# Chapter 5 - Boundary Surveys

## Policy Statement

Any survey which locates or establishes land boundaries, rights of way, or centerline alignments, collectively referred to herein as "boundary surveys", shall conform to the specifications as defined in this document.

## General

Boundary surveys shall conform to a minimum combined (relative) positional accuracy of **1:10,000** (at a 95% confidence level, or 2 sigma), or a combined distance error of **≤ 0.033 feet** for connection distances shorter than **330 feet**. Relative positional accuracy is a measure of the accuracy of point positions in relation to each other, and is not to be confused with the measure of traverse closure expressed as a ratio.

This **1:10,000** standard shall be met whether the survey is conducted by GPS (static or RTK), conventional traverse (total station), or any combination thereof.

Following are guidelines for GPS and conventional traverse methodology:

## Static GPS

Primary control for a boundary project may be established by static (or fast-static) GPS procedures. While a network adjustment may be performed using only GPS vectors (stand-alone), combining conventional traverse data with GPS vectors will sometimes result in a network with higher relative positional accuracy.

Design of the network and occupation scheme will be determined by the Party Chief in conformance with ***Chapter 1 – Static GPS***. When selecting points to be included in the static network, consideration must be given as to strength of figure and adequate spacing. The minimum allowable spacing for points in stand-alone networks shall be dictated by the following criteria:

- Trimble R10 receivers, rated for static surveys at 3mm + 0.5 ppm at 68% confidence level (1 sigma): a minimum spacing of **500 feet** when tied to CGPS stations at an average distance of 32,000 feet, and a minimum spacing of **300 feet** when tied to primary project control or legacy control at an average distance of 4,000 feet
- Minimum spacing for GPS receivers with static survey ratings different from those listed above can be computed using the formula shown in "***Appendix A, Section 1***"

## RTK GPS

RTK is generally not to be used as a stand-alone measurement tool when performing a boundary survey. RTK is best used to bolster the control network, not define it. In order to ensure realization of the **1:10,000** criteria, the network shall be adjusted using RTK measurements together with conventional traverse data.

RTK occupation points are selected in such a way as to maximize strength of figure, while leaving the bulk of the data to be captured by conventional traverse. The occupation scheme will be determined by the Party Chief in conformance with ***Chapter 2 – RTK GPS.***

The minimum recommended spacing for points in RTK surveys shall be dictated by the following criteria:

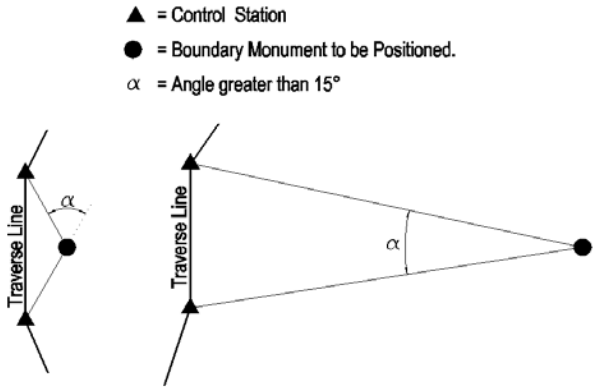
- Trimble R10 receivers, rated for RTK surveys at 8mm + 1 ppm at 68% confidence level (1 sigma): a minimum spacing of **1200 feet** when tied to OCRTN stations at an average distance of 32,000 feet; a minimum spacing of **700 feet** when tied to local project control in a base-rover configuration at an average distance of 4,000 feet
- Minimum spacing for GPS receivers with static survey ratings different from those listed above can be computed using the formula shown in "***Appendix A, Section 1***"

## Conventional Traverse (Total Station)

The method selected for traversing and tying in boundary monuments using a total station shall be limited to the following options, listed in order of descending accuracy:

- **Traverse through each monument:** This option generally delivers the highest accuracy. This method may be impractical or impossible, as many monuments lie adjacent to obstructions or in areas of heavy vehicular traffic. In some cases, poor geometry may be introduced into an otherwise sound network.
- **Double determination from two or more control stations:** This is an acceptable method when monuments lie adjacent to obstructions, or in the event of short sighting distances or multiple flat horizontal angles. If a monument is tied to only two control stations, the resulting deflection angle or included angle should be greater than 15 degrees (see ***Figure 1***).

**Figure 1 – Double Determination**



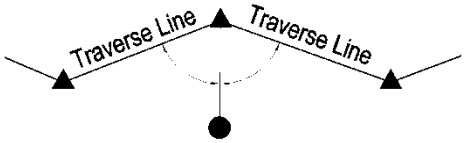

- **Double backsight:** This is achieved by observing a monument from a single control station by making two or more independent observations, each using a different backsight point (see ***Figure 2***). Double backsight may be the preferable method in the instance of a monument falling within dense foliage or under a wall footing, where there is a narrow window through which to observe the monument. Although this method does eliminate the possibility of a blunder and provides better modeling of the

network adjustment than a simple single determination, it is to be used as a last resort. Other methods shall be deemed impossible or degrading to the network before double backsight is employed. If this method is to be used, the instrument setup must broken down and re-erected between measurements.

**Figure 2 – Double Backsight**

▲= Control Station

●= Boundary Monument to be Positioned.




**General Procedural Notes:**
It is preferable to include as much redundancy as possible; if points are intervisible, measure between them. When possible, each pair of adjacent boundary monuments that are intervisible should be directly measured, as this best represents the boundary line being retraced. This is especially critical in the case of monuments that are close together, such as the radius point and centerline terminus of a cul-de-sac, or a jog in a property line or centerline. Very short lines of this nature should be chained, and the resultant distance weighted appropriately in the network adjustment.

**Field measurements shall meet the following specifications:**

- Horizontal Angles: Minimum of two direct (face 1) and two reverse (face 2) with a maximum residual of 5 seconds; exception granted for sights closer than 300 feet.
- Distances: Measured to backsight and foresight; minimum of two direct and two reverse with a maximum residual of 0.007 feet.

## Monumentation

Monuments set during the course of a boundary survey shall meet the following criteria:

**Boundary Corners**
Monuments set at boundary corners for Tract Maps or Parcel Maps, or on any interior lot or parcel lines to be further subdivided, or for future subdivision Records of Survey:

- Monuments which fall in the surface of concrete paving shall consist of a tag secured in a lead plug or set in epoxy.
- Monuments which fall in the surface of asphalt paving shall consist of a durable spike (minimum 4 inches in length) with a washer.
- Monuments which fall in non-paved areas shall consist of a 2 inch diameter iron pipe with a tag or disk.
- All tags/washers/disks referenced above shall be stamped with the agency name or the license number of the surveyor in responsible charge.

- Tags set in iron pipes shall be of a diameter less than that of the inside diameter of the pipe. Disks affixed to iron pipes shall be of a diameter equal to that of the outside diameter of the pipe.
- Under no circumstances are plastic plugs to be used with iron pipe.

**Lot and Parcel Corners**
Monuments set at lot and parcel corners for Tract Maps, Parcel Maps, Records of Survey, Corner Records, Lot Line Adjustments, and Certificates of Compliance:

- Monuments which fall in the surface of concrete paving shall consist of a tag secured in a lead plug or set in epoxy.
- Monuments which fall in the surface of asphalt paving shall consist of a durable spike (minimum 4 inches in length) with a washer.
- Monuments which fall in non-paved areas shall consist of a 1 inch diameter iron pipe with a tag.
- All tags/washers referenced above shall be stamped with the agency name or the license number of the surveyor in responsible charge.
- Tags set in iron pipes shall be of a diameter less than that of the inside diameter of the pipe.
- Under no circumstances are plastic plugs to be used with iron pipe.

**Street Centerline Points**
Monuments set at street intersections, the controlling points along the centerlines of streets, and where boundary lines are produced to intersect street centerlines:

- Monuments which fall in the surface of concrete paving shall consist of a tag secured in a lead plug or set in epoxy.
- Monuments which fall in the surface of asphalt paving shall consist of a durable spike (minimum 4 inches in length) with a washer. A Survey Monument Type “A” (monument well), per OC Public Works Standard Plan 1405, may be set in lieu of spike and washer described above. The number and location of Type “A” monuments shall be as directed by the County Surveyor.
- Monuments which fall in non-paved areas shall consist of a 1 inch diameter iron pipe with a tag. A Survey Monument Type “B”, per OC Public Works Standard Plan 1406, may be set in lieu of iron pipe and tag described above. The number and location of Type “B” monuments shall be as directed by the County Surveyor.
- All tags/washers referenced above shall be stamped with the agency name or the license number of the surveyor in responsible charge.
- Tags set in iron pipes shall be of a diameter less than that of the inside diameter of the pipe.
- Under no circumstances are plastic plugs to be used with iron pipe.

**Reference Points (Tie Points)**
Monuments which represent tie points set for the purpose of monument perpetuation and/or preservation:

- Monuments which fall on concrete curbs or in the surface of concrete paving shall consist of a tag secured in a lead plug or set in epoxy and countersunk so as to be flush with the concrete surface.
- Monuments which fall on asphalt dikes or in the surface of asphalt paving shall consist of a spike or "MAG" nail with a washer.
- Monuments which fall in non-paved areas shall consist of a 1 inch diameter iron pipe with a tag.
- All tags/washers referenced above shall be stamped with the agency name or the license number of the surveyor in responsible charge.
- Tags set in iron pipes shall be of a diameter less than that of the inside diameter of the pipe.
- Under no circumstances are plastic plugs to be used with iron pipe.

**Control Points**
Monuments set as control points during the course of a survey:

- Monuments which fall on concrete curbs or in the surface of concrete paving shall consist of a tag secured in a lead plug or set in epoxy.
- Monuments which fall on asphalt dikes or in the surface of asphalt paving shall consist of a spike or "MAG" nail with a washer.
- Monuments which fall in non-paved areas shall consist of an iron pipe with a tag or disk, or a rebar with an aluminum cap. Rebar must be set a minimum of 3 inches below the ground surface.
- All tags/washers/disks/caps referenced above shall be stamped with the agency name or the license number of the surveyor in responsible charge, and shall also be stamped "CP" or "CONTROL POINT".
- Tags set in iron pipes shall be of a diameter less than that of the inside diameter of the pipe. Disks affixed to iron pipes shall be of a diameter equal to that of the outside diameter of the pipe.
- Under no circumstances are plastic plugs to be used with iron pipe or rebar.

## Adjustment of the Network

All GPS and conventional data shall be adjusted by least squares adjustment software, in conformance with ***Chapter 12 – Network Processing*.**

Statistical analysis of the adjustment shall be performed to ensure that a minimum combined (relative) positional accuracy of **1:10,000** has been achieved for all connected monument pairs, and for all adjacent monument pairs (consecutive points along an alignment or boundary line), whether or not they are connected within the network. Although this computation is automatically performed in most network adjustment software, the formula for this computation is shown in *"Appendix A, Section 2."*

Connections of very short distances often will not meet this **1:10,000** standard. An alternative standard for distances of less than **330 feet** is shown in *"Appendix A, Section 3."*

In the event one or more pairs of monuments fail to pass these relative positional accuracy criteria, the network adjustment shall be reviewed and a determination made by the Senior

Land Surveyor (or Project Manager) as to whether or not additional observations will made in order to improve geometry, increase redundancy, or further isolate errors.

**Important Note:**
Once a network has been adjusted and coordinates are reported to another entity (e.g.: Boundary Analysis Unit or Mapping Unit), these coordinates shall be deemed final. Should supplemental control or boundary ties be needed, the primary coordinates shall be fixed in subsequent adjustments. Only in the event that erroneous data is discovered will previously reported coordinate values be changed.

## Equipment Selection and Use

Specific notes on equipment selection and usage are outlined below:

- Static GPS Surveys: Receivers shall be mounted on a tripod/tribrach configuration. One acceptable alternative mounting is a "four-legged" fixed height or locking-pin rod. This rod shall have three support legs and a center leg which freely turns 360 degrees. A standard layout rod with supporting bipod shall NOT be used for static GPS occupations.
- RTK Surveys: Receivers may be mounted on a standard layout rod with supporting bipod. If this configuration is used, the session should be split, with the rod being turned 180 degrees between sessions, so as to cancel out error introduced by improper adjustment of the plumb bubble.
- Conventional Surveys: Measurements should be made to a prism mounted on a tripod/tribrach configuration, unless impractical or impossible. If a layout rod is used in place of a tripod mounted target, a bipod or other suitable stabilizing element should be employed. The rod should be turned 180 degrees between measurements, so as to cancel out error introduced by improper adjustment of the plumb bubble. A hand held "peanut prism" may be placed directly on a monument, provided a plumb bubble is incorporated into the prism assembly. This prism should be turned 180 degrees between measurements as well. Prisms designated as 360 degree prisms are NOT to be used for a boundary survey. Atmospheric PPM correction shall be computed and applied as needed throughout the survey, however when measured distances exceed 400 feet, temperatures shall be measured with a thermometer, and not simply estimated.

# Appendix A – Formulas

1. Minimum spacing for new control points to be positioned using GPS can be computed using the following formula:

   **$D = 10{,}000 \times \sqrt{(2 \times \{ [(1.96)(a)]^2 + [(1.96)(b)]^2 + c^2 \})}$**
   where:

   - D = minimum spacing (in feet) between static or RTK occupation stations
   - a = manufacturer's millimeter rating at a 68% confidence level, (converted to feet)
   - b = manufacturer's ppm rating at a 68% confidence level, times the average distance (in feet) from legacy control stations, and divided by 1,000,000
   - c = estimated receiver positioning error (rod plumb or tribrach errors), commonly estimated to be 0.007 feet
   - 1.96 = the multiplier from a 68% confidence level (1 sigma) to a 95% confidence level (2 sigma)

2. All connected monument pairs shall pass the following mathematical test:

   **$D \div \sqrt{(x^2 + y^2)} \geq 10{,}000$** (or $\geq$ 20,000 where required above)
   where:
   - D = distance (in feet) between the pair of monuments being examined
   - x = error ellipse semi-major axis for monument #1 (at 95% confidence)
   - y = error ellipse semi-major axis for monument #2 (at 95% confidence)

3. Connections of very short distances often will not meet the **1:10,000** standard defined by the formula in Section 2 above. An alternative standard for distances of less than 330 feet follows:

   **$\sqrt{(x^2 + y^2)} \leq 0.033$ feet**
   where:
   - x = error ellipse semi-major axis for monument #1 (at 95% confidence)
   - y = error ellipse semi-major axis for monument #2 (at 95% confidence)