Lab Manual
to Accompany

LANDSCAPE CONSTRUCTION
Second Edition

DAVID SAUTER
Lab Manual to Accompany Landscape Construction

Second Edition

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Landscape construction can be difficult to learn without the opportunity to practice construction techniques. While instructional methods such as lectures, written assignments, and demonstrations are important, they fail to capture the type of pragmatic learning that happens when work is actually performed. The variability of sites, materials, and work settings necessitates that students practice landscape construction skills before facing real-life projects. The purpose of this lab manual is to offer a set of exercises designed to provide instruction and practice in the basic techniques of the profession.

**EMPHASIS ON BASIC CONSTRUCTION TECHNIQUES**

Attempting to walk onto a site and execute a landscape design without knowledge of the fundamentals of contracting is a prelude to disaster and disappointment. Like any other occupation, landscape contracting requires the development of a basic set of skills, which then leads to success in higher-level activities. Operation of equipment, working with materials, and performing essential functions should be mastered before combining these basics into comprehensive construction techniques.

The scope of techniques presented in *Landscape Construction* includes both basic and advanced activities. Because of the need to develop fundamental skills, this lab manual does not provide a practice exercise for every construction technique presented in the textbook.

This lab manual presents a set of exercises that covers core construction techniques referenced in the textbook. Primary exercises focus on performing basic math calculations, operating construction tools, cutting materials, and laying out site improvements. Later exercises build upon these fundamentals to teach basic drainage techniques, wall construction, stair construction, paving, and carpentry. Once mastered, these skills are a foundation for more advanced and complex landscape contracting.

**SAFETY IN THE WORKPLACE**

When engaged in the activities suggested in this manual, it is critical that safety be a primary concern. Hazards exist in the site, the activities, the materials, the equipment, and many other aspects of landscape construction. Awareness of the potential hazards and engaging in the means necessary to prevent accident and injury will enhance enjoyment of the profession.

Review the contents of Chapter 6, Safety in the Workplace, of *Landscape Construction* before beginning any activity in this manual.

**LAB MANUAL ORGANIZATION**

When appropriate, the following information is provided for each exercise:

- **Title of exercise**
- **Objective of exercise:** A general statement of the educational competencies to be attained upon successful completion of the exercise.
- **Cautions:** The potential for injury exists in every landscape construction activity. When an activity contains a specific safety concern, that concern is highlighted with a caution note.
- **Reference to pertinent chapters in the textbook:** Cross-references are provided to the *Landscape Construction* textbook so students can gain greater detail regarding the subject material.
Introduction:
   Background information is provided for the topic, including a list of steps necessary to complete the task assigned.
Discussion:
   In selected exercises, discussion topics are suggested.
Prerequisite exercises:
   Notice is provided if any exercise requires prerequisite skills.
Materials required to complete exercise:
   A list of tools, materials, and supplies required to complete the exercise.
Description of exercise:
   The educational activity to be completed is described.
Exercise 1

Construction Math

OBJECTIVE
The objective of this exercise is to properly perform construction-related math equations.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 4, Construction Math.

INTRODUCTION
Whether counting the number of shrubs needed for a planting bed or determining how much concrete to order, the landscape contractor must successfully complete a wide range of construction-related math equations. In fact, performance of math calculations is required in virtually every aspect of landscape construction. Math requirements for construction are basic, primarily involving counting, basic calculations, and the use of a set of geometry formulas. Accurate completion of these basics is essential when working on a project, as contractors typically build upon primary calculations to determine subsequent numerical values.

The basic math functions covered by this lab manual include performing item counts, calculating averages, making linear measurements, and calculating perimeters, areas, volumes, and weights. It is assumed that the reader has already mastered basic math calculations such as addition, subtraction, multiplication, and division of whole numbers, fractions, and decimals. For the reader’s reference, a written description of geometric shapes is provided in Table 1–1, and formulas for use in perimeter, area, and volume calculations are featured in Figures 1–2, 1–5, and 1–6.

Item Counts
Many quantity measurements in landscaping are simply counts of an actual number of items. An example would be counting the number of each variety of shade tree planted in a given area or counting the

<table>
<thead>
<tr>
<th>Table 1–1 Common geometric shapes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Square/ rectangle/ parallelogram: Shapes with two sets of parallel sides. Squares and rectangles have right-angled corners and parallelograms have no right-angled corners.</td>
</tr>
<tr>
<td>- Trapezoid: Shape with four sides, but only one set of parallel sides.</td>
</tr>
<tr>
<td>- Triangle (right or equilateral): Shape with three sides. Right triangle has one right angle; equilateral triangle has three sides of equal length.</td>
</tr>
<tr>
<td>- Circle: Round shape with edges equidistant from center.</td>
</tr>
<tr>
<td>- Circle sectors: Partial segments of a circle. Defined by length of the outside arc or the enclosed angle of a circle measured in degrees.</td>
</tr>
<tr>
<td>- Ellipse: Rounded egg shape with edges at variable distances from center.</td>
</tr>
<tr>
<td>- Irregular round: Kidney or irregularly shaped circles for which an approximate center radius point can be located.</td>
</tr>
</tbody>
</table>
number of light standards needed for a project. To perform an item count, use a plan or installed design to count how many of a particular object are used in a project. Performing item counts for bids, estimates, and material ordering may require separating items into groups of materials that are the same.

**Averages**

Averages are used when the contractor needs to calculate one typical, or average, number from several different numbers. An example would be calculating the typical width of an irregularly shaped paved area by using several width measurements, each taken at different locations. The formula for calculating an average is:

\[
\text{Average} = \frac{\text{Sum of all numbers}}{n}
\]

where \( n \) equals the number of numbers.

When performing landscape calculations:

- Decimals should not be rounded any smaller than hundredths (two places).
- Fraction additions require determining the lowest common denominator.

**Linear Measurements**

A foundational measurement used in landscape contracting is the linear measurement, or length, of a particular distance or the dimensions of an object. Items such as edging, fencing, and wiring are often purchased by linear foot. Other items that are ordered by area, volume, or weight require linear measurements to perform quantity calculations. Three methods are common when performing linear measurements for landscape purposes: direct measurement, pacing, and estimation. Descriptions of each of these three methods follow. Pacing is further described in Exercise 2.

**Direct Measurement.** Direct measurement involves the use of a tape measure, measuring wheel, or other measuring device to determine the distance between two points.

To direct measure:

- On flat surfaces, stretch or run the measuring device between the two points to be measured and record the distance.
- On sloped surfaces, extend a tape measure from the highest point along the distance being measured to a lower point along the plane. At the low point, suspend a plumb bob vertically, and raise the tape measure along the plumb bob line until the tape measure is level. Read and record the measurement where the tape and plumb bob line intersect. Long measurements may require that this process be repeated several times. (Note: this method will give an accurate measurement of the horizontal distance between the two points along the slope, not the diagonal distance.) (Figure 1-1.)

**Pacing.** The pacing method of measurement uses an individual’s typical step to determine distances. Pacing and the method for calculating pace are explained in Exercise 2.

**Estimation.** Estimating requires determining a distance based on comparison with a known dimension. When accuracy is not critical, estimating linear dimensions is a viable option.

Estimation can be performed by:

- Comparison. This requires visually comparing the distance to be measured to an object with known measurements. Items such as door

---

*Figure 1-1* Making accurate horizontal measurements on a hillside.
openings (usually 7 feet high), and sidewalk squares can be used to make comparative measurements.

- Visual observation. This requires the estimation of distances without any use of measurement. These skills are developed through time and experience.

**Perimeter Measurements**

Perimeter calculations determine the total linear measurement of the outside edges of an area or object. Perimeter measurement totals are typically expressed in linear footage, or LF. To perform perimeter calculations, use the following steps:

- Identify the subject being measured as one of the standard geometric shapes identified in Table 1–1 or as an irregular shape.
- If the subject is a standard geometric shape, perform the necessary linear measurements required to calculate the shape’s perimeter. Use the formula listed in Figure 1–2 to discern what linear measurements need to be performed, and how to calculate the shape’s perimeter with

---

**Figure 1–2** Perimeter and area formulas.

---
those measurements. See Figure 1-3 for examples.

- If the subject is an irregular shape, the fastest way to measure its perimeter is to pace or take a direct measurement of the outside edge. If an irregularly shaped subject is composed of several standard geometric forms, partial perimeters of those forms can be added together.

**Area Measurements**

Area calculations determine the surface area of objects and spaces found in the landscape. Area measurement totals are typically expressed in square footage, or SF. Before performing area calculations, the contractor must determine if the object or space being measured matches a typical geometric form or is irregularly shaped.

**Area Measurements for Standard Geometric Shapes.**

When an area calculation needs to be performed for an object or space that matches a standard geometric form, such as those described in Table 1–1 and depicted in Figure 1–2, use the following steps:

- Perform the necessary linear measurements required to calculate the subject's area, as listed in Figure 1–2.
Exercise 1  Construction Math

A. Identify shapes and measure dimensions of each

B. Add together areas for each of the shapes identified within the project area boundary (refer to Figure 1–2 for formulas for each shape)

<table>
<thead>
<tr>
<th>Shape</th>
<th>Area Calculation</th>
<th>Result (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Square</td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>B (Half) Circle</td>
<td>314/2</td>
<td>157</td>
</tr>
<tr>
<td>C Triangle</td>
<td></td>
<td>12.5</td>
</tr>
<tr>
<td>D Trapezoid</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td>E Rectangle</td>
<td></td>
<td>180</td>
</tr>
<tr>
<td>F (Half) Circle</td>
<td>176/2</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>± 912.5</td>
</tr>
</tbody>
</table>

Figure 1–4 Calculating area for irregular shapes.

• Use the formula listed in Figure 1–2 to calculate the area. See Figure 1–3 for examples.

Area Measurements for Irregular Shapes. Most objects and spaces in the landscape can be broken down into a collection of shapes that approximate measurable geometric forms. Once the dimensions of these shapes are determined, their areas can be calculated and added together to obtain the total area of the object or space. This method has the potential to contain a substantial margin of error, so if material orders are critical, a more precise method of measurement should be sought. To calculate area by using the “sum of shapes” method, follow these steps:

• Analyze the object or space for which an area measurement is required. Observe what geometric forms are recognizable within the boundaries of the overall shape. These shapes should cover the majority of the space being measured without much overlap. (Figure 1–4, Step A.)
• Using the formulas in Figure 1–2, take the necessary linear measurements and perform the calculations required for each identified shape.

• Total the answers to obtain the area for the entire object or space. Be certain all calculations are correct, and that area calculations for individual shapes were appropriately reduced if only partial shapes could be identified (Figure 1–4, Step B). Some typical conversions applicable to area measurements include the following:
  • If the measurement required must be expressed as square yards, divide the square foot total by 9.
  • To obtain the number of acres, divide the square footage by 43,560.
  • To obtain squares for sod, divide the square footage by 100. To obtain rolls of sod (each sod roll being 1 SY), divide square footage by 9.
  • Conversions such as number of unit pavers require the square footage derived from the previously mentioned calculations and a conversion number provided by the manufacturer of the material (such as 4.5 bricks required for every square foot of paved area). Multiply the conversion number by the square footage to obtain a material quantity estimate.
Volume Measurements

Volume calculations provide the three-dimensional bulk, or cubic, measurement of materials used in landscaping. Volume measurement totals are typically expressed in cubic feet, or CF. To calculate volumes for landscaping, follow these steps:

- Calculate the square footage of the area that is to be filled.
- Determine the depth of the layer to be filled.
- Place the numbers in the following formula:

\[
\text{Area (in SF) \times Depth (in inches)} \div 12 = \text{CF (cubic feet)}
\]

Examples:
A. 6” layer of topsoil over square shape of 81 SF

\[
\frac{81 \times 6}{12} = 40.5 \text{ CF}
\]

\[
\frac{40.5}{27} = 1.5 \text{ CY (cubic yard)}
\]

B. 4” layer of mulch over ellipse shape of 113 SF

\[
\frac{113 \times 4}{12} = 37.6 \text{ CF}
\]

\[
\frac{37.6}{27} = 1.4 \text{ CY}
\]

Figure 1-5 Calculating volumes for layered materials.

Volume of Sphere:

Formula: \(4.18 \times R \times R \times R = CI\)

Example: \(4.18 \times 8 \times 8 \times 8 = 2140 \text{ CI}\)

Conversion to CF:

\[
\frac{CI}{1728} = \text{ CF}
\]

\[
\frac{2140}{1728} = 1.24 \text{ CF}
\]

Volume of Cylinder:

Formula: \(\text{area of circle \times HT.} = \text{CF}\)

Example: \((.5 \times .5 \times 3.14) \times 1.5 = 1.18 \text{ CF}\)

Figure 1-6 Calculating volumes for spheres and cylinders.

Note that the depth is not converted to feet, but is left in inches. Examples are shown in Figure 1-5. To calculate the volume of a cylinder use the following formula (Figure 1-6). Both area and height must be expressed as feet or decimal portions of feet.

\[
\text{Area} \times \text{Height} = \text{CF}
\]

Calculating the volume of a sphere is a necessary first step in determining the weight of plant rootballs. Once the volume has been calculated, a weight conversion can be used to convert to pounds. The formula for calculating the volume of a sphere is as follows (Figure 1-6):

\[
4.18 \times R \times R \times R = CI \text{ (cubic inches)}
\]

when \(R\) is expressed as inches. Expressing \(R\) as feet (or decimal portions of feet) will provide an answer in cubic feet (CF).
Some conversions applicable to volume measurements include:

- If the measurement carried out is in cubic feet and must be expressed as cubic yards (CY), divide the cubic foot total by 27.
- If the measurement carried out is in cubic inches and must be converted to cubic feet, divide the cubic inches total by 1,728.

**Weight Calculations**

Many landscape materials are purchased by weight rather than by volume. For those materials use the following chart to convert volume to weight by multiplying the cubic feet or cubic yards by the conversions:

- 1 CF soil, dry and loose = 90 pounds
- 1 CF soil, moist = 75 to 100 pounds
- 1 CF sand, dry = 100 pounds
- 1 CF limestone, uncrushed = 160 pounds
- 1 CF concrete = 140 pounds
- 1 CY fill dirt = 1.2 tons (2,400 pounds)
- 1 CY concrete sand = 1.5 tons (3,000 pounds)
- 1 CY aggregate (class 5 aggregate, 1 inch roadstone, or equal) = 1.25 tons
- 2,000 pounds = 1 ton

**Comprehensive Process of Converting Measurements**

If this section has been followed from beginning to end, it should be apparent that primary measurements and calculations, such as linear measurements and area calculations, can be used to determine subsequent numerical values during the course of a project.

Consider the task of calculating materials for patio construction as an example of how this process might work. The contractor takes linear measurements that determine the quantity of edger needed. These linear measurements are then used to calculate surface area, thereby allowing the contractor to determine the quantity of unit pavers needed at the site. The area measurement is then used to calculate volumes of base and setting bed materials. Volumes can next be converted to weights for ordering. Clearly, following this logical process improves the contractor’s efficiency by eliminating the need to begin each calculation from scratch using linear measurements.

**PREREQUISITE EXERCISES**

None.

**MATERIALS REQUIRED**

- Calculator
- Writing materials
- 100 foot tape measure or measuring wheel
- 25 foot tape measure or other measuring device

**EXERCISE DESCRIPTION—PART A**

To complete this exercise perform the average calculations for each of the problems in Figure 1–7.

**EXERCISE DESCRIPTION—PART B**

To complete this exercise select a site or a design plan for a project and perform item counts of the objects identified by the instructor.

**EXERCISE DESCRIPTION—PART C**

To complete this exercise, perform direct measurements and estimations of linear dimensions for objects identified by the instructor.

**EXERCISE DESCRIPTION—PART D**

To complete this exercise perform perimeter calculations for each of the shapes shown in Figure 1–8. Place your responses in the form in Figure 1–9.

**EXERCISE DESCRIPTION—PART E**

To complete this exercise perform area calculations for each of the shapes shown in Figure 1–8. Place your responses in the form in Figure 1–9.
### Exercise 1

**Construction Math**

#### Figure 1-7 Calculating averages problem set.

<table>
<thead>
<tr>
<th>A. Whole numbers</th>
<th>B. Decimals</th>
<th>C. Fractions</th>
</tr>
</thead>
</table>
| \[
\begin{align*}
1 \quad & \frac{39 + 27 + 18 + 9 + 3}{n} = \\
2 \quad & \frac{4 + 2 + 16 + 7}{n} = \\
3 \quad & \frac{3 + 12 + 5 + 11 + 6 + 19}{n} = \\
4 \quad & \frac{6 + 18 + 3}{n} = \\
5 \quad & \frac{17 + 1 + 15 + 5 + 4 + 2}{n} = \\
6 \quad & \frac{14 + 11 + 21 + 39 + 22}{n} = \\
7 \quad & \frac{5 + 6 + 11 + 4}{n} = \\
8 \quad & \frac{24 + 48}{n} = \\
9 \quad & \frac{17 + 1 + 8}{n} = \\
10 \quad & \frac{3 + 5 + 7 + 11 + 13}{n} = \\
\end{align*}
\] |
| \[
\begin{align*}
1 \quad & \frac{2.2 + 1.7 + 8.3 + 7.7}{n} = \\
2 \quad & \frac{3.3 + 7.6 + 9.1 + 2.6 + 1.0}{n} = \\
3 \quad & \frac{6.6 + 12.2 + 1.1 + 4.75 + 2.3}{n} = \\
4 \quad & \frac{8.67 + 5.1 + 4.37 + 5.85}{n} = \\
5 \quad & \frac{38.33 + 11.9 + 7.35}{n} = \\
6 \quad & \frac{15.53 + 6.33 + 7.2 + 1.11 + 3.2}{n} = \\
7 \quad & \frac{4.13 + 3.44 + 2.88}{n} = \\
8 \quad & \frac{23.2 + 14.6 + 2.11 + 4.7}{n} = \\
9 \quad & \frac{3.33 + 1.9 + 11.37}{n} = \\
10 \quad & \frac{6.75 + 7.11 + 13.97 + 3.0}{n} = \\
\end{align*}
\] |
| \[
\begin{align*}
1 \quad & \frac{1 \frac{1}{2} + 3 \frac{1}{2} + 5 \frac{1}{2}}{n} = \\
2 \quad & \frac{3 \frac{1}{4} + 1 \frac{3}{8} + 5 \frac{5}{16}}{n} = \\
3 \quad & \frac{4 \frac{3}{8} + 1 \frac{3}{16}}{n} = \\
4 \quad & \frac{5 \frac{5}{8} + 3 \frac{1}{2} + 2 \frac{1}{8} + 3 \frac{3}{2}}{n} = \\
5 \quad & \frac{4 \frac{1}{2} + 6 \frac{1}{4} + 7 \frac{3}{4}}{n} = \\
6 \quad & \frac{9 \frac{5}{8} + 5 \frac{7}{16} + 11 \frac{1}{4}}{n} = \\
7 \quad & \frac{11 \frac{1}{4} + 12 \frac{2}{8} + 9 \frac{5}{8} + 1 \frac{1}{8}}{n} = \\
8 \quad & \frac{13 \frac{7}{4} + 1 \frac{1}{2} + 4 \frac{3}{6} + 5 \frac{1}{8} + 9 \frac{13}{16}}{n} = \\
9 \quad & \frac{2 \frac{1}{2} + 7 \frac{1}{4} + 3 \frac{1}{4} + 8 \frac{1}{2}}{n} = \\
10 \quad & \frac{6 \frac{11}{16} + 1 \frac{9}{16}}{n} = \\
\end{align*}
\] |
Figure 1-8 Shapes used for performing perimeter, area, volume, and weight calculations.
**EXERCISE DESCRIPTION—PART F**

To complete this exercise perform volume calculations on each of the shapes shown in Figure 1–8 for each the following materials. Place your responses in the form in Figure 1–9.

- 1 inch thick layer of concrete sand, express answers in cubic yards (CY)
- 2 inch thick layer of mulch, express answers in cubic feet (CF)
- 4 inch thick layer of concrete, express answers in cubic yards (CY)
- 6 inch thick layer of aggregate base material, express answers in cubic yards (CY)
- 8 inch thick layer of dry, loose soil, express answers in cubic yards (CY)

**EXERCISE DESCRIPTION—PART G**

To complete this exercise perform weight conversions for each of the concrete sand, aggregate, and dry, loose soil quantities calculated in Part F. Place your responses in the form in Figure 1–9.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perimeter</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (CY)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1” concrete sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (CF)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2” mulch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (CY)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4” concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (CY)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6” aggregate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (CY)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8” soil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1-9** Response sheet for perimeter, area, volume, and weight calculations for shapes shown in Figure 1–8.
Exercise 2

Pacing

OBJECTIVE
The objective of this exercise is to calculate a person’s average pace, which can then be used for measurement purposes.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 4, Construction Math.

INTRODUCTION
When building landscapes it will often be necessary to calculate linear measurements in the field. Three methods for performing linear measurements—direct measurement, pacing, and estimating—are commonly used. The choice of method for making linear measurements will be determined by the level of accuracy that is required. Direct measurement provides the highest level of accuracy. Pacing can provide accuracy to within 5 percent if properly practiced. Estimating is acceptable when performing rough estimates or to obtain an idea of project size and scope.

Of these three methods, pacing can be useful because it requires no special tools and can be adapted to nearly every site or terrain. However, pacing relies upon consistent stepping to derive accurate linear measurements of a site. To properly establish and use pacing as a measurement tool, it is necessary to understand the site and human conditions that may alter a person’s normal pace.

It is important, both when calculating average pace and when performing measurements with this method, that a normal stride be maintained. Attempting to step a predictable distance or altering the normal step will produce inconsistent results. When performing calculations be aware that distances will be affected when pacing up or down slopes, or through sites with obstructions. Make an effort to identify pacing lines that are not affected by these conditions.

Procedure for Calculating Pace
(Figure 2-1, Step A)
• Set up a course that is 100 feet long.
• Pace the course three times, counting the number of steps each time. Maintain a normal step to obtain consistent results.
• Calculate the average number of steps.
• Divide the 100 foot distance by the average number of steps to determine the average pace, or the number of feet covered in every step.

Procedure for Checking Pace
(Figure 2-1, Step B)
• Set up four varied test courses with one pair of flags per course.
• Pace the distance between the flags, recording the number of steps taken per course.
• For each course, multiply the number of steps taken by the average pace.
• Test accuracy by direct measuring the actual length of each course.
• Subtract the paced distance from the actual length to determine discrepancy. If the paced distance is longer than the actual length, subtract the actual length from the paced distance to determine discrepancy.
• Divide the discrepancy amount by the actual length of the course, then multiply the answer by 100 to obtain your percentage of error. If the...
Exercise 2  Pacing

A. Establishing pace
1. Set up 100 foot course.
2. Pace course three times.

(Note: Course should be level and free of obstacles)

3. Average the number of steps.
   1st pass: _______________
   2nd pass: _______________
   3rd pass: _______________

   Total paces \( \div 3 = \frac{1 + 2 + 3}{3} \) = Average number of steps.

4. Divide average number of steps into 100 feet to obtain typical step.

   \[
   \frac{100 \text{ feet}}{\text{average number of steps}} = \text{Average pace}
   \]

B. Practicing and checking pace

<table>
<thead>
<tr>
<th>Test Pace</th>
<th>Number of Steps</th>
<th>Average Pace</th>
<th>=</th>
<th>Your Distance</th>
<th>Measured Distance</th>
<th>Difference F–G or G–F</th>
<th>% error H/G \times 100 = %</th>
</tr>
</thead>
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**Figure 2-1** Establishing, practicing, and checking pace.

- Error percentage exceeds 5 percent, repeat the test pace with a new practice course. If the error percentage on the second try exceeds 5 percent, redo the average pace section and retest.

**PREREQUISITE EXERCISES**
Students should have successfully completed Exercise 1, Construction Math, before beginning this exercise.

**MATERIALS REQUIRED**
- Writing materials
- Calculator
- 100 foot tape measure
- Surveyor’s flags

**EXERCISE DESCRIPTION**
To complete this exercise set up a course to establish the average length of your pace. Use the steps described previously and shown in Figure 2-1 to determine your average pace.
Exercise 3

Measuring with Architects’ and Engineers’ Scales

OBJECTIVE
The objective of this exercise is to properly use architects’ and engineers’ scales to measure lines.

TEXTBOOK REFERENCE
Activities related to this activity can be found in the Landscape Construction textbook in Chapter 3, Interpreting Construction Documents.

INTRODUCTION
When working with landscape plans it will be necessary to measure the lines, shapes, and other elements of a design. Because construction plans cannot be drawn life-size, they must be reduced to fit on a sheet of paper using a standard set of conversion measurements. These measurements are called scales.

The concept of drawing scale can best be described as equating a measured distance on a drawing to an actual distance on a site. An example would be equating 1 inch on a drawing to 10 feet at an actual site. Using such an equation would allow a designer to draw a 2 inch line that equals 20 feet on a site, or a 3 inch line that equals 30 feet. In the landscape design field many scales can be used. Common scales used for landscape work include 1 inch = 10 feet (used in the previous example), 1 inch = 20 feet, 1 inch = 30 feet, 1/4 inch = 1 foot, and 1/8 inch = 1 foot. In each of these scales the first number indicates the distance on the drawing and the second number indicates the distance on the actual site.

Preparing and interpreting scaled landscape drawings requires the use of special instruments, also termed scales. These measuring instruments feature divisions and markings that are calibrated to match the common drawing scales. To accommodate the large number of drawing scales available, two types of measuring scales are typically used: an architect’s scale and an engineer’s scale. The architect’s scale includes divisions and markings for drawing scales that use fractions. The engineer’s scale includes divisions and markings for scales that use multiples of ten. With these two scales, most landscape drawings can be prepared and measured.

Measurement Using an Architect’s Scale
Measurement of a landscape drawing with an architect’s scale can be somewhat confusing, as every edge of the scale has two scales: one running from left to right, the other running in the opposite direction. The instructions that follow assume that measurements are being made on a scale running left to right, but can modified easily for use on a scale running right to left.

- Determine the scale of the drawing to be measured, and locate that scale on the measurement instrument.
- Identify a line to be measured on the drawing.
- Set the scale next to the line being measured and adjust the scale so that the left end of the line is in the inch measurement area (the finely divided area behind the zero). (Figure 3–1.)
- Adjust the scale left or right until the right end of the line being measured aligns with a foot mark along the scale, and the left end remains within the inch area.
- Add the foot reading and inch reading to obtain the measurement. Obtain the proper foot reading by beginning your count from the 0 by...
Exercise 3  Measuring with Architects’ and Engineers’ Scales

the inch markings. Inch markings on the architect’s scale may represent inches or fractions of inches depending on the accuracy of the scale. The inch portion of the scale always contains 1 foot divided into proportional segments.

Measurement Using an Engineer’s Scale
Measurement of a landscape drawing with an engineer’s scale should follow these steps:

- Identify a line to be measured on the drawing.
- Place the zero mark from the correct scale at one end of the line (Figure 3-1).
- Read the markings along the scale to determine line length. Each mark on an engineer’s scale represents 1 foot. On an engineer’s scale, inches can only be estimated based on where the line ends between marks.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 1, Construction Math, before beginning this exercise.
**Exercise 3**  Measuring with Architects’ and Engineers’ Scales

**MATERIALS REQUIRED**
- Writing materials
- Architects’ scale
- Engineer’s scale

**EXERCISE DESCRIPTION**
To complete this exercise, measure the lines shown to the right of the answer blank in Figure 3–2 using the scale indicated. Mark your answer in the blank provided.

---

Figure 3–2  Scale measurement practice set.
OBJECTIVE
The objective of this exercise is to identify and calculate quantities of materials used in a landscape design.

Before performing material take-offs, become familiar with the reading and interpretation of landscape construction documents. Failure to properly interpret construction documents may create significant errors in material and labor calculations. Verify utility locations before performing any work on a site.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 3, Interpreting Construction Documents, Chapter 4, Construction Math, and Chapter 5, Project Pricing.

INTRODUCTION
To obtain work the landscape contractor must prepare estimates and bids based on design ideas that are often expressed in graphic form. This price preparation begins with reviewing the design and identifying the types of work and materials required by the design. A second step in the process is calculating the quantity of materials required to complete the work. Material calculations use measurement and math skills common to landscape construction. The result of these calculations is termed a take-off, referring to calculations which are “taken off” of the design. When take-offs are complete, labor costs can be added to complete the estimate or bid.

Performing the take-off requires a consistent process of examining the design for materials and construction activities, measuring the design, and calculating quantities. To complete the materials take-off for a landscape design, use the following procedure:

I. Identify all documents that contain information regarding the landscape design. This could include graphic drawings or written specifications.
   A. Review the drawing(s) for orientation, scale, topographic elevations, and materials legend. The design may also include a listing of all or part of the materials used in the project. Review the symbols, textures, and abbreviations used on the construction plan(s). Locate and read any special notes.
   B. Locate any design details that relate to landscaping. Measurement of plans should be coordinated with any details provided with the design. Plans will show the horizontal aspects of the design, while details will often show vertical dimensions and specific construction information.
   C. Read the sections of specifications that relate to landscaping work. Specifications, if prepared for the project, often provide detailed descriptions of the materials, installation techniques, and conditions under which the work must be completed.

II. Identify and list all landscape construction work required by the design. To keep this task organized, use the steps of the construction process to organize the work tasks. For each task identify all...
materials—even minor products—that will be necessary to install that portion of the work. Following is a list of the construction steps along with typical construction activities and units of measurement used in preparing take-offs.

A. Site preparation and/or demolition. Locate any area that will be disturbed by construction, particularly those that require the removal of existing materials.
1. Removal of trees and shrubs, typically calculated for each removal
2. Removal of sod and scrub plant material, typically calculated by the square foot (SF)
3. Removal of undesired paving, typically calculated by SF
4. Installation of site perimeter protection or fencing, typically calculated by the linear foot (LF)
5. Sodding, seeding, or other restoration work required when construction is complete

B. Grading and erosion protection. Identify any location where the site is disturbed and/or the finish grade differs from the existing grade.
1. Relocation of earth on the site, typically calculated by the cubic yard (CY)
2. Removal of excess soil, or purchase and distribution of additional soil, typically calculated by CY
3. Installation of silt fence, calculated by LF
4. Installation of erosion mat, calculated by SF
5. Installation of drainage tile, calculated by LF
6. Installation of drainage structures, each calculated individually

C. Utility installation. Identify any utility lines or landscape lighting systems.
1. Installation of utility lines, typically calculated by LF
2. Installation of lighting systems, typically calculated by individual components purchased for a system
3. Length of wire used to connect lighting, typically calculated by LF
4. Footings required for lighting or site amenities. Each footing requires calculation of materials used in construction.

D. Wall construction. Identify all wall materials used for construction and the dimensions.
1. Measure each wall installation, separated by different materials. Review any available details and calculate the square footage of the surface of the wall, including the portion buried below grade.
2. Measure the length of all walls and the amount of capstone that may be required, typically calculated by LF.
3. Calculate the quantities of any materials placed for base below the wall or as fill behind the wall, typically calculated by the ton (T) or CY.
4. Calculate the quantities of any drainage materials needed behind the wall, typically calculated by LF.
5. Calculate the quantity of any additional stone or soil fill required behind the wall, typically calculated in CY or tons.

E. Paving installation. Locate all paved areas and identify the materials used for construction and the dimensions.
1. Measure each paved area separated according to paving type, typically measured in SF. Calculate the amount of paving material required. This unit calculation will depend on the type of material used.
2. Using any available details, determine what type of base and setting bed materials are necessary, typically calculated by T or CY.
3. Calculate any edge restraint necessary, typically calculated by LF.

F. Wood construction. Identify all wood structures on the site.
1. Identify the wood members used in the design.
2. Perform an item count of the number, size, and length of each member required.
3. Calculate the connectors and fasteners needed for the project. Each individual piece should be counted.

G. Fencing or freestanding wall construction. Identify all locations where fences or freestanding walls will be used. Identify the dimensions and materials for each installation.
1. Freestanding walls are typically calculated by estimating the tons of materials required. Masonry walls will require item counts of all materials and estimation of CF of mortar.
2. Determine the fencing material. Each fencing type requires an item count of all materials used. Chain link fence fabric may be ordered by LF.

H. Amenity installation. Locate each site amenity required by the design.
1. Perform an item count for each different amenity. Group according to similar amenity type and style.
2. Include quantities of materials required to install, anchor, or support the amenities, including footings.
I. Installation of plantings and establishment of turf.
1. Determine the amount of seeded area, typically by SF, 1,000 SF, or acre.
2. Determine the amount of sodded area, typically by square, or 100 SF units.
3. Perform an item count for each tree; total by species and size.
4. Perform an item count for each shrub; total by species and size.
5. Calculate the amount of each different ground cover, typically by SF.

III. Measure and calculate the quantities of each material used in the design, identified in the previous step. The techniques identified in Exercise 1 for linear, perimeter, area, volume, and weight measurement provide the tools to perform these calculations. Prepare a separate calculation for each different material for each step. For bulk materials, wall and paving materials, sod, and seed, an overage (extra amount) may be necessary. This overage accommodates any material loss due to shipping, breakage, or cutting. Overages can range from 5 percent for wall and paving materials to 10 percent for bulk materials and sod.

IV. Place the material calculations in a format that is easy to read and allows labor costs to be calculated for each activity.

PREREQUISITE EXERCISE
Students should have successfully completed Exercise 1, Construction Math, and Exercise 3, Measuring with Architects’ and Engineers’ Scales before beginning this exercise. Experience reading and interpreting construction documents is also necessary.

MATERIALS REQUIRED
• Calculator
• Writing materials
• Engineer’s scale

EXERCISE DESCRIPTION
To complete this exercise prepare a materials take-off for the design shown in Figure 4–1. Begin by identifying the construction activities and materials necessary to install the design shown in Figure 4–1 and detailed in Figure 4–2. Group the materials according to related

---

Figure 4-1 Project design.
construction categories and list them on the form in Figure 4–3. Assume that the site is currently an undeveloped turf area, and that no additional soil cutting or filling will be required to establish site grades. Also assume that no equipment needs to be rented to complete the work tasks.

When all activities and materials are identified, calculate the material quantities necessary to complete the design. Coordinate the estimate of materials for the paved patio and retaining wall with the details shown in Figure 4–2. Install these quantities in the form in Figure 4–3. Include any overages for bulk materials, wall and paving materials, and sod.

---

**Cross section – Segmental Unit Wall**

- Segmental precast wall units, no capstone
- 6" Zone of free draining angular fill
- 4" Perf plastic tile along entire length of wall, free out at west end
- 6" Deep x 24" wide compacted base along entire length of wall
- 2' Typical height

---

**Cross section – Brick Patio and Edge Restraint**

- 4" Wide x 9" deep stone edge restraint
- Paving brick, 4" x 8"
- 1" Sand setting bed
- 4" Compacted granular base
- Compacted subgrade

Figure 4–2 Project design details.
### MATERIAL TAKE-OFF FORM

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
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<th>Notes</th>
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**SITE PREPARATION**

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**WALL INSTALLATION**

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**PAVING INSTALLATION**

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**PLANT MATERIAL**

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**EDGER/LIGHTING**

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**ADDITIONAL ITEMS**

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<th>Over.</th>
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*Figure 4-3* Project take-off form.
Exercise 5

Tool Operation and Construction Techniques

OBJECTIVE
The objective of this exercise is to review proper excavation tool operation and basic piping and carpentry techniques.

CAUTION
Serious injury or death could result from improper use of construction equipment. Read and follow manufacturer’s instructions with use of all tools. Wear proper safety equipment, including gloves, safety glasses, ear protection, a dust mask, protective footwear, and a hard hat when performing construction work. Activities in this exercise should be performed under supervision.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 7, Basic Construction Techniques and Equipment Operation.

INTRODUCTION
Landscape construction requires that the contractor be capable of using a variety of tools and performing a number of basic construction techniques. Most tools and techniques require an initial introduction to the proper procedures for use, followed by practice to master the skills necessary for correct operation. Procedures for using landscape tools and performing basic construction techniques are outlined in this exercise.

Steps for Excavating with a Shovel
- Select the proper shovel.
- Position the shovel with the blade perpendicular to the ground. When trenching, turn the blade at a 45 degree angle to the side of the trench.
- Use the instep of the foot to push the blade completely into the ground (Figure 5–1). Use the handle to leverage the material out. Do not attempt to remove more material than the shovel can hold.

Steps for Excavating with a Breaker Bar
- Lift and thrust breaker bar downward onto hard soil (Figure 5–2).
- Break apart large sections of earth, then excavate using a shovel or posthole excavator.

Steps for Posthole Excavation Using an Auger
- Position the auger over the hole location and turn it until the auger is full (Figure 5–3).
- Lift auger from the hole and tap it on the ground, away from the hole, to remove the excavated material.
- Continue auguring until the proper depth is reached, checking the hole periodically for depth and plumb.
Steps for Posthole Excavation Using a Clamshell
- Hold the handles together and drive the blades into the ground at the hole location by dropping or thrusting the tool downward with the arms. Avoid pinching fingers between the handles.
- Spread the handles to capture a load of material and lift out of the hole (Figure 5–3).
- Tap clamshell on the ground to empty it of loosened soil.
- Continue this process until the hole is excavated.

Steps for Excavating with a Power Auger
- Ensure that two people are present to operate the power auger.
- Clear the area around the hole of all unnecessary objects.
- Use a shovel to excavate a centering hole 6 inches deep, shaped like a cone, at the point where the power auger will drill.
- Each operator should firmly grasp the handles of the power auger. Start the engine and push the auger into ground via the centering hole (Figure 5–4).
- Maintain the auger in plumb alignment, and work the machine up and down to clear the blade periodically. Avoid pulling the auger completely out of the hole.

Steps for Compacting Materials with a Vibratory Plate Compactor
- With assistance, set the compactor on the site.
- Fill the compactor with fuel and, if necessary, fill the reservoir of the compactor with water to increase its weight.
- Adjust the throttle and setting.
Auger operation

Place auger in hole and twist to loosen soil

When auger is full, lift from hole and empty soil load to side of hole

Clamshell operation

Thrust clamshell into hole with handles together

Spread handles to capture soil load

Lift from hole and hold over disposal area, squeeze handles together and strike against ground to release soil load

Figure 5-3  Steps for using posthole excavators.
• Start the compactor. It moves forward without pushing.
• Steer using the handle. To turn sharp corners lift the handle vertically and spin the compactor.
• When work is complete, shut off compactor and lift off site.

Steps for Cutting and Joining Poly Pipe
• Use a cutter or saw to make a square cut at the desired location (Figure 5–5).
• Slide a clamp over the end and down the pipe a short distance. Fully insert a fitting into the open pipe and slide the clamp back down the pipe until it rests over the fitting (Figure 5–6).
• Tighten the clamp securely (Figure 5–7).

Steps for Cutting and Joining PVC Pipe
• Use a cutter or saw to make a square at the desired location (Figure 5–8).
• Clean any burrs from the inside of the cut pipe with a reaming tool, wire brush, or sandpaper. Wipe dirt and dust from the outside and inside of both the pipe end and the PVC fitting.
• Brush the ends of the pipe and fitting liberally with primer. While primer is still wet, apply PVC joint compound to both parts (Figure 5–9). Push them firmly together, and twist one-eighth to one-quarter turn (Figure 5–10).
• Verify that the alignment of the fitting is correct. The compound will set in approximately 10 seconds.
Steps for Measuring and Marking

- Hook measuring tape over end/edge of material.
- Locate desired measurement.
- Mark measurement with a V, with the point of the V indicating the desired measurement (Figure 5–11).

Steps for Marking Square Cuts

- Mark cut location.
- Position carpenter’s square with one leg resting on cut mark and the other leg resting flush against the side of the material (Figure 5–11).
While holding square firmly against edge of material, draw a line that passes through the cut mark.

Steps for Cutting with a Hand Saw
- Rest the lumber on sawhorses or on a flat surface, with the trim portion extending beyond the edge of the support (the trim is the shortest dimension left after the cut).
- Place saw on cut mark (Figure 5–12A). The blade may be held in position with the thumb placed against the flat side surface of the saw. Begin with a short stroke until a groove that will hold the saw blade in position is cut along the mark.
- When cut is approximately 1 inch deep, withdraw the thumb and position the hand to hold the board. Extend the stroke to the full length of the blade. Downward pressure on the saw is not required to cut.
- Most short pieces being trimmed off can be cut without being supported and allowed to fall after being cut. If the trimmed portion is over 1 foot long, it needs to be supported by hand while cutting. Be certain the support does not bind the saw blade. The holder should not grasp the piece of lumber, but instead place a hand below the wood and allow it to rest lightly.

Steps for Cutting with a Circular Saw
- Rest the lumber on a sawhorse or a flat, solid surface, with the portion to be trimmed extending beyond the edge of the surface. Support the trimmed portion as described in hand sawing. Set the direction of the saw cut so the weight of the circular saw motor rests on the supported portion of the lumber. The sole plate of the saw should rest flat on the lumber being cut.
- Position the body so that both the mark and the blade at the point of the cut can be observed while sawing. Verify that the power cord is not near the saw blade.
- Align the blade or directional mark on the sole plate of the saw with the mark on the lumber (Figure 5–12B).
- Steady the material with the free hand if necessary. A second person may be needed to hold material while cutting.
- Start the saw and run the motor to full speed. Slowly push the saw forward along the mark (Figure 5–13).
- As the cut nears completion, support the trim portion to prevent the blade from being pinched and/or possible kickback.
- When cutting thick materials such as 4 × 4s, it may be necessary to mark on both the top and bottom of the lumber, cut the top, and turn the lumber over to make a second cut aligned with the first.

Steps for Cutting with a Reciprocating Saw
- Rest the lumber on a flat, solid surface with the portion to be trimmed extending beyond the edge of the support. Support the trimmed...
portion as described in hand sawing. Posts or vertical pieces may not require support.

- To reduce the heavy vibration caused with the reciprocating saw, hold the blade guide firmly against the piece being cut (Figure 5–12C).
- Position the body so that both the mark and the blade at the point of the cut can be observed while sawing. Verify that the power cord is not near the saw blade.
- Align the blade or directional mark on the guide with the mark on the lumber.
- Start the saw and run the motor to full speed. Slowly push the saw forward along the mark.
- As the cut nears completion, support the trim portion. Support vertical trim pieces from behind the direction of the cut.

Steps for Installing Screws with a Power Drill

- Install the appropriate bit for the drill. Tighten and secure the bit using the **chuck key**.
- Place the fastener on the drill bit and, while holding the fastener, position the tip at the location where the fastener is to be installed.
- Hold the drill and fastener at the angle desired for driving the fastener.
- Lightly hold the top portion of the fastener shank while slowly starting the drill (Figure 5–14A).
- When the fastener “bites,” or begins to enter into the wood, release the shank.
- Increase the drill speed, apply downward pressure on the drill with the free hand, and continue driving until the fastener is

---

**Figure 5-12** Sawing and cutting techniques.
Deep or wide holes may require that the bit be pulled out of the hole every 2–3 seconds to clear the wood shavings from the hole.

**Steps for Drilling and Driving Spikes for Wood Retaining Walls**
- Drill a **pilot hole** at the location where the spike is to be driven. Follow the steps for drilling holes as outlined previously. Most timbers will require the use of a long bit, which should be lifted from the hole every 5–10 seconds to clear wood shavings from the hole.
- Place tip of spike into pilot hole and support lightly with hand.
- Tap with **sledgehammer** to start spike into hole (Figure 5–14C).
- When spike stands upright by itself, remove hand and finish driving with sledge until head is flush with surface of wall material.

**Steps for Hand Nailing**
- Position the nail at the location where it is to be installed, holding the nail lightly between the thumb and index finger and at a right angle to the face of the wood.
- Grasp the end of the **claw hammer** handle and lightly strike the nail until it has been driven into the wood far enough that it stands on its own. To avoid missing or misdriving the nail, focus the eyes on the head of the nail during the entire driving process (Figure 5–15).
- Steadily increase striking strength to full force. Continue driving the nail until the head is flush with the piece of lumber.

**PREREQUISITE EXERCISES**
None.

**MATERIALS REQUIRED**
- Proper clothing and safety equipment, including: safety glasses, work gloves, hard hat, dust mask, ear protection device, and work boots
- Carpenter’s square
- Carpenter’s pencil or permanent marker
- Tape measure
- Hand saw
- 50–100 foot heavy-duty grounded extension cord, if necessary to reach a 120V GFCI outlet
- Circular saw with blade
- Reciprocating saw, extra blades, and blade wrench

Completing the entire exercise requires the use of hand tools and the ability to complete tasks with precision and accuracy.

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**Figure 5-13** Proper cutting technique for a circular saw.
Exercise 5  Tool Operation and Construction Techniques

- Power drill and 1/2 inch, 3/4 inch, and 1 inch wood bits (regular and spade type), 3/8 inch bit with long shank, and screwdriver bits
- Claw hammer
- 5 pound sledgehammer
- Two sawhorses
- Straight-handled shovel
- D-handled spade
- Clamshell type posthole excavation tool
- Auger-type posthole excavation tool
- Vibratory plate compactor with fuel
- Power auger with fuel
- Base material for compaction
- Supply of 1/2 inch plywood—1 inch, 2 inch, and 4 inch dimensioned stock
- Box of 8d nails
- Box of 16d spikes
- Box of 12 inch spikes

Figure 5–14 Drilling and fastening with a power drill.

A. Inserting screw
   a) Place screw on mark or pilot hole. Hold shank of screw loosely with fingers.
   b) With screwdriver bit installed, place bit on screw top and slowly depress trigger until screw begins to turn.
   c) Gradually decrease pressure on trigger as screw head nears the surface of material, being careful not to strip opening. When screw will stand without support, release fingers.

B. Drilling hole
   a) Locate and mark spot to be drilled.
   b) Place point of bit on mark and start drill.
   c) Apply downward pressure until bit begins to penetrate material. If material is thick, back drill out to remove excess cuttings then continue and repeat process if necessary.

C. Drilling pilot hole
   - Light downward pressure with hand
   - Position bit over hole position
   - Spike
   - Timber
   - Pilot hole through wood
End nailing

A. Hold nail loosely with fingers. Tap nail lightly with a hammer until nail "bites" into wood and stands alone.

B. Hold end of hammer and drive nail taking full swings.

Figure 5–15 Proper hand nailing technique.

Exercise Description

To complete this exercise perform the required number of repetitions or length of operation for each of the activities on the following list.

- Measure and mark dimensions: 10 repetitions
- Mark square cuts: 10 repetitions
- Hand saw 1 inch and 2 inch stock dimensioned lumber: 5 repetitions each
- Cut 1 inch, 2 inch, and 4 inch stock dimensioned lumber using a circular saw: 5 repetitions each
- Cut 1 inch, 2 inch, and 4 inch stock dimensioned lumber using a reciprocating saw: 5 repetitions each
- Drill 1/2 inch, 3/4 inch, and 1 inch holes in 1 inch, 2 inch, and 4 inch stock dimensioned lumber: 5 repetitions each
- Hand drive 8d and 16d nails into/through 1 inch, 2 inch, and 4 inch stock dimensioned lumber: 10 repetitions each
- Drill 3/8 inch pilot hole and drive 12 inch spike into landscape timber: 5 repetitions
- Drive and remove deck screws into/through 1 inch and 2 inch stock dimensioned lumber: 10 repetitions each
- Excavate a 2 foot wide × 2 foot deep × 2 foot long hole: 1 repetition
- Excavate a 10 inch wide × 1 foot deep × 5 foot long trench: 1 repetition
- Excavate a posthole 3 foot deep using an auger: 2 repetitions
- Excavate a posthole 3 foot deep using a clamshell excavator: 2 repetitions
- Compact a granular base area using a vibratory plate compactor: 5 minutes of activity
- Cut and join poly piping: 2 repetitions
- Cut and join PVC piping: 2 repetitions

Box of deck screws
Pipe cutter or hacksaw
Supply of poly pipe
Supply of poly pipe barbed fittings
Supply of poly pipe clamps
Supply of 1/2 inch PVC piping
Supply of 1/2 inch PVC fittings
Supply of PVC primer and glue

Wear proper safety clothing and devices. Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions. See the cautions stated at the beginning of this exercise.

Caution
Exercise 6

Cutting of Paving and Wall Materials

OBJECTIVE
The objective of this exercise is to execute the proper cutting of paving and wall materials using a brick set and hammer, hydraulic splitter, cutoff saw, wet masonry saw, and chain saw.

CAUTION
Serious injury or death could result from improper use of construction equipment. Tools used to cut materials present a significant safety risk. Read and follow manufacturer’s instructions with use of all tools. Wear proper clothing and safety equipment, including gloves, safety glasses, ear protection, dust mask, footwear, and hard hat when performing construction work. Activities in this exercise should be performed under supervision.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 7, Basic Construction Techniques and Equipment Operation.

INTRODUCTION
Construction materials often require cutting to fit project design dimensions. While the tools and techniques described in Exercise 5 are adequate for cutting many wood and metal materials, cutting of stone, brick, precast concrete, and thick wood materials requires specialized cutting and cleaving equipment.

Common tools used to cleave stone, brick, or concrete materials are the brick set, which concentrates the downward force of a hammer along a line to split material, and the hydraulic splitter, which uses a bar under high pressure to split material. Both tools can be used to cleave material of any size, but the hydraulic splitter is best for large units.

Typical tools used for cutting paving and wall materials are the cutoff, or chop, saw, which uses a dry high-speed circular blade; the wet masonry saw, which uses a wet high-speed circular blade; and the chain saw, which uses a lubricated linked blade. The cutoff saw can be used for larger stone and wall pieces, but should not be used for wood or smaller units such as brick and precast concrete paving block. The wet masonry saw can be used for stone and masonry units of all sizes. The chain saw is designed for cutting large dimensioned wood stock.

Successful cleaving and cutting require accurate marking of the material. To mark for cutting, hold the material in position and use a pencil to transcribe the cut location directly onto the material. Marking with a magic marker provides better visibility of the mark when using a wet saw. Place marks on the scrap side of the cut so the mark will not be visible when the material is placed.

Measuring requires that a high degree of accuracy be maintained. Most paving and wall material must be cut to within 1/8 inch of the required dimensions to avoid problems with fit. Irregular and angle cuts may take two fittings to get the correct shape. Available cutting methods make curved cuts difficult, and notching is difficult to obtain with all cutting tools except a wet masonry saw.

Procedures for using the various cleaving and cutting tools are described in the following sections.
Steps for Using a Brick or Stone Set to Cleave Stone, Concrete Paving, and Brick Materials
- Wear proper safety equipment and clothing.
- Place the material on sand and align the set along the desired location for cleaving.
- Tap the set lightly to score the material along the desired cleave line.
- Strike the end of the set sharply with a hammer (Figure 6–1). The material should cleave along that angle.

Steps for Using a Hydraulic Splitter to Cleave Stone, Precast, and Brick Materials
- Wear proper safety equipment and clothing.
- Mark the cleave location.
- Set material on the table with the cleave location directly below the striking bar (Figure 6–2A).
- Lower the bar to the stone manually and tighten (Figure 6–2B). If the splitter is equipped with a tilting base plate, angle paving material downward away from the cleave location when the bar is lowered.
- Press repeatedly on the foot pedal (Figure 6–2C). When the cylinder reaches the correct pressure the material will cleave.
- Raise the bar and remove cleaved material.

Steps for Using a Cutoff Saw to Cut Stone and Precast Materials
- Wear proper safety equipment and clothing.
- Mark the cut location.
- Anchor the material to avoid movement while cutting. Place a block underneath the material if necessary to avoid cutting into the surface below.
- Start the saw and position it over the material to be cut (Figure 6–3).
- Run the saw to full speed and slowly lower it onto the paving material.
- Apply light downward pressure, but do not force the saw into the material. Let the saw pass completely through the material before removing the blade from the cut.

Steps for Using a Wet Masonry Saw to Cut Precast Stone and Brick Materials
- Wear proper safety equipment and clothing.
- Fill reservoir of saw with water.
- Mark the cut location.
- Before starting the saw, place the material on the moving table and adjust the saw blade to the proper depth.
- Start the saw and verify that the water is flowing.
Set the paver against the guide on the moving cutting table and align the cut mark on the paver with the saw blade.

Hold the material firmly against the guide with both hands positioned away from the saw blade. If trimming only a small portion, hold only the larger portion of material.

Slowly pass the paver through the blade (Figure 6-4). If the motor begins to slow (indicated by a lowering of the pitch of the motor), back the material up and restart the pass through the blade at a slower pace.

Pass the material completely by the saw blade to complete the cut.

Turn off the saw.

When the blade stops turning, remove the cut material and scrap.

Steps for Using a Chain Saw to Cut Wood Materials

Do not cut with the tip of the saw blade. Use only the flat bottom portion of the blade while holding the body of the saw against the material. Read chainsaw operating instructions before beginning.

- Wear proper safety equipment and clothing.
- Mark the cut location.
- Place the wood so that the longer portion will have adequate support.
- Use one foot to safely anchor the tie/timber or have a coworker, standing at a safe distance, help hold the piece.
- With the chain saw resting on the ground, start the saw.
- Pick up the saw and run the motor to full speed, then slowly lower it into the material at the mark (Figure 6-5).
- Using a slight rocking motion with light pressure, make a square cut through the material beginning on the top side. Let the shorter piece fall freely when cut.
PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before beginning this exercise.

MATERIALS REQUIRED
- Proper clothing and safety equipment, including: safety glasses, work gloves, hard hat, dust mask, ear protection device, and work boots
- Tape measure
- Carpenter’s pencil/permanent marker
- Carpenter’s square/protractor
- Supply of stone, bricks, concrete paving blocks, precast concrete wall units, and wood retaining wall timbers
- Hydraulic splitter
- Brick set
- 2 pound sledgehammer or brick hammer
- Cutoff saw with fuel
- Wet masonry saw
- Access to water and GFCI circuit
- 50 foot heavy-duty grounded extension cord, if necessary
- Chain saw, fuel, and blade maintenance wrench

EXERCISE DESCRIPTION
To complete this exercise perform each of the following activities.

- Mark and square cut one piece of stone, one brick, and one concrete paving unit using a brick set and hammer, one repetition for each material.
- Mark and square cut one piece of stone, one brick, one concrete paving unit, and one precast concrete wall unit using a hydraulic splitter, one repetition for each material.
- Mark and square cut one piece of stone and one precast concrete wall unit using a cutoff saw, one repetition for each material.
- Mark and square cut one piece of stone, one brick, one concrete paving unit, and one precast concrete wall unit using a wet masonry saw, one repetition for each material.
- Mark and square cut a wood landscaping timber using a chain saw, five repetitions.
Exercise 7

Excavation Tool Maintenance

Objective
The objective of this exercise is to execute proper cleaning, storage, and sharpening of excavation tools.

Caution
Serious injury or death could result from improper use of construction equipment. Tools used to clean and cut present a significant safety risk. Read and follow manufacturer’s instructions with use of all tools. Use caution when working around sharp edges. Do not direct compressed air stream at any body part.

Textbook Reference
Information related to this activity can be found in the Landscape Construction textbook in Chapter 7, Basic Construction Techniques and Equipment Operation.

Introduction
Tools that are not maintained in good condition will reduce productivity of workers and affect project success. Key among the maintenance tasks are the proper cleaning, storage, and sharpening of tools. Proper cleaning and storage prevents the weakening of tools due to oxidation of surfaces. Maintaining the sharpness of excavation tools allows for maximum efficiency when digging. Steps for performing these maintenance tasks follow.

Steps for Cleaning and Storing Excavation Tools
- Wash and rinse soiled tools in water, using a wire brush to remove deposits.
- Spray with compressed air to remove any remaining soil or water.
- Wipe dry with an oil-soaked rag.
- Place in dry storage until next use.

Alternative Method for Storing Excavation Tools
- Remove soil or deposits on equipment using compressed air or wire brush.
- Plunge tools in oil/sand mixture to further remove deposits and coat surface.
- Store tools in oil/sand mixture until next use.

Steps for Sharpening Excavation Tools
- Hold tool at the base of the blade with the tip facing away.
- Turn blade upside down.
- Sharpen the tool by running a rat tail file along the edge of the blade in a series of short, successive strokes until desired angle is achieved, remembering to always push the file away in a downward motion, working toward the front of the tool (Figure 7–1).
- In the shop the same results can be achieved by placing the shovel in the jaws of a bench vise and repeating the process described previously.
A benchgrinder may be substituted for a file, but care must be taken not to oversharpen and weaken the blade by making the edge too thin. A blade edge made uneven by nicks and dents can be ground even, then sharpened to the desired angle.

**MATERIALS REQUIRED**
- Unsharpened round-nosed spade, square-nosed shovel, trenching spade, and clamshell posthole excavator
- Water hose with nozzle (prepared for operation)
- Air compressor with hose and nipple (prepared for operation)
- Wire brush
- Rat tail file
- 2 feet × 2 feet × 10 inch deep box filled with a mixture of sand and 2 quarts used motor oil
- Access to water and electricity for compressor

**EXERCISE DESCRIPTION**
To complete this exercise clean, sharpen, and store the following excavation tools:
- Round-nosed spade
- Square-nosed shovel
- Trenching spade
- Clamshell posthole excavator

**PREREQUISITE EXERCISES**
None.
Exercise 8

Construction Staking

OBJECTIVE
The objective of this exercise is to demonstrate staking and measurement techniques used to lay out projects.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 8, Construction Staking.

INTRODUCTION
Identifying the location of proposed improvements on a site is necessary when constructing any landscape project. Accurate layout of the elements of a landscape design requires mastery of the techniques and methods of construction staking. Techniques for construction staking are singular tasks used to discern right angles, locate radius points, project curves, and perform other basic layout activities. Methods for construction staking are systematic processes that combine individual techniques and should be used when many points need to be located in a design or on a site. Successful staking requires an understanding of both techniques and methods.

Staking Techniques
Following are step-by-step descriptions of the techniques that can be used to accurately locate points and lines within a project. Each technique can be used alone to locate key points on a site or can be used in combination with other techniques to implement staking of an entire design. These techniques are building blocks for the more comprehensive layout methods described later in this exercise.

Locating Points Using Triangulation
- Identify two known points in a landscape that are within a short distance of the object being located.
- Measure from each point to the object being located (Figure 8–1A).
- On a plan that shows the two known points, draw an arc from each that has a radius equal to the distance that was measured. Be sure to adjust for scale. Where the arcs intersect is the location of the unknown point (Figure 8–1B). This process can be reversed for locating an object in the field.

Layout of Right Angles Using 3, 4, 5 Triangle
- Locate an existing straight edge at the project site.
- Locate the point along that edge where you need to create a right angle (point A in Figure 8–2).
- From point A, measure 3 feet down the edge and locate point B (point B in Figure 8–2).
- From point A, stretch a tape in the direction you want the right angle to head (tape A, Figure 8–2).
- From point B, stretch a second tape that crosses over the first (tape B, Figure 8–2).
- Adjust both tapes until the 4 foot mark on tape A and the 5 foot mark on tape B intersect. Mark directly below that point (point C, Figure 8–2).
- The line traveling from point A and passing through point C will be at a right angle to the first edge.

Layout of a Right Angle Using the Equilateral Triangle Method
- From the point where a right angle is to be measured (point A in Figure 8–3), measure two
points, B and C, equal distance on either side from point A along an existing straight edge (baseline) at a project site. The distance is not critical as long as it is the same on both sides, but minimum measurements of 3–5 feet are recommended.

• From points B and C, stretch tape measures (tapes A and B in Figure 8–3) in the direction of the desired perpendicular.
• Select a measurement on tape A and match it with the same measurement on tape B.
• Mark the point where these like measurements intersect (point D, Figure 8–3).
• A line laid out from point A through point D will be at a right angle to the baseline.

**Using Diagonal Measurements to Check for Square**

• When laying out a landscape element that must maintain a square (or rectangular) form, check your work using diagonal measurements. Using two tapes, measure from diagonal corners and compare measurements. If the measurements are equal, the shape is square (Figure 8–4).
• If one measurement is longer than the other, the long corner must be pushed in slightly and the short corner pulled out slightly until the measurements match.

Locating Radius Points and Marking Curves
• Locate the point where the curve is to begin along a baseline at the site (tangent) (Figure 8–5A). Identify the general location of the radius point of the curve.
• Extend a tape measure from the baseline point in the direction of the radius point, ensuring the tape remains perpendicular to the baseline.
• Adjust the tape so it is the exact length of the radius of the curve. The point where the tape ends is the precise location of the radius point. Mark this point with a stake.
• To locate the end of the curve, measure out the curves angle with a transit or a large protractor, using the perpendicular line created earlier as a baseline for the angle measurement (Figure 8–5B). Mark the angle by driving a stake into the ground at an angle point.
• Extend a tape measure from the radius point in the direction of the endpoint. The tape should pass through the angle point.
• Adjust the tape so it is the exact length of the radius of the curve. The point where the tape ends is the precise location of the endpoint. Mark this point with a stake.
• Anchor the tape measure at the radius point with a screwdriver and pull the tape taut (Figure 8–5C). Swing the tape from the beginning point of the curve to the curve's endpoint, placing stakes at various points along the curve to guide construction. The distance between the radius point and each of these guide stakes should be the length of the radius.
• If another curve is to immediately follow the first curve staked at the site, create a new baseline (tangent) that is at a right angle to a line drawn between the first curve's radius point and its endpoint (Figure 8–5D). Once this baseline is created, repeat these instructions from the beginning to stake the second curve.
Construction Staking Methods

The techniques described earlier can be used to locate individual components of a design, but a consistent method needs to be employed when an entire design needs to be staked. Several methods are available for project layout, but three methods are most often used: grid layout, baseline layout, and object dimensioning. Selection of a layout method may be determined by construction documents prepared for a project. If a set of plans indicates location of elements using a particular layout method, that method should be followed. If no specific layout plan is dictated for a project, the contractor must choose a method.

Another consideration for project layout is whether the work should be performed by the contractor or by a land surveyor specializing in construction staking. A surveyor should be used when a project is large, includes several angled and curved shapes, or involves paved roadways, utilities, and structures. Using a surveyor should also be considered when contractors are unsure of their layout abilities. Mistakes in performing layout can be expensive, and contractors should not undertake a project that is beyond their abilities.

The following paragraphs describe steps to measure and lay out projects using grid layout, baseline layout, and object dimensioning. To use each of these layout methods a scaled, measurable plan of the project design must be available.

Grid Layout. Grid layout uses a pair of coordinate measurements, also called Cartesian coordinates, to locate points on a site (Figure 8–6A). These coordinates will be located off a pair of baselines set up at right angles to each other.

To create grid layout measurements for a project use the following steps:

- On the plan draw two perpendicular baselines. The intersection of these two baselines is the starting point for the grid layout and should correspond to an existing landmark that can be easily located on the site. The two baselines

A. Grid layout

B. Baseline layout

C. Object dimensioning

Figure 8–6 Construction staking methods.
should also correspond to natural baselines in
the field, such as walkways, fence lines, or
structural walls, or through an open area where
a tape measure can be placed to act as a
temporary baseline.
* Label one of the baselines X and the other
  baseline Y.
* Select a point on the design to be measured.
* Draw a guideline perpendicular to the X
  baseline that passes through the selected point.
* Measure along the X baseline from the starting
  point to the guideline. This measurement will
  be called the X measurement.
* Repeat this process for the Y guideline.
* You should now have X and Y measurements
  for the point you selected.
* Repeat those steps until each point to be
  located has an X and Y measurement.

To locate grid measurements on a project site use
the following steps:

* Identify the starting point, the X baseline, and
  the Y baseline on the project site. Stretch a tape
  measure along both baselines.
* Locate the X measurement for a point along the
  X baseline. From that measurement, extend a
  line perpendicular to the X baseline in the
  direction and slightly beyond where you
  estimate the point should be located.
* Locate the Y measurement for a point along the
  Y baseline. From that measurement, extend a
  line perpendicular to the Y baseline slightly
  beyond where you estimate the point will be
  located. This line should intersect with the line
  created in the previous step.
* The intersection of the two lines is the location
  of the point you are trying to locate.
* Repeat this process for all points that require
  locating.

**Baseline Layout.** Baseline layout is similar to the
grid layout method but uses only one baseline for
making measurements and placing stakes rather than
two. It is useful for sites where only one clear baseline
can be identified or established or for sites that are
long and narrow. To use this method, a starting point
is identified and a baseline drawn from this point (Fig-
ure 8-6B). Landscape elements are located by extend-
ing perpendicular guidelines from the elements being
located to the baseline. The length of the perpendicular
guideline is recorded. The distance between the
baseline starting point and the point at which the
guideline intersects the baseline is then also recorded.

To create baseline layout measurements for a proj-
et, use the following steps:

* Draw one baseline on the plan. The baseline
  should be in a location that can be easily laid
  out on the site. Mark one end of the baseline as
  the beginning point.
* Select a point on the design to be measured.
* Draw a guideline at a right angle to the baseline
  that passes through the selected point.
* Measure along the baseline from the beginning
  point to the guideline. This measurement will
  be called the X measurement.
* Measure along the guideline from the baseline
to the point. This measurement will be called
  the Y measurement.
* You should now have X and Y measurements
  for the point you selected.
* Repeat this process until each point to be
  located has an X and Y measurement.

**Object Dimensioning.** Object dimensioning is used
when the location of improvements can be measured
off existing landmarks such as structures (Figure 8-6C).

To create object dimensioning measurements for a
project use the following steps:

* On the plan locate a point that is to be
  measured. Locate a nearby existing object.
* Measure from the existing object to the
  proposed point. Layout of objects is easier if
  the measurements can be made at a straight or
  right angle to the proposed object. If a straight
  or right-angled measurement is not possible,
  estimate the angle for the measurement or
  align the measurement with a second existing
  object.
* The existing object, or the measurement point
  of the first object located, is then used to
  continue measuring other points for the
  project.
To locate object dimensions on a project site, use the following steps:

- Identify the existing object used to establish dimensions. Establish the proper angle and dimension to the proposed point.
- Locate the proposed point.
- Repeat this process for all points that require locating. Once proposed improvements have been located they may be used to establish locations for other points.

**Staking Offsets**

Stakes and original markings are often disturbed during the construction process. To avoid the process of restaking a site, use offsets. To do so, use the following steps:

- Stake out the construction points of a project.
- Place a second set of stakes at a consistent, predetermined distance and direction away from the first set of stakes. Typically, the second stake is placed 5 feet to the outside of the first stake at all points, but the distance and direction will vary depending upon project conditions. So long as the offset is consistent for every stake within a set of points, it makes little difference what the distance or direction is.

**DISCUSSION**

Following completion of the exercise discuss which layout method worked best for staking the site. Which was the easiest to use? Which provided the most accurate information? Which method would work best on other types of sites?

**PREREQUISITE EXERCISES**

Students should have successfully completed Exercise 1, Construction Math, and Exercise 3, Measuring with Architects' and Engineers' Scales, before beginning this exercise.

**MATERIALS REQUIRED**

- Four tape measures: feet/inches, feet/tenths (two should measure 100 feet or more)
- Mason's twine
- Forty surveyor's flags
- Marking spray paint
- Architect's scale and engineer's scale
- Writing materials

**EXERCISE DESCRIPTION—PART A**

To complete this exercise use the techniques described previously to lay out each of the objects shown in Figures 8–7 and 8–8. The drawings are to scale and must be measured before staking.

**EXERCISE DESCRIPTION—PART B**

To complete this exercise install construction staking for the project identified in Figure 8–9 first using grid layout and then with baseline layout.

**Figure 8–7** Laying out and checking for square. Locate the corners of the square shown in this drawing along the straight edge of a paved area.
Exercise 8  Construction Staking

Figure 8–8  Laying out curves and straight lines. Locate the dimensional line shown in this drawing on a level, open site.

Figure 8–9  Site used for layout methods exercise.
Exercise 9

Grade Staking

OBJECTIVE
The objective of this exercise is to mark grade stakes for a project using a dumpy level and a laser level.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 8, Construction Staking.

INTRODUCTION
Grading determines site drainage, sets the height of walls and paving, and establishes vertical relationships between site improvements. Staking grades properly is therefore critical to a project’s success. As with construction staking, a choice must be made with regard to who should perform grade staking. When the project is large or involves structures, paving, and/or significant drainage areas, a land surveyor should be contacted to perform the staking. Residential projects and smaller projects that incorporate surface drainage only can typically be staked by a contractor using stringlines, levels, and batterboards, or by using surveying instruments such as dumpy levels and laser levels.

Establishing the Benchmark
- Locate the object that is identified as the benchmark. Identify the point on this object for which the benchmark elevation is noted (such as the top of a fire hydrant or a mark on a walkway or curb).

Grade staking using a dumpy level or a laser level provides a higher level of precision than that which can be obtained through the use of stringlines. The process for setting grades using these levels is more involved than the previous methods, but works well when accurate dimensions are required for a variety of site elements. Before performing grade staking the key elements of a project must be located. Refer to Exercise 8 for methods of project layout. Grade staking using a dumpy or laser level includes the following steps: establishing the benchmark, setting up and leveling the instrument, measuring elevations and calculating existing grades, then calculating cut and fill amounts and marking grade stakes. Detailed instructions for each of these steps follow.

Note: The following instructions establish grades for projects with a grading plan. Projects without a grading plan will require estimating or calculating elevations and setting a temporary benchmark. Use only positive numbers for elevations.
Setting Up and Leveling the Instrument

- Place the level at a location that has good visibility of the benchmark and all locations that will require construction staking. This site should be in as level an area as possible where construction traffic and activity will not disturb the instrument.
- Set the tripod first by spreading the legs and positioning them with the mounting plate at a comfortable height and as close to level as possible. When mounted, the instrument should be at eye level for ease of operation. Push the legs of the tripod securely into the ground to avoid accidental movement.
- Remove the instrument from its case and secure it to the mounting plate by turning onto the threads on the mounting plate. Some levels have a threaded connector that is attached through the mounting plate. Turn the leveling screws gently until all four are in contact with the mounting plate.
- Level the telescope using the four thumb screws that support the instrument on the mounting plate. A small bubble level below the telescope indicates if the instrument is properly leveled. Note that a self-leveling laser requires only that the instrument be set up as level as possible, as the motors within the instrument will adjust the level automatically. For dumpy levels and manually adjusted laser levels, level the instrument using the following steps:
  - Turn the telescope so it is aligned with one pair of thumb screws.
  - Turn the thumb screws in opposite directions to center the bubble. If the level bubble needs to move to the left, turn both screws toward the center of the mounting plate (Figure 9-1). If the level bubble needs to move to the right, turn both screws toward the edge of the mounting plate. Continue adjusting until the level bubble is centered.
  - Turn the telescope 90 degrees to the right and repeat the leveling operation with the second pair of screws.
  - When level in that direction, turn the telescope back to the original direction and repeat the leveling process.
  - The telescope should now be level. Test by turning the telescope in all directions and verifying that the bubble stays centered. If the bubble is not centered, repeat the leveling process. The base of the thumb screws should always remain in contact with the mounting plate. If any screw is not in contact with the plate, lower the screw to the plate and repeat the entire leveling process.

Measuring Elevations and Calculating Existing Grades

Note: For more efficient layout, calculate cut/fill for each grade stake immediately after existing grade has been determined.

- Place the **survey rod** on the **benchmark**.
- Aim the survey instrument toward the benchmark, focus on the survey rod, and read the number in the center of the cross hairs (backsight) (Figure 9–2).
- Add that reading to the benchmark elevation to establish the height of the instrument.
- Set the survey rod by the base of the first grade stake.
- Aim the survey instrument toward the first grade stake, focus on the survey rod, and read the number in the center of the cross hairs (foresite).
- Subtract that foresite reading from the height of the instrument to obtain the existing grade at
Mark the grade on the stake or grading plan. To aid the contractor performing the grading work, a dark line can be drawn on the stake to indicate proper fill level.

- When using a laser level, the instrument will send out a level beam in an arc around the construction site. Operators holding rods with laser receptors will position themselves wherever a sighting is required. The operator will raise or lower the receptor until the beam is captured, usually indicated by a beeping noise from the receptor. The reading is taken from the receptor rod, completing the backsight or foresight.
- Repeat the foresights and calculations with each grade stake.

**Figure 9-2** Performing elevation calculations.
Calculating Cut and Fill Amounts and Marking Grade Stakes

• Select a grade stake at which to begin. Read the proposed grade for that point on the construction grading plan. If the proposed grade shown on the plan for that point is greater than the existing elevation, subtract the existing grade from the proposed grade. Write the difference on the stake with the word “fill.” If the proposed grade shown on the plan for that point is less than the existing elevation, subtract the proposed grade from the existing grade. Write the difference on the stake with the word “cut.”

• Repeat these calculations for each grade stake.

PREREQUISITE EXERCISES

Students should have successfully completed Exercise 8, Construction Staking, and Exercise 1, Construction Math, before beginning this exercise.

MATERIALS REQUIRED

• Four 2 × 2 stakes, 2 feet long, with pointed ends
• Two pound sledgehammers
• Two tape measures
• Broad tip marking pen
• Transit/dumpy level
• Laser level
• Survey rod
• Writing materials and paper
• Calculator

EXERCISE DESCRIPTION

To complete this exercise mark the proper amount of cut or fill at each corner stake for the design shown in Figure 9–3. This will require locating the corners of the project (see Exercise 8), selecting a temporary benchmark, setup of a dumpy level, setup of a laser level, measuring the existing grade at each corner of the project, calculating the amount of cut or fill for project spot elevations, and marking the corner stakes for cut or fill.
Exercise 10

Batterboard Construction

OBJECTIVE
The objective of this exercise is to construct batterboards to align corners and grades for a project.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 8, Construction Staking.

INTRODUCTION
Alignment of both project edges and grades can be maintained through the use of batterboards. Batterboards are wood frameworks, constructed just outside the edges of a project, that hold stringlines to mark the correct alignment and grade of project edges. The stringlines connected to the batterboards can be moved out of the way while construction takes place in the area and then replaced to check the accuracy of the work. Cross pieces hold the batterboard framework together and are the units within the framework to which the stringlines are attached. Following are steps for constructing batterboards for one corner of a project:

• Select three, pointed 2 × 2 stakes that are 4 feet long and two 1 × 6s that are 4 feet long.
• Mark two adjacent edges of the project by laying down stringline. Extend the stringlines 4 feet beyond the corner of the project in each direction.
• Drive the three stakes into the ground. The stakes should be in an L pattern, with each leg of the L paralleling one side of the project. The L should be located 2 feet outside the project edges and should straddle the stringlines (Figure 10-1A).
• Halfway up each stake along one side of the L, connect a 1 × 6 cross piece between the two stakes. Using deck screws allows connections to

Figure 10-1 Batterboard construction.
be made with minimal disturbance to the stakes.

- Connect the other 1 × 6 cross piece between the two remaining stakes.
- Connect a second set of stringlines to the 1 × 6 cross pieces with a small nail, using the stringlines on the ground as a guide for proper placement (Figure 10-1B).
- To use the batterboards for vertical as well as horizontal layout, ensure that the tops of the 1 × 6 cross pieces are in line with the project corner's proposed elevation.

**PREREQUISITE EXERCISES**

Students should have successfully completed Exercise 1, Construction Math, Exercise 5, Tool Operation and Construction Techniques, and Exercise 8, Construction Staking before beginning this exercise.
MATERIAL REQUIRED
- Twelve 2 × 2 stakes, 4 feet long
- Eight 1 × 6s, 4 feet long
- 200 feet of mason’s twine
- Two hammers: 16 ounce claw, 5 pound sledgehammer
- Fifty 1.5 inch deck screws
- Twenty 4d nails, 1.5–2 inches long
- Rechargeable drill/ screwdriver
- Tape measure

EXERCISE DESCRIPTION
To complete this exercise lay out the sides of the site shown in Figure 10–2 and construct batterboards to locate the alignment of each corner of the project.
Exercise 11

Plant Protection

OBJECTIVE
The objective of this exercise is to identify plant material that is at risk from construction activities and select methods to protect such plants.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 9, Preservation of Existing Site Elements.

INTRODUCTION
The root zone of a plant extends from the trunk to at least the drip line, or the imaginary line on the ground directly below the outermost foliage. Depending on plant species and environmental situations, many plants have root zones that extend beyond the drip line. Compaction, trenching, mixing of chemicals, excavation, storage of materials, and related construction activities within the drip line of a plant will damage the plant’s root system, eventually leading to damage to the remainder of the plant.

To reduce the potential damage to plants from construction activities, plant protection must extend at least to the drip line of the plant, and in some cases consideration must be given to restricting activities outside the drip line. Because of their size and vigor, many shrubs are fairly durable when exposed to construction activities. However, shrubs should be afforded the same protection given trees to enhance the chances of plant survival.

Protection methods for plant material can include fencing at the drip line, construction of an elevated walkway through the root zone, or deep mulching at the root zone. These techniques will reduce the compaction of root zone soil. Fencing a plant at the drip line and leaving the fence in place throughout construction will divert traffic and activities away from the plant. If traffic within a drip line is a necessity, accommodate it by building an elevated wood boardwalk or by placing 8–10 inches of loose, organic mulch over the ground within the drip line. Avoid piling mulch against the trunk of any plant; however. Maintain the mulch by restoring and “fluffing” compacted areas, and assist the protected plants with daily watering.

To assess a site for potential damage to plant material from construction activities use the following steps:

- Identify the construction site and boundaries.
- Familiarize yourself with the construction plans, including the location of areas on the site that will be disturbed by building, trenching, storage, and access.
- Identify plant material within the areas that is worthy of preservation but likely to be disturbed.
- Assess the risk to these plants.
- Develop a plan for protection of at-risk plants.

DISCUSSION
Review a design and the site on which the design is to be constructed. What impact will the design have on the site? What types of disruptions may not be obvious? Which protection techniques will be most feasible?

PREREQUISITE EXERCISES
None.
MATERIALS REQUIRED
• Writing materials

EXERCISE DESCRIPTION
To complete this exercise assess the potential construction site identified by the instructor to determine which plant materials need to be protected and what methods would best provide the necessary protection. Prepare a written summary listing the plant material at risk and the protection techniques recommended for each.
Aeration of Trees

OBJECTIVE
The objective of this exercise is to aerate tree root zones.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 9, Preservation of Existing Site Elements.

INTRODUCTION
The general health of plant material can be harmed by compaction of soil in the root zone. While aeration is not a substitute for keeping traffic away from the root zone, it can reduce the damage caused by compaction by providing pathways for oxygen, water, and nutrients to the plant root zone. Two methods to aerate the root zone are vertical mulching and radial trenching, both techniques that create openings in the surface and replace compacted materials with loose fill. Not all plants require aeration, nor will all plants benefit from aeration techniques.

VERTICAL MULCHING
Vertical mulching involves drilling vertical holes in an even pattern throughout the root zone, then filling those holes with a loose, porous material that allows air and water to penetrate plant roots. To perform vertical mulching, use the following steps:

- Drill 3 inch diameter holes that are 12 inches deep every 3 feet throughout the root zone according to the pattern shown in Figure 12–1.
- Fill the holes with pea gravel, peat moss, or mulch.
- Properly dispose of the excavated soil.

Radial Trenching
Radial trenching requires the excavation of narrow trenches from a point near the base of the tree trunk outward toward the edge of the root zone. Several trenches are excavated and then filled with a loose growing medium that allows air and water to penetrate the plant roots. In addition to aerating the root zone, radial trenching encourages new growth on roots damaged by construction. To perform radial trenching, follow these steps:

- Select five to seven straight excavation paths radiating out from the trunk of a tree, avoiding major roots if possible.
- Starting approximately 4 feet from the trunk, excavate a 12 inch deep by 2 inch wide trench along each path that extends to the plant drip line.
- Backfill the trench with loose soil or compost (Figure 12–2).
- Properly dispose of excavated soil.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before completing this exercise.
Exercise 12  Aeration of Trees

OPERATE POWER EQUIPMENT UNDER SUPERVISION. SERIOUS INJURY OR DEATH COULD RESULT FROM IMPROPER USE OF EQUIPMENT. FOLLOW MANUFACTURER’S INSTRUCTIONS.

MATERIALS REQUIRED
- Two trees growing on a flat expanse of ground that have compacted root zones. The trees should have a caliper of approximately 6 inches or greater, a canopy spread of approximately 30 feet, and be on barren ground or with turf planted in the root zone.

Figure 12-1  Vertical mulching.
EXERCISE DESCRIPTION
To complete this exercise, aerate one tree using the vertical mulching instructions, and aerate the second tree using the radial trenching instructions.

- Pea gravel, ground mulch, compost, or loose soil to fill excavations
- 3 inch diameter hand or power auger
- Trenching shovel or 2 inch wide power trencher
- Round-nosed shovel
- Wheelbarrow
OBJECTIVE
The objective of this exercise is to properly grade a landscape berm.

CAUTION
Locate all utilities before beginning construction.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 11, Site Grading.

INTRODUCTION
One primary function of landscaping is to shape the topography of a site to suit the functional and aesthetic needs of a design. Berming, or mounding the soil, can meet both of these needs. Typically recognized as a decorative element of the landscape, the berm can also direct runoff and screen views. Berms are extremely versatile considering they can take any shape or size required by the designer.

Berm construction requires the placement and shaping of soil to match the desired contours. The steps required to construct a berm include the following:

- If necessary, strip topsoil from the area within the perimeter of the berm.
- Deposit soil in the berm area. The type of soil used will be based on the size and depth of the berm. Typical berm construction uses quality fill soil to create the general shape of the berm, with a layer of topsoil over the fill. The thickness of this layer will be based on the plant type being used on the berm. Berms constructed completely of topsoil are ideal for planting, but may settle over time.
- Rough grade the soil to approximate the desired shape.
- Taper the edges of the soil to meet the existing grade.
- Verify the contours, elevations, and slopes required by the design.
- Finish grade the surface.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before beginning this exercise.

MATERIALS REQUIRED
- Round-nosed shovels
- Garden rakes
- Wheelbarrows
- Dumpy level and surveying rod
- 50 foot tape measure
- Marking spray paint
- Sod cutter (prepared for operation)
- Topsoil
- OPTIONAL: Skid-steer and dump truck
EXERCISE DESCRIPTION
To complete this exercise construct the berm to the dimensions shown in Figure 13-1.

CAUTION
Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.

Figure 13-1 Plan and cross section for berm construction.
Exercise 14

Tile System and French Drain Construction

OBJECTIVE
The objective of this exercise is to properly construct a french drain and a tile drainage system with an inlet.

Locate all utilities before beginning construction.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 12, Site Drainage.

INTRODUCTION
Draining surface and subsurface water from a project may be necessary to protect landscape improvements. Solutions to drainage problems range from sloping the grade to allow for surface drainage to installation of expensive concrete inlets and storm sewer piping. A solution that lies between these options is the installation of a drainage tile system. Drainage systems can be designed to store excess surface water in a closed system or to remove water via a tile drainage system.

French Drain to Store Excess Surface Water
When a project has an enclosed, low area that is continually wet from excess surface drainage, a french drain can be constructed to mitigate the problem. A french drain is an underground sump that temporarily holds excess runoff until it can percolate into the surrounding soil. Please note that a french drain is not a permanent solution to a drainage problem and will not work in areas with heavy runoff. When the problem is short-term standing water, however, the french drain can be effective for several years. The proper length of the french drain should be calculated by an experienced contractor or design professional. Use the following steps to construct a french drain:

• If the site will not accommodate a single trench, the length may be split into separate trenches placed at least 36 inches apart.
• Flag the location for each trench. To be effective the trench should be located directly under the wet area.
• Excavate a trench 1 to 2 feet wide and 42 inches deep along the lines marked. In turf areas the sod may be removed and set aside for reuse. Save approximately 10% of the soil excavated from the trench for cover.
• For each trench cut two lengths of 48 inch wide landscape fabric 2 feet longer than the trench length.
• Place the first piece of landscape fabric up one side of the trench. Fold the top over the outside edge of the trench. It is not necessary to cover the entire bottom of the trench.
• Repeat this process with the other piece of landscape fabric on the opposite side of the trench.
• Fill the trench with 1 to 2 inch diameter washed river rock (Figure 14–1) to within 6 inches of the top. Use care when filling the trench so the landscape fabric is not disturbed.
Fold the remaining landscape fabric over the top of the river rock.
Backfill the trench with the soil set aside earlier and compact. If sod was saved, replace over the fill.

**Tile Systems to Drain Surface Areas**
In areas where drainage problems are minor, but cannot be solved through sloping or french drains, a tile system may be required. Tile systems can collect and remove surface water or can drain subsurface water depending on their design. A surface drainage system requires sloping the project surfaces to an inlet, or a series of inlets, which drain into a nonperforated drain tile that leads to an outlet. To install a tile system with inlets follow these steps:

- Flag inlet point(s) and an outlet point.
- Beginning at the outlet point, excavate an 8–12 inch wide trench along the entire length of the collection system. The trench should be deep enough that the grade can fall at a minimum 1% rate from the highest inlet to the outlet point.
- Beginning at the highest end of the trench, lay 4 inch diameter nonperforated tile that begins at the surface and runs to the bottom of the trench (Figure 14–2). Continue running tile along the bottom of the trench for its entire length. Place a carpenter's level on top of the tile every 5 feet to verify the downhill slope of the pipe.
- At the beginning of the tile, cut the tile flush with the surface and install a cap. This cap will serve as a clean-out should the tile become plugged.
- At each location where an inlet is planned, cut the tile with a carpet knife and insert a premanufactured tee connection. In the top opening of the tee, insert a vertical tile (riser) running from the tee to approximately 12 inches above the surface. Continue laying tile and inserting tees until the entire system is complete. Apply duct tape around any connections and joints to reduce the chance that a connection pulls apart.
- Backfill the system to the surface, lightly compacting the backfill after every 6 inch layer.
- At each inlet location, excavate the surface finish grade to slope downward toward the riser.
- Cut each riser flush with the surrounding elevation and place a premanufactured fiberglass inlet into the end of the riser.

![Figure 14-1 French drain cross section.](image1)

![Figure 14-2 Tile system cross section.](image2)
Tile Systems to Drain Subsurface Water
Tile used to mitigate subsurface water problems is laid out so as to cover the entire project site. Using parallel tiles spaced according to the soil type, rainfall, and severity of water problem, the water is intercepted and removed from the site before it reaches and affects the surface. At the low end of these parallel tiles a collector tile intercepts the drainage and routes it to an outlet point.

Installation of a subsurface drainage system is similar to that of a surface drainage system with one primary exception. Subsurface systems use perforated tile to allow water to enter the pipe and do not require surface inlets. To reduce the potential of silt filling a perforated tile, backfill the first 12 inches above the tile with coarse backfill material such as pea gravel or use a perforated tile with a geotextile sock.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before beginning this exercise.

MATERIALS REQUIRED
- Survey stakes/flags
- Carpenter's level
- Round-tipped shovels
- D-handled, flat spades
- Pick
- 50 foot and 100 foot tape measures
- Utility knives
- 30 feet of 4 inch nonperforated plastic drainage tile
- T, fiberglass honeycomb, 90° elbow and plastic cap fittings for 4 inch nonperforated plastic drainage tile
- Duct tape
- 1–2 inch washed river rock
- 30 linear feet of 48 inch wide landscape fabric

NOTE: Material quantities allow for a single installation of each exercise.

EXERCISE DESCRIPTION—PART A
To complete this exercise trench and install a 10 foot long french drain (Figure 14–3) with landscape fabric liner and washed river rock fill. The drain should be 3 feet deep by 1 foot wide and centered in the low area of the practice site. Place 6 inches of soil cover over the river rock core of the drain. Resod if the drain is installed in a turf area.

EXERCISE DESCRIPTION—PART B
To complete this exercise trench and install a 20 foot run of nonperforated 4 inch diameter tile with a honeycomb surface inlet at one end. The tile should be placed 18 inches below grade. If possible, the outlet end should be directed to a free out or connected to a tile system or storm sewer system (Figure 14–4). If these solutions are not available, cap the outlet end.
OBJECTIVE
The objective of this exercise is to properly install erosion silt fence.

CAUTION
Locate all utilities before beginning construction.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 13, Erosion Control.

INTRODUCTION
Disturbed sites that are exposed to the elements can lose excessive amounts of soil through surface erosion. When water runoff is concentrated, the possibility that deep channels will cut through the site also exists. To counter the effects of soil loss and gullying, silt fence can be installed. Silt fence works by interrupting the flow of runoff water, slowing the water to the point where the sediment it carries is dropped. While silt fence does not stop erosion, it can assist in reducing damage both on and off the construction site. Use the following steps to install silt fence:

- Mark the locations where fences need to be installed. For channel installations silt fence should be placed across the channel perpendicular to the direction of the water flow.

The fence should run from the top edge of one side of the channel to the top edge of the other side of the channel. A slight V alignment can assist in storing additional sediment. If installed with a V alignment, the V should point downstream.

- Clear weeds and debris for a 2 foot wide path along the area identified for the silt fence.
- Excavate a 6 inch wide by 12 inch deep trench along the path.
- Cut a length of premanufactured silt fence the length of the channel. Cut so a stake is at each end of length. If the length of the fence is too long for the trench, roll the fabric around the stake until the desired length is obtained. The silt fence should be completed using a single piece of material.
- Set the cut length of fence in the channel with the fabric on the upstream side. Beginning at one edge of the channel, drive the first stake into the bottom of the trench (Figure 15–1).
- Stretch the silt fence out along the length of the trench. With each successive stake, stretch the fabric taut between the stakes and drive the stake into the bottom of the trench.
- Complete the installation by backfilling and compacting the trench, burying the bottom 1 foot of fabric.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before beginning this exercise.
MATERIALS REQUIRED
- Square-nosed shovels
- Round-tipped shovels
- 30 feet of premanufactured silt fence material with stakes
- 5 pound sledgehammer
- Survey stakes/flags

EXERCISE DESCRIPTION
To complete this exercise trench and install silt fence in a V shape across the swale. The point of the V should be placed in the center of the swale, and the legs of the V should run to the edges of the swale. The legs of the V should be angled slightly upstream with the point of the V aimed downstream.

Figure 15-1 Silt fence installation and layout plan.
Exercise 16

Installing Wattles

OBJECTIVE
The objective of this exercise is to install wattles.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 13, Erosion Control.

INTRODUCTION
Slowing drainage water as it passes over a sloped surface will cause it to drop sediment carried in the water, thus reducing erosion. Methods available to the landscape contractor to slow drainage water temporarily include mulching, installing silt fences (see Exercise 15), installing erosion control blankets (see Exercise 17), or installing wattles. Wattles are tubular shaped nylon nettings filled with straw or fibers. The tubes are anchored in the bottom of a shallow trench that runs perpendicular to the flow of drainage water. As drainage water passes over a surface it encounters the wattle, slows, and drops the sediment load. In addition to reducing surface erosion on slopes, wattles can be used around the rims of storm drains and in locations where it is desirable to reduce sedimentation, or soil washing off of a construction site. Wattles are a temporary erosion control measure. The materials used to fill wattles degrade over time, so wattles should not be left in place after permanent cover or erosion control is in place. To install a wattle use the following steps:

- Mark the proposed alignment of the wattle.
- Measure for length by laying out the material near the location where it is to be installed.
- Cut the wattle to the desired length using tin snips or a knife. Reseal the cut end of the netting using a twist tie.
- Along the alignment excavate a shallow concave trench approximately 2 inches deep and 6 inches wide.
- Place the wattle in this trench. Ensure the wattle has good contact with the soil along the entire length of the trench. Stake it into place using 12 inch long 2 x 2 wood stakes spaced every 5 feet (Figure 16–1).
- Use excavated soil to backfill along the front of the wattle.

Figure 16-1  Wattle installation.
PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before completing this exercise.

MATERIALS REQUIRED
- Gently sloped area approximately 20 feet by 20 feet. A barren unplanted area works best.
- 15 linear feet of wattle material
- Five 12 inch long, 2 × 2 wooden stakes
- Twist ties
- Marking spray paint
- Tin snips or utility knife
- 5 pound sledge hammer
- Round-nosed shovel
- Wheelbarrow

EXERCISE DESCRIPTION
To complete this exercise, install a wattle according to the plan shown in Figure 16-2.
Exercise 17

Erosion Mat Installation

OBJECTIVE
The objective of this exercise is to properly install erosion mat.

CAUTION
Locate all utilities before beginning construction.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 13, Erosion Control.

INTRODUCTION
Erosion of surface material can create problems for any disturbed site, whether completed or under construction. One method of controlling surface erosion is the use of erosion control blankets (ECBs) or erosion mats. Erosion mats consist of a layer of biodegradable materials sandwiched between two layers of lightweight netting, anchored with large metal staples. Mats of this type are intended to be anchored to a disturbed surface that has been seeded and are meant to degrade over time. The lightweight netting is ground up by mowers or imbedded into the ground cover that eventually covers the site. Erosion mats provide a stable form of protection for gradual slopes. Erosion mat installation is accomplished using the following steps:

- Identify the area to be covered with erosion blankets.
- Prepare the entire seedbed below the area where the mat is to be placed. Place starter fertilizer and seed over mat area. The surface must be smooth and without ridges or valleys.
- Excavate a 6 inch deep trench the width of the mat along the high side of the installation (Figure 17-1A).
- Beginning at the high edge of the slope, roll out mats in the direction that water will run. Where two mats are adjacent to one another, overlap the mats by 12 inches. Mats can also be overlapped if there is excess material in odd shaped areas. Overlap by placing the mat from the higher side over the mat on the lower side, then secure with staples (Figure 17-1B).
- Verify that there is good mat-to-soil contact.
- Tuck the mat into the trench at the high side and secure every 12 inches with staples at the bottom of the trench (Figure 17-1C). Cut off any excess material using a utility knife.
- Install sod staples or metal stakes every 12 inches around all edges of the mat.
- Place staples in staggered rows 18 inches apart along the length of the mat (Figure 17-1D).
- Backfill and compact the trench.

For installations where the slope length is over 20 feet from top to bottom, install an additional row of stakes across the width of the mat every 10 feet (Figure 17-2). For additional stability, the mat can be wrapped around a 1/2 inch wood dowel or piece of #8 rerod at various points on the sloped surface. The dowel or rerod should be perpendicular to the direction of the water drainage and mat and should be secured with stakes (Figure 17-3).
If the probability of water running under the mat is high, check slots can be created to fasten the mat more securely to the ground. To construct a check slot, follow these steps:

- Excavate a 6 inch deep by 6 inch wide trench along the entire width of the slope at the point where a check slot is needed.
- Roll the blanket into the trench and staple at the bottom, then fold the blanket uphill on top of itself (Figure 17-4A).
- Fill the trench and compact.
- Continue rolling the blanket down the hill (Figure 17-4B).
- It is advisable to remove all stakes and staples that can be found after the ground cover is established but prior to the first mowing. This will reduce the chance of mowers “throwing” loose stakes as projectiles and protect mowing equipment from damage.

**PREREQUISITE EXERCISES**

Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before beginning this exercise.
MATERIALS REQUIRED
- Garden rakes
- Square-nosed shovels
- Drop spreader
- Utility knife
- Claw hammers
- Rubber mallet
- Landscape staples or sod staples
- 60 feet of 48 inch wide erosion mat material
- Fertilizer
- Seed (preferably ryegrass or buffalo grass)

EXERCISE DESCRIPTION
To complete this exercise cover a 10 foot × 10 foot gradually sloped area with erosion mat. Anchor the high side of the mat, and overlap/staple the mat along two seams.

Figure 17–4  Securing erosion mat using a check slot.
Exercise 18

Cellular Confinement Systems

OBJECTIVE
The objective of this exercise is to install cellular confinement erosion control.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 13, Erosion Control.

INTRODUCTION
When exposed slopes are steep, the methods used to reduce erosion most provide a higher level of protection than mulches or erosion control blankets. Cellular confinement systems use a web of geotextile pockets filled with soil to hold the surface of a slope in place against erosion forces. Drainage water passes over and through the soil fill and cellular material, with the pockets functioning like small dams that hold the soil and slow the water running down the hillside (Figure 18-1). On steep slopes the cellular confinement system can be filled with granular material or concrete to provide additional stability. To install a cellular confinement system follow these steps:

- Remove all debris and irregularities from the surface to be protected.
- Excavate a 12 inch wide by 12 inch deep trench along the entire top edge of the slope to be covered.
- Place an erosion mat (ECB) over the entire slope and fold it into the trench (Figure 18-2). The mat should be placed with the long dimension running down the slope, in the same direction as the runoff. Staple the erosion mat onto the soil surface every 12 inches along all seams and edges and every 18 inches throughout the center of the material.
- Supporting lines, or tendons, are anchored in the trench at the top of the slope using rerod, stakes, or specialty fasteners supplied by the manufacturer, such as ATRA© anchors, or DUCKBILL© anchors. Anchor the tendons, spacing them to match the openings in the cellular confinement system.
- Stretch the unexpanded cellular confinement system along the top of the slope next to the anchored tendons.
- Thread the tendons through the openings in the unexpanded cellular confinement system. To make the threading easier, push a hook through the unexpanded tendon hole from the bottom side to catch the tendon and pull it
back through the opening. Threading can also be made easier by placing a small hollow tube through the opening and threading the tendon through the tube.

- Pull the tendons down the slope and space them parallel to one another.
- Anchor the top edge of the confinement material at the top of the slope. Place one anchor through the bottom of a cell between each tendon location.
- Expand the cellular confinement system down the slope. If the slope is irregular some cells can be partially expanded or tapered to match the slope irregularity.
- Anchor the bottom of the cellular confinement system by knotting the tendon just past the last cell and anchoring the tendon just beyond the last cell.
- Fasten runs of cellular material to each other by stapling cells along the edge of the material.
- Anchor the installation internally by staking the tendons at 5 foot intervals down the slope.
- Fill the cellular confinement system from the top of the slope working downward. Gently place fill material by hand or using excavation equipment. Evenly distribute the material throughout the cells.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before completing this exercise.

MATERIALS REQUIRED
- Gradually sloped barren area approximately 20 feet by 20 feet. An unplanted area with a total vertical drop of 3 feet to 5 feet works best.
- Erosion mat to cover a 10 foot × 10 foot area, including stakes
- A 10 foot × 10 foot section of cellular confinement system, including tendons and stakes
- Enough soil or granular material to fill cells of confinement system
- Marking spray paint
- Tin snips
**Exercise Description**

To complete this exercise, install a 10 foot by 10 foot section of cellular confinement system according to the plan shown in Figure 18–3.

- Scissors
- Rubber mallets
- Claw hammers
- Utility knife
- 5 pound sledgehammer
- Square-nosed shovels
- Round-nosed shovels
- Garden rakes
- Wheelbarrow
DC Lighting Installation

OBJECTIVE
The objective of this exercise is to properly install direct current low-voltage landscape lighting.

LOCATION OF UTILITIES
Locate all utilities before beginning construction. Use caution when working with electricity. Verify that electrical circuits have been turned off before working on a lighting system. Exterior lighting systems should be connected only to GFCI circuits. Follow the manufacturer's instructions for all lighting installations.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 14, DC Site Lighting and Related Electrical Work.

INTRODUCTION
Adding lighting to a landscape has been made easier with the availability of DC lighting kits. These kits provide the parts necessary to connect to an exterior receptacle and illuminate several fixtures along a lengthy electrical cable. DC systems allow for a variety of lighting fixture styles to be featured on a site and have enough lighting power to perform decorative functions in the landscape.

Installation of DC lighting requires a minimal number of tools, and DC cables can be placed directly on the ground as there is a low risk of shock if the cable is cut. Typical installations place the cables through planting beds covered by mulch, but this shallow placement does create an opportunity for the cable to be easily severed by construction and gardening activities. If severed, or if additional cable length is required, splicing kits that clamp the ends of two cables together to complete circuits are available.

Steps for Installing DC Lighting
Note: Instructions may vary from manufacturer to manufacturer. Follow directions supplied with lighting kit if different than those that follow.

- Place light fixtures in desired locations.
- Locate AC power source. Power source must be ground fault protected (GFCI).
- Mount transformer near selected outlet.
- Connect controller (controllers may include timers, photocells, or similar circuit controls) to transformer if it is a separate unit. Both should be placed where easily accessible.
- Lay cable to location of first fixture and install first light fixture. Connect as follows:
  - Insert bulb into lamp base socket.
  - Attach lens to lamp base. Lenses will snap or twist into the base.
  - Run a loop of cable through the mounting stem bracket.
  - Connect the lamp base to the cable by pressing the cable onto the metal prongs projecting from the lamp base. These prongs puncture the cable and make contact with each conductor in the wire. One metal prong must make contact with each side of the cable. Use care not to bend the prongs.
  - Attach a threaded cap to hold the cable in place.
Slide the mounting stem bracket into place over the threaded cap. Insert the mounting stem into the mounting stem bracket. Gently push the fixture into the ground. 

- Repeat installation steps for all fixtures along the cable. 
- Plug the transformer into the AC power source.

Ground-level lights may have the stem and fixture in a single unit, allowing the installer to connect the light and insert the mounting stem into the ground in a single operation. Mounted lights may require the fixture be snapped or bolted to a mounting base.

**EXERCISE DESCRIPTION**

To complete this exercise install and test a DC exterior lighting system (Figure 19–1). The system should include a controller with timer and photocell, spotlighting, and area lighting.

**CAUTION**

Follow manufacturer's instructions. Verify that power has been turned off before working with electrical systems.

**PREREQUISITE EXERCISES**

None.

**MATERIALS REQUIRED**

- Premanufactured DC lighting kit with the following:
  - Controller
  - 50 foot cable
  - Two area light units
  - Two spot light units
  - Wire cutters
  - Standard head screw driver
  - Claw hammer
OBJECTIVE
The objective of this exercise is to assemble a basic irrigation system.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 15, Water and Irrigation System Installation.

INTRODUCTION
Irrigation systems provide water for plant growth in all types of landscape settings. Effective irrigation systems begin with the careful design and planning of the entire installation. Considerations that must be incorporated into the design of an irrigation system include:

- System layout with “zones,” or sections with specific watering requirements. Most irrigation sites have zones with varying water demands that require a similar method of water delivery.
- Access to a reliable water supply. The water source must provide adequate pressure and volume to deliver the required amount of water to all zones in the system. Large sites often require the creation of zones simply to provide for ample water pressure and volume throughout the site.
- Connection to the water supply. Connecting to a water source will require plumbing from the water source to a point where a backflow prevention device is installed. An emergency shutoff and drain should also be installed in the connection supply line.
- Installation of a backflow prevention device. Before completing any irrigation system, a backflow prevention device must be installed to prevent contamination of the water source to which the system is connected. All backflow devices require that the mounting height of the valve be above the highest irrigation head, with most ordinances requiring that the backflow prevention device be installed a minimum of 1 to 2 feet above the highest head.
- Location of the controller. The controller is a switch that turns irrigation zones on and off. This controller must be located with access to power through a dedicated GFCI circuit, easy connection to the irrigation system, and a location where the system operator can gain access for maintenance. Any sensors that monitor or control the system must also be accessible to the controller.

Failure to properly install a backflow prevention valve when connecting an irrigation system to a potable water supply may lead to contamination of the water supply.

Connection to a water supply and electricity source requires the assistance of a licensed plumber and electrician.

Once planning is complete and the water service has been installed up to the backflow prevention...
device, the distribution and control system can be installed. The following sections outline the steps typically included in each phase of irrigation system installation.

**Trenching**
Trenching for irrigation projects can be completed by hand or with rented trenching machines. Excavate only the amount of trench that will be worked on in any given session. Excavation depths vary depending on the design, plumbing codes, the type of line, and the geographic location of the installation. The burial depth of nonpressurized lines can vary from 10 inches to 14 inches, and piping in locales that experience cold temperatures can be buried deeper to protect them from frost. Trenches should be at least 4 to 6 inches wide with a smooth bottom. The trench should be free of debris and large clods of earth before the pipe is laid into the trench.

**Installing Wiring**
After trenching is complete, install the control wiring from the controller to the manifold or to each valve. Wiring connections should be made using waterproof wire nuts to reduce the chance of system failure due to corrosion. Most wiring installations for irrigation are 18 gauge, but 14 or 12 gauge will carry more voltage. Control wires should be run from the controller to each valve in the manifold or each individual valve placed around the site. The wires should be positioned 2 to 4 inches away from the main line piping, and preferably below the pipe. This position will provide some protection for the wiring when repairs are required.

Loose wiring should be taped together every 5 feet with electrical tape, or all wires can be placed in a 1 inch diameter conduit placed in the trench. Leave ample wire to make connections at the manifold or valve box locations.

**Main Line Installation**
Connecting pipes outside the trench makes for easier work and reduces the possibility that foreign materials will enter piping.

- Beginning at the backflow prevention device, lay out piping along the trenched route, leading from the backflow prevention valve to the valve manifold or each valve location.
- Trim the pipe to the proper length and connect pipes.
- Gently place the lines into the trench, using caution to not get any dirt or debris in the pipes.

**Manifold and Valve Installation.**
Systems may be designed to use a valve manifold situated in one location or valves that are positioned near the beginning of each irrigation zone. Most manifolds are a series of aboveground valves mounted on risers that extend upward from the supply line. A second set of lines exit the valves and return below ground to function as laterals that supply the irrigation heads. Assemble a manifold, place it in the trench, and connect it to the supply main. Then bring the control wires up the manifold risers and connect them to the valves.

Valves that are distributed throughout the site are set below grade and placed in valve boxes. To position and assemble this type of valve, follow these steps:

- At each location where a valve is to be located, excavate an opening the size of the valve box, plus 6 inches on each side and 4 inches below. The location for the excavation should be centered on the valve location straddling the main. If the piping from the main to the valve is entering from below, center the box location on this pipe. Use caution not to damage the controller wires and main line already installed.
- In locations where freezing temperatures are a possibility, install a backdrain at key points in the system. Under each valve location dig an 8 inch diameter by 2 feet deep sump hole and fill the hole with pea gravel.
- Place 4 inches of free draining angular fill in the bottom of the valve box excavation.
- Hold the valve in the desired location and mark the main for trimming.
- Trim the main.
- If a sump has been installed, place a tee connected to a ball valve drain directly over the sump. Add 6 inches of piping to the valve side of the tee. Glue all fittings together.
- Glue the fitting onto the cut end. When the glue has set, thread the valve onto the main fitting.
- If a sump is installed, glue or thread the ball valve to the tee.
- Connect the laterals to the valve after laterals and risers are assembled.
- Place valve boxes after laterals and risers are installed.

**CAUTION**
PCV piping, solvents, and primers are highly flammable. Use caution when joining pipe using these materials. Keep away from open flames, and work in a well-ventilated place.
Lateral and Riser Installation
From each valve location extends a network of pipes that thread through the site or zone, connecting the valves to each irrigation head location. These pipes are called **lateral**s. At each irrigation head location, a connecting pipe called a **riser** runs from the lateral to the irrigation head. Each lateral in an irrigation system typically has several riser locations.

- To install laterals, lay out lateral piping next to the appropriate trench.
- Trim the pipe to the proper length and make all fitting connections outside of the trench. When making connections, start with piping closest to the valve, moving outward to the end of the irrigation line. Do not connect the lateral piping to the valve at this time.
- When a riser location is encountered, cut the lateral and glue a tee at the cut end. Verify that the placement of the tee and riser will position the irrigation head in the correct location without twisting or bending the riser. Do not install the head at this time. Risers can be a **nipple** (vertical pipe), a swing ell (assembly of pipe and joints that gives the riser flexibility), or a flexible pipe (Figure 20–1).
- Temporarily cover the riser with a threaded cap and continue installing the lateral and risers until the end of the irrigation line is reached (Figure 20–2).
- When all risers are installed carefully, place the lateral and risers in the trench (Figure 20–3).
- Connect the lateral to the valve.

Valve Box Installation and Valve Wiring
- Place a valve box over the valve and seat the box securely on the granular base.
- Verify that the controller wires are inside the valve box.
- Cover any openings in the box by duct taping heavy pieces of plastic to the outside of the box.
- To keep excess wire out of the way, coil the control wire around a 1/2 inch dowel. After the wire is completely wound, slide the coiled wire off the dowel.

Complete the control wire connections by connecting the “hot,” or colored, lead to the colored lead on the valve. Connect the “common” lead (typically white or green) to the common lead on the valve. The common leads for all valves can be connected at one point and then continued on to the next valve box, while the hot leads must be matched with the correct wire from the
controller. Some wiring schemes may be different, so verify the correct connections on the wiring diagram.

**Backfilling and Flushing**

- Carefully backfill the irrigation lines to half to two thirds full. Do not backfill around riser locations. Do not compact the backfill at this time and avoid stepping on the lines.
- When the partial backfilling is complete, uncap the risers.
- Turn the irrigation system on and flush each valve zone for approximately 5 minutes. Keep the open end of the risers out of the soil to prevent debris from flowing back into the lines.
- Allow water to enter the trenches to help settle the soil around the piping.
- Recap the risers and begin a second flushing, this time going riser to riser and removing one riser cap at a time. In each zone, first remove the cap on the riser closest to the valve and flush for 2 minutes, then recap the riser and repeat for the next riser in line. Repeat for each riser in each zone.
- Continue flushing until all risers have been cleaned.
- After this second flushing, finish backfilling the trenches.

**Head Installation**

Once the lines have been cleared of debris and backfilled, heads and distribution lines can be attached. When installing, use caution not to bend or kink the risers or to damage the equipment.

**Rotor, Spray, and Impact Heads**

- Most heads are threaded onto risers and set slightly above finish grade (Figure 20–4).
- When installing shrub heads or other riser-mounted heads that project out of the ground, place a post or #4 rerod next to the riser for stability. Bury the post or rerod at least 2 feet into the ground.

**Drip Tubes**

- Lines for drip irrigation are connected to the risers using a threaded compression fitting. Many systems connect drip distribution lines using barbed fittings, or fittings with a series of angled rings that grip the pipe when it is slid over the rings. One style of drip has emitters built into the tubing, evenly distributing water over the entire area where the line is laid. Custom drip systems require a hole be punched in the drip line using a special tool; then a barbed emitter is inserted into the hole. Yet another type of emitter is pushed into the distribution line, punching its own hole and snapping into position.
- When the emitters are in place, the lines should be flushed for 2 minutes.
- After flushing, the end of each distribution line is bent back on itself and clamped to close off the open end of the line.
- Lines are then anchored to the ground using sod staples.
Distribution Tube

- Lines for distribution tubes (spaghetti tubes) should be connected to risers using a threaded connection. These lines are laid near the area to be irrigated.
- A punch opens a small hole in the line and distribution tubes are inserted into the holes. Most distribution tubes have weights at their ends to hold them in position.

PREREQUISITE EXERCISES

Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before completing this exercise.

CAUTION
Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.

MATERIALS REQUIRED

- Access to water source using a 1/2 inch garden hose and a GFCI duplex outlet
- One irrigation controller with a minimum of two zones. Controller should be wired with a grounded plug.
- 50 feet white 14 ga. irrigation controller wire
- 25 feet green 14 ga. irrigation controller wire
- 25 feet red 14 ga. irrigation controller wire
- Two 3/4 inch irrigation valves with male connectors
- 50 linear feet of 1/2 inch PVC pipe
- 50 linear feet of 3/4 inch PVC pipe
- Two valve boxes
- Three assembled swing ells with 1/2 inch Mips
- Two flexible risers with 1/2 inch Mips
- One fitting 3/4 inch S×S×S tee
- One fitting 1/2 inch S×S 90 degree elbow
- Three fittings 3/4 inch S×S 90 degree elbows
- Four fittings 1/2 inch S×S×Fips threaded tee
- One adapter 1/2 inch to 1/2 inch S×Fips
g• One elbow 1/2 inch 90 degree S×Fips
g• Two adapters 3/4 inch S×Mips
g• Two reducing adapters 3/4 inch (threaded end) to 1/2 inch (slip end) S×Mips
g• One reducing adapter 3/4 inch (slip end) to 1/2 inch (threaded end) S×Fips (for hose connection)
g• Assorted 1/2 and 3/4 inch threaded and slip 90 degree elbows, couplings, and caps
g• Assorted waterproof wire nuts
• Joint tape
• 3 foot section of #4 rebar
• Electrical ties
• Pipe cutters
• Wire cutters
• Tape measure
• 50 foot 1/2 inch garden hose
• 50 foot grounded power cord
• 5 pound sledgehammer
• Adjustable crescent wrenches
• Small table on which to set controller

EXERCISE DESCRIPTION

To complete this exercise, install the basic irrigation system shown in Figure 20–5. To provide water, connect the system to a water supply using a garden hose. Place the controller on a table near the connection to the water supply and begin the wire feed to the controllers at the water supply point. Excavate trenches 12 inches deep.

Alternative Exercise

This alternative exercise provides practice in pipe cutting, fitting, and valve and irrigation head installation. Without trenching, cut and dry-fit assemble (connect without gluing) the basic irrigation system shown in Figure 20–5. No trenching, gluing, controller/wiring, or water supply is necessary for this version of the exercise. Please note that this exercise is to practice pipe cutting and assembly for a basic irrigation system.
Notes:
- All pipe and fittings ¾" PVC from supply to valves
- All pipe and fittings ½" PVC beyond valves
- Burial Depth 12"

Figure 20-5 Irrigation system exercise.
Wall Base Preparation

OBJECTIVE
The objective of this exercise is to properly install the base material for a landscape retaining wall.

CAUTION
Locate utilities before beginning construction. Follow manufacturer’s instructions when using equipment.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 16, Materials and Installation Techniques for Retaining Walls.

INTRODUCTION
The longevity of a landscape retaining wall depends on several factors, including the quality of the base upon which the wall rests. Proper preparation of the site and wall base requires that the area under the wall be excavated and the soil replaced with stable material capable of supporting the weight of the wall. Excavation to a depth that allows the first course of the wall to be buried is required, including for those sections where the wall steps up or down a hill. Base material typically consists of a granular footing placed below the first course of the wall. In situations where soils are unsuitable for granular footings, an engineer should be consulted to design the base structure.

To prepare a granular base for a landscape retaining wall, use the following steps:

- Lay out the wall alignment and grades.
- Excavate sod from 2 feet in front of to 2 feet behind the wall for the entire wall alignment (Figure 21-1).
- Excavate soil from the area, including the space in front of and behind the wall, to a depth that is approximately 8 inches lower than the desired finish grade along the front of the wall. This depth is necessary because the first course of any wall is placed below finish grade. The trench should follow the elevation of the alignment. Excavate stepped portions of the wall separately. When excavating, any loose or unstable materials encountered should be removed and replaced with granular backfill.
- After rough trenching is complete, restore the alignment and grade markings.
- In the rough trench excavate a level trench to be filled with base material. The trench should match the wall alignment and be 6 inches deep and 12 inches wider than the wall material being used. When the depth of this level trench exceeds the thickness of the wall material being used, the wall should step up one level (see Exercise 22).
- Fill this trench with free-draining angular 3/4 inch to 1 inch crushed stone.
- Level the base material end to end and front to back for each level of the wall.
- Compact using a vibratory plate compactor.
- The addition of a 1/2 inch to 1 inch layer of finer granular material will accommodate the leveling of the first course of wall material when placed in the trench. Crushed stone that passes
CAUTION

a 3/8 inch sieve is suitable for this purpose.
Relevel and recompact after granular material
is added.

PREREQUISITE EXERCISES

Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 8, Construction Staking, and Exercise 9, Grade Staking, before beginning this exercise.

MATERIALS REQUIRED

• Proper clothing and safety gear
• Mason's twine
• Survey stakes
• Hammers
• 100 foot tape measure (tenths)
• Round-point shovels
• Square-nosed shovel
• Mason's level (48 inch preferred)
• Torpedo level (6 inch)
• Line level
• Vibratory plate compactor (prepared for operation)
• Two wheel barrows
• Garden rake/screed
• Granular base material, 3/4 inch to 1 inch
• Granular base material, 3/8 inch

EXERCISE DESCRIPTION

To complete this exercise prepare a 10 foot long base for a landscape retaining wall (Figure 21–2). This base can be on a level surface that cuts across the run of a slope or can parallel the run of a slope, gradually stepping up it.

CAUTION

Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer's instructions.

Note: This exercise practices installation of a base with relative grades. When construction plans detail a specific grading scheme, a survey level must be used to establish the precise elevation of the base.
Wall First Course Installation/Stepping First Course

OBJECTIVE
The objectives of this exercise are to properly install the first course of a landscape retaining wall using ties/timbers, segmental concrete wall units or stone, and to properly step the first course of the wall as the base grade changes.

Follow manufacturer's instructions when using equipment. Use caution when cutting and installing wall materials. Obtain assistance when lifting wall materials.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 17, Tie and Timber Retaining Walls, Chapter 18, Segmental Precast Concrete Retaining Walls, and Chapter 19, Dry-Laid Stone Retaining Walls.

INTRODUCTION
Installation of a wall's first course is a critical stage in wall construction. Failure to establish proper alignment and elevation will result in the creation of a wall that does not meet project requirements, and it will ultimately be the contractor's responsibility to make any necessary changes. Failure to properly level a wall will create problems that multiply as wall height increases. Stepping the first course up a hillside can also create potential problems if the level and alignment are not maintained through the steps. When walls encounter embankments, this stepping may occur rapidly. Walls should never step up more than one course at a time, and the course on the bottom should always be covered by grade. The following pages outline the techniques for properly installing and stepping the first course of a variety of common wall materials.

Tie/ Timber Walls

Placement and Leveling of First Course
• Place a tie/timber on the base material, ensuring the tie/timber's front is properly aligned. If the project requires the top of the wall stop at a particular elevation, use a survey instrument to verify elevations (Figure 22–1).
• Using a carpenter's level, check for level end to end. If tie/timber is not level, add or remove base material under the tie/timber as necessary.
• Using a carpenter's level, check for level front to back or for the proper leaning batter. If the level is not correct, tip the tie/timber forward or backward and remove or add base material as necessary.
• Recheck for level in both directions after adjustments have been made.
• Once the first course is correctly positioned and level, place the next tie/timber. The second tie/timber must be flush with the first. If a corner needs to be turned, trim the tie/timber to the correct length.

Stepping First Course
• In instances where the wall steps up, complete the lower course of wall to the point where the step occurs.
• Prepare the granular base for the upper course so that it is level with the top of the lower tie/timber.
• Sweep any base material off ties/timbers. Set a second course of ties/timbers so that it straddles the base and the lower course. Do not interrupt the staggered pattern when the wall steps up. If necessary, trim a tie/timber to maintain a consistent staggered pattern.

Segmental Unit and Stone Walls
Perform the following checks before placing the first course for segmental units:

• Measure the distance between the beginning point (walls should always begin at the low point) and corners or ending points. This may allow for slight adjustments in unit placement so that cutting is minimized.
• Verify which side of the block is up. For pinned units the top side should have openings for placing pins and the bottom should have openings to receive pins. For lipped units the bottom will have a thickened lip. This lip should be knocked off with a hammer for all blocks used on the base course. An alternative to knocking the lip off would be to turn the bottom course upside down and backward for the base only. This will place the lip up and at the front of the base course.

Placement and Leveling of the First Course
• Spread a 1/2 inch to 1 inch thick layer of fine granular material over the compacted granular base to speed the leveling process.
• Place the first unit or stone, ensuring the front of the block is properly aligned (Figure 22–2).
• Check for level side to side. If the block is not level, adjustments may be made by scratching away base material or adding base material under the block. Minor changes can also be made by twisting the block into place or by tapping it lightly with a rubber mallet.
• Check for level front to back. If the block is not level, adjustments may be made by twisting the block into place or by tapping it lightly with a rubber mallet.
• Recheck for level from all directions after all adjustments have been made.
• Place the second unit next to the first and use the palm of the hand to verify that second timber is flush with first. Repeat steps A–D for second timber.

Figure 22–1 Installing tie/timber wall first course.
process along the entire length of the wall’s first course, checking for level periodically using a level long enough to cover three units. Use caution not to disturb adjacent units that have already been set, and verify that the edges of the units are still in contact with each other after each adjustment.

Stepping First Course
- If the wall is to step up only one course or slowly, create a base for the upper course using the instructions in Exercise 21. The base material for the upper course should be level with the top of the blocks in the lower course and should be long enough to support all blocks in the step. If the wall is to step up many courses or rapidly, simply fill the void beyond the end of the last block in the lower course with base material and compact, ensuring the material is level with the top of the lower course (Figure 22–3).

- Sweep any base material off of lower units. Place a unit straddling the last block in the lower course and the new base material. If using pinned blocks, place a pin in the last block on the lower course. Set the unit over the pin and on the base for the upper course.
- Check for level and adjust if necessary.
- Place the entire first course of the step. After the entire course has been placed, create the base for the next step and lay its course. Continue until the wall is complete.
PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 6, Cutting of Paving and Wall Materials, Exercise 8, Construction Staking, Exercise 9, Grade Staking, and Exercise 21, Wall Base Preparation, before beginning this exercise.

MATERIALS REQUIRED
• Proper clothing and safety gear
• Mason's level (48 inch)
• Torpedo level (6 inch)
• Permanent felt tip marker
• Square-nosed shovel
• Rubber mallet
• Whisk broom
• Claw hammer
• Vibratory plate compactor (prepared for operation)
• Hydraulic block splitter or cutoff saw, or wet masonry saw (prepared for operation)
• Chain saw (prepared for operation)
• Supply of wall materials, including: ties/timbers, segmental concrete wall units (including pins), stone wall materials
• Granular base material

EXERCISE DESCRIPTION
To complete this exercise construct a 20 foot long base segment of landscape retaining wall two courses high using both ties/timbers and segmental units or stone (Figure 22–4). This wall should include a 10 foot long level section and a 10 foot long section that steps up a gradual slope. Complete the base as directed in Exercise 21.

Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer's instructions.

Note: This exercise practices installation of a wall with relative grades. When construction plans require specific grades, a survey level must be used to establish the elevation of the base and first course.
Exercise 23

Installing Angled Corners in Segmental Unit Retaining Walls

OBJECTIVE
The objective of this exercise is to properly construct angled corners using segmental unit retaining wall materials.

CAUTION
Follow manufacturer’s instructions when using equipment. Use caution when cutting and installing wall materials. Obtain assistance when lifting wall materials.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 18, Segmental Precast concrete Retaining Walls.

INTRODUCTION
Turning corners with any wall material is a challenge. In addition to the craftsmanship required, corners must maintain the proper angle and level of the wall. Constructing angled corners with stone and wood is made easier by the workability of the material. Stone wall materials contain pieces of varying lengths, allowing corners to be turned with ease. Wood can be trimmed to desired lengths. Creating corners with segmental wall units, however, requires that blocks be properly positioned, cut, and joined.

Outside angled corner construction with segmental wall units should be executed as follows:

- Mark the alignment of the units on the base material using marking spray paint. Ensure the front of the units will be correctly positioned according to project requirements.
- Lay the first course so that two full units meet at the corner. If necessary, trim blocks in the middle of the course to ensure that the corner units are whole blocks.
- Trim half of the corner angle from each corner block (e.g., for a 90° corner, trim both units 45°) and position them correctly in the corner of the first course (Figure 23–1A). Note: if using pinned units, pins may need to be left out of corner units due to trimming.
- Set the second course with the desired batter using a running bond pattern. For this course, a partial block is put into place on the corner, secured to the lower course with adhesive (Figure 23–1B). However, the blocks adjacent to this corner piece must still touch at the back of the corner to provide structural support for the wall. Trim each of these three blocks as necessary to fit properly in the course. Note that the corners of the two adjacent blocks will need to be trimmed at an angle if they are to touch.
- Continue placing courses in this manner until the adjacent corner blocks are smaller than half a unit (Figure 23–1C). At that point, configure the blocks so that full units are yet again at the corner edges of the course.
- Trim the caps as required once the wall is complete.

Inside angled corner construction with segmental wall units should be executed as follows:

- Mark the desired alignment on the base material using marking spray paint. The front of the units should set along the alignment.
• Install the first course. Run the left side of the course past the point where the corner turn is to begin (Figure 23-2A). Install the right side of the course so that it terminates by directly abutting the left side of the wall. If trimming of a unit is necessary to ensure proper fit of the right side of the course, trim the unit closest to new corner.

• On the second course reverse the pattern used for the first course (Figure 23–2B). If the bond pattern does not carry to the back of the wall, place a support piece secured with construction adhesive (Figure 23–2C). Note: When using pinned units, the pins may need to be left out of corner units due to trimming.

• Alternate the pattern on subsequent courses.

• Caps should be trimmed at an angle matching the corner angle and secured with construction adhesive.

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**Figure 23-1** Outside angled corner with segmental units.

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**PREREQUISITE EXERCISES**

Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 6, Cutting of Paving and Wall Materials, Exercise 21, Wall Base Preparation, and Exercise 22, Wall First Course Installation/Stepping First Course, before beginning this exercise.

**MATERIALS REQUIRED**

- Proper clothing and safety gear
- Cutoff saw or wet masonry saw (prepared for operation)
- Claw hammer
- 25 foot tape measure
- Construction adhesive
- Mason’s level (48 inch)
- Torpedo level (6 inch)
- Permanent felt tip marker
Exercise 23 Installing Angled Corners in Segmental Unit Retaining Walls

Exercise Description

To complete this exercise construct the segment of landscape retaining wall shown in Figure 23-3. Complete the base as directed in Exercise 21. The retaining wall should be constructed three courses high. This wall should include inside and outside angled corners with short straight sections at either end. The wall should be built across slope as shown.

- Marking spray paint
- Speed square
- Segmental retaining wall units (including pins)

**CAUTION**
Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.

Note: This exercise practices installation of a wall with relative grades. When construction plans require specific grades, a survey level must be used to establish the elevation of the base and first course.

**Figure 23-2** Inside angled corner with segmental units.

A. First side bypasses second; second side trimmed to fit

B. Second side bypasses first; first side trimmed to fit

C. Repeat step A, using piece for support in back
Figure 23-3 Angled corner layout plan.
Exercise 24

Installing Radius Corners in Segmental Unit Retaining Walls

OBJECTIVE
The objective of this exercise is to properly construct radius corners using segmental unit retaining wall materials.

CAUTION
Follow manufacturer’s instructions when using equipment. Use caution when cutting and installing wall materials. Obtain assistance when lifting wall materials.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 18, Segmental Precast Concrete Retaining Walls.

INTRODUCTION
Construction of radius corners using segmental unit wall materials requires patience. Adjusting unit spacing and modifying materials takes time, and the difficulty in constructing radius corners only increases as the radius decreases. Most wall materials are manufactured with tapered tails that can be squeezed together to create a range of radii, but as the wall height increases trimming might be required to maintain batter.

Outside, or convex, radius corner construction with segmental wall units should be executed as follows:

• Mark the desired radius on the base material using marking spray paint. The fronts of the units should set on the radius line.

• First course installation should use full units placed so the tapered back edges are spaced close together (Figure 24–1). The amount that the units are spaced will be determined by the design radius, with the spacing evenly distributed over the entire curve.

• Each subsequent course should be installed with the units spaced tighter and tighter. If using lipped units, the lip may have to be removed to allow for tight spacing. Pinned units may require use of the front pin location to allow for closer spacing. If the radius becomes tighter than the tapered tails allow, units will have to be trimmed to fit. Batter may need to be reduced or eliminated to maintain a running bond pattern around the radius.

• Caps should be trimmed to completely cover the voids in the wall below.

Inside radius, or concave, corner construction with segmental wall units should be executed as follows:

• Mark the desired radius on the base material using marking spray paint. The fronts of the units should set on the radius line with edges touching.

• First course installation should use full units placed with the back edges of the units fanned (Figure 24–1). The amount that the units are fanned will be determined by the design radius, with the spacing evenly distributed over the entire curve.

• Each subsequent course should be installed with the units fanned wider and wider. Pinned units may require use of the back pin location.
CAUTION

to allow for wider spacing, and in some cases one pin may have to be left out to accomplish the desired turn. As the radius widens the running bond pattern will be more difficult to maintain. Constructing a vertical wall for inside radii may allow spacing and pattern to be continued.

- Caps should be trimmed to cover the voids in the wall below to the extent possible.

PREREQUISITE EXERCISES

Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 6, Cutting of Paving and Wall Materials, Exercise 2, Wall Base Preparation, and Exercise 22, Wall First Course Installation/Stepping First Course, before beginning this exercise.

MATERIALS REQUIRED

- Proper clothing and safety gear
- Cutoff saw or wet masonry saw (prepared for operation)
- Claw hammer
- 5 pound sledgehammer
- 25 foot tape measure
- Marking spray paint
- Mason’s level (48 inch)
- Torpedo level (6 inch)
- Permanent felt tip marker
- Speed square
- Construction adhesive
- Segmental retaining wall units (including pins)

EXERCISE DESCRIPTION

To complete this exercise construct the segment of landscape retaining wall shown in Figure 24–2. Complete the base as directed in Exercise 21. The wall should be constructed three courses high. This wall should include inside and outside radius sections with short straight sections at either end. The wall should be built along slope as shown.

CAUTION

Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.
Note: This exercise practices installation of a wall with relative grades. When construction plans require specific grades, a survey level must be used to establish the elevation of the base and first course.

Figure 24-2 Radius corner layout plan.
Retaining Wall Drainage

OBJECTIVE
The objective of this exercise is to properly install tile drainage behind retaining walls.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 16, Materials and Installation Techniques for Retaining Walls.

INTRODUCTION
Retaining wall failure is often caused by the buildup of water pressure behind the wall. Efforts to anchor the wall provide a partial solution, but it is also necessary to reduce water pressure by removing the water. Partial removal of water is accomplished through the jointing system of most walls. Water will pass through the openings between units of wall material. Openings called weepholes can also be drilled through the face of the wall to allow water to drain from behind the wall.

The most effective method of reducing water pressure is the placement of a proper drainage system behind the wall. This drainage system is composed of a tile that runs behind the first course of the wall, above which a zone of free-draining angular fill is installed. As water approaches the wall, it drains down through the fill to the tile and is transported away from the wall. This method is effective for walls that do not exceed 4 feet in height. Walls greater than 4 feet tall should have an anchoring and drainage system engineered and installed.

To install a tile drainage system behind a retaining wall, follow these steps:

- Following the installation of the first course of a retaining wall, place a socked, 4 inch diameter perforated plastic drain tile behind the entire length of the wall. Placement of the tile should be directly behind the wall with the bottom of the tile at the same elevation as the bottom of the first course.
- Locate the low point of the wall for installation of an outlet drain. Complex walls may have multiple low points requiring multiple outlet drains.
- If the low point is at one end of the wall, extend the tile around the end of the wall and trim at the face of the wall. Cap the opposite end.
- If the low point(s) is(are) in between the ends of the wall, cut a 5 inch wide gap in the first course at that low point (Figure 25–1). Cut the tile behind this gap and insert a tee connector that projects into the gap in the wall. Add a short segment of tile to the tee and extend this tile to the front of the wall.
- Verify the water draining from this outlet drains away from the wall. If necessary, adjust the grade so proper drainage will occur, or plan to extend this tile underground to an outlet point.
- Cut a 12 inch × 12 inch section of landscape fabric and duct-tape it over the open end of the tile that projects through the wall. Cap the tile at both ends of the wall.
- Backfill over the tile with 3/4 inch to 1/2 inch clean, free-draining, angular granular material.
- Continue installing subsequent courses of the wall. As each course is added, backfill behind the wall with 3/4 inch to 1/2 inch clean free-draining, angular granular material. Fill beyond
that 12 inch drainage zone can be site or engineered fill material. Compact each layer as installed.

**PREREQUISITE EXERCISES**
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 6, Cutting of Paving and Wall Materials, Exercise 21, Wall Base Preparation, and Exercise 22, Wall First Course Installation/Stepping First Course before beginning this exercise.

**MATERIALS REQUIRED**
- Proper clothing and safety gear
- Utility knife
- Round-nosed shovel
- Cutoff saw or wet masonry saw (prepared for use)
- Permanent felt tip marker
- Square-nosed shovel
- 25 feet of 4 inch diameter socked perforated plastic drain tile
- Two caps and one tee connector for 4 inch plastic drain tile
- Duct tape
- Two 12 inch × 12 inch squares of landscape fabric
- Free-draining, clean angular fill

**EXERCISE DESCRIPTION**
To complete this exercise install wall drainage behind the segment of wall constructed for Exercise 22, 23, or 24 or for a project.

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**Figure 25–1** Placement of drain tile behind retaining wall.
OBJECTIVE
The objective of this exercise is to execute anchoring for landscape retaining walls using verticals (vertical timbers), deadmen, and geogrid.

CAUTION
Follow manufacturer’s instructions when using equipment. Use caution when cutting and installing wall materials. Obtain assistance when lifting wall materials.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 16, Materials and Installation Techniques for Retaining Walls.

INTRODUCTION
Landscape retaining walls need to be anchored to improve stability and counter the forces of gravity and soil/water pressure that are working to overturn the wall. Walls that exceed 2 feet in height, or two courses of material, should implement some form of anchoring. Aside from burying the first course of a wall, the simplest method for providing wall stability is to batter the wall. Batter is the backward lean or stepping backward of materials to create a wall face that is not vertical. Most walls combine batter with some form of structural anchoring—either vertical timbers, deadmen, or geogrid.

Vertical timbers are buried wood members placed in an upright position directly in front of the joints of stacked timber walls. Deadmen are horizontal timbers placed behind staggered-joint timber walls. Deadmen are anchored into the hillside to provide resistance to forces pushing the wall forward. Geogrid is a fabric-like landscape material that is hooked or sandwiched between segmental units and buried in the fill material behind a wall. It too provides resistance to forces pushing forward on a retaining wall. Installation techniques for each of these wall anchoring systems are described in the following paragraphs.

Batter
To construct a wall with step-back (or stair-step) batter, use the following steps:

- Place the first course level.
- On each subsequent course slide the wall material back from the front of the previous course. A typical dimension for this setback would be 1 inch, but it may vary based on manufacturer recommendations. Many segmental units have lips of pins that, when properly installed, create a step-back batter (Figure 26–1).

To construct a wall with leaning batter do the following:

- Tilt the base course slightly backward during installation (approximately 1/4 inch fall from front to back). This will cause all subsequent
courses to lean in the same direction when placed (Figure 26–1).

**Vertical Timbers**

To install vertical timber anchoring use the following steps:

- Following completion of the second or third course, auger 1 foot diameter holes in the ground in front of the wall and centered on the joints between timbers (Figure 26–2). The recommended depth for the holes is frost depth, but they should be at least two thirds the height of the wall. (Note that this will limit the height of the wall to the length of the timber minus the amount buried.) Use caution not to disturb the courses when auguring the holes.
- When all courses of timbers have been placed, place the vertical timbers in the holes.
- Lean the timbers back in the holes against the wall overlapping the joint.
- Backfill and tamp around the vertical timber.
- For decoration, the tops of the verticals may be trimmed at an angle.
- A vertical must be placed on both sides of a corner.

**Deadmen**

Deadmen should be installed every fourth vertical course of a tie/timber wall. Measuring horizontally from the end of the wall, install a deadman every 8 feet.

To construct deadman anchoring use the following steps:

- Cut an opening in the appropriate course of the wall equal to the width of the deadman.
- In this opening, set the end of a tie that runs perpendicular to the face of the wall (Figure 26–3). The length of the deadman should extend 4 feet to 8 feet back into the hill. It will sometimes be necessary to trim the deadman if the full length interferes with an obstacle behind the wall. Excavating a trench for placement of the deadman is also sometimes necessary.
- At the hill end of the deadman, place a 3 foot timber crosspiece parallel to the face of the wall under the deadman.
- Connect the deadman to the crosspiece by drilling a 3/8 inch pilot hole and driving a 12 inch nail through the pilot hole into the timber below.
- When placing the next wall course, connect it to the deadman with a 12 inch nail.
- Backfill and compact over the deadmen when the wall is complete.

Geogrid
Manufacturers or design professionals must calculate if a wall requires anchoring with geogrid fabric. These calculations should indicate the course in which the geogrid should be placed and the width of the fabric behind the wall. If the wall is tall enough to require geogrid, it will need to be placed between the appropriate courses before the wall can be built any higher. Because geogrid comes in rolls, it can be easily cut to the width required using a knife or fine-toothed saw. The required orientation must be maintained for various types of geogrid in order to maximize its strength. Proper orientation is determined by the direction of the bonded and loose strands. Bonded strands are load bearing and should be placed perpendicular to the face of the wall. Loose strands should run parallel to the face of the wall.

To install geogrid anchoring use the following steps:

- After compacting the backfill for the course below the geogrid, roll the geogrid out flat behind the wall along the entire length of the area to be reinforced. The backfill area may have to be widened to accommodate the width of the geogrid.
- Sweep backfill off tops of wall units.
- Slide the geogrid to within 2 inches of the front of the wall units (Figure 26-4). Pull the material back slightly if any will be exposed when later courses are added.

For pinned units place the pins for the next course so that they pass through one of the grids.

Figure 26-2 Installing vertical timber anchoring.

Figure 26-3 Rear view of deadman installation and location.
Lipped units may be set in place with the geogrid installed between courses.

- Place the next course of blocks and then stretch the geogrid away from the wall to remove any slack.
- Backfill and compact over the geogrid.

**PREREQUISITE EXERCISES**

Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 6, Cutting of Paving and Wall Materials, Exercise 21, Wall Base Preparation and Exercise 22, Wall First Course Installation/Stepping First Course, before beginning this exercise.

**MATERIALS REQUIRED**

- Proper clothing and safety gear
- Power auger (12 inch diameter) (prepared for operation)
- Chain saw (prepared for operation)
- 25 foot tape measure
- Permanent felt tip marker
- Tamping tool (2 × 4)
- Torpedo level
- Power drill
- Extended 3/8 inch auger bit
- 50 foot heavy-duty extension cord and access to a 120V GFCI circuit
- Utility knife with extra blades
- Fine-toothed wood saw
- Round-nosed shovel
- Trenching shovel
- Square-nosed shovel
- Whisk broom
- Supply of wall materials, including ties/timbers and segmental retaining wall units (including pins)
- 12 inch spikes
- Geogrid material
- Free-draining angular fill

**EXERCISE DESCRIPTION**

To complete this exercise, install the anchoring method appropriate for each segment of wall. This exercise can be combined with Exercises 22, 23, 24, and/or 25.

CAUTION

Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.

Figure 26-4 Geogrid placement.
Exercise 27

Stairs

Objective
The objective of this exercise is to properly install butt and interlocking stairs as part of a landscape retaining wall project.

Follow manufacturer instructions when using equipment. Use caution when cutting and installing wall materials. Obtain assistance when lifting wall materials.

Textbook Reference
Information related to this activity can be found in the Landscape Construction textbook in Chapter 18, Segmental Precast concrete Retaining Walls and Chapter 21, Stairs.

Introduction
Movement from one level to another in the landscape is typically accomplished through the use of stairs. Stairs can be freestanding (placed on an embankment without enclosing walls for support) or constructed as part of a retaining wall system. When incorporated into a retaining wall, stair construction can take two forms: interlocking or butt. Interlocking stairs weave the treads into the cheek, or sidewalks. Butt stairs sit adjacent to cheek walls. Stair construction techniques are similar for all common retaining wall materials. To help clarify instructions throughout this exercise, the term riser refers to the vertical portion of a step, tread refers to the horizontal portion of the step, and stairs refer to a group of steps.

Interlocking Stair Installation
Interlocking stairs should be constructed as the wall is being erected, with the first course of the stairs installed as the first course of the wall is installed, continuing as such for each subsequent course. The following instructions are intended for stair tread widths that are slightly shorter than the width of a single piece of wall material. For wider stair treads additional material will be required. If special solid blocks are available for stairs, or if alternative tread materials are used, increase the number of wall blocks below the tread to match the dimension required.

Use the following steps to install interlocking stairs:

• Widen the granular base trench where the stair is to be installed. The stair trench should be 24 inches longer than the actual length of the stair opening 12 inches on each side), and must accommodate at least three widths of stair material extending back from the front of the wall alignment (Figure 27–1A).

• Fill this widened trench with base material and compact.

• Place the first course of the wall.

• Place the material for the first step directly behind the first wall course. The step material should extend an extra 12 inches on both sides of the stair opening, covering the base material for the stair created earlier (Figure 27–1A). Because the first course of the wall will be buried for stability purposes, this level will serve only as a landing.

• Route any drainage tile around the back of the first course and stair.

• Backfill and compact behind the wall and step.
Excavate a base trench behind the first step for the second step. This trench should be 18 inches wide (or the width of two pieces of wall material), 6 inches deep, and match the length of the first stair trench. Fill the trench with base material and compact. If a tile is present, fill over the tile without disturbing its level. Smooth the base material so that it is flush with the top of the previous step.

Construct the second course for the wall and stop short of the stair opening on each side of the stair.

Place material for the second step across the opening for the stairs. The second step should overlap the back of the first tread enough to create the desired tread on the first step. If a cap stone is used for the tread, the overlap should equal the wall material width minus the cap width (Figure 27–1B).

Build the cheek wall by filling any gap between the back of the wall and front of the step with wall material. The cheek wall should be perpendicular to the wall face. Trim block as required to fit. If building the wall with wood or stone, remember that the cheek wall must interlock with the wall face and that alternate courses of the cheek wall will run to the face of the wall (Figure 27–1C).

Backfill and compact behind the wall, cheek wall, and step.

Repeat the preceding instructions for each subsequent course of the wall and stairs.

If used, place capstone coverings over all treads, trimming along the edges as necessary to fit the opening.

**Butt Stair Installation**

While butt stairs are simpler to construct, they are not as stable as interlocking stairs. Because butt stairs are not interlocked into the cheek wall, they may move up or down at a different rate than the walls next to them, causing unevenness or irregularity. The following instructions are intended for stair tread widths that are slightly shorter than the width of a single piece of wall material. For wider stair treads additional material will be required. If special solid blocks are available for stairs, or if alternative tread materials are used, increase the number of wall blocks below the tread to match the dimension required.

Construct butt stairs using the following process:

- Retaining walls and cheek walls can be constructed prior to or concurrently with butt stair installation. The cheek walls are perpendicular to the retaining wall and must extend beyond the back of the stairs. Leave an opening for stairs when constructing the wall and verify that the wall material on each side of the opening is level across the opening. Adjusting the width of the opening to match material dimensions is also desirable. Use of a batter on cheek walls will require cutting material to fit.

- Widen the granular base trench at the stair location enough to accommodate three widths of stair material for the entire length of the stair opening. This trench should be at the
same elevation as the base trench for the wall (Figure 27–2).
• Fill this widened trench with base material and compact.
• Place stair material between the cheek walls flush with the first wall course (Figure 27–2). Because the first course of the wall will be buried for stability purposes, this level will serve only as a landing. Install this material with a slight (1/4 inch or less) fall toward the front if possible. Trim material along the sides if required.
• Route any drainage tile around the back of the step.
• Backfill and compact behind the step.
• Excavate a base trench behind the first step. This trench should be 18 inches wide (or the width of two pieces of material), stair 6 inches deep, and match the length of the first stair trench. Fill the trench with base material and compact. If a tile is present, fill over the tile without disturbing its level. Smooth the base material so that it is flush with the top of the previous step.
• If building walls and stairs concurrently, continue construction of the wall and check wall before installing the second tread. With wood and stone wall materials, the wall and cheek wall must interlock where they intersect.
• Place material for the second step across the opening for the stairs. The second step should overlap the back of the first tread enough to create the desired tread width on the first step. If a capstone is used for the tread, the overlap should equal the wall material width minus the cap width (Figure 27–2C).
• Backfill and compact behind the step.
• Repeat the preceding steps for each subsequent step until the top of the wall has been reached.
• If used, place capstone tread coverings over all treads, trimming along the edges as necessary to fit the opening.

**PREREQUISITE EXERCISES**
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 6, Cutting of Paving and Wall Materials, Exercise 21, Wall Base Preparation, Exercise 22, Wall First Course Installation/Stepping First Course, and Exercise 24, Installing Radius Corners in Segmental Unit Retaining Walls, before beginning this exercise.

**MATERIALS REQUIRED**
• Proper clothing and safety gear
• Cutoff saw or wet masonry saw (prepared for operation)
• Chain saw (prepared for operation)
• Vibratory plate compactor (prepared for operation)
• Claw hammer
• 5 pound sledgehammer
• Round-nosed shovel
• Square-nosed shovel
• 25 foot tape measure
• Mason’s level (48 inches)
• Torpedo level (6 inch)
• Utility knife
• Permanent felt tip marker
• Speed square
• Wall materials
• Granular base material
• 25 feet of socked drainage tile

**EXERCISE DESCRIPTION**

To complete this exercise construct two short wall segments three courses high, one with a 4 foot wide set of interlocked stairs in the center of the wall and the second with a 4 foot wide set of butt stairs in the center of the wall (Figure 27-3). Stairs can be constructed from any of the available wall materials. If stairs are not a permanent installation, courses do not need to be fastened together. The stairs should run from a flat area up a gradual slope.

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**CAUTION**

Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.
OBJECTIVE
The objective of this exercise is to properly prepare a granular base for a paving project and prepare a sand setting bed for unit pavers and dry-laid stone.

CAUTION
Locate utilities before beginning construction. Follow manufacturer’s instructions when using equipment.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 22, Materials and Site Preparation for Paving, and Chapter 24, Unit Pavers.

INTRODUCTION
The success of a paving project begins with the installation of a sound base upon which to build. Regardless of the type of paving to be placed, the lack of solid support base will eventually lead to maintenance and durability problems. Granular base is the most common material used for paving preparation. Placed as a layer below the paving, the granular material provides the necessary structural support for many types of paving.

Development of a granular base requires removal of any unstable materials, identification of unsuitable subsoils, addition of appropriate base material, and compaction and leveling of the base. The thickness and type of this granular material should be determined by an engineer or based on the paving manufacturer’s recommendations. When installing unit pavers or dry-laid stone, a setting bed of concrete sand will need to be placed over the granular base. The thickness of the setting bed will vary depending on the paving material used, but typically is between 1 inch and 1 1/2 inches thick. Paving manufacturers should indicate the recommended depth for their product.

Placement of Granular Base
Preparation of a granular base for paving should follow these steps:

• Stake the site to be paved. The area that needs to be prepared for the base will typically extend 12 inches outside the dimensions of the proposed paved area (Figure 28–1).
• Remove and dispose of all vegetative cover. Excavate and remove remaining roots of larger plants.
• Excavate to proper subgrade. Check the depth and cross-slope of the subgrade often by running a string between the grade stakes and measuring down with a tape measure (Figure 28–2).
• Examine subgrade for potential soil and water problems. Remaining topsoil, soils that are soft, or soils that contain vegetative matter should be removed to a depth of 12 inches and replaced with granular backfill. If the subgrade is wet or has standing water, a tile system should be installed before proceeding with base installation. If problems are not corrected by these actions, an engineer should be consulted for solutions.
• Place Class 2 (National Stone Association grading specifications) granular material in the excavation (Figure 28–3). Material should be placed in lifts, or layers, of no more than 2 inches deep.
• Roughly level the material using a rake.
• Run a vibratory plate compactor over the surface after each lift. Work from the outside edges into the center, and then repeat at a 90° angle to the direction of the first pass.
• Use a 2 × 4 wood screed to level each lift to within 3/8 inch of its desired grade (Figure 28–4). Verify actual elevations using a survey instrument. Mark low areas, add base material, and recompact. Use a rake to remove high areas and recompact. Check for irregularities using a long pipe rolled over the surface.

**Placement of Setting Bed**

Preparation of the setting bed for unit pavers and dry-laid stone should use the following steps:

- Select clean, coarse, damp, concrete sand for the setting bed. Dry sand will need to be sprayed lightly with water before screeding.
- Spread the sand evenly over the prepared base material.
- Screed the sand to the proper thickness, with the surface following the desired grade and direction of slope. Precise screeding of the setting bed can be accomplished using a board notched to fit adjacent pavement or preplaced edging. Screeding can also be accomplished by working off screed rails set directly on the base. Rails should be the same diameter as the bed.
thickness. Screed perpendicular to the rails when possible.

- Screed only the area of setting bed that will be immediately paved. Small sections may need to be screeded to match existing grades.
- When screeding is complete, lift out any temporary screed rails. Fill the voids left by the rails with additional sand. Smooth the fills to match the surrounding level with a steel trowel.

**DISCUSSION**
How do you determine if the subgrade is stable?

**PREREQUISITE EXERCISES**
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 8, Construction Staking, and Exercise 9, Grade Staking, before beginning this exercise.

**MATERIALS REQUIRED**
- Proper clothing and safety gear
- Wheelbarrows
- Garden rakes
- Square-nosed shovels
- Round-nosed shovels
CAUTION

- 48 inch carpenter's level
- Surveying instrument
- Steel trowel
- 8 foot long, straight 2 x 4
- Two 8 foot long 1 inch diameter straight pipes (for use as screeding rails)
- Sod cutter (prepared for operation)
- Vibratory plate compactor (prepared for operation)
- Two 25 foot tape measures
- Surveyor's flags
- Marking spray paint
- Class 2 aggregate base material
- Clean, coarse concrete sand

EXERCISE DESCRIPTION

To complete this exercise prepare the base for the unit paver project identified in Figure 28-5. The base area will support an approximately 8 foot x 8 foot square patio with a 2 percent (1/4 inch per foot) cross-slope from the high side to the low side. When the base is complete, install a 1 inch deep sand setting bed over the entire paved area.

CAUTION

Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer's instructions.

Note: This exercise practices installation of base with relative grades and cross-slopes. When construction plans require specific grades, a survey level must be used to establish the elevation of the base.
Pavement Edge Restraint Installation

OBJECTIVE
The objectives of this exercise include the identification of edge restraint alternatives for paving projects and the proper installation of selected edge restraints.

CAUTION
Follow manufacturer’s instructions when using equipment. Use caution when cutting and installing materials.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 22, Materials and Site Preparation for Paving.

INTRODUCTION
Paving surfaces created with dry-laid, unit, and granular materials require the construction of a stable edge to contain the paving surface. Depending upon the edging material, these edges are installed either before or after the paving is installed. Edge restraints created out of concrete curb are installed before the base material is laid. Precast concrete blocks and bender board should be placed after the base material is laid but before the setting bed and pavers are installed. Edge restraints created out of metal or vertical bricks should be put in place when paving is nearly complete, but before paving edge pieces are put in place. A few edge restraints, including those created out of stone, plastic and wood, can be installed either before or after the paving process. Installation techniques for all of the aforementioned edge restraints are identified in this exercise (Figure 29–1).

Stone (Pre- or Postpaving Placement)
- Select a heavy wall stone material, typically 4 inches to 8 inches wide. Longer stones make for a more stable installation; shorter stones are used to turn corners.
- Mark the alignment of the edge restraint.
- Excavate a trench around the area to be paved and set the stone level with the desired finish grade for the patio.
- If desired, a strip of landscape fabric can be placed under the stone to reduce weed growth between blocks.
- Backfill and compact around the edge restraint.

Concrete Curbing (Prepaving Installation)
- Mark the alignment of the edge restraint.
- Excavate a trench along the perimeter where the curb is to be placed. Make sure the depth is correct for the thickness of the curbing selected. If too deep, adjust the depth using granular backfill. Construct forms (see Exercise 30) with the top of the forms set at the finish elevation of the paved area.
- Fill with concrete and finish.
- Remove forms and backfill.

Precast Concrete (Prepaving Installation)
- Mark the alignment of the edge restraint.
- Set the blocks in place on the compacted base material.
- If openings for spikes are available, secure into the base using 10 inch spikes.
Exercise 29  Pavement Edge Restraint Installation

Figure 29-1 Pavement edge restraints.
• Fill any voids between paver and edge restraint with base material.
• Backfill and compact along the outside edge prior to placing the setting bed or pavers.

Composite Materials and Bender Board (Prepaving Installation)
• Mark the alignment of pavement edge.
• Excavate a 6 inch wide trench slightly deeper than the edge restraint width along the entire alignment of the pavement edge.
• Remark the exact pavement edge using marking paint.
• Install treated 12 inch long 1 × 2 or 2 × 2 stakes every 18 inches along the alignment of the edge restraint. The top of the stakes should be driven at least 1 inch below the top to the elevation of the pavement surface.
• Hold the restraint to the stakes and drive galvanized 10d nails through the edger into the stake. Rust-resistant 2 1/2 inch screws may be used instead of nails to lessen disruption of the stakes. If necessary, adjust the elevation of the stake before fastening.
• Trim the edge restraint to the proper length before installing the final section.
• When sections of restraint need to be joined, drive a stake into the ground that overlaps the ends of both restraints. Fasten stake to both restraints.
• Fill pavement base against the inside of the restraint and place pavement.
• After pavement is installed, backfill and compact along the outside edge of the restraint.

Plastic (Prepaving Installation)
• Mark the alignment of pavement edge.
• Place the edge restraint firmly on the base.
• Secure using stakes or 10 inch spikes.
• Trim edging to fit. Joint should be as tight as possible, with gaps covered by geotextile to prevent setting bed sand from seeping out.

Plastic (Postpaving Placement)
• After pavers are placed, use a steel trowel to cut a vertical edge down from the pavers through the setting bed sand to the base.
• Scrape this sand away.
• Beginning at a structure or a corner, take a length of the edge restraint and, with minimal disturbance to the elevation of the pavers, tuck the notched side of the edge restraint under the setting bed. Placing the edge restraint directly under the setting bed and on top of the base will ensure that enough of the paver is covered to hold it in place.
• Slowly work the edge restraint under and tightly against the pavers along the length of the side. If necessary, lightly tap the edge restraint with a rubber mallet to force it into place.
• Verify that at least half the length and thickness of each paver is covered with edge restraint. Trim off extra.
• Place and drive metal edging stakes or 10 inch spikes through the openings and into the pavement base at 1 foot increments along the edge. Driving the stake or spike at a slight angle toward the pavement base will draw the edging in tighter against the pavement.
• Fill any voids between the edge restraint and paver with base material.
• Backfill and compact along the outside of the edge restraint.

Metal (Postpaving Installation)
• After pavers are placed, measure and precut pieces of metal edge restraint for each side of the paved area so that the entire perimeter is covered.
• Use a steel trowel to cut the setting bed sand away in a vertical edge along the pavers to the base.
• Starting at a corner, hold the metal edge 1 inch below the top of, and against, the sides of the pavers.
• Through the notches in the edging, drive metal edging stakes into the base at 1 foot increments along the edge.
• Backfill and compact immediately along the outside of the edge restraint.

Vertical Bricks (Postpaving Installation)
• After all pavers are installed, carefully excavate a 9 inch deep trench along the entire perimeter of the paved area. The trench must form a vertical edge cut straight down along the outside of the pavement.
• Place a small amount of granular material in the trench.
• Place brick vertically against the pavement.
• Adjust the height of the brick so that it is flush with the paved surface by adding or removing the granular material in the trench.
• Backfill and compact immediately along the outside of the edge restraint.
Wood (Pre- or Postpaving Insulation)
• Select a decay-resistant dimensioned lumber, typically a 6 × 6 (occasionally 2 × dimensioned lumber is used).
• Cut to length for each side of the paved area. Retreat cut ends with a wood preservative.
• Excavate a vertical trench 6 inches deep along the outside edge of the paved surface. Place the lumber segments in the trench tightly against the pavers. Treated 2 × 2 or 1 × 4 stakes can be fastened to the outside edge of the lumber to improve stability. Drive the tops of the stakes 2 inches below the top of the lumber at 2 foot increments along the edge. Fasten with rust-resistant deck screws.
• Backfill and compact the trench.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, and Exercise 6, Cutting Paving and Wall Materials, before beginning this exercise.

MATERIALS REQUIRED
• Proper clothing and safety gear
• Hand or circular saw
• 50 foot heavy-duty extension cord and access to a 120V GFCl circuit
• 25 foot tape measure
• Carpenter’s square
• Carpenter’s pencil
• Trenching spade
• Round-nosed shovel
• Square-nosed shovel
• Steel trowel
• Rubber mallets
• 5 pound sledgehammer
• Brick hammer
• 24 inch carpenter’s level
• Tin snips
• Marking spray paint
• Utility knife and extra blades
• Weed barrier
• Edging materials, stakes, and fasteners for each material
• Granular backfill material

EXERCISE DESCRIPTION
To complete this exercise install an 8 foot length of each of the following paving edges using the procedures described:
• Stone
• Precast concrete
• Bender board
• Plastic, prepaving
• Plastic, postpaving
• Metal
• Wood, prepaving
The base area constructed as part of Exercise 28 may be used for edge restraint practice.

CAUTION
Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.
Exercise 30

Concrete Form Preparation

OBJECTIVE
The objective of this exercise is the proper installation of straight and curved forms for a concrete pour.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 23, Concrete Paving.

INTRODUCTION
Successful concrete pours require proper installation of forming materials. Forms must be constructed to create the desired shapes, maintain the correct grades at the edges of the project, and withstand the weight and force of the concrete placed inside them.

Form construction begins with selecting the proper materials. Most slabs can be formed using 2 × 4 for straight portions, with wider lumber used in thicker pours. Curved sections can be formed using masonite strips. In special cases metal forms can be rented. Stakes should be 2 × 2 or 1 × 4 material and 8 inches longer than the slab is thick (i.e., 12 inch stakes for a 4 inch slab). Form nails are the best choice for nailing dimensioned lumber forms because the double heads make them easy to remove, but using deck screws to connect forms will reduce the disruption of forms due to hammering. When fastening a masonite form, nursery nails or deck screws are installed from the inside edge of the form.

Installation of Straight Forms
- Clear the area where the pour is located (Figure 30–1).
- Set a 2 × 4 on edge along the outside of the project edge. At one end of the form, drive one of the stakes along the outside edge of the 2 × 4.
- Drive a form nail through the stake and into the form, holding the top at the desired elevation for the top of the slab. Placing the head of a sledge on the inside of the form, opposite the nail, will make driving the nails easier.
- Repeat this stake installation at the other end of the form. Adjust the elevation of the form by tapping the stakes down or prying the form up until the entire form is set at the required grade. Excavate high points under the form if necessary. If specific grades are required use a surveying instrument to set forms at design elevations.
- Locate and install the form on the opposite side using the aforementioned steps. Place a 2 × 4 across the forms with a carpenter's level on top to establish the elevation of the opposite side.
- Add additional stakes along all forms every 2 feet, driving and nailing carefully so that the elevation is not disturbed. Once secure, move to the next form in line and repeat the process, using the top of the first form to set the grade for the second.
- Backfill along the outside edge of the forms when complete. Trim the tops of the stakes flush with the form.
Installation of Curved Forms

- Clear the area where the pour is located (Figure 30–2).
- Set a piece of masonite on edge along the outside of the project edge. At the high end of the form, drive one of the stakes along the outside edge of the masonite.
- Install a nursery nail or deck screw through the form and into the stake, holding the top of the form at the desired elevation for the top of the slab. Placing the head of a sledge on the outside of the stake, opposite the nail, will make driving the nails easier.
- Repeat this stake installation at the opposite end and in the middle of the form. Adjust the elevation by tapping the stakes down or prying the form up until the entire form follows the required grade. Excavate high points under the form, if necessary. Use a surveying instrument to set forms if specific elevations are required.
- Measure to the other side of the project and repeat the aforementioned steps. Place a 2 x 4 across the forms with a carpenter’s level on top to establish the elevation of the second side.
- Add additional stakes along curved forms every 1 foot, driving and fastening carefully so that the elevation is not disturbed. Once in place, move to the next form in line and repeat the process, using the top of the first form to set the elevation for the second.
- Backfill along the outside edge of the forms when complete. Trim the tops of the stakes flush with the form.

Installation and Leveling of Base Material

- Complete backfilling on the outside of the forms and trimming of stakes before filling inside.
- Place fine aggregate between the forms and establish rough grade using a garden rake.
- Construct a base screed with two 12 inch 1 x 4 handles placed flat on and screwed to the top of each end of a 2 x 4 cut 6 inches shorter than the width of the pour.
- Pull the screed over the base material to level (Figure 30–3).
- Compact using a vibratory plate compactor.
- Recheck grade, raking out high points and filling low points. Rescreed to verify base elevation.

PREREQUISITE EXERCISES

Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 9, Grade Staking, and Exercise 28, Pavement Base and Setting Bed Preparation, before beginning this exercise.
Exercise 30  Concrete Form Preparation

A. Clear location for forms. Attach stake to form at one end and adjust up or down to proper elevation

B. Drive stake and fasten to form at opposite end of form. Adjust to proper elevation. Excavate under form if necessary

C. Add stakes every 2 feet, adjusting form each time to proper elevation. Trim stakes flush with top of forms

D. Repeat steps A through C for forms on opposite side of pour. Use 2 x 4 and level to obtain proper cross-slope

Figure 30–2  Curved form installation.

Figure 30–3  Base installation and leveling.

MATERIALS REQUIRED
- Proper clothing and safety gear
- Carpenter’s level
- Square-nosed shovel
- Garden rakes
- Wheelbarrow
- Base screed (a straight 2 x 4 with two 12 inch 1 x 4 handles)
• Hand saw
• Cordless drill and bits
• 50 foot heavy-duty extension cord and access to a 120V GFCI circuit
• Claw hammer
• 3 pound sledge
• 25 foot tape measure
• Supply of straight 2 × 4s and masonite cut into 4 inch wide by 12 foot long strips
• Form nails, deck screws, nursery nails
• 2 × 2 or 1 × 4 stakes, minimum of 12 inches long
• Base material
• 6 foot long straight 2 × 4

EXERCISE DESCRIPTION
To complete this exercise construct forms for a 5 foot wide concrete walkway that includes a 10 foot long straight section and a 5 foot radius curved section as shown in Figure 30–4. The forms should be constructed with a 2 percent (1/4 inch per foot) cross-slope from the high side to the low side. When finished forming, place granular base and screed to a uniform depth.

Note: This exercise practices installation of forms with relative grades and cross-slopes. When construction plans require specific grades, a survey level must be used to establish the elevation of the tops of the forms.

Figure 30-4  Forming plan.
Concrete Pour

**OBJECTIVE**
The objective of this exercise is to practice the proper execution of a concrete pour.

**CAUTION**
Concrete contains caustic chemicals. Exposure of the skin to concrete can cause burns. Wear protective clothing and immediately wash any areas where skin comes in contact with concrete. Follow manufacturer’s instructions when using equipment. Use caution when cutting and installing materials. Watch for backing vehicles. Locate a route for delivery vehicles that avoids overhead and underground utilities.

**TEXTBOOK REFERENCE**
Information related to this activity can be found in the Landscape Construction textbook in Chapter 23, Concrete Paving.

**INTRODUCTION**
One of the most versatile landscape paving materials available is concrete. Concrete is durable, can be altered in many ways to enhance aesthetics, and can be formed to almost any shape. However, installation of concrete surfaces requires practice in forming, pouring, and finishing techniques. Successful installation can be quickly derailed by failure in any of these three areas.

**Steps for a Concrete Pour**
- Before beginning a pour verify that forms are secure and all tools and laborers are present. Lightly wet pavement base if it is dry enough to blow dust.
- Pour concrete in a pile at the beginning point of the pour. Begin work in remote portions opposite the access point.
- Spread concrete between forms using garden rakes.
- Work screed in sawing motion over concrete to level and compact surface (Figure 31–1). Repeat screeding if necessary. Surface after screeding should be level and free of holes or voids.
- Push and pull bull float back and forth across surface in repeated motions until concrete surface is smooth. By raising and lowering the float handle the leading edge of the float can be held off the surface of the concrete. The float can be pushed with a jerking motion to begin leveling the surface. When one area is complete, pick up the float and carry it to the next location.
- When concrete loses its sheen (wet look), work the surface with a trowel. Sweep the trowel in an arcing motion to continue to push the aggregate into the surface and bring a thin layer of concrete to the top. Work one area until surface is free of holes, then move to the next area.
- Allow concrete to begin to set. When the sheen is gone apply any special surfacing options such as aggregate, broom, or float finish.
- Before concrete hardens, joint using a jointing tool run across the surface guided by a 2 × 4. Finish one joint, then lift the 2 × 4, place it at
the next joint location, and repeat the operation. Work the jointer by placing pressure on the trailing edge of the tool and lifting the leading edge off the surface.

- Edge the pour by running the edging tools along the forms.
- When the pour is complete cover with plastic sheets.
- Remove forms 48 hours after pour.

**PREREQUISITE EXERCISES**

Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 9, Grade Staking, Exercise 28, Pavement Base and Setting Bed Preparation, and Exercise 30, Concrete Form Preparation, before beginning this exercise.

**MATERIALS REQUIRED**

- Proper clothing and safety gear, including tall rubber boots
- Straight 2 × 4 screed, 24 inches wider than the pour
- Square-nosed shovel
- Round-nosed shovel
- Garden hose with spray nozzle and access to a water hydrant
- Garden rakes
- Wheelbarrows
- Concrete finishing tools, bull float, hand floats, edgers, and jointers
- 25 foot tape measure
- Plastic cover sheets
- Concrete (4,000 psi for typical landscape paving)

**Exercise 31 Concrete Pour**

A. Screed surface flat with sawing motion

B. Push bull float pack and forth, keeping the front edge off the surface

C. Trowel surface with arcing motion. Special surfaces may be applied at this stage

D. Jointers and edgers are run against forms or guide boards. Push down on back edge of tool

**Figure 31-1** Steps for pouring concrete.
EXERCISE DESCRIPTION
To complete this exercise, pour and finish concrete in the forms constructed for Exercise 30.

CAUTION
Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions. Concrete contains caustic chemicals. Immediately wash any area where skin comes in contact with concrete.
Exercise 32

Paving Pattern Practice

OBJECTIVE
The objective of this exercise is to practice proper installation of common unit paving and stone paving patterns.

CAUTION
Follow manufacturer’s instructions when using equipment. Use caution when cutting and installing materials.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 24, Unit Pavers, and Chapter 25, Dry-Laid Stone Paving.

INTRODUCTION
The quality of a paving job is usually judged by the complexity of the pattern installed and the craftsmanship of the work. To create complex patterns and ensure a project’s longevity, the contractor must understand how to properly sequence a variety of patterns and how to properly prepare and place pavers. Sequencing and installation instructions for both unit pavers and dry-laid stone are identified in this section.

Installation of Unit Pavers
Selection of a paving pattern for a site depends upon the shape and dimension of the paving material chosen and the aesthetic results desired. Certain paving materials are amenable to any type of pattern. For instance, a unit paver with a length that is twice its width can be sequenced in almost any way. Pavers that are not rectangular are limited to a few standard patterns, such as stacked or running bond. Specialty pavers often require installation in a pattern specifically designed for that unit.

Use the following steps to install standard patterns:

- Depending upon the edging material chosen, install edging now or later.
- Prepare the base and setting bed.
- Locate a beginning point for the pattern. This point should be located along either a straight edge or in a square corner.

If using a straight edge as the beginning point, set up a chalkline that is perpendicular to the straight edge, chalking it directly onto the base material for use as a permanent guide. The pattern will begin along this chalkline and work back to the straight edge.

If using a square corner as the beginning point, the pattern will work diagonally outward from the corner. (Note: using this starting pattern with unit pavers may require significant amounts of trimming if the pattern does not maintain the square of the starting corner.)

- Consider installing a soldier course of unit pavers to help guide installation.
- Begin placement of pavers according to the numbered sequence shown for each pattern:
  - Stacked bond (Figure 32–1)
  - Running bond (Figure 32–2)
  - Basket weave (Figure 32–3)
  - Herringbone (Figure 32–4)

- Set each paver by lowering it straight down on the setting bed. Do not twist, drop, or slide the paver. If the setting bed is disturbed, remove
A. Consider installing soldier course around edge
B. After placing paver 17, continue stacking diagonal pattern until surface is covered
C. Cut pavers if necessary to fit edges of paved area

the paver and relevel the bed with a steel trowel. Each paver should be set touching adjacent pavers with spacing recommended by the manufacturer.

- Avoid stepping within 1 foot of an unrestrained edge.
- Check alignment of pavers often, using a stringline or straightedge. Do not go more than 10 courses without checking for alignment. Adjust using a putty knife or prybar.
- Continue placing pavers in the pattern established by the numbered sequence. Cut partial pavers when required. (Note: An alternative to cutting half or partial pavers while the pattern is being installed is to place all full pavers first, then mark, cut, and place partial pavers to complete the surface. This will concentrate cutting into a single activity. Use caution not to alter the pattern when placing full pavers).
- Seating and finishing steps recommended by the paver manufacturer can now be implemented. Many unit paver surfaces are finished by sweeping concrete sand into pavement joints. Segmental concrete paving blocks are also “set” into the surface using a vibratory plate compactor.
Installation of Stone Paving

The aforementioned paving patterns work well with unit pavers, as they rely upon the pavers’ uniform size and shape to create simple sequences that can be repeated over large areas. Stone pavers, however, can be irregular and inconsistent in size and shape, requiring the installer to examine each piece for fit with the pattern. The installer must not only view the piece from an aesthetic perspective, but also must select and, when necessary, trim pieces to address the pattern’s structural needs.

Installation of four common stone patterns is executed as follows:

- Depending upon the edging material chosen, install edging now or later.
- Prepare the base and setting bed.
- Locate a beginning point for the pattern. This point should be located along a straight edge or in a square corner.
- Begin placement of stone approximating the numbered sequence shown for each pattern. This sequence will be based on the size and shape of stone available and is intended only to illustrate the selection and placement of stone. Work across the surface one row at a time.

Random irregular (Figure 32–5)
- A. Begin with stone that matches corner angle
- B. Lay straight-edged stones along sides
- C. Fill center with stones that create three friction points with adjacent stone and joints 1/2" or less
- D. Adjust stones so they are flush with adjacent stones
- E. Mix small and large stones randomly in pattern; avoid aligning stones with straight joints

Random fitted (Figure 32–6)
- A. Joints stagger each subsequent row
- B. Cut stone as necessary to finish edge

Modular running bond (Figure 32–7)
- A. Joints align along evenly spaced grids.
- B. Mix large and small, long and square stones: avoid aligning joints for long runs.
- C. Cut stones as necessary to finish edge.

Modular irregular (Figure 32–8)
- A. Begin with stone that matches corner angle
- B. Lay straight-edged stones along sides
- C. Fill center with stones that create three friction points with adjacent stone and joints 1/2" or less
- D. Adjust stones so they are flush with adjacent stones
- E. Mix small, large, and horizontal stones: strong horizontal and vertical joint lines should appear

Figure 32-5 Random irregular pattern installation.

Figure 32-6 Random fitted pattern installation.

Figure 32-7 Modular running bond pattern installation.

Figure 32-8 Modular irregular pattern installation.
with adjacent stones in three places and should leave joints between stones of 1/2 inch or less. Check to see that each stone is flush with surrounding stones when placed. If not flush, lift and add or remove sand as necessary.

- Stones with irregular edges can be shaped slightly by striking with a stone hammer.
- Avoid stepping within 1 foot of an unrestrained edge.
- If necessary, mark, cut, and place partial stones to complete the surface.
- Finishing steps can now be implemented. Typical finish for dry-laid stone is to sweep concrete sand into the joints.

DISCUSSION
Which patterns will provide a look of craftsmanship? Are there any patterns that would not work in a particular situation?

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 6, Cutting of Paving and Wall Materials, and Exercise 28, Pavement Base and Setting Bed Preparation, before beginning this exercise.

MATERIALS REQUIRED
- Proper clothing and safety gear, including knee pads
- Wet masonry saw or hydraulic splitter (prepared for operation)
- Brick hammer
- Carpenter’s square or two 25 foot tape measures
- Mason’s twine
- Rubber mallet
- Base screed
- Permanent marker
- Steel trowel
- Putty knife or prybar
- Concrete sand
- Supply of paving materials

EXERCISE DESCRIPTION
To complete this exercise fill an 8 foot × 8 foot practice square with the designated pattern for each of the pavement types indicated.

- Unit pavers with stacked bond
- Unit pavers with running bond
- Unit pavers with basket weave
- Unit pavers with herringbone
- Stone paving with random irregular pattern
- Stone paving with random fitted pattern
- Stone paving with modular running bond pattern
- Stone paving with modular irregular pattern
Exercise 33

Framing Wood Structures

OBJECTIVE
The objective of this exercise is to properly construct framing for wood structures.

CAUTION
Follow manufacturer's instructions when using equipment. Use caution when cutting, drilling, and fastening materials.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 29, Wood Decks and Platforms.

INTRODUCTION
Two basic choices are available when building the substructure for a deck—traditional post and beam framing (also called drop beam or plank and beam) or platform framing (also termed box or flush beam). Post and beam uses a system of posts to support heavy construction beams. These beams in turn support structural joists onto which the surfacing material is applied. Platform framing consists of a rim joist box that runs around the outside of the structure inside which the joists are hung. This platform is connected directly to the posts, bypassing the requirement for beams. There is little difference between the two methods in terms of structural soundness.

Post and Beam Framing
• Select a method for attaching beams to posts or structure (Figure 33-1).

Platform Framing
• Construct rim joist platform frame and attach to posts or structure.
  If attaching to posts, mark and trim posts at correct height. If posts are used for railing support posts, do not trim. Tack joist to post with 16d nails. Drill pilot holes and install carriage bolts (Figure 33–2).
  If attaching to a ledger plate, connect using a joist hanger (Figure 33–3).
• Check box frame for square and level.
• Mark joist locations inside box frame.
• Install joist hangers at each joist location.
• Cut and trim joists.

If using a ledger plate, beam should be hung from plate using joist hangers.
If resting beam on top of posts, calculate and mark proper post height. Cut post and rest beam on top. Fasten using a single saddle connector or by attaching T brackets to both sides.
If using grab beams (beams attached to each side of a post), mark and trim post to correct height. Tack grab beams in position with 16d nails, then drill pilot holes and install carriage bolts.
• Recheck framework for square and proper level.
• Mark joist locations on top of beams.
• Set joists at markings and toenail into beam.
• Trim joists to proper length at edge of structure.
• Locate position for railing support posts. Tack posts in position with 16d nails, drill pilot holes, and install carriage bolts.
Top of the post is set below the top of the ledger at dimension equal to the thickness of the joist plus the beam, plus any desired cross-slope.

Figure 33-1 Three types of post and beam framing.
• Install and fasten onto joist hangers.
• Locate position for additional railing support posts. Tack posts in position with 16d nails, drill pilot holes, and install carriage bolts.

DISCUSSION
Compare the two forms for framing. What are the positive and negative aspects of both? Review possible locations for deck attachment to a structure, and discuss which framing method would work best for each location.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 4, Material Take-offs, and Exercise 5, Tool Operation and Construction Techniques, before beginning this exercise.

MATERIALS REQUIRED
• Cordless drill and bits
• Socket wrench and sockets
• Circular saw

Figure 33–2 Platform framing with posts.

Figure 33–3 Platform framing with ledger plate.
EXERCISE DESCRIPTION—PART A
To complete this exercise, calculate and procure the required materials and install post and beam framing as detailed in the plan and elevation shown in Figure 33–4. Framing installation should also include installation of intermediate posts for railing as shown.

- 50 foot extension cord and access to a 120V GFCI circuit
- Claw hammer
- Carpenter’s level
- Carpenter’s pencil
- 25 foot tape measure
- Lumber
- Fasteners

EXERCISE DESCRIPTION—PART B
To complete this exercise, calculate and procure the required materials and install platform framing as detailed in the plan and elevation shown in Figure 33–5. Framing installation should also include installation of intermediate posts for railing as shown.

The deck structure in the exercise is not designed to carry a live load. The deck is designed for demonstration purposes only. Do not walk on the structure.
Exercise 34

Surfacing Wood Structures

OBJECTIVE
The objective of this exercise is to properly surface wood structures.

CAUTION
Follow manufacturer’s instructions when using equipment. Use caution when cutting, drilling, and fastening materials.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 29, Wood Decks and Platforms.

INTRODUCTION
Deck surfacing comes in a variety of materials. Before making a selection, review the structural and aesthetic requirements of a project. Deck surfacing must be applied at an angle to the joists for maximum support. Right angles provide maximum support, but angles of up to 45 degrees are acceptable. If one piece of decking material will not cover the length of an entire deck, butt a second piece of surfacing material against the first, straddling the joist upon which they both rest.

Selection of an installation starting point for deck surfacing depends upon the surfacing pattern and edge treatment desired. Beginning at an outer edge and working inward prevents the problem of having a partial piece installed on an outer edge, but may instead require that a partial piece be installed next to an adjacent building. To prevent water damage to a structure, flashing should be placed at any point where surfacing touches a structure.

Surface Installation
- Select a starting point for installation of the surfacing material.
- Snap parallel chalklines on top of the joists to help guide installation (Figure 34-1).
- Attach cleats to posts to help support surfacing material.
- Position deck material on joists with the bark side up to prevent cupping. Ensure the ends of the surfacing are staggered. Trim material if necessary to ensure surfacing always ends on a joist. Consistently space deck material using a shim or nail placed between the boards. Typical spacing for 2 × 4s is 3/16 inch, but 2 × 4s that are still wet from preservative treatment and 5/4s cedar should be spaced 1/8 inch to allow for shrinkage (Figure 34-2).
- Fasten material to joists using two nails or deck screws at each joist location, each nail placed 1 inch in from the edge of the surfacing and centered over the joist.
- At edges where the surfacing material overhangs the frame of the deck, snap a chalkline along the alignment of the outside edge of the structure. Trim by running a circular saw from one end to the other. For a straighter edge, attach a trimming jig, or guide, which will hold the saw in the proper location along the entire cut.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, and Exercise 33, Framing Wood Structures, before beginning this exercise.
Figure 34–1 Snapping parallel chalklines to guide deck surfacing installation.

Figure 34–2 Deck surfacing.

**MATERIALS REQUIRED**
- Cordless drill and bits
- Socket wrench and sockets
- Circular saw
- 50 foot extension cord and access to a 120V GFCI circuit
- Claw hammer
- Carpenter's level
- Carpenter's pencil
- 25 foot tape measure
- Lumber
- Fasteners
EXERCISE DESCRIPTION
To complete this exercise, calculate and procure the required materials and install the surfacing for the framework constructed in Exercise 33, part A or B.

CAUTION
Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.

CAUTION
Deck surfacing and structural support constructed in this exercise are not designed to carry a live load. Do not walk on deck’s surface.
Exercise 35

Constructing Wood Railings and Stairs

Objective
The objective of this exercise is to plan and construct wood stairs and railings.

Textbook Reference
Information related to this activity can be found in the Landscape Construction textbook in Chapter 30, Wood Stairs, Railings, Seating, and Skirting.

Introduction
After surfacing a deck, the finishing touches can be added by building stairs and constructing railings. Stairs are fairly uniform in style and construction, but proper installation is essential to ensure the safety of those who use the deck. While the structural design of railings is also relatively standard, surfacing material for railings can vary depending upon the aesthetic requirements of a project. Procedures for installing notched stairs and horizontal board railings are presented in the following text.

Notched Stairs
Stairs consist of a collection of steps that allow for easy travel up and down steep grades. Key components of a step include the tread, which is the horizontal portion of the step, and the riser, which is the vertical portion of the step. Surfacing material must always be put on the tread of a step, and exterior stairs occasionally feature surfacing on the riser. Stairs are supported by joist-like structural members called carriages. Carriages are 2 × lumber that are either notched and placed under the treads of a stairwell, or uncut and placed along the sides of a stairwell with supports for the treads to set upon. Once the carriages are installed, tread surfacing is put into place and the stairs are ready for use.

Use the following steps to measure, cut, and install notched stairs:

- Identify location for stair placement. Calculate how many carriages are required to support the stairs. Carriages less than 4 feet long should be spaced no more than 16 inches apart. Consult an engineer to determine spacing for carriages longer than 4 feet.
- Calculate the riser and tread dimensions using the formulas presented in Figure 35–1 and Table 35–1.
- Use the following process to mark and cut the carriages using the calculated riser and tread dimensions. Construction of notched carriages requires selection of lumber that is approximately 2 feet longer than the diagonal measurement that must be covered by the stairs. Lumber 2 × 12s are a typical choice for runs with five stairs or less.
- Place lumber on supports.
- On the outside ruler of a carpenter’s square, locate the riser dimension on the short side and the tread dimension on the long side (Figure 35–2A).
- Beginning near one end of the board, place the square so that the riser and tread
Exercise 35  Constructing Wood Railings and Stairs 129

Measurements line up with the edge of lumber. The corner of the carpenter’s square should be off the board (Figure 35–2B). Trace along the long side of the square to mark the location of the top tread.

- Measure out the length of the tread along this line as shown (Figure 35–2C). At the end of the square (the corner), trace along the short side of the square to mark the location where the carriage will connect flush with the deck.
- Position the square so that the riser and tread measurements line up with the edge of the lumber and the corner of the square is resting on the board. The tread measurement should be on the left, and the riser measurement should be on the right (Figure 35–2D).
- Adjust the position of the square along the edge of the board so that the riser measurement aligns with the end of the original tread marking. Along both sides of the square, trace the riser and tread locations.
- Slide the square down the lumber and align the riser measurement with the end of the previous tread mark. Along both sides of the square, trace the riser and tread locations (Figure 35–2D).

Table 35–1 Relationship Between Riser Height and Tread Length in Stairs

<table>
<thead>
<tr>
<th>Riser Height</th>
<th>Tread Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 inches</td>
<td>18 inches</td>
</tr>
<tr>
<td>5 inches</td>
<td>16 inches</td>
</tr>
<tr>
<td>6 inches</td>
<td>14 inches</td>
</tr>
<tr>
<td>7 inches</td>
<td>12 inches</td>
</tr>
<tr>
<td>8 inches</td>
<td>10 inches</td>
</tr>
</tbody>
</table>

Note: Some formulas use values of 27 or 28 inches to replace the 26 inches shown in this formula. Building codes may dictate the dimensions used.

*Stairs that do not match slope dimensions with riser/tread combinations in Table 35–1 will require special design considerations. Consult a design professional.

Figure 35–1 Stair calculations.
**Railings**

Railings enhance both the safety and appearance of a deck and should be considered for installation on any deck that is above grade. Minimum railing heights are dictated by local code, but the standard railing height requirement is 42 inches between deck surfacing and the top of the railing. Railings can be constructed in a variety of ways. They typically rise up out of the deck, are attached to the outside of the deck structure, or are incorporated into seating. Railings can be surfaced with a variety of materials in a number of patterns; horizontal boards, vertical boards, and **balusters** are the most surfacing common materials and patterns used.

Key components of deck railings include the posts; structural supports which are typically incorporated into the deck structure; **stringers**, which support vertical surface covering; and the surfacing. Railings can also be designed to include trim and caps.

Use the following steps for installing a typical horizontal board surface railing. (Note: Construct railings according to the construction documents provided for a design. This installation procedure is typical of only one type of railing installation.)

- Verify location of railing posts. Maximum spacing should be 4 feet, with a post at every corner and at locations where railing changes direction. If it is not installed with the deck structure, notch the deck surfacing and bolt additional 4 × 4 posts to deck framework where necessary.
- Railings at inside corners will need 2 × 4 cleats attached to the surface of the 4 × 4, to which fence surfacing can be attached (Figure 35–3).
- Carefully mark out surfacing locations on the posts. Measure surface board locations on corner posts and snap a chalkline to mark intermediate posts. Review spacing guidelines with building officials to avoid the potential of children falling through or becoming trapped between railing surfacing.
- Starting at the top of the posts, attach surfacing material flat against the posts. Each piece of
material should cover at least three posts. Fasten securely to posts using deck screws. Common surfacing materials include 2 × 6s, 2 × 8s, and a combination of 1 × and 2 × lumber.

When two boards meet on a post, the joint should be centered (Figure 35–3). A miter cut is preferred for stability and appearance. Inside and outside corners require miter cutting of ends (Figure 35–3).

- Continue adding surfacing until the bottoms of the posts are reached.
- Attach a 2 × 8 rail cap running flat over the top of the posts. Fasten using two deck screws per post. Typical rail caps are 1 × or 2 × lumber wide enough to cover all structural components.

PREREQUISITE EXERCISES

Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, Exercise 33, Framing Wood Structures, and Exercise 34, Surfacing Wood Structures, before beginning this exercise.

MATERIALS REQUIRED

- Cordless drill and bits
- Circular saw
- 50 foot extension cord and access to 120V GFCI circuit
- Hand saw

EXERCISE DESCRIPTION

To complete this exercise, calculate and procure the required materials and install the railing surfacing shown in the plan and cross section in Figure 35–4. Also plan and construct wood stairs to fit the opening and grades of the deck constructed in Exercises 33 and 34.

CAUTION

Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.

CAUTION

Deck railing and stairs constructed in this exercise are not designed to carry a live load.
OBJECTIVE
The objective of this exercise is to properly install chain link fencing.

CAUTION
Verify utility locations before beginning construction. Follow manufacturer's instructions when using equipment. Use caution when cutting and fastening materials. Use caution when releasing tension after stretching fencing fabric.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 32, Fencing.

INTRODUCTION
A common fencing material used in the landscape industry today is chain link. This versatile material provides for boundary definition and enclosure, and if desired, can be modified for use as a screen. Chain link fencing is installed in several steps, beginning with the installation of heavy gauge corner/gate posts and light gauge line posts. The fence framework is installed next, and the fabric placed last. Gates can be fabricated with readily available parts or purchased preassembled for easy installation. Surface treatments are also available that can turn the transparent fencing into a partial visual screen.

Successful installation of chain link fencing requires anchoring sections of fence at each corner. If corner posts are not securely anchored, the fence will fail.

Fabric is installed by stretching it between and bolting it to corner posts. The maximum run for stretching fabric is approximately 100 feet. It is not uncommon for fabric that is stretched tightly by hand to be stretched another 1 to 2 feet using jacks or mechanical stretchers. Fabric can be stretched over straight runs and around the outside of curved installations, but inside curves cannot be easily stretched. If the fence runs up a slope, corner posts must be set at the top and bottom of the slope and fabric for that section stretched separately.

Pieces of fence fabric can be spliced together by overlapping links of the fabric and placing a stretcher bar through this overlap. A more attractive splice is achieved by using a single link of fabric to join two pieces. Overlap the pieces and start weaving this link from top to bottom by rotating the link. When joined, twist a bend in the top and bottom of the link to prevent unraveling. Fabric pieces can be shortened by reversing this process, straightening the bends at the top and bottom of a link then unweaving the link from the fabric.

Follow these steps to install a chain link fence.

Setting Corner, Gate, or End Posts
- Excavate an 8 inch diameter hole to frost depth at each corner and gate post location. Using a permanent marker, mark posts with a line at the correct burial depth.
- Fill the holes with a stiff concrete mix and set the corner/gate posts in the holes. If the posts sink, remove them and wait 15 minutes before resetting (Figure 36–1A).
- After the post is placed in the concrete, check for plumb every 15 minutes until the concrete
is set. If the concrete is soft, the post may need to be braced into position.

- Wait 48 hours for the concrete to completely set before continuing fence construction.

**Installing Line Posts**

- Between the tops and bottoms of corner posts, connect a stringline to guide the alignment of the fence.
- Using a fence post driver, drive a line post at each location marked along the alignment. Check often for plumb and alignment. Typical spacing for panels is 10 feet, but spacing can be reduced to maintain even panel dimensions or to conform to a project design.
- An alternative to driving the line posts is to dig or auger holes and place the posts in the holes. Partially backfill the holes with gravel and adjust the height to match the stringline. Check for level in each direction and continue to backfill with soil. Compact the soil after every 6 inches of fill.

**Installing Framework**

- Install top rail caps on each corner, gate, and line post. Corner post caps have openings that accommodate the end of a railing, while the line caps slip on top of line posts and have an opening through which the top railing runs (Figure 36–1B).
- Top rail has a tapered end designed to join with the end of another section. Place the nontapered end in an end post cap.
- Beginning at one end of the fence, slide a section of top rail through the line post caps. When fully inserted, lower the rail in the end post cap onto the end post.
- Place a second section of top railing through the next line post caps and join with the first section by sliding the nontapered end over the tapered end of the previously installed section.
- Continue placing top rail until a section passes over the corner post at the other end of the run.
- At the end of the run hold the top rail against the corner post cap and mark where the end of

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**Figure 36-1** Chain link fence installation.
the rail will meet the back of the opening in the cap.
• Using a reciprocating saw with a metal cutting blade, cut the top rail at the mark.
• Lift the corner post cap and insert the cut end of the top rail in the opening.
• Lower the cap back on the corner post.
• Continue this process for installing top rail between all pairs of end posts.

Installing Mid Rail
A mid rail is installed on tall fences for stability, and at each panel adjacent to corners and gates for any fence over 4 feet tall.

• Loosely bolt the rail holder fitting around a corner post at approximately mid level.
• Measure and cut a piece of top rail that will fit between the corner and first rail post. Be sure the measurement takes into account the fitting on each end.
• Insert the cut rail into the first fitting and slip a second fitting over the other end.
• Clamp this second fitting around the first line post. Tighten the rail holder fitting at both posts.
• Repeat this process for every panel that requires a mid rail.

Fabric Application and Stretching
• Roll the fabric out along the fencing run and lean it against the posts to roughly determine the length of fabric needed (Figure 36–1C).
• At one end of the run, insert a stretcher bar through the first loop of the fence.
• Fasten clamps around this stretcher bar and the corner post. Install one clamp for each foot of fence height.
• Stretch the fabric as tightly as possible by hand along the entire run.
• Mark the link 2 inches back from the end post. For hand-stretched fabric, disconnect the links at this point to create the fabric end. For mechanically stretched fabric, subtract an additional 2 inches for every 10 feet of fence to locate the new end of the fabric.
• Return the fabric to the ground and disconnect (or add) sections of fencing to obtain the proper length.
• Lean the fabric back against the line posts.
• Measure back from the new end of the fabric the same distance that the fence is to be stretched plus 12 inches. Locate a loop at this point and insert a double stretcher bar.

• Position two jacks beyond the end of the fence. Attach the jacks to the double stretcher bar at locations near the top and bottom of the bar. At the same rate with both jacks, slowly jack the material toward the second corner post. Lift and drop the fabric in a bouncing motion while stretching to free the material from any hang-ups along the ground (Figure 36–1D).
• When the new end of the fabric reaches the corner post, insert a single stretcher bar through the last loop in the fabric and install clamps around the corner post and stretcher bar. Install one clamp for each foot of fence height.
• Loosen the jacks and remove the double stretcher bar from the fabric.
• Attach the fabric to the top rails and posts using aluminum fence ties. Work from the side of the fence opposite the fabric. Place the hook end of the tie over a strand of the fabric. Holding the hook in place, use one finger to bend the tie around the post or rail. Push the straight end of the tie back through the fabric and bend it around a strand of fabric. Repeat every 2 feet on posts and every 4 feet along the top rail (Figure 36–1E).

Installing Tension Wire
• Attach clamps around the base of each corner post (Figure 36–1F).
• Connect the tension wire to one clamp and stretch tightly between the two corner posts.
• Attach the wire to the clamp at the base of the second corner post.
• Connect fabric to tension wire every 2 feet using aluminum ties.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, and Exercise 8, Construction Staking, before beginning this exercise.

MATERIALS REQUIRED
• Proper clothing and safety gear
• Posthole auger
• Mason’s twine
• 25 foot and 100 foot tape measures
• Socket wrench and sockets
• Vise grips
• Pliers
• Screwdriver
Exercise 36  Chain Link Fence Construction

- Carpenter’s level
- Permanent felt tip marker
- Fencing tool
- Two lever jacks
- Fencing materials
- Concrete

EXERCISE DESCRIPTION
To complete this exercise construct a 15 foot long segment of 4 foot tall chain link fence on a level surface connected to a 15 foot long segment of fence that is stepping up a slight slope (Figure 36–2).

CAUTION
Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.
Exercise 37

Pool Liner Installation

OBJECTIVE
The objective of this exercise is the proper installation of a flexible pool liner for a decorative pond.

Verify location of utilities before construction. Follow manufacturer’s instructions when using equipment. Use caution when cutting and installing materials.

TEXTBOOK REFERENCE
Information related to this activity can be found in the Landscape Construction textbook in Chapter 34, Water Features and Bridges.

INTRODUCTION
Pool liners have eased the difficulty of pool installation. For residential and small commercial applications, flexible liners have expanded the possibilities for use of water in the landscape. Flexible liners are heavy-duty vinyl sheets that can be cut to the sizes and shapes required by a design. Like other pools, the lined pool must have a ledge that is at the same elevation around the entire perimeter to keep water in. The edge of the pool is often covered by coping, which hides the liner.

Pool liners do have limitations. In particular, drains cannot be installed at the bottom of the pool. Difficulties might also be encountered when using liners in multilevel pools. As with other pools, lighting, plants, and fountains can be added to lined pools to enhance their appearance.

To install a lined pool follow these instructions:

• Mark the pool basin location (Figure 37–1A).
• Excavate the pool basin to proper depth. Designs that angle the sidewalls steeply work the best (Figure 37–1B). Remove all rocks and prune any roots protruding into the pond basin.
• Excavate a ledge for coping around the edge of the basin. The ledge should be the same thickness as the coping material and have a width slightly more narrow than the width of the coping material. Verify that the ledge is level along the entire perimeter. Use a 2 × 4 with a level resting on top to verify level across the pool. Adjust grade if necessary (Figure 37–1C).
• Irregularities in the bottom or sides of basin walls can be corrected by filling holes with sand.
• Install a spunbond geotextile protective barrier (liner pad) over the entire basin, including the sides and coping ledge. Trim the barrier at the back of the coping ledge.
• Lay out liner and trim to rough dimensions according to the following formulas. These formulas will leave excess liner that can be trimmed after placement. The shallower the side slope angle, the greater the excess (Figure 37–1D).

Liner length in feet = L + 2D + 3, where L equals pool length at the rim and D equals pool depth

Liner width in feet = W + 2D + 3, where W equals pool width at the rim and D equals pool depth

For irregularly shaped pools, measure length, width, and depth using maximum possible dimensions (Figure 37–2).
Step A. Mark pool basin location.

Step B. Excavate pool basin to proper depth with proper side angle. Shelves of varying levels can be created by adjusting the depth of the excavation.

Step C. Excavate ledge for coping.

Step D. Lay out liner and check for proper dimensions.

Step E. Center liner over pool basin and push into basin. Smooth and adjust liner location.

Fold excess under at coping ledge

Fold at corners

Step F. Fold excess liner under at back edge of coping ledge.

Step G. Install coping.

Step H. Clean and fill pool.

Figure 37–1 Installation steps for a flexible pool liner.

- Center liner over basin opening (Figure 37–1E). Push liner into basin. If using your feet to push liner, remove shoes. After molding the liner to the basin shape, add a few inches of water to the pool to assist in forming the liner to the bottom of the excavation.
- Adjust liner to cover the basin sides and ledge. Tuck and fold the liner where necessary to accommodate grade changes. Fold excess liner under at the back edge of the coping ledge, trimming liner if necessary to create a nice fold (Figure 37–1F).
- Install coping (Figure 37–1G).
- Clean inside of pool. Fill pool.

PREREQUISITE EXERCISES
Students should have successfully completed Exercise 5, Tool Operation and Construction Techniques, before beginning this exercise.
MATERIALS REQUIRED

- Marking spray paint
- Round-nosed shovel
- Square-nosed shovel
- 2 × 4
- Hand saw
- Carpenter’s level
- Utility knife
- 25 foot tape measure
- Sponge
- Hoses and access to water hydrant
- Wheelbarrow
- Pool liner
- Coping material
- Sand

EXERCISE DESCRIPTION

To complete this exercise excavate the site as shown in Figure 37–3 and install a flexible pool liner.

CAUTION

Operate power equipment under supervision. Serious injury or death could result from improper use of equipment. Follow manufacturer’s instructions.
Glossary

A

AC (alternating current). High voltage electrical current.

Architect’s scale. One of two scales used by designers to reduce large measurements onto one sheet of paper through the use of fractions (i.e., 3/8 inch = 1 foot).

Auger. A hole excavator that requires twisting a rounded blade to remove materials.

B

Backdrain. A valve and housing that allows water to be drained out of an irrigation system.

Backfill. The stone, sand, and/or soil used to fill in the void created when holes or trenches are excavated.

Baluster. A narrow post used for railing surfacing.

Baseline. A layout technique that locates objects using measurements made at right angles at calculated points along a straight line.

Base material. Crushed stone used as support material for most paving material. Also referred to as aggregate, gravel, roadstone, and other regional names.

Batter. Backward lean of a retaining wall for stability.

Batterboards. Angled wooden frameworks used to mark corners, edges, and elevations of project.

Benchmark. A fixed reference elevation.

Berm. Mounded and shaped soil.

Breaker bar. A heavy metal bar with flared and/or pointed ends, used to break hard soil.

Brick set. A large chisel used to score brick and stone surfaces, making straight breaks possible.

Bull float. A metal tool with a long handle used to smooth and level concrete.

Butt Stairs. Stairs that have tread material that butts up against check walls.

C

Carpenter’s square. A flat metal tool with two legs set at right angles to allow square markings.

Carriage. Joist-like structural members that support stairs.

Cartesian coordinates. A measurement and layout system that locates objects using measurements off two baselines set at right angles to each other.

Cellular Confinement System. An erosion control system composed of a web of geotextile pockets spaced down a slope and filled with soil, granular material, or concrete. The system is anchored at the top and bottom of the slope.

Chain saw. A gas-powered saw with sharpened chain links used to cut large wood members.

Cheek wall. A side wall that runs perpendicular to the face of a retaining wall into which stairs butt or are interlocked.

Chuck key. Small wrench used to tighten and loosen the chuck, or clamp, that holds bits in drills.

Circular saw. A hand-operated saw using a blade that operates in a circular motion.

Clamshell. A hole excavator that uses two opposing blades to remove material.

Claw hammer. A hammer with a flat driving surface and a two-pronged pulling tool.

Cleave. To split stone, masonry, or clay brick materials.

Concrete. A mixture of cement, sand, water, and aggregate (stone) that hardens to create a solid paving surface.

Coping. Edging placed around a pool to cover the top edge of the pool.
**Cut and fill.** The process of removing or adding soil to a site to achieve desired grades.

**Cutoff saw.** A gas-powered saw with a circular blade used for cutting masonry and stone.

**DC (direct current).** Low voltage electrical current.

**Deadman.** An anchor connected to the face of a wall and buried into a hill behind the wall for stabilization. Deadman can also refer to anchors used to stabilize large plant material.

**Drip line.** The imaginary line on the ground directly below the farthest extent of a plant’s canopy.

**Dumpy level.** A tripod-mounted telescope that can be leveled and used to measure elevations.

**Edge restraint.** Material used along edges to hold paving materials in place. Used with unit pavers and granular material, edgers can be concrete, stone, brick, wood, metal, or plastic.

**Engineer’s scale.** A scale used by designers to accommodate the scale of large projects by multiplying by factors of ten (i.e., 1 inch = 10 feet) and thereby reducing the overall size of the drawing.

**Erosion mat.** A layer of biodegradable materials sandwiched between two layers of lightweight netting.

**Form nails.** Special nails used in form construction that have two heads to make removal from forms easier.

**Forms.** Pieces and strips of wood or metal placed to shape concrete slabs. Forms are secured to the ground and tops are set at the desired height for concrete.

**Free-draining angular fill.** Crushed stone that does not have rounded edges or fine granular material that is used as fill behind a wall.

**French drain.** A gravel-filled, subsurface trench installed to temporarily store surface drainage.

**Garden rake.** A rake with short, heavy-duty tines used for moving soil and heavy materials.

**Geogrid.** Open-weave fabric used to stabilize retaining walls.

**Geotextile sock.** Interwoven drainage fabric wrapped around perforated tile to reduce infiltration of soil into the tile.

**GFCI (Ground fault circuit interrupt).** A circuit engineered to automatically shut off if voltage fluctuations are detected.

**Grade staking.** The process of installing stakes marked with proposed changes in grade.

**Head.** An irrigation component that distributes water to plants. Can use spray, flood, or drip methods to distribute water.

**Hydraulic splitter.** A table-mounted masonry cleaving tool that uses hydraulic pressure on a cleaving bar to split materials.

**Inlet.** A concrete or plastic structure into which water runoff flows.

**Interlocking stairs.** Stairs with treads that interlock with cheek walls.

**Irrigation.** A system or piping, valves, and sprinklers designed to water plant material.

**Jacks.** Ratchet tools used to stretch fencing materials.

**Jig.** Wood or metal strip attached to a surface, used to guide saw cuts.

**Joists.** Wood structural members that support the surfacing of a deck.

**Landscape fabric.** Woven geotextiles used to reduce erosion and weed growth.

**Laser plane level.** Surveying instrument that uses a rotating light projected in a level plane to locate elevations.

**Lateral line.** A secondary irrigation line that carries water from valves to irrigation heads.

**Leaning Batter.** Batter for a retaining wall created by tilting wall material toward the back.

**Ledger plate.** A piece of dimensioned lumber attached to a structure that supports decks and roofs.

**Levels.** A family of tools used to determine if installed materials are level.

**Line level.** A small level hung from a stringline to determine level between two points.

**Main line.** A primary irrigation line that carries water to valves.

**Mason’s twine (mason’s line).** Heavy-duty string used in construction.

**Nipple.** A short pipe connecting two irrigation components.

**Nonperforated drain tile.** Solid tile used to conduct water.

**Perforated tile.** Tile with small slit openings molded into the sides to allow water to enter the tile.
Pick. A pointed tool used to chop at soil, paving, roots, and other solid materials.

Pilot hole. A hole drilled into or through an object into which a bolt or screw is inserted.

Plumb. Placement of an object so that it is vertical on all sides.

Pool liner. A waterproof plastic or vinyl sheet that is used to line water features.

Power auger. A gas powered digging tool with a spiral blade that is turned into the ground to remove soil.

Power drill. A heavy-duty electrical drill.

Precast concrete paving block. Unit paving material composed of molded, cured concrete. Pavers come in a variety of shapes (H-shaped, uni-decor, S-shaped) and colors, are 3.5 inches thick, and have a typical average strength of 8,000 PSI.

PVC. Polyvinylchloride pipe.

Reciprocating saw. An electrical power saw that drives a long narrow blade up and down to cut materials.

Riser. The piping that connects an irrigation head to the lateral line.

Root zone. The area surrounding a plant where feeder roots are most prominent, (i.e., beneath the canopy of a tree).

Sawhorse. A device used to support materials that are to be cut.

Scales. Ruler-like instruments used for measuring dimensions on landscape plans. See Architect’s Scale and Engineer’s Scale.

Screed. A tool—typically a straight 2 × 4 a couple feet longer than the width of the concrete pour—used to level concrete after it is initially placed. Also refers to the act of leveling concrete after a pour.

Segmental concrete wall unit. Wall building material that is premanufactured from cast concrete.

Setting bed. An approximately 1 inch thick layer of sand on which unit pavers are set.

Sidewalls. Retaining walls that run along the side of stairs. Also called cheek walls.

Silt fence. Woven plastic fabric stretched across waterways to reduce soil erosion.

Skid-steer. A small end-loader that operates by alternately moving the drive wheels in the same or opposite directions.

Sledgehammer. A heavy hammer with flat driving surfaces.

Sod cutter. A manual or motorized device used to scrape sod with enough soil and roots that it can be transplanted.

Soldier course. A stacked bond of unit pavers placed around the edge of a paved area. Used to eliminate the placement of cut pavers against edge restraint.

Stretcher bar. A long, thin metal bar inserted through chain link fence fabric and clamped to a post to hold fence fabric taut.

Stringer. A structural support for railing or fence surfacing.

Stringline. String used to identify the location and/or elevation of the edge of a project.

Sump. A recessed area at the bottom of an inlet that captures runoff.

Survey rod. A pole-like instrument with markings on one side that is used to calculate heights when observed through a survey instrument.

Swale. A low ditch designed to occasionally carry water runoff.

Take-off. The process of measuring a drawing to obtain material quantities.

TEE. See T connection.

Tee connection. A specialized piece of tile shaped like the letter T used to channel the flow of water and connect pipes.

Tension wire. A thin wire stretched between fence posts to which chain link fabric is fastened to prevent curling.

Transformer. An electrical component engineered to reduce voltage in current.

Trowel. A wedge-shaped metal hand tool used to mix and place mortar or concrete.

Unit pavers. Bricks, paving block, or other man-made paving materials that are placed one at a time.

Utility knife. A knife that uses razor blades to cut various construction materials.

Valve. A mechanical device used to regulate the flow of water.

Valve Manifold. A series of valves placed at the beginning of an irrigation system to control the water distributed to irrigation zones.

Verticals. Ties or timbers placed with the long dimension set vertically; usually buried in front of a wall to prevent the wall from falling forward.

Vibratory plate compactor. A self-propelled tool with a motor that vibrates a large metal plate mounted on the base. It is used to compact base materials.
**W**

**Waterproof wire nut.** A wire connector designed to protect the connection from water by surrounding it in a waterproof substance.

**Wattle.** Tubular-shaped nylon nettings filled with straw or fibers, used for erosion control.

**Weepholes.** Openings in the face of a retaining wall that allow water to drain from behind the wall.

**Wet masonry saw.** A table-mounted circular saw that uses water to aid in cutting masonry materials.

**Wheelbarrow.** A metal tub with handles and wheels used to haul small amounts of material.