CONSTRUCTION STAKEOUT
Survey classifications can describe the survey activity (such as construction surveys) or the survey methodology (such as geodetic surveys). Following are some of the types of surveying available:

- **Geodetic Surveys:** This type of survey has occurred in Nevada since 1965 and establishes control networks on a mathematical datum that closely approximates the shape of the earth. The introduction of the Global Positioning System (GPS) made this type of surveying easier and essential on most contracts.

- **Control Surveys:** This type of survey establishes the horizontal or vertical positions of arbitrary points to be used as a reference in past and future surveys.

- **Cadastral/Boundary Surveys:** This type of survey retraces and establishes property boundaries, including highway right-of-way. To conform to state law, a Professional Land Surveyor (PLS) must perform these surveys.

- **Topographic Surveys:** This type of survey determines the ground configuration (contour and relief) and location of physical or manmade objects.

- **Engineering Surveys:** This type of survey helps to estimate the design and cost of fixed works.

- **Route Surveys:** This type of survey helps to do the following:
  - Locate, design, and construct transportation facilities.
  - Establish construction control monuments.
  - Establish alignment for proposed roadways, structures, and other appurtenances.
  - Determine the terrain and the location of significant features, such as structures and utilities along the proposed route.
  - Establish the location of the route by survey lines.

- **Construction Surveys:** This type of survey establishes ground stakes and other reference points at known horizontal and vertical positions. These stakes define the construction location and size, which enables contract inspection and provides a basis for payment for work.

- **Aerial Survey or Photogrammetry:** This is a measurement method applicable to various surveying activities. Normally, it utilizes aerial photographs and specialized office equipment to perform control, engineering, topographic, and other surveys.

The construction surveys for a roadway consist essentially in (1) staking out earthwork and structures preparatory to, and during the process of, grading and construction, and (2) making the measurements necessary to determine the volume of work actually performed up to a given date, as a basis for payment to the Contractor.

Construction survey parties are under the direction of the Resident Engineer, and it is necessary that they be familiar with effective methods of staking. The Resident Engineer is directly responsible for survey marks and stakes set. Regardless of how the survey parties are organized, the Resident Engineer must have full knowledge of the methods used and results accomplished.

The contractor’s operations dictate surveying activities during construction. For example, if the contractor is planning to clear and grub, the survey crew completes surveying to support the clearing and grubbing operation. Detailed planning, with the coordination of the Contractor, and timely start of staking is required. The Resident Engineer should instruct his Surveyor to anticipate as near as possible the Contractor’s needs in regard to staking or taking measurements. Under no circumstances shall any delay in staking be permitted that will hinder the construction operation. The Contractor shall provide a written request for survey to the Resident Engineer/Crew Chief, who will track all requests.
Survey operations on a contract may consist of any or all of the following:

- Reproducing centerline
- Referencing control points
- Setting clearing and grubbing limits
- Setting slope stakes
- Staking culverts and structures
- Data collection (pre-and post-construction)
- Signs and electrical
- Staking permanent survey monuments
- Setting construction bench marks
- Staking Right of Way fences
- Cross sectioning and measuring borrow pits, etc.
- Preserving monuments and markers
- Staking curb/gutter, barrier rail, and guardrail

Survey field notes shall be recorded in a manner that allows for easy access and retrieval. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred. Notes shall be clear and in sufficient detail to be thoroughly understood by anyone not familiar with the contract. Too much detail is better than too little.

FIELD OFFICE PREPARATION

The Resident Engineer must rely to a large extent upon crew personnel to prepare the necessary stakeout data prior to the start of construction on a contract. For this reason, it is essential that the Resident Engineer select and train competent personnel for utilization in the field office.

Preliminary plans are generally submitted prior to award of the contract. Most stakeout calculations can be started and some may even progress to a completion stage before the final plans are received. If this occurs, all data should be checked for accuracy before any field stakeout begins.

As in all phases of construction engineering, a general order for stakeout computation completion can be created, but the sequence will not apply in all instances. The following list will provide a very brief overview of some of the initial computations which must be made prior to the start of construction:

- Alignment: Construction alignment books should be compiled as soon as possible. In most cases, the original alignment must be reproduced and any changes in length noted and necessary distance measurements adjusted. All curve deflections, tangent lengths, etc., should be calculated and checked prior to sending the book to the field.

- Slope stake: Slope stake data for the roadways must be prepared and checked. The slope stake books should include all of the information necessary for the construction crew to accurately set the slope stakes in the field. Stations, grade percent, vertical curve information, elevations, shoulder distance, ditch, and slope information must all be indicated in the slope stake book.

- Structures: Structure books must be completed for the culvert and bridge structures if required. Care should be exercised when calculating structures as they have a definite bearing on the durability of the finished roadway.

- Grade books: Grade books should be completed by the time subgrade is complete to aid the construction crew in setting “red heads” or grade stakes.
It should be stressed that the above stakeout computations should be accurate and complete. All computations and all other stakeout data must be checked and verified.

**NOTE:** If mistakes are made, line them out and write the correction above or below. Never erase or use correction fluid, ink, or tape.

**GRADE STAKES**

Use grade stakes, or “Red Heads,” to control the required grade for subgrade and gravel base courses. Follow these guidelines when setting grade stakes:

- Typically, set grade stakes on the shoulders, centerline, and intermediate points on the roadway. Must be close enough for moldboard to span grade stakes.
- Set grade stakes for subgrade at all stations and half stations.
- Set the grade stakes at closer intervals on sharp horizontal curves and vertical curves.
- Always set grade stakes at right angles to centerline.
- Set the top of the grade stakes within 0.03 foot of the desired grade.
- When the roadway grades are less than one percent, also set the grade stakes in the roadway ditch every 50 feet.

Grade stakes for the gravel base course are set on the same stations and half stations as for subgrade. Grade stakes should be long enough to ensure they will not be moved or pulled out while the contractor is grading. Use a steel pin to make a pilot hole to make driving the grade stake easier.

**GRADE FOR MACHINE LAY DOWN**

Specifications that require mixing and machine lay down of base and surface aggregates have created the need for more exacting methods of grade and slope control. The specific method used depends on the contractor's preferences and the type of equipment used.

Shortly after construction begins, determine the type of placement equipment that will be used. This information is important for preparing grade books and placing grade controls in the field.

You can use several methods for grade control, depending on equipment or contractor preference. Coordinate between the survey crew chief and the contractor to determine the best grade control method.

For elevation control, drive a metal pin, long nail, or hub with nail in convenient locations near, but outside, the roadway section, at least every 50 feet. In curves, you may need control points at 25-foot intervals. You may need control points on only one side of the roadway. In this case, establish alternate check controls on the opposite side of the roadway at 100-200 foot intervals.

The Resident Engineer and the contractor should determine the transverse location of the control points. In most cases, locate control points in accessible and convenient positions. You can protect the control point by placing the top of the control point approximately 0.1 foot beneath the surface of the subgrade or select material base.

Following are the two methods to set elevation control points. Maintain uniformity with either method:

- Drive them to a specific elevation below finish grade, for example, 25 inches below finish grade (24 inches surfacing, 1 inch beneath subgrade).
- Drive them to a random elevation below finish grade, and compute the fill to the finish grade.

Provide a reference or guard stake for each elevation control point. The reference stake should show the amount of fill to finish grade as well as the cross slope or crown at the particular station. The contractor should be familiar with the information on the reference stake and should ensure that grade setters and equipment operators are also familiar with the information. The Resident Engineer should set elevation control points only once to avoid confusion.
COMMON STAKES AND MARKERS

HUB

Wood (1 1/2” x 1 1/2” x 12”) to be used (with a “hub tack”) for all control points.

Figure 7-1: Hub

GUINEA

Wood (3/4” x 3/4” x 6” or 8”) to be used for all non-control points (centerline, slope stakes, fence points, guide posts, etc.)

Figure 7-2: Guinea
LONG STAKE

Wood (1 1/2" x 3/4" x 16") to be written on with “lumber crayon” or “paint pen” to provide information about the “Hub”, “Guinea”, or any other point which it is witness to. It should be driven near (6 to 12 inches) the point it describes (leaning slightly toward it) and far enough away as to not disturb the point.

Figure 7-3: Long Stake

SHORT STAKE

Wood (1 1/2" x 3/4" x 8") to be used for grade stakes (redheads), level loops, etc.

Figure 7-4: Short Stake

“PK” NAIL, BOAT NAIL, AND RAILROAD SPIKE

Metal (various sizes) to be used as a hub in surfaces too hard for wood.
CONCRETE NAIL AND SHINER

Metal (various sizes) to be used as a Guinea in surfaces such as asphalt or concrete.

LATH

Wood (3/8" x 1 1/2" x 36") to be used to mark all points of importance. Care should be taken as not to cover any information on the stake nor disturb the “Hub” or “Guinea” when setting the lath. When cut into thirds or quarters, they are used to guard “redheads”.

Figure 7-5: Railroad Spike

Figure 7-6: Concrete Nail and Shiner
FLAGGING

Plastic ribbon is tied onto lath in order to help identify just what the point is that the lath is set next to.

Control points shall be color-coded as follows:

- Orange with White: Centerline control and reference points (alignment)
- Red with White: Reserved for Bench Marks (usually “barber-poled” around lath)
- Blue with White: Drainage, Pipe, Drop Inlets, RCB Stakeout
- Yellow with White: Electrical stakeout
- Green with Orange: Slope stakes
- Red with Blue: Right-of-Way Fence stakeout, temporary easements
Combinations of flagging are used in order for our points not to be confused with the Standard Flagging being used by utility companies.

**NOTE:** Other combinations should be used to mark points which are not covered previously.

### ALIGNMENT AND HORIZONTAL CONTROL

Establishing alignment and horizontal control is one of the initial field activities undertaken by the survey crew. The horizontal control is typically established with Total Station or GPS instruments.

The centerline of construction shall be reproduced from the plans and shall be marked by witness stakes driven on centerline facing the initial station of the survey.

In case the line to be constructed differs from the line originally staked, the line to be constructed shall be established to connect with adjacent portions of the centerline. In staking these revisions, care should be exercised to ensure that the relationship is maintained between the original and revised line. An accurate tie shall be made to the original line at the end of the revision.

When reproducing centerline and a discrepancy is found with that shown on the plans, the work shall be checked until the Resident Engineer is satisfied that a discrepancy exists and the location and amount of discrepancy is known. At the point where the discrepancy is found, an equation shall be made and the plan station shall then be carried forward from that point. This must be done so that construction records will agree closely as possible to the plans and estimates designed for the contract.
Reference points may be set at the same time that the centerline is being reproduced, or immediately thereafter. A sufficient number of control points shall be referenced so that the centerline can be reproduced at any time without retracing any great length when only a short section is required.

Reference points should be placed in such places so that they are protected from any construction operation. They should be set so that the point referenced can be reestablished in the same manner as the original. The angle of intersection between the reference line and the centerline shall be measured and noted in the transit book along with the horizontal measurements to the reference hubs. As far as possible, the measurements should be made without the benefit of slope chaining or breaking chain. For horizontal control, the survey accuracy is 0.02 foot.

The planned location of Right-of-Way monuments should be reviewed prior to referencing, as it is entirely possible that staking of the Right-of-Way monuments and the referencing of centerline points may be accomplished at the same time.

**NOTE:** Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
STAKE PLACEMENT FOR CENTERLINE AND REFERENCE POINTS

Figure 7-9: Sample Alignment Stakes

CENTERLINE STATIONING
To be used with a guinea. The stake should be set ahead on line, facing toward the guinea.

CENTERLINE CONTROL POINT
To be used with a hub. The stake should be set to the side, facing toward the hub.

REFERENCE POINT
To be used with a hub. The stake should be set to the outside of the hub, facing the hub.
Figure 7-10: Centerline Stake

Figure 7-11: Reference Point
VERTICAL CONTROL

Establish construction benchmarks no more than 500 feet apart. In case a benchmark is disturbed, this spacing provides a nearby benchmark. To preserve benchmarks and reduce the possibility of disturbance, establish benchmarks away from construction activities, such as near the right-of-way line.

A benchmark establishes vertical control and is a stable, physical point, such as a length of reinforcing steel driven into the ground or a railroad spike driven into a utility pole, with the elevation of the point written on a witness stake.

Construction bench marks should be set to avoid running level circuits a considerable distance to establish an elevation. Construction bench marks are usually required near major structures, special construction areas, or where the terrain is rugged and preliminary bench marks are difficult to reach. Construction bench marks shall be established by the same procedure and to the degree of accuracy as required for preliminary bench marks set by the Location Division. All bench marks, whether they are Line Designated (“X” BM) or Construction Designated (Con. BM), should be numbered to coincide with the stationing. (i.e. Con. BM #1 would be located either left or right of station 13+00.)

DEGREE OF ACCURACY

Closed Circuit Accuracy – 0.02 ft between established bench marks

Structures, Culverts, Bridges, etc. – 0.02 ft between bench marks

BENCH MARK STAKES

To be used as a witness stake to a steel pin or any other object designated to be the bench mark. The stake should be driven far enough away from the bench (front facing centerline) so as not to disturb it.

![Sample Bench Mark Stake](Figure 7-12)

CROSS SECTIONS

Cross sections may be required in some cases due to alignment change, insufficient cross sections taken during original survey, or for various other reasons. When this is required, the same minimum requirement as set out for location surveys will be followed.
CONSTRUCTION STAKEOUT

Cross sections shall normally be taken on stations, plus 50’s and equations. Additional plus stations shall be added as necessary to show such things as drainage, slip outs, drop-offs, etc. Cross sections shall be taken at right angles to the centerline on tangents and on radial lines on curves. If this is not possible due to physical limitations or obstacles, enter the reason for deviating and the angle that it was taken on.

NOTE: Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.

SLOPE STAKES

Slope stakes are set at locations where the top of cut slopes and the toes of fill slopes meet the original ground and shall be known as the “catch point”. The markings on slope stakes pertaining to the cut or fill and the distance shall be large enough to be easily read, and the back of the slope stake shall have the station of the section staked. The sides of the slope stake should contain all pertinent information necessary, such as subgrade shoulder distance, slopes, depth of roadway ditches, etc.

A guinea shall be set at the catch point and at the same elevation as the catch point was computed. The cut or fill information shall be written on the slope stake, and it shall be driven far enough beyond the guinea so as not to disturb it. The cut or fill information shall face centerline of the roadway. A guard lath shall be placed 6 to 8 inches back on-line from the guinea to protect it.

The use of a guinea has a two-fold purpose. The guinea shows the contractor where the rod reading (shot) was taken, and that he has a definite take-off point to begin construction. Also, if the slope stake is accidentally knocked out or moved during construction, the catch point can be recovered. If a slope stake has been stuck in the ground and no guinea is present, the contractor and the engineering personnel will know immediately that it is not a catch point.

Slope stakes shall be set at right angles to the centerline on tangents and on the radial lines of curves. Use an instrument for this if necessary. Stations, plus 50’s and equations shall be slope staked and any other pluses that will be helpful to the contractor to produce a well contoured roadway.

Elevations and distances are measured and recorded to the nearest tenth of a foot. Only cloth tapes that are in good shape shall be used.
Slope stakes may be set by several different methods, depending upon the terrain of the area. The most efficient method shall be used. The selection shall be based on the judgment of the Resident Engineer.

The following methods apply:

- The use of level, tripod, level rod, and cloth tape. This method is generally best suited to relatively flat terrain where it is possible to run the profile of centerline and set the slope stakes while at the same instrument set up. It is often supplemented by use of the hand level to establish slope stakes when it is not possible to set the stakes from the instrument set up.

- Use of a hand level, level rod, and cloth tape. Prior to use of this method of slope staking, it is necessary to run a centerline elevation and determine the cut or fill. From the centerline data, it is then possible to set the slope stakes by use of the hand level. This method is suited to locations where visibility with an instrument is restricted, or where the terrain is moderately rough.

- Use of instrument, level rod, and tape or electronic measurement. This method is employed in any terrain but especially mountainous country where it is more expedient to transfer elevations and distances by means of slope measuring than by hand leveling.

- Due to advancements made in technology, especially with the advent of the Total Station and GPS, there is now the “radial method” of slope staking. This is one of the most expedient methods in use today. However, as with any method used, care must be exercised in establishing all points being occupied.

**NOTE:** No matter which method is employed to slope stake, all work (calculations, angles, distances, etc.) must be recorded in an appropriate manner so that it may be checked in the field office. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
Figure 7-14: Typical Roadway Section

Figure 7-15: Sample Slope Stake Book
WRITING SLOPEstakes

* NOTE: THE FRONT ON THE STAKE IS TO FACE CENTERLINE *

**LEFT SLOPEstakes**

- "Fr" 11+50
- "Fr" 11+00
- "Fr" 10+50
- "Fr" 10+00

**RIGHT SLOPEstakes**

Figure 7-16: Sample Slope Stakes
Figure 7-17: Catch Points of Various Typical Sections
Figure 7-18: Various Methods to Establish Catch Points
Figure 7-19: Field Report of Slope Stakes
Figure 7-20: Slope Stake Showing Cut/fill Information; Backslope, Ditch and Foreslope

Figure 7-21: Slope Stake Showing Station, Superelevation, and Shoulder
Figure 7-22: Slope Stake on I-580 (Contract 3292)

Figure 7-23: Slope Stake on I-580 (Contract 3292)
Figure 7-24: I-580 Freeway Prior to Construction

Figure 7-25: I-580 Freeway Under Construction
DRAINAGE

Pipe and storm drain should be staked as soon as possible and the "pipe list" prepared. Delay in staking of pipe can cause delay in the contractor’s operation, which may lead to delay of the contract and/or a claim against the Department. Construction bench marks (Con. BM’s) set near the pipe, as well as preparing a pipe book with all pertinent information, will expedite the staking and also give better control for installing the same. Further aid in the staking of pipe can be accomplished by having the pipe stations located at the same time the centerline is being reproduced.

The centerline of pipe shall be indicated by hubs driven on the centerline produced at such a distance from the end of pipes (or headwall) to protect them from disturbance. Elevations should be taken on the hubs and the cut or fill to flow-line of the pipe determined, and the necessary information plainly marked on the stakes. Designers typically add additional length to culverts depending on fill slope. Be sure to reference the minimum culvert installation detail in the Standard Plans if additional length of culvert is necessary.

Figure 7-26: RCP Stakeout (1 of 3)
Figure 7-27: RCP Stakeout (2 of 3)

Figure 7-28: RCP Stakeout (3 of 3)
Reinforced Concrete Boxes should be staked as soon as possible also. This information is very important to you as well as the contractor. If there are any changes, such as length or skew, all concrete and reinforcing steel will require recalculation.

Figure 7-29: Reinforced Concrete Box Stakeout

NOTE: The following samples include various stakeout data for drainage features recorded in “traditional” field books. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
Figure 7-30: Manhole Layout
Figure 7-31: Pipe Run Sample (1 of 15)

Figure 7-32: Pipe Run Sample (2 of 15)
Figure 7-33: Pipe Run Sample (3 of 15)

Figure 7-34: RCB Layout Sample (4 of 15)
Figure 7-35: Pipe Run Sample (5 of 15)

Figure 7-36: Drop Inlet Sample (6 of 15)
Figure 7-39: Manhole Sample (9 of 15)

Figure 7-40: Manhole with Pipe Run Sample (10 of 15)
Figure 7-41: RCB with Headwalls Sample (11 of 15)

Figure 7-42: RCB with Headwalls Sample (12 of 15)
Figure 7-43: RCB with Headwalls Sample (13 of 15)

Figure 7-44: RCB with Headwalls Sample (14 of 15)
BORROW PITS

The reason for layout and cross sectioning a borrow pit is usually to enable us to determine the cubic yards of Borrow Excavation used on a particular contract.
The actual cross sectioning is very similar to that shown in “Cross Sections”, in this chapter; the layout, however, is somewhat more involved. As you are taking the “original” cross sections, you should keep in mind the fact that you really do not know exactly how the contractor is going to mine the withdrawal area. Consequently, you must be sure to catch all “breaks” which lie within the withdrawal limits.

By using a Total Station or GPS, it is possible to data collect the borrow pit before and after to get a total withdrawal for the area by comparing the two surfaces. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
Curb/Gutter and Sidewalk

As when staking anything, extreme care must be taken when staking curb or curb and gutter. Not only is it highly visible, but it is almost always designed to carry drainage away from roadways. Additionally, many times it is placed prior to paving.

Figure 7-47: Curb and Gutter Stakeout

Consequently, it becomes the control for placement of the plantmix bituminous surface. Good communication with the contractor is essential so that distances along lay out line and lay out line offsets are most effective, yet will not be disturbed.

NOTE: The following samples include various stakeout data for Type 5 Curb recorded in “traditional” field books. Methods for recording data vary. TBC reports, IDR’s, or other electronic forms of reporting data collection are preferred.
## Figure 7-48: Stakeout Data Curb Sample (1 of 2)

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<td>+ 50</td>
<td>10.30</td>
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<td>+ 100</td>
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<td>+ 150</td>
<td>11.40</td>
<td>5.88</td>
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<td>1500.00 m x ( L^2 )</td>
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## Figure 7-49: Stakeout Data Curb Sample (2 of 2)

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Barrier rail and guardrail are typically staked to the front face of rail. The beginning, end, terminals, transitions or angle points are some examples of items which need stakes. As noted before, good communication with the contractor is essential so that distances along lay out line and lay out line offsets are most effective, yet will not be disturbed.

Figure 7-50: Barrier Rail Stakeout
Signs, pull boxes, transformers, cabinets, lights, etc. are typically staked out to the center of the installation. In some cases, offset stakes will be necessary to assist with proper alignment of the installation. Refer to the Standard Plans to ensure proper stakeout and placement.
Utilities Referencing

In urban areas, utility access points, such as manholes and valve box covers, are commonly located in the roadway. If planned construction will disturb or alter the utility access point, the utility access point must be preserved. To do this, the cover is first lowered and the roadway is constructed. Each access point is then relocated and adjusted to match the final roadway elevation. At times, contractors have not found all of the lowered access points. To help relocate access points, identify and reference the location of existing utility access points before construction begins.