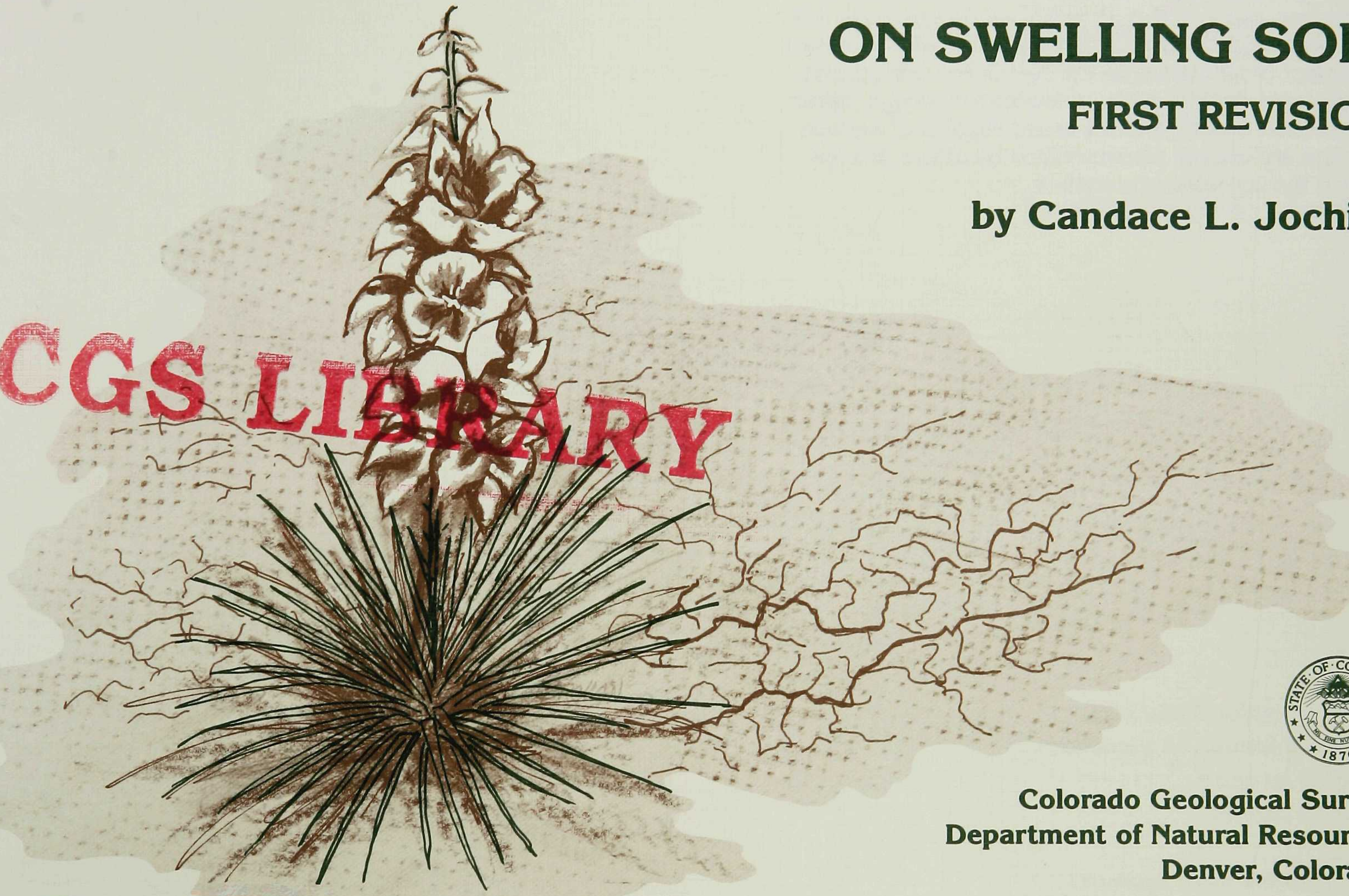
For Colorado Homeowners...

Special Publication 14

HOME LANDSCAPING AND MAINTENANCE ON SWELLING SOIL

FIRST REVISION

by Candace L. Jochim



Colorado Geological Survey
Department of Natural Resources
Denver, Colorado

About this publication . . .

The information contained in this publication is intended to assist Colorado homeowners in minimizing damage caused by swelling bentonite soil. Although we have emphasized improvements that homeowners themselves can and should make, we do not imply that all or even most swelling soil-related damage is caused by neglect or ignorance on the part of the homeowner. In fact, major factors such as foundation design, basic construction quality, and the broad aspects of surface drainage are usually predetermined by others and are beyond the homeowner's control.

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INTRODUCTION

Each year in the State of Colorado thousands of homes are damaged by swelling soils. The extent of damage ranges from cracked driveways, sidewalks, and basement floors to severe structural distress and breakage of pipes and sewer lines. The cost amounts to millions of dollars yearly — more than the cost for all other natural hazards combined.

Although Colorado is only one of many areas in the United States that have swelling soils, its semiarid climate and geology combine to make it one of the most severely affected.

Even a house with the proper foundation, interior structure, and drainage design may be damaged if good landscaping and maintenance practices are not carefully followed.

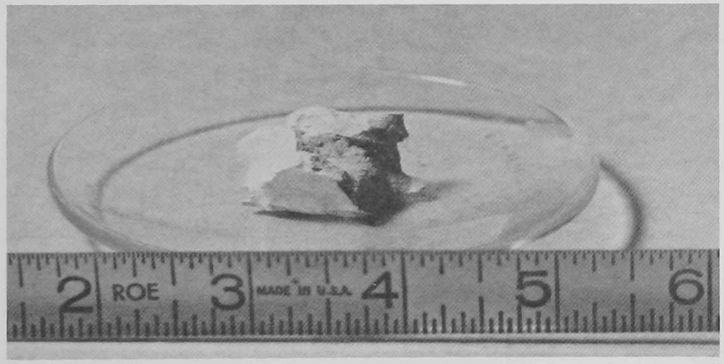
Landscaping should include the shaping of the land and moisture control as well as the planting of vegetation. Good landscaping and maintenance are essential to reducing the amount of water that infiltrates the ground causing swelling soils to swell. If landscaping is carefully planned and maintained, damage from swelling soils can be minimized.

This book was prepared to give Colorado homeowners the information necessary to develop good landscaping and maintenance practices.

SWELLING SOILS

What are swelling soils?

Swelling soils (also called "expansive," "shrinking and swelling," or "bentonite" soils) are soils which contain certain clay minerals that swell upon wetting and shrink upon drying (Fig. 1). The clay mineral responsible for most swelling soil damage in Colorado is montmorillonite.



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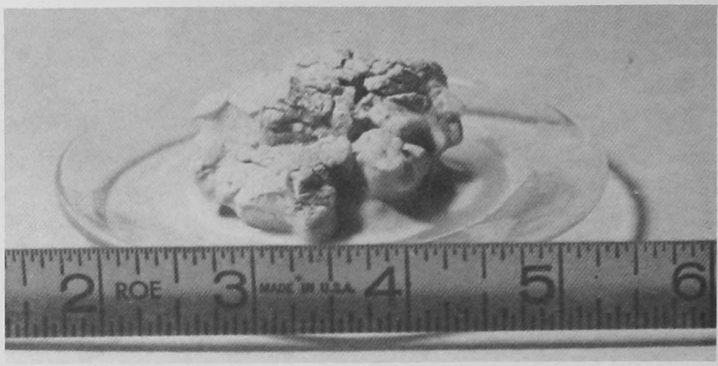


(c)

(d)

Figure 1. *The addition of water to a rock containing swelling clay illustrates swell potential. (a) shows piece of rock before addition of water. (b) as water is added, the clays immediately begin to swell. (c) nine hours later the volume of the rock has almost doubled. (d) twenty-four hours later the rock is drying out. Note the cracks.*

How and when do swelling soils cause damage?

Damage from swelling soil occurs when the clay minerals in the soil change volume (shrink or swell) due to moisture change. The change in volume is caused by the chemical and physical attraction of water molecules to the clay minerals. When swelling soils are wetted, layers of water molecules are added between the flat plates of the clay minerals. As more layers of water molecules are added, the clay plates are pushed farther apart as shown in Figure 2. This pushing apart or swelling causes increased volume and high swell pressures within the mass of soil that is being wetted. The amount of volume change depends on (1) the swell potential of the soils, (2) the availability of water, and (3) the restraining pressure on the soils.

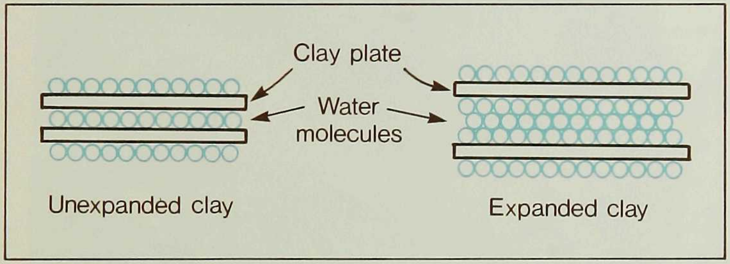


Figure 2. Sketch of expanding clay plates (from Hart, 1974).

The swell potential of a soil depends on the type and amount of clay that the soil contains. With respect to swelling, soils are rated as having no, low, moderate, high, or very high swell potential. Soils that contain certain nonswelling clays such as kaolinite and nonclay minerals such as quartz or feldspar may have no swell potential. This is because the crystal structure of these minerals doesn't allow them to add layers of water molecules the way montmorillonite does. Besides the type of clay, the amount of clay present influences the swell potential of a soil. The more swelling clay present in the soil, the greater the swell potential. However, soils containing no clay at all can have swell potential if they contain minerals such as gypsum that swell during crystal growth.

Swelling occurs when the soils become wet. Wetting is generally caused by poor surface drainage, excessive lawn and shrub irrigation, sprinkler system or water main leaks, poorly consolidated backfill, or a rise in the ground water table.

Shrinkage, the opposite effect of swelling, occurs when the soils dry out. Sometimes swelling soils or bedrock are located below the ground water table and have expanded as much as possible. In this case, damage can occur if the ground water table is lowered and the clays begin to dry out. Occasionally damage from shrinkage occurs because foundations were constructed during wet weather followed later by dry weather, or because moisture-loving trees or shrubs were planted near the foundation.

Either swelling or shrinking may cause damage, but swelling accounts for most of the damage in Colorado.

Multistory buildings have heavily loaded foundations that resist the pressure generated when swelling soils expand, but houses are "light" structures that must be carefully engineered to resist the strong pressures. Swelling soil damage can range from cracked sidewalks and basement floors to severe structural distress and breakage of pipes and sewer lines. Floor slabs and

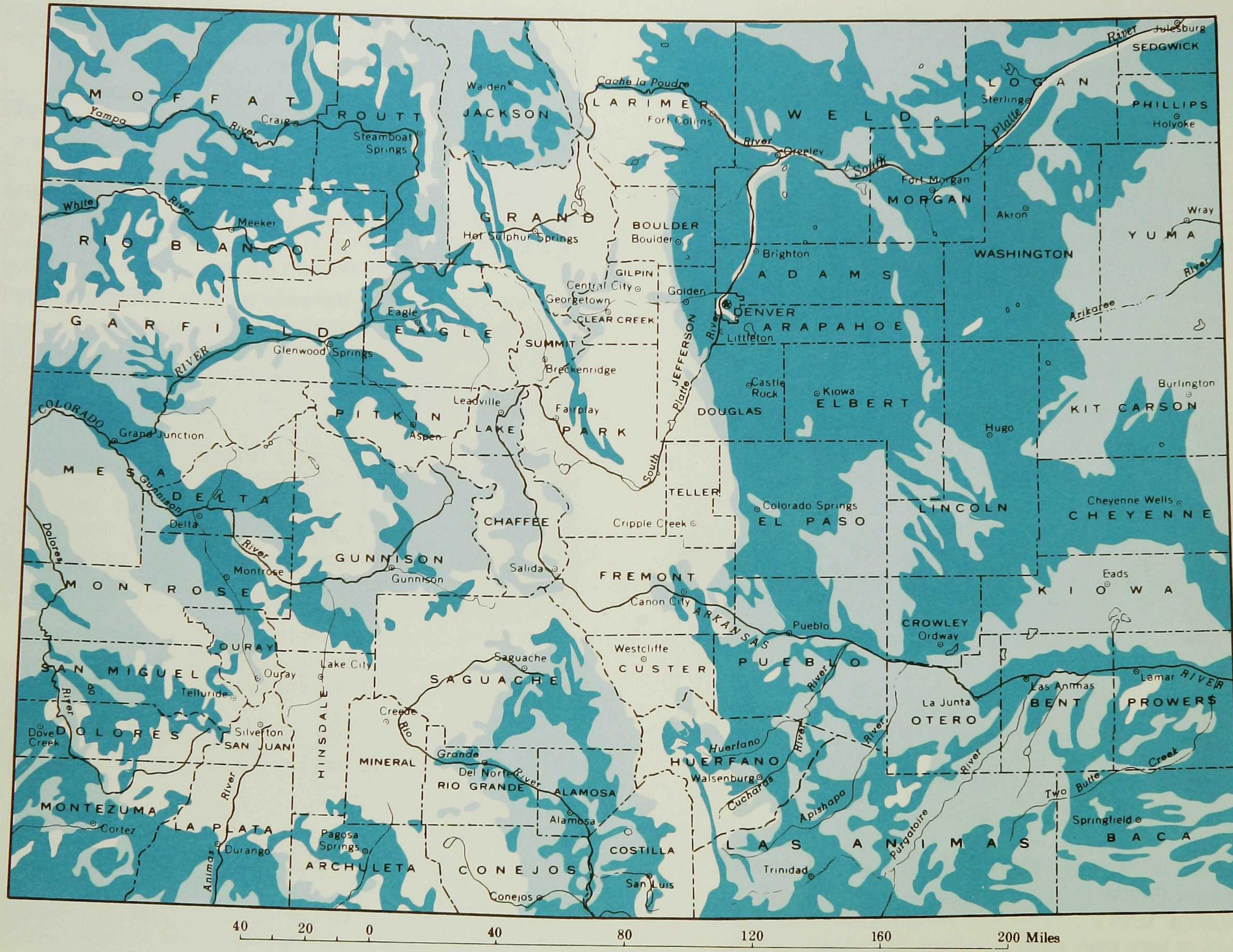


Figure 3a. Map showing generalized distribution of swelling soil and shallow swelling bedrock in Colorado.

exterior flatwork are the greatest problem where swelling soils or rock are present because not enough dead load can be placed on them to resist the uplift pressure generated when the swelling materials are wetted.

Where do swelling soils occur in Colorado?

All major population centers on the Eastern Slope and many of those on the Western Slope are partially located on potentially swelling soils (Figs. 3a, 3b). However, because of local variations, many specific sites within these areas may not have such soils.

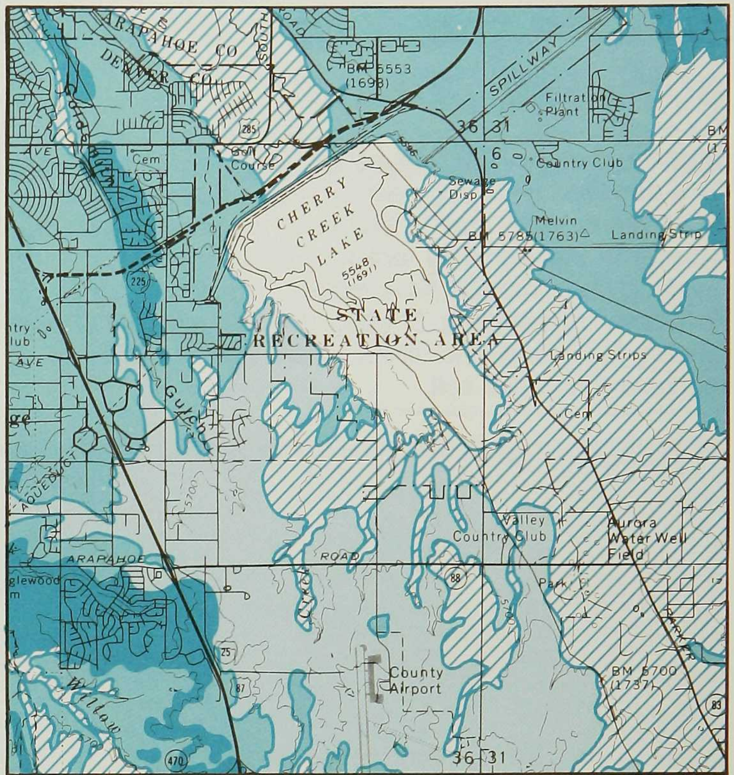
Figure 3a. EXPLANATION

SWELL POTENTIAL

- Moderate to very high
- Low to moderate
- None to low (mostly crystalline bedrock)

This is a generalized map. The swell potential of soils at any specific location can only be determined by site-specific testing.

Map modified from "Shrink - Swell Potential" map, Colorado Land Use Commission, 1973.



0 ½ 1 Mile

EXPLANATION

SWELL POTENTIAL

- Very high
- High
- Moderate
- Low

N

Figure 3b. Detail of a map showing local distribution of swelling soil in the Denver area. (modified from Hart, 1974).

How to tell if swelling soils are present

Positive identification of swelling soils should be made by a qualified soils engineer or engineering geologist. However, an easy way to find out if swelling clays are present in the soil is by looking. Soils containing swelling clays usually have cracks (Fig. 4) or a puffy, "popcorn" texture (Fig. 5) when dry, and are very sticky when wet. This will not show where topsoil covers or replaces the native soil.

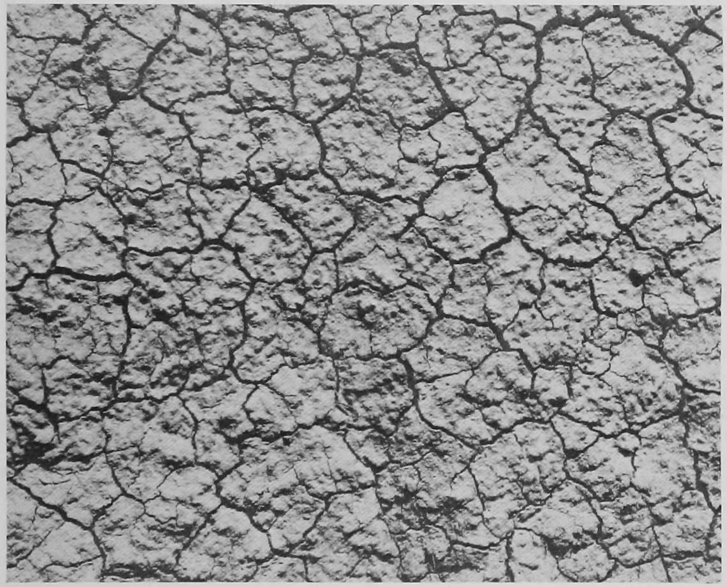


Figure 4. *Example of cracking in soil containing swelling clay.*

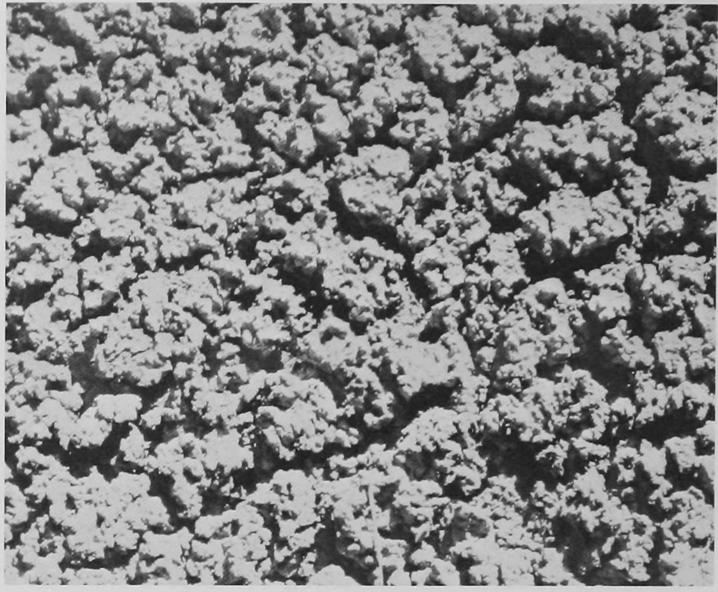


Figure 5. *Example of "popcorn" texture in soil containing swelling clay.*

Although the presence of cracks will tell you that swelling clays are present in the soil, they do not tell how high the swell potential is. This is best determined by engineering tests that indicate the severity of the swelling soil problem. Information from the tests is used to design foundations for buildings based on the specific soil conditions.

GROUND WATER

What is ground water?

Ground water is the water contained in certain layers of rock or soil under the ground. Those layers that both store and transmit water are called aquifers. Aquifers are either "confined," "unconfined," or "perched."

Confined aquifers are layers of water-filled rock sandwiched between layers of impermeable rock through which water cannot pass (Fig. 6).

Unconfined aquifers are layers of water-filled rock that rest on layers of impermeable rock and are covered by layers of permeable rock or soil through which water can pass. The upper surface of an unconfined aquifer is called the water table (Fig. 6). A well or excavation that extends down into a water table will fill with water. This includes basements.

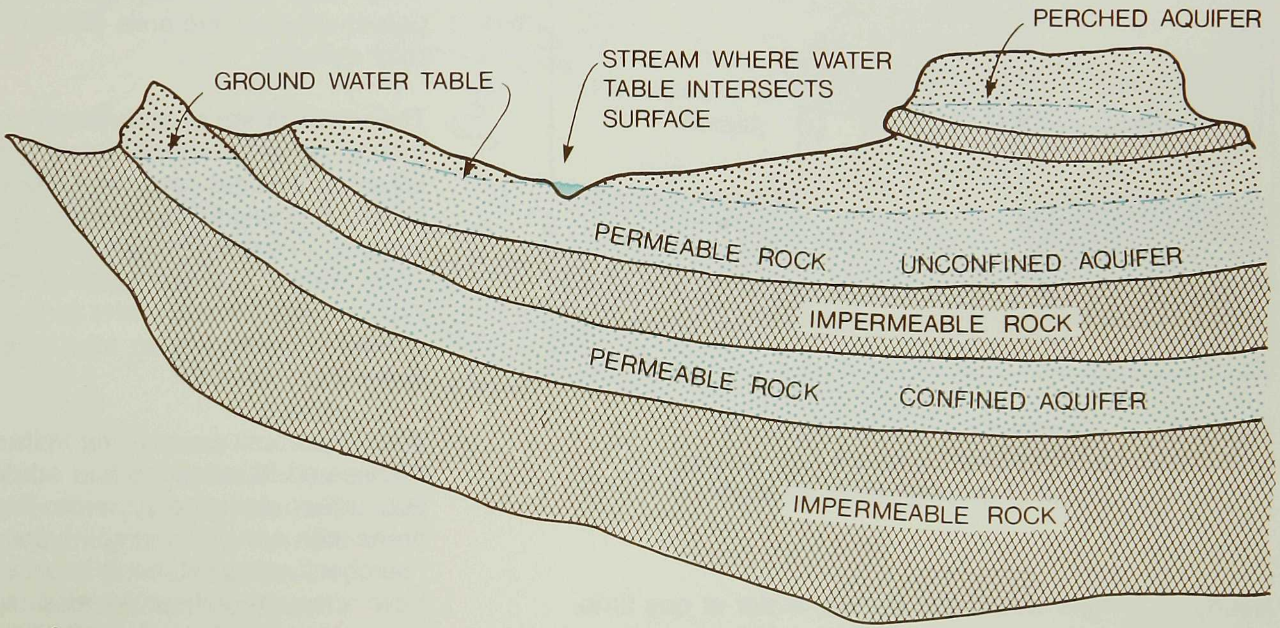


Figure 6. Types of aquifers.

A perched aquifer is a special kind of unconfined aquifer. It occurs when a small body of ground water is separated above the main body of ground water (Fig. 6). Perched ground water can also occur when an artificial depression such as a basement excavation is formed in impermeable soil or rock (Fig. 7).

Because the water table moves up and down depending on the supply of water, the depth below the ground to the surface of the water table may not always be the same at a fixed location. Also, because there can be more than one aquifer, there can be more than one water table.

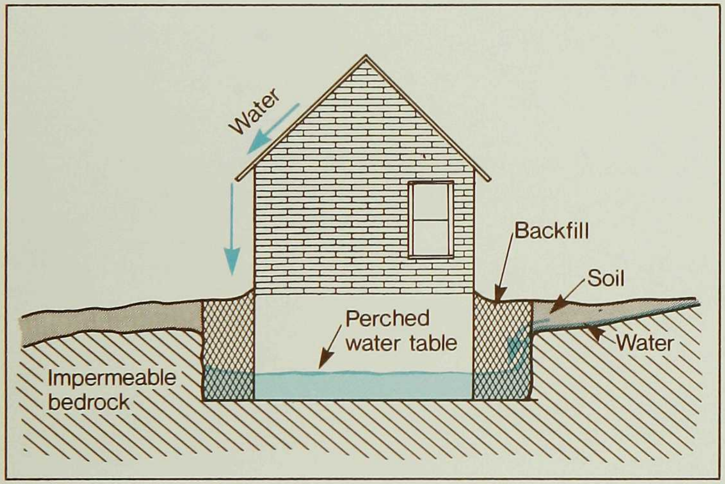


Figure 7. A house excavation formed in impermeable bedrock has caused perched ground water to form.

Nearly all ground water was surface water at one time. Sources of ground water include rainfall, snowmelt, and seepage from streams, lakes, oceans, and irrigation canals (Fig. 8).

Why is ground water important?

The presence of ground water can cause serious problems for a house built on potentially swelling soils. As mentioned before, the depth to the ground water table is variable, since it depends on the amount of surface water that percolates (seeps through) to the aquifer. During the spring and winter when precipitation and percolation are heavy, the ground water table may rise. During the dry season it may fall. If the ground water table rises enough to come into contact with potentially swelling soils beneath a house, problems may develop.

The urbanization of an area can change the natural ground water condition, creating an undesirable situation that did not exist before development. A common scenario develops in Colorado when houses are built in areas of shallow impermeable bedrock. Lawn watering and/or seepage from individual septic systems add excess water to the ground, and a perched aquifer is created in an area where no ground water previously existed.

Structures built on swelling soils should have engineered foundations and adequate surface and subsurface drainage systems. For structures built in areas with nonswelling soil types but with potential "perched" water tables, it is usually only necessary to have adequate subsurface drainage systems. These will prevent the build-up of water near the foundation.

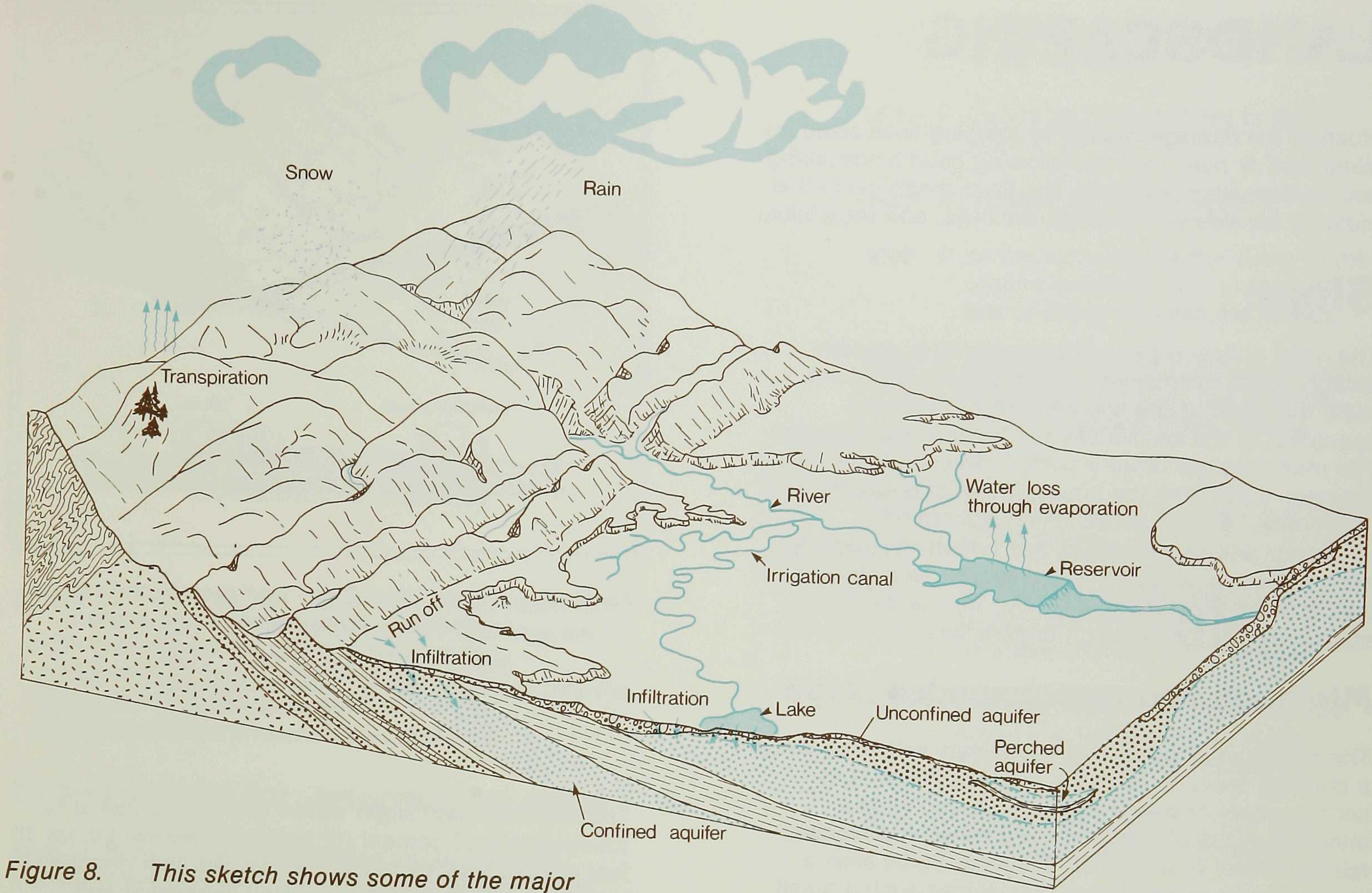


Figure 8. ***This sketch shows some of the major sources of the water that infiltrates the ground to become ground water (modified physiographic diagram from "Landforms in the Boulder - Fort Collins - Greeley Area, Front Range Urban Corridor," Colorado, USGS, Map I-855-H, 1978).***

LANDSCAPING

Much of the damage caused by swelling soils could be eliminated or minimized by following good landscaping and maintenance practices. The three major items that must be considered are slope, drainage, and vegetation.

Slope

The most critical aspect of landscaping is properly designed and maintained slopes. When houses are built, the building site should have been graded according to the specifications of a qualified 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. 9), precipitation will run off, infiltration will be minimized, and potentially swelling soils will not have a chance to become wet. However, if the lot is not properly graded (Fig. 10), the water may stay on the lot long enough to percolate into the soil.

Minimum and recommended slope

The *minimum* slope or "fall" necessary within 10 feet of a building depends upon the type of surface land- scaping. Bare or paved areas should maintain a minimum slope of 1 percent (1 to 2 inches of vertical fall for 10 feet of horizontal distance). Since even a small amount of settlement can reverse such a small slope, a much greater slope is desirable. Vegetated areas should maintain a minimum 5 percent slope (6 inches of vertical fall for 10 feet of horizontal distance). These are *minimum* slopes.

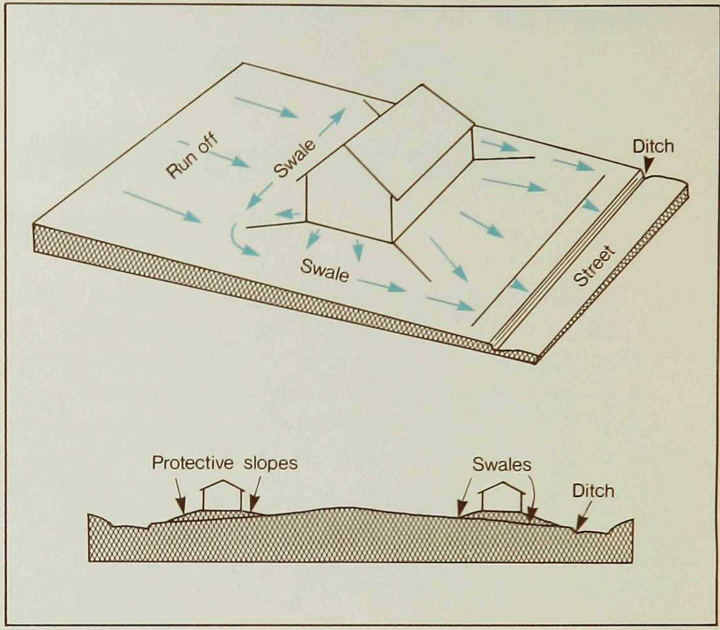


Figure 9. Carefully planned and maintained slopes provide positive drainage and prevent water from ponding on the property (from "A Guide for Erosion and Sedimentation Control in Urbanized Areas of Colorado." U.S.D.A. Soil Conservation Service, 1978).

The *recommended* slope within the first 10 feet of a foundation is 10 percent (12 inches of vertical fall for 10 feet of horizontal distance). Flat slopes limit drainage but steep slopes result in downhill movement and erosion of the soil. For this reason slopes greater than 15 percent are not recommended.

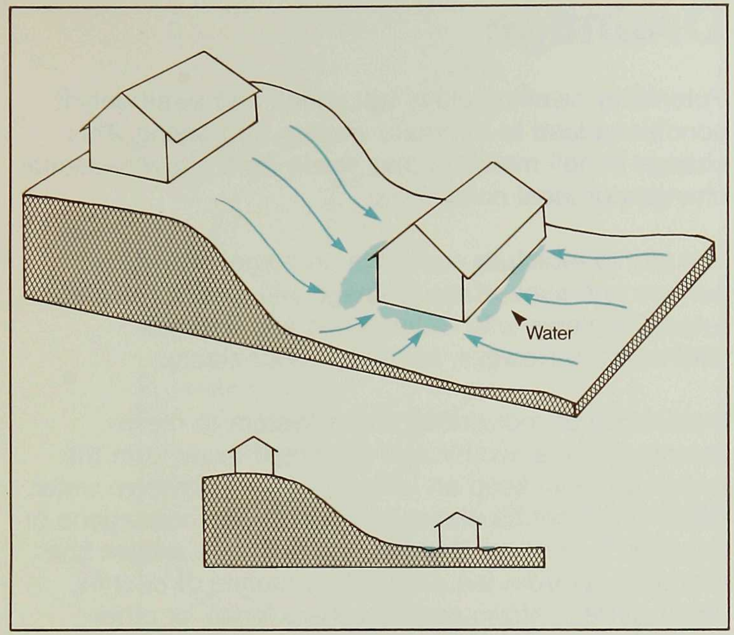


Figure 10. This sketch shows how poorly planned lot grading can result in poor drainage and allow water to pond around the foundation where it can percolate into the soil.

Easy method for determining slope

Here is an easy way to determine slope. The only materials required are (1) a string level, (2) two wood stakes (3 feet long), (3) 12 feet of string, (4) a marking pen, (5) a measuring tape or yardstick, and (6) a hammer.

step 1. place one stake in the ground next to the foundation.

step 2. tie one end of the string to the stake.

step 3. measure off 10 feet of string.

step 4. tie the loose end of the string to the second stake. Be sure to leave 10 feet of string between the stakes.

step 5. stretching the string perpendicular to (straight out from) the building, push the second stake into the ground.

step 6. attach the string level to the middle of the string.

step 7. hammer the second stake into the ground until the string level indicates that the string is level.

step 8. measure the distance between the string and the ground on stake number one. Call this distance "x."

step 9. on stake number two, mark the distance "x" below the string.

step 10. now measure the distance between "x" and the ground on stake number two. This distance is called "y."

step 11. determine the slope by using "y" in this equation:

$$\text{slope} = \frac{Y}{120} \text{ (in inches)} \times 100$$

EXAMPLE: looking at Fig. 11, y = 6 inches.

So, $\frac{6}{120} \times 100 = 5$. The slope is 5 percent.

To correct the slope, first determine what it should be. For example, at a distance 10 feet from the foundation, the recommended slope is 10 percent, or 12 inches of fall. To get a 10 percent slope, it is necessary to have "y" equal to 12 inches. This can be accomplished by lowering the slope until 12 inches can be measured below "x" on the stake, or if "y" is greater than 12 inches, the careful addition of soil would reduce it to 12 inches.

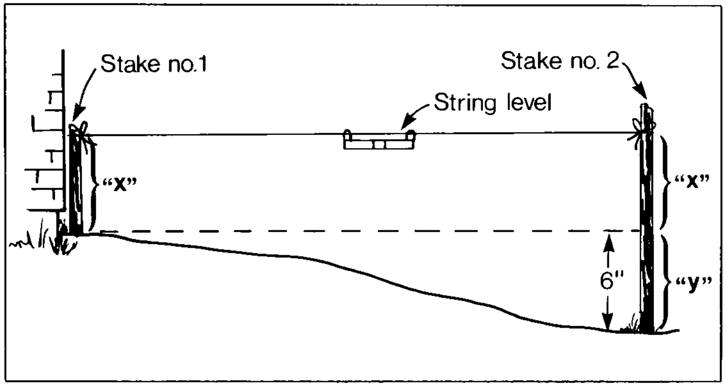


Figure 11. Determining slope.

Drainage

Potentially swelling clays will shrink and swell only if conditions lead to alternate wetting and drying. This change in soil moisture may result from either seasonal changes or local conditions.

The key to moisture control is drainage. Control of surface and subsurface drainage will reduce the risk of future problems with foundations and flatwork (sidewalks, driveways, basement floor slabs).

Installation of roof drains and a system to move accumulated rainwater and snowmelt away from the house will help keep an area free from excessive water. Water must not be allowed to pond near foundations or flatwork. It must be directed into drainage swales and moved away from the property by means of ditches, street gutters, storm sewers (where legal), or other available means.

Surface drainage

The surface drainage system consists of a roof drainage system and a slope drainage system. These two systems work together to channel and move accumulated rainwater and snowmelt away from the house.

Roof drainage system. The roof drainage system is composed of gutters, downspouts, and splashblocks (Fig. 12).

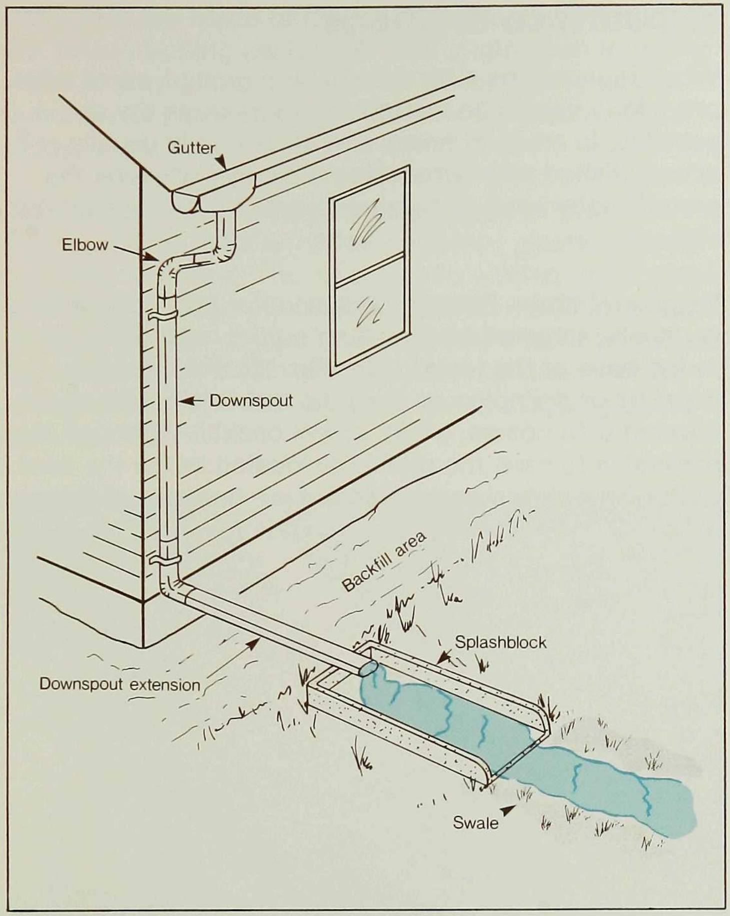


Figure 12. Roof drainage system.

Figure 13. The lack of gutters on this house has allowed snowmelt to run over the eaves and pond next to the foundation.

If a roof drainage system is not installed, rainwater and snowmelt will drip over the eaves and fall next to the foundation where poorly compacted backfill may allow the water to percolate directly to the area of the foundation and floor slab (Fig. 13).

Slope drainage system. Slope drainage can be collected and moved away from the house by ditches and swales. These are simply shallow trenches (ditches) or depressions (swales) which collect and move rainwater, snowmelt, and excess irrigation water away from the house and off the property.

When a roadway crosses a drainage ditch, a culvert (piece of pipe) should be installed so that the water can flow under the road (Fig. 14).

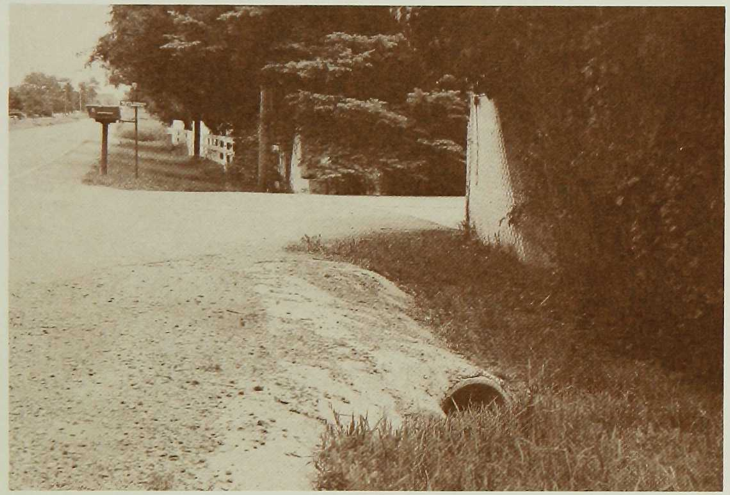


Figure 14. Culvert.

Care must be taken to insure that the surface water channeled away from one structure is not directed against a neighboring structure where it may cause similar problems.

Subsurface drainage

When foundations extend below the ground water table, provisions should be made to keep them as dry as possible. In areas of heavy clay soils this is usually accomplished with subsurface drainage, whereby the ground water level is lowered to a depth below the floor slab.

Peripheral drain. Subsurface drainage around foundations is usually achieved by installing a peripheral drain next to the base of the foundation (Fig. 15). This system consists of drainpipe or drain tile laid in a trench and covered with coarse, clean, gravel backfill. Although it is preferable to have the drainpipe located below the level of the floor slab, this is seldom done because of the extra cost of deepening the excavation.

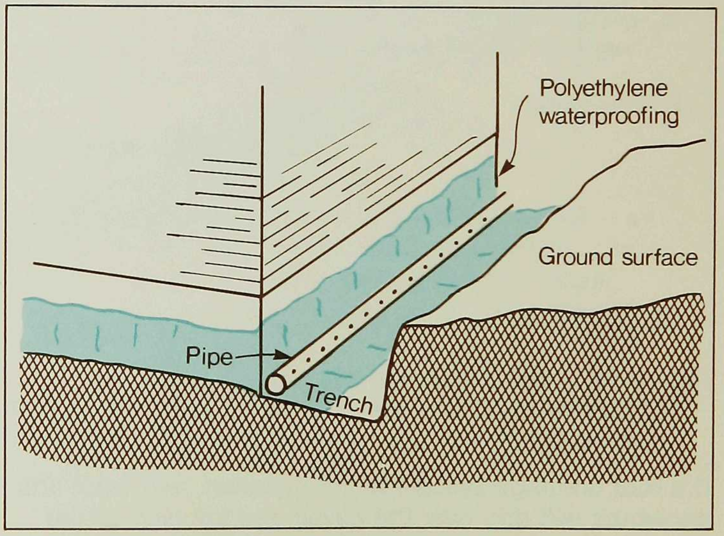


Figure 15. Peripheral drain.

Drain tiles are made of clay or concrete. Sections of tile are placed butting each other with joints open to permit water to enter them. Because of the convenience and durability of plastic pipes, drain tiles are seldom used today.

Drainpipes are made of perforated metal or plastic. Since swelling soils are often corrosive, plastic pipe is generally preferred. The pipe may be slotted on all sides (16a) or have only two rows of perforations (16b). If there are only two rows of perforations, they should be placed facing the sides of the trench. Filter material must be placed around the drainpipe to prevent clogging of the perforations.

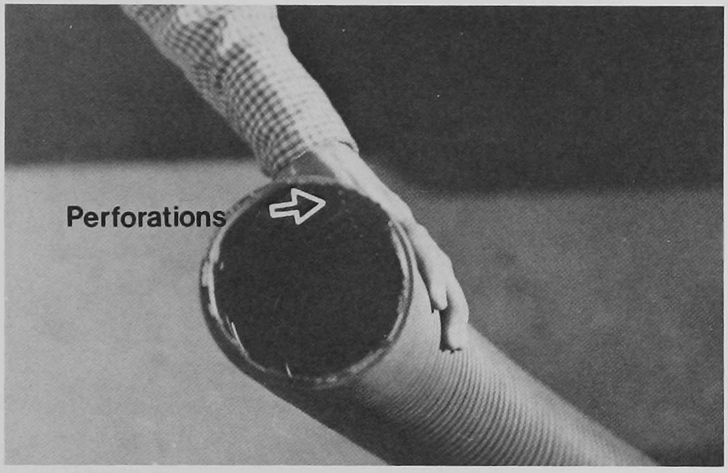


Figure 16a. 4-inch-diameter corrugated, slotted plastic drainpipe.

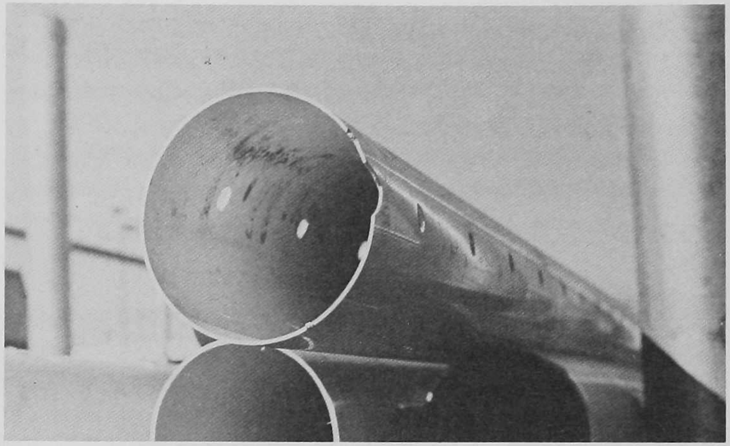
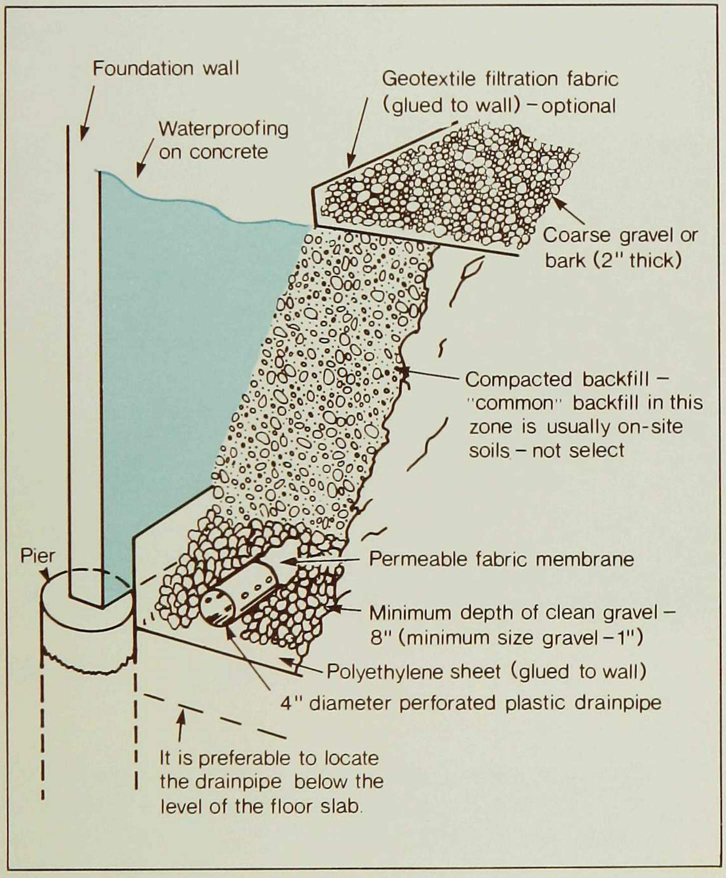


Figure 16b. 4-inch-diameter plastic drainpipe with two rows of perforations.

A commonly used filter consists of coarse gravel and a permeable fabric membrane. In this arrangement the membrane may be wrapped around the pipe or placed above the gravel but below the backfill (Fig. 17). The gravel must be sized larger than the slots or holes in order to prevent clogging.



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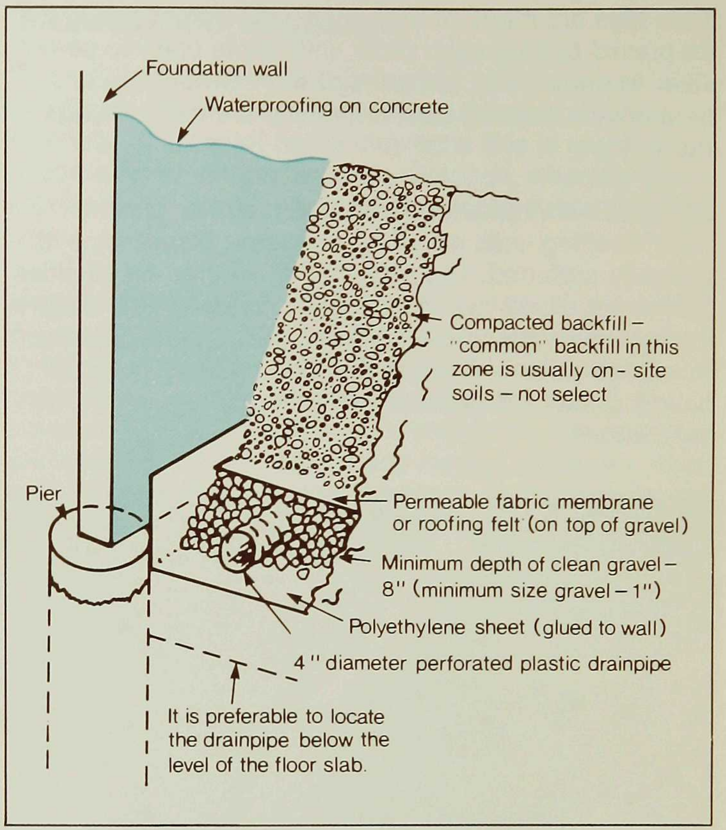

(b)

Figure 17. Details of a typical peripheral drain. (a) shows permeable fabric membrane wrapped around the drainpipe. (b) shows the fabric membrane placed above the gravel filter but below the backfill. Either way is acceptable.

Peripheral drains should be installed on a slope (1/8 -1/4 inch per foot) so that gravity will control the flow of the water. Most important of all, the drain must discharge into a ditch, sump, or other acceptable area. It is critical that a drain discharge be provided and kept open. Otherwise, the system will back up and serious problems will develop.

Interceptor drain. This type of drain is 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. 18).

Interceptor drains are used to collect subsurface water. This type of drain can only be used when the source of water is uphill from the area to be protected. If gravity and shallow impermeable bedrock cause the water to move downhill, a drain can be placed between the source of water and the area to be protected. This will help collect the water and divert it to a more acceptable place.

In Colorado this system is occasionally used to protect a few houses or a small neighborhood from seepage from unlined irrigation canals (Fig. 19).

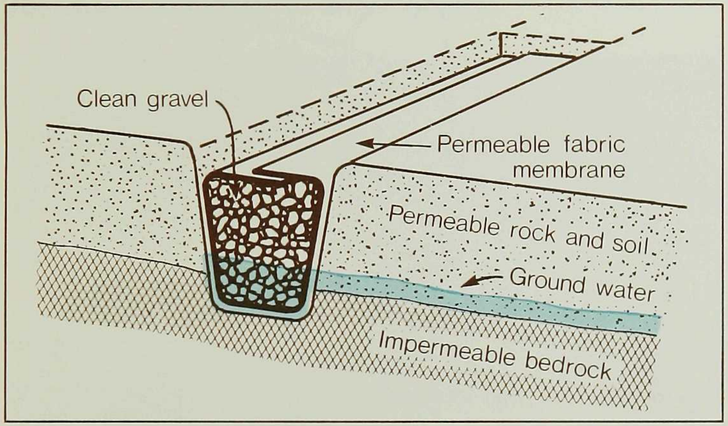

Figure 18. Details of interceptor drain.

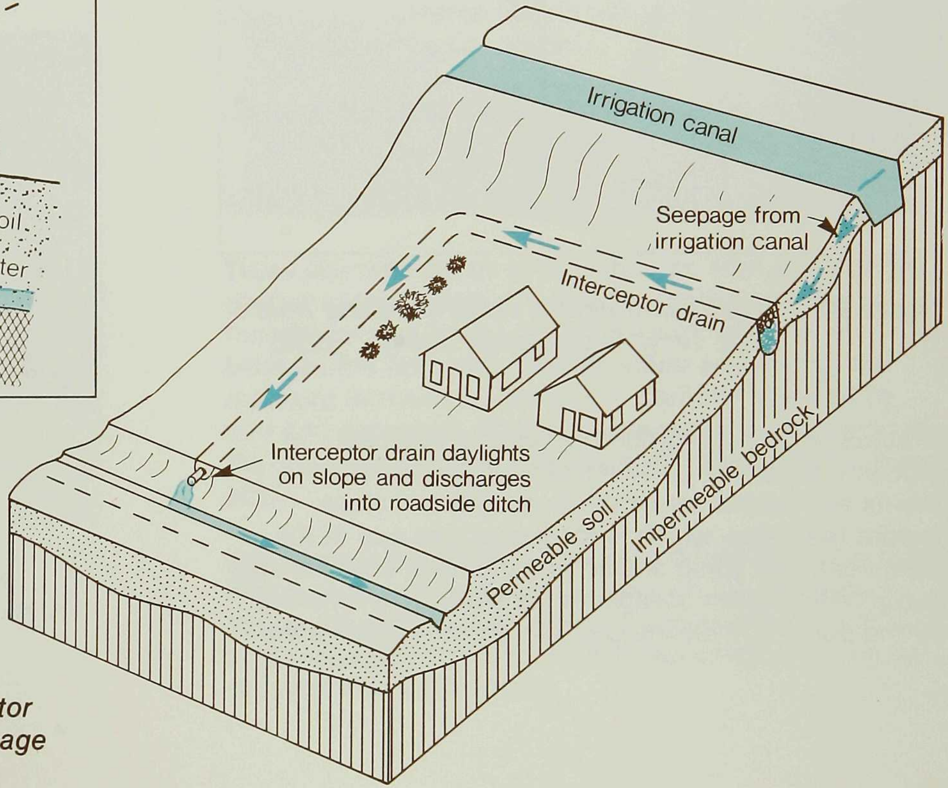

Figure 19. This sketch shows how an interceptor drain can be used to intercept seepage from an irrigation canal.

Sump. A sump is a low area that serves to collect water from the surrounding area (Fig. 20) and is designed for use with a pump to remove the collected water. It works best in areas where the rate of movement of water through the soil is slow, since the effectiveness of the system is limited by the rate at which the collected water can be removed.

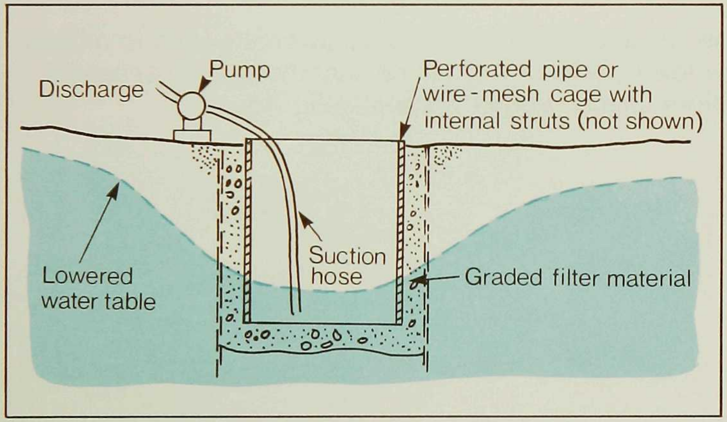

Figure 20. Details of a typical sump (modified from W.C. Teng, "Foundation Design," 1962).

In areas where high ground water is a seasonal problem, a sump may be installed in the basement. Drains are located under the floor slab and slope toward the sump, which is located at one end of the basement. The sump should be fitted with an automatic pump. When water collects in the sump, it is removed by the pump and discharged into an acceptable area.

Sometimes houses are built in areas so flat that it is not possible to get enough slope on the lot to have gravity controlled drainage. In these cases, both the surface and subsurface drainage systems may be connected to a sump located in the yard. The water collects in the sump and is then pumped to a suitable area off the property (Fig. 21).

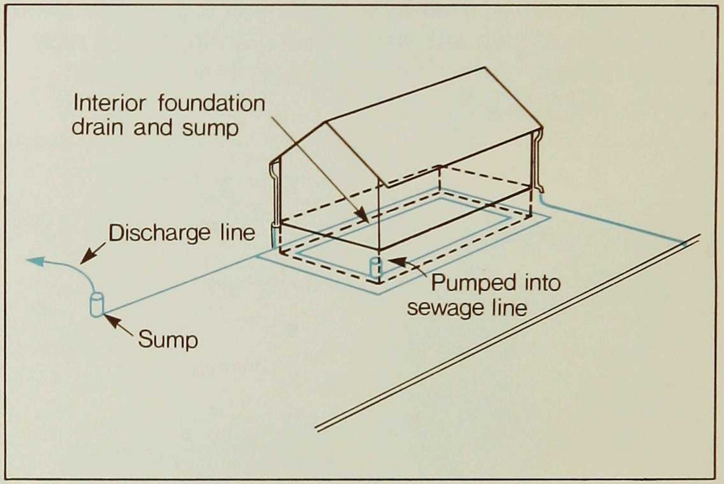

Figure 21. Sump located in yard.

Vegetation

Effects of vegetation on house and yard

Vegetation, especially trees, can cause significant changes in soil volume due to changing water demand.

People tend to plant trees and other greenery close to their house. A flower bed next to the foundation is a common sight (Fig. 22). Poorly planned lawn and shrub watering is the direct cause of much of the damage sustained by houses on swelling soils.

Figure 22. People often remove the downspout extension so that their flower bed can be watered by storm runoff.

If your house is located on swelling soils, some basic ground rules 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 watered.

Although the general rule is to avoid all plantings near the foundation, an exception could be groundcovers. If native or comparable groundcover plants with low water requirements are used, they can act to shelter the soil and reduce extreme moisture fluctuation.

(2) sprinkler systems should not spray any closer than 5 feet from the foundation.

(3) trees should not be planted closer than 15 feet from the foundation.

See Appendix A for some suggestions on vegetation.

Trees can dry out the soils within the area of influence of their root systems. If a tree is planted near the foundation of a house, it can draw moisture from beneath the floor slab. During winter and spring, the moisture removed by the tree is partially replaced by rain and snowmelt. This alternate wetting and drying of the soils can result in heaving and cracking of the floor slab.

The amount of drying due to trees depends on the type, size, age, and location of the tree. As the tree grows larger, the area of influence of its roots also grows larger. Also, some kinds of trees have higher moisture requirements than others.

It is important that trees be watered during long, dry periods. This will keep them from extending their root systems and drawing large amounts of water from the surrounding area.

Landscaping with rock or gravel

With the increasing price and decreasing availability of water in some areas, many people are turning to landscaping with rock. This may be in the form of rock gardens or crushed rock or gravel lawns.

Rock gardens

Rock gardens can be a pleasant substitute for the conventional grass lawn and flower bed arrangement. Advantages include low maintenance and, if planted with native vegetation or adapted plants, low water requirements.

Just remember, you still have to play by the rules. You must still maintain good drainage and not plant trees or shrubs too close to the foundation.

Crushed rock or gravel lawns

One of the major effects of replacing grass with crushed rock or gravel is an increase in surface runoff. Because a geotextile fabric is placed under the rock to control weed growth, water that would have percolated into the ground before can no longer do so. Uncontrolled, concentrated runoff can cause serious property damage. It is important that runoff be channeled away from the house, but at the same time not directed toward a neighbor's house or property.

In fact an edging of gravel and geotextile fabric can be used very effectively around a house to prevent percolation of water into the soils next to the foundation. When used for this purpose, the edging should extend at least 5 feet out from the house. The fabric should lap onto the foundation wall and be glued in place. It is important that a good quality, non-woven geotextile fabric be used. The use of plastic sheeting is discouraged because it tends to trap moisture and prevent normal evaporation from occurring. Non-woven geotextile fabrics control weeds and retard infiltration, but still permit evaporation. A border of corrugated metal or thick plastic can be used to hold the outer edge of the liner in place.

Although replacing a grass lawn with crushed rock or gravel has the advantages of no water requirement and low maintenance, it also has disadvantages. Chief among these is the dramatic increase in radiated heat. In the summer it can be comparable to living in the middle of a parking lot. Because of the additional heat and reflected sunlight, any trees or islands of vegetation will need to be very tolerant to heat and sunscald. Adequate pathways should be provided in areas landscaped with crushed rock, because walking on the rock will damage the fabric liner. Finally, the fabric will eventually deteriorate, and if it is not replaced, weeds will soon take over and water will be able to enter the soil.

Many people take advantage of the positive aspects of landscaping with rock while minimizing the disadvantages by using it only in selected areas of the yard. By using gravel edgings with rock gardens or groundcover and perhaps a limited central area of lawn, one can create an attractive, relatively low maintenance landscape (Figs. 23, 24, 25).

◄ *Figure 23.* *Landscaping with gravel and islands of vegetation.*

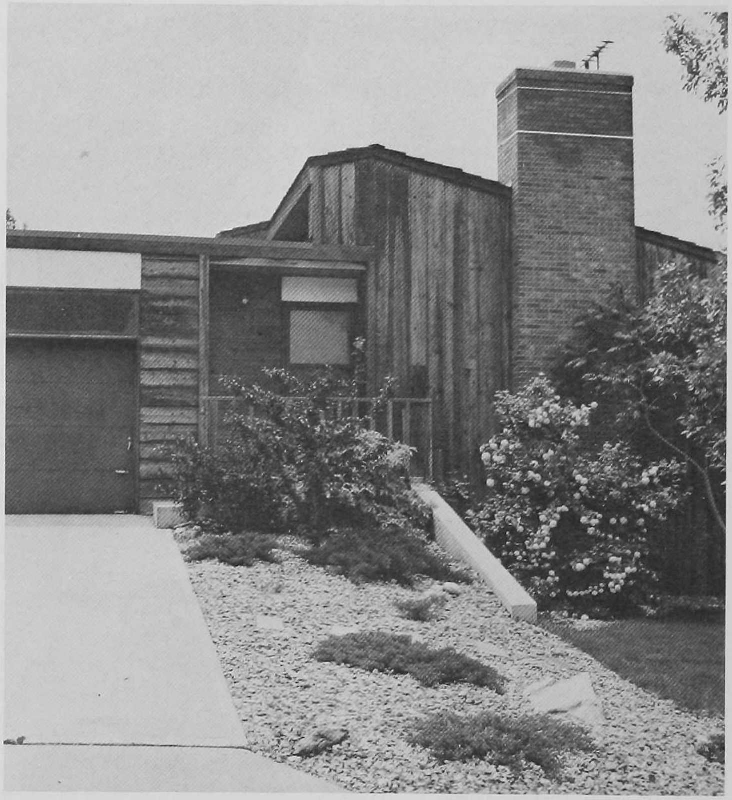

Figure 25. *Gravel edging.*

◄ *Figure 24.* *Central lawn area accented by gravel edging.*

MAINTENANCE

Much of the damage caused by swelling soils is due to lack of timely maintenance by the homeowner. Problems are caused by:

(1) neglecting to maintain adequate slopes for good drainage,
(2) neglecting to clean gutters and downspouts,
(3) oversaturating foundation soils by excessive landscape watering,
(4) planting trees, shrubs, and flowers too close to the foundation,
(5) changing the lot drainage pattern by constructing patios, fences or other obstructions that dam and pond water, or
(6) failing to seal old construction joints and cracks that develop over time in the flatwork.

Slope maintenance

Maintaining a positive slope in the backfill area next to the house is the most critical aspect of slope maintenance.

The excavated area outside the foundation is usually filled with loose soil fill when a house is constructed. This is called the backfill area (Fig. 26). During the first few months or years, this material settles. Often there is enough settlement to reverse or flatten the slope next to the foundation. Reverse or negative drainage will cause ponding of water during precipitation or heavy irrigation. Ponding allows an excessive amount of water to percolate into the ground next to the foundation. To avoid this, the homeowner should periodically compact the backfill area by tamping with a heavy piece of wood such as a 4" x 4." Hand compaction works best after rain or snowmelt has dampened the ground or with the very careful addition of small amounts of water by the homeowner. Additional soil should be added as necessary to maintain a positive slope away from the foundation.

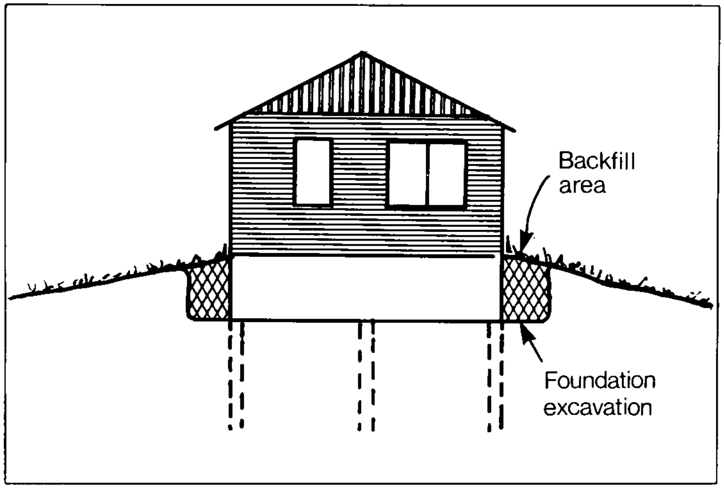

Figure 26. This sketch shows the relationship of the backfill area to the house.

When the backfill area is covered by concrete before adequate compaction is achieved, settlement of the fill material may cause the concrete to settle and break. If the amount of settlement exceeds the original slope, ponding results. This together with cracking will allow water to infiltrate the soils next to the foundation (Fig. 27).

Figure 27. Settlement of the fill material has resulted in reversed drainage next to the foundation.

If tilting of the concrete results in ponding, the concrete should be replaced. If a positive slope of at least 1 percent is retained, it is only necessary to seal all the cracks.

Drainage maintenance

Because drainage systems are essential to reducing the amount of water that infiltrates the ground, they must be kept in good working order. By taking the time to maintain and repair these systems, you will increase the life of your house and minimize costly repairs.

Surface drainage maintenance

Gutters should be inspected twice a year, once in the spring and again in the fall. All debris should be cleaned out and metal gutters checked for rust. If there are trees near the roof, gutters may have to be cleaned out more often.

Check the slope of the gutters. Poor slope causes water to accumulate in low spots, building up debris and accelerating rusting. The slope of the gutters should be 1/8th of an inch of fall for each foot of length. The gutter can be installed so that it drains in one direction. However, if any single length of gutter is more than 35 feet long, it should be installed to drain both ways from the center (Fig. 28).

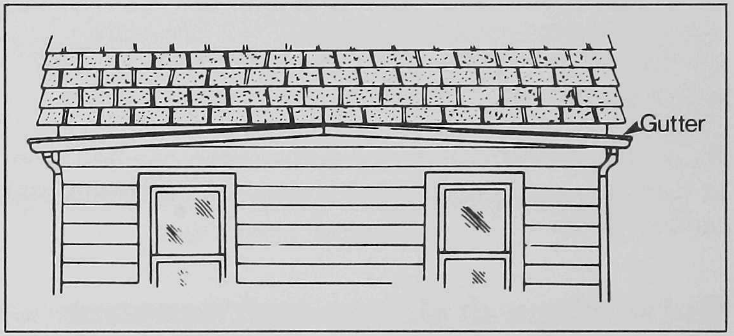

Figure 28. Installation of gutter longer than 35 feet.

The easiest way to check the slope of the gutter is to use a garden hose or pour a bucket of water into it and see if the water flows out smoothly or ponds in low spots. The gutters should be adjusted to remove any high or low spots that prevent the smooth flow of water.

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. If there is a problem with leaves, a leaf strainer or leaf guard is a good buy.

Splashblocks should be long enough and sloped enough to carry all water well away from the foundation and beyond the backfill area. Water should be discharged no closer than 5 feet from the foundation. Usually it is necessary to add a downspout extension in order to get the water far enough away from the foundation. It is possible to purchase extensions that have a flexible elbow that can be bent up to make it easier to mow the lawn. The extension should be left down at all other times. Special roll-up type downspout sheets (plastic tubes) that attach to the end of the downspout are also available. They extend when filled with water and roll up when empty.

Products and instructions for gutter repair can be found at most hardware stores, do-it-yourself departments, and lumber yards.

Subsurface drainage maintenance

If correctly installed, subsurface drains should require little maintenance. The most important thing to remember is to avoid covering or obstructing the drain 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 a house is fairly old, it may have drain tiles instead of pipe. If heavy trucks or equipment have been driven over these drains, some of the tiles may be broken.

If the subsurface drainage system is not working, it may have been broken or installed incorrectly or not at all. The bad news is, you may have to dig it up and start again.

Flatwork maintenance

Every homeowner should conduct a yearly inspection of concrete flatwork and do any maintenance necessary to improve drainage and minimize infiltration of water from rain, snowmelt, and lawn watering. This is especially important during the first five years for a newly built house because this is usually the time of the most severe adjustment between the new construction 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 most new concrete flatwork. However, cracking tends to be more severe and common on swelling soils. If cracks are not sealed, they can cause the flatwork problem to get worse and contribute to deeper saturation that may damage foundations or basement floors.

All cracks in flatwork 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.

APPENDIX A

A few words on vegetation

When selecting vegetation for home landscaping, it is important to realize that environmental conditions in Colorado are different from most other parts of the country. The biggest differences are in the elevation, soils, and water availability.

The average elevation in Colorado is 6,800 feet above sea level. Most large population centers are between 4,000 and 6,000 feet. The most obvious effect of the high elevation is a short growing season.

Colorado's soils are alkaline. The soils on the East Slope are calcium rich, while those on the West Slope are sodium rich. Swelling soils are characterized by having poor aeration (air supply) and poor drainage.

Water availability is a critical issue in Colorado. Because Colorado has a semiarid climate, water is in short supply. Occasional droughts are normal and are to be expected.

Because of the rapidly increasing population, the amount of treated water available is quickly falling behind demand. Water rationing during the summer months has become common practice in many communities.

People who come to Colorado from areas of abundant moisture must change their habits related to water use. With an expanding population and other demands, we cannot afford to use the water needed to grow dense, luxuriant vegetation. We must accustom ourselves to the beauty and practicality of native vegetation — plants that require little water and are well adapted to the soils and climate (Fig. 29).

Figure 29. Landscaping with native grasses, shrubs, and Lyons Sandstone.

For more detailed information as to the kinds of vegetation to plant in your area, contact your local office of the Colorado State University Cooperative Extension Service. It should be listed in the white pages under "Colorado, State Of" or under the County Government listing.

The following tables list some of the vegetation that does well in the heavy alkaline clay soils found along the Front Range (Table A) and on the West Slope (Table B).

TABLE A
(EAST SLOPE)

TREES

	COMMON NAME	BOTANICAL NAME
DECIDUOUS	ASH, GREEN	*Fraxinus pennsylvanica lanceolata*
	ASH, MOUNTAIN	*Sorbus aucuparia*
	CATALPA, WESTERN	*Catalpa speciosa*
	HONEY LOCUST (Thornless)	*Gleditsia triacanthos inermis*
	MAPLE, NORWAY	*Acer platanoides*
	OAK, BUR	*Quercus macrocarpa*
	RUSSIAN OLIVE	*Elaeagnus angustifolia*
EVERGREEN	JUNIPER, ROCKY MOUNTAIN	*Juniperus scopulorum*
	PINE, PIÑON	*Pinus cembroides edulis*
	PINE, PONDEROSA	*Pinus ponderosa*
	SPRUCE, COLORADO	*Picea pungens*

GROUND COVERS

COMMON NAME	BOTANICAL NAME
JUNIPER, CREEPING	*Juniperus horizontalis*
JUNIPER, MOUNTAIN COMMON	*Juniperus communis*
POTENTILLA	*Potentilla sp.*
SEDUM	*Sedum sp.*
YARROW	*Achillea sp.*

TABLE B
(WEST SLOPE)

TREES

	COMMON NAME	BOTANICAL NAME
DECIDUOUS	HACKBERRY, WESTERN	*Celtis occidentalis*
	HAWTHORN, SHINY-LEAVED	*Crataegus erythropoda*
	OAK SPECIES	*Quercus sp.*
EVERGREEN	JUNIPER, ROCKY MOUNTAIN	*Juniperus scopulorum*
	PINE, PIÑON	*Pinus cembroides edulis*
	PINE, PONDEROSA	*Pinus ponderosa*

APPENDIX B

Checking for swelling soil damage

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.

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 where the driveway and the garage door meet. If the driveway is high in the center and there are gaps where it meets the doorway, heaving has probably occurred (Fig. 30).

Check the driveway concrete for cracking. Cracking may be due to swelling soils, settling, frost heave, or a combination of these. Flaking (spalling) of the concrete may be a sign of poor quality concrete, damage from deicing chemicals, or ordinary concrete used on corrosive soils.

Keep in mind that frost action causes cracks that allow water to infiltrate the soil beneath the flatwork where it can cause swelling soil damage. Once cracks appear, the condition may rapidly worsen even with moderately swelling soils.

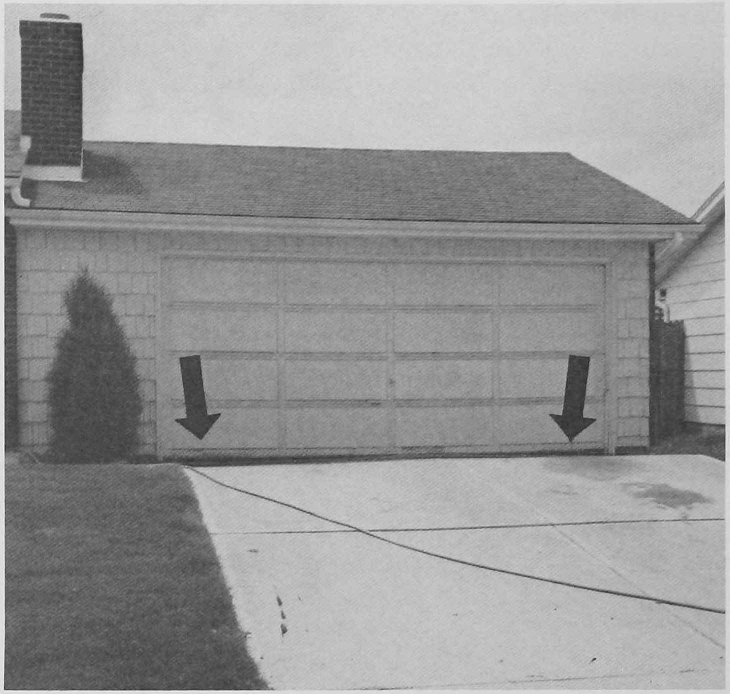

Figure 30. *Swelling soil has caused this driveway to heave. Note the gaps where the garage door meets the driveway.*

Asphaltic concrete is sometimes used for flatwork in areas with swelling soils because it is more flexible and may not damage as easily as concrete.

Sidewalk, curb and gutter. All exterior concrete flatwork should be checked to see if any cracking or heaving has occurred (Fig. 31). These conditions may be caused by swelling soils or by settling due to improper compaction of backfill. Openings in the concrete provide access for water and accelerate the rate at which damage is occurring.

Figure 31. *Swelling soil is responsible for the destruction of this sidewalk.*

Chimney. Check the chimney for separation from the outside wall and for cracks in the masonry. A damaged chimney can be very dangerous (Fig. 32).

Figure 32. *The chimney of this house located in a southwest Denver suburb separated from the house and had to be removed before it collapsed. It was damaged by swelling soils.*

Now go closer to the house and look at the following items:

Foundation walls. If you cannot see the foundation because of shrubs and flowers, you should read the section on "effects of vegetation on house and yard." In any case, inspect the foundation wall for cracks. Almost without exception, every house will have some cracks in the foundation. These are the result of (1) shrinkage due to curing of the concrete and (2) tension cracks due to minor settling. This type of crack is on the order of 1/8 of an inch wide or less. Large cracks are probably the result of severe foundation movement (Fig. 33).

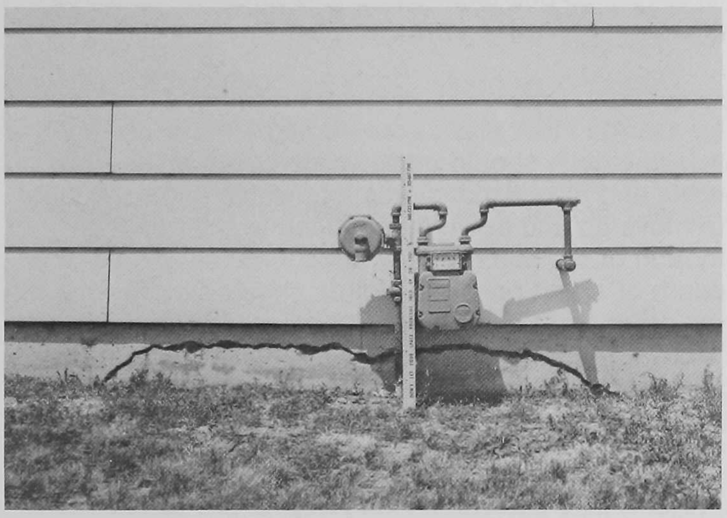

Figure 33. The crack in this foundation was caused by highly swelling soil.

Structural brick. For a structural brick house, check for cracks in the outside wall. Cracks will generally follow mortar lines (Fig. 34) but have been known to split bricks in extreme cases (Fig. 35).

While you are still outside, take a look at the soils for cracking. This will not be possible if the native soil is covered by topsoil.

Figure 34. Cracks in this building were caused by swelling soil.

Patios and porches. Be sure to check patios and porches for cracking and heaving. Also, be sure they do not slope toward the house. There should be a 1 to 2 percent slope away from the house in order to keep water away from the foundation.

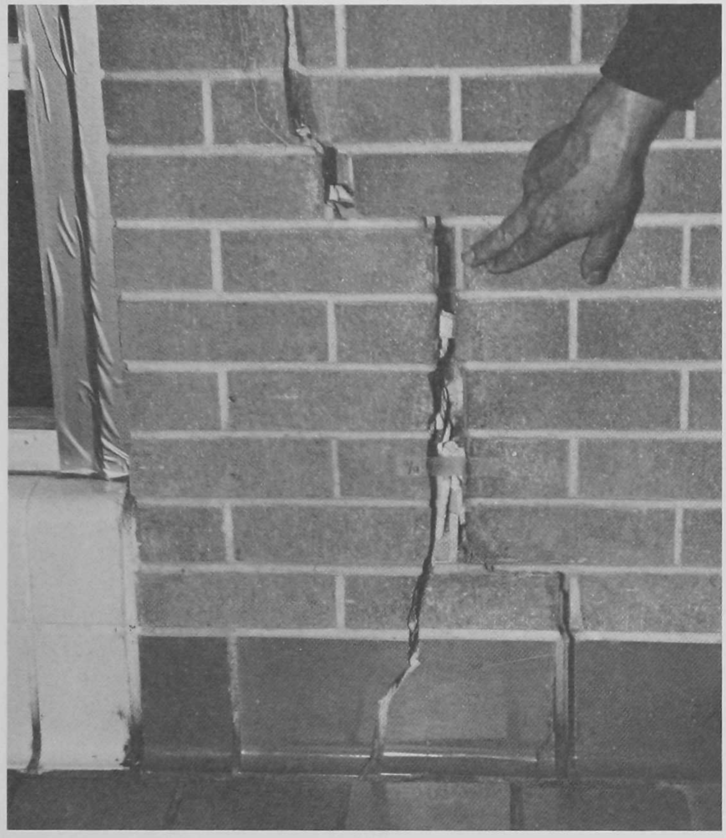

Figure 35. The bricks in this wall were split by pressures from swelling soil.

Now check the inside of the house.

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. If they are diagonal, they are probably the result of swelling soils, settling, or other foundation movement.

Doors and windows. Doors and windows that don't open and close properly or have gaps between the frame and the door or window, are distorted. This distortion may be due to heaving from swelling soils. However, green wood can cause similar damage.

Floors and ceilings. Cracks usually show up in corners where stress and strain are greatest. Green wood may also be responsible for these cracks.

Basement. Check the basement walls and floor slab for cracks. Floor slabs constructed directly on swelling soils should be separated from all bearing walls and have expansion joints which allow the slab to move up and down in response to the heaving motion of the soil. All flatwork should be scored to a depth of about one inch. Joints should be provided on the order of 15 feet center to center. Basements with this arrangement should remain unfinished or have specially designed partitions to accommodate some vertical movement of the slab.

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 without breaking.

Cracks in walls, floor slabs, and exterior flatwork should be monitored over time. This can be done by measuring the width of certain cracks every month and noting if the cracks stay the same, steadily increase in size over time, or expand and contract with the seasons.

APPENDIX C

Suggestions for further reading

1. HOME CONSTRUCTION ON SHRINKING AND SWELLING SOILS, Holtz, Wesley G., and Hart, Stephen S. Colorado Geological Survey Special Publication 11, 1978, 18 p.

2. HOW TO INSPECT A HOUSE, Hoffman, George. Delacorte Press/Seymour Lawrence, 1972, 198 p.

3. LANDSCAPING FOR WATER CONSERVATION IN A SEMIARID ENVIRONMENT, Rondon, Joanne. City of Aurora, 1980, 95 p.

4. NATURES BUILDING CODES — GEOLOGY AND CONSTRUCTION IN COLORADO, Shelton, David C., and Prouty, Dick. Colorado Geological Survey Special Publication 12, 1979, 72 p.

5. POTENTIALLY SWELLING SOIL AND ROCK IN THE FRONT RANGE URBAN CORRIDOR, COLORADO, Hart, Stephen S. Colorado Geological Survey Environmental Geology 7, 1974, 23 p., 4 plates.