

Coordinate Reference Systems and Baseline Survey Guidelines

Introduction:

The purpose of baseline surveys, as opposed to traditional alignment surveys, is to reduce the amount of time spent hubbing, staking, flagging, and profiling a proposed alignment, which may be revised. By providing a baseline rather than a specific alignment, the route location engineer can gather and evaluate data needed for design, while at the same time leaving the roadway design engineer free to alter or revise the proposed alignment (the final design alignment). The Route Location Engineer and the field crew are free to concentrate on the important aspects of the survey – what data is collected, accuracies, thoroughness of data – rather than concerning themselves with setting points at specific location, or staying out of traffic on a busy roadway. Also, baseline surveys enhance the increased usage of Digital Terrain Model (DTM's) in the collection of data and in the design of highways.

Survey Baselines have been in existence on route location projects and highway designs since the first engineer established the first line for the first road. The only difference between then and now is that the initial baselines included curves, spirals, and tangents. Now, due to the technological advancements in surveying equipment, computer aided drafting and design (CADD), and removing the restriction of alignment related data for mapping, several alignments may be evaluated once the designer has an opportunity to evaluate the more detailed digital data. More information is needed at a much higher level of accuracy to utilize the skills and technology now available in designing the best facilities. Having the capability to merge data collected by field teams with data gathered photogrammetrically allows the designer access to a broader and more detailed corridor for evaluation.

In times past, surveyors collected data based upon station and offset. This same method of data identification was used in the design process. Now, with CADD and software such as GEOPAK, engineers and surveyors can utilize coordinates in a digital environment. The surveyor can collect coordinate-based information rather than station and offset to a preliminary alignment. Because those coordinates are relative to the project control network (North and East, or X and Y), the information collected has a more accurate relationship to any proposed alignment. This gives the designer the ability to place the design alignment in the most functional location.

The primary concern of the Route Location Engineer and the survey party is the collection and evaluation of data for the design and construction of the transportation facility. Independent baselines enable the surveyor to establish a controlled survey line on the ground and collect necessary information, without spending time and effort setting pre-calculated points. The proposed alignment serves as a guide in establishing the baseline. The surveyor has the flexibility to set control points as necessary based upon terrain or critical features while

avoiding environmentally sensitive areas and lessening impacts to private property. Those who follow after the initial surveyors also have the assurance that, no matter what proposed alignment may be used, any designed information generated from field data will be applicable, because that data was measured from the one constant - the baseline. The location, documentation, and preservation of the baseline from which survey information is gathered is of vital importance, both to those working on the project during the Design phase and those working on the project during the Right of Way and Construction phases. For this reason, certain procedures and guidelines have been established which should be used for all highway Design Branch projects.

Coordinate Reference Systems

All TIP projects surveyed and designed for the North Carolina Department of Transportation should be referenced to the NC State Plane Coordinate System (NCSPC). Reference control stations or azimuth marks should be adjusted to the High Accuracy Reference Network (HARN) with coordinate values that are current and meet reference network accuracy standards (See GPS Survey Guidelines). If there are insufficient number of HARN reference monuments in a specified area, NCDOT will coordinate with NCGS to establish additional HARN monumentation in the area. The Horizontal Datum for the HARN network is NAD 1983/95. NAVD88 will be the vertical datum. Any deviation from this should be discussed with representatives from Photogrammetry and representatives of the Roadway Design Unit or Design Services Unit if the project is contracted to a consultant. Also, any deviation in vertical datum should be discussed with representatives of the Hydraulics Unit, to ensure no problems or conflicts with FEMA mapping or other hydraulic data will be created. Although these will be the preferred datums, it may be necessary to use existing monumentation with NAD83 and/or NGVD29 in order to keep consistency with previously controlled projects or with standalone projects such as bridge projects. It will be the responsibility of the Locations and Surveys Unit in consultation with those Units listed above to determine the datum(s) to be utilized on a case by case basis.

NCSPC coordinates can be referenced to a project either through traversing from available geodetic monumentation (USGS, NCGS, or other monumentation providing a HARN NCSPC reference) or by using GPS technology. However the method, State Plane Coordinates, HARN NAD83/95, should be established on the project. For preliminary mapping projects, all photo control will be provided in NCSPC coordinates referenced to the HARN network. The preliminary mapping will be generated in NCSPC coordinates. For plan sheet mapping projects, one HARN NCSPC reference point will be held, using this coordinate to establish a localized coordinate system that will be relative to that project. Photo control and the plan sheet mapping will be generated in the localized coordinate system. For planning purposes, for extensions or additions, or for additional projects tying together, sufficient forethought should go into the decision of what reference coordinate and combined grid factor will be used to establish the localized coordinate system on a project.

Datum Description:

Grid monumentation, with combined grid factor (ground to grid) used to localize this coordinate system, horizontal and vertical datum, stamped station name, and published coordinates of the monument or geodetic station about which the project is localized, should be provided in a text alignment file (See Attachment #4 for naming convention). The same information will be supplied in the graphical baseline file. NCDOT supplies a Datum cell for this through NCMAP. This datum description should be displayed on all NCDOT plans for the Highway Design Branch on the initial plan sheet (Page 4 of the highway plans) (See Attachment #2) and remain on the plans throughout the life of the project and shown on the final right-of-way plans which are recorded in each county's Register of Deeds office. The datum description and tie (based upon local ground coordinates) from the monument to the "Begin Construction" or "Begin Project" station will be computed and placed in the datum description by the Roadway Design Unit's Project Design Engineer or by the private engineering firm's Roadway Design Engineer for contracted projects through the Design Services Unit.

Types of Baselines

Project Control Baseline (BL & BY):

The Project Control Baseline will be the control alignment placed on the ground for the project. This alignment will be generated in both text and graphics format. The minimum ratio of precision for baselines, including secondary baseline alignments, is 1:20,000 closure. Baselines are to begin with station 5+00.00 and should be placed such that the baseline covers the limits of the project. On North/South projects, the baseline stationing should begin with the Southernmost point with 5+00.00 and progress northward with increasing stationing. Conversely, on East/West projects, the baseline stationing should begin with the Westernmost point with 5+00.00 and progress eastward with increasing stationing. All baselines for -Y- lines should begin at the furthestmost left point with station 5+00.00, if looking up station of the baseline (BL), and continue with increasing stationing to the right till the end of the project limits or intersection with -BL-. Obviously, sequential numbering of baseline points is the goal; however, due to additional requested work, required intersection points, etc. these types of acceptable exceptions may inhibit sequential numbering to be achieved in all cases.

Baseline Field Location:

Baseline traverse points should be inter-visible on the ground and spaced at approximately 300 to 1000 feet intervals where possible. Also, baseline traverse points should be set when possible in the vicinity of all -Y- line intersections and -T- lines where there is the potential for major structure construction (i.e. bridges or box culverts). Baseline control points should be labeled by alignment, (i.e.-BL-point number, -BY1-point number, etc) and numbered such that there is no repetition of point

number (i.e., If there are BL points 7-19, the first BY point would be BY-20. If BY had points 20-22, the first point on BY1 would be BY1-23.) It is assumed that the initial point numbers will be used in the azimuth pairs set for the project. In general, on North/South projects, the BL baseline point numbering should begin with the Southernmost point with BL-# (first available number following azimuth pairs) and progress northward. Conversely, on East/West projects, the BL baseline point numbering should begin with the Westernmost point with BL-# (first available number following azimuth pairs) and progress eastward. All baselines for -Y- lines should begin at the furthestmost left point with BY#-#, if looking up stationing of the baseline (BL), and continue until the end of the project limits or intersection with -BL-. Any -BY- lines should have at minimum two set points (one may or may not be an intersection with the -BL-). If the intersection point with the -BL- and the -BY- is not set, then a computed intersection point should be computed and shown in the text and graphics file and labeled "not set".

Baselines denote a level of accuracy not available in secondary traverses. On non-paved surfaces, baseline points should be a 24"-36" capped rebar with witness post (exceptions may be due to utility locations or soil characteristics). Caps (provided by NCDOT) should be stamped with appropriate baseline name (i.e., BL-6, BY1-12, etc.). In instances with intersection points, a cap does not need to be stamped with two names. The cap should be stamped with the most controlling alignment (i.e., BL and BY3, BL would control, B3282-1 and BL, B3282-1 would control). On paved surfaces, baseline points should be PK nails or equivalent. Witness posts should be red carsonite markers (provided by NCDOT) labeled "NCDOT Traverse Station". In developed areas, red topped wooden stakes should be used near roadways where station and point name are painted on the road. All witness posts or painted pavement should show station and point name. Points set for secondary traverses on non-paved surfaces should be bridge spikes or nails.

In staking the alignment, stations are to be staked at 50 or 100 feet intervals depending on visibility, accurate to +/- 2 feet, when circumstances allow. Exceptions would include cultivated fields, multi-lane transportation facilities, rivers, lakes, ponds, etc. Additional stakes with full station values should be set at edges of woods, edges of pavement (paint) when a baseline crosses a road, and at tops of stream and river and banks to assist other personnel when trying to locate the baseline alignment in the field. Stakes should be 18" orange plastic, with full station values in permanent black ink. Station intervals for baselines along existing roads can be painted on the EOP. Full station values should be placed on all stakes or painted on pavement.

Text file:

This will be an ASCII generated file. (See Attachment #4 for naming convention). All text alignments will include all control points (traverse points) with point numbers,

North and East Coordinates with Elevations, station of points, and type of point set (i.e., iron pin and cap, PK nail etc.). Bearing and distance should be provided between adjacent points. Location & Surveys has developed a standard format for text alignments (See Attachment #1). If an existing roadway is used as a baseline or in some other case where curves are built into the baseline, standard curve data should be included in the text. Intersection points should be established with other baselines, such as -BY- or any -T- line. Intersection points with existing centerlines (best-fit alignments) are not necessary unless the -EL- line is the baseline. The text file should include Hydraulic -T- Line alignments with intersection points to the -BL- or -BY- and a separate section for Bench Marks should be included at the end of the baseline alignment text file. (See Bench Marks, Page 12 and -T- Lines, Page 6 & 7)

Graphics Format:

This will be a Microstation CADD file generated by utilizing Geopak software (See Attachment #4 for naming convention). Stations, bearings, and tics need to be generated, as this is the alignment in existence on the ground. In the graphics file, Route Location & Survey Engineer will provide a station and point number at each control point. Intersection points with other baselines should be displayed in the graphical baseline file. Baseline control points will appear with the standard symbol, baseline station value, point number, and the offset distance and station to the designed alignment (this information to be placed in the graphics file by roadway design engineer). (See Attachment #2). The graphical baseline with stations should remain on the plans through the right-of-way plan submittal to the Right of Way Branch. After this phase, the roadway design engineer can remove the connecting lines from the file. The actual baseline point with standard symbol, point number, and the offset distance and station to the designed alignment should remain on the plans throughout the life of the project. However, baselines may be provided on construction plans at the request of the Division Construction Engineer on a project specific basis. This should be decided at the combined or final field inspection, unless the Division has agreed on a policy for placing baselines on plans.

The roadway designer will provide an alignment relationship between the baselines and the designed alignments in a text format to other units as requested (i.e. Geotechnical, Hydraulics, etc.). This relationship will show the station and offset from the baseline to the designed alignment at 50 feet intervals on all alignments. This relationship between 50 feet station interval points on the baseline will be computed perpendicular from the baseline to the designed alignment. The relationship between the baseline control points (i.e. BL-1, BL-2, etc.) and the designed alignment will be computed perpendicular to the designed alignment and shown on the plan sheets. The information shown will include the baseline station, control point number, designed alignment station, and the offset distance.

Baseline for Hydraulics (-T- Line)

The purpose of the Hydraulic -T- line is only to provide a baseline on the ground from which preliminary hydraulic data can be collected by the route location & survey engineer and additional information can be obtained as needed by the Hydraulics Unit or the contracted Hydraulic Engineer. -T- lines should be established in the field at all waterways (i.e. rivers, creeks, streams, branches, ditches, etc.) that have a consistent 3 feet base width through the project survey limits. If the waterway is generally parallel with the baseline (-BL-) and in close proximity, a separate -T- line is not required. The -BL- will serve as the hydraulic control baseline to obtain hydraulic data in these instances.

-T- line Field Location:

-T- lines should be set generally parallel with the waterway and in the vicinity of the top of bank of the waterway. Nails or spikes should be used to indicate a secondary traverse. If iron pins and caps are used, the traverse should meet controlled baseline standards. At the request of the State Hydraulics Engineer, for proposed bridges, the length of the -T- line should extend at a minimum from the proposed -L- line crossing of the waterway the greater of 200 feet or 2 bridge lengths (greater of the existing bridge length or the proposed bridge length) downstream and upstream or to the requested DTM limits, whichever is greater (See Figure 6 of Hydraulic Survey Guidelines). Any -T- lines should have at minimum two set points, one of which should be an intersection point with the (-BL-). The intersection point should be an actual -BL- point with an iron pin and cap if there is the potential for major structure construction. If there is only a minor drainage system planned and no potential for any major structure construction, an intersection point set in line between two -BL- points will suffice. If the intersection point is set in line between two -BL- points, it will be considered a part of the -T- line only and not a control point on the -BL-. A 12" spike nail, rebar with no cap, or equivalent will suffice as durable construction for later use by the hydraulics engineer. A red topped wooden survey stake or red carsonite marker should be placed next to the set point with the point number and station labeled on the stake. -T- Line control points should be numbered and labeled by alignment, (i.e.-T1-101, -T1-102, T2-101, etc, where T# is the -T- line number and -### is the point number). All baselines for -T- lines should begin at the furthestmost left point with T#-###, if looking up stationing of the baseline (BL), and continue until the end of the project limits. All -T- lines should be stationed and begin at the furthestmost left point of the -T- line limits with station 5+00.00, if looking up stationing of the baseline (BL), and continue with increasing stationing to the right till the end of the -T- line limits. Stationing of the -T- line control points and inter-visibility between -T- line points is required; however, intermediate staking is not necessary. (See Hydraulic Survey Guidelines, Page 6 & 7).

Text File and Graphics Format:

-T- lines will be documented in the baseline alignment text file and the Microstation graphics file. All -T- line text alignments will include all traverse points with point numbers, North and East Coordinates with Elevations, station of points, and type of point set (i.e., nail set, PK nail etc.). Bearing and distance should be provided between adjacent points in the text file. The following statement should be included in the text file:

Caution: This -T- Line is a secondary traverse only and should not be used for construction of complex structures. For more information please contact Locating Engineer in charge of surveys.

In the graphics format, -T- lines should appear in the Microstation CADD file generated for the -BL- and -BY- alignments on Level 45. -T- line traverse points will appear with the default point standard symbol, -T- line station value, point number, elevation, and bearing labeled on connecting lines. (See Attachment #2 and Hydraulic Survey Guidelines, Page 6 & 7).

Please Note: Upon acceptance, this guideline supercedes contradictory statements in prior dated versions of the Hydo Manual.

Types of Alignments

Proposed Project Alignments (ALN):

The roadway design engineer will supply the proposed project alignment to the route location engineer in Geopak format as part of the original request. The proposed project alignments are to be used as a guide for establishing the project control baseline on the ground. Efforts should be made to place the baseline as near as possible to the proposed alignment, typically within 10 feet. Exceptions would be detouring around such objects as buildings, large trees, topographic features, etc.

This proposed design alignment will generally be computed using actual NC State Plane grid coordinates based on preliminary mapping and should begin with station 10+00.00. The roadway design engineer will also begin the final design alignment with station 10+00.00. This proposed project alignment should be localized and shown in a graphics CADD file. This will be a Microstation CADD file generated by utilizing Geopak software (See Attachment #4 for naming convention). No text file is required on the proposed alignment. Stationing will be required due to property references for appraisal data.