cracking and buckling caused by uneven ground movements in areas of steeply dipping bedrock.

Structural floors have been used increasingly in Colorado since the mid-1980s. This type of flooring typically consists of wood or composite decking supported on wood or steel beams (floor joists). The floor assembly is supported by the outer foundation walls and is suspended above the soils at the bottom of the foundation (Fig. 17B). This design effectively isolates the floor from the soils. The weight of the floor and all objects on the floor is transferred directly to the foundation, thus increasing the foundation's resistance to heaving. A shallow **crawl space**, at least 18 inches high, is created between the floor and the soil surface. This allows for owner access to inspect for ground heaving, and proper ventilation to reduce humidity and therefore wood rot and deterioration beneath the floor. Structural floors are most often used in areas where soils have high to very high swell potentials. The higher initial cost of a structural floor may be offset by better long-term performance (as compared to floating slab floors) in those areas.

Homebuyers should be aware that floating slab floors may be installed by a builder even though the project engineer may have originally recommended a structural wood floor. Most engineering reports allow for this option at the discretion of the owner (who, at that time, is the developer or builder in most cases). A builder may choose this higher-risk option because a floating slab costs several thousand dollars less for materials and installation, a savings that may be passed on to the homebuyer. However, the homebuyer may eventually incur the cost of repairs for damaged slab floors, and any damage to the rest of the house, resulting from slab heave that occurs after the expiration of the builder's warranty.

The homebuyer should refer to the soils report to determine the engineer's recommendations for the flooring in any new home. The risk of damage from swelling soils should be lessened considerably, although not eliminated, if the builder followed the engineer's recommendations. If the builder elected not to follow the engineer's recommendations, you should carefully weigh the initial cost savings against the possible consequences of damage. This may involve considering whether you intend to use the basement as an unfinished storage area or as a fully finished living area, in addition to considering the site's swell potential. The use of a structural floor is frequently specified if the basement is to be used as a living space.

Interior Construction

Special interior construction is necessary for any house built on swelling soils. The actual designs may vary depending on the type of foundation and flooring in the house, as well as the degree of swell potential of the soil. The basic considerations are the same regardless of whether or not the house has a basement. Many of these designs were developed for use with floating slab floors, where it is assumed that the floor will heave or settle independently of the rest of the house, to some degree.

Interior walls. Some interior walls are designed to help support the weight of the roof and upper stories of a house, while others are used primarily as room partitions and support only their own weight. They are called **load-bearing** and **non-load-bearing walls**, respectively. Load-bearing interior walls may be affected by heaving of the foundation, and they may transmit deformation and damage to other parts of the house.

Non-load-bearing interior walls used with floating slab floors commonly employ a gap or void constructed at the bottom of the wall so that it is suspended a specified distance above the floor slab (Fig. 18). Extra-tall baseboard or headboard moldings are used to cover the void. Should the floor heave, the floor and interior wall will shift toward each other and reduce the void, but no damage should occur as long as some void remains. There are many cases in Colorado where the amount of floor heave has exceeded the partition void space, placing the wall in direct contact with the floor slab. In such cases, deformation and damage may be transmitted to the interior wall and other parts of the house.

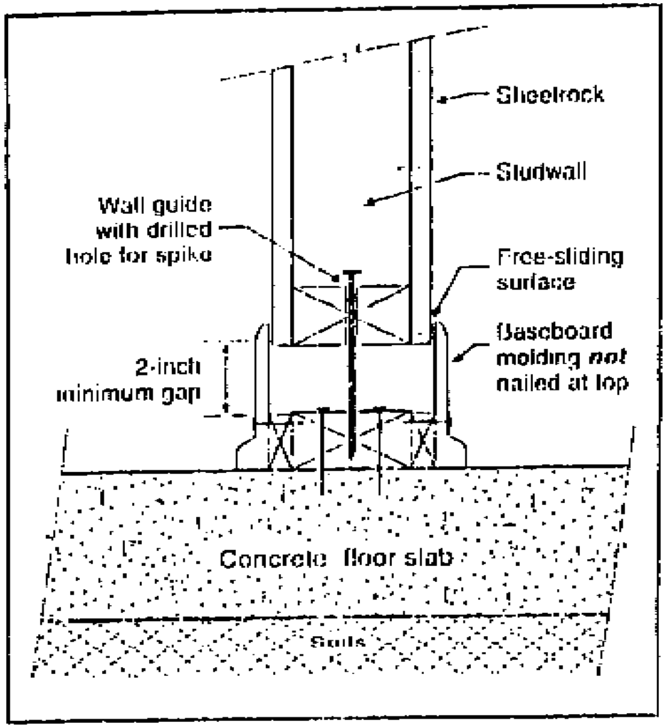


Figure 18. Detail of the bottom part of a suspended, non-load-bearing interior wall. (Modified from Holtz and Hart, 1978.)

Stairs. Stairs supported on floating slab floors should not have fixed connections. An accepted design is to attach the top of the stairway to the house frame by means of a strap connection. The base of the stairway rests on the slab floor but is not connected to it. This design allows the stairway to rotate up or down to accommodate a certain amount of floor movement.

Doors and windows. Doors and windows may be significantly affected by swelling soils. Their frames may be deformed to a point where they bind and do not open easily, or they may be rendered totally inoperable. In other cases, they may be separated from their frames to the extent that they cannot be closed or latched. Windows may be stressed to a point where the glass breaks. Ideally, door frames resting on floating slab floors should be designed with some amount of void or head space to allow for adjustment in the event of heaving. This design will tolerate minor amounts of heaving, but large amounts of heaving will affect the frames.

Gas, water, and sewer lines. Natural gas, propane, water, and sewer lines should be designed so that they are completely isolated from floating slab floors, structural floors, and foundations (Fig. 19). Ruptured pipes may result if the pipes are rigidly attached to a floor or foundation that heaves. The hazard resulting from the rupture of a natural gas or propane pipe is serious in terms of human health and safety. Ruptured water and sewer lines, while they do not directly affect human health and safety, may have a significant effect on the stability of the house itself. This is because the water leaking from the ruptured pipe may infiltrate the ground and cause additional swell in the soil.

Furnace. Furnaces mounted on floating slab floors may be crushed between the floor and ceiling framing in the event of heaving, unless special precautions are taken. A properly designed furnace in this case will have a flexible and collapsible cowling, or **boot**, in the ductwork at the top (Fig. 20). If significant heave occurs, the boot will shorten but the furnace system will remain operable. The cowling should be designed so that it can shorten or extend several inches in the event of heaving orsettling.

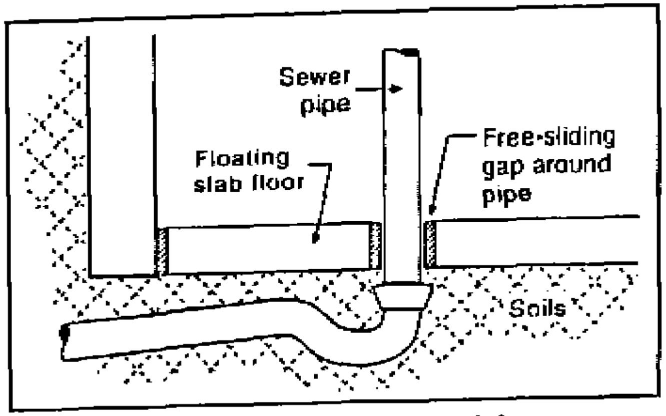


Figure 19. Detail of a sewer line where it leaves a house. (Modified from Holtz and Hart, 1978.)

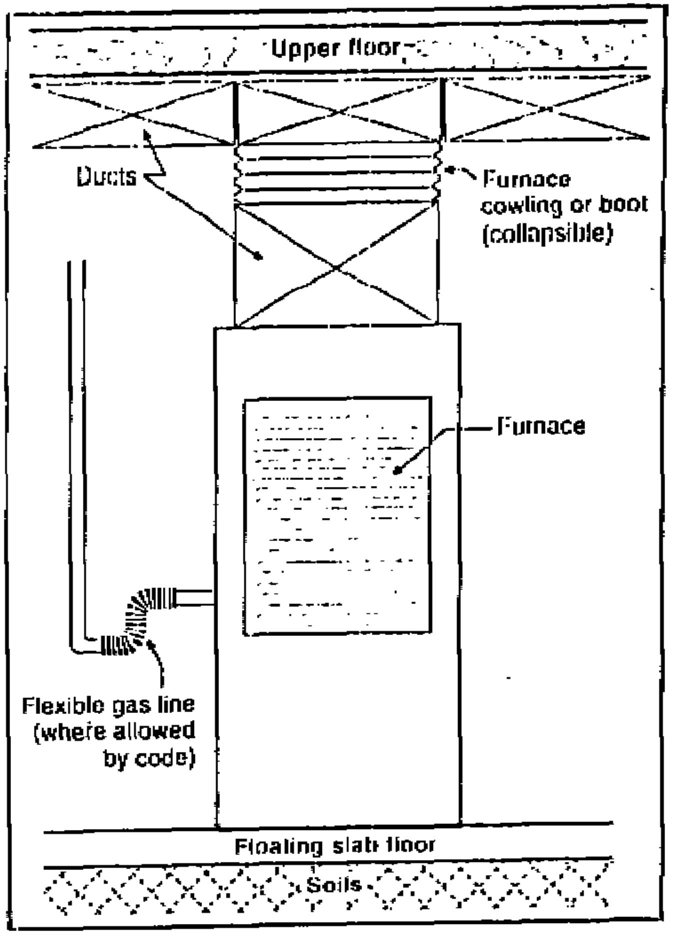


Figure 20. Furnace cowling or boot. (Modified from Holtz and Hart, 1978.)

Exterior Flatwork

Most exterior flatwork (i.e., driveways, sidewalks, patios, and porches) has in the past been constructed with unreinforced concrete. However, flatwork on moderately to very highly swelling soils should be designed and constructed with adequate strength according to the site's soil characteristics. In some cases, the concrete must be formulated to resist corrosion and deterioration due to alkaline chemistry of the ground water and soil. Unfortunately, concrete slabs cannot be designed to resist vertical heaving because uplift pressures exerted by swelling soils can greatly exceed the weight of the slab. Homeowners in Colorado should accept the fact that exterior flatwork is likely to undergo some heaving and cracking in areas of swelling soils. Long-term flatwork repair and replacement is not guaranteed under the provisions of most builder's and structural homeowner's warranties. Since flatwork replacement may be costly, it is essential to minimize potential flatwork damage through proper engineering design and construction. Homebuyers should ask the builder what precautions were taken and should verify that no "corner-cutting" was done against flatwork design, reinforcement, and thickness specifications.

Concrete porches and patios may require their own drilled pier foundations, or some other form of support, to avoid heaving, tipping, or settling. Porches supported directly on swelling soils may react seasonally, rising as the soils become wet during late winter and spring and sinking as the soils dry out later in the year. They are also susceptible to settling due to consolidation and settlement of the underlying backfill adjacent to the house foundation, and to frost heaving. Wood decks can be used in lieu of concrete patios and should be designed to allow for adjustments when soils swell and heave near the support posts. Porches and patios should be isolated from the main structure in all cases to prevent more widespread damage should movement occur.

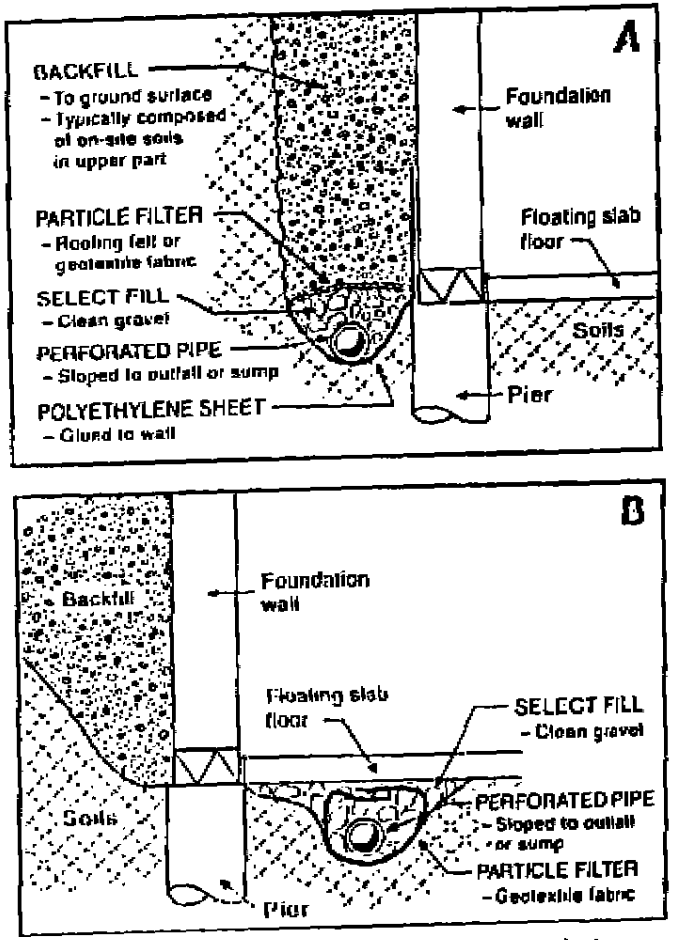


Figure 21. Components of a typical perimeter drain, A) Exterior, B) Interior.

Asphalt can be used as an alternative to concrete flatwork, especially for driveways. The asphalt is generally more flexible than concrete. However, asphalt driveways and walkways may still be prone to cracking due to swelling of soils with moderate to very high swell potentials, and they may require a great deal of maintenance.

SUBSURFACE DRAINAGE

Subsurface drainage systems are used to remove excess water that moves freely through the soil. They can be effective in reducing swelling soils damage, although they will not completely eliminate the increase in soil moisture that occurs after development. The components of a subsurface drainage system may include a perimeter drain, a sump or other outlet, and in some cases, an interceptor drain or an area drain.

Perimeter drain. Subsurface drainage around the foundation is achieved by installing a perimeter drain near the base of the foundation. This system consists of a trench (either inside or outside of the foundation wall) that contains a drain pipe; coarse, clean gravel; a geotextile drainage fabric or perforated roofing felt as a particle filter; and backfill material (Fig. 21). The highest level of the drain pipe should be several inches below the level of the floor slab and/or base of the foundation wall. Perimeter drains should be installed with a slope of 1/8–1/4 inch per foot so that gravity will allow and control the flow of the water. The drain must discharge into a sump, an area underdrain, or a suitable gravity outlet. The down-gradient extension of a perimeter drain should not terminate beneath the yard and discharge directly into the soils under any circumstances.

Drain pipes are made of perforated metal or plastic. Plastic pipe is generally preferred because it resists corrosion, and can be either flexible or rigid. The pipe may be slotted on all sides (Fig. 22A), or

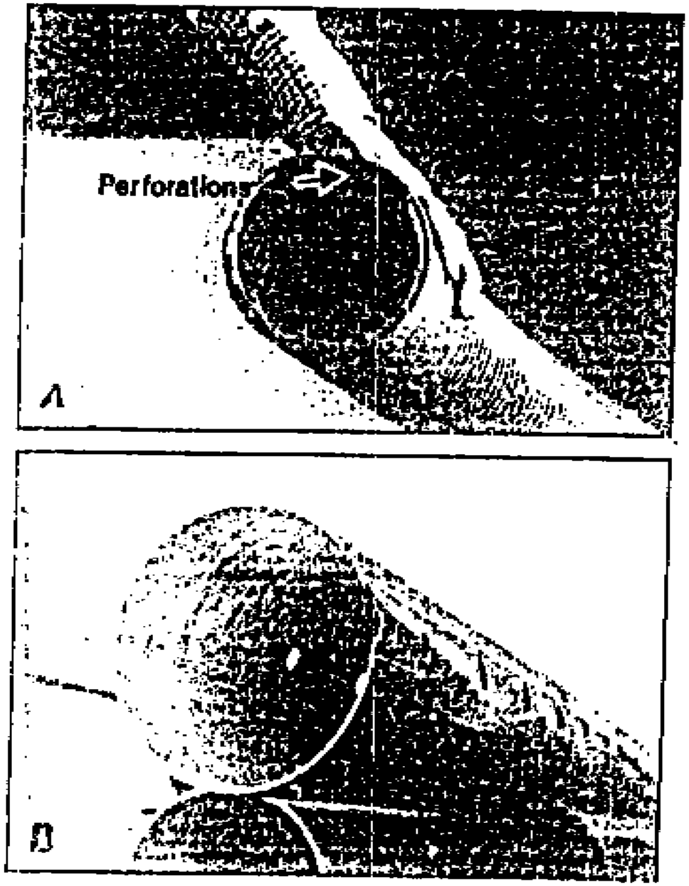


Figure 22. Two types of 4-inch-diameter plastic drain pipe. A) Corrugated and slotted on all sides. B) Perforated on two opposing sides. (From Jochim, 1987.)

it may have two rows of opposing perforations (Fig. 22B) that should be placed facing the sides of the trench. Pipes with large perforations should be wrapped with a fabric membrane to reduce clogging.

Sump system. A sump is an enclosed pit or low area that collects water (Fig. 23). Water from the perimeter drain system flows to the sump by gravity drainage. When water collects in the sump, it should be removed by an automatic submersible pump and discharged into an acceptable area. Perforated pits are used in many older houses, but

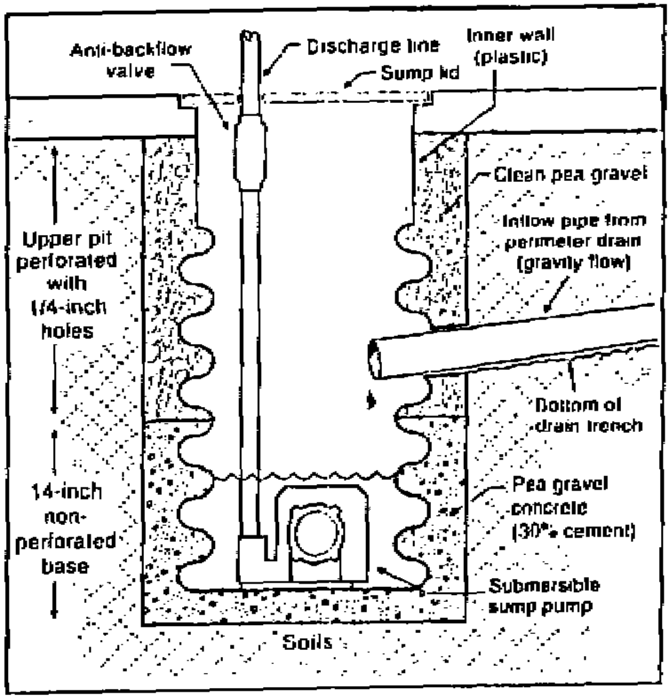


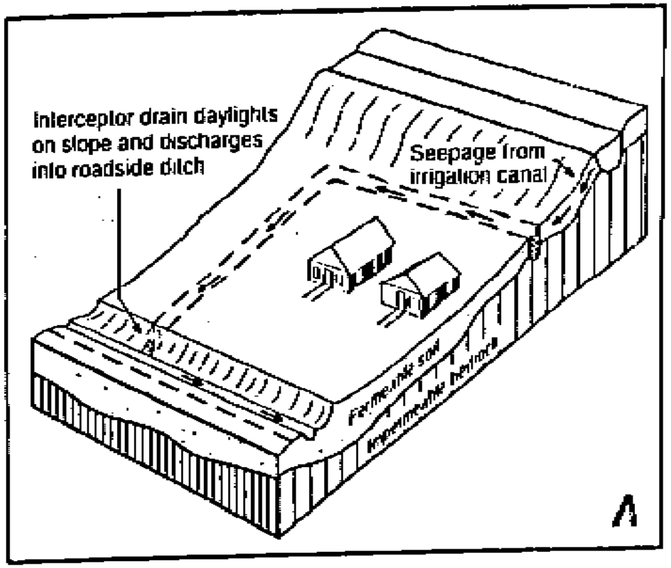
Figure 23. Sump system with a non-perforated base.

sump pits having non-perforated bases are best for areas of swelling soils because they keep the water from entering the surrounding soils. Sumps are usually installed in a basement. As an alternative, they can be installed outside in the yard.

Sumps work most effectively in areas where the rate of movement of water through the soil is slow, and are especially appropriate where clay soils and bedrock are present. A good-quality pump is required that removes even shallow water, because any appreciable build-up of water may infiltrate the surrounding soils and cause localized swelling and heaving. The effectiveness of the system may be reduced if larger amounts of water constantly flow into the sump, as may be the case in sandy soils or fractured bedrock having shallow ground water conditions.

Interceptor drain. Interceptor drains are used to collect subsurface water and divert it to an acceptable outfall. This type of drain is often used when the source of water is uphill from the area to be protected. Historically, it has been used in Colorado to protect individual houses or small neighborhoods from seepage from unlined irrigation canals (Fig. 24A). A typical interceptor drain consists of a gravel or sand-filled trench, either with or without a drainpipe. It may be lined with a permeable fabric membrane to help prevent clogging (Fig. 24B), or it may include an impervious membrane on the down-hill side of the trench.

Area drain. An area drain is similar in construction to an interceptor drain. Typically, these drains run beneath streets and gather subsurface water from the perimeter drains of individual



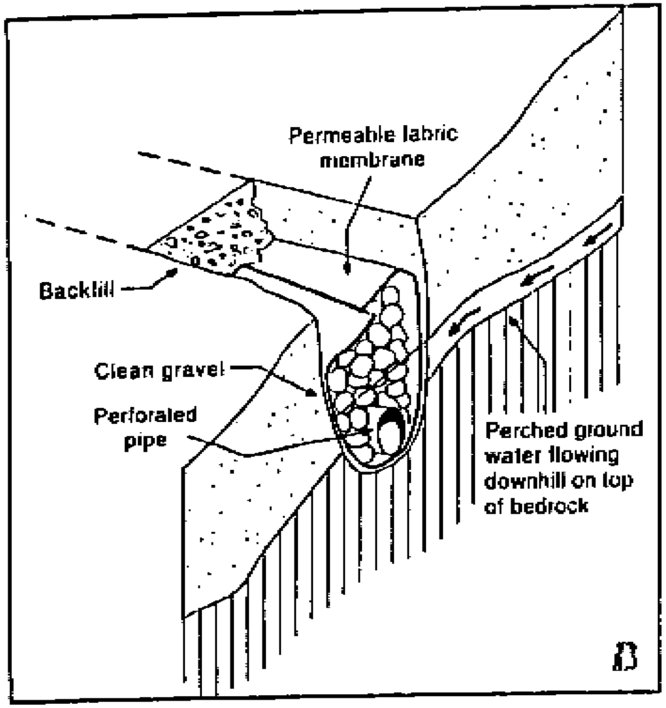


Figure 24. Interceptor drain system. A) Layout of an interceptor drain used to intercept seepage from an irrigation canal. B) Details of an interceptor drain. (Modified from Jochim, 1981).

houses and other errant sources (such as excess irrigation, or leaking water and sewer lines), and divert it to an acceptable gravity outfall (Fig. 25). The trenches for the drain are typically dug down to below the level of other utility lines. The upper part of the trench is most often filled with compacted native backfill. Area drain systems are common in newer subdivisions along Colorado's Front Range as an alternative to individual sump systems. They have the advantage of intercepting

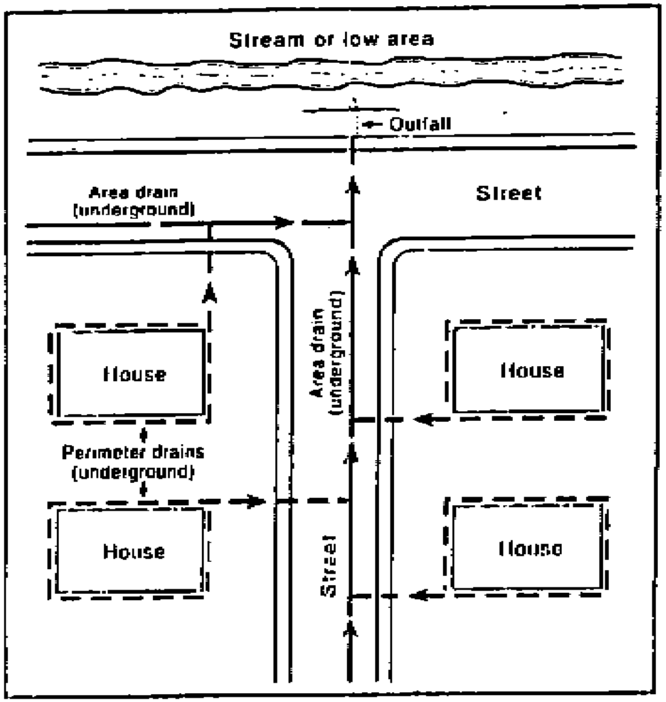


Figure 25. Map view of a typical area drain layout.

numerous sources of subsurface water from a relatively large area. They require careful sloping and an outfall location that will allow gravity drainage. The system must be maintained and inspected regularly, because covering or clogging of the outlet may lead to widespread water build-up and possible swelling soil damage.

Septic systems. Septic systems with leach fields are often installed for houses in rural settings. Leach fields are a source of liquids that infiltrate the ground, and therefore should be located well

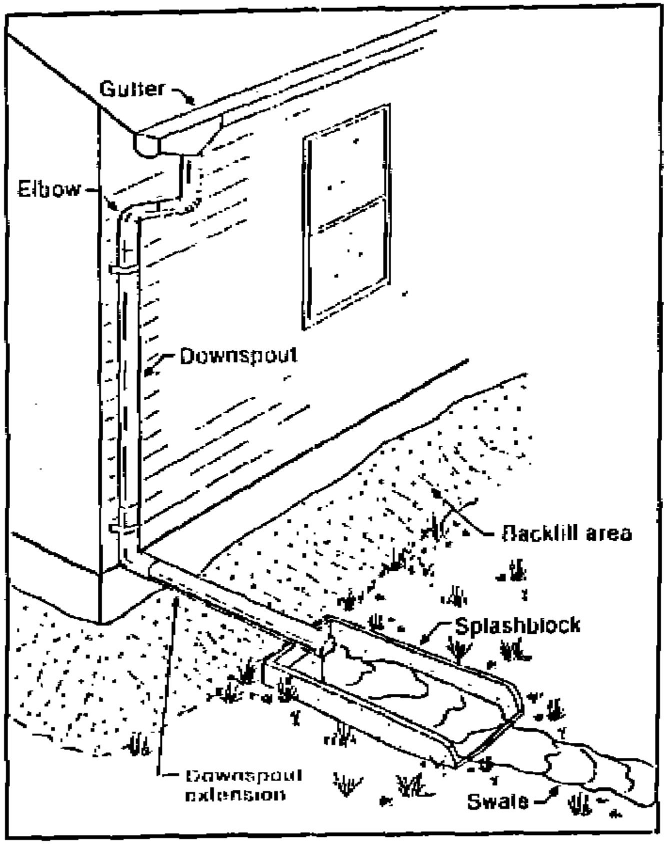


Figure 26. Components of a roof drainage system. (Modified from Jochim, 1987.)

away and downslope from the house if swelling soils are present. *Proper siting of leach fields is* necessary so that the resulting perched water does not flow toward or affect soils around any nearby houses.

SURFACE DRAINAGE

Proper **surface drainage** is critical for houses built on swelling soils. Water from rainfall, snowmelt, and irrigation must not be allowed to pond and infiltrate the soil near foundations or flatwork. Instead, it must be directed into drainage swales and carried away from the property by means of ditches, street gutters, storm drains (where legal), or other available means. The surface drainage system for an individual house consists of a roof drainage system, a slope drainage system, and ditches and swales.

Roof drainage. The roof drainage system is composed of gutters, downspouts, and splashblocks (Fig. 26). Its purpose is to keep rainwater and snowmelt from pouring or dripping over the eaves and falling next to the foundation. Fixed **downspout extensions** and **splash blocks** are two acceptable means of carrying water away from the house beyond the backfill area. A swale should be provided in the yard at the end of the downspout extension or splash block to allow water to flow even further away from the house, preferably to a street or ditch. All roof runoff should be carried at least 5 feet, and preferably 10 feet, away from the building.

Slope drainage. A properly designed and maintained slope next to the house is a critical aspect

of surface drainage. When houses are built, the
slope and adjacent ditches and swales should be
graded according to the specifications of a quali-
fied engineer. The main purpose of lot grading is
to provide positive drainage away from the
house. If the lot is sloping and well drained (Fig.
27A), precipitation will run off and infiltration
near the house will be reduced. However, if the
lot is not properly graded (Fig. 27B), the water
may pond and infiltrate the soil, and swelling
soils damage may result.

The **minimum slope** or fall necessary within 10
feet of a building depends upon the type of sur-
face and/or landscaping. Paved areas should
maintain a minimum slope of 1 percent (1 to 2
inches of vertical fall for 10 feet of horizontal dis-
tance). A greater initial slope of 2 to 5 percent is
desirable, however, since even a small amount of
settling can reverse such a small slope and cause
water to pond.

Landscaped areas next to a house should consist
of a **runoff slope** (Fig. 28) that extends 10 feet
outward from the foundation into the yard, where
possible. The fall of the slope should be at least 10
percent (i.e., 1 foot of vertical fall for every 10 feet
of horizontal distance). Many newer houses built
on small lots have slopes as steep as 33 percent.
Where houses are closer than 20 feet apart, the
slopes should direct runoff water to a low swale
between the houses and away from the area. All
slopes should be properly landscaped with rocks
or other mulches (see Chapter 4) to prevent ero-
sion. Soil beneath the slope surface should be
well compacted and fine-grained so that water
will not easily infiltrate the backfill.

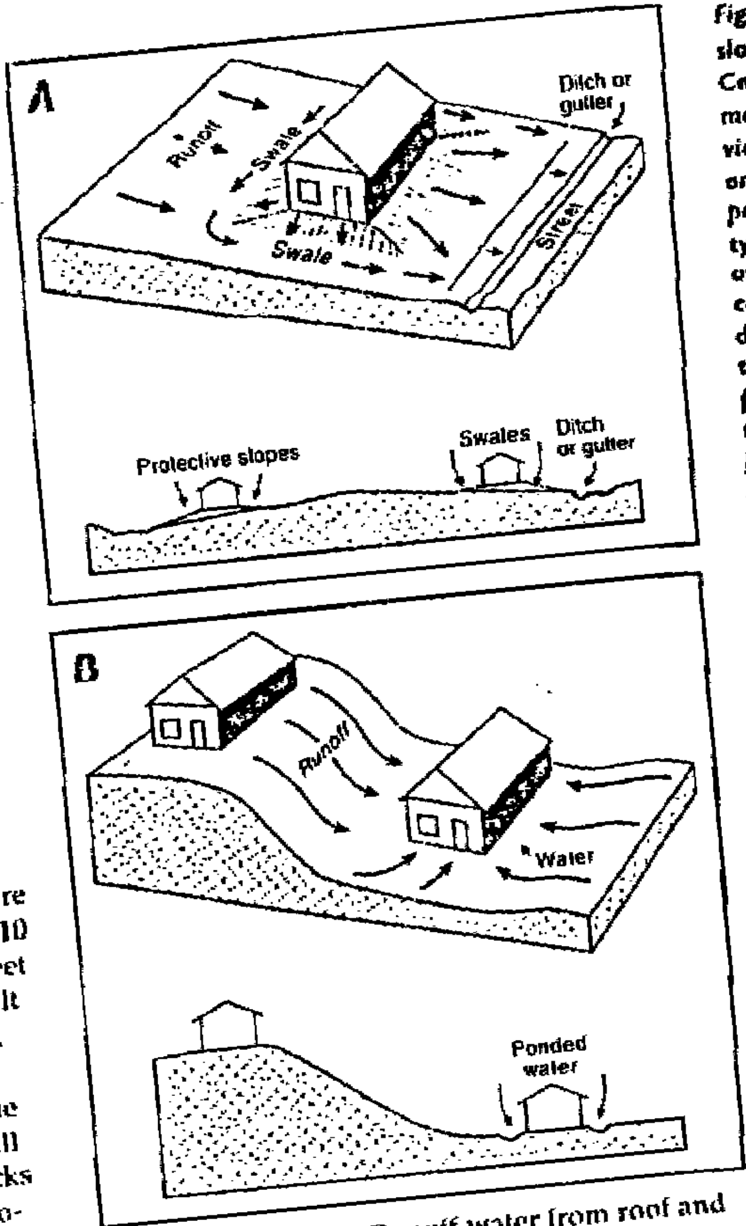


Figure 27. Effect of slopes on drainage. A) Carefully planned and maintained slopes provide positive drainage and prevent water from ponding on the property. B) Poorly planned and maintained slopes can result in poor drainage, allowing water to pond around the foundation and infiltrate the soil. (Modified from Jochim, 1987.)

Ditches and swales. Runoff water from roof and
slope drainage systems can be collected and car-

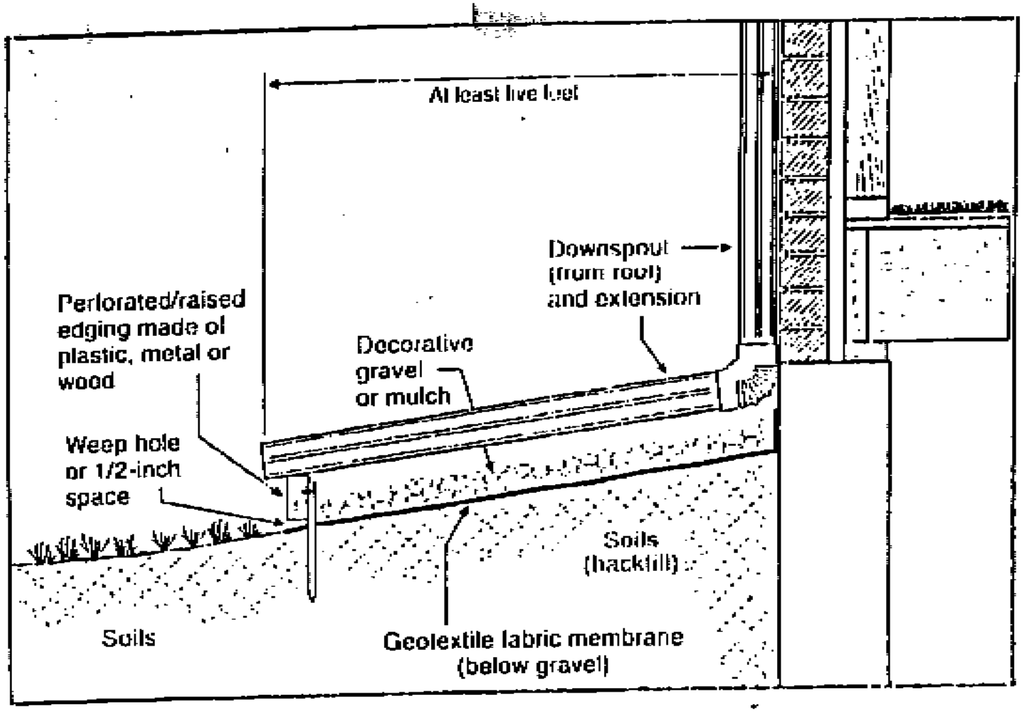


Figure 28. Properly designed runoff slope next to a house foundation. Note that roof drainage is carried by a downspout extension to a point beyond the slope. (From Holtz and Hart, 1978.)

ried away from the house by ditches and swales. These are simply shallow trenches (ditches) or depressions (swales) in the yard that are graded to collect, direct, and convey rainwater, snowmelt, and excess irrigation water away from the house and off the property. Care must be taken to ensure that the surface water channeled away from a structure is not directed toward neighboring structures. Ditches and swales may drain into commonly shared concrete gutters and storm sewers in suburban areas. In many areas, culvert pipes are installed so that so that runoff water can flow under roadways (Fig. 29).

Construction Quality Control

Quality control is perhaps the most important aspect of construction, especially in areas of swelling soils. Even though soil water conditions may be initially responsible for swelling soils movement, poor construction quality can add significantly to the total amount of damage to a house. Any one of the construction designs and methodologies described in this chapter may be rendered useless unless it is done carefully and correctly. Chapter 7 at the end of this book will show you how to look for house damage that may have been caused by swelling soils and/or poor design or construction, as well as how to obtain professional assistance to assess a house for damage or repairs.

Figure 29. Culvert and drainage swale along a rural road. (From Jochim, 1987.)

LANDSCAPING ON SWELLING SOILS

Chapter 4

Much of the damage that could be caused by swelling soils can be reduced by proper landscaping. As a homeowner, you can be creative about vegetation choice and layout as a means of protecting your property against swelling soil damage. This chapter addresses the critical roles of vegetation and irrigation as they pertain to swelling soil behavior and gives several landscaping tips.

EFFECTS OF LANDSCAPING ON SWELLING SOILS

The landscaping conventionally used in Colorado consists of luxuriant bluegrass lawns, showy gardens, and large shade trees. Many of these plants originated in more temperate climates, and have water requirements that cannot be satisfied by rainfall alone. As a result, we augment nature's precipitation with large amounts of water. This practice is known as **irrigation**.

Swelling soil behavior is affected by conventional landscaping practices in four ways:

1) A significant amount of irrigation water meant for plants **infiltrates** the ground. Clay soils can forcibly take in and hold this excess water. This causes the soils to swell.

2) Irrigation water can form a **perched water table** (see Chapter 2) on top of clay soils and can migrate underground along the top surface of the clay layer to new areas. This means that the clay soils can be wetted (and can swell) across an area larger than the area irrigated.

3) Trees and shrubs can **transpire** large amounts of water out of the soils within the area of influence of their root systems. This causes the soils to shrink and settle, especially during conditions of drought.

4) **Impervious covers** used in conjunction with landscaping, such as concrete walkways, porches, and courtyard slabs, cut off much of the evaporation that would normally remove moisture from the soil to the atmosphere. This increases the soil moisture and causes the soils to swell.

As a result of these practices, the soil beneath a property usually takes on additional or **excess water** after the property is developed. If the soils contain **swelling clay**, damage to houses may occur for as long as the soils continue to take on water. Most geologists and engineers who work with soils in Colorado agree that *excess water is the most significant and direct causes of swelling soils damage*.

People tend to plant trees, flowers, and other water-dependent vegetation close to their houses (Fig. 30). This should be avoided in areas of swelling soils, where the primary concern is to

Figure 30. An example of how not to landscape for swelling soil conditions. A garden has been planted next to the foundation, and the downspout extension has been removed.

keep excess moisture away from the foundation.
Trees and large shrubs may cause soil shrinkage
and foundation settling during droughts as their
root systems pull moisture from the soils.

Water-dependent bluegrass lawns and exotic gar-
dens are a problem even when they are located
away from the house because the excess water
generated by their irrigation often infiltrates
downward to a perched water table. The water
may flow laterally through the soil to other loca-
tions, causing soils to swell beneath nearby hous-
es or roads. Swelling soils will also draw moisture
toward foundations much like a sponge. It is
imperative to control irrigation in all parts of the
yard to reduce damages caused by swelling soils.

GUIDELINES FOR LANDSCAPING

Landscaping on swelling soils should be geared
toward reducing the amount of excess water that
infiltrates the ground, especially in the immediate
area around the house foundation. Some basic
guidelines are:

1) Do not plant flowers or shrubs closer than
5 feet from the foundation, unless they
have very low water requirements and are
hand- or drip-line watered. Native or com-
parable groundcover plants with low water
requirements can be used to shelter the soil
and reduce extreme moisture fluctuation.

2) Plantings near the foundation should not
disturb the slope around the house. Storm
runoff from the roof should be directed
away from the slope and foundation, and
not into the plantings.

3) Trees should not be planted closer than 15
feet from the foundation. Trees with high
water requirements or with extensively
wide, shallow root systems (such as wil-
lows or poplars) should be avoided.

4) **Sprinkler systems** should not spray water
any closer than 5 feet from the foundation.
Automated sprinkler systems can be
adjusted to the monthly water require-
ments for various plants, reducing the infil-
tration of excess water into the soil.

5) Use **low-water vegetation** throughout your
property, including gardens and lawns. By
doing this, you will reduce the overall
build-up of subsurface moisture and save
on your water bill as well.

6) Be sure to water existing trees near to a
house during long, dry periods. This will
keep them from extending their root sys-
tems and drawing large amounts of water
from the surrounding area.

7) Poor-quality, "heavy" clay soils should be
improved and conditioned by mixing in or-
ganic material. This improves the fertility
and air and water circulation within the top-
soil.

8) Group plants according to similar water
needs so that different areas of vegetation
can be irrigated in a water-wise manner. If
you wish to have a high-water lawn or
garden, restrict it to as small an area as

possible, and locate it well away from the house foundation.

9) Irrigation should be limited to the amount necessary to keep plants healthy. This is especially important for bluegrass lawns. Overwatering, even away from a house, can lead to an increased likelihood of damage to structures and flatwork due to swelling soils.

Xeriscaping: A Practical Alternative

Landscaping conditions in Colorado are different from most other parts of the country. The state's high elevation and semi-arid climate give rise to a short growing season, low precipitation (at least around the major population centers), and occasional droughts. The soils tend to be alkaline, and are calcium-rich on the Eastern Slope and sodium-rich on the Western Slope. The clay soils are characterized by having poor aeration (air circulation) and poor drainage.

Another serious constraint on landscaping is the large amount of water needed to grow a conventional lawn and garden. More than half of residential water use typically goes to outdoor landscape watering. The water used by Coloradans comes from streams, supplied by snowmelt, and wells, supplied by aquifers. These water supplies are being stressed because of the rapidly increasing population. Water rationing during the summer months has become common practice in many communities.

Xeriscape™ is a practical solution to landscaping under these seemingly unfavorable conditions.

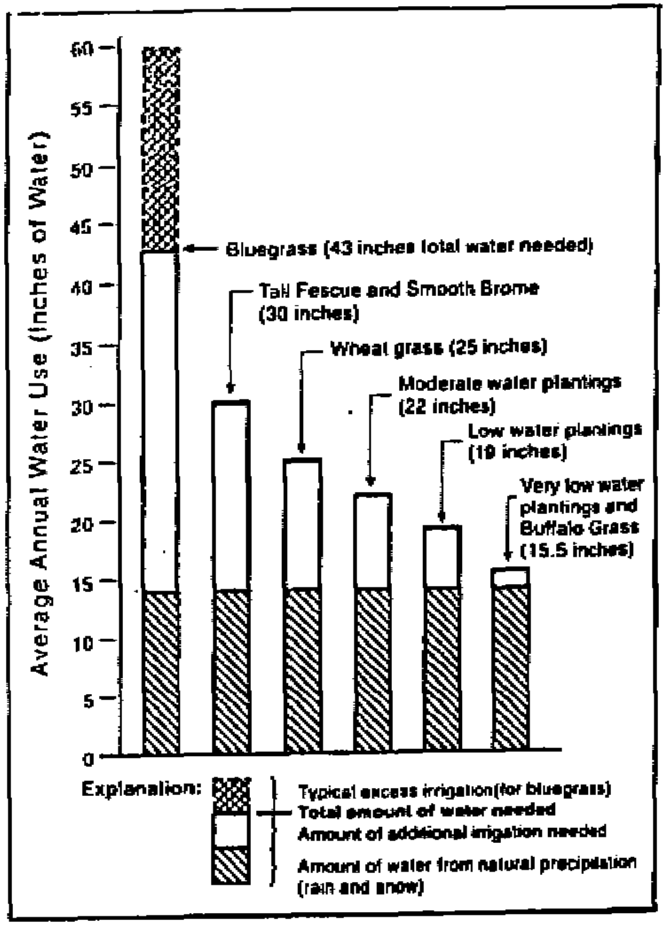


Figure 31. Average annual water use for different types of plants for an area having 14 inches of natural precipitation. The native grasses are a water-wise alternative to conventional bluegrass lawns because they only use 5 to 55 percent as much additional irrigation water. (Modified from Xeriscape Colorado!, Inc., undated.)

Pronounced "Zeer'-is-scape," the term was coined by Denver Water (formerly Denver Water Department). It means "water-wise landscaping" (from "xeros", the Greek word for dry). Xeriscaping is a process aimed at conserving water, based on proper planning and design, use of mulches and/or turf alternatives, zoning of plants, soil improvements, efficient irrigation, and appropriate maintenance (Xeriscape Colorado!, Inc., undated pamphlet).

A Xeriscape requires little maintenance after it is established. This means less watering (and less mowing!). There is a dramatic difference in the water demands of a conventional bluegrass lawn versus Xeriscape plantings (Fig. 31). Colorado homeowners have been able to reduce their total household water use by as much as 50 percent, and have saved as much as 30 percent on the cost of their annual water bills by installing water-wise landscaping (Denver Water Department, 1988).

An important benefit of Xeriscaping is that it can help to reduce swelling soils damage to a home.

Some people mistakenly think of a Xeriscape as a gravel and yucca wasteland or a weed patch. The truth is, however, that areas of mulch, and low-water plants and turfs can be used creatively to suit a homeowner's needs. The results can be practical, colorful, and appealing (Fig. 32). Numerous plants, both native and introduced, are well adapted to Colorado's climate and soils. Table 1 lists several of these trees, shrubs, ground covers, wildflowers, and turf grasses.

There are several excellent resources available to homeowners who are looking for information and ideas on Xeriscaping and water conservation, including Denver Water, U.S. Soil Conservation

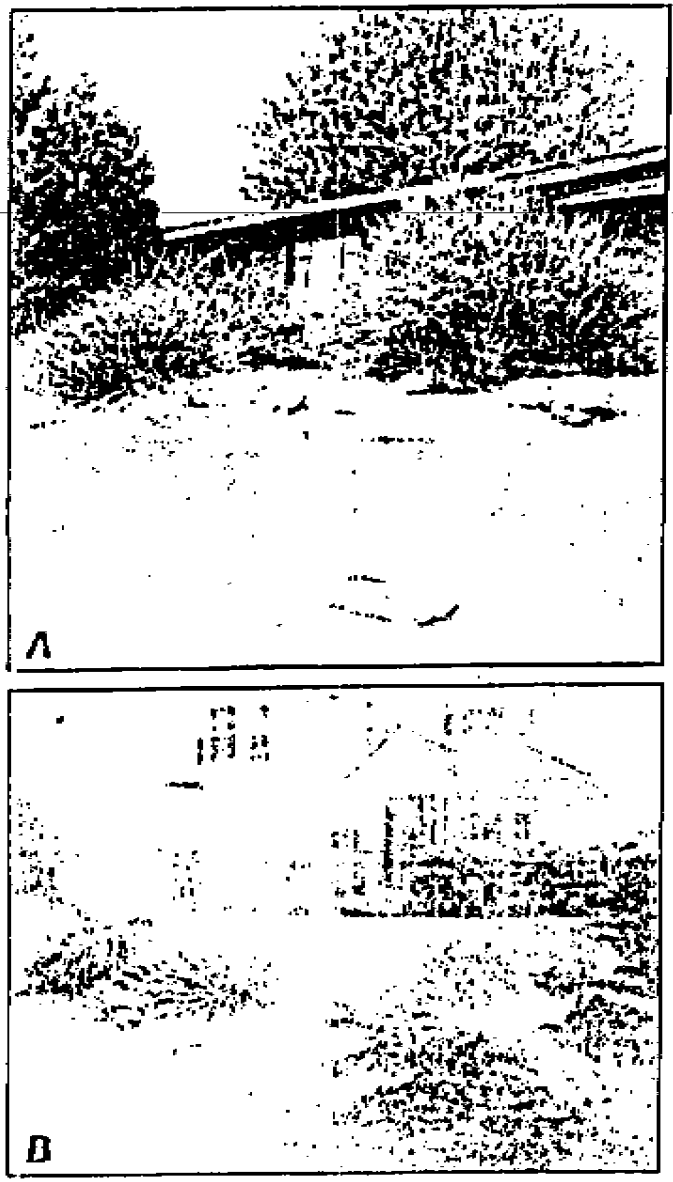


Figure 31. Examples of shrubs, mulches, boulders, and native turfs used to add interest to Xeriscapes. A) Buffalograss lawn with a walkway made of slabs of Lyons Sandstone (from Jochim 1987). B) A gravel edging accented by decorative grasses and shrubs.

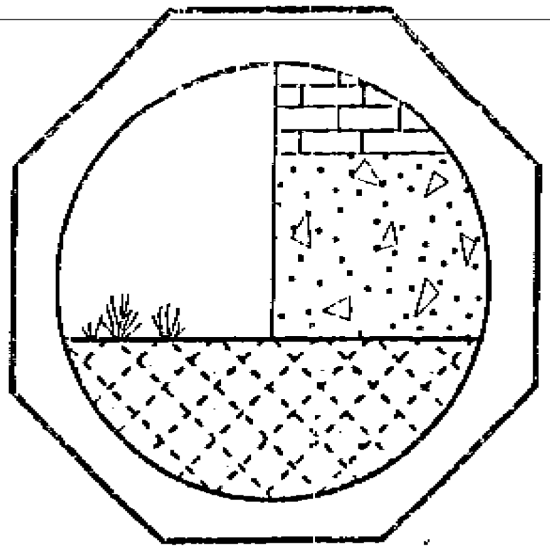
away during a hard rainfall. Heavier gravel and cobbles should be used if the mulch is to cover a steep slope, such as a runoff slope around a house.

4) Walking on areas of crushed rock may damage the fabric liner. Adequate pathways made of concrete or flat stones should be provided.

5) The geotextile fabric will eventually deteriorate, although this may take a long time. Weeds can take over, and water will be able to enter the soil if the fabric is not replaced.

6) Organic mulches will decompose naturally. This adds nutrients to the soil but necessitates adding new material at periodic intervals.

These inherent disadvantages can be controlled through proper planning and maintenance of the landscaped areas. The bottom line for mulch covers, and Xeriscaping in general, is that the potential benefits far outweigh the problems, especially when it comes to reducing swelling soils damage.



Home Maintenance on Swelling Soils

Chapter 5

The lack of timely maintenance to critical slope, drainage, and landscape areas around a house is another important factor that can contribute significantly to swelling soils damage. Severe problems may result from poor maintenance practices such as:

1) neglecting to maintain adequate slopes for good drainage,
2) neglecting to clean gutters and downspouts,

3) overwatering lawns and gardens,
4) neglecting to adjust and maintain sprinkler systems,
5) planting trees, shrubs, and flowers too close to the foundation,
6) constructing patios, fences, or other obstructions that dam and pond water, or
7) neglecting to seal old construction joints and cracks that develop over time in the flatwork.

It is essential that the homeowner understands how to check and maintain all of the different systems that were designed to protect a house against swelling soils damage. The following sections describe the typical types of periodic maintenance that should be conducted if your house is built on swelling soils. (For more details on the design considerations for these systems, see Chapter 3).

Concrete Floor and Wall Maintenance

Every homeowner should conduct a yearly inspection of **concrete slabs and walls,** both inside and outside of the house. This is especially important during the first five years after a new house is built because this is usually when the most severe adjustment occurs between the house and its environment. The process of inspection and maintenance should continue over the years, but cracking, settling, and other problems should become less common.

Some cracking will occur in virtually all new concrete slabs. However, cracking tends to be more common and more severe in areas of swelling soils. Cracks in concrete slabs and walls should be sealed as soon as possible. Quality exterior acrylic caulking compounds or equivalent products manufactured for this purpose can be purchased at most hardware stores, do-it-yourself departments, and lumber yards. Unsealed cracks may allow more water to infiltrate the ground, and could cause the cracking to worsen.

Cracks should be regularly monitored by measuring the width of a number of cracks every month, at a designated spot along each crack. Note if the cracks stay the same width, steadily increase in size over time, or expand and contract with the seasons. This can be helpful information in the event that a professional damage-and-repair consultant needs to be called.

Structural Wood Floor Maintenance

Ventilation of the **crawl space** beneath a structural wood floor is essential, and contributes to the proper performance and durability of the floor. Moisture may build up below the house, and the wood may rot and deteriorate if the crawl space is not adequately ventilated. Passive or active ventilation systems should be built into any house with a structural floor to prevent moisture and humidity build-up beneath the floor. Such systems should be installed in accordance with the governing building code. Homeowners should be familiar with any maintenance and special requirements of structural floors and any attendant systems. Because structural wood floors are expensive, these steps should be taken to prevent unnecessary repairs.

Subsurface Drainage Maintenance

Subsurface drains should require little maintenance if they were correctly installed. For gravity-discharge perimeter or interceptor drain systems, it is extremely important to avoid covering or obstructing the drain at the point where it discharges. It may occasionally be necessary to clean out roots, nests, or other debris from the discharging end of the drain pipe. If the subsurface drainage system is not working, it may have been broken, installed incorrectly, or even not installed at all. Older houses may have drain tiles that could break if driven over by a heavy truck. In any of these cases, it will probably be necessary to dig up the drain in order to diagnose the problem and make the appropriate repairs.

If an **area drain** is installed in a subdivision, the homeowners association should be aware of its location and should have the system maintained regularly.

Sump systems require periodic inspection and, if water has entered, cleaning of the sump pit and maintenance of the submersible sump pump. Perforated sump pits are not recommended in swelling soils because they allow standing water to infiltrate the surrounding soils. It may be advisable to upgrade such a system with a non-perforated sump pit.

Surface Drainage Maintenance

Surface drainage systems are designed to reduce the amount of water that infiltrates the ground, and they must be kept in good working condition. By taking the time to maintain and repair these systems, you will increase the life of your house and reduce the potential for costly repairs.

Roof gutters should be inspected at least twice a year, in the spring and fall. All debris should be cleaned out and metal gutters checked for rust. They may have to be cleared out more often if there are trees near the roof. Check the slope of the gutters. If the slope is too low, water will accumulate in low spots, building up debris and accelerating rusting. The easiest way to check the slope of the gutter is to use a garden hose or pour a bucket of water into the gutter at its high end. Note if the water flows out smoothly or ponds in low spots. The gutters should be adjusted to remove any high or low spots.

Downspouts should be checked for clogging at the same time the gutters are checked. Clogging often occurs at the elbow where the downspout and gutter meet. The elbow can be removed for cleaning but it may be necessary to use a plumber's snake to clean the downspout. A leaf strainer or leaf guard should be installed at the top of the downspout if there is a problem with leaves. Products and instructions for gutter repair can be found at most hardware stores, lumber yards, and do-it-yourself sections in department stores.

Downspouts and splashblocks should be long enough and sloped sufficiently to carry all water well away from the foundation and backfill area. Water should be discharged no closer than 5 feet from the foundation. **Downspout extensions** with fixed elbows are preferable to those with flexible elbows, as many homeowners forget to bend the flexible elbows back into their "down" position.

Drainage swales should be regularly maintained. Avoid building fences or other obstructions across swales or other designed surface-drainage features.

Sprinkler systems, both manual and automatic, should be checked and maintained often to prevent leakage into the ground from cracks in hoses and loose-fitting joints. Watering schedules should be adjusted according to the season and types of vegetation present. Denver Water distributes a pamphlet called "Great Timing" that tells how to time watering in order to reduce outdoor water consumption (see "Information Sources", at end of book).

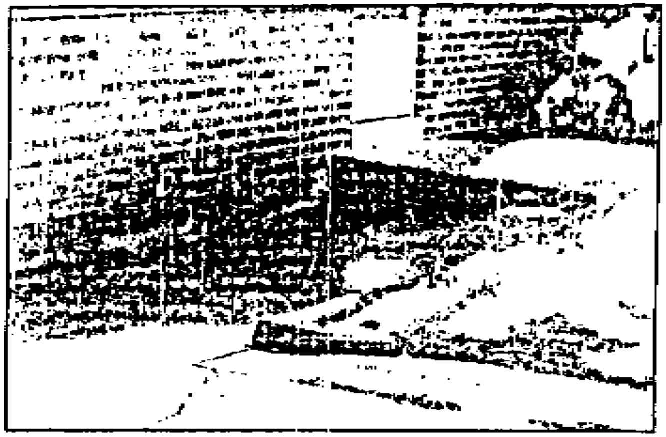


Figure 35. Settling of the backfill material has caused this sidewalk slab to settle and crack, resulting in reversed drainage and ponding next to the foundation. (From Jochim, 1987.)

Slope Maintenance

The most critical aspect of slope maintenance is maintaining a positive slope over the backfill area next to the house (see Figs. 26–28). This area outside the foundation is usually excavated and then filled with soil when a house is constructed. This material may settle enough to reverse or flatten the slope next to the foundation. **Reverse or negative drainage** will cause ponding of water during precipitation or heavy irrigation, allowing water to infiltrate the ground next to the foundation.

To maintain the slope around a house, the homeowner should periodically compact the soil at the surface of the slope by tamping it down with a heavy piece of wood and adding new fill material as needed. Hand compaction works best after rain or snowmelt has dampened the ground or with the very careful addition of small amounts of water. Additional soil should be added and compacted as is necessary to maintain a positive slope away from the foundation. The box on page 51 contains easy directions for determining and correcting slope.

Settling of the backfill material may cause concrete sidewalk and porch slabs to settle and crack, in some cases resulting in ponding and infiltration of water next to the foundation (Fig. 35). If the concrete has settled to this degree, it should be removed. Additional soil should be replaced to created proper drainage, and a new concrete section should be installed. If the slab still has a positive slope of at least 1 percent, however, it is only necessary to seal the cracks.

An Easy Method for Determining Slope

Here is an easy way to determine slope for the purpose of maintaining proper surface drainage away from a house. The only materials required are a string level or line level (available at most hardware stores), two 3-foot long wood stakes, 12 feet of string, a marking pen, a measuring tape or yardstick, and a hammer.

1) Hammer one stake into the ground next to the foundation.
2) Tie one end of the string to the stake.
3) Measure off 10 feet, or 120 inches, of string away from the stake. Mark that spot on the string.
4) Tie the loose end of the string to the second stake. Be sure to leave exactly 10 feet of string between the stakes.
5) Push the second stake into the ground after stretching the string straight out from the building.
6) Attach the string level to the middle of the string.
7) Hammer the second stake into the ground until the string level indicates that the string is level. After the first seven steps, your setup should look like Figure 36.
8) Measure the distance, in inches, between the string and the ground on stake number one. Call this distance "x."
9) On stake number two, mark the distance "x" below the string.
10) Now measure the left-over distance between "x" and the ground on stake number two, in inches. This distance is called "y."
11) Determine the slope by using "y" in this equation:

Slope = "y" ÷ 120 × 100.

EXAMPLE:

Looking at Figure 45, the distance "y" = 6 inches. Therefore:

Slope = 6 ÷ 120 × 100 = 5.0 percent.

To correct an existing slope that is too flat, first determine what the slope should be. For example, to get a 10 percent slope (1 foot of fall within 10 feet from the foundation), the distance "y" in Figure 36 should equal 1 foot, or 12 inches. This slope can be attained by raising the slope until 12 inches can be measured below "x" on the stake, either adding dirt at the top next to the house, or removing dirt beyond the slope toe to create a swale. Remember to tamp the dirt where it has been added to achieve proper compaction.

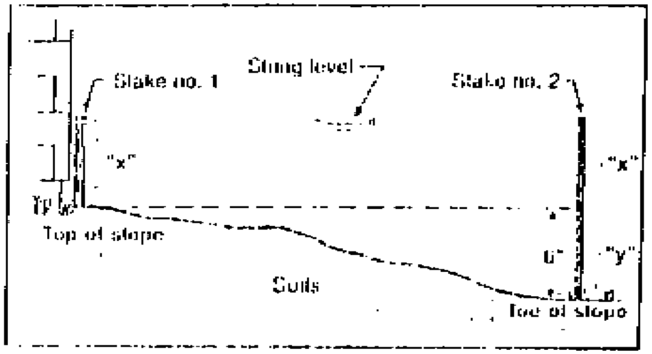


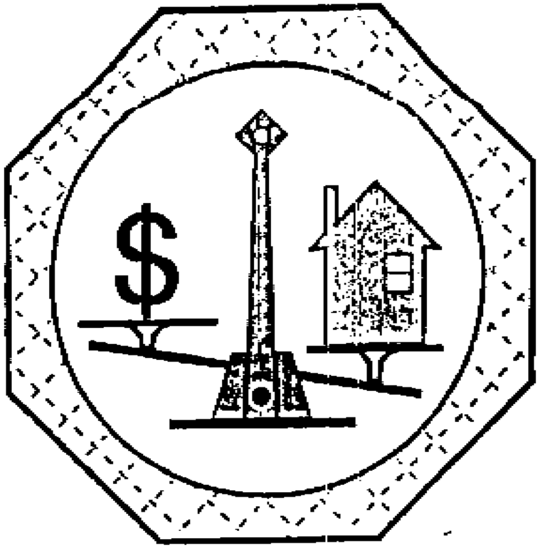
Figure 36. Setup for determining slope.

Landscaping Maintenance

It may be prudent to delay installing any landscaping adjacent to the foundation until the backfill has had a chance to settle. Otherwise, it may be costly and time-consuming to remove existing landscaping over a backfill area that has settled.

Xeriscapes are known for their low water and maintenance requirements. They do, however, require greater amounts of watering and maintenance for the first few years after planting than is required thereafter. Periodic maintenance is still needed after the Xeriscape is established to keep weeds out and to ensure the performance of the plants and mulches.

The topic of landscape maintenance is much too broad to be covered completely in this guide. The benefits of wise landscaping include swelling soils mitigation and much more. Homeowners are advised to call one of the agencies listed in the "Information Sources" at the end of this book for more information.



Swelling Soils and Homeowner Risk

Chapter 6

This chapter discusses statutes and disclosure requirements designed to inform homebuyers in Colorado about swelling soils. It also summarizes the most important things to consider as you evaluate your situation as a homebuyer or homeowner. Ultimately, there are few easy or clear-cut decisions when it comes to swelling soils.

The Colorado Geological Survey strongly advocates an informed decision on the part of a potential buyer of a new or resale home or a present owner considering improvements or repairs to a home. An informed decision involves knowing the potential severity of swelling soils beneath the house along with other important considerations such as location, lifestyle and affordability. It involves a realization, and acceptance, of the risks that are inherent in owning a home built on swelling soils.

Disclosure Statutes

For **new homes**, Colorado Senate Bill 13 (1984), C.R.S. 6-6.5-101, describes the responsibility of a builder of a new home to **disclose** evidence of any significant soil hazards, including swelling and expansive soils, to a potential buyer. This Colorado Geological Survey book is designed to satisfy the disclosure requirements in Part 1 of the statute:

> **At least fourteen days prior to closing the sale of any new residence for human habitation, every developer or builder or their representatives shall provide the purchaser with a copy of a summary report of the analysis and the site recommendations. For sites in which significant potential for expansive soils is recognized, the builder or his representative shall supply each buyer with a copy of a publication detailing the problems associated with such soils, the building methods to address these problems during construction, and suggestions for care and maintenance to address such problems.**

There are no criteria in the statute for determining "significant" potential for expansive soils. In practice, the potential may be seen as "significant" when the project geotechnical engineer recommends using certain construction methods and designs specifically to reduce the effects of swelling soils. This information should be included in a summary **soils report for each lot or for a** larger project area. Ideally, a soils report should include the swell potential, observations, and recommendations given for the subject home-site. The information provided should be the most specific information available for the site. It should include the engineering information used by the builder or developer in determining the site's building recommendations.

If you are considering purchasing a new home and have received this book as part of the Senate Bill 13 disclosure requirements prior to closing, you may be facing a difficult last-minute decision on whether to go ahead with the purchase or to look elsewhere for a home that may be less affected by swelling soils. Some steps that may help you with your decision are listed in Chapter 7.

In Colorado, buyers of resale homes are also protected by disclosure legislation. Real estate brokers are required to disclose all adverse material facts under the provisions of Senate Bill 223 (1993), C.R.S. 12-61-801 et seq. *The presence of swelling soils, although not specifically named, may be considered an adverse material fact, because it can affect the physical condition of or cause defects in the property.* A violation of disclosure requirements by the real estate broker may be investigated by the Colorado Real Estate Commission under C.R.S. 12-61-113(1).

The seller of a resale home should be asked to fill out form LC18-9-95, Seller's Property Disclosure, which specifically lists the presence of expansive soil as a hazardous condition in part 4. This form is supplied by the real estate broker and was created by the Colorado Real Estate Commission. Both the buyer and the seller sign the form as part of the property sale. Non-disclosure of adverse material facts by the seller may constitute misrepresentation or fraud, and is covered by common law.

As a homebuyer, you should not rely solely on disclosure information for a variety of reasons. For example, the present homeowner may not understand or have any knowledge of swelling soils, and may attribute structural movements to settling or poor construction alone. They may be genuinely unaware of previous problems or repairs if the home has had multiple owners. In any case, make sure that you ask the homeowner specific questions about the property's soil conditions as well as existing and past damage and repairs.

It may be possible to determine if swelling soils have affected a resale home by looking for telltale signs of damage and/or repairs. If you are considering buying a resale home, or have lived in a home for awhile and are curious about whether it has been affected by swelling soils, Chapter 7 tells how to inspect a home for swelling soils damage. You should hire a structural engineer to assess the physical condition of the home, the soil report, and the foundation design.

Presence and Potential Severity of Swelling Soils

Swelling soils are widespread in Colorado and are not easily avoided. Therefore, as a homebuyer, you need to be aware of the distinction between the presence and potential severity of swelling soils. The mere presence of swelling soils beneath a property gives no definitive indication of the potential severity of the swelling hazard. You should be more concerned about the soil's swell potential (Is it low, moderate, high, very high, or non-swelling?) and how the home was designed and built with regard to those actual soil conditions.

The potential severity of damage due to swelling soils can be significantly reduced if steps are taken to recognize the problem and then design, construct, landscape, and maintain the home in a responsible manner (Fig. 37A). However, leaving out or cutting corners on any one of these steps can lead to dramatic and devastating results (Fig. 37B). The risks associated with swelling soils and bedrock can be reduced, but not eliminated, by careful design and construction procedures. The homebuilding industry has developed design and construction methods that have reduced the frequency of foundation movements and distress, especially over the past 10 to 20 years. Homeowners must accept that slab-on-grade construction and, in some instances, foundations may be affected to some extent by swelling soils and bedrock. Heaving of flatwork such as driveways, patios, garage floors, and basement slabs cannot

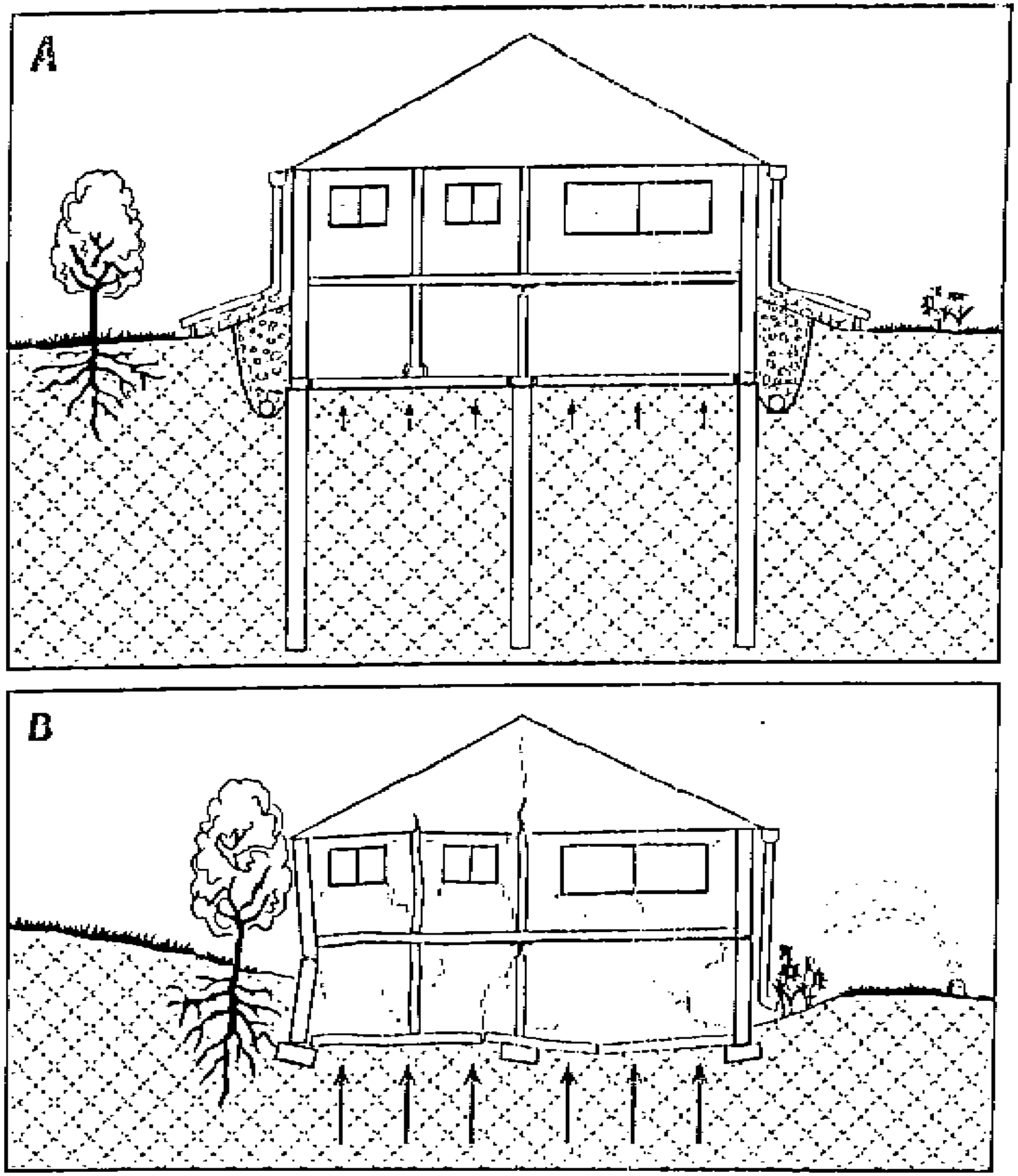


Figure 37. The results of A) proper versus B) improper design, construction, landscaping, and homeowner maintenance for homes built on swelling soils. (Modified from Holtz and Hart, 1978.)

be eliminated for residential construction in most cases, but it can be decreased to an acceptable level if proper engineering designs and construction methods are applied.

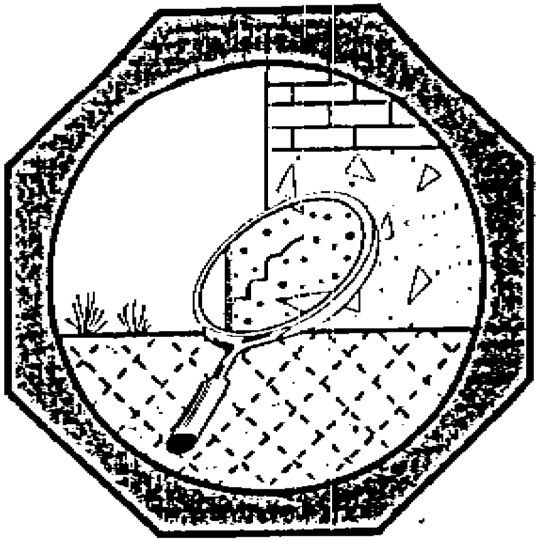
Other Buyer Considerations

Swelling soils will not be your only consideration when it comes to house-hunting in Colorado. There are many other important factors to consider including the location of the home or property with respect to work, schools, parks, recreational facilities, and views. The cost of the home or property will also be of great importance to you.

Modern technology and construction practices have improved performance of new houses built on swelling soils. However, one should expect that swelling soils will expand and heave to some degree in response to development and irrigation. Any corner-cutting in the proper design, construction, landscaping, and maintenance that results in an initial savings to a homebuyer could be negated by the cost of repairs many years later. We hope that this will convince you to consider swelling soils seriously, along with the other decision factors that are important to you.

The Final Decision

The final decision to purchase (or to not purchase) a particular house on swelling soils is yours, and yours alone. Find out all you can about the geology beneath the house and how the house foundation was built. If you have been furnished a written warranty, read it carefully. Damage from swelling soils can occur even if the home is new, and you should be aware of what your builder may or may not be responsible for repairing. Hire a professional engineer to assist you with your decision, as explained in Chapter 7. Your choice will ultimately rest on your own judgement and tolerance of risk. Many people will understand and accept the risk of living on swelling soils, while others may choose to look for a home on non-swelling soil. If you choose to buy a house on swelling soils, we sincerely hope that you will use the information in this book to help maintain your property and protect it against this potentially powerful geological hazard.



How to Check a Property for Swelling Soils

Chapter 7

It is important to find out if swelling soils are present, and how severely the soils have heaved or may heave in the future, if you are thinking of buying a resale or new home or an undeveloped property. There is often evidence swelling in the case of older, resale homes in the form of actual damage or as detailed in repair reports. For newer homes and undeveloped land, the buyer

inspections, city or county design and construc-
tion regulations, structural warranty company
construction standards, and the ability of the
developer and builder to recognize swelling soils
and to design and construct a home accordingly.
Beginning around 1990, many building practices
were updated and mandated by municipalities,
counties, and warranty companies; older houses
may not meet these updated practices.

This chapter gives some general guidelines for
finding out if swelling soils are present and, if
they are, how you can enlist professional help to
assess if the soils are a potential problem. You
may want to use the following items as a check-
list for highlighting potentially serious conditions.

Resale Homes

Much of the damage caused by swelling soils can
be detected by thoroughly inspecting the house
and yard. *To begin the inspection, stand across the
street from the house, so that you have a full view of
the front. Note the following items closely:*

1) **Driveway.** An inspection of the driveway is
often one of the most revealing. Look to see
if the driveway has a smooth surface or if it
has a wavy appearance. Check the point
where the driveway and the garage door
meet. If the garage slab is high in the center
and there are gaps where it meets the door-
way, heaving caused by swelling soils has
probably occurred (Fig. 38). On the other
hand, if the garage slab is flat and the drive-
way appears bowed and tilts toward the

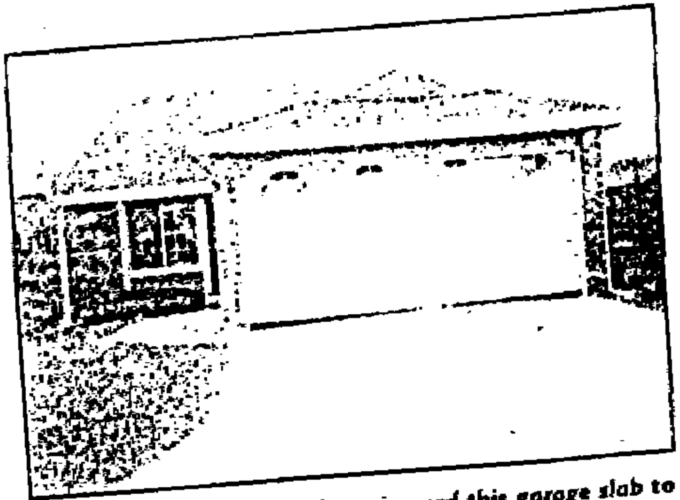


Figure 38. Swelling soils have caused this garage slab to heave and bow at its center. Note the gaps or "batwings" on both sides of the center, where the garage door meets the slab.

garage, settlement of the backfill may have
occurred. This latter condition, although it
may need to be fixed, does not reveal any
information about swelling soils.

Check the driveway concrete for cracking.
Some cracking of concrete is considered
normal in Colorado, and may be attributed
to any number of causes (swelling soils,
concrete shrinkage, settling, frost heave,
tree roots, poor quality of concrete or
installation). Excessive or severe cracking is
undesirable because it allows water to infil-
trate the soils beneath the flatwork, where
it can cause or intensify swelling soil heav-
ing. The condition of flatwork may rapidly
worsen once cracks occur, even with mod-
erately swelling soils.

Look to see if all or part of the concrete in the driveway has been recently replaced. This may be a sign that swelling soils caused damage to the previous slabs. If only the slabs and sidewalk sections next to the house are newer than other sections, it may indicate that a trench was dug around the house for structural or drainage system repairs.

Asphaltic concrete is sometimes used for flatwork in areas with swelling soils because it is more flexible and may not be damaged as easily as concrete. Its presence may indicate that a former slab was replaced. Check all asphalt areas for excessive or severe cracking and heave deformation.

2) **Sidewalks, curbs, and gutters.** All exterior flatwork should be checked to see if any cracking or heaving has occurred (Fig. 39). Small "hairline" cracks are common and are often the result of concrete shrinkage. Wider cracks may be the result of swelling soil heaving or, alternatively, localized settling due to improper compaction of backfill. Large open cracks in the concrete are undesirable, as they provide access for water and accelerate the rate of heaving or settlement damage. The presence of new sections of sidewalks and gutters may indicate that swelling soils damage has occurred, although there can be other reasons for replacement.

3) **Streets.** The presence of multiple asphalt patches may indicate that the streets or the underlying utility lines have been damaged over a period of time, possibly by swelling soils. The presence of "roller-coaster roads" (especially in areas of steeply dipping bedrock) may indicate that heaving of certain layers of bedrock is occurring.

Now go closer to the house. Walk around the house and carefully look at the following items, all at the same time if possible:

4) **Exposed soils.** Take a look at the soils for desiccation cracks or "popcorn" textures (see Fig. 6). This may not be possible if the native soil is covered by topsoil or turf.

Notice the slope of the soil surrounding the house. Under optimal conditions, the soil will slope away from the house and there will be no evidence of water ponding against the foundation. If swelling soils are present, areas of flat or poorly drained soil

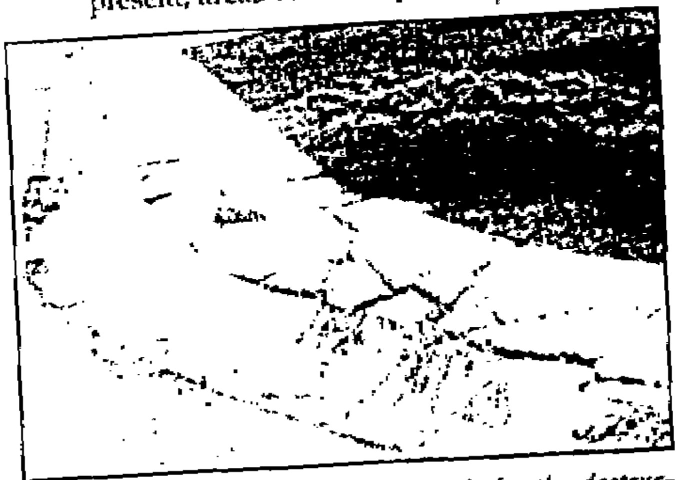


Figure 39. Swelling soils are responsible for the destruction of this sidewalk. Note the ponded water in the street, which could make the situation worse by infiltrating through the cracks and into the soil.

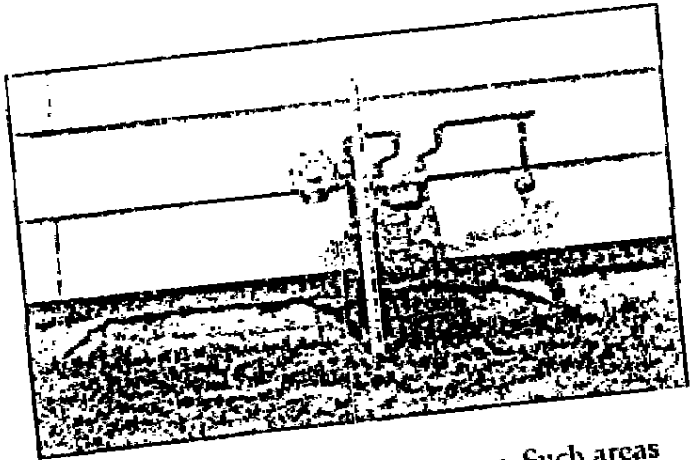


Figure 40. Large foundation crack caused by lateral pressures from highly swelling soils. This situation could be dangerous if the heaving ruptures the natural gas line. (From Jochim, 1987.)

will make the problem worse. Such areas will need to be built up and sloped to carry runoff water away from the house and prevent water from ponding.

5) **Patios, porches, and sidewalks.** Check patios, porches, and sidewalks beside the house for cracking and heaving. Make sure they do not slope toward the house. There should be a gentle, one to two percent slope away from the house in order to keep water away from the foundation.

6) **Foundation walls.** Inspect the foundation wall for cracks around the entire house. Almost without exception, every house will have some cracks in the foundation as a result of shrinkage due to curing of the concrete and tension cracks due to minor movement. This type of crack is typically 1/16 of an inch wide or less. Larger cracks (Fig. 40) may indicate more serious foundation movement.

7) **Brick and block walls.** Check for significant cracks in the outside walls of houses built with brick veneer, structural bricks, or concrete or masonry blocks. Cracks will generally follow mortar lines (Fig. 41) but have been known to split bricks in extreme cases (Fig. 42). Brick veneer may separate and lean away from the wood frame of the house in cases of extreme swelling soils damage.

8) **Chimney.** Check the chimney for separation from the outside wall and for cracks in the masonry. A damaged chimney can be

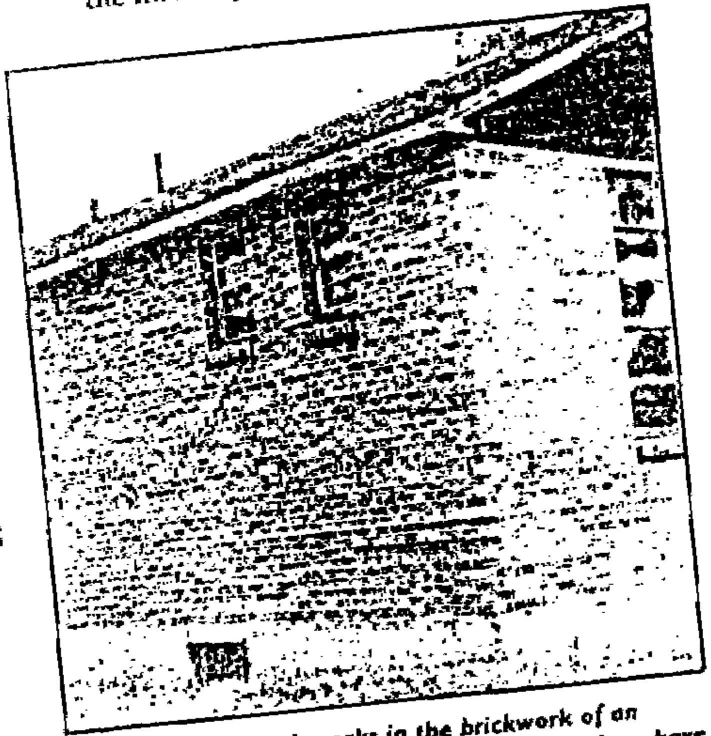


Figure 41. Diagonal cracks in the brickwork of an abandoned building. Note how the small windows have been rotated and distorted by the movement. (From Jochim, 1987.)

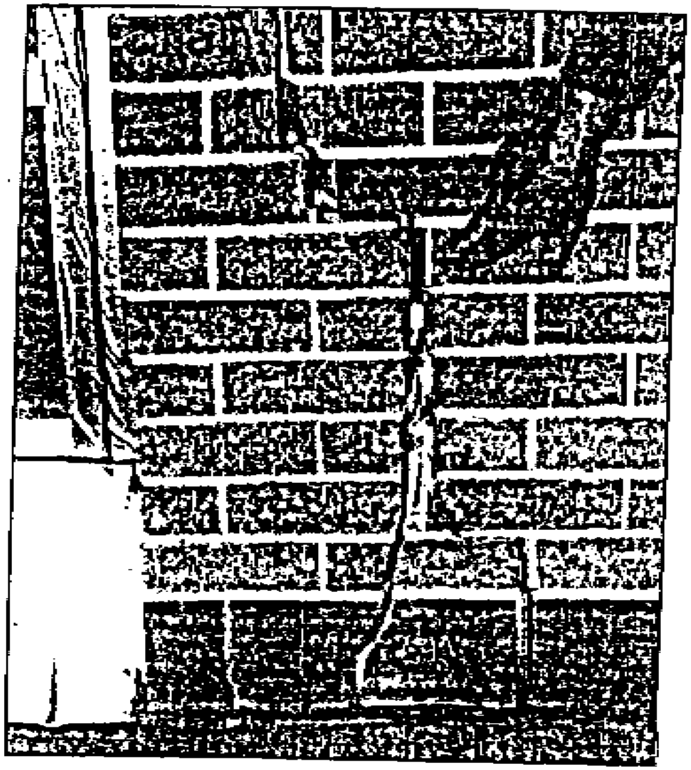


Figure 42. Split bricks and damaged window framing (on left). (From Jochim, 1987.)

very dangerous in terms of human safety (Fig. 43).

9) **Perimeter Drain.** Ask the owner where the perimeter drain discharges. If it discharges to a gravity outfall, check the outfall location. The pipe should be clear of debris and in good working condition.

Now check inside the house:

10) **Interior walls.** Check interior walls for cracks in plaster, drywall, or wallpaper. Cracks are most common around door and window frames. If the cracks are straight, they may be the result of poor sheetrock taping or shrinkage of green (uncured) wood. Diagonal cracks (Fig. 44) may be the result of heave or settling of the foundation. Make sure that the walls have not pulled away where they meet the floor and ceiling.

11) **Doors and windows.** Check all doors and windows to see if they open and close properly. Binding or inoperable doors and windows, distorted glass panes, and wedge-shaped gaps at the top or bottom

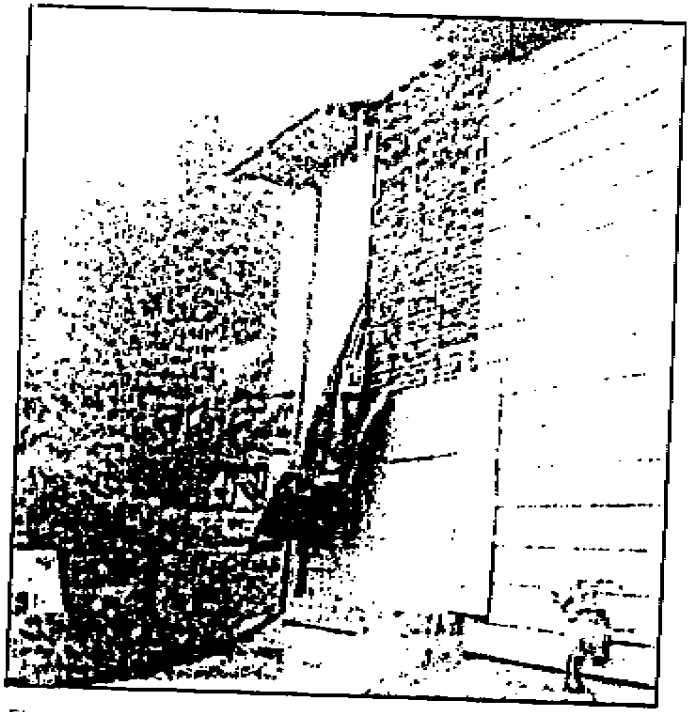


Figure 43. The chimney of this house had separated and tilted away due to swelling soil heaving, and had to be removed before it collapsed. (From Jochim, 1987.)

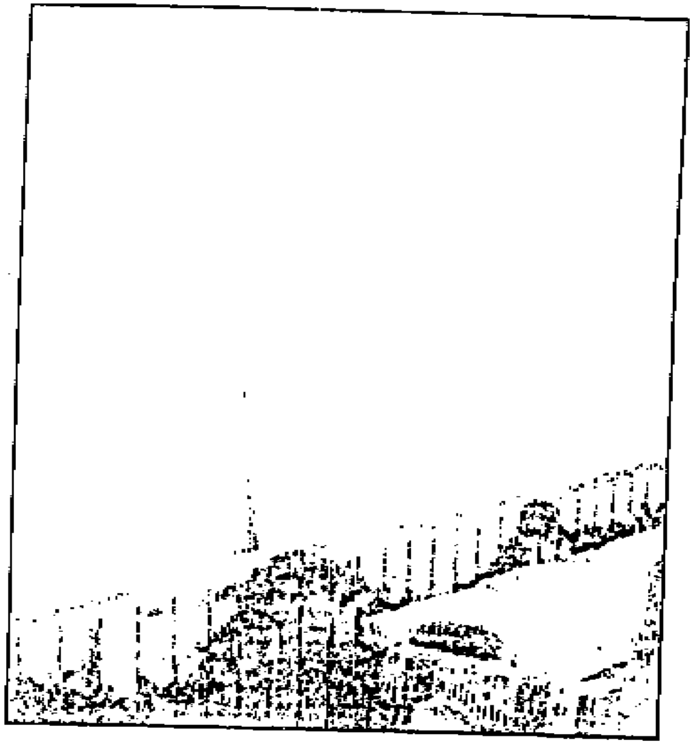


Figure 44. Diagonal cracks in an interior wall, caused by soil heaving or settling.

(Fig. 45) may be due to foundation heave or settlement. However, the use of green wood or poor construction quality may cause similar conditions.

12) **Floors and ceilings.** Look for cracks in the corners of ceilings where stress is greatest. Check for unusual high or low spots in floors and ceilings as you walk around. Swelling soils or green wood may be responsible for these cracks and surface distortions.

13) **Basement and basement floor.** Check the basement walls and floor slab for significant cracks and offset across the cracks (one side higher than the other). The walls should not bow or lean excessively into the room near the middle of their span; if they do, they may be under excess pressure from swelling soil or improperly placed backfill.

Floor slabs constructed directly on swelling soils should be separated from all outer walls and have expansion joints that allow the slab to move up and down in response to the heaving motion of the soil. All slabs should be jointed or scored, with the joints spaced on the order of 15 feet apart (or as recommended by the soils report). Basements on floating slab floors should remain

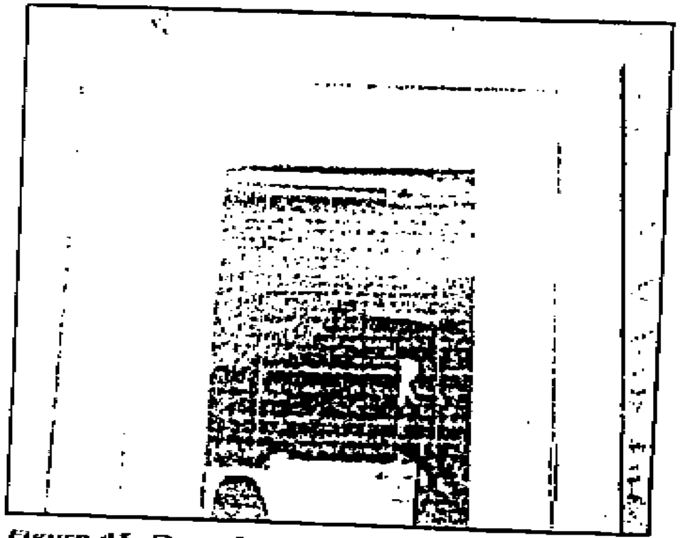


Figure 45. Door frame wedged against the door jamb by heaving of swelling soils. The door binds and does not open or shut easily.

unfinished or have specially designed partitions to accommodate some vertical movement of the slab.

Structural, or suspended, floors are much less likely to show damage from swelling soils. This type of flooring should have a shallow "crawl space" underneath. Take a flashlight and inspect the crawl space (be sure to wear old shoes and clothes if you actually enter...this part can get muddy!). Check to see that there is some kind of ventilation system to keep moisture from building up in the crawl space.

Check to see whether the soil surface under the house looks flat or if it has heaved upward. Make sure that the soil has not heaved to a point where it has closed the void space and is in contact with the concrete grade beam at the bottom of the foundation wall. The void space will be 4 to 6 inches high for a new house. If the soil is in contact with, or close to, the grade beam, there is a chance that the soil could push up against the grade beam and damage the house.

14) **Utility pipes.** Water, sewer, and gas pipes should be inspected to see if they are bowing or pulling apart. Where plumbing lines enter through the floor, they should be designed to absorb movement or slip through the floor without breaking. Gas lines should have a flexible connection (where allowed by code) to reduce the chances of breaking as a result of movement.

15) **Furnace (on slab-on-grade floor).** Check the ducts above the furnace to see that they are not crushed, bent, or crowded against the ceiling. Furnaces in many newer homes contain flexible duct connections (boots) to reduce the potential for damage as a result of slab heaving. The rigid parts of the duct should be separated by several inches across the boot.

16) **Sump.** If the basement contains a sump pit, inspect the sump. Note whether the sump is currently wet or dry. Ask the owner how the sump operates and how often the pump has been activated. Check to see if the lower part of the sump pit is perforated or non-perforated. A non-perforated base is better if swelling soils are present.

17) **Owner's records.** Ask the owner about whether the house has undergone heave or settlement. The owner is legally required to disclose any information they have about previous damage or repairs. Ask for a copy of previous inspection, appraisal, damage, soil, or repair reports prepared by home inspectors, house appraisers, engineers, or contractors, or a written statement regarding the owner's property history. You may need to hire a structural engineer to read and assess these technical reports or written statements.

You should watch out for cases where prior damage has been temporarily fixed or "hidden." This is another instance where the assistance of a structural engineer may be useful. Your local (county or city) building department may contain records for remedial repair permits.

If significant cracking has occurred in the driveway, sidewalks, or internal or basement walls, find out if the owner has monitored the displacement of the cracks. If the cracks are growing steadily larger, or if they expand during the wet season and contract with the dry season, then swelling soils may be present and active beneath the house.

New Homes and Undeveloped Properties

It is not possible to tell if a new home or undeveloped property will be affected by swelling soils using visual inspection alone because movement and damage have not yet occurred. The same is true for many recently built resale homes. The only way to identify whether there is swelling soil under the house or property in these cases is to obtain a soil report (sometimes called a soil and foundation report).

Soil reports are prepared by a geotechnical engineer, who drills one or more borings at the house site, identifies the types of soil and bedrock present underneath the property, and evaluates their engineering behavior. This is done to design a foundation for the house that is appropriate for the actual geologic conditions. It is important that swelling soils are recognized and tested so that the house can withstand heaving pressures. The soil report for an individual house can sometimes be obtained from the builder or, in some cases, from the county or city building department.

Once you have a copy of the soil report for the house, it is important to answer three basic questions:

1) Is there swelling soil (or swelling bedrock) beneath the house?
2) If so, what is the degree or severity of potential swelling?
3) Is the house designed and built with proper consideration for the actual soil conditions?

To answer these questions, you will need to hire a specialist to read and interpret the soil report. In most cases, a structural engineer (for the structural integrity of already constructed houses) and/or a geotechnical engineer (for assessments of soil reports for sites before they are/were constructed) will have the necessary expertise to assist you with your final decision. An engineer's review of a soil report and structural review of the house typically costs around $200–800. Be a good consumer and look for an engineer who will perform a comprehensive inspection, with no "corner-cutting." For a listing of professional engineering consultants, look in the local yellow pages under "Engineers-Foundation," "Engineers-Geotechnical-Soils," or "Engineers-Structural."

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References and Suggestions for Further Reading

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Shelton, D.C., 1979, Nature's building codes - Geology and construction in Colorado: Colorado Geological Survey Special Publication 12, 72 p.

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INFORMATION SOURCES

The following agencies may be sources of helpful information on swelling soils and related topics:

SWELLING SOILS

Colorado Geological Survey, Colorado Department of Natural Resources, 1313 Sherman Street, Room 715, Denver, CO 80203. (303) 866-2611.

U.S. Geological Survey, U.S. Department of the Interior, Information Services, Box 25286, Denver Federal Center, Denver, CO 80225-0046. (303) 202-4700 or (800) 435-7627.

U.S. Natural Resources Conservation Service (formerly U.S. Soil Conservation Service), U.S. Department of Agriculture, 655 Parfet Street, Lakewood, CO 80401 (Front Range area). (303) 236-2886. For local listings, look in the U.S. Government section of the phone book blue pages, under "Agriculture Dept of."

XERISCAPING AND SOIL IMPROVEMENT

Colorado State University Cooperative Extension Service. See local phone book listing in the County Government section in the phone book blue pages under "Colorado State University" or "Extension Office."

Denver Water (formerly Denver Water Department), 1600 West 12th Avenue, Denver, CO 80254. (303) 628-6000.

U.S. Natural Resources Conservation Service. See previous section.

Xeriscape Colorado!, Inc. See listing for Denver Water, above.

BUILDING REQUIREMENTS, MAPS, AND RECORDS

Look under the government blue pages in the phone book for the appropriate city or county planning department or building department.

REAL ESTATE

Colorado Real Estate Commission and Board of Appraisers, Colorado Department of Regulatory Agencies, 1900 Grant Street, Suite 600, Denver, CO 80203. (303) 894-2166.