CHAPTER 2

ROAD SURVEYING

Section I. RECONNAISSANCE SURVEY

PREPARATION AND SCOPE

The reconnaissance survey is an extensive study of an entire area that might be used for a road or airfield. Its purpose is to eliminate those routes or sites which are impractical or unfeasible and to identify the more promising routes or sites.

Existing maps and aerial photographs may be of great help. Contour maps show the terrain features and the relief of an area. Aerial photographs show up-to-date planimetric details.

The reconnaissance survey must include all possible routes and sites. The reconnaissance survey report should summarize all the collected information, including a description of each route or site, a conclusion on the economy of its use, and, where possible, appropriate maps and aerial photographs.

Design

Design and military characteristics should be considered during the reconnaissance survey. Keep in mind that future operations may require an expanded road net. A study of the route plans and specifications is necessary. If these are unavailable, use the following as guides.

- Locate portions of the new road along or over existing roads, railroads, or trails, whenever possible.
- Locate the road on high-bearing-strength soil that is stable and easily drained, avoiding swamps, marshes, and organic soil.
- Locate the road along ridges and streamlines, keeping drainage structures to a minimum. Keep the grade well above the high waterline when following a stream.
- Select a route as near to sources of material as practical, and locate the road along contour lines to avoid unnecessary earth work.
- Locate the road on the sunny side of hills and canyons, and on that side of the canyon wall where the inclination of the strata tends to support the road rather than cause the road to slide into the canyon.
- Locate roads in forward combat zones so that they are concealed and protected from enemy fire. This may at times conflict with engineering considerations.
- Select locations which conserve engineer assets, avoiding rockwork and excessive clearing.
- Avoid sharp curves and locations which involve bridging.

Roadway Criteria

To insure satisfactory results, study the engineering specifications of the road to be built. If these are not available, use the information provided in table 2-1.

Table 2-1. Road specifications

WIDTHS

One-way road—11.5 feet or 3.5 meters minimum.

Two-way road—23 feet or 7.0 meters minimum.

Shoulders (each side)—4 feet or 1.5 meters minimum.

Clearing—6 feet or 2 meters each side of roadway.

GRADES

Absolute maximum—determined by the lowest maximum gradeability of vehicles using the road.

Normal maximum—10 percent.

Desired maximum—less than 6 percent; on sharp curves, less than 4 percent.

HORIZONTAL CURVES

Desired minimum radius—150 feet or 46 meters.

Absolute minimum radius—80 feet or 25 meters.

VERTICAL CURVES

Minimum length on hill summits—125 feet or 40 meters per 4 percent algebraic difference in grades.

Minimum length in hollows—100 feet or 30 meters per 4 percent algebraic difference in grades.

SIGHT DISTANCES

Absolute nonpassing minimum—200 feet or 60 meters.

Absolute passing minimum—350 feet or 110 meters.

SLOPES

Shoulders—¾ inch per foot (in/ft) or 6 percent.

Crown (gravel and dirt)—½ to ¾ in/ft or 4 to 6 percent.

Crown (paved)—¼ to ½ in/ft or 2 to 4 percent.

Cut and fill—variable, but normally about 1 ½ to 1.

DRAINAGE

Take advantage of natural drainage.

Locate above high waterline near streams or creeks.

Grade at least 5 feet or 1.6 meters above groundwater table.

TRAFFIC

Overhead clearance—14 feet or 4.3 meters minimum.

Traffic volume—2,000 vehicles per lane per day.

Load capacity—sustain 18,000 pound equivalent axle load.

Turnouts (single lane)—minimum every ¼ mile or 0.4 kilometers recommended.

COLLECTION OF DATA

Upon completion, the reconnaissance survey should support the routes surveyed and provide a basis of study showing the advantages and disadvantages of all routes reconnoitered. Typical data collected in a reconnaissance survey are—

- Sketches of all routes reconnoitered.
- Reports of feasible routes. Data on clearing and grubbing.
- The number of stream crossings involving bridge spans exceeding 20 feet or 6 meters.
- The approximate number of culverts and spans less than 20 feet or 6 meters.
- Descriptions and sizes of marsh areas and other natural obstacles.
- Unusual grade and alignment problems encountered.
- Anticipated effects of landslides, melting snow, and rainfall.
- Soil conditions and stream and substrata conditions at proposed bridge sites.
- Discrepancies noted in maps or aerial photographs.
- Availability of local materials, equipment, transportation facilities, and labor.
- Photographs or sketches of reference points, control points, structure sites, terrain obstacles, and any unusual conditions.

USE OF MAPS

The procurement of maps is a very important phase of the reconnaissance. The surveyor should locate and use all existing maps, including up-to-date aerial photographs of the area to be reconnoitered. Large scale topographic maps are desirable because they depict the terrain in the greatest detail. The maps, with overlays, serve as worksheets for plotting trial alignments and approximate grades and distances.

The surveyor begins a map study by marking the limiting boundaries and specified terminals directly on the map. Between boundaries and specified terminals, the surveyor observes the existing routes, ridge lines, water courses, mountain gaps, and similar control features. The surveyor must also look for terrain which will allow moderate grades, simplicity of alignment, and a balance between cut and fill.

After closer inspection, the routes that appear to fit the situation are classified. As further study shows disadvantages of each route, the surveyor lowers the classification. The routes to be further reconnoitered in the field are marked using pencils of different colors to denote priority or preference. Taking advantage of the existing terrain conditions to keep excavation to a minimum, the surveyor determines grades, estimates the amount of clearing to be done on each route, and marks stream crossings and marsh areas for possible fords, bridges, or culvert crossings.

Section II. PRELIMINARY SURVEY

PREPARATION AND SCOPE

The preliminary survey is a detailed study of a route tentatively selected on the basis of reconnaissance survey information and recommendations. It runs a traverse along a proposed route, establishes levels, records topography, and plots results. It also determines the final location from this plot or preliminary map. The size and scope of the project will determine the nature and depth of the preliminary survey for most military construction.

PERSONNEL

The survey effort establishes a traverse with control and reference points, or it may expand to include leveling and topographic detail. Normally, obtaining the traverse, leveling, and topographic data are separate survey efforts, but this does not preclude combining them to make the most efficient use of personnel and equipment.

Traverse Party

The traverse party establishes the traverse line along the proposed route by setting and referencing control points, measuring distances, numbering stations, and establishing points of intersection. The party also makes the necessary ties to an existing control, if available or required. When no control is available, the party may assign a starting value for control purposes which can later be tied to a control point established by geodetic surveyors.

Level Party

The level party establishes benchmarks and determines the elevation of selected points along the route to provide control for future surveys, such as the preparation of a topographic map or profile and cross-section leveling. The level party takes rod readings and records elevations to the nearest 0.01 foot or 0.001 meter. It sets the benchmarks in a place well out of the area of construction and marks them in such a way that they will remain in place throughout the whole project.

If there is no established vertical control point available, establish an arbitrary elevation that may be tied to a vertical control point later. An assigned value for an arbitrary elevation must be large enough to avoid negative elevations at any point on the project.

Topographic Party

The topographic party secures enough relief and planimetric detail within the prescribed area to locate any obstacles and allow preparation of rough profiles and cross sections. Computations made from the data determine the final location. The instruments and personnel combinations used vary with survey purpose, terrain, and available time. A transit-stadia party, plane table party, or combination of both may be used.

Transit-Stadia Party. The transit-stadia party is effective in open country where comparatively long, clear sights can be obtained without excessive brush cutting.

Plane Table Party. The plane table party is used where terrain is irregular. For short route surveys, the procedure is much the same as in the transit-stadia method, except that the fieldwork and the drawing of the map are carried on simultaneously.

Section III. FINAL LOCATION SURVEY

PREPARATION AND SCOPE

Prior to the final location survey, office studies consisting of the preparation of a map from preliminary survey data, projection of a tentative alignment and profile, and preliminary estimates of quantities and costs are made and used as guidance for the final location phase. The instrument party carefully establishes the final location in the field using the paper location prepared from the preliminary survey. The surveyor should not make any changes without the authority of the officer-in-charge.

RUNNING THE CENTERLINE

The centerline may vary from the paper location due to objects or conditions that were not previously considered. The final centerline determines all the construction lines. The surveyor marks the stations, runs the levels, and sets the grades.

The centerline starts at station 0+00. The surveyor numbers the stations consecutively and sets them at the full 100-foot or 30-meter stations. The surveyor also sets stakes at important points along the centerline. These may be culvert locations, road intersections, beginnings and ends of curves, or breaks in the grade. When measurements are made in feet, these stations are numbered from the last full station (+00). They are called plus stations. A station numbered 4+44.75 would be 44.75 feet away from station 4+00 and 444.75 feet from the beginning of the project.

When using the metric system, the total distance from the beginning of the project would be 135.56 meters and would be numbered 135.56.

REFERENCE STAKES

Referencing of stations is described in TM 5-232.The control points established by the location survey determine the construction layout. Therefore, these points must be carefully referenced. The surveyor should set the control point references far enough from the construction to avoid disturbance.

PROFILE AND CROSS SECTIONS

After the centerline of the road, including the horizontal curves, has been staked, the next step in the road layout is the determination of elevations along the centerline and laterally across the road. The surveyor performs these operations, known as profile leveling and cross-section leveling, as separate operations but at the same time as the elevation of points along a centerline or other fixed lines.

The interval usually coincides with the station interval, but shorter intervals may be necessary due to abrupt changes in terrain. The plotting of centerline elevations is known as a profile. From this profile, the design engineer determines the grade of the road.

The cross-section elevations make it possible to plot views of the road across the road at right angles. These plotted cross sections determine the volume of earthwork to be moved. The surveyor establishes the cross-section lines at regular stations, at any plus station, and at intermediate breaks in the ground and lays out the short crosslines by eye and long crosslines at a 90-degree angle to the centerline with an instrument.

All elevations at abrupt changes or breaks in the ground are measured with a rod and level, and distances from the centerline are measured with a tape. In rough country, the surveyor uses the hand level to obtain cross sections if the centerline elevations have been determined using the engineer level.

Section IV. CONSTRUCTION LAYOUT SURVEY

PREPARATION AND SCOPE

The construction layout is an instrument survey. It provides the alignment, grades, and locations which guide the construction operations. The construction operations include clearing, grubbing, stripping, drainage, rough grading, finish grading, and surfacing. The command must keep the surveyors sufficiently ahead of the construction activity in both time and distance to guarantee uninterrupted progress of the construction effort. Note the following suggested distances.

- Keep centerline established 1,500 feet or 450 meters ahead of clearing and grubbing.
- Keep rough grade established and slope stakes set 1,000 feet or 300 meters ahead of stripping and rough grading.
- Set stakes to exact grade, 500 feet or 150 meters ahead of finish grading and surfacing.

ALIGNMENT

The surveyor must place the alignment markers ahead of the crews engaged in the various phases of construction. The surveyor may do a hasty alignment, marked by flags and rods, suitable for guiding the clearing and grubbing operations. However, a deliberate location of the centerline is necessary for the final grading and surfacing operations.

The surveyor marks the curves and minor structures concurrently with the layout of the centerline. Major structures such as tunnels and bridges involve a site survey. The general demarcation of the site boundaries is carried on with the establishment of the route alignment. The layout of the site proper is a separate survey.

SETTING GRADE STAKES

Grade stakes indicate the exact grade elevation to the construction force. The surveyor consults the construction plans to determine the exact elevation of the subgrade and the distance from the centerline to the edges of the shoulder.

Preliminary Subgrade Stakes

The surveyor sets preliminary subgrade stakes on the centerline and other grade lines, as required. First, the surveyor determines the amount of cut or fill required at the centerline station. The amount of cut or fill is equal to the grade rod minus the ground rod. The grade rod is equal to the height of instrument minus the subgrade elevation at the station. The ground rod is the foresight reading at the station. If the result of this computation is a positive value, it indicates the amount of cut required. If it is negative, it indicates the amount of fill.

For example, given a height of instrument (HI) of 115.5 feet, a subgrade elevation of 108.6 feet, and a ground rod reading of 3.1 feet, the grade rod = 115.5 feet -108.6 = +6.9 and cut or fill = 6.9 -3.1 = +3.8, indicating a cut of 3.8 feet. The surveyor records the result in the field notes and on the back of the grade stake as C $3\underline{^{8}}$ (figure 2-1, example a).

Sometimes, it is necessary to mark stakes to the nearest whole or half foot to assist the earthmoving crew. In the example given, the surveyor would measure up 0.2 foot on the stake and mark it as in figure 2-1, example b. If at this stake a fill of 3.8 feet was required, the surveyor would measure up 0.3 foot and mark the stake as in figure 2-1, example c. Figure 2-1, example d, shows a case where the actual subgrade alignment could be marked on the stake. The number under the cut or fill represents the distance the stake is from the road centerline. The surveyor normally makes rod readings and computations to the nearest 0.1 foot or 0.01 meter.

During rough grading operations, the construction crew determines the grades for the edges of the traveled way, roadbed, and ditch lines. However, if the road is to be superelevated or is in rough terrain, the survey crew must provide stakes for all grade lines. These would include the centerline, the edge of the traveled way, the edges of the roadbed, and possibly, the centerline of the ditches. The surveyor sets those stakes by measuring the appropriate distance off the centerline and determines the amount of cut or fill as outlined. The surveyor offsets the stakes along the traveled way, roadbed, and ditches to avoid their being destroyed during grading operations. The construction foreman, not the surveyor, makes the decision as to how many and where grade stakes are required.

Final Grade Stakes

Once the rough grading is completed, the surveyor sets the final grade stakes (blue tops). The elevation of the final grade is determined and the value of the grade rod reading is computed. The surveyor uses a rod target to set the grade rod reading on the rod. The rod is held on the top of the stake. The stake is driven into the ground until the horizontal crosshair bisects the target and the top of the stake is at final grade. The surveyor marks the top of the stake with a blue lumber crayon to distinguish it from other stakes.

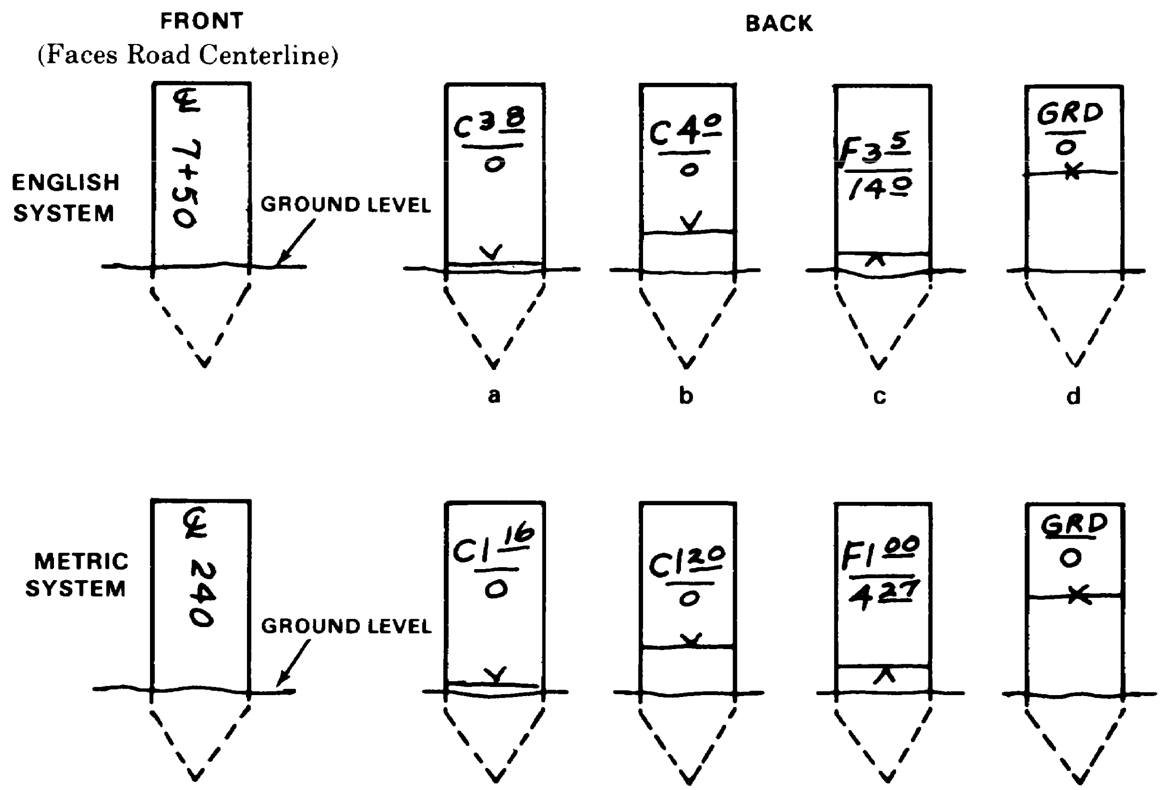

Figure 2-1. Grade stakes

The surveyor should provide blue tops on all grade lines. However, the final decision as to what stakes are required lies with the construction foreman. To set final grade, the surveyor normally makes rod readings and computations to 0.01 foot or 0.001 meter.

Special Cases

Where grade stakes cannot be driven, as in hard coral or rock areas, the surveyor must use ingenuity to set and preserve grade markings under existing conditions. Often, such markings are made on the rock itself with a chisel or a lumber crayon.

SETTING SLOPE STAKES

Slope stakes indicate the intersection of cut or fill slopes with the natural groundline. They indicate the earthwork limits on each side of the centerline.

Level Section

When the ground is level transversely to the centerline of the road, the cut or fill at the slope stake will be the same as at the center, except for the addition of the crown. On fill sections, the distance from the center stake to the slope stake is determined by multiplying the center cut by the ratio of the slope (for example, horizontal distance to vertical distance) of the side slopes and adding one half the width of the roadbed. On cut sections, the surveyor can find the distance from the center stake to the slope stake by multiplying the ratio of slope by the center cut and adding the distance from the centerline to the outside edge of the ditch.

In either case, if the ground is level, the slope stake on the right side of the road will be the same distance from the centerline as the one on the left side of the road. On superelevated sections, the surveyor must add the widening factor to determine the distance from the centerline to the slope stake. This is because the widening factor is not the same for both sides of the road, and the slope stakes will not be the same distance from the centerline.

Transversely Sloping Ground

When the ground is not level transversely, the cut or fill will be different for various points depending upon their distance from the centerline. The surveyor must determine the point, on each side of the centerline, whose distance from the center is equal to the cut or fill at that point multiplied by the slope ratio and added to one half the roadbed width for fills, and the slope ratio multiplied by the distance from the centerline to the outside of the ditches for cuts.

A trial and error method must be used. The surveyor will soon attain proficiency in approximating the correct position of the slope stake, and the number of trials can generally be reduced to two or three. The surveyor will mark the cut or fill on the slope stake and record it in the notebook as the numerator of a fraction whose denominator is the distance out from the centerline. Three-level, five-level, and irregular sections present this problem. Figures 2-2 through 2-5 illustrate the procedure involved in setting slope stakes on sloping ground for three typical cases.

Cut Section

The cut section in figure 2-2 has the level set up with an HI of 388.3 feet. The subgrade elevation at this centerline station is set at 372.5 feet for a 23-foot roadbed with 1.5:1 side slopes, 4-foot shoulders, and 7-foot ditches. The "grade rod" is the difference between these two elevations or 388.3 -372.5 = +15.8 feet. The rodman now holds the rod on the ground at the foot of the center grade stake and obtains a reading of 6.3 feet, a "ground rod." The recorder subtracts 6.3 from the grade rod of 15.8, which gives +9.5 feet or a center cut of 9.5 feet. On slope stakes, the cut or fill and the distance out from the centerline are written facing the center of the road. The backs of the slope stakes show the station and the slope ratio to be used.

The recorder estimates the trial distance by multiplying the cut at the centerline (9.5) by the slope ratio (1.5) and adding the distance from the centerline to the outside edge of the ditch (22.5).

9.5 x 1.5+ 22.5= 36.8 (to the nearest tenth of a foot)

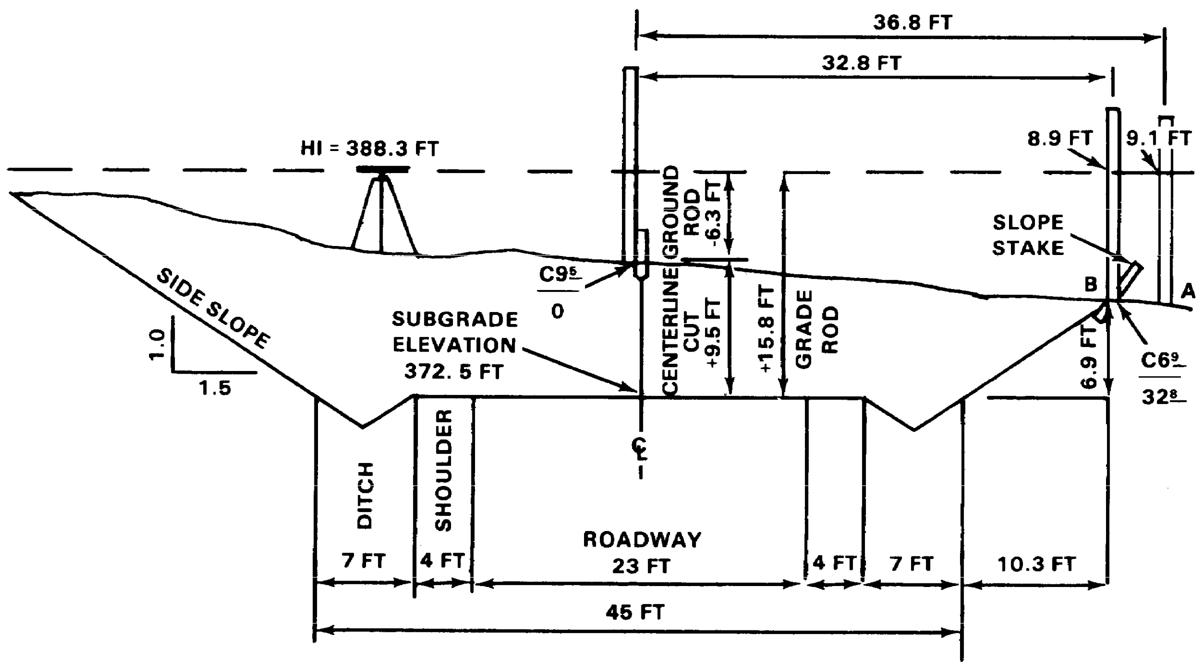

Figure 2-2. Setting slope stakes

The rodman now moves to the right at right angles to the centerline the trial distance (36.8 feet). The rod is held at A and a reading of 9.1 is obtained, which, when subtracted from the grade rod of 15.8, gives a cut of 6.7 feet. The recorder then computes what the distance from the centerline to A should be. This is done by multiplying the cut of 6.7 by the slope ratio and adding one half the roadbed width, which gives 32.6 feet.

However, the distance to A was measured as 36.8 feet instead of 32.6, so the position at A is too far from the centerline. Another trial is made by moving the rod to 32.6 feet from the centerline (B), where a reading of 8.9 is made. The cut at B is now 15.8- 8.9= +6.9, and the calculated distance from the center is 6.9 x 1.5 + 22.5 = 32.8 feet. The distance actually measured is 32.8 feet. Therefore, B is the correct location of the slope stake and is marked C6^{9}. Since moving the rod one or two tenths of a foot would not materially change its reading, greater accuracy is unnecessary. After a few trials, the rodman locates the slope stake on the left in a similar manner. The instrumentman verifies the figures by computation. When placed in the ground, the stakes will appear as in figure 2-3.

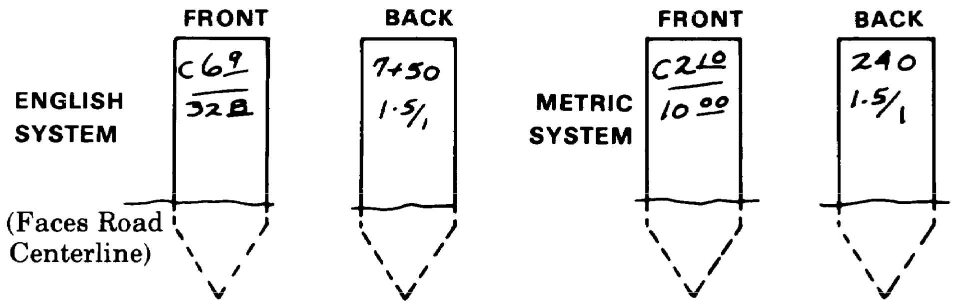

Figure 2-3. Marking slope stakes

Fill Section (HI Above Grade Elevation)

Figure 2-4 illustrates a fill with the HI of the level set up above the subgrade elevation of the 31-foot roadbed. In this case, the grade rod will always be less, numerically, than rod readings on the ground. The grade rod in this problem is +2.8; the rod reading at the center stake is 6.5; and the difference is 2.8-6.5= -3.7 feet. The minus sign indicates a center fill. The rodman finds the positions of the slope stakes by trial, as previously explained.

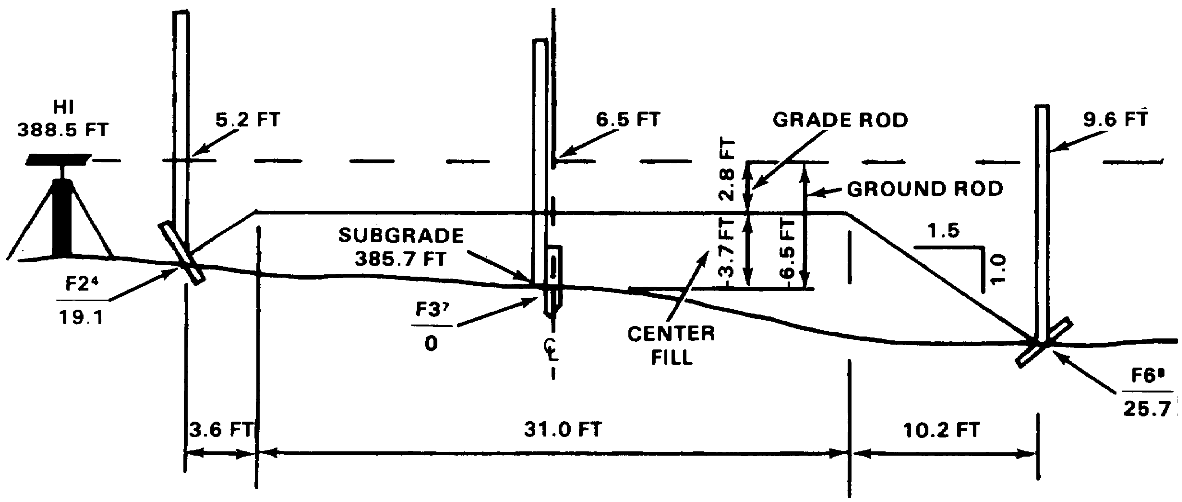

Figure 2-4. Slope stakes (HI above grade elevation)

Fill Section
(HI Below Grade Elevation)

Figure 2-5 illustrates a fill with the HI of the level below the grade elevation of the future roadbed. Therefore, the grade rod has a negative value. Adding the negative ground rod to the negative grade rod will give a greater negative value for the fill. For example, at the center stake, the fill equals (-2.40 meters) + (-2.35 meters) or -4.75 meters. Otherwise, this case is similar to the preceding ones.

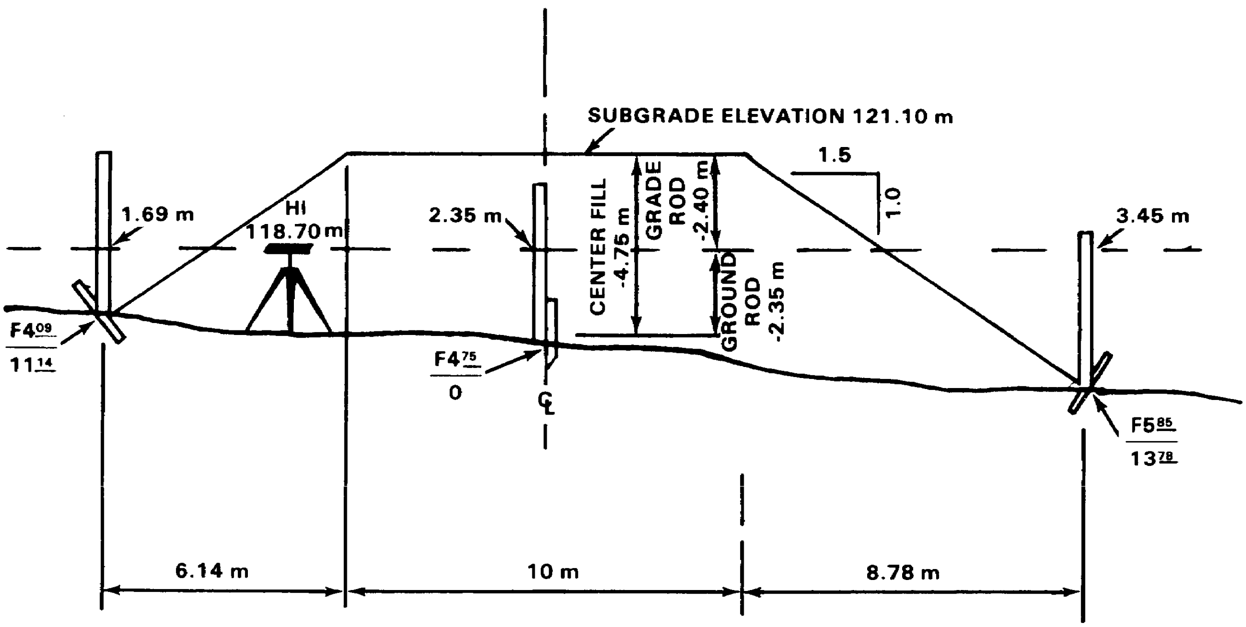

Figure 2-5. Slope stakes (HI below grade elevation)

CULVERT LOCATION

To establish the layout of a site such as a culvert, the surveyor locates the intersection of the roadway centerline and a line defining the direction of the culvert. Generally, culverts are designed to conform with natural drainage lines. The surveyor places stakes to mark the inlet and outlet points, and any cut or fill, if needed, is marked on them. The construction plans for the site are carefully followed, and the alignment and grade stakes are set on the centerlines beyond the work area. Thus, any line stake which is disturbed or destroyed during the work can be replaced easily.

The surveyor should also set a benchmark near the site, but outside of the work area, to reestablish grades. Figure 2-6 shows atypical layout for a culvert site. Circumstances or practical considerations may dictate that certain types of surveys will be eliminated or combined. For example, the location and construction surveys may be run simultaneously. (Refer to TM 5-330.)

DRAINAGE

The construction of drainage facilities is an important part of any project. The surveyor must anticipate drainage problems and gather enough field data to indicate the best design and location for needed drainage structures. (Refer to TM 5-330.)

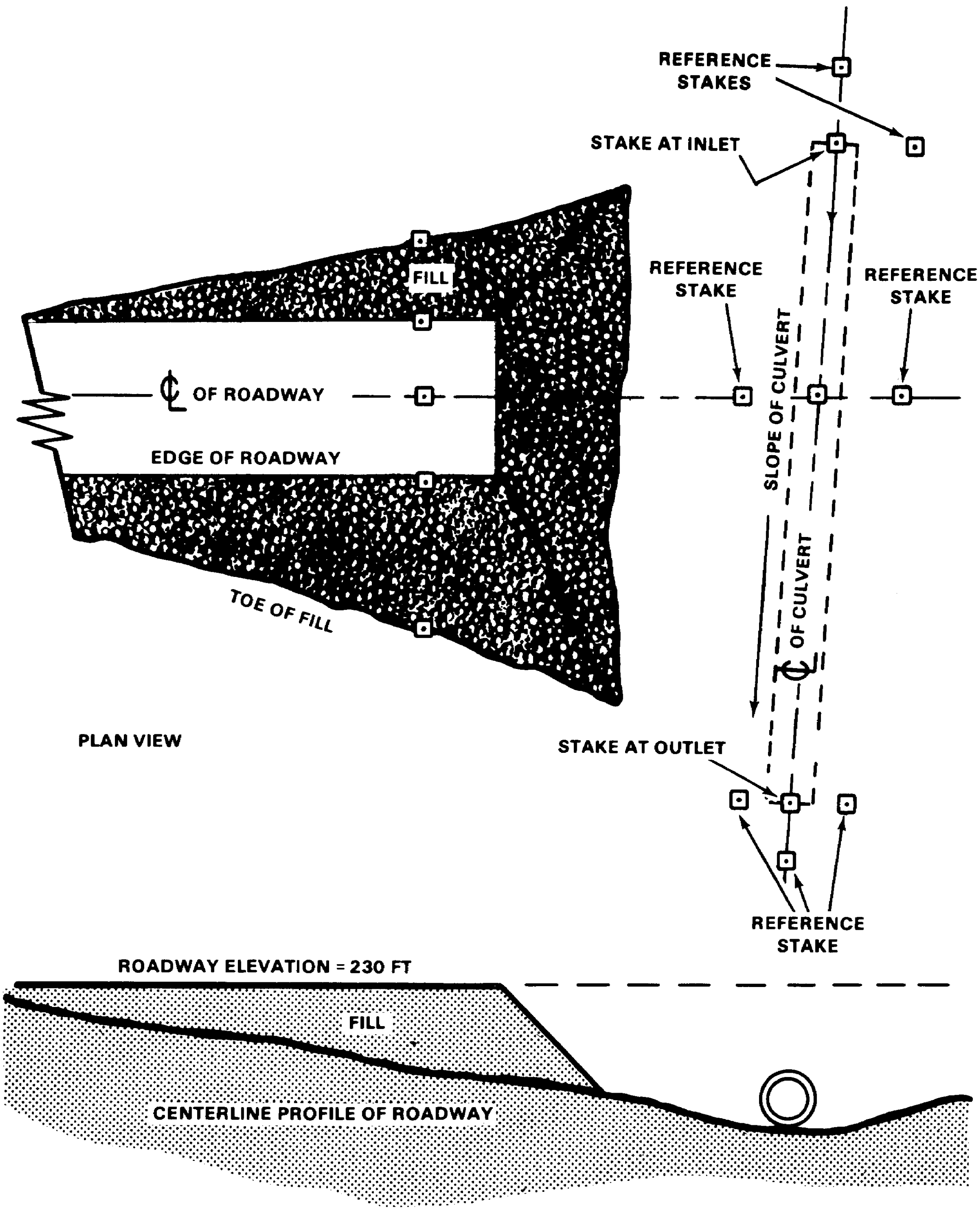

Figure 2-6. Layout of a culvert

The problem of adequate drainage is important to the location, design, and construction of almost any type of military installation. Proper drainage is of primary importance with respect to the operational requirements and the desired useful life of an installation. Inadequate drainage causes most road and airfield failures. The surveyor must see that these and similar facilities are well drained to function efficiently during inclement weather. Temporary drainage during construction operations cannot be ignored since it is vital to prevent construction delays due to standing water or saturated working areas.

Proper drainage is an essential part of road construction. Poor drainage results in mud, washouts, and heaves, all of which are expensive in terms of delays and repairs to both roads and vehicles.