Survey Manual

Chapter 5

Preliminary Surveys

Colorado Department of Transportation
October, 2016

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Chapter 5 – Preliminary Surveys

5.1 General

5.1.1 Purpose

The purpose of this chapter is to define the specifications that shall be followed while performing preliminary surveys for CDOT by CDOT surveyors or contract consultant surveyors.

Any variation from the specifications shall have the prior approval of the Region Survey Coordinator.

5.1.2 Types of Preliminary Surveys

When a project has been identified to be built, a survey has to be completed to select the route, to locate existing features of the route, to identify areas of environmental impacts, to identify areas of Right of Way acquisition, to help to determine the costs of the project and to design the project. There are several types of preliminary surveys that may need to be completed prior to design and construction of the project as follows:

1. Reconnaissance Survey
2. Control Survey
    a. Horizontal
    b. Vertical
3. Right of Way Survey
    a. Preliminary
    b. Final Right of Way *
4. Topographic Survey
    a. InRoads TMOSS
    b. Aerial
    c. InRoads TMOSS Aerial Supplemental Survey

5. Drainage Survey
6. Utility Survey
7. Staking for appraisal

* There are two phases of the Right of Way Survey, preliminary and final. The specifications for both of these phases are the same and as such both are included in this chapter.

5.1.3 Presurvey Conference – Preliminary Survey

Prior to beginning any preliminary survey activities a Presurvey Conference for Preliminary Surveys shall be held. Any known error or oversight on the plans or specifications shall be discussed at the presurvey conference. The project manager shall notify all parties listed below at least two weeks prior to the presurvey conference. The following individuals should attend the Presurvey Conference for Preliminary Surveys:

1. Region Survey Coordinator or designee
2. Region Right of Way Plans Coordinator or designee
3. Design Engineer or designee
4. Project Manager or assistant Project Manager
5. Hydraulic Engineer or designee
6. Bridge Engineer or designee
7. Environmental Manager or designee

8. Resident Engineer or designee
9. Survey Crew Chief
10. Any appropriate subcontractor personnel

If the preliminary survey work is to be performed by a contract consultant, either as a prime or sub-contractor, the professional land surveyor who will be responsible for the survey work performed shall attend the presurvey conference. If the contract includes design processes, the contract consultant should be strongly urged to send the design engineer who will be responsible for that portion of the work.

The presurvey conference at a minimum shall include a Presurvey Conference - Preliminary Survey Form and CDOT Standard Specifications for Road and Bridge Construction, Section 629 – Survey Monumentation.

The presurvey conference should be held at the site of the proposed project, or a tour of the area to be surveyed should be scheduled in a timely manner that is mutually convenient to all attendees. All those attending the presurvey conference shall sign the Presurvey Conference Agenda and indicate whether or not they toured the site of the proposed work.

The surveyor in responsible charge for the survey work shall have the following reference materials at the Presurvey Conference for Preliminary Surveys:

1. Project Plans if available (*e.g.* Project Control Diagram if supplied by CDOT)
2. Preliminary Survey Scope Form 1217a
3. CDOT Standard Specifications for Road and Bridge Construction
4. CDOT Standard Plans (M & S Standards)
5. CDOT Survey Manual
6. CDOT Right of Way Manual if Right of Way is required
7. Manual of Uniform Traffic Control Devices (MUTCD)

One of the primary purposes of the presurvey conference is to delineate the requirements and limits of the upcoming survey. While precise horizontal and vertical control may not be necessary for a simple pavement overlay, it may not be obvious that this control may be required for the design and construction of structures. The presurvey conference provides an opportunity to determine the type and amount of survey activities to be done, and will prevent over-surveying as well as under-surveying of the project.

http://www.coloradodot.info/library/forms/cdot1217.pdf/view

5.1.4 Equipment Checking and Calibration

Checks and calibrations on all types of electronic survey equipment are essential to obtain and maintain the minimum tolerances required in this chapter. Equipment must be properly maintained, regularly checked, and calibrated for accuracy at the beginning of any survey project to ensure that the equipment is operating properly in accordance with Chapter 2 – General Procedures, and Chapter 3 – GPS Surveys. Errors due to poorly maintained or malfunctioning equipment will not be accepted. If any equipment errors are found to exist they must be reported to the Region Survey Coordinator prior to the start of the survey. These errors will need to be verified and eliminated prior to performing any survey. For surveys lasting longer than six months, the checking, and calibration of equipment shall be repeated once every six months to show that the equipment is staying within acceptable tolerances.

See Chapter 2 - General Procedures, and Chapter 3 – GPS Surveys, for additional information.

5.1.5 Staking Color Codes

Type of Stake and/or Monument	Color Flagging, Paint, Etc.
Primary Control, Right of Way (ROW), Boundary, Public Land Survey System (PLSS)	Orange
Secondary Control, Structure Control	Yellow
Benchmarks (Primary and Secondary)	Blue
Easements (Permanent and Temporary)	Florescent Lime or Green
Alignment Centerline (Permanent and Temporary)	Red
Alignment Reference	Red and White
Slope Stakes	White
Structure Reference (Major and Minor)	Yellow and White
Test Holes (Geotechnical)	Pink
Utility Locates	White

Table 5 – 1

See Chapter 6 – Construction Surveys, for additional information.

5.2 Reconnaissance Survey

5.2.1 General

A reconnaissance survey gathers information for planners, engineers, environmental and Right of Way designers, and can be described as a "paper survey" as it is compiled mostly from information already gathered by Geographical Information Systems (GIS) and other such databases. A reconnaissance survey does not provide construction data, rather it provides information and data pertaining to general location possibilities, feasibility and probable costs of Right of Way, construction and maintenance. It is an overall look at the terrain, land parcels, utilities, existing structures, and environmental issues that might affect the routes of a project by an extensive study of an area, not just of an alignment and may include many proposed routes. The study must be made of the area of all practical routes. Location of existing features is required to determine the cost and feasibility of a proposed route. The type of project and the nature of the terrain will determine the extent of the area to be studied.

5.2.2 Requirements

For highway locations along an established route, a reconnaissance survey may require only a visit to the site. For a new location of a highway, an extensive reconnaissance survey of many square miles may be required. Both conventional and photogrammetric methods are used to gather data for reconnaissance surveys.

5.2.3 Geographical Information System

CDOT's Division of Transportation Development (DTD) is responsible for the acquisition and maintenance of a statewide Geographical Information System (GIS). This system provides databases of information such as land use, environmental terrain, and elevation from a wide range of resources.

CDOT's GIS section has historically provided its data to internal users by use of the program Maps 2, a customized ArcView program. This program is being phased out over several years and replaced with the Online Transportation Information System (OTIS), another customized program.

For internal CDOT personnel see the following link for additional information on OTIS:

http://dtdintapps/OTIS/

For external CDOT users see the following link for basic GIS information available to the general public:

http://www.dot.state.co.us/App_DTD_DataAccess/index.cfm

5.2.4 Aerial

Photogrammetry or other aerial data is often used in highway reconnaissance as well as for design purposes. Aerial maps, USGS topographic maps and aerial photography are all good sources of data.

See Chapter 4 – Aerial Surveys, for additional information.

5.3 Research

5.3.1 General

The location, re-establishment, and perpetuation of land corners involving highway Right of Way are of the utmost importance to the department and to the public. If any of these corners are incorrectly positioned, the resulting disruption of property boundaries could result in costly litigation. The research performed before and during the preliminary phases of a project will determine the quality of the finished product and the costs related to the project. Improper research may result in needless delays and add substantially to the costs of a project. For CDOT purposes, the following requirements for research shall apply:

1. Investigate thoroughly

2. Perform a careful and diligent search

3. Make studious inquiry or examination; investigation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts or practical applications of such new or revised theories or law.

5.3.2 Types of Research

It cannot be overstated that the proper research will result in a better all around project and it will make your survey analysis more secure. You may find in your research that you may not utilize information or monuments currently in use, or will end up working with a completely different set of data and monuments as the requirements of research implies. Always keep an open mind to allow for the inclusion of new data and information discovered by your research. Research can be broken into two phases as follows:

1. Office Research (*e.g.* records)
2. Field Search (*e.g.* physical evidence)

The office phase is that portion of the research performed in your office or somebody else's office to gain information of record regarding boundaries, Public Land Survey System (PLSS), Rights of Way, property boundary, easements, points etc. The field search is the recovering and locating of physical evidence of these items by finding and locating survey monuments such as PLSS, Right of Way, property boundary, easement, etc.

5.3.3 Office Research

As much of the office research should be conducted by the surveyor in responsible charge as possible. The office phase of the research consists of contacting various agencies that may have information of record such as deeds, subdivision plats, land survey plats, Bureau of Land Management (BLM) plats, mining claim maps, monument records, etc for the area affecting the project.

The primary source of property records is the county office of the clerk and recorder in which the subject property is located. Although limited, some county offices are making their records available online through the Internet. Once the researcher has been to this office, the following county agencies will usually be able to provide useful information:

1. Assessor's office: current landowner's information with their address and a brief description of the property.

2. Clerk and recorders office: copies and original deeds, documents, subdivision plats, land survey plats and monument records.

3. County commissioners records: information on road petitions, commission decisions, rulings, agreements, etc.

4. Court records: information on court decisions, rulings, and court ordered surveys, etc.

5. Engineering records: information on public works projects involving Right of Way.

6. County surveyor's office: information on Right of Way, easements, land survey plats, boundary disputes, etc.

Some cities and counties have their own engineering departments and/or survey crews. These municipalities have information on Right of Way, easements, section corner locations, benchmark, block and lot corners within a subdivision, etc.

Title companies also have some of the above stated information that the county clerk has.

5.3.4 Land Survey Plats Deposited

Colorado law requires certain land surveys to be deposited in the appropriate county records designated by the county commissioners as Land Survey Plats (LSP). It is important for the surveyor performing the research to know that these deposited LSP are deposited for the sole purpose of recording information on surveying monumentation in order to provide survey data for subsequent surveyors and does not constitute notice. Typical CDOT surveys that are deposited in the county records as Land Survey Plats are as follows:

1. Project Control Diagrams (not required to be deposited with the appropriate county but may be if so desired)

2. Land Survey Control Diagrams (required to be deposited with the appropriate county within twelve months from the Right of Way Authorization Plans submittal date.)

3. Right of Way Plans (required to be deposited with the appropriate county within six months after the ROW monuments are set)

4. Survey Plats (may or may not be required to be deposited with the appropriate county depending on the field evidence found or set)

5.3.5 Colorado Counties Online

Contact information for all of the municipal cities and counties within Colorado can be found online on various websites as follows:

http://www.elections.colorado.gov/DDefault.aspx?tid=147

http://www.colorado.gov/cs/Satellite/CO-Portal/CXP/1184337612761 http://www.ccionline.org/

5.3.6 Agency Contact Information

For CDOT contact information See Chapter 1 – General.

Information on National Geodetic Survey (NGS) geodetic horizontal and vertical points, GPS points, calibrated baselines, control index maps, etc can be obtained by contacting the NGS advisor:

See Chapter 1 – General, for additional information on the NGS advisor.

NOAA/NGS Colorado Geodetic Advisor
Pamela Fromhertz
4201 E. Arkansas Ave., 4th Floor
Denver, Colorado 80222
email: pamela.fromhertz@dot.state.co.us
email: pamela.fromhertz@noaa.gov
phone: 303-202-4082

Information on NGS geodetic horizontal and vertical points, GPS points, calibrated baselines, control index maps, etc can be obtained by contacting the NGS:

National Geodetic Survey
1315 East-West Highway
Silver Springs, Maryland 20910-3282
Phone: 301-713-3194
http://www.ngs.noaa.gov/

See Chapter 3 – GPS Specifications, for additional information.

Information on US Geological Survey horizontal and vertical control points, maps, and geological data such as earthquakes, landslides, photos, etc:

U.S. Geological Survey
Rocky Mountain Mapping Ctr.
USGS National Mapping Discipline
MS 306
PO 25286, Federal Center
Denver, Colorado 80225
phone 303-202-4400
Map sales phone 1-888-275-8747
http://www.usgs.gov/

Information on projects under their control:

U.S. Bureau of Reclamation
PO 25007, Federal Center
Denver, Colorado 80225
phone 303-445-2267
http://www.usbr.gov/

Information on projects under their control, also a limited amount of horizontal and vertical control:
U.S. Forest Service
Rocky Mountain Regional Office
740 Simms Street
Golden, Colorado 80401
phone 303-275-5221
http://www.fs.fed.us/
http://www.fs.fed.us/r2/recreation/map/colorado/index.shtml

Information on their projects within project area:
U.S. Soil Conservation Service
Colorado State Office
USDA Natural Resources Conservation Service
655 Parfait Street, Suite 201 Room E200C
Lakewood, CO 80215
phone 720-544-2840
http://soils.usda.gov/

Original Public Land Survey System (PLSS) notes for section corners, township corners, township and section breakdown etc.
Bureau of Land Management
2850 Youngsfield Street
Lakewood, Colorado 80215
phone 303-239-3600
http://www.blm.gov/co/st/en.html
http://www.co.blm.gov/directory.htm

CDOT Right of Way plans, previous construction projects, highway maps, traffic counts, bridge plans, monument records, horizontal and vertical control data:
Colorado Department of Transportation
4201 East Arkansas Avenue
Denver, Colorado 80222
phone (303) 757-9331
http://www.dot.state.co.us/

Information on Public Land Survey System Monument Records:
Board of Registration for Professional Engineers and Professional Land Surveyors
1560 Broadway, Suite 1370
Denver, CO 80202
phone 303-894-7788
http://www.dora.state.co.us/aes/index.htm
http://www.dora.state.co.us/aes/monumentrecords.htm

Information on projects under their control:
Mineral Management Service (US)
Denver Federal Center
Information phone 303-231-3162
http://www.mms.gov/

Information on state engineering projects; dams, etc:
Dept. of Natural Resources – Department of Water Resources
State Engineers Office
1313 Sherman
Denver, CO 80203
phone 303-866-3581
http://www.water.state.co.us/

Information on projects and surveys for the Denver Water Board:
Denver Board of Water Commissioners
1600 West 12th Ave.
Denver, CO 80254
phone 303-628-6000
http://www.denverwater.org/

Information on surveys, state owned lands, state leased lands, etc. under their control:
Department of Natural Resources
Division of Parks and Outdoor Recreation
1313 Sherman
Denver, CO 80203
phone 303-866-3437
http://www.parks.state.co.us/

Information on surveys, state owned or leased lands under their control:
Department of Natural Resources
Colorado Division of Wildlife
6060 Broadway
Denver, CO 80216
phone 303-297-1192
http://www.wildlife.state.co.us/

State Land Board:
Department of Natural Resources
State Board of Land Commissioners
1127 Sherman St, #300
Denver, CO 80203
phone 303-866-3454
http://trustlands.state.co.us/Pages/SLB.aspx

Information on surveys and reclamation projects under their control (coal, gravel mines etc.):
Department of Natural Resources
Mined Land Reclamation Division and Board
1313 Sherman, Room 215
Denver, CO 80203
phone 303-866-3567
http://www.dnr.state.co.us/

State archives have access to old records, documents, reports, and other data. They may be able to give information on other sources of information:

State of Colorado
Archives and Public Records
Research Services
1313 Sherman
Denver, CO 80203
phone 303-866-2358
http://www.colorado.gov/dpa/doit/archives/
http://www.colorado.gov/dpa/forms/doit/archives/request.htm

Information on lands under their jurisdiction:

Colorado Commission of Indian Affairs
http://www.colorado.gov/ltgovernor/initiatives/indianaffairs.html
http://www.cr.nps.gov/nagpra/DOCUMENTS/ResMAP.htm

The U.S. Corps of Engineers have control over all waterways within the state with regard to flood control and may have information on projects along waterways and flood control projects:

U.S. Corp of Engineers
Omaha District Office
public affairs 402-221-3908
http://www.usace.army.mil/

Law libraries have information on court decisions and rulings within the state, also precedents:

Supreme Court Library
State Judicial Bldg.
2 East 14th Avenue, Room B112
Denver, CO 80203
phone 303-861-1111
http://cscl.colibraries.org/

Opinions on rulings and legal opinions on conflicts that may not yet have been tried in court:

Office of the Attorney General
1525 Sherman Street, 7th Floor
Denver, CO 80203
http://www.ago.state.co.us/index.cfm

U.S. Government Bookstores:

1660 Wynkoop
Denver, Co. 80202
http://www.access.gpo.gov/
http://bookstore.gpo.gov/

Airports information generally related to Primary Airport Control (PAC) and Secondary Airport Control (SAC) as well as survey information about their boundaries.

http://www.ngs.noaa.gov/AERO/aero.html
http://www.colorado-aeronautics.org/

Utility companies have information on their Right of Ways, easements, type of utility and purpose.

Irrigation companies have information on ditch names, flow quantities, capacities, names of individuals served by ditches in their area.

Landowners, surveyors, consultant firms, and other individuals may have a vast knowledge of land corners, surveys, subdivisions, and other engineering projects.

All of these sources and others not mentioned are potential research sources for the project. This list should be used as a tool to check possible research sources, avoid overlooking obvious sources, and identify new sources. As many of these potential sources as possible should be checked prior to any fieldwork. Sometimes the checking of one source may lead you to another source and so on.

5.3.7 Field Search

After the office research is conducted a field search shall be performed to locate all possible physical evidence that may exist in the field. The field search shall consist of a search for existing survey monuments identified by the office research. A few examples of the office research material used during the field search is as follows:

1. Ties from previous surveys (*e.g.* subdivision plats, land survey plats, deeds, easements, mining claim maps, Work Program of America (WPA) ties, etc)
2. BLM notes and plats
3. Monument records
4. Right of Way plans
5. Construction plans
6. Railroad maps
7. Topographic maps
8. Aerial photos
9. Assessors maps
10. Other maps
11. Parole evidence

For private surveyors or contract consultant firms working in or near to the existing CDOT Right of Way a Special Use Permit Form 1283a, shall be obtained with the survey option completed (See Chapter 2 – General Procedures, for additional information).

All found monuments and physical evidence found shall be located and tied into the CDOT Primary Control Monumentation for the project in accordance with the appropriate Minimum Horizontal and Vertical Accuracy Tolerance for the type of survey being performed.

5.3.8 Guide for Field Search

The following should be used as a guide in your field search:

1. Reference / accessory ties from monument records for PLSS land corners to verify the corner. Any discrepancy shall be noted.

2. If nothing is found using ties, check for the point using a metal detector. A search of road intersections, fence corners and other areas where land or property corners may exist is sometimes productive.

3. If nothing is found excavation of the area may be necessary. Excavation should be such that either the point is recovered or determined not to exist at that location. Whatever means are used,

care should be exercised to prevent damage to the point. Excavation should be limited unless evidence indicates a corner may exist, such as reference ties on poles or by metal detector. Photos should be taken of any recovered evidence and should show the found evidence's relationship to occupation lines and other physical evidence to help aid in the re-establishment of the monument in the event it is lost in the future. Any damage caused by excavation shall be repaired immediately.

See Chapter 1 – General, CDOT Standard Specifications for Road and Bridge Construction, Section 629 – Survey Monumentation, for additional information.

5.3.9 Interview of Property Owners and Local Residents

Property owners and local residents may have knowledge of important information about the location of corners and monuments that should not be overlooked. These individuals should be interviewed for their knowledge of such corners and monuments and this information made part of the project records. Such interviews should be conducted to leave the person with a favorable opinion of CDOT and of the project. The following should be a guide to conducting these interviews:

1. Try to get all of the information in one interview.

2. Be knowledgeable of the extent of the project and know the limits on the information that CDOT wants given out.

5.3.10 Interview Format

Interview format for property owners, local residents and other individuals should be as follows:

1. Introduce yourself by name, title, office location, and contact information by handing out your business card.

2. Get the name and contact information of the individual being interviewed.

3. Inform the person being interviewed of:

    a. The project you are working on
    b. Nature of the project
    c. Information needed
    d. When CDOT or consultants may return to do other work in the area
    e. Arrange for a convenient time to return if more information is needed

4. Start the interview by giving an informal statement on the need for the information desired. At the same time, have a list of questions prepared to lead into details relating to the information needed. Questions that could be asked are:

    a. How many years have you lived in the area?

    b. How many years have you owned or occupied this property?

    c. How long has a specific improvement (road, fence, building, etc.) existed?

    d. Did the improvements replace a previous improvement?

e. Was the improvement placed by a survey? If yes, who did the survey and when? Who had the survey performed and when? Who had improvements built and when? May I see a copy of the survey if you have one?

f. Do you have knowledge of your property monument locations? If yes, would you help show me where the location of these monuments are?

g. Has there been any property disputes or legal proceedings over the property boundaries in the vicinity?

h. Do you have knowledge of the location of PLSS section, quarter-section, meander, or any judicial monuments in the area?

i. Do you have knowledge of where any ditches, drains, or field lines are located?

j. Do you have any knowledge of elevations, horizontal position or dates of the limits of high water during floods, snows etc.?

k. Do you have any knowledge of underground utility locations such as leach fields, wells, septic tanks or storage tanks?

l. Do you have any knowledge of the location of any hazardous materials on the property?

5.4 Railroad Research

5.4.1 Railroad Office Research

Researching of railroad Right of Way is a unique process, one that involves patience and knowledge of working with railroads. Contacting the proper railroad for their Right of Way maps is critical. It is important to know the history of each railroad when determining which railroad may have the maps you are seeking as most railroads have changed hands many times and may not have the original maps for their lines. It is important to work with the proper maps when retracing their Right of Way. CDOT has some railroad maps, however they may not be complete or current.

The Colorado Railroad Museum has many RR maps and plats and is a valuable source of information:
Colorado Railroad Museum
17155 west 44th Avenue
Golden, Colorado 80402
phone 1-800-365-6263
http://www.crrm.org/

The U.S. National Archives and Records Administration (NARA) also has important information:
8601 Adelphi Road
College Park, Maryland 20740
phone 1-866-272-6272
http://www.archives.gov/

Other useful railroad research websites:
http://www.aar.com/
http://www.aar.org/
http://www.arema.org/eseries/scriptcontent/index.cfm
http://www.bnsf.com/
http://www.coloradohistory.org/
http://www.co-ol.org/
http://www.cumbresandtoltec.com/
http://www.deseretgt.com/
http://www.dora.state.co.us/puc/index.htm
http://www.durangotrain.com/
http://www.fra.dot.gov/
http://www.gtownloop.com/
http://www.leadville-train.com/
http://www.memory.loc.gov/ammem/index.html
http://www.omnitrax.com/
http://www.railamerica.com/
http://www.rrb.gov/
http://www.stb.dot.gov/
http://www.ttci.aar.com/
http://www.up.com/

5.4.2 Railroad Field Search

Common mistakes when field searching railroad Right of Way:

1. Railroad Right of Way vs. railroad construction
2. Center of track mainline curve may not be center of Right of Way
3. Railroad Right of Way is generally simple curves even when the centerline is spiral
4. Center of track mainline tangent may not be center of Right of Way
5. Railroad curves are defined by the chord definitions
6. Slope chaining
7. Strip Conveyances
8. Milepost
9. Control points (T rails)
10. Assessors map is usually wrong
11. Equations and scaled items
12. Interpreting chaining and map calls
13. Right of entry for performing surveys

5.4.3 49 CFR 214 – Railroad Right of Entry

Railroad property is private property, as such individuals seeking access to railroad property for any reason are required to contact the railroad prior to entering the property. It is typically railroad policy to treat anyone found on railroad property without authorization as a trespasser. Most railroads charge a fee to provide you with the right to enter their property. The time it takes to submit the right to enter form and receive entry approval can take anywhere from 60 – 90 days or more. Early anticipation and preparation to obtain right of entry will benefit you in performing your survey within the allotted time frame.

Depending on the railroad and the particular situation, the railroad may require a flag person be present for safety before authorization of the right to enter is obtained. Railroads typically charge the flag person's time to the one gaining the right to enter and this cost may be substantial.

Prior to entry onto railroad property the surveyor should contact the railroad and inquire about taking a Railroad Engineering Contractor Orientation Course, an example of which follows:

http://www.contractororientation.com/

5.5 Minimum Horizontal Accuracy Tolerance

5.5.1 FGCD Standards and Specifications

There are two types of specifications that shall be followed while performing surveys for CDOT as follows:

1. FGDC/FGCC Standards and Specifications - for surveys that are submitted for inspection and acceptance into the **National Spatial Reference System** (NSRS) database by federal approval (See Chpater 3 – GPS Surveys for additional information.)

2. CDOT Specifications - for surveys that are not to be submitted for inspection and acceptance into the national database by federal approval.

Index of FGDC Accuracy Standards:

http://www.fgdc.gov/standards/standards_publications/index_html

The above link provides downloads of the following FGDC Accuracy Standards.

5.5.2 Minimum Horizontal Accuracy Tolerances

Accuracy Tolerance at 95% Confidence: Is the computed horizontal ground distances between different datasets for the same point by multiple observations, either by GPS, conventional methods or a combination of both. Accuracy reported at the ninety five percent ninety five percent (95%) confidence level means that ninety five percent ninety five percent (95%) of the positions in the dataset will have an error with respect to the horizontal ground position that is equal to or smaller than the required accuracy. It is not observations closures itself within a survey that shall meet the ninety five percent ninety five percent (95%) confidence level, but the ability of that survey to duplicate horizontal values.

CDOT Class A – Primary: Accuracy of a primary point is a value that represents the uncertainty of a point at the ninety five percent ninety five percent (95%) confidence level with respect to all other points in the primary survey and referenced to the geodetic datum. The geodetic datum referenced is considered to be error free. Once the data for the primary survey has been adjusted, accepted, and finalized, the primary survey shall be considered to be error free and any secondary surveys referenced to the primary survey shall not include the accuracy error of the primary survey.

All primary control monuments either set or re-established as part of the CDOT approved Primary Control Survey shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class A – Primary Survey at the ninety five percent ninety five percent (95%) confidence level.

CDOT Class B – Secondary: Accuracy of a secondary point is a value that represents the uncertainty of a secondary point at the ninety five percent ninety five percent (95%) confidence level with respect to all other directly connected points within the secondary survey. The accuracy error of the primary survey is considered to be error free and is not to be included in the secondary survey.

Accuracy of a secondary survey for locating or setting any secondary points by RTK or PPK methods is analyzed by independent locations of the base receiver and the initialization for a particular group of secondary points. The accuracy for that particular group of points shall be verified within itself. Once the base receiver is moved to a different point and/or a new initialization is gained, a new group of points is being collected that is independent from the previous group of points. A new accuracy shall be verified for the new group of points independently from that of the previous group. (See Chapter 3 – GPS Surveys, for additional information)

Accuracy of a secondary survey for locating or setting any secondary points by conventional methods is analyzed by independent locations of the survey instrument setup and the reference instrument backsight for a particular group of secondary points. The accuracy for that particular group of points shall be verified within itself. Once the survey instrument is moved to a different point and/or a new backsight is referenced a new group of points is being collected that is independent from the previous group of points. A new accuracy shall be verified for the new group of points independently from that of the previous group. (See Right of Way Survey, for additional information)

All secondary monuments either set or re-established as part of the CDOT approved Secondary Survey shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary Survey at the ninety five percent ninety five percent (95%) confidence level.

CDOT Class C and D – TMOSS: Accuracy of a TMOSS point is a value that represents the uncertainty of the point at the ninety five percent ninety five percent (95%) confidence level with respect to the survey being performed for a particular group of points.

Accuracy of a TMOSS Survey performed by RTK or PPK methods is analyzed by independent locations of the base receiver and the initialization for a particular group of points .The accuracy for that particular group of points shall be verified within itself. Once the base receiver is moved to a different point and/or a new initialization is gained, a new group of points is being collected that is independent from the previous group of points. A new accuracy shall be verified for the new group of points independently from that of the previous group. (See Chapter 6 – GPS Surveys, for additional information)

Accuracy of a TMOSS Survey performed by conventional methods is analyzed by independent locations of the survey instrument setup and the reference instrument backsight for a particular group of points. The accuracy for that particular group of points shall be verified within itself. Once the survey instrument is moved to a different point and/or a new backsight is referenced a new group of points is being collected that is independent from the previous group of points. A new accuracy shall be verified for the new group of points independently from that of the previous group. (See Topography Survey, for additional information)

All Class C or D TMOSS points collected as part of the CDOT approved TMOSS Survey shall meet the Minimum Horizontal Accuracy Tolerance for either a CDOT Class C or D – TMOSS Survey respectively at the ninety five percent ninety five percent (95%) confidence level.

5.5.3 Minimum Horizontal Accuracy Tolerance Table

The following Minimum Horizontal Accuracy Tolerance Table is based on the Geospatial Positioning Accuracy Standards Part 2, Standards for Geodetic Networks FGDC-STD-007.2-1998 as published by the Federal Geodetic Control Subcommittee (FGCS) of the Federal Geographic Data Committee (FGDC).

These accuracy tolerances have been modified to best suit the needs of surveying for CDOT.

Minimum Horizontal Accuracy Tolerance Table:

Classification Type	Accuracy Tolerance – 95% Confidence
CDOT Class A - Primary Primary Control points	**0.020 meters or** **0.07 feet**
CDOT Class B - Secondary Secondary Control points Aerial Survey Photo Control points (center & wing) Public Land Survey System points Right-of-way points Boundary points Easement points Survey Alignment points Etc.	**0.040 meters or** **0.13 feet**
CDOT Class C - TMOSS Concrete and asphalt surfaces Roadway striping Bridge structures Drainage structures Etc.	**0.060 meters or** **0.20 feet**
CDOT Class D - TMOSS Earth terrain Tops and toes of slopes Staking for Appraisal Etc.	**0.200 meters or** **0.66 feet**

Table 5 – 2

5.6 Control Survey

5.6.1 General

The purpose of a control survey is to establish a network of physically monumented coordinate points in and along a highway corridor that provide a common horizontal and vertical datum for the entire project. Normally there are many survey points in a control survey that are not intended as control points. These points are, by their nature, peripheral to a control point. Examples of peripheral points are unoccupied reference and azimuth marks.

The control survey provides the means for tying all of the geographic features and design elements of a project to one common horizontal and vertical coordinate system for the following:

1. Aerial
2. Environmental
3. Design
4. Right of Way
5. Property Management
6. Maintenance

5.6.2 Performed by Professional Land Surveyor

The Memorandum of Understanding (MOU) between CDOT and the State Board of Registration for Professional Engineers and Professional Land Surveyors requires that control surveys from which the Right of Way or any land boundary will be calculated, described or monumented, be performed under the direction and control of a Colorado professional land surveyor.

See Chapter 1 – General, for additional information.

5.6.3 Types of Control Surveys

The following types of control surveys are performed for CDOT:

1. Horizontal
2. Vertical

5.6.4 Types of Control Survey Monuments

CDOT has two distinct control monumentation categories as follows:

1. Primary
2. Secondary

It is important for the surveyor to have an understanding of the difference between these two categories and the purpose for which they serve.

5.6.5 Primary Control Monumentation

Primary control monuments consist of the horizontal and vertical control monuments established on the ground as the framework for the primary control survey network. This includes the existing control monuments used as reference for the establishment of the primary control network.

Examples of primary control monuments include but are not limited to the following:

1. Existing High Accuracy Reference Network (HARN) monuments included in the National Geodetic Survey's (NGS) National Spatial Reference System (NSRS) as approved by the Region Survey Coordinator for use to establish a CDOT control network. (See Chapter 3 – GPS Surveys, for additional information on HARN)

2. Existing monuments referenced to the North American Vertical Datum of 1988 (NAVD 88) such as NGS, United States Coast & Geodetic Survey (USCGS), and United States Geological Survey (USGS) as approved by the Region Survey Coordinator for use to establish a CDOT control network.

3. Any other existing monumentation as approved by the Region Survey Coordinator for use to establish a CDOT control network.

4. Any existing and/or set CDOT Type 2 monuments as approved by the Region Survey Coordinator for use to established a CDOT control network.

CDOT primary control monuments and the monuments used as reference for the establishment of the primary control monuments are considered primary control. Any additional control set from these primary control monuments shall be considered secondary control.

See Chapter 3 - GPS Surveys, for additional information.

For replacing of primary control monuments see Chapter 6 - Construction Surveys, for additional information.

5.6.6 Setting of Primary Control Monumentation

It is critical that before setting any primary control monumentation the project needs are identified. This is typically done through the initial scoping of the project to determine the project limits, factors, and requirements. After the scoping has been completed the project surveyor shall identify areas to install CDOT Type 2 control monuments. The following considerations shall be taken into account when identifying a site for installing primary control monumentation:

1. Global positioning sites should be free of vertical obstructions blocking the horizon such as buildings, overhangs, terrain, trees, fences, utility poles, overhead lines, or any other visible obstructions. Non-obstructed skies 15 degrees above the horizon is best (See Chapter 3 – GPS Surveys, for additional information).

2. Global positioning located close to radio transmitters including cellular phone equipment may disrupt satellite signal reception.

3. Sites close to large flat surfaces such as signs, fences, glass, or utility boxes should be avoided.

4. Sites shall provide direct line of site between adjacent control monuments.

5. Sites shall not exceed 0.6 mile between adjacent intervisible control monuments.

6. Establish a minimum of four primary control monuments for each project.

7. If feasible, sites should not be disturbed by future construction activities and should be outside the design toe of slopes and top of cuts for the project.

8. When practical sites shall be located within the existing highway Right-of-Way. When sites can not be located in the existing ROW the following procedure should be followed:

    a. If a site is located outside the existing highway Right-of-Way a permission to enter property form should be completed, and if necessary an easement for access, installation, and maintenance of the control monument should be acquired in CDOT's name for the benefit of the public for the purpose of performing a land survey.

    b. If a site is located inside a local public agency Right-of-Way (*e.g.* city or county) a permission to enter property form should be completed, and if necessary an easement for access, installation, and maintenance of the control monument should be acquired in CDOT's name for the benefit of the public for the purpose of performing a land survey.

After the monumentation sites are identified for installation each site shall be marked and utility locates called for. (See Chapter 2 – General Procedures, Underground Utility Locates Prior to Installing Monumentation, for additional information.)

Primary control monuments shall have a witness post installed within two ft and facing the control monument, or as approved by the Region Survey Coordinator. CDOT typically uses the following types of witness post:

1. Orange carsonite (typically used on the plains of Colorado)

2. Green carsonite (typically used in the mountains of Colorado)

3. Metal license plate type (typically used in areas subject to animals or unique situations requiring a more robust witness post)

Primary control monuments and witness posts materials shall be furnished by CDOT in accordance with M & S Standards M-629-1.

http://www.dot.state.co.us//DesignSupport

All CDOT primary control monuments shall be established within the Minimum Horizontal and Vertical Accuracy Tolerance as required in this chapter for a CDOT Class A - Primary monument.

See Chapter 3 - GPS Surveys, for additional information.

Unless directed otherwise by the Region Survey Coordinator, whenever a primary control monument is set the monument cap shall be stamped with a new and unique point number in order to identify it by milepost. The milepost point number shall be carried out to one-hundredth of a mile (*e.g.* if the primary control monument's location is at milepost 252.31 the point number shall be stamped as 5231). Care needs to be taken to ensure that primary control monument point numbers will not interfere with any TMOSS or other point numbers that may be needed.

For replacing of primary control monuments see Chapter 6 - Construction Surveys, for additional information.

5.6.7 Secondary Control Monumentation

Secondary control monumentation are those monuments set from the approved primary control monumentation. These secondary control monuments are typically established as survey work points in areas that require additional control be set at a lesser accuracy than that of the primary control network. These work points shall be established with the concurrence of the Region Survey Coordinator only for the following areas that prove to be difficult to survey:

1. Area of obstructions of line of site for conventional surveying

2. Area of obstructions of the sky for Global Positioning System surveys

3. Area requiring additional control for construction staking

Examples of secondary control monuments include but are not limited to the following:

1. Work points established to obtain data to perform topographic surveys

2. Work points established to obtain data to perform drainage surveys

3. Work points established to obtain data to perform utility surveys

4. Work points established to obtain data to perform appraisal staking

5. Work points established to obtain data to perform construction staking (See Chapter 6 - Construction Surveys, for Minimum Horizontal and Vertical Accuracy Tolerances)

Work points are established to obtain data for the following types of monumentation and features:

1. Public Land Survey System (PLSS)
2. Right of Way
3. Property boundary
4. Easement
5. Topography and terrain

5.6.8 Setting of Secondary Control Monumentation

CDOT control monument caps or disks shall not be set for any secondary control monument point**.**

All secondary control monuments shall be set solidly into the ground and shall consist of a material that will prove to hold the required Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class B - Secondary monument as required in this chapter for the entire time the particular point is needed for the project. These monuments shall be set in locations not to be confused as being property boundary monuments. If a cap is placed on the secondary control monument it should be stamped “Work Point” along with it’s identifying point number, and be punched marked with a point not larger than 3 mm. If a reinforcing bar is used, the point shall be punched in the steel.

After the monumentation sites are identified for installation each site shall be marked and utility locates called for. See Chapter 2 – General Procedures, Underground Utility Locates Prior to Installing Monumentation, for additional information.

All CDOT secondary control monuments shall be established within the Minimum Horizontal and Vertical Accuracy Tolerance as required in this chapter for a CDOT Class B - Secondary monument.

See Chapter 3 - GPS Specifications, for additional information.

5.6.9 Setting of Secondary Control Monuments for Construction Staking

For setting of secondary control monuments for construction staking see Chapter 6 - Construction Surveys, for the Minimum Construction Horizontal and Vertical Accuracy Tolerance required for the item being staked.

5.7 Horizontal Control Survey

5.7.1 Types of Horizontal Control Surveys

The following types of horizontal control surveys are typically performed for CDOT:

1. Global Positioning System (GPS) Surveys
    a. Static
    b. Fast Static
2. Conventional survey methods
    a. Traverse (angles & distances)
    b. Triangulation (angles)
    c. Trilateration (distances)

Unless field conditions do not permit, (*e.g.* obstructions of the sky by trees, buildings, etc.) only Global Positioning System (GPS) survey methods shall be performed for all CDOT horizontal control surveys. Those horizontal control surveys not performed by GPS methods shall have the prior approval of the Region Survey Coordinator.

See Chapter 3 - GPS Surveys, for additional information.

5.7.2 Primary Horizontal Control Survey

All primary horizontal control surveys shall be referenced to and tied into the Colorado High Accuracy Reference Network (CHARN) as defined by the National Geodetic Survey (NGS) National Spatial Reference System (NSRS).

NGS defines and manages the NSRS, the framework for latitude, longitude, height, scale, gravity, and orientation throughout the United States. NSRS provides the foundation for transportation, communication, and defense systems, boundary and property surveys, land records systems, mapping and charting, and a multitude of scientific and engineering applications. NGS also conducts research to improve the collection, distribution and use of spatial data.

The NSRS is a system of permanently monumented survey marks and their corresponding geodetic data reference to the North American Datum of 1983 (NAD 83). The NSRS is made of Federal Base Networks (FBN), Cooperative Base Networks (CBN), and User Densification Networks (UDN), all of which are known as Colorado's High Accuracy Reference Network (CHARN, and Colorado's CHARN Densification surveys (CHARND) as defined by CDOT in cooperation with NGS.

See Chapter 3 - GPS Surveys, for additional information on CHARN and NSRS.

5.7.3 GPS Primary Horizontal Control Survey Methods

All primary horizontal control surveys performed by GPS methods shall be performed in accordance with Chapter 3 – GPS Surveys of this manual and shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class A – Primary survey.

5.7.4 Conventional Primary Horizontal Control Survey Methods

All primary horizontal control surveys performed by conventional methods shall consist of closed traverse or closed loop surveys in accordance with this chapter and shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class A – Primary survey.

Each item of conventional survey data collected must be obtained with a minimum of four sets of observations. Distances will be measured in both direct and reverse positions (face 1 and face 2) of the telescope with a minimum of two sets from each terminus for a total of four sets. Angles will be repeated, observing direct and reverse positions (face 1 and face 2) of the telescope (*i.e.* 1 set), either by accumulating angles or closing the horizon.

The raw unadjusted data is to be analyzed statistically to assure the following minimum specified accuracy level is achieved. The rejection limit for any observation shall be 0.02 feet from the mean distance and 5 seconds of arc from the mean angle. This raw data will be adjusted only with the approval of the Region Survey Coordinator.

5.7.5 Secondary Horizontal Control Surveys

All secondary horizontal control surveys shall be referenced to and tied into an approved CDOT primary horizontal control survey.

5.7.6 GPS Secondary Horizontal Control Survey Methods

All secondary horizontal control surveys performed by GPS methods shall be performed in accordance with Chapter 3 – GPS Surveys of this manual and shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey.

5.7.7 Conventional Secondary Horizontal Control Survey Methods

All secondary horizontal control surveys performed by conventional methods shall consist of closed traverse or closed loop surveys in accordance with this chapter and shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary Survey.

Each item of conventional survey data collected must be obtained with a minimum of two sets of observations. Distances will be measured in both direct and reverse positions (face 1 and face 2) of the telescope with a minimum of one set from each terminus for a total of two sets. Angles will be repeated, observing direct and reverse positions (face 1 and face 2) of the telescope (*i.e.* 1 set), either by accumulating angles or closing the horizon.

The raw unadjusted data is to be analyzed statistically to assure the following minimum specified accuracy level. The rejection limit for any observation shall be 0.04 feet from the mean distance or 5 seconds of arc from the mean angle. This raw data will be adjusted only with the approval of the Region Survey Coordinator.

5.8 Vertical Control Survey

5.8.1 General

Acquiring the knowledge and skills needed for obtaining accurate elevations is essential to maintaining effective vertical control. Differential leveling is the CDOT approved process for determining and establishing elevations of primary control monuments, and for differences in elevations between points and controlling grades in construction surveys.

There are many different types of leveling such as differential, stadia, reciprocal, profile, trigonometric, and barometric. While differential leveling is discussed in this manual, the theory and application of all other leveling methods will not be discussed, rather information on these types of leveling can be found in most surveying text books.

Trigonometric leveling shall be used only when approved in advance by the Region Survey Coordinator.

5.8.2 North American Vertical Datum of 1988 (NAVD 88)

Elevations for all vertical control surveys shall be established from existing national benchmarks, referenced and tied to the North American Vertical Datum of 1988 (NAVD 88). The following are some examples of these types of benchmarks:

1. National Oceanic and Atmospheric Administration (NOAA)
2. National Geodetic Survey (NGS)
3. United States Coast & Geodetic Survey (USCGS)
4. United States Geological Survey (USGS)

If there is a choice between a First Order benchmark and any lower order benchmark, the higher order benchmark will be used. The past practice of referencing to a fictitious elevation datum such as an assumed elevation at the top of fire hydrant has been discontinued. The use of existing municipal datum will not be allowed unless approved in advance by the Region Survey Coordinator.

A complete description of the benchmark used and the date on the datasheet that states the elevation must be included in the survey project file.

5.8.3 Benchmarks

A complete and accurate network of vertical control monuments (benchmarks) must be established for preliminary and construction surveying. Benchmarks for CDOT project control consist of the primary control monuments and their corresponding elevation data shown on the Project Control Diagram.

<u>CDOT Primary Control Monuments and Benchmarks are typically one of the same</u>.

5.8.4 Setting of Primary Control Benchmarks

Primary control benchmarks shall be set in accordance with this manual, and set in locations that will not be disturbed by or conflict with the project, construction, or maintenance activities. The primary control benchmark spacing shall not exceed 0.6 mile from other benchmarks. Primary control benchmarks shall have a witness post installed within 2 ft and facing the benchmark, or as approved by the engineer. Primary control benchmarks and witness posts materials shall be furnished by CDOT in accordance with M & S Standards M-629-1. (See Chapter 1 – General, for additional information)

Differential leveling is the CDOT approved process for determining and establishing elevations of any primary control benchmark. Only closed level circuits will be allowed for primary elevation control.

The primary control benchmark spacing requirement is based on the limitations of leveling equipment. The spacing requirement may be varied only if the leveling procedure, such as differential leveling, trigonometric leveling, or GPS established elevations, produces acceptable results in tolerance, and is approved by the Region Survey Coordinator. Proof that required tolerance has been attained shall be documented in the field notes.

Primary control benchmarks shall meet the Minimum Vertical Accuracy Tolerance in accordance with this chapter.

5.8.5 Setting of Secondary Control Benchmarks

Secondary control benchmarks shall be set in accordance with this manual in locations that will not be disturbed by or conflict with the project, construction, or maintenance activities. Secondary control benchmark spacing shall not exceed 0.1 mile (500 feet) from other benchmarks. Secondary control benchmarks shall be set solidly into the ground and consist of a material that will hold the required Minimum Vertical Accuracy Tolerance as required in this manual for the entire time of the survey.

Differential leveling is the CDOT approved process for determining and establishing elevations of any secondary control benchmark. Only closed level circuits will be allowed for secondary elevation control. EDM methods shall only be used when approved in advance by the Region Survey Coordinator.

The secondary control benchmark spacing requirement is based on the limitations of leveling equipment. The spacing requirement may be varied only if the leveling procedure, such as differential leveling, trigonometric leveling, or GPS established elevations, produces acceptable results in tolerance, and is approved by the Region Survey Coordinator. Proof that required tolerance has been attained shall be documented in the field notes.

Secondary control benchmarks shall meet the Minimum Vertical Accuracy Tolerance in accordance with this chapter.

5.8.6 Minimum Vertical Accuracy Tolerance

The following Minimum Vertical Accuracy Tolerance shall apply to all CDOT Class A – Primary control benchmarks and surveys, and all CDOT Class B – Secondary control benchmarks and surveys, including aerial photo control surveys (center and wing points):

In feet, the square root of the total horizontal distance of the differential level loop in miles multiplied by 0.035 feet.

$$0.035\,ft\sqrt{d}\ miles$$

The results of this evaluation shall be recorded in the field book for each differential level loop. At least two established benchmarks on the same or mathematically related datum shall be used to verify that the starting mark has not been disturbed. No adjustments of the data used for this evaluation will be allowed.

5.9 Differential Leveling

5.9.1 General

Differential leveling is the most common and economical method for a proficient crew. Differential leveling theory and application can be expressed by two equations as follows:

Elev. A + B.S. (backsight) = H.I. (height of instrument)

H.I. - F.S. (foresight) = Elev. B.

5.9.2 Leveling Definitions

Benchmark (BM): A permanent point of elevation.

Temporary Benchmark (TBM): A semi-permanent point of elevation.

Turning Point (TP): A point temporarily used to transfer an elevation.

Backsight (BS): A rod reading taken on a point of known elevation in order to establish the elevation of the instrument line of sight.

Height of Instrument (HI): The elevation of the line of sight through the level.

Foresight (FS): A rod reading taken on a turning point, benchmark, or temporary benchmark in order to determine it's elevation.

Intermediate Foresight (IS): A rod reading taken at any other point in order to determine it's elevation.

5.9.3 Curvature and Refraction

The line of sight through a well maintained, and adjusted level, is in fact almost a horizontal line perpendicular (or plumb) to the pull of gravity at the level's particular location. All rod readings taken with the level will contain errors over a distance known as curvature and refraction. Curvature is the result of the curvature of the Earth, and refraction is the result of light bending as it passes through one medium into another. Although the effect of curvature is quite small (about 0.024 feet over a 1000 foot distance) the combined effect of curvature and refraction has a significant effect on leveling as shown in the table below:

Effects of Curvature and Refraction:

Distance (m)	30	60	100	120	150	300	1 km
(c + r)m	0.0001	0.0002	0.0007	0.001	0.002	0.006	0.068
Distance (Ft)	100	200	300	400	500	1000	1 mile
(c + r)ft	0.000	0.001	0.002	0.003	0.005	0.021	0.574

Table 5 – 3

The following leveling techniques shall be used to minimize the effects of curvature and refraction:

1. Site distances shall average 250 feet in length.

2. Site distances between turning points shall not exceed 500 feet maximum.

3. HI differences shall be as such to minimize the temperature differences due to air temperature graduates between instrument heights.

4. The level shall be setup midway between the BS and FS turning points, keeping the sights balanced.

5.9.4 Equipment Types

The dumpy level is the basic leveling instrument. At one time it was used extensively on all engineering projects. Today however, it has been replaced by more sophisticated level instruments as follows:

1. Automatic optical levels
2. Automatic digital levels

The digital level is the preferred instrument for CDOT primary and/or secondary control level work. The advantages of the digital level is the electronic recording of data opposed to hand written field notes, as well as the level's capabilities to electronically perform calculations for balancing sites, distances, elevation differences and level circuit closures, to name a few. A digital bar code level rod is required to take readings with a digital level, however, most digital levels are also capable of being used as an optical level as well.

When optical levels are used, the Philadelphia rod shall be utilized to obtain rod readings. Fiberglass or other types of so called "Sewer Rods" or telescoping rods shall not be used for any primary or secondary control level work. Hand levels can be used as an aid in preventing the instrument from being set up too high or too low.

5.9.5 Methods

There are four methods commonly used for differential leveling:

1. Single-wire
2. Direct reading rod (Lenker Rod)
3. Double rod

4. Three-wire

Three-wire leveling is used in conjunction with an invar rod to obtain higher orders of accuracy for work such as relocating NGS, USGS, or other such benchmarks. Leveling is generally run in two directions, the original run and the return run.

5.9.6 Single Wire

Single-wire leveling is the most common method of leveling and is used extensively throughout preliminary and construction surveying.

5.9.7 Direct Reading Rod (Lenker Rod)

The direct reading rod, also known as the lenker rod, shall not be used in place of a Philadelphia rod for running primary or secondary control level circuits.

5.9.8 Double Rod

Double rod leveling is the most reliable method for eliminating blunders and errors. It is also the most time consuming and should not be used except when a very high degree of precision is required. Extreme precaution must be taken to prevent errors in recording.

In double rod leveling, plus and minus sights are taken from two rods (on separate lines) for each setup of the instrument. These are carried in separate columns of the field notes. From these rod readings, two heights of instruments will be computed. Any considerable discrepancy between the two H.I.'s for one setup will indicate that a mistake has been made and the readings shall be re-taken.

5.9.9 Profile Leveling

Profile leveling notes record the elevation and description of points along the centerline or control line that have previously been surveyed or staked. The arrangement is much the same as that of level notes. The station numbers are entered in the first column, and for clarity, the profile elevations are shown in a column separate from the turning point. The descriptions of the elevation points on the right hand page should be kept brief. Obtaining profile elevations directly from a direct reading rod saves considerable time. Profile leveling is generally used if the cross sections are going to be taken by transit or theodolite methods.

5.9.10 Reduction of Errors

The following precautions and techniques should be observed in order to eliminate or reduce the effect of errors:

1. Length of sights should be limited to a distance that permits rapid, distinct reading of the rod without eyestrain. For average conditions, this would be approximately 250 feet. For consistent results, the length must be shortened as observing conditions change. Back sights and foresights from any one setup must be practically equal. This will minimize the effect of curvature, refraction, and imperfection in the instrument. Paced distances are usually close enough. The distance between turning points should never be more that 500 feet.

2. Height observation should be such that the difference in refraction of backsights and foresights is negligible. Refraction varies with the difference in temperature between the ground and the air above it. Usually, reading the rod one foot or higher above ground level will be satisfactory.

Early morning and late afternoon are the most critical times of day.

3. The speed of reading the backsights and foresights from any given setup has as much effect on accuracy as any leveling operation. It is essential that all observations from any one HI be rapidly completed. The greater the time interval between backsights and foresights, the greater the change in conditions affecting the stability of the instruments. Hesitation in reading the rod will increase eyestrain and fatigue, possibly detracting from the readings accuracy. The instrument should be set up on firm, stable ground whenever possible, to help prevent settling of the tripod legs.

4. A wind velocity that does not cause a noticeable disturbance in the stability of the level and rod positions is beneficial. This is particularly true on sloping terrain. Wind has the effect of mixing the air and thus reducing differential refraction.

5. To ensure a more accurate reading, the rod person should lean the rod slowly toward and then away from the level, passing through vertical each time, this is know as tilting the rod. The lowest reading on the rod is the correct value and the same as if the rod were held perfectly plumb. For less accurate work, the rod person can balance the rod between his fingers. When available, rod levels can also be used and offers a great advantage over tilting the rod.

6. Targets should not be used except for reciprocal leveling. Their use in differential leveling wastes time and reading precision is frequently less than by direct reading.

7. Telescope observations are to be made using one place on the cross hair. This will eliminate errors due to inclined horizontal cross hairs. A good place is just right or left of the vertical cross hair.

8. It is essential that the bubble be in the same position for both the backsights and foresights. In Dumpy levels, the level vials are usually graduated in 2 mm intervals. The angular value per graduation for most engineering levels used is 20 or 30 seconds. One division of a 30 second vial at 150 feet could cause an error of 0.015 foot. The instrument person must be in the habit of always checking the bubble just before and just after taking a reading.

9. "Double Turns" can be used to prevent the common one foot bust. double turns consist of setting an extra turning hub at an approximate one foot difference in elevation from the regular turning hub. Thus, one foot errors can readily be caught.

10. If rerunning portions of the leveling work is required because of errors or blunders, longer sights and fewer setups are used to detect large mistakes.

11. Instruments should be checked for adjustment prior to running a bench line. Two pegging the level is a good check. The field notes for this test must be recorded and maintained as a portion of the instrument calibration requirements. (See Two Peg Test for Levels, for additional information)

12. All turning points and benchmarks must be firm and definite to the extent that the shoe or foot of the rod will make contact at only one point. When the point is on a rock or on a paved surface, it should be circled with keel or paint. On single wire leveling, as many turning points as necessary should be semi-permanent, but identified so they may be recovered to close the circuit.

13. Benchmarks must be objects that can be easily described and positively identified. Benchmarks shall be set at locations least likely to be disturbed. In areas subject to freezing, the base of the

support must extend well below the freezing zone so that frost action will not cause heaving. Benchmarks should not be placed in poles because frequently poles are moved, or they may settle or spike may cause personal injury. In areas where a pole would be the most desirable location, the benchmark should be placed in the ground a safe distance from the pole and referenced to the pole.

14. Benchmarks set in trees using horizontal spikes should be avoided because this scars or injures the tree.

15. Finished gradeline should always be considered in setting a bench. The spacing of benchmarks shall be such that any finished grade point will be within instrument sight of an established benchmark. There are situations where this is impractical. In any case, the distance between benchmarks should not exceed 500 feet. It is just as easy to set a benchmark as it is to set a turning point when you are in a place where it may be useful during construction.

5.9.11 Field Notes

Field notes for level work shall contain sufficient data and information to follow in the footsteps of the surveyor who performed the level work. Field notes for level work require but are not limited to the following:

1. BM monument descriptions (including all monument stamping).
2. BM establishing authority (*i.e.* NGS, USC&GS, USGS, CDOT).
3. BM monument locations (such as highway, milepost, cross streets, to reach descriptions).
4. Benchmark record elevation and datum (include any BM datasheets into the survey project records).
5. Description of all set or found TBM and/or TP used as part of the level circuit.
6. All BS and FS rod readings.
7. All calculated HI.
8. Minimum Vertical Accuracy Tolerance calculations and checks.
9. All adjustments made to the level data.
10. All final BM , TBM, and TP elevations.

5.9.12 Two Peg Test Method for Levels

Prior to the start of any level circuit the level shall be checked by the two peg test method. The two peg test method for levels checks that the line of site through the level’s optical telescope is horizontal when the instrument is plumb (*i.e.* perpendicular to the pull of gravity at the level’s particular location).

To perform the test, two stakes are driven firmly into the ground on a relatively level surface at a distance of 250 – 300 feet apart. The level is then setup midway between the two stakes and rod readings are taken at both locations. If the line of sight through the level is out of adjustment, (therefore is not horizontal), the error of the rods readings will be identical at both rods due to the fact that the level is halfway between the two stakes. Due to this fact, the calculated differences in elevation between the two stakes will be the true difference in elevation.

The level is then moved to either one of the two stakes within a distance equal to the minimum manufactures sight distance of the instrument. Rod readings are again taken on both rods and the elevation difference is then calculated and compared to that of the first elevation differences calculated from when the level was setup midway between the stakes.

If the two sets of elevation differences exceed the instrument's manufactures stated accuracy, the level is out of adjustment. Either a collimation correction shall be performed if the level is capable of doing so, or the level shall be taken to the manufactures shop for repair.

5.10 Project Control Diagram

5.10.1 General

The purpose of the Project Control Diagram (PCD) is to graphically show how the survey was performed in the field. The Project Control Diagram is a diagram for primary control monumentation and the control survey performed to obtain the horizontal and vertical data for the primary control monuments meeting the Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class A – Primary survey as required in this chapter. This is either for a large-scale corridor control survey, a small-scale control survey, or a re-observation of already existing primary control monuments to obtain new and updated data. Whenever a primary control monument is established in the ground a control survey is performed and this diagram completed showing all primary control monumentation and the final survey data obtained for the monumentation. **It is not necessary for aliquot, Right of Way, property, land, or any other property boundary monuments to be shown on this diagram. This diagram shall be filed with the Region Survey Coordinator. This diagram is not required to be deposited with the appropriate county but may be if so desired.**

http://www.coloradodot.info/business/manuals/right-of-way/Chapter%202%20-%20Plans/ROW%20Plan%20Templates/Project%20Control%20Diagram%20Sheets

5.10.2 Minimum Standards

The Project Control Diagram at a minimum shall:

1. Be prepared on half size 11” X 17” sheets in color.

2. Be prepared on CDOT Form 126/126R PCD border sheet with the following contained in the title block:

    a. Project Control Diagram
    b. CDOT Project name
    c. CDOT Project number
    d. CDOT Project Code number
    e. Creation date
    f. Last modified date
    g. Total number of sheets

3. Be prepared at a readable scale using as many sheets as required to readily identify the location of primary control monuments.

4. Show prominent topographic features with names labeled such as highways, roads, streets, milepost, fences, lakes, rivers, streams, tunnels, and buildings, to readily identify the location of primary control monuments.

5. Show all found and set primary horizontal and vertical control monument locations with a solid triangle symbol.

6. Show descriptions of all found and set primary horizontal and vertical control monument material and cap markings including any point numbers or names, and milepost. State if the monument was found or set.

7. Contain a **CHARND Geodetic Coordinate Summary Table** showing all existing CHARND primary control monuments and Continuously Operating Reference Stations (CORS) used to reference and tie in the survey, and their record geodetic control data.

    a. Point's Designation
    b. Latitude
    c. Longitude
    d. Ellipsoid height
    e. Orthormetric height (NAVD 88 elevation)
    f. Mapping angle
    g. Grid Scale Factor
    h. State plane coordinate North
    i. State plane coordinate East
    j. Point description

8. Contain a **Geodetic Coordinate Summary Table** showing the following primary control monument final adjusted geodetic control data.

    a. Point's four digit number
    b. Latitude
    c. Longitude
    d. Ellipsoid height
    e. Orthormetric height (NAVD 88 elevation)
    f. Mapping angle
    g. Grid Scale Factor
    h. State plane coordinate North
    i. State plane coordinate East
    j. Point description (including, highway, milepost, and monument type, *e.g*. Type 2)

9. Contain a **Project Coordinate Summary Table** showing the following primary control monument final adjusted project control data.

    a. Point's four digit number
    b. Northing
    c. Easting
    d. NAVD elevation
    e. Point description (including, highway, milepost, and monument type, *e.g*. Type 2)

10. Show Section, Township, Range, and Principal Meridian designations.

11. Show County, City, and State designations.

12. Have a bar scale and a statement of scale.

13. Have a north arrow.

5.10.3 Minimum Notes and Surveyors Certification

The Project Control Diagram shall, at a minimum, contain the following notes and statement titled as follows:

1. **Surveyor's Statement**

   I, __________________, a professional land surveyor licensed in the State of Colorado, do hereby state to the Colorado Department of Transportation this Project Control Diagram was prepared and the field survey it represents was performed under my responsible charge and, based upon my knowledge, information and belief is in accordance with applicable standards of practice defined by Colorado Department of Transportation publications. This statement is not a guaranty or warranty, either expressed or implied.

   ________________________ ____________

   xxxxxxxx PLS No. xxxxx Date

2. **Basis of Bearing** stating the bearing between two primary control monuments along with a description of the monuments and the datum referenced.

3. **Basis of Elevation** describing at least one existing primary control monument with a NAVD 88 elevation of record, along with a description of the monument, it's location, and the datum referenced.

4. **Coordinate Datum** stating how to convert from state plane coordinates to project coordinates, the statement shall include the following:

   a. Project Elevation
   b. State plane Coordinate Zone
   c. Project Combined Factor
   d. Meters to Feet Conversion (U.S. Survey Foot = 3937/1200)
   e. Northing Reduction (truncated)
   f. Easting Reduction (truncated)
   g. A detailed statement of how to convert from state plane coordinates to project coordinates.

5. **NOTICE:** According to Colorado law you **must** commence any legal action based upon any defect in this survey within three years after you first discover such defect, in no event may any action be commenced more than ten years from the date of certification shown hereon.

6. **NOTE:** This Project Control Diagram is prepared for CDOT purposes only. It is not a Boundary Survey, Land Survey Plat or Right of Way Plat.

5.10.4 Re-use of Previous or "Historical" Control Surveys

Previous or "Historical" Control Surveys may be re-used for new projects in lieu of performing another Primary Horizontal and/or Vertical Control Survey thereby eliminating the need to produce a new Project Control Diagram if the following conditions are met and documented:

1. A previous or "Historical" Control Survey exists.

2. The Control Survey is signed and sealed by a Professional Land Surveyor licensed in Colorado.

3. The Control Survey's Primary Control monuments have been recovered and found undisturbed.

4. The Control Survey's Geodetic and Project control coordinates and elevations have been field verified to be within the horizontal and vertical survey tolerance required for the new project.

5. The re-use of the existing Control Survey has been approved by the Region Survey Coordinator.

Once the above conditions have been met and documented a note similar to the following shall be added to the existing Control Survey for its re-use and inclusion into the new project plans:

> Note: This Control Survey was completed under Project Number: _____________ Project Code: _____ on ___________. A signed and sealed copy is on file within the records of CDOT Region __ Survey office. The information contained hereon has been approved by the CDOT Region Survey Coordinator for re-use on Project Number: _____________ Project Code: _____. All future survey data for this project was acquired using the information on this Control Survey.

Additional information about the new project such as project number, project code, designation, and dates should be added to the Control Survey only as necessary to establish the relationship between the old and the new projects.

5.11 Right of Way Survey

5.11.1 General

There are two phases of the Right of Way survey as follows:

6. Preliminary
7. Final

The preliminary Right of Way phase gathers data of the existing physical evidence found in the field in order to determine the existing Right of Way boundary. The final Right of Way phase is to design the new Right of Way boundary, and to monument that boundary in the field by setting Right of Way monumentation. The following specifications shall apply to both the preliminary and final Right of Way phases, from the gathering of preliminary field data, to setting of the final Right of Way monumentation in the field.

5.11.2 Performed by Professional Land Surveyor

The Memorandum of Understanding (MOU) between CDOT and the State Board of Registration for Professional Engineers and Professional Land Surveyors requires that Right of Way Surveys and boundary monumentation be performed under the direction and control of a Colorado professional land surveyor.

See Chapter 1 – General, for additional information.

5.11.3 Preliminary Phase

The preliminary phase of the Right of Way Survey consists of locating all existing monumentation in field such as:

1. Public Land Survey System (PLSS) aliquot monuments
2. Right of Way monuments
3. Property boundary monuments
4. Easement monuments
5. Survey alignment monuments
6. Any other monuments identified in the Preliminary Survey Scope

After both the office research and the preliminary phase are complete, a boundary analysis is performed to determine the Right of Way geometry and boundary limits. This analysis may include other types of surveys such as topographic surveys.

> **<u>Under no circumstances shall any PLSS, Right of Way, easement, or property boundary monument used for the boundary analysis be located by topography survey accuracy tolerances or methods.</u>**

5.11.4 Accuracy Tolerance

All Right of Way surveys (preliminary and final) shall be tied to the CDOT approved primary control survey referencing the primary control monument data shown on the Project Control Diagram and shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey as required in this chapter.

5.11.5 GPS Survey Methods

All Right of Way surveys (preliminary and final) performed by GPS methods shall be performed in accordance with Chapter 3 – GPS Specifications of this manual meeting the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey as required in this chapter.

5.11.6 Conventional Survey Methods

All Right of Way surveys (preliminary and final) performed by conventional survey methods shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey as required in this chapter by performing one or more of the following methods as approved by the Region Survey Coordinator:

1. The monuments (found or set) shall be tied to the primary control survey by closed traverse methods consisting of direct and reverse (face 1 and face 2) instrument readings, beginning and ending on two different primary control monuments. The closed traverse shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey as required in this chapter. No adjustment of the data will be permitted without the consent of the Region Survey Coordinator. The final coordinate data for the Right of Way monument shall be obtained from the unadjusted closed traverse.

2. The monuments (found or set) shall be tied to the primary control survey by double side shots consisting of direct and reverse (face 1 and face 2) instrument readings from one primary control monument with the backsight referencing another primary control monument, then a second set of direct and reverse readings are taken from a different primary control monument. The difference of these observations shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey as required in this chapter. No adjustment of the data will be permitted without the consent of the Region Survey Coordinator. The final coordinate data for the Right of Way monument shall be the average of the sets of double side shots.

3. The monuments (found or set) shall be tied to the primary control survey by direct and reverse (face 1 and face 2) instrument readings in both angle right and angle left modes (*i.e.* closing the horizon). The difference of these angle right and angle left observations shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey as required in this chapter. No adjustment of the data will be permitted without the consent of the Region Survey Coordinator. The final coordinate data for the Right of Way monument shall be the average of the angle right and angle left observation sets.

4. Open ended traverse or single side shots shall not be accepted for any preliminary or final Right of Way survey.

5.11.7 Right of Way Monuments Defined

Right of Way monuments are defined by the Memorandum of Understanding between CDOT and the State Board of Registration for Professional Engineers and Professional Land Surveyors as “Markers” used to define the Colorado state transportation boundaries in the field as per CRS 38-51-104. These markers are not to be confused with aliquot corners or corners that define the intersecting property lines with the highway boundary.

Furthermore, boundary surveys of adjacent properties are not completed by CDOT and any discrepancies observed are not adjusted or resolved. Right of Way monuments are NOT set to delineate the property boundary lines of adjacent landowners.

5.11.8 Final Phase (Right of Way Monumentation)

Right of Way monuments shall be set at their corresponding coordinates as shown on the monumentation sheet of the Right of Way Plans. When monumenting the Right of Way, it is the surveyor's responsibility to verify the latest set of Right of Way plans are being used. After the Right of Way monument locations are staked in the field, any necessary utility locates should be called for prior to setting the monument. (See Chapter 2 – General Procedures, Underground Utility Locates Prior to Installing Monumentation, for additional information.)

All Right of Way monuments set shall be established within the Minimum Horizontal Accuracy Tolerance as required in this chapter for a CDOT Class B – Secondary survey.

Right of Way monuments shall be set at the locations as shown on the Right of Way Plans, which include the following locations:

1. All angle points or changes of directions.

2. At the beginning and ending of curves.

3. At the points of change of direction or changes of radius of any boundary defined by circular arcs.

4. Not to exceed 1400 feet apart along any straight boundary line.

5. Any other points as approved by the Region Survey Coordinator due to field conditions encountered during setting of the Right of Way monumentation.

Right of Way monuments shall have a witness post installed within 2 ft and facing the monument, or as approved by the Region Survey Coordinator. For setting easement monuments the witness post requirement may be waived by the Region Survey Coordinator.

CDOT typically uses the following types of witness post:

1. Orange carsonite (typically used on the plains of Colorado)

2. Green carsonite (typically used in the mountains of Colorado)

3. Metal license plate type (typically used in areas subject to animals or unique situations requiring a more robust witness post)

All Right of Way monument caps set in the field shall be stamped with the following:

1. CDOT Project Code number
2. Point number as shown on the Right of Way Plans
3. Colorado PLS number setting the monument

All Right of Way monuments set in the field shall be shown on the Final set of Right of Way Plans in accordance with the CDOT Right of Way Manual, Chapter 2 – ROW Plans. The Colorado PLS who is in responsible charge for setting the Right of Way monuments shall stamp her/his number on the monument cap, and shall certify on the Right of Way Plans to setting of the Right of Way monuments in the field.

Often the surveyor in responsible charge of the Right of Way Plans and the surveyor in responsible charge of setting the Right of Way monuments in the field is not the same individual. Care must be taken to ensure any monuments set in the field at locations different than that shown on the Right of Way Plans are communicated to the Right of Way plans section, and the final Right of Way Plans are corrected to show these new monument locations and descriptions prior to depositing the plans with the appropriate county and the Region Survey Coordinator.

Right of Way monuments, witness posts, and monument box materials shall be furnished by CDOT in accordance with M & S Standards M-629-1 (See Chapter 1 – General, for additional information).

5.11.9 PLSS Aliquot Monuments

The Colorado professional land surveyor in responsible charge shall make a diligent search for any required aliquot monuments, and shall restore, rehabilitate, upgrade and file monument records for any aliquot monuments used as boundary control, or as required in the Preliminary Survey Scope, within the survey project limits in accordance with Colorado Revised Statutes, State Board bylaws and rules, and the Memorandum of Understanding between CDOT and the State Board of Registration for Professional Engineers and Professional Land Surveyors. The procedures used shall be as specified by Colorado Revised Statutes, and the current BLM Manual of Survey Instructions of the Public Lands of the United States.

CDOT as well as contract consultants performing work for the department shall strictly adhere to the restoration and upgrading of monuments, and filing of monument records.

The Colorado professional land surveyor in responsible charge shall file monument records with the State Board of Registration for Professional Engineers and Professional Land Surveyors, a signed and sealed monument record shall be sent to the Region Surveyor Coordinator. The Colorado PLS who is certifying the monument record shall be the same PLS whose number is stamped on the monument in the field.

Photographs of all aliquot monuments restored, rehabilitated, or upgraded shall be sent to the Region Survey Coordinator. The photographs at a minimum shall show:

1. Close up of the existing found monument showing the cap markings.
2. Each cardinal direction with the monument and the horizon in view.
3. Close up of the restored, rehabilitated, or upgraded monument.

Aliquot monuments, witness posts, and monument box materials shall be furnished by CDOT in accordance with M & S Standards M-629-1 (See Chapter 1 – General, for additional information).

Setting of any aliquot monument shall meet the Minimum Horizontal Accuracy Tolerance for a CDOT Class B – Secondary survey as required in this chapter.

5.11.10 Aliquot Reference Monuments

Aliquot monuments may require reference monuments be established for ease of access and instrument occupancy. CDOT has a long-standing procedure for establishing reference monuments that has proven to be useful for both public and private surveyors. In certain circumstances, the occupation of reference monuments will make it safer, and more convenient than occupying the original aliquot monument.

CDOT Type 1 or Type 5 monuments shall be set for aliquot reference monuments.

All distances shall be measured to 0.01 feet.

Reference monuments shall have a witness post installed within two ft and facing the reference monument, or as approved by the Region Survey Coordinator.

Reference monuments and witness posts materials shall be furnished by CDOT in accordance with M & S Standards M-629-1 (See Chapter 1 – General, for additional information).

Reference monuments shall be established by one of the following methods as specified by the Region Survey Coordinator:

2-Point

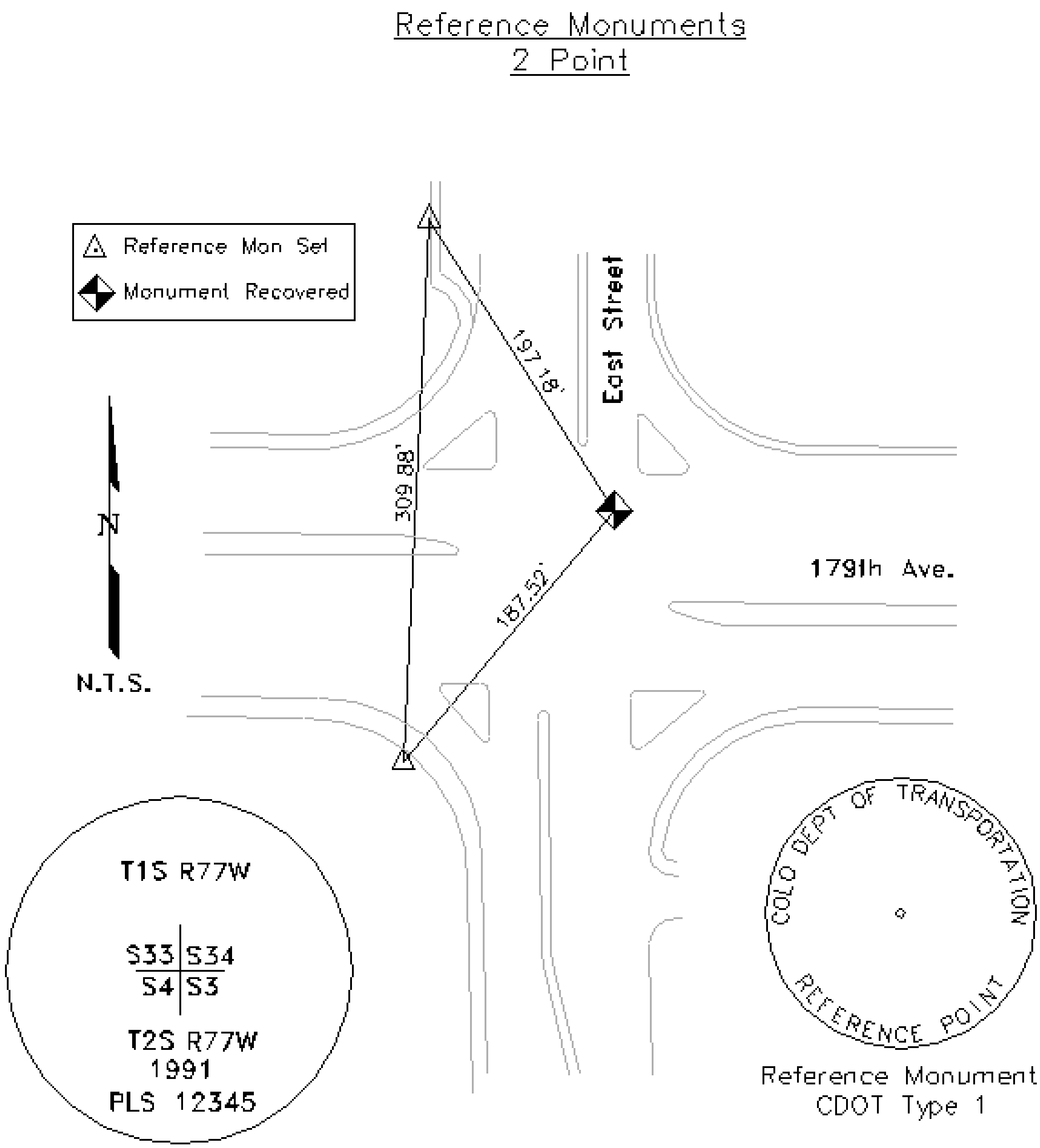

Figure 5 – 1

3-Point

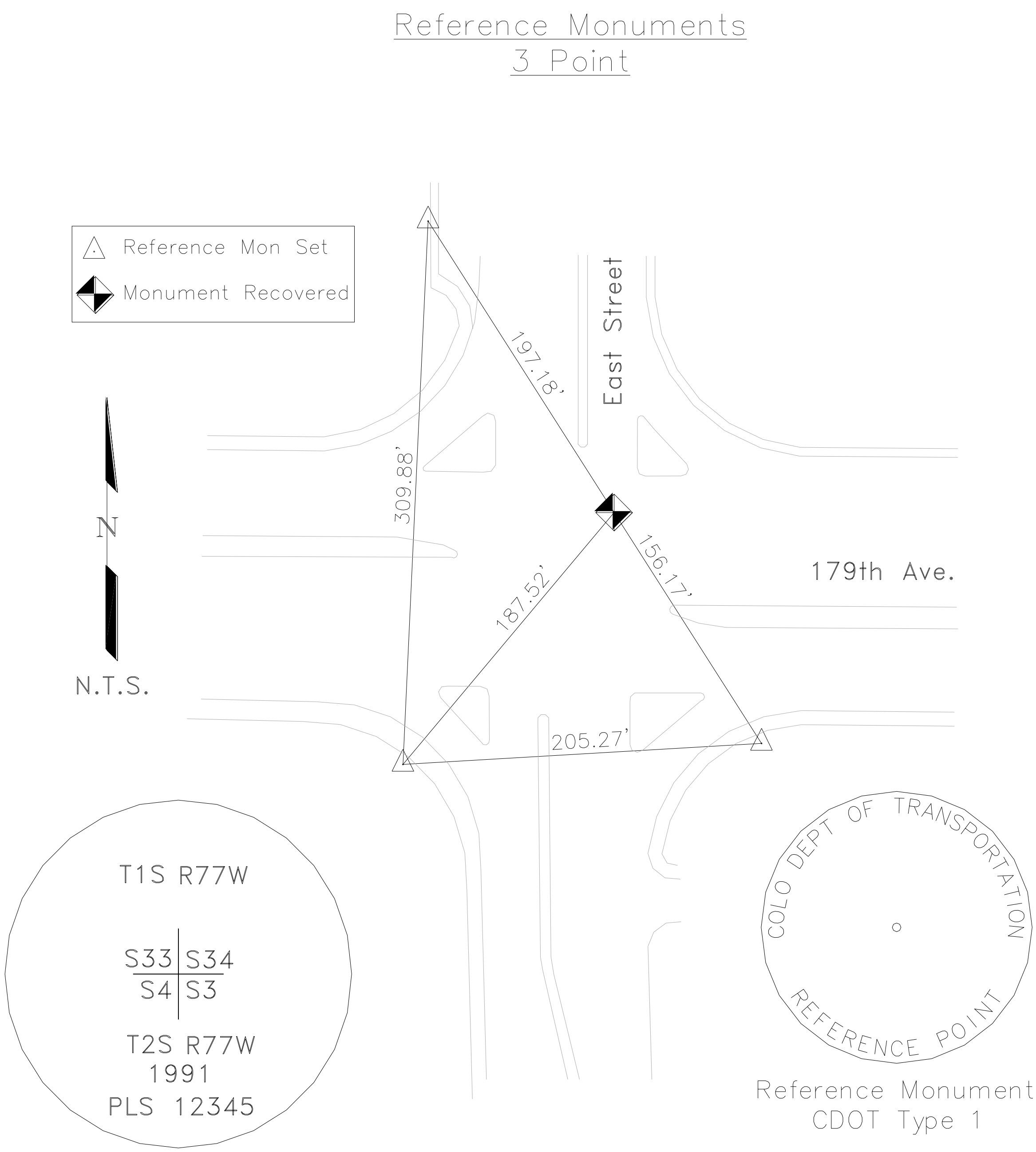

Figure 5 – 2

4-Point

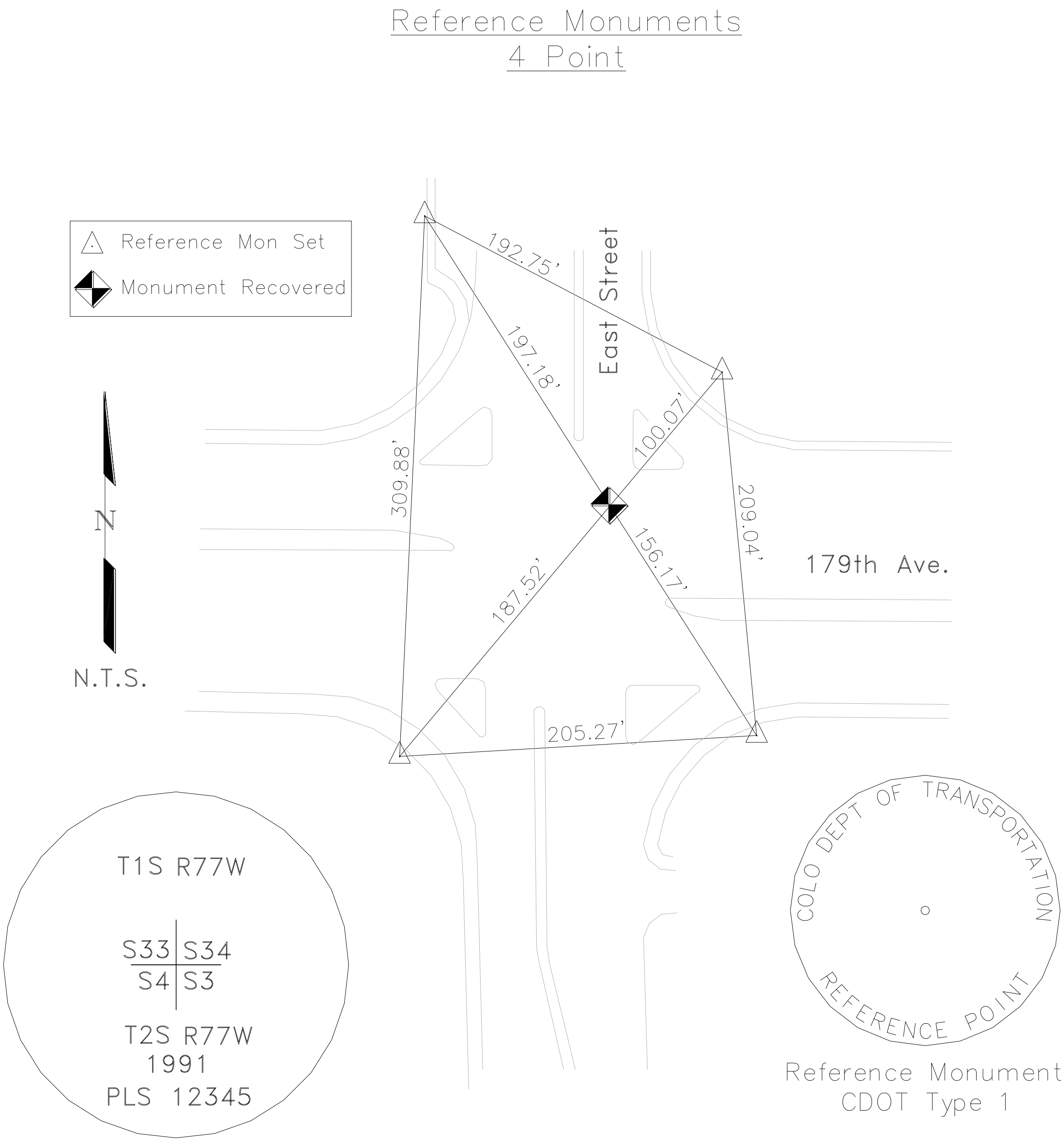

Figure 5 – 3

5.12 Land Survey Control Diagram

5.12.1 General

The purpose of the Land Survey Control Diagram (LSCD) is to graphically show how the survey was performed in the field and present evidence found in the field. The Land Survey Control Diagram is a diagram for land property boundary monumentation and the land survey performed to obtain the horizontal and vertical data for the land property boundary monumentation meeting the Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class B – Secondary survey as required in this chapter. **This diagram shows all aliquot, Right of Way, property, land, easement, and any other property boundary monuments along with the final data obtained for these monuments.** No determination shall be made as to if these found monuments are in their proper position and if they are in fact at the corners they are intended to monument. Additional monumentation and the final data obtained for these monuments may be shown as determined necessary by the Region Survey Coordinator (*e.g.* control monuments). **This diagram shall be filed with the Region Survey Coordinator. This diagram is required to be deposited with the appropriate county within twelve months from the Right of Way authorization plans submittal date.**

http://www.coloradodot.info/business/manuals/right-of-way/Chapter%202%20-%20Plans/ROW%20Plan%20Templates/Land%20Survey%20Control%20Diagram%20Sheets

5.12.2 Minimum Standards

The Land Survey Control Diagram at a minimum shall:

1. Be prepared on half size 11” X 17” sheets in color.

2. Be prepared on CDOT Form 126/126R LSCD border sheet with the following contained in the title block:

    a. Land Survey Control Diagram
    b. CDOT Project
    c. CDOT Project number
    d. CDOT Project Code number
    e. Creation date
    f. Last modified date
    g. Total number of sheets

3. Be prepared at a readable scale using as many sheets as required to readily identify the location of evidence found in the field.

4. Show all surveyed topographic features including edge of roadways, trails, paths, utility locations, and possession lines such as fences, buildings, and retaining walls.

14. Show prominent topographic features with names labeled such as highways, roads, streets, milepost, fences, lakes, rivers, streams, tunnels, and buildings, to readily identify the location evidence found in the field.

15. Show all found boundary monument locations with black solid circle symbols. Show all found aliquot monuments locations with diamond symbols.

16. Show descriptions of all found boundary monument materials and cap markings.

17. Show all aliquot monument upgrades describing the upgrade monument materials set and cap markings.

18. Contain the following found monument coordinate tables titled as follows:

    a. **Found Aliquot Monument Coordinate Table**

    b. **Found Right of Way Monument Coordinate Table**

    c. **Found Boundary Monument Coordinate Table**

    d. **Found Easement Monument Coordinate Table**

    e. Each of the above found monument coordinate tables shall show the following monument project data.

        i. Point's four digit number
        ii. Northing
        iii. Easting
        iv. NAVD elevation (only if required)
        v. Point description (including, monument material and cap markings)

19. Show Section, Township, Range, and Principal Meridian designations.

20. Show County, City, and State designations.

21. Have a bar scale and a statement of scale.

22. Have a north arrow.

5.12.3 Minimum Notes and Surveyors Certification

The Land Survey Control Diagram shall at a minimum, contain the following notes and statement titled as follows:

1. **Surveyor's Statement**

   I, ___________________, a professional land surveyor licensed in the State of Colorado, do hereby state to the Colorado Department of Transportation this Land Survey Control Diagram was prepared and the field survey it represents was performed under my responsible charge and, based upon my knowledge, information and belief is in accordance with applicable standards of practice defined by Colorado Department of Transportation publications. This statement is not a guaranty or warranty, either expressed or implied.

_________________________ ____________
xxxxxxxx PLS No. xxxxx Date

2. **Basis of Bearing** stating the bearing between two primary control monuments along with a description of the monuments and the datum referenced. **(Shall be the same basis of bearings used for the Project Control Diagram)**

3. **Basis of Elevation** describing at least one existing primary control monument with a NAVD 88 elevation of record, along with a description of the monument, it's location and the datum referenced. **(Shall be the same basis of elevation as for the Project Control Diagram.)**

4. **Coordinate Datum** shall make reference to the Project Control Diagram that the Land Survey Control Diagram coordinates are tied into. **(The description of how to convert from state plane coordinates to project coordinates shall not be shown on this diagram as the geodetic coordinates are not listed on this diagram).**

5. **NOTICE:** According to Colorado law you **must** commence any legal action based upon any defect in this survey within three years after you first discover such defect, in no event may any action be commenced more than ten years from the date of certification shown hereon.

7. **NOTE:** This Land Survey Control Diagram is prepared for CDOT purposes only. It is not a Boundary Survey, Land Survey Plat, or Right of Way Plat. No determination has been made to determine if the found monuments as shown are in their proper position or if they are at the corners they are intended to monument.

6. **NOTE:** Title Policy, Title Commitment, and title research, are not a part of this survey, therefore easements, rights, and restrictions of record were not researched and are not shown on this diagram.

7. **NOTE:** All monuments are located from existing CDOT Primary Control Monuments. The Primary Control Survey was performed at a higher degree of accuracy than the secondary control survey shown on this diagram.

5.13 Boundary Analysis

5.13.1 General

After the office research, field search, and preliminary Right of Way survey are complete, the office information is merged with the field evidence located, and a boundary analysis is performed to determine the Right of Way boundaries. This analysis may include other types of surveys such as a topographic survey. Generally, the analysis should result in a reconstruction of the original survey by "following in the footsteps of the original surveyor". The final boundary analysis shall be made by the Colorado professional land surveyor in responsible charge of the Right of Way Plans.

Under no circumstances shall any PLSS, Right of Way, easement, or property boundary monument used for the boundary analysis be located by topography survey accuracy tolerances or methods.

5.14 InRoads TMOSS

5.14.1 Topography MOdeling Survey System (TMOSS)

InRoads Topography MOdeling Survey System (TMOSS) is a CDOT developed coding system designed to automate and standardize surveying and photogrammetric mapping. InRoads TMOSS coding is a standard alpha/numeric code compatible for processing InRoads software.

InRoads TMOSS codes shall be used when any control, topographic, drainage, utility, or aerial survey data is collected for CDOT use.

InRoads TMOSS Code books are available through CDOT Bid Plans by contacting the following:

Colorado Department of Transportation
4201 E. Arkansas Ave., Room 117
Denver, CO 80222
(303) 757-9313

CDOT TMOSS:

The above link provides information on obtaining InRoads TMOSS Code Manuals.
http://www.coloradodot.info/library

See Chapter 9 – InRoads Survey CDOT Best Practices for additional information.

5.14.2 Special Requirements

The following information shall be included with the InRoads TMOSS code along with descriptive notes and field sketches as necessary to provide additional information not contained in the code:

1. Primary control monuments shall include a detailed description of the physical monument material and cap markings.

2. Secondary control monuments (including boundary monuments) shall include a detailed description of the physical monument material and cap markings.

3. Access Code 277 - for county roads, streets, or subdivisions, public or private, driveways, and field approaches, residential, agricultural, or commercial (this must be for a observation taken on the access).

4. Drainage Code 283 - for drainage structure outlets (this must be for a observation taken on the drainage structure).

5. Advertising Signs - show dimensions, whether lighted or non-lighted, owner, and state highway registration number. Tie down to show skew, placement, etc.

6. Bridges and CBC's - the minimum information that should be collected on all major structures is the feature carried, feature crossed, structure number and structure type. Then collect sufficient information to establish the curb to curb width, curb or sidewalk widths, number of spans, span lengths, wing wall lengths, and angles, skew of abutments and piers, and the utilities present.

7. Special cases will arise in the form of structures to be widened or rehabilitated and in these instances staff bridge or the structure consultant will submit any special requirements at the presurvey conference. Check to see if there is a set of as constructed plans available, these could be of great value in showing what parts are being tied and/or measured.

8. Buildings, Foundations or Basements - show dimensions, and type of construction. Collect shots at all possible corners to show skew.

9. Irrigation Structures - include a detailed drawing of the structure with dimensions and elevations. Show name of ditch and owner of ditch (this may require additional research).

10. Miscellaneous Codes - all shots coded as being a miscellaneous feature will have a description of the feature included in the note field associated with that code.

11. Overhead Power and Telephone Lines - show pole and direction of lines as well as overhead wire elevations when appropriate (observations should be taken at the edge of traveled surface or painted lane lines). Show name of owner and capacity of lines.

12. Sanitary and Storm Sewer Lines - show size, type, and manhole locations. Include invert, and rim elevations and indicate direction of flow. Observations should be connected to each manhole and inlet on the line.

13. Underground Power and Telephone Lines - show locations and direction of lines. Show name of owner.

14. Water and Gas Lines - show size, type of pipe and location of valves. Show name of owner.

15. Wells - show size of well and type of pump.

See Chapter 9 – InRoads Survey CDOT Best Practices for additional information.

5.15 Topographic Survey

5.15.1 General

The purpose of a topographic survey is to gather field data to determine the configuration (relief) of the surface of the earth (ground) and the location of natural and artificial objects thereon.

CDOT utilizes the data from topography surveys for the following purposes:

1. Design for construction
2. Hydrology
3. Right of Way design
4. Environmental
5. Maintenance
6. Property Management

5.15.2 Types of Topographic Surveys

The actual collecting of topographic data can be accomplished in a variety of ways, each having their own unique accuracies, cost and production times. A few examples of the methods for collecting topographic data is as follows:

1. Survey methods
    a. Conventional methods
    b. Global Positioning System methods
2. Aerial photogrammetry survey methods
    a. Supplemental Survey
3. Remote Sensing methods
    a. Light Detection and Ranging (LIDAR)
    b. 3D laser scanning
    c. Satellite imagery

It is critical that before selecting the topographic survey method to be used that the project needs are identified. This is typically done through the initial scoping of the project to determine the projects limits, factors, and requirements. After the scoping has been completed the Region Survey Coordinator shall identify the appropriate topographic survey method that shall be used.

All topographic surveys performed by CDOT or contract consultants shall be performed utilizing InRoads TMOSS coding with file formats accepted for use by InRoads.

See Chapter 9 – InRoads Survey CDOT Best Practices for additional information.

Right of Way surveys are not included as part of the topography surveys due to the fact that the accuracy tolerance and survey methods for Right of Way surveys are more stringent than that of topography surveys. If any boundary monuments are located during the topographic survey they shall be located by the methods and accuracy tolerances of a CDOT Class B – Secondary survey as required in this chapter.

Under no circumstances shall any PLSS, Right of Way, easement, or property boundary monument used for the boundary analysis be located by topography survey accuracy tolerances or methods.

5.15.3 Topographic Surveys for use by 3D Engineered Construction Surveys (3DECS)

3DECS is the use of Global Positioning System (GPS) and/or Robotic Total Station (RTS) instruments to guide construction equipment operations by comparing 3D model information in real time.

During 3DECS the construction contractor may use 3D model information (i.e. DTM) provided by CDOT, or as generated by the contractor in conjunction with construction equipment controlled by GPS and/or RTS instruments to guide the equipment during construction operations of specific items such as subgrade, subbase, base course and other roadway structure materials, ditches and other planned excavations and embankment of the project.

Unlike design processes that use profiles, cross sections, and templates for calculations of cuts and fills, 3DECS is undertaken by comparing 3D model information of the topographic survey and the design 3D models in real time. Any major design "event points" where grade changes or transitions may occur in the design model are directly affected by how well the topographic survey represents the existing ground, and how well it correlates to the design model.

These event points should be considered prior to performing any topographic survey that will eventually be used as part of a 3DECS design process to ensure a condensed number of 3D points are collected for the topographic model. The desired result of a condensed topographic survey is a better relationship between topographic points and the design event points.

For topographic design surveys TMOSS data collection methods a reduction of 25% to the typical interval in-between topographic points collected in and around the area of event points is recommended, this equates to reducing the distance between topo points collected by 25' for every 100'. The field surveyor may verify whether or not this reduction was sufficient enough when the topographic survey and design event points are compared to one another within the 3D models, and may make any necessary adjustments to the intervals for any future topographic surveys. If it is shown that more of a reduction is needed this section of the survey manual may be revised.

For 3DECS topographic surveys collected by photogrammetry, imaging, or remote sensing methods, the condensing of the topographic survey is achieved in the office by using a condensed number of topographic points generated within the software being used, therefore no adjustments to the field data collection processes is needed.

The field surveying methods and procedures described in this survey manual shall be followed for any 3DECS topographic survey as they are for non-3DECS topographic surveys. The following are reminders of some of the do's and don'ts to keep in mind while preforming topographic surveys for 3DECS. Additional information may be found in this survey manual:

- Use a fixed height pole for the prism or GPS rover whenever possible.
- Conventional topographic observations shall not exceed 750 feet from the instrument setup for any CDOT Class C – TMOSS surveys.
- Conventional topographic observation shall not exceed 1000 feet from the instrument setup for any CDOT Class D – TMOSS surveys.
- Topographic surveys shall be referenced and tied to CDOT's primary horizontal and vertical control monuments. <u>Do not used assumed coordinates or elevations.</u>

- The horizontal and vertical accuracy tolerances as stated in this survey manual for either a CDOT Class C or Class D – TMOSS survey shall be followed.

- Topographic surveys by Real Time Kinematic (RTK) GPS methods shall use a CDOT approved site calibration, with GPS initializations checked in the field before and after each session of topographic data collection.

- Daily QA/QC of the data collected shall be performed by downloading and viewing the data in MicroStation. The creation of a Triangulation Integration Network (TIN), Digital Terrain Model (DTM) and 3D contours shall be used as part of the QA/QC process.

Additional information about collecting TMOSS data for 3DECS may be found in Chapter 6 – Construction Surveys, and CDOT's Standard Specifications for Road and Bridge Construction Section 625 – Construction Surveying. See Chapter 9 – InRoads for examples of condensed topographic surveys.

5.15.4 Horizontal Accuracy Tolerance

All topographic surveys shall be tied to the CDOT approved primary control network referencing the primary control monument data shown on the Project Control Diagram and shall meet the Minimum Horizontal Accuracy Tolerance for either a CDOT Class C – TMOSS survey or a CDOT Class D – TMOSS survey as required in this chapter.

5.15.5 Vertical Accuracy Tolerance

CDOT Class C – TMOSS surveys within the existing constructed transportation corridor template, shall have a minimum of ninety five percent (95%) of all elevations collected must be within ± one tenth foot (0.10) of the true elevation at a ninety five percent ninety five percent (95%) confidence level in relation to the primary control monuments.

CDOT Class D – TMOSS surveys outside the existing constructed transportation corridor template shall have a minimum of ninety five percent (95%) of the elevations collected by topographic survey data shall have an accuracy with respect to true elevation of ± one half (½) contour interval or better at the ninety five percent ninety five percent (95%) confidence level in relation to the primary control monuments.

No elevations determined by any topographic survey shall deviate from the true elevations by more than one contour interval in relation to the primary control monuments.

5.15.6 Existing Constructed Transportation Corridor Template

The existing constructed transportation corridor template is defined as the area between the points of slope selection. Typically for a two lane highway, this area includes the transportation corridor Z distance, the transportation corridor shoulder, and the transportation corridor traveled way on both sides of the centerline. For an interstate highway, this area includes all of the median as well as the area described above. In urban areas, this includes all the area between the backsides of the sidewalks on both sides of the street.

5.15.7 Method of Verifying Accuracy Tolerance

Accuracy tolerance requirements are evaluated by comparing a cross section string, or a series of random points taken in the field with a the same cross section location, or series of random point locations, extracted from a terrain TIN model produced from the original topographic survey data. The field cross-section string is collected by conventional topographic survey methods and is held as the true representation of what exists in the field in relation to the primary control monuments. The interval between observations on the cross section shall be taken at a minimum of 30 feet, and shall not exceed the interval of the topographic survey at the particular cross section.

The field cross section string or random points are then processed and compared to the TIN model cross section or random points. The difference between the sections is evaluated to determine if the delivered product is within the minimum horizontal and vertical tolerances for either a CDOT Class C or D TMOSS survey as applicable to the cross section being evaluated.

The number of observations which exceed the minimum tolerances shall be totaled, divided by the number sampled to calculate a percent failing. One hundred minus the percent failing yields the percent passing.

No payment will be made for topographic survey data (paper or electronic) until the data has been verified (see Method of Verifying Accuracy Tolerance, for additional information) to be within the required Minimum Horizontal and Vertical Accuracy Tolerances. Any areas determined not to be within the required tolerances will be rejected, reworked by the consultant, re-verified (by cross section or random point locations) to be within required tolerances, and re-submitted at no additional cost to CDOT.

5.15.8 Conventional Survey Methods

All topographic surveys performed by conventional survey methods shall meet the Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class C or D – TMOSS survey as required in this chapter.

> <u>**Due to the effects of curvature and refraction (see Differential Leveling, Curvature and Refraction Table, for additional information) no CDOT Class C - TMOSS conventional topographic observation shall exceed 750 feet from the instrument setup. No CDOT Class D – TMOSS conventional topographic observation shall exceed 1000 feet from the instrument setup.**</u>

Conventional topographic survey methods when performed in accordance with this manual are considered to be the most accurate method of collecting field InRoads TMOSS data for CDOT’s use.

5.15.9 GPS Survey Methods

All topographic surveys performed by GPS methods shall be performed in accordance with Chapter 3 – GPS Surveys and shall meet the Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class C or D – TMOSS survey as required in this chapter.

GPS topographic survey methods when performed in accordance with this manual are considered to be the second most accurate method of collecting field topographic survey data for CDOT’s use.

5.15.10 Aerial Photogrammetry Methods

An aerial photogrammetry survey method utilizes photographic, electronic, digital or other data obtained from an airborne station (*e.g.* a airplane or helicopter). The advantage of obtaining topographic data by aerial survey methods is the efficiency in which large areas of the Earth can be mapped and large volumes of topographic and planimetric data can be obtained. The disadvantage of aerial mapping is that it requires more advanced planning and lead time than conventional or GPS survey methods. The accuracy of aerial surveys are typically much less than that of conventional or GPS survey methods, particularly when there is heavy vegetation or areas of drastic changes in elevation such as mountainous terrain.

Topography surveys are performed to supplement aerial surveys. The purpose of the supplemental survey is to locate those features that require a higher level of accuracy than that of the aerial survey, to locate those features that can not be located by the aerial survey, and to collect information not apparent to the photogrammetrist from the aerial survey.

See Chapter 4 – Aerial Surveys, for additional information.

5.15.11 Remote Sensing Methods

Remote sensing methods includes technology such as Light Detection and Ranging (LIDAR), 3D laser scanning, and satellite imagery. CDOT surveyors shall stay current on advances made in remote sensing technology through education, training, seminars and dealer demonstrations. It is important for CDOT surveyors to take it upon themselves to improve their knowledge and understanding of the appropriate use of such technology. Pilot projects should utilize such technology when it is cost effective and appropriate to do so.

Some of the possible benefits that should be considered are:

1. Savings in survey crew hours, cost, and time.

2. Increased safety by remotely collecting data, therefore removing survey crews from dangerous situations such as traffic.

3. Increase in the number of points collected providing more overall coverage.

As advances in remote sensing technology are made in hardware and processing software that prove the required accuracy tolerance is more easily attained and more cost effective, new specifications for CDOT shall be developed and sections of this chapter shall be revised to stay current with those advances.

5.16 Drainage Survey

5.16.1 General

The purpose of a drainage survey is to ensure that the necessary information needed for hydraulic design will be included in the topographic survey. The following guidelines shall be followed when drainage surveys are conducted:

The Preliminary Survey Scope Form 1217a, shall include all drainage structure requirements of the survey. This form shall be supplemented or confirmed through direct contact with the hydraulic engineer. The project manager should contact the hydraulic engineer at least two weeks prior to the presurvey conference. After the survey requirements have been determined and included on the survey scope, a transmittal of the requirements will be submitted to the Region Survey Coordinator. Following these guidelines will provide the hydraulic engineer with an adequate drainage survey.

If there are any questions about the needed information, the hydraulics engineer should be contacted before starting the survey. The hydraulics engineer will be able to supply predicted design flows, special survey requirements, and potential use of upstream area for detention ponding.

All drainage surveys performed by CDOT or contract consultants shall be performed utilizing InRoads TMOSS coding with file formats accepted for use by InRoads.

Good drainage surveys are necessary for complete hydraulic designs. Channel locations and changes, bridge skew, water stage, and structure relocations are all determined from the drainage survey.

See Chapter 9 – InRoads Survey CDOT Best Practices for additional information.

5.16.2 Horizontal Accuracy Tolerance

All drainage surveys shall be tied to the CDOT approved primary control network referencing the primary control monument data shown on the Project Control Diagram and shall meet the Minimum Horizontal Accuracy Tolerance for either a CDOT Class C – TMOSS survey or a CDOT Class D – TMOSS survey as required in this chapter.

5.16.3 Vertical Accuracy Tolerance

CDOT Class C – TMOSS surveys within the existing constructed transportation corridor template, shall have a minimum of ninety five percent (95%) of all elevations collected must be within ± one tenth foot (0.10) of the true elevation at a ninety five percent ninety five percent (95%) confidence level in relation to the primary control monuments.

CDOT Class D – TMOSS surveys outside the existing constructed transportation corridor template shall have a minimum of ninety five percent (95%) of the elevations collected by drainage survey data shall have an accuracy with respect to true elevation of ± one half (½) contour interval or better at the ninety five percent ninety five percent (95%) confidence level in relation to the primary control monuments.

No elevations determined by any drainage survey shall deviate from the true elevations by more than one contour interval in relation to the primary control monuments.

5.16.4 Method of Verifying Accuracy Tolerance

Accuracy tolerance requirements for drainage structures are evaluated by comparing an independent field location collected in the field with a point extracted from a terrain TIN model produced from the original topographic survey data. The field location is collected by conventional topographic survey methods and is held as the true representation of what exists in the field in relation to the primary control monuments.

The field location is then compared to the TIN model. The difference between the field location and the TIN model are evaluated to determine if the drainage structure is within the Minimum Horizontal and Vertical Accuracy Tolerances for either a CDOT Class C or D - TMOSS survey.

No payment will be made for drainage survey data (paper or electronic) until the data has been verified (see Method of Verifying Accuracy Tolerance, for additional information) to be within the required Minimum Horizontal and Vertical Accuracy Tolerances. Any data not within the required tolerances will be rejected, reworked by the consultant, re-verified to be within required tolerances, and re-submitted at no additional cost to CDOT.

5.16.5 Conventional Survey Methods

All drainage surveys performed by conventional survey methods shall meet the Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class C or D – TMOSS survey as required in this chapter.

> **Due to the effects of curvature and refraction (see Differential Leveling, Curvature and Refraction Table, for additional information) no CDOT Class C - TMOSS conventional drainage observation shall exceed 750 feet from the instrument setup. No CDOT Class D – TMOSS conventional drainage observation shall exceed 1000 feet from the instrument setup.**

Conventional drainage survey methods when performed in accordance with this manual are considered to be the most accurate method of collecting field drainage survey data for CDOT's use.

5.16.6 GPS Survey Methods

All drainage surveys performed by GPS methods shall be performed in accordance with Chapter 3 – GPS Surveys and shall meet the Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class C or D – TMOSS survey as required in this chapter.

GPS drainage survey methods when performed in accordance with this manual are considered to be the second most accurate method of collecting field drainage survey data for CDOT's use.

5.16.7 Aerial Photogrammetry Methods

An aerial photogrammetry survey method utilizes photographic, electronic, digital or other data obtained from an airborne station (*e.g.* a airplane or helicopter). The advantage or obtaining topographic data by aerial survey methods is the efficiency in which large areas of the Earth can be mapped and large volumes of topographic and planimetric data can be obtained. The disadvantage of aerial mapping is that it requires more advanced planning and lead time than conventional or GPS survey methods. The accuracy of aerial surveys are typically much less than that of conventional or GPS survey methods, particularly when there is heavy vegetation or areas of drastic changes in elevation such as mountainous terrain.

Drainage surveys are performed to supplement aerial surveys. The purpose of the supplemental survey is to locate those features that require a higher level of accuracy than that of the aerial survey, to locate those features that can not be located by the aerial survey, and to collect information not apparent to the photogrammetrist from the aerial survey.

See Chapter 4 – Aerial Surveys, for additional information.

5.16.8 Photographs

If the hydraulic engineer deems photographs necessary, they will be requested in the drainage survey requirements transmittal. When requested, photographs shall show existing inlet and outlet configurations, areas of erosion, structures that experience distress during floods, and natural features of the drainage basin. Photographs shall be labeled with the project number, date of photo, description of photo, orientation of the camera, and the photographer's name.

5.16.9 Guidelines

Guidelines for the extent of a drainage survey upstream and downstream are as follows:

1. **Large Bridges**
   [Design flows greater than 20,000 cfs or spans greater than 250']

   a. Consult with the hydraulics engineer before scoping the survey. Requirements will be further discussed at the presurvey conference.

   b. Aerial surveys should be considered for these sites.

2. **Large Culverts/Medium Bridges**
   [Design flows of 2,000 to 20,000 cfs or 20' X 10' CBC to 250' Total Span Bridge]

   a. The survey shall extend 1200 ft. upstream and 1200 ft. downstream from the existing roadway centerline.

   b. Additional survey data must be taken near the upstream and downstream edges of the existing structure including the abutments.

   c. The elevations of the existing structures lowest girders or clearance must be included.

   d. The width of the survey will be determined by the hydraulic engineer.

   e. Survey requirements will be discussed at the presurvey conference.

3. **Medium to Large Culverts**
   [Design flows of 200 to 2,000 cfs or 72" Pipe to 20'X10' CBCs (openings of 28 sq. ft. to 200 sq. ft.)]

   a. The survey shall extend 500 ft. upstream and 500 ft. downstream from the roadway centerline.

   b. Additional survey data must be taken near the upstream and downstream end of the existing structure.

c. The width of the survey will be determined by the hydraulic engineer.

d. Survey requirements will be discussed at the presurvey conference.

4. Small Culverts

[Design flows less than 200 cfs or pipes smaller than 72" (less than 28 sq. ft. openings)]

a. The survey shall extend 100 ft. upstream and 100 ft. downstream from the roadway centerline.

b. Survey data must also be taken at each end of the culvert to determine the structure centerline, the depth of silt, headwall dimensions or type of end section, condition of the present structure, type of flow, vegetation and soil type of banks and bottom.

c. Form 283 is to be supplied for the benefit of the hydraulic section.

d. Discuss further needs at the presurvey conference.

5. Irrigation Canals

a. The water surface profile and the channel invert must both be surveyed. This may result in two separate surveys, unless the surveyors could mark the water surface elevation during flow and take the measurements at a later date when the canal is not in operation.

b. The survey shall extend 1000 ft. upstream and 2000 ft. down stream from the roadway centerline. The downstream portion of the survey will not need to extend the full 2000 ft. if a difference in the water surface elevation of 1/2 ft. has been achieved. Measurements of the water surface profile shall be taken at 100 ft. intervals to +/- of 0.05 ft. The date and time of the water surface profile shall be recorded.

c. Name and address of the ditch owner should be noted. Inquire as to the discharge at the time of the water surface profile. This information should be available from the ditch rider.

d. If the Department's liability is lessened by using the ditch company’s water flow information this should be the procedure used to determine the water surface profile.

6. Storm Drains

a. Survey data must be taken of the profile grade and gutter flow line elevations of the main roadway. The survey must cover all areas of the roadway that contribute drainage. This may entail surveying beyond the project limits. For example, if the project ends in the middle of a vertical curve, the survey must continue to the top of the curve.

b. Survey data must be taken of the profile grade and gutter flow line elevations of all cross streets or road approaches. The survey shall extend up the road approach or cross street 500 ft. or to it's highest point, whichever is less.

c. The location of all curbs, gutters, inlets, culverts, and manholes must be determined. Indicate inlet and pipe depths and sizes (rim and invert elevations). Note the direction of flow in the pipes.

d. The location of all utilities must be determined. Indicate the type, size, and depth of the utilities.

7. Existing Upstream Detention Ponds

a. Detention pond surveys must be accurate enough to draw a contour map with three to five contours.

b. The survey data shall extend up to an elevation equal to the pond overflow elevation.

c. Show any significant topography within the ponding area, such as building foundations, ground floor elevations, and outlet structures.

5.17 Utility Survey

5.17.1 General

The purpose of a utility survey is to gather data of underground and above ground utilities. This is typically accomplished during the topographic survey.

Utility surveys include both above, and below ground utilities as required on the Preliminary Survey Scope Form 1217a, as follows:

1. Gas
2. Transmission
3. Electric
4. Telephone
5. Water
6. Sanitary
7. Television
8. Pipelines
9. Irrigation
10. Fiber Optics
11. Etc.

All utility surveys performed by CDOT or contract consultants shall be performed utilizing InRoads TMOSS coding with file formats accepted for use by InRoads. If underground utilities are located from utility locates marked on the ground by paint, flag, or markers, or by pot holes, the InRoads TMOSS codes shall include a note for the type of locate being collected.

See Chapter 9 – InRoads Survey CDOT Best Practices for additional information.

5.17.2 9-1.5-103 CRS, Plans and Specifications – Notice of Excavation Duties of Excavators - Duties of Owners and Operators

9-1.5-103 CRS

(1) Architects, engineers, or other persons designing excavation shall obtain general information as to the description, nature, and location of underground facilities in the area of such proposed excavations and include such general information in the plans or specifications to inform an excavation contractor of the existence of such facilities and of the need to obtain information thereon pursuant to subsection (3) of this section.

See Chapter 2 – General Procedures, for additional information.

5.17.3 Horizontal Accuracy Tolerance

All utility surveys shall be tied to the CDOT approved primary control network referencing the primary control monument data shown on the Project Control Diagram and shall meet the Minimum Horizontal Accuracy Tolerance for either a CDOT Class C – TMOSS survey or a CDOT Class D – TMOSS survey as required in this chapter.

5.17.4 Vertical Accuracy Tolerance

CDOT Class C – TMOSS surveys within the existing constructed transportation corridor template, shall have a minimum of ninety five percent (95%) of all elevations collected must be within ± one tenth foot (0.10) of the true elevation at a ninety five percent (95%) confidence level in relation to the primary control monuments.

CDOT Class D – TMOSS surveys outside the existing constructed transportation corridor template shall have a minimum of ninety five percent (95%) of the elevations collected by utility survey data shall have an accuracy with respect to true elevation of ± one half (½) contour interval or better at the ninety five percent ninety five percent (95%) confidence level in relation to the primary control monuments.

No elevations determined by any utility survey shall deviate from the true elevations by more than one contour interval in relation to the primary control monuments.

The Vertical Accuracy Tolerance for Utility Surveys may be waived by the Region Survey Coordinator.

5.17.5 Method of Verifying Accuracy Tolerance

Accuracy tolerance requirements for utility surveys are evaluated by comparing an independent field location taken in the field with a point extracted from a terrain TIN model produced from the original topographic survey data. The field location is collected by conventional topographic survey methods and is held as the true representation of what exists in the field in relation to the primary control monuments.

The field location is then compared to the TIN model. The difference between the field location and the TIN model are evaluated to determine if the utility survey is within the Minimum Horizontal and Vertical Accuracy Tolerances for either a CDOT Class C – or D TMOSS survey.

No payment will be made for utility survey data (paper or electronic) until the data has been verified (see Method of Verifying Accuracy Tolerance, for additional information) to be within the required Minimum Horizontal and Vertical Accuracy Tolerances. Any data not within the required tolerances will be rejected, reworked by the consultant, re-verified to be within required tolerances, and re-submitted at no additional cost to CDOT.

5.17.6 Conventional Survey Methods

All utility surveys performed by conventional survey methods shall meet the Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class C or D – TMOSS survey as required in this chapter.

> **Due to the effects of curvature and refraction (see Differential Leveling, Curvature and Refraction Table, for additional information) no CDOT Class C - TMOSS conventional utility observation shall exceed 750 feet from the instrument setup. No CDOT Class D – TMOSS conventional utility observation shall exceed 1000 feet from the instrument setup.**

If elevations are not required, the above conventional utility observation distances may be waived by the Region Survey Coordinator.

5.17.7 GPS Survey Methods

All utility surveys performed by GPS methods shall be performed in accordance with Chapter 3 – GPS Surveys and shall meet the Minimum Horizontal and Vertical Accuracy Tolerance for a CDOT Class C or D – TMOSS survey as required in this chapter.

5.17.8 Aerial Photogrammetry Methods

An aerial photogrammetry survey method utilizes photographic, electronic, digital or other data obtained from an airborne station (*e.g.* a airplane or helicopter). The advantage or obtaining topographic data by aerial survey methods is the efficiency in which large areas of the Earth can be mapped and large volumes of topographic and planimetric data can be obtained. The disadvantage of aerial mapping is that it requires more advanced planning and lead time than conventional or GPS survey methods. The accuracy of aerial surveys are typically much less than that of conventional or GPS survey methods, particularly when there is heavy vegetation or areas of drastic changes in elevation such as mountainous terrain.

Utility surveys are performed to supplement aerial surveys. The purpose of the supplemental survey is to locate those features that require a higher level of accuracy than that of the aerial survey, to locate those features that can not be located by the aerial survey, and to collect information not apparent to the photogrammetrist from the aerial survey.

See Chapter 4 – Aerial Surveys, for additional information.

5.18 Staking for Appraisal

5.18.1 General

The purpose of staking for appraisal is to give the landowner and the appraiser a visual reference on the ground of the area effected by the acquisition. The staking for appraisal points shall be staked with lath at the following locations:

1. Both the existing and the proposed Right of Way and easements.

2. All parcel points shown on the Right of Way Plans.

3. All easements points shown on the Right of Way Plans (including temporary easements).

4. Points on Line (POL) or Points on Curve (POC) shall be staked at locations where the points being staked exceed 300 feet, or in areas where direct line of sight from one appraisal stake to the next is difficult or impossible.

5. Locations opposite buildings, features, and other improvements that may effect the acquisition.

6. In areas where lath may conflict with the safe movement of people and/or traffic, an offset stake should be set.

5.18.2 Coordination of Staking

When staking for appraisal it is the surveyor's responsibility to verify the latest set of Right of Way Plans are being used. The surveyor should be in contact with the appraiser to address any specific concerns or unique situations that may require additional stakes. The parcels being staked and the time at which they are staked shall be coordinated through the appraiser.

During the staking the surveyor shall make a visual comparison of the area affected by the acquisition and the Right of Way Plans. If features are found to exist that are missing or shown incorrectly on the Right of Way Plans the surveyor shall contact the appraiser and inform her/him of such features. The appraiser may request the surveyor locate such features during the staking.

5.18.3 Stake Requirements

All appraisal stakes set shall at a minimum have the following:

1. Staked with a lath having a minimum length of four feet.
2. Colored paint and/or colored flagging.
3. Point number shown on the Right of Way Plans.
4. Parcel or easement number as shown on the Right of Way Plans.
5. Offset distance (if an offset stake is set).

5.19 References

CDOT Survey Manual – CDOT, 1992, 2003

CDOT Right-of-Way Manual – CDOT, July 2002

Geospatial Positioning Accuracy Standards Part 2: Standards for Geodetic Networks - FGDC-STD-007.2-1998, Federal Geographic Data Committee

Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques – Version 5.0: May 11, 1988, Reprinted with minor corrections: August 1, 1989

National Society of Professional Surveyors Model Standards for Surveys, Section A, B, C, E, F, and G – National Society of Professional Surveyors, Draft 3/12/02

Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys – as adopted by ALTA/ACSM/NSPS, 1999

Standards and guidelines for Cadastral Surveys Using GPS Methods – USDA/USDI/BLM, Version 1.0, May 9, 2001

Engineering Surveys – California Department of Transportation, Survey Manual, Chapter 9, May 1998

Right of Way Mapping Handbook – Florida Department of Transportation, Effective January 2003

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