CHAPTER 5 - SURVEYING AND MAPPING

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CHAPTER 5 - SURVEYING AND MAPPING

5.1 GENERAL

This chapter provides guidelines to engineers and technicians who are responsible for surveying and/or mapping. A definition of data required and the sources of such data is provided in this chapter as well as guidelines for gathering, processing and documenting the data. Suggested note formats for both conventional and automated surveys with references to mapping standards are provided.

This chapter presents many of the established surveying and mapping methods along with some of the modern techniques now in use. It is not the purpose of this chapter to be all inclusive. Specific information concerning techniques, theory, and methodology can be obtained from the list of reference materials contained in Section 5.2.

Surveying for highway engineering involves the gathering of field information and measurements for use in locating, designing, and constructing highways and other related features. Field data is collected by ground surveys, aerial surveys, or by a combination of these two methods. Establishing controls for construction is generally done by ground surveying techniques.

The safety of field crews and the traveling public is a high priority. The road or bridge construction work environment often presents potential hazards that must be evaluated on a project by project basis. Surveying activities are not to be attempted on or adjacent to a traveled roadway until appropriate traffic warning and/or control measures have been implemented. Traffic control devices shall conform to standards in the MUTCD.

There are generally four stages of survey activities in the progression of a highway project from start to finish. These are:

*Reconnaissance
*Preliminary
*Location
*Construction

A. Reconnaissance. The reconnaissance survey is normally performed in connection with early scoping activities on a project.

A reconnaissance survey of an area is the examination of a large area to determine feasible highway corridors or alternate locations within a corridor between designated termini. The evaluation of feasible alternatives is a comparison of these corridors or alternative locations in sufficient detail to select the corridor or alternative locations deserving further study.

Aerial photography, Geological Survey quadrangle maps, and Forest Service mapping are often useful for reconnaissance purposes.

B. Preliminary. Preliminary surveys are normally performed during the environmental planning and conceptional study phases of project development.

The following are considered preliminary surveys:

Aerial Control Surveys
Ground Control Surveys
Topographic Surveys
Planimetric Surveys
Bridge Site Surveys
Cadastral Surveys
Preliminary Alignment Surveys
Special Surveys (for retaining walls, drainage structures, borrow pits, quarry sites, etc.)

Preliminary surveys provide the necessary data to be used in environmental planning, conceptional studies, bridge design, and highway design. Typically, the direct derivatives of preliminary surveys are topographic and planimetric maps, digital terrain data, and survey monumentation.

Aerial surveying is the process of obtaining ground measurements from photographs rather than from field techniques. Where visibility permits, this method of surveying provides substantial savings in manpower for information gathering, and mapping.

C. Location. Location surveys involve establishing previously designed data on the ground. In many ways, location surveys are the inverse of preliminary surveys. Preliminary surveys are used to extract and collect field data. Location surveys normally disseminate data back to the field. Location surveys always include the establishment of the highway centerline and reference points, and may include setting construction slope stake reference hubs and other preconstruction controls as required.

D. Construction. Construction surveys include establishing points in addition to those placed during the location survey. These include slope stakes, grade stakes, and culvert and bridge control stakes.

5.2 GUIDANCE AND REFERENCES

The publications listed in this section provided much of the fundamental source information used in the development of this chapter. This list is not all inclusive and there are numerous manuals, technical documents, and journals that explain the techniques and formulas required to perform proper and accurate surveying and mapping.

Abbett. *American Civil Engineering Practice.* Volume I. New York. McGraw Hill. 1978.

Bouchard, H. and Moffitt, F.H. *Surveying.* 6th ed. Scranton, PA. International Textbook Company. 1982.

Hickerson, Thomas F. *Route Location and Design.* New York. McGraw Hill. 1972.

Rubey, H. *Route Surveys*. New York. The MacMillan Company. 1951.

Wolf, P.R. *Elements of Photogrammetry*. New York. McGraw Hill. 1974.

Geodetic and Topographic Surveying, Manual of Photogrammetry. American Society of Photogrammetry. Volumes I and II. 3rd ed. 1966.

Manual of Surveying Instructions. Technical Bulletin No. 6. Department of the Interior, Bureau of Land Management. 1973.

Reference Guide Outline, Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways. Department of Commerce, Bureau of Public Roads. 1958. (Out of print).

Surveying and Mapping Manual. DOT, FHWA. 1985.

Metric Practice Guide for Surveying and Mapping, ACSM, 1992

Refer to the glossary in Chapter 1 for definitions of the most common terms used. If a more detailed definition on a specific subject is desired, consult the glossaries in the reference manuals listed.

5.3 INFORMATION GATHERING

Information gathering, as it relates to surveying, actually consists of two parts:

(1) An examination of existing information about the project.

(2) The physical gathering of the ground information.

Both information gathering actions are of equal importance. Careful attention to detail during this process can often result in substantial savings in time and effort. The surveyor should use as much of the existing information as practical to reduce the time spent gathering actual field data.

A. Existing Sources. Before any type of survey occurs, perform a search for existing information. For the most part, the information described below can be obtained from other government agencies. However, do not limit the search to these agencies. Much valuable information may be available from private consulting engineering firms that have worked near a specific highway project.

Sources of information that are helpful during the course of a survey include the following:

- Survey control data.
- As-constructed plans.
- Existing photography (both aerial and ground).
- Existing maps.
- Legal property descriptions.
- Local land owners.
- Agency contacts.

1. Survey Control Data. Horizontal and vertical control is crucial to performing an accurate and correct survey. Whenever practical, base the survey on horizontal coordinates and vertical elevations from established National Geodetic Survey (NGS) first order or second order control points.

The horizontal and vertical control information can be obtained by writing to:

Director, National Geodetic Survey Division
1315 East-West Highway, Room 9535
Silver Spring, MD 20910-3282

Each FLHD office should establish and maintain a file of the control data for their respective areas. Make arrangements with the agencies mentioned above to receive the periodic information concerning existing control points and the location of new points. For a small fee, NGS will provide horizontal and vertical control data on floppy disks for individual counties or on CD-ROM's for entire regions of the country.

a. Horizontal Control. The NGS publishes a map showing the status of the horizontal control that exists in the United States. Triangulation maps are also available for each State. These triangulation maps show the monumented points and their general location throughout the State. The names and index numbers for these monuments are given, along with their line of observed triangulation.

Upon request, NGS furnishes the following information for each monument:

- Monument name.
- Location (State, county, etc.).
- Year the monument was established.
- Geodetic latitude and longitude.
- Order of accuracy.
- Elevation.
- State plane coordinates in meters (NAD83 datum).
- Geoid height and scale factor (NAD83 datum).
- Monument description and historic data.
- Azimuths and distances to neighboring monuments.
- Station recovery/condition notes.

b. Vertical Control. The NGS publishes an index map for control leveling that covers each State. This index map shows the level circuits that exist in the State. These circuits are generally located along existing highways or railroad right-of-ways. The index map numbers the circuits for filing purposes. The degree of accuracy of each level line is also indicated on the index map.

Using the numbers assigned to a particular level line, the surveyor is able to obtain detailed information on each Bench Mark (BM) along the circuit. The BM information is on the following items:

- BM type and Identification Code. (The ID code is generally stamped on the monument cap).
- Location (including State, county, and nearest town or community).
- Elevation (meters and feet).
- Accuracy.
- Date established and by whom.
- Station recovery/condition notes.

When an elevation is stamped on a bench mark, it is usually to the nearest foot. If needed, the actual documentation will provide further accuracy, and the elevations may have already converted to metric units.

2. As-Constructed Plans. Since the majority of highway construction activity concerns the rehabilitation and/or reconstruction of existing highway facilities, as-constructed plans can be an excellent source of preliminary information. Depending on the composition of the construction plans, a surveyor may obtain the position and condition of existing control points, right-of-way monuments, bench marks, and construction monuments.

If it is desirable to use the existing centerline stationing and location, the center-line control points (such as PC, PT, POT) can be obtained from the as-constructed plans. The horizontal alignment information is also often obtained from these plans.

Other information available from the as-constructed plans includes the types and locations of drainage systems, structures and special features, property descriptions, and boundary lines.

Along with as-constructed plans, often times the original survey notes still exist and can be obtained. The information contained in these original survey notes can be very helpful to the surveyor.

It is also recommended that the as-constructed plans from adjoining projects be used to achieve consistency between projects. Use of adjacent plans allows for the continuity of stationing and control throughout an entire route.

In addition to the as-constructed plans pertaining to existing bridge projects, the surveyor also should make use of the information contained in the bridge inspection report. As these reports are generally made biannually, the information is usually more useful and reliable than the original construction plans.

As-constructed plans, original survey notes, and bridge inspection plans can be obtained from the agency responsible for that particular section of highway. Records on projects originally constructed by FLH may be obtained from the applicable Federal Records Center. The data in as-constructed plans will frequently be in English units and will have to be converted to the metric system of units before use.

3. Photography. The use of photography as a source of preliminary surveying information is somewhat limited. General project layouts can usually be obtained from readily available maps rather than from photographs. On the other hand, existing aerial photographs for a current project can often be used by the photogrammetric engineer. If the control points that are referenced in the photographs can be reestablished by a ground survey and the physical topography of the route has not been altered, the photographs may be usable.

Sometimes routes or portions of routes have been photologged for maintenance or planning purposes. When available, a photolog can be a source of valuable data. The existence of old aerial photographs often indicates the presence of aerial maps. Final construction reports may also be a source of helpful photographs. The surveyor should check into these possible sources for information.

Aerial photographs are usually available from highway agencies, appropriate Federal agencies, or private consulting firms.

4. Existing Maps. Generally 7-1/2 minute or 15 minute quadrangle (topographic) maps are available covering the desired project limits. These quadrangle maps are available from both the U.S. Geological Survey offices and from many private vendors for a minimal fee. They provide a wide variety of control and terrain information.

For most types of survey projects there exists a variety of available maps. By using these maps, much of the field gathering of information can be reduced.

A list of agencies that provide maps containing survey information follows:

- **U.S. Geological Survey (USGS), Department of the Interior**

  Quadrangle, topographic, and index maps.
  Bench mark locations, level data and tables of elevations.
  Stream flow data.
  Water resources.
  Geologic maps.
  Horizontal control data.
  Monument locations.

- **National Geodetic Survey (NGS), Department of Commerce**

  Topographic maps.
  Coastline charts.
  Topographic and hydrographic studies of inland lakes and reservoirs.
  Bench mark locations, level data, and tables of elevations.
  Horizontal control data.
  State plane coordinate tables for Lambert and transverse Mercator projections.
  Tide and current tables.
  Coast pilots information.
  Seismological studies.
  Magnetic studies.
  Aeronautical charts.
  Charts of the Great Lakes and connecting waters.

- **Bureau of Land Management (BLM), Department of the Interior**

  Township plots, showing land divisions.
  State maps showing public lands and reservations.
  Survey progress map of the United States showing the progress of public land surveys.

- **Defense Mapping Agency, Aerospace Center, Department of Defense**

  Topographic maps and charts.
  Nautical charts, navigational manuals.
  Aeronautical charts.

- **Corps of Engineers, Department of Defense**

  Topographic maps and charts.
  Nautical charts, navigational manuals.
  Aeronautical charts.

- **Board of Engineers for Rivers and Harbors**

  Maps and charts of ports and harbors.
  Permits for construction of structures other than bridges in navigable rivers and harbors.
  Beach erosion data.

- **Coast Guard, Department of Transportation**

  Permits for bridges in navigable water.
  Designation of special anchorage areas.
  Regulations for drawbridges and obstructive bridges.

- **Mississippi River Commission, Department of the Army**

  Hydraulic studies and flood control information.

- **Natural Resources Conservation Service, (NRCS) Department of Agriculture**

  Soil charts, maps, and indexes.

- **Forest Service (FS), Department of Agriculture**

  Forest resource maps including topography, culture, and vegetation classification.

- **U.S. Postal Service**

  Rural free delivery maps by counties showing roads, streams, etc.

- **International Boundary Commission, United States, Alaska and Canada**

  Topographic maps for 0.5 to 4 km on either side of the United States-Canadian boundary.

- **Local Governments: State, county, city**

  Street and zoning maps.
  Drainage and utility maps.
  Horizontal and vertical control data.

The maps and related coordinate data in will frequently be in English units and will have to be converted to the metric system of units before use.

5. Property Descriptions. One of the oldest forms of property descriptions available in the Public Land states are the Government Land Office (GLO) plats. These plats are available from the Bureau of Land Management (BLM). Besides the plats, which depict the original bearings and distances of land corners, many of the original field notes are available. This information is stored by the BLM on microfilm. The BLM sells enlargements of these slides for a minimal charge.

These property descriptions provide information concerning the identity and location of property corners. The surveyor shall make ties to the property corners during the cadastral survey portion of the field work. This data is used by the designer and right-of-way engineer in acquiring additional property for highway projects. Outside Public Land states, property description information is found in the property records of the local jurisdiction where the property is located.

6. Agency Contacts. Before any surveying activity begins on a project, contact the local representatives of any concerned agency. The purpose of this contact is to inform the agency that a survey is about to be performed. Briefly describe the surveying activities at this time. Special restrictions desired by these agencies, such as fire restrictions, recreational uses, scenic routes, limitations on cutting vegetation, and noise requirements, should be discussed. The agency contact will often provide additional information about availability of existing survey data and the type of ground survey desired. The names of specific agency contacts are usually identified in the reconnaissance report or in the scoping document.

Affected property owners should also be contacted. A letter to the property owner asking permission to make the survey across their property and/or personal contact with the owner is suggested. Retain any signed documents in the project files. Where contact cannot be made or permission granted, the surveyor should contact an immediate supervisor rather than trespass.

B. Surveys. The type of information gathered during preliminary surveys can be broken down into three different categories: planimetric, topographic, and cadastral.

1. Planimetric. Planimetric data consists of natural and political boundaries, natural vegetation, and cultural items such as sign posts, trees, buildings, etc. Using ground surveying techniques, these items are located relative to control survey monuments. Specific items are located with side shot measurements taken from these control points. Only the horizontal positioning (coordinates) for each point is required to plot the item on a planimetric map. However, when using total station surveying equipment, it is recommended that the elevation of each point be obtained. This additional data aids the plotting of contour intervals during the topographic mapping process.

2. Topographic. Topographic information gathering begins where planimetric information leaves off and consists of obtaining horizontal coordinates and vertical elevations of ground points. The intent of topographic data gathering is to obtain enough ground points to accurately describe the general relief of a specific area.

There are three general methods of canvassing a given area with topographic shots. The first is to use a *preliminary alignment and cross sections*. The preliminary line is usually a straight line connecting the ground control points. The survey crew then establishes points at given intervals, usually 20 m, and topographic breaks along this preliminary line. The spacing of these points is based on the type of land features and relief along the route. Cross sections are taken perpendicular to the preliminary line at these regular intervals. The points along the cross section lines essentially form a grid of coordinates that are used to construct the contour map.

The second method used to obtain topographic information is the use of *radial surveying*. The instrument is set up on a point with known elevation, and coordinates and readings are taken in a radial pattern around the instrument. Major breaks in the terrain (such as edges of shoulders, catch points, and drainages) are usually strung together in a series of sequential shots. These data points are called discontinuities and are treated differently from other random shots. The intent is to obtain a general description of the terrain, using a digital terrain model (DTM) to build an accurate contour map.

The third method is the use of *aerial photography* to plot topographic data. Viewing a given section of the project, the operator locates the discontinuities in a photograph with a series of shots.

The lines that connect these discontinuities divide the area to be mapped into segments. These segments are then digitized with a series of topographic shots taken along uniformly spaced scan lines. This process effectively covers the area with a grid of topographic points for use by the DTM.

3. Cadastral. A cadastral survey is used to locate property boundaries and monuments and determine the respective coordinates. This information may be obtained disregarding elevation. Since property and right-of-way documents are often based on the actual location of cadastral monuments, the engineer should verify these points by running traverses through them or by using the mean of two independent side shots.

5.4 APPLICATIONS

The process of surveying a highway project involves many small individual tasks (i.e. measurements of distances) that when combined into an established format (i.e. bridge surveys) produce an accurate description of the area under consideration. For simplicity, these small individual surveying tasks have been combined into a category called *general surveying procedures*. These procedures are discussed in more detail in the following section. A brief description of the mapping procedures used by both the photogrammetrist and the field surveyor are also contained within this chapter.

A. General Surveying Procedures. The techniques presented herein can be found in most standard surveying textbooks. The discussions are general in nature and are intended to provide a basic guideline for the entry level field surveyor. The following are some of the covered topics:

- Measurement of horizontal distances.
- Leveling procedures.
- Measurement of angles.
- Traverse surveys and computations.
- Horizontal and vertical curves.
- Coordinate systems.
- Topographic surveys.
- Photogrammetry.
- Global positioning satellite systems (GPS).

The recording and documentation required by each of these particular surveying operations is discussed in Section 5.5.

1. Measurement of Horizontal Distances. One of the basic operations of surveying is determining the horizontal distance between two points on the surface of the earth. The distance between two points at different elevations is obtained either by computing the horizontal distance from a measured slope distance or by direct horizontal measurement. Distances may be measured by pacing, odometer, stadia, taping, light waves, radio waves, infrared waves, or *GPS*.

Where approximate results are satisfactory, distances can be obtained by *pacing*. The length of a person's pace can be determined by walking over a line of known length several times, while maintaining a natural walking stride. When available, a measuring wheel can be used to obtain more accurate distances. Regular vehicle odometers will give fairly reliable distances along highways, provided the odometer is periodically checked against a known distance. For more accuracy, high quality electronic odometers can be installed and used for location and photologging purposes.

Another method of determining the distance between two points is to use stadia. Since the use of stadia has essentially been replaced by electronic distance measuring (EDM) devices, the stadia method of determining distances will not be discussed. Details of this method may be found in any standard surveying textbook.

Taping a distance with either a steel or a cloth tape is one method of obtaining the distance between two points. Where high accuracy is not required, cloth tapes are recommended. Cloth tapes are likely to change length with age, moisture condition, and use. Better accuracies can be obtained with steel tapes if proper taping techniques and corrections are applied for temperature, sag, and tension errors.

Most Government land surveys recorded distances in chain measurements. Two kinds of chains were formally used in surveying--the 100-foot [30.48-meter] engineer's chain and the 66-foot [20.12-meter] Gunther's chain.

Both were divided into 100 links. A link of an engineer's chain is therefore 1-foot [304.8-millimeter] long, and a link of a Gunther's chain is only 0.66 feet long [201.2 millimeters]. Typically when a distance was recorded in chains, the implied chain is the 66-foot Gunther's chain.

Most distances are now measured using electronic distance measurement (EDM) devices. These machines use light, radio, micro, or infrared waves to determine the distances between two points. The systems typically consist of a transmitter/receiver unit and a reflector device. The reflector generally is a glass prism. These EDMs are capable of high accuracies over both short and long distances. The operation and limitations of these instruments should be understood before incorporating their use into daily practice.

2. Leveling Procedures. Leveling is the surveying operation performed to determine elevations of points, to determine differences in elevations between points, and to control grades and roadway templates in construction surveys. The traditional instrument used is a spirit level that establishes a horizontal line of sight by a telescope fitted with a set of cross hairs and a level bubble. Other instruments used for determining vertical distances are the *transit, total station, aneroid barometer, and hand level*. *GPS* may also provides sufficiently accurate elevations for many purposes.

When differences of elevation are determined either trigonometrically or by using a level and a rod, the effects of curvature and refraction must be considered. This is particularly true when the horizontal distances are long and when a high degree of precision is required. The curvature error results from measuring distances horizontally (flat) instead of measuring them along the arc or curvature of the earth. Refraction errors occur because the earth's atmosphere bends light waves from the horizontal towards the earth's surface.

The combined effects of curvature and refraction may be negated in differential leveling by balancing the foresights and backsights. They may also be negated by using the mean of the vertical angles looking both ahead and back when using trigonometric leveling. Should the occasion arise where negating curvature and refraction is not practical, formulae for the corrections may be found in any standard surveying textbook.

The traditional method of determining differences of elevation is with the spirit level and a rod. By placing the level between the two points and recording the rod readings from both points, the elevation from one point can be used to determine the elevation of the other point. This method of leveling is called *differential leveling*. *Three-wire leveling*, also referred to as *precise leveling*, is a process of direct leveling where three cross hairs are read and recorded rather than the single cross hair.

The difference in elevation between two points can also be determined by measuring the vertical angle of the line from one point to the other and then computing the difference in elevation. Use either the slope distance or the horizontal distance between the two points. This method is called *trigonometric leveling*. The difference between the height of instrument and height of target has to be considered to obtain a true elevation difference between the points occupied.

Stadia leveling combines features of trigonometric leveling with those of direct differential leveling. Again, consult a standard surveying textbook before undertaking this method.

Leveling with a *total station* is the fastest and simplest method of determining elevation differences. A total station includes an electronic transit/theodolite combined with an EDM. The EDM measures the slope distance to the point in question and uses the vertical angle from the transit/theodolite to reduce the slope distance to horizontal distance and vertical difference.

Atmospheric pressure decreases as the altitude increases, enabling the engineer to use an *aneroid barometer* to determine rough elevations. Aneroid barometers produce results within 2 to 3 meters from actual measurements. Where accurate beginning elevations are not required (i.e., reconnaissance work), the aneroid barometer provides an alternative to a level loop.

The *hand level* consists of a short metal or plastic tube with a small level bubble mounted on the top. A prism on the inside of the main tube enables the user to tell when the level is being held horizontally. The hand level is used where accuracy is not critical, such as in taping to determine when the tape is being held horizontally.

A bench mark may be established by the engineer or surveyor at predetermined intervals along the survey. A good bench mark is a bronze disk set either in the top of a concrete post or in the foundation wall of a structure. Other locations for bench marks are the top of a culvert headwall, the top of an anchor bolt, or the top of a spike driven into the base of a tree. The elevations of bench marks are determined to varying degrees of accuracy by the particular field operation.

Profile leveling is used to determine the elevations of the ground surface along a given line. In highway applications, profile levels are often performed on centerline stations and on cross section reference points. The elevations at these points are crucial to the construction of the highway.

3. Measurement of Angles. A horizontal angle is the angle formed by two intersecting vertical planes. The vertical planes intersect along a vertical line which contains the vertex of the angle. In surveying, an instrument for measuring angles occupies this vertex. A horizontal angle in surveying has a direction. That is, it is measured to the right or to the left, or it is considered clockwise or counter-clockwise. Angles measured to the left are considered to be negative. The common methods of measuring horizontal angles are by the total station and transit/theodolite.

A transit (a deflection angle instrument) or a theodolite (a single directional instrument) have horizontal and vertical circles that are graduated into fractions of minutes and/or seconds. Electronic theodolites display the angular readings and their differences, eliminating interpolation errors.

The number of times an angle must be measured and the required accuracy of the instrument will vary depending on the type of survey. The requirements of surveying accuracies for various types of survey projects are listed in Section 5.4.C.

4. Traverse Surveys and Computations. A traverse is a series of connected lines of known length and course direction. The lengths of the lines are determined by direct measurement of horizontal distances, by slope measurements, or by other methods as described in section 5.4.A.1. The angles at the traverse stations between the lines of the traverse are measured with either a transit, a theodolite or a total station instrument. The angles can be either deflection angles or angles to the right.

The results of field measurements related to a traverse will be a series of connected lines whose lengths and azimuths or bearings are known. The course directions may be azimuths from North or South or bearings. Either may be true, grid, magnetic, or assumed.

Some of the many purposes for which traverse surveys are made are listed below:

- To determine the boundaries of individual property.
- To determine the position of arbitrary points from which data may be obtained for preparing various types of maps.
- To establish ground control for photogrammetric mapping.
- To establish control for gathering data regarding earthwork quantities for highway construction.
- To establish control for locating highway projects.

In general, traverses may be of two classes. The first class is an *open traverse*. It starts either at a point of known horizontal position with respect to a horizontal datum or at an assumed horizontal position, and ends at an unknown horizontal position. The second type of traverse is known as a *closed traverse*. A closed traverse starts at an assumed or known horizontal position and ends at either the same point, or at another known horizontal position. A known horizontal position is defined by one or more of the following:

- Geographic latitude and longitude.
- X and Y coordinates on a grid system.
- Location on or in relation to a fixed boundary.

To make an open traverse more reliable, several techniques may be employed:
(1) Each distance can be remeasured; (2) The measurements of the angles at the stations can be repeated; (3) The directions of the lines can be checked by magnetic bearings or solar/polaris observations.

Use care in running an open traverse because it contains no checks for mistakes or errors.

A traverse that closes on itself affords a check on the accuracy of the measured angles, as well as an indication of the consistency of measuring distances.

A closed traverse that starts at one known position and closes on another is the most reliable, because the position of the final point checks both the linear and angular measurements of the traverse. A point of known position must have been located by procedures at least as accurate as those used in the traverse being executed.

There are several different methods employed in running a given traverse. Each method has a specific set of guidelines that govern their execution. Traverse methods include interior-angle, deflection-angle, angle-to-the-right, azimuth, and compass traverse. The deflection-angle, angle-to-the-right, and compass traverse are most often used by highway engineers.

Two methods of traverse adjustment are normally used in highway surveying. The *compass method*, assumes that both distance and angular measurements are of equal precision. The method of *least squares adjustment*, allows weights to be applied to any measurement. The compass adjustment is the easiest to use and generally provides acceptable results. There are many forms of the least squares adjustment and care must be exercised when using them so error is not introduced to the traverse through a misunderstanding. Consult a standard surveying textbook before using either of the adjustment procedures.

5. Horizontal and Vertical Curves. The horizontal alignment of a highway consists of a series of curves connected with straight lines. The grade line on a profile is likewise made up of straight lines and curves. These curves may be arcs of circles, parabolas, or spiral curves. The parabola is generally used as a vertical curve on grade lines, while the circle and/or the spiral curves are used as horizontal curves. On many highways, the horizontal curves are made up of circles with transition spiral curves at the two ends. See Chapter 9 for the notations and formulas commonly used to describe circular curves.

6. Coordinate Systems. Computations of traverse point locations are reduced to a series of X and Y coordinate pairs. Often a point of origin is assumed and the traverse points referenced to this point. This use of an assumed coordinate system works quite well on small survey projects but a problem arises when the engineer attempts to relate the points from one survey project to those of another. The Y-axis of the plane coordinate system for each of the two surveys is assumed to be parallel to the true meridian. Meridians converge as one moves toward the poles and are not parallel. Assuming that meridians are parallel may result in major coordinate differences.

The solution to this problem lies within the methods of *geodetic surveying techniques.* In geodetic surveying, distances are reduced to a common reference surface conforming closely to sea-level. Angles in geodetic surveys are considered spherical angles. The coordinate systems developed using geodetic surveying techniques are referenced to parallels of latitude and meridians of longitude by using angles computed near the center of the earth. Geodetic surveying is more precise over long distances without suffering the limitations of plane surveying methods.

Use caution when applying a State plane coordinate system to projects where either elevation or scale factors would make an appreciable difference in ground and grid distances. When this occurs, use a "modified" plane coordinate system to allow field measurements to be taken directly from map calculations.

For more than a century, the National Geodetic Survey, has established horizontal control monuments throughout the country. These stations have been located by geodetic surveys. All the points throughout the country bear a relationship to each other. State *plane coordinate systems* are a result of this network.

When practical, convert the highway survey to the State plane coordinate system. The following are advantages of using the State coordinate system:

- A traverse of relatively low accuracy run between a pair of control points is actually raised in accuracy after an adjustment between the control points is made.

- The use of well-established control points in a traverse eliminates many serious mistakes often made in measuring both distances and angles.

- A point whose X- and Y- coordinates have been determined can, if lost, always be replaced with the degree of precision with which it was originally established.

- Maps that have been controlled by coordinated points will always conform when joined, no matter how unrelated the projects which necessitated the maps.

- The use of a common reference system for surveys reduces or eliminates costly duplication in the way of many control surveys over the same area by various engineers and surveyors.

- The use of the State coordinate system permits surveys to be carried over statewide distances by using plane surveying methods with results which approach those obtained by geodetic methods.

- State coordinate definitions may be required for ROW deeds.

- Photogrammetric mapping can be conducted at much less expense when all control points in the area to be mapped are on the same system.

When using a plane coordinate system, elevations and scales will be slightly different than ground and grid distances. These differences can be computed and their significance determined.

Where an assumed datum of coordinate system is used, all field note books and any maps or plans compiled from the data should have a note so stating. Assumed vertical elevations shall be at least 100 meters different from the true elevation beginning with even hundreds. Assumed coordinates shall be at least 100 000 meters different from the true coordinates shall be at least 100 000 meters different from the true coordinate positions beginning with even hundred thousands. Azimuths shall be determined from astronomical observations to third order accuracy.

7. Topographic Surveys. Topographic surveying is the process of determining the positions of the natural and artificial features of a given locality as well as determining the configuration of the terrain. The horizontal location of the features is referred to as planimetry and the configuration of the ground is referred to as topography. The purpose of the survey is to gather data necessary for the construction of a topographic map. Such a map shows both the horizontal scales of the features and their elevations above a given datum. Often the type and limits of vegetation are also shown on topographic maps.

Contour lines are typically used to represent relief on a topographic map. A contour line is a line that passes through points having the same elevation. The contour interval for a series of contour lines is the constant vertical distance between adjacent contour lines. Contour lines on a map are drawn in their true horizontal positions with respect to the ground surface. A topographic map containing contour lines shows not only the elevations of points on the ground, but also the shapes of the various topographic features, such as hills, valleys, escarpments, and ridges.

The area to be mapped for highway location and design is usually a strip of land varying in width from one hundred meters to one thousand meters. The *cross section* method is usually used to obtain topography on ground surveys with heavy vegetation and/or rugged terrain. A base line is established from the control points, usually in the form of a traverse with intermediate points established at 20- to 30-meter intervals. The intermediate points are identified by elevation and distance (called stations) from the traverse points. These points also are the centerline points of the cross section which is measured normal to the traverse line. When an area of limited extent is moderately rolling and has many constant slopes, points forming a grid are located on the ground and the elevations of the grid points are determined. This is the *grid method* of obtaining topography. Another approach, *radial topography*, may also be used. In radial topography the instrument is placed over one of the control points and ground elevations are obtained radially around the control point.

Topography measurements can be obtained by total station, theodolite and EDM, level and tape, arc and tape, or any other method of measuring elevation and distance. The choice of equipment is usually based on the degree of accuracy desired.

In compiling topography, the positions of all planimetric features (such as buildings, fences, and streams) are located with respect to the control line. These items are also plotted on the topographic map. Often these items are located by azimuth angle and distance techniques (radial survey methods).

The grid method of obtaining topography may be used in areas of limited extent where the topography is fairly regular. Either a theodolite with EDM or a level may be employed. The area to be mapped is usually bound by a traverse and a grid of squares or rectangles inside the area to be laid out. The dimensions of these divisions depend on the required accuracy and the regularity of the topography. The elevations of all the gridpoints are recorded, and the points are used to generate the contour map.

In radial topographic surveys, the instrument is placed relative to the control points and topographic shots are taken in a radial pattern around the point. Take care to cover the area with sufficient points to obtain an accurate representation of the relief. By using this method, the engineer is able to obtain a concentrated number of points in an area where the terrain rapidly changes and fewer points where the terrain is fairly regular. Radial surveys also allow for local *discontinuities* to be outlined on the ground by a series of topographic points. Discontinuities are terrain features that reflect breaks in contour intervals. The bottom of draws and the edges of ridge lines are two such examples.

8. Photogrammetry. Photogrammetry is the science of making measurements on photographs. Terrestrial photogrammetry applies to the measurement of photographs that are taken from a known ground station, while aerial photogrammetry applies to the measurement of photographs taken from the air. Aerial photogrammetry is most often used in highway design applications and terrestrial photogrammetry finds uses in structural and land deformation. The science of aerial photogrammetry has come to include all operations, processes, and products using aerial photographs. Among these are included the measurement of horizontal distances, the determination of elevations, and the compilation of planimetric and topographic maps.

For a discussion of the exact processes involved in aerial photogrammetry the engineer should consult a standard photogrammetry textbook. These manuals describe in detail the types and uses of aerial cameras, the types of required photographs, the associated scaling factors, the principals behind measuring relief, and the operating procedures for various stereoplotting equipment.

In order that aerial photographs may be used for making simple measurements of distance and elevations, some ground control is necessary to fix the scale of the map and to establish a vertical datum with which to establish contour lines on the map.

Usually a system of control points and special points called wing points are located on the ground and then targeted so they can be identified in the aerial photographs. A traverse is run through these points and their coordinates and elevations determined.

Positively identify wing points between the photograph and the ground. They must be sharp and well defined as seen on the photograph under magnification.

The location of the wing points is usually predetermined by the engineer to avoid having a point fall near the edge of a photograph. These points should be reasonably accessible from the ground to keep the expense of the ground control survey to a minimum. Typical targeting is described in the photogrammetry reference materials.

The main advantages to compiling topographic maps by using aerial photographs over ground methods are as follows:

- Expandable map widths.
- Reduced compilation time.
- Reduced control surveying time.
- Highly accurate location of planimetric features.
- No interference by adverse weather and inaccessible terrain.
- Uniform accuracy throughout the map.

By the proper selection of flying heights, focal lengths, plotting instruments, and placement of ground controls, photogrammetric mapping can be designed for any map scale ranging from 1:100 to 1:20 000 and smaller. Contour intervals can also range down to 0.2 meters.

Among the disadvantages of mapping using aerial photographs are the following:

- Difficulty plotting areas containing heavy ground cover, such as high grass, timber, and underbrush.
- High cost per hectare to map areas of 2 hectare or less.
- Difficulty locating positions of contour lines on flat terrain
- Difficulty scheduling photographic flights (most jobs can not be flown in winter or summer).

Supplemental ground survey is required where the ground cannot be seen in the spatial model because of ground cover and where such planimetric features as overhead and underground utility lines must be located on the map. Editing is necessary to include road classification; property boundary lines not shown on the photography; drainage classification; and names of places, roads, and other map features.

9. Global Positioning Satellite System. Global positioning satellite (GPS) systems are the methods and equipment used to determine the three-dimensional coordinates of any point within the spherical world using satellite technology. The system consists of NAVSTAR satellites that transmit signals toward the earth. Special receivers record these signals and using computer programs interpret the signals and determine the coordinates and elevation of the location of the antenna receiver. There are a wide variety of receivers and data processing programs now available.

At present there are 21 satellites transmitting signals back to the earth. This coverage means that a receiver is able to record the signals from at least four satellites at the same time. The more satellites a receiver processes, the higher the accuracies and the less time spent recording data.

Using GPS systems for establishing ground control is currently cost effective for the majority of FLH projects. In areas where geodetic control is difficult and costly to use, GPS surveying should be considered.

B. Instrument Care and Adjustments. As surveying equipment becomes increasingly complex and expensive, care and maintenance becomes more imperative. Place total station, theodolites, levels, data collectors, EDMs, and all other equipment in their protective cases when not in service. Always place instruments in their cases when being transported. During wet periods, store the instruments in a dry place and in their cases, but with the case lid left open. This will allow moisture trapped within the instruments to escape.

Similarly, keep tripods, rods, and range poles clean and stored in either carrying cases or bins built into the survey vehicles. To avoid swelling of the wooden parts of these pieces, wipe them dry after exposure to moisture. Place the top plate covers on the tripods when not in use.

Inspect, axes, saws, machetes, and other metal equipment daily for condition. When being stored for extended periods, wipe them with an oiled cloth and store in a dry place.

All of the electronic surveying equipment will require periodic adjustments to ensure their accuracy. Manuals that describe how to calibrate and make minor adjustments to the instruments are provided by the manufacturer. Keep these manuals with the instruments in their field cases. Make an accuracy check on the instrument before initial use on a project and on a weekly basis thereafter. Check the equipment anytime accuracy is suspect. In addition to their regular maintenance, total station, theodolites and EDMs should have a manufacturer's cleaning and lubrication at least every 2 years.

C. Classification and Accuracy. Surveys are classified into order and class on the basis of the accuracy and precision used in the survey. See Table 5-1. Accuracy and precision is dependent on the quality of the instruments and equipment employed, the methods and procedures used, the repeatability of measurements, and the ability and experience of the personnel.

The following sections identify the standards for the classification of geodetic control as recommended by the Department of Commerce, National Geodetic Survey.

Surveys are accepted or rejected on the basis of the accuracy attained. Accuracy is the degree of conformity to a true standard or the degree of perfection obtained. This degree of conformity is shown by the computed survey closure.

Traverses qualifying for a specific classification on the basis of the precision used will ordinarily not only meet the accuracy requirements for that classification, but will generally provide closures for about one-third of that specified. If closures exceed one-half the closure specified, a review of equipment, measurements, and procedures shall be made. For example, a Third Order Class I traverse is acceptable if its closure error does not exceed 1 part in 10 000. A closure error of 1 part in 30 000 should be expected. If the closure error is more than 1 part in 20 000, perform a search for possible errors.

Table 5-1
Survey Standards

Item	First Order Surveys		Second Order Surveys		Third Order Surveys	
	Horizontal Controls					
			Class I	Class II	Class I	Class II
Relative accuracy between directly connected adjacent points (at least)	1 part in 100 000		1 part in 50 000	1 part in 20 000	1 part in 10 000	1 part in 5000
	Vertical Controls					
	Class I	Class II	Class I	Class II		
Relative accuracy between directly connected points or benchmarks (standard error)	$4mm\sqrt{k}$	$mm\sqrt{}$	$6mm\sqrt{k}$	$8mm\sqrt{k}$	$12mm\sqrt{k}$	
	Traverse Controls					
			Class I	Class II	Class I	Class II
Recommended spacing of principal stations	Network stations 10-15 km. Other surveys seldom less than 3 km.		4 km	2 km	1 km	1 km
Smallest reading of horizontal circle on instrument	0.2 second		0.2 second	0.2 second	1.0 second	1.0 second
Number of horizontal observations	16		8	6	4	2
Rejection limit from mean	4 seconds		4 seconds	4 seconds	5 seconds	5 seconds
Number of and spread between vertical angle observations	3 D/R 10 seconds		3 D/R 10 seconds	2 D/R 10 seconds	2 D/R 10 seconds	2 D/R 10 seconds
Number of angle points	5 or 6		10 to 12	15 to 20	20 to 25	30 to 40
Angular closure not to exceed	1.0" per km station or $2''\sqrt{n}$		1.5" per km station or $3''\sqrt{n}$	2.0" per km station or $6''\sqrt{n}$	3.0" per km station or $10''\sqrt{n}$	8.0" per km station or $30''\sqrt{n}$

Note: k = distance in kilometers.n = number of angle points. "D" = Direct and "R" = Inverted

D. Specific Survey Procedures. By using the methods discussed in the previous section, the engineer can perform the more common highway surveying assignments. Typical highway surveying projects include the following:

- Control surveys for both ground and aerial projects.
- Reconnaissance surveys.
- Preliminary surveys.
- Location surveys.
- Property surveys.
- Construction surveys.
- Bridge surveys.
- Sundry surveys.

1. Control Surveys. Control surveying is the process of establishing a line or grid of points throughout the project limits. These points are the traverse points on a traverse line running between two or more points of known geodetic position. This traverse line contains the points from which all measurements within the project are made. Since the entire project will be relative to these points, give extra care to their accuracy and location.

Depending on whether the project will be measured by ground methods or by aerial photogrammetry, different requirements exist for the frequency and location of the traverse points. The next two sections describe in more detail the specific procedures to be followed when placing control survey points.

a. Ground Control. Begin and end the control survey on a first or second order geodetic monument. The coordinates for the monuments should be on the State plane coordinate system. When this is not practical, run a circuit from the end of the survey back to the point of beginning to achieve a closure or establish beginning and ending coordinates using GPS systems.

When placing supplemental points for an aerial survey or when establishing centerline, the circuits shall be closed traverses of the same accuracy as the primary control circuit.

Reference control lines with approved permanent type monuments at a recommended maximum spacing of three kilometers. Set monuments to prevent water from ponding above the caps and to ensure visibility to other control line monuments, triangulation points, or monumented azimuth markers. The monuments shall have their field locations referenced with approved witness type markers. It is recommended that these witness markers be a steel post with an aluminum identification plaque attached. The documentation should also describe bearings and distances from the monument to at least two other objects. See Exhibit 5.1 for an example of monument documentation.

When necessary to set semi-permanent points between monuments, place the monuments far enough below ground to be safe from ordinary maintenance operations. Use magnetic markers such as a 10M steel reinforcing bar capped with a yellow plastic cap. This permits locating the markers with metal detectors. Identification plaques need not be posted on semi-permanent points, but reference the points with an approved marker and record their locations.

Control surveys shall be performed with Second Order, Class II accuracy. See Section 5.4.C. As stated in that section, surveys shall close within an error of 1 in 20 000 before adjustment. On long traverses, use eccentric points or check circuit points to secure an azimuth check on every 20 angles or less. The closure at any azimuth check shall not exceed 2 seconds per angle or 6 seconds times the square root of the number of angles, whichever is less. Before computing coordinates, adjust the angles to effect a flat closure. The above values are minimum figures. With the equipment now in use, expect much higher accuracies without loss of production.

Number all monumented control survey points consecutively from the beginning to the end of the route. The monument designation will consist of the route number followed by a number or a number and/or a letter. All monuments set by the survey crew shall be identified by a primary number. Identify all supplemental points set by a number and a letter. All points set outside the control circuit by the survey crew shall be identified with a primary number and a parenthesized number.

Identify all existing points incorporated in the control circuit by a description. Identify all the check-circuit points with an eccentric number. See Figure 5-1.

b. Aerial Control. Control for aerial surveys shall consist of both horizontal and vertical control, targeted on the ground and visible from the air.

Horizontal control shall conform to the requirements of Section 5.4.D.1.a and usually will be the primary project control with no supplemental control required. In all cases involving aerial photography, those points required to control the mapping shall be placed in accordance with the furnished flight strip map. Give special attention to their location in relation to the flight line to ensure they are not obscured by shadows or other objects. (See Figures 5-2 and 5-3.)

Targets must not be placed on steep slopes since elevation orientation on a photogrammetric instrument becomes difficult and many times inaccurate.

Vertical control shall conform in all respects to the requirements outlined in Section 5.4.C. Those points that are required for vertical control shall be placed in accordance with the requirements of the horizontal control points to ensure that they too are visible on the photographs.

There are two types of targets, designated primary and supplemental control targets, used to identify ground control points in aerial photographs. Primary control targets are used to identify the main coordinate references from the photographs. Supplemental control targets are used to provide additional coordinate control and to serve as backup to the primary targets.

See Figures 5-4, 5-5, and 5-6. Prepare a sketch showing the location of all targets to ensure accurate photographic identification later. Target composition and size shall be determined by background and photo scale.

If preprinted targets are not practical or available, an appropriate white cross or wye shall be used with overall dimensions equal to those in the figures.

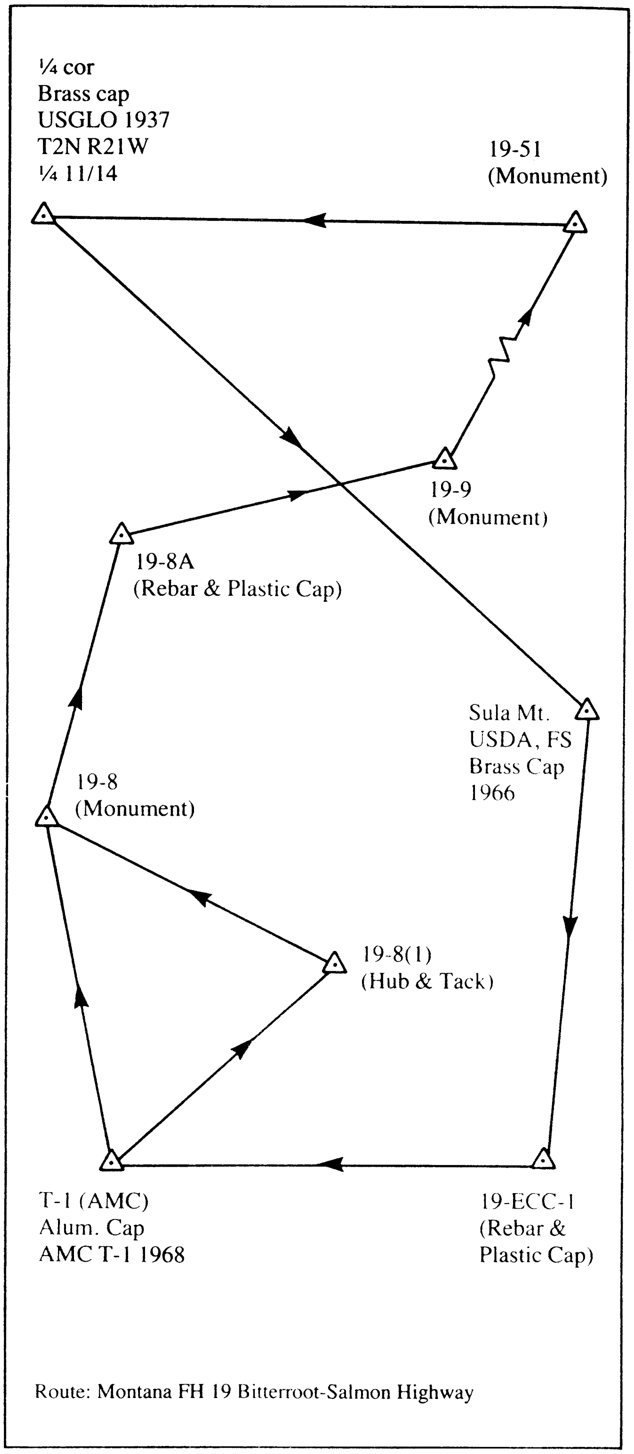
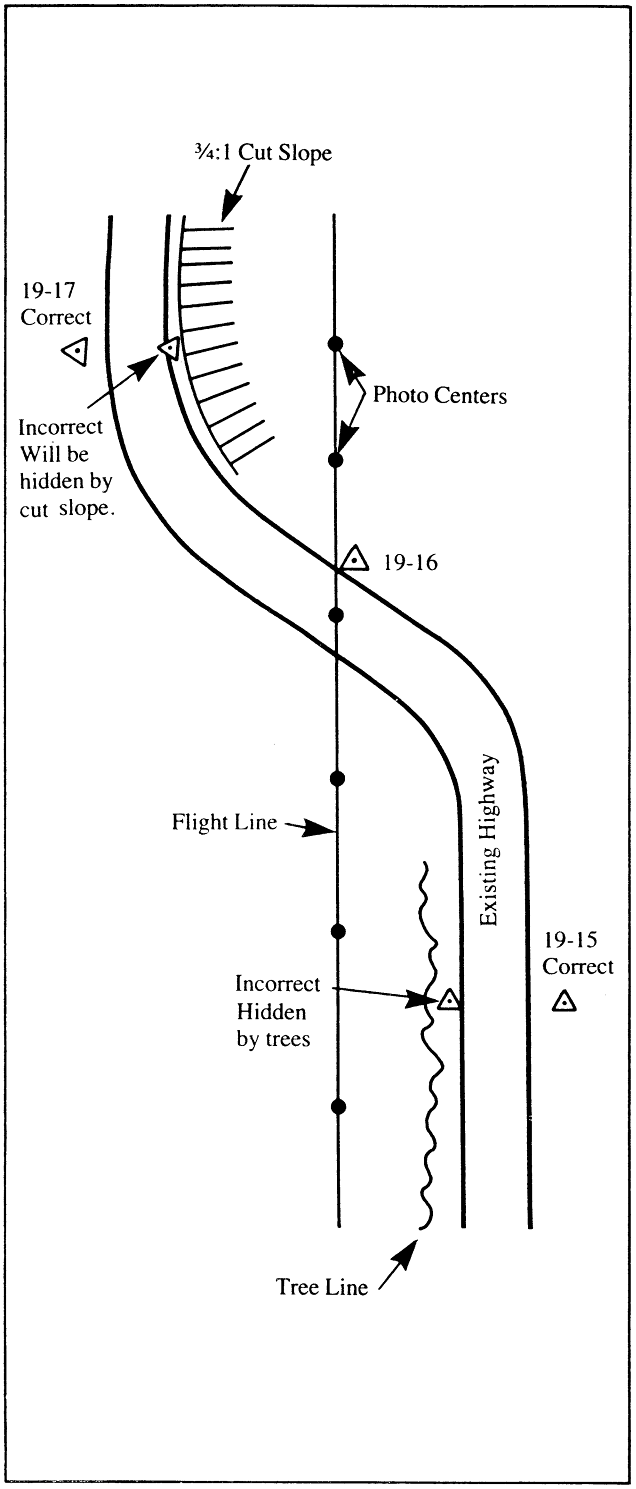
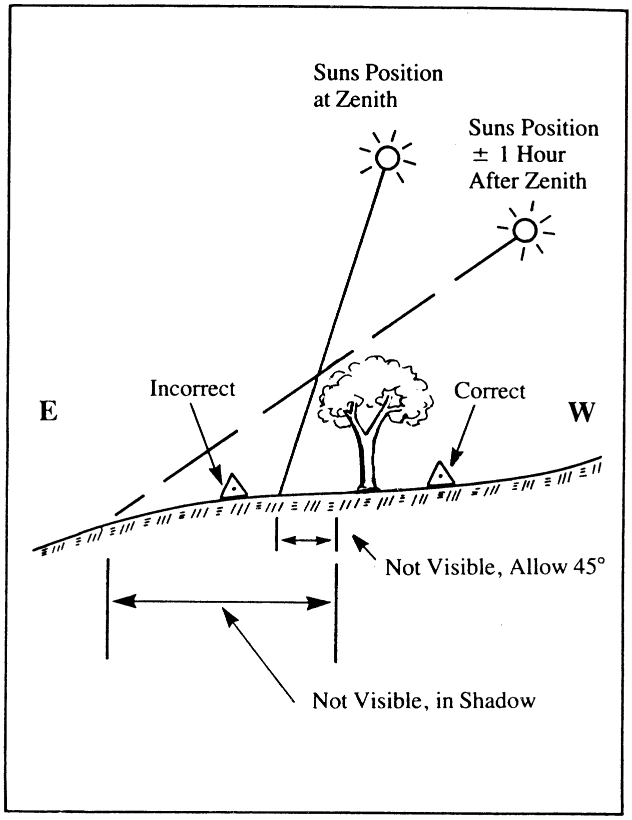
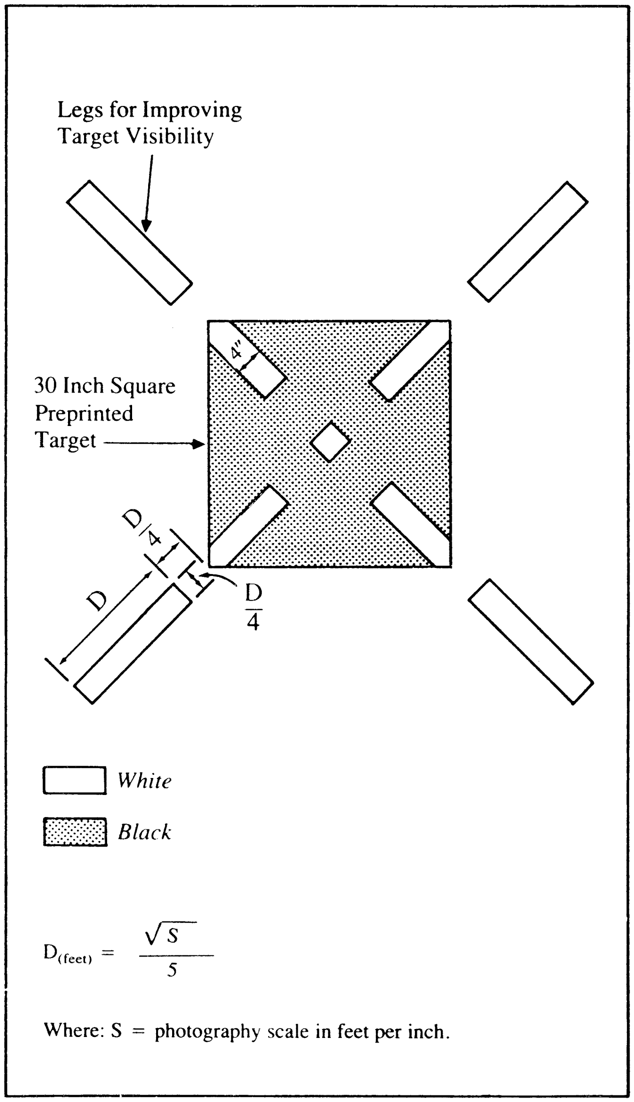


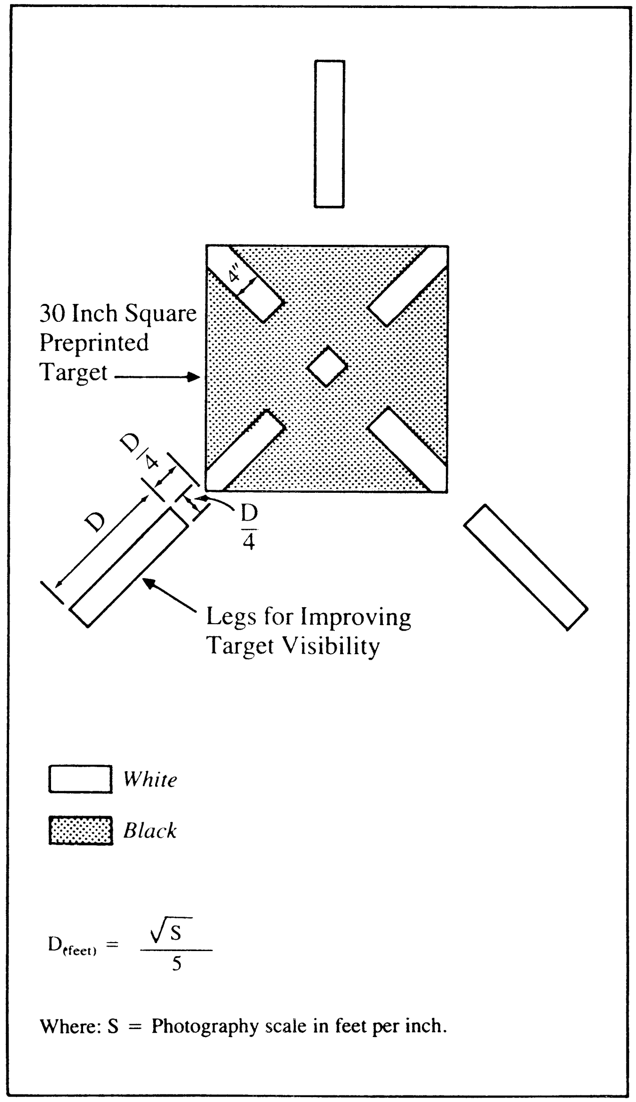
FIGURE 5-1
Exmple of a Monument Numbering System



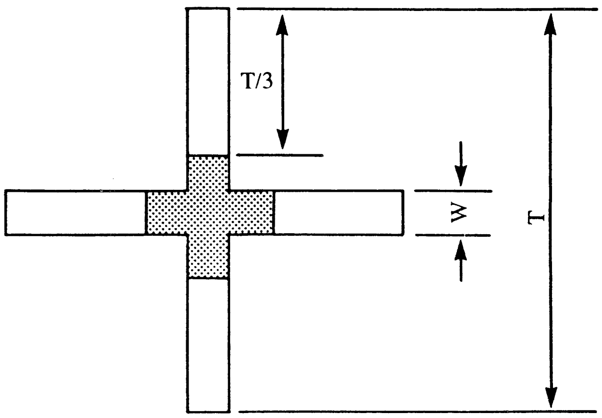


FIGURES 5-2 AND 5-3
Monument Positioning

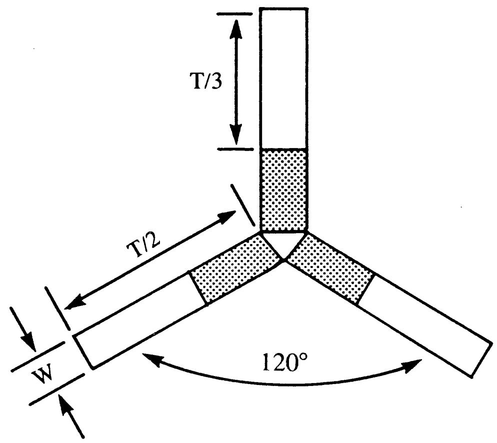




FIGURES 5-4 AND 5-5
Control Targets



Primary



Supplemental*

White

Black

$T_{(feet)} = \frac{S}{50}$

$W_{(inches)} = \frac{S}{60}$

Where: S = Photography scale in feet per inch

*To be used for all Wing Points, Supplemental Control, L-line Points, and Property or R/W Corners.

FIGURE 5-6
Alternate Targets

2. Reconnaissance Surveys. Reconnaissance surveys are divided into two parts, a survey of the area and an evaluation of feasible route alternatives.

For scoping purposes, horizontal and vertical information about the area is needed as well as information about cover and culture. This information can be obtained by field surveys; from existing maps or maps compiled specifically for the project; or it can be extracted from aerial photographs which is probably the most efficient method. Vertical aerial photographs represent the ground surface with sufficient accuracy to determine a feasible corridor.

Topography, geology, land use, ecology, and other features are immediately evident or readily interpreted by stereoscopic examination of the photographs. Elevations are easily derived from parallax measurements on the photographs. Horizontal distances measured on the photographs are converted to ground distances using local scales determined by parallax measurements. If topographic maps of the area are available, elevations and distances may by taken from them.

3. Preliminary Surveys. Preliminary surveys generally are line traverses (P-line) placed in the field in close proximity to where the final alignment of the future road or highway is to be placed. The points established by this survey serve as a base for locating the proposed road. These surveys are necessary to obtain all the field information needed to design the highway. The surveys are also used to locate and define private property, establish the relationship between natural and physical topography, and provide vertical and horizontal control. The control is derived from established control points placed during a previous control survey.

a. Accuracy. Preliminary surveys are normally third order, class II traverses and are tied to the control surveys. The points established shall be measured as specified in Table 5-1.

b. Monumentation Guidelines. A reinforcing steel bar, usually a 10M or 15M, with a plastic or aluminum cap shall be used. Return traverse points shall consist of hubs with tacks or nails driven into the roadway surface. Both double guard stakes and a lath shall be used to mark the angle points.

P-line stakes should be at least 600 millimeters in length and identified by the color red. The stake shall face ahead on line and be labeled with the station or appropriate section number. The section method for identifying preliminary survey sections is preferred over the more traditional stationing method. Angle points are designated in numerical sequence (P1, P2, P3, etc.). Intermediate points are designated with a slash (P2/1, P2/2, P2/3, etc.). The number following the slash corresponds to the number of the intermediate ahead of the angle point. Should an additional section be required after staking, it can be added by using a decimal (P4/6.1 means a section was added between the sixth and seventh section between angle points 4 and 5). The section method allows traverse adjustments to be made without changing the value of the station. It also enables the crew to positively identify the point prior to determining the true stationing.

Offset stakes shall be used when there is a good possibility that the centerline stakes maybe lost. The offset stakes shall contain either the station or the section number, with the offset distance circled and facing the centerline point. When offset stakes are set, some other means of identifying the centerline point shall be used (nails, small wooden pegs, etc.).

On preliminary surveys, a minimum of one tangent every 2 kilometers should be referenced on both ends using the double-point method with semi-permanent monuments. These reference points shall contain both horizontal and vertical values. Each angle point not referenced under the above guidelines shall be referenced using a double-swing tie to a standard aluminum tag. Both horizontal distances and the magnetic bearings, or azimuths, shall be recorded on the tag.

4. Location Surveys. A location survey is the placement of the final alignment of the highway (often called L-line) as it is to be constructed. Typically, during a location survey, the engineer will establish the following items along the project route. Other actions may be included in the location survey process.

- Centerline (L-line) of the roadway alignment.
- Right-of-way (R/W) limits.
- Reference points (RP).
- Project control points.

Often, other actions are included in the location survey process. These include the marking of the clearing limits, the movement of temporary bench marks from inside to outside the construction limits, and the running of profile and RP levels.

The centerline is marked with either a small wooden peg or a nail to indicate the point. In addition to the cross section centerline points, the alignment control points (i.e., PC, PT) may be staked and marked.

If required, the R/W line is designated with a stake placed along the cross section or at intervisible limits. Major breaks in the R/W line are marked with a lath and a small wooden peg.

When the clearing limits are set, they are marked by a lath. Bench marks are reset as indicated in the earlier section on leveling.

Discrepancies between the design and the actual ground can be determined by comparing the centerline and RP elevations. Re-cross sectioning may be required where the values vary more than an acceptable amount. Sometimes this resurveying is brought about by changes in the design alignment.

Additional control points placed outside the construction limits provide an extra layer of control coverage. Rather than running a long traverse to replace points disturbed by construction activities, they can easily be reestablished from these additional control points.

5. Property Surveys. A property survey is a means by which the ownership boundaries along the route can be represented on the various survey maps. If property lines can be determined in the field, they shall be tied to the traverse line. The methods used to tie property markers will be of an accuracy that is equal to that of the traverse.

a. Land Corners. Locate and tie the nearest section corners or quarter corners on both sides of the route (Public Land states only). To aid in the search of these corners, copies of the original land survey notes and township plats are available for all surveyed lands. These documents are available through the Bureau of Land Management. The local government agencies that have jurisdiction over land through which the project passes shall be contacted for additional information they may have on the location and condition of section corners.

Upon beginning a survey that involves much private property, a property search along the proposed route shall be performed. The county courthouse can provide the names, addresses and property descriptions of the land owners involved. If the task is substantial, the option of contracting the property search to a title company may be desirable. The search for section corners can sometimes be aided by contacting the appropriate land owner.

Refer to the *Manual of Instructions*, 1973, Department of Interior, BLM for detailed information regarding public land surveys.

b. Lot Corners and Subdivisions. Ties shall be made to all existing property corners necessary to establish property boundaries. These ties will include tract subdivisions, 1/16 corners, centers of sections, and monuments, when available. Mutually agreed to fence corners or fence lines should also be tied in the absence of monuments.

Most all tract subdivisions of later dates are platted and approved by county officials before lot sale and occupancy. These official plats are on record at the assessor's office in the local county courthouse and are available upon request. Copies of these plats can be used as an aid in defining the property and locating the corners within the subdivision.

c. Right-of-Way Monuments. Accurately tie existing right-of-way monuments. The monuments were originally set to define the right-of-way of the existing roadway, so they are actually property corners. Ties to right-of-way monuments should be consistent with other property ties.

d. Records. Submit copies of all records and agreements obtained during the preliminary survey to the Division survey staff upon the completion of the survey. The following are typical documents:

- Copies of the original government field notes for Township, subdivision, government land survey plats, etc., and homestead entry surveys.
- Prints of any subdivision plats and replats within the area.
- Prints of the county assessor's maps covering the general area.
- Copies of any Records of Survey made in the general area and filed in the county.
- Copies of surveys by various organizations (such as railroad companies; counties and cities; irrigation, water and drainage districts; power companies; gas and telephone companies; Federal agencies, etc).
- Copies of any deeds obtained.
- County court orders dedicating roads or establishing right-of-way widths.
- Copies of boundary line agreements.

e. Miscellaneous Monuments. Ties will be made to all monuments, memorials, and objects of antiquity of a permanent or semi-permanent nature found within the general area of the preliminary line. These monuments may also include cadastral survey references, government survey stations, bench marks, azimuth marks, or other similar items. These ties shall be made even though the monuments will not be destroyed by the alignment of the proposed highway.

f. Political Boundaries. Tie State, county, and city boundary lines where they cross the preliminary survey line. Also locate boundary lines for national forests and parks, State and county parks, and other such boundaries.

6. Construction Surveys. A construction survey is the process by which construction stakes are placed on the ground that allow the contractor to begin building the roadway template. These points include slope stakes, blue tops, red tops, and minor structure stakes (i.e., culverts and drop inlets). The location and elevation of these grade stakes may be determined from the plans or from computer printout sheets.

The techniques of placing these points are described in most surveying textbooks. The *FHWA Construction Manual* also contains procedures for construction project stakeout. Construction surveys (staking) may be performed by the contractor as a bid item or as a subsidiary obligation.

7. Bridge Site Surveys. The field work of performing a bridge site survey is similar to a normal preliminary survey. The activities of placing project control, running levels, taking cross sections, and making ties to cultural features and land corners are still required. However, for bridges and culverts over an estimated size of 2400-millimeter diameter, the engineer shall obtain the following additional information.

a. Stream cross sections. Obtain a minimum of three cross sections of the stream and flood plain. These sections shall be about 150 meters apart if practical. Take the middle section close to centerline with the other sections upstream and downstream. Take care to ensure that these sections are typical of the stream section. Show the stream bottom, with a note about the composition of the bed material, the water elevation, high watermarks and date of high water, if available.

b. Water surface profile. Determine a water surface profile, when requested, between the cross sections and any high water marks recorded.

c. Improved land. Note any improved land adjacent to the structure site that may be inundated, and determine the elevation to control flooding.

d. Fish passage. Note any existing obstructions to fish passage and any details concerning fish passage.

e. Existing bridges. Tie existing bridges in the immediate vicinity upstream and downstream of site and record type, condition, location, and ownership. Note the number and length of spans, pier orientation, elevation, date and source of high water, any overtopping of fills, and the cross section of the waterway under the bridge.

f. Effect of adjacent structures. Document any information available on the size and location of dams, flumes, spillways, etc., adjacent to the bridge site that may affect the water passage at the bridge.

g. Drift. Estimate the amount and kind of drift and debris that will occur during high water.

h. Photographs. Photograph each site looking ahead and back on line. Include views upstream and downstream from the proposed crossing.

i. Flood plain. Where the proposed road will encroach on the flood plain of streams having a design flow of about 15 cubic meters per second or greater, the engineer will take cross sections of the flood plain where the size of the stream changes. The engineer will also note the type and height of vegetation covering the flood plain. The hydraulic and environmental sections of this manual, list other more specific surveying requirements for addressing wetlands and particular hydraulic structures.

8. Sundry Surveys. Sundry Surveys is a term for describing all other miscellaneous types of survey activities. These surveys are information gathering in nature and consist of establishing a control line and then either cross sectioning the area in question or blanketing the area with a series of side shots ties. Typical sundry surveys include quarry sites, landslide areas, and parking or vista areas.

These surveys are to be monumented similarly to preliminary surveys.

9. Automated Surveys. The surveying procedures as described in the preceding sections have been the traditional methods used to gather and process surveying information. The use of computers have allowed surveying to be automated.

The overall concept of automated surveying and mapping is shown in Exhibit 5.2. This exhibit shows the flow of survey information as it is collected by either ground or aerial surveying techniques. The data passes through a variety of processing equipment and is delivered to the designer in the form of maps, paper listings, and computer files.

No matter what kind of data collector is used to record an item of survey information, a system of feature codes is required to indicate special topographic and planimetric items. A code is entered into the data collector when a recording is made of the unknown point. These feature codes are carried through the system and are used by the CADD system to plot appropriate symbols for each code. See Exhibit 5.3 for a listing of suggested numeric codes.

5.5 RECORDS AND REPORTS

As with any engineering activity, the process of recording activities and preparing reports is essential to an efficient and timely operation.

The most important information that is recorded during a survey is that of actual field measurements. This information may be recorded in a variety of formats and media. Typically, these measurements are recorded in electronic notebooks and data collectors although field notebooks are still in use .

Besides the daily note keeping required during the performance of normal surveying activities, the surveyor is required to prepare various other reports. Two such reports are the weekly progress reports and the project cost report. These reports permit the engineer to make estimates regarding production rates for a variety of situations and to also provide cost estimates for accounting purposes. Refer to Exhibits 5.4 and 5.5 for sample formats of these reports.

A. Field Notes for Traditional Surveys. Unless data collectors or electronic notebooks are used on the project, several types of notebooks shall be maintained. Begin each book with an introductory identification page. (See Exhibit 5.6). Include the date, names of crew members and their assignments, instrument ID numbers when applicable, and the weather. Depending on the size and complexity of the survey, these notebooks may be combined.

The exact format and type of record to be maintained will be as approved by the location and/or survey engineer.

A description of the various types of notes follows. See Exhibit 5.7 for sample formats.

1. Index. An index or index book shall be made for each project. It will contain indexes to the other field books used on the project. It will also contain indexes and references to the other various maps (such as plats and utility plans). The index will be sectioned off into categories and kept current.

2. Traverse Notes. Traverse notes will contain all field data relative to either control or preliminary traverses. Include any references and descriptions of control ties used to establish the preliminary traverse. Notes are to run up the page.

3. Cross Section Notes. Cross section notes must clearly identify the method used to obtain the measurements, as well as listing the abbreviations and symbols used at the beginning of each book. Notes are to run up the page with the right and left sides correctly oriented.

4. Project Notes. Record any miscellaneous field notes to describe special features and activities throughout the project, such as instructions for execution of the survey and other similar items of information.

5. Level Notes. The level notes contain the location and description of all bench marks as well as all profile and closure loops. Notes are to run down the page.

6. Drainage Notes. List all drainages that the project crosses from the beginning of the book as they occur along the line of the survey. Make an estimate of the size of the culvert or structure required, with pertinent notes regarding drift, grade, foundations, fish passage, etc. All existing culverts or structures shall be measured with notes for condition, material type, type of corrugation, etc. See Chapter 7, Section 7.3 for more details.

Show a sketch of any stream bed for 150 meters upstream and downstream from the site. Include profile elevations for streams requiring culverts over 900 millimeters in diameter and less than 2400 millimeters in diameter. Show a cross section of the stream bed. Include a high water mark if possible.

7. Classification Notes. Identify the soil type by visual classification, such as clay, silt, sand, gravel, boulders, and rock type; record the location of each type.
Locate wetlands and areas of potential slides and give a recommendation as to possible mitigation measures.

Identify deposits of gravel or rock on or near the line.

The notes should include design recommendations as to location of the final line, its grade, and possible channel changes.

8. Cultural Notes. Ties can be shown on sketches showing the angle and distance from centerline points, or the angles from the centerline point to the object can be numbered, the distance shown and the actual angle placed on the other page of the notes.

9. Section Corner/Property Tie Notes. Show traverses to corners in standard traverse form on the left side of the notes with sketches showing what was done on the right side. Describe in detail and sketch their location.

B. Field Notes for Automated Surveys. At least one field book shall be used for each project. (See Exhibits 5.8 and 5.9 for recommended formats.) Provide an index to show major headings. Any rolls, maps or other books that are not practical to include directly in the *field book* are to be cross-referenced. There are different formats for preliminary and location surveys. Control surveys shall be considered preliminary surveys.

C. Mapping Procedures. The planimetric, topographic, and cadastral maps are the means by which survey information is passed to the roadway designer. These maps can be drawn by hand, but are normally processed by the computer.

Two other types of maps are often discussed in the field of highway design. These are the detail map and the vicinity map. The detail map (manuscript) is a combination of the planimetric, topographic, and cadastral maps. The detail map is used to evaluate various highway corridors and roadway alignments. Vicinity maps are detail maps that are used to show a small section of the project in large detail. These maps are typically used at bridge and quarry sites.

1. Conventional. Conventional mapping refers to the process of transferring the survey information collected during a ground survey onto the detail map. The procedure for this type of mapping is to establish the coordinate system and stationing layout as described in Section 5.4. Once this has been done, the control traverse line is plotted using the coordinates. From this base, the cross section points and culture ties can be located. The engineer then interpolates the contour lines and draws them on the map. Special notes are added to complete the map.

Manual plotting has been nearly replaced by the Computer Aided Design and Drafting (CADD) system and digital terrain modeling (DTM) computer programs. These tools transfer the survey data into a graphics design file where mapping technicians add the final modifications to the map.

2. Aerial. Aerial mapping refers to the process of using a stereoplotter to draw a planimetric and topographic map from aerial photographs and local ground control points. The process of adjusting the stereoplotter by setting scales, calibration, orientation, and optic adjustments is explained in photogrammetry manuals.

The process of using a coordinate system is essentially the same as that of mapping by conventional means. The points obtained from the aerial photographs are digitized and plotted by a computer program that interpolates the contours.

3. Mapping Guidelines. Maps, conventional or photogrammetric, shall be prepared in accordance with the guidelines set forth in Chapter 9. In addition, the following criteria are also applicable.

- Indicate the basis for the bearings and the level datum used. Where applicable, show the datum adjustment factor on each map sheet by a note.
- Show the coordinates of all section corners, permanent monuments, etc. on the map.
- Show the grid lines or grid ticks of the mapping coordinate system on all maps. Space the gridlines or ticks at 200 mm regardless of map scale.
- Plot all planimetric and topographic features on the maps. Plot spot elevations on the maps.
- Show the ownership and/or deed references of all property abutting or adjacent to the survey on the map.
- Locate and describe all sections, plats, lots, blocks, political subdivision lines, and property corners.
- Show, identify, and give right-of-way dimensions for existing roads, railroads, streets, alleys, lanes, etc.
- Identify and give dimensions for easements for public utilities, drainages, districts.
- Give complete information regarding all parts of the old right-of-way.
- Show the location of all geotechnical boring holes.
- Show the length and size of all existing bridges, culverts and drainage structures.
- Give the names of streams and their direction of flow.
- Show the direction of flow, elevation and gradient; typical cross section; size of existing structures; and required and anticipated future flow in cubic meters per second for irrigation canals and ditches.
- Show utility facilities with the approximate elevation to the lowest wire--or if underground, the depth below the surface. Show exact position of poles, and manholes. Show the ownership and any joint usage of poles.

Drafting should be in accordance with the drafting standards in Chapter 9, Section 9.6.A.

4. Layout. All maps will be plotted by the coordinates used for traverse computations. The stationing on the map should increase northerly on North-South routes and easterly on East-West routes. Stationing must increase on the map from left to right. Rotate the coordinate grid to meet the stationing direction requirements.

5. Symbols. Standard mapping symbols and legends for use in the preparation of contract plans have been adopted and are shown in Exhibit 9.31 in Chapter 9.

6. Scales and Contour Intervals. See Table 5.2 for mapping scales and contour intervals to be used in compiling maps.

Table 5-2
Mapping Scales and Contour Intervals

Purpose of Maps	Map Scales	Contour Interval (m)
Reconnaissance Studies		
Topography-Mountainous	1:20 000	10
Rolling to Flat	1:20 000	5
Location Studies		
Topography-Mountainous	1:5000 Max.	5
Rolling to Flat	1:5000	2
Rural Design		
Topography-Mountainous	1:500, 1:1000 or 1:2000	2
Rolling to Flat	1:1000 or 1:2000	1
Urban Design	1:500	0.5
Selected Site Design	1:100 to 1:200*	0.2
Selected Site Design for Structures Less Than 40 m Long	1:100*	0.2

* Maps can be developed from ground survey data or by photographically enlarging smaller scale maps.

7. Automated Mapping. Once the data is processed by the field project engineer it is then transmitted to the Division office for further processing using the digital terrain modeling program . This program uses three-dimensional data from field surveys and by a triangulation algorithm produces a highly accurate contour map. The planimetric features, which were recorded using feature codes during the ground survey, are plotted by DTM onto the map. The mapping engineer uses a CADD work station (see Exhibit 5.2) to edit and add enhancements to the generated map. Besides producing a contour map, the DTM program also produces a data base of triangles which connects every ground point located during the survey. Both the map and the data base are given to the designer.

The designer is able to place any highway alignment into the DTM tin file data base and generate cross sections taken, not at a skewed angle to the original ground survey, but, at right angles to the desired alignment.

The stereoplotter operator digitizes the planimetric and topographic features of the project by using a stereoplotter connected to the CADD system. The graphic capabilities of the CADD system allow the operator to place the planimetric symbols and features with a single push of a button. The operator uses both the CADD station and the stereoplotter during this operation (see Exhibit 5.2). After the photographs have been digitized with discontinuity and scan lines, the resulting design file is processed through the DTM program.

The DTM program generates the same triangular data base file and three-dimensional contour map as it does for the ground survey data. The program also allows the blending of the two data types into one common map and data base.

The Geopak system is the main design tool of the FLH Divisions. This system includes a fully integrated DTM program and no additional modifications are required.

5.6 (RESERVED)

5.7 DIVISION PROCEDURES

Reserved for Federal Lands Highway Division office use in supplementing the policy and guidelines set forth in this chapter with appropriate Division procedures and direction.

LIST OF EXHIBITS

Exhibit

Control Monument Data

State: Montana

Projection: Transverse Mercator **Order of Survey:** Third

Zone: Central **State Plane Coordinate System:** Adjusted Idaho

Name of Station: 19-11 **County:** Ravalli **Year 19** 70

X =

Y =

Vert. Datum:

Elevation (feet): 4633.18

Established by: FHWA

Year: 19 70

Distances and directions to reference marks and prominent objects observed at station

Object	Distance – Feet	Grid Azimuth
19 - 10		
19 - 12		
Sula Peak (Forest Service)		

The coordinates listed hereon have been adjusted to a project datum. The Datum Adjustment Factor (DAF) used is 1. 00032215 **. To reduce coordinates to the** sea level **datum, divide by the DAF.**

Party Chief: J. M. Kirkpatrick ☒ Established ☐ Recovered (check one) **Date:** 1970 **Condition:** Excellent

Description and Sketch of Station:

Station is located 2.2 miles south along U.S. Highway 93 from the post office at Sula, Montana. Station is in a pasture approximately 120 feet east of the highway at the end of a long tangent and in a through cut section approximately 1,500 feet south of the Sula Ranger Station. Station is a standard FHWA brass cap set in a concrete monument and stamped "19-11, 1970". Station is marked by a standard FHWA plaque on a steel post 2.0 feet northeast of the cap.

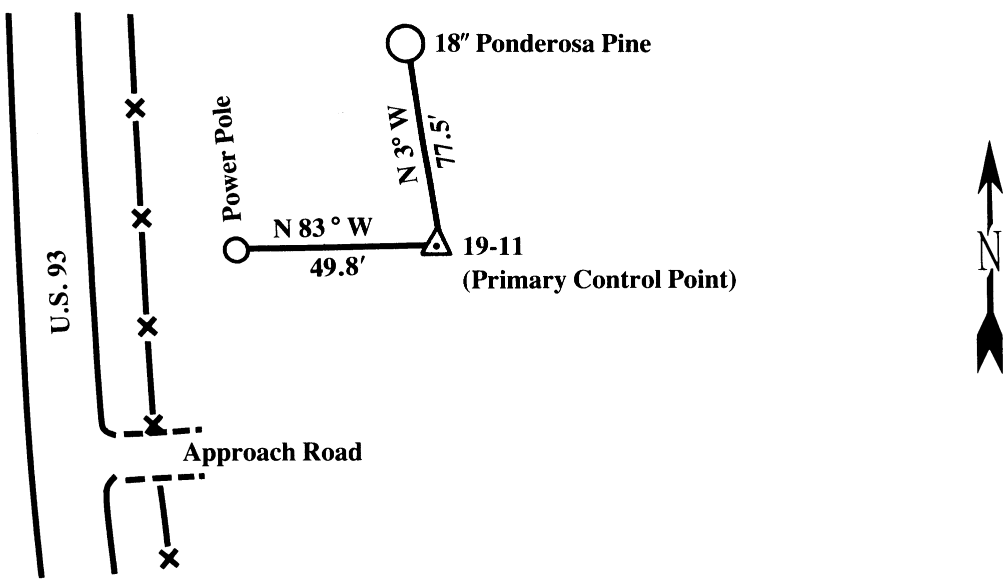
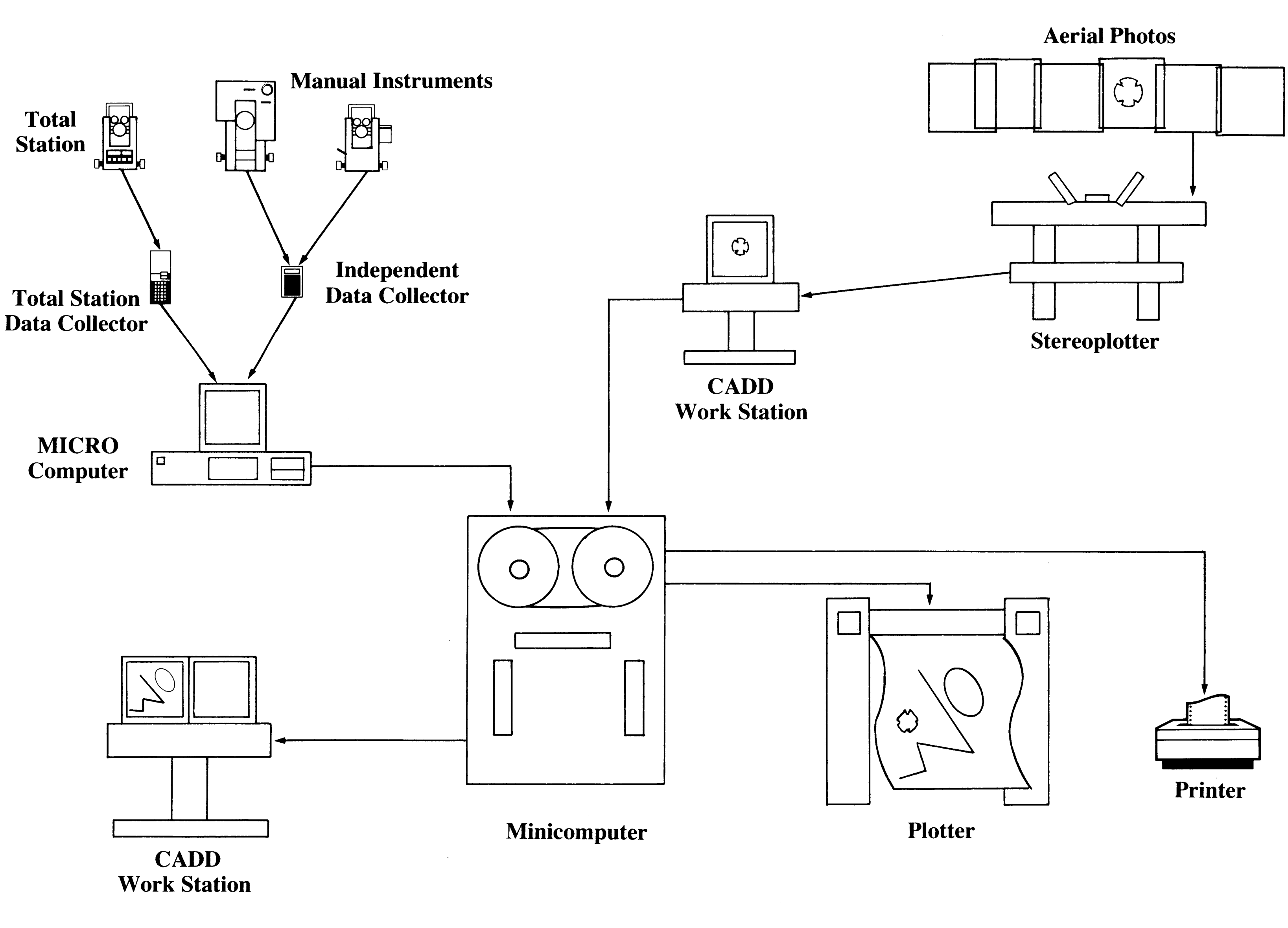


EXHIBIT 5.1
Sample of Documented Monument Reference

EXHIBIT 5.2
Flow Chart of Automated Surveying and Mapping

Automated Surveying and Mapping Data Collection Process



Side Shot Features

Code (a)	Facility
11	Power Pole
12	Telephone Pole
13	Utility Pole
14	Service Pole
15	Underground Power
16	Underground Telephone
17	Underground Water
18	Storm Sewer
19	Sanitary Sewer
20	Underground Gas
21	Street Light
31	Right Edge of Road
32	Left Edge of Road
33	Right Edge of Pavement
34	Left Edge of Pavement
35	Right Edge of Curb
36	Left Edge of Curb
37	Right Edge of Approach Road
38	Left Edge of Approach Road
39	Guardrail
40	Sign
45	Bridge
46	Round Metal Culvert - (size)
47	Metal Pipe Arch - (size)
48	Round Concrete Pipe - (size)
51	House
52	Barn
53	Shed
54	Out Building
55	Well
56	Septic Tank
57	Property Corner
58	Monument
66	Steel Gate - (size)
67	Wire Gate - (size)
68	Wood Gate - (size)
70	Centerline
71	Ditch
72	Edge of Clearing
73	Edge of Water
74	Top of Cut
75	Edge of Pavement
76	Toe of Fill
78	Reference Point (R.P.)
79	Edge of Road
80	Fence

Note: *(a) Unlisted code numbers may be used for site specifics.*
(b) Enter code after shot.

Traverse/Side Shots

Code (a)	INF1	INF2	INF3	INF4
1	Instrument Station	H.I.	Ref. Elev.	
2	Backsight Station	H.I.		
3	Foresight Station	H.I.		
4	Intermediate Station	H.I.		
5	Side Shot Station	H.I.	Feature	Size
8	Boot Amount			

Straight Topog

Code (a)	INF1	INF2	INF3	INF4
6	X-Section Station	H.I.	Offset Distance	Offset Rod
7	Reference Elevation			
8	Boot Amount			
10	Turn (b)			
70	Centerline Shot (b)			
71	Ditch (b)			
72	Edge Clearing (b)			
73	Edge Water (b)			
74	Top of Cut (b)			
75	Edge Pavement (b)			
76	Toe of Fill (b)			
77	Reference Point (R.P.) (b)			
78	Edge Rock (b)			
79	Edge Road (b)			
80	Fence (b)			
			Side	
100	Rod	Dist.	Side	
104	% Slope	S. Dist.	Side	
107	Degree of Slope	S. Dist.		

X-Point Topog

Code (a)	INF1	INF2	INF3	INF4
1	Inst. Station	H.I.	Ref. Elev.	
2	B.S. Station	H.I.		
6	X-Section Station	H.I.	Offset	
8	Boot Amount		Dist.	
70	Centerline Shot (b)			
71	Ditch (b)			
72	Edge Clearing (b)			
73	Edge Water (b)			
74	Top of Cut (b)			
75	Edge Pavement (b)			
76	Toe of Fill (b)			
77	Reference Point (R.P.) (b)			
78	Edge Rock (b)			
79	Edge Road (b)			
80	Fence (b)			

EXHIBIT 5.3
Standard Coding for Data Collection

Survey Weekly Report for Week Ending ____________

Routing
- ☐ Survey __________
- ☐ Design __________
- ☐ Other __________
- ☐ Files __________

Project: ____

Engineer: ____

____
(Type of Survey)

Date Work Began: ____________________ **Length (km):** ____________________

Estimated Completion: ____________________ **Beginning Station:** ____________________

Percent Complete: ______________ **%** **Ending Station:** ____________________

Personnel: ____________ ____________ ____________
____________ ____________ ____________
____________ ____________ ____________

Remarks: ____
____
____

Weather: ____

Safety Meeting: ____

Progress Chart

Description of Work		Percent Complete* 0	10	20	30	40	50	60	70	80	90	100
Brush	________											
Line	________											
Topog	________											
Ties	________											
Row	________											
RP's	________											
Levels	________											
Misc.	________											

*Completed previously - use lower case x
Completed this week - use upper case X

EXHIBIT 5.4 Sample Weekly Report
(page 1 of 2)

Survey Weekly Report for Week Ending ____________

Project: FDR N90 Cougar Wa.

Engineer: Jay S. Worthington

Single Pass Survey
(Type of Survey)

Routing
- ☒ Survey
- ☐ Design
- ☐ Other
- ☒ Files

Date Work Began: 03-09-87 **Length (km):** 24.8

Estimated Completion: 05-12-87 **Beginning Station:** 5 + 450

Percent Complete: 55 % **Ending Station:** 30 + 300

Personnel:

Jay S. Worthington	Glen Kutzera	Daniel Jackson AOP 4/6/87
Jack S. Bright	Barbara Rippey AOP 4/6/87	
David B. Jackson	Barry Marshall AOP 4/6/87	

Remarks: Turned X-line angles X113 to X134 EOP P-line P161 to P434 EOP Chain tied X1 to X134 EOP. Culture taken in conjunction with angles & P-line. Topog P1 to P55.

Weather: Rain all week

Safety Meeting: Safe driving, care of vehicles

Progress Chart

Description of Work	Percent Complete* (0 10 20 30 40 50 60 70 80 90 100)
Brush	
Line	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxXXXXXXXX
Topog	XXX
Ties	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxXXXXXXXX
Row	
RP's	
Levels	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxXXXXXXXX
Misc.	

*Completed previously - use lower case x
Completed this week - use upper case X

EXHIBIT 5.4 Sample Weekly Report
(page 2 of 2)

Report of Survey

Project: ______________________________

State: ______________________ **Time:** ______________

Type: ______________________ **Cost:** ______________

Began: ______________ **End:** ______________ **Engineer:** ______________

Terrain: ______________________________

Cover: ______________________________

Weather: ______________________ **Length:** ______________

Working Hours per Day: ______________________ **Overtime Used:** ______________

Item	Work Hours	Work Hours per km	% of Total Time	Cost per km
Brushing				
Line				
Levels				
Topog				
Ties				
Clearing				
Misc.				
Totals				

Cost of Distribution	
Type	% of Total
Salaries	
Per Diem	
Equipment	
Miscellaneous	
Total	

Remarks:

Engineer: ______________________________
Signature

Date: ______________________________

EXHIBIT 5.5
Sample Report of Survey

U.S. Department of Transportation
Federal Highway Administration

IDENTIFICATION

IF THIS BOOK IS FOUND PLEASE DROP IN
ANY GOVERNMENT MAIL BOX OR POST OFFICE
NO POSTAGE WILL BE REQUIRED

RESERVED FOR PROJECT STAMP

BOOK NO. ____________ **TYPE OF NOTES:** ____________

PROJECT NAME: ____________

ACCOUNT NO. ____________

ROUTE NO. ____________ **SECTION NO.** ____________

COUNTY: ____________ **STATE:** ____________

____________ **LOCATION**
FOREST, PARK, OR OTHER **CONSTRUCTION**

CONTRACTOR: ____________

ENGINEER: ____________ **YEAR:** ____________

This space reserved for headquarters use.

EXHIBIT 5.6
Identification Format for Field Note Books

EXHIBIT 5.7
Sample Page for Recording Field Data
(page 1 of 4)

PAGE

DATE ___________ LINE ____________ PARTY __________

PROJECT

(Back)

PAGE______

U.S. Department of Transportation
Federal Highway Administration

Transit

(Front)

DATE: ________ PARTY: ______________________

LINE: ________ ______________________

PROJECT:

Type of TOPOG
- ☐ Straight
- ☐ Percent
- ☐ Degree

STATION	Elevation		Cross-Section
	GRADE	GROUND	LEFT

(Back)

U.S. Department of Transportation
Federal Highway Administration

PAGE _____

Cross-Section

READINGS		REMARKS AND / OR SKETCHES
℄	RIGHT	

(Front)

EXHIBIT 5.7
(page 3 of 4)

DATE: ______ LINE: ______ PARTY ______

PROJECT ______

(Back)

U.S. Department of Transportation
Federal Highway Administration

Misc. Construction Notes

(Front)

COMPUTER BY: ______ CHECKED BY: ______
DATE: ______ DATE: ______

Field Book Format—Preliminary Survey

A. Introduction
   1. Basis of survey control
      a. Coordinates
      b. Bearing/azimuth
      c. Elevation
   2. Narrative of survey
      a. Describe the type of survey, beginning and ending dates, and the terrain in general.
      b. Describe the major design standards used (horizontal curvature, gradient, typical section).
      c. Describe the control used, the kinds of referencing used, and other features of the survey.
      d. Describe each pass; what was done and the average crew size.
      e. Describe any work not completed or partially completed and reasons for such.

B. Sketches
   1. Control diagram
   2. Control point references
   3. Angle point (P-line) references
   4. Existing structures
   5. Other culture
   6. Miscellaneous

C. Design Data
   1. Classification
      a. Soils (visual). Include cut and fill slope recommendations and shrinkage factors. Note natural angles of repose and the degree of any fracture plans.
      b. Clearing and grubbing (visual). Identify growth (light, medium, heavy). Merchantable Timber?
   2. Recommendations
      a. Design, including horizontal and vertical controls, walls, wet areas, slides, etc.
      b. Drainage, including existing sizes, recommended sizes, existing channel condition, inlet or outlet control, etc.
      c. Existing drainage structures suitable for extension or modification. Show size, type, type of material, size and type of corrugation, length of damaged portion to be removed, slope of bevel, etc.

D. Miscellaneous
   1. Photographs sufficient to cover the entire project without gaps, looking both ahead and back.
   2. Photographs showing specific problem areas of existing structural details.
   3. List of property owners contacted for permission to survey and notes regarding any problems.
   4. Names and titles of other agency personnel contacted.
   5. Copies of deeds and/or plats showing ownership and public rights-of-way.
   6. List of all other rolls, maps, and books used on the survey with a description and file number (if known).

EXHIBIT 5.8
Field Book Format for Preliminary Survey

Field Book Format—Location Survey

A. Introduction
   1. Narrative of survey
      a. Describe the type of survey, beginning and ending dates, and the terrain in general.
      b. Describe the major design standards used.
      c. Describe the control used, the kinds of referencing used, and other features of the survey.
      d. Describe each pass; what was done, and the average crew size.
      e. Describe any work not completed or partially completed and reasons for such.

B. Additional Staking
   1. Describe areas where R/W was staked
   2. Describe area where clearing was staked

C. Sketches
   1. Control point references which were changed or added
   2. Miscellaneous

D. File Data
   1. Names of all files used
      a. Traverse (control and P-line)
      b. Horizontal Alignment
      c. Earthwork Design
      d. Final Topog

E. Miscellaneous
   1. Photographs sufficient to cover the entire project without gaps, looking both ahead and back.
   2. Photographs showing specific problems or conditions.
   3. List of property owners contacted for permission to survey and notes regarding any problems.
   4. Names and titles of other agency personnel contacted.
   5. List of rolls, maps, or other books used on the survey by description and file number (if known).

EXHIBIT 5.9
Sample Field Book Format for Location Survey