

# 11 Engineering Surveys

Engineering surveys gather data for use by planners and engineers. The products resulting from engineering surveys are generally topographic maps and/or a digital terrain model (DTM). Both conventional (on the ground) and photogrammetric methods are used to gather data for engineering surveys. This section provides standards, procedures, and general information for performing conventional engineering surveys using the Caltrans Total Station Survey System (TSSS), GPS, and differential leveling. For a discussion of photogrammetric surveys, see Chapter 13, “Photogrammetry Surveys.”

## 11.1 Responsibilities

Successful engineering surveys require close cooperation between Planning/Design and Surveys.

### **Project Manager**

The Project Manager leads the Project Development Team and is responsible for overall project planning and completion.

It is the responsibility of the Project Manager to:

- Ensure that all survey requests are accurate and specific.
- Obtain right of entry, as needed, for surveys outside existing Caltrans right of way.

### **Project Surveyor**

The Project Surveyor is appointed by the District Surveys Manager to:

- Participate as a member of the Project Development Team.
- Coordinate with other functional areas.
- Review and schedule each engineering survey request.
- Determine the appropriate method to accomplish the requested surveys in cooperation with the project manager.
- Create and maintain a survey project file.

## 11.2 Prejob Meeting

As soon as a project is known, e.g., appears on the Status of Projects Report or an initial survey request is received, the Project Surveyor should schedule a meeting with the Project Manager to discuss anticipated survey requests. The meeting with the Project Manager should cover:

- Project Schedule
- Acquisition of any critical information not included in the initial survey request such as as-builts, alignments, etc.
- Overall project survey needs
- Alternative survey methods
- Safety considerations
- Recommendations for survey methods
- Appointment of Project Surveyor to the Project Development Team
- Surveys that might be eliminated because of existing data
- Accuracy requirements for the survey
- Additional surveys needed (right of way, construction, etc.)

## 11.3 Engineering Survey Request

All engineering surveys are initiated by a written request from the Project Manager or designee. Requests should be directed to the District Surveys Manager or the Project Surveyor if one has been appointed.

Survey requests should contain the following information:

- Requestor's name, phone number, and functional area
- Date of request
- County, Route, and post mile (kilometer post) of beginning and end of project
- Expenditure Authorization (E.A.) and special designation
- Applicable work breakdown (WBS) codes
- Specific date needed (ASAP is not acceptable)
- Description of work requested
- Expected work product
- Sketch of the area to be surveyed showing lateral limits for the survey and beginning and end of work area
- Signature of the Project Engineer or Project Manager (senior level or above)

See Figure 11-1 for sample survey request form.

Survey requests should be date stamped and then reviewed by the District Survey Manager, the Surveys Project Management Coordinator, or the Surveys Request Coordinator.



## 11.4 Planning

Planning begins with the meeting between the Project Surveyor and the Project Manager to discuss the proposed survey request. See Section 11.2, “Prejob Meeting.” From a planning perspective, an important part of this meeting is obtaining information about anticipated future related survey requests for the project. Consideration of future right of way surveys and construction surveys should be part of the planning process so that the most efficient survey work plan for the overall project can be formulated.

A work plan for engineering surveys is prepared by the Project Surveyor. This work plan should contain:

- A list of the required engineering survey products
- A schedule for the requested project surveys, including critical milestones
- Resource needs (personnel, equipment, cash overtime, travel expense)

**Planning may require contact with the following offices:**

<b>Caltrans Program</b>	<b>Information to Request</b>
Permits	Will consultants, contractors, or others be working in or near the project area?
Traffic Operations	What is the average daily traffic, peak hour traffic, and feasibility of traffic controls, including lane and shoulder closures?
Maintenance (Maintenance Engineer or Area Superintendent)	Are lane closures currently planned in the area by Maintenance and, if so, can they be jointly used for the survey effort?
Safety	Advice concerning non-routine safety issues.
Environmental	Information concerning any potential environmentally sensitive aspects.
Hazardous Waste	Does the area contain hazardous waste? Is special training needed?

### 11.4-1 Safety Planning

Safety should be a prime consideration in all survey planning and especially with engineering surveys, which often require work in and around traffic. A key planning consideration is to reduce (minimize) the overall exposure of surveyors to traffic. This can be accomplished in part, by carefully selecting the survey method, choosing the time to perform the survey, and employing special survey techniques. See Section 11.7-3, “Pavement Elevation Surveys – Safety” and Chapter 2, “Safety.”

## 11.5 Research

Research for the engineering surveys should be part of the research for the overall project. Research for engineering surveys and control surveys should be undertaken at the same time.

Identify existing survey control in the area. When necessary, plan a control survey that will meet the requirements of the initial survey request as well as anticipated future project surveying needs. See Chapter 9, “Project Control Surveys.”

Research information in Caltrans files so that all existing aerial photos, topographic mapping, monumentation maps, USGS maps, and as-built plans are identified. This will ensure that work accomplished on a previous project or survey request will not be duplicated.

Search the records and files of other government agencies, utility companies, and railroads for information on facilities located in the project area. Potential agencies include, but are not limited to:

- Federal agencies: Bureau of Land Management, Bureau of Reclamation, Army Corps of Engineers, and U.S. Forest Service.
- Other State agencies: Department of Parks and Recreation, Department of Water Resources, and State Lands Commission.
- Local public agencies: County and city public works departments, transit districts, reclamation districts, flood control districts, public utility districts, park districts, water districts, and community service districts.
- Private utility companies: Railroad, electrical power, telephone, cable TV, natural gas, pipeline companies, and water companies.

Each Surveys Branch should maintain a database of local contacts for survey research efforts. A simple, searchable, digital database can be used for this purpose. Each record should contain the name of the agency or company, address, phone numbers, and the name of contacts. Special care should be taken to keep contacts friendly. Letters thanking cooperative staff go a long way to improving research efforts.

## 11.6 Office Preparation

The Project Surveyor, in consultation with the field supervisor and party chief, is responsible for the development of the necessary instructions and information (field package) for performing the requested engineering surveys. Surveys office staff, under the direction of the Project Surveyor, generally prepare the field package using information obtained from the research, together with other compiled and computed data. The field package should contain all the necessary information and data to efficiently complete the field work required by the survey request. Typical information/data that may be included are:

- Copy of survey request (always included)
- Special instructions including safety and hazardous waste considerations (always included)
- Control diagram and station listing
- As-built plans
- Monumentation and right of way maps and monument listing
- Maps of record
- Utility maps
- Utility easement descriptions
- Data in digital format
  - Control data: descriptions, coordinates, elevations
  - Monumentation data: descriptions, coordinates
  - Topo data: descriptions, coordinates, elevations
  - Alignment data

## 11.7 Field Work

Field work should not be initiated without a completed field package, including survey request form and written instructions designating any special survey needs.

### 11.7-1 General

Data collectors should be downloaded daily. Files should be transferred to a laptop computer hard drive and then backed up to other media. File naming conventions can be used to keep track of raw data files for each day of work for large survey requests. Data files for each job should be located in a job directory. Any comments, descriptions of special circumstances, and narratives of the work should be stored in a subdirectory of the job directory.

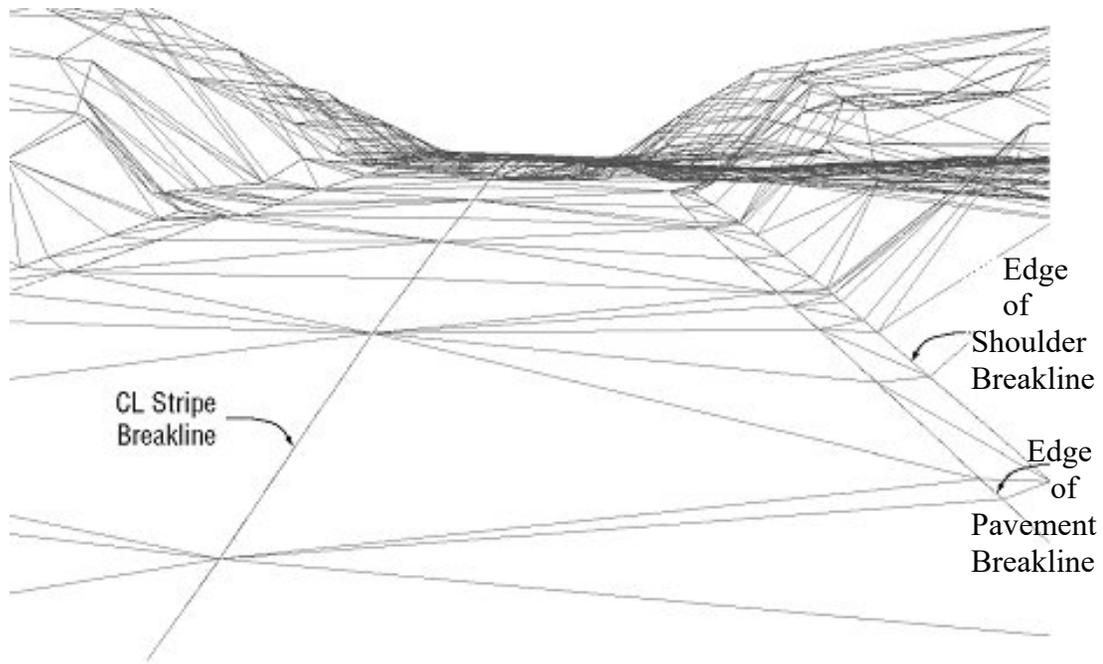
Field crews should check their own work before sending it to the office section. Field crews located in remote areas must check their work before returning to their headquarters office. All work by field crews must be independently checked in the district office. Responsibility for final checking of all survey products, including digital terrain models (DTMs), rests with the district office data processing supervisor.

### 11.7-2 Topographic Survey

Topographic surveys are undertaken to determine the configuration of the earth's surface and the locations of natural and manmade objects and features. The products of topographic surveys, DTMs and topographic maps are the basis for planning studies and engineering designs.

A DTM is a representation of the surface of the earth using a triangulated irregular network (TIN). The TIN models the surface with a series of triangular planes. Each of the vertices of an individual triangle is a coordinated (x,y,z) topographic data point. The triangles are formed from the data points by a computer program, which creates a seamless, triangulated surface without gaps or overlaps between triangles.

Triangles are created so that their sides do not cross breaklines. Triangles on either side of breaklines have common sides along the breakline. (See Figure 11-2.)



**Figure 11-2**

Breaklines define the points where slopes change in grade (the intersection of two planes). Examples of breaklines are the crown of pavement, edge of pavement, edge of shoulder, flow line, top of curb, back of sidewalk, toe of slope, top of cut, and top of bank. Breaklines within existing highway rights of way are clearly defined, while breaklines on natural ground are more difficult to determine.

DTMs are created by locating topographic data points that define breaklines and random spot elevation points. The data points are collected at random intervals along longitudinal break lines with observations spaced sufficiently close together to accurately define the profile of the breakline. Like contours, breaklines do not cross themselves or other breaklines.

Cross-sections can be generated from the finished DTM for any given alignments.

Method: When creating field-generated DTMs, data points are gathered along DTM breaklines, and randomly at spot elevation points, using the TSSS radial survey method. This method is called a DTM breakline survey. Because the photogrammetric method in most cases is more cost effective, gathering data for DTMs using field methods should be limited to small areas or to provide supplemental information for photogrammetrically determined DTMs. The DES/Office of Photogrammetry routinely merges field-generated terrain data (often pavement elevations) with photogrammetric data to produce a DTM.

The number of breaklines actually surveyed can be reduced for objects of a constant shape such as curbs. To do this, a standard cross section for such objects is sketched and made part of the field notes. Field-collected breaklines are identified by line numbers and type on the sketch along with distances and changes in elevation between the breaklines. With this information in the field notes, only selected breaklines need to be located in the field, while others are generated in the office based on the standard cross section.

#### **Advantages of DTM breakline surveys:**

- Safety of field crews is increased because need to continually cross traffic is eliminated.
- Observations at specific intervals (stations) are not required.
- New sets of cross sections can be easily created for each alignment change.

#### **DTM survey guidelines:**

- Remember to visualize the TIN that will be created to model the ground surface and how breaklines control placement of triangles.
- Use proper topo codes, point numbering, and line numbers.
- Use appropriate terrain coding for critical points between breaklines, around drop inlets and culverts, and on natural ground in relatively level areas.
- Do not change breakline codes without creating a new line.
- Take shots on breaklines at approximately 50 foot intervals and at changes in grade.
- Locate data points at high points and low points and on a grid of approximately 50 foot centers when the terrain cannot be defined by breaklines.
- If ground around trees is uniform, tree locations may be used as DTM data points by using appropriate terrain coding.
- Keep site distances to a length that will ensure that data point elevations meet desired accuracies.
- Gather an extra terrain line 15 to 30 feet outside the work limits.

Accuracy Standard: Data points located on paved surfaces or any engineering works should be located within  $\pm 0.03$  foot horizontally and  $\pm 0.02$  foot vertically. Data points on original ground should be located within  $\pm 0.1$  foot horizontally and vertically.

Checking: Check data points by various means including reviewing the resultant DTM, reviewing breaklines in profile, and locating some data points from more than one setup.

Products: The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be kept in digital form and include the following items:

- Converted and adjusted existing record alignments, as requested.
- Surveyed digital alignments of existing roadways and other facilities.
- DTM surface files.
- 3-D CADD Microstation design files, .dgn format.
- File of all surveyed points with coordinates and descriptions. (\*.tss, \*.rpt, or other appropriate format)

### 11.7-3 Pavement Elevation Surveys

A significant portion of today's transportation program consists of rehabilitation and other improvements of existing facilities. For these projects, elevations of existing pavements are often required to develop accurate plans, specifications, and estimates. Because of safety considerations, surveyors need to carefully select methods and procedures for conducting pavement elevation surveys.

Until recently, the only practical method to acquire pavement elevation data was through conventional leveling or TSSS methods. Both of these methods require surveys to be performed in, or adjacent to, moving vehicular traffic and can necessitate the use of temporary traffic controls including lane closures.

Alternate methods for determining pavement elevations, such as remote observations and photogrammetry, are now available and should always be considered. It is the responsibility of the Project Surveyor, in cooperation with the field supervisor and the requesting Project Manager, and with the assistance of Safety, Traffic Operations, Maintenance, and Permits functions, to determine the survey method or system that is most appropriate for a project.

When a request for a pavement elevation survey is received, the Project Surveyor should cooperate with staff from the following functional areas:

Requesting Project Engineer: Determine (a) the overall objectives of the survey, (b) possible areas that can be eliminated to reduce the amount of data collection required and field crew traffic exposure time, (c) realistic delivery times, and (d) the pavement elevation accuracy requirements. Key objective: determine, in cooperation with the Project Engineer, what is the minimal amount of data, if any, that is necessary to obtain a quality design.

- Permit Engineer: Determine if consultants, contractors, or others are, or will be, working near the project location.
- Traffic Operations: Obtain information on average daily traffic, peak hour traffic, and feasibility of traffic controls, including lane and shoulder closures.
- Maintenance: Coordinate survey activities with the maintenance engineer and area superintendent. Determine if maintenance activities, which will require lane closures, are planned for the survey area. Possibly, a maintenance lane closure can be jointly used for the survey effort.
- Safety: Solicit comments and advice from the District Safety Office whenever safety issues arise that are not routine.

**Note:** Remember, the need for a pavement elevation survey should always be questioned. The use of as-built information, existing survey data, or other record data should be considered before performing a pavement elevation survey. Request the Project Engineer to consider alternate design methods or procedures that do not require pavement elevations or require less accurate pavement elevations.

For instance, if concrete barriers will be installed for construction, discuss with the Project Engineer the feasibility of collecting accurate pavement elevations after the barriers are installed, but before establishing (staking) the final grade. With this method, the design is based on available data and then refined based on accurate pavement elevations collected during construction.

### **Safety**

Pavement elevation surveys are one of the most hazardous activities performed by Caltrans surveyors. It is imperative that safe surveying practices be employed for such surveys.

Caltrans Director's Policy Number 03 states in part that "Caltrans conducts its business, provides services, and designs, constructs and maintains facilities in the safest possible manner consistent with applicable laws, rules, and policies."

In accordance with Caltrans "Code of Safe Surveying Practices" (see Chapter 2, "Safety"), safety shall be given top priority in the planning of all surveys. For pavement elevation surveys, a key planning consideration is to reduce (minimize) the overall exposure of surveyors to traffic. This can be accomplished, in part, by carefully selecting the survey method, choosing the time to perform the survey, and employing special survey techniques. In addition, when planning pavement elevation surveys, safety of the traveling public must be a priority consideration.

Prior to commencing each pavement elevation survey, a tailgate safety meeting shall be conducted. All those involved in the pavement elevation survey must participate in the meeting and discuss all safety aspects of the survey. The meeting must be documented.

Close coordination between the Surveys Office and the District Safety Office must be maintained.

**Method:** Innovative methods for pavement elevation surveys have been developed by Caltrans and others. Whenever appropriate, new surveying technologies should be employed to reduce exposure of surveyors to traffic hazards. See Section 11.7-4, "Pavement Elevation Survey Methods."

**Accuracy Standard:** Data points should be located within  $\pm 0.03$  foot horizontally and  $\pm 0.02$  foot vertically.

Checking: Data points are checked by various means including reviewing breaklines in profile and locating some data points from more than one setup.

Products: The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- CAiCE DTM surface files. (CAiCE project subdirectory)
- Files of all surveyed points with coordinates and descriptions. (.tss, .rpt, or other appropriate format)

## 11.7-4 Pavement Elevation Survey Methods

Various pavement survey methods are discussed in detail below to aid in the selection of the best method for a given survey.

### 1. Conventional (TSSS) Survey:

Description: Locate data points on pavement breaklines using a conventional (infrared) total station instrument and the TSSS radial survey method. See section 11.7-2, "Topographic Survey."

Several methods have been used successfully to aid the surveyor to continually monitor traffic while making observations at the edge of a roadway. Two of these methods are:

- Stand to the side of the pavement breakline and hold the prism rod inverted, at an angle, with the prism directly on the pavement surface. The instrument operator sights the center of the prism (height of target measured to center of prism for coaxial instruments).
- Utilize an expendable prism (sign reflector) mounted in a small (2.5" diameter) piece of material from a cone base. The expendable prism is placed directly on the point of observation, and the instrument operator sights as noted above. A disadvantage of this method is that if the prism is destroyed, debris may be left in the roadway.

The main disadvantage of the conventional total station DTM breakline method is that it normally cannot be used to obtain interior breakline elevations (e.g., crown lines) without lane closures.

Production: Production varies depending on traffic, road profile, and number of breaklines. A four-person survey party is recommended. In light-to-moderate traffic, 200 to 300 observations per day can be expected. This equates to 3500 feet to 5000 feet per day of roadway, with four to five pavement breaklines. Production is reduced significantly by heavy traffic conditions and complexity of highway cross sections. Additional breaklines significantly reduce production. Survey costs increase significantly if lane closures are necessary.

## 2. **Reflectorless Total Station Remote Observations:**

Description: Locate data points on pavement breaklines optically using a reflectorless (laser) total station instrument and TSSS radial survey method. See section 11.7-2, “Topographic Survey.”

Employing reflectorless (laser) total station technology generally requires the instrument to be set up in high locations where it can aim down on the pavement.

- The instrument operator sights and measures directly to the pavement surface near the edge of pavement. Spacing between measurements is estimated by the instrument operator.
- Additional measurements can be taken on interior pavement breaklines.

The main disadvantage to the Reflectorless DTM breakline method is that the maximum sight distances are more restrictive than conventional infrared total station surveys, and set-ups which are not sufficiently elevated may result in less accurate laser measurements. Checks to measurements taken to a prism using infrared are advisable.

Production: Production varies depending on traffic, road profile, and number of breaklines. A four-person survey party is recommended. In light-to-moderate traffic, 150 to 250 observations per day can be expected. This equates to 2500 feet to 4000 feet per day of roadway, with four to five pavement breaklines. Production is reduced significantly by heavy traffic conditions and complexity of highway cross sections. Additional breaklines significantly reduce production. Survey costs increase significantly if lane closures are necessary.

### 3. **Vehicle Mounted Total Station Remote Observations:**

Description: This system allows DTM data to be collected remotely from a survey vehicle (van) located on the shoulder of a roadway using a reflectorless total station mounted in a turret. During data collection operation, the van proceeds in a “stop-and-go” process with each stop lasting five to ten minutes while observations are conducted for 100 feet to 300 feet of roadway. Use of the system is dependent on availability of a firm or paved shoulder wide enough for the van to provide separation from traffic. Accuracy of survey data points is within 0.02 foot.

Surveys can be performed with this system without surveyors working in traffic using minimal traffic control (except in the case of ramp gores and bridges). The system does require a previously densified control network and movement of sights.

Production: Once the monumentation for the primary control is set, production rates of 3500 feet to 5000 feet per day can be expected for 4 to 5 breaklines (one roadway). Additional lines do not significantly increase overall time as long as the lines are on the traveled way.

### 4. **Terrestrial Laser Scanning Surveys:**

Description: This system allows DTM data to be collected by a tripod-mounted or vehicle-mounted laser scanner. The scanner uses Light Detection and Ranging (LIDAR) to take thousands of measurements per second creating a very dense “point cloud” of data. The resulting information is extremely detailed. Multiple scans or “point clouds” can be combined in the office. Individual data points are selected to create a DTM model, mapping of planimetric features, and other products.

The Office of Land Surveys is currently evaluating this technology.

## 11.7-5 Utility Surveys

Utility surveys are undertaken to locate existing utilities for (a) consideration in engineering design, (b) purposes of utility relocation, and (c) right-of-way acquisition and negotiation.

Survey limits and types of utilities to be located should be shown on the Survey Request and/or its attachments. The field survey file should include all utility maps and drawings and descriptions of easements.

For additional information, refer to the *Project Development Procedures Manual, Appendix LL: Policy on High and Low Risk Underground Facilities Within Highway Rights of Way*.

It is important to locate all significant utility facilities. The following are lists of facilities and critical points to be located for various utilities. Be sure to check the field package for any required special facilities not listed. Underground utilities should be potholed only if specifically requested on the Survey Request. Potholing is to be undertaken by the utility company.

### Oil and Gas Pipelines

- Intersection point with centerlines and/or right of way lines
- For lines parallel to right of way – location ties necessary to show relationship to the right of way lines
- Vents
- Angle points
- Meter vaults, valve pits, etc.

### Water and Sewer Lines

- Intersection point with centerlines and/or right of way lines
- For lines parallel to right of way – location ties necessary to show relationship to the right of way lines
- Manholes, valve boxes, meter pits, crosses, tees, bends, etc.
- Elevation on waterlines, sewer inverts, and manhole rings
- Fire hydrants
- Curb stops

**Overhead Lines**

- Supporting structures on each side of roadway with elevation of neutral or lowest conductor at each centerline crossing point.
- On lines parallel to roadway, supporting structures that may require relocation, including overhead guys, stubs, and anchors.

**Underground Lines**

- Cables/lines (denote direct burial or conduit, if known), etc.
- Manholes, pull boxes, and transformer pads
- Crossing at centerline or right of way lines
- For lines parallel to right of way – location ties as necessary to show relationship to the right of way lines

**Railroads**

- Profile and location 200 feet each side of the proposed roadway right of way lines.
- Switch points, signal, railroad facilities, communication line locations, etc.

Method: TSSS radial survey, GPS fast static, kinematic or RTK.

Accuracy Standard: Data points located on paved surfaces or any engineering works should be located within  $\pm 0.03$  foot horizontally and  $\pm 0.02$  foot vertically. Data points on original ground should be located within  $\pm 0.1$  foot horizontally and vertically.

Checking: Utility data should be checked by the following means:

- Compare field collected data with existing utility maps
- Compare field collected data with the project topo map/DTM
- Review profiles of field collected data
- Include field collected data, which have elevations, in project DTM
- Locate some data points from more than one setup

Product: The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- DTM surface files (within project subdirectory)
- 3-D digital topographic map (\*.dgn, format)
- Hard copy topographic map with border, title block, labeled contours, and planimetry
- File of all surveyed points with coordinates and descriptions (\*.tss, \*.rpt, or other appropriate format)

### 11.7-6 Archaeological Site/Environmentally Sensitive Area Survey

Archaeological and environmental site surveys are performed for planning and engineering studies. Survey staff must work closely with the appropriate specialists and the survey requestor to correctly identify archeological and environmentally sensitive data points.

Method: TSSS radial survey, GPS fast-static, kinematic or RTK

Accuracy Standard: Data points located on paved surfaces or engineering works should be located within  $\pm 0.03$  foot horizontally and  $\pm 0.02$  foot vertically. Data points on original grounds should be located within  $\pm 0.1$  foot horizontally and vertically. Review field survey package for possible higher required accuracy.

Checking: Check data points by various means including, reviewing the resultant DTM, reviewing breaklines in profile, and locating some data points from more than one setup.

Product: The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- 3-D digital graphic file of mapped area (\*.dgn, format)
- Hard copy topographic map with border, title block, and planimetry (contours and elevations only if specifically requested)
- File of all surveyed points with coordinates and descriptions (\*.tss, \*.rpt, or other appropriate format)

### 11.7-7 **Spot Location or Monitoring Surveys**

Monitoring surveys are undertaken for monitoring wells, bore hole sites, and other needs.

Method: TSSS radial survey, GPS fast static or kinematic

Accuracy Standard: Data points located on paved surfaces or any engineering works should be located within  $\pm 0.03$  foot horizontally and  $\pm 0.02$  foot vertically. Data points on original ground should be located within  $\pm 0.1$  foot horizontally and vertically.

Checking: Observe data points with multiple ties. See Section 7.4-2 “TSSS Specifications - Methods.”

Product: The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- File of all surveyed points with coordinates and descriptions (\*.tss, \*.rpt, or other appropriate format)
- Sketch or map showing locations of data points

### 11.7-8 **Vertical Clearance Surveys**

Vertical clearance surveys are undertaken to measure vertical clearances for signs, overhead wires and bridges.

Method: TSSS radial method.

Accuracy Standard: Data points located on paved surfaces or any engineering works should be located within  $\pm 0.03$  foot horizontally and  $\pm 0.02$  foot vertically. Data points on original ground should be located within  $\pm 0.1$  foot horizontally and vertically.

Checking: Observe data points with multiple ties. See Section 7.4-2 “TSSS Specifications – Methods.”

Product: The Surveys Branch is responsible for developing and delivering final, checked engineering survey products, including DTMs, to the survey requestors. Products can be tailored to the needs of the requestor whenever feasible, but normally should be in digital form and include the following items:

- File of all surveyed points with coordinates and descriptions (\*.tss, \*.rpt, or other appropriate format)
- Sketch or map showing vertical clearances

## 11.8 Office Data Processing

Data processing includes preparing and checking survey products for delivery to the survey requestor. Processing, editing, and transferring data is all done using data processing programs. Supplemental control established during the engineering survey must be adjusted by least squares constrained to existing project control before calculating coordinates for topographic data points.

### 11.8-1 DTM Processing

The primary steps in processing a DTM are:

1. Create a survey database file within the data processing software, adjust control network, compute adjusted coordinates (x,y,z) for all DTM data points, edit known coding problems and create a Total Station Survey (\*.tss) file.
2. Review .tss file to verify checks shots and validate field procedures such as proper entry of instrument and prism height.
3. Import the \*.tss file into a DTM program.
4. Check the survey chains (DTM breaklines) in plan and profile for errors: incorrect positions, points skipped, crossing breaklines, and mislabeled data.
5. Generate parallel breaklines from standard cross sections in survey notes: for instance, from measured curb flowline, generate lip and top of curb.
6. Create DTM surface database, calculate DTM triangles, compute DTM contours.

7. Check the DTM by creating either “freehand” or regular interval cross sections from the DTM contours.
8. Return to step 1 and make corrections to database noted from steps 3-7 and create corrected \*.tss file. Repeat steps 3-8 as necessary.
9. Import corrected \*.tss file into DTM program on workstation.
10. Repeat steps 4-7 as necessary, making any needed corrections.

Steps 1-8 are normally done on a PC either in the office or field. Steps 9-10 are done on the office workstation.