A Guide to Swelling Soils for Colorado Homebuyers and Homeowners

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Information on evaporation was provided by Nolan Doesken, Colorado Climate Center. Certain photographs and illustration templates were provided by KLP Consulting Engineers, Inc. (Figs. 15–18 and 21), CTL/Thompson, Inc. (Fig 21), AKM Engineering Consultants, Inc. (Fig. 23), and Home Owners Warranty Corporation (Fig. 30).
Swelling soils are a common problem in Colorado. They can cause damage that includes cracked and heaved driveways, sidewalks, basement walls, and floors; broken pipes and water lines; and, in some cases, severe damage to house foundations. Although many areas in the United States have swelling soils, Colorado’s semiarid climate and geology combine to make it one of the most severely affected. Nationwide, the cost of repairing damage caused by swelling soils amounts to several billion dollars yearly, more than the cost for all other natural hazards combined.

Swelling soils are capable of causing severe damage to houses, roads, and other engineered structures. The damage may occur slowly over time, and individual houses in a neighborhood may be affected at different times. Special insurance or federal emergency funds typically do not exist for swelling soils damage. Builder’s and homeowner’s warranties may be available but the coverage they offer is usually limited in scope, amount, and duration. In general, owners of older homes will be solely responsible for the cost of repairing damages.

If you are thinking of buying or building a home on swelling soils, or if you already own a home that may be affected by swelling soils, you need to have a basic knowledge of:

1) What swelling soils are, and how they behave in general;
2) How the build-up of moisture in the soil contributes to swelling soils damage;
3) How homes can be designed and built to resist damage from swelling soils;
4) How to properly landscape and maintain a homesite to reduce damage; and
5) What risks a homebuyer must accept when purchasing a home on swelling soils.

The purpose of this book is to assist Colorado homebuyers and homeowners in reducing damage caused by swelling soils. Although risks from swelling soils cannot be completely eliminated, they can be significantly reduced through proper site-investigation, design, construction, landscaping, and maintenance practices. An awareness of these topics may be critical for the Colorado homeowner whose house is built on swelling soils.
How to Use This Book

This book is divided into two parts. Part I contains a short summary of swelling soils information. It outlines six categories of important facts that homebuyers should know about swelling soils in accordance with the disclosure requirements of Colorado Senate Bill 13 (1984), C.R.S. 6-6.5-101. Prospective homebuyers should read the Part I summary carefully and then utilize the text and figures from Part II to learn more about these topics.

Part II is a more extensive guide to swelling soils for homebuyers and homeowners. It contains seven chapters, arranged in the same order as the six categories outlined in the summary. Important aspects of swelling soils, subsurface moisture, and specialized construction, landscape, and maintenance procedures for swelling soils are explained. Chapter 7 is a step-by-step guide to inspecting a house for swelling soils damage. Several federal, state, and local agencies that may be sources of helpful information about swelling soils and related topics are listed at the end of the book.

Prospective homebuyers should use Part II to get a better understanding of the topics introduced in Part I. Homeowners can use all parts of the book to help maintain the long-term integrity of their home and their investment.

In all of the chapters and appendices, important terms will be highlighted in boldface type and explained where they first appear. These terms are used by professional geologists, engineers, and homebuilders, and many of them may be unfamiliar to the first-time reader. However, you may find an understanding of them to be extremely useful when you are dealing with swelling soils, or with housing and construction in general.

Replacement of Older CGS Publications

PART I

SUMMARY OF CHAPTERS 1–6
The Geology of Swelling Soils
(Summary of Chapter 1)

- Swelling soils and bedrock contain clay minerals that attract and absorb water. As a result, they swell in volume when they get wet and shrink when they dry (refer to Figs. 1-3, p. 16 and 17). Many geologists, engineers, and builders use the term "swelling soil" to include both soil and bedrock.

- "Bentonite" is a term that is often used synonymously with "swelling soil." Some bentonite layers are comprised of pure volcanic ash that has been weathered to clay. This type of bentonite may have extremely high swell characteristics.

- There are many factors that control how much a soil can swell, including the type and concentration of minerals, soil density, the amount of moisture change that can occur, and the restraining pressure of the surrounding soil.

- Swelling soils and bedrock may be found throughout Colorado, with the general exception of the highest mountain areas (refer to Fig. 4, p. 18).

- The swell potential of soils beneath any particular property depends on the local geology. Exploratory drilling or trenching, accompanied by sampling and laboratory testing, are necessary to evaluate the swell potential of subsurface layers at different depths (refer to Fig. 7, p. 21).

- Layers of swelling claystone bedrock that dip (tilt) into the ground at steep angles near mountain uplifts constitute a distinct geological hazard called "heaving bedrock" (refer to Figs. 8 and 9, p. 22 and 23). Jefferson and Douglas counties have adopted land development regulations to address this special geologic hazard.

- See Chapter 1 and Figures 1-9, starting on p. 15, to learn more about the geology of swelling soils.
LANDSCAPING ON SWELLING SOILS
(SUMMARY OF CHAPTER 4)

♦ Many conventional landscaping practices (such as planting bluegrass lawns, trees, and gardens near foundations) are not recommended for areas of swelling soils because they contribute excess water to the soils (refer to Figs. 30 and 31, p. 48 and 50).

♦ There are some simple landscaping guidelines that should be followed in order to reduce swelling soil problems. The sloped area immediately adjacent to the house is an especially critical area for landscaping (refer to Fig. 34, p. 53).

♦ Irrigation should be limited to the amount necessary to maintain vegetation. This applies to all portions of your yard. Excessive watering, even with good drainage, drives water into the soil and increases the likelihood of swelling soil problems.

♦ Xeriscape™ landscaping is an attractive and cost-effective way to reduce swelling soils activity and conserve water. Other advantages include lower maintenance and less mowing.

♦ Xeriscaping makes use of many types of water-wise plants, and can include use of rock and organic mulches (refer to Figs. 32 and 33, p. 51 and 52 and Table 1, p. 52). The possibilities for creating a pleasing and effective Xeriscape are endless.

♦ There are numerous sources for information and ideas when it come to Xeriscaping. Some of these are listed in "Information Sources", p. 76.

♦ See Chapter 4 and Figures 30–34, starting on p. 47, to learn more about landscaping on swelling soils.
Home Maintenance on Swelling Soils
(Summary of Chapter 5)

- Homeowners should routinely inspect and maintain all of the different systems that were designed to protect the house from swelling soils damage, including slabs, walls, subsurface and surface drainage, slopes, and landscaping.

- Proper maintenance and irrigation practices are absolutely necessary to help prevent a house from being damaged by swelling soils and reduce potentially costly repairs.

- Conversely, the lack of proper maintenance and irrigation practices can contribute significantly to conditions that cause swelling soils damage.

- This is one of the most important chapters if you are a homeowner. See Chapter 5 and Figures 35 and 36, starting on p. 55, to learn more about home maintenance on swelling soils.
Swelling Soils and Homeowner Risk
(Summary of Chapter 6)

- Under Colorado law, the presence of swelling soils beneath a new house must be disclosed, and background information must be furnished to a homebuyer by the builder. During resale of an existing house, disclosure of pertinent soil conditions as well as any known damage or repairs must be given by the homeowner and the real estate broker. However, the homebuyer should not rely solely on this information.

- 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/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. (Ideally, a summary soils report should include the swell
potential, observations, and recommendations given for the subject homesite. 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.

- Designs for houses are based on the potential severity of swelling soils. The design of the house should be specifically tailored to the amount of uplift or heave that is expected due to soil swelling for a particular homesite.

- Swelling soils should be considered seriously along with other common factors such as location and cost when you are thinking of buying a house.

- Find out everything you can about a particular new or resale house, especially how (and if) it was actually constructed with regard to the soil conditions. Look for signs of damage and/or repairs, and poor landscaping and maintenance practices, as shown in Chapter 7, and hire a structural engineer to assess the house if you have concerns or want more information.

- The final decision to purchase a house on swelling soils is yours. It should reflect a knowledge and acceptance of the risks involved. It may be extremely useful to hire a professional house inspector or engineer to help you with your decision.

See Chapter 6 and Figure 37, starting on p. 61, to learn more about swelling soils and homeowner risk.
PART II

GUIDE TO SWELLING SOILS
Swelling soils and swelling bedrock contain clay minerals that can attract and absorb water. As a result, these materials swell in volume when they get wet and shrink when they dry (Fig. 1). They are also called expansive, shrinking and swelling, bentonitic, heaving, or unstable soils and bedrock. When engineers or geologists talk about swelling soils, they are using a general term that may include swelling bedrock. The difference is that...
swelling soils contain clay, while swelling bedrock contains claystone. In this book, we will use the general term “swelling soils” to include soils and bedrock that exhibit swelling behavior. Figure 2 shows some common occurrences of soil and bedrock in Colorado.

**Smectite (montmorillonite)** is the clay mineral responsible for most swelling soil and bedrock damage in Colorado. Bentonite is a special type of smectite that was originally deposited as ash from ancient volcanoes. **Bentonite** may have especially high swelling characteristics. **Illite** and mixed **illite-smectite** are common clay minerals that may swell, but to a lesser degree than smectite.

### Swelling and Shrinking Behavior

Damage from swelling soils occurs when the soil changes volume as a result of a moisture change. **Swelling** occurs when moisture is added. Certain clay minerals may exert a chemical and physical attraction on the moisture, pulling layers of water molecules into microscopic areas between the flat clay plates. The clay plates are pushed farther apart as more water layers are pulled in (Fig. 3). This pushing apart (swelling) can cause high swell pressures and/or an increase of volume within the mass of soil that is being wetted.

**Shrinkage**, the opposite effect of swelling, occurs when the soils dry out. As drying occurs, layers of water molecules are pulled out from between the clay plates by evaporation or by capillary forces from plant roots. This causes the area between clay plates to collapse on a microscopic
level, and may cause a decrease in volume within the mass of soil that is being dried.

Swelling accounts for most of the damage to structures and roads in Colorado. Colorado soils are usually dry in their natural condition, but tend to become wetter after subdivisions are constructed and occupied because additional sources of water become available. The relationship between swelling soils, subsurface moisture, and subdivision development activities is discussed in Chapter 2.

**Swell potential** and **swelling pressure** are two measurements of a soil's ability to expand against different restraining pressures under laboratory conditions. Soils are typically rated as having either very high, high, moderate, low, or no swell potential. Swelling pressure is the pressure exerted by the soil mass against a restraining force when it is wetted. Typical swelling pressures for expansive soils in Colorado can reach 15,000 pounds per square foot. Soils having such high swelling pressure are capable of causing uplift to concrete slabs and footing-type foundations, which exert relatively low loading pressures.

The potential volume expansion of a soil under actual field conditions depends on five main factors:

1) **Type of minerals.** Smectite and (to a lesser degree) illite are the most common types of clay minerals in swelling soils in Colorado. Soils that contain relatively stable clay minerals such as kaolinite, or non-clay minerals such as quartz or feldspar, usually have no swell potential.

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**Figure 2.** Soil and bedrock as they commonly occur in Colorado. A) A hogback ridge of upturned (steeply dipping) bedrock along the edge of a mountain range. B) A mesa with flat-lying bedrock layers, and thin soil deposits at the bottom of the slope.

**Figure 3.** Expanding clay plates, as seen at a microscopic level. (Modified from Hart, 1974.)
2) **Concentration of swelling clay.** The more particles of swelling clay present in a piece of soil or bedrock, the greater its swell potential.

3) **Density.** A dense material containing swelling clays will have more clay particles and fewer air-filled voids than a loosely packed material of similar mineral composition. As a result, the dense material will have a greater swell potential.

4) **Moisture change.** A dry soil has the potential to absorb more moisture than a wet soil, and can subsequently undergo a greater amount of volume expansion. The amount of moisture change that can occur in a soil is a function of the initial amount of moisture in the soil (natural moisture content), the ability of the clays in the soil to pull in additional moisture (swell potential), and the amount of free-draining water and/or water vapor available to the soil.

5) **Restraining pressure.** A layer of swelling soil that occurs near the ground surface may swell significantly and cause uplift and heaving because there is very little restraining pressure to prevent it from swelling. However, the swell potential of a similar layer that occurs several feet below the surface is restrained by the weight of the surrounding and overlying soil (overburden). If the overburden weight is greater than the soil's swelling pressure, then actual swelling and uplift are unlikely.

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**Occurrence of Swelling Soils in Colorado**

Swelling soils are widespread throughout Colorado. They cover broad areas of the eastern plains, and are found mainly in valleys and on mesa slopes in western Colorado (Fig. 4). A majority of the state's major population centers are located in areas of potentially swelling soils and bedrock. On a smaller scale, however, individual sites within these areas may not have swelling soils beneath them because of localized geological variations (as in Fig. 5).

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**How to Recognize Swelling Soils**

One way to find out if swelling clays are present is by simply looking at the ground surface. Soils

![Table](#)

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- ☐ 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.


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Figure 4. Explanation.
Figure 4. Generalized distribution of swelling soils and shallow swelling bedrock in Colorado. (From Jochim, 1987.)
Figure 5. Example of a map showing local distribution of swelling soils. Maps of this type available from the Colorado Geological Survey for the Front Range urban corridor area, from Pueblo to Fort Collins (in publication EG-7 by Hart, 1974).

Figure 6. Evidence of swelling soils at the ground surface. A) Small-scale desiccation cracks in soil containing swelling clay. Note tire tracks for scale. B) “Popcorn” texture in soil containing swelling clay having very high swell potential. Note footprint for scale.
containing swelling clays will be very sticky when wet, and may display **desiccation cracks** (Fig. 6A) or a puffy "**popcorn**" texture (Fig. 6B) when dry. Heat and evaporation may cause larger cracks, on the order of several feet deep and up to an inch wide, to open up in the ground. These features may not be evident where topsoil or heavy vegetation covers the native soil.

It is far more important to identify whether deeper layers or lenses of swelling soil are present beneath a property. The evaluation of subsurface layers is most often done by drilling one or several test holes or by digging a trench (Fig. 7).

**Drilling** is effective for relatively flat-lying soil and bedrock because it allows for inspection and sampling of successively deeper layers, while **trenching** is effective in areas underlain by steeply dipping bedrock because it exposes many near-surface bedrock layers for inspection and sampling. Samples taken from test holes or trenches are tested for swell potential and swelling pressure in a laboratory. This information is used to design foundations for buildings. Such evaluations are a required practice in many areas of Colorado where swelling soils are anticipated.

*Figure 7. Exploration methods used to identify and test different soil and bedrock layers for swell potential and other engineering properties. A) Trenching, B) Drilling.*

Colorado Geological Survey
Steeplingly Dipping Bedrock Areas

Heaving bedrock is a distinct geological hazard in certain areas of Colorado near the base of mountains where the sedimentary bedrock layers are steeply dipping (upturned and tilted, as shown in Fig. 3A). In such areas, the bedrock layers may swell unevenly to form linear heave features along the ground surface (Fig. 8). Houses built over such heave features may be subjected to extreme amounts of vertical and lateral stress, and the resulting damage can be severe.

The mechanisms responsible for heaving bedrock movements are geologically complex. Heaving may occur due to uneven swelling of individual bedrock layers, each having a different swell potential (Fig. 9A), or due to shear-slip movements along bedding planes or fracture surfaces (Fig. 9B). The processes that cause heaving bedrock are not well known. Rebound (expansion of the clay minerals as a result of sudden unloading) may be a factor, in addition to water-induced swelling of clay particles in the bedrock. Moisture can penetrate a greater depth into steeply dipping bedrock than in flat-lying bedrock, resulting in a deeper zone of potential swelling.

Many construction designs commonly used to mitigate the impacts of swelling soils have met with limited success in areas of heaving bedrock. For example, drilled pier foundations (see Chapter 3) have been damaged in numerous cases. The basic assumption for those designs is that the bedrock is stable. This is not the case for heaving bedrock because the bedrock itself is moving. One method that may counteract the differential heaving is overexcavation and fill replacement, whereby a house is isolated from the heaving bedrock by a thick pad of engineered fill (see Chapter 3).

Jefferson and Douglas counties now require more detailed site investigation and specialized building techniques where heaving bedrock conditions exist. These areas are defined by overlay maps that show the extent of potentially heaving bedrock. Houses in the overlay areas constructed before 1995 may not have been built with current state-of-the-art construction practices. Similar geological conditions where heaving bedrock may occur exist at other locations along the Front Range foothills and on the Western Slope of Colorado.

Figure 8. This "roller-coaster road" is the result of uneven swelling and heaving of steeply dipping bedrock layers.
Figure 9. Different types of heaving bedrock. A) Symmetrical heave features caused by uneven swelling of individual bedrock layers. B) Asymmetrical heave features caused by shear-slip movement along bedding planes and/or fracture surfaces. (Modified from Noe and Dodson, 1995.)
We learned in the first chapter that swelling soils cause damage by attracting and absorbing water. This chapter will show how water exists in the ground under natural climatic conditions, and how the amount of subsurface moisture usually increases after development. In most cases where significant swelling soil damage occurs, the damage is triggered by an increase in subsurface moisture.
The hydrologic cycle (Fig. 10). Water falls from the clouds as precipitation and enters the ground through infiltration. It can also leave the ground by vaporizing due to heating and drying (evaporation) or by being used by green plants (transpiration); the cumulative effect is called evapotranspiration or ET loss.

The mountainous areas of Colorado usually have a surplus of surface and subsurface water as a result of high rates of precipitation and a cool climate. The eastern plains and western valleys, where most of Colorado’s swelling soils are found, receive less precipitation (8 to 16 inches per year, on average, for the major population centers; Colorado Climate Center, 1984), are hotter, and have high rates of evapotranspiration (30 to 40 inches, on average, for May-October shallow lake surface evaporation; Farnsworth et al., 1982). As a result, the lower-elevation areas of the state are characterized by an overall deficit of water during much of the year, and the near-surface soils are typically dry.

**Types of Subsurface Moisture**

Water exists beneath the ground surface in two forms. It is called ground water where the soil or rock is saturated, and ground moisture where the soil is unsaturated. Layers of saturated soil or rock that store and transmit water are called aquifers. The upper saturated surface of a shallow (unconfined) aquifer is called the water table. A perched water table may develop on top of impervious soil or bedrock as a result of subdivi-
How Subsurface Moisture Affects Swelling Soils

The presence of subsurface moisture can cause serious problems for a house built on potentially swelling soils. The amount and distribution of subsurface water may vary seasonally under natural conditions. The amount of subsurface moisture increases during the late winter and spring, when rates of precipitation and infiltration are high, and during periods of artificial irrigation. During the dry season it may decrease again. Similarly, the water table may rise during wet periods and fall during dry periods. The depth below the ground surface where soils undergo seasonal wetting-drying cycles is called the active zone or zone of moisture change. The natural active zone along Colorado’s eastern plains is typically 7 to 10 feet deep.

Under natural conditions, seasonal wetting and drying cycles cause swelling soils to swell and shrink to some extent. This is not a problem if the land is being used for agriculture or is undeveloped. However, building a subdivision in an area can significantly alter the natural moisture content of the soil. Water infiltration increases due to irrigation of lawns and gardens and, in some cases, leakage from septic systems and water or sewer pipes. At the same time, evaporation is reduced by impervious roadways, parking lots, driveways, sidewalks, and buildings. Off-site water may migrate into an area through backfilled trenches and gravel bedding. A perched water table may develop. The overall result is a net increase in soil moisture. The post-construction zone of wetting typically increases to depths...
of 10 to 15 feet along Colorado's eastern plains. In areas of steeply dipping bedrock, the zone of wetting may increase to depths of 35 feet after a subdivision is built and the houses are occupied. If newly introduced subsurface water comes into contact with potentially swelling soils beneath a house, the soils may swell and cause damage.

One of the most important means of reducing the risk of swelling soils damage is to control the amount of moisture that infiltrates the soil. Structures built on swelling soils should, in every case, have adequate surface and subsurface drainage systems. Successful design, construction, landscaping, and maintenance practices for swelling soils all depend to a large degree on reducing the effects of subsurface water, as we will see in the following chapters.

**Droughts and Shrinking Soils**

Colorado is subject to occasional periods of drought. During a drought, evapotranspiration will exceed water infiltration, and the active zone will dry out. If swelling soils are present in the active zone, they will undergo volume shrinkage. This may reverse the direction of heaving and reduce the amount of damage that has occurred during earlier periods of swelling, or it may cause additional damage due to surface settlement of the soil.

Desiccation cracks (Fig. 6A) typically form when near-surface swelling soils dry out. Large cracks, with depths of up to several feet, may form during extended dry periods. These larger cracks play an important role in swelling soil behavior, as they allow deep penetration of water during subsequent wet periods.

Certain types of trees and plants will pull large amounts of moisture out of the soil during drought periods. This may cause localized shrinkage and settling of the ground surface in the immediate area of the tree. Damage to structures may occur if the tree is located close to a house foundation. Chapter 4 gives tips on how to avoid this type of problem by using proper landscaping techniques.
This chapter describes the advantages (and some of the pitfalls) of certain specialized designs used in house construction for various degrees of soil swell potential. Swelling soils influence the preparation and grading of the site, as well as the design and construction of foundations, floors, interior walls and piping, and subsurface and surface drainage systems. Quality control of construction is crucial for each step of the construction process.
The design and construction of a house and its individual elements should ideally reflect the condition of the soils beneath it. The actual designs are usually chosen by the homeowner after considering recommendations from engineers and taking other factors, such as house affordability, into account. A prospective homeowner should be aware of swelling soils and the types of designs and precautions used to control swelling soil problems. Many variations of a design are possible, and the actual designs used for any particular house may differ to some degree from those shown in this chapter.

**Ground Preparation and Grading**

Before any houses can be built in a new subdivision, the site is usually graded and shaped, and utilities and roads are installed. This may involve cutting away topographically high areas such as hills and filling in lower areas. Swelling soils or bedrock may be exposed or brought nearer to the surface in grading cuts, and they may make up a sizable portion of the materials used to construct fill pads for houses and roads. There are several methods of site preparation available to reduce the potential swelling of fills and natural soils. The effectiveness of any particular method depends on the actual conditions at each subdivision or site.

**Fills.** It is common engineering practice to reduce the swelling potential of graded fills by controlling their moisture and density. The fill soils are typically spread out on the ground surface in thin layers. Water is added to each new layer to induce a certain amount of swelling. Afterwards, a machine compacts the layer to a recommended density. The final moisture content of an engineered fill is almost always greater than for most Colorado soils in their natural condition. As a result, the fills may be less prone to swell. Construction of engineered fills may result in mixing of non-swelling materials such as sand or low-swell clays with higher-swell clays, which may effectively reduce the overall concentration of swelling clays.

**Cuts.** Cut areas exposed by grading are susceptible to swelling because the natural restraining loads have been removed, exposing soil or bedrock layers that have not previously swelled to their full potential. Such areas can dry out to some depth after grading, thereby increasing the swell potential. In some cases, grading exposes fractures or other water conduits that were not open to moisture intrusion prior to grading (Fig. 12). The overexcavation method of cutting and fill replacement is sometimes used in areas of highly swelling soils and bedrock. Overexcavation involves cutting and removing the soils to a prescribed depth, usually 3 to 10 feet below the anticipated lowest foundation or road level. The cut is then fully or partially filled with uniform layers of original or imported soils under controlled moisture and density conditions. This fill creates a buffer between the foundation or road and the underlying swelling soils. Overexcavations and deep fills may be recommended in certain Colorado counties where steeply dipping, heaving bedrock is encountered.
Chemical treatments. Another means of reducing swell potential is to mix or inject chemicals into the soil. This is typically done after site grading. Chemical treatments are specially formulated to change the clay chemistry and mineralogy so that the clays become less expansive. Chemical treatments are used mainly for roads and larger commercial building sites. They are less commonly used for single-family residential dwellings. A main drawback of chemical treatments is that the treatments may not penetrate very deeply or uniformly into most swelling soil and bedrock due to the presence of fractures, low-permeability layers, and other geological complexities. Another drawback is that the chemicals may be leached out of the soils over time.

Foundations

House foundations must be properly engineered to account for geological conditions at any given homesite. Depending on the site's swell potential, swelling soils may or may not be a primary consideration. Several different types of foundations are commonly used in areas of swelling soils in Colorado. The actual choice of foundation type depends on numerous geologic and non-geologic factors, and may reflect common regional practices and individual preferences of foundation engineers.

The foundation of a typical house consists of a basal element that is in direct contact with the soil, and a wall element that rests upon or spans the basal elements and retains the backfill along the side of the house. These elements are made from concrete and may contain steel bars as reinforcement. The foundation ideally transfers the weight of the house to the soil in such a way that the house will not heave or settle significantly.

Foundations are termed "shallow" or "deep" depending on the configuration of their basal

Figure 12. How bedrock fractures are exposed by grading cuts. A) Under natural conditions, fractures are covered by soils and are not directly exposed to water infiltration. B) After grading and cutting the fractures are exposed at the surface, and water can now infiltrate more easily into the ground through the exposed fractures.
elements. **Shallow foundations** have basal elements that are directly supported by soil, bedrock, or fill along the bottom of the foundation excavation. They are used in many areas of Colorado where the soil has negligible to moderate swell potential, or in conjunction with overexcavated and replaced fills where highly expansive soils and/or rock are present. **Deep foundations** have basal elements that penetrate the soil and/or rock to some depth below the base of the foundation wall, essentially anchoring the foundation into the ground and transferring much of the load to deeper strata. Deep, drilled pier foundations are used in many areas of Colorado where the soils are expansive or otherwise unstable.

Different foundation types commonly used in Colorado and their suitability for swelling soil areas are discussed in the following paragraphs.

**Shallow Foundations**

A **spread footing foundation** (Fig. 13a) consists of a continuous strip of concrete, typically 16 inches wide but occasionally narrower or wider (between 12 and 20 inches wide), upon which the foundation wall is placed. The footing has a relatively large bearing area (basal area) in contact with the ground, which spreads out rather than concentrates the weight of the house. This type of foundation works best in loose, non-swelling soils to reduce settlement. It is generally not recommended where moderately to highly swelling soils are encountered, unless it is used as part of an overexcavation and fill replacement design.

A **footing pad foundation** (Fig. 13b) consists of discontinuous concrete pads that are spaced apart
at specified intervals. Between the pads are void spaces filled with a collapsible material that does not transmit loads. The pads and void spaces are spanned by a grade beam, a steel-reinforced foundation wall. The load of the house is supported by the grade beam and pads. This type of foundation may be appropriate for soils having very low to moderate swell potentials.

A wall-on-grade foundation (Fig. 13c) consists of a continuous foundation wall that rests directly on the soil. The wall exerts a moderate pressure on the soil due to its rather small bearing area. This type of foundation has been used in Colorado for soils having low to moderate swell potentials. It is becoming less common in construction in most areas of the state.

A voided wall-on-grade foundation differs from a wall-on-grade foundation in that rectangular void spaces are formed into the bottom of the wall at specified intervals. The decreased bearing area concentrates the house load on the underlying soils. This type of foundation has been used in Colorado for soils having moderate to high swelling pressures. However, in recent years it has been largely supplanted for new construction by drilled pier foundations.

A mat foundation, or raft foundation, is a distinct type of shallow foundation that includes some type of concrete slab. One type of mat foundation used for swelling soils in Colorado is a post-tensioned slab-on-grade (Fig. 14). It consists of a concrete element that has waffle-like beams along the lower side and is smooth on the upper side. Strong steel cables, called tendons, cross through the slab. These tendons are tightened...
(tensioned) at intervals of time after the concrete is placed, so that the slab becomes stronger and more rigid as the concrete cures. The load-bearing walls of the building rest on the upper surface of the slab. Post-tensioned slabs have relatively large bearing areas and may be uplifted by moderately to highly swelling soils. However, the rigidity of the slab may allow the building to move as a unit to reduce damage. This type of foundation is most often used in Colorado for commercial or multi-family buildings that have large floor areas. It is rarely used for residential buildings with basements.

**Deep Foundations**

**Drilled pier foundations** (Fig. 15) are the deep foundation systems most often used in areas of moderately to very highly swelling soils in Colorado. Drilled piers for houses are typically constructed by drilling specifically positioned holes, usually 8 to 16 inches in diameter, into the ground. Steel reinforcement rods are lowered into the hole, after which the hole is filled with concrete. After the concrete hardens sufficiently, a grade beam is constructed over the piers to create a load-bearing span between them. Void spaces, filled with collapsible material such as corrugated cardboard, are created between the piers to separate the top of the soil from the bottom of the grade beam. Drilled piers typically range between 10 and 30 feet in length from top to bottom, depending on the soil and subsurface moisture conditions.

Drilled pier foundations have been specifically adapted for different swelling soil conditions. The design allows the load of the house to be concentrated on a relatively small number of piers. This allows the piers to resist uplift pressures from swelling soils. The piers must be drilled to a depth below the zone of expected post-construction moisture penetration (Fig. 16), or else they may heave and damage the house. Drilled pier foundations may reduce the effects of swelling soils when designed and constructed properly. There are certain geological situations in Colorado, however, where drilled piers may not be the most appropriate foundation design (e.g., in areas of steeply dipping bedrock, where the

![Figure 15. Drilled pier foundation. (Modified from Holtz and Hart, 1978.)](image)
bedrock may be unstable to depths of more than 30 feet.

Several types of drilled pier configurations are typically used in Colorado. They may be straight-shafted or may have grooves cut near the base of each pier (Fig. 16). End-bearing drilled piers are drilled into bedrock, at least for the lower-most several feet. The load-carrying capacity of the pier is developed against a socket of stable bedrock at the bottom of the pier. (However, not all bedrock is stable; especially in areas having steeply dipping bedrock.) Friction drilled piers are drilled into thick soil deposits where the underlying bedrock is too deep to be reached. The load-carrying capacity of the pier is developed by friction along the shaft of the drilled pier. Helical steel piers (Fig. 16) are used in areas of Colorado as a remedial installation to replace previously damaged foundation elements. Helical piers consist of a steel shaft with auger-like blades near the tip. The tip is advanced into the ground by rotation until it meets a prescribed torque resistance or depth.

**Lateral Support for Foundation Walls**

Foundation walls require reinforcement or additional supports to resist lateral pressures exerted by the adjacent soils and backfill. This is especially true when the soils and backfill are composed of swell-prone clays. The exact design depends on the length, height, and general configuration of the walls, as well as soil and subsurface water conditions. Reinforcement may be provided by steel bars or beams or by wing-like walls (buttresses or counterforts) that extend outward from the foundation wall at a right angle. An improperly designed wall is at risk of buckling or bow-

![Figure 16. Three types of drilled piers commonly used in Colorado. A) Straight-shafted concrete pier; B) Concrete pier with grooves near base; C) Helical steel pier. All piers should extend well below the anticipated zone of moisture penetration.](image-url)
Floor Construction

There are two primary types of floors used in Colorado when swelling soils are present.

Floating slab floors lie in contact with the soil and are designed to accommodate some amount of soil heaving, while structural floors are completely isolated from the soil surface. These floor systems are used for basements in many areas, especially in the Front Range urban corridor, but may be used for at-grade construction in cases where basements are not used. A short description of each floor type follows:

Floating slab floors are the oldest type of flooring designed specifically for swelling soils. They usually consist of a non-reinforced concrete slab that rests directly on soil or fill (Fig. 17A). The slab is isolated from the outer foundation walls by a slip joint. The slip joint allows the slab to move up and down, or “float”, independently from the foundation as the soils below swell and shrink. This design allows the floor to undergo 2 to 4 inches of vertical heaving without causing appreciable damage to the rest of the house. Special interior construction is necessary when floating slab floors are used (as explained in the next section).

Floating slab floors perform well for soils that are non-swelling or have low to moderate swell potential. They are also commonly used in conjunction with overexcavations, where a thick layer of non- to moderately swelling material separates the slab from the underlying soils. However, floating slabs installed directly upon highly swelling soils may undergo significant heaving, cracking, and buckling. This is because they do not weigh enough to resist the uplift pressure generated when the soils are wetted. As a result, floating slab floors are most commonly installed where the swell potential is low to moderate, and structural floors are most commonly used where the swell potential is high to very high. Floating slab floors are especially prone to
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.

**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

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*Figure 18. Detail of the bottom part of a suspended, non-load-bearing interior wall. (Modified from Holtz and Hart, 1978.)*
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 cowl ing 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 cowl ing should be designed so that it can shorten or extend several inches in the event of heaving or settling.

**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 under-drain, 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 Jachim, 1987.)](image-url)
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 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

![Diagram of Sump System](image-url)

*Figure 23. Sump system with a non-perforated base.*
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, 1987).

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 outlet 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 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 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. 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 surface 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 distance). 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 erosion. 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 Jachim, 1987.)

**Ditches and swales.** Runoff water from roof and slope drainage systems can be collected and car-
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 28. Properly designed runoff slope next to a house foundation. Note that roof drainage is carried by a downsput extension to a point beyond the slope. (From Holtz and Hart, 1978.)

riced 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).

Figure 29. Culvert and drainage swale along a rural road. (From Jochim, 1987.)
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. Even in clay soils, 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 gardens 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 locations, causing soils to swell beneath nearby houses 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 comparable 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 willows 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 requirements for various plants, reducing the infiltration 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 systems and drawing large amounts of water from the surrounding area.

7) Poor-quality, “heavy” day soils should be improved and conditioned by mixing in organic material. This improves the fertility and air and water circulation within the topsoil.

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.

![Average Annual Water Use for Different Types of Plants](image)

**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 plantings, 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....
Table 1. Some water-wise plants for Coloradans (from Jochim, 1987; City of Aurora, 1989; Denver Water, undated; Denver Water, 1996).

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deciduous Trees</strong></td>
<td></td>
</tr>
<tr>
<td>Bigtooth Maple</td>
<td>Acer grandidentatum</td>
</tr>
<tr>
<td>Bur Oak</td>
<td>Quercus macrocarpa</td>
</tr>
<tr>
<td>Flowering Crabapple</td>
<td>Malus sp.</td>
</tr>
<tr>
<td>Gambel (Scrub) Oak</td>
<td>Quercus gambeli</td>
</tr>
<tr>
<td>Hackberry</td>
<td>Celtis occidentalis</td>
</tr>
<tr>
<td>Thornless Honey Locust</td>
<td>Gleditsia triacanthos x bentinis</td>
</tr>
<tr>
<td>Western Catalpa</td>
<td>Catalpa speciosa</td>
</tr>
<tr>
<td>White Ash</td>
<td>Fraxinus americana</td>
</tr>
<tr>
<td><strong>Evergreen Trees</strong></td>
<td></td>
</tr>
<tr>
<td>Colorado (&quot;Blue&quot;) Spruce</td>
<td>Picea engelmannii</td>
</tr>
<tr>
<td>Douglas Fir</td>
<td>Pseudotsuga menziesii</td>
</tr>
<tr>
<td>Pinon Pine</td>
<td>Pinus edulis</td>
</tr>
<tr>
<td>Ponderosa Pine</td>
<td>Pinus ponderosa</td>
</tr>
<tr>
<td>Rocky Mountain Juniper</td>
<td>Juniperus scopulorum</td>
</tr>
<tr>
<td><strong>Shrubs and Groundcovers</strong></td>
<td></td>
</tr>
<tr>
<td>Althea (Rose of Sharon)</td>
<td>Hibiscus syriacus</td>
</tr>
<tr>
<td>Chokecherry</td>
<td>Prunus virginiana</td>
</tr>
<tr>
<td>Cinquefoil (Potentilla)</td>
<td>Potentilla fruticosa</td>
</tr>
<tr>
<td>Creeping Oregon Grape Holly</td>
<td>Mahonia repens</td>
</tr>
<tr>
<td>Common Lilac</td>
<td>Syringa vulgaris</td>
</tr>
<tr>
<td>Buffalo Juniper</td>
<td>Juniperus sabina</td>
</tr>
<tr>
<td>Golden Currant</td>
<td>Ribes aureum</td>
</tr>
<tr>
<td>Hardy Ice Plant</td>
<td>Delosperma nuttallianum</td>
</tr>
<tr>
<td>Heat n chicks</td>
<td>Sempervivum</td>
</tr>
<tr>
<td>Mountain snowrose</td>
<td>Rhus glabra esmondense</td>
</tr>
<tr>
<td>Native Pink Rose</td>
<td>Rosa woodsii</td>
</tr>
<tr>
<td>Sedums (various types)</td>
<td>Sedum sp.</td>
</tr>
<tr>
<td>Yucca</td>
<td>Yucca sp.</td>
</tr>
<tr>
<td><strong>Wildflowers</strong></td>
<td></td>
</tr>
<tr>
<td>Baskets-of-Gold</td>
<td>Aurinia saxatilis</td>
</tr>
<tr>
<td>Blanket Flower (Indian Blanket)</td>
<td>Gaillardia aristata</td>
</tr>
<tr>
<td>Coreopsis</td>
<td>Coreopsis tinctoria</td>
</tr>
<tr>
<td>Cosmos</td>
<td>Cosmos bipinnatus</td>
</tr>
<tr>
<td>Double Bubble Mums</td>
<td>Agastache cinnamomea</td>
</tr>
<tr>
<td>Harebell</td>
<td>Campanula rotundiflora</td>
</tr>
<tr>
<td>Iceland Poppy</td>
<td>Papaver nudicaule</td>
</tr>
<tr>
<td>Prairie Zinnia (Paperflower)</td>
<td>Zinnia grandiflora</td>
</tr>
<tr>
<td>Prairie Wine Cup</td>
<td>Coreopsis miniata</td>
</tr>
<tr>
<td>Purple Coneflower</td>
<td>Echinacea purpurea</td>
</tr>
<tr>
<td>Rocky Mountain Penstemon</td>
<td>Penstemon strictiss</td>
</tr>
<tr>
<td>Yarrow</td>
<td>Achillea millefolium</td>
</tr>
<tr>
<td><strong>Turf (Grasseses)</strong></td>
<td></td>
</tr>
<tr>
<td>Blue Grama</td>
<td>Bouteloua gracilis</td>
</tr>
<tr>
<td>Buffalo grass</td>
<td>Buchloe dactyloides</td>
</tr>
<tr>
<td>Crested Wheatgrass</td>
<td>Agropyron cristatum</td>
</tr>
<tr>
<td>Smooth Brome</td>
<td>Bromus inermis</td>
</tr>
<tr>
<td>Tall Fescue (turf-type)</td>
<td>Festuca arundinacea</td>
</tr>
</tbody>
</table>

Figure 33. Examples of mulch ground covers. A) Crushed-rock garden with islands of low-water vegetation. (from Jochim, 1987). B) Central lawn area accented by gravel edging.
Service, and your county office of Colorado State University Cooperative Extension Service. These agencies are listed at the end of this book. Local libraries, bookstores, and nurseries and garden centers, as well as various municipal agencies, are also good places to look for information on Xeriscaping.

**Landscaping with Mulch Covers**

An important component of Xeriscaping, especially for areas of swelling soils, is using **mulch** as a cover in selected areas of the yard. A mulch landscape consists of two parts, a geotextile fabric base and an overlying mulch cover. A good-quality geotextile fabric will control weeds and retard infiltration, but will still permit evaporation. The use of plastic sheeting is discouraged because it is impermeable and prevents normal evaporation from occurring. Mulches can be **organic** (bark, wood chips, etc.) or **inorganic** (boulders, cobbles, gravel, or crushed rock). An attractive, relatively low-maintenance landscape can be created by using **gravel edgings**, **rock gardens**, low-water ground cover, and perhaps a limited central area of lawn (Fig. 33).

One of the most effective ways to reduce infiltration of water next to a house foundation is to construct a **runoff slope** and cover it with a mulch landscape (Fig. 34). When used for this purpose, the mulch landscape should extend at least 5 feet out from the house. A perforated border or edging should be used to hold the outer edge of the liner in place, and to allow passage of free water away from the mulch area. Just remember, you still have to maintain good surface drainage and irrigation control, and not plant trees or shrubs too close to the foundation.

Replacing a lawn or garden with an organic or inorganic mulch landscape has some disadvantages. The most significant ones are listed as follows:

1. There is a marked increase in radiated heat and reflected sunlight in rock gardens and gravel lawns, especially in the summer. Trees or islands of vegetation will need to be tolerant of heat and resistant to sunscald.

2. There is an increase in surface runoff away from the house. This water must be properly drained through a system of slopes, swales, or ditches (see Chapter 3).

3. Organic mulches and certain types of rocks are so lightweight that they may wash...
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.
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.
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 create 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:

\[
\text{Slope} = \frac{y}{120} \times 100.
\]

EXAMPLE:

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

\[
\text{Slope} = \frac{6}{120} \times 100 = 5.0 \text{ percent}.
\]

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.
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 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
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

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 construction 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 checklist 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 doorway, heaving caused by swelling soils has probably occurred (Fig. 38). On the other hand, if the garage slab is flat and the driveway appears bowed and tilts toward the 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 infiltrate the soils beneath the flatwork, where it can cause or intensify swelling soil heaving. The condition of flatwork may rapidly worsen once cracks occur, even with moderately 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

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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.)
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 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

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."
REFERENCES
AND SUGGESTIONS
FOR FURTHER READING

Colorado Climate Center, 1984, Colorado Average Annual Precipitation 1951-1980: Colorado State University, Department of Atmospheric Science, map scale 1:500,000.
Colorado Division of Real Estate, 1995, Division of Real Estate manual.
Denver Water, undated, Great grasses! (pamphlet).
Denver Water Department, 1988, Xeriscape plant focus '88 (pamphlet).

Xeriscape Colorado!, Inc., undated, At home with Xeriscape (pamphlet).
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.


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.
The purpose of this book is to assist Colorado homebuyers and homeowners in reducing damage caused by swelling soils. Although risks from swelling soils cannot be completely eliminated, they can be significantly reduced through proper site investigation, design, construction, landscaping, and maintenance practices. An awareness of these topics may be critical for the Colorado homeowner whose house is built on swelling soils.