Route Survey Manual
State of Vermont
Agency of Transportation
Version 2008

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OVERVIEW

This manual covers route surveying work performed for the Agency and the management of data used by the Agency. It is written primarily for Agency party chiefs and supervisors. It also serves as a reference for setting the technical requirements of consultant contracts and as a reference for consultant party chiefs.

The manual focuses on equipment used by the Agency's route survey crews, such as total stations and data collectors, but it includes other types of equipment, such as automatic levels. Because the manual is written for party chiefs and supervisors, rather than for crew members, the manual emphasizes standards and guidelines and excludes almost all elementary concepts, details of field methods, rationales for and details of calculations and adjustments, etc.

Typical Work

Survey requests for roadway design, structures, and construction account for nearly all of the work performed by the Route Survey Unit. Other work includes:

- Railroad crossings and airport surveys
- Retracement of right-of-way surveys for State highways
- Property surveys for Agency land
- Boundary surveys as requested by the Attorney General or Secretary of State, such as determining county or State lines and verifying the presence of monuments along boundaries
- Representing the Agency on survey matters in courts of law
- Processing 3D survey files for the requestor
- Maintaining survey CADD files

Aerial photography is not used by the Route Survey Unit. If a consultant uses aerial photography, the Geodetic Survey Unit provides control

Metric Use

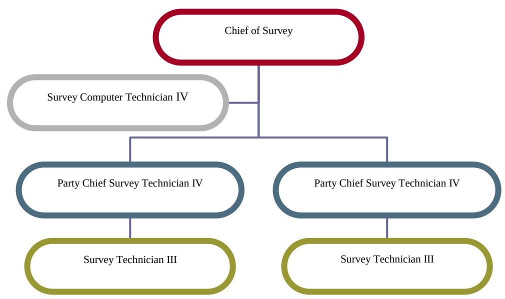
It is the intention of the Agency to use English Survey foot measurements unless there is an overriding reason to do otherwise.

INTERNAL ORGANIZATION AND RESPONSIBILITIES

The Route Survey Unit is headed by the Chief of Survey and is supported by a survey computer technician and two or three survey crews, each made up of a party chief and a survey technician. The organization chart for the Unit appears in Figure 1-1.

The Chief of Survey assigns work based on the priorities of the outstanding requests for survey. Party chiefs are responsible for submitting all completed survey information to the survey computer technician for checking and processing.

Figure 1-1. Route Survey Unit Organization Chart



PUBLIC RELATIONS

Gaining Access to Private Property

Before entering private land for survey work, it is the party chief's responsibility to attempt to contact each property owner and request permission for entry. Any special information, such as contacting property owners by phone before working, is given in the request for survey.

There are certain steps you should follow when introducing yourself to a property owner. If you have an ID card, present it to the property owner. Otherwise give your name, job title, and the agency for which you work. Next, tell the owner why you are there and the nature of your work. Then ask permission to enter. Although most people know that they cannot legally refuse you, they appreciate being asked. Remember, your visit may be the first contact the owner has with the Agency. The impression you make will be the basis of the property owner's reception of future Agency employees and contractors.

Be sure to point out that your job is simply to collect information. The information will then be used by decision makers and designers to determine the location of the road, bridge, bike path, etc. Do not offer any "unofficial" guesses as to where something will be built. However, take time to explain how traverses and geodetic points are used if the owner is trying to find out more about what you are doing.

Be courteous at all times. If the property owner presses for more information regarding future construction, provide the name and phone number of the contact shown on the request for survey. If you are refused entry, leave. Then notify the Chief of Survey. Rarely, and only as a last resort, use the current "Letter to Property Owners" shown in Figures 1-2 and 1-3, to gain entrance to the property.

On large projects, where many property owners will be affected, it’s a good idea to notify town officials of the upcoming survey work. Property owners may be more receptive to your presence when they expect to see you.

Dealings with the Media

Follow the same conduct with the media as with a property owner. Never speculate about the possible location of future construction.

Respect for Private Property

Always treat private property in the way you want others to treat your property. To that end, use roads if they are available. If off-road travel is necessary, avoid driving through wet areas to prevent ruts.

Cut and trim as few trees as possible. Stack cut brush neatly but not in an area where livestock graze—cut brush can cause injury or death to livestock if consumed. Also, be sure to close gates behind you to prevent livestock from escaping.

Avoid cutting, trimming, or harming ornamental or shade trees, hedges, and other plants near a residence. Report the extent of any damage caused by the survey crew, in writing, to the Chief of Survey.

To prevent damage to vehicle tires, countersink hubs and iron pins in and along roadways. Always check the area before leaving to be sure nothing is inadvertently left behind. Hubs, iron pins, nails, and the like can cause damage to vehicles and farm equipment and can cause injury or death to livestock.

Accessing Railroads and Airports

Always notify the appropriate railroad company or airport manager before arriving and when leaving. Make a list of the phone numbers of all railroad companies and airports and keep it up to date. Contact the appropriate Rail, Air, or Public Transportation unit for more information.

Figure 1-2

Letter to Property Owners—Front Side

STATE OF VERMONT
Agency of Transportation
Program Development Division
1 National Life Drive, 4th Fl/
Montpelier VT 05633

Dear Property Owner:

This will introduce who is employed by the Agency of Transportation, State of Vermont.

The Agency of Transportation is conducting an engineering and/or property survey for a proposed public project and needs to have its surveying personnel enter upon your lands for that purpose, as permitted by statute. An extract of the pertinent statutes is shown on the attached sheet.

Federal and State regulations require the Agency to obtain comment from property owners, local officials and other interested people before deciding upon the final details of a project. The survey is intended to give our personnel a complete picture of the area so they can determine with some accuracy what effects of the project will be.

Please understand that the stakes as set out by Survey personnel may only be a reference line for surveying purposes.

We appreciate your cooperation and assistance and hope that the results of the survey will be helpful to you and your neighbors when the time comes to decide on the project's location and scope.

If you desire additional information, please feel free to telephone me at (802) 828-_____

Sincerely,

Director of Program Development

Attachment

Vermont is an Equal Opportunity Employer

Figure 1-3

Letter to Property Owners—Back Side

TITLE 19, VERMONT STATUTES ANNOTATED

Section 35. Entrance upon lands for survey.

Employees or agents of the agency, a municipality, or a utility authorized by law shall be allowed to enter a property for the purpose of making the necessary surveys and examinations for construction of or improvements and repairs to transportation and utility facilities, doing as little damage as possible, subject to liability for actual damages. Whenever practicable, advance notice of the proposed survey or examination shall be given to the owner or occupant of the property to be entered. No owner or occupant of property entered upon under authority of this section shall be liable for any property damage or personal injury resulting from work done by the agency, a municipality or a utility under authority of this section.

TITLE 19, VERMONT STATUTES ANNOTATED

Section 502(a). Authority; precondemnation procedure.

The transportation board, when in its judgment the interest of the state requires, shall request the agency to take any land or rights in land, including easements of access, air, view and light, deemed necessary to lay out, relocate, alter, construct, reconstruct, maintain, repair, widen, grade, or improve any state highway including affected portions of town highways. All property rights shall be taken in fee simple whenever practicable. In furtherance of these purposes, the agency may enter upon land adjacent to the proposed highway or upon other lands for the purpose of examination and making necessary surveys. However, that work shall be done with minimum damage to the land and disturbance to the owners.

TITLE 19, VERMONT STATUTES ANNOTATED

Section 4. Right of entry for survey.

In cases wherein the title to lands, tenements or hereditaments may come in question, or in order to establish boundaries between abutting parcels, a licensed surveyor with the necessary assistants employed by any of the parties to such disputed title, may enter upon such lands or real estate or other lands for the purpose of running doubtful or disputed lines and locating or searching for monuments, establishing temporary monuments and ascertaining and deciding the location of the lines and monuments of a survey, doing as little damage as possible to the owners of such lands.

TITLE 19, VERMONT STATUTES ANNOTATED

Section 651. Exercise of right of eminent domain.

The agency or a town, city or village which is authorized, in accordance with the provisions of this part of this title or special legislation, to acquire, maintain and operate an airport, landing field, or air navigation facility, or two or more municipalities which are authorized, whenever it is necessary to acquire property within this state or some easement or other right in property in order that it may render adequate service to the public in the operation of an airport, landing field, or air navigation facility may acquire by eminent domain in the manner provided in this subchapter, such property or right either within or without its territorial limits, or both, as provided by legislation, for the construction, establishment, enlargement or improvement of an airport, landing field or air navigation facility.

VEHICLE RULES AND REGULATIONS

Refer to Administrative Bulletin No. 2.3 for rules and regulations concerning the use of state-owned and privately owned vehicles. The Agency's *Policies and Procedures Manual* and *Safety Manual* also contain important information regarding vehicle use.

The State may not be required to reimburse you for personal injury, property damage, and liability when you are involved in an accident while using a privately owned vehicle for State business.

SAFETY

All employees, and consultants working on State projects, should be familiar with the *Safety Manual*. In addition, there are a number of safety issues of particular interest to survey crews that are addressed here and referenced in other documents.

Working near the Traveled Way

When working near any roadway, wear a safety vest or VAOT-approved brightly colored clothing. When possible park the survey vehicle off the traveled way and use the vehicle's strobe lights. If a lane closure is required, contact the district maintenance office for assistance.

Personal and Protective Equipment

Different job conditions require different personal protection, so plan ahead and use common sense. A few examples follow:

- When working close to the traveled way, wear a safety vest and use signs in accordance with the *Worksite Traffic Control Manual*.
- If you are allergic to poisonous plants, such as poison ivy, dress so that your skin is covered as much as possible.
- In cold weather, wear multiple layers of clothing, with the outermost layer loose, so that your freedom of movement is not hindered.
- Plan your work so that you are not in wooded areas during deer hunting season. If that's not possible, wear brightly colored clothing.
- If you are working on a construction project, dress appropriately as required by the resident engineer.

Always be sure that a fully stocked first aid kit is stowed in the survey vehicle.

Tools and Equipment

As a member of a survey crew, you should observe the following general rules:

- Do not carry unguarded, sharp-edged or pointed tools in your pocket.
- Store all tools in a well-designed compartment in the vehicle, separate from crew members.
- Be sure that the area is clear of other people before swinging any tool.
- Always use sharp tools to prevent rebounding.
- Stay at least 10 feet from other people when cutting brush.
- Always chop away from the body.

- Clear small vegetation before clearing larger vegetation.
- Be sure you have firm footing before swinging any tool.
- Keep your eyes on the spot you are cutting or chopping.
- Keep all sharp tools in a sheath when not in use.
- Make sure the head of an axe or maul is tight on the handle before using it.
- Avoid chopping frozen wood or knots.
- When trimming limbs from a fallen tree trunk, stand to the side of the tree opposite the limb.
- Hold the brush hook like you would an axe, except keep your upper hand a little more toward the cutting edge to give you better balance when making a low cut.
- Strike at the base of plants when using a brush hook.
- Carry a brush hook like you would an axe. Keep your hand close to the head. Always point the head to the front and never carry a brush hook on your shoulder.
- Comply with all instructions on the labels of spray paint cans.

Dig Safe

Contact Dig Safe (1-888-344-7233) at least 48 hours before you need to drive any items longer than 1 foot into the ground. You may also have to contact utility companies that are not part of Dig Safe.

If you are unsure of the presence of utilities, use wooden hubs or reinforcing bars less than 1 foot long.

Color Code for Marking Underground Utility Lines

- **Red** Electric
- **Yellow** Gas-Oil-Steam
- **Orange** Communication CATV
- **Blue** Potable Water
- **Purple** Reclaimed Water
- **Green** Sewer
- **Pink** Temporary Survey Markings
- **White** Proposed Excavation

Electrical Hazards

Always be aware of your surroundings. Power lines can be overhead, underground, and attached to buildings. Regard all power lines as dangerous and high-voltage lines as extremely dangerous. Electricity can arc from high-voltage lines at a ratio of 1 inch for every 1000 volts.

When you have to survey near power lines, all equipment should be at least 10 feet away from the nearest line. Never make direct measurements of the height of a power line. Use triangulation or a range finder.

If you get caught in an electrical storm, discontinue working and:

- Avoid touching metallic objects.
- Keep away from wire fences, telephone lines, metal tools, rivers, and lakes.
- Avoid tops of ridges, hilltops, wide-open spaces, ledges, and outcrops of rocks.
- Sit or lie down if you are in open country.
- Don’t group together.
- Avoid large or isolated trees, caves, and ledge overhangs.
- Get away from horses and livestock.
- Get into the cab of a rubber-tired vehicle, if possible.
- Choose building shelters if available, but avoid small sheds in exposed locations.
- Seek shelter in dense woods, a depression in the ground, or a deep valley.

If you are outside on a humid day when a thunderstorm threatens and you notice a sensation that your hair is beginning to stand on end, there is a high potential for a lightning strike; lie down quickly in a ditch or depression.

Restricted Areas

In accordance with Route Survey Unit policy, do not enter confined spaces (see VOSHA Regulation 1910.146). Confined space means a space that:

1. Is large enough and so configured that an employee can bodily enter and perform assigned work.
2. Has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
3. Is not designed for continuous employee occupancy.

If you have any questions concerning confined spaces, contact the VAOT Safety Officer.

Wooded Areas

There are a number of safety hazards in wooded areas: barbed wire fences; bee, hornet, and wasp nests; snakes; spiders; and poisonous plants. To avoid these hazards, expect the unexpected and avoid sitting on the ground or on logs. Additionally, avoid moving or disturbing rocks, stumps, and leaves. All of these can hide yellow jacket nests and poisonous snakes and spiders. You should also inspect your clothing and hair from time to time for ticks. These are especially abundant in trees, grass, weeds, and pastures. Avoid strange-acting animals because of the potential for rabies.

Ledges

Stay completely away from the tops of ledges in the winter and avoid wet ledges at all times. If you have to be out on a dry ledge, stay away from loose material. Use a hard hat, safety line, and harness, when necessary.

Water

- Take small steps and make sure you have a good footing whenever working in water or wetlands.
- Avoid entering any body of water with a strong current.
- Avoid walking on ice-covered streams, ponds, or lakes unless the ice is at least 3 inches thick. If you fall through the ice, put your arms on solid ice, kick to keep your body level, crawl forward on your stomach until your hips reach the ice, then make a quick full-length roll onto the ice. Keep rolling until you are safe. If the ice is too thin to support you, break away the ice toward shore with one hand and support yourself with the other.

Railroads

Prior to working on or around any rail a railroad Clearance Form needs to be filed with the rail section and appropriate railroad line. This form can be acquired from the Agency Rail Operations section.

Keep metallic objects away from railroad tracks because they may activate the signals.

Always be alert for oncoming trains. Never crawl under stopped cars and do not cross tracks between cars—they may move at any time.

Do not leave stakes protruding above ground within 12 feet of the track centerline, and do not park vehicles within 25 feet of the tracks.

Also keep in mind that different colors mean different things to different railroad companies. Orange, for example, may mean “remove rail.” If you are unsure of the colors to use, discuss the matter with the railroad company before you begin work.

Airports

Always notify the airport manager before arriving. Find out where you should and should not drive and whether to use the strobe lights on the vehicle. These procedures vary from one airport to another.

Accident and Injury Reporting

Refer to the *Safety Manual* for details concerning accident and injury reporting. Remember, all accidents and injuries must be reported within 72 hours.

MANAGEMENT

Almost all route survey work follows this sequence:

1. A request for survey is given to the Route Survey Unit.
2. The Route Survey Unit requests control from the Geodetic Survey Unit.
3. The Route Survey Unit requests existing information from the Right-of-Way Section.
4. The Route Survey Unit requests an account for the survey from the Computer Aided Design Section.
5. The Route Survey Unit replies to the request for survey with a time and cost estimate for the survey.

6. The district maintenance office is notified that the surveyors will be performing a survey for a certain project.
7. Depending on the nature of the work (wetlands, historical sites, etc.), the Route Survey Unit may also request information from other agencies or notify them of the impending survey.
8. The party chief meets with the requestor before performing the survey to review the request.
9. The Route Survey Unit completes the survey.
10. The Route Survey Unit processes the survey files (creates the model, etc.).
11. The Route Survey Unit transfers the survey to the requestor.

Request for Survey

The request for survey is a four or five page submittal consisting of a cover sheet, project details, to include project limits sketch of area and a town map (see Figures 1-4 through 8). The cover sheet lists any special job requirements, the survey method and units to be used, the date the survey should be completed, and the contact personnel. The project details include location information, the project number, the accounting number, pin number (NO exceptions if programed) any additional notes, and funding information. The town map is a standard Agency map detailing all roads, bridges, and other features in the project area.

Request for Horizontal and Vertical Control

After receiving the request for survey, the Chief of Survey requests the Geodetic Survey Unit to furnish horizontal and vertical control. This request identifies the town, project number, route number, bridge number, and a USGS map with the project location defined (see Figure 1-9).

The Geodetic Survey Unit returns adjusted coordinates (Figure 1-10), and monumentation and marker information (Figures 1-11 through 14).

Request for Right-of-Way Information

After receiving the request for survey, the Chief of Survey requests the Right-of-Way Section to furnish right-of-way information in the area of the project. This request identifies the town; project number, PPMS number, the route number, and the expected start date of the survey (see Figure 1-15).

Reply to Request for Survey

After receiving information from Geodetic Survey and Right-of-Way, the Chief of Survey responds to the requestor with an estimate of time and money needed to complete the survey (see Figure 1-16).

Processing of Survey Files

After a survey is complete, the party chief checks and edits the files collected in the field. The files include:

- Raw data file (electronic field book file)
- A legal file that has not been edited
- Coordinate file (points and descriptions)

The party chief may have other material to submit, such as photographs, horizontal and vertical control information, reference files for wetlands or changes and additions, etc. After completion of fieldwork editing, the survey personnel create a model and check it for quality control.

Survey Transfer

When the survey is complete, transfer the survey to the requestor by memo. Include in this memo the type of survey and units used, identification of horizontal and vertical datum, and the titles of all computer files (see Figure 1-17).

Survey Crew Report

Be sure to fill out the survey crew report (see Figure 1-18) every day and submit it weekly. Number the cards sequentially in the upper right-hand corner of the card for each project.

For centerline surveys, record station information in the section of the card above “Remarks.” Use the “Remarks” section to list property owner contacts and other pertinent information. Use the back of the card, if necessary.

Enter the hours worked each day. Commuting time may be included on Monday and Friday if travel on State time is authorized.

Enter the hours worked to the nearest 15 minutes for each crew member.

Figure 1-4

Request for Survey—Cover Sheet

AGENCY OF TRANSPORTATION **STRUCTURES SECTION**

TO:_______________, Chief of Survey

FROM:_______________, Structures Engineer

DATE: *June 10, 1996*

SUBJECT: **SURVEY REQUEST:** *Hardwick TH3-9526 T.H. 29 BR#9*

Please provide us with necessary survey on the above referenced project. We are currently planning to (replace, widen, rehabilitate) the structure at this site.

The survey chief should check with DTA, ________ before starting the survey in order to determine if any extenuating circumstances exist. A copy of this memo is being sent to the DTA so that he/she will have comments ready for the survey crew chief.

A copy of this memo is being sent to ____________, Hydraulics Engineer, so that he can identify the site relative to NAVD88 Elevation Datum.

The survey request form and copy of the town map are attached. The town map is marked up in red showing the location of the above project for your information and use.

The project (~~is~~) (is not) programmed for Federal funding.

We would like this survey completed and returned to us by *7-17-96* in order to maintain the current project schedule. If you find that you will be unable to comply with this request, or if you find you have additional questions concerning the work required, please contact __________ __________ in the Structures Division.

Thank you for your assistance with this project.

Surveying Method:

[ ] **Conventional Station/Offset Survey**
[X] **Total Station Survey**

[X] **English**
[ ] **Metric**

cc: ________________, Hydraulics Engineer
________________, DTA, District
File

Figure 1-5

Request for Survey—Details

VERMONT AGENCY OF TRANSPORTATION—ROUTE SURVEY UNIT

3 **SURVEY REQUEST**

ROUTE: *T.H. 29* MM: — to — TOWN: *Hardwick*

BRIDGE: *9* LENGTH: *14.25 m* PROJECT: *TH3-9526*

LOCATION: *In Hardwick on T.H. 29* PPMS NUMBER: *95J308*

1 KM northeast of intersection with T.H. 3 REQUESTED BY:__________

ASSIGNED TO:__________

DISTRICT: *7*

FOR INFORMATION SEE:__________

WORK REQUIRED :(Sketch Attached) *New Structure*

NOTES: *300 ft either side of bridge and necessary intersections. Channel for 120 ft upstream and downstream of existing bridge.*

FUNDING INFORMATION

EA/SUBJOB#: *139526-100* ACTIVITY: *2110* P.C.:_____ DIST:_____ TOWN:__________

DATA: VERTICAL NAVD 19_____;_____ HORIZONTAL DATUM NAD 19_____;______

TERM: SHORT______LONG______MONTPELIER TO PROJECT:____________________MILES

CREW DAYS—ESTIMATED:________ACTUAL:__________NOTES:________________

WORK STARTED:__________________ WORK ENDED:________________________

LENGTH:_______________TOPO POINT______________________to_________________________.

PROJECT TYPE:____

NOTES:____.

Figure 1-6

Request for Survey-Map

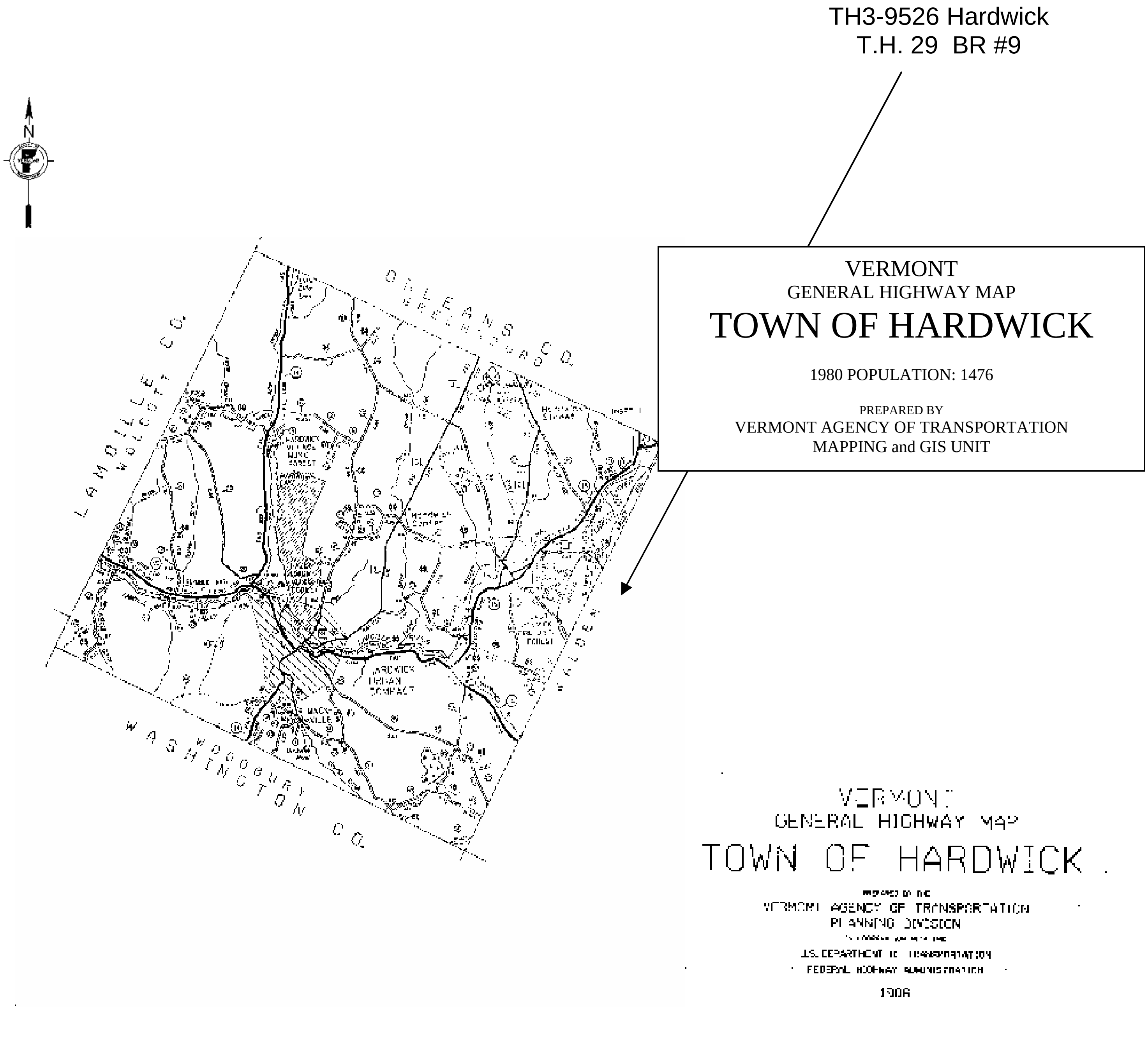
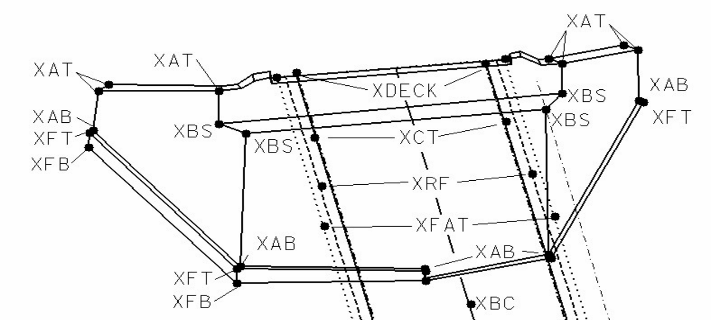


Figure 1-7

Point Location – Bridge Abutment



Deck:

- X (XDECK) Deck Begin & End
- ☐ (XBC) Bridge Center
- X (XRF) Rail Face
- X (XCT) Curb Top
- X (XCB) Curb Bottom
- ☐ (XFAT) Fascia Top
- ☐ (XDRAIN) Bridge Drain
- ☐ Bridge Joints

REMARKS:

Abutment:

- X (XAT) Abutment Top
- X (XAB) Abutment Bottom
- X (XBS) Bridge Seat Elevation – Back **Visual Only**
- ☐ (XBS) Bridge Seat Elevation – Back - ** Computed XBS Location **
- X (XBS) Bridge Seat Elevation – Front
- ☐ Bridge Seat Step
- X (XFT) Footing Top
- ☐ End WW Location & Elev.
- X (XFB) Footing Bottom

REMARKS:

Bridge Support – Member Features:

- X (XST) Support Top (Bearing)
- ☐ (XSB) Support Bottom (Bearing)
- X (XBIB) Bottom of Iron / steel beam
- ☐ (XTIB) Top of Iron / steel beam
- ☐ Number of Diaphragms

REMARKS:

Pier Features:

- X (XPT) Pier Top
- X (XPB) Pier Bottom
- X Pier Bottom Footing
- ☐ (XPF) Top of pier at fascia
- X Pier Bridge Seats
- ☐ Size of Columns and Location
- ☐ Pier Seat Steps

REMARKS:

Miscellaneous Bridge Features:

- ☐ **(XSF) Special Feature**
- ☐ Clearance for Bridge over Road
- ☐ **(XOT) Opening Top (Box Culvert)**
- ☐ (XOB) Opening Bottom (Box Culvert)

REMARKS:

Figure 1-8

Site Sketch

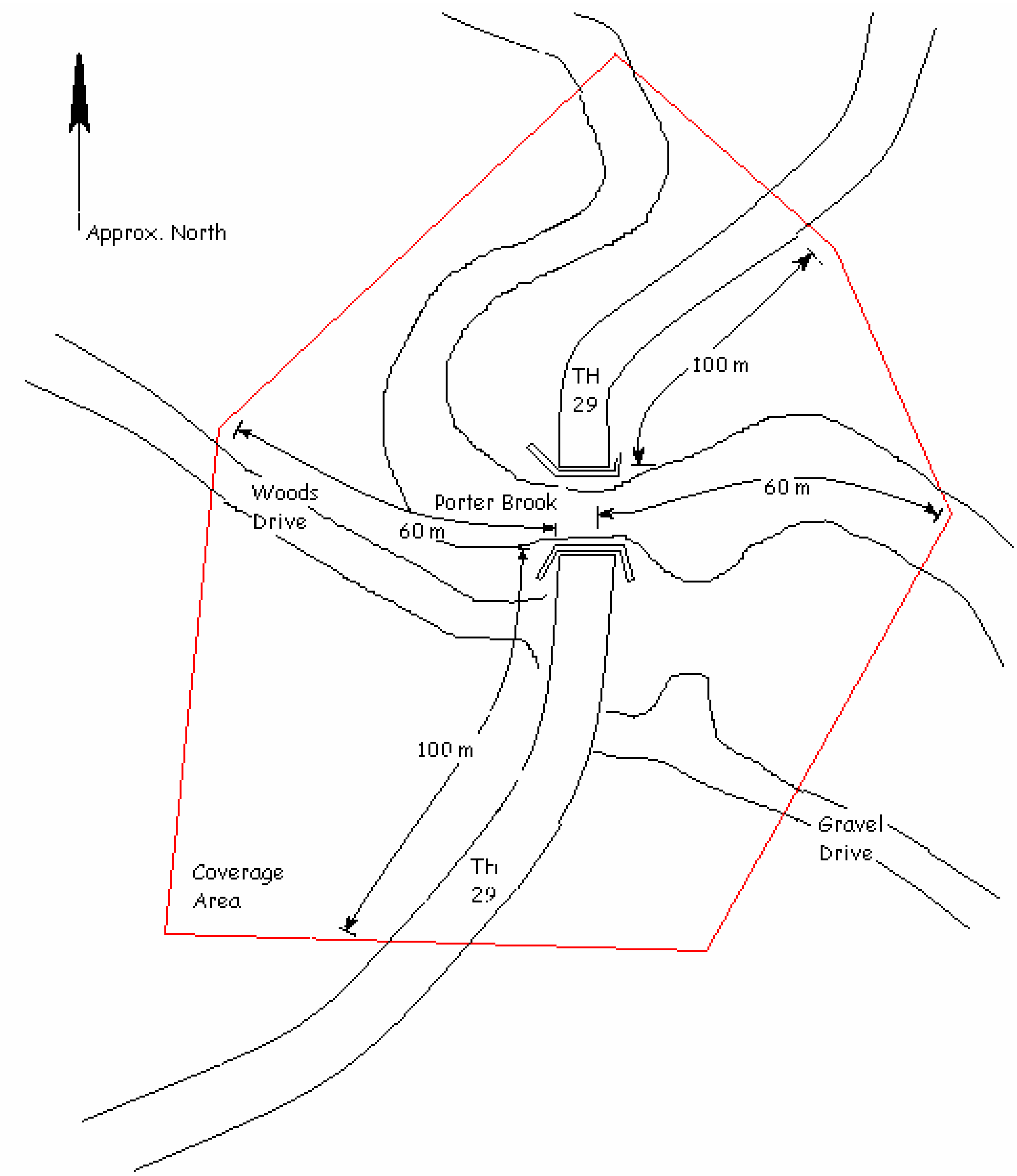


Figure 1-9

Request for Control

AGENCY OF TRANSPORTATION

PROJECT DEVELOPMENT

ROUTE SURVEY UNIT

TO: ______________, Geodetic Survey Supervisor #__*145*__________

FROM: ______________, L.S., Chief of Survey

DATE: *6 / 18 / 96*

SUBJECT: Control Data

Please provide horizontal and vertical control for the following project:

Town: *Hardwick*

Project: *TH3 - 9526*

Route: *T.H. 29*

Bridge: *BR 9*

CNTRLDAT.FRM

cc: **Central Files via**
Survey File
Survey Crew Chief
Chrono

Figure 1-10

Adjusted Coordinates

Hardwick TH1-9525 & TH3-9526
****** Adjusted Coordinates ******

Projection Group:	NAD-83 SP TM
Zone Name:	Vermont
Linear Units:	feet
Angular Units:	degrees
Datum Name:	NAVD-83(92)

Station Short Name	Station ID	North	Easting	Ortho. Height
Hill	HILL	735307.072	1684154.392	1141.07
Hill AZ Mk	HIAZ	733372.289	1682802.059	1136.02
TF 18	TF	731358.671	1674319.740	
TF 18 AZ Mk	TFAZ	732546.713	1673595.080	

Figure 1-11

Original Description—Example 1

```
***************>  D  E  S  C  R  I  P  T  I  O  N    F  I  L  E  <**************

Input D-FILE Used: G:\PlanSupp\Geodetic\PROJECTS\GPS\Hardwick\Hill.dsc
 Report File Used: G:\PlanSupp\Geodetic\PROJECTS\GPS\Hardwick\Hill.prn
       Sort Order: keyed-in order

=== PROJECT HEADER RECORD ==================================================
            FILE             SOURCE
     SUB-  FORMAT  CREATION PROGRAM/ SUBMIT JOB  ACCESSION PART    MIN/MAX LAT
TYPE TYPE VERSION    DATE   VERSION  AGENCY CODE   CODE    CODE    MIN/MAX LON
--------------------------------------------------------------------------------
 D    N   02.01.02 20030106 WDESC                                   N443102       /
                            06.00.18                              N443500
                                                                  W0721956      /
                                                                  W0733250
  TITLE:

COMMENT:

=== DESCRIPTION ==============================================================

=== DESCRIPTION HEADER RECORD ================================================
KEYED-IN ORDER:0001         SSN:0001  CONDITION:G                      PID:
   DESIGNATION:HILL
         ALIAS:
      QUADNAME:
       COUNTRY:US         STATE:VT       COUNTY:CALEDONIA                 007
--------------------------------------------------------------------------------
 MONUMENT:DD          SETTING:00     SPECIFIC:CONCRETE MONUMENT
MAGNETISM:B         STABILITY:C     SATELLITE:Y          APPLICATIONS:
      FPR:R 7    CM  ROD/PIPE:         SLEEVE:
 STAMPING:HILL 1996
 ESTAB BY:RIM                                      SETTING DATE:1996
     LOGO:VTAT
REPORT BY:VTGS                                         REPORT DATE:20030102
TRANSPORT:C         PACK TIME:00:00                              COP:CHR

=== POSITION RECORDS =========================================================
                                        POSITION POSITION  POSITION   ADJUSTMENT
DATUM EPOCH LATITUDE    LONGITUDE        SOURCE    ORDER   TECHNIQUE     DATE
--------------------------------------------------------------------------------
 83         N443102       W0721956

=== DESCRIPTIVE TEXT RECORD ==================================================
Text Status:
GENERAL LOCATION, HARDWICK, VT. TO REACH FROM THE INTERSECTION OF VT ROUTE 14 AND
VT ROUTE 15 IN HARDWICK VILLAGE (BLINKING LIGHT), GO EAST FOR 0.1 MI ON VT ROUTE
TO NORTH MAIN STREET, LEFT. TURN LEFT AND PROCEED NORTHERLY FOR 015 MI TO CHURCH
STREET (GREENSBORO ROAD), RIGHT. GO EAST FOR 1.25 MI TO PORTER BROOK ROAD (TH 29),
RIGHT. GO EAST FOR 0.65 MI TO THE GRAVEL DRIVE, LEFT. GO NORTH FOR 0.2 MI TO THE
MARK ON THE LEFT.
THE MARK IS SET EVEN WITH THE GROUND SURFACE IN THE TOP OF A 12 IN CONCRETE MONUMENT.
IT IS 27 M WEST OF THE NORTHWEST CORNER POST OF CAR PORT, 11.6 M SOUTH OF A 2 IN
APPLE TREE, AND 1 M EAST OF A FENCE CORNER POST IN LINE WITH THE FENCE GOING EAST-
WEST.
```

Figure 1-12

Original Description—Example 2

```
***************> D E S C R I P T I O N   F I L E <**************

Input D-FILE Used: G:\PlanSupp\Geodetic\PROJECTS\GPS\Hardwick\HiAz.dsc
 Report File Used: G:\PlanSupp\Geodetic\PROJECTS\GPS\Hardwick\HiAz.prn
       Sort Order: keyed-in order

=== PROJECT HEADER RECORD ===============================================================
            FILE              SOURCE
     SUB-  FORMAT  CREATION PROGRAM/ SUBMIT JOB  ACCESSION PART    MIN/MAX LAT
TYPE TYPE VERSION    DATE   VERSION  AGENCY CODE   CODE    CODE    MIN/MAX LON
-----------------------------------------------------------------------------------------
 D    N   02.01.02 20030106 WDESC                                  N443102       /
                            06.00.18                             N443500
                                                                 W0721956      /
                                                                 W0733250
  TITLE:

COMMENT:

=== DESCRIPTION =========================================================================

=== DESCRIPTION HEADER RECORD ===========================================================
KEYED-IN ORDER:0001        SSN:0002  CONDITION:G                        PID:
   DESIGNATION:HILL AZ MK
         ALIAS:
      QUADNAME:
       COUNTRY:US         STATE:VT       COUNTY:CALEDONIA                  007
-----------------------------------------------------------------------------------------
 MONUMENT:DD          SETTING:00     SPECIFIC:LEDGE OUTCROP
MAGNETISM:B         STABILITY:A     SATELLITE:Y          APPLICATIONS:
      FPR:R 7    CM  ROD/PIPE:         SLEEVE:
 STAMPING:HILL AZ MK 1996
 ESTAB BY:RIM                                          SETTING DATE:1996
     LOGO:VTAT
REPORT BY:VTGS                                             REPORT DATE:20030102
TRANSPORT:C         PACK TIME:00:00                                COP:CHR

=== POSITION RECORDS ====================================================================
                                        POSITION POSITION  POSITION   ADJUSTMENT
DATUM EPOCH LATITUDE    LONGITUDE        SOURCE    ORDER   TECHNIQUE     DATE
-----------------------------------------------------------------------------------------
 83         N443043       W0722015

=== DESCRIPTIVE TEXT RECORD =============================================================
Text Status:
GENERAL LOCATION, HARDWICK, VT. TO REACH FROM THE INTERSECTION OF VT ROUTE 14 AND
VT ROUTE 15 IN HARDWICK VILLAGE (BLINKING LIGHT), GO EAST FOR 0.1 MI ON VT ROUTE
TO NORTH MAIN STREET, LEFT. TURN LEFT AND PROCEED NORTHERLY FOR 015 MI TO CHURCH
STREET (GREENSBORO ROAD), RIGHT. GO EAST FOR 1.25 MI TO PORTER BROOK ROAD (TH 29),
RIGHT. GO EAST FOR 0.45 MI TO THE GRAVEL DRIVE, LEFT. TURN LEFT AND PROCEED NORTH
FOR 0.09 MI TO THE MARK ON THE RIGHT.
THE MARK IS SET IN A DRILL HOLE IN A LEDGE OUTCROP.IT IS SET WITH CONCRETE NAILS
FOR MAGNETIC LOCATION IF NECESSARY.
IT IS 23 M EAST OF THE POWER POLE WITH THE METER, 19.5 M SOUTH OF THE SOUTHEAST
CORNER OF A 1 ½ STORY HOUSE, 13.5 M SOUTHEAST OF AN ARTESIAN WELL.
```

Figure 1-13

NGS Data Sheet – Example 1

```
1        National Geodetic Survey,      Retrieval date = 05/09/2001
 VT0228 *********************************************************************
 VT0228 *********************************************************************
 VT0228 **   THIS DESCRIPTION WAS CREATED BY THE VERMONT GEODETIC SURVEY    **
 VT0228 **          PLEASE PAY CLOSE ATTENTION TO ALL NOTES BELOW           **
 VT0228 *********************************************************************
 VT0228 *********************************************************************
 VT0228  DESIGNATION -  TF 18
 VT0228  VT PID      -  VT0228
 VT0228  STATE/COUNTY-  VTCALEDONIA
 VT0228
 VT0228  HORZ DATUM  -  NAD 83(1992)
 VT0228  VERT DATUM  -  NAVD 88
 VT0228
 VT0228  POSITION    -  44 30 23.10974  N    072 22 12.16577  W
 VT0228  SPC VT (m)  -  222918.569  N        510333.678  E
 VT0228  ELLIP HEIGHT-  219.801  (meters)
 VT0228  ORTHO HEIGHT-  247.70   (meters)
 VT0228 *********************************************************************
 VT0228
 VT0228  HISTORY     -  Year Condition            Recov. By / Chief
 VT0228  HISTORY     -  1964 STATION MONUMENTED   VTDH      /
 VT0228  HISTORY     -                                      /
 VT0228 *********************************************************************
 VT0228
 VT0228  TRANSP CODE -       PACK TIME -  0000
 VT0228
 VT0228 *********************************************************************
 VT0228
 VT0228 *The horizontal coordinates were established by GPS observations and
 VT0228 *and adjusted by the Vermont Geodetic Survey.
 VT0228  The orthometric height was established by GPS observations.
 VT0228
 VT0228
 VT0228  STATION MARK IS A BENCH MARK DISK
 VT0228  WITH SETTING: SET IN THE ABUTMENT OR PIER OF A LARGE BRIDGE
 VT0228  DISK FROM: VTDH
 VT0228  THE MARK IS STAMPED: TF 18 1964
 VT0228  SATELLITE: THE SITE IS SUITABLE FOR GPS OBSERVATIONS
 VT0228
 VT0228' GENERAL LOCATION, HARDWICK, VT.
 VT0228'
 VT0228' TO REACH FROM HTE JUNCTION OF VT ROUTE'S 14 AND 15 IN HARDWICK
 VT0228' VILLAGE (BLINKING LIGHT) , GO WEST ON VT ROUTE 15 FOR 0.15 MI
 VT0228' (0.24 KM) TO THE MARK ON THE RIGHT.
 VT0228'
 VT0228' THE MARK IS SET ON THE SOUTHEAST BRIDGE ABUTMENT ON THE WEST CHURCH
 VT0228' STREET BRIDGE OVER THE LAMOILLE RIVER.
 VT0228'
 VT0228' IT IS 31 FT (9.4 M) NORTH OF THE CENTERLINE OF VT ROUTE 15, 16 FT
 VT0228' (4.9 M) EAST OF THE CENTERLINE OF WEST CHURCH STREET, AND 5 FT
 VT0228' (1.5 M) NORTH OF POWER AND TELEPHONE POLE NUMBER 3.
```

Figure 1-14

NGS Data Sheet—Example 2

```
1        National Geodetic Survey,      Retrieval date = 05/09/2001
 VT0229 ***********************************************************************
 VT0229 ***********************************************************************
 VT0229 **   THIS DESCRIPTION WAS CREATED BY THE VERMONT GEODETIC SURVEY    **
 VT0229 **          PLEASE PAY CLOSE ATTENTION TO ALL NOTES BELOW           **
 VT0229 ***********************************************************************
 VT0229 ***********************************************************************
 VT0229  DESIGNATION -  TF 18 AZ MK
 VT0229  VT PID      -  VT0229
 VT0229  STATE/COUNTY-  VTCALEDONIA
 VT0229
 VT0229  HORZ DATUM  -  NAD 83(1992)
 VT0229  VERT DATUM  -  NAVD 88
 VT0229
 VT0229  POSITION    -  44 30 34.85278  N    072 22 22.13993  W
 VT0229  SPC VT (m)  -  223280.685  N        510112.801  E
 VT0229  ELLIP HEIGHT-  218.347  (meters)
 VT0229  ORTHO HEIGHT-  246.25   (meters)
 VT0229 ***********************************************************************
 VT0229
 VT0229  HISTORY     -  Year Condition            Recov. By / Chief
 VT0229  HISTORY     -  1996 STATION MONUMENTED   VTAT      / RIM
 VT0229  HISTORY     -                                      /
 VT0229 ***********************************************************************
 VT0229
 VT0229  TRANSP CODE -      PACK TIME -  0000
 VT0229
 VT0229 ***********************************************************************
 VT0229
 VT0229 *The horizontal coordinates were established by GPS observations and
 VT0229 *and adjusted by the Vermont Geodetic Survey.
 VT0229  The orthometric height was established by GPS observations.
 VT0229
 VT0229  STATION MARK IS A SURVEY DISK
 VT0229  WITH SETTING: SET IN TOP OF CONCRETE MONUMENT (ROUND)
 VT0229  DISK FROM: VTAT
 VT0229  THE MARK IS STAMPED: TF 18 AZ MK 1964
 VT0229  SATELLITE: THE SITE IS SUITABLE FOR GPS OBSERVATIONS
 VT0229
 VT0229' GENERAL LOCATION, HARDWICK, VT.
 VT0229'
 VT0229' OWNERSHIP, MRS BROCHU OR THE VILLAGE OF HARDWICK.
 VT0229'
 VT0229' TO REACH FROM THE JUNCTION OF VT ROUTE'S 14 AND 15 IN HARDWICK
 VT0229' VILLAGE (BLINKING LIGHT) , GO WEST ON VT ROUTE 15 FOR 0.45 MI
 VT0229' (0.72 KM) TO THE MARK ON THE LEFT.
 VT0229'
 VT0229' THE MARK IS A STATE OF VERMONT SURVEY DISK SET IN A 12 IN CONCRETE
 VT0229' MONUMENT EVEN WITH THE GROUND SURFACE.
 VT0229'
 VT0229' IT IS 68 FT (20.7 M) NORTHWEST OF POWER AND TELEPHONE POLE L
 VT0229' 8-1/8/1H, 39 FT (11.9 M) NORTH OF UNION STREET CENTERLINE, 31 FT
 VT0229' (9.4 M) WEST OF VT ROUTE 15 CENTERLINE, 9 FT (2.7 M) NORTH OF A FIRE
 VT0229' HYDRANT, AND 4.5 FT (1.4 M) WEST OF THE FACE OF A GRANITE WALL.
```

Figure 1-15

Request for Right-of-Way Information

AGENCY OF TRANSPORTATION

PROJECT DEVELOPMENT

ROUTE SURVEY UNIT

TO: ________________, Right-of-Way Agent

FROM: ________________, L.S., Chief of Survey

DATE: *8 / 19 / 96*

SUBJECT: Right-of-Way Data

Please provide any existing Right-of-Way information in the area of the following project:

Town: *Hardwick*

Project Number: *TH3 - 9526*

PPMS: *95J308* **EA:** *139526-100*

Route: *T.H. 29* **Mile Marker:** ________ **To:** ________

Bridge: *9*

Other: ________________

Estimated Start Date: *11 / 4 / 96*

ROW.FMT

cc: **Central Files via**
Survey File
Survey Crew

Updated 02/04/03

Figure 1-16

Reply to Request for Survey – Survey Estimate

AGENCY OF TRANSPORTATION

PROJECT DEVELOPMENT

ROUTE SURVEY UNIT

TO: ___________________, Structures Engineer

FROM: ___________________, L.S., Chief of Survey

DATE: *6/18/96*

SUBJECT: *Project: Hardwick TH3-9526*

This is to acknowledge receipt of your survey request dated *6 / 10 / 96* for the above project.

Based on the current and anticipated survey workload, and my understanding of the work requested, I estimate the following date for this request:

Crew Days Required *5* (*2* - person crew).

Est. start date: *10* / *14* / *96*

Est. completion date: *10* / *19* / *96*

Est. Survey cost: *$2,500*

The above estimates (do)(do not) include tying the survey to the State Plane Grid.

The vertical datum will be (USGS)(assumed).

The survey will be done using (3D electronic)(2D electronic)(conventional station/offset) procedures.

Other comments:____

____

____

____

If you have any questions or comments regarding the above, please do not hesitate to call me at 828-2576. If any of the above dates or estimates are anticipated to change significantly, I will do my best to notify you in advance.

cc: **Central Files via**
Survey Crew Chief
Chrono

Figure 1-17

Survey Transfer Memorandum

Survey # ______

AGENCY OF TRANSPORTATION

PROJECT DEVELOPMENT

ROUTE SURVEY UNIT

SURVEY TRANSFER MEMORANDUM

FROM:________________ , L.S., Chief of Survey

TO: ____________________ **DIVISION**: *Structures* **DATE**: *10/19/96*

PROJECT: *Project: Hardwick TH3-9526* **EA:** *0395026-100*

ROUTE *TH 29* **BRIDGE** *16* **OTHER** _____________ **PHOTOS** *yes*

UNITS *ft* **SURVEYOR** _______ **CHECKED BY** _______ **MODELER** _______

Horizontal Datum NAD83(96); Vertical Datum NAVD88 unless otherwise noted.

LOCATION on AOTCADD [M:]

Projects\ *95j308* \Survey\ *x95j308* .rw5 ______________

Projects\ *95j308* \Survey\ *x95j308og* .alg ______________

Projects\ *95j308* \Survey\ *x95j308sv* .dgn ______________

Projects\ *95j308* \Survey\ *x95j308og* .dtm ______________

Projects\ *95j308* \Survey\ *x95j308ti* .dgn ______________

Projects\ *95j308* \Survey\ *x95j308* .fwd ______________

Projects\ *95j308* \Survey\ *x95j308* .log ______________

Projects\ *95j308* \Survey\ *x95j308* .ics ______________

SEE .RW5 FILE FOR ADDITIONAL SURVEY INFOMATION

OTHER NOTES: ____

RECEIVED BY: _______ **DATE**: _______ **DATE RETURNED TO SURVEY**: _______

Figure 1-18

Survey Crew Report

SURVEY DAILY REPORT

Date 10/14/96 **Weather** Wind & Cold

Project Hardwick TH3-9526

No. 95j308 **Length** 0.09 **Mi.**

Topo

Complete topo to north end of bridge

OVER

Hours CT	Worked OT	Total OT	Name
2		2	Bob Plumb
2		2	Rod Level **P.C.**

Completion Date

Chapter Two

.

Equipment

OPERATOR MANUALS

Refer to the operator’s manual for the equipment you are using for details of operation, maintenance, troubleshooting, and other information. Keep the operator’s manuals with the equipment.

CARE OF EQUIPMENT

Overall guidance for equipment care is below.

- Inspect all equipment at the start of the day for physical condition and cleanliness. Clean the exterior of equipment frequently.
- Keep equipment in padded cases if not in use.
- Handle instruments only by the designated grip points.
- Secure the positioning of instruments around traffic or construction equipment. Use cones or a vehicle to delineate the position.
- Don’t leave an instrument standing alone during high winds. It may throw the instrument off level or topple it.
- Don’t attempt to repair an instrument. Take it to a qualified repair shop.

Care of total stations is covered later in this chapter of the manual. Additional guidance for specific equipment units is below.

- Check prisms daily to ensure that they are not cracked, are in their assemblies correctly, and are clean.
- Don’t charge NiCad batteries unless they have completely discharged.

ADJUSTMENT AND MAINTENANCE OF EQUIPMENT

Check equipment for adjustment at least quarterly, or sooner if problems arise. Maintain equipment as indicated in the operator's manual. Use the checklist shown in Figure 2-1. In the top row of the form, write the date that you or an outside source adjusted or maintained the equipment. Place checkmarks in the main body of the form to indicate which equipment was adjusted or maintained. Add equipment to the list, if needed.

Figure 2-1 Adjustment and Maintenance Checklist

Adjustment Checklist

NAME:

Equipment	Dates of Adjustment											
Total Station												
Tribrachs												
Prisms												
Telescoping plumb pole												
Data Collector												

CARE AND ADJUSTMENT OF TOTAL STATIONS

General Care

Follow the guidelines below when using a total station.

- Avoid high or low temperature use for prolonged periods.
- Avoid use on rainy days. The electrical components may malfunction.
- Avoid use during a rapid change in temperature. Condensation, or calibration error, may result.
- Shield the instrument from very dusty conditions, such as may be found when working around construction equipment.
- Take the instrument off of its tripod if moving to a new position.
- During shutdown, wipe the total station of dust and moisture.

If a total station is not used for an extended period, take it out of its case and expose it to fresh air.

Field Checks

Prior to working on a project, check the total station with two GPS points used for providing control. Compare the inverse with the accepted distance between the points.

Calibration Base Lines

Check total stations with a calibrated base line quarterly, before major projects, or if field checks indicate it's needed. Use the total station's most accurate mode during the check. Proceed as follows:

- Adjust the tribrach and ensure that the total station is properly secured on the tribrach.
- Adjust the collimation.
- Telescoping prism pole: adjust bubble and check for worn-down point.
- Measure the base line.
- Use software such as Calibrate to reduce and analyze measurements and, thus, verify PPM ratings.

Send the instrument in for adjustment if the recommended tolerances are exceeded.

Adjustment Documentation

Field checks and checks with calibration base lines should always be documented. The documentation can be extremely valuable in court testimony regarding the integrity of surveys.

ADJUSTMENT OF AUTOMATIC LEVELS

The main adjustment is to make the circular bubble center when the azimuth axis is vertical. The compensator is most accurate in correcting for the tilt of the telescope when the azimuth axis is vertical.

The line of sight seldom gets out of adjustment. It should be adjusted only when the circular level is in proper adjustment.

Adjustment Setup

- Choose a firm support for the instrument. Usually, a firm support can be found only outdoors. The floor of a building, even a concrete floor, deflects if the observer moves around the instrument.
- Choose a cloudy day, if practicable. If the sun is shining, work in the shade but in good light.
- Allow the level between 30 and 60 minutes to accommodate itself to the temperature. The time depends on the temperature difference between the test site and storage area.
- Watch for creep. Creep is caused by settlement of the tripod or a change in the temperature of the instrument. After setting a bubble or the line of sight, let the level stand for a few seconds to see that no movement occurs.

Circular Level

Test of the Circular Level

Turn the telescope in azimuth until it's parallel to a pair of leveling screws. Center the bubble. Turn the telescope 180 degrees until it's parallel to the same leveling screws. If the bubble does not remain centered, adjustment is needed.

Adjustment of the Circular Level

1. Unscrew the lock ring at the base of the observation prism and remove the prism unit. If the instrument is not equipped with an observation prism, unscrew the adjusting screw-guard ring that surrounds the circular level.
2. Locate the three slotted-head adjusting screws. The circular vial is supported by a resilient washer that forces it upward against the screws. With a screwdriver, loosen or tighten all of the screws until they are finger-tight.
3. Repeat the test in the previous section, as the bubble may be thrown farther out of adjustment.
4. If the bubble fails to center, bring it halfway to the center with the leveling screws. Bring it to the center by tightening the most logical adjusting screws. Don't loosen any of the adjusting screws.
5. Turn the telescope 180 degrees in azimuth until it's parallel with the same set of leveling screws. If the bubble fails to center, bring it halfway to the center with the leveling screws. Bring it to the center by tightening the most logical adjusting screws.
6. Repeat the test and, if needed, the adjustment until the bubble remains centered.
7. When the adjustment is completed, all of the screws must be firm but not tight.

Line of Sight

Test for Line of Sight

The test checks whether the line of sight using the cross hairs is parallel to the axis of the level-bubble tube. Figure 2-2 diagrams the test setups.

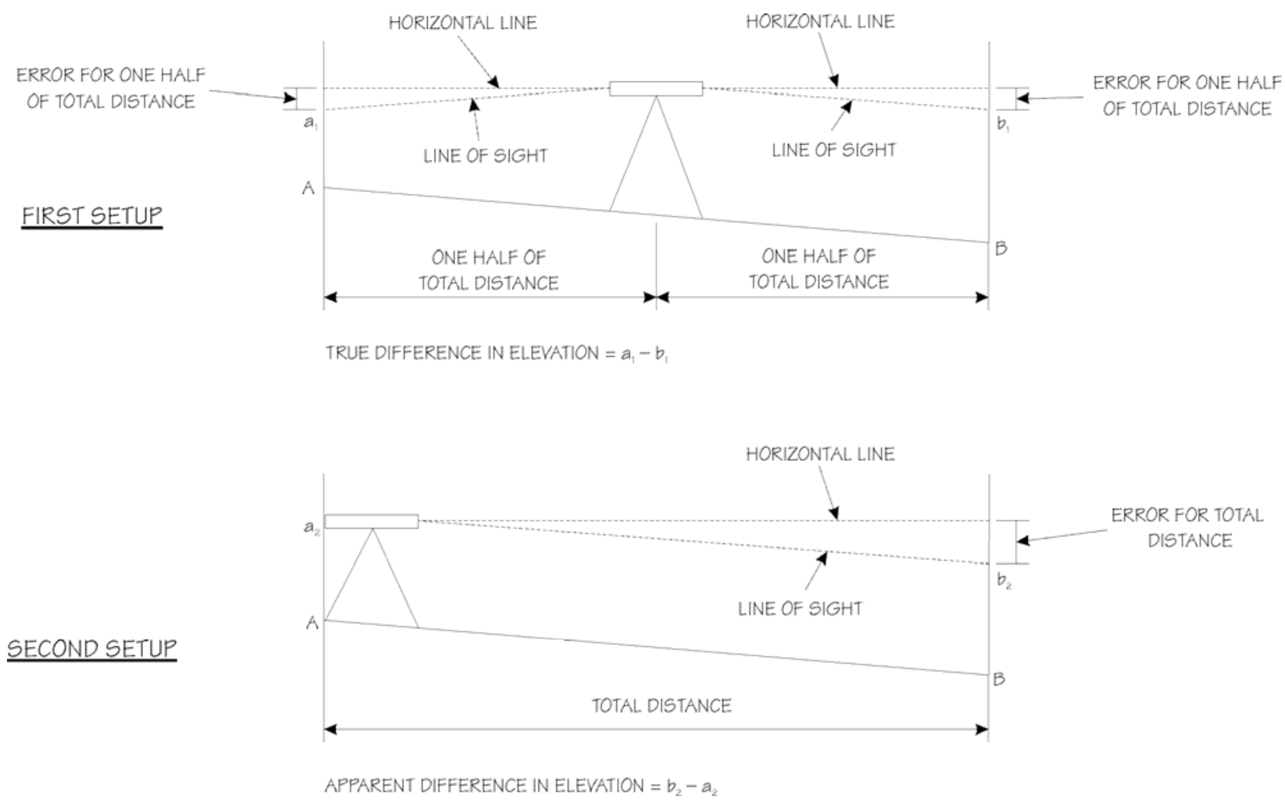
1. Place two stakes about 200 to 300 feet apart.
2. Set up midway between the points and take rod readings on both points.
3. Calculate the true difference in elevation by subtracting the two readings. Any error in the line of sight will cancel out because you set up midway between the two points.
4. Set up at one of the points so that the eyepiece just touches the rod when it is placed on the point.
5. Take a rod reading by looking through the objective end of the telescope at the rod held on the point closest to the setup. Slide a pencil along the rod to help determine the reading.
6. Take the second rod reading in a normal manner for the point 200 to 300 feet away.
7. Calculate the apparent difference in elevation by subtracting the two readings.
8. Calculate the error by subtracting the true and apparent differences in elevation.

If there is an error, the line of sight needs to be adjusted. Calculate the target by adding the error to the rod reading in Step 6 above.

Adjustment for Line of Sight

After the target has been set, unscrew the reticle cover. The cover is a circular cap with a diameter of about 1¼" It's at the end of the telescope, just in front of the eyepiece. The adjustment screw under the cover raises and lowers the cross hairs against a spring loading. Bring the cross hairs on target by turning the screw.

Figure 2-2
Peg Test Setups



Chapter Three

Quality Control

BLUNDERS

A blunder is a mistake. It may lead to other errors, especially if computer software is involved. A blunder may have occurred if you notice unusual data entries generated electronically.

The best way to check the quality of a survey is to view it graphically. Consider the following sources of blunders when a survey is obviously incorrect:

- Communicating poorly within the survey party
  - Misunderstanding a call-out
  - Recording all rod height changes
- Inputting data incorrectly (wrong coordinates, HI, unit of measurement, etc.)
- Misidentifying descriptions
- Recovering the wrong point
- Misidentifying point numbers (occupying or backsight)
- Shooting off the wrong object (a vehicle taillight, for example)
- Failing to set the backsight to zero
- Going in the wrong direction when making an offset center-shot
- Setting prism offsets incorrectly
- Setting up the instrument incorrectly (not attaching the instrument to the tribrach securely, for example)
- Allowing the telescoping rod height to slip unnoticed
- Sighting through glass, such as a car window

CLASSIFICATION OF ERRORS

Errors are classified as systematic or random.

Systematic errors can be predicted in both magnitude and sign. They can be corrected by following the recognized correction procedures. For example, changes in atmospheric conditions can be corrected by proper setting of parts per million in the instrument.

Random errors cannot be predicted in either magnitude or sign. They are introduced into each measurement because no human can perform perfectly. Fortunately, they tend to cancel each other mathematically, giving the appearance of accurate work. However, random errors from careless or unskilled work can cause problems.

SOURCES OF ERROR

There are three primary sources of error: instrument, human, and natural.

Instrument Errors

Level Bubbles and Optical Plummet

Normal measuring procedures do not compensate for maladjustment of either the plate bubbles or the optical plummet. These components must be checked more frequently than others.

On control traverse projects, check the optical plummet. Check the plate bubbles routinely on each setup. If you detect error, set the bubbles for the mean of the error or adjust the bubble. Refer to the manual supplied with the instrument.

Double Centering

Double centering compensates for lack of adjustment of almost all components of an instrument. You should make double centering standard practice for all angles measured with a transit, theodolite or total station. Make a minimum of two observations, one direct and one reverse. Then use the mean position.

Parallax

Parallax occurs if the focal point of the eyepiece doesn’t coincide with the plane of the cross hairs. The condition varies for each observer because the focal length depends in part on the shape of the observer’s eyeball. Parallax is also a major concern in the optical plummet.

Check for parallax if you begin to operate a new instrument or one that has been operated by someone else. Check the optical plummet on every setup, particularly if the HI is significantly different from the last setup.

To check for parallax, focus the telescope on some well-defined distant object. Slowly move your head back and forth, about 1 inch from the eyepiece, while watching the relationship of the object to the cross hairs. If the object appears to move, parallax exists.

To eliminate parallax, rotate the knurled eyepiece ring until the cross hairs are the thickest and blackest, refocus the instrument, and check for parallax as described earlier. If parallax still exists, repeat the procedure.

Human Errors

Instrument Setups

Use the guidelines below for setting up an instrument.

- Be sure the tripod is in good condition and all hardware is snugly fitted.
- Push the tripod shoes firmly into the ground. Don't stamp on the tripod feet. Pressure should be parallel to each leg.
- Place the legs in positions that result in a minimum of walking around the setup.
- In windy conditions, set one leg downwind to gain additional stability.
- On hillsides, set two legs downhill.
- If the ground is soft or muddy, drive 2" × 10" wedges into the ground to support the tripod legs. Use boards to support the instrument operator.
- If the ground is frozen, use flat boards for the legs or, if possible, pile snow around the legs to prevent settling.
- If setting up on hot pavement, use flat boards for the legs to prevent settling.
- Be sure that the instrument is attached to the tribrach and that all screws are tightened.
- Be sure the instrument is exactly over the point.
- Check the optical plummet after the instrument is set up and just before moving to another point. If the instrument has moved, check the angle just measured.
- Recheck the instrument level. The bubble should remain within one graduation when the instrument is smoothly turned through one circle (if the instrument is shaded).

Setting Sights

If tribrach-mounted targets are used, take the same precautions as if setting up an instrument. "Leap Frogging" between targets and total station (and vice versa) greatly decreases the effects of plumbing errors in traverse closures. Leap frogging is especially beneficial in short-course traverses.

Leap frogging is the traverse procedure in which backsight, instrument point and foresight alternate setting on the same points. If a tribrach is set over a point, it stays mounted on the tripod over that point for all uses. The instrument and sights are transferred from point to point without disturbing the tribrach setup. This is standard procedure for the control traverse.

Use these guidelines for setting sights:

- Always check a backsight before picking up, to see that it has not changed.
- If you're setting a pole sight, plumb it with a precision equal to that required for the total survey. Sight as close to the ground as possible for the most accurate angular sighting.
- If a sight is set near ground level, check the line of sight for obstructions or for excessive heat waves. On very sunny days, avoid using ground-level sights.

Cross Hair Use

Sight each object with the same part of the cross hair, preferably near the center of the field of view. This practice minimizes small residual adjustment errors.

The human eye can estimate the center of a wide object more accurately than it can line up two objects. For this reason, use different pointing techniques, depending on the type and apparent size of the sight in the telescope.

If you're pointing on narrow sights, such as the center of a red-and-white target or a distant range pole, straddle the sight with the double cross hairs. If you're pointing on wide sights, such as a lath or a range pole at close range, split the sight with the single cross hair.

Measuring Angles

Measure angles as rapidly and as comfortably possible, with a uniform rhythm. Take the first reading at an object, rather than fidgeting with the tangent screw trying to improve the pointing. Too much pointing time increases the probability of error through instrument settlement or atmospheric changes. However, don't cultivate speed at the expense of good results. Accuracy is more important than speed.

Communication

Carefully call out and report information to be recorded so that blunders are avoided.

Field Notes

If you are using an electronic data collector, don't input any measurements manually.

You can catch many inconsistencies by carefully analyzing the observations. These items should be checked in the field by the recorder, if you are using paper notes, and always checked in the office. Examples are:

- Spreads between the seconds of direct and reverse readings should be consistent and in the same direction throughout the set.
- The sums of the direct and reverse zenith angles should be consistent.
- When the direct and reverse observations of a position are in different minutes, be sure the average second value is coupled with the correct minutes value.

Natural Factors

Differential Heat

Bright sunlight striking certain parts of the instrument may cause differential expansion of the metal components of the instrument, resulting in small errors.

Heat Waves

On a hot or sunny day, heat waves can cause distortion of lines of sight near a reflecting surface. Stop performing control traverses if excessive heat waves are present.

Phase

If a sight is not evenly lighted on both sides, an instrument operator tends to point toward one side. This phenomenon, called "phase," can be reduced by using a target with a flat surface pointed directly toward the instrument. The targets attached to the prism are useful in reducing phase.

Refraction

If light waves pass from a medium of one density into a medium of a different density, the rays change in direction (bend). The change in direction is called "refraction." Because sight lines are light rays, they are refracted, or bent, by changes in the atmosphere, causing small errors in angular measurement.

Lateral refraction is insignificant in most surveys, but its effects can be minimized further by understanding and avoiding situations producing the largest refraction of line of sight. Some of these situations are:

- When the sun shines on a barren, dark surface, the surface warms relatively quickly. This warms the air, and if calm, it produces a column of warm, light air rising from the surface. Examples—
  - Dark, freshly plowed fields lying between lighter-colored areas of growing crops
  - Large paved areas, such as roadways, runways, and parking lots
  - Clear areas between heavy forests
  - Large bodies of warm water between land areas
- Open valleys bordered by bluffs on either side can result in refraction. If a line must pass over a valley, set the observation points as far back from the edges of the valley as possible.
- Air tends to layer parallel to the slopes of embankments or the bases of foothills.

If refraction is probable in angles to be measured or is suspected in angles that have been measured, recon the survey area and plan station locations to avoid the problem conditions listed above.

Traversing and Leveling

This chapter covers control traverses and bench runs, as well as general information that applies to all traversing and leveling. Specific information about surveys other than control traverses or bench runs can be found in Chapter Five, “Topography,” and Chapter Six, “Other Surveys,” which covers right-of-way surveys, airport surveys, and surveys for construction

Chapter One, “Operations,” discusses the research that occurs prior to control traverses and bench runs.

TRAVERSING

Accuracy

A minimum accuracy for a control traverse is 1:20,000. If practicable, improve accuracy by:

- Turning a set (direct and reverse) for each angle that you measure. The tolerance is 10 seconds between the angles in a set.
- Measuring each line twice.

Configuration

In general, all traverses should be closed. It may not be practical, however, to close all side-line traverses.

The legs of control traverses should be as long as possible but still be useful for topography and, if needed, trigonometric levels.

Monumentation

Mark traverse points with reinforcing bars and plastic caps, if practicable. Reinforcing bars should be a minimum 7/8” diameter (No. 19M) and 3 feet long, with a drill hole or plastic cap set flush with or below ground level. Use wooden hubs if underground obstructions are likely. PK nails may be used in pavement. Traverse monumentation should be out of harm’s way and protected for future use.

At least two marks on a job must be permanent or semipermanent. Reinforcing bars are considered semipermanent.

For control traverses, two or three marks for each project should be tied to the state plane coordinate system.

Meteorological Readings

If running a control traverse with a total station, take the temperature and barometric pressure readings at the beginning of the day and when temperature or pressure changes seem significant, such as when a storm front approaches. Apply the corrections to the distances.

Numbering Points

Number points in sequence, using the range of numbers appropriate for your type of work:

Figure 4-1. Point Numbering Ranges

Type of Work	Range
Control Traverse	1-99
Side Lines	100-499
Topography	500 and up

Basis of Bearing and Origin of Coordinates

The Geodetic Survey Unit typically provides a pair of intervisible GPS points that are on the state plane coordinate system. Use them to obtain the basis of bearing and origin of coordinates. If a bearing must be assumed, use magnetic direction. If using magnetic direction, avoid high-tension lines and large metal objects.

Ties

Tie at least three control traverse points.

Guidelines for setting ties are below.

- Set ties in objects that are unlikely to be disturbed or removed.
- Set a minimum of three ties for each point.
- Avoid setting ties so that two tie and the traverse point are in a straight line.
- Use horizontal distances, not slope distances, for measuring to tie points.
- Don’t damage private property.
- Avoid valuable trees, especially hardwoods. Spikes stain wood and can be hazardous to someone cutting down a tree. Reduce the chance of creating a hazard by placing a spike close to the ground line.

Use ties for locating a previously tied point. Use the ties for resetting the point only as a last resort.

Adjustments

The compass method or least-squares adjustment is acceptable for adjusting a closed traverse. A least-squares adjustment must be used if positional tolerances must be met.

Leveling

Either differential or trigonometric leveling may be used if accuracy standards are met. See Figure 4-2.

Bench Runs

If possible, a bench run should be tied to the latest vertical datum. A beginning elevation can be assumed if permitted on the Request for Survey.

Number benchmarks consecutively.

The maximum desirable distance between shots for trigonometric leveling is 1300 feet.

Benchmarks

Establish a minimum of two benchmarks on each project. It is desirable to establish a benchmark at each traverse point.

Establish benchmarks on permanent objects outside of the construction limits but easily accessible for construction purposes. Good locations are:

- Near bridges
- At the bottoms of deep gullies
- At the tops of large cuts

Adjustments

The compass rule or least-squares method may be used. Paper notes may be adjusted on a proportional basis.

Notes

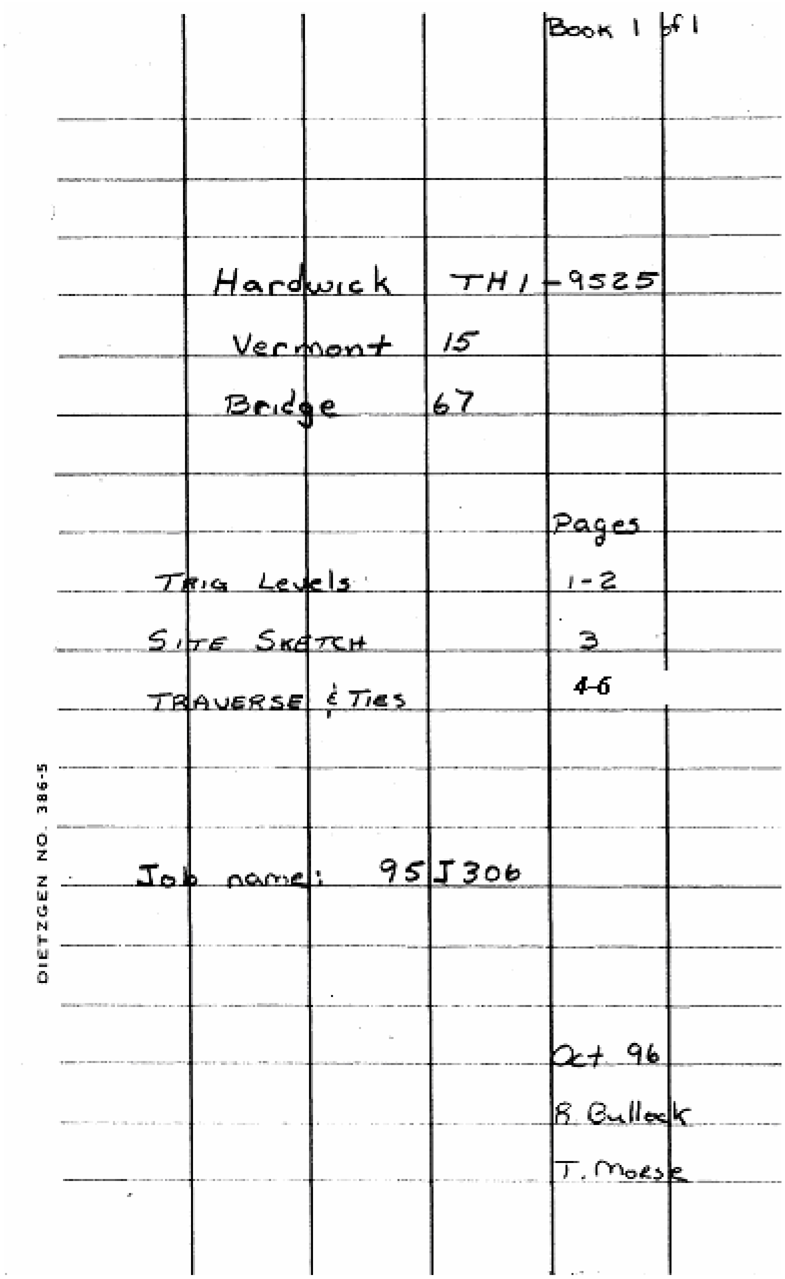
Use either electronic or paper notes. Electronic notes are preferred.
Ties must be included in electronic field files and paper notes.
Examples of paper notes are in Figure 4-3.

Figure 4-2. Accuracy Standards

Order Class	First I	First II	Second I	Second II	Third
Section misclosures					
(backward and forward) Algebraic sum of all corrected section misclosures of a leveling line not to exceed (mm)	3√L	4√L	6√L	8√L	12√L
Section misclosure not to exceed (mm)	3√D	4√D	6√D	8√D	12√D
Loop misclosures					
Algebraic sum of all corrected misclosures not to exceed (mm)	4√E	5√E	6√E	8√E	12√E
Loop misclosure not to exceed (mm)	4√E	5√E	6√E	8√E	12√E

L – shortest one-way length of leveling line in km
D – shortest one-way length of section in km
E – length of loop in km

Figure 4-3
Example Notes


Book 1 of 1

Hardwick TH 1-9525
Vermont 15
Bridge 67

Pages
TRIG Levels 1-2
SITE SKETCH 3
TRAVERSE & TIES 4-6

Job name: 95J306

Oct 96
R. Bullock
T. Moerse

DIETZGEN NO. 386-5

Figure 4-3 (continued)

Example Notes

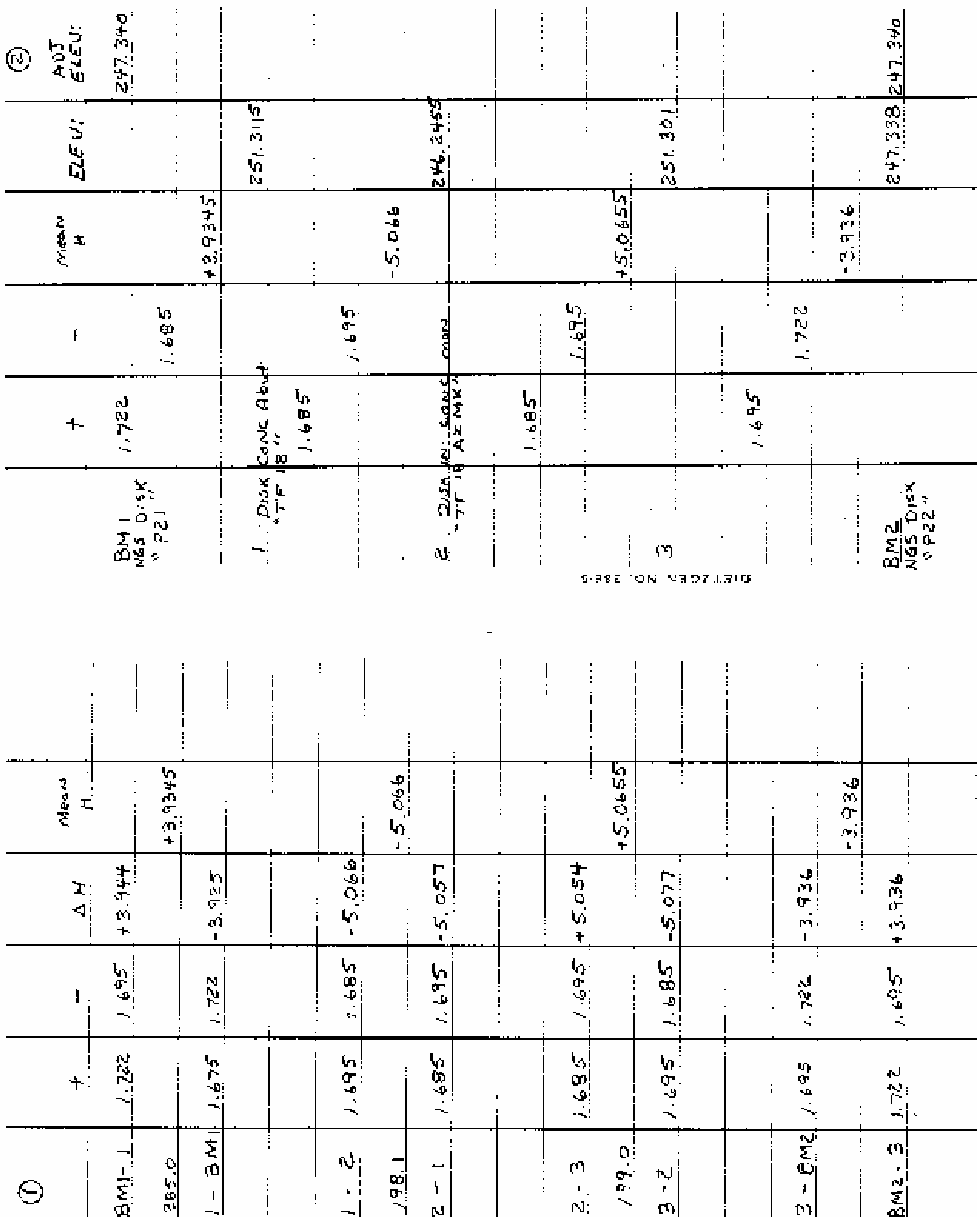


Figure 4-3 (continued)

Example Notes

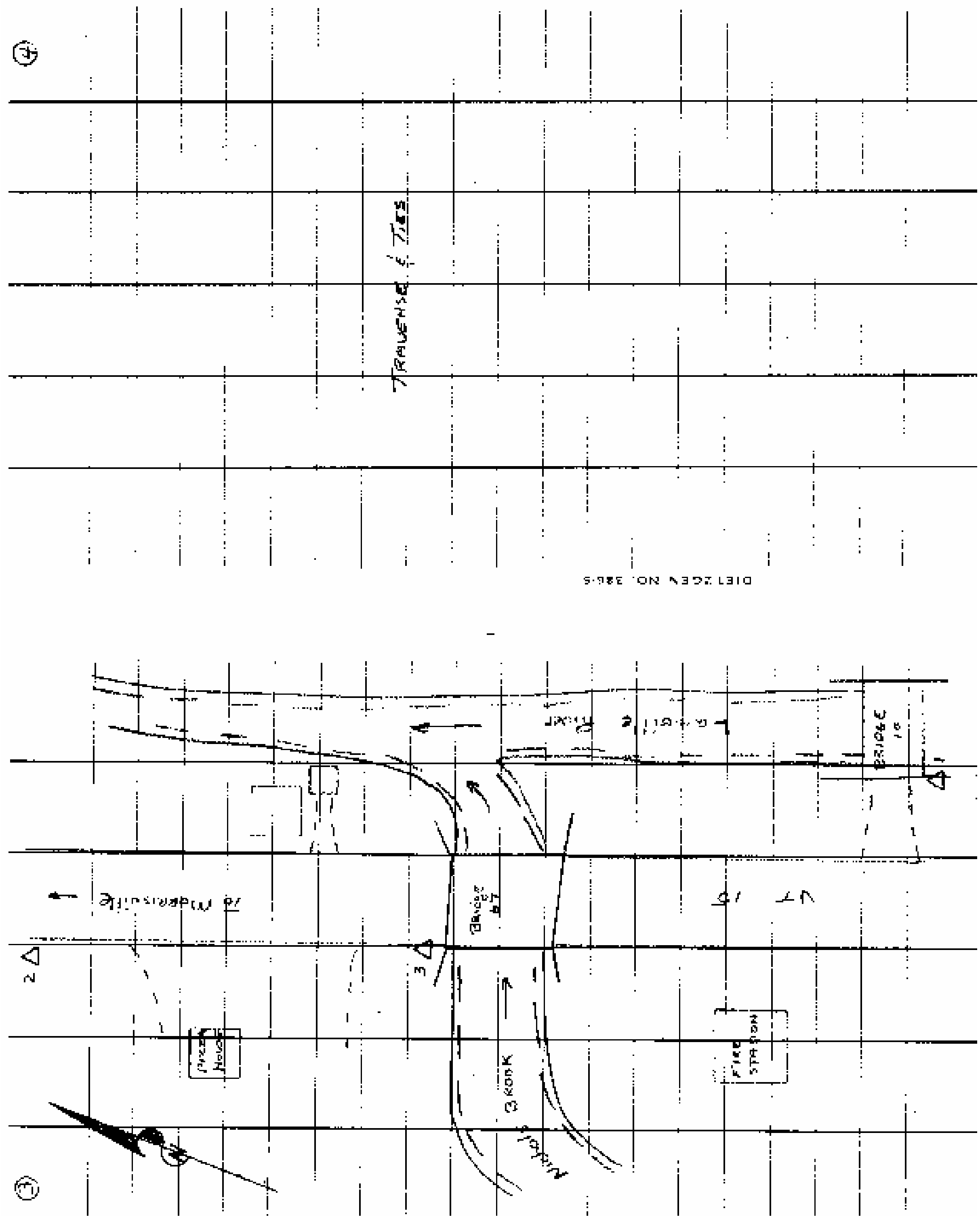
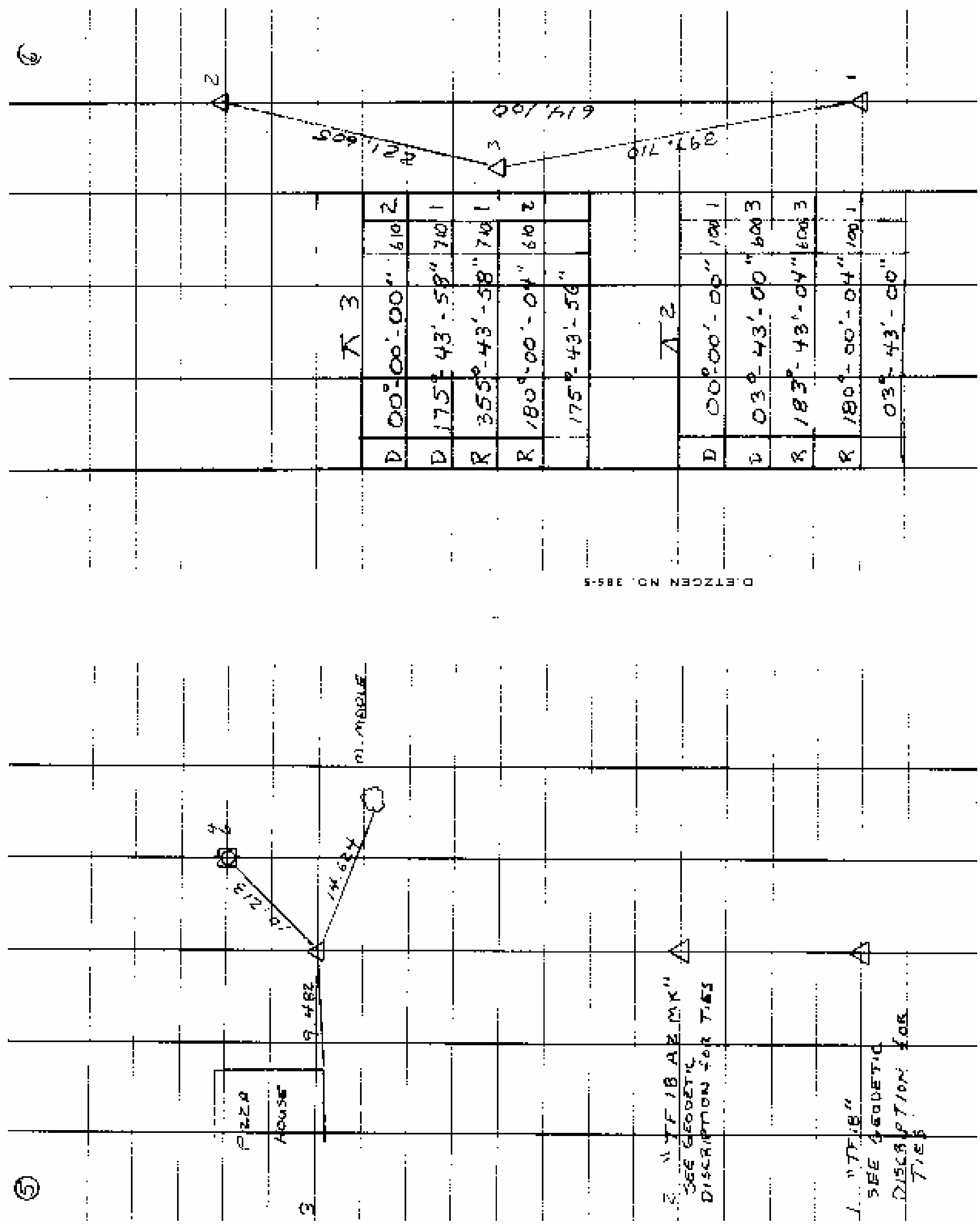


Figure 4-3 (continued)

Example Notes



Topography

This chapter describes the procedures for VAOT. Procedures may vary in other organizations according to the equipment and software used.

ACCURACY

Accuracy for topography is based on the control traverse. See Chapter Four, “Traversing and Leveling,” for control traverse accuracy standards. Before any data has been gathered verify the control points that are being occupied are correct by using a backsite check that will check for a difference in distance and elevation.

A shot for topography should be taken at the center of an object.

PREFERENCES

Preferences define the codes and description of topographic features. The VAOT CADD Support Unit issues and maintains preferences. See Appendix A for the list.

The list of preferences indicates which points are included in the DTM (digital terrain model). Other points on the list are included in the topography but not in the triangulated model.

The output of software used for topography must match the DTM software used by the CADD Support Unit. If needed, check with the CADD Support Unit prior to performing a topographic survey.

DEFINITIONS

- *Random point*. A data point with a number, northing, easting, elevation, and description generated from a field survey.
- *Breakline point*. A data point with a number, northing, easting, elevation, and description generated from a field survey and designating segment ends of a breakline.
- *Breakline*. A series of segments connecting breakline points that represents a change of ground slope (for example, the top of slope) or a physical feature (for example, the edge of roadway).

  Some breaklines (for example, fences, stone walls, and tree lines) may not represent a change in ground slope but are treated as such in DTM creation. Extra topography shots may be necessary to make an accurate representation of the existing ground surface.
- *Inferred point*. A computer-generated data point interpolated along breakline segments at a specific interval, usually used to densify the model.

- *DTM (Digital Terrain Model)*. A computer-generated numerical representation of a ground surface. A surface may not contain any vertical surfaces, overhangs, facets, tunnels, caves, etc.

FIELD PROCEDURES

General Guidelines

The guidelines below apply to DTM modeling regardless of the method that is used to collect data.

- A breakline is made up of actual measured data points defining the ground feature. It must be located in sufficiently short segments to accurately represent a curve.
- Breaklines are three-dimensional. They shouldn't cross each other at different elevations. They should only meet or cross at common vertexes.
- The DTM software doesn't recognize vertical faces such as those that may exist for bridge abutments, retaining walls, and curbs. Offset the data measured at the top and bottom of a vertical face.
- If breaklines are close together, the best DTM models are built if pairs of points are taken opposite each other, as shown on the next page in Figure 5-1. This will result in fewer crossed breaklines, especially for roadway curves and features with near-vertical surfaces, such as curbs.
- Measure data points at intervals of 66 feet or less, regardless of the roadway characteristics or the accuracy of the individual points. Use a 66 foot interval for straight segments of road that have a constant slope. For curves, decrease the length of the interval as the radius of the curve decreases. The midpoint of the chord between two data points must not vary significantly from the curve on the ground.

Figure 5-2, on Page 5-4, illustrates common problems to avoid.

Point Location Guidelines

Use the feature descriptions and point location figures in this section to help determine where to take topographic shots. In general, a data point is needed anywhere the slope of the surface changes. Clarify shots, if needed, with notes in the field file.

"Left" and "Right"

Features can be labeled either "left" or "right." Determine the label by facing the direction in which the prism is traveling as you take the survey. Figure 5-3, at the end of the chapter, illustrates how to determine "left" or "right."

Figure 5-1

Appropriate DTM Data Point Locations

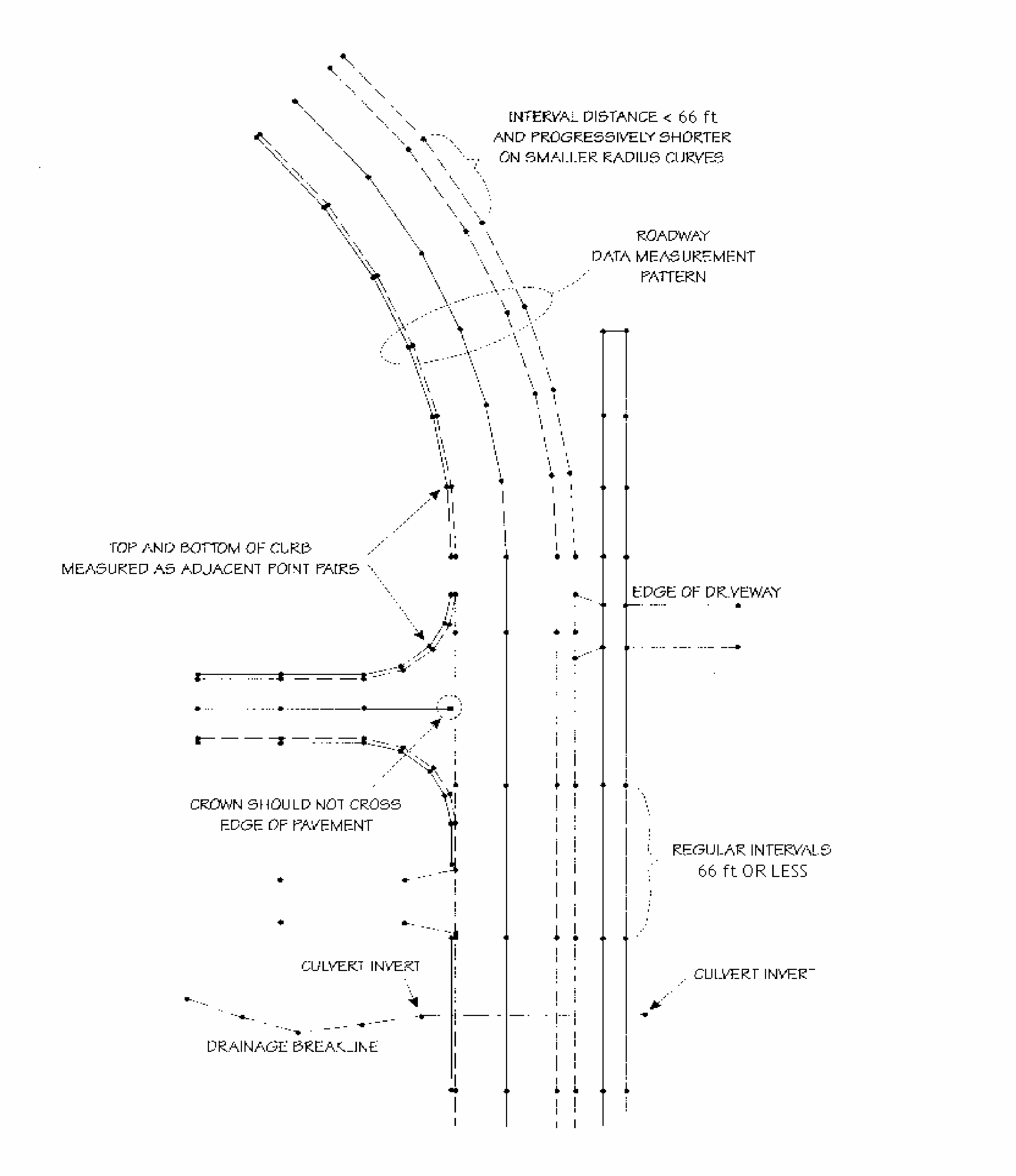
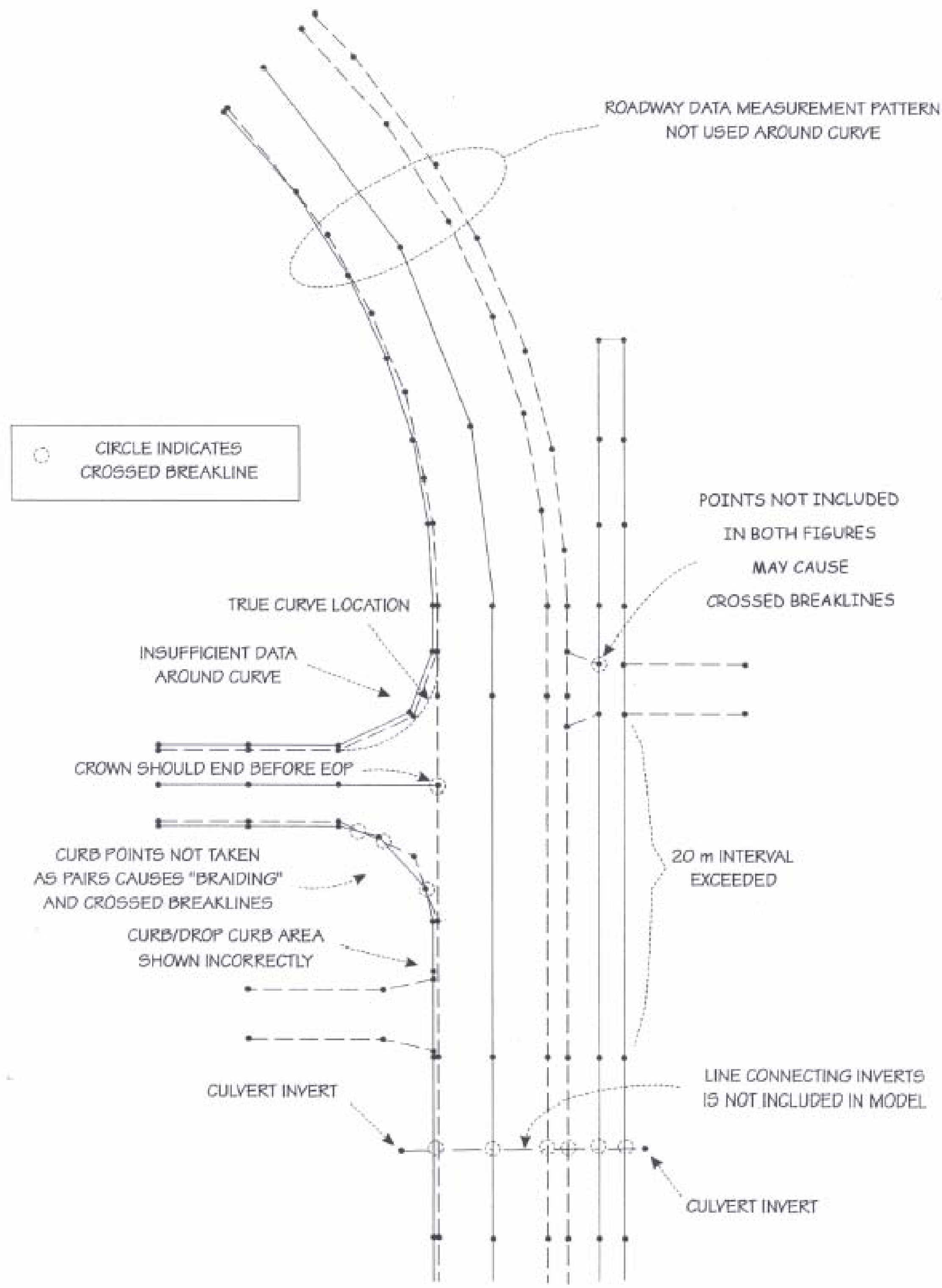


Figure 5-2

Common Problems in DTM Data Point Locations



Location Sketches

Figure 5-4 shows the point locations for a typical rural area. Figure 5-5 shows an urban area.

Curb

For a curb of constant cross section, provide the width. Use the edge of pavement for the bottom of curb and provide data for a breakline along the front edge of the curb.

Intersecting Side Roads

There are many breaklines at the intersection of a side road and the mainline. Don't cross them. For example, the pavement crown of a side road should end before the edge of pavement for the mainline. Provide additional points for tight radii.

Driveways and Sidewalks

If driveways need to be shown, locate both edges. Locate the crown of the driveway if one exists. Locate the edges of sidewalks if required. Driveways and sidewalks should only cross each other at common points.

Drainage

Figure 5-6 shows the point locations for a drop inlet.

Take shots to determine the size of an underground pipe and any changes in the size.

Steps and Walls

Figure 5-7 shows a retaining wall.

Breakline points for stone walls should be taken at ground elevation on the centerline of the wall. Note the height and width.

Bridges

Figure 5-8 is a bridge deck, Figure 5-9 is an isometric view of a bridge abutment, and Figure 5-10 shows elevation views of a pier and an abutment.

On bridge decks, measure points at expansion joints, piers, and the pavement crown in addition to the standard points.

Figure 5-11 is the end view of a large pipe.

Railroads

Figure 5-12 shows point locations for a railroad.

Subsurface Features

Take surface shots on the marks made by Dig Safe and others.

Photograph Guidelines

Take photographs to supplement and clarify topographic surveys of bridges and channels. Photographs should be taken upstream and downstream of a bridge and of each abutment and pier. Label each photograph on its back with the date, direction of the shot, the subject, and the project number and name. Take photographs of major differences in terrain for any topographic survey. Again, label each photograph on its back with the information listed above.

Wetlands

Guidelines

Wetlands should be delineated prior to the survey, if it can be arranged. The VAOT Environmental Section (or consultants employed by them) delineates wetlands.

Don't label an area as a wetland until it has been delineated by a qualified Environmentalist. You can label an area with standing water as "wet" prior to delineation.

Wetlands typically are not located as a breakline for a ground model.

Definitions

Various types of wetlands are defined below.

- *Forested wetlands* are dominated by trees. There are three types, distinguished by the types of trees that dominate them.
  - Hardwood forested wetland
  - Softwood forested wetland
  - Mixed forested wetland
- *Shrub swamps* are woody swamps that are dominated by species that are not trees, such as alders and willows. You can identify a shrub swamp by the presence of multistemmed woody vegetation less than 15 feet high.
- *Emergent wetlands* are dominated by nonwoody or grasslike vegetation. An example is a cattail swamp.
- *Wet meadows* tend to be drier than other types of wetlands. They generally are spongy and are often used for agriculture. Examples are wet pastures and hay fields.
- *Open-water wetlands* do not have vegetation protruding through the water surface, although there may be submerged vegetation.

By law, an area with water deeper than three feet is not a wetland.

Historical Sites

The VAOT Technical Services Division decides which areas are historical sites. Planning marks the sites, and Route Survey locates them. It's desirable that Planning mark the sites prior to the start of a survey.

Figure 5-3

Point Location – “Left” and “Right”

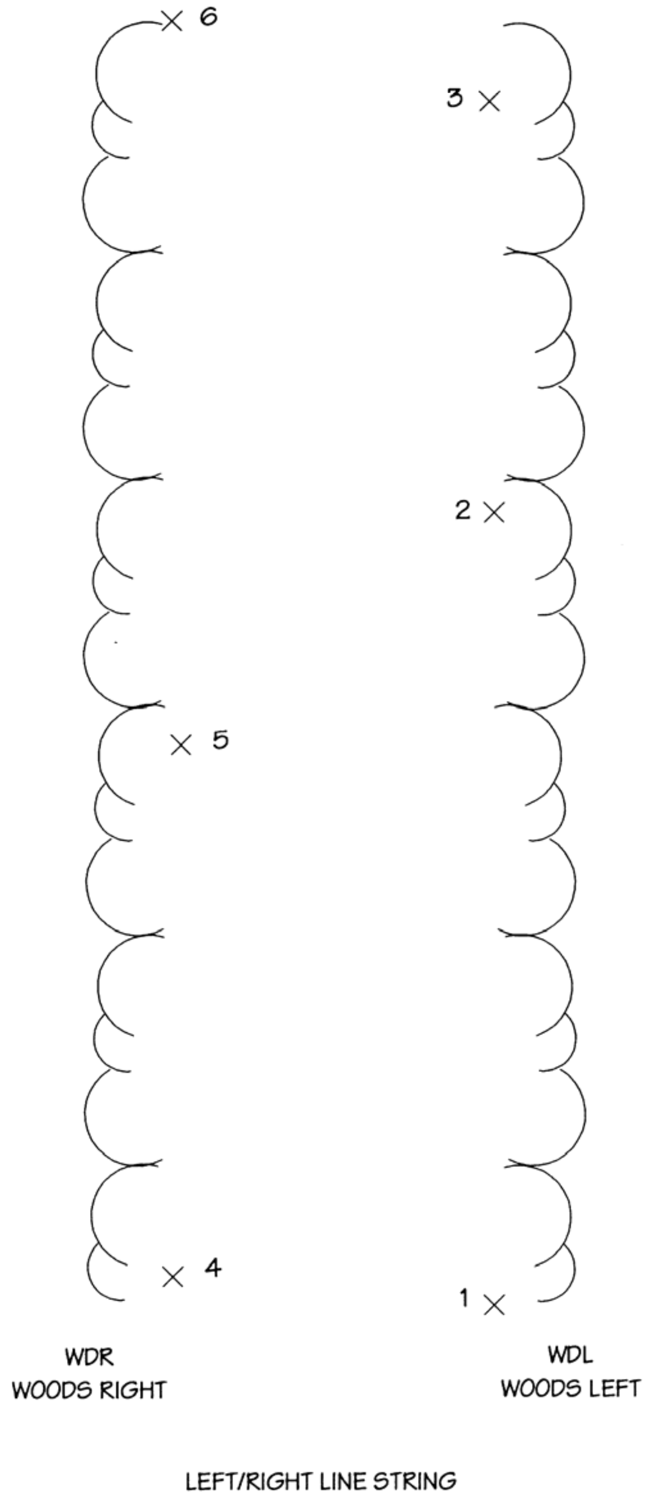


Figure 5-4

Point Location – Rural Area

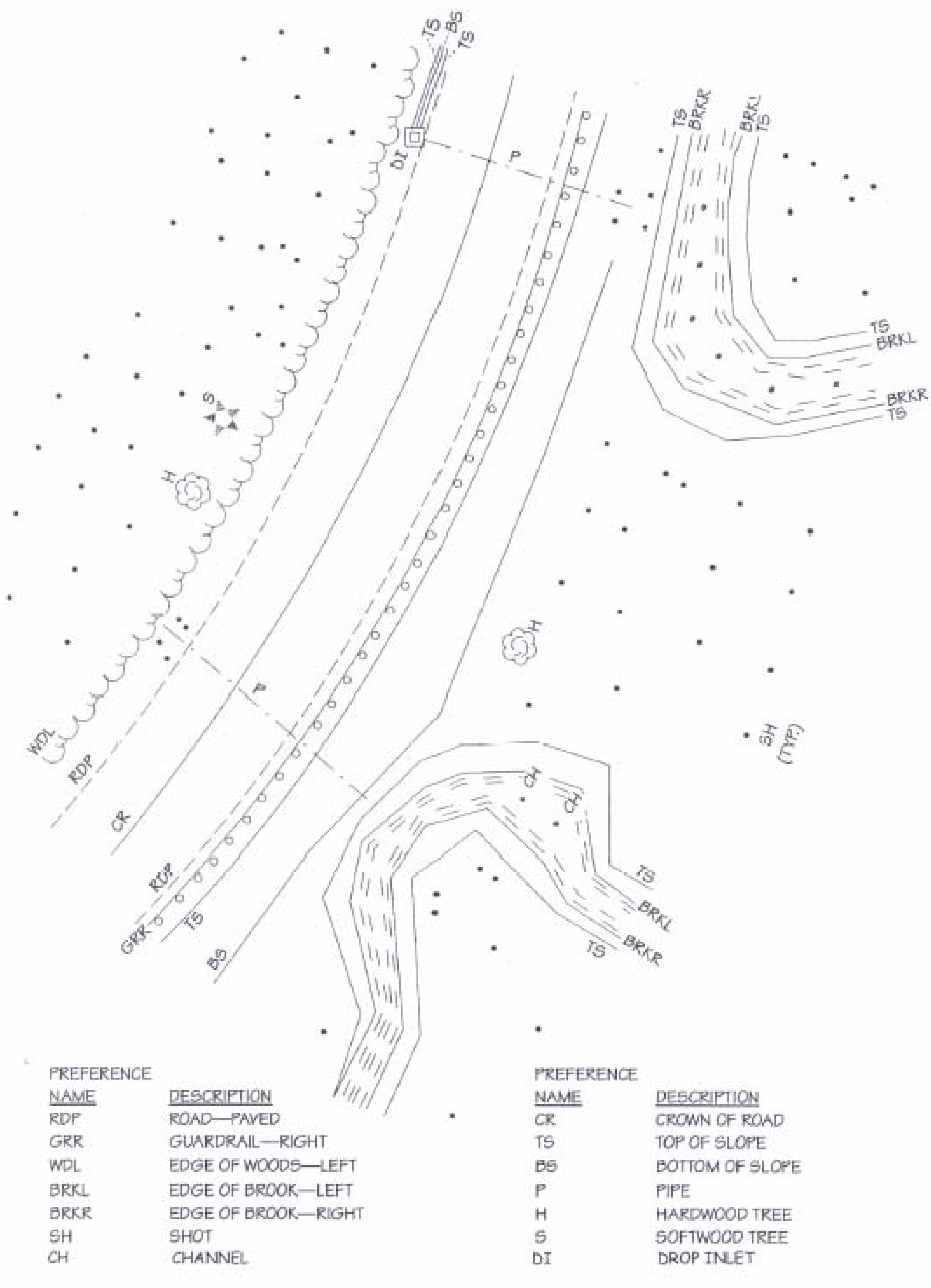


Figure 5-5

Point Location – Urban Area

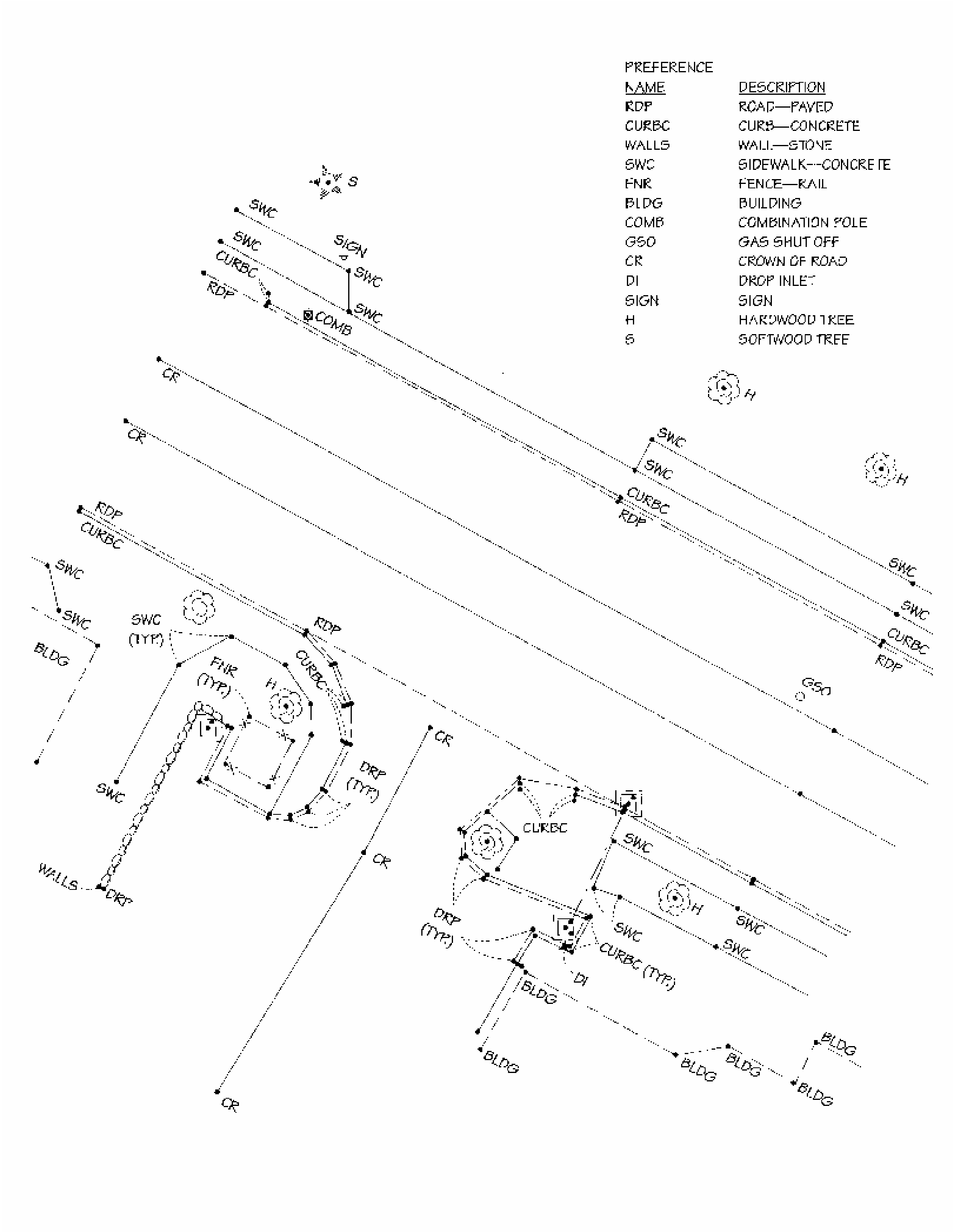
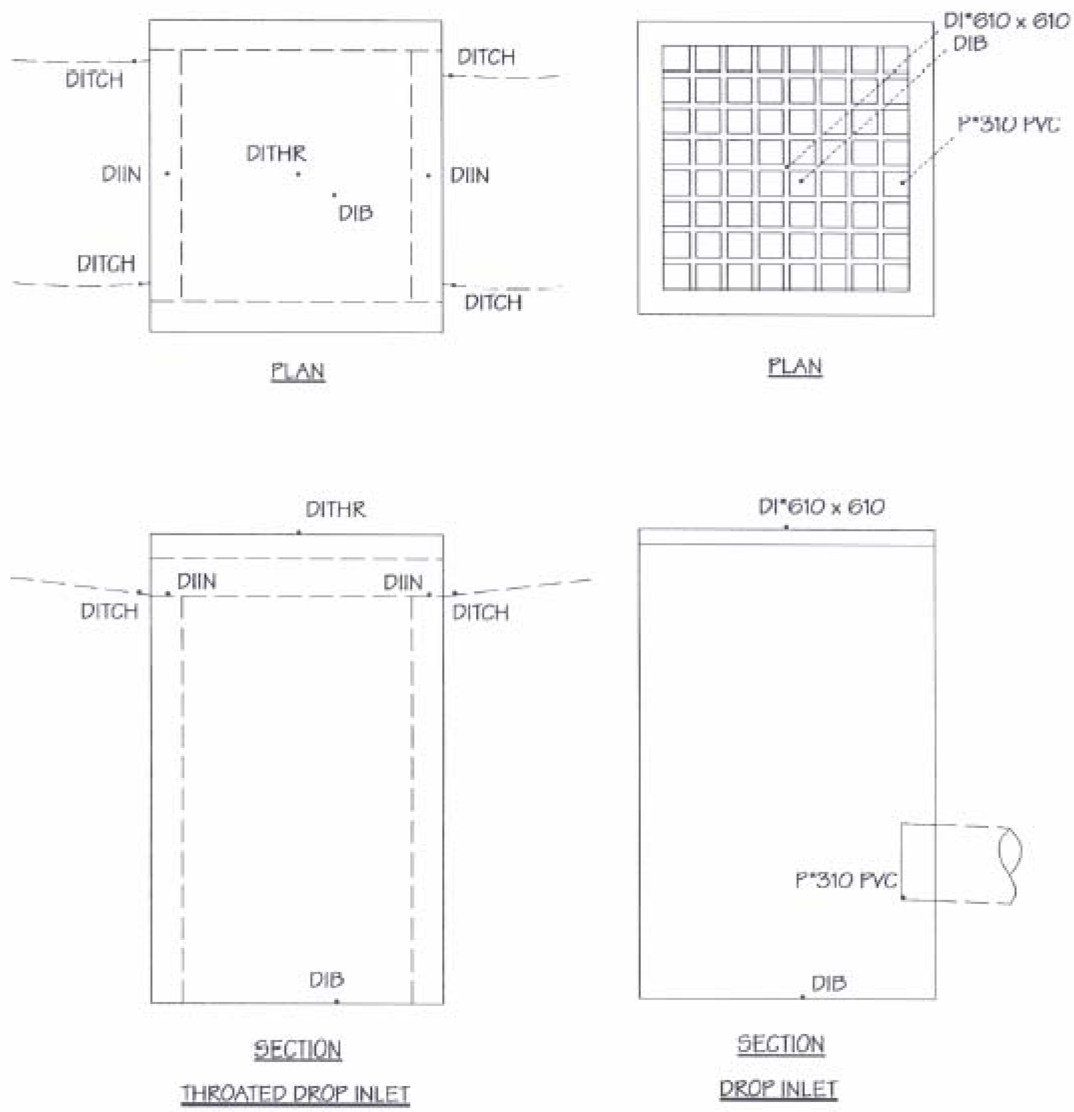


Figure 5-6

Point Location – Drop Inlet



PREFERENCE NAME	DESCRIPTION
DITCH	DITCH
DI	DROP INLET
DIB	BOTTOM OF DROP INLET
DIIN	INLET—THROAT OF DI
DITHR	THROATED DI
P	PIPE

Figure 5-7

Point Location – Retaining Wall

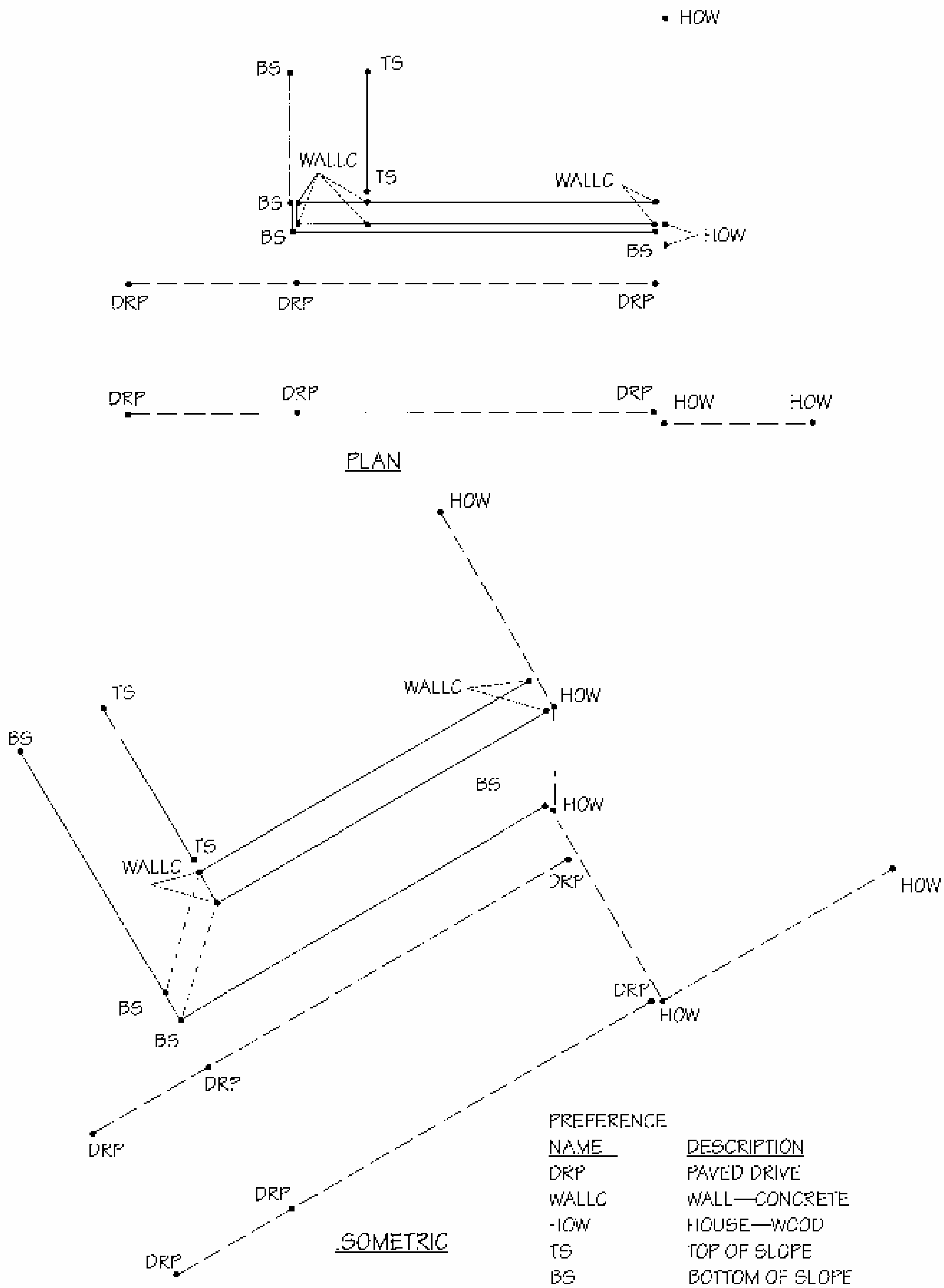
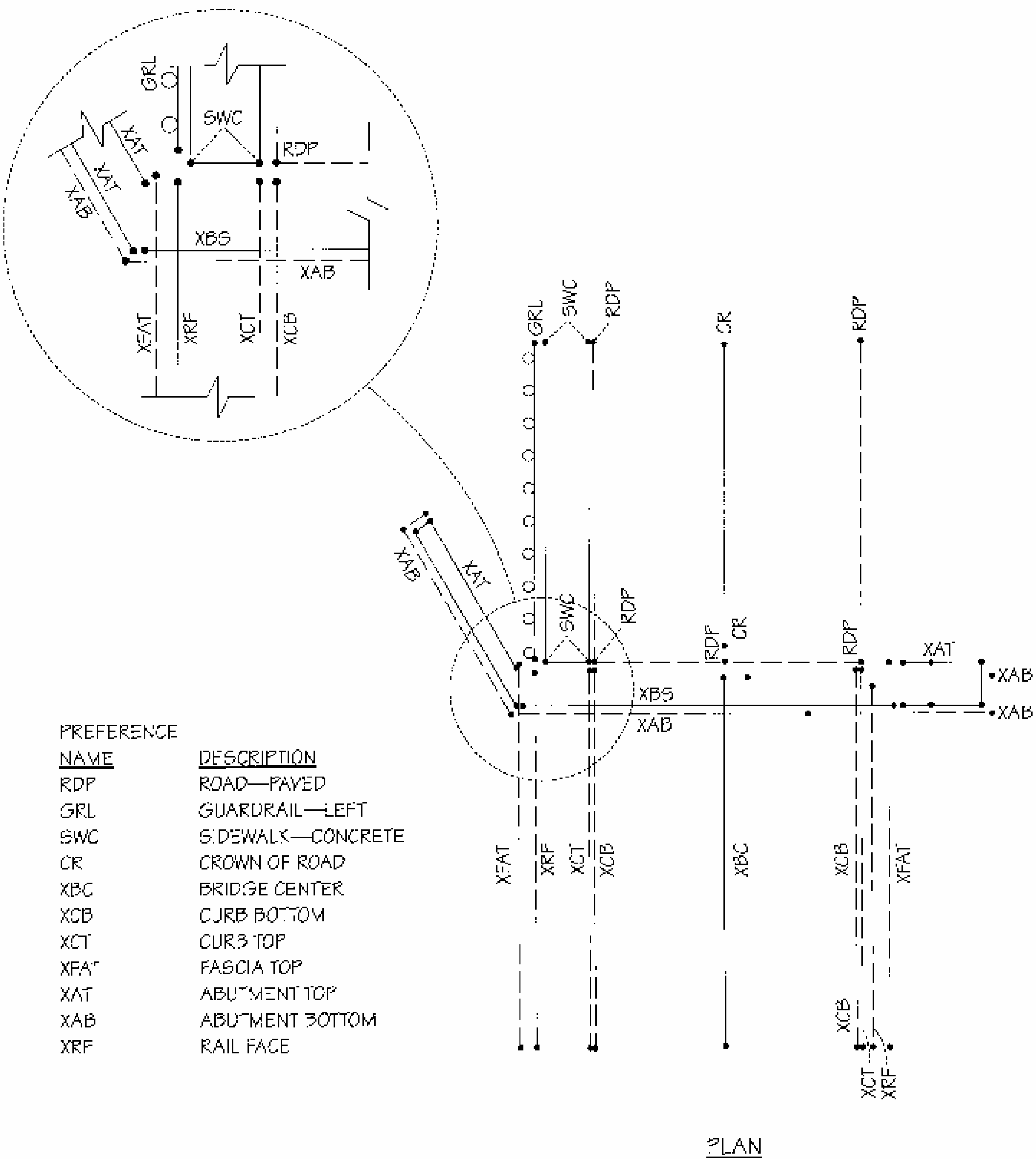


Figure 5-8

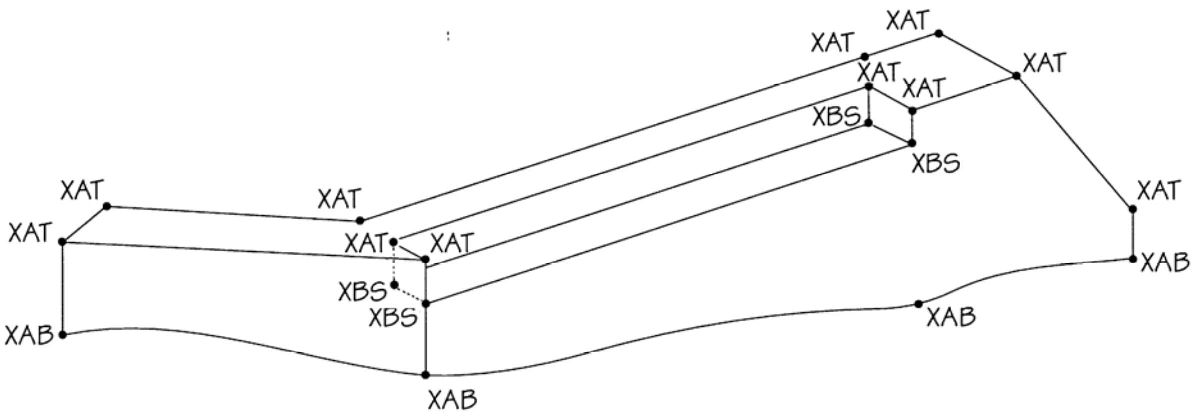
Point Location – Bridge Deck



PREFERENCE NAME	DESCRIPTION
RDP	ROAD—PAVED
GRL	GUARDRAIL—LEFT
SWC	SIDEWALK—CONCRETE
CR	CROWN OF ROAD
XBC	BRIDGE CENTER
XCB	CURB BOTTOM
XCT	CURB TOP
XFAT	FASCIA TOP
XAT	ABUTMENT TOP
XAB	ABUTMENT BOTTOM
XRF	RAIL FACE

Figure 5-9

Point Location – Bridge Abutment

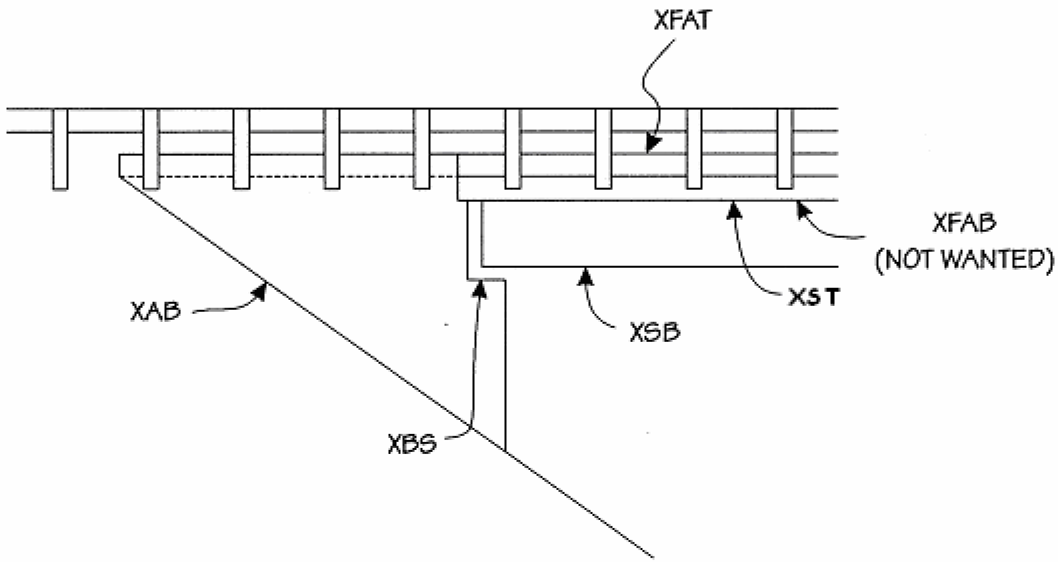


ISOMETRIC

PREFERENCE NAME	DESCRIPTION
XAT	ABUTMENT TOP
XAB	ABUTMENT BOTTOM
XBS	BRIDGE SEAT

Figure 5-9a

Point Location – Bridge Abutment (Side View)

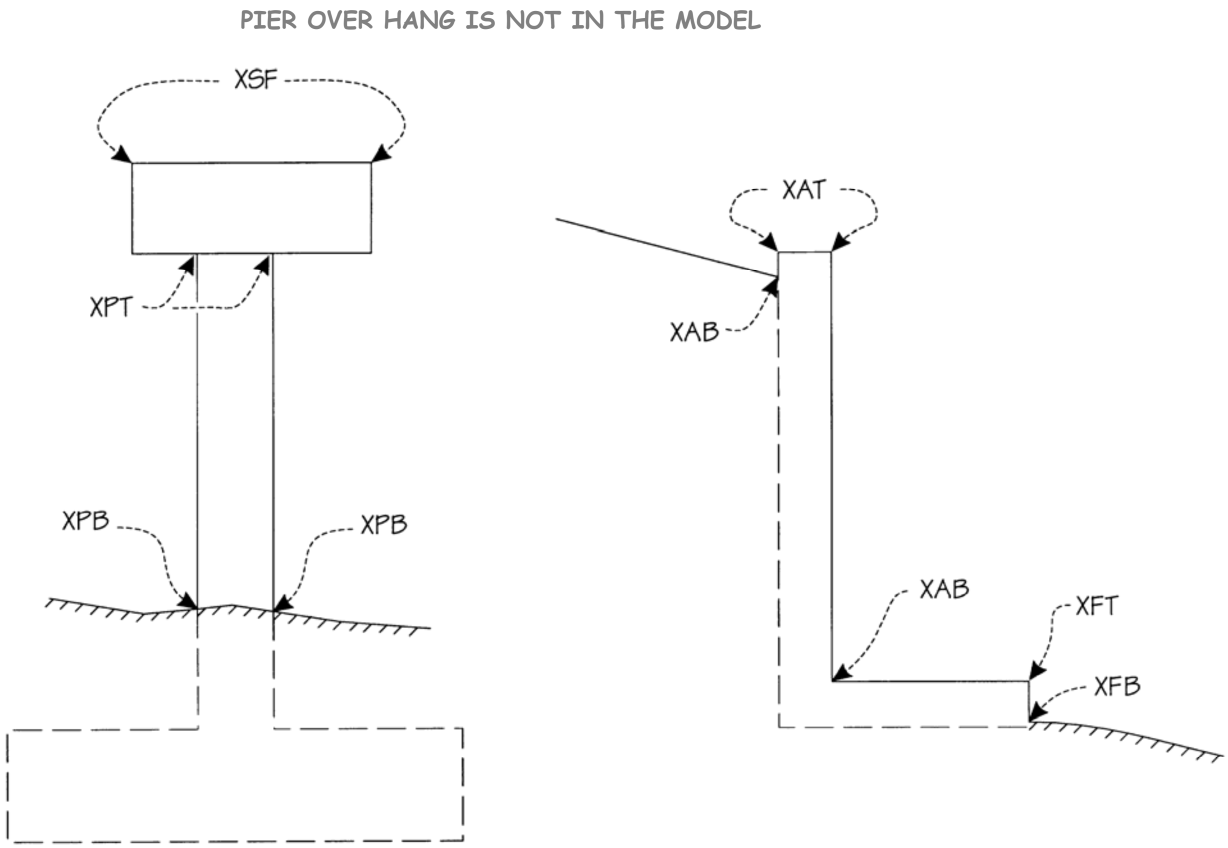


USE FEATURE XSF TO SHOW ALL NECESSARY THINGS ON THE BRIDGE NOT OTHERWISE DESIGNATED BY A FEATURE TABLE FEATURE

PREFERENCE NAME	DESCRIPTION
XAB	ABUTMENT BOTTOM
XBS	BRIDGE SEAT
XFAB	FASCIA BOTTOM
XFAT	FASCIA TOP
XSB	SUPPORT BOTTOM
XST	SUPPORT TOP
XSF	SPECIAL FEATURE

Figure 5-10

Point Location – Pier and Abutment



PREFERENCE NAME	DESCRIPTION
XAB	ABUTMENT BOTTOM
XAT	ABUTMENT TOP
XFB	FOOTING BOTTOM
XFT	FOOTING TOP
XPB	PIER BOTTOM
XPT	PIER TOP
XSF	SPECIAL FEATURE (NOT IN THE MODEL)

Figure 5-11

Point Location – Large Pipe

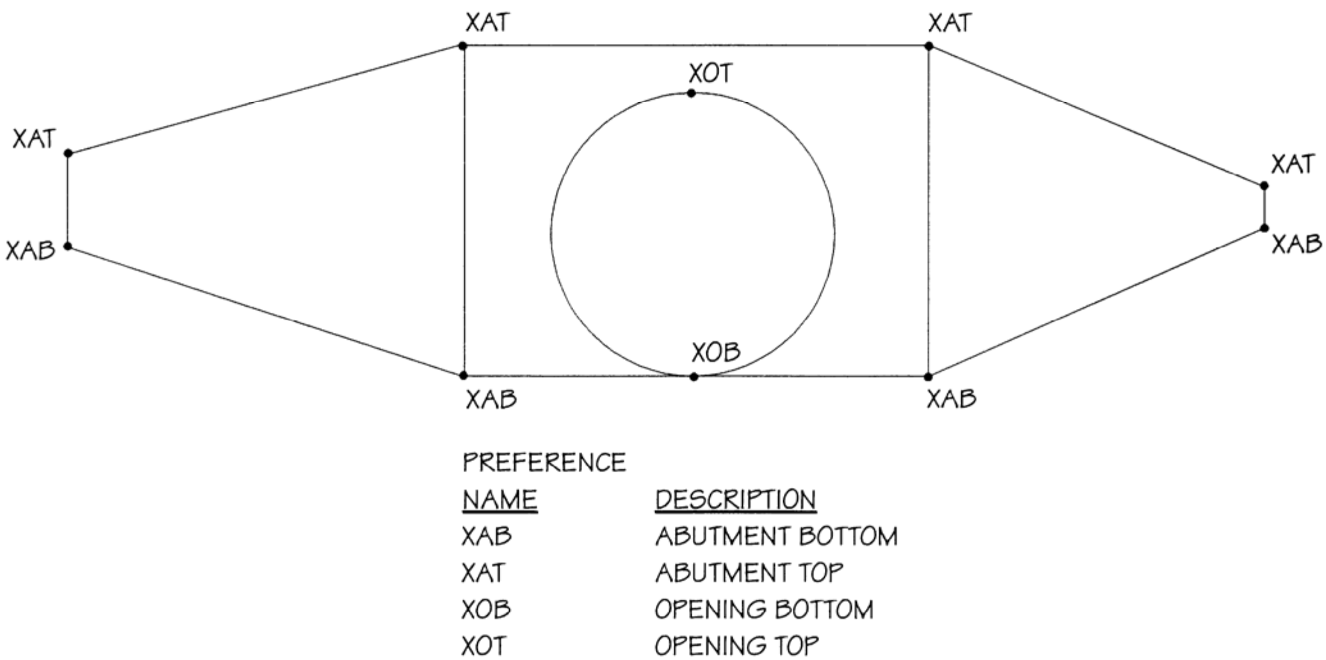
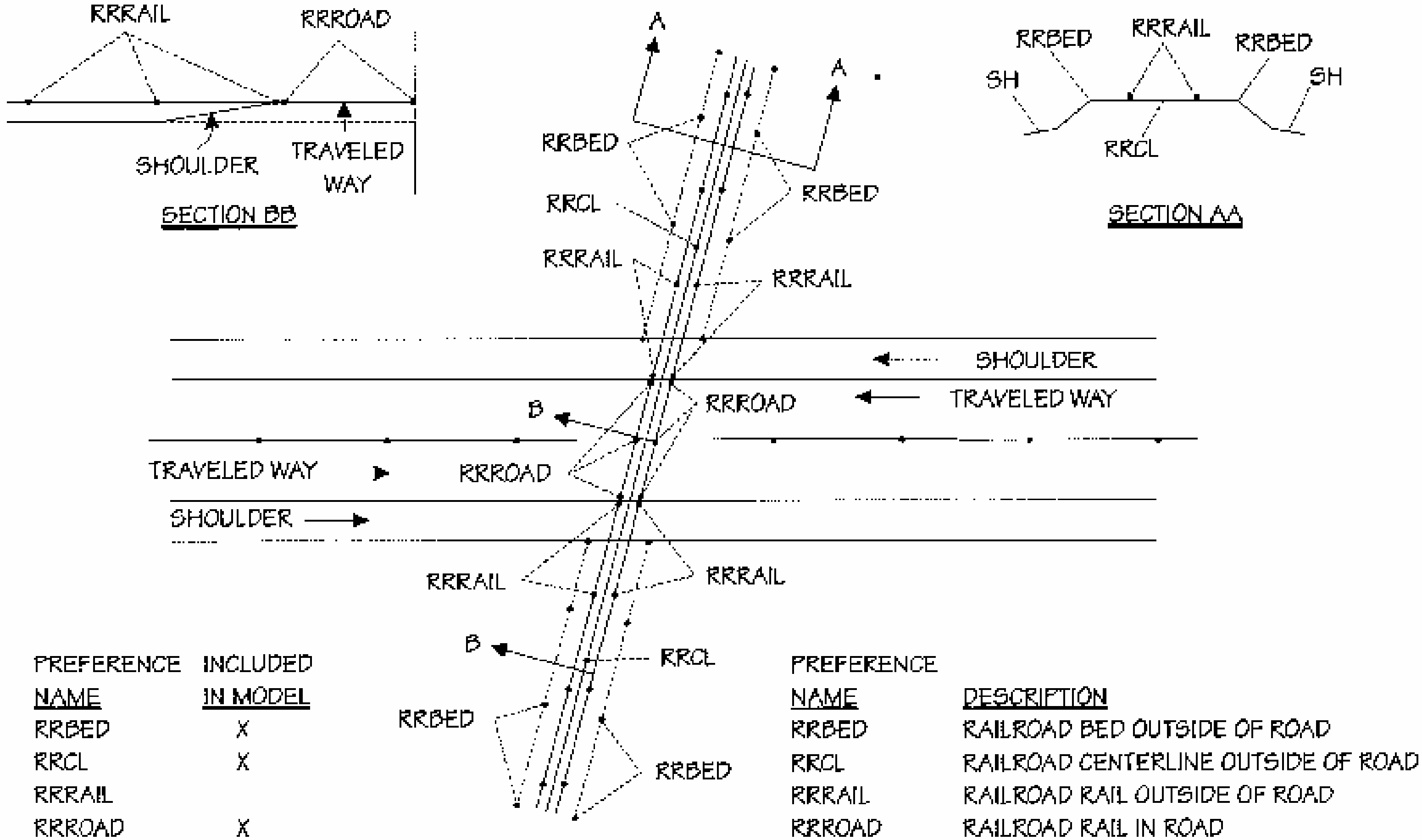


Figure 5-12

Point Location – Railroad



PREFERENCE NAME	INCLUDED IN MODEL
RRBED	X
RRCL	X
RRRAIL	
RRROAD	X
SH	X

PREFERENCE NAME	DESCRIPTION
RRBED	RAILROAD BED OUTSIDE OF ROAD
RRCL	RAILROAD CENTERLINE OUTSIDE OF ROAD
RRRAIL	RAILROAD RAIL OUTSIDE OF ROAD
RRROAD	RAILROAD RAIL IN ROAD
SH	SHOT

Other Surveys

RIGHT-OF-WAY SURVEYS

Accuracy for Boundary Surveys

The accuracy for boundary surveys must be in accordance with a memorandum from the Vermont Board of Land Surveyors, dated August 1, 1994, titled “Standards for the Practice of Land Surveying”

The memorandum includes standards for both accuracy and precision measurements, along with guidelines for classifying boundary surveys.

Accuracy Measurements

The minimum positional tolerances of a point on a boundary are in Figure 6-1 below.

Figure 6-1. Positional; Tolerances for Boundary Surveys

Urban	Suburban	Rural	Mtn./Marshland
0.03 feet plus 1:10,000	0.05 feet plus 1:5000	0.25 feet plus 1:5000	1:500

Precision Measurements

The minimum traverse position ratios, after angles are balanced and closure is calculated, are in Figure 6-2 below.

Figure 6-2. Precision Ratios for Boundary Surveys

Urban	Suburban	Rural	Mtn./Marshland
1:10,000	1:5000	1:5000	1:500

Survey Classification Definitions

Urban

Surveys of land lying within or adjoining a city or town. The classification includes the surveys of commercial or industrial properties. It includes condominiums, town houses, apartments, and other multiunit developments, regardless of location.

Suburban

Surveys of land lying outside of urban areas and used almost exclusively for single family residences or residential subdivisions.

Rural

Surveys of lands such as farms and other undeveloped land outside of suburban areas that may have a potential for future development.

Mountain or Marshland

Surveys in remote areas with difficult terrain, usually of land that has limited potential for development.

Retracement Surveys

Procedure

The Right-of-Way Section requests the retracement of old “compass and rod” surveys. Route Survey conducts the research and the survey.

Topography

Topography for retracement surveys is much like that for any other survey. The topographic features needed will be in the Request for Survey.

All projects should be on the state plane grid and the most current national vertical datum.

In retracement surveys, a major concern is locating historical sites.

Locating and Staking Property Corners

Property corners need to be located and staked if pins might be disturbed by construction, or if special requests are made, etc. Locating a property corner must be conducted in accordance with Vermont statutes under the supervision of a licensed surveyor. See appendix C [Boundaries]

Setting Right-of-Way Bounds

Route Survey sets right-of-way bounds.

As of November 1994, setting right-of-way bounds must be done under the supervision of a licensed surveyor. Monuments must be set according to the laws and standards of the State and Agency. See appendix C [Boundaries]

Blazing Property Lines and Using Paint

If you mark blazes with paint, paint the blaze and surrounding bark. Don’t use excessive amounts of paint, especially around settled areas, such as in the vicinity of a house.

Right-of Way Information Request

The Right-of-Way Section prepares a request for items that aren't included in the plans. For example, they might prepare a request for a tie that doesn't show on the plans, such as a tie to a culvert. The request is also used for locating property corners.

AIRPORT SURVEYS

Route Survey may be requested by a Division within the Agency of Transportation to locate obstructions to air space or survey for runway extensions or beacon locations.

Gaining Access to Airports

As indicated in Chapter One, "Operations," contact the airport manager prior to starting work at an airport. Information for contacting the manager can be obtained from the requester.

The airport manager should issue notices to pilots who use the airport. If coordination problems occur, contact the requestor.

Obstructions to Air Space

Obstructions occur if objects penetrate the imaginary surfaces that define the air space that should be free of objects. Figure 6-3 illustrates the imaginary surfaces. As indicated in the figure, the dimensions of the imaginary surfaces vary with the type of runway.

The typical problem for an airport is that trees at the end of a runway grow through one of the imaginary surfaces. However, utility poles, houses, etc., may also be obstructions.

SURVEYS FOR CONSTRUCTION

Route Survey conducts construction surveys if requested by a project's resident engineer.

Borrow Pits

Try to use DTM (digital terrain modeling) for borrow pits. Using DTM is not always a good choice, though. The pit can have overhangs that cause difficulties if modeling, or previous surveys may have used the conventional base-line-and-section method and, thus, cannot be easily correlated with a DTM model for volume computations.

The work, whether DTM or conventional base line and sections, is essentially the same as topography. See Chapter Five.

Roadway Sections

Roadway sections are similar to borrow pits in two respects: DTM should be used, if practicable, and the field work is essentially the same as that for topography. Using DTM for roadway sections may not be a good choice if previous surveys have used the station-offset method and, thus, present difficulties in volume computations.

Centerline

Stake centerline from existing control when requested or when the project is ready for construction.

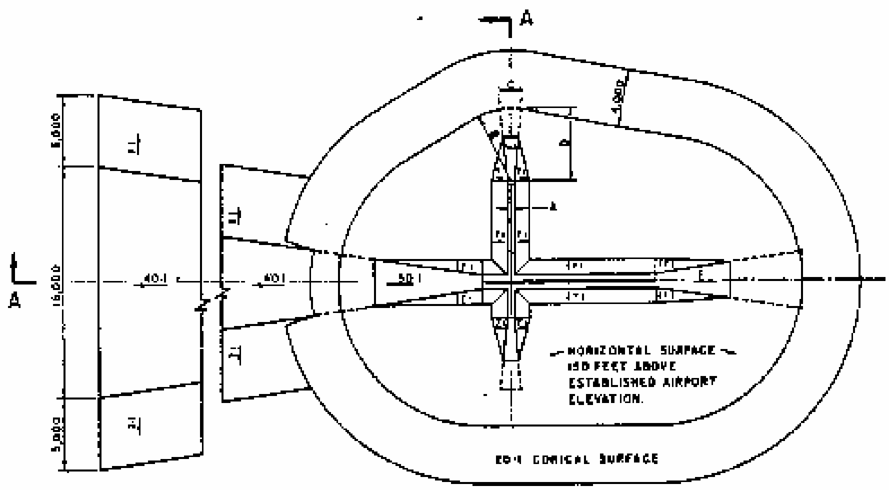
Tie PCs, PTs, etc., if you are requested to do so by the resident engineer. Ties should be similar to those for control points. Control-point ties are covered in Chapter Four, "Traversing and Leveling."

Offsets

Resident engineers typically request random offsets rather than offset lines. Put in offsets where they won't be disturbed, preferably beyond the construction limits.

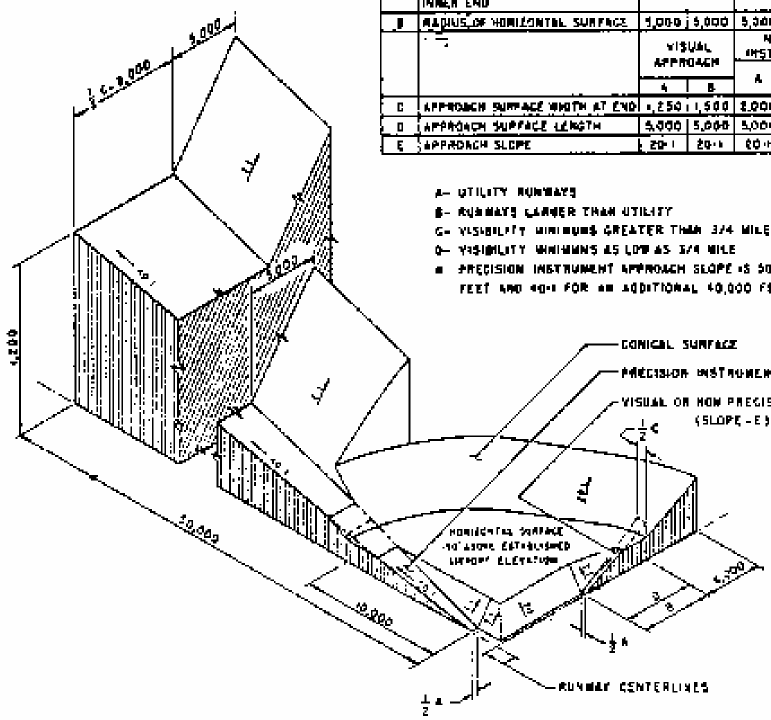
Figure 6-3

Imaginary Surfaces at Civil Airports



DIM	ITEM	DIMENSIONAL STANDARDS (FEET)					
		VISUAL RUNWAY		NON-PRECISION INSTRUMENT RUNWAY			PRECISION INSTRUMENT RUNWAY
		A	B	A	B C	B D	
A	WIDTH OF PRIMARY SURFACE AND APPROACH SURFACE WIDTH AT INNER END	250	500	500	500	1,000	1,000
B	RADIUS OF HORIZONTAL SURFACE	5,000	5,000	5,000	10,000	10,000	10,000
		VISUAL APPROACH		NON-PRECISION INSTRUMENT APPROACH			PRECISION INSTRUMENT APPROACH
		A	B	A	B C	B D	
C	APPROACH SURFACE WIDTH AT END	1,250	1,500	2,000	3,500	4,000	16,000
D	APPROACH SURFACE LENGTH	5,000	5,000	5,000	10,000	10,000	*
E	APPROACH SLOPE	20:1	20:1	20:1	34:1	34:1	*

A– UTILITY RUNWAYS
B– RUNWAYS LARGER THAN UTILITY
C– VISIBILITY MINIMUMS GREATER THAN 3/4 MILE
D– VISIBILITY MINIMUMS AS LOW AS 3/4 MILE
* PRECISION INSTRUMENT APPROACH SLOPE IS 50:1 FOR INNER 10,000 FEET AND 40:1 FOR AN ADDITIONAL 40,000 FEET

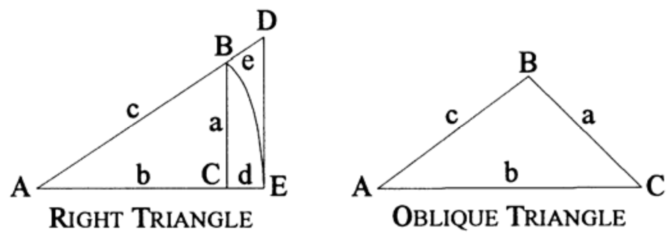


ISOMETRIC VIEW OF SECTION A-A

Tables and Formulas

Figure A-1

Basic Trigonometric Formulas



$\sin A = \frac{a}{c} = \cos B$ $\qquad$ $\sec A = \frac{c}{b} = \text{cosec } B$

$\cos A = \frac{b}{c} = \sin B$ $\qquad$ $\text{cosec } A = \frac{c}{a} = \sec B$

$\tan A = \frac{a}{b} = \cot B$ $\qquad$ $\text{vers } A = \frac{c - b}{c} = \frac{d}{c} = 1 - \cos$

$\cot A = \frac{b}{a} = \tan B$ $\qquad$ $\text{exsec } A = \frac{e}{c} = \sec A - 1$

$a = c \sin A = c \cos B = b \tan A = b \cot B = \sqrt{c^2 - b^2}$

$b = c \cos A = c \sin B = a \cot A = a \tan B = \sqrt{c^2 - a^2}$

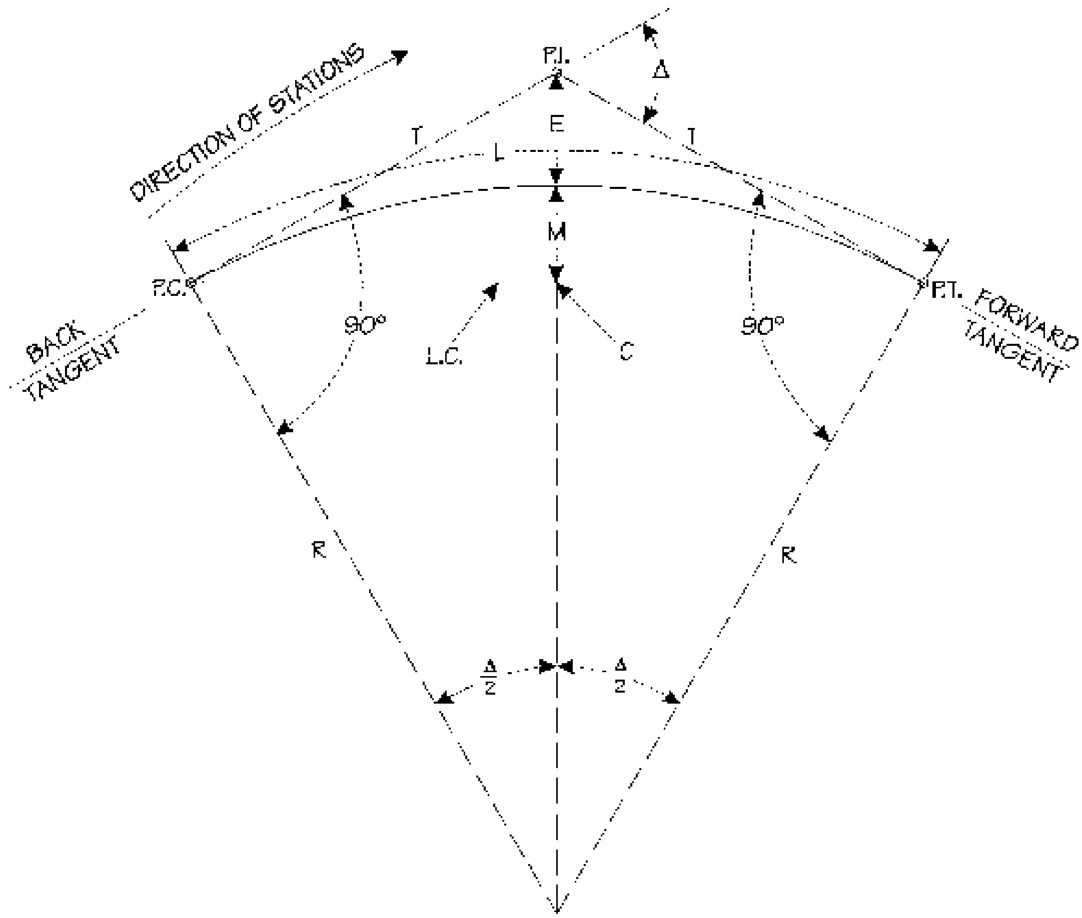
$c = \sqrt{a^2 + b^2}$ $\qquad$ $d = c \text{ vers } A$ $\qquad$ $e = c \text{ exsec}$

OBLIQUE TRIANGLES: $A + B + C = 180°$; $s = \frac{1}{2}(a + b + c)$

Given	Sought	Formulas
A, B, a	b, c	$b = \frac{a}{\sin A} \cdot \sin B \quad c = \frac{a}{\sin a} \cdot \sin(A + B)$
A, a, b	B, c	$\sin B = \frac{\sin A}{a} \cdot b \quad c = \frac{a}{\sin A} \cdot \sin C$
C, a, b	A, c, B	$\tan A = \frac{a \sin C}{b - a \cos C} \quad c = \frac{a \sin C}{\sin A}\ b > a$
C, b, a	B, c, A	$\tan B = \frac{b \sin C}{a - b \cos C} \quad c = \frac{b \sin C}{\sin B}\ a > b$
A, b, c	a	$a^2 = b^2 + c^2 - 2bc \cos A$
B, a, c	b	$b^2 = a^2 + c^2 - 2ac \cos B$
C, a, b	c	$c^2 = a^2 + b^2 - 2ab \cos C$
a, b, c	A, B, C	$\sin^2 \frac{1}{2} A = \frac{s - b}{b} \cdot \frac{s - c}{c}$
		$\sin^2 \frac{1}{2} B = \frac{s - a}{a} \cdot \frac{s - c}{c}$
		$\sin^2 \frac{1}{2} C = \frac{s - a}{a} \cdot \frac{s - b}{b}$
a, b, c	A, B, C	$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$
		$\cos B = \frac{a^2 + c^2 - b^2}{2ac}$
		$\cos C = \frac{a^2 + b^2 - c^2}{2ab}$

Figure A-2

Circular Curve Sketch



P.I. = POINT OF INTERSECTION
P.C. = POINT OF CURVATURE
P.T. = POINT OF TANGENCY
Δ = DEFLECTION ANGLE BETWEEN TANGENTS
T = TANGENT DISTANCE
E = EXTERNAL DISTANCE
R = RADIUS OF CURVE
M = MIDDLE ORDINATE
L.C. = LONG CHORD (DISTANCE BETWEEN P.C. AND P.T.)
C = MIDPOINT OF LONG CHORD
D = DEGREE OF CURVATURE
L = LENGTH OF CURVE

Figure A-3

Formulas and Procedure for Circular Curves in Metric Units

Formulas

$$T = R \tan \frac{\Delta}{2}$$

$$L.C. = 2\ R \sin \frac{\Delta}{2}$$

$$E = T\ \tan \frac{\Delta}{4} \quad \text{or } E = R\ \text{exsec} \frac{\Delta}{2} \quad \text{or } E = R\ \sec \frac{\Delta}{2} - R$$

$$M = E \cos \frac{\Delta}{2} \quad \text{or} \quad M = R\left(1 - \cos \frac{\Delta}{2}\right)$$

$$L = 2\pi R \frac{\Delta}{360}$$

$$\text{station of P.C.} = \text{station of P.I.} - T$$

$$\text{station of P.T.} = \text{station of P.C.} + L$$

$$\text{deflection angle} = \left(\frac{\text{arc}}{L}\right) \frac{\Delta}{2}$$

$$\text{subchord} = 2\ R \sin(\text{deflection angle})$$

1. Calculate the needed stations.
2. Calculate the deflection angles.
3. Calculate the subchords.

A running total of station deflections gives the total deflection angle from the P.C. The total deflection angle to the P.T. must equal $\frac{\Delta}{2}$.

Note:	Metric curves are based on the radius. Metric stationing is based on a kilometer (0+000.000). Standard stationing is at 20-meter intervals.

Figure A-4

Formulas and Procedure for Circular Curves in English Units

Formulas

$$T = R \tan \frac{\Delta}{2}$$

$$L.C. = 2\,R \sin \frac{\Delta}{2}$$

$$E = T \tan \frac{\Delta}{4} \text{ or } E = R \operatorname{ex sec} \frac{\Delta}{2} \text{ or } E = R \sec \frac{\Delta}{2} - R$$

$$M = E \cos \frac{\Delta}{2} \text{ or } M = R\left(1 - \cos \frac{\Delta}{2}\right)$$

$$D = \frac{5729.578}{R}$$

$$L = \frac{100\,\Delta}{D}$$

$$\text{station of P.C.} = \text{station of P.I.} - T$$

$$\text{station of P.T.} = \text{station of P.C.} + L$$

$$\text{deflection angle for a full station} = \frac{D}{2}$$

$$\text{deflection angle (in degrees)} = 0.005\,D\,(\text{arc length}), \text{ for D in degrees}$$

$$\text{deflection angle (in minutes)} = 0.3\,D\,(\text{arc length}), \text{ for D in degrees}$$

$$\text{subchord} = 2\,R \sin(\text{deflection angle})$$

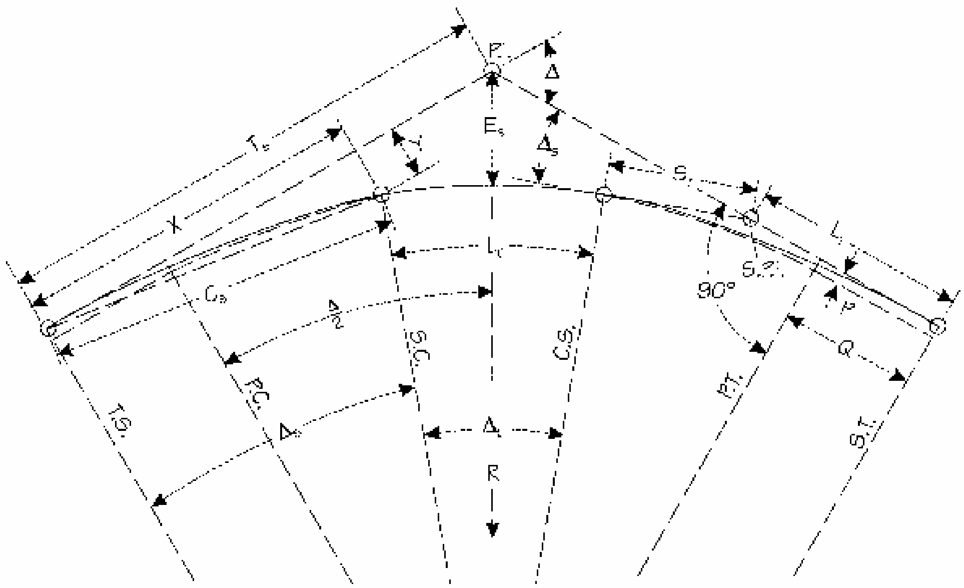
1. Calculate the needed stations.
2. Calculate the deflection angles.
3. Calculate the subchords.

A running total of station deflections gives the total deflection angle from the P.C. The total deflection angle to the P.T. must equal $\frac{\Delta}{2}$.

Note: English curves are based on the degree of curvature. Stationing is based on 100 feet (0+00.00). Standard stationing is at 50-foot intervals.

Figure A-5

Spiral Curve Transition Sketch



L_s = LENGTH OF SPIRAL
D = DEGREE OF CURVATURE OF THE CIRCULAR CURVE
T_s = TANGENT DISTANCE
Δ = DEFELCTION ANGLE BETWEEN THE MAIN TANGENTS (T_s)
Δ_s = SPIRAL ANGLE
Δ_c = CENTRAL ANGLE BETWEEN THE S.C. AND C.S.
E_s = EXTERNAL DISTANCE
C_s = LONG CHORD
L_t = LONG TANGENT (SPIRAL)
S_t = SHORT TANGENT (SPIRAL)
L_c = LENGTH OF CIRCULAR CURVE
X = SPIRAL COORDINATE (ABSCISSA)
Y = SPIRAL COORDINATE (ORDINATE)
Q = SIMPLE CURVE COORDINATE (ABSCISSA)
P = SIMPLE CURVE COORDINATE (ORDINATE)
Δ = DEFLECTION ANGLE OF SPIRAL CURVE
T.S. = TANGENT TO SPIRAL
S.C. = SPIRAL TO CURVE
C.S. = CURVE TO SPIRAL
S.T. – SPIRAL TO TANGENT
R = RADIUS OF CIRCULAR CURVE
S.P. = SPIRAL PI

Figure A-6

Formulas and Procedure for Spiral Curve Transitions in Metric Units

$$T_s = (R + P)\tan\frac{\Delta}{2} + Q \text{ or } T_s = T + Q + P\tan\frac{\Delta}{2}$$

$$E_s = \frac{(R + P)}{\cos\frac{\Delta}{2}} - R \text{ or } E_s = (R + P)\operatorname{exsec}\frac{\Delta}{2} + P$$

$$\Delta_s = \frac{90\,L_s}{\pi R}$$

$$\Delta_c = \Delta - 2\Delta_s$$

$$L_c = \frac{2\pi R \Delta_c}{360}$$

$$\text{station of T.S.} = \text{station of P.I.} - T_s$$

$$\text{station of S.C.} = \text{station of T.S.} + L_s$$

$$\text{station of C.S.} = \text{station of S.C.} + L_c$$

$$\text{station of S.T.} = \text{station of C.S.} + L_s$$

$$\text{spiral deflection}, \theta_s \approx \frac{\Delta_s}{3}$$

$$\text{deflection angle for distance } l, \phi = \left(\frac{l}{L_s}\right)^2 \theta_s$$

1. Calculate the tangent distance.
2. Calculate the spiral curve angle and circular curve angle and arc length.
3. Calculate the key points.
4. Calculate lengths to and deflection angles for the key points.

Note: Metric curves are based on the radius. Metric stationing is based on a kilometer (0+000.000). Standard stationing is at 20-meter intervals.

Figure A-7

Formulas and Procedure for Spiral Curve Transitions in English Units

$$T_s = (R + P)\tan\frac{\Delta}{2} + Q \quad \text{or} \quad T_s = T + Q + P\tan\frac{\Delta}{2}$$

$$E_s = \frac{(R + P)}{\cos\frac{\Delta}{2}} - R \quad \text{or} \quad E_s = (R + P)\text{ex}\sec\frac{\Delta}{2} + P$$

$$\Delta_s = \frac{D\,L_s}{200}$$

$$\Delta_c = \Delta - 2\Delta_s$$

$$L_c = \frac{100\Delta_c}{D}$$

$$\text{station of T.S.} = \text{station of P.I.} - T_s$$

$$\text{station of S.C.} = \text{station of T.S.} + L_s$$

$$\text{station of C.S.} = \text{station of S.C.} + L_c$$

$$\text{station of S.T.} = \text{station of C.S.} + L_s$$

$$\text{spiral deflection}, \theta_s \approx \frac{\Delta_s}{3}$$

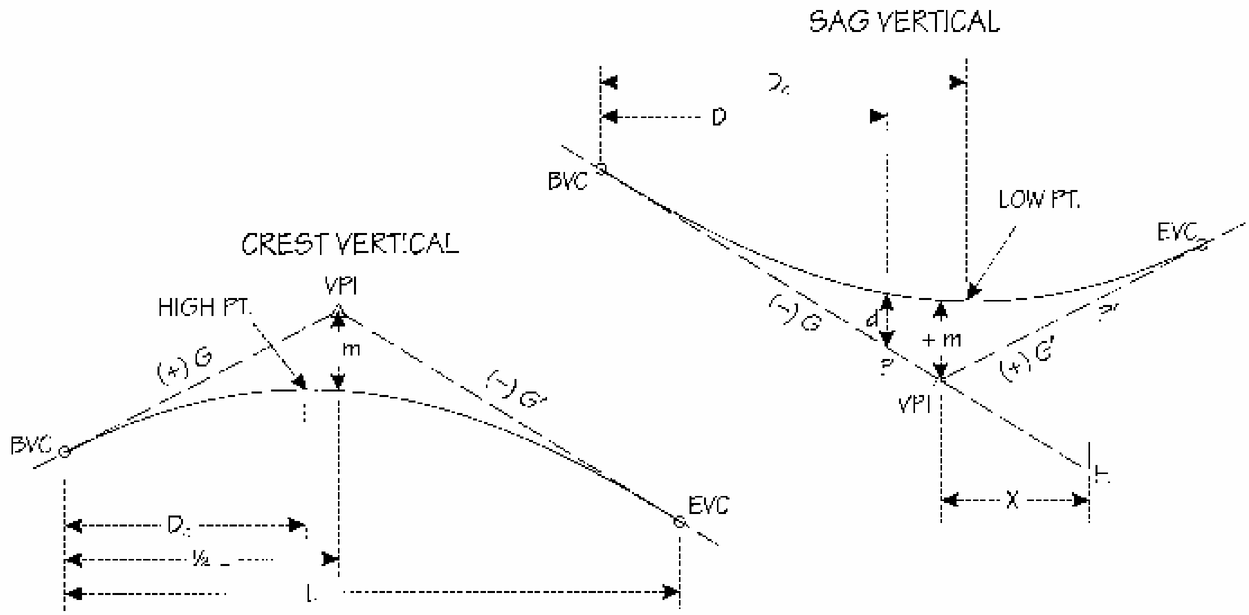
$$\text{deflection angle for distance } l, f = \left(\frac{l}{L_s}\right)^2 \theta_s$$

1. Calculate the tangent distance.
2. Calculate the spiral curve angle and circular curve angle and arc length.
3. Calculate the key points.
4. Calculate lengths to and deflection angles for the key points.

Note:	English curves are based on the degree of curvature. Stationing is based on 100 feet (0+00.00). Standard stationing is at 50-foot intervals.

Figure A-8

Parabolic Vertical Curve Sketch



L = LENGTH OF CURVE, IN STATIONS

G, G' = GRADE RATES IN PERCENTAGES (NOT DECIMALS), WITH PROPER SIGNS

m = MIDDLE ORDINATE

d = CORRECTION, WITH PROPER SIGN, FROM GRADE LINE TO CURVE

S = SLOPE, IN PERCENTAGE, OF THE TANGENT TO THE CURVE AT ANY POINT ON THE CURVE

X = DISTANCE FROM P' TO VPI

H = ELEVATION OF POINT H, WHICH IS ON GRADE "G"

P, P' = ELEVATIONS ON RESPECTIVE GRADES

D_0 = DISTANCE, IN STATIONS, TO LOW OR HIGH POINT FROM BVC OR EVC

D = DISTANCE, IN STATIONS, FROM BVC OR EVC TO ANY POINT ON THE CURVE

BVC = BEGINNING OF VERTICAL CURVE

VPI = VERTICAL POINT OF INTERSECTION

EVC = END OF VERTICAL CURVE

Figure A-9

Formulas and Procedure for Parabolic Vertical Curves in Metric or English Units

$$S = G + \frac{D(G' - G)}{L}$$

$$D_o = \frac{LG}{(G - G')}$$

$$m = \frac{1}{2}\left(\frac{BVC_{elev} + EVC_{elev}}{2} - VPI_{elev}\right) \text{ for a sag curve}$$

$$m = \frac{1}{2}\left(\frac{BVC_{elev} + EVC_{elev}}{2} + VPI_{elev}\right) \text{ for a crest curve}$$

$$d = \frac{mD^2}{\left(\frac{L}{2}\right)^2} = \frac{4mD^2}{L^2}$$

$$X = \frac{100(H - P')}{(G - G')}$$

1. Calculate the difference in grade, length of curve, and distance to the high or low point.
2. Calculate the elevations of the grade lines at BVC, EVC, and other required stations.
3. Calculate the tangent offset at the PVI, m.
4. Calculate the tangent offsets, d, at the other required stations.
5. Calculate the elevation of the curve:
   a. Add d to the grade line elevations for sag curves
   b. Subtract d from the grade line elevations for crest curves.

Figure A-10

Survey Units Conversion Table

Unit	Multiply By	Unit	Multiply By
Length			
inch → mm	25.400 050 75	mm → inch	0.039 37
ft → km	0.304 800 61	m → ft	3.280 833 3
mile → km	1.609 344	km → mile	0.621 371 2
Area			
$ft^2 \rightarrow m^2$	0.092 903 04	$m^2 \rightarrow ft^2$	10.763 910 42
acre → m^2	4046.856	m^2 → acre	0.000 247 105
acre → ha	0.404 685 6	ha → acre	2.471 054 76
Volume			
$ft^3 \rightarrow m^3$	0.028 316 8	$m^3 \rightarrow ft^3$	35. 314 724 83
$yd^3 \rightarrow m^3$	0.764 555	$m^3 \rightarrow yd^3$	1.307 950 376
Temperature			
°F → °C	(°F – 32) ÷ 1.8	°C → °F	(1.8 × °C) + 32

Note. Conversion based on U.S. survey foot: one meter = 3937/1200 feet

Figure A-11

Feature Table

Feature Description	Alpha Code	Point Type	Style
BARN :O:	BARN	Breakline	x_BARN
BASELINE :O:	BL	Breakline - DNT	x_BL
BENCH MARK (REVISED) :O:	REVBM	Breakline - DNT	x_BM_1
BENCH MARK :O:	BM	Breakline - DNT	x_BM
BLAZE :O:	BLZ	Breakline - DNT	x_BLZ
BORING :O:	BOR BORING	Breakline - DNT	x_BOR
BOULDER :O:	BDR BOULDER	Breakline - DNT	x_BOULDER
BOUND :O:	BND	Breakline - DNT	x_BND
BOUND APPARENT LOCATION :O:	APL	Breakline – DNT	x_APL
BOUND NOT SET:O:	BNDNS	Breakline - DNT	x_BNDNS
BOX CULVERT :O:	BOX	Breakline - DNT	x_BOX
BOX CULVERT CONCRETE :O:	BOXC	Breakline - DNT	x_BOXC
BOX CULVERT STONE :O:	BOXS	Breakline - DNT	x_BOXS
BRIDGE ABUTMENT BOTTOM :X:	XAB	Breakline	x_XAB
BRIDGE ABUTMENT TOP :X:	XAT	Breakline	x_XAT
BRIDGE BEAM BOTTOM :X:	XBIB	Breakline - DNT	x_XBIB
BRIDGE CENTER :X:	XBC	Breakline - DNT	x_XBC
BRIDGE CURB BOTTOM :X:	XCB	Breakline - DNT	x_XCB
BRIDGE CURB TOP :X:	XCT	Breakline - DNT	x_XCT
BRIDGE DECK :X:	XDECK	Breakline - DNT	x_XDECK
BRIDGE DRAIN :X:	XDRAIN	Breakline - DNT	x_XDRAIN
BRIDGE FASCIA BOTTOM :X:	XFAB	Breakline - DNT	x_XFAB
BRIDGE FASCIA TOP :X:	XFAT	Breakline - DNT	x_XFAT
BRIDGE FOOTING BOTTOM :X:	XFB	Breakline	x_XFB
BRIDGE FOOTING TOP :X:	XFT	Breakline	x_XFT
BRIDGE OPENING BOTTOM :X:	XOB	Breakline - DNT	x_XOB
BRIDGE OPENING TOP :X:	XOT	Breakline - DNT	x_XOT
BRIDGE PIER BOTTOM :X:	XPB	Breakline	x_XPB
BRIDGE PIER TOP :X:	XPT	Breakline	x_XPT
BRIDGE PIER TOP AT FASCIA :X:	XPF	Breakline - DNT	x_XPF
BRIDGE RAIL FACE :X:	XRF	Breakline - DNT	x_XRF
BRIDGE SEAT :X:	XBS	Breakline	x_XBS
BRIDGE SPECIAL FEATURE :X:	XSF	Breakline - DNT	x_XSF
BRIDGE SUPPORT BOTTOM :X:	XSB	Breakline - DNT	x_XSB
BRIDGE SUPPORT TOP :X:	XST	Breakline - DNT	x_XST

Figure A-11 (continued)

Feature Table

Feature Description	Alpha Code	Point Type	Style
BUILDING :O:	BLDG	Breakline	x_BLDG
CATCH BASIN :O:	CB	Breakline - DNT	x_CB
CHANNEL SHOT ON BOTTOM :O:	CH	Random	x_CH
CHURCH :O:	CHURCH	Breakline	x_CHURCH
COMBINATION POLE :O:	COMB	Random	x_COMB
CONCRETE PAD :O:	CONCPAD CPD	Breakline	x_CONCPAD
CONTROL HORIZONTAL :O:	HCTRL	Breakline - DNT	x_HCTRL
CONTROL HORIZONTAL AND VERTICAL :O:	HVCTRL	Breakline - DNT	x_HVCTRL
CONTROL VERTICAL :O:	VCTRL	Breakline - DNT	x_VCTRL
CURB BITUMINOUS :R:	CP CURBB	Breakline	x_CURBB
CURB CONCRETE :R:	CC CURBC	Breakline	x_CURBC
CURB GENERIC :R:	CRB CURB	Breakline	x_CURB
CURB GRANITE :R:	CG CURBG	Breakline	x_CURBG
CURB WOOD :R:	CURBW CW	Breakline	x_CURBW
DITCH :O:	DIT DITCH	Breakline	x_DITCH
DRAINAGE :O:	DRA	Breakline	x_DRA
DRAINAGE PIPE :O:	P	Breakline - DNT	x_P
DRIVE CONCRETE :R:	DRC	Breakline	x_DRC
DRIVE FIELD :R:	DRF	Breakline	x_DRF
DRIVE GRAVEL :R:	DRG	Breakline	x_DRG
DRIVE PAVED :R:	DRP	Breakline	x_DRP
DRIVE WOOD :R:	DRW	Breakline	x_DRW
DRIVEWAY OR SIDE ROAD :R:	DR	Breakline	x_DR
DROP INLET :O:	DI	Random	x_DI
DROP INLET BOTTOM :O:	DIB	Breakline - DNT	x_DIB
DROP INLET NEW :O:	NDI	Breakline - DNT	x_NDI
DROP INLET THROAT :O:	DIIN	Random	x_DIIN
DROP INLET THROATED DNC :O:	DITHR	Breakline - DNT	x_DITHR
EDGE BROOK LEFT :O:	BRKL	Breakline	x_BRKL
EDGE BROOK RIGHT :O:	BRK BRKR	Breakline	x_BRKR
EDGE BRUSH LEFT :O:	BRL	Breakline	x_BRL
EDGE BRUSH RIGHT :O:	BRR	Breakline	x_BRR
EDGE LAKE LEFT :O:	LAKEL	Breakline	x_LAKEL
EDGE LAKE RIGHT :O:	LAKER	Breakline	x_LAKER

Figure A-11 (continued)

Feature Table

Feature Description	Alpha Code	Point Type	Style
EDGE LEDGE :O:	LE	Random	x_LE
EDGE LEDGE LEFT :O:	LEL	Breakline	x_LEL
EDGE LEDGE RIGHT :O:	LER	Breakline	x_LER
EDGE OF A LAKE :O:	LAKE	Breakline	x_LAKE
EDGE POND LEFT :O:	PONDL	Breakline	x_PONDL
EDGE POND RIGHT :O:	PONDR	Breakline	x_PONDR
EDGE RIVER :O:	RVR	Breakline	x_RVR
EDGE RIVER LEFT :O:	RVRL	Breakline	x_RVRL
EDGE RIVER RIGHT :O:	RVRR	Breakline	x_RVRR
EDGE WOODS :O:	WD	Breakline	x_WD
EDGE WOODS LEFT :O:	WDL	Breakline	x_WDL
EDGE WOODS RIGHT :O:	WDR	Breakline	x_WDR
ELECTRIC POLE :O:	EL	Random	x_EL
ELEVATION UNKNOWN :O:	NOELEV	Breakline - DNT	x_NOELEV
FEATURE MAN MADE :O:	MMF	Breakline	x_MMF
FEATURE NATURAL :O:	NF	Random	x_NF
FENCE BARBED WIRE :O:	FNBW	Breakline	x_FNBW
FENCE CHAIN LINK :O:	FNCHL	Breakline	x_FNCHL
FENCE GENERIC :O:	FN	Breakline	x_FN
FENCE RAIL :O:	FNR	Breakline	x_FNR
FENCE WOOD :O:	FNWD	Breakline	x_FNWD
FENCE WOVEN/WELDED WIRE :O:	FNWW	Breakline	x_FNWW
FLAG POLE :O:	FPOLE	Random	x_FPOLE
FOUNDATION :O:	FDN FOUNDATION	Breakline	x_FOUNDATION
GARAGE :O:	GAR GARAGE	Breakline	x_GARAGE
GARDEN :O:	GARDEN GARDENL GARDENR GDN	Breakline	x_GARDEN
GAS FILLER :O:	GASFIL	Random	x_GASFIL
GAS SHUT OFF :O:	GSO	Breakline - DNT	x_GSO
GATE VALUE :O:	GV	Breakline - DNT	x_GV
GRAVE STONE (HEADSTONE) :O:	GRAV GRAVE	Random	x_GRAV
GUARD RAIL :O:	GR	Breakline	x_GR
GUARD RAIL LEFT :O:	GRL	Breakline	x_GRL
GUARD RAIL RIGHT :O:	GRR	Breakline	x_GRR
GUIDE POST :O:	GP	Random	x_GP
GUY POLE :O:	GUY GUYP	Random	x_GUY

GUY WIRE :O:	GUYW	Random	x_GUYW

Figure A-11 (continued)

Feature Table

Feature Description	Alpha Code	Point Type	Style
HEDGE :O:	HED HEDGE	Breakline	x_HEDGE
HOUSE :O:	HO, HOB HOS, HOW	Breakline	x_HOUSE
HUB :O:	HUB	Breakline - DNT	x_DEFAULT_1
HYDRANT :O:	HYD	Random	x_HYD
IRON PIN :O:	IP	Breakline - DNT	x_IP
IRON PIPE :O:	IPIPE	Breakline - DNT	x_IPIPE
LIGHT - STREET OR YARD :O:	LI	Random	x_LI
MAIL BOX :O:	MB	Random	x_MB
MANHOLE (MH) :O:	MH	Random	x_MH
MH ELECTRIC :O:	MHE	Random	x_MHE
MH GAS :O:	MHG	Random	x_MHG
MH SEWER :O:	MHS	Random	x_MHS
MH TELEPHONE :O:	MHT	Random	x_MHT
MH WATER :O:	MHW	Random	x_MHW
MILE MARKER :O:	MM	Random	x_MM
ORIGINAL GROUND PERIMETER :O:	OG	Breakline	x_OG
PARKING METER :O:	PM	Random	x_PM
PAVEMARKING :O:	PAVEMARKING PVMK	Random - DNT	x_PAVEMARKING
POOL :O:	POOL	Breakline	x_POOL
PORCH OR DECK :O:	DECK POR PORCH	Breakline	x_PORCH
POST STONE/WOOD :O:	POSTS POSTW	Random	x_POST
PROJECT MARKER :O:	PMK PROJ PROJMKR	Random	x_PMK
RAIL ROAD RAIL :R:	RAIL RL RRRAIL	Breakline - DNT	x_RRRAIL
RAIL ROAD SIGNAL :R:	RRS RRSIG RRSIGNAL	Random	x_RRSIG
RAILROAD BED OUTSIDE OF ROAD :R:	BED RB RRBED	Breakline	x_RRBED
RAILROAD CENTERLINE OUTSIDE OF ROAD :R:	RRCL	Breakline	x_RRCL
RAILROAD RAIL IN ROAD :R:	RR RRROAD	Breakline	x_RRROAD

Figure A-11 (continued)

Feature Table

Feature Description	Alpha Code	Point Type	Style
ROAD CENTER LINE :R:	CL	Breakline - DNT	x_CL
ROAD CROWN :R:	CR CROWN	Breakline	x_CR
ROAD GRAVEL :R:	RDG	Breakline	x_RDG
ROAD PAVED :R:	RDP	Breakline	x_RDP
ROADS :R:	RD	Breakline	x_RD
SATELLITE DISH :O:	SAT	Random	x_SAT
SCHOOL :O:	SCHOOL	Breakline	x_SCHOOL
SEPTIC SYSTEM :O:	SEPTIC SSDA	Breakline	x_SEPTIC
SHED :O:	SHED	Breakline	x_SHED
SHOT :O:	SH	Random	x_SH
SHOULDER GRAVEL :R:	SHG	Breakline	x_SHG
SHOULDER PAVED :R:	SHP	Breakline	x_SHP
SHRUB :O:	SHRUB	Random	x_SHRUB
SIDEWALK :R:	SW SWB SWC SWP SWS	Breakline	x_SW
SIGN :O:	SIGN	Random	x_SIGN
SIGN W/DOUBLE POST :O:	TSIGN	Breakline	x_2SIGN
SILL OF HOUSE :O:	SILL	Breakline - DNT	x_SILL
SLOPE BOTTOM :O:	BS	Breakline	x_BS
SLOPE CHANGE :O:	CS	Breakline	x_CS
SLOPE TOP :O:	TS	Breakline	x_TS
STAKE (WITNESS) :O:	STAKE	Breakline - DNT	x_DEFAULT
STEP :O:	STEP STP STPB STPC STPS STPW	Breakline	x_STEP
STONE :O:	STN STONE	Breakline	x_STONE
STUMP :O:	STUMP	Random	x_STUMP
SUBSURFACE CABLE (TV) :O:	SUBC	Breakline - DNT	x_SUBC
SUBSURFACE ELECTRIC LINE :O:	SUBE	Breakline - DNT	x_SUBE
SUBSURFACE GAS LINE :O:	SUBG	Breakline - DNT	x_SUBG
SUBSURFACE MISCELLANEOUS :O:	SUB	Breakline - DNT	x_SUB
SUBSURFACE SEWER LINE :O:	SUBS	Breakline - DNT	x_SUBS
SUBSURFACE TELEPHONE CABLE :O:	SUBT	Breakline - DNT	x_SUBT

SUBSURFACE WATER LINE :O:	SUBW	Breakline - DNT	x_SUBW

Figure A-11 (continued)

Feature Table

Feature Description	Alpha Code	Point Type	Style
SWAMP :O:	SWAMP	Random	x_SWAMP
TELEPHONE POLE :O:	TEL	Random	x_TEL
TIE :O:	TIE	Breakline - DNT	x_TIE
TRAILER :O:	HOM TRAILER	Breakline	x_TRAILER
TREE HARDWOOD :O:	H	Random	x_H
TREE SOFTWOOD :O:	S	Random	x_S
UNDER DRAIN :O:	UND	Breakline - DNT	x_UND
UTILITIES :O:	FUEL UTIL	Random	x_UTIL
WALL CONCRETE :O:	WALLC	Breakline	x_WALLC
WALL GENERIC :O:	WALL	Breakline	x_WALL
WALL HEADER :O:	WALLH	Breakline	x_WALLH
WALL STONE :O:	WALLS	Breakline	x_WALLS
WALL WOOD :O:	WALLW	Breakline	x_WALLW
WATER COURSE :O:	WC	Breakline	x_WC
WATER SHUT OFF :O:	WSO	Breakline - DNT	x_WSO
WELL :O:	SPRING WELL	Breakline - DNT	x_WELL
WET AREA :O:	WET	Breakline	x_WET
WETLANDS DESIGNATION :O:	WETL WETLAND	Random	x_WETLAND

Figure A-12

Legend:

Feature** :R: Roadway Feature

Feature** :O: Other feature

Feature** :X: Bridge Feature

Point Type	Random	Random point that influences the model
Point Type	Breakline	Will not allow triangles to cross
Point Type	Breakline – DNT [do not triangulate]	Point type will not influence the creation of the model

Vermont Coordinate System

Figure B-1

Vermont Coordinate System

Central Meridian and Lines of Exact Scale

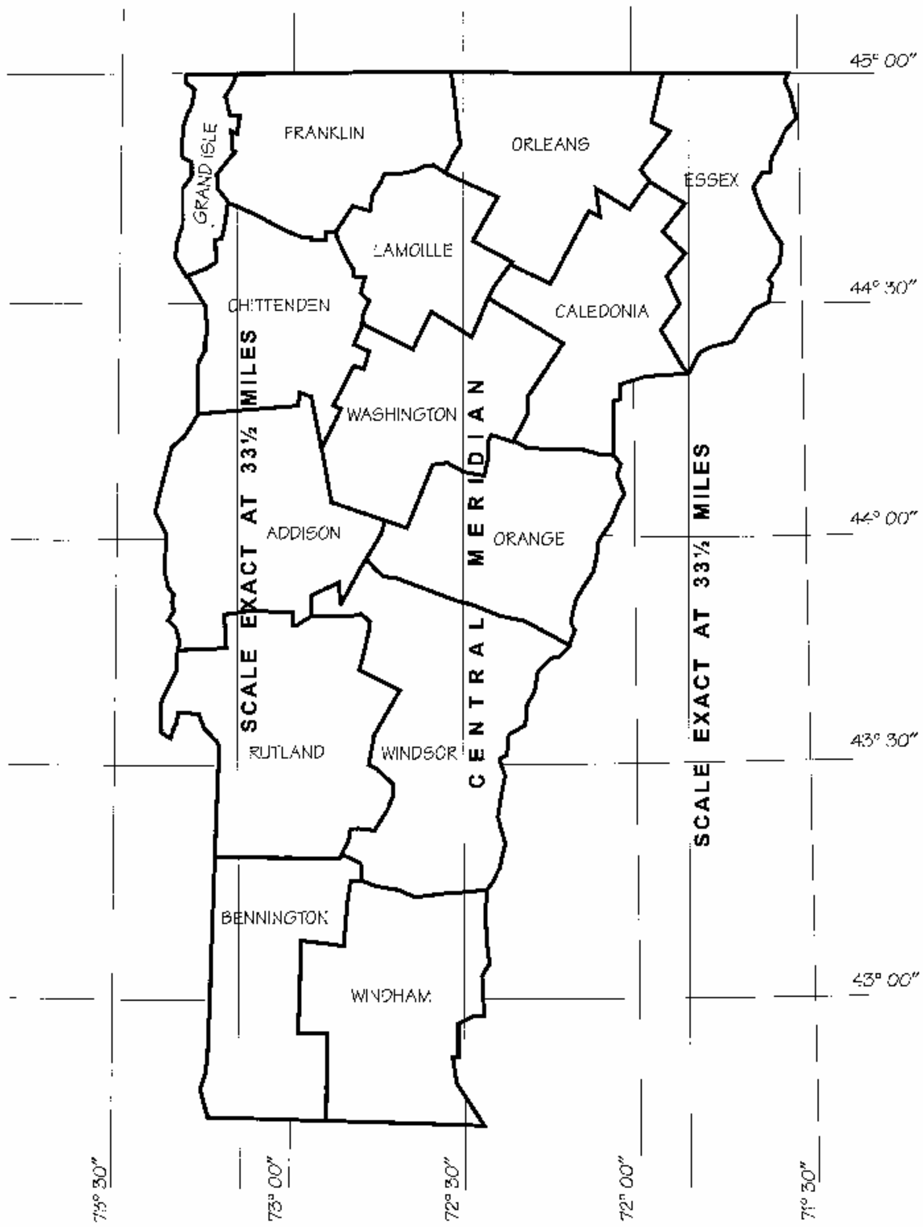


Figure B-2

Table of Ellipsoid Corrections for Vermont

Orthometric Height in Feet

	0–1000	1000–2000	2000–3000	3000–4000	4000–5000
0	1.00000439	0.99995656	0.99990873	0.99986091	0.99981309
100	0.99999961	0.99995178	0.99990395	0.99985613	0.99980831
200	0.99999483	0.99994700	0.99989917	0.99985135	0.99980353
300	0.99999004	0.99994221	0.99989439	0.99984656	0.99979875
400	0.99998526	0.99993743	0.99988960	0.99984178	0.99979397
500	0.99998048	0.99993265	0.99988482	0.99983700	0.99978918
600	0.99997569	0.99992786	0.99988004	0.99983222	0.99978440
700	0.99997091	0.99992308	0.99987526	0.99982744	0.99977962
800	0.99996613	0.99991830	0.99987047	0.99982266	0.99977484
900	0.99996134	0.99991352	0.99986569	0.99981787	0.99977006
1000	0.99995656	0.99990873	0.99986091	0.99981309	0.99976528

Figure B-3

Transverse Mercator Projection for Vermont

x Feet	Scale in Units of 7th Place of Logs	Scale Expressed as a Ratio	x Feet	Scale in Units of 7th Place of Logs	Scale Expressed as a Ratio
0	–155.1	0.9999643	175,000	– 3.2	0.9999993
5,000	–155.0	0.9999643	180,000	+ 5.6	1.0000013
10,000	–154.6	0.9999644	185,000	+ 14.7	1.0000034
15,000	–154.0	0.9999645	190,000	+ 24.0	1.0000055
20,000	–153.1	0.9999647	195,000	+ 33.5	1.0000077
25,000	–152.0	0.9999650	200,000	+ 43.3	1.0000100
30,000	–150.6	0.9999653	205,000	+ 53.3	1.0000123
35,000	–149.0	0.9999657	210,000	+ 63.6	1.0000146
40,000	–147.2	0.9999661	215,000	+ 74.2	1.0000171
45,000	–145.0	0.9999666	220,000	+ 85.0	1.0000196
50,000	–142.7	0.9999671	225,000	+ 96.0	1.0000221
55,000	–140.1	0.9999677	230,000	+107.3	1.0000247
60,000	–137.2	0.9999684	235,000	+118.8	1.0000274
65,000	–134.1	0.9999691	240,000	+130.6	1.0000301
70,000	–130.8	0.9999699	245,000	+142.6	1.0000328
75,000	–127.2	0.9999707	250,000	+154.9	1.0000357
80,000	–123.3	0.9999716	255,000	+167.4	1.0000385
85,000	–119.2	0.9999726	260,000	+180.2	1.0000415
90,000	–114.9	0.9999735	265,000	+193.2	1.0000445
95,000	–110.3	0.9999746	270,000	+206.5	1.0000475
100,000	–105.5	0.9999757	275,000	+220.0	1.0000507
105,000	–100.4	0.9999769	280,000	+233.8	1.0000538
110,000	– 95.1	0.9999781	285,000	+247.8	1.0000571
115,000	– 89.5	0.9999794	290,000	+262.0	1.0000603
120,000	– 83.7	0.9999807	295,000	+276.5	1.0000637
125,000	– 77.6	0.9999821	300,000	+291.3	1.0000671
130,000	– 71.3	0.9999836	305,000	+306.3	1.0000705
135,000	– 64.7	0.9999851	310,000	+321.6	1.0000741
140,000	– 57.9	0.9999867	315,000	+337.1	1.0000776
145,000	– 50.8	0.9999883	320,000	+352.8	1.0000812
150,000	– 43.5	0.9999900	325,000	+368.8	1.0000849
155,000	– 35.9	0.9999917	330,000	+385.1	1.0000887
160,000	– 28.1	0.9999935	335,000	+401.6	1.0000925
165,000	– 20.1	0.9999954	340,000	+418.4	1.0000963
170,000	– 11.8	0.9999973	345,000	+435.4	1.0001003
			350,000	+452.6	1.0001042

Figure B-4

Example Calculation 1

Problem: Find the combined scale factor for the line from station HILL to HILL AZ.

Station	North	East	Ortho Height
HILL	224 122.044 m	513 331.286 m	347.80 m
HILL AZ	223 532.321 m	512 919.094 m	346.26 m

See Figure 1-9 for the printout of the data.

1. Adjust the east coordinate for each station and convert from meters to feet.

HILL

$$513\,331.286\text{ m} - 500\,000\text{ m} = 13\,331.286\text{ m}$$

$$13\,331.286\text{ m} \times 3.280\,833\,3\text{ ft / m} = 43\,737.727\text{ ft}$$

HILL AZ

$$512\,919.094\text{ m} - 500\,000\text{ m} = 12\,919.094\text{ m}$$

$$12\,919.094\text{ m} \times 3.280\,833\,3\text{ ft / m} = 42\,385.394\text{ ft}$$

2. Use the adjusted coordinate values to interpolate horizontal scale factors from Figure B-3, “Transverse Mercator Projection for Vermont.”

HILL

$$\frac{43\,737.727\text{ m} - 40\,000\text{ m}}{45\,000\text{ m} - 40\,000\text{ m}} = 0.748$$

$$\begin{aligned}\text{scale factor} &= 0.999\,966\,1 + 0.747(0.999\,966\,6 - 0.999\,966\,1)\\ &= 0.999\,966\,1 + 0.000\,000\,4\\ &= 0.999\,966\,5\end{aligned}$$

HILL AZ

$$\frac{42\,385.394\text{ m} - 40\,000\text{ m}}{45\,000\text{ m} - 40\,000\text{ m}} = 0.477$$

$$\begin{aligned}\text{scale factor} &= 0.999\,966\,1 + 0.477(0.999\,966\,6 - 0.999\,966\,1)\\ &= 0.999\,966\,1 + 0.000\,000\,2\\ &= 0.999\,966\,3\end{aligned}$$

3. Calculate the average horizontal scale factor for the two stations.

$$\text{average horizontal scale factor} = \frac{0.999\,966\,5 + 0.999\,966\,3}{2} = 0.999\,966\,4$$

Figure B-4 (continued)

Example Calculation 1

4. Convert the orthometric height for each station from meters to feet.

HILL

$347.80\,\text{m} \times 3.280\,833\,3\,\text{ft / m} = 1141.074\,\text{ft}$

HILL AZ

$346.26\,\text{m} \times 3.280\,833\,3\,\text{ft / m} = 1136.021\text{ft}$

5. Calculate the average elevation for the two stations

$$\text{average elevation} = \frac{1141.074 + 1136.021}{2} = 1138.548$$

6. Use the average elevation to interpolate the elevation factor from Figure B-2, “Table of Ellipsoid Corrections for Vermont Orthometric Height in Feet.”

$$\frac{1138.548 - 1100}{1200 - 1100} = 0.385$$

$$\begin{aligned}\text{elevation factor} &= 0.999\,517\,8 + 0.385(0.999\,947\,00 - 0.999\,95178)\\ &= 0.999\,95178 + 0.000\,001\,84\\ &= 0.999\,949\,94\end{aligned}$$

7. Calculate the combined factor by multiplying the average horizontal scale factor from Step 3 and the elevation factor from Step 6.

$$\begin{aligned}\text{combined factor} &= (0.999\,966\,4)(0.999\,949\,94)\\ &= 0.999\,916\,34\end{aligned}$$

Note:	Average factors can be calculated by either (1) averaging factors for each point or (2) inter-polating factors for average line values.

Figure B-5

Example Calculation 2

Problem: Find the ratio of the difference in grid and GPS adjusted distance to the grid distance.

Data Set	Slope Distance	Zenith Angle
1	719.541 m	90.0751°
2	719.555 m	90.0748°

combined factor = 0.99 916 34
GPS adjusted distance = 719.497 m

1. Calculate the average horizontal ground distance.

Data Set 1

$(719.541\text{m})(\cos 0.0751°) = 719.540\,\text{m}$

Data Set 2

$(719.555\,\text{m})(\cos 0.0748°) = 719.554\,\text{m}$

$$\text{average horizontal ground distance} = \frac{719.540\,\text{m} + 719.554\,\text{m}}{2} = 719.547\,\text{m}$$

2. Calculate the grid distance.

$(\text{ground distance})(\text{combined factor}) = (719.547\,\text{m})(0.999\,916\,34) = 719.4867\,\text{m}$

3. Calculate the ratio of the difference in grid and GPS distance to the grid distance.

$$\text{ratio} = \frac{719.497\,\text{m} - 719.487\,\text{m}}{719.487\,\text{m}} = \frac{0.010}{719.487} = \frac{1}{71948.7}$$

Figure B-6

Example Calculation 3

Problem: Calculate station corrections.

Combined scale factor for ground to grid measurements = 0.999 966 4

Solution:

$$\text{factor for grid to ground} = \frac{1}{0.999\,966\,4} = 1.000\,033\,6$$

$$\text{for each 100 foot station, measure: } 100\text{ ft} \times 1.000\,033\,6 = 100.003\text{ ft}$$

$$\text{for each 20 meter station, measure: } 20\text{ m} \times 1.000\,033\,6 = 20.000\,6\text{ m}$$

Boundaries

A land surveyor who conducts a survey of property (for the AOT) shall set monuments when needed to adequately perpetuate the location of corners and boundaries of the property being surveyed.

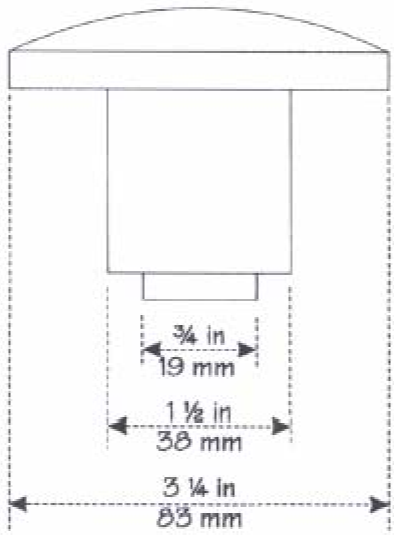
- The monuments shall be durable and stable.
- The monuments shall be identified with the license number of the surveyor in responsible charge.
- Monuments that replace inadequate monuments shall conform to the minimum standard as defined by 26VSA Section 2502.
- The setting of monuments shall meet the minimum standard for setting monuments by a land surveyor licensed by the State of Vermont.

See Figures C-1 and C-2 for marker and monument specifications.

Figure C-1

Specifications for AOT Boundary Markers

Reinforcing-Bar-and-Cap Type



Aluminum Cap for Reinforcing Bar

Domed forged 6000-series aluminum with dissimilar-metal corrosion protection. Similar to Bersten RBX8325.

Markings for Reinforcing-Bar Cap

3/16-in (5-mm) standard marking

Boundary specific drill hole: 1/8-in (3-mm) diameter × 1/8 in (3 mm) deep, drilled after the mark is set

3/16-in (5-mm) project specific marking

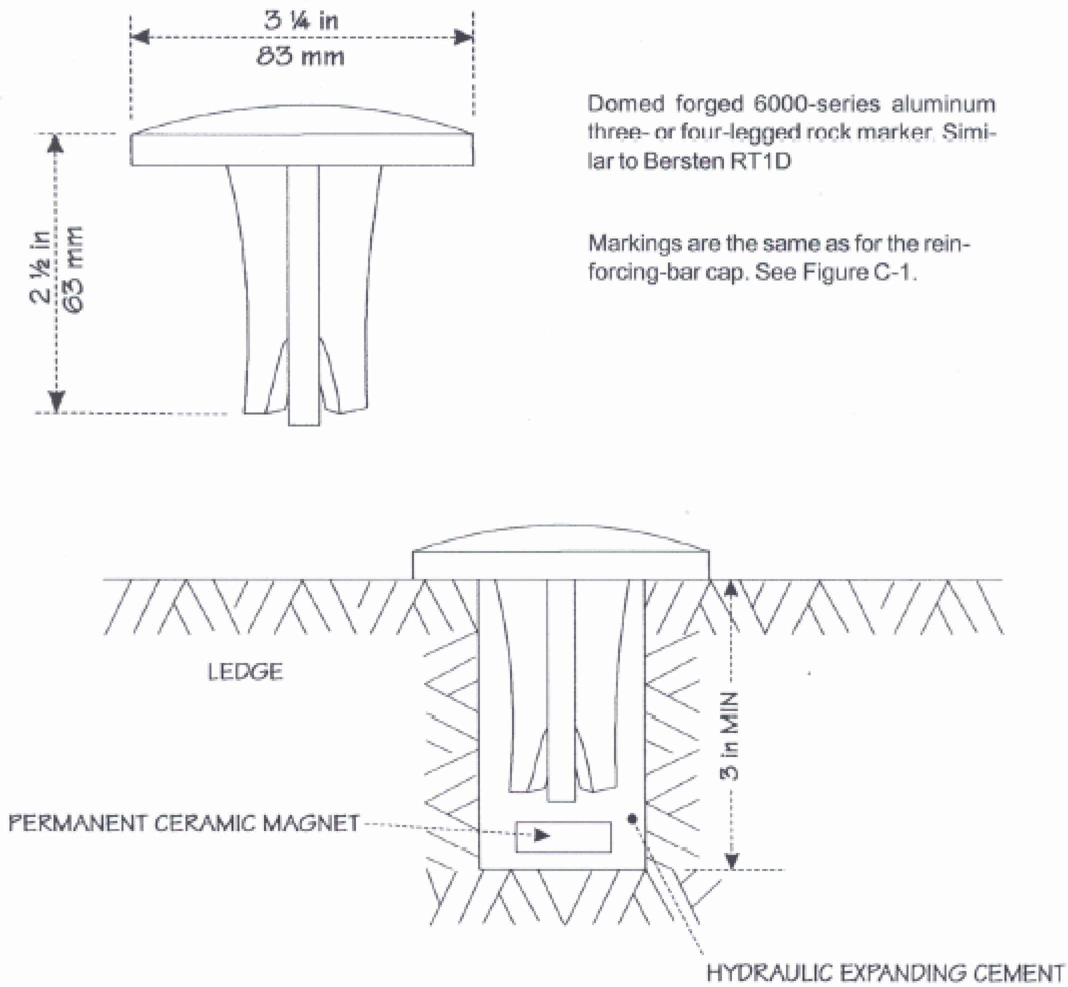
Reinforcing bar shall be No.19M (3/4 in), 1.2 m (4 ft) long. The reinforcing bar shall be either (1) driven to refusal, a minimum of 600 mm (2 ft), and cut or (2) on the right-of-way line, with the distance to the point marked on the cap.

Caps placed on reinforcing bar are to be set flush or below grade as directed by the engineer, in a manner similar to Bersten item C1D.

Figure C-2

Specifications for AOT Boundary Markers

Ledge Type



Note: 4½-ft (1.4-m) concrete boundary markers may be used, with the ledge-type monument drilled and cemented on top.

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