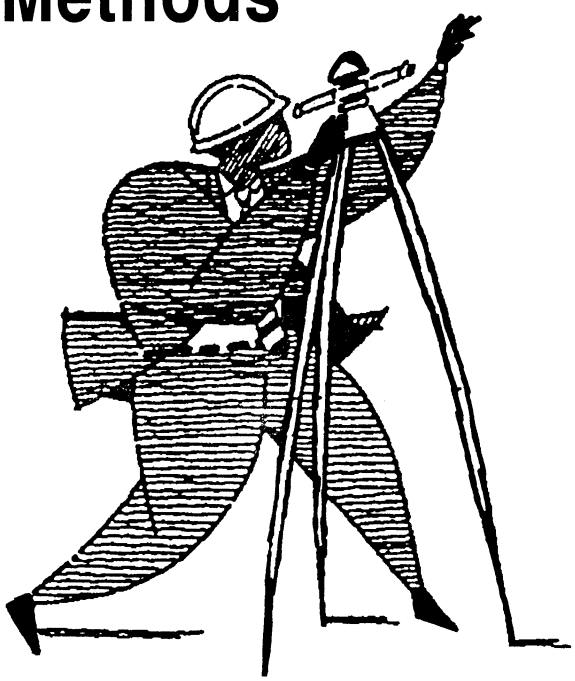
Surveying Methods for Local Highway Departments



Introduction

Surveying is the science of determining relative positions of objects or points on the earth's surface. These points may be any physical thing, whether it's a highway, bridge, culvert, or drainage inlet. The horizontal positions of these points are calculated from distances and directions. The vertical positions are calculated from differences in elevations, which are measured individually or in combination to a certain degree of accuracy and referenced to a determined location or set of information. Accuracy is important, and the degree of accuracy must fit the situation. Some points must be located to the nearest 1/100 foot horizontally and vertically. Others may be located to the nearest foot horizontally and nearest tenth of a foot vertically.

While surveys come in many types, this article concentrates on highway work, especially cross sections, profiles, and culverts. Some very basic elements of surveying will be covered here, including:

- Surveying terminology
- How to measure horizontal and slope distances
- How to measure vertical distances by "leveling"
- Staking

I. Terminology

Accuracy
Relates to the quality of result in relation to a standard or the actual value.

Angle
The difference in direction between two lines that meet at one point.

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Backsight
A point to be used to determine the placing and/or elevation of the surveying instrument.

Balancing a Survey
Eliminating the error of closure by dispersing corrections through a traverse or level run.

Bearing of Line
The direction of a line. It is expressed by the acute angle with respect to a reference meridian, or a north-south reference line. An example of bearing of line is N67•12'E.

Bench Mark
A natural or artificial, relatively permanent object, whose elevation above or below an established level surface is known.

Chain
A chain (66 ft.) is a unit of length used in proration of U.S. land; convenient length for land measurement because ten square chains equals one acre. The chain was also an instrument used for linear measurements. The steel tape now supersedes the chain.

Contour
An imaginary line with all points at the same elevation.

Control Point
A point having precise enough location on which to base other surveys. Control points are set at permanent locations to establish either vertical or horizontal locations.

Cross Section
Horizontal grid network set up on the ground to determine the contours, quantities of earthwork, etc., by means of elevations of the grid points. A vertical surface ground section measured at right angles to a center line.

Electronic Distance Measurement (EDM)
Measurement made with instruments that compare the phase difference between transmitted and returned electromagnetic waves, of known speed and frequency, or the round-trip travel time of a pulsed signal from which the distance is calculated.

Error of Closure
The difference between a value of a quantity determined by surveying and the theoretical value for the same quantity.

Foresight
The instrument sights to a point or object for measuring, or determining the elevation and/or horizontal position.

Height of Instrument
The elevation of the center of the telescope (fixed in a horizontal position) above ground.

Horizontal Plane
A plane perpendicular to the plumb line.

Level Circuit
Measurement of bench mark elevations by bubble level in two different directions from one end of a circumference to another.

Leveling
The process of establishing the difference in elevation between two points.

Leveling Rod
Straight wooden or metal bar or rod with a flat face marked in linear units, starting with zero at the bottom. Used to measure the vertical distance between an established point and the horizontal line of sight as seen through the instrument.

Profile
A vertical section of the face of the earth and/or basal strata, along any position.

Stadia
A method of distance measurement wherein the surveyor reads the intercept subtended on a graduated rod between two marks on the telescope reticle, the distance of the rod in proportion to the rod intercept. A stadia rod is especially designed for this method; the reticle marks are called stadia wires. This stadia surveying is also called tacheometry.

Stake-Out
The locating on the ground of previously determined points. Types of points include boundary corners and construction stakes.

Surveying
The gathering of all important measurements in space to establish the relative position of points and/or data on the chemical and physical features on, or near, the earth's surface.

Surveying, Construction
While construction is in progress, measurements are taken to control altitude, horizontal positions, and dimensions.

Surveying, Topographical
To designate the relief of the earth's surface and the position of natural and man-made objects upon it.

Theodolite
A precision surveying instrument constructed of an alidade with a telescope mounted on a graduated circle, and equipped with levels and reading devices. There are two general classifications: direction and repeating.

Topo
A topographical map produced from a topographical survey that determined the location and quantity of topographical features, such as mountains, valleys, roads, or buildings.

Transit
A surveying instrument consisting of three basic parts: an alidade, horizontal and vertical circles, and a leveling head. It is used for the measurement of horizontal and vertical angles, as well as angle-checking and line extensions.

Turning Point
A temporary bench mark. Before the instrument is moved, the elevation of the turning point is applied to establish the height of the instrument for resetting.

II. Horizontal Distance Measuring

Distances are measured both horizontally and vertically. In highway construction, horizontal (level) distances are always used instead of slope distance (see Figure 1).

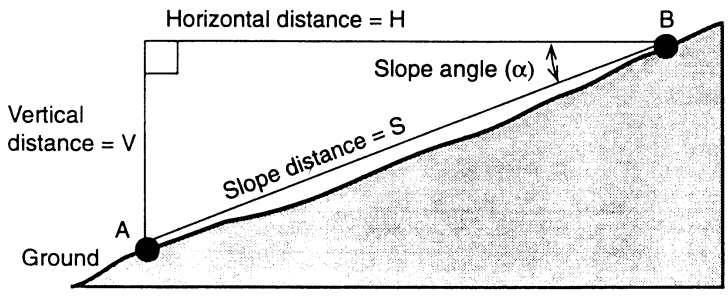


Figure 1: Horizontal distance measurement

Horizontal distances can be established two ways:

1. A distance measured on a slope (S) can be converted to a horizontal (H) distance by applying the trigonometry formula below:

$$H = \sqrt{S^2 - V^2}$$

Or

2. You can hold the measuring tape level.

Several other measuring methods are available to accomplish these tasks:

A. *Pacing*

Pacing consists of counting the number

of steps or paces in a required distance. To use this method you must first determine the length of your pace. This is best done by walking with natural steps back and forth over a measured level course at least 300 ft. long, and dividing the known distance by the average number of steps.

B. *Odometer readings*
An odometer is used to convert the number of revolutions of a wheel of known circumference to a distance. Lengths measured by an odometer on a vehicle are suitable for some preliminary surveys in route-location work. They also serve as a rough check on measurements made by other methods.

C. *Taping*
A tape measure is stretched between 2 points to obtain a distance. It is important that the tape is held level and care be given to where measurements begin on the tape.

D. *Electronic Distance Measurement (EDM)*
Measurement made with instruments that compare the phase difference between transmitted and returned electromagnetic waves, of known speed and frequency, or the round-trip travel time of a pulsed signal from which the distance is calculated.

III. Leveling

The hand level, shown in Figure 2, is a non-magnifying tube fixing a line of sight, with a bubble level attached.

The observer sees the target and the bubble simultaneously while holding the instrument to the eye (perhaps braced against the ground by a range pole for added rigidity). It is not a precise instrument, but it can serve adequately for many simple tasks (see Figure 3).
Usually with a hand level, one reads a level rod, a

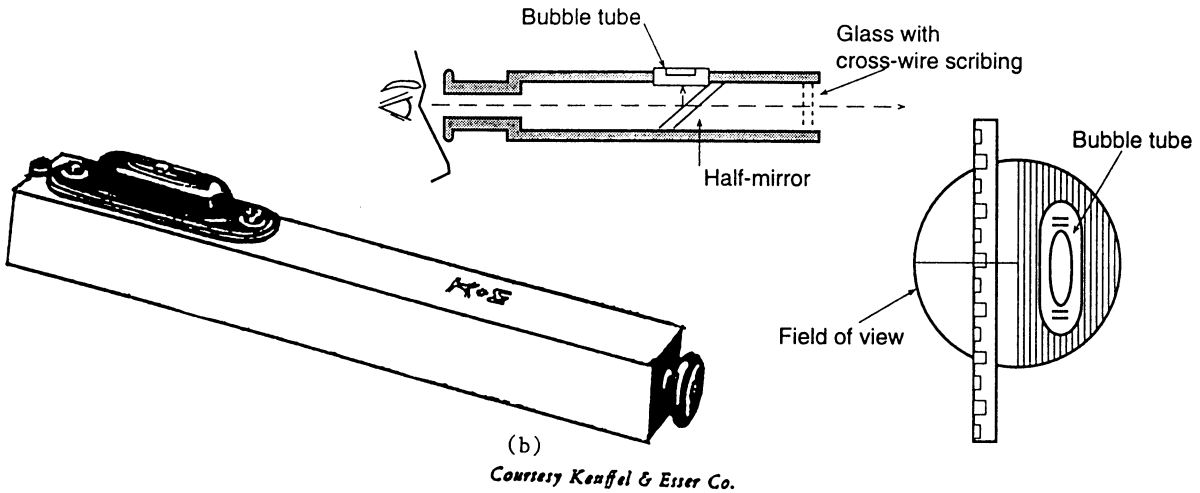


Figure 2: The hand level

carpenter's rule, or a simply marked stick for determining differences of elevation for a quick, rough result. In setting slope stakes on a highway or giving a rapid reading for construction grading, for example, it can serve a useful purpose, For more precise work, a tripod-mounted, engineer's level is preferred. It operates on the same principles described for hand leveling.

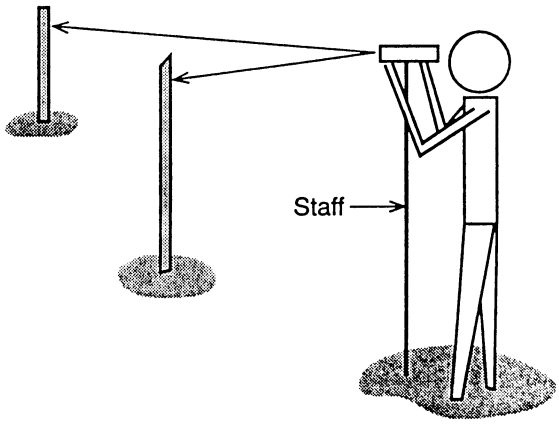


Figure 3: Use of hand level to compare elevations

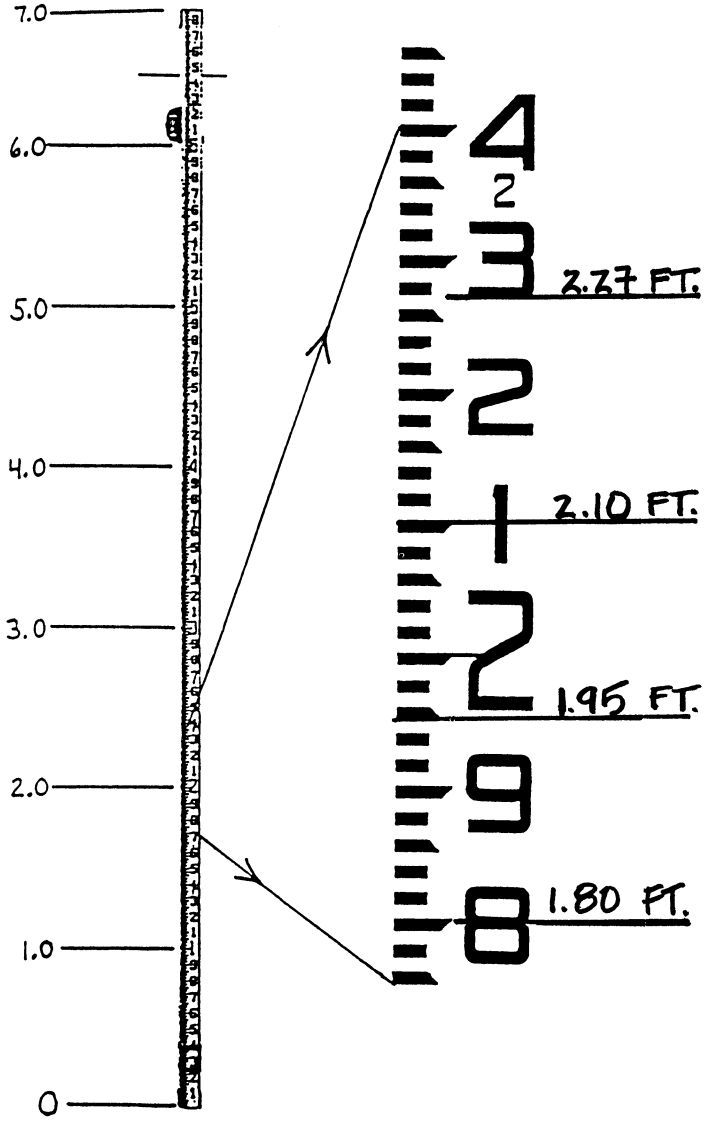


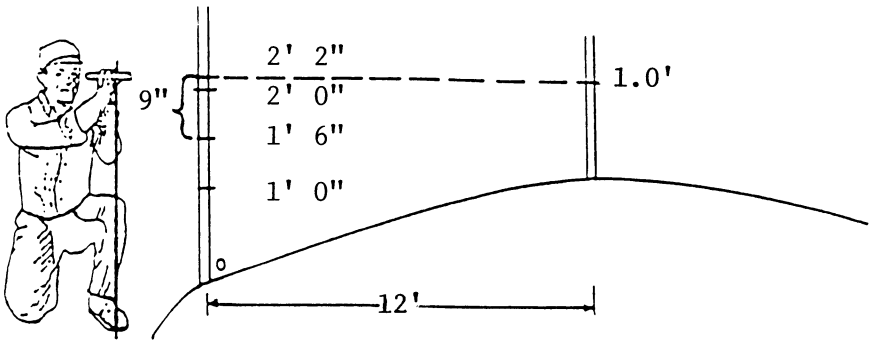
Figure 4: Standard leveling rod

How to read a standard leveling rod: Readings are made directly to the nearest 1/100 of a foot by reading the tops or bottoms of the black marks, as shown (see Figures 4 & 5).

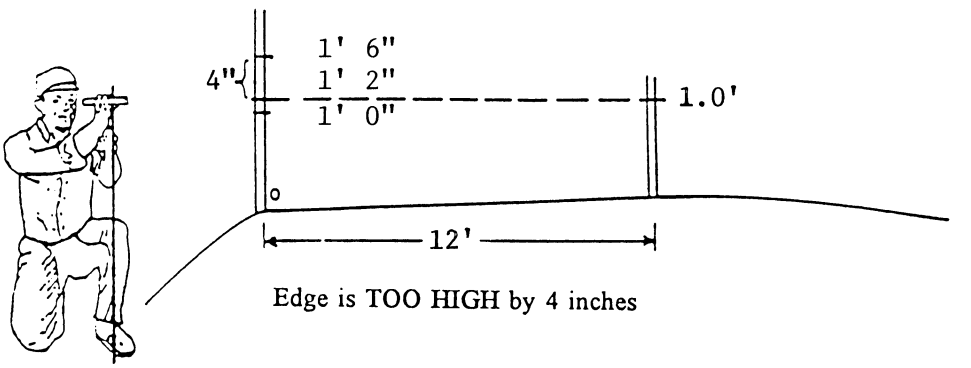
Common avoidable leveling mistakes and solutions:

1. Reading wrong foot or reading foot mark above. *Always read up the rod / ruler.*
2. Reading wrong foot or rod partially obscured. *Have rod person point to reading.*
3. Rod section skipped. *Raise rod sections in sequence.*
4. Rod section not locked. *Pull sections all the way out.*
5. Rod not vertical. *Stand directly behind rod. Hold rod on sides with two hands. Hold rod plumb (upright).*
6. Rod held on the wrong point. *Communicate clearly to rod person. Never make assumptions, things are not as they appear looking from behind instrument. Physically show the rod person the desired measure ment location.*

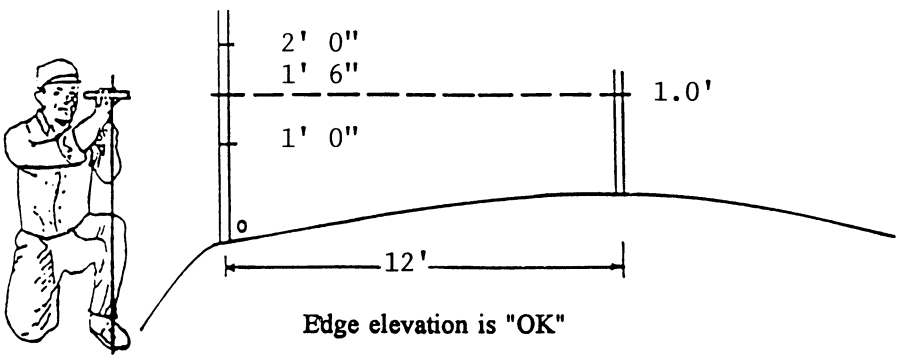
At 1/2 inch per foot, crown for 12-foot lane should be 6 inches
(1/2 inch/foot x 12 feet = 6 inches)



Edge is TOO LOW by 8 inches



Edge is TOO HIGH by 4 inches



Edge elevation is "OK"

Figure 5: Use of a hand level

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Terminology courtesy of the *Public Works Journal*, May 1991, Vol. 122. No. 5, pp.46-48.