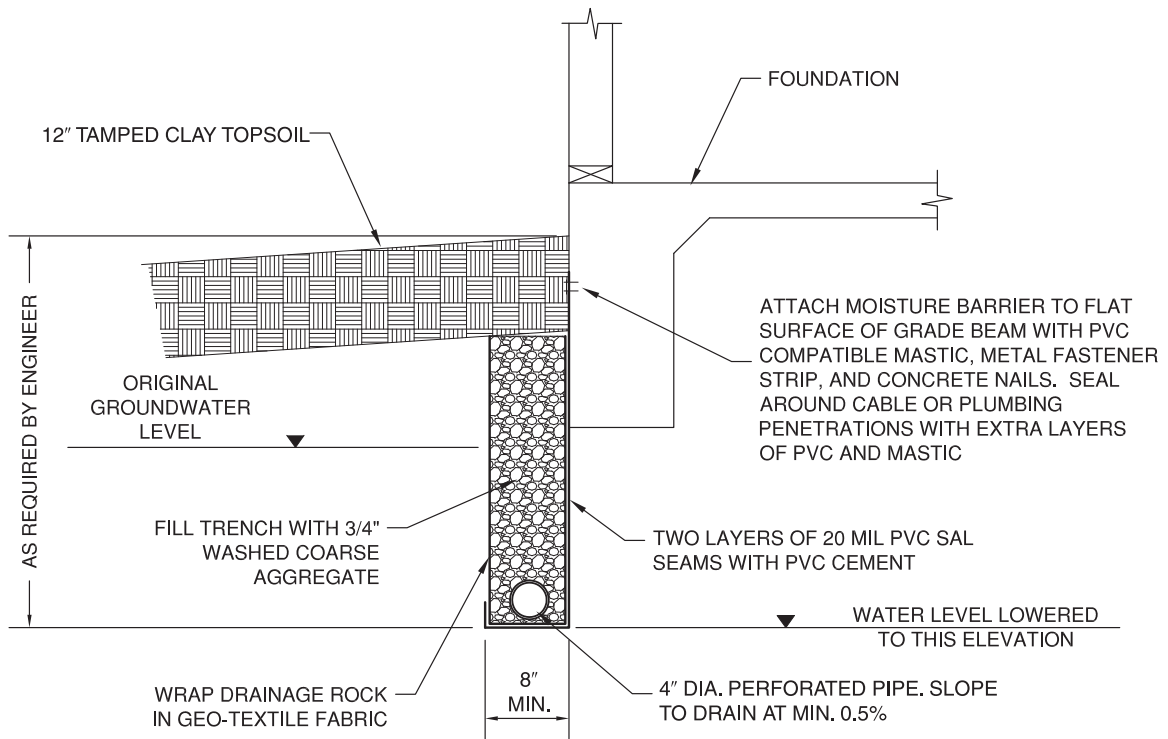
6.4.3 Subsurface drainage techniques. If subsurface water is a problem, drainage must be provided to remove the water down to a specified level within the soil. This is frequently done with something called a “French drain,” also called a subsurface drain. These drains consist of sand or gravel placed in a trench, usually draining to a slotted or perforated pipe in the bottom of the trench. This pipe will collect the water and draw the surface of the water down to the level of the pipe if it is properly designed and constructed. The pipe and trench bottom should be sloped at a minimum of 0.5 percent, which is a 6 inch fall in 100 feet, to provide positive drainage. A greater slope is preferable if feasible. Subsurface drains’ trench bottoms should not be permitted to be constructed with sags or “bellies” that will collect water and hold it for an extended period of time. Sags or “bellies” may defeat the purpose of the subsurface drain. The perforated drain pipe should rest directly on the trench bottom, not over several inches of sand or gravel, to avoid the reservoir effect.

Walls of basements or split-level construction should be protected with an adequate drain as described above, with the pipe bottom at least 6 inches below the floor to be protected, using proper pipe slope. In addition, occupied areas should be protected with a waterproofing material on the outside of the walls. Waterproofing alone generally cannot prevent all water penetration if a significant quantity of water collects at elevations above the finished floor. It usually takes a combination of sub-surface drains and waterproofing to properly protect habitable areas. All subsurface drains should continuously slope to a “daylight” discharge.

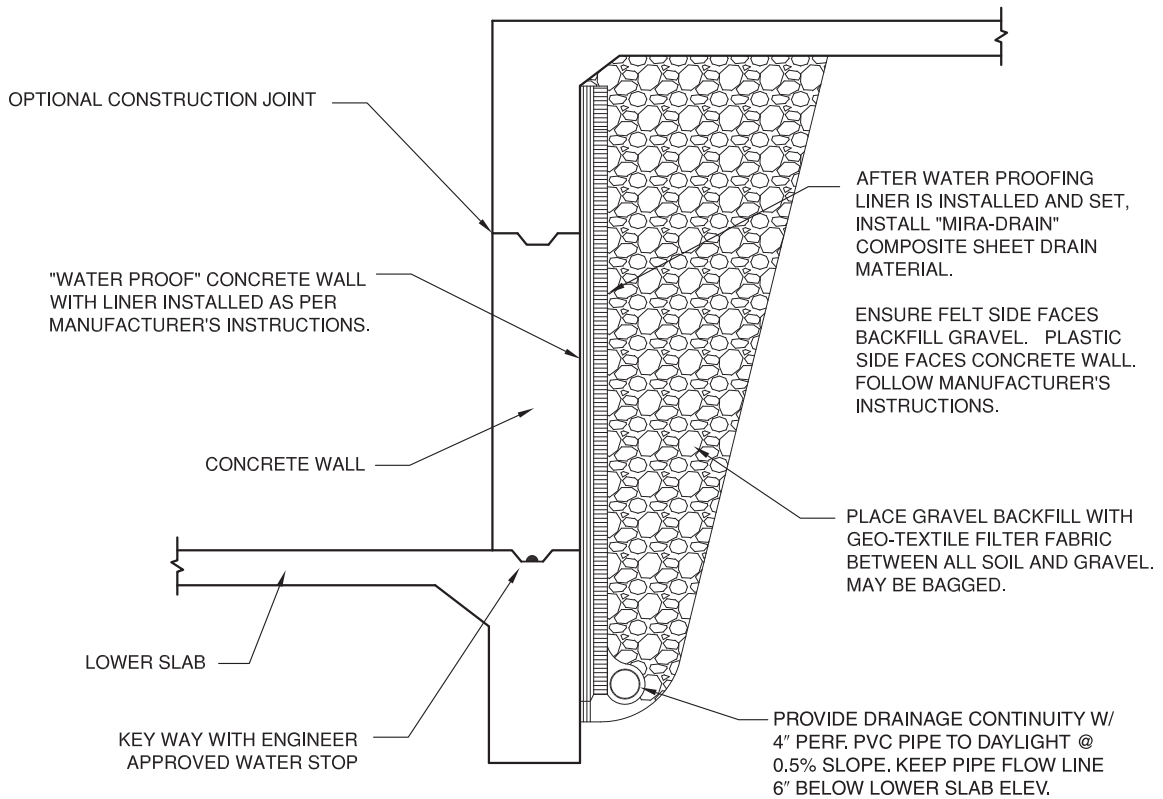
Running sub-surface drains to a so called “dry well” is rarely effective and frequently makes the problem worse. Sump pumps should only be used as a last resort because sump pumps can fail unnoticed for long periods of time. On the other hand, gravity drainage is constant and requires no maintenance or monitoring other than making sure the discharge location does not get buried or covered. Sometimes it is important to keep moisture from penetrating underneath foundations, either because capillary action or vapor rise in the foundation generates moisture within the structure or because there are expansive clays underneath the foundation that should be protected from water increase. In these cases, a “barrier drain” is often employed. This consists of a French drain as described above with the addition of a waterproofing membrane up the side of the protected foundation, wrapping under the drain pipe. Any water that passes toward the sub-surface drain would be collected and carried away and none would be permitted to pass through the adjacent soil wall barrier, even in vapor form. Figures 6.2 and 6.3 illustrate typical sections of sub-surface drains and barrier drains. Figure 6.4 illustrates a typical detail for protecting below-grade habitable areas.



**FIGURE 6.2
SUBDRAIN DETAIL**



**FIGURE 6.3
BARRIER AND SUBDRAIN**



**FIGURE 6.4
PROTECTION FROM WATER PENETRATION OF HABITABLE AREAS BELOW GRADE**

6.4.4 IBC Sections 1805, 1805.2, 1805.3 and 1805.4. In general, Section 1805 of the 2024 IBC requires that walls that retain earth and enclose interior habitable spaces along with floors below grade are to be waterproofed and damp-proofed. It also specifies that where the ground-water table is lowered and maintained at an elevation of 6 inches below the bottom of the lowest floor, the floor and walls are only to be dampproofed. However, the design of the system to lower the ground-water table is to be based on accepted principles of engineering with consideration given to permeability of the soil, rate at which water enters the drainage system, rated capacity of pumps, head against which pumps are to operate and the rated capacity of the disposal area of the system.

Section 1805.2 of the 2024 IBC deals with dampproofing of floors and walls. Dampproofing is used to prevent the penetration of ground moisture from entering a building. This does not include elevated ground water but simply includes any ambient moisture or related moisture vapor. Dampproofing measures required by the code for slabs include a 6-mil polyethylene vapor barrier below the slab or, where approved, a mopped-on 4-mil thick bitumen polyethylene on top of the slab. Dampproofing measures required by the code for walls include a bituminous material or acrylic modified cement or any of the waterproofing measures in Section 1805.3.2 applied to the exterior face of the wall.

Section 1805.3 discusses waterproofing of floors and walls when a hydrostatic condition exists. Waterproofing is used to prevent ground water from entering a building. Waterproofing measures required by the code for slabs include a membrane of rubberized asphalt, butyl rubber, fully adhered/fully bonded HDPE or polyolefin composite membrane installed below the slab. Waterproofing measures required by the code for walls include two-ply hot-mopped felts, polyvinyl chloride, polymer-modified asphalt, or polyethylene. These measures are to be applied from the bottom of the wall to 12 inches above the maximum elevation of the ground-water table.

Section 1805.4 deals with subsoil drainage systems in areas subject to hydrostatic loads. This section states that a drain is to be placed around the perimeter of a foundation consisting of gravel or crushed stone covered with an approved filter membrane material. It also states that the drain shall extend not less than 12 inches beyond the outside edge of the footing.

Even though permitted by the code, waterproofing without a ground-water control system is likely to fail since even a small gap in the waterproofing membrane can permit water penetration. If the ground water can rise above the finished floor level, the situation is similar to that of a boat hull in the water; a boat is carefully built to be waterproof, but bilge pumps are still provided.

6.4.5 IRC Sections R405, R406. Chapter 4 of the 2024 IRC contains considerations, provisions and prescriptive requirements related to subsurface drainage. Specifically, Section R405 requires subsurface drains around concrete or masonry foundations that retain earth and enclose habitable spaces. Similar to the provisions in the IBC, the IRC requires the drains to consist of gravel or crushed stone and perforated pipe at or below the top of the footing to discharge by gravity or mechanical means into an approved drainage system. It also requires a 6-mil-thick polyethylene vapor barrier below the basement floor and a sump to capture and carry away water from below the slab.

Section R406 of the 2024 IRC addresses concrete and masonry foundation waterproofing. The prescriptive requirements found in this section are aimed at accomplishing the same goals as the performance provisions in the IBC.

6.5 TEST QUESTIONS

MULTIPLE CHOICE

1. Uncontrolled runoff of surface water can result in the following (select one):
 - a. erosion
 - b. water penetrations into structures
 - c. swelling of expansive clays
 - d. all of the above
2. If ground water is not encountered in soil borings (select one):
 - a. there will never be a groundwater problem
 - b. the borings were in error
 - c. groundwater is never a problem
 - d. groundwater may be seasonal and appear later
3. To ensure that below-grade habitable areas of a building are not affected by groundwater penetration it is necessary to (select two):
 - a. ensure good vibration of concrete during construction
 - b. seal the upper ground surface
 - c. provide waterproofing and water-control drains
 - d. use two coats of paint

4. The best time to find groundwater is (select one):
 - a. during construction excavation
 - b. before construction begins
 - c. at the end of construction

5. The water table elevation of an aquifer may fluctuate depending on (select two):
 - a. weather cycles
 - b. groundwater pumping
 - c. alignment of the moon
 - d. wildlife density

6. A geologic formation that contains a large volume of groundwater is commonly referred to as (select one):
 - a. a water table
 - b. an aquifer
 - c. a water bearing soil
 - d. a perched water soil

7. Continuously sloping swales to convey surface water from a site should be sloped at a minimum of (select one):
 - a. 8 percent
 - b. 1 percent
 - c. 15 percent
 - d. 5 percent