

# Locating the House on the Building Site

## Section 9.1

Basic Site Layout

## Section 9.2

Establishing Lines & Grades

### Chapter Objectives

After completing this chapter, you will be able to:

- **Create** a simple building layout, working from an existing reference line.
- **Identify** the basic types of surveying instruments and list their limitations.
- **Use** a builder's level to lay out a right angle.
- **Describe** how to set up batter boards.
- **Explain** how to measure a difference in elevation between two points using a level or transit.
- **Calculate** the volume of soil excavated for a house foundation.



### Discuss the Photo

**Surveying** Many surveying and layout tasks require two people to work together as a team. *What features of this instrument allow one person to complete the task?*



### Writing Activity: Step-by-Step Directions

Many locating tasks have step-by-step directions. Preview the step-by-step activities in this chapter. Then, create step-by-step directions for a simple task, such as hammering a nail into a board.

# Chapter 9 Reading Guide



## Before You Read Preview

Before a house can be built, its location on the plot of land must be accurately established. Choose a content vocabulary or academic vocabulary word that is new to you. When you find it in the text, write down the definition.

### Content Vocabulary

- plot plan
- station mark
- porosity
- site layout
- batter board
- overdig
- theodolite
- differential leveling
- bench mark
- bearing capacity

### Academic Vocabulary

You will find these words in your reading and on your tests. Use the academic vocabulary glossary to look up their definitions if necessary.

- methods
- locate
- visible

### Graphic Organizer

As you read, use a chart like the one shown to organize content vocabulary words and their definitions, adding rows as needed.

Content Vocabulary	Definition
theodolite	a transit that reads horizontal and vertical angles electronically

Go to [glencoe.com](http://glencoe.com) for this book's OLC for a downloadable version of this graphic organizer.

### Academic Standards



#### Mathematics

**Measurement:** Apply appropriate techniques, tools, and formulas to determine measurements (NCTM)  
**Geometry:** Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships (NCTM)



#### English Language Arts

Use information resources to gather information and create and communicate knowledge (NCTE 8)



#### Science

**Science and Technology:** Abilities of technological design (NSES)  
**Science in Personal and Social Perspectives:** Science and technology in local, national, and global challenges (NSES)

#### Industry Standards

Measuring Distance  
 Leveling  
 Site Layout

**NCTE** National Council of Teachers of English  
**NCTM** National Council of Teachers of Mathematics

**NSES** National Science Education Standards

## Basic Techniques

### What is a reference line?

The **plot plan** is the part of the house plans that shows the location of the building on the lot, along with related land elevations (see Section 2.3). The location of the building must then be marked out on the land itself, in a process referred to as **site layout**. This may be done by a surveyor or by a builder familiar with basic surveying **methods**.

The purpose of site layout is to position the house correctly on the lot. The position of the house on the site must meet local building and zoning codes. Other factors also apply, such as the placement of utilities. The position may have been chosen to take advantage of views, to increase privacy, or to avoid a site feature such as a ledge (area of rock below grade) or a stream.



### Build It Green

The position of the house may also have been chosen to maximize solar heat gain for increased energy efficiency, as shown in **Figure 9-1**.



**Figure 9-1 Solar Electricity**

**Using the Sun** This house uses photovoltaic panels to generate electricity from the sun. For these to work efficiently, the house must be placed properly on the lot.

Two basic methods can accurately determine the location of a proposed building on a property:

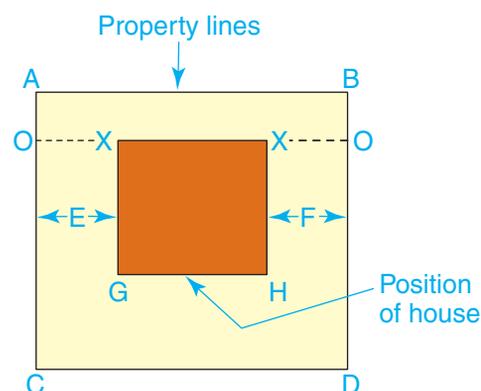
- Measuring from an existing reference line.
- Using a surveying instrument such as a level or a transit.

### Measuring From a Reference Line

A building may be planned so that it is parallel to an existing line, such as a street or marked property line. Such a line can then be used as a guide, or *reference line*. This makes it possible to stake out the site without using a surveying instrument. When working in this way, it is best to make a drawing of the property first. Such a drawing is shown in **Figure 9-2**. Rectangle ABCD represents the property lines, and boundary AB is the reference line.

### Using Surveying Instruments

When a building cannot be laid out by working from reference lines, the builder or surveyor can use one of several kinds of surveying instruments. These instruments work with either optical or laser technology, though some are based on GPS (global positioning system) technology.



**Figure 9-2 Staking a Building**

**Simple Layout** Staking out a rectangular building without the use of a surveying instrument.

Users of optical instruments rely on line-of-site observations to determine position. The user must look through the instrument's telescope to spot a target or leveling rod held by an assistant. A *leveling rod* is a slender, straight rod marked with graduations in feet and fractions of a foot. The rod is held in a vertical position during use.

Laser instruments do not have a telescope. Instead, a highly focused beam of light is aimed at the target. The user does not need to look through the instrument, so an additional person is not required. One person can set up the laser and then move to another portion of the site and determine level by holding an electronic detector against a leveling rod. When the detector senses the reference plane projected by the laser, it signals the user with a light or sound. The disadvantage of a laser instrument is that its light can be difficult to see in bright daylight.

GPS instruments are the newest development in surveying systems. GPS stands for *global positioning system*. GPS consists of two parts, handheld instruments and 24 satellites evenly distributed around Earth's orbit. Each of these satellites transmits a unique signal, and when a GPS instrument receives several signals, it is able to **locate** its position on Earth's surface with great accuracy. These systems are much more expensive than optical or laser surveying instruments, but they are being used increasingly for construction site layouts.

## Types of Instruments

The two basic types of surveying instruments commonly used in residential construction are *levels* and *transits*. Both sit atop a tripod.

**Levels** The telescope of a level is fixed in a horizontal plane. It can be used only for measuring horizontal angles because it cannot be tilted up or down. It can only be turned from side to side. This is sufficient for most building layouts. There are three types of levels.

A *builder's level*, shown in **Figure 9-3**, is sometimes called a *dumpy level*. It is the least expensive surveying instrument. It must be set up carefully to ensure accurate results. A good quality model is usually accurate to within  $\pm\frac{1}{4}$ " at a distance of 75'.

An *automatic level*, as shown in **Figure 9-4**, automatically adjusts for variations in setup. It takes less time and effort to set up than a builder's level. It is also more accurate, usually to  $\pm\frac{1}{4}$ " at 100'. Some are accurate to  $\pm\frac{1}{16}$ " at 200'.

A *laser level*, as shown in **Figure 9-5** on page 238, does not have a telescope, but is set up on a tripod like other levels. It projects its intense beam of light along a horizontal plane. The light shows up as a small red dot at great distances. Some models continually rotate atop the tripod. They project what appears to be a solid, level line around the job site. Other laser levels can be



**Figure 9-3 Builder's Level**  
**Least Expensive** A builder's level is suitable for small or simple layout tasks.



**Figure 9-4 Automatic Level**  
**Improved Accuracy** An automatic level is more accurate than a builder's level.



**Figure 9-5 Laser Level Remote Control** A laser level makes it possible for one person to determine elevation points.

rotated as needed using a remote control. Some laser levels use an audible sound to signal a certain level point.

**Transits** The transit, shown in **Figure 9-6**, is sometimes called a transit level. Unlike the telescope of a level, the telescope of the transit can be moved up and down as well as from side to side. A transit can measure horizontal angles and vertical angles as well. It can also be used to determine if a post or wall is plumb.



**Figure 9-6 Transit Plumb and Level** A transit can be used for site layout but can also determine if parts of the building are plumb.

A transit is classified by the smallest increment that can be read on its *vernier scale*. (A vernier scale slides along a longer scale.) The graduations on a vernier scale are in minutes or seconds. A transit may be referred to as a five-minute transit, a one-minute transit, or a twenty-second transit. Measurements made in seconds are more accurate. A **theodolite**, as shown in **Figure 9-7**, is a transit that reads horizontal and vertical angles electronically. It needs no vernier scale. It displays the measurements on an LCD (liquid-crystal display) screen. It is used when extremely accurate measurements are required. A device called an electronic field book can be attached to a theodolite to store information. A theodolite is easy to set up.

### Reading Check

**Recall** What are the two tools used to determine the location of a building on the site?

### Basic Layout with a Level or Transit

Most of the basic layouts described on the following pages can be made with a level.



**Figure 9-7 Theodolite Tracking Information** This surveyor is entering information into a theodolite, or electronic transit. *What information might be entered?*

## Step-by-Step Application

**Leveling a Transit Head** After you have chosen a position for the transit or level, level the instrument's head:

**Step 1** Loosen the horizontal clamp screw and turn the telescope until the bubble is in line with one set of opposing leveling screws. Grip the screws, one in each hand, using a thumb and forefinger. Loosen one screw as you tighten the other to center the bubble. Keep the screws snug on the foot plate but do not overtighten them. Continue to adjust the screws until the bubble is centered. See **Figure 9-8**.

**Step 2** Rotate the telescope 90° so that it is over the second set of leveling screws and repeat the process described in Step 1.

**Step 3** Return the telescope to the first position. Check the bubble to be sure it is centered, and readjust if necessary. Recheck the second position.

**Step 4** Continue to check the bubble in both positions until it is within one graduation on either side of center in the bubble tube.

 Go to [glencoe.com](http://glencoe.com) for this book's OLC for additional step-by-step procedures, applications, and certification practice.

All of them can be made using a transit. The same concepts apply to the use of other surveying instruments, although layout methods will differ.

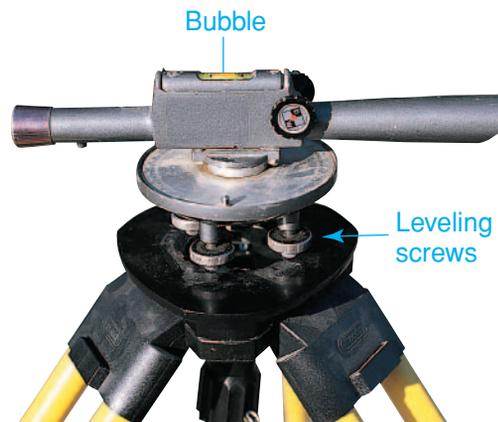
**Locating a Bench Mark** To lay out a building using a transit or a level, you must first have a basic starting point. This starting point, from which measurements can be made, is usually called the **bench mark**, or *point of reference (POR)*. A bench mark may be a mark on the foundation of a nearby building. More often it is a stone or concrete marker placed on the ground at a certain location. The location of the bench mark may appear on the architect's drawings. If so, the plans will usually be oriented to that point.

**Setting Up a Transit or Level** Set up the transit or level in a position outside the expected flow of activities on a job site. This will prevent it from being accidentally disturbed.

The point over which the level is directly centered is called the **station mark**. The layout is sighted from this point. The station mark may be a bench mark or a corner of the lot, but it should be where the lot can be conveniently sighted. (If the bench mark and the station mark are not the same, be sure you can sight the bench mark easily.)

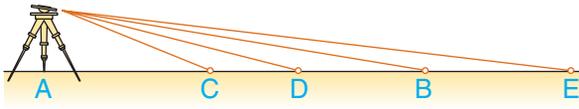
A plumb bob is suspended from a hook beneath the head of the instrument. Use this plumb bob to center the level or transit directly over the station mark. Adjust the tripod so that it rests firmly on the ground, with the telescope at eye level.

Once a level or transit has been properly set up, be careful not to move or jar the tripod. If this occurs, the instrument must be readjusted. Some or all of the sightings may have to be redone.



 **Figure 9-8 Leveling Controls**

**Level with Care** The level of the head of the instrument can be adjusted by using the leveling screws and checking the bubble.



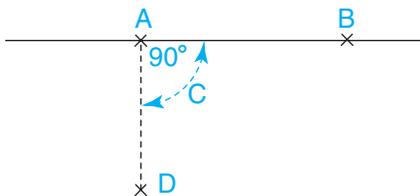
**Figure 9-9 Points on a Line**  
Using a Transit Establishing points on a line.

Surveying measurements are based on degrees of a circle. A circle is divided into 360 degrees. To increase the accuracy of surveying measurements, degrees are further subdivided into minutes and seconds. A minute is  $\frac{1}{60}$  of a degree. A second is  $\frac{1}{60}$  of a minute.

**Establishing Points Along a Line** To establish points along a line, you must use a transit. Use the plumb bob to center the transit accurately over one point on the line. Then level the instrument. Sight the telescope on the most distant visible point along the same line. Lock the horizontal clamp screw to hold the telescope in position. Then adjust the instrument to place the vertical crosshair exactly over the distant point. Now, by tipping the telescope up or down, you can determine the exact location of any number of points on the line, as shown in **Figure 9-9**.

**Laying Out a Right Angle** Using a plumb bob, set up the level or a transit directly over the point where the right angle is to be located. This is Point A in **Figure 9-10**. Sight a reference point along a base line and set the  $360^\circ$  scale to zero. The reference point is Point B, and the base line is  $\overline{AB}$ . Turn the telescope until the scale indicates that an arc of  $90^\circ$  has been completed.

Next, place a leveling rod in a vertical position along this second line at the desired distance, as shown in **Figure 9-11**. This is shown as Point D in **Figure 9-10**. A line drawn



**Figure 9-10 Right Angle**  
Swing an Arc Laying out a right angle with a transit or a level.

from Point A to Point D will be perpendicular to the base line. Thus a right angle is formed where the lines intersect at Point A.

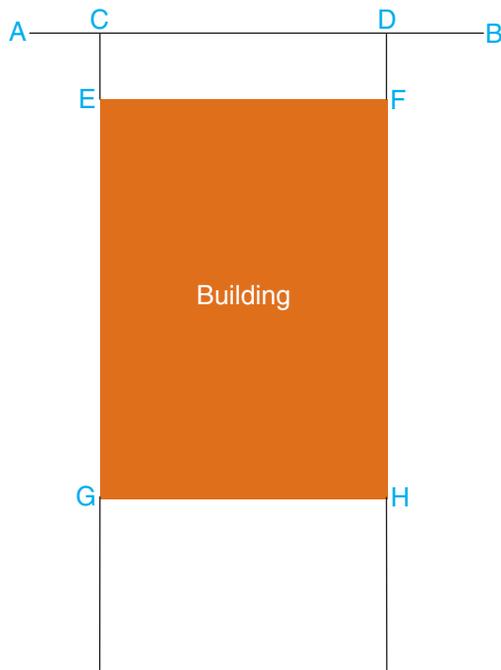
For accurate work, a spirit level (carpenter's level) may be attached to the leveling rod to check if the rod is being held plumb. The rod can also be kept plumb by aligning it with the vertical crosshair in the telescope. The person at the telescope can tell the rod holder which way to move the top of the rod in order to make it plumb. The rod holder should move the target up or down until the crossline on the target aligns with the crosshair sights in the telescope.

**Laying Out a Simple Rectangle** To perform this operation you must work from an existing line such as a road, street, or property line. In **Figure 9-12** on pge 241, this reference line is shown as  $\overline{AB}$ . Locate the point (C) that represents the side limit for a front corner of the building. Set up the level or transit at Point C. Lay out a simple rectangle parallel to the existing line as follows:

1. Set the telescope at Point C to sight down line  $\overline{AB}$ .
2. Measure from Point C to establish Point D. This dimension will be found on the



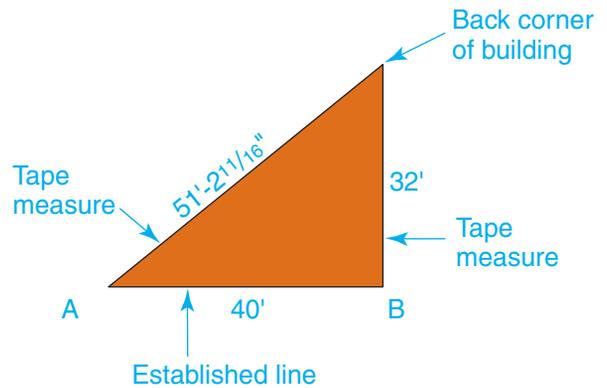
**Figure 9-11 Leveling Rod**  
Locating the Target The target on the leveling rod can be moved up or down. The rod is divided into whole feet, tenths, and hundredths of a foot.



**Figure 9-12 Rectangle Layout: Method #1**  
**Basic Layout** Laying out a square or rectangular building with a level or transit.

- building plans. It represents the width of the building.
3. Turn the telescope  $90^\circ$  and establish Points E and G by measurement.
  4. Move the level or transit to Point D and sight through the telescope to Point C.
  5. Turn the telescope  $90^\circ$  and establish Points F and H by measurement.
  6. Points E and F represent the front corners of the building. To check your accuracy, measure lines  $\overline{EF}$  and  $\overline{GH}$ . They should be the same length. Check the layout for square by measuring diagonally from Point E to point H, and from Point F to Point G. If these two measurements are identical, the layout is square.

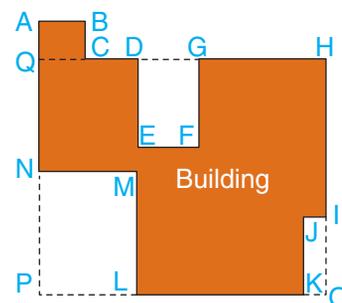
Another method of laying out a rectangular project is to figure the diagonal of the rectangle, as shown in **Figure 9-13**. After one side of the project is established ( $\overline{AB}$ ), usually the front setback line, the rectangle can be laid out accurately by using two long tape measures. The side and end measurements are input as *rise* and *run* into a construction



**Figure 9-13 Rectangle Layout: Method #2**  
**Using Two Tapes** Measure from each end of the established line AB. The back corner will be where the diagonal measurement ( $51'-2\frac{11}{16}''$ ) and the end measurement (32') intersect.

calculator, and the diagonal of the rectangle is figured automatically. Using one tape measure, measure the desired distance from one end of line AB. Then, with a second tape measure, measure the diagonal. The lines will intersect precisely at one of the corners. Do this from both ends of the established line and a perfect rectangle is established. The example in **Figure 9-13** shows a house that is 40' long and 32' deep. It has a diagonal of  $51'-2\frac{11}{16}''$ .

**Laying Out an Irregularly Shaped Building** When the building is not regular in shape, it is usually best to start by laying out a large rectangle that will take in all or most of the building. This is shown in **Figure 9-14** as QHOP. After the large rectangle is established,



**Figure 9-14 An Irregular Shape**  
**Multiple Shapes** Laying out an irregularly shaped building made of a series of squares and rectangles.

the remaining portion of the layout will consist of small rectangles. Each small rectangle can be laid out and proved separately. These rectangles are shown as NMLP, ABCQ, DGFE, and JIOK.

Even if the outline of a building is not a rectangle, the process for establishing each point is basically the same. More points must be located, and the final check is more likely to reveal a small error.

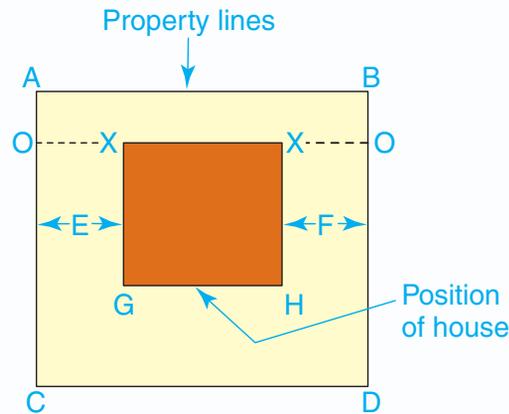
## Step-by-Step Application

**Staking Out the Site** To stake out the site in the drawing, proceed as follows:

**Step 1** Check the plot plan to find the setback distance. The *setback distance* is the minimum space allowed by local codes between a house and the property lines. Codes also specify setback distances between the house and utility lines, streams, and ponds. Along boundaries  $\overline{AC}$  and  $\overline{BD}$ , measure this distance back from front line  $\overline{AB}$ . In the drawing, the setback is shown by segments  $\overline{AO}$  and  $\overline{BO}$ .

**Step 2** Stretch a line tightly between the points marked O. The front corners of the building will be located on line  $\overline{OO}$ . There are two ways to locate them. You can obtain the measurement from the plot plan to see how far the corners should be from the side boundaries. Then, along line  $\overline{OO}$ , measure the indicated distances in from  $\overline{AC}$  and  $\overline{BD}$ . Xs represent the front corners of the building in Figure 9-2. If the building is to be centered between the side boundaries, you need not refer to the plot plan. Instead, subtract the length of the building from the length of  $\overline{OO}$ . Then measure half this distance in from each end of  $\overline{OO}$ . Measure the distance between the two points marked X and check this distance with the plans. The distance  $\overline{XX}$  represents the length of the building. It must be accurately measured and match the length on the plans.

**Step 3** Check the plans to determine the depth of the building (how far back it will extend from the front corners). Mark off the depth by extending lines back from the two points marked X. If the boundary lines of the lot form a  $90^\circ$  angle at the corners, these lines should be parallel to  $\overline{AC}$  and  $\overline{BD}$ . Note that E is the same as  $\overline{OX}$ , and F is the same as  $\overline{XO}$ . Thus, E and F show the distance between the sides of the building and the side boundary lines of



the lot. Points G and H represent the rear corners of the building.

**Step 4** The boundary lines of the lot may not be at right angles to each other. If this is the case, you will need to first establish the corner of the building that will be closest to a boundary line. Next, make certain that the minimum front and side yard requirements are established from this point. Then lay out the building by using the methods described on page 240, "Laying Out a Right Angle" and "Laying Out a Simple Rectangle." Establish a line to indicate the rear of the building. This is shown by  $\overline{GH}$  in Figure 9-2.

**Step 5** If the building is complicated, divide it into smaller rectangles. Establish more lines such as  $\overline{OO}$  to indicate the front of each rectangle. You can get the necessary information from the plans. Then carry out the same steps to establish the rest of each rectangle. The result will be a group of adjoining rectangles that will show the total outline of the building.



Go to [glencoe.com](http://glencoe.com) for this book's OLC for additional step-by-step procedures, applications, and certification practice.

 **After You Read: Self-Check**

1. What is a plot plan?
2. Name one advantage of surveying instruments based on laser technology.
3. What is the difference between a level and a transit?
4. What is the purpose of the hook under a level or transit?

 **Academic Integration: Mathematics**

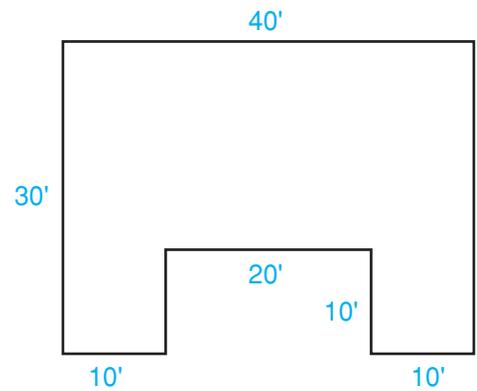
5. **Area of Irregular Shapes** Structures are not always regular shapes such as quadrilaterals. For example, some structures are L-shaped or U-shaped. The floor plan for the structure shown below is drawn to scale. Some of the dimensions on the floor plan are missing. Find all of the missing dimensions, then calculate the area of the structure.

**Math Concept** Area measures the size of a surface.

The area ( $A$ ) of a regular quadrilateral is calculated using the formula  $A = \text{length} \times \text{width}$ . You can calculate the area of an irregular shape below by dividing the shape into multiple rectangles.

**Step 1:** Divide the shape into a number of regular quadrilaterals.

**Step 2:** Calculate the sum of the areas of each shape that makes up the structure.



 Go to [glencoe.com](http://glencoe.com) for this book's OLC to check your answers.

**Establishing Lines & Grades****Lines & Grades***What is an excavation?*

After its location and alignment have been determined, a rectangle showing the outer dimensions of a structure is staked out. If the building is to form a simple rectangle, the staked-out area will follow the foundation line exactly.

**Grade**

The grade refers to the level of the ground where it will meet the foundation of the completed building. The grade is found on the building plans. Grade must be established accurately because it is used for making important measurements. From the grade, you can find the depth of

## Step-by-Step Application

**Setting Up Batter Boards** Refer to Figure 9-15. After the corners of the building have been located, set up the batter boards as follows:

**Step 1** Drive three 2×4 stakes at each corner of the building, at least 4' beyond the foundation lines.

**Step 2** Nail 1×6 or 1×8 boards to the stakes horizontally. The top of each board must be level. All boards must be level with each other. Use a level or transit to locate the height of the boards.

**Step 3** Stretch string across the tops of boards at opposite corners and align it exactly over the nails in the corner stakes. A plumb bob is handy for setting the lines.

**Step 4** Make a shallow saw kerf where the string overlaps the boards. This will keep the string from sliding. It will also make it easy to reposition the string if it must be temporarily removed to let equipment or machinery pass. Make similar cuts in all eight batter boards.

**Step 5** Tie the string to the boards, using the saw kerfs to position it (see Figure 9-16 on page 245). This establishes the lines of the house.

**Step 6** Check the diagonals again to make sure the corners are square. (The area for an L-shaped building can be divided into rectangles and the diagonal measurement of each rectangle can be checked.)

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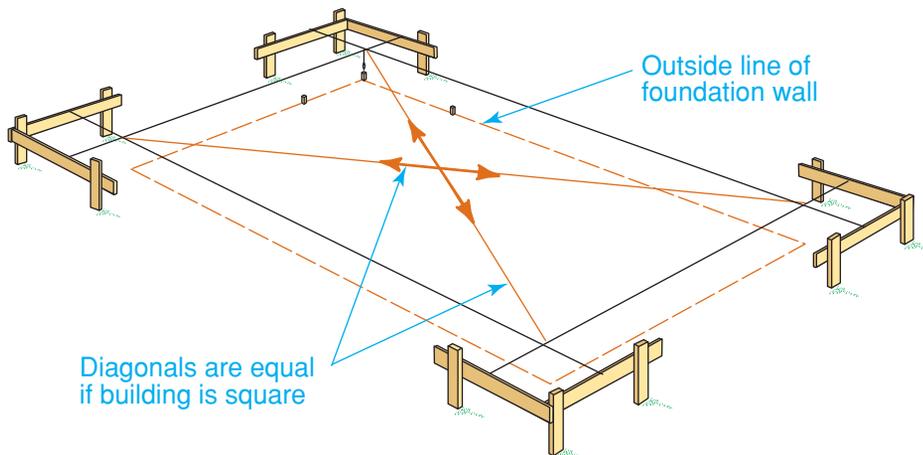
the excavation. An excavation is a cut, cavity, trench, or depression made by removing earth.

Sometimes the bench mark is used as a reference point for establishing the grade. At other times, the grade may be located in relation to the level of an existing street or curb. The grade is indicated on a stake driven into the ground outside the excavation area.

You can also use the grade to establish other points, such as the height of a foundation or the elevation of the first floor.

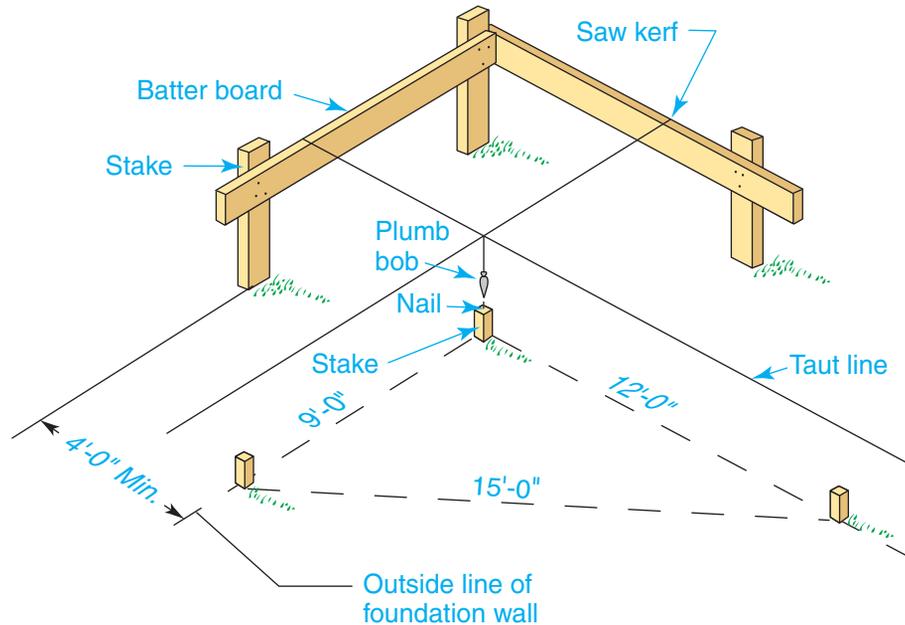
### Batter Boards

After the grade and the corners of the house have been established, building lines must be laid out as aids in keeping the work level and true. A **batter board** is a board



**Figure 9-15 Using Batter Boards**

**Building Outline** Using batter boards to establish the outline of the foundation wall. The top edge of a batter board represents the height of the foundation wall.



**Figure 9-16 Batter Board Detail**  
**Squaring a Corner** You can check that the corners of a layout are square by using the 3-4-5 system.

fastened horizontally to stakes placed to the outside of where the corners of the building will be located. These boards and the string tied between them locate and mark the outline of the building as shown in **Figure 9-15**. The height of the boards may be the height of the foundation wall. Before setting up batter boards, locate the corners of the building precisely by one of the methods already discussed. Drive nails into the tops of the stakes that indicate the outside edge of the foundation walls.

Setting up batter boards is explained in the Step-by-Step Application.

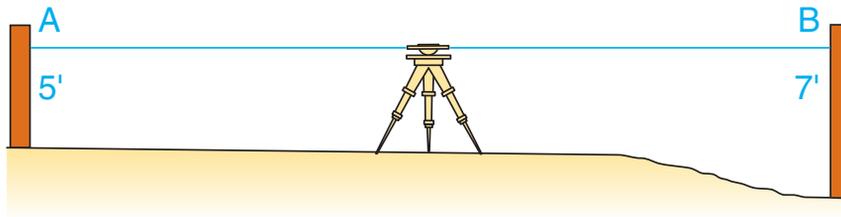
To be certain that the corners are square, use the following procedure:

1. Measure the diagonals of the completed layout to see if they are the same length, as shown in Figure 9-15.
2. The corners can also be squared by using the *3-4-5 method* shown in **Figure 9-16**. This is done by measuring a distance along one side in 3' increments, such as 6, 9, or 12.

3. Measure along the adjoining side in the same number of 4' increments (8, 12, or 16). The diagonal drawn between the end points will then measure in an equal number of 5' units (10, 15, or 20) when the unit is square. Thus, a 9' distance on one side and a 12' distance on the other should result in a 15' diagonal measurement if the corner is a true 90°.

### Land Elevations

Check the architect's plan to see where elevations are to be determined. Set up a level or transit. Be certain that the locations can be seen through the telescope. Place a leveling rod upright on any location to be checked. Then sight through the telescope at the leveling rod. Take a reading of where the horizontal crosshair in the telescope crosses the rod. Then move the rod to the second location to be established. Raise or lower the rod until the reading is the same as for the first point. The bottom of the rod is then at the same elevation as the original point.



**Figure 9-17 Elevation Difference #1**

**Points Visible** Obtaining the difference in elevation between two points that are visible from an intermediate point.

**Measuring a Difference in Elevation** To learn the difference in elevation between two points, such as A and B in **Figure 9-17**, set up a transit or level at an intermediate point. With the measuring rod held at point A, note the mark where the horizontal crosshair in the telescope crosses the rod. Then with the rod held at point B, sight the rod and note the point where the horizontal crosshair crosses the rod. In our example, the difference between the reading at A (5' 0") and the reading at B (7' 0") is the difference in elevation between A and B. Thus the ground at point B is 2' lower than the ground at point A. This technique can be used to position foundation footings and other points below grade.

Sometimes it is not possible to sight two points from a single point between them. A high mound can cause this difficulty. To solve this problem, one or more additional intermediate points, such as C and D shown in **Figure 9-18**, must be used for setting up

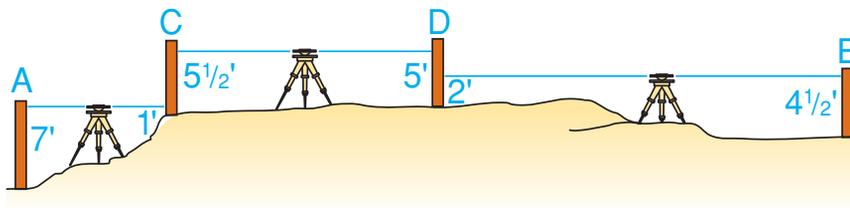
the instrument. The process of determining differences in elevation between points that are remote from each other is called **differential leveling**.



**Recall** What points can be established using the grade?

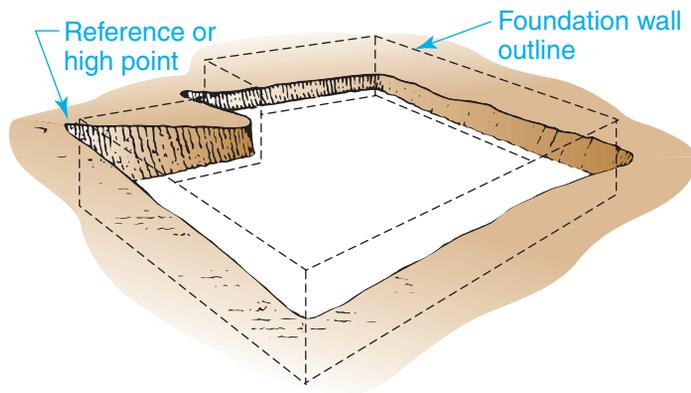
### Foundation Wall Height

The foundation wall footings must rest on firm soil below the frost line. Footings are continuous concrete pads that support a foundation wall. The depth of the frost line varies according to the local climate and is given in local building codes. This determines how deep the excavation must be. To determine this depth, it is common practice to use the highest point on the perimeter of the excavation as the reference point, as



**Figure 9-18 Elevation Difference #2**

**Points Not Visible** Obtaining the difference in elevation between two points not visible from a single intermediate point.



**Figure 9-19 Determining Excavation Depth**  
**Highest Point** To establish the depth of the excavation, use the highest point around the excavation as the reference point.

shown in **Figure 9-19**. This is true for both graded and ungraded sites.

Good drainage is ensured if sufficient foundation height is allowed for the sloping of the finish grade, as shown in **Figure 9-20**. *Finish grade* is the level of the ground when grading is completed. Foundation walls at least 7'-4" high are necessary for full basements, and 8' walls are common.

The top of the foundation wall must be at or above a minimum height set by code. This distance is often at least 8" above the finished grade, but this may vary with local code. This allows the siding and framing members to be protected from soil moisture and places them well above the grass line. In termite-infested areas, this makes it possible to observe signs of any termite activity between the soil and the wood. Protective measures can then be taken before the wood is damaged.

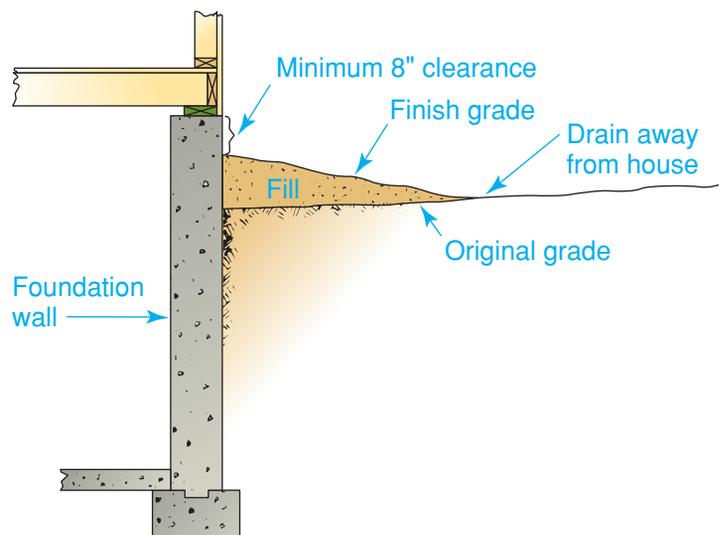
Crawl spaces should have enough height to permit inspections for termites and to allow plastic soil covers to be installed. Soil covers reduce the effect of ground moisture on framing members. Ordinarily, there should be at least 18" between the undersides of the joists and the highest point of ground enclosed by the foundation walls.

If the ground beneath the structure is excavated or is otherwise lower

than the outside finished grade, measures must be taken to assure good drainage. The finished grade should always slope away from the house, as shown in **Figure 9-20**. Below-surface drainage systems might also be required.

## The Excavation

Any variation from standard construction practices increases the cost of the foundation and footings. This might influence the design of the house. Before excavating for a new home, subsoil conditions should be determined by test borings or by obtaining soil samples in some other way. This has several purposes. It helps the excavators to determine whether any special precautions will be necessary. Unusually soft or hard soil conditions may call for special excavation techniques or equipment. It is also important to know the bearing capacity of the soil. **Bearing capacity** is a measure of how well the soil can support the weight of a house. Another purpose of soil testing



**Figure 9-20 Proper Drainage**  
**Finished Grade** Added fill brings the finish grade above the original grade and ensures drainage away from the house.

is to determine its porosity. **Porosity** is the measurement of the ability of water to flow through the soil. If the soil does not drain well, additional material may have to be excavated and replaced with better soil.

Test borings will also identify problems that could significantly affect the cost of the house. A rock ledge may require costly removal. A high water table may require design changes from a full basement to a crawl space or concrete slab construction. If there has been a previous excavation on the site, the soil may have been disturbed and may not have sufficient bearing strength for footings.

Several types of earth-moving equipment, such as a power shovel or backhoe, can be used for basement excavations. Topsoil is often stockpiled by a bulldozer, a front-end loader, or a grader for future use, as in **Figure 9-21**. Power trenchers are often used in excavating slab footings or shallow foundation walls.

It is best to excavate only to the top of the footings or the bottom of the basement floor. The soil must be stable enough to prevent cave-ins, and some soil becomes soft upon

**JOB SAFETY**

**CALL BEFORE YOU DIG** Utility lines that are accidentally severed can pose a serious risk to workers. Before excavating, contact the local utility companies for information about the location of sewer, telephone, fuel, electric, water, or cable lines that may cross the area. Locations should then be clearly marked.

Go to [glencoe.com](http://glencoe.com) for this book's OLC for more on job safety.

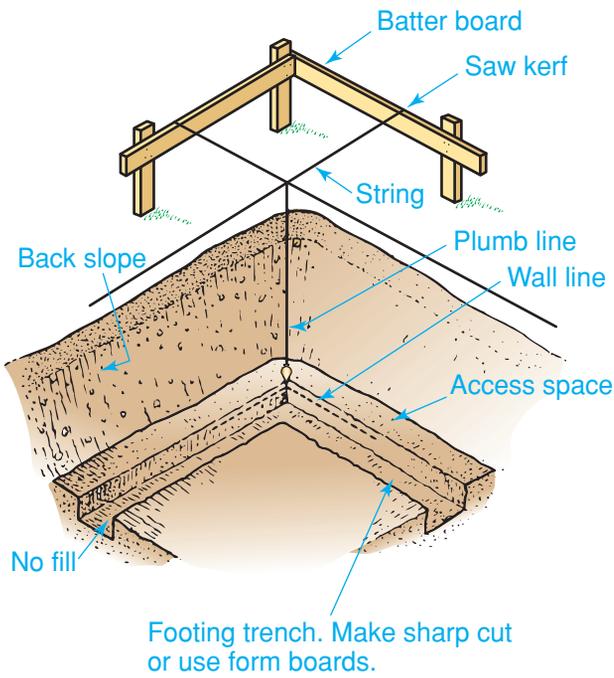
exposure to air or water. Thus, unless form boards are to be used, it is advisable not to make the final excavation for footings until it is nearly time to pour the concrete.

The excavation must be wide enough to provide space to work, as shown in **Figure 9-22**. For example, there must be enough room to install and remove concrete forms, to lay up block, to waterproof the exterior surfaces of the walls, and to install foundation drainage. **Overdig** is the term used to describe the additional excavation needed to provide clearance for work. The sides of the



**Figure 9-21 Grading the Site**

**Stockpiling Topsoil** A grader being used to strip the topsoil from a building site in preparation for excavating the basement.



**Figure 9-22 Excavation Detail**

**Back Slope** The basement excavation is back-sloped to prevent cave-ins. Note the use of the plumb line for accurately locating the foundation wall line.

excavation may have to be sloped to prevent them from caving in. This is sometimes called *back slope*. The steepness of the back slope of the excavation is determined by the type of subsoil.

Once soil is excavated, the sides of the excavation are exposed to the weather. They will dry out and may become unstable. Allow sufficient overdig and back slope to reduce the hazards. Follow OSHA regulations for slopes and check local building codes for information regarding soil types.

When excavating for basements, some contractors *rough-stake* only the outline of the building to indicate where earth must be removed. When the proper elevation has been achieved for the basement floor, the footings are laid out and the final excavation dug. After the footings have been placed and the concrete has hardened somewhat, the building wall outline is

## JOB SAFETY

**ESCAPE ROUTES** Any excavation or trench that is more than 4' deep must be provided with a stairway, ladder, ramp, or other safe means of escape. This includes foundation excavations. The escape devices must be within 25' of a worker.

Go to [glencoe.com](http://glencoe.com) for this book's OLC for more on job safety.

established on the footings and marked to indicate the position of the formwork or concrete block wall.

Excavation costs are based on the total cubic yards of earth to be removed. To determine the volume of material, multiply the length of the excavation times the width times the depth. Calculating is usually done in decimals. See **Table 9-1** for conversion figures and **Table 9-2** on page 250 for excavating features for standard depths.

Inches	Feet
1	0.083
2	0.167
3	0.250
4	0.333
5	0.417
6	0.500
7	0.583
8	0.667
9	0.750
10	0.833
11	0.916
12	1



This estimating and planning exercise will prepare you for national competitive events with organizations such as SkillsUSA and the Home Builder's Institute.

## Excavation Volume

### Excavation Costs

Multiply the length of the excavation times the width times the depth to determine the volume of the material to be removed.

- For the house shown in the floor plan below, multiply 7' (depth of excavation) times 30' (26' width of house plus 2' clearance at each end, between the excavation and the outside of the foundation wall) times 44' (40' length of house plus 2' clearance at each end). The answer is 9,240 cubic feet.
- There are 27 cubic feet in 1 cubic yard. To convert cubic feet to cubic yards, divide by 27:

$$9,240 \div 27 = 342.2$$

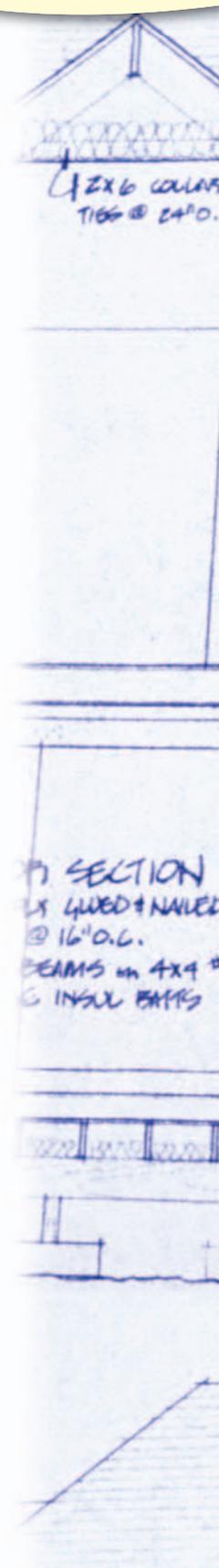
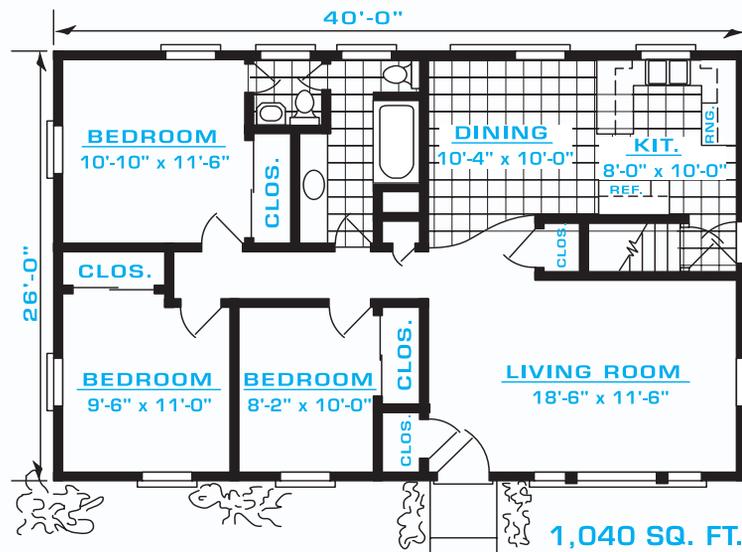
Rounded off, approximately 342 cubic yards of material will have to be excavated.

There is another method to determine the cubic yards of material to be removed. It can be used if the excavation depth is a standard one as shown on Table 9-2.

- Refer again to the floor plan. The excavation needed for this house is 30' wide, 44' long, and 7' deep. Multiply the width by the length to find the area of the excavation.
- Refer to Table 9-2. For an excavation 7' deep, 0.259 cubic yards of material are removed for each square foot of area. Multiply the area of the excavation by 0.259 to find how many cubic yards of material will be removed. Round up.

Depth per Square Foot	Cubic Yards Removed	Depth per Square Foot	Cubic Yards Removed
2"	0.006	4'-6"	0.167
4"	0.012	5'-0"	0.185
6"	0.018	5'-6"	0.204
8"	0.025	6'-0"	0.222
10"	0.031	6'-6"	0.241
1'-0"	0.037	7'-0"	0.259
1'-6"	0.056	7'-6"	0.278
2'-0"	0.074	8'-0"	0.298
2'-6"	0.093	8'-6"	0.314
3'-0"	0.111	9'-0"	0.332
3'-6"	0.130	9'-6"	0.350
4'	0.148	10'-0"	0.369

*Note: To find the factor, first locate the excavation depth. The factor is in the column to the right.*



**Trenches** The amount of material that will be removed from trenches, such as those trenches that might be dug for utilities, can be calculated by using **Table 9-3**. For example, if a trench is to be 42" deep and 18" wide, the table shows that 19.4 cubic yards of material will be removed for every 100 lineal feet. Such a trench might be dug for a house with a 30' setback. To determine how much material would be removed, multiply 19.4 by 0.30 (because 30' is about 0.30 of 100'). The answer is that 5.82 cubic yards of material would be removed.

**Table 9-3: Cubic Yard Content of Trenches per 100 Lineal Feet**

Depth in Inches	Trench Width in Inches						
	12	18	24	30	36	42	48
6	1.9	2.8	3.7	4.6	5.6	6.6	7.4
12	3.7	5.6	7.4	9.3	11.1	13.0	14.8
18	5.6	8.3	11.1	13.9	16.7	19.4	22.3
24	7.4	11.1	14.8	18.5	22.2	26.0	29.6
30	9.3	13.8	18.5	23.2	27.8	32.4	37.0
36	11.1	16.6	22.2	27.8	33.3	38.9	44.5
42	13.0	19.4	25.9	32.4	38.9	45.4	52.0
48	14.8	22.2	29.6	37.0	44.5	52.0	59.2
54	16.7	25.0	33.3	41.6	50.0	58.4	66.7
60	18.6	27.8	37.0	46.3	55.5	64.9	74.1



**Mathematics: Measurement**

**Volume** How many cubic yards of material will be removed for a trench that is 24" deep, 24" wide, and 100 lineal feet long?

**Starting Hint** Consult Table 9-3.

**Section 9.2 Assessment**



**After You Read: Self-Check**

1. What are three possible reference points for establishing a grade?
2. What is a batter board and what is its purpose?
3. Briefly describe the process of identifying the difference in elevation between two points.
4. What is overdig?



**Academic Integration: Science**

5. **The Water Table** During excavation, soil samples must be obtained to identify any potential problems that could significantly affect the cost of construction. For example, a high water table may require design changes from a full basement to a crawl space or concrete slab construction. Find out more about the science of the water table. Write a few sentences about your findings. Be sure to define *water table*, then explain the difference between the saturated zone and the unsaturated zone.



Go to [glencoe.com](http://glencoe.com) for this book's OLC to check your answers.

# Review and Assessment

## Section

## 9.1

## Chapter Summary

A house can be positioned or located on a piece of property either by measuring from an established reference line or by using an instrument such as a level or a transit. Most layouts begin at a bench mark. Surveying instruments include levels and transits. The point at which they are set up is called the station mark.

## Section

## 9.2

String stretched between batter boards is used to establish the outline of a house. Once this has been done, the excavation can proceed. The excavation must be wide enough to provide space to work. Soil taken from an excavation is measured in cubic yards.

## Review Content Vocabulary and Academic Vocabulary

1. Use each of these content vocabulary and academic vocabulary words in a sentence or diagram.

### Content Vocabulary

- plot plan (p. 236)
- site layout (p. 236)
- theodolite (p. 228)
- bench mark (p. 239)
- station mark (p. 239)

- batter board (p. 244)
- differential leveling (p. 246)
- bearing capacity (p. 247)
- porosity (p. 248)
- overdig (p. 248)

### Academic Vocabulary

- methods (p. 236)
- locate (p. 237)
- visible (p. 240)

## Speak Like a Pro

### Technical Terms

2. Work with a classmate to define the following terms used in the chapter: *reference line* (p. 236), *leveling rod* (p. 237), *builder's level* (p. 237), *dumpy level* (p. 237), *automatic level* (p. 237), *laser level* (p. 237), *vernier scale* (p. 238), *3-4-5 method* (p. 245), *finish grade* (p. 247), *back slope* (p. 249), *rough-stake* (p. 249).

## Review Key Concepts

3. **Describe** how to work from an existing reference line to establish a simple building layout.
4. **Describe** the different types of surveying instruments.

5. **Demonstrate** how to use a builder's level to lay out a right angle.

6. **Demonstrate** how to set up batter boards.

7. **Explain** how to use a transit or level to measure a difference in elevation between two points.

8. **Explain** how to determine the depth of an excavation for a house foundation.

## Critical Thinking

9. **Infer** How could you best keep the cost of foundations and footings for a building at a minimum?

## Academic and Workplace Applications

### STEM Mathematics

- 10. Finding Volume** A rectangular excavation 5' deep is needed to build a building that is to be 26' by 32'. How many cubic yards of material should be removed if a 2' clearance is needed outside the foundation walls?

**Math Concept** The formula for finding the volume of a rectangular prism is  $V = lwh$ . To determine the actual dimensions of the excavation, draw a picture and label the length and width to account for the building and the clearance all around.

**Step 1:** Draw a picture of the dimensions of the building. Then add the clearance.

**Step 2:** Multiply the length by the width. Then multiply the result by the depth of the excavation.

**Step 3:** Use cubic units to express the volume of the material. Convert cubic feet to cubic yards.

### STEM Engineering

- 11. Measurement Accuracy** A surveyor makes a measurement of  $60\frac{1}{2}'$  using a laser measure. It is accurate to within  $\pm\frac{1}{4}"$ . What is the range within which the actual length could fall?

**Starting Hint** All measurements fall within a range of accuracy depending on the size of the smallest mark on the measuring device used and the quality of the device. Determine the lower end of the range by subtracting the accuracy factor.

### 21st Century Skills

- 12. Career Skills: Problem Solving** You are a member of a surveying crew that has been hired to survey a building site this Saturday. On Friday evening, the other two members of your crew call to inform you

that they will not be able to work on Saturday. The job needs to be completed before Monday. You were planning on working with your crew members and have all of the optical instruments ready to use. Now you will have to determine how you will complete the surveying job alone. Describe what changes you can make in order to complete the job yourself in a one-page summary. Identify the equipment you will need and explain why this equipment will be suitable for the situation.

### Standardized TEST Practice



#### Multiple Choice

**Directions** Choose the phrase that best completes the following statements.

- 13.** The top edge of a batter board represents the \_\_\_\_\_.  
a. depth of the foundation wall  
b. outside edge of the foundation wall  
c. height of the foundation wall  
d. width of the foundation wall
- 14.** A measure of how well the soil can support the weight of a house is called \_\_\_\_\_.  
a. a bench mark  
b. the bearing capacity  
c. an overdig  
d. the station mark
- 15.** The purpose of a site layout is to \_\_\_\_\_.  
a. position a house correctly on the lot  
b. determine the depth of an excavation  
c. locate a bench mark  
d. maximize solar heat gain

#### TEST-TAKING TIP

*Skipping a question when you do not know the answer can waste valuable time. A better strategy is to mark the answer you believe to be correct and come back to the question after you finish the test.*

\*These questions will help you practice for national certification assessment.