



***Requirements and Procedures
For
Control, Design,
And
Land Surveys***

Surveys Division

Arkansas Highway and Transportation Department

Published: December 31, 2013

Update Page

Date	Who	Chapter	Section/Change	Page
12/31/2013	MSK	All	Initial Distribution	

AHTD DATA FILE REQUIREMENTS

The AHTD utilizes the AASHTO SDMS (Survey Data Management System) data format for survey data collection, processing, and data archives. The AHTD SDMS data collection software shall be utilized for all data collection unless otherwise noted. The Public Domain version of the SDMS Processor (formerly AASHTOWare SDMS Processor) shall be utilized for survey data processing and coordinate computations.

Microstation is a registered trademark of Bentley Systems, Inc.

InRoads is a registered trademark of Bentley Systems, Inc.

Microsoft is a registered trademark of Microsoft Corporation.

Trimble is a registered trademark of Trimble Navigation Limited.

Sokkia is a registered trademark of Sokkia Corporation

TopoDOT is a registered trademark of Certainty 3D

Leica is a registered trademark of Leica Geosystems – part of Hexagon

SURVEYS DIVISION CONTACTS

For information and help the following people based out of Little Rock, Arkansas, may be contacted.

Our support team may be reached at surveysupport@ahtd.ar.gov.

Updates to this manual or other procedures can be found at:
http://www.ahtd.ar.gov/surveys_division/manuals/Surveys.pdf

For questions on policies and procedures, or data request, contact any of the below personnel:

Name	Area of Responsibility	Phone	Email
Michael Kelly, PE, PS	Division Head	(501) 569-2341	Michael.Kelly@ahtd.ar.gov
David Hall, PE, PS	Asst. Division Head	(501) 569-2535	David.Hall@ahtd.ar.gov
Chris Melhorn, PE	Design & Control Surveys	(501) 569-2015	Chris.Melhorn@ahtd.ar.gov
Travis House, PE	State Aid Project & Hydrographic	(501) 569-2386	Travis.House@ahtd.ar.gov
Paul Howard, EI	Design & Control Surveys	(501) 569-2067	Paul.Howard@ahtd.ar.gov
Brian Freyaldenhoven	Photogrammetry/LiDAR	(501) 569-2410	Brian.Freyaldenhoven@ahtd.ar.gov
Jim Tadel, PS	Land Surveys	(501) 569-2094	Jim.Tadel@ahtd.ar.gov
Tom Elkins, PS	Land Surveys	(501) 569-2097	Tom.Elkins@ahtd.ar.gov
Jeff Lenard	Technical Data Coordinator	(501) 569-2383	Jeff.lenard@ahtd.ar.gov

Contents

<u>1</u>	<u>GENERAL REQUIREMENTS</u>	<u>6</u>
1.1	Project Notifications & Right of Entry	6
1.2	Project Set-Up	6
1.3	Data File Types	7
1.4	File Naming	7
1.5	File Maintenance	8
1.6	Typical Point Numbering Ranges	9
1.7	Feature Codes	10
<u>2</u>	<u>CONTROL SURVEYS</u>	<u>11</u>
2.1	General Control & Project Datums	11
2.2	Positional Accuracies and Methods	11
2.3	Control Point Description File	13
2.4	Elevation Control	13
2.5	Horizontal Control	17
2.6	Remote Sensing Control	18
2.7	GPS Surveys	19
2.8	OPUS Positions	21
2.9	Solar Observations	22
2.10	Conventional Traverse	22
2.11	Project Control References	22
<u>3</u>	<u>DESIGN SURVEYS</u>	<u>23</u>
3.1	Notifications and Checklist Information	23
3.2	Data Collection Software and Hardware	23
3.3	Topographic, Terrain, & Utility Data	23
3.4	Traverse Points and Control Checks	24
3.5	Data Collection for Bridges and Culverts	24
3.6	Data Collection for Various Features	27
3.7	Default Sideshot Sequence	30
3.8	Sequences for Topographic and Terrain Data	30
3.9	Pavement Marking	36
3.10	Subsurface Utility Engineering	37
3.11	Data Compilation	37
<u>4</u>	<u>REMOTE SENSING</u>	<u>39</u>
4.1	Photogrammetry	39
4.2	LiDAR	43
4.3	SoNAR	46
<u>5</u>	<u>LAND SURVEYS</u>	<u>47</u>
5.1	General Requirements	47
5.2	Field Procedures	47
5.3	PLSS & Land Monuments	48
5.4	Existing Highway ROW	48
5.5	Parcel Surveys	50

<u>6</u>	<u>ROW MONUMENTING.....</u>	<u>54</u>
6.1	ROW Staking for Appraisals & Utilities.....	54
6.2	Permanent ROW Monumenting.....	54
6.3	Final Survey Plats.....	56

1 GENERAL REQUIREMENTS

This manual is intended to be a general reference for surveying procedures performed by and for the Arkansas State Highway and Transportation Department (AHTD). This manual is not a step-by-step instruction manual or a surveying textbook. The purpose of its publication is to establish minimum standards, policies, and procedures of surveying for AHTD. This is a living document and is subject to change daily. Please refer to the web site for a current copy of this manual or any other related information at http://www.ahtd.ar.gov/surveys_division/manuals/Surveys.pdf.

1.1 PROJECT NOTIFICATIONS & RIGHT OF ENTRY

It is the intent of the Surveys Division and the AHTD that the general public be aware that AHTD personnel or certified Engineering/Surveying firms are performing surveys. In order to inform the public, it is required to notify all property owners adjacent to the project and the local AHTD District Engineer and District Construction Engineer.

The AHTD District Engineer and District Construction Engineer may be notified via email. The notification shall include the Crew Chief (or responsible party) name, mobile phone number, and hotel name (if overnight travel); field crew vehicle numbers (or license plates); and project information. The project information shall include as a minimum the AHTD Job number and name, route, county, and type of work. The current list of District Engineers & Construction Engineers can be downloaded from the link below:

http://www.ahtd.ar.gov/construction_division/ListofDistricts1.pdf

In accordance with ACA 17-48-303, Surveyors have the right to enter public or private land or waters to perform surveys and be immune from arrest for trespass when performing their duties. The survey crew shall maintain and carry proper identification and present such identification if requested. It should be noted that this law only protects the surveyor for entry and immunity from trespass. The surveyor shall seek permission before entry. If entry is denied, report the denial to the Surveys Division. It is required to obtain permission from the property owner to drive vehicles, trim or cut trees or bushes, and/or set any control monuments.

If any damages occur during the survey, such as broken fences or vehicle ruts, the surveyor shall be responsible for fixing or correcting such damages.

It is required to utilize the "Property Notification" form provided by the Surveys Division for property owner notification. The form may be altered based on the type of work and personnel involved with the project. Any major alterations shall be submitted and approved by the Surveys Division.

1.2 PROJECT SET-UP

All projects shall be setup using the procedures that follow:

- During data-collection of any kind to include: control traversing, radial topography, and parcel measurements, THE HORIZONTAL CIRCLE OF THE INSTRUMENT SHALL NOT BE SET TO ZERO (0) OR ANY OTHER SPECIFIC AZIMUTH ANGLE FOR THE BACKSIGHT OR FORESIGHT. The azimuth angle that is displayed by default on the instrument shall be the recorded angle at the beginning and during data-collection.
- All tripods used shall be wide frame heavy duty wooden tripods.
- The current time (TM:) and date (DT:) shall be recorded on every measurement.
- The instrument height (IH:) and staff height (SH:) shall be recorded on everything which utilizes Horizontal (HZ:), Vertical (VT:), and Slope Distance (DS:).
- All linear measurements shall be made in US Foot units unless specified otherwise.
- Linear measurements from a Total Station shall be recorded to three (3) decimal places (####.###).

Chapter 1 – General Requirements (cont.)

1.3 DATA FILE TYPES

The following data file types and extensions shall be used for all data collection, processing, and archiving:

- AHTD Survey Data File .SDF
- SDMS Project File .PRJ
- SDMS Edited Project File .EDI
- SDMS Control File .CTL
- SDMS Points and Chains File .PAC
- SDMS Alignment File .ALI
- SDMS Sequence File .SEQ
- EFBP Observation File .OBS
- EFBP Control File .CCC
- Leica Digital Level File .GSI
- Trimble Data Collector File .DC
- Microstation Design File .DGN
- InRoads Geometry File .ALG
- InRoads DTM File .DTM
- LandXML Exchange File .XML

1.4 FILE NAMING

The file naming format for data collection shall be as follows:

<job number> <task> <file number>.prj

Where:

...job number - the existing job number up to 6 characters. If the job number is longer than 6 characters, then use your judgment as to properly label the files.

...task - one of the following characters

E	-	Bench and check levels
L	-	Parcels & land ties
M	-	Monumentation
R	-	Radial topography
T	-	Traverse

...file number - numbered from A to Z

EXAMPLES

the first bench level run for job R30006 would be:

R30006EA.PRJ

the second bench level run for job R30006 would be:

R30006EB.PRJ

the fifth traverse for job 60209 would be:

60209TE.PRJ

When submitting a project to the Surveys Division office, the files shall be edited for blunders, processed and appended utilizing the SDMS Processor. This appended file shall be submitted as the final edited file

Chapter 1 – General Requirements (cont.)

to be used for processing. Each task, as described above, shall have its own appended file. The file naming format for edited appended files is as follows: <job number> <task1>.edi. For example,

Project Name	Segments	Appended File Name
R30006	EA,EB,EC,ED	R30006E1.edi
R30006	RA,RB,RC,RD	R30006R1.edi

It should be noted that **ALL** raw SDF and PRJ files and **ALL** individual EDI files shall be turned in with the project for archiving purposes.

1.5 FILE MAINTENANCE

At the close of each day's data collection, the surveyor should download data from the collector and store the data on back-up media. Also, for some of the larger jobs being processed in SDMS Processor, archiving the job daily could save some time later.

1.5.1 PROCESSING THE JOB FILES IN SDMS

After collecting data and closing the project, copy the **.PRJ** file to the same filename with an extension **.EDI**. DO NOT edit the .PRJ file. Any required edits or changes necessary shall be made to the **.EDI** file. The **.EDI** file shall be used for processing. Both the **.PRJ** and **.EDI** files are to be archived. Also when a file is imported into SDMS Processor a copy is automatically made and given the extension **.ORG**. This file is considered the unedited project file unless an unedited project file is submitted.

NOTE: Both project files (.PRJ) and edited files (.EDI) shall be turned in as a part of any given design survey project. Edited files should be corrected so that no other AHTD Surveys office editing is required. When additional data is required to fix, correct or supplement any given file that data shall be added into the pertinent file so that it will process completely with only minimal revision.

Chapter 1 – General Requirements (cont.)

1.6 TYPICAL POINT NUMBERING RANGES

Point Range	Feature Code	Identity
1 – 199	CTL	Primary Control points excluding GPS points
100 – 150	GPS	High Precision Geodetic Control points
200 – 599	IP, FC	Land or Property corner monuments
600 – 699	VPT	Photogrammetry/LiDAR vertical control targets
700 – 799	HPT	Photogrammetry/LiDAR horizontal control targets
800 – 899	CTL	Additional Primary Control points
900 – 989	TBM	Temporary Project Benchmarks
990 – 999	BM	Geodetic Benchmarks
1000 – 1099	CTL	Return traverse points (for traverse control loops
1100 – 1199	TV	Topography random control traverse points
1200 – 1499	TV	Land Survey random control traverse points
1500 - 1999	RCP, CTL	Reference Control points
2000 – 2999	LC, RE	Land Survey Calculated points
3000 – 6999	XR, PL	Right-of-Way Division Calculated points
7000 – 7999	LC, RE	Additional Land Survey Calculated points
8000 – 8999	CO	Roadway Alignment points (PC, PT, POT, CC, & PI)
10000 – xxx		Topographic, Terrain, & Utility field collection points

Chapter 1 – General Requirements (cont.)

1.7 FEATURE CODES

FIELD COLLECTED POINT FEATURES

BE - ELECTRIC BOX	IP - FOUND MONUMENT	SI - RR SIGNAL BOX
BET - ELEC TRANSFORM BX	LA - LIGHT POLE W/ ARM	SK – SPRINKLER HEAD
BM - BENCHMARK	LL – LANDSCAPING LIGHT	SN - SIGN
CP - COMBINATION POLE	LM - LOG MILE MARKER	TA - TANK
CTL - PRIMARY CONTROL	LP - LIGHT POLE	TB - TELEPHONE BOX
DO - DRAIN OUTLET STRUCT	MB - MAILBOX	TBM - TEMPORARY BM
DS - SATELLITE RECEIVER	MH - MANHOLE	TE - TREE EVERGREEN
ER – ELECTRIC RECEPTACLE	MS - MISC. STRUCTURES	TO - MISC TOPO POINTS
FC - FENCE CORNER	MW - MONITORING WELL	TP - TELEPHONE POLE
FF - FLAG POLE	PA - SIGNAL POLE W/ ARM	TR - TREE DECIDUOUS
FH - FIRE HYDRANT	PG - GUY POLE	TS - SURVEY TEXT
GL - GAS LIGHT	PH - PUBLIC TELEPHONE	TSB - TRAF SIGNAL BOX
GM - GAS METER	PN - POLE W/ PHONE BOX	TU - TOMBSTONE
GP - SMALL GENERIC POLE	PO - PROPERTY OWNER	TV - TRAVERSE POINTS
GPS - GPS POINT	PP - POWER POLE	UM - UTILITY MARKER
GV - GAS VALVE	PS - SERVICE POLE	UT - UNDRGRND TANK CAP
GY - GUY WIRE	PT - TRAFFIC SIGNAL POLE	VI - VENT
HE – ELEC SERV MANHOLE	PU - BOTTOM OF MANHOLE	VPT - VERT. PT (PHOTO)
HHW - HIST HIGH WATER	RM - RR MILE MARKER	WH – WATER HYDRANT
HM - STORM SWR MANHOLE	RCP - REFERENCE CTL	WM - WATER METER
HPT - HZ POINT (PHOTO)	RPV - REVERSE PRESS VALVE	WV - WATER VALVE
HS - SAN SWR MANHOLE	RS - RAILROAD SIGNAL	WW - WATER WELL
HT - PHONE MANHOLE	SB - RR SWITCH BOX	XS - RANDOM POINT

FIELD COLLECTED LINE FEATURES

BF - BUILD FOUNDATION	EW - EDGE WATER	RR - RAILROAD
BL - BREAKLINE	FE - FENCE	SH - SHOULDER
BR - BRIDGE	FOC - FIBER OPTIC CABLE	SP - SWAMP
BU - BUILDING	GA - GAS LINE	SR - SHRUB
CA - CATCH BASIN	GD - GUARDRAIL	SS - SAN SWR LINE
CB - CURB	GPI - GAS PUMP ISLAND	ST - STREAM
CR -PAVEMENT CROWN	GR - EDGE OF GRAVEL	STS - STORM SWR LINE
CU - CROSS DRAIN CULVERT	GT - GATE	SW - SIDEWALK
CUS - SIDE DRAIN CULVERT	HR - HEDGE ROW	TL - TRAILS
DI - DROP INLET	HW - HEADWALL	UC - UNDERGROUND CABLE
DL - DITCH LINE	LB - LANDSCAPING BORDER	WA - WATER LINE
DW - DRIVEWAY	LV - LEVEE	WD - DECIDUOUS WOODLINE
EB - EDGE BITUMINOUS	MP - PIPELINE	WE - EVERGREEN WOODLINE
EC - EDGE CONCRETE	OHE - OVERHEAD ELEC	WL - WALL
EP - EDGE PAVEMENT	PK - PARKING	WR - RETAINING WALL
ES - SIGN EDGE	PRP – PRECAST RR CROSSING	

OFFICE GENERATED FEATURES

BD – BOUNDARY	MBD - STD BDY MONUMENT	RE - R/W EXISTING
COA - CONTROL OF ACCESS	MRW-STD R/W MONUMENT	SC - SECTION LINE
EA - EXISTING ALIGNMENT	MON - NON-STD SET MONS	SD - SUBDIVISION LINE
ET - TEMPORARY EASEMENT	PI - PI DATA POINT	TC - SIXTEEN SECTION LINE
LC - CALCULATED CORNER	PL - PROPERTY LINE	TRWP - TEMP R/W POINT
ML - MEANDER LINES	QC - QUARTER SECT LINE	XR - PROPOSED R/W

2 CONTROL SURVEYS

Control surveys establish a common, consistent network of physical points that are the basis for controlling the horizontal and vertical positions of highway projects and facilities. Project control surveys provide consistent and accurate horizontal and vertical control for all subsequent project surveys to include: photogrammetric and LiDAR mapping; topography, terrain, and utility mapping; land & property surveys; construction layout; and right of way surveys.

2.1 GENERAL CONTROL & PROJECT DATUMS

The AHTD Surveys Division utilizes several different datums for statewide and project survey control. It is the intent of the Surveys Division to maintain a robust statewide control network with the use of high precision GNSS technologies and geodetic leveling. The Staff Surveys Engineer for Control is responsible for overseeing and managing activities affecting this network. This staff engineer should be consulted for guidance on datum selection.

The North America Vertical Datum of 1988 (NAVD 88) shall be used for elevations. The National Geodetic Vertical Datum of 1929 (NGVD) may be utilized only with the approval by the Division Head of Surveys. The vertical datum shall be recorded in the header of the control file and level files.

Arkansas State Plane Coordinate System reference to the North America Datum of 1983 (NAD 83) shall be used for the Horizontal datum for all projects. The appropriate NGS Zone (0301 – Arkansas North or 0302 – Arkansas South) shall be determined by the Surveys Division and recorded in all appropriate files.

The NGS continuously monitors and readjusts the NAD83 datum. These datum adjustments are typically published and annotated with year like NAD 83 (1997) or NAD83 (2007). These different adjustments have different published Latitudes, Longitudes, and Ellipsoid Heights. The current adjustment years in use by the AHTD are 1986 (original NAD83), 1997 (HARN), & 2007. The horizontal datum adjustment year will be selected by the Surveys Division as appropriate for each project. It is of the utmost importance to document which adjustment is being utilized for any given project.

With the use of GPS, a Geoid model is necessary to produce orthometric heights or elevations. A Geoid model is geo-potential surface that utilizes gravity for a given horizontal position that relates the ellipsoid to “mean sea level”. The AHTD currently utilizes Geoid 1996 and 2009. Due to the nature and inaccuracies of a Geoid model, the surveyor will have to select a Geoid by trial and error to determine which model is most appropriate. This selection should be based on project elevations derived from local benchmarks.

A project combination and adjustment factor (CAF) will be computed by the Surveys Division to minimize the distortion between state plan Grid and Ground distances. This CAF will be computed based on the state plane Grid Scale factor near the midpoint of the project and an average elevation factor. A CAF from nearby/adjacent projects may be utilized if the distortion is acceptable.

Prior to beginning work, refer to [General Requirements](#) (Chapter 1), for required notifications and checklist information. Arkansas One Call (800) 482-8998 or 811 shall be contacted to locate and mark underground utilities within the project limits or where any control monuments will be established.

2.2 POSITIONAL ACCURACIES AND METHODS

It is the intent of the AHTD that all horizontal and vertical control points be established in a manner to produce the highest accuracy and precision that is possible. However, there are practical limits to accuracy and precision. The surveyor shall make and reduce measurements, perform a properly constrained least-squares adjustment, and report the positional accuracy for the survey. The positional accuracy for the Primary Horizontal & Vertical Control shall be reported in terms of the Local Accuracy and the Network Accuracy. The remaining control points and right of way (ROW) monuments shall be reported in terms of the Local Accuracy.

Chapter 2 – Control Surveys (cont.)

The *local positional accuracy* of a control point is a number that represents the uncertainty, at the 95% confidence level; in the coordinates of this control point relative to the coordinates of other directly connected or measured adjacent control points. The reported local accuracy is an approximate average of the individual local accuracy values between this control point and other observed control points used to establish the coordinates of the control point.

The *network positional accuracy* of a control point is a value that represents the uncertainty in the coordinates of the control point with respect to the geodetic datum at the 95-percent confidence level. For horizontal and ellipsoid coordinates, the geodetic datum is referenced to the geodetic values at the Continuously Operating Reference Stations (CORS) supported by NGS. For vertical/elevation heights, the geodetic datum shall be referenced to the local benchmark datum.

The below table shall be used to determine the minimum positional accuracies.

Type of Survey	Network Horz Pos. Accy.	Local Horz Pos. Accy.	Network Vert. Pos. Accy.	Local Vert. Pos. Accy.
Primary Control State Highways	1 cm + 10ppm	1 cm + 5ppm	0.6cm +10ppm	0.6cm +10ppm
Primary Control State-Aid	10cm+100ppm	1 cm + 10ppm	0.6cm +10ppm	0.6cm +10ppm
Primary Control City/County Signal	10cm+100ppm	1 cm + 10ppm	10cm+100ppm	0.6cm +10ppm
Secondary Control (1-99)	n/a	1 cm + 10ppm	n/a	0.6cm +10ppm
Remote Sensing CTL (600/700)	n/a	2 cm + 50ppm	n/a	1.5cm +50ppm
Random Trav. DTM CTL (1100)	n/a	2 cm + 50ppm	n/a	0.6cm +10ppm
Random Trav. Parcel CTL (1200)	n/a	2 cm + 50ppm	n/a	10cm+100ppm
Reference CTL (1500)	n/a	1 cm + 10ppm	n/a	1.5cm+50ppm
Benchmarks (900s)	n/a	10 m	n/a	0.6cm +10ppm
Land/Property Mons.	n/a	2 cm +100ppm	n/a	10cm+100ppm
ROW monuments	n/a	2 cm + 50ppm	n/a	10cm+100ppm

Chapter 2 – Control Surveys (cont.)

The below table shall be used to determine the Survey method for Horizontal and Vertical Control.

Type of Survey	Horizontal Control Method	Vertical Control Method
Primary Control State Highways	High Precision Static GPS	3-Wire
Primary Control State-Aid	OPUS or Solar*	3-Wire
Primary Control City/County Signal	OPUS, Solar, or Assumed*	3-Wire
Secondary Control (1-99)	RTK or Traverse	3-Wire
Remote Sensing Control (600/700)	RTK or Traverse	RTK or 3-Wire
Random Trav. DTM CTL (1100)	Traverse	3-Wire
Random Trav. Parcel CTL (1200)	Traverse	Trig
Reference CTL (1500)	RTK or Traverse	Trig or 3-Wire
Benchmarks (900s)	Handheld GPS	3-Wire
Land/Property Mons.	RTK or Traverse	RTK or Trig
ROW monuments	RTK or Traverse	RTK or Trig

* Note: If Parcel surveys are required for any project, the horizontal control shall be based on High Precision GPS or OPUS position tied to the NGS National CORS.

2.3 CONTROL POINT DESCRIPTION FILE

At the commencement of establishing the Baseline project control, the surveyor shall create a Control Description File. The file shall be in the AASHTO SDMS PRJ or PAC format. This file is the basis for feature coding, point descriptions, location attributes, approx. latitude/longitude, and any other pertinent control point data that will help the subsequent surveyors to recover the control points.

The surveyor setting the control points shall utilize the Description Sequence file (DES.seq) to record the attribute information. The following is the minimum information that shall be recorded for each control point:

- PN: Point Name
- PD: Description of Monument (5/8" Rebar w/2" Alum Cap Stamped T-11)
- LT: Latitude
- LG: Longitude
- HY: Nearest Highway or Street
- CM: Distance to references (5.0' west of pavement edge or 15.1' northeast of Stop Sign)

2.4 ELEVATION CONTROL

The elevation/vertical control network shall be established from a minimum of two (2) NGS First or Second Order benchmarks. Differential leveling techniques as further defined in this chapter shall be utilized to establish elevations on the required project control points.

All level work shall be at a minimum of Second Order Class II accuracy. In order to achieve 2nd Order accuracy, an automatic level with a vertical accuracy specification of 0.8mm standard deviation for 1km of double run leveling without the use of a micrometer and a high quality, well maintained Philadelphia style leveling staff or a leveling staff with temperature expansion coefficient of 10ppm/C° or less shall be used.

A geodetic quality Digital Level and Bar Code rod may be utilized if approved by the Surveys Division. The digital level shall have a vertical accuracy of 0.8mm standard deviation for 1km of double run leveling

Chapter 2 – Control Surveys (cont.)

or better. The barcode leveling rod with temperature expansion coefficient of 10ppm/C° or less shall be used. The leveling staff be one (1) piece or be connected in such a manner that the pieces do not move while in use.

All NGS benchmarks of 2nd order accuracy or higher shall be located and leveled to if they exist within one mile in any direction of the job site. As time permits, benchmarks of lower accuracy may also be measured. The NGS station name and PID shall be recorded with all measurements and description files in addition to the project point number.

Temporary project benchmarks shall be established at ½ mile intervals from the Government Benchmark to the project. These temporary benchmarks shall be a chiseled square in concrete culverts or bridges. Benchmark discs shall be used if they exist in these bridges or culverts. Temporary project benchmarks shall be established on all major culverts or bridge throughout the length of the project or at ¼ mile intervals if drainage structures do not exist. A minimum of three (3) project benchmarks shall be established for the project. The BMs and TBMs shall be described utilizing the SDMS BM sequence. The latitude and longitude shall be measured and recorded from a handheld GPS unit if a horizontal location has not been previously measured.

Objects that are acceptable as benchmarks are as follows:

- Chiseled square in concrete
- 2" aluminum cap on 24" or longer rebar
- AHTD BM domed cap

Objects that shall not be used as benchmarks are as follows:

- Concrete nails
- PK nails
- 8" spikes
- RR spikes
- Cotton Picker spindles
- or similar items

Utility poles and trees shall not be utilized for benchmark locations unless approved by the Surveys Division. At no time can wooden stakes or wooden hubs be utilized for elevation/vertical control monuments.

2.4.1 DIFFERENTIAL LEVELING

All level work shall be performed using the AHTD-SDMS Collector software using the 3 Wire Level Task or Digital Bar Code leveling and according to the requirements specified. Digital Bar Code Leveling can only be used by the AHTD or Certified Consultant. Trigonometric Leveling shall not be used for this task.

It is recommended that fixed leg tripods be utilized when performing differential leveling tasks. Extra care should be taken if a slip leg tripod is used. At no time shall the surveyor utilize aluminum tripods for leveling tasks.

Turn points using solid objects, such as protruding bed rock; protruding aggregates fixed solidly in concrete or asphalt pavement; or, rounded head turning pins of adequate length driven to an adequate depth to provide stability during the leveling process shall be used.

Bench level runs through the job are to include measurements to all primary control points and random traverse points. The nail heads or caps of the points may be used for turns.

All level runs shall be a closed loop beginning and ending on the same point. Including two (2) or more benchmarks with known elevations is encouraged, but a closed loop back to the starting benchmark is still required.

Chapter 2 – Control Surveys (cont.)

2.4.2 LEVEL RUN STANDARDS

The below standards are based on “Standards and Specifications for Geodetic Control Networks” publication by the Federal Geodetic Control Committee. (See Section 3.5 Geodetic Leveling)

- To achieve Second Order Class II Accuracy, the level runs shall consist of closed loops not to exceed of 1.2 miles (2.0 km) in total length between temporary bench marks. That is 0.6 miles (1 km) out and 0.6 miles (1 km) back.
- The maximum length of sight (foresight or backsight) is 230 feet (70 m)
- The maximum set-up imbalance distance between backsight and foresight at each instrument setup shall be 32 feet (10 m) or less.
- The maximum accumulated imbalance distance for a loop (section) shall be 32 feet (10 m) or less.
- The minimum ground clearance (middle wire reading) shall be 1.5 feet (0.5 m) or greater to include ground humps between the instrument and the leveling rod.
- Maximum vertical loop closure must less than:
 - ± 0.035 ft times the square root of the length in miles ($\pm 0.035\sqrt{Dist(miles)}$) or
 - ± 8 mm time the square root of the length in kilometers ($\pm 0.008\sqrt{Dist(km)}$)

2.4.3 LEVEL RUN PLAN

If requested by the Surveys Division, an elevation control plan shall be prepared for leveling runs greater than two (2) miles from the project. The plan shall include a narrative and a layout on an at least 1”=2000’ aerial photograph or USGS Quadrangle sheet. The plan shall include:

- The NGS Bench Marks found and to be used.
- The proposed elevation control route
- The proposed locations marks will be established along the elevation control route.
- The types of marks that will be established.

Data for each Bench Mark used and set shall include:

- The type of mark set/used
- A physical description of the location of the mark. The description should include such information as the side of the road it falls on, distance to nearby landmarks, etc.
- LT: and LG: of the mark. The format is LT:ddd.mmsss

2.4.4 CONVENTIONAL 3-WIRE LEVELS

All level work shall be collected with AHTD-SDMS Collector. All level work should be calculated in the field using the collector software to check for mis-closures. This closure tolerance does not ensure closure to NGS specifications. All elevation loops shall be computed and checked using the 1-D Closure test in SDMS Processor.

Chapter 2 – Control Surveys (cont.)

EXAMPLE OF 3 WIRE LEVELS			
TK:3WR			
AC:PR	{NEWPR.SEQ starts automatically}		
...	answer questions pertaining to NEWPR.SEQ		
AC:OS			
PN:	point number		
FE:	Feature		
PD:	point description	{INFORMATION ABOUT BENCHMARK}	
ZC:	elevation		
AC:BS	backsight	{BACKSIGHT SHOT FROM LEVEL TO BENCH}	
R1:	top wire:		
R2:	middle wire		
R3:	bottom wire		
{CHOOSE EITHER FORESIGHT OR TURNPOINT}			
AC:FS	Foresight (to BM or TBM or Control)	AC:TP	turn point
PN:	point number	R1:	top wire
FE:	feature	R2:	middle wire
PD:	point description	R3:	bottom wire
R1:	top wire		
R2:	middle wire		
R3:	bottom wire		
AC:BS			
R1:	top wire	{BACKSIGHT SHOT FROM LEVEL TO PREVIOUS POINT}	
R2:	middle wire		
R3:	bottom wire		
REPEAT WITH EITHER FORESIGHT OR TURNPOINT			

2.4.5 DIGITAL LEVELS

AHTD utilizes the Leica DNA03 digital barcode leveling system for NGS 1st order and AHTD project elevation control. Other digital levels may be approved at a later date.

Consultants shall be certified and approved for differential leveling with the Digital Level system prior to use on AHTD projects. Certification will be based on the Surveys Division test leveling circuit near the AHTD Central Office in Little Rock.

All raw files shall be converted to SDMS formatted PRJ & EDI files to be computed in SDMS Processor.

Leveling procedures shall follow techniques as outlined in the previous sections of this manual. Line Leveling shall be used with the Leica system for all level loops.

Chapter 2 – Control Surveys (cont.)

The following setting for the Leica DNA03 system shall be used for AHTD project control:

Units Settings		Measurement Mode	
• Distance	:Feet	• Mode	:Mean s
• Temp.	:°F	• n	:leave blank
		• n min	:3
Measurement Settings		• n max	:10
• CodeSet	:Before	• sDevM / 20m	:0.002 F
• Decimals	:0.001F		
• GSI-Format	:GSI – 8	Tolerance Settings	
• EarthCurv	:No	• DistBal	:32.0
		• MaxDist	:230
		• StafLow	:1.5

2.4.6 BENCHMARK RECOVERY

It is required that a benchmark recovery report be prepared for each project. The report will include all benchmarks searched for, found, and updated descriptions. All NGS benchmarks that have been searched for or recovered shall be entered into the NGS recovery webpage:

http://www.ngs.noaa.gov/ngs-cgi-bin/recvy_entry_www.pl

The project report shall document benchmark recovery reports that have been submitted to the NGS.

2.5 HORIZONTAL CONTROL

Horizontal project control surveys establish control for the highway construction projects. Whenever feasible, the horizontal control is based on high-precision static GPS observations. This task shall be performed by AHTD Surveys Division personnel or approved certified consultants. Based on the type of project and approval from the Division Head of Surveys, minimum GPS static observations and the Online Point User Service (OPUS) provided by the NGS may be utilized for primary project control. When GPS observations are not available, then astronomic observations with conventional traverses are utilized.

All primary control points (PN:100 – 150) set shall be a 5/8" rebar minimum 48" long, with a 2 1/2" aluminum cap stamped with GPS Point Number. Rebar of sufficient length shall be used to provide stability for the soil conditions encountered for each point set. Each point shall be stamped accordingly using the AHTD marking and numbering system. The Surveys Division shall mark and designate all GPS control prior to the start of the project. Caps will be furnished by the Department. These points shall be set at a minimum of 800 feet and a maximum of 1500 feet apart. These points may be set along county roads or outside of the ROW (with permission from the property owner) to avoid destruction during roadway construction. These points shall consist of inter-visible pair of points. One point shall be designated the station monument and one as an azimuth mark. The monuments shall be placed at 2-3 mile intervals along the length of the project.

A sign and sign post shall be placed designating the location of the GPS point. The sign is white and rectangular, and denotes AHTD GPS SURVEY MONUMENT. The azimuth and distance from the sign post to the monument shall be stamped on back of the sign. The distance shall be stamped in both meters and feet.

All baseline control points (PN:1 -99) set shall be a 5/8" rebar minimum 24" long, with a 2" cap stamped with Point Number. These points shall be set at a minimum of 500 feet apart and a maximum of 800 feet, in an area least likely to be disturbed, along the entire length of the project. Baseline control points shall

Chapter 2 – Control Surveys (cont.)

be set such that at least two (2) other baseline control points are visible with the exception at the ends of a project. Remember that these points, in order to be GPS points need to be set in open areas clear of tree overhangs.

2.6 REMOTE SENSING CONTROL

Remote Sensing control surveys consists of placing targets or locating photo identifiable features and making necessary measurements to compute a 3d position for location, orientation, and scale for Remote Sensing mapping to include Photogrammetry, LiDAR, and Sonar. Refer to [Remote Sensing](#) (Chapter 4) for more details on mapping with these technologies.

Horizontal Panel Targets (HPT) and Vertical Panel Targets (VPT) are the traditional nomenclature for Aerial Photogrammetry mapping projects. Traditionally six feet (6') by six inch (6") white targeting material is placed as a "+" on the ground surface. In the past, paint on hard surfaces has been utilized in lieu of target material on the ground. Paint shall not be used on any AHTD projects without prior approval from the Division Head of Surveys.

Current procedures allow for locating photo identifiable or "Pick" points in lieu of placing targets. HPTs are normally located near the center of the flight line and the VPTs near the 70% lines of the photography based on NEAT model. The NEAT model represents the approximate mapping area of each pair of overlapping aerial photographs, (width) x (breadth).

If targets are set for HPTs, then a 5/8" rebar and 2" aluminum cap shall be set in the center of the target. These points should be located so they can be part of the primary control baseline. If targets are for VPTs, then an 8" spike may be set in the center of the target. If the soil conditions are poor, then a rebar and cap should be set for VPTs. If the targets are set in areas that require the monument to be set below the surface, the monument and the ground surface shall have an elevation measured and recorded. Photogrammetry requires a surface measurement to be recorded.

When placing aerial targets, the following information shall be written on one of the legs:

Aerial Photography Target
Surveys Division, AHTD
Job # _____
Point # _____
Phone 501 569 2341

If photo identifiable or "Pick" points are utilized, then an 8" spike, cotton picker spindle (CPS), or concrete nail shall be set to ensure the surveyor measures the same point with redundant procedures. If the photo identifiable feature has moved or changed since the aerial photography was acquired, the surveyor will need to contact Photogrammetry Section to find an alternative feature.

Terrestrial or Static LiDAR sensors normally utilize existing baseline control points, therefore do not utilize permanent targets. LiDAR mapping, with Airborne or Mobile sensors, normally utilize targets placed as a chevron or X on hard surfaces like pavement. Due to the fact that all Airborne and Mobile LiDAR mapping is performed by consultants, the LiDAR consultant is responsible for determining the shape, size, and placement of targets. The amount of targeting material and proposed shape, size, and placement shall be included in the project proposals.

The surveyor will need to be very selective for the location of the targets. If GPS technologies are utilized, the surveyor will need a clear view of the southwest sky with minimum obstructions in the other quadrants. The surveyor will also need to be aware of the traffic and safety needs of workers and the traveling public.

Chapter 2 – Control Surveys (cont.)

2.7 GPS SURVEYS

The Global Navigation Satellite System (GNSS) uses the Global Positioning System (GPS), GLONASS, and other space based satellite systems to measure latitude, longitude, and altitude. The AHTD utilizes this system along with ground based control monuments, and Continuously Operating Reference Stations (CORS) to assist with establishing project horizontal and vertical project coordinates. Ground based receivers and antennas are utilized to collect electronic radio signals from the GNSS satellites. The sections that follow describe the required equipment and procedures.

GNSS and GPS can be considered interchangeable throughout the remainder of this manual unless specifically noted.

AHTD Surveys Division utilizes the AASHTO SDMS data format for all control, design, and land surveys. In order for a surveyor to utilize GPS systems, the system shall be able to export a SDMS formatted file with X, Y, & Z coordinates with feature codes and other attributes. Currently, there is no adopted industry standard for RTK observations with point feature codes and attributes, and, the AHTD Surveys Division utilizes Trimble equipment and software. Therefore, it is required that all Fast-Static & RTK projects be submitted to the AHTD in the Trimble format along with the calculated data in the AASHTO SDMS PAC, CTL, or CAL format.

2.7.1 GNSS EQUIPMENT

The GNSS equipment which includes the receiver and antenna shall at a minimum collect signals from the GPS satellites. The receivers shall be geodetic quality L1/L2 Dual Frequency with full-wavelength capabilities and they must be capable of tracking satellites down to a 5-degree elevation angle. The receivers shall record the full wavelength, carrier phase, and signal strength of both the L1 and L2 frequencies, and track at least eight satellites simultaneously on parallel channels. Dual frequency instruments are required for all baselines. Data collection must be accomplished as specified in the field utilizing the dual-frequency receiver in the compressed mode at a 15-second epoch collection interval.

The receiver, along with any necessary software, shall be capable of producing the Receiver Independent Exchange (Rinex), Version 2.1, data format. The specifications for this data format can be found at: <http://www.ngs.noaa.gov/CORS/RINEX211.txt>

The antenna models used for AHTD GPS surveys shall be on the list of calibrated/modeled antenna by the National Geodetic Survey. This list may found at: <http://www.ngs.noaa.gov/ANTCAL/>

Fixed-height tripods are preferred for all antenna and receivers. The plumbing bubbles on the antenna pole of the fixed-height tripod must be shaded when plumbing is performed. Also, the perpendicularity of the poles must be checked at the beginning of the project and any other time there is suspicion of a problem.

When a fixed-height tripod is not used, the height of the antenna must be carefully measured to prevent station set-up blunders from occurring. Tribrachs used for these set-ups must be checked and adjusted when necessary. Totally independent measurements of the antenna height above the mark in both metric and English units must be made before and after each session. The measured antenna heights shall be recorded and submitted with the project data.

Some antennas have detachable ground planes and radomes. Radomes shall not be utilized for AHTD GPS surveys. In order to help identify what exactly was used at a particular site, a digital picture should be taken and submitted with the project.

2.7.2 HIGH PRECISION GEODETIC STATIC GPS SURVEYS

All GPS control surveys for highway projects shall be established from first order (1:100,000) NGS control points and Continuous Operating Reference Stations (CORS) in the area based on NAD 83. First order (1:100,000) accuracy shall be maintained on all baselines. Procedures for GPS shall comply with those

Chapter 2 – Control Surveys (cont.)

set out in Geometric Geodetic Standard and Specifications for using GPS Relative Positioning Techniques, by the Federal Geodetic Control Committee, version 5.0 (Reprinted 8/1/1989), or later.

2.7.2.1 STATIC OBSERVATIONS

The observing scheme shall be arranged so that for each station the start time of one of the observing sessions shall be at least four (4) hours different from the other two. The observing scheme shall be arranged to ensure that adjacent stations are directly connected in at least one observing session, and at least half of all base lines are repeated. Three (3) sessions of two (2) hours each shall be observed on each control point. In order to provide a check, the equipment shall be broken down and reset with a minimum of 15-30 minutes between the three sessions.

A typical schedule is as follows:

Monday / Travel Day		Tuesday – Thursday (cont.)	
8:00 am – 11:00 am	Travel	12:00 pm – 12:30 pm	Setup
11:00 am – 12:00 pm	Lunch	12:30 pm – 2:30 pm	Session B
12:00 pm – 12:30 pm	Setup	2:30 pm – 3:00 pm	Break / Setup
12:30 pm – 2:30 pm	Session A	3:00 pm – 5:00 pm	Session C
2:30 pm – 3:00 pm	Break / Setup		
3:00 pm – 5:00 pm	Session B	Friday / Travel Day	
		8:00 am – 8:30 am	Setup
Tuesday – Thursday		8:30 am – 10:30 am	Session A
8:00 am – 8:30 am	Setup	10:30 am – 11:00 am	Break / Setup
8:30 am – 10:30 am	Session A	11:00 am – 1:00 pm	Session B
10:30 am – 11:00 am	Break	1:00 pm – 2:00 pm	Lunch
11:00 am – 12:00 pm	Lunch	2:00 pm – 5:00 pm	Travel

This schedule should be adjusted accordingly so that optimum satellite coverage is utilized and occupation times should correspond to the operation times of area AHTD CORS Sites. The observation schedule shall be provided to the Surveys Division at the beginning of each project and whenever the Consultant/Surveyor revises the observation schedule.

Below are the minimum requirements for static GPS collection

- Minimum of 6 sv's at a PDOP of less than 5
- All observations will be done using only fixed height or slip-leg tripods and with tribrachs.
- A minimum of 4 receivers observing simultaneously
- Must tie to a minimum of 3 HARN or CORS stations in 3 different quadrants
- All observations shall be a minimum of 2 hours unless approved by the Surveys Division.
- Longer observation times may be required if there are significant obstructions on the horizons

Data from the CORS in the region shall be used in the processing. The data can be downloaded from <http://www.ngs.noaa.gov/UFCORS/> .

A rubbing of the stamping of the mark shall be made at each visit to a station. If it is impossible to make a rubbing of the mark, a plan sketch or digital picture of the mark must be substituted, accurately recording all markings.

For each station visited, a visibility obstruction diagram must be prepared and the TO-REACH description carefully checked for errors or omissions.

The following shall be recorded at each occupation of a station:

- Receiver manufacturer;
- Antenna manufacturer;
- Receiver model number (part number);
- Antenna model number (part number);
- The complete serial number of the receiver, and;
- The complete serial number of the antenna.

Chapter 2 – Control Surveys (cont.)

For each GPS Station occupied and each GPS session, the following information is to be completed:

- NGS GPS Control Observation Log Form
- NGS GPS Recovery Form
- NGS GPS Visibility Form
- NGS GPS Pencil Rubbing Form or digital picture.

These forms can be supplied by the Surveys Division or found on the Internet at www.ngs.noaa.gov.

2.7.3 FAST-STATIC & RTK SURVEY

Fast-static, also known as Rapid Static, is similar in concept to traditional Static surveys. The difference is the length of time of the GPS observations. Fast Static observations range from 8-30 minutes. The observation times will be based on the site conditions and satellite signals.

Real-Time Kinematic (RTK) is similar to static observations with the exception of receiving a real-time differential correction via a radio or cellular modem from the base station. The typical observation times are 15-30 seconds based on site conditions.

All control points positioned utilizing Fast-Static or RTK shall measure and store four (4) baselines with two (2) baselines from one known Static GPS base station and two (2) baselines from a different known Static GPS base station. The roving station shall be “broken down” and lose initialization between the two (2) baseline measurements from the same GPS base station. Whenever possible, the known Static GPS base stations should be at least 2-3 miles apart.

The GPS base stations shall be in the same project datum to be utilized in the Fast-Static or RTK surveys. During the Fast-Static or RTK survey, the surveyor shall take measurements on other known GPS stations. This will be considered a “Check” shot to assist with troubleshooting any problems that may arise during the survey.

Benchmarks that are not intended to be used as primary horizontal control points may be stored with only one measurement. The position will be for general location only. If the benchmark to be located cannot be directly measured (i.e. vertical benchmark or tree canopy), an offset point with an azimuth and distance can be recorded in lieu of the direct measurement.

2.7.3.1 STANDARDS FOR COLLECTION OF FAST STATIC & RTK

The below parameters shall be used for Control Points:

- All the control points shall be measured and stored as an “Observed Control Point”.
- Maximum baseline lengths of 2.5 miles (11,200 feet)
- Minimum of 15 epochs for RTK observations
- Horizontal Precision: $\pm 0.035'$
- Vertical Precision: $\pm 0.05'$
- 13° Elevation Mask
- PDOP less than 6

If during the observations the surveyor notices high RMS or other problems, then the surveyor should make and record additional measurements. These additional measurements allow bad measurements to be discarded during the network analysis. Additional measurements at a different time with a different satellite constellation may be necessary.

2.8 OPUS POSITIONS

The Online Point User Service (OPUS) provided by the NGS may be utilized for certain projects. The intended use of this service for AHTD projects is to provide a position and basis of bearing when High Precision Static GPS is not practical. OPUS positions should not be utilized on projects that are longer than 2 miles in length. Bridge & Approach and short State Aide projects are normally the type of projects that utilize this positioning technique.

Chapter 2 – Control Surveys (cont.)

The surveyor will need to set at least two (2) primary control points with a clear view of the sky. Three (3) points are preferred if terrain and topography allows intervisibility. These points shall have a minimum of two (2) or more hours of GPS observations. It is preferred that two (2) or more of the points be observed simultaneously. The GPS observations will be downloaded and submitted to NGS via the OPUS website: <http://www.ngs.noaa.gov/OPUS/>. The surveyor shall submit the raw data and the OPUS report from NGS to the AHTD.

2.9 SOLAR OBSERVATIONS

In the event that precise GPS observations are not practical or available, the surveyor shall perform a solar observation or “Sun Shot” to create a basis or bearing for the project. The surveyor can utilize a handheld GPS or USGS quad map to determine latitude and longitude of the observation point.

Two (2) independent solar observations shall be made at the same point. The two (2) computed azimuths from the solar observations shall be within 10 seconds of each other. It is preferred that the observation point be at the beginning or end of the project. If the project is over 2 miles in length, additional solar observations shall be made at control points near 2 mile intervals.

2.10 CONVENTIONAL TRAVERSE

Conventional traversing with an Electronic Theodolite and Distance Meter or Total Stations is utilized to establish horizontal positions on points. Under normal circumstances, traversing is used to supplement measurements performed with GPS techniques.

When performing conventional traversing for the primary control baseline (CTL), the SDMS TRAV.seq shall be utilized. The sequence requires the surveyor to measure two (2) sets of direct and reverse horizontal and vertical angles with accompanying slope distances. The traverse loop closure for primary baseline control shall be a minimum of 1:50,000. This relates to a positional accuracy of 2cm + 20ppm.

When performing conventional traversing for the random traverse control (TV) for topography and land surveys, the SDMS TRAVP.seq shall be utilized. The sequence requires the surveyor to measure at least one (1) set of direct and reverse horizontal and vertical angles with accompanying slope distances. The traverse loop closure for random traverse control shall be a minimum of 1:20,000. This relates to a positional accuracy of 2cm + 50ppm.

2.11 PROJECT CONTROL REFERENCES

2.11.1 REFERENCE CONTROL POINTS

Reference Control Points (RCP or CTL) can be established during the initial control surveys, design surveys, or ROW staking phase of the project. The intent of the RCP is to provide supplemental primary control outside of the proposed construction limits that can be utilized for Construction Layout or ROW Monumentation. The measurements techniques and standards for the RCP shall be at the same level of the primary control baseline (CTL). Therefore, 3-wire differential leveling techniques will be required if control points are to be used for elevations.

2.11.2 TOPOGRAPHIC REFERENCES

Topographic references will normally be established using the CADD generated information. Field references will only be set if specified by the staff supervisor.

3 DESIGN SURVEYS

The AHTD Surveys Division utilizes conventional field surveys (on the ground), LiDAR, and photogrammetric methods to gather data for the development of the Digital Terrain Model (DTM) and topographic features model that are provided to designers. This chapter provides requirements, procedures, and information for conventional survey methods only. For discussion of design surveys using remote sensing equipment, including Aerial Photogrammetry, LiDAR, and Sonar, see [Remote Sensing](#) (Chapter 4).

3.1 NOTIFICATIONS AND CHECKLIST INFORMATION

Prior to beginning work, refer to [General Requirements](#) (Chapter 1), for required notifications and checklist information. Arkansas One Call (800) 482-8998 or 811 shall be contacted to locate and mark underground utilities within the project limits. The surveyors may set-up an account and file an e-ticket in lieu of calling. The field crew chief should be the contact person. The crew chief's mobile phone number should be the phone number submitted on the request.

Surveys Division Staff Supervisors will submit the e-ticket for consultants on AHTD projects. If a consultant surveyor requests utility locates from Arkansas One Call directly, the consultant surveyor will be responsible for any charges.

3.2 DATA COLLECTION SOFTWARE AND HARDWARE

All data shall be collected in electronic form using AHTD Survey Data Management System (SDMS) Collector and processed using SDMS Processor. Collector and Processor software will be provided to AHTD consultants at no charge. Users should familiarize themselves with the SDMS data structure and naming conventions. The *AASHTO SDMS Getting Started Manual* and *AASHTO SDMS Technical Data Guide (2000)* are available for free download in PDF format from the following websites: http://arkansashighways.com/surveys_division/manuals.aspx.

Of particular importance for topographic and terrain data collection are the sections of the technical guide discussing methods of point connectivity with SDMS to create a survey chain. Point connectivity by Figure Code (FG:) is used extensively by AHTD to collect breakline data and other field collected line features, such as waterlines and buildings. With this method, all measured points assigned the same figure code will create a survey chain connecting the points in the order shot.

While SDMS maintains flexibility for most data collection, data collection for certain features, such as box culverts and storm drains has been defined by AHTD Surveys Division through the use of specific sequence files. This is necessary to expedite data collection, ensure all relevant data is collected, and maintain consistency in the topographic and digital terrain models provided to designers.

The feature codes (FE:) defined in [General Requirements](#) (Chapter 1) should be strictly adhered to during data collection. These feature codes are utilized with the AHTD's automation software to generate CADD drawings with correct line weight, color, level, and symbology. File naming conventions used during design survey data collection shall conform to requirements specified in [General Requirements](#) (Chapter 1).

3.3 TOPOGRAPHIC, TERRAIN, & UTILITY DATA

AHTD Surveys Division has traditionally classified field surveys as "Full Survey" and "Utility & Drainage" (U&D) surveys. A "Full Survey" is where the surveyor measures and records the location of all pertinent topographic, terrain, and utility features. A "Utility & Drainage" (U&D) survey utilizes mapping from Photogrammetry, LiDAR, and/or Sonar for most of the area. The surveyor would need to map all the utilities and features that are not mapped from these other technologies. Areas that cannot be mapped

Chapter 3 – Design Surveys (cont.)

from Photogrammetry or LiDAR are considered to be “Obscure” areas. For both types of Design Surveys, additional Control Surveys may be required to densify the control network.

When collecting data for the DTM, all data shall be obtained using breaklines generated in the field. A breakline is defined as a line segment with a constant linear slope between two points. Breaklines shall be collected on features such as crown of pavement, edge of pavement, edge of shoulder, back of curb, ditch flow line, natural ridges, etc., with the appropriate feature code assigned. Data for large natural areas with no distinct grade changes shall be collected with a random breakline meandering through the area. Gridded spot elevations will not be accepted. Using breaklines to develop the DTM ensures greater control during the triangulation process to develop the triangulated irregular network (TIN) so that natural and man-made features are accurately represented in the DTM.

In the effort to maintain a vertical and horizontal positional accuracy of 0.15' (5 cm) for DTM hard surface features, drainage and utility structures, and other elevation critical features, the maximum length of measurement from the surveying instrument (Total Station) to the measured point shall not be greater than 450'. The primary control network density is normally established at 800' intervals or less to accommodate this requirement. Topographic points and chains may be measured at a maximum distance of 750'.

3.4 TRAVERSE POINTS AND CONTROL CHECKS

3.4.1 TRAVERSE POINTS

It may be necessary to set additional random (move up) points for occupation while collecting topography terrain, and utility data. The traverse point should be set so that a second control point, or previously established traverse point, is visible as a checkshot. Traverse points shall be established taking a minimum of one set of direct and reverse readings with the instrument. If hard surfaces are to be shot from the traverse point, the elevation shall be established utilizing 3-wire or digital leveling techniques.

3.4.2 CONTROL CHECK

Control Checks are required while collecting field data. A checkshot (AC:CC) using sequence CC.seq shall be taken a minimum of every one hour and prior to ending setup at each station. The checkshot may be taken on a point in the primary control file or on a random (move up) point. **Never** take a checkshot on the same point used for the backsight (AC:BS). The checkshot is intended to provide redundancy of measurements for geometry adjustment during post processing.

Elevation control checks (AC:EC) may be utilized by making measurements to a know benchmark or project temporary benchmark.

3.5 DATA COLLECTION FOR BRIDGES AND CULVERTS

Time and care should be spent to accurately record the hydraulic conditions at and around all drainage structures. Previous construction plans (if available) shall be reviewed and compared to the existing structures to verify dimensions and type of culverts.

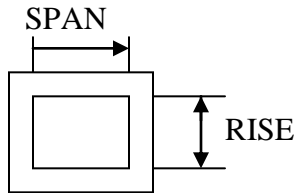
It is of the utmost importance to record the existing dimensions, condition, and flowlines of the culverts. During widening projects, the culverts are often extended instead of replaced. The surveyor is required to dig down to the floor of the culvert to ensure the flowline is located and dimensions accurately measured. If the culvert does not have a floor (bottomless culvert), then the surveyor shall record that the culvert has an earthen floor in the point description.

Breaklines shall be recorded to accurately model areas with excessive silt and scour. The amount of fill shall be recorded for both ends of the pipe with the condition (CN:) data tag.

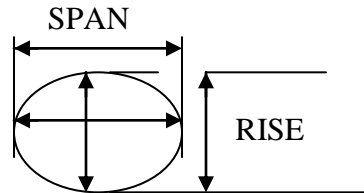
Chapter 3 – Design Surveys (cont.)

Standard AHTD procedures state culverts are to be measured in feet and inches depending on the structure. The diameter (DI:), width (WD:), and height (HT:) for circular and arch pipes shall be measured in inches. The width (WD:), and height (HT:) for box culverts shall be measured in feet. The length (LN:) shall be measured in feet for all culverts. Always record the dimensions as span (WD) by rise (HT) by length (LN).

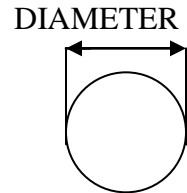
All culverts are to be measured with a tape, not estimated from the monopole. These measurements are to be inside dimensions. Measure the width square with the structure, not along the skew.



R.C. BOX CULVERT



ARCH PIPE CULVERT

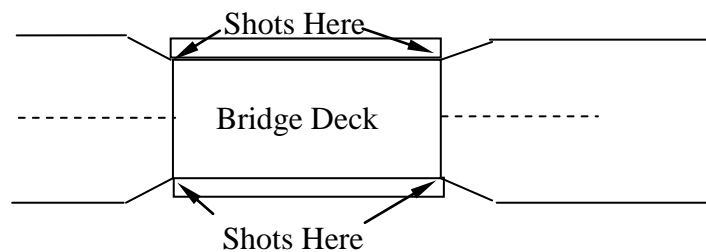
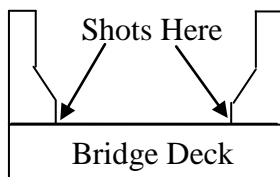


CIRCULAR PIPE CULVERT

3.5.1 BRIDGE SURVEYS

The following information shall be collected, at a minimum, for bridge surveys:

1. Record as a text shot (FE:TS), the log mile and bridge number.
2. Record as a Text Shot (FE:TS), bridge type, number of spans, number and type of bents.
3. The historic high water mark shall be recorded on all bridges as FE:HHW. Provide approximate date of high water and source of information.
4. In accordance with the Migratory Bird Treaty Act (As Amended 1989), if there are signs of migratory birds, primarily swallows, a survey text shot shall be collected indicating their presence.
5. Breakline of existing topography should be intensified through and around bridges. It is important that tops, toes, and grade breaks are accurately established regardless of water level.
6. A breakline around the edge of the water (FE:EW) should be collected.
7. Maintain connectivity of breakline features under existing bridges.
8. The bridge deck shall be tied as one survey chain with shots taken on the deck at the abutments just inside the wheel guards.



Chapter 3 – Design Surveys (cont.)

3.5.2 BOX CULVERTS

The information that follows shall be collected, at a minimum, for box culverts. This information may be collected concurrently with the culvert sequence (CU.SEQ).

1. Record the culvert shot at the interior corners of each barrel (remove sediment if necessary). Each barrel shall be connected as one survey chain.
2. Record the type of structure and number of barrels under the data tag Type (TY:). For example, a reinforced concrete box culvert with two 4'x4' openings is recorded as TY:DBL RCBOX.
3. Box culvert and arch pipe culvert dimensions, span by rise by length, shall be recorded under the data tags WD: (width), HT: (height), and LN: (length), respectively. These are interior dimensions and shall be measured perpendicular to the structure. Box culvert dimensions shall be recorded in feet.
4. Record the percent filled with sediment on each end of the pipe with the data tag CN:.
5. The wingwall shall be tied with a minimum of six shots along the center as FE:HW (headwall). The points shall be connected as a survey chain using SDMS connectivity functions. The width of the wingwall shall be indicated with the WD data tag.

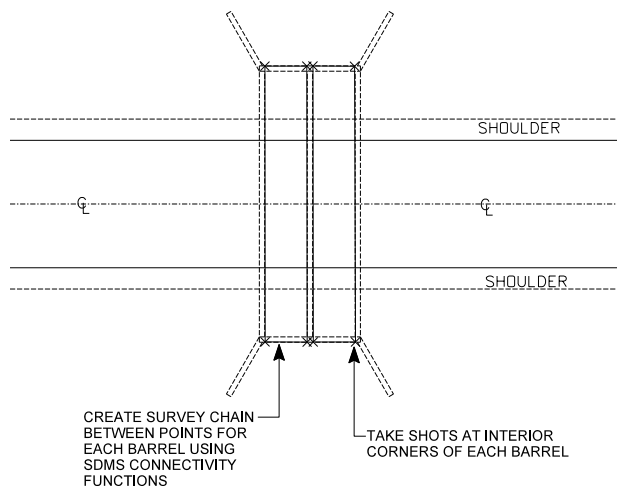


Figure 3-1. Recording information for box culvert.

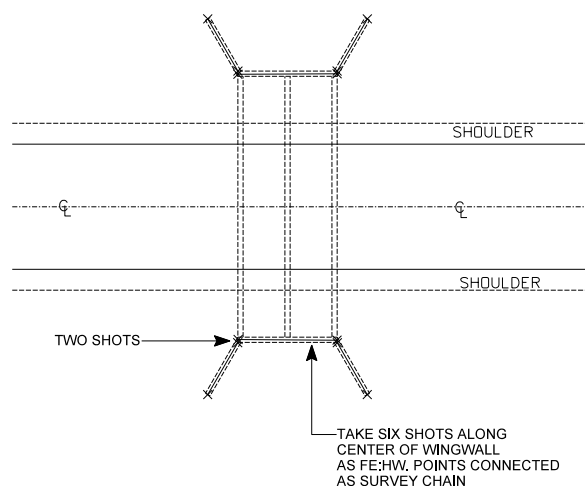


Figure 3-2. Recording information for wingwall.

3.5.3 PIPE CULVERTS

The information that follows shall be collected, at a minimum, for pipe culverts. This information may be collected concurrently with the culvert sequence (CU.SEQ). Care should be taken when measuring the diameter on a Pipe Culvert with a flared-end section. The pipe dimension shall be measured and recorded inside the pipe, not the flared-end section.

1. Record the culvert shot at the center, flowline (remove sediment if necessary) of each pipe. Each pipe shall be connected as one survey chain.
2. Record the type of structure under the data tag Type (TY:). For example, a corrugated metal pipe with a flared end section will be recorded as TY:CMP W/FES.
3. Arch pipe culvert dimensions, span by rise by length, shall be recorded under the data tags WD: (width), HT: (height), and LN: (length), respectively. For circular pipe culverts, the diameter shall be recorded with the data tag DI: (diameter). Circular pipe and arch pipe dimensions shall be recorded in inches.
4. Record the percent filled with sediment on each end of the pipe with the data tag CN:.
5. If headwalls are present, they shall be tied as FE:HW (headwall) along the center of the headwall. The width of headwall shall be indicated with the WD data tag.

Chapter 3 – Design Surveys (cont.)

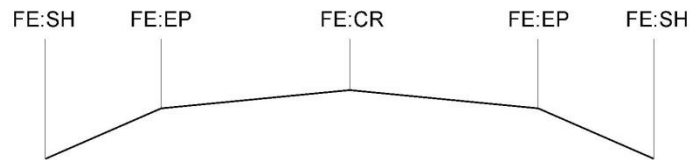
3.6 DATA COLLECTION FOR VARIOUS FEATURES

3.6.1 ROADWAY

The roadway and pavement profile data is utilized by roadway designers to establish proposed locations and widening. The existing pavement crown (FE:CR), edge of travel lane or roadway pavement (FE:EP), and shoulder (FE:SH) have special significance to the designer. In the cross-section of the highway,

- FE:CR Crown – The high point of the roadway (in non-super elevated sections; or
- FE:CR Crown – The pavement seam near the center in a super elevated section
- FE:EP Edge of Pavement – The pavement seam near the outside traveled lane; or
- FE:EP Edge of Pavement – The outside edge of pavement if no shoulder exists
- FE:SH Shoulder – The outside edge of pavement or gravel

The type (TY:) tag shall be recorded with type of shoulder (i.e. TY:Concrete, TY:Asphalt, or TY:Gravel). These procedures are reserved for Highways, County Roads, and City Streets only.



Driveways and other pavements shall utilize the other appropriate feature codes.

- FE: DW Driveways
- FE: EB Edge of Asphalt (Bituminous) Pavements or Pull-outs
- FE:EC Edge of Concrete

If the existing centerline is calculated from Construction or ROW plans, use the existing alignment feature code (FE:EA). This centerline shall not be utilized in the DTM model.

3.6.2 ROADWAY DITCHES

Roadway drainage is a significant part of all proposed designs. The proposed designs often attempt to maintain and utilize the existing ditch profiles. The ditchlines parallel to an existing roadway shall utilize the ditchline feature code (FE:DL). This ditchline normally will be in the center or low point of the ditch. These drainage ditches need to have adequate breaklines to model the existing capacity. Very few ditches are considered “V” bottom ditches. Therefore, the surveyor will need several breaklines to define these drainage ditches.

3.6.3 TRIBUTARY CROSSINGS

Topographic and terrain data shall be collected a minimum of 300 feet upstream and downstream of tributaries crossing the roadway. This includes stream meanders, man-made features, and breakline features to accurately model the tributary and adjacent floodplain area. The stream flowline shall be recorded with the stream feature code (FE:ST). In some cases, it may be necessary to collect data for the full width of the flood plain. The Surveys Division engineering staff may modify the limits of coverage depending on the significance of the tributary.

3.6.4 INTERSECTING AND PARALLEL RAILROADS

At all railroad crossings, the railroad rails must be tied a minimum distance of 1000 feet on each side of the roadway. For railroads paralleling the roadway, the railroad shall be tied throughout the portion

Chapter 3 – Design Surveys (cont.)

paralleling the roadway. Railroad mile posts shall be recorded with the railroad log mile feature code (FE:RM). Necessary permitting for entering railroad property should be obtained prior to surveying on railroad right of way.

3.6.5 INTERSECTING ROADWAYS

Topographic and terrain data shall be collected on all intersecting roadways a minimum distance of 300 feet from the edge of pavement. Record a sideshot with feature code FE:TS and a point description (PD:) the name of all intersecting roads and county roads.

3.6.6 UTILITIES

All utilities within the survey limits, above ground and below ground, shall be located. The low wire of overhead utility transmission lines crossing the roadway shall be accurately located using trigonometric measurements (see Utility Elevation Activity Section, AC:UE later in this chapter). Low wire elevations are not required for overhead service lines serving individual homes or businesses. Utility pole locations should be recorded with the prism placed on the road side of the utility pole.

Locations for underground water, gas, electrical, telecommunication, and any other utility lines shall be recorded based on paint locate markings provided by the utility locate company. However, all boxes, meters, valves, or other appurtenances to these facilities shall be measured and recorded. A higher quality locate, using potholing, geophysical scanning, probing, or other acceptable methods, may be required for these facilities (see Subsurface Utility Engineering section).

3.6.7 STORM & SANITARY SEWERS

All storm and sanitary sewer systems shall be located within the surveys limits. The manhole rim elevation, manhole invert elevation, pipe sizes, pipe type, and pipe flowline elevations shall be recorded. Storm sewer systems shall be located at least one (1) block away from the existing centerline or to the system outlet.

For catch basins and junction boxes, a breakline (FE:EC) shall be collected around the perimeter of the structure. For grate inlet structures, the size of the grate shall be recorded (PD:2'X1.5'),

3.6.8 EXISTING BENCHMARKS

Existing benchmarks recovered while performing topographic and terrain surveys shall be tied with a sideshot to establish horizontal coordinates on that mark. Describe the benchmark and what it is located on with a point description tag (PD:).

3.6.9 ADVERTISEMENT SIGNS

All fixed and permanent advertisement signs on and adjacent to the ROW shall be measured while performing topographic and terrain surveys. The name on the sign as well as the permit number for the sign shall be recorded in addition to the location. The Edge of Sign Sequence (ESIGN.SEQ), shall be used to record this information.

Highways signs do not need to be surveyed. This includes, but is not limited to, speed limit, stop, yield, and highway information signs.

3.6.10 BUILDINGS

Buildings shall be located by recording sideshots at the location of the roof overhang (dripline of roof or awning). The type of building and number of stories shall be recorded in the point description. If the

Chapter 3 – Design Surveys (cont.)

building has been located with Photogrammetric methods, it is not necessary to re-measure the location of the structure unless the structure has been changed.

If the building or structure is near an apparent floodplain, the finished floor elevation shall be measured and recorded.

3.6.11 PEDESTRIAN TRAILS

Worn paths or pedestrian trails adjacent to roadways shall be recorded as part of topographic and terrain surveys to show the presence of pedestrian traffic that may warrant consideration of sidewalks in construction projects.

3.6.12 FENCES

All fences on and adjacent to the right of way shall be recorded as part of topographic and terrain surveys. A data tag indicating fence type (TY:) should be included (i.e. TY:3 STRAND BARBWIRE).

3.6.13 RETAINING WALLS

Information for retaining walls (FE:WR) shall be collected with a continuous survey chain along the center of the retaining wall. The width of the retaining wall shall be recorded (WD:). The construction material used for the retaining wall shall also be recorded (TY:ROCK). Breaklines shall be recorded at the base along all sides of the wall.

3.6.14 UNDERGROUND TANKS

All underground fuel storage tanks on and adjacent to state, county, and city highways and streets are to be located.

3.6.15 HEADWALLS

Headwalls (FE:HW) for drainage structures shall be collected by creating a continuous survey chain along the center of the headwall. The width of the retaining wall shall be recorded (WD:). The construction material used for the retaining wall shall also be recorded (TY:CONCRETE). Breaklines shall be recorded at the base along all sides of the wall.

3.6.16 HISTORIC HIGH WATER MARK

Historical high water mark shall be located for all bridge projects. The approximate date of high water, description of location, and source of information of information shall be recorded. The surveyor shall use the Historical High Water feature code (FE:HHW).

3.6.17 SURVEY NOTES AND TEXT

Use survey text (FE:TS) feature code to record the name of all intersecting roads, land owners, names of streams, and or other project information without a specific feature code.

Chapter 3 – Design Surveys (cont.)

3.7 DEFAULT SIDESHOT SEQUENCE

The sequence shown below will be used to collect the majority of field collected line and point features during topographic and terrain data collection.

SDMS Data Tag	Description
AC:SS	Activity:Sideshot
PN:	Start with 10,000 or increment up from last PN
FE:	Feature Code of item being shot
FG:	Assign figure number if part of a breakline or survey chain
GM:	Geometry: P (line) or C (curve)
PD:	Point Description
HZ:	Horizontal Angle: polled from the instrument
VT:	Vertical Angle: polled from the instrument
DS:	Slope Distance: polled from the instrument
SH:	Staff Height

The data tags shown above are the minimum required information for each sideshot. Additional tags, such as comment (CM:), may be added if more information is needed on the individual shot.

3.8 SEQUENCES FOR TOPOGRAPHIC AND TERRAIN DATA

The sequences that follow have been developed by the AHTD Surveys Division to collect the minimum required information for selected features. These sequences may be modified as necessary to accommodate conditions encountered in the field.

3.8.1 NEW PROJECT SEQUENCE (NEWPR.SEQ)

Generally, a new project (.PRJ) file is to be started for each day of data collection. Each project (.PRJ) file will contain a header at the top of the file. The header information is used to describe the type of project and other related data. This sequence is used for starting a new project. This is the minimum project header information.

AC:PR	Activity Project
ID:	Job Number
HY:	Highway
CO:	County
IT:	Instrument Type & Driver
SN:	Instrument Serial Number
NM:	Crew Name or Number
OB:	Observer (Instrument Man)
RE:	Data Collector Operator (Recorder)
I5:	Rodman 1
I6:	Rodman 2
ZN:	State Plane Coordinate System Zone or Assumed
HD:	Horizontal Datum
VD:	Vertical Datum
WE:	Weather Conditions
TE:	Temperature
PO:	Prism Offset (-40mm)

Chapter 3 – Design Surveys (cont.)

3.8.2 COLLECTING DATA FOR BOX CULVERTS OR ARCH PIPE (CU.SEQ)

The following sequence may be used to collect the minimum information required for box culverts or pipe culverts. For multi-barrel box culverts, the WD, HT, LN, and TY data tags are only required in the initial sideshot sequence. The WD and HT data tags should be replaced with a DI (diameter) data tag for pipe culverts.

AC:SS	(Begin Sideshot Activity, shot taken at corner of barrel or center of pipe)
PN:	(Point Number)
FE:CU	(Feature:Culvert)
FG:	(Assign Figure Number to Survey Chain)
GM:P	(Geometry: Linear)
HZ:	(Horizontal Angle polled from instrument)
VT:	(Vertical Angle polled from instrument)
DS:	(Slope Distance polled from instrument)
SH:	(Staff Height)
WD:	(Box or arch pipe width, internal dimension)
HT:	(Box or arch pipe height, measured internally)
LN:	(Box or arch pipe Length)
TY:	(Box or arch pipe type, e.g. RCP, CMP)
CN: % FILL	(% filled with sediment at inlet or outlet)
AC:SS	(Begin Sideshot Activity for opposite end of barrel or arch pipe)
PN:	(Point Number)
FE:CU	(Feature:Culvert)
FG:	(Figure Number for connectivity to PN:10001)
GM:P	(Geometry: Linear)
HZ:	(Horizontal Angle polled from instrument)
VT:	(Vertical Angle polled from instrument)
DS:	(Slope Distance polled from instrument)
CN: % FILL	(% filled with sediment at inlet or outlet)

3.8.3 COLLECTING DATA FOR OVERHEAD UTILITY LINES

The following sequence may be used to collect data for the low wire of overhead utilities crossing the roadway. A sideshot is taken under the lowest point on the bottom utility line for horizontal location. The vertical angle to the low point of the line is then recorded for office calculations.

AC:SS	(Sideshot Activity)
PN:	(Point Number)
FE:TS	(Feature:Survey Text)
GM:P	(Geometry:Point)
HZ:	(Horizontal angle polled from instrument)
VT:	(Vertical angle polled from instrument)
DS:	(Slope distance polled from instrument)
SH:	(Staff Height)
PD:POINT ON ROAD UNDER LOWEST LINE	(Point Description)
AC:UE	(Utility Elevation)
PN:	(Point Number)
FE:OHE	(Feature:Over Head Electric)
VT:	(Enter vertical angle from instrument, DD.MMSS)
PD:LOWEST UTILITY LINE	(Point Description)

Chapter 3 – Design Surveys (cont.)

3.8.4 COLLECTING DATA FOR STORM OR SANITARY SEWERS

The following sequences for collecting storm and sanitary sewer data utilizes the Acivity UE function to collect information for underground features. The information is essentially collected in two sequences, the first sequence collects information for the manhole and the second sequence collects information for pipes entering and exiting the manhole.

3.8.4.1 MANHOLES

A shot is taken at the top of the manhole. A level rod or other measuring device is then used to determine the distance to the bottom of the manhole. This distance is recorded as the RR under AC:UE for the manhole.

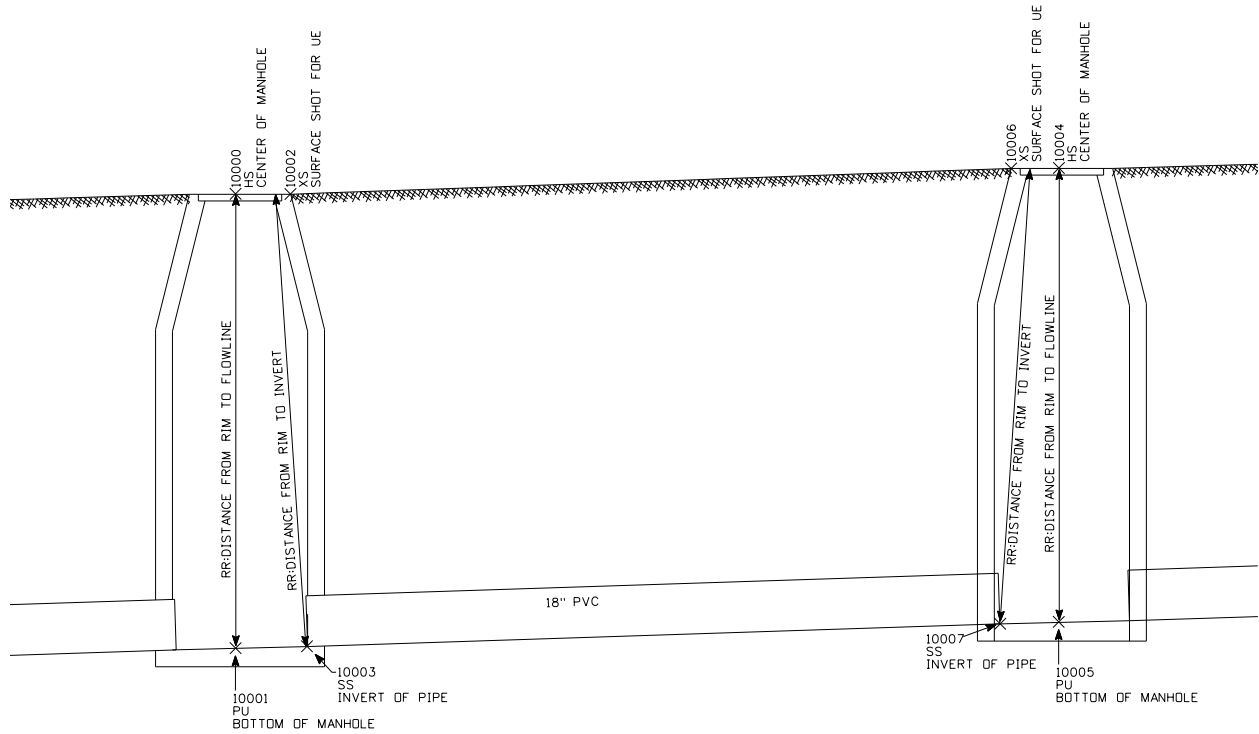
AC:SS	(Sideshot Acitivity)
PN:	(Point Number)
FE:HM	(HM-storm sewer manhole, HS-sanitary sewer manhole)
GM:P	(Geometry:Point)
HZ:	(Horizontal angle polled from instrument)
VT:	(Vertical angle polled from instrument)
DS:	(Slope distance polled from instrument)
SH:	(Staff Height)
PD:TOP OF MANHOLE	(Point Description)
AC:UE	(Utility Elevation Activity)
PN:	(Point Number)
FE:PU	(PU-bottom of manhole)
GM:P	(Geometry:Point)
RR:	(Distance in feet measured to bottom of manhole from rim)
TY:	(Material manhole constructed from; conc, masonry, etc.)
PD:BOTTOM OF MANHOLE	(Point Description)

3.8.4.2 PIPES

A shot is taken over the pipe at the location it enters or exits the the manhole. A level rod or tape measure is used to determine the distance to the invert of the pipe. This distance is recorded as RR under AC:UE for the pipes. A figure number or OD tag with point numbers is required for survey chain connectivity to the next shot on the pipe. The diameter and type of pipe shall be recorded with the DI and TY data tags.

AC:SS	(Sideshot Acitivity, shot taken over pipe)
PN:	(Point Number)
FE:TS	(Point on rim above pipe)
GM:P	(Geometry:Point)
HZ:	(Horizontal angle polled from instrument)
VT:	(Vertical angle polled from instrument)
DS:	(Slope distance polled from instrument)
SH:	(Staff Height)
PD:SURFACE SHOT FOR UG PIPE	
AC:UE	(Utility Elevation Activity)
PN:	(Point Number)
FE:STS	(STS-storm swr line, SS-san swr line)
GM:P	(Geometry:Linear)
FG:	(Figure Number for connectivity)
RR:	(Distance in feet measured to invert of pipe)
DI:	(Diameter of Pipe)
TY:	(Material pipe constructed from; conc, pvc, etc.)
PD:INVERT OF PIPE	(Point Description)

Chapter 3 – Design Surveys (cont.)



3.8.5 COLLECTING DATA FOR PARALLEL FIGURES

The sequence that follows may be used to create chains and points parallel to survey chains and points previously collected. This sequence may take place at any time during data collection. Additional discussion of parallel figures can be found on page 112 of the AASHTO SDMS Technical Guide.

When creating parallel figures for curb FE:CB, the chain should be created from the edge of pavement (EP) outward towards the right of way as opposed to the back of curb in towards the centerline.

The horizontal offset (OF:) is measured as a positive direction to the right proceeding along the chain in the direction of increasing point numbers. Negative offset is measured to the left along the chain proceeding in the direction of increasing point numbers.

- AC:CH (Chain Activity)
- FE: (Feature Code for chain to be generated)
- CD: (Chain description for chain to be generated, optional)
- CH: (Figure number of chain to be copied)
- OF: (Horizontal offset from chain to be copied)
- DV: (Vertical offset from chain to be copied)

Other valid attribute tags may be inserted during data collection as needed. This includes CD:, CM:, CL:, additional PL: and CH: tags if needed, etc.

Chapter 3 – Design Surveys (cont.)

3.8.6 PERPENDICULAR AND LENGTH OFFSETS

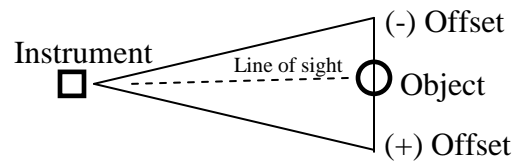
Perpendicular Offsets Left and Right

If the surveyor cannot sight or is unable to place the target directly on the desired point, the target may be perpendicularly offset from the line of sight to the right or left of the desired object. A sideshot is taken to the target and the taped offset is entered with the OF: (offset) data tag.

When facing the desired point from the instrument, a right offset is entered with a positive number, such as OF:13.5. A left offset is represented by a negative number, such as OF:-5.4.

The following is a sample perpendicular offset entry, with the target placed to the left of the desired point:

AC:SS
PN:15
PD:TREE
HZ:34.112
VT:90.251
DS:132.943
OF:-12.5



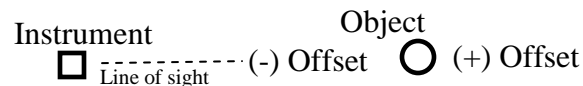
Length Offsets Front and Back

If the surveyor cannot sight or is unable to place the target directly on the desired point, the target may be directly offset along the line of sight in front or in back of the desired object. A sideshot is taken to the target and the taped offset is entered with the LO: (length offset) data tag.

When facing the target from the instrument, an offset in front of the point is entered with a negative number, such as LO:-15.9. An offset behind the point is represented by a positive number, such as LO:3.7.

The following is a sample length offset entry, with the target placed in front of the desired point:

AC:SS
PN:75
PD:TREE
HZ:34.112
VT:90.251
DS:132.943
LO:-6.2



3.8.7 TAPING ACTIVITY

Taping is an activity specifically designed for defining chains around buildings or other figures when it may not be practical or desirable to use a surveying instrument (total station) to collect all of the points that define that building or figure.

This procedure allows the user to tape the horizontal distance along each side to approximate the direction, and to indicate the approximate difference in elevation, between two angle points. Before the taping activity can be used, two points must be recorded, using the sideshot activity, to establish a beginning reference line for the taped measurements. Typically, the total station is used to measure these two points immediately before beginning the taping activity. The points can be recorded at any time in the project file, but must be recorded before the taping activity in which they will be used.

The backsight point number data item (BS:) and the occupied station point number data item (OS:) are used with the taping activity to specify the point numbers to be used for the backsight and occupied station respectively.

Chapter 3 – Design Surveys (cont.)

Within the taping activity, taped measurements begin at the occupied station point number (OS:). **The direction of the reference line is from the occupied station point number (OS:) to the backsight point number (BS:).** The points assigned to the OS: and BS: are included as part of the taped figure.

In the example shown below, you **MUST** have previously shot points 9 and 10 before performing the Taping Activity.

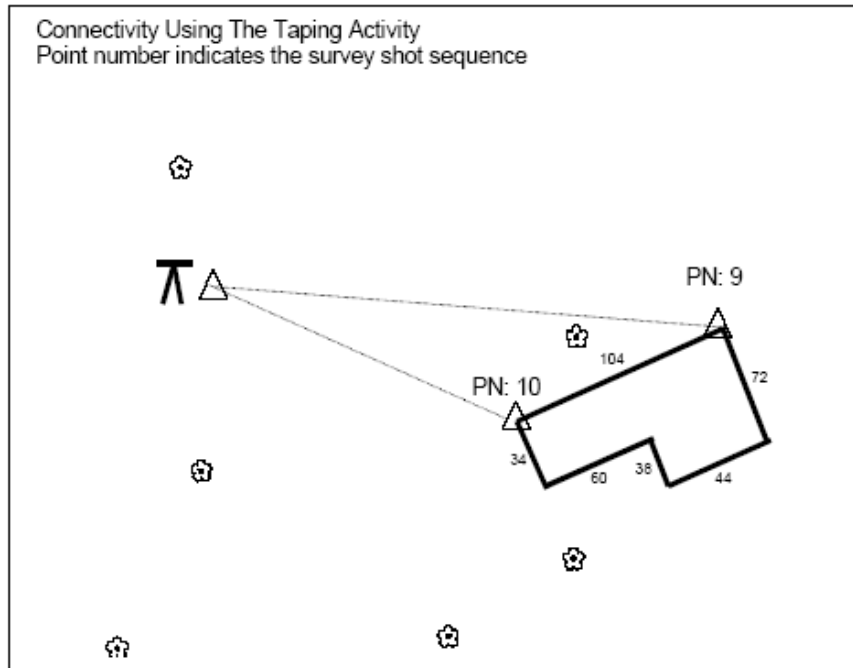


Figure 6.1 The Taping Activity

The default sequence for this activity is: (Using above example)

- AC:TA (Begins Taping activity)
- OS:10 (Point Number of the point to be used as the occupied station. This is the second point in the chain being defined within the taping activity.)
- BS:9 (Point Number of the point to be used as the back sight. This is first point in the chain being defined within the taping activity.)
- PN:30000 (Beginning point number to be used for the points computed within the taping activity)
- FE:BU (Feature to be used for the new chain)
- FG:5 (Figure Code to be used for the chain)
- CD:HOUSE (Chain Description)
- AD:R,34, (90° HZ Right 34 feet, use the same elevation as PN:10)
- AD:R,60,3.2 (90° HZ Right 60 feet. Add 3.2 feet to the elevation of the preceding point)
- AD:L,38 (90° HZ Left, 38 feet. Elevation the same as the preceding point.)
- AD:R,44 (90° HZ Right 44 feet. Elevation the same as the preceding point.)
- AD:R,72, -3.2 (90° HZ Right 71 feet. Subtract 3.2 feet from the elevation of the preceding point.)
- AD:R,104 (90° HZ Right 104 feet. Elevation the same as the preceding point)

Two radial measurements establish the first segment of the chain within each taping activity. These points are used as the back sight (BS:) and occupied station (OS:) to start defining the figure to be taped.

Note: The BS: and OS: data items are required for the post processing software to generate data for the taped points. Therefore, both data items must contain a response for each taping activity entered in a project file.

Chapter 3 – Design Surveys (cont.)

The Point Number (PN:) indicates the point number to be used for the first point taped. Subsequent point numbers will increment as defined in the TAGS.HLP file. The feature code data item (FE:) designates the feature of the chain being built by the taping activity. The figure code data item (FG:) designates the Figure Code of the chain being defined.

The angle distance list defines the direction, horizontal distance, and difference in elevation from the preceding point to the point that follows. The format is: AD:Direction,Horizontal Distance,Vertical Distance

3.8.8 EDGE OF SIGN SEQUENCE (ESIGN.SEQ)

This sequence can be used to record the edge of a sign. It should be noted that the overhang of the sign is to be tied and not the post of the sign.

AC:SS	(Sideshot Activity)
PN:	(Point Number)
FE:ES	(Feature:Edge of Sign)
FG:	(Figure Number)
GM:P	(Geometry: Linear)
CL:F	(Class: Feature)
HZ:	(Horizontal Angle polled from instrument)
VT:	(Vertical Angle polled from instrument)
DS:	(Slope Distance polled from instrument)
SH:	(Staff Height)
I8:NAME ON ES	(Name on sign)
I9:PERM. NUM.	(AHTD Permit Number from sign)
I7:DIST TO POST	(Distance from edge of sign to post)
TY:	(Sign construction material)

3.9 PAVEMENT MARKING

DO NOT PAINT ON ROADWAY SURFACES FOR ANY REASON. Flags are to be used to mark the location of points. The only exception will be points that fall within an area that will be reconstructed after DSUR is completed. That means no painting at all for monumenting projects that are done after construction is completed.

3.10 SUBSURFACE UTILITY ENGINEERING

Subsurface Utility Engineering, also known as SUE, is a process that utilizes existing utility records and maps; surface geophysical instruments; and test hole to locate and measure subsurface (underground) utility features. The American Society of Civil Engineers (ASCE) has published guidelines for SUE titled *Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data*. It is the intent of the AHTD to follow these guidelines.

The ASCE SUE guidelines classify different levels of accuracy for utility location and attributes, to include type, size, and depth. There are four recognized quality levels range from Quality Level D, the lowest accuracy level, to Quality Level A, the highest accuracy level. The highest level of accuracy and comprehensiveness is generally not needed at every point along a utility's path, only where conflicts with highway design features are most likely to occur. Hence, lesser levels of information may be appropriate at points where fewer conflicts or no conflicts are expected.

The following is an excerpt from the FHWA website:

- **Quality Level D.** QL-D is the most basic level of information for utility locations. It comes solely from existing utility records or verbal recollections, both typically unreliable sources. It may provide an overall "feel" for the congestion of utilities, but is often highly limited in terms of comprehensiveness and accuracy. QL-D is useful primarily for project planning and route selection activities.
- **Quality Level C.** QL-C is probably the most commonly used level of information. It involves surveying visible utility facilities (e.g., manholes, valve boxes, etc.) and correlating this information with existing utility records (QL-D information). When using this information, it is not unusual to find that many underground utilities have been either omitted or erroneously plotted. Its usefulness, therefore, is primarily on rural projects where utilities are not prevalent, or are not too expensive to repair or relocate.
- **Quality Level B.** QL-B involves the application of appropriate surface geophysical methods to determine the existence and horizontal position of virtually all utilities within the project limits. The information obtained in this manner is surveyed to project control. It addresses problems caused by inaccurate utility records, abandoned or unrecorded facilities, and lost references. The proper selection and application of surface geophysical techniques for achieving QL-B data is critical. Information provided by QL-B can enable the accomplishment of preliminary engineering goals. Decisions regarding location of storm drainage systems, footers, foundations and other design features can be made to successfully avoid conflicts with existing utilities. Slight adjustments in design can produce substantial cost savings by eliminating utility relocations.
- **Quality Level A.** QL-A, also known as "locating", is the highest level of accuracy presently available and involves the full use of the subsurface utility engineering services. It provides information for the precise plan and profile mapping of underground utilities through the nondestructive exposure of underground utilities, and also provides the type, size, condition, material and other characteristics of underground features.

After the utilities has been located and marked by SUE techniques, the surveyor shall utilize procedures outlined previously in this chapter to measure and record all positions, depths, type of utilities, and any other attribute information.

3.11 DATA COMPILATION

Data compilation consists combining data from Topographic & Digital Terrain Model fieldwork, Photogrammetric, and LiDAR surveys. This includes preparing all CADD drawings (DGN), geometry databases (ALG), and digital terrain models (DTM). The surveyor shall utilize the Bentley Systems, Inc., Microstation and Inroads V8i – Select Series 2 (8.11.7.xx or higher). The cell library, seed file, level library, feature table, and preference table furnished by the AHTD shall be used.

Chapter 3 – Design Surveys (cont.)

3.11.1 CADD DRAWINGS (.DGN)

The CADD graphics file shall include the following drawing models:

Topo Model

This model includes all planimetric, utility, and control data collected from field surveys, photogrammetry, and LiDAR datasets. This information is normally the background mapping shown on the design and ROW plans. All field survey that is located in the ALG file shall be plotted and annotated in the Topo Model. Select features will be plotted from DTM file.

If features are duplicated with field surveys and photogrammetry, the photogrammetry features shall be removed from the final drawing. The field surveyed features shall remain.

DTM Model

This model will contain graphics that represent data that is stored in the InRoads DTM file. Contours should be plotted at 1' intervals for performing quality control. Contours and DTM Triangles shall be removed from the file prior to submittal.

CTL Model

The control baseline and primary control points shall be plotted and annotated with control baseline preference. The survey control table shall be created from the X,Y,&Z coordinates with Error Estimates and placed into a text block. The notes within the table shall comply with the current *Survey Control Display Requirement* document.

Survey Notes Model

This model shall include a report of the survey in a text block. The notes will include all known sources of data (i.e. Photogrammetry, LiDAR, or Field survey); any blunders that were encountered during the data processing; and all personnel involved with the compilation process.

3.11.2 GEOMETRY DATABASE (.ALG)

The geometry database (ALG) shall be created from data from the InRoads Survey fieldbook utilizing the "Survey to ALG" survey feature filter. The survey feature filter excludes items that will be loaded into the DTM. A survey control baseline shall be stored including the baseline control points (PN:1-199).

3.11.3 DIGITAL TERRAIN MODEL (.DTM)

The digital terrain model (DTM) shall be created from data from the InRoads Survey fieldbook utilizing the "Survey Surface" survey feature filter. The survey feature filter includes items with the following feature codes: BL, BF, CB, CR, DL, DW, EB, EC, EP, EW, GR, HW, LV, PK, SH, SP, ST, SW, TL, WL, WR, and XS.

Breaklines and Obscure areas created from Photogrammetry shall be edited, trimmed, or deleted graphically in areas where field surveys exist. The remaining breaklines and obscure areas shall be imported into the DTM utilizing the "Import Surface Advanced" command with the "Photo Surface" filter selected.

Features extracted from LiDAR datasets shall be edited, trimmed, or deleted graphically in areas where field surveys exist. The remaining features shall be imported into the DTM utilizing the "Import Surface Advanced" command with the "LiDAR Feature" filter selected.

The DTM shall be triangulated with a maximum triangle length of 125 feet. Contours and Triangle shall be plotted to perform quality control checks to assist with blunder detection. Once all blunders have been resolved, the contours and triangles shall be removed from the graphics file.

4 REMOTE SENSING

Remote Sensing is the process of acquiring information from an object without making physical contact with the object. The AHTD utilizes several remote sensing technologies to locate and record positional and attribute data of ground features along highway corridors. Some of the technologies are Aerial Photogrammetry, LiDAR, and Sonar.

It is the intent of the AHTD that these mapping activities meet the *National Standard for Spatial Data Accuracy* provided by the Federal Geographic Data Committee. If the mapping does not meet the standard, the portion of the mapping that does not meet shall be noted. The standard can be downloaded from <http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/index.html>.

The American Society of Photogrammetry and Remote Sensing (ASPRS) published the *ASPRS Accuracy Standards for Large-Scale Maps* in July 1990. This standard is considered the previous "National Mapping Accuracy Standard" and has been replaced by the above *National Standard for Spatial Data Accuracy*.

4.1 PHOTOGRAMMETRY

Photogrammetry is a technology that utilizes aerial photographs in stereo pairs to map topographic and terrain features. The process includes flight and control planning, aerial image acquisition, ground control, aerial triangulation, and photogrammetry mapping. Ortho-rectified images are a by-product that is utilized as a reference to project topography.

4.1.1 ACCURACY STANDARDS

The AHTD normally creates maps and drawings to be utilized in roadway/bridge design and earthwork quantities also known as Design Level Mapping. AHTD also provides ortho-rectified images to be utilized for planning, location, and environmental feature mapping also known as Planning Level Mapping. The AHTD is conducting research for mapping assets along highways. This mapping is considered Asset Level Mapping. The mapping level has to be determined prior to starting the photogrammetry process.

It is the intent of the AHTD to meet the *National Standard for Spatial Data Accuracy* for horizontal and vertical positions on mapped features. In order to meet these accuracies, the below parameters shall be followed.

Mapping Level	Design	Asset	Planning Level 1	Planning Level 2
Mapping Scale	1:600/1"=50'	1:1200/1"=100'	1:12000	1:24000
Max. Flying Altitude above AMT	1800'	3600'	6000'	12000'
Min. Contour Interval	1.0'	2.0	5'	10'
AeroTrig Horz RMSE	0.2'	0.4'	0.6'	1.2'
AeroTrig Vert RMSE	0.2'	0.4'	0.6'	1.2'
Elev Accuracy – Spots/DTM	0.35'	0.7	n/a	n/a
Elev Accuracy – Planimetrics	0.70'	1.4	n/a	n/a
Horizontal Feature Accuracy	1.0'	2.5	n/a	n/a
Ortho Pixel Resolution	0.25'	0.5'	1'	2'

4.1.2 FLIGHT AND CONTROL PLANNING

Flight and Control planning involves determining the flight-line path, overlap, control layout, and flying altitude. These parameters are based on the intended use of the photography and the NEAT model.

Aerial photography normally is obtained between mid-December and mid-March for design level mapping projects. This allows for maximum ground exposure (low vegetation is dead and no leaves on trees). Aerial photography may be flown at other times of the year for planning and location ortho-imagery.

Chapter 4 – Remote Sensing (cont)

All aerial photography shall be taken with a sun elevation angle at a minimum of 30 degrees. The sun elevation angle can be determined with the NOAA solar calculator: <http://www.esrl.noaa.gov/gmd/grad/solcalc/>

The overlap shall be sufficient to provide full stereoscopic coverage as follows: The end-lap (overlap in the line of flight) shall average 60% plus or minus two (2) percent. End-lap of less than 55% or more than 65% in one or more exposures may be cause for rejection of the flight line. Any flight line with an exposure having side-lap (overlap of parallel strips of vertical photography) of less than 20% or more than 40% may be rejected. Side-lap, per strip, shall average 30% plus or minus five (5) percent.

Aerial photography shall be acquired at an altitude above mean terrain based on the accuracy requirement. The departure above or below the required height above mean terrain shall not exceed four (4) percent.

4.1.3 AERIAL IMAGE ACQUISITION

Aerial image acquisition is the process of flight line layout, image acquisition, and image processing for photogrammetry. The AHTD currently utilizes images obtain from large-format film cameras and digital cameras. Currently the AHTD owns and operates a Leica RC30 aerial camera mounted in a Cessna 206 fixed-wing aircraft. All digital imagery is currently acquired by certified surveying consultants.

Photography shall not be taken unless visibility is greater than 10 nautical miles and sustained winds are less than 20 mph. Wind gusts shall not be more than 40 percent of the sustained winds. Photography shall not be accepted when the ground is obscured by snow, haze, fog, smoke, dust, clouds, or cloud shadows. The sun shall be not be obscured by clouds so that objects on the ground cast sharp shadows. Light haze is acceptable.

Tilt (departure of the aerial camera axis from the vertical line at the time of exposure) shall not exceed four (4) degrees for any exposure and shall not exceed five (5) degrees between any two successive exposures. The average tilt for the entire flight line shall not exceed one (1) degree.

Crab, as measured from the line of flight and as indicated by the principal points of consecutive photographs, shall not exceed five (5) degrees between any two consecutive photographs, and shall not average more than three (3) degrees on any one flight line.

The camera(s) used shall be equipped with a gyro-stabilized mount to reduce the amount of tip and tilt and helps eliminate incorrect over-lap percentages.

Photography shall be geo-referenced, using GPS, at the center of each photo negative. Precision of the photo center shall be +/-100 feet. Geo-reference information shall be provided in an ASCII comma delimited format. The information requested is: Roll number, frame number, Latitude, Longitude, Date, and Time (RN, FN, LAT, LONG, DATE, TIME).

4.1.3.1 AERIAL FILM IMAGERY

All aerial film cameras utilized for image acquisition shall have a calibration with a certificate within the last three years by the U. S. Geological Survey Optical Calibration Laboratory. The lens shall have an area weighted average resolution (AWAR) of at least 88 line pairs per millimeter as determined from the USGS Report of Calibration.

A blank frame shall be exposed between each flight line. If 500 foot rolls of film are being used, at or about frame 250 - 290 and at the end of a flight line, five blanks shall be exposed and the roll number advanced by one and the frame counter number reset to frame 1. Flight lines shall be continuous and unbroken throughout their length. All re-flights shall utilize the same camera system as used in the original photography unless the camera system is damaged.

The aerial film camera(s) used shall be of the precision aerial mapping, vertical format type capable of taking 9" x 9" aerial photographs using a 6" focal length. The camera shall have a glass filter with a metallic antivignetting coating. The filter shall be the same filter used for the calibration and report and

Chapter 4 – Remote Sensing (cont)

shall be appropriate for the film used. The camera shall provide for recording of flight data annotation on each film exposure. The information shall consist of the following:

- Camera name
- Camera identification number
- Camera serial number
- A clock
- An exposure counter
- Film speed
- Shutter speed
- f-stop
- Filter factor
- Correction factor
- Selected overlap
- Error code
- Lens cone type, number, and focal length
- Forward Motion Compensation (F. M. C.) will be on
- Roll Number
- Frame Number
- Date of Photography (Date photography accomplished)
- Photo Scale Reciprocal (P. S. R.)
- Job Number
- Pilot and Photographers names (Last names of pilot and photographer)
- Latitude
- Longitude

The aerial film shall be fine-grained, high speed color film capable of producing a negative that can be digitally scanned at fourteen microns. The film shall possess contrast and sharpness adequate to photogrammetrists with the ability to perform accurate design level 3d mapping. The aerial film shall have the minimum requirements that follow:

1. Dimensions:
 - a. Width – 24cm (9.5 in)
 - b. Thickness – 137 microns with the following layers
 - i. 100 micron polyester base
 - ii. 31 micron color layers
 - iii. 6 micron back layer
2. Linear Expansion
 - a. Thermal – 0.0018% per degree of Celsius of change in the range of -20 °C to +50 °C
 - b. Humidity – 0.00247% per 1% relative humidity (RH) of change in the range of 30% RH to 60% RH
3. Speed: 400 ISO or equivalent

Film with an age beyond the expiration date will not be accepted. The film is to be stored and handled in accordance with the manufacturer's recommendations. All aerial film will be spooled, placed in its original container and made "light tight" before delivery. Film will be processed in accordance with the manufacturer's specifications. Exposure of the film shall be such that the negative images will be of high quality with good density and the best possible image resolution. A separate sheet with the following information related to the camera settings is to be sent with each processed roll of film:

- spiral
- overlap
- FMC
- Image motion
- film speed
- pem (auto or manual)
- filter factor

The aerial film shall be scanned at 14 micron resolution or finer using a Z/I Imaging 2000 or equivalent calibrated photogrammetric scanner to produce digital image files. Prior to ortho-photo correction, the scanned images shall be checked on a workstation for completeness, cleanliness, and image quality.

Chapter 4 – Remote Sensing (cont)

4.1.3.2 AERIAL DIGITAL IMAGERY

The photogrammetrist or surveyor may utilize a Large or Medium format Aerial Digital Camera in lieu of a Film camera with approval from the AHTD. The digital camera shall produce aerial imagery equivalent to the Leica RC30 or better. The Flying Altitude shall be such that mapping can be provided at a same accuracy, or better than the accuracy provided by using a Leica RC30 camera.

All Aerial Digital Cameras utilized shall maintain calibrations with certificates from the vendors within the past 3 years.

4.1.4 ANALYTICAL AERO-TRIANGULATION (AT)

Full analytical aero-triangulation is necessary to extend control throughout project photography for digital mapping. Selection of photogrammetric points for control extension will be performed with strict adherence to rigid geometric and photogrammetric principles. Measurements will be made utilizing Intergraph ISAT (Image Station Automatic Triangulation) V6.0 or later software.

Following data analysis and refinement, the photogrammetrist shall perform a simultaneous least square block adjustment of all measurements to obtain the final results. The block adjustment combines the mathematical constraints of the co-linearity equations with rigorous statistical analysis to ensure accurate results.

Interior orientation is performed whereby calibrated image fiducial marks are measured to establish a photo coordinate system.

Exterior orientation is performed, whereby coordinates and angles representing camera position and altitude (exterior orientation) are determined by aero-triangulation. The exterior orientation facilitates transforming the photo coordinates to mapping ground coordinates.

4.1.5 DESIGN LEVEL MAPPING

Photogrammetric digital data shall be collected and compiled in a method such that the horizontal and vertical accuracies are met in the above standards for Design Level Mapping. AHTD provided cell libraries (CEL), level libraries (DGN), and seed files shall be utilized throughout the process.

The planimetric feature collection and digital terrain model (DTM) collection shall utilize stereo compilation methods. Stereo compilation shall be performed using Intergraph Image Station Stereo Display (ISSD) software or equivalent software. All stereo-compiled data will be collected directly from stereo plotters and/or workstations. Collection of planimetric features from ortho-rectified images will not be accepted.

AHTD utilizes the Bentley Microstation CADD platform for photogrammetry mapping. The planimetric features shall be placed in the "Topo" model. The DTM features shall be placed in the "DTM" model. All features, planimetric and DTM, shall be placed at their true elevation.

The following features shall be collected, drawn, and labeled in the CADD file as a minimum for Design Level mapping.

- Buildings
- Roads
- Railroads
- Ditchlines
- Bridges
- Culverts
- Fences
- Driveways
- Utility Poles
- Sidewalks
- Trees
- Fire Hydrants
- Manholes
- Catch Basins
- Walls
- Retaining Walls
- Parking
- Patios
- Decks
- Tanks
- Ruins
- Swimming Pools
- Cattle-Guard
- Gate
- Cemetery
- Concrete Pads
- Billboard
- Traffic Light
- Brush Piles
- Paved Drains
- Ponds
- Swamps
- Open Storage
- Gardens
- Cultivated Fields

DTM will be developed using breakline profile method. Profile distances will be based on the elevation differential and complexity of terrain. Data points along the profiles are collected as the photogrammetrist maintains a consistent reference to the ground surface. The points are collected as the delta elevation changes by a pre-specified amount, usually equivalent to the particular mapping scale, or at a distance equal to predetermined grid spacing.

DTM data will be collected in a manner that will accurately depict the terrain and will meet or exceed specified accuracy requirements. Random points shall not be collected, only breaklines and closed obscure area lines. Breaklines shall not be extended through any obscure areas. Breaklines will be collected provided the ground can be seen along a sufficient number of points on the breakline so that the photogrammetrist is confident that no grade breaks are missed along the breakline.

4.1.6 ORTHO-RECTIFIED IMAGES

Ortho-rectified images provide a background reference to mapping and design CADD data. The image files shall have a pixel resolution based on the mapping level. All images shall have tiled overviews and be geographically referenced to the project datum. The image format shall be compatible with use in Bentley Microstation CADD platform.

Differential rectification is performed using an algorithm (that utilizes an elevation model in conjunction with the exterior orientation to correct displacement of ground features) to resample the image producing a geo-referenced orthophoto. Existing government digital elevation model (DEM) and photogrammetrically collected DTM data shall be utilized for the orthophoto rectifications.

4.2 LIDAR

Laser scanning or Light Detection and Ranging (LiDAR) systems use lasers to make measurements from a tripod or other stationary mount, a mobile surface vehicle, or an aircraft. The term LiDAR is sometimes used interchangeably with laser scanning. The AHTD utilizes these technologies to map ground features, measure horizontal and vertical clearances.

4.2.1 TERRESTRIAL (STATIC) LIDAR

Terrestrial LiDAR utilizes a stationary or tripod mounted laser scanning sensor to collect data. Since a laser scanner is capable of scanning features over long distances, and since the accuracy of the scan data diminishes beyond a certain distance, care should be taken to ensure that the final dataset does not include any portion of point cloud data whose accuracy is compromised by measurements outside the useful range of the scanner. The range for laser scanning shall be limited to 200' from the sensor.

Scanning targets are placed over known control points to assist the Laser Scanner to establish the position of the point cloud. When the scanner is set-up over a known control point, a minimum of two (2) other targets set at a maximum distance of 400' from the scanner shall be utilized to provide orientation and redundancy. If the Laser Scanner is not set-up over a known control point, the Laser Scanner will have to compute its position by resection methods. A minimum of three (3) targets shall be utilized with four (4) as the preferred minimum.

LiDAR data collection shall be conducted in such a manner as to ensure redundancy of the data through overlapping scans. The data should be collected so that there is a 5% to 15% overlap (percentage of scan distance) from one scan to the next adjacent scan. The scan point density shall be of 0.10' or less at a distance of 125' from the scanner.

Chapter 4 – Remote Sensing (cont)

4.2.2 MOBILE LiDAR

Mobile LiDAR is a technology that uses laser scanner technology in combination with Global Navigation Satellite Systems (GNSS) and other sensors to produce accurate and precise geospatial data from a moving vehicle. The LiDAR sensor collects laser measurement data continuously throughout each run. The position and orientation of the scanner(s) are determined using a combination of data from GNSS, an inertial measurement unit (IMU), and possibly other sensors, such as precise odometers.

Due to the vertical accuracy limitations of GNSS/GPS, additional control points (local transformation points) within the scan area are required to calibrate the point cloud data to known elevation points. The point cloud is adjusted by a local transformation to well defined points throughout the project area to produce the final geospatial values. The procedures in [Control Surveys](#) (Chapter 2) shall be utilized to establish these elevation points.

LiDAR data collection shall be conducted in such a manner to ensure redundancy of the data through overlapping scans. The data should be collected so that there is a 5% to 15% overlap (percentage of scan distance) from one scan to the next adjacent scan. The scan point density shall be a minimum of 100 points/square meter in areas along the highway pavement.

The surveyor shall utilize High Precision Static GPS stations with project control elevations during the Mobile LiDAR data collection mission. The control stations will be provided by the AHTD.

Ground truthing or check shots shall be collected to validate LiDAR data. The surveyor shall measure and records breaklines and spot measurements to assist with data validation.

4.2.3 AIRBORNE LiDAR

Airborne LiDAR is a technology that uses laser scanner technology in combination with Global Navigation Satellite Systems (GNSS) and other sensors to produce accurate and precise geospatial data from a fixed-wing aircraft or helicopter. The LiDAR sensor collects laser measurement data continuously throughout each mission. The position and orientation of the scanner(s) are determined using a combination of data from GNSS, an inertial measurement unit (IMU), and possibly other sensors, such as precise odometers.

Due to the vertical accuracy limitations of GNSS/GPS, additional control points within the scan area are required to calibrate the point cloud data to known elevation points. The point cloud is adjusted by a local transformation to well defined points throughout the project area to produce the final geospatial values. The procedures in [Control Surveys](#) (Chapter 2) shall be utilized to establish these elevation points.

LiDAR data collection shall be conducted in such a manner as to ensure redundancy of the data through overlapping scans. The data should be collected so that there is a 5% to 15% overlap (percentage of scan distance) from one scan to the next adjacent scan. The scan point density shall be a minimum of 40 points/square meter in areas along the highway pavement.

The surveyor shall utilize High Precision Static GPS stations with project control elevations during the Airborne LiDAR data collection mission. The control stations will be provided by the AHTD.

Ground truthing or check shots shall be collected to validate LiDAR data. The surveyor shall measure and records breaklines and spot measurements to assist with data validation.

4.2.4 LiDAR POINT CLOUD PROCESSING, CLASSIFICATION, AND DELIVERABLE

The orthometric heights (elevations) shall be derived from the project control orthometric heights. The surveyor shall utilize a geoid model that best matches the project control that is derived from 3-wire leveling techniques. The most current geoid model published by the National Geodetic Survey agency may not be the appropriate model.

Chapter 4 – Remote Sensing (cont)

The point cloud shall be transformed to the project datum and zone. This datum will be based on the Arkansas State Plane, North America Datum 1983. No transformation to HPGN/HARN or other NGS datum adjustments will be necessary.

The LiDAR data set (point cloud) shall be classified into the following classes at a minimum: Unclassified, Ground, Vegetation, Pavement, and Bridges. Traffic noise, spurious points, and sun spires shall be removed from point cloud.

Utilizing the ground truthing or checkshots, the Consultant shall provide a report indicating the horizontal and vertical accuracy of the LiDAR data set according to procedures established by the National Standard for Spatial Data Accuracy (NSSDA).

The deliverable shall be a cleaned, classified, and tiled point cloud in LAS format. A tile index shall be included in Microstation DGN format. Deliverables may be provided by FTP, external hard drive, or DVD.

4.2.5 LIDAR FEATURE EXTRACTION

LiDAR Feature Extraction is the process of creating DTM breaklines and topographic features from the LiDAR point cloud inside of the CADD environment. TopoDOT™ software is used by the AHTD to perform this work. This data will be utilized in conjunction with photogrammetric and traditional field survey data in developing a digital terrain model and topographic models.

The features extracted are based on the type of corridor and shall be furnished to the AHTD as follows:

- Data furnished as a Microstation DGN file.
- Line work and point features shall be provided in the appropriate DGN model corresponding with the topographic feature or DTM feature.

Feature codes, levels, and line work shall be consistent with current Surveys Division Microstation preference files. The table below indicates the Microstation levels corresponding to selected roadway features. This table is not comprehensive, for features modeled that are not included in the table below, refer to current Surveys Division feature table and Microstation preference files.

FEATURE	MICROSTATION LEVEL	COLOR	LINE STYLE	WEIGHT
BREAKLINE (PBL)	S_LIDAR_BREAKLINE	4	0	1
BRIDGE DECK (BR)	S_BRIDGE	3	0	1
CROWN (CR)	S_PAVEMENT_CROWN	3	0	2
CURB (CB)	S_CURB	7	0	1
DRIVEWAY (DW)	S_DRIVEWAY	0	4	0
EDGE PAVEMENT (EP)	S_EDGE_PAVEMENT	0	0	2
ROADWAY POINT (XS)	S_RDWY_PT_SYM	0	0	0
SHOULDER (SH)	S_SHOULDER	0	3	1
SIDWALK (SW)	S_SIDEWALK	0	0	1
WALL (WL)	S_WALL	3	0	1

Chapter 4 – Remote Sensing (cont)

4.2.6 EXTRACTED FEATURES BY CORRIDOR TYPE

The sections that follow indicate the minimum data to be extracted based on corridor type.

Interstate Corridors

- Extract roadway surface breaklines including edge of pavement (EP), shoulder (SH), and crown (CR) (if applicable). For modeling purposes, the edge of pavement is considered the striped outside line in most cases. The edge of pavement shall be one continuous line string throughout the limits of main lanes modeled. Maintain continuity of the edge of pavement along outside main lane through ramps at interchanges.
- Transverse roadway breaklines (PBL) created using key points at 0.02' tolerance at fifteen feet step intervals.
- Extract concrete barrier walls (WL), with breaklines for the base of wall and top of wall.
- Extract the bridge decks (BR).

Urban Corridors

- Extract roadway surface breaklines including back of curb (CB), face of curb (BL), gutterline (BL), edge of pavement (EP), and crown (CR). At side road intersections, extract data through curb return radius.
- Transverse roadway breaklines (PBL) created using key points at 0.02' tolerance at ten feet step intervals.
- Extract sidewalks (SW) adjacent to roadway.
- Extract bridge decks (BR).
- Extract driveways (DW) adjacent to roadway.
-

4.3 SONAR

Sound Navigation and Ranging (SoNAR) is a technology that uses sound waves to detect and locate objects under the surface of the water. AHTD utilizes Single-Beam and Multi-Beam echo-sounders to perform Hydrographic Surveys. This consists of mapping underwater topographic and terrain features.

4.3.1 SINGLE BEAM SURVEYS

The AHTD uses a Sonarmite™ single beam echosounder to measure the depth of the water above the ground surface. The Sonarmite system is set-up to communicate with via a Bluetooth NMEA data string with RTK surveying systems or Robotic Total Stations. The RTK system or Total Stations are use for X,Y, & Z positioning of the Sonarmite system

4.3.2 MULTI-BEAM SURVEYS

Multi-beam surveys utilizes a multi-beam echo sounder, motion sensors, sound velocity profilers, GPS heading and positioning systems to collect soundings and underwater features up to 512 beams simultaneous.

5 LAND SURVEYS

AHTD Surveys Division perform Land Surveys to retrace the existing highway Rights of Way, adjoining real property boundaries, and Public Land Survey System (PLSS) lines for the purpose of acquiring additional Highway Rights of Way on proposed roadway, bridge, and transportation construction projects.

5.1 GENERAL REQUIREMENTS

The level of Land Surveys required will depend on the type of project as determined by the Division Head of Surveys. Per AHTD policy, any construction project located on routes that are classified as an Arterial or Interstate will require the proposed Rights of Way be purchased in Fee. These surveys are considered a boundary surveys and are subject to the Arkansas Annotated Code ~17-48-100 and the Arkansas Standards of Practice for Property Boundary Surveys and Plats.(See the below section on Parcel Surveys).

Construction projects located on routes classified as a Collector normally have the proposed Rights of Way purchased as a Court Order easement. When ROW is purchased as an easement, measurements to PLSS corner monuments and the existing ROW is required.

No project done by the AHTD is based on TRUE Bearings. The "Basis of Bearings" shall be one of the following:

- Bearings are Grid based on GPS
- Bearings are Grid based on Solar Observation
- Bearings are Grid based on Assumed Bearing
- Bearings are Grid based on Job #####.

The appropriate basis of bearings shall be placed on each parcel sheet. Do not use Azimuths on parcel surveys or land monument measurements.

5.2 FIELD PROCEDURES

All crews should be able to recognize obvious, apparent, or probable land corner monuments by referring to their positions on quad maps, county maps, aerial photos, or other available information. Measurements are to be made to all obvious land corners and property corner monuments encountered by any survey crews. All visible front property corners shall be measured and recorded by the survey crew.

During the field reconnaissance phase, the surveyor shall make every reasonable effort to follow in the footsteps of the original surveyor. This requires the surveyor to walk and measure (tape measure or pacing) along the PLSS lines, property boundary lines, and ROW lines to observe and record evidence of the original surveyor, possible encroachments, and other information that may assist with determining the property boundaries.

Land corner monuments, to include PLSS, property, and ROW monuments, shall be measured and recorded utilizing the AHTD SDMS collector. SDMS sequences shall be used to assist with the proper feature coding and attribution. In general, most land corner monuments will be recorded with the feature code (FE:) IP. These monuments shall be measured and recorded with one (1) set of two (2) angles, one (1) direct and one (1) inverted.

All monuments that are located, measured, and recorded shall have adequate descriptive information to clearly identify the monument. The monument type, dimensions, material, and markings are essential information that shall be recorded. Example monument type and materials are rebar, iron rod, square iron rod, iron pipe, axle, railroad rail, railroad spike, railroad splice bar, grader blade, pine knot, rich pine stake, cotton picker spindle, stone, concrete monument, or other. The monument dimension shall be recorded in inches.

Chapter 5 – Land Surveys (cont.)

Monuments that have a survey cap affixed shall have the material, size, color, Professional Surveyor number, and other markings recorded in the data file.

In the event that monuments are located a significant distance from the project baseline control, the surveyor may request to utilize GPS procedures to measure the position. Utilizing GPS procedures for measuring land monument positions shall be approved by the Surveys Division Staff Land Surveyor, Assistant Division Head, or Division Head prior to beginning work. GPS positioning requirements for land monuments are the same as primary control points as outlined in the [Control Surveys](#) (Chapter 2) of this manual.

5.3 PLSS & LAND MONUMENTS

The Public Land Surveying System is the framework for all property boundaries and land surveying in the state of Arkansas. Measurements and connection to the PLSS is required for all projects that require additional ROW. This includes projects with Court Order Easements and Parcels purchased in Fee.

Land monuments are necessary for obtaining highway rights of way. On projects less than one mile in length, a minimum of two land monuments will be required. On longer projects, at least one land monument per mile shall be measured and recorded.

When locating the land lines, it should be remembered that a measurement to only one point on that line does not establish its bearing. Therefore, one point on a line is of little value. One monument on a line should be made only when no other corner monuments, accessories, or references can be found. The AHTD Land Surveys staff shall be consulted if only one monument is available.

In locating land lines and corners, accept division fences as correct only when the owners of each side of the line agree that the fence does in fact mark the land line, and if it checks reasonably well with the survey as shown on the PLSS Township Plat. These plats, when needed, are available at the Surveys Division office. Quadrangle sheets that show the relative location of section corners and lines are also available.

In addition to the obvious land corner and property corner monuments, measurements should be made to other physical monuments which are apparently at property corners or land corners. Measurements should be made to all visible monuments, fences, roads, etc., and described adequately to locate 1/16, 1/4, and section lines and at least apparent corners that are within the project limits.

In the absence of obvious land corner monuments, the following may be physical evidence of land corners and/or property corners and shall be measured and recorded.

- Fence corners at apparent section, 1/4 section and 1/16 section corners.
- Roads intersections at apparent section, 1/4 section and 1/16 section corners.
- Tree lines cornering at apparent section, 1/4 section and 1/16 section corners.
- Fence lines or tree lines along apparent section, 1/4 section and 1/16 section lines that would intersect or cross the highway, if extended.

5.4 EXISTING HIGHWAY ROW

Right of Way monuments on many state highways can be scarce, nonexistent, or incorrectly set. They may have been destroyed over the years by many causes. And, they may have been incorrectly set due to blunders, techniques, and in years past (especially concrete monuments) set by the construction contractor. The information that follows can be an aid in making decisions on the best way to establish highway right of way.

- The AHTD has used a number of different monument types and the markings vary based on what a monument is set to represent.
 - Concrete monuments are normally 5" x 5".
 - Starting around 1980, rebar and aluminum caps have been set.

Chapter 5 – Land Surveys (cont.)

- The older versions of these monuments (3/4" rebar with 1 1/2" aluminum caps) will be stamped with either "AHTD R/W" or "AHTD BDY" and other information. Old caps should have the number of the PS that set that cap if not set by AHTD personnel.
- Newer monuments will be 5/8" rebar with 2" aluminum caps and the stamping may be similar to the stamping on the older caps. New caps (including those set by the Surveys Division, AHTD) will include the PS number of the Surveyor who was in responsible charge.
- Monument witness post/sign
 - Orange Triangle – Will be found **in front of or behind** the monument
 - Yellow Rectangle – Is set in front of (highway centerline side) of the monument
- Due to the lack of right of way monuments or accurately set monuments in an area, it is recommended the centerline stationing be used to aid in establishing the right of way. Structures (bridges and cross drains) on the interstate highways are generally built very close to the plan location. Therefore, it is also recommended the structures indicated on the layouts be located and used to verify centerline stationing.
- The bridge end stationing on the plan and profile sheets and the bridge plans is defined as the back face of the end bent back wall. The bridge end point may be indicated by a center punch mark in the steel angle.
- The distance between structures (when three or more are tied) will also be an indicator of the linear measurement error that can be expected in that area of the project. The right of way monument set on the project would have been set by the plus and out from centerline. Therefore, this will also aid in determining whether the distance along the right of way is shorter or longer than the plan distances.
- Many highways have been constructed with spiraled curves. The Right of Way was intended to be based on the original circular curve not the spiraled curve. Therefore, the centerline of the pavement within the area of the spiraled curve may not necessarily be used to establish the right of way. The original curve (defined in the Court Order) normally will be used to establish the Right of Way.

The existing ROW monuments may have been set based on the constructed centerline (along the spirals) instead of the centerline of ROW. Based on acquiescence, it may be necessary to yield to the monuments as set.

- Court Ordered Right of Way - What should be used to establish the right of way – The Court Ordered centerline description or existing monuments? Due to the inherent errors in both the original survey and in the placement of the monuments during construction, there is no absolute answer.

The centerline of the road as built will normally follow the original survey and can indicate where measurement errors (both systematic errors and blunders) exist. This can aid in determining where errors in the Court Order description may exist. But, there may have been changes made during construction that did not get updated in the Court Order. In that case it will have to be determined by the AHTD whether the Court Order should be held or whether corrections will need to be made to correct the record.

In all cases it will be required to establish a significant amount of the centerline in the area of the survey to be able to determine whether the road indicates the "center" of the right of way or meanders within the right of way.

- Rebar and caps set by the AHTD will normally be checked from two or more control points and should be within specified tolerance. But, on occasion, errors have been found in the control used after the fact and the monuments are not in the correct location, but are in harmony with each other and may appear to be correctly set. Therefore, multiple monuments

Chapter 5 – Land Surveys (cont.)

on both sides of the roadway should be tied and used in the analysis to determine whether blunders may have been made when the monuments were originally set.

- Right of Way monuments have been disturbed and reset by property owner, utility companies, etc. The monuments are normally reset by “eye” and may or may not be at or near the original location. Therefore, it is best not to yield to a monument just because it exists. It is also difficult to say what a reasonable error is. Therefore, it is recommended Surveys Division be contacted for advice when these situations are encountered.

5.5 PARCEL SURVEYS

Parcel Surveys are normally only performed on projects that are located on routes classified as arterials or in an urbanized area. Areas are considered “Urban” where the property boundaries are in close proximity to each other as in a subdivision. Parcel Surveys may be required for other projects as designated by the Division Head of Surveys.

All parcel surveys shall be conducted under direct supervision of a Professional Surveyor (PS) currently licensed in the State of Arkansas. This shall be for surveys performed by the AHTD or certified consultants. All parcel surveys shall be in accordance to the Arkansas Standards of Practice for Property Boundary Surveys and Plats.

5.5.1 TITLE RESEARCH

Title research or Title Abstracting is the process of finding the property deeds, easement, or any other legal documents related to real property. The AHTD needs this information to ensure clear title can be obtained when purchasing property for ROW purposes.

During this process, the research technician or surveyor is required to research and make copies of the current owner’s deed; all available survey plats; and subdivision maps. The research technician or surveyor is required to compile the data and prepare a book of the Certificates of Title and a strip map of plotted deeds along the project corridor.

5.5.1.1 CERTIFICATES OF TITLE

A Certificate of Title shall be furnished for each parcel of land fronting or touching each side of the highway along the length of the project. A copy of the record property description of any contiguous lands owned by the person or persons listed in the certificates of title shall also be furnished.

Each certificate will be for the current ownership as of the date of the certificate of title shall contain the following data:

- AHTD Job Number;
- AHTD Job Name, Review Date;
- County,
- Grantee(s) Name and Address;
- Parcel (tax) ID;
- Land Value;
- Improvements Value;
- Area (acres);
- Type of Instrument;
- Date of Instrument;
- Date Filed;
- Record Book and Page and/or Instrument Number;
- Grantor(s) name(s)
- The Record Description per the deed.
- A Certificate Number shall be assigned and shall be displayed in the lower right hand corner of each certificate.

Certificate numbers shall be grouped together for all parcels within each land section and within each subdivision involved. The certificates with corresponding deeds are to be numbered and indexed by number and the owner's name. The certificates are to be furnished in booklet form with the index at the front of each booklet. The name, address, and telephone number of the firm that obtains the deed is to be on the index as well as on each certificate.

Chapter 5 – Land Surveys (cont.)

5.5.1.2 DEEDS

An actual legible copy of each deed, (either photo copied or scanned), including acknowledgments, stamps, and recording data is to be furnished for each parcel and contiguous lands.

5.5.1.3 SURVEY PLATS

Where deeds refer to surveys by a surveyor, a complete and legible copy (border to border) of the surveyor's plat is to be furnished. All other related surveys that come to light during the course of research are also to be furnished.

5.5.1.4 SUBDIVISION PLATS

Where parcels are deeded per subdivision plats of record or where deeds make reference to subdivision or survey plats, recorded or unrecorded, complete and legible copies (border to border) of said subdivision or survey plats are to be furnished, along with any accompanying bills of assurance. All other related subdivision plats that come to light during the course of research are also to be furnished.

5.5.1.5 STRIP MAP

The strip map is to show the approximate location of the highway project, as well as all intersecting streets, roads and highways, including their names and/or numbers. The relative location of the parcels with their certificate numbers is to be shown. Where the parcels are described by metes and bounds, their relationship is to be shown within sixteenth sections, section, township and range. Where the parcels are described within subdivisions, either recorded or unrecorded, their relationship within the subdivision is to be shown. This includes certificate numbers, lot and block numbers, street names, and subdivision names. The approximate boundaries of subdivisions are to be delineated on the strip map. The strip map is to be plotted at a scale large enough to show deed calls.

5.5.2 PARCEL COMPUTATIONS & WORKSHEETS

The parcel computations and worksheet drawings are the deliverable products from the surveyor to the AHTD. These drawings shall be created and compiled to represent a professional product. The normal process for computations and worksheets includes PLSS sectional breakdown, establish the existing ROW, calculating property boundaries adjacent to the highway, and preparing drawings and notes.

It should be noted that the surveyor needs to be mindful of the entire project and the interaction of each piece. As an example, it is often necessary to compute individual property boundaries before the PLSS or ROW can be resolved.

During this process, the surveyor shall prepare all drawings, maps and plats using the Bentley Systems, Inc., Microstation and Inroads, Version 8.11 (V8i) or higher. The cell library, seed files, feature table, and preference tables furnished by the Department shall be used. The drawings shall be in the DGN format and the Geometry Database shall be in the ALG format.

Coordinate geometry (cogo) commands shall be utilized to compute geometry points and elements. CADD graphical intersections shall not be used for final position calculations. Points shall be computed at the intersection of ROW lines and property lines, ROW lines and PLSS lines, and property lines and PLSS lines in addition to boundary corners.

During the process of evaluating and calculating land corner positions and boundaries, the surveyor may compute positions of points that are within the positional tolerance of the measurements of the field located monuments. In the event that a calculated point is close to a found and accepted monument, the surveyor shall re-name the calculated point to the same name as the field located monument with a suffix of A. This re-named point shall have all the attributes and descriptions from the monument be made part of the re-named calculated point.

Chapter 5 – Land Surveys (cont.)

An example would be the calculated position of the existing ROW point name 2005 that is 0.1 foot from an existing concrete R/W monument named 206. Point 2005 would be renamed to 206A. All the attributes, feature codes, and descriptions would be transferred from point 206 to 206A. Point 206 would be removed from the geometry database. Point 206A would retain the position from the COGO computations.

Professional judgment will have to be used to determine the distance tolerance to utilize this procedure. It is the intent of the AHTD to accept local survey monuments, when the survey monuments do in fact represent the boundary corner. This procedure should minimize calculated points being used instead of field monuments that are not exactly on a boundary line.

5.5.2.1 PLSS SECTIONAL SUBDIVISION

As noted in the sections above, the Public Land Survey System (PLSS) is the framework for all properties in the state of Arkansas. When Parcel Surveys are required for a project, measuring and computing the locations of PLSS corners and lines are required as a minimum for each 1/16th Section (1/4 of 1/4 Section or 40 acre tract). It is often required to survey several sections or possibly multiple townships.

The *Manual of Surveying Instructions*, 2009 Edition, U.S. Department of Interior BLM; the *Handbook for Arkansas Land Surveys*, 2nd Edition, 1981; and *The US Public Land Survey System for Arkansas* by Dr. Elgin and Dr. Knowles shall be used as guidelines for surveying lines and corners in the PLSS. All corners, found monuments and computed points, shall be designated as defined in these manuals and shall have complete descriptions.

Measurements shall be made to corners, monuments, corner accessories and other relevant witness information which control the location of said 1/16 section lines and corners; the surveyor's basis of acceptance and/or computations thereof, and the originating source of found monument. If a local monument is rejected for a PLSS corner, the reason for rejection and other notes shall be in the Parcel Worksheet drawings and the monumentation final survey plats.

A digital photograph may be taken of monuments with PLSS designated markings, or other pertinent markings to assist with the decision making process.

In the Parcel Worksheet phase of the project, a separate drawing is normally prepared for PLSS section subdivision. This drawing is the place to make notes concerning decisions made on PLSS corners and lines. This drawing normally will consist of all PLSS monuments and calculated corners with descriptions; PLSS lines annotated with GLO record dimension and measured distances; any notes relevant to the PLSS; and approx. centerline of highway project for reference. All PLSS Townships, Sections, 1/16th Section, and Lots shall be clearly labeled and identifiable.

Use the following abbreviations to describe PLSS corners:

- QC - Quarter Corner
- SC - Section Corner
- TC - Sixteenth Corner

The parcel worksheet designated as the section subdivision (section breakdown) shall be submitted separate from the parcel worksheets. Section subdivision shall be by 1/16 Section. The scale used is determined by the amount of information required to justify and explain the methods and results being submitted. The scale shall be a standard Engineering Scale.

5.5.2.2 EXISTING ROW

The existing Right of Way can often be the most difficult boundary to be determined. This is true for highways, railroads, utilities, and county and city roads. ROW and Construction plans along with the Court Order shall be reviewed in the process. Under normal circumstances, the Court Order or Deeds will govern over maps/plats.

For AHTD highway ROW, the surveyor shall use the RE feature code. The original point maybe a found monument (IP) or a calculated point (LC). The existing centerline of ROW shall be calculated and annotated with the EA feature codes. The existing ROW shall be calculated and annotated with the RE

Chapter 5 – Land Surveys (cont.)

feature code. The ROW lines shall utilize a continuous figure or chain through the corridor, except where the ROW breaks. All alignment points shall be stored as coordinate geometry points.

5.5.2.3 PARCEL BOUNDARIES

Point numbers shall be assigned to each point measured or computed. Computed points shall use the LC feature code for graphics and the point number range as described in [General Requirements](#) (Chapter 1) of this manual. All parcel tracts shall be stored as closed polygon alignment chains. All computed points not used in the final product shall be deleted from the data base.

During the calculation of parcel boundaries, the surveyor may identify areas of overlaps and gaps. The surveyor shall identify these areas. Additional title research may be required to resolve these areas. The surveyor shall make reasonable efforts to resolve the gaps and overlaps if possible. The surveyor shall make notes and provide an opinion on possible resolutions, if they exist.

5.5.2.4 WORKSHEETS

The CADD graphics and hard copy sheets shall be set up and submitted as 11" x 17" size sheets. The text shall be of a sufficient font (size) that it is legible on an 8.5" x 11" sheet when reduced on a copier. All sheets scales shall be standard Engineering scales. Each sheet may display as many ownership certificates as practical based on the scale used. The scale used is determined by the amount of information required to justify and explain the methods and results being submitted. Enlarged detailed sketches should be included on sheets with congested areas.

The worksheets shall consist of the following as a minimum:

- The existing right of way centerline and right of way lines noted, annotated and described.
- The construction centerline if furnished by the Owner.
- Property lines, with bearings and distances, and platted additions or subdivisions with lot and block numbers.
- Description of land corners and property corners located and other physical evidence of land lines; the basis of acceptance and/or computations thereof; and, the originating source of any found monument.
- Easements of record shall be shown on the plat.
- All gaps and overlaps found shall be clearly identified. An explanation for the gaps and overlaps shall be included in the surveyor's notes
- Basis of bearings and coordinates.
- Surveyor's notes, text notes, and any legal descriptions displayed on the worksheet and/or plat shall be part of the Microstation DGN file.
- Highways, roads, and streets should be described by name and/or number.
- Topographic survey data shall be in a referenced DGN file.
- All pertinent graphical data shall be part of the DGN file being submitted, to include project data, text, and sheet borders.

Parcel work sheets shall be submitted for review and approval at the following phases of development:

- Phase I - Preliminary Subdivision of Section Subdivision, with surveyor's notes.
- Phase II - Determination of any existing Rights of Way, including pertinent surveyor's notes.
- Phase III - Any conflicts in ownership encountered (Gaps, overlaps, etc.).
- Phase IV - Preliminary parcel sheets

6 ROW MONUMENTING

Right of Way monumenting is the process of placing markers, temporary or permanent, at the angle points of proposed or acquired Right of Way boundary. Close coordination will be needed with the AHTD ROW Division's Engineering, Appraisal, and Utility Sections and the Construction Resident Engineer overseeing the project during the ROW staking and monumenting processes.

6.1 ROW STAKING FOR APPRAISALS & UTILITIES

ROW staking during the Preliminary Engineering (pre-construction) phase is normally performed for ROW appraisals and negotiations. Utility relocations may require ROW staking.

ROW plans and geometry databases are developed by the ROW Engineering Section. These plans and geometry points shall be utilized to create files compatible with the AHTD datacollection software. The points and lines that are staked shall utilize the geometry points and lines from the ROW database. The construction centerline should be used as reference to stationing and offsets.

For appraisal and utility purposes, Right of way flags, which are the solid pink flags with the AHTD logo and "Proposed Right Of Way" stamped on them, shall be set within 0.3ft accuracy. For locating the position of any new fencing to be constructed, a 20D nail adjacent to a right of way flag shall be set within 0.2ft accuracy. The 20D nail cannot be used for monumenting or any control work. A total station or RTK system may be utilized to locate the points. The most efficient tool should be utilized based on the terrain and site conditions.

The ROW flags shall have the following written on the back of the flag:

- Complete Station (i.e. 100+18.52)
- Offset with Left or Right designations (i.e. 50L)
- Point Number (i.e. PN:3005)

6.2 PERMANENT ROW MONUMENTING

The Arkansas Highway and Transportation Department is required to comply with the Arkansas Minimum Standards for Property Boundary surveys and plats. Therefore, all property purchased by AHTD must be monumented with permanent markers, as shown on the Right of Way Plans and final plats.

AHTD property monuments may be used as control during the construction phase of a project to facilitate the reestablishment of highway centerlines and rights of way. The monuments will also aid AHTD in resolving legal claims involving highway rights of way. Therefore, these monuments shall be set as accurately as possible.

Prior to beginning work, refer to [General Requirements](#) (Chapter 1), for required notifications and checklist information. Arkansas One Call (800) 482-8998 or 811 shall be contacted to locate and mark underground utilities within the project limits and where any control or ROW monuments will be established.

Due to the nature of highway construction, a secondary control baseline shall be established outside the construction limits prior to the start of construction. This secondary control baseline shall be established at the same horizontal quality and positional accuracy of the primary control baseline.

Permanent property boundary monument, witness posts and identification tags shall be set at all property corners, ROW boundary line angle points, intersecting property lines and intersecting land lines of property purchased in fee and based on land surveys certified by the Engineer of Surveys or a certified licensed Professional Surveyor under contract with the Department. **The monuments shall be set by AHTD personnel under the direct supervision of the Engineer of Surveys or by a certified licensed Professional Surveyor (PS) under contract with the Department.**

Chapter 6 – ROW Monumenting (cont.)

The permanent monument shall consist of a five-eighths (5/8) inch reinforcing bar (rebar) a minimum of twenty-four (24) inches in length with a two (2) inch minimum diameter aluminum alloy cap affixed to its top and stamped with the appropriate markings. The witness post will consist of a four to six foot section of signpost driven in front of the monument with a yellow, metal, square boundary marker sign mounted to the post. Property boundary monumenting and referencing shall be scheduled coordinated with the Resident Engineer responsible for the construction of the project. The coordination shall begin prior to construction of the project.

6.2.1 LOCATION OF MONUMENTS

Monuments shall be set:

- At all AHTD property boundary points.
- On tangent lines, at approximate intervals of 500 feet.
- As witness monuments when the property boundary angle point cannot be set due to an obstruction (stream, large tree, boulder, etc.). One point shall be set on each line leading to the angle point. If the obstruction will be removed during the construction phase of the project, set and reference a temporary witness corner. The permanent monument will be set upon completion of the construction project.
- At the intersection of proven land lines and property lines.
- On the angle points of permanent construction easements.

If the property boundary point falls within a temporary construction easement, a monument shall not be set until completion of construction work in this area. If the property boundary points fall in a water body, then a monument shall be along the boundary line outside the limits of the water as a reference monument.

6.2.2 MONUMENT INSTALLATION

The procedures that follow shall be used to install monuments after the right of way has been purchased.

1. The cap shall be driven flush with or slightly below ground level. In cultivated areas the monument should be at least six (6) inches below the ground surface. Adjust the monument as necessary so the proposed point falls at or near the center of the cap.
2. If the point falls on solid rock or on a concrete slab that cannot be penetrated with a rebar, a star drill or hammer drill and bit may be used to drill a hole of sufficient diameter and depth to install the cap. The cap shall be secured using epoxy.
3. The cap shall be stamped with the appropriate markings after the monument cap is driven flush with or below ground level.
4. A center punch shall be used to mark the exact location property boundary point on the cap.
5. Drive the proper length of witness post approximately six (6) inches to twelve (12) inches in front of the monument leaving approximately two and one half (2 ½) to three (3) feet of the post above ground. An aluminum yellow boundary sign shall be attached to the signpost.

The information that follows shall be placed on the back of the property boundary sign for each point.

- JOB NUMBER
- **PN** (Point Number) assigned for this project
- **STA/OFF** (Station and Offset, Left or Right), if applicable

The information can be printed on the sign using a paint pen (oil or mineral based - The UNI PAINT MARKER, PX-20 (Black) by FaberCastell® is recommended) or stamped using metal stencils.

Note: Witness posts shall not be set in open areas such as residential or business yards, parks, etc. Witness posts can be set at fences, open fields, and in wooded lots, including urban areas.

Chapter 6 – ROW Monumenting (cont.)

6.2.3 MONUMENT CAP MARKINGS

The monument cap shall be marked using 3/16-inch die stamp letters. The imprints made in the cap surface shall be of sufficient depth to remain permanently inscribed. All monuments set by AHTD personnel shall include the Professional Surveyor (PS) license number of the Division Head of the Surveys Division. Monuments set by a certified licensed Professional Surveyor (PS) under contract with the Department shall stamp their license number on the cap.

Standard boundary monuments shall be stamped "AHTD BDY". Monuments that are placed on Court Order ROW shall be stamped "AHTD R/W". Monuments that are placed on permanent construction easements shall be stamped "PCE".

6.2.4 EXISTING LAND CORNER MONUMENTS

Land corner monuments shall be measured and recorded prior to construction that fall inside the AHTD boundary; a permanent easement; or, temporary construction easement

ROW monuments or control points may be used as reference points when practical. These land corners may be reestablished by the Surveys Division or certified Professional Surveyor (PS) under contract by the AHTD upon completion of the construction project using the AHTD standard 5/8" rebar and two (2) inch aluminum cap. The cap shall be stamped with the correct PLSS designation. PLSS corners utilized as a Point of Commencement in the property description shall be monumented if no monument exists.

6.2.5 MONUMENT MEASUREMENTS

All ROW and Land corner monuments that have been set with the above procedures shall have the positions measured and recorded. These measurements shall follow the same procedures for secondary control points outlined in the [Control Surveys](#) (Chapter 2). If the monument cannot be set-up over with a tripod, then redundant measurements shall be made from at least two (2) know control points utilizing a prism and prism pole. RTK GPS positioning measurements are acceptable as part of the redundant measurements.

6.3 FINAL SURVEY PLATS

A final plat shall be prepared using the same software requirements described in the [Land Surveys](#) (Chapter 5) of this manual. The plat shall show all pertinent topography, both roadway and structures, and all monuments set including the markings placed on each cap. The plat shall meet the current Arkansas Minimum Standards for Property Boundary Surveys and Plats as well as AHTD requirements. Therefore, it may be necessary to incorporate information contained on the parcel worksheets and the right of way plans to complete the final plat.

The boundary lines shown on this plat shall not have the word "Proposed" as used on the plans for right of way acquisition. The plat shall have a seal affixed by the Professional Surveyor (PS) who has oversight over the project as well as the Professional Surveyor (PS) responsible for establishing the monuments if not the same person. The Professional Surveyors' seal shall be signed and dated.



Chapter 6 – ROW Monumenting (cont.)

The final plat shall be recorded in the State Land Surveyor's Office. Each plat shall have an instrument number assigned by the State Land Surveyor's Office and the date affixed by an official in the State Land Surveyor's Office. Original versions of the recorded plat(s), as well as the electronic files for those plat(s), shall be furnished to the Surveys Division of the AHTD.

Copies of the recorded plat(s) shall be furnished to the Surveys Division of the AHTD, and, the Circuit Clerk's Office of the county or counties involved if the Circuit Clerk requests the plats.