MDOT SURVEY MANUAL

Mississippi DOT 10/1/98

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INTRODUCTION

PURPOSE AND AUTHORITY

This manual establishes uniform policies and procedures for surveys within the Mississippi Department of Transportation. The principal purpose of this manual is to secure an optimum degree of statewide uniformity in surveying procedures, to establish and maintain survey standards, and to improve the overall efficiency of the Department's survey function. The manual was created by an active committee comprised of representatives from each District, Roadway Design, Bridge, Right of Way, Contract Administration, and Construction divisions.

A legal standard for surveys is not established or intended. It is published solely for information, guidance and training of the Department's employees.

The Manual does not establish any legal or administrative interpretations of the Department's contracts. In the case of a conflict between the requirements of this manual and the requirements of the contract documents, the contract documents shall take precedence.

APPROVED FOR DISTRIBUTION

Deputy Executive Director/Chief Engineer — 10/2/98 Date

MANUAL INFORMATION

The manual is divided in four sections and each section has its own Table of Contents. The sections are shown below.

1. INTRODUCTION
2. PROJECT CONTROL
3. PRELIMINARY SURVEYS
4. CONSTRUCTION SURVEYS

The manual is available at this time through the department's Intranet Site http://mdotissrv006/roadway/ under the RESOURCES heading. The manual is available in two formats, HTML for online viewing and Microsoft Word documents for printing. The manual will be released on the department's Internet site in the near future.

MAINTENANCE AND UPDATING MANUAL

Two forms are provided on the Intranet site for users of this manual, one to provide their email address for notification of revisions (Manual User), the other (Suggestion Form) for users to submit suggestions or report errors. A Revision Section will be added to the web page in the future to explain changes to the manual in detail.

Field Data Collection

PROJECT CONTROL

Mississippi DOT 10/1/98

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Contact Jeff Fracchia or Keith Boteler of Roadway Design if you find errors in it. (601-359-7287)

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OVERVIEW

The District Control crew should normally establish Horizontal and Vertical control for all Projects. As a rule, the horizontal and vertical control for a project should be planned concurrently so that both types of surveys can use the same permanent marks whenever practicable. When possible, monuments should be placed where they will be GPS observable and just outside the limits of the proposed project. These control monuments shall be established at each end of the project and additional stations spaced from 0.5 to 2.0 kilometers throughout the project. These monuments will serve as a reference for all subsequent surveys, including control for aerial photography, design surveys, right of way surveys, and construction surveys. This control will be referred to as “Primary Control” in the remainder of this manual.

This initial control established by the District Control crew shall be tied to the State Plane Coordinate system. A minimum of three 1st order (1:100,000) stations will be established and connected to a minimum of three existing control stations that surround the project, two of which should be B-Order (1:1,000,000) HARN stations. All observations and computations involving the control net will be maintained in a project control folder.

Vertical control with second-order elevations should be present on these monuments. A second-order line of levels should be run across the monuments unless existing first or second-order control is already available. This line of levels should be run using the double-scale rod method. If these superior rods are unavailable, use of lovar yard rods and the 3-wire leveling method will be acceptable. All elevations will be recorded in meters, referenced to the NAVD'88 datum.

Ties should also be made to position many of the section and quarter section corners that surround the project by the District Control Crew. Although not required, it is preferred that the District Control Crew establish the Main Baseline Alignment.

HORIZONTAL CONTROL

BACKGROUND HISTORY

220BC A Greek scholar, Erastosthenes, computed the circumference of the earth
1817 U.S. Coast Survey established a 11 station triangulation-net with two base lines
1832 USCS started the Eastern Oblique Arc from Calies ME to New Orleans LA
1871 USCS started the 2750-mile 39th Parallel Arc across the U.S.
1879 New England Datum established based on Clarke 1866 ellipsoid
1897 The 39th Parallel Triangulation Arc completed
1899 The Eastern Oblique Arc completed with 1200 stations covering 9000 sq. mi.
1917-1926 Traverse replaced triangulation due to high lumber prices
1926 The Bilby steel tower developed
1930 NAD27 developed from 370km spaced bases, 240km spaced LaPlace stations, and 25,000 stations
1933 The State Plane Coordinate Systems (SPCS) developed for each state
1940-1950 UTM system developed for the military
1948 First Geodimeter EDM was introduced
1953 USC&GS began measuring base lines with Model 4 Geodimeters
1957 The Tellurometer EDM using microwaves was introduced
1957 Doppler signals from SPUTNIK I led to NNSS with 6 satellites – required the observation of 40 passes for 0.5 m accuracy - 50 stations on TCT
1960 WGS60 developed by Defense Mapping Agency (DMA)
1961-1976 High Precision Traverse of 13,660 miles across 44 states with 2750 stations spaced at 10 miles -Two nights observations with 1" spread
1964 USN TRANSIT (Doppler) began operation
1966 WGS66 developed by DMA
1967 TRANSIT (NNSS) made available for civilian use
1971 Hewlett-Packard introduced the HP-3800 EDM for local surveyor use
1972 WGS72 developed by DMA
1973 DOD began development of NAVSTAR GPS system
1974 NGS began establishing EDM Calibration Base Lines in the U.S.
1974 Start of NAD83 adjustment - 250,000 points & 500,000 unknowns with 2.5 million horizontal observations, 150 Doppler positions, 5,000 projects
1978 Feb 22 Launch of first NAVSTAR Block I GPS satellite
1982 Launch of first of 8 GLONASS GPS satellites
1984 WGS84 developed by DMA
1986 Jan 28 Challenger shuttle disaster delayed NAVSTAR schedule
1986 July NGS completed NAD83 readjustment to geocentric GRS80 ellipsoid
1986 STARFIX developed for Gulf of Mexico oil drilling operations
1988 Kinematic method developed
1989 Feb 14 Launch of first Block II GPS satellite
1990 NADCON developed
1990 Nov 26 Launch of first Block IIA GPS satellite
1993 Dec 8 Initial Operation Capability began
1994 Jan 31 Antispoofing (A/S) activated
1995 NAVSTAR became fully operational

STATE PLANE COORDINATES

OVERVIEW

The State Plane Coordinate System (SPCS) was developed in 1933 by the USC&GS at the request of a North Carolina D.O.T. engineer. Only latitudes and longitudes were being published for the national control monuments. Local engineers and surveyors not versed in spherical trigonometry and geodesy were unable to utilize the control for their needs. The SPCS provided an easy way to incorporate all surveys into a common datum with only a knowledge of plane trigonometry. The system was designed such that the difference between the grid and geodetic distances would not exceed 1:10,000 which was considered excellent accuracy at that time. This limited the width that could be covered by one zone to 158 miles. Mississippi, like most states, is wider than 158 miles and therefore required two zones. With Mississippi being longer in the North-South direction, an East and West zone utilizing the Transverse Mercator Projection was developed. The dividing line between the two zones follow along county boundaries so that the entire county will be in a single zone. No change was made in the zone boundaries with NAD'83. The central meridians for the two zones was and still is located at 88 50' and 90 20' longitude. Under the NAD'27 datum, an X value of 500,000 feet was assigned to both meridians and a distortion of 1:17,000 was placed on the West Zone and 1:25,000 placed on the East Zone which had less width to cover. Under the present NAD'83 datum, both meridians have the same distortion of 1:20,000 assigned but the East meridian has an East coordinate of 300,000 meters and the West meridian has an East coordinate of 700,000 meters. The origin of both zones is now located on the 29 30' latitude line. The grid and geodetic meridians coincide only at the two central meridians. The angle between the two is called the convergence angle and increases in value with an increase in distance from the central meridian. With the latitude and longitude known, the convergence angle will be equal to the longitude difference times the sine of the latitude. With the North and East coordinates known, the convergence angle can be calculated to sufficient accuracy from the formula ME', where E'= E-Ecm and M is interpolated from a table as a function of the North coordinate.

Many advantages are available by using the State Plane Coordinate System (SPCS). The main advantage of using SPCS is that your data will be in a common coordinate system which can be re-produced in the future. It provides the easiest way to deal with the convergence of the geographic meridians. The entire project is oriented to a single meridian (the central meridian of the zone) and therefore avoids the convergence problem. A geodetic bearing or azimuth can be obtained easily at any location by applying the convergence angle at that location to the grid azimuth. The grid and geodetic meridian and convergence angle have a similar relationship as the magnetic and true meridian and magnetic declination. The observed delta angles at the PIs are really geodetic and not grid angles. The difference is less than a second, therefore can be neglected. Using the SPCS will allow the coordination of many GLO corners or evidence of their location. More evidence of the GLO net can be obtained economically with the use of GPS making it possible to isolate bad corners. All evidence that has been coordinated with the SPCS will be indirectly tied to all other surveys that utilize the system.

USING THE SPCS ON MDOT PROJECTS

All MDOT projects where R.O.W. will be acquired shall use the SPCS. These projects must have a minimum of three 1st order (1:100,000) control stations positioned to FGCC standards. These 1st order control

stations will be positioned from the three nearest 1st order or B-order (1:1,000,000) HARN stations using dual-frequency GPS receivers. Orientation of the project can be obtained by establishing intervisible pairs of stations spaced at a minimum of 400 meters apart or by Polaris observations. Additional stations will be required along the route at a spacing from 0.5 to 2.0 kilometers.

The project control traverse will commence at a 1st order station with a 2nd order azimuth and close on another 1st order station with another 2nd order azimuth. This traverse will be run to 2nd order class II (1:20,000) specifications and will not exceed 3 kilometers in length or 20 instruments stations without closing on another first or second order control station. The distances observed in this traverse will be reduced to the ellipsoid then to the grid surface prior to the coordinate computations. The District Surveyor will analyze the effect of using single elevation and scale factors for the entire project or certain segments of the project. If the error introduced by using single factors is acceptable, which it usually is, then all horizontal distances can be reduced directly to the grid surface by multiplying them by a single combined grid factor.

If the surveying error between two adjacent control stations meets the second order (1:20,000) specifications, the compass rule or least squares adjustment will be used to distribute the error throughout the traverse. This adjustment will be made independently between each pair of control stations. After the adjustment, SPCS stations will be established for each PI and POT. After the roadway is designed, SPCS stations will be established on all other control points, such as PCs and PTs. Inversing between any two intervisible stations will provide the required grid azimuth for proper orientation. The difference between the grid length and the horizontal length that is needed for stakeout work will usually be less than 50 ppm. This amounts to less than 5mm at 100 meters which will cover many stakeout situations. In cases where precise stakeout is required, the inversed grid distance can be divided by the combined grid factor to produce the desired horizontal distance. **Where data collectors or total stations are used for the stakeout, the value of one minus the combined grid factor expressed in ppm can be entered into one or the other, not both, to produce the desired horizontal distance.** This entry is similar to the present ppm entry for atmospheric conditions.

The orthometric (Geoid) elevation in Mississippi varies from near zero on the coast to less than 250 meters on Woodall Mountain near Iuka in the northeast corner of the state. The Geoid separation varies from about -26 meters along the west side of the state to nearly -29 meters on the east side of the state. These combine to produce ellipsoidal heights from -29 meters near the coast to less than +220 meters on Woodall Mountain. These parameters produce elevation factors from 1.000004 on the coast to 0.999965 in the northeast corner of the state for a total change of about 40 ppm. Within the limits of a single project, the change in the Geoid separation will usually be negligible compared to the elevation change. Even on projects where the elevation changes as much as 50 meters, the error introduced by using a single elevation factor will be less than 4 ppm which is acceptable for most construction. The 4 ppm amounts to only 0.4 of a millimeter at a distance of 100 meters.

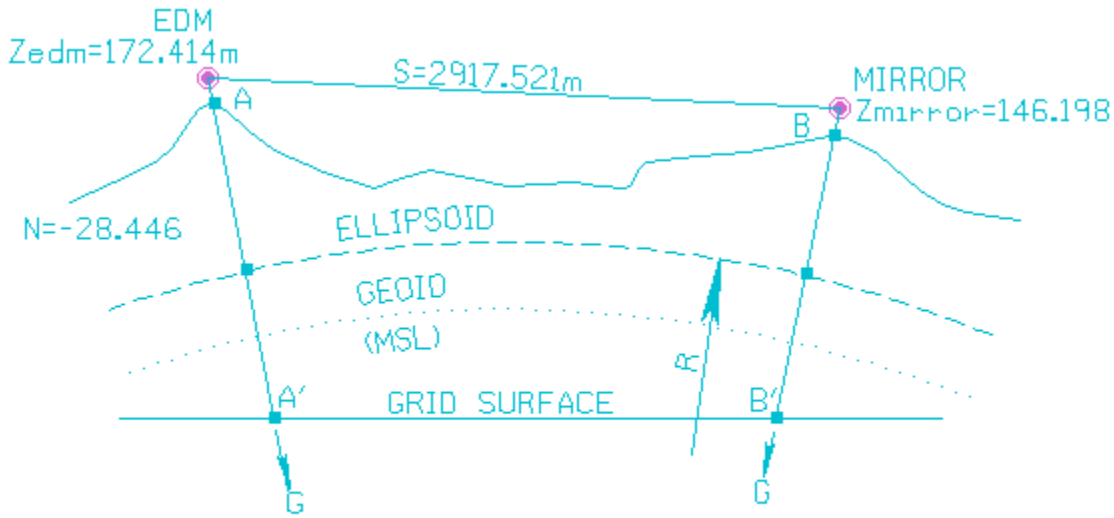
The central meridians for both zones in Mississippi now (NAD'83) have distortions of 1:20,000 which is equal to a scale factor of 0.999950 or 50 ppm. The scale factor will increase with the distance from the meridians until it reaches 1.000000 at the lines of exact scale located about 64 kilometers from each meridian in each direction. Only a small percentage of the state is outside these lines of exact scale. Adams and Wilkinson Counties are located the farthest from the central meridians. The scale factor reaches a maximum of 1.00010 or 100 ppm along the Mississippi River in these two counties. Within the limits of a single 10 kilometer East-West project, the error introduced by using a single scale factor will be less than 5 ppm which is acceptable for most construction. The 5 ppm amounts to only 0.5 of a millimeter at a distance of 100 meters. Since the scale factor varies only in the East-West direction, only the East-West component of the project will influence it. The large scale factors near the edge of the two zones in Mississippi will reduce the combined grid factor but the rate of change is the greatest in these areas. Long east-west projects near the zone edges should be analyzed to determine if more than a single combined grid factor would be required.

NAD'83(93) coordinates should be used on all projects and labeled as such. Observed distances must be reduced to the ellipsoid then further reduced to the grid surface before being used to compute grid coordinates. The reduction to the ellipsoid (geodetic) surface is accomplished with an elevation factor. This factor is equal to R / (R+H+N) where R is the radius of the earth which can be taken as 6,372,000 meters, H is the average orthometric elevation of the line and N is the Geoid height which varies from -26 to -

29 meters in Mississippi. Scale factors are used to convert the geodetic or ellipsoidal distances to grid distances. The scale factors in Mississippi will start at 0.99995 on each central meridian and increase to slightly larger that 1.0000 at the edges of the zones. The scale factor at any location can be computed with sufficient accuracy from scaled data from USGS quad sheets. A precise value can be obtained by using the CORPSCON program.

Observed astronomic azimuths will have to be reduced to geodetic, then further reduced to grid azimuths by using the convergence angle. The convergence angle can be obtained from the CORPSCON program butwith the latitude and longitude known, it can be obtained by multiplying the change in longitude from the central meridian by the sine of the latitude. When an inverse is made between two stations with grid coordinates, the inversed azimuth will be a grid azimuth and the convergence angle will not be needed unless the grid azimuth needs to be converted to geodetic (true). There has been very limited use of the SPCS in Mississippi in the past but their use will increase rapidly in the future due to GPS.

SPCS CALCULATION EXAMPLE



PROBLEM: Compute the State Plane Coordinates for Point B
GIVEN: Na=417,392.639, Ea=286,679.355, AZo (Observed or Astronomical Azimuth)= 27^17'17.3"
Slope distance to B from A = 2917.521
Zedm = 172.414
Zmirror = 146.198

SOLUTION:

I. GRID AZIMUTH

Ma = 0.021194 (From Table in Appendix, M is a function of the North Coord.)
Ea' = Ea-Eo = 286,679 - 300,000 = -13,321 (Distance from the Central Meridian)
G (in Seconds) = ME' = -282.3" = -4' 42.3"
AZgrid = AZo - G = 27^21'59.6"

II. GRID DISTANCE

Zc (Change in Z) = Zedm-Zmirror = 26.216m
H (Horizontal Length) = Square Root (S^2-Zc^2)=2917.403m
Za (Z average) = (172.414 + 146.198)/2 = 159.306m
h (Ellipsoidal height) = Za + N = 159.306 - 28.446 = 130.860m
N = Geoid separation from Ellipsoid (From Geoid 96 program or from Geoid Contour Map in this manual).
EF (Elevation Factor) = Re/(Re + h) = 6,372,000/(6,372,000+130.860) = 0.99997946m
where Re = Radius of Earth = 6,372,000m
GeoDetic Length = HxEF = 2917.403 x 0.99997946 = 2917.343
Departure of AB = Hx SIN AZgrid = 1341 m
Eave = Average East Coordinate between A & B = 287350m
Eave' = 287350 - 300000 = -12650m
SF(Scale Factor) = 0.99995 + 1.23258×10^{-14}(Eave')^2 = 0.99995197
Lgrid = GRID DISTANCE = Geodetic Length x SF = 2917.343 x 0.99995197 = 2917.203m

III. COORDINATES

Nb = Na + Lgrid x COS AZgrid = **419,983.360m**
Eb = Ea + Lgrid x SIN AZgrid = **288,020.339m**

PROGRAMS AVAILABLE FOR AID IN CONVERTING TO STATE PLANE COORDINATES:

NGS provides many programs which aid in the conversion to state plane coordinates, eliminating the need for hand computations as shown in the example above. Some of the key programs are listed below. These programs can be obtained from:

http://www.ngs.noaa.gov/PC_PROD/pc_prod.html

Phone: (301) 713-3242

I. CORPSCON

CORPSCON, Version 4.11, is an MS-DOS based program which allows the user to convert coordinates between Geographic, State Plane and Universal Transverse (UTM) on both North American Datum of 1927 (NAD 27) and North American Datum of 1983(NAD 83). CORPSCON uses the National Geodetic Survey (NGS) program NADCON to convert between NAD 27 and NAD 83. CORPSCON, Version 4.11, also performs vertical conversions to and from the National Geodetic Vertical Datum of 1929 (NGVD 29) and the North American Vertical Datum of 1988 (NAVD 88). Vertical conversions can be performed for the continental U.S. only. CORPSCON V5.0 has the ability to perform conversions based on High Accuracy Reference Networks (HARN's).

II. NADCON

Transforms geographic coordinates between the NAD 27, Old Hawaiian, Puerto Rico, or Alaska Island datums and NAD 83 values. Recommended for converting coordinate data for mapping, low-accuracy surveying, or navigation.

III. SPCS83

Converts NAD 83 state plane coordinates to NAD 83 geographic positions and conversely. Includes defining constants for NAD 83 coordinate zones. State plane coordinates are entered or computed to 1 mm accuracy, while the latitudes and longitudes entered or computed correspond to approximately 0.3 mm accuracy.

IV. GEOID96

Computes Geoid height values for the conterminous United States, Alaska, Puerto Rico, Virgin Islands, and Hawaii. Suitable for conversion of NAD83 GPS ellipsoidal heights into NAVD88 orthometric heights.

V. DEFLEC96

Computes deflections of the vertical and Laplace corrections for the conterminous United States, Alaska, Puerto Rico, Virgin Islands, and Hawaii.

VI. GEOPAK SURVEY

Steps will be written in the near future for this.

SPCS MDOT PROJECT EXAMPLES

Analysis was done on three MDOT projects to see the effect of using State Plane Coordinates. These projects run East to West, are above average in length, and two are located far from the Central Meridian, therefore they show some worst case scenarios for errors if one grid factor or no grid factors are used during stakeout of a project.

MDOT PROJECT DATA

	Kosciusko	Prentiss	Starkville
Project Length	2.89 km	7.98 km	7.66 mi.
Miles from C.M.	44	31	4
Limits in feet (From USGS 7.5-minute quad sheets)			
Min NAD27 Y	1,220,700	407,000	1,392,400
Max NAD27 Y	1,224,100	417,500	1,394,400
Change in Y	3,400	10,500	2,000
Min NAD27 X	264,500	652,000	458,750
Max NAD27 X	272,600	676,700	498,800
Change in X	8,100	24,700	40,050
Elevations			
Low-High (Ft)	380-450	350-490	220-320
Change (Ft)	70	140	100
Geoid Height (meters)	-27	-27	-27
NAD83 Scale Factors			
West end	1.0000135	0.9999765	0.9999520
East end	1.0000092	0.9999856	0.9999500
Average	1.0000114	0.9999811	0.9999510
Error if sgl SF (ppm)	2.2	4.6	1.0
Error as ratio	1:450,000	1:220,000	1:1000000
NAD83 Elevation Factors			
Low Elevation	0.9999860	0.9999874	0.9999937
High Elevation	0.9999827	0.9999808	0.9999889
Average	0.9999844	0.9999841	0.9999913
Error if single hF (ppm)	1.7	3.3	2.4
Error as ratio	1:590,000	1:300,000	1:420,000
NAD83 Grid Factors			
Low	0.9999919	0.9999573	0.9999389
High	0.9999995	0.9999730	0.9999457
Average	0.9999957	0.9999652	0.9999423
Error if single GF (ppm)	3.8	7.9	3.4
Error as ratio	1:260,000	1:130,000	1:290,000
Error (mm/100m)	0.4	0.8	0.3
Error if no GF (ppm)	4.3	34.8	57.7
Error as ratio	1:230,000	1:29,000	1:17,000
Error (mm/100m)	0.4	3.5	5.8
Convergence in seconds = ME'			
West end	-25'07.9"	+15'21.4"	-4'29.0"
East end	-24'15.7"	+17'52.3"	-0'07.9"

```
Change                    0'52.2"      2'30.9"      4'21.1"
M value                  0.021004     0.019904     0.021384

                      ***** NOTE *****
       GRID DISTANCE = GROUND DISTANCE X GRID FACTOR
       GROUND DISTANCE = GRID DISTANCE / GRID FACTOR
       GROUND DISTANCE = GRID DISTANCE + CORRECTION PPM
       GEODETIC AZIMUTH = GRID AZIMUTH + ME'
```

AVAILABILITY AND RECOVERY OF EXISTING CONTROL

1. Check the appropriate geodetic control diagram to determine the general plan for horizontal control plan in the project area. The latest NGS CD-ROM should be examined to determine the condition of the available control in the database that may be in or near the project site.
2. Other agencies such as the USGS, TVA and USACE should be consulted for any additional control not available on the CD-ROM.
3. The U.S. Geological Survey (USGS) horizontal control will usually consist of third order transit-tape (TT) or electronic traverse (ET) monuments. TT or ET will be stamped on their disk as well as the designation and date if the monument has a horizontal position available.
4. Most older USACE marks were brass caps on 5 foot iron pipes projecting one foot above ground. The later marks are precast concrete posts with brass disk in the top and set flush with the ground.
5. Most first and second order control has been established by the U.S. Coast and Geodetic Survey (now the National Geodetic Survey (NGS)). Their horizontal control consist mostly of triangulation stations spaced from 5 to ten miles apart throughout the U.S. and located on the highest hills in the area. A triangulation station is usually designated with a local name plus the year that it was established.
6. Triangulation stations usually consist of five monuments. To help maintain the primary station position, an underground monument is established directly beneath the station surface mark and two reference marks (RMs) are established within 50 meters of the station mark. To assist local surveyors in orienting a traverse from the station mark, an azimuth mark is established from 0.2 to 1.0 kilometer from the station mark.
7. The data sheets for these stations contains all of the data for the station including all past recoveries. The position of the station is given in three different systems. Rectangular coordinates in meters are given in the State Plane Coordinate System and the Universal Transverse Mercator (UTM) System. Geographic coordinates are given in latitude and longitude. The latitude indicating the distance north of the equator and the longitude indicating the distance west of the Zero Greenwich meridian in England.
8. If the last description is old or you anticipate difficulty in the recovery of a mark, you should plot or prepare a sketch of the site and data available from the data sheets prior to the recon trip. This will reduce the time in the field and increase the chances for finding the marks.
9. Any existing control that falls within the NGS 20 percent rule must be recovered and ties will have to be made. This rule states that when the distance between two unconnected survey points is less than 20 percent of the distance between the two points traced along existing or new connections, a direct connection should be made between the points.
10. Plot all of the available control and the project limits on a USGS quad sheet or other appropriate map. Plot the project limits and the three nearest HARN stations that enclose the site on a smaller scale map.

11. A two-man party should make a recon trip to recover and redescribe the control in or near the project area and select sites for new control needed.
12. Have the following equipment and supplies when you attempt to recover control: odometer, 165 foot/50 meter tape, hand level and compass, probing rod, shovel, data sheets, flagging and several pencils.
13. Record odometer readings and other data on the way to the station so that a TO REACH paragraph can be prepared for the description.
14. Once the mark has been found, face north and prepare a field sketch of the site showing objects to be referenced and other pertinent data.
15. After recovering the control station, you must verify it by making the necessary measurements to show that it still occupies the same position as it did when its position was determined. The distance and direction to each RM is usually checked against the published values. If these checks fail or the mark appears to have been disturbed, additional checks will be needed.
16. Record the property owner's name, address and phone number.

LOCATION AND CONSTRUCTION OF NEW MONUMENTATION

1. Sites for new control stations should be selected and described during the reconnaissance trip to recover the existing control.
2. The type and spacing of monumentation to be established will be determined by the District Surveyor based on the terrain and the needs of the particular project.
3. All projects that utilize the State Plane Coordinate System will require a minimum of three 1st order (1:100,000) horizontal control stations.
4. A single or dual station will be established at each end of the project and additional stations spaced from 0.5 to 2.0 kilometers throughout the
project.
5. The selected sites for new monumentation should be in a stable, open, and safe area with easy access. When possible the sites selected should also double for vertical control monuments.
6. An eccentric monument will be established in an open area near existing horizontal control that cannot be occupied by GPS and is too far from the project to be tied with a second-order conventional traverse.
7. New monuments may be set pipe or precast concrete, poured-in-place concrete, driven rods, or disk cemented in drilled and countersunk holes in stable concrete structures.
8. Precast concrete post should be at least 150 mm at the top, 200 mm at the bottom and 1.0 meter long set flush or below the ground surface.
9. Poured-in-place concrete posts should be at least 200 mm in diameter with the bottom belled out and set at a depth of 0.7 meters. The top of the monument should be set flush or slightly below the ground surface. All loose dirt should be removed from the hole or well tamped to prevent settlement.
10. Driven rods should be at least 15 mm in diameter with a metal cap attached to the top. The depth of the rods will be established by the District Surveyor based on the location and spacing of the monuments.
11. Pipe and precast concrete monuments should be set on solid earth and tamped in firmly. All loose dirt from the bottom of the hole must be removed or tamped in firmly prior to setting the monument.
12. Two reference marks should be set for some primary control monuments to verify the marks position at a later date. These reference marks can be inexpensive 0.5 meter driven rebar with a plastic cap. They should be set 90 degrees apart with an open line between the two. The reference marks can be omitted entirely where control monuments are closely spaced.
13. A sketch and a detailed description will be prepared and filed for each monument established or recovered. The description should contain a paragraph of how to reach the site from a well-known landmark. The azimuth and distance to five objects near the monument and in varying directions should be observed to allow for quick location of the monument. A GPS obstruction diagram should be prepared showing all obstructions above 20 degrees. Typical reference objects to use would be roads, fences, building corners, walls, projected walls, utility poles, lone or unique trees, and end of culverts.
14. The location and data for all existing and new monumentation shall be shown on the construction plans.

FIRST ORDER GPS OBSERVATIONS

1. A minimum of three 1st order (1:100,000) control points will be established on all projects that utilize the SPCS. These stations will be positioned from the three nearest 1st-order or B-order (1,000,000) HARN stations that enclose the project using dual frequency GPS receivers. Two of the stations must be HARN stations.
2. First order stations must be established at each end of the project, the project at a spacing from 0.5 to 2.0 kilometers, and one will be established near all major angle points. The District surveyor will establish the required spacing based on the terrain and other construction considerations.
3. Fixed height tripods should be used when available. Otherwise two antenna height measurements will be required, one in meters and one in feet, one before and one after the observation. The two heights must be checked and agree before removing the antenna.
4. Geometric Survey Standards and Specifications for Geodetic Surveys using Relative Positioning GPS Techniques will be complied with.
5. The HARN station ties will verify that the equipment and observing procedures are adequate for the project.
6. All GPS ties to other control in the project area will be made to firs order standards to ensure that all control will be acceptable for use.
7. Eccentric stations will be established in an open area nearby if the existing control is not GPS observable and is too far to be tied by conventional traverse.
8. The establishing agency will be consulted if any of their control fail to meet their stated accuracy and a copy of the new position and supporting data will be transmitted to them.
9. At least 10 percent of all stations must be independently occupied a minimum of three times.
10. At least 30 percent of the new stations must be independently occupieda minimum of two times.
11. All vertical control stations must be independently occupied twice.
12. At least 25 percent of the horizontal control stations must be independently occupied at least two times.
13. All station pairs must be independently occupied twice.
14. There must be at least two independent observing sessions in all loop closure circuits.
15. No loop closure should contain more than 10 base lines.
16. No more than 30 percent of the base lines can be outside a loop closure.
17. No more than 15 percent of all stations can be outside a loop closure.
18. When a station is occupied during two or more sessions, back to back, the antenna/tripod must be reset and replumbed between sessions to meet the criteria for an independent occupation. When the fixed-height tripods are not used, the antenna for the second session must have a different height to verify that it was reset.
19. Redundant occupations are required when pairs of intervisible station are established to meet azimuth requirements when the distance between the station pair is less than 2 kilometers.

SECOND ORDER CONVENTIONAL TRAVERSES

1. The interior portion of a project can be controlled by conventional traverse if GPS is unavailable or not useable due to tree cover or other reasons. This traverse will establish the secondary (supplemental) control to be used by all subsequent surveys. Nearby existing horizontal control can also be tied by conventional traverse where the station is not GPS observable.
2. A good reconnaissance must be made prior to beginning the traverse to select station sites that will be capable of producing acceptable accuracies. Long lines with minimum horizontal refraction will be required.
3. The traverse should be run as straight and with as equal length lines as possible between two control stations so that the adjustment will be valid and the resulting errors can be attributed to either angle or distance.
4. Directional changes in the traverse greater than 30 degrees should be avoided. When unavoidable, a GPS control station should be established at the angle or a Polaris shot taken to control the orientation of the traverse.
5. Centering and plumbing errors must be minimized on short lines and leveling errors minimized in rugged terrain where steep sights are involved. Observing procedures will not cancel these errors.
6. You should avoid stopping or starting the traverse at a short line. The setup error will be magnified and create an orientation problem.
7. Accurate heights of the theodolite and prism target will be recorded to the nearest millimeter so that trigonometric elevations can be carried through the traverse. Trigonometric elevations should not be carried through more than 10 stations without a tie to a bench mark.
8. One pressure and two temperatures will be observed for each EDM measurement.
9. Two sets of zenith distances with a maximum spread of 10 seconds will be observed along all lines where the EDM will be used to measure the distance. In lieu of zenith distances, two elevation differences can be recorded as observed with a total station.
10. EDM distances will be observed from both ends of all lines in the traverse to avoid a blunder going undetected. Ten readings will be recorded for each measurements with a maximum spread of 5mm or 1mm per 100 meters. The criteria that allows the larger spread can be used.
11. EDMs will be calibrated on one of the nine NGS Calibration Base Lines in the state at least annually. Frequent checks on a local base line will be made and a log maintained to verify that the EDM is operating properly.
12. Eight positions with a 1-second theodolite and a 5-second rejection limit will be observed for the horizontal angles on most traverses. The number of positions can be reduced to four where short lines and a short traverse is run between two closely spaced control stations.
13. Azimuths must never be carried through more than 20 stations without an azimuth check and closure. Azimuth closures should never exceed 4 seconds per angle or 8 seconds times the square root of the number of angles.
14. Position closures will never be allowed in excess of 1:20,000. Equipment and observational procedures should be evaluated and improved anytime the closures approach this maximum value.
15. The instrument and targets should be interchanged leaving the tripod and tribrach until all observations have been completed. Instrument and target heights above the tribrach should be equal.

STEPS IN ESTABLISHING PROPOSED ROADWAY ALIGNMENT

1. Using GPS or conventional traverse, establish horizontal control monuments along the route corridor at a spacing from 0.5 to 2.0 kilometers.
2. From this control, determine coordinates of any point that will control the roadway alignment.
3. Make the initial alignment by establishing tentative coordinates for the BOP, EOP, and all PIs.
4. Make a tentative design of all curves and calculate coordinates for all PCs, PTs, and for every full station.
5. Using the tentative design coordinates, stake the centerline in any questionable area and revise the alignment and coordinates where necessary.
6. Finalize the horizontal alignment by fixing coordinates for the BOP, EOP, all PIs, PCs, PTs, and every full station.
7. The Proposed centerline must be hubbed in the field for a field review, which will be conducted and approved by the Department prior to proceeding with additional work. Stake the centerline of the entire project with treated stakes on 25m (100 feet) stations in preparation for centerline inspection.
8. Reference Centerline: All P.C.'s, P.I.'s, P.T.'s and tangents longer than 300m (1000 feet). Each reference point for assembly shall include a point 60 m (200 feet) from the centerline of the survey and an additional point 15m (50 feet) (more or less) farther and should be designated by a 2"x2" treated hub with a 1" – 4' flagged guard stake indicating its location. All stakes and hubs shall be treated.
9. After location approval, establish coordinates on the available evidence of the GLO net and property lines in the project area and analyze for adequacy.
10. During the design of the vertical alignment, establish coordinates for all bridges and culverts and establish the right-of-way requirements.
11. Calculate coordinates of all R/W monuments needed.
12. Any point on the centerline or R/W can be staked using GPS or conventional from the control monuments that were initially established.

SECTIONAL LAND TIES

1. All of the land titles in Mississippi are derived from the old GLO rectangular land net of townships and sections that was extended across the state from 1803 until around 1850 by over 150 deputy surveyors serving under 14 different surveyor generals. When compared to today's technology, the surveys were inaccurate and the monumentation inadequate. Magnetic compasses were used to establish directions, 33 or 66-foot chains composed of 50 or 100 links were used to measure distances, and wooden posts were used to monument the corners.The wooden posts had an extremely short life but the distance and direction to bearing trees were recorded to permit their replacement. If new bearing trees had been marked 50 and 100 years ago, while evidence of the previous trees remained, the GLO net would still be a viable net. The failure to maintain or perpetuate the original monuments and bearing trees over the past 150 years has resulted in an extensive obliteration of the original net. The reestablished net has been greatly distorted in many areas due to the failure to account for the 20 to 40 feet per mile excess. To re-establish the monuments and lines in most areas with any degree of certainty requires extensive resurveys.
GPS and the SPCS will not eliminate the problem but can assist in its evaluation and prevent its magnification and perpetuation. With each new connection, a better understanding of the quality, scale, and orientation of the GLO land net is possible.
2. GPS has made it possible to evaluate a larger area of the old GLO surveys economically. With more ties to the GLO net available, blunders and past distortions can be detected and accounted for.

3. An effort should be made to position as most of the section and quarter-section corners that surround the project. A report will be prepared and filed on each corner positioned, showing what evidence was available and exactly what point was positioned. A sketch of the survey showing how the position was determined will be included to assist in the evaluation of the position.
4. An analysis of the GLO net in the project area will be made after all the positions have been obtained to determine the validity of the evidence positioned. A report of this analysis will be filed with the project file.

CARE AND USE OF EQUIPMENT

1. All tripods used for any type of control work must be checked frequently to ensure that no loose connections exist at the head, shoe, or extension joint.
2. Check each leg one at a time by raising it slightly and applying a twisting action. Tighten any connection where movement is observed or felt.
3. Always place the tripod legs on solid ground even if it means spading away the grass and top layer of soil under each shoe.
4. Covers should be kept on the head of all tripods to prevent scarring which will cause problems with centering and leveling.
5. Any tripod with a warped head should be replaced.
6. Instruments must be attached to the tripod when they are first placed there to avoid damage. The attachment must be snug enough to hold without movement but not so tight as to stress the tripod head or tribrach.
7. Spread the legs of tripods enough so that the wind will not blow over the instrument.
8. The tension on the legs at the tripod head should be adjusted to allow the legs to fall slowed.
9. All equipment including tripods should be free of mud before putting away for the day.
10. The optical plummet and circular level of tribrachs must be checked frequently and kept in good adjustment. Tribrachs must be carried in cushioned containers to maintain their adjustment.
11. Even though the tribrachs' circular bubble is kept in good adjustment, the more sensitive tubelar bubble should be used for the final leveling for targets.
12. Tribrachs should be centered and leveled accurate enough to produce a maximum of 1 mm eccentricity.
13. Targets should be selected that will not introduce phase error into the angle observations.
14. All prisms should be numbered and the prism constant determined for each.
15. The prism type and number should be recorded for each EDM distance observed.
16. Prisms should be kept clean to increase their effectiveness and in protective cases when not in use to prevent damage to the glass.
17. No lens or glass of any kind should ever be touched with the fingers. The moisture will damage the protective coating and reduce the effectiveness of the equipment.
18. All equipment should be kept as free of dust and moisture as possible. Remove dust with a soft camel's hair brush. Allow wet instruments to air dry in the office. The moisture will migrate to the insides of the instrument and cause damage if left wet in the case.
19. Instruments should be carried in their carrying case. On very short moves they may be allowed to remain on the tripod if carried in the vertical position.
20. Instruments transported in vehicles should be confined inside padded compartments.
21. Clamps should never be viced down but brought only to a snug pressure to prevent movement.
22. Never allow total stations to be pointed to the sun unless an objective filter is attached and a solar observation is in progress.
23. Never lean any piece of equipment against trees, vehicles or buildings where it can fall.
24. Fingers should be kept from the face of level rods to preserve the graduations. Rotating the rod 90 degrees will place them on the side and avoid the damage to the graduated strip.

ANGLE OBSERVATIONS WITH THEODOLITES

1. Repeating theodolites can be used to measure angles where high accuracy is not required.
2. A minimum of one direct and one reverse measurement will be made to detect blunders, cancel most instrumental errors, and provide some measure of the quality of the measurement.
3. If additional measurements are needed to increase the accuracy or reliability, an equal number of directs and reverses will be used.
4. In repeating the angle, the angle will be accumulated on the circle and not set back to zero to avoid the limitation of the scale resolution.
5. The final mean angle will be the last value divided by the number of repetitions. This value must be comparable with the other readings before accepting it.
6. Directional theodolites are preferred to repeating theodolites. Like repeating theodolites, a minimum of one position (one direct and one reverse measurement) will be used to provide a check, to cancel most instrumental errors, and to provide an indication of the quality of the measurement.
7. When additional positions are required to increase the accuracy or reliability of the measurement, the circle and micrometer settings will be advanced evenly throughout the span to distribute circle graduation errorsand the run of the micrometer.
8. The number of positions required will depend on the specifications for the survey which will be established by the District Surveyor.
9. The rejection limit for 2nd order surveys is 5 seconds from the mean.
Reobserve rejected positions with the initial settings used before.
10. Reobserve angles that show a progressive change or where the first half differ significantly from the second half of the observations. Check for an unstable setup, tripod movement, or changing refraction along a grazing line.
11. You can expect horizontal refraction errors if lines are close to sloping surfaces or other objects. The closer the object is to the line of sight and the instrument, the greater the error.
12. Never park you vehicle near the instrument or line of sight.
13. Observe lines with possible horizontal refraction problems on overcast days or when the wind is blowing into the slope or object.
14. Check for stability by sighting a target and have recorder walk around the tripod while you are observing the target.
15. Rotate alidade horizontally and scope vertically several times to distribute the oil evenly over surfaces before beginning the observations.
16. Step wide around the tripod legs and make rapid, methodical, but not careless pointing.
17. Place no lateral thrust on the instrument with scope, clamp, or tangent screws. Use a purely rotary motion on all knobs. Use a clockwise motion (against the spring) for all pointings.
18. Don't intermingle short sights like RMs with the main skeme stations. All distant targets should be observed first, leaving the nearby targets to be observed last, just prior to reversing the scope. This will produce better accuracies on the more important targets by isolating the short targets that require changes in focus and reduce the time required to sight the targets.
19. Allow the instrument to acclimate to the air before observing. One minute per degree change is desired.
20. Instruments should be protected from the sun and wind, especially while centering and leveling. Standards or graduated circles in the sun will expand causing unknown errors and the bubble in a level vial will migrate to the heated end of the vial.
21. Leveling nor parallax errors will not be canceled by any observing procedure, therefore pay special attention to leveling errors along steep lines and parallax on all lines.
22. Omit calling out units but pause between units to allow the recorder time to record without getting confused.
23. The random component of angles accumulate as the square root of the positions, therefore the observations must be quadrupled to reduce the error by one half. The standard error of a single angle will be the loop error divided by the square root of the number angles, not the number of angles.
A 16-angle traverse with a 8-second closure error would indicate that the individual angle error is 8/4 or 2 seconds, not 8/16 or 0.5 seconds.
24. An abstract and list of directions will be prepared by the recorder and checked by the observer for all stations occupied. The degrees and minutes must be determined four times in the field notes to guard against blunders.

25. Field observed angles are actually geodetic not grid angles. The difference is sometimes called the t-T or second term correction. The correction becomes significant only on long north-south lines located at a great distance from the central meridian of the zone.

DISTANCE MEASUREMENTS WITH TAPES

1. Short distances can be measured faster and in some cases more accurate with a steel tape than with EDM but long distances should always be measured with an EDM.
2. Where high accuracy is required for a taped distance the tape should be calibrated to determine its length at a set temperature under a specific tension and method of support (either supported throughout or only at each end). A correction for the calibrated length should be made.
3. A slope correction must be made if the tape is not held horizontally. To make this correction, the vertical or zenith angle or the elevation change between the tape ends must be determined. Elevation change is usually used for taping and zenith angle used with EDM observations.
4. The horizontal length can be computed using standard formula or a close approximation of the correction can be determined with the formula Correction = elevation change squared divided by twice the slope
5. The length of a 100-foot steel tape will change 0.01 foot for each 15 degree change in temperature therefore a temperature correction will need to be made to account for the temperature change from when it was calibrated.
6. A sag correction will be required if the tape is held under some condition of support other that how it was during calibration.
7. A normal weight steel tape will sag (shorten) by 0.03 foot under the standard 20 pounds of tension but the sag will increase to 0.13 foot if the tension is reduced to 10 pounds.
8. A normal 100-foot tape will stretch 0.01 foot with an increase of 15 pounds in tension. This correction should be avoided by calibrating the tape with the same tension to be used in the field.

EDM CALIBRATION AND PRISM CONSTANTS

1. All EDMs must be calibrated on one of NGS's Calibration Base Lines (CBL) at least yearly and more often on a local base line.
2. The instrument-prism constant must be determined and accounted for.
3. NGS calibration lines are available at Batesville, Gulfport, Brookhaven, Bolton, Greenwood, Hattiesburg, Newton, and Starkville.
4. Tripods heights will be regulated to allow all observations to be made without new setups.
5. Tribrachs must be in good adjustment and precisely leveled and centered over the monuments on a stable tripod.
6. Removing or covering prisms must be done with care to avoid disturbing the setup.
7. The constant and scale error of the EDM will be determined along with statistics to indicate the quality of the data.
8. If different prisms are to be used with the EDM, then constants must be determined for each. Readings should be taken to all prisms available while they are exchanged in a stable tribrach. The prisms will have to be numbered and the prism number recorded each time they are used if the constants are different.
9. A three mark auxiliary base line should be established near the office to monitor the performance of the EDM more closely. The three marks should preferable be in line producing one short and one long line.
10. The short line can monitor the setup error and instrument-prism constant error and the long line can monitor the frequency and atmospheric (scale error) of the EDM.
11. This auxiliary baseline should be measured just prior and immediately after using one of the NGS CBLs.
12. A log book should be kept with each EDM to verify that it is stable and measures accurately.

EDM ATMOSPHERIC AND GEOMETRIC REDUCTION

1. The speed of light in air depends on the temperature, pressure, and to some degree the relative humidity. Corrections for these variables must be made manually or input into the EDM and let the EDM software make the correction.
2. All EDMs observe slope distances. Most EDMs have the capability to reduce the observed slope distance to horizontal by using data input by the observer or automatically sensed by the instrument.
3. New EDMs must be checked to ensure that the automatic reduction process used is valid.
4. Station elevations or zenith distances can be used to reduce the slope distances to the horizontal.
5. One pressure and two temperatures readings should be observed on all lines measured with an EDM.
6. The temperature probe should be held as high as feasible, in the shade and wind or in a shielded case with a fan pulling air through the tube.
7. A temperature error of 1-degree Celsius will introduce an error of 1 ppm into the distance.
8. The barometer should be shaded.
9. A pressure error of 0.1 inch will produce an error of 1 ppm.
10. Each EDM has a preset refractive index with an associated formula to correct for variances in the index. The EDM manual must be consulted to determine the appropriate formula and constants to be used with that instrument.
11. After the observed EDM distance has been reduced for atmospheric conditions, the corrected slope distance must be reduced for geometric conditions.
12. Accurate heights of the instrument and prism will be required in either case.
13. For geodetic work the horizontal distances will have to be reduced to the ellipsoid by multiplying the horizontal distance by an elevation factor.
14. The elevation factor for NAD'83 distances is R / (R+H+N) where
R = 6,372,000 meters, H = orthometric elevation, and N = Geoid height
The Clarke 1866 ellipsoid used for the NAD'27 datum was designed to fit the
Geoid for the United States therefore N was assumed to be zero and the orthometric elevation could be used directly in the elevation factor.
15. For State Plane Coordinate work, the geodetic or ellipsoidal distance must be multiplied by a scale factor to obtain a grid distance.
16. The NAD'83 scale factor for both zones in Mississippi will be 0.99995 plus a correction term that is a function of the distance from the central meridian.
It can be obtained from a formula or from the NGS' CORPSCON program. A distortion of 1:20,000 was placed on both central meridians for the NAD'83 datum whereas the NAD'27 datum had 1:17,000 on the West Zone and 1:25,000 on the East Zone.
17. The Geoid height (N) can be obtained accurately from the NGS GEOID96 program or its value can be interpolated from a plotted contour map. In Mississippi, N only varies from -26.4 to -29.0 meters. It takes a 6 meter change in N to amount to 1 ppm error in distance, therefore the interpolated value is more than adequate for distance reduction. The NGS program must be used when elevations are being determined that involve the Geoid height.

AZIMUTHS FROM POLARIS OBSERVATIONS

1. Polaris observations will produce very accurate azimuths if proper procedures are followed.
2. The tripod must have a very solid footing and remain stable throughout the observation.
3. The leveling of the theodolite must be very accurate as the altitude of Polaris will average about 33 degrees in Mississippi. A 20-second level vial one division out of level will produce a 13-second error in the azimuth.
4. The backsight target should be a minimum of 400 meters (0.25 mile) away to reduce focusing and eccentric setup errors.
5. NGS's DEFLEC96 program can be used to determine the LaPlace correction to convert the astronomic to geodetic azimuth. This correction is small in Mississippi varying from +1 to -4 seconds. For all but the most accurate work, the correction can be interpreted from a contour plot.
6. The grid azimuth of lines east of the central meridians will be smaller than the geodetic azimuth and the reverse will apply for lines west of the central meridians.
7. Inclinations of the horizontal axis can be obtained by reading both ends ofthe plate bubble at each pointing on the star.
8. An alternate method of determining the inclination is to read the vertical circle 90-degrees right and left of the star but this will require additional time and movement around the tripod.
9. The final leveling of the theodolite prior beginning the Polaris shot should be made using the sensitive vertical circle compensator in the plane perpendicular to the star.
10. The final leveling with a transit should be done with the telescope bubble, which is two to four times more sensitive than the plate bubbles.
11. When the latitude and longitude is known, the convergence will be equal to the longitude difference from the central meridian times the sine of the latitude.
12. When the North and East coordinates are known, the convergence will be equal to the change in East coordinate from the central meridian (E') times a M value, interpolated from a table using the North coordinate.
13. A stable setup and precise leveling is a must anytime elevated targets are observed such as for Polaris and solar observations.
14. Time can be obtained by radio from the National Bureau of Standards station WWV located at Ft. Collins, Colorado or Canada's station CHU.
15. WWV broadcast on frequencies of 5, 10, 15, and 20 megahertz or you can obtain the signal by phone at 303-499-7111.
16. After the 5" rejections have been made, 75 percent of the original twelve positions must remain and have a standard error less than 1.5 seconds.
17. The scope should be reversed on the star each time and the time lapse between the two sightings should be less than 3 minutes to avoid having to make a curvature correction for the path of the star.
18. Just prior to bisecting the star, the observer will call "standby" to alert the recorder to watch the clock and record a precise time at the "tip" call tofollow.

AZIMUTHS FROM SOLAR OBSERVATIONS

1. Sun shots are more convenient because of the time and illumination factor but are less accurate than Polaris shots.
2. The precautions for centering, leveling, and having a stable setup is the same as for a Polaris shot.
3. Hour Angle Solar shots should be taken in early morning or late evening when the sun is low in the sky so instrument leveling error will be less critical.
4. Azimuths accurate to 10 seconds should be obtainable with a 1-second theodolite if taken when the sun's altitude is below 20 degrees.
5. Accurate time is required when using the preferred hour-angle method.
6. Direct time from WWV including the number and sign of the double-clicks is required. Each double-click represents a correction of 0.1 second. A plus correction is made for double-clicks before the 8-second click and a negative correction for double-clicks after the 9-second click.
7. The time must be recorded to the 0.1 second because each 0.1 second error in time will produce from 0.5 to 1.5 seconds error in the azimuth.
8. The altitude method should be limited to low accuracy requirements and then only when accurate time is not available.
9. Any coordinates derived from an orientation by a solar observation will be in suspect and will be so noted.
10. Since time is so critical for hour-angle solars, the observer must operate the stop watch himself and not try to relay the time to the recorder.
11. Three pointing on the sun's trailing edge is usually obtained for each pointing on the azimuth mark. One set will consist of 3D & 3R pointings on the sun and 1 D & R pointing on the azimuth mark. Three independent sets should be observed to establish an azimuth for a line.

AZIMUTHS FROM CONTROL STATIONS

1. The azimuth accuracy from two control stations will depend on the distance between the stations and also the accuracy of their positions. The azimuth accuracy naturally increases as the spacing and positional accuracy increases.
2. A 3 mm positioning or centering error at stations spaced 400 meters (0.25 mile) apart can produce a 3-second error in azimuth.
3. A 10 mm positioning error at stations spaced 400 meters (0.25 mile) apart can produce a 10-second error in azimuth.
4. Azimuths to reference marks can be in error by 2 minutes or more and should not be used except as a check against blunders from higher order azimuths. Many of the directions to reference marks were made from the top of tall Bilby steel towers resulting in very steep and short lines making accuracy very difficult.
5. Azimuths from azimuth marks are usually accurate to within 10 seconds but most of them are destroyed or blocked by trees or buildings. These marks are "no check" observations for NGS and therefore must be used with caution.
6. With EDMs to measure distances, blocked azimuths can still be used to obtain an azimuth by making one or two extra setups between the station and azimuth.
7. Occupying the station mark with an eccentric target at the azimuth mark is the preferred method of obtaining an azimuth. This will allow angles to be turned to the RMs for a rough check against any large blunders.
8. Azimuths should not be obtained by an inverse from two positioned stations that are closer than 400 meters apart.
9. When two intervisible stations are positioned by GPS for the purpose of obtaining an azimuth, both stations must be occupied twice, independently.
10. The inverse between two control stations with State Plane Coordinates will produce the grid azimuth which is needed for this system.

VERTICAL CONTROL

BACKGROUND HISTORY

1666 Level vial invented
1740 Y-level invented
1845 Dumpy level invented
1856 First geodetic leveling in US for tide study along NY Bay & Hudson River
1875 US Lake Survey (USACE) started level line to Great Lakes from New York
1875 US Geological Survey (USGS) founded for topographic mapping
1877 Double-simultaneous leveling using two pairs of rods introduced by USACE
1877 Leveling along the 39th transcontinental arc of triangulation began at BM A in Hagerstown MD to control trigonometric elevations determined from vertical angles observed along the arc to Golden Gate, CA
1878 Geodetic term added to change U.S. Coast Survey to USC&GS
1881 Levels from New Orleans LA to Greenville MS completed
1882 Method of 3-wire leveling introduced
1884-1890 Level line from N.O. LA to Mobile to Corinth to Cairo to TC arc in IL
1899 A total of 25 level circuits completed
1900 Fisher geodetic invar level introduced and used until around 1967
1900 First General Adjustment of 4200 BMs, 21,095 km of geodetic leveling to 5 tidal stations (4 on east coast plus 1 at Biloxi MS)
1903 Second adjustment of 6900 BMs, 31,789 km leveling to 8 tidal BMs
1907 Third adjustment of 9100 BMs, 38,359 km to 9 tidal BMs including the first spirit-level connection to the Pacific Coast at Seattle WA
1912 4th adjustment of 11,100 BMs, 46,462 km plus Galveston & San Diego tidal BM
1912 First orthometric corrections applied but only west of Mississippi River
1916 Improved leveling rods of INVAR rather than brass introduced
1927 Special adjustment of closed loops with only the Galveston tidal BM fixed
1929 Special adjustment of closed loops with only the great lakes region fixed
1929 General adjustment of 75,000 km & 21 tidal BMs in US & 32,000 km & 5 tidal BMs in Canada (693 links, 450 jct pts, 246 closed + 25 sea level circuits)
1934-1935 Rapid progress (WPA) with many supplemental adjustments
1955 International Great Lakes Datum based on MSL at Father's Pt St Law. River
1973 Sea Level Datum of 1929 renamed NGVD'29 to avoid terminology confusion
1976 NGS started recording level observations on programmable calculators
1978 Leveling & gravity surveys began for a new adjustment
1988 NAVD88 scheduled completion date
1991 June NAVD88 readjustment completed with 625,000 km of additional leveling 81,500 km of 1st-II releveling using double-simultaneous method Elevations changed from -0.4 to +1.5 m in CONUS and +0.94 to +2.40 m in AK. Adjacent BM elevations changed less than 10 mm

AVAILABILITY AND RECOVERY OF EXISTING CONTROL

1. Any agency that may have established control in the project area should be contacted to obtain all available data. Example agencies other than MDOT would be the National Geodetic Survey (NGS), U.S. Geological Survey (USGS), U.S. Army
Corp of Engineers (USACE), and the Tennessee Valley Authority (TVA).
2. The latest geodetic control diagram and CD-ROM from the National Geodetic
Survey (NGS) should be examined to determine all available control already in the national database.
3. The NGS has run first-order lines at approximately 160 km intervals. Three class A monuments are usually set near the junction of first order lines and one at five mile intervals along first order lines. The area within the first order lines are subdivided with second-order level lines spaced at 40 and 80 kilometer intervals and in certain sections, second-order lines from 8 to 16 kilometers apart. Most of the older level lines followed railroads to take advantage of easy grades for economy and the later lines have followed highways for improved access.
4. Stability B or C monuments are usually placed at 1 mile intervals along all new lines of levels.
5. NGS marks contain consecutive letters from A to Z (O & I omitted) throughout a number, then the number is advance one, then A to Z again. The year is always stamped below the letter and number. Example: B 134 1998
6. MSHD marks are stamped BM with the highway number followed by a "V" and consecutive numbers starting with 1, with the year below the designation. Example: BM 82V123 1964
7. Most of the USGS leveling is to third order accuracy established for control of topographic mapping. The accuracy is increased to second order only when the level line will exceed the 30-mile maximum length for third-order lines. Their marks are aluminum disks (tablets) stamped with the initials of the party chief, preceded by consecutive numbers, and followed by the year established. Example: 33 REB 1972
8. After collecting data for all available control in the project area, plot or locate it on a suitable map such as USGS 7.5 or 30x60 minute maps.
9. Make a reconnaissance trip to search for the control and also to select sites for new monuments that will be needed for the project. Elevations should be established on any horizontal control monument that is within two kilometers of the level line to be run.
10. Two people with a 50-meter tape, probe, compass, spade, flagging and stakes are needed for this recovery and recon phase.
11. Prepare a report on all marks searched for and make a pencil rubbing of all marks found. Rubbings are made by placing a piece of light to medium weight paper over the disk and rubbing over the paper with a hard pencil to bring out the stampings on the disk.
12. Redescribe all marks found that are still usable and send a copy to the establishing agency.
13. Descriptions should contain the USGS 7.5-minute quad sheet, township and sectional reference, 3 airline references, a TO REACH paragraph, distance and azimuth from 5 objects as references, agency and all stamped (not cast in) data on the disk, projection and one elevation reference. All directions should be from the reference object to the mark. Typical reference objects are building corners and walls or projected walls, roads, utility poles, ends of culverts, fences, lone or unique trees and the like. Start with the longer or more obvious objects and work toward the mark. At least one very permanent reference must be made along the road to verify general location of the mark. A culvert under the road or a road crest will usually serve this purpose.

LOCATION AND CONSTRUCTION OF NEW MONUMENTATION

1. The value of a line of levels depends upon the distribution and permanency of the bench marks established or tied during the leveling. The bench marks are the only visible evidence of the work, and the necessary time and money should be spent to perpetuate the line by making the marks of a substantial character and by placing them in locations where they will be as free as possible from the usual causes of disturbance or destruction.
2. As a rule, the horizontal and vertical control for a project should be planned concurrently so that both types of surveys can use the same permanent marks whenever practicable. When possible, monuments should be placed where they will be GPS observable.
3. All bench marks established should possess permanency and vertical stability.
4. The stability of monuments are rated from A to D with A being the best.
5. "A" stability is a rod monument driven to refusal with the top portion isolated from the ground surface with a PVC sleeve set in a bored hole.
6. "B" stability is a rod monument driven to refusal but has no isolation sleeve.
7. "C" stability is the usual concrete monuments set to a depth of 0.7 meter.
8. "D" stability has a lower stability than the concrete monuments.
9. Based on a USGS study, ten-foot rod monuments are twice as stable and half as expensive as concrete monuments.
10. Rod monuments may come in 2, 3, or 4-foot sections and are crimped together with 3-inch sleeves or connected with threaded couplings. The rods may be aluminum, copper-coated steel or stainless steel with the disk crimped or soldered to the rod. A 6-inch by 12-inch drain tile or PVC pipe should surround the bench mark for protection. Due to the acidic soil in Mississippi, few sites will be suitable for the aluminum rods.
11. Bench marks exhibit an annual cyclic change in elevation with upheaval in the spring and summer and a settling in the fall and winter. The elevation change varies inversely with the rod length.
12. Poured-in-place concrete monuments should be a minimum of 200 mm in diameter and set to a depth of 0.7 meter with the top flush or slightly below ground. The holes should be belled out at the bottom for anchorage and loose dirt removed or well tamped to prevent settlement.
13. When precast concrete monuments are used, all of the dirt in the bottom of the hole must be removed or tamped thoroughly to minimize settlement and the backfill must be well tamped to set the post firmly.
14. Disk can be star-drilled and cemented into rock or existing concrete structures that are solid and stable.
15. The designation and year established should be stamped on the disk.
16. Witness posts should be set 0.5 meter from each monument.
17. Alternate the sides of a road for monuments in case the road is four-laned.
18. Quality monuments should be placed at each end of every project and at intervals from 0.5 to 1.0 kilometers. A sketch of the site and a complete description must be prepared. Monuments that cannot be found are useless.
19. Two monuments should be placed near the site of every major drainage structure. A vertical control disk will be placed in all major drainage structures before the concrete sets up. After the structure has made its initial settlement, the elevation will be transferred to the mark from the two vertical control marks nearby. Micrometer single-wire leveling will be appropriate for this phase. Double run levels from both nearby marks will insure against a blunder in the transfer of the elevation.
20. All existing and new monuments near the project must be shown on the construction plans along with the control data.

DATUM TIES

1. In general, a line of levels will begin and end on published USGS or NGS bench marks of 3rd order or better accuracy.
2. At least two bench marks which, as shown by new leveling, have not changed their relative elevations must be recovered at each end of the line and at any intermediate junction of the line with previous leveling.
3. A satisfactory tie should check the old elevation difference between the two marks within the accuracy to which they were set or the accuracy of the new level line.
4. Failure of the new leveling to check the original observed difference between two bench marks within the specified limits shall be construed to indicate movement of at least one of the marks, requiring a tie to another mark to determine which mark has moved. Notify the agency that set the marks of the discrepancy.
5. The two tie marks should not be in the same structure or close together, such as a triangulation station and reference mark, to avoid both marks being affected by the same disturbance.
6. When a level line parallels another line within 3 kilometers, ties should be made every 8 kilometers. Loop closures are checked using both the new plus the old leveling results.
7. Lines may be run in only one direction if the double scale rods are used except for first-order lines, spurs, and lines involving marks where movement is suspected. Lines run using the three-wire method will be double run.
8. Elevations will be referenced to the current NAVD and so labeled.
9. For projects too far from existing control, the ellipsoid height at one of the GPS stations can be converted to an orthometric height and used as the datum but it must be identified as such and well documented in the control file.

LEVEL RODS AND STAYS

1. Two one-piece invar rods should be used, graduated in feet, yards, or meters. Two-piece rods always have an unknown error at the joint and are therefore unacceptable for precise leveling of third-order or higher. Rods may be of the single-scale type which are usually block-graduated or the double-scale type which are line-graduated. Levels with wedge reticles and micrometers are needed with line-graduated rods.
2. Store rods in a vertical or fully supported horizontal position to prevent warpage. They should be transported in well padded boxes to prevent any damage. Never leave rods leaning insecurely against a tree, pole or other prop and never lay face down on the ground for possible damage.
3. Check the rod bubble adjustment for rod verticality at least weekly. This can be done with the level's vertical crosshair if the rod is checked from the front, then turned 90 degrees and checked from the side. Rods can be checked against the wall of a vertical building or with offset measurements from a long string plumb bob inside a building. With the rod bubble held at the center, the deviation of the face and the edge of the rod from the vertical must be recorded. If the deviation from the vertical in either direction exceeds 10 millimeters on a three-meter length of the rod, the rod level must be adjusted.
4. Rods should be a "matched" set with calibrations very close to each other.
5. Using two rods reduces the time lapse between the backsight and foresight to reduce error from tripod settlement or rebound, refraction change and relaxation of the compensator.
6. Rods should be of "T" cross-section to reduce warpage and wind sway.
7. Rods should have a rigid precise shoe to produce the same reading regardless of its position on the turning point.
8. The main graduations should be on an invar strip attached at the base and under tension at the top of the rod.
9. The rod bubble should be at least semi-permanently attached to the rod and provision for the thermometer bulb to be in contact with the invar strip from the rear.
10. The coefficient of expansion for invar is +- 0.00000022/degree F, which is much lower than steel.
11. Stays or struts should be used to hold the rod steady for all readings. They are mandatory for micrometer leveling but not for 3-wire leveling.
12. When necessary, an inexpensive set of telescoping stays can be made from two sections of slightly different diameter electrical tubing.

RODMEN

1. The rodmans' work is a very mundane task, yet he can make or break a level circuit as quickly as the observer or recorder.
2. Turning pin movement is a common source of error in leveling. It is usually caused from setting the pins poorly or from rod movement on the pin. No undue force should be exerted on the rod at any time during the period that the pin is holding the elevation. The rod should rest on the pin under its own weight, and it should be turned very carefully so as to keep the weight on the pin constant.
3. Turning pins should always be set very stable in firm ground with only one high point. Turning plates should seldom be used as they settle from 3 to 5 times more than pins. Settling is most rapid during the first 20 seconds and then it slows down. A forming nail can be set in the top of a driven stake for a turning point in extremely soft soil.
4. Replace rods on turning points very carefully if removed. It is better to keep them vertical with little motion between foresight and backsight to prevent turning pin movement.
5. Be sure the rod shoe is clear of mud or dirt at each turn.
6. To prevent the deterioration of the rod graduations be sure that fingers are kept on the side of the rod and not on the face where the graduations are located.
7. The rodmen must be very safety conscience around traffic due to the long length and extended position of the one-piece rods.
8. The backsight and foresight distances are balanced by pacing and verified by stadia data. Although 10 meters out of balance is allowed, the balance should be kept within half that value.
9. The observer will regulate the length of sights to use based on the prevailing atmospheric conditions.
10. Be extra careful with rod plumbing for all high rod readings as plumbing errors increase with the higher rod readings.
11. An 3.000 meter rod reading will be in error by 1.7 mm if the top of the 3-meter rod lacks 0.1 meter being plumb. The same plumbing error would produce an error of 0.5 mm in a 1.000 meter rod reading.
12. Rods will be leapfrogged with rod A being used on all bench marks. An even number of setups will be used between adjacent bench marks thus canceling any rod index error.

TRIPODS AND LEVELS

1. The use of tall fixed-leg tripods will prove more stable, provide for longer sights, and keep the line-of-sight farther from the weather layer.
2. Tripod legs should have large shoes and cleats for better stability and less settlement. The amount and direction of the tripod displacement will depend on the hardness of the ground. Turning pins and tripods will actually rebound instead of settling in some soils.
3. Connections at the head, joints, and shoes should be kept tight to prevent unwanted movement.
4. Test the tripod by lifting and twisting one leg at a time while watching for any movement.
5. Use the appropriate quality level for the accuracy desired. Second order leveling requires a level that has a compensator with a setting accuracy of 0.5 seconds for its line-of-sight. The Princeton Test will indicate the quality of the level and should be run when the level is in doubt. The NGS uses Jenoptik
NI 002 reversible compensator levels with micrometers and also the Zeiss NI-1 and MOM NI-A31 compensator levels with Kern 0.5-cm invar rods with low and high numbered scales. Their observations are keyed into programmable calculators which make all checks, sum stadia and elevation differences, stores the data, and displays accumulated stadia distance imbalance so corrective action can be taken on the next setup when needed.
7. Use a level with a wedge reticle and micrometer for line-graduated rods and the standard reticle for block-graduated rods.
8. The quality of the optics, compensator, and workmanship will determine the quality of the level. All compensator levels are sensitive instruments and must be handled with care. Levels should be protected from shock while being transported by placing them on a thick mat of foam rubber and never on the bare floor of a truck.
9. Large objective lens will allow more light inside the telescope to produce better images.
10. Tilt the level up and down slowly with a leveling screw while observing a rod. If the compensator is adjusted properly, the compensation will cease in each direction when the bubble is at equal distances from the center.
11. Use a level with a 0.3:100 stadia ratio with yard rods and three-wire leveling. Use the standard 1:100 stadia ratio for other types.

C-FACTORS

1. A C-Factor must be run at the beginning of any level line and at daily or weekly intervals as specified by project instructions. No adjustment is necessary if C is less than 0.00010. If an adjustment is made, always re-run the C-factor to verify the adjustment. After the adjustment the C should be less than 0.00005 or (0.05 mm/meter).
2. The amount to adjust a level will equal the C-factor times the distance to the far rod from setup #2. Lower the reading for a negative C-factor and raise the reading for a positive C-factor as the C stands for correction, not error.
3. The C-Factor consists of a short closed circuit of leveling that exaggerates the difference between the backsight and foresight distances and produces a closure proportional to the collimation error of the level. The C-factor represents the amount the line of sight of the level diverges from the horizontal and will be used to correct elevation difference for any remaining out-of-balance between two adjacent vertical control marks.
4. C-factors tend to change frequently on automatic levels therefore sights must be balanced at all time. C-factors exhibit a change as a function of the temperature and therefore should be run about the same time each day to establish their stability. Their value can exhibit a 3-second change for a 10 degree Fahrenheit change in temperature. New levels should always be tested daily and then the frequency can be reduced to weekly once the stability of the C-factor has been established.
5. To run a C-Factor, establish two solid turning points about 50 meters apart on fairly level ground.
6. Make setup #1 about 10 meters from Rod A and setup #2 about 10 meters from Rod B.
7. Be sure to read Rod A first from each setup but the near rod will always be recorded as the backsight and the far rod as the foresight.
8. Calculate a curvature and refraction correction for the two long shots, add these together and reduce the sum of the distant rod readings by this amount.
9. C-Factor = (Sum Near RR - Sum Far RR) / (Sum Far RI - Sum Near RI) where RR is rod reading and RI is rod intercept.

OBSERVERS

1. Observers should keep both eyes open while observing to reduce eye strain.
2. Be sure parallax is removed before observing. This is done by pointing the telescope toward the sky or any light-colored surface and focusing the eyepiece on the cross wires so that they appear sharp and black. Next focus the objective on a distant leveling rod and test for parallax by moving the eye slowly across the exit pupil. If the wires appear to move over the image of the graduations, parallax is present. The parallax may be due to poor focusing of either the eyepiece or the objective. To eliminate the parallax, refocus the objective until no parallax is present, then, if the image of the graduations is not distinct, move the eyepiece the small amount necessary to make it appear distinct. This adjustment should be tested frequently while observing because the eyes of the observer tire and the focal distance of the lens of the eye change causing a blurring of the cross wires, which should be corrected by refocusing the eyepiece.
3. Be sure the circular bubble is in excellent adjustment and is precisely centered, not just inside the circle to avoid over or under compensation. To adjust the bubble, rotate the level 180 degrees after precisely centering the bubble. Move the bubble half way toward the center of the ring with the adjusting screws and the remainder of the way with the leveling screws. Repeat this operation until the bubble will stay in the center of the ring with the telescope in any orientation.
4. Never relevel an automatic level between the backsight and foresight and keep the sights balanced so that refocusing is not required.
5. Place one tripod leg uphill and two downhill on slopes to improve stability and reduce settlement of the tripod.
6. The maximum length of shots is 60 and 70 meters for second order leveling under ideal conditions and will have to be reduced as the atmospheric conditions deteriorate.
7. Take no rod readings below 0.5 meters to avoid bad refraction in the weather layer near the ground surface.
8. Use procedures that will cancel most systematic errors and minimize random errors.
9. Alternate the order of observing by reading the back sight first on all odd number setups and fore sights first on all even number setups to cancel many systematic errors. Leapfrogging the rods and observing rod A first at every setup will automatically alternate the observing correctly.
10. Orient the level and the same part of the tripod toward rod A at each setup then center the bubble with this orientation before observing. This will reduce error due to the compensator action in automatic levels, will reduce error caused by unequal heating of the level, and will reduce error caused by stress in the tripod.
11. Always end with an even number of setups between adjacent bench marks to cancel rod index error.
12. When leveling is temporary halted at a point other than a monument, due to rain or other causes, a check point should be established at least one setup of the instrument away and at an elevation difference greater than 0.5 meter. When leveling is continued from or to such a pair of points, the instrument should be set up midway between them and rod readings taken on each point, in order to determine if either of the points has been disturbed. If the new difference does not agree with the first determination, releveling must be extended to other points to verify the stability of the point used in carrying the elevation ahead through the line. When establishing a pair of points as provided above, decide at the time they are established which one is to be the bench mark and which one is to be the check point.
13. Half of the sections in a single run line should be run from each direction. Divide into days or half-days and reverse direction of levels at least every other day to reduce the accumulation of small systematic errors along the level line.
14. The backward run of double run lines should be under different atmospheric conditions, i.e., morning and afternoon or a minimum of 4-hours apart.
15. Never read rod A until rod B is in position and can be read without waiting which will allow additional time for the tripod to settle.
16. Never use a side shot on any bench marks. You must turn through all marks.
17. Where long shots are unavoidable such as river crossings, simultaneous reciprocal observations will be taken. The two observers with their level will switch sides and make a second set of simultaneous reciprocal observations after the first set is completed.
18. Keep sights balanced at all times because C-factors in automatic levels tend to change frequently.
19. Refraction is a major source of error in leveling. It changes as a function of the height above ground because the layering of the air tends to follow the contour of the ground. This means that sights up grade will be refracted more than sights down grade. As temperature rises, refraction increases which will bend the line

of sight down to a greater extent. The magnitude of the refraction error also increases as the square of the length of sights. Reducing the sight lengths will therefore reduce the refraction error.
20. The maximum out-of-balance allowed on an individual setup or on the accumulation within a level segment is 10 meters but should be kept within half that value. Any out of balance should be made up in the next few setups and kept within half the allowable.

RECORDERS AND FIELD NOTES

1. In control levels, elevations are not kept in the field notes, only rod readings and elevation differences.
2. Notes should be designed for ease of recording, use, and clarity.
3. Neatness and legibility of numbers are of extreme importance.
4. Explain any unusual condition or situation, but don't clutter notes with unnecessary figuring.
5. All bench marks used must be identified by the agency and contain all stamped (not cast in) information including the year.
6. The recorder must be extremely careful not to reverse the backsight and foresight in the notes as this mistake can go undetected and is easy to make as the order of observing them is alternated. Using a rod pair with different rod constants will detect and prevent this blunder.
7. The setup's, not the turning points, are numbered in control leveling.
8. The recorder is responsible for insuring that all readings are acceptable and that all specifications are met.
9. When available, electronic recording for control leveling should be used to speed the operation and produce less mistakes than hand recording.

MICROMETER SINGLE-WIRE LEVELING

1. Micrometers will usually divide each rod graduation into 100 divisions. This will allow readings on a Philadelphia rod to be observed to 0.0001 foot. Stays or struts attached to the rod will be required to justify these readings.
2. Single-wire leveling will be limited to short double run lines as no internal checks are available. Transferring the elevation from one mark to another nearby mark is an example of where this can be used but two totally independent setups must be made.
3. Trying to place the wire on the division line of a block-graduated rod will obscure the division and prevent an accurate placement. Therefore with block-graduated rods, move the x-hair midway of a division every time with the micrometer. Your eye can bisect small divisions with extreme accuracy. Read the graduation immediately below the center wire, then add the micrometer value to the rod value for the final rod reading.

THREE-WIRE LEVELING

1. Most existing bench marks have been established by 3-wire leveling but this method is being replaced by double scale rod leveling.

2. Three-wire leveling can be considered as using the mean of three level circuits run simultaneously. The stadia data provides a record of the balance and length of sights. This data is needed to make an adjustment for any remaining balance, to determine the length of the circuit and to verify that the specifications were met.
3. You must use a level with a stadia ratio greater than the usual 1:100 to utilize the best part of the optics and to allow greater length of sights.
4. A level with a stadia ratio of 0.3:100 is preferred with yard rods. Each yard of intercept will equal 1000 feet of distance therefore the intervals will give the sight lengths directly in feet.
5. Use block-graduated rods, preferably yard rods as the sum of the three wires will produce foot readings and the back strip in foot units give an excellent check. Observe only the center wire on the back check strip. This reading must agree with the sum of the three front face readings within 0.01 foot or the readings must be reobserved.
6. Observe the top, center, bottom wire in that order, omitting the decimal point.
7. Comparing the top and bottom half-intervals provide a check on the readings before the level is moved and also forces the observer to have parallax under control. Both are very important on long level lines.
8. Allow the difference between the top and bottom half-intervals to be a maximum of two units.

DOUBLE-SCALE ROD LEVELING

1. This is the latest and preferred method because of its advantages. The wedge reticle of the level is placed directly on one of the line graduations with the parallel plate micrometer. The micrometer value is added to the centerwire graduation to produce an extremely accurate centerwire reading. Without moving the micrometer, the top or bottom stadia wire is read to determine the distance to the rod. One figure is estimated past the graduation. The difference between this value and the centerwire graduation (without the micrometer reading) will produce the sight length.
2. The order of reading is backsight low scale center wire, backsight stadia wire, foresight low scale center wire, foresight stadia wire, relevel or reverse compensator, foresight high scale center wire, backsight high scale center wire.
3. Rods are line-graduated with two sets of graduations offset on the same invar strip.
4. Two independent elevation differences are determined and their difference compared with the maximum allowed for the order of levels being done.
5. Stays are required to hold the rods vertical and stationary.
6. An even number of setups is required between every pair of bench marks so that any rod index error will be canceled.
7. The rods will be leapfrogged with the A or #1 rod being on all bench marks.
8. The right or high scale of the rods is offset a constant distance from the left or low scale. This allows for a check to be made to insure that the two readings are valid. Some of the newer rods have a different constant for Rod B from Rod A to distinguish between the rod readings. This can be used to detect the transposition of backsight and foresight readings.

CONTROL SUBMITTAL

OVERVIEW

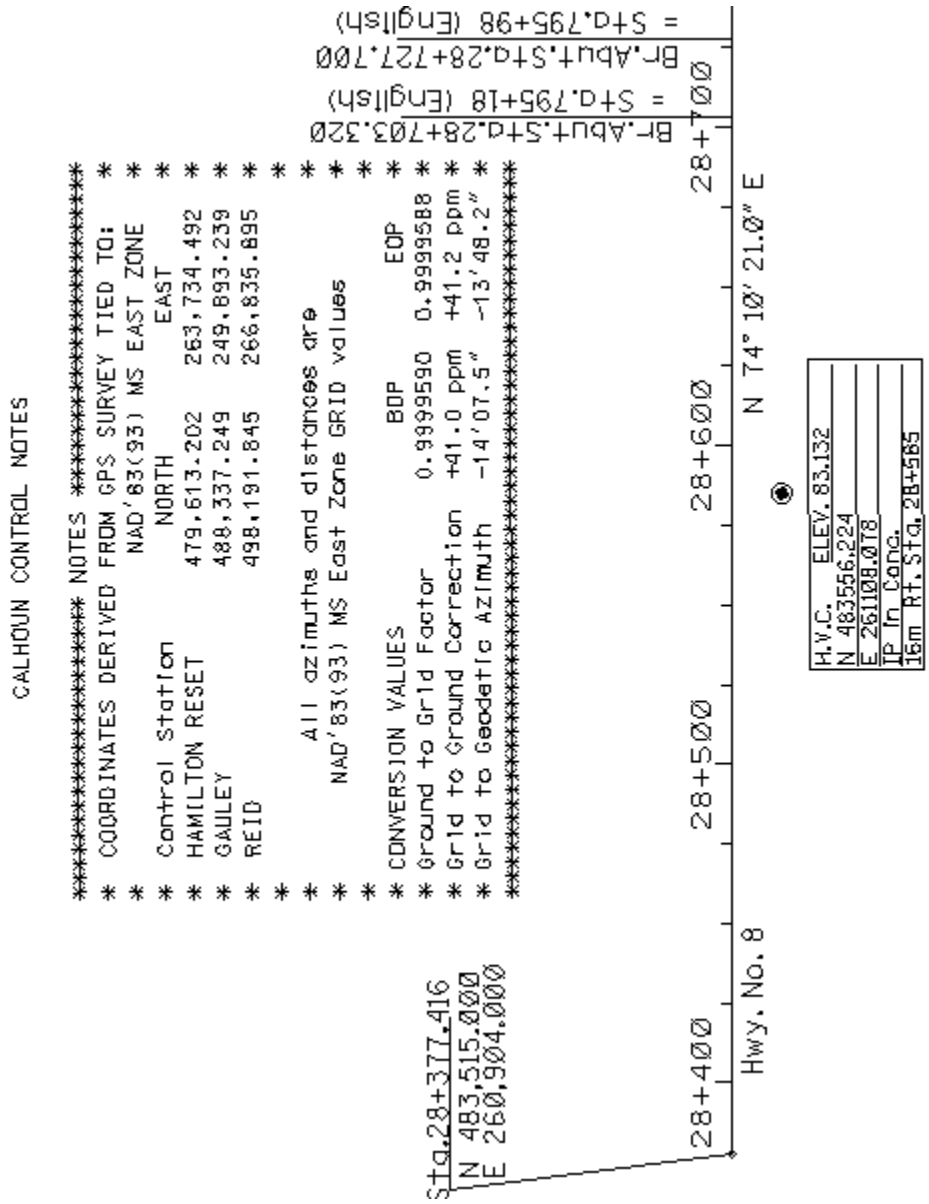
Upon the District Control crews completion of establishing initial control for a project, a 2D design file called CONTROL.DGN should be submitted to the Project Office containing a control note as shown in the example below, all control established shown, and alignment if it has been established. Alignment information would include all curve data, tangent bearings, and BOP-EOP stations/coordinates. The control note shall appear on the Cover sheet of all projects with the following equations also shown:

GROUND DISTANCE = GRID DISTANCE / GRID FACTOR

GROUND DISTANCE = GRID DISTANCE + PPM

GEODETIC AZIMUTH = GRID AZIMUTH + ME' (SHOWN AS GRID TO GEODETIC AZIMUTH BELOW)

Example of CONTROL.DGN



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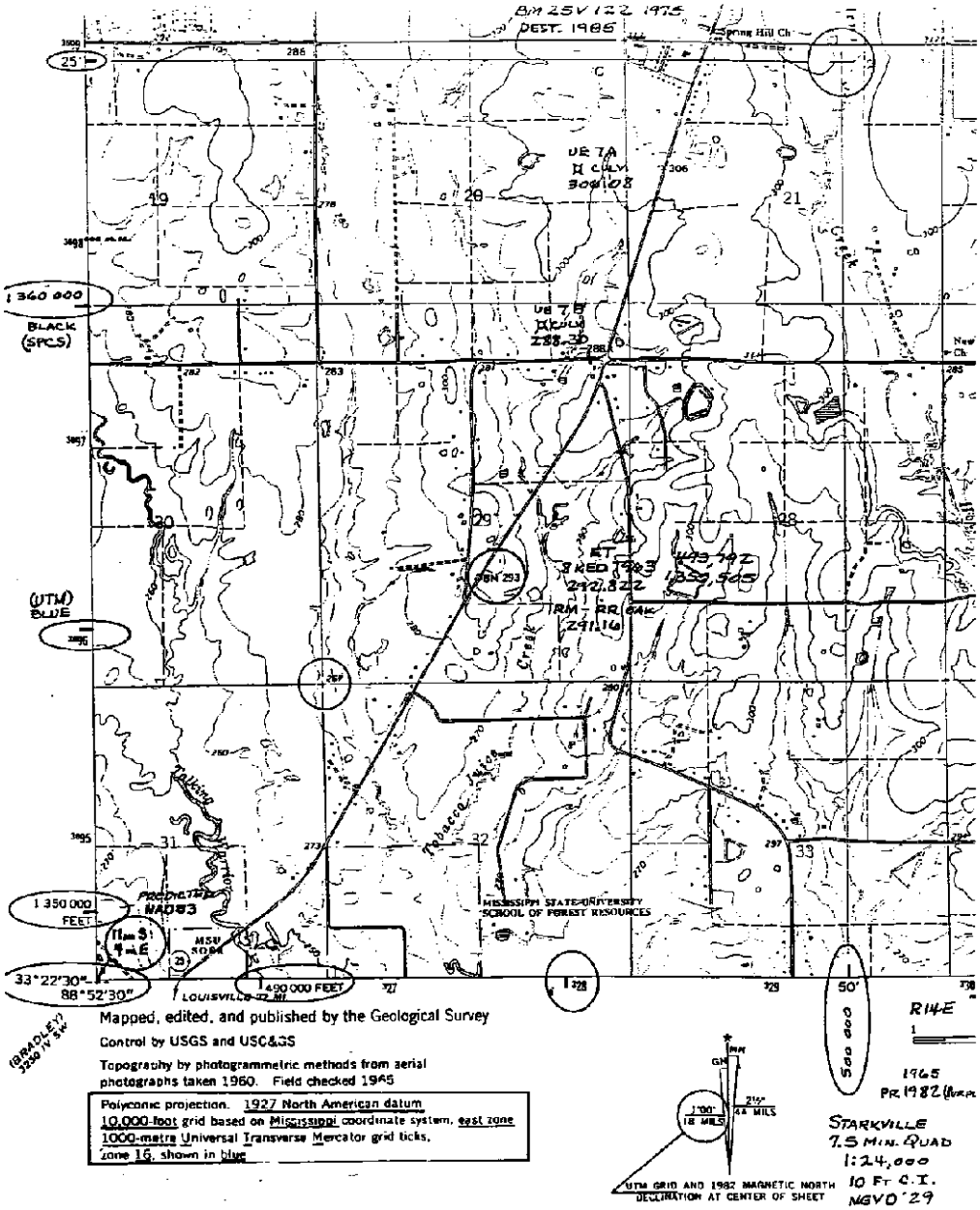
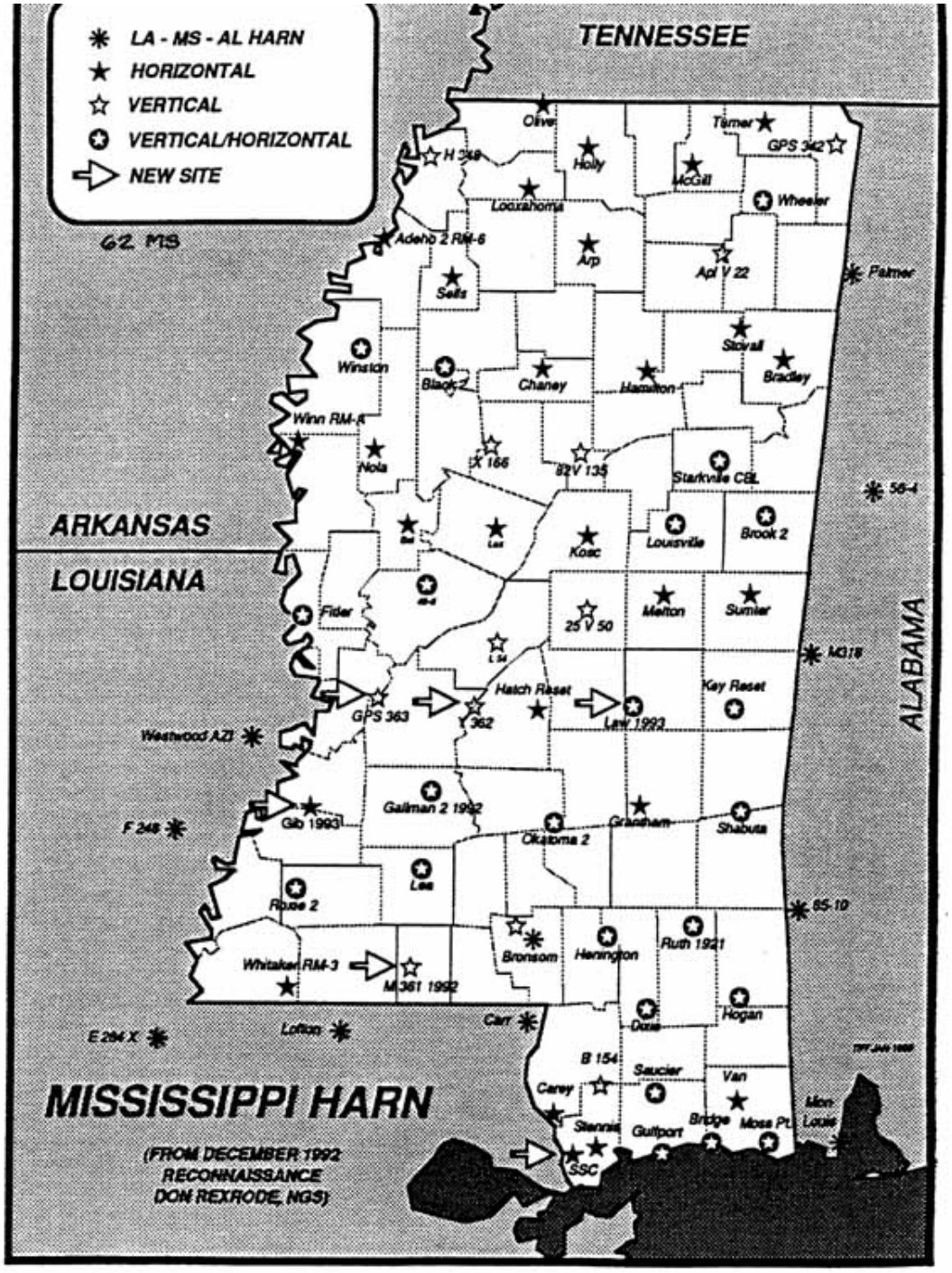
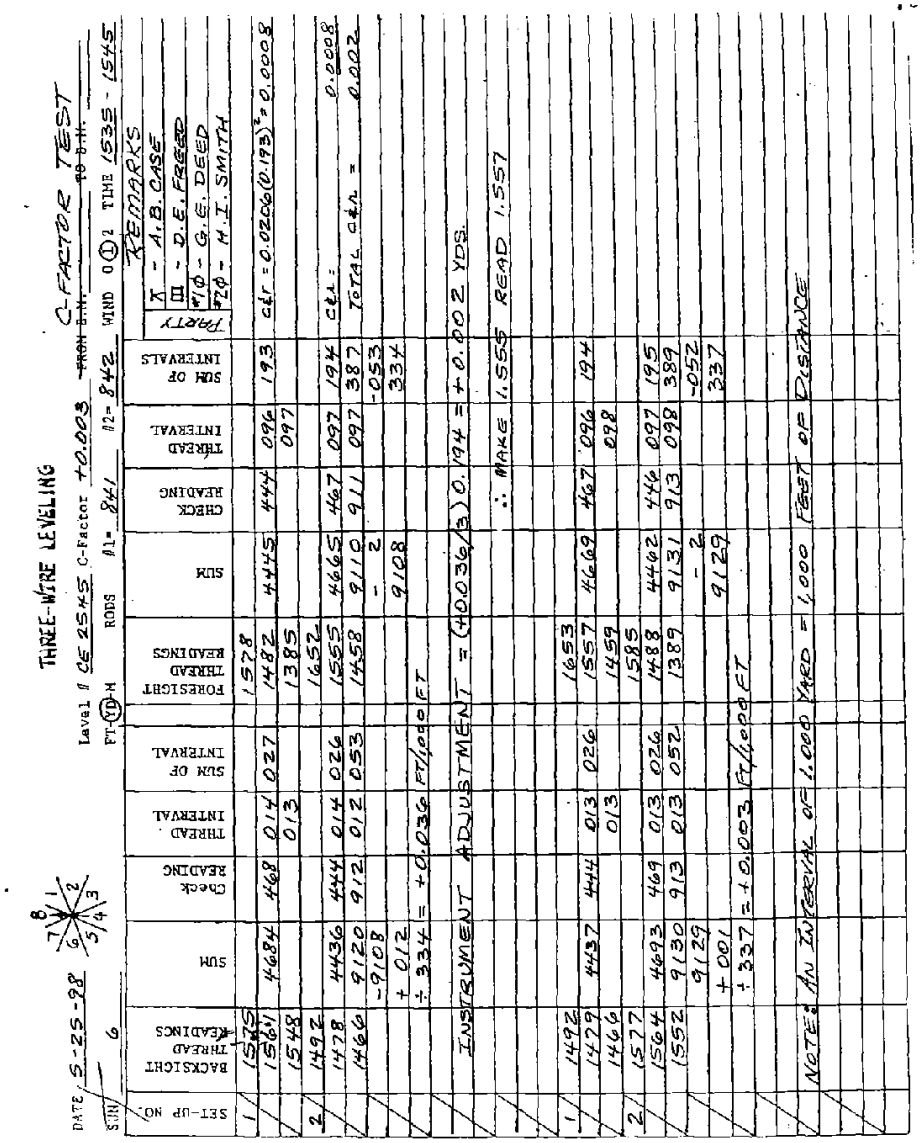


1. Data available on 7.5 minute (1:24,000) USGS quad maps



2. General location of HARN stations in Mississippi



THREE-WIRE LEVELING — C-FACTOR TEST

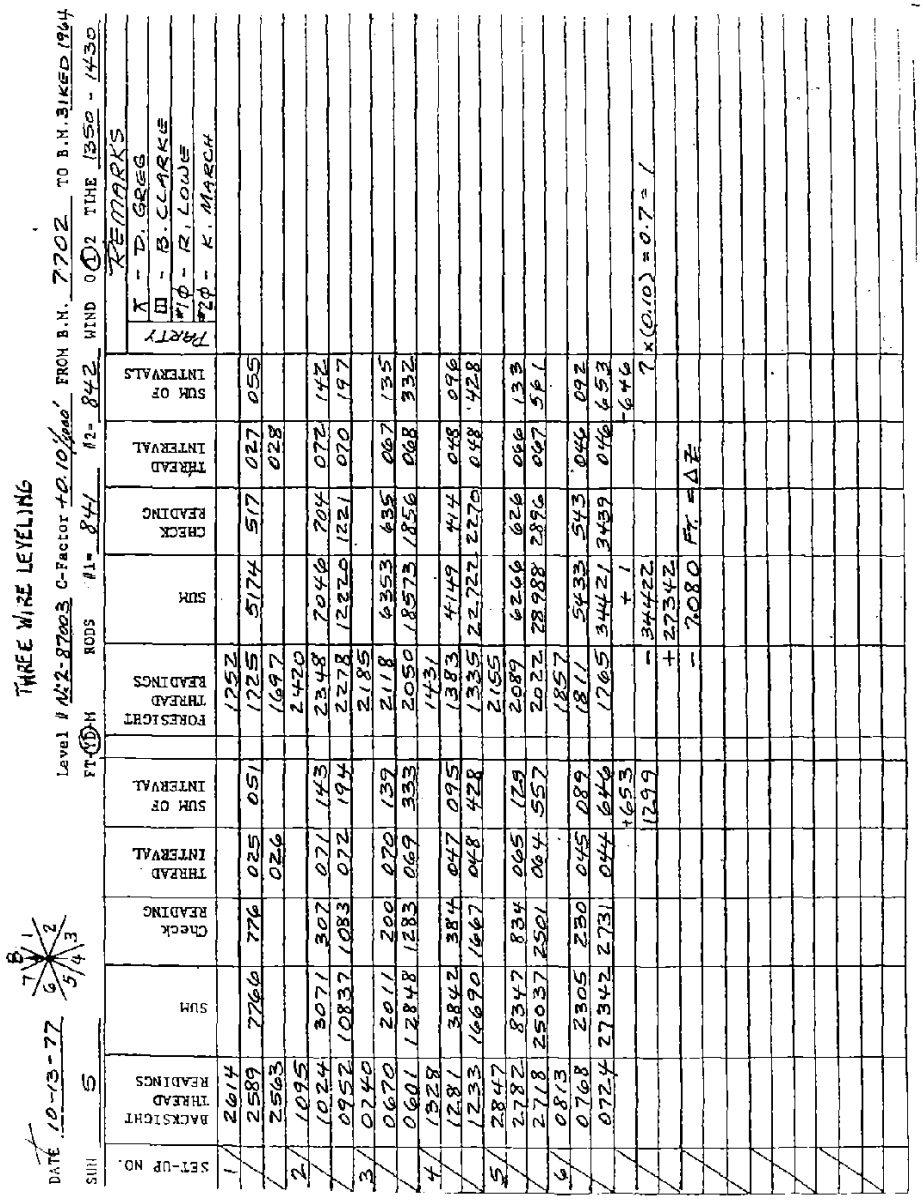
DATE 5-25-98 — Level # CE 25HS — C-Factor +0.003 — ~~FROM B.M.~~ ~~TO B.M.~~ — FT-(10)-M — RODS #1- 841 #2- 842 — WIND 0(1)2 — TIME 1535 - 1545

SET-UP NO.	BACKSIGHT THREAD READINGS	SUM	Check READING	THREAD INTERVAL	SUM OF INTERVALS	FORESIGHT THREAD READINGS	SUM	CHECK READING	THREAD INTERVAL	SUM OF INTERVALS
1	1575					1578				
	1561	4684	468	014	027	1482	4445	444	096	193
	1548			013		1385			097	
2	1492					1652				
	1478	4436	444	014	026	1565	4665	467	097	194
	1466	9120	912	012	053	1458	9110	911	097	387
		-9108					-2			-053
		+012					9108			334
		+334	= +0.036		FT/1000 FT					
	INSTRUMENT ADJUSTMENT = (40036/3) 0.194 = +0.002 YDS.									
							∴ MAKE 1.555 READ 1.557			
1	1492					1653				
	1429	4437	444	013	026	1557	4669	467	096	194
	1466			013		1459			098	
2	1577					1585				
	1564	4693	469	013	026	1488	4462	446	097	195
	1552	9130	913	013	052	1389	9131	913	098	389
		9129					-2			-052
		+001					9129			337
		+337	= +0.003		FT/1000 FT					
	NOTE: AN INTERVAL OF 1.000 YARD = 1.000 FEET OF DISTANCE									

3. Sample C-Factor test and level adjustment

Procedures to DETECT/CONTROL ERRORS	Rod error in individual graduations	Refraction	Pointing error	Scintillation, short period	Random:	Under or over compensation	Collimation	Collimation fluctuations with temperature	Collimation change with refocusing	Between setups	During setup observations	Gradual vertical movement of turning pins/plates:	Movement of tripod during setup	Rod index error	Rod invar thermal expansion	Rod scale error	Rod verticality error	Diurnal Earth tides	Gravity anomalies	Systematic:	Backsight and foresight reversed for setup	0.5 cm or larger errors in reading the rod	Forward pin or plate movement between setups	BLUNDERS:
Field, standard NGS practices used:																								
Leap-frog rods between setups															x		x							
Minimum sight ground clearance, 0.5 m		x																						
Use turning pins when they can be driven										x	x													
Check/adjust rod levels weekly																	x							
Use rods with braces																	x							
Use rods with two offset scales each	x																					x		
Check new leveling against old																						x		x
Check loop closures																						x		x
Field, 1st order class III procedures																								
Rod observing sequence A_L, A_S, B_L, B_S, B_R, A_R		x									x		x											
Always observe rod A on bench mark															x									
Level the instrument while pointing at rod A							x																	
Reverse direction of running on alternate days		x								x			x											
Maximum allowable (Δ_{hL} - Δ_{aR}) for setup, + 0.25mm			x	x							x		x									x		x
Use rod pairs with different scale offsets																						x		
Use NI-002 or NIA31 level							x	x	x	x														
Pause 20 seconds after setup before observing											x		x											
Maximum imbalance, backsight and foresight distances, 5 m / Setup, 10 m accumulative for a section		x																						
Check collimation and compensation weekly							x	x																
Office:																								
Correct elevation differences for rod scale errors																x								
Correct elevation differences for rod (invar) temperature															x									
Correct elevation differences for refraction (model)						x																		
Correct elevation differences for Earth tides																		x						
Compute in geopotential height system																				x				
Correct elevation differences for collimation error							x																	

4. Leveling error sources and procedures for detection and control



THREE WIRE LEVELING

DATE 10-13-77 SUN 5

Level # N2-87003 C-Factor +0.10/1000' FROM B.N. 7702 TO B.N. BIKED 1964

FT. ⊕ N RODS #1= 841 #2= 842 WIND 0 ⊕ 2 TIME 1350 - 1430

SET-UP NO.	BACKSIGHT THREAD READINGS	SUM	Check READING	THREAD INTERVAL	SUM OF INTERVALS	FORESIGHT THREAD READINGS	SUM	CHECK READING	THREAD INTERVAL	SUM OF INTERVALS	PARTY	REMARKS
1	2614	7766	776	025	051	1252	5174	517	027	055		
	2589					1225						
	2563			026		1697			028			
2	1095					2420						
	1024	3071	307	071	143	2348	7046	704	072	142		
	0952	10837	1083	072	194	2278	12370	1221	070	197		
3	0240					2185						
	0670	2011	200	070	139	2118	6353	635	067	135		
	0601	12848	1283	069	333	2050	18573	1856	068	332		
4	1328					1431						
	1281	3842	384	047	095	1383	4149	414	048	096		
	1233	16690	1667	048	428	1335	22,727	22,270	048	428		
5	2847					2155						
	2782	8347	834	065	179	2089	6266	626	066	133		
	2718	25037	2501	064	557	2022	28988	2896	067	561		
6	0813					1857						
	0768	2305	230	045	089	1811	5433	543	046	092		
	0724	27342	2731	044	646	1765	34421	3439	046	653		
					+653					+646		
					1299			+ 1				7 x (0.10) = 0.7 = 1
						-	34422					
						+	27342					
						-	7080	Ft. = ΔE				

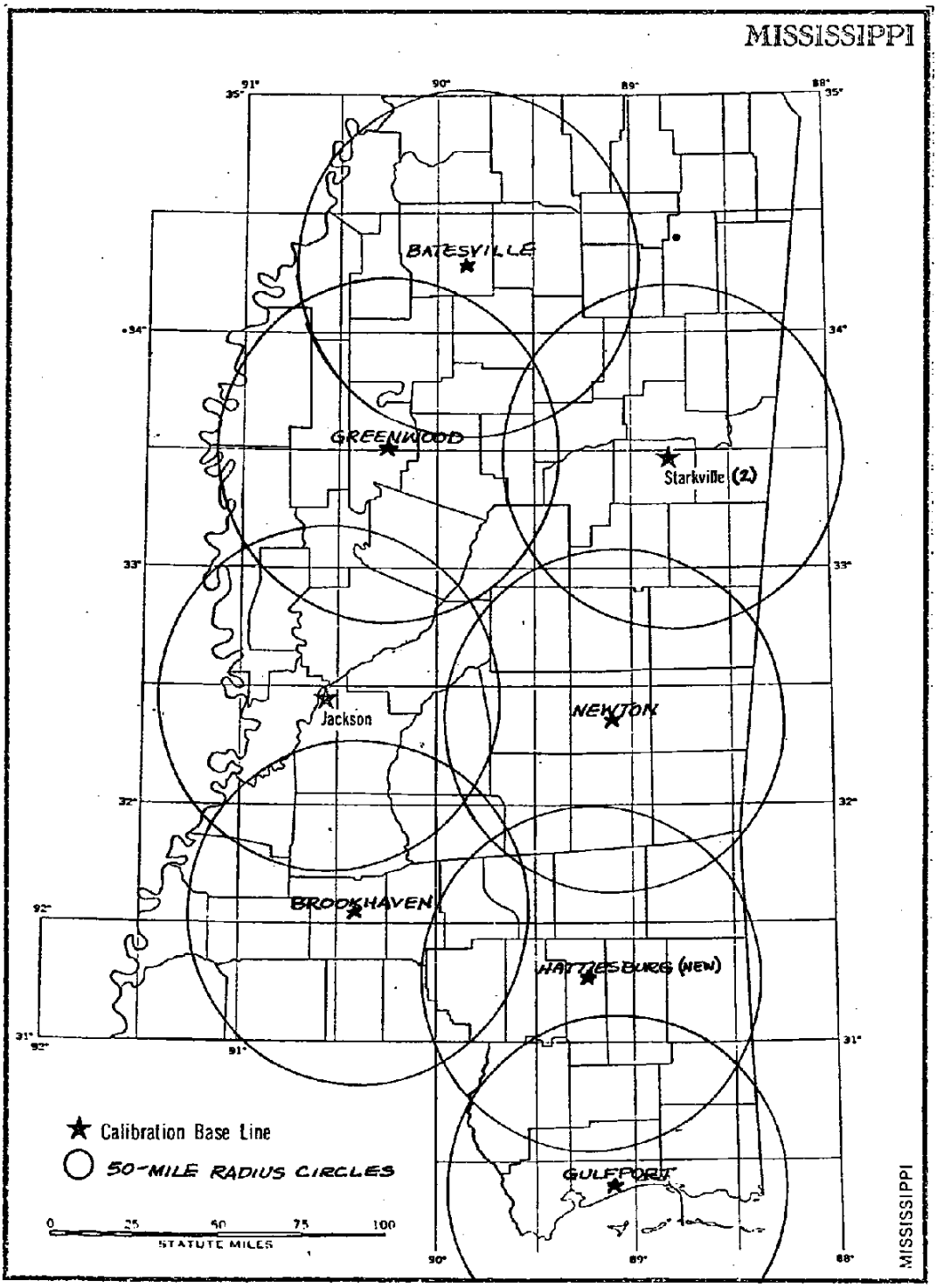
5. Sample three-wire level notes

TABLE 2.—Continued

TRAVERSE

Classification	*First-Order*	*Second-Order*		*Third-Order*	
		Class I	*Class II*	*Class I*	*Class II*
Recommended spacing of principal stations	Network stations 10-15 km Other surveys seldom less than 3 km.	Principal stations seldom less than 4 km except in metropolitan area surveys where the limitation is 0.3 km.	Principal stations seldom less than 2 km except in metropolitan area surveys where the limitation is 0.2 km.	Seldom less than 0.1 km in tertiary surveys in metropolitan area surveys. As required for other surveys.	
Horizontal directions or angles [a]					
Instrument	0".2	0".2	0".2	1".0	1".0
Number of observations	16	8 or 12*	6 or 8*	4	2
Rejection limit from mean	4"	4" or 5"	4" or 5"	5"	5"
Length measurements					
Standard error [b]	1 part in 600,000	1 part in 300,000	1 part in 120,000	1 part in 60,000	1 part in 30,000
Reciprocal vertical angle observations [c]					
Number of and spread between observations	3 D/R—10"	3 D/R—10"	2 D/R—10"	2 D/R—10"	2 D/R—20"
Number of stations between known elevations	4-6	6-8	8-10	10-15	15-20
Astro azimuths					
Number of courses between azimuth checks [f]	5-6	10-12	15-20	20-25	30-40
No. of obs./night	16	16	12	8	4
No. of nights	2	2	1	1	1
Standard error	0".45	0".45	1".5	3".0	8".0
Azimuth closure at azimuth check point not to exceed [g]	1".0 per station or 2" $\sqrt{N}$	1".5 per station or 3" $\sqrt{N}$. Metropolitan area surveys seldom to exceed 2".0 per station or 3" $\sqrt{N}$	2".0 per station or 6" $\sqrt{N}$. Metropolitan area surveys seldom to exceed 4".0 per station or 8" $\sqrt{N}$	3".0 per station or 10" $\sqrt{N}$. Metropolitan area surveys seldom to exceed 6".0 per station or 15" $\sqrt{N}$	8" per station or 30" $\sqrt{N}$
Position closure [h] after azimuth adjustment	0.04m $\sqrt{K}$ or 1:100,000	0.08m $\sqrt{K}$ or 1:50,000	0.2m $\sqrt{K}$ or 1:20,000	0.4m $\sqrt{K}$ or 1:10,000	0.8m $\sqrt{K}$ or 1:5,000

* May be reduced to 8 and 4, respectively, in metropolitan areas.



7. Location map of EDM Calibration Base Lines in Mississippi

US DEPARTMENT OF COMMERCE - NOAA
NOS - NATIONAL GEODETIC SURVEY
SILVER SPRING MD 20910 - SEPTEMBER 18, 1996

CALIBRATION BASE LINE DATA
BASE LINE DESIGNATION: GULFPORT CBL
PROJECT ACCESSION NUMBER: 15705
NEAREST TOWN: GULFPORT

QUAD: N300892
MISSISSIPPI
HARRISON COUNTY

LIST OF ADJUSTED DISTANCES (SEPTEMBER 10, 1996)

FROM STATION	ELEV. (M)	TO STATION	ELEV. (M)	ADJ. DIST. (M) HORIZONTAL	ADJ. DIST. (M) MARK - MARK	STD. ERROR (MM)
0 M 1996	7.721	150 M 1996	7.891	150.0022	150.0023	0.1
0 M 1996	7.721	430 M 1996	7.912	429.9946	429.9946	0.1
0 M 1996	7.721	1200 M 1996	7.548	1199.9848	1199.9848	0.2
150 M 1996	7.891	430 M 1996	7.912	279.9924	279.9924	0.1
150 M 1996	7.891	1200 M 1996	7.548	1049.9826	1049.9827	0.1
430 M 1996	7.912	1200 M 1996	7.548	769.9902	769.9903	0.1

DESCRIPTION OF GULFPORT BASE LINE
YEAR MEASURED: 1996
LATITUDE: 30 22 22
LONGITUDE: 089 04 40
AZIMUTH: 75 DEGREES TRUE NORTH

THE BASE LINE IS LOCATED ALONG THE NORTHERN RIGHT-OF-WAY OF THE L AND N RAILROAD, IN GULFPORT, MS. IT IS AN EAST-WEST LINE IN AZIMUTH OF ABOUT 75 DEGREES WITH THE 0-METER POINT BEING AT THE WEST END. THERE IS NO 100 FT. TAPE CALIBRATION MONUMENT AT THIS BASE LINE.

THE BASE LINE IS AN EAST-WEST LINE WITH THE 0-METER POINT ON THE WEST END. IT CONSISTS OF THE 0, 150, 430, AND 1200 METER POINTS. THERE IS NO 100 FT. TAPE CALIBRATION MONUMENT AT THIS BASE LINE.

TO REACH 0-METER POINT FROM THE JUNCTION OF I-10 AND U.S. HIGHWAY 49 (EXIT 34), ABOUT 4 MILES (6.4 KM) NORTH OF THE CENTER OF GULFPORT, GO SOUTH ON U.S. HIGHWAY 49 FOR 3.9 MI TO THE JUNCTION OF 19TH STREET, TURN LEFT AND GO EAST ON 19TH STREET FOR 0.4 MI TO THE JUNCTION OF 20TH AVE, TURN RIGHT AND GO SOUTH ON 20TH AVE FOR 0.1 MI TO THE L AND N RAILROAD TRACKS AND THE 0-METER POINT ON THE LEFT.

THE 0-METER POINT IS A STANDARD NGS CALIBRATION BASE LINE DISK, STAMPED "0 M 1996" SET IN THE TOP OF A 30 CM DIAMETER CONCRETE POST, FLUSH WITH THE SURFACE OF THE GROUND. IT IS 20.5 M (67.3 FT) NORTHEAST OF RAILROAD SIGNAL IN SOUTHEAST QUADRANT OF RAILROAD CROSSING, 17.5 M (57.4 FT) EAST OF THE CENTER OF 20TH AVE, 8.7 M (28.5 FT) SOUTH OF CENTER OF EAST RAILROAD STREET, 8.4 M (27.6 FT) SOUTHWEST OF A TELEGRAPH POLE AND 6.9 M (22.6 FT) NORTH OF THE NORTH RAIL OF A SINGLE RAILROAD TRACK.

THE 150-METER POINT IS A STANDARD NGS CALIBRATION BASE LINE DISK, STAMPED "150 M 1996" SET IN TOP OF A 30 CM DIAMETER CONCRETE POST, FLUSH WITH THE SURFACE OF THE GROUND. IT IS ABOUT MIDWAY BETWEEN 18TH AND 19TH STREETS AND IN LINE WITH AN ALLEY LEADING NORTH. IT IS 11.1 M (36.4 FT) SOUTH SOUTHWEST OF A SEWER MANHOLE COVER IN CENTER OF EAST RAILROAD STREET, 6.8 M (22.3 FT) NORTH OF THE NORTH RAIL OF RAILROAD TRACK AND 6.2 M (20.3 FT) SOUTHWEST OF A TELEGRAPH POLE.

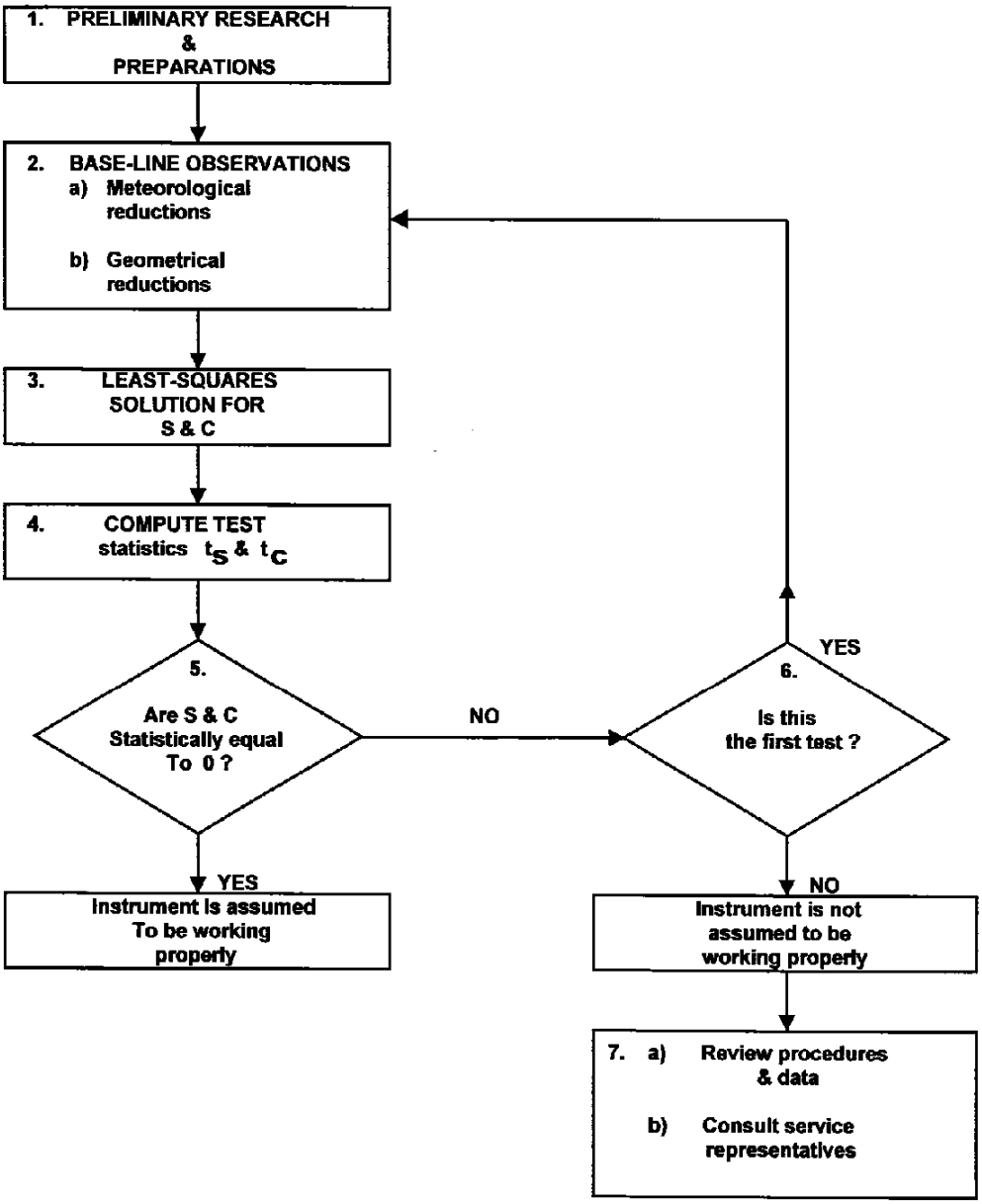
THE 430-METER POINT IS A STANDARD NGS CALIBRATION BASE LINE DISK, STAMPED "430 M 1996" SET IN THE TOP OF A 30 CM DIAMETER CONCRETE POST, FLUSH WITH THE SURFACE OF THE GROUND. IT IS 14.6 M (47.9 FT) SOUTHEAST OF A POWER POLE WITH WIRES IN THREE DIRECTIONS, 12.5 M (41.0 FT) SOUTHWEST OF A 24 INCH OAK TREE, 12.4 M (40.7 FT) SOUTH OF THE CENTER OF EAST RAILROAD STREET, 6.9 M (22.6 FT) NORTH OF THE NORTH RAIL OF RAILROAD TRACK, 4.9 M (16.1 FT) SOUTHEAST OF A TELEGRAPH POLE.

THE 1200-METER POINT IS A STANDARD NGS CALIBRATION BASE LINE DISK, STAMPED "1200 M 1996" SET IN THE TOP OF A 30 CM DIAMETER CONCRETE POST, FLUSH WITH THE GROUND. IT IS 29.3 M (96.1 FT) WEST SOUTHWEST OF A POWER POLE WITH TRANSFORMER, 14.4 M (47.2 FT) SOUTH OF THE CENTER OF EAST RAILROAD STREET, 10.8 M (35.4) SOUTH SOUTHWEST OF A FIRE HYDRANT, 6.9 M (22.6 FT) NORTH OF THE NORTH RAIL OF RAILROAD TRACK, 6.6 M (21.7 FT) SOUTHWEST OF A TELEGRAPH POLE AND 6.1 M (20.0 FT) EAST OF THE PROJECTED CENTERLINE OF BULLIS AVE.

USER NOTES: CBL USERS SHOULD TAKE CARE IN PLUMBING OVER ALL POINTS.

THE BASE LINE WAS ESTABLISHED IN CONJUNCTION WITH MAPS, MSU, AND JAMES R. CLARKE AND ASSOCIATES. FOR MORE INFORMATION PLEASE CONTACT BUDDY CLARKE AT 601-868-1121.

8. Calibration Base Line Data for Gulfport



Schematic of test procedure for EDMI at calibration base line.

9. Schematic of test procedure for EDM at a calibration base line

ANALYSIS
STANDARD CALIBRATION TEST
STARKVILLE BASE LINE

OWNER _____ **DATE** _____ - _____ - _____

EDM _____ **SPEC.** _____ **mm +** _____ **PPM**

OBS	$_N D_A$ M		Δ m x 10^{-3}		$D_A\Delta$ m^2		V m x 10^{-3}	V^2 $m^2 x10^{-6}$	D_A / Δ $x10^3$
1	150	(-)	1.7	(-)	0.26	(-)	2.5	6.2	88
2	150	(-)	0.9	(-)	0.14	(-)	1.7	2.9	167
3	280	(+)	3.0	(+)	0.84	(+)	1.8	3.2	93
4	280	(+)	2.7	(+)	0.76	(+)	1.5	2.2	104
5	430	(+)	0.9	(+)	0.39	(-)	0.8	0.6	478
6	430	(+)	2.5	(+)	1.08	(+)	0.8	0.7	172
7	700	(+)	2.7	(+)	1.89	(+)	0.2	0.0	259
8	700	(+)	4.3	(+)	3.01	(+)	1.8	3.2	163
9	980	(+)	4.3	(+)	4.21	(+)	0.9	0.8	228
10	980	(+)	5.6	(+)	5.49	(+)	2.2	4.8	175
11	1130	(+)	0.7	(+)	0.79	(-)	3.2	10.1	1614
12	1130	(+)	2.9	(+)	3.28	(-)	1.0	1.0	390
Σ	7340	(+)	27.0	(+)	21.34	(-)	0.0	35.7	328
									174 (MEDIAN)
M_N	612	(+)	2.25						

COMPUTATIONS

1. $\Delta = D_A - D_H$
2. $S = [0.6508\ \Sigma (D_A \Delta) - 398.1\ (\Sigma \Delta)] \times 10^{-6} = (+)\ 3.139 \times 10^{-6}$
3. $C = [326.8\ (\Sigma\Delta) - 0.3981\ \Sigma(D_A\Delta)] \times 10^{-3} = (+)\ 0.33 \times 10^{-3}$
4. $C = \bar{\Delta} - 612\ S = (+)\ 0.33 \times 10^{-3}$ (CHECK ONLY)
5. $V_i = \Delta_i - SD_A - C$
6. $\sigma_s = [65{,}080\ (\Sigma Y^2)]^{1/2} \times 10^{-6} = 1.52 \times 10^{-6}$
7. $\sigma_c = [32{,}680\ (\Sigma V^2)]^{1/2} \times 10^{-3} = 1.08 \times 10^{-3}$
8. $t_s = | S / \sigma_s | = 2.07$
9. $t_c = | C / \sigma_c | = 0.31$
10. IF t_s and t_c ARE BOTH LESS THAN 3.17, S AND C ARE STATISTICALLY EQUAL TO ZERO – EDM IS ACCEPTABLE.

10. Sample analysis of HP 3805 EDM test at Starkville CBL

NGM PROGRAM CALABRATE
FROM & TO STATION & DISTANCE

PUBLISH	OBSERVED
0,150,150.0037	0,150,150.0054
0,430,430.0052	0,430,430.0043
0,1130,1129.9954	0,1130,1129.9947
150,430,280.0015	150,1130,979.9874
150,1130,979.9917	150,430,279.9985
430,1130,699.9902	150,0,150.0046
	430,0,430.0027
	430,150,279.9988
	430,1130,699.9875
	1130,430,699.9859
	1130,150,979.9861
	1130,0,1129.9925

HP-3805

03-31-1997

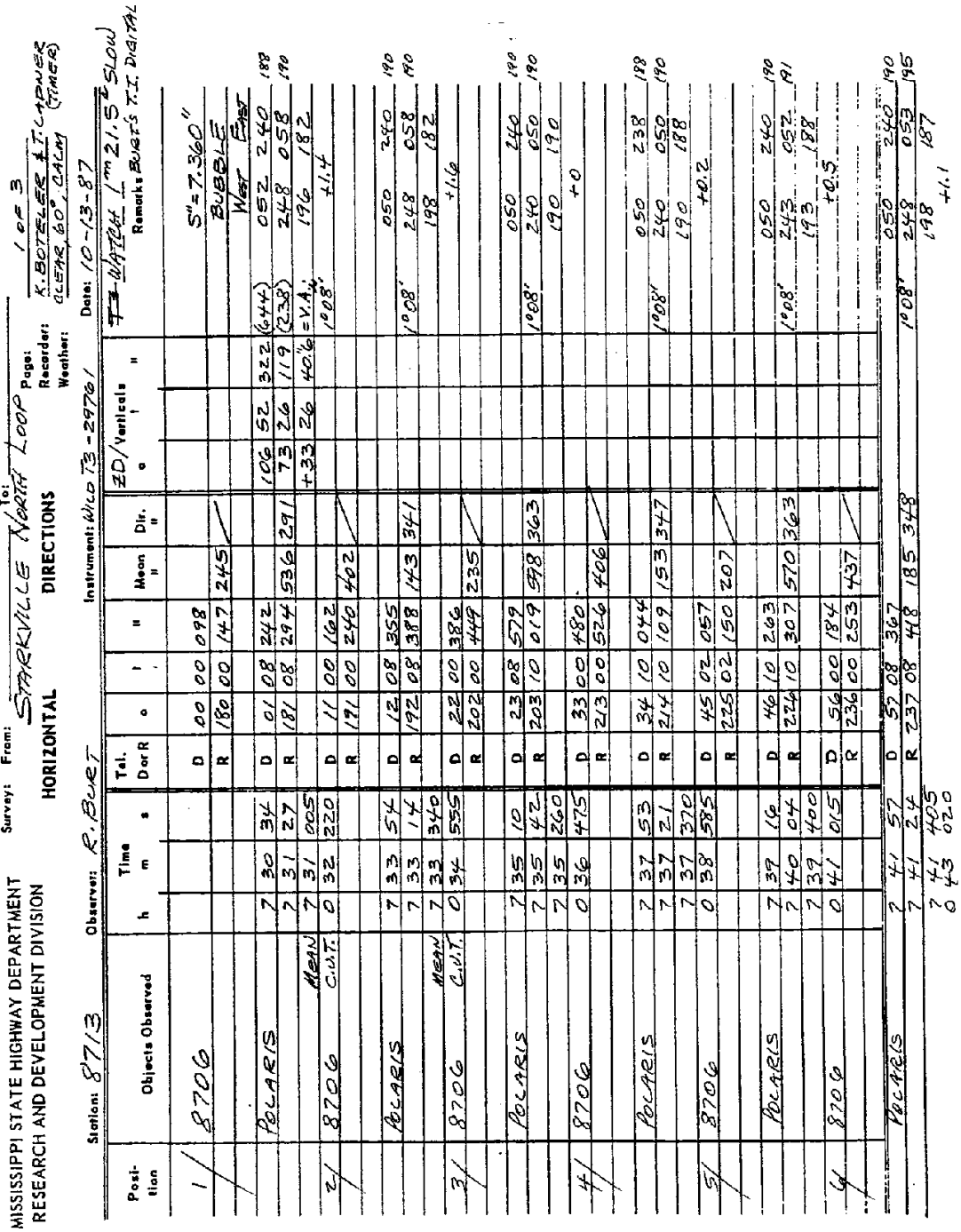
MANUFACTURER'S SPECIFICATIONS: +7 MM
+10 PPM

SCALE ERROR	=	+ 4.1522 PPM
STANDARD ERROR OF SCALE	=	+ 1.6609 PPM
CONSTANT ERROR	=	- 0.0002 METERS
STANDARD ERROR OF CONSTANT	=	+ 0.0009 METERS

VARIANCE OF UNIT WEIGHT	=	+ 0.0411
COVARIANCE	=	+ 1.2751
CORRELATION	=	+ 0.8256

PUBLISHED (METERS)	OBSERVED (METERS)	DIFFERENCE (METERS)	RESIDUAL (METERS)
150.0037	150.0054	- 0.0017	- 0.0021
430.0052	430.0043	+ 0.0009	- 0.0007
1129.9954	1129.9947	+ 0.0007	- 0.0038
979.9917	979.9874	+ 0.0043	+ 0.0004
280.0015	279.9985	+ 0.0030	+ 0.0020
150.0037	150.0046	- 0.0009	- 0.0013
430.0052	430.0027	+ 0.0025	+ 0.0009
280.0015	279.9988	+ 0.0027	+ 0.0017
699.9902	699.9875	+ 0.0027	- 0.0000
699.9902	699.9859	+ 0.0043	+ 0.0016
979.9917	979.9861	+ 0.0029	- 0.0016

11. Sample data from NGS PC program CALIBRAT for scale and constant errors



MISSISSIPPI STATE HIGHWAY DEPARTMENT
RESEARCH AND DEVELOPMENT DIVISION

Survey: HORIZONTAL DIRECTIONS — From: POLARIS SHOT — To: SPARKVILLE NORTH LOOP — Page: 1 of 3

Station: 8713 — Observer: R. BURT — Instrument: WILD T3 - 29761 — Recorder: K. BOTELER II (CAPNER TIMER) — Weather: CLEAR, 60°, CALM — Date: 10-13-87

Position	Objects Observed	Time h	Time m	Time s	Tel. D or R	°	'	"	Mean ° ' "	Dir. ° ' "	ZD/Verticals °	'	"	Remarks: BURT'S T.I. DIGITAL SLOW
1	8706				D	00	00	098						S"=7.360"
					R	180	00	147	245					BUBBLE
	POLARIS	7	30	34	D	01	08	242			106	52	322	West East 052 240 188
		7	31	27	R	181	08	294	536	291	73	26	119	(644) (238) 248 058 190
	MEAN	7	31	005							+33	26	40½	=V.A.; 196 182
2	8706	0	32	220	D	11	00	162						1°08' +1.4
	C.U.T.				R	191	00	240	402					
	POLARIS	7	33	54	D	12	08	355						050 240 190
		7	33	14	R	192	08	388	743	341				1°08' 248 058 190
	MEAN	7	33	340										198 182
3	8706	0	34	555	D	22	00	386						+1.6
	C.U.T.				R	202	00	449	835					
	POLARIS	7	35	10	D	23	08	579						050 240 190
		7	35	42	R	203	10	019	598	363				1°08' 240 050 190
		7	35	260										190 +0
4	8706	0	36	475	D	33	00	480						
					R	213	00	526	406					
	POLARIS	7	37	53	D	34	10	044						050 238 188
		7	37	21	R	214	10	109	153	347				1°08' 240 050 190
		7	37	320										190
5	8706	0	38	585	D	45	02	057						+0.2
					R	225	02	150	207					
	POLARIS	7	39	16	D	46	10	263						050 240 190
		7	40	04	R	224	10	307	570	363				1°08' 243 052 191
		7	39	400										193 188
6	8706	0	41	015	D	56	00	184						+0.5
					R	236	00	253	437					
	POLARIS	7	41	57	D	57	08	367						050 240 190
		7	41	24	R	237	08	448	185	348				1°08' 248 053 195
		7	41	405										198 187
		0	43	020										+1.1

12. First page of the field notes of a Polaris shot

POLARIS OBSERVATION

@ STA. 8405
ϕ = 33° 28' 37".1088
λ = 88° 44' 04".7855
RA = 2h 12m 08s.854
SHA = 2h 37m 54s.516
δ = 89° 11' 44".877
VA_L = + 33° 37' 32"
VA_f = + 33° 42' 54"
VA = + 33° 42' 43"

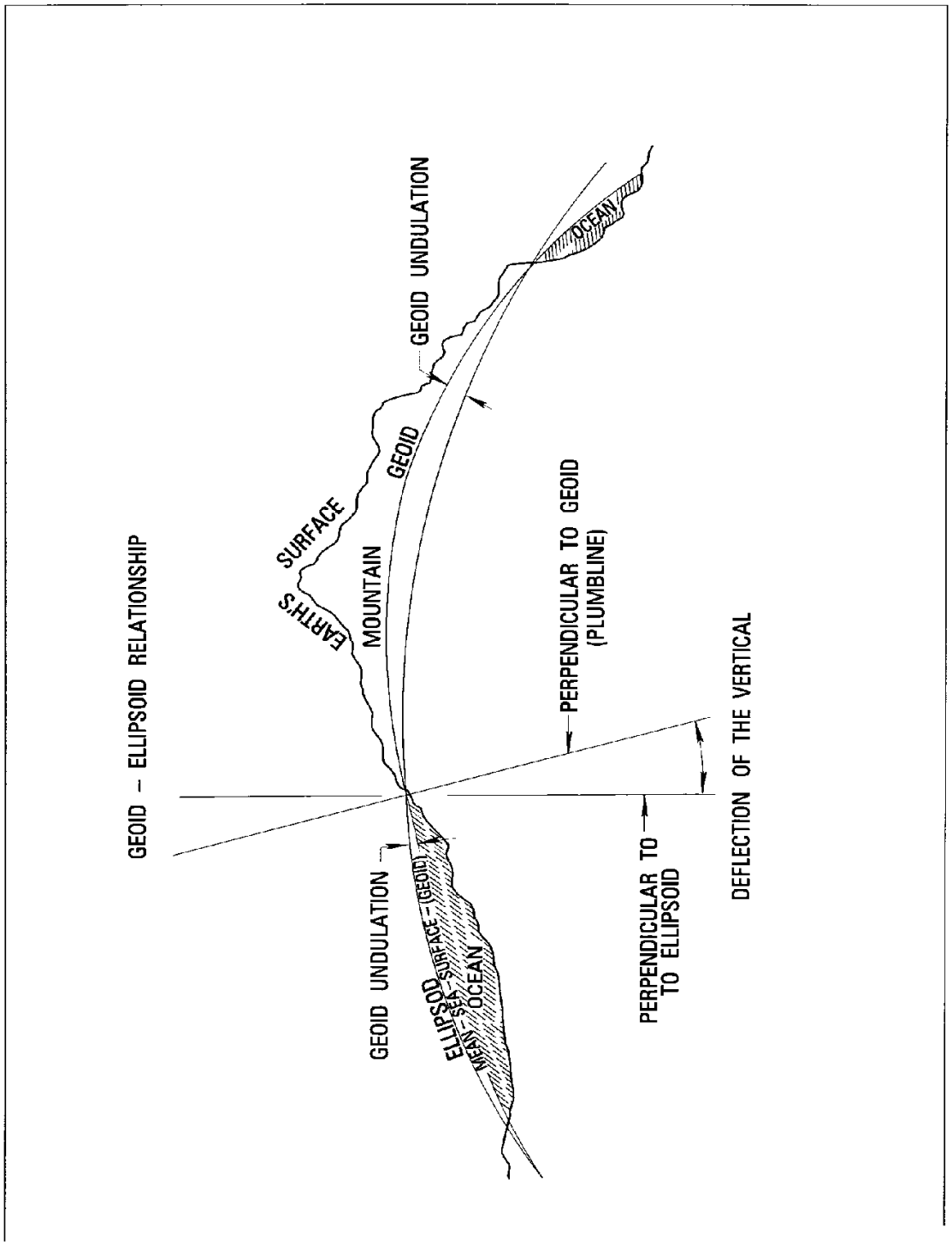
π WILD T3 - 29761
OBS. R. BURT
REC. M. BRENT
TIME BURT; TI DIG.
e_i = 5s SLOW
e_f = 5s SLOW
S" = 7".360
POWER = 30X

B.S. STA. 8402
TARGET WILD ILLUM.
LOCAL DATE 10-30-84
(CST(6)) CDST(5)
TEMP. 80°
CLOUDS CLEAR
WIND CALM

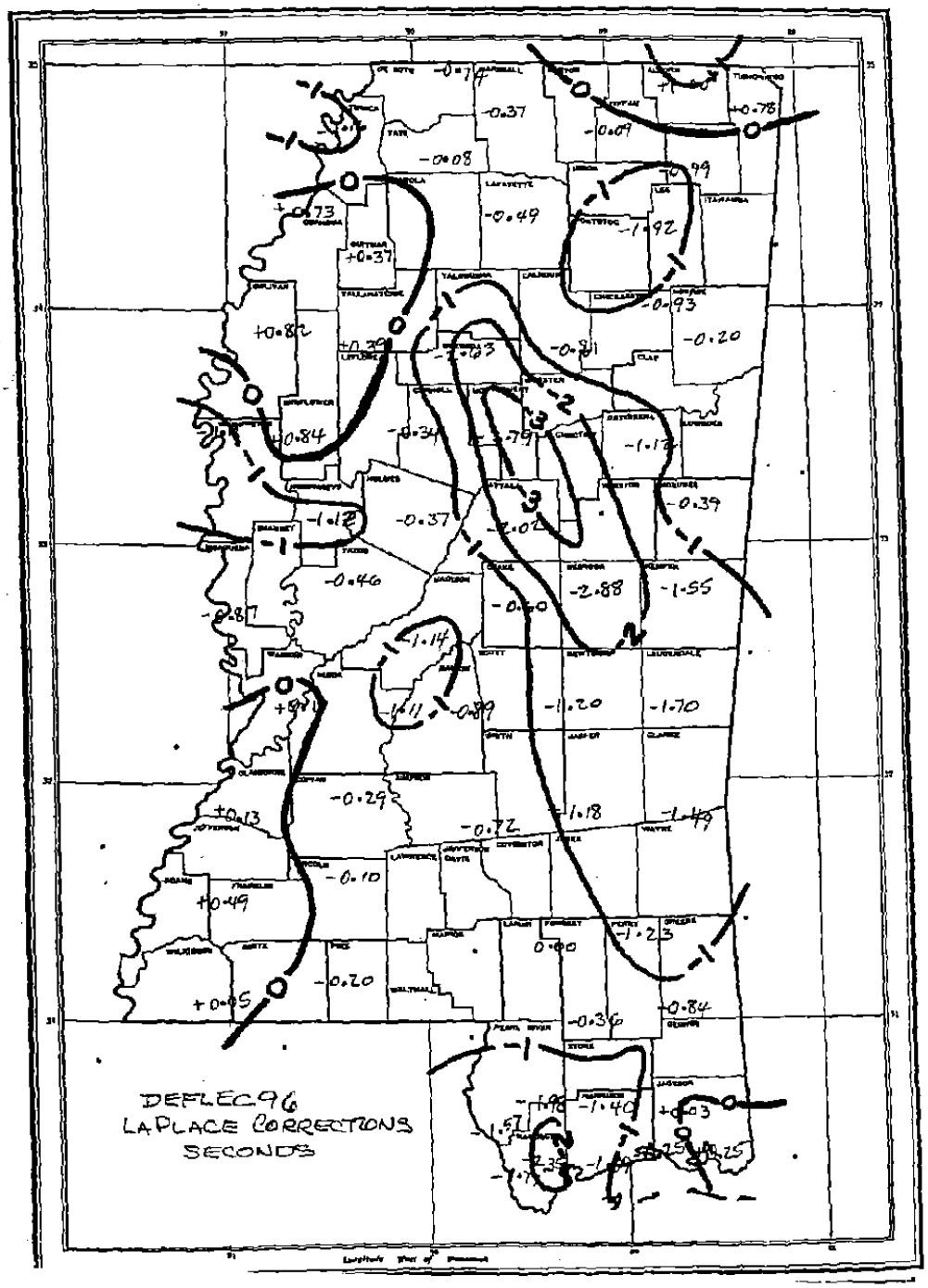
Obs.	CUT DATE & TIME	24 To Polaris	Corr. 4xDiv.	OBS. AZ.	NOTES
	10-31-84	91°		269° 43'	
1	0h 11m 31s.0	13' 44".5	+0.1	25".34	
2	15 04.0	36.6	+1.0	23.44	
3	17 23.5	31.8	-0.2	23.58	
4	19 37.5	27.9	+0.3	20.63	
5	22 05.0	20.3	+0.4	20.87	
6	24 18.5	11.3	+0.7	22.61	
7	26 20.0	06.9	-0.1	21.43	
8	28 09.5	12 59.1	+0.6	22.24	
9	30 22.5	52.8	+0.1	21.40	
10	32 13.5	45.8	+0.4	21.33	
11	34 07.0	41.6	-0.3	19.30	
12	36 01.0	31.2	+0.5	21.36	
13	38 04.0	30.0	-0.2	(15.22)R	
14	39 56.5	19.9	+0.4	16.85	
15	41 56.0	08.8	-0.1	20.10	
16	43 54.0	11 57.9	+0.6	21.54	
17					
18					
19					
20					
MN				21.47	σ_0 = 1".97 $\sigma_{\bar{x}}$ = 0".51

MN. OBS. AZ.	269°	43'	21".47
D.A.			+0".32
ASTRO. AZ.	269°	43'	21".79
LAPLACE CORR.			-0".95
GEODETIC AZ.	269°	43'	20".84
$\Delta\alpha$	-	3'	15".94
GRID AZ.	269°	40'	04".90
COMP. AZ.	---°	--'	--.--"
DISC./ERROR		-	--.--"
NO. ANGLES	--		"
CORR./ANGLE			--.--"

13. Sample reduction and results of a Polaris shot



14. Sketch showing Geoid, ellipsoid, and deflection of the vertical



15. Contour map showing Laplace corrections over Mississippi

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        National Geodetic Survey,   Retrieval Date = FEBRUARY 26, 1997
BW2341 ***********************************************************************
BW2341  DESIGNATION -  HALL
BW2341  PID         -  BW2341
BW2341  STATE/COUNTY-  MS/COPIAH
BW2341  USGS QUAD   -  SMYRNA (1964)
BW2341
BW2341                          *CURRENT SURVEY CONTROL
BW2341
BW2341* NAD 83(1993)-  31 52 25.35799(N)    090 36 17.16863(W)     ADJUSTED
BW2341* NAVD 88     -        91.     (meters)     299.     (feet)  SCALED
BW2341
BW2341  LAPLACE CORR-          -0.22  (seconds)                     DEFLEC96
BW2341  GEOID HEIGHT-         -26.00  (meters)                      GEOID96
BW2341
BW2341  HORZ ORDER  -  THIRD
BW2341
BW2341.The horizontal coordinates were established by classical geodetic method
BW2341.and adjusted by the National Geodetic Survey in May 1994.
BW2341
BW2341.The orthometric height was scaled from a topographic map.
BW2341
BW2341.The Laplace correction was computed from DEFLEC96 derived deflections.
BW2341
BW2341.The geoid height was determined by GEOID96.
BW2341
BW2341;                      North         East     Units   Scale       Converg.
BW2341;SPC MS W     -   263,178.430   674,317.333   MT  0.99995813 -0 08 36.0
BW2341;UTM  15      - 3,528,939.379   726,581.332   MT  1.00023320 +1 15 55.2
BW2341
BW2341:                 Primary Azimuth Mark                      Grid Az
BW2341:SPC MS W     -   GLANCY                                    137 27 24.2
BW2341:UTM  15      -   GLANCY                                    136 02 53.0
BW2341
BW2341|-----------------------------------------------------------------------|
BW2341| PID    Reference Object                     Distance       Geod. Az   |
BW2341|                                                            dddmmss.s |
BW2341|        HALL RM 2                            20.925 METERS  00141     |
BW2341| BW2339 GLANCY                              APPROX. 8.0 KM  1371848.2  |
BW2341|        HALL RM 1                            19.200 METERS  24223     |
BW2341|        HALL AZ MK                                          2910410.1 |
BW2341|-----------------------------------------------------------------------|
BW2341
BW2341                          SUPERSEDED SURVEY CONTROL
BW2341
BW2341  NAD 83(1986)-  31 52 25.37229(N)    090 36 17.16475(W)     ADJUSTED
BW2341  NAD 27      -  31 52 24.79600(N)    090 36 16.81400(W)     ADJUSTED
BW2341
BW2341.Superseded values are not recommended for survey control.
BW2341.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
BW2341.See file format.dat to determine how the superseded data were derived.
BW2341
BW2341_MARKER: DS = TRIANGULATION STATION DISK
BW2341_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT (ROUND)
BW2341
BW2341  HISTORY     - Date     Condition        Recov. By
BW2341  HISTORY     - 1948     MONUMENTED       CGS
BW2341  HISTORY     - 1955     GOOD             CGS
BW2341  HISTORY     - 1965     GOOD             MSHD
BW2341  HISTORY     - 1982     GOOD             NGS
```

16. NGS new format data for station HALL in Copiah County

JULY 1968
U.S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
COAST AND GEODETIC SURVEY

HORIZONTAL CONTROL DATA

by the
Coast and Geodetic Survey
NORTH AMERICAN 1927 DATUM

QUAD 310904 STATION 1017
MISS
LATITUDE 31°30' TO 32°00'
LONGITUDE 90°30' TO 91°00'
DIAGRAM NH 15-3 NATCHEZ

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
Form 522
Rev. Oct., 1952

DESCRIPTION OF TRIANGULATION STATION

Name of Station: HALL
Chief of Party: F.X. Popper
State: Mississippi County: Copiah
Year: 1948 Locality: Barlow

Surface-station mark, Note.* 1a
Underground-station mark, Note.* 7a
Reference mark, No. 1 Note.* 11a
Reference mark, No. 2 Note.* 11a
Azimuth mark, Note.* 11a
Witness mark, Note.*
Height of light above station mark 26 meters.
Height of telescope above station mark 23 meters.†

DISTANCES AND DIRECTIONS TO REFERENCE MARKS AND PROMINENT OBJECTS WHICH CAN BE SEEN FROM THE GROUND			
Object	Distance	Direction	Azimuth
			° ′ ″
CLANCY	meters	00° 00′ 00.0	
Reference mark No. 1	19.200	105 03 48 ×	
Azimuth mark, approx.	0.3 mile	153 45 21.9 ×	
Reference mark No. 2	20.925	224 21 45 ×	

Detailed description: Station is located about 4 miles northeast of Barlow, 165 feet west-southwest of the southwest corner of the Hall Hill Baptist Church, 150 feet north of a wood gate, 21 feet northwest of the center of a farm lane, and 7 feet south-southwest of a witness post. It is stamped HALL 1948, and projects 8 inches.

Reference mark No. 1 is 62.99 feet southwest of the station, 23 feet northwest of the center of the farm lane, and 10 feet east of a wire fence. It is stamped HALL NO 1 1948, and projects 10 inches.

Reference mark No. 2 is 68.65 feet north of the station, 65 feet west of the center of the farm lane, 41.5 feet northwest of the witness post, and 35 feet east of the wire fence. It is stamped HALL NO 2 1948, and projects 12 inches.

The azimuth mark is approximately 0.3 mile west-northwest of the station, 70 feet north of the center of a gravel road, 55 feet southeast of the southeast corner of a farm house, 15 feet west of the center of a farm lane, and 3 feet north of a witness post. It is stamped HALL 1948, and projects 10 inches.

To reach the station from the intersection of U.S. Highway 51 and State Highway 20 in Hazlehurst, go westerly on No. 20 for 3.05 miles to a fork; then right, westerly, on a gravel road for 10.75 miles to the Hall Hill Baptist Church and the station on the left.

To reach the azimuth mark from the station, continue westerly on the gravel road for 0.3 mile to the mark on the right.

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
Form 522
(Rev. Feb. 1956)

RECOVERY NOTE, TRIANGULATION STATION

R

Name of Station: HALL
Established by: F.X.P. Year: 1948 State: Mississippi
Recovered by:* R.A.E. Year: 1955 County: Copiah

Detailed statement as to the fitness of the original description; including marks found, stampings, changes made, and other pertinent facts:

The station was visited 10-11-55 and all the marks were found in good condition. The azimuth mark is not visible from the station without extensive clearing. The description is adequate with a corrected "to reach" which follows:

To reach the station from the Courthouse in Hazelhurst go north on U.S.Highway 51 for 0.4 mile to the junction with State Highway 20, turn left on State Highway 20 and go 3.0 miles to a crossroad, turn right on hard surfaced road and go 4.25 miles to a side road left and a store in the southeast angle, keep straight ahead for 1.75 mile to a fork, take left fork, hard surfaced road, and go 4.0 miles to the Hall Hill Baptist Church on left, turn left on driveway to the church, pass to the left of the church and go 0.15 mile to the mark on the right, at the "T" intersection of dirt roads.

11-2-65)

RECOVERY NOTE, TRIANGULATION STATION

R

Name of Station: HALL
Established by: C&GS Year: 1948 State: Mississippi
Recovered by:* H.B.T. (MSHD) Year: 1965 County: Copiah

Detailed statement as to the fitness of the original description; including marks found, stampings, changes made, and other pertinent facts:

The station was visited 12-9-65 and all marks were found in good condition. A new "To Reach" follows. The station is reached from the front entrance of the U. S. Post Office on Highway 51 in Hazlehurst. Go north for 0.35 mile to Highway 28. Turn left on Highway 28 and go 0.95 mile to interstate 55 overpass. Continue straight for 2.15 miles to an intersection. Turn right and go 10.4 miles to a side road left just west of Hall Hill Church. The station is located 0.05 miles up this sideroad on the right. To reach the azimuth, continue on main road for 0.3 miles to a gap and the mark on the right.

Station disk is stamped HALL 1948 and projects 8 inches. It is 165 feet southwest of southwest corner of the church, 25 feet west of a farm lane, 13 feet west of power pole no. 635 and 1.5 feet southwest of a metal witness post.

R. M. 1 is 27 feet west of a farm lane and 10 feet east of a wire fence, is stamped HALL NO 1 1948 and projects 10 inches.

R. M. 2 is 65 feet west of center of a farm lane and 35 feet east of a wire fence, is stamped HALL NO 2 1948 and projects 12 inches.

Azimuth mark is 70 feet north of a gravel road, 6.6 feet east of a power pole and 1.5 feet east of a metal witness post, is stamped HALL 1948 and projects 10 inches.

ADJUSTED HORIZONTAL CONTROL DATA

Name of Station: HALL
State: MISSISSIPPI Year: 1948 SECOND order
Locality: PORT GIBSON AREA
Source: G-7939 Field Sketch: MISS 17

Geodetic Latitude:	31° 52′ 24.796″	Elevation:	Meters
Geodetic Longitude:	90 36 16.814		Feet

State Coordinates (Ft)				
State & Zone	Code	X	Y	Grid Azimuth
MISS. W.	2302	415,768.84	499,696.07	− 0° 08′ 36″

To Station or Object	Geodetic Azimuth (From north)	Plane Azimuth (From north)	Code
AZIMUTH MARK	111° 04′ 08.6″	111° 12′ 45″	2302

4 July 70

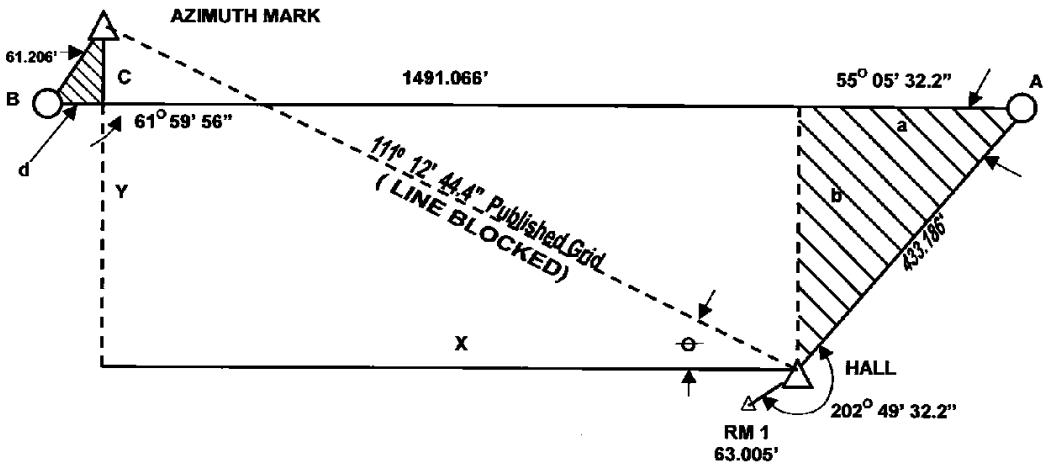
C&GS FORM 9402

.07-473

USCOMM—NOAA—ASHEVILLE

17. NGS old format data for station HALL in Copiah County

OBTAINING AN AZIMUTH FROM BLOCKED AZ. MK.



X = 1491.066 – 433.186 COS A – 61.206 COS B = 1202.190'

Y = 433.186 SIN A + 61.206 SIN B = 400.418'

Tan θ = y/x θ = 18° 25' 17.6"

OBSERVED				NGS PUBLISHED			
111°	12'	44.4"	H-a_x	111°	12'	44.4"	HALL – AZ MK
-18	25	17.6	θ	-153	45	21.9	
92	47	26.8	A-B	317	27	22.5	HALL-GLANCY
-53	05	32.2	A	+105	03	48	
39	41	54.6	A-HALL	62°	31'	10"	HALL-RM #1
219	41	54.6	HALL-A				
+202	49	32.2	HALL				
62°	31'	26.8"	HALL – RM #1				

AZIMUTH CHECKS

62.99'

63.005'

DISTANCE CHECKS

(RM #2 DESTROYED)

18. Example of an azimuth from the blocked azimuth mark at HALL

SURVEYING AND MAPPING, December 1967

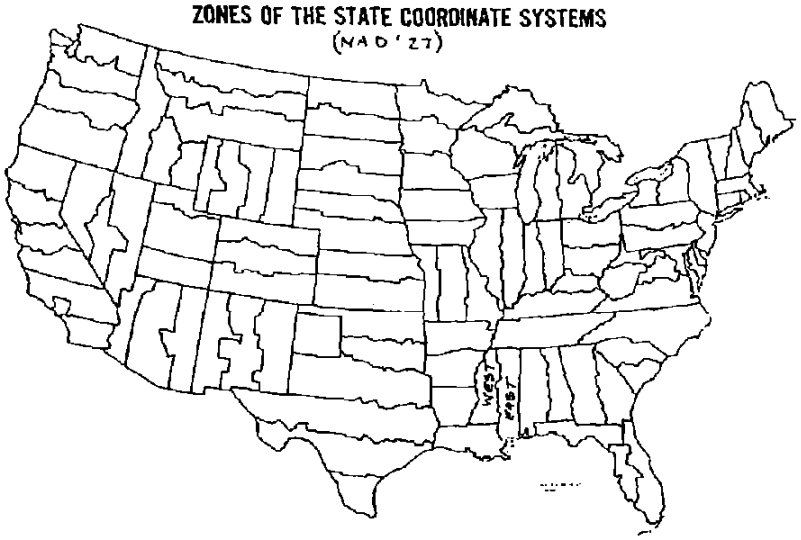


Figure 1.

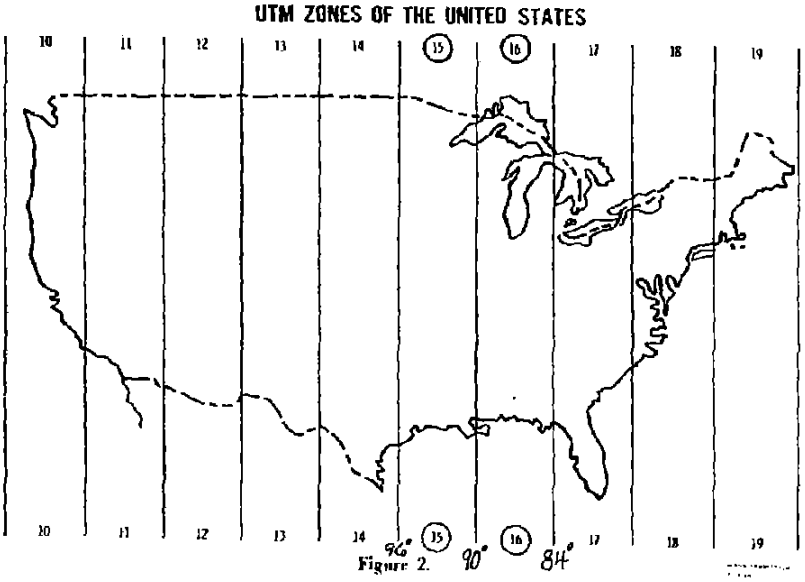
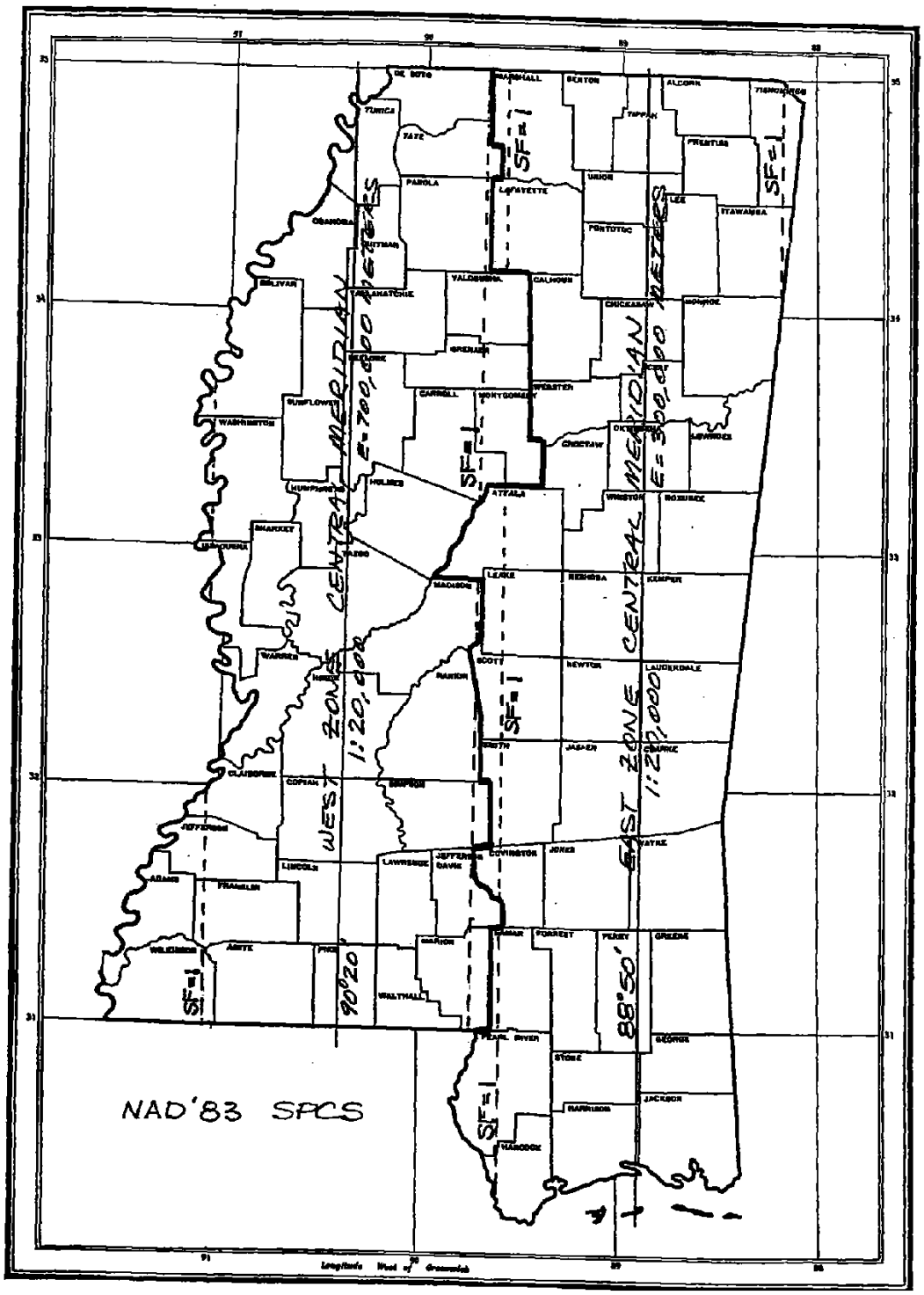


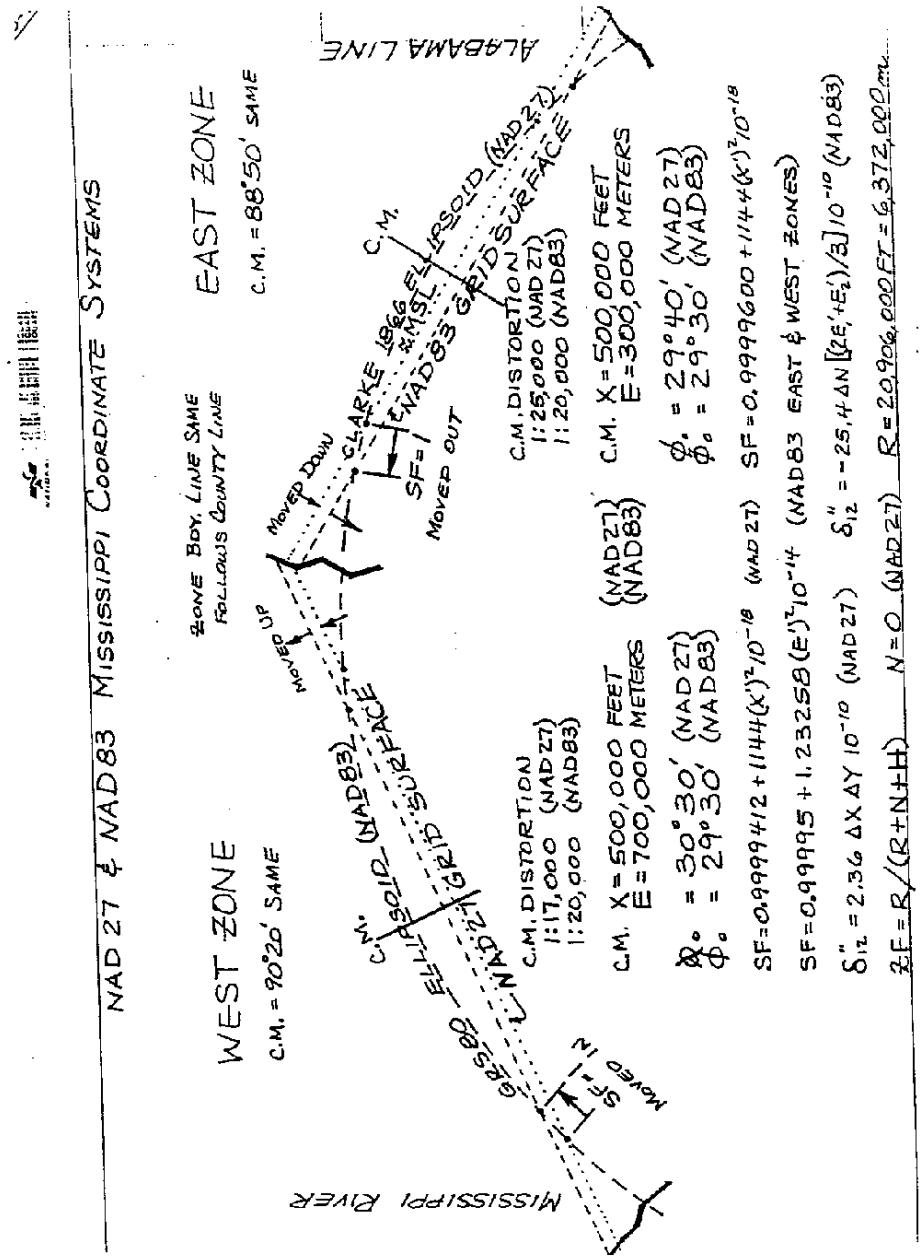
Figure 2.

E_{CM} = 500,000m SF_{CM} = 0.9996 = 1: 2,500
EDGE = 1: 1,250

19. Unites States map showing SPCS and UTM zones



20. Location of central meridians and zone boundary in Mississippi



21. NAD'27 and NAD'83 SPCS data for Mississippi

NAD 83 SPCS
Mississippi

2301	EAST ZONE	E_O = 300,000 m	λ_O = 88° 50'
2302	WEST ZONE	E_O = 700,000 m	λ_O = 90° 20'

BOTH $N_O = O$ $\phi_O = 29° 30'$ $k_O = 0.99995$

DISTANCES

$hF = R/(R+H+N)$

R = 6,372,000 m
H = ORTHO. ELEV.
N = GEOID HEIGHT

$SF = 0.99995+1.23258 (E' / 10^7)^2$

$E' = E - E_O$

GRID = HORIZ. X hF X SF

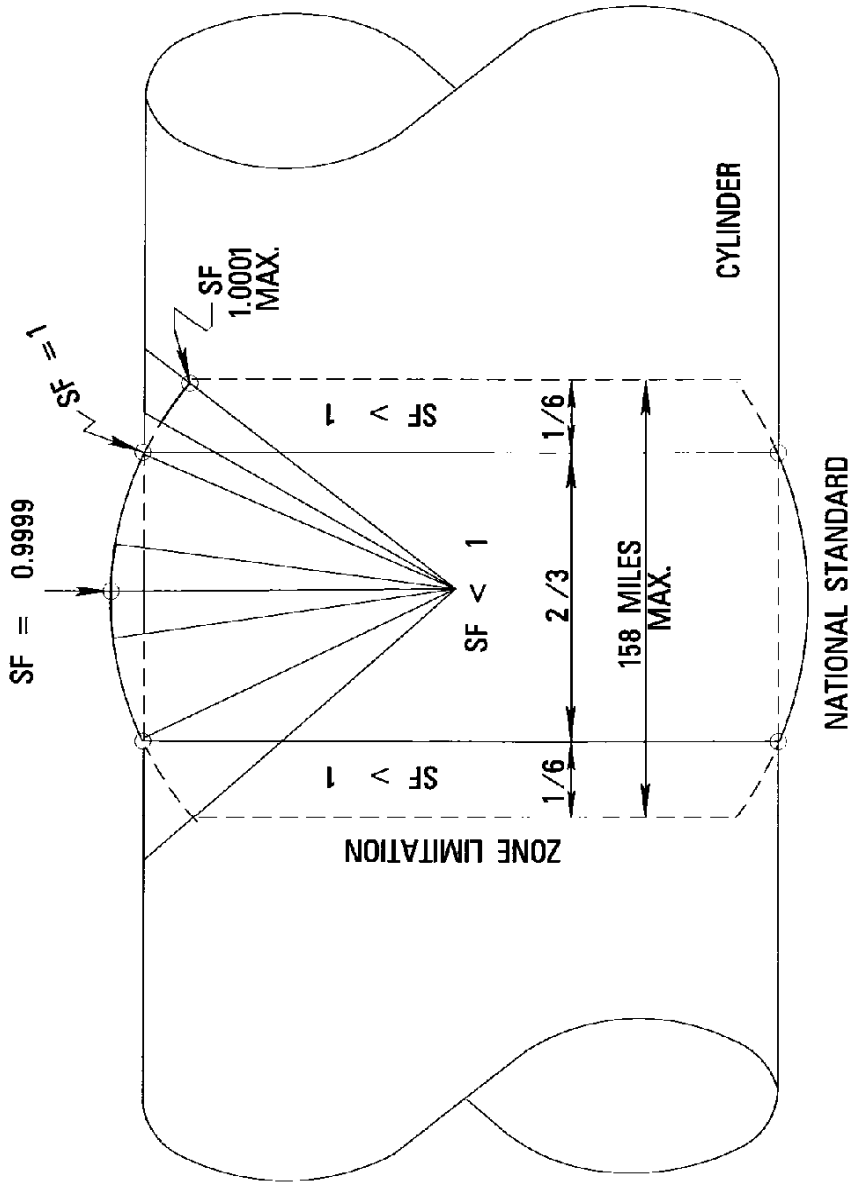
AZIMUTHS

$GRID = GEODETIC - GAMMA + \delta - GAMMA'' \frac{N}{} ME'$

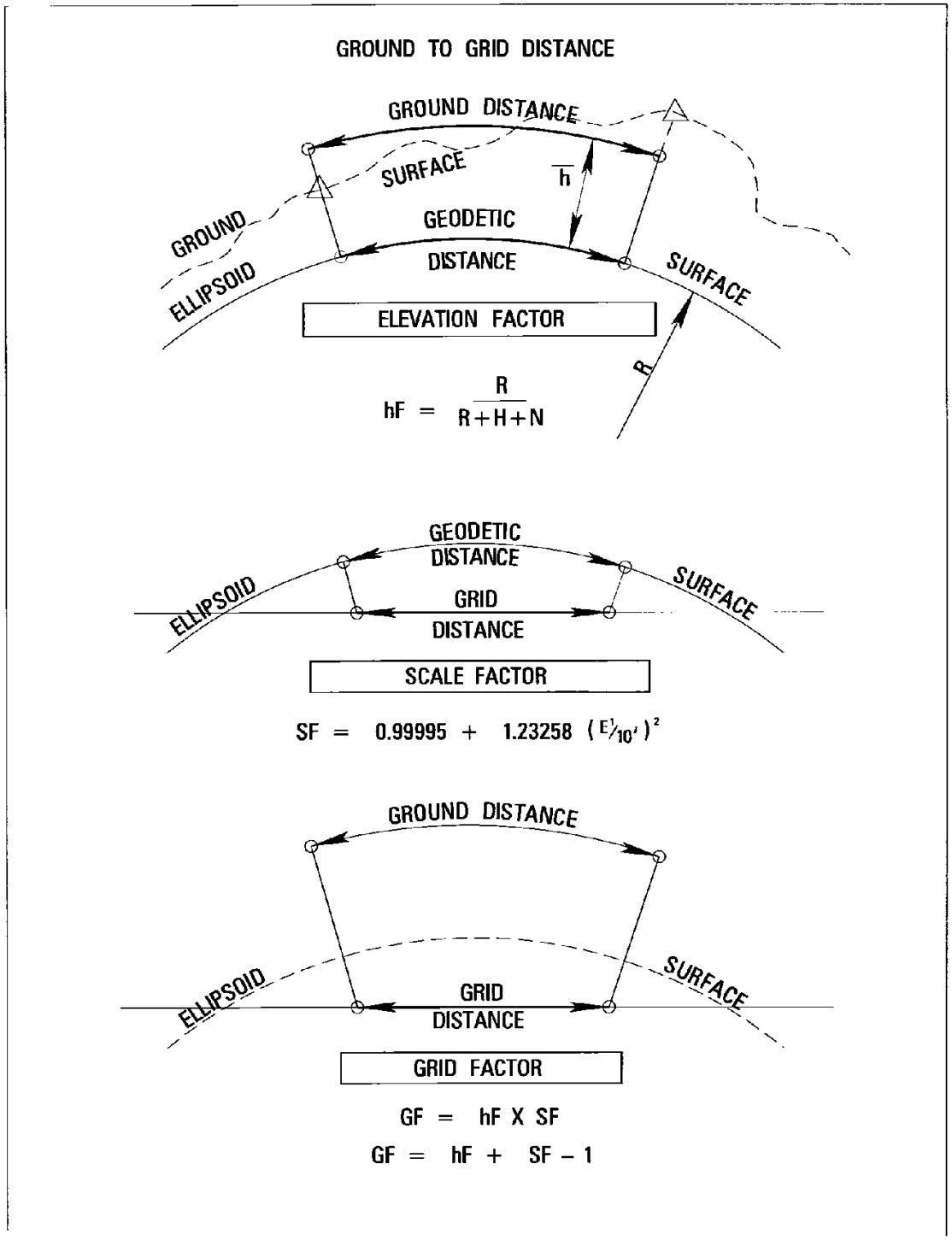
$\delta'' = -25.4 \Delta N \left(\frac{2E_1' + E_2'}{3} \right) 10^{-10}$

N	M	ΔM
0	0.018282	677
100,000	0.018959	690
200,000	0.019649	702
300,000	0.020351	716
400,000	0.021067	732
500,000	0.021799	746
600,000	0.022545	763
700,000	0.023308	

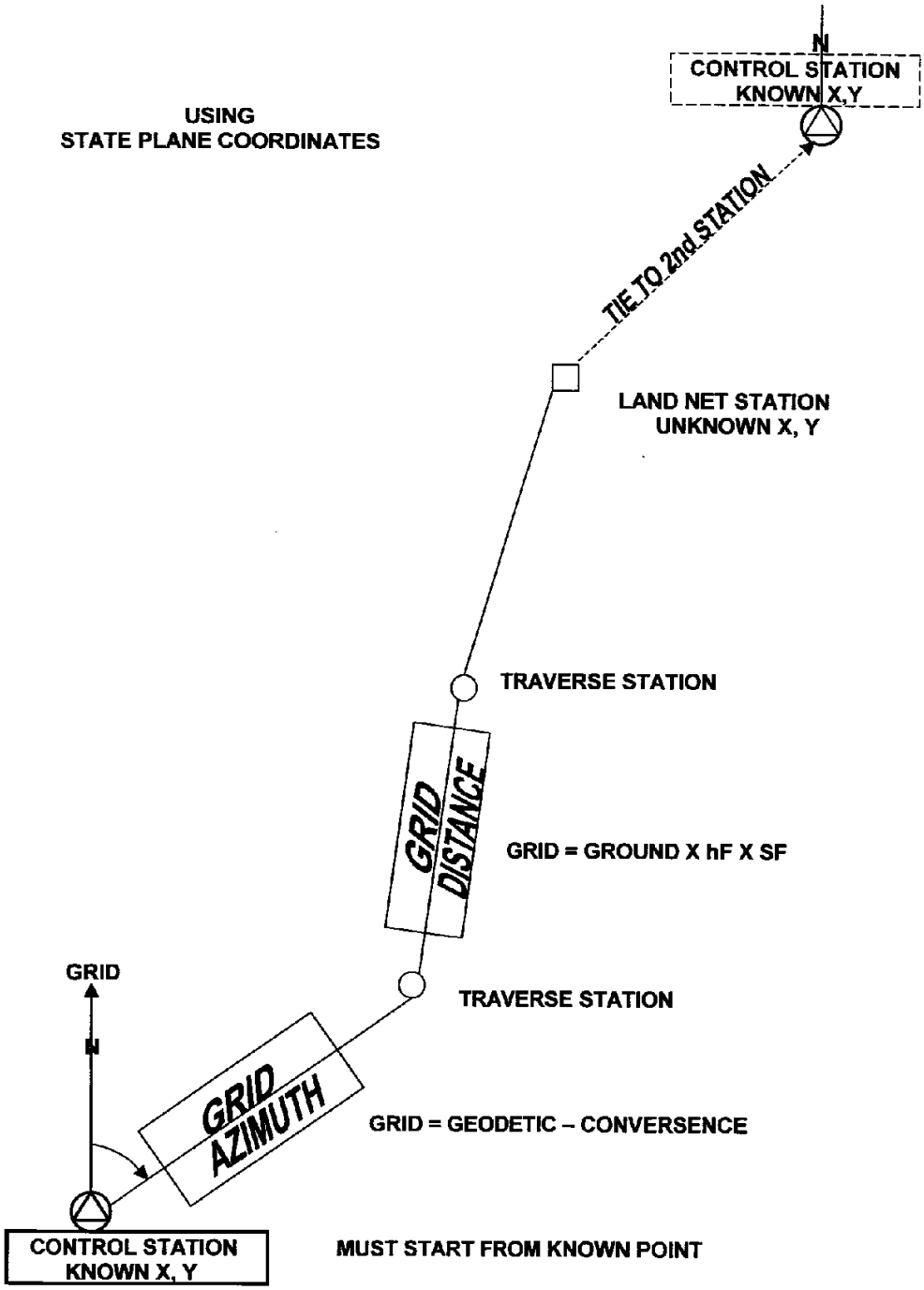
22. NAD'83 constants, formulae and table for Mississippi SPCS



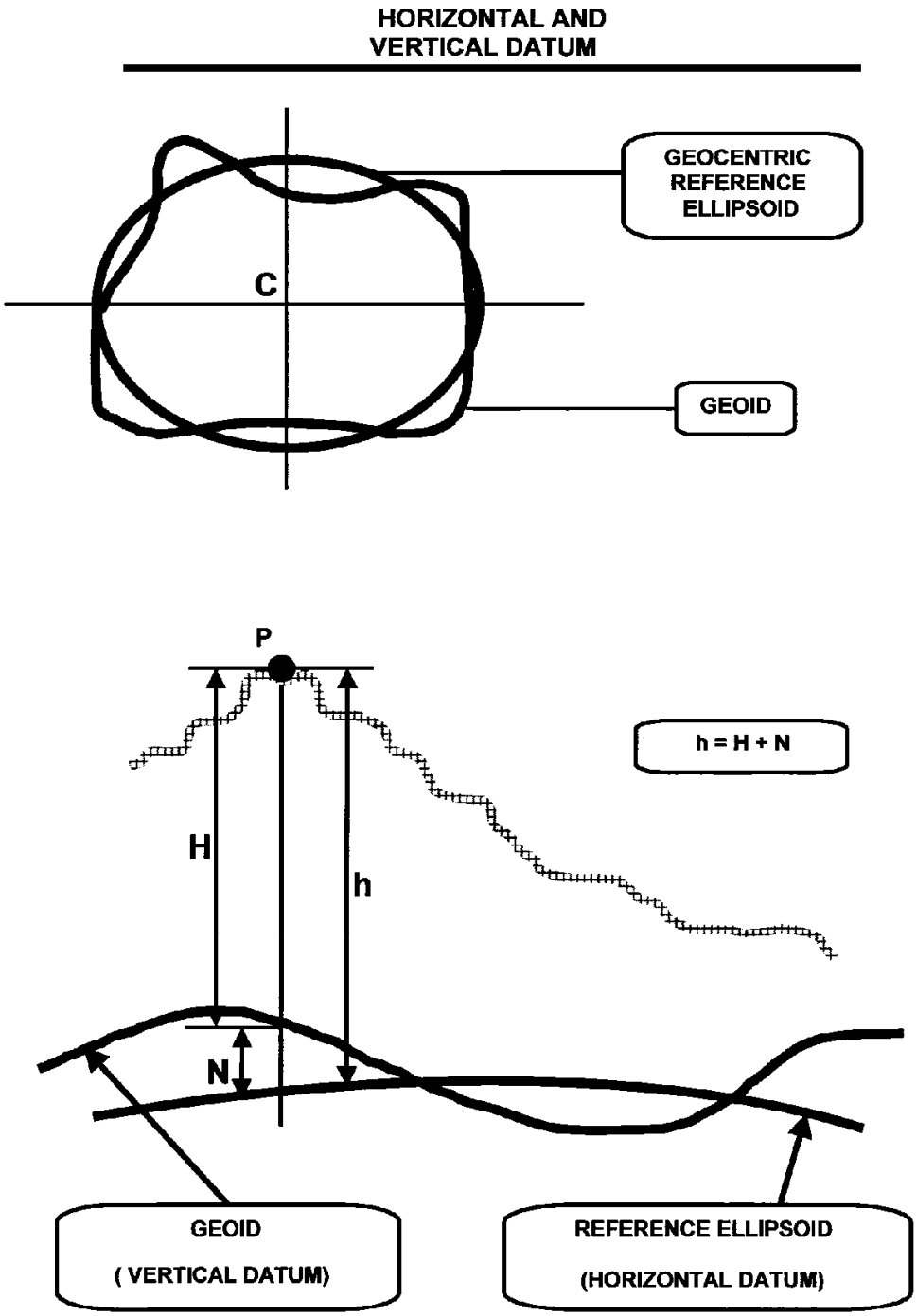
23. National standard for the State Plane Coordinate System



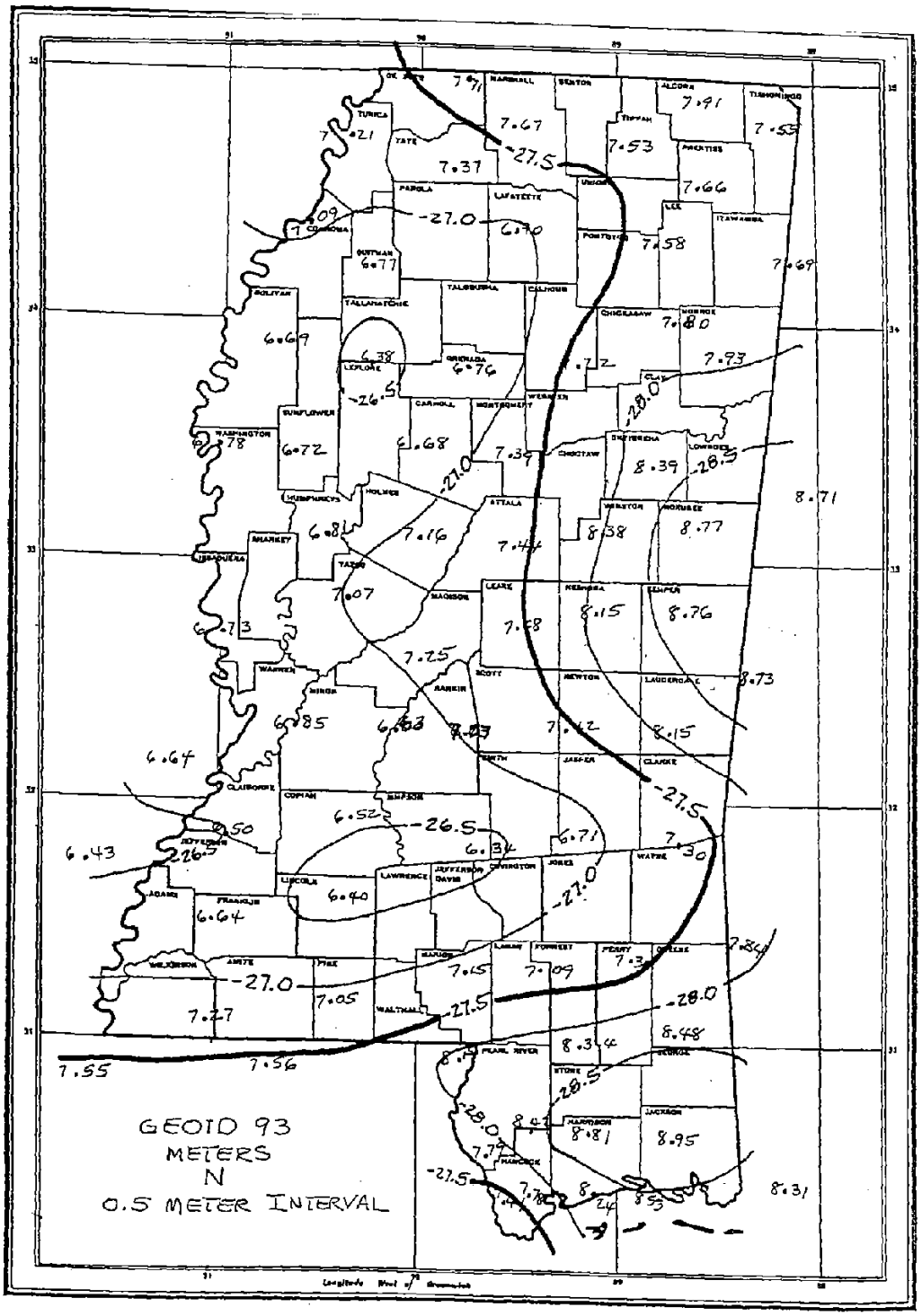
24. Procedure for reducing horizontal ground distances to the grid



25. Three changes required when using the State Plane Coordinate System



26. Sketch showing relationship between horizontal and vertical datums



27. Contour map showing Geoid heights for Mississippi

U.S. ARMY TOPO. ENGINEERING CENTER, CORPSCON BETA V 4.1

Original Coords. On NAD 83 Geographic Coordinates
Translated Coords. On NAD 83 State Plane – MS East 2301, METERS
Input Vertical – NGVD 29, U.S. FT
Output Vertical – NAVD 88, METERS

NAME	INPUT	OUTPUT
TEST	33 33 33.33333 N 088 47 47.77777 W	450064.00193 N 303410.39837 E
Heights	333.33300	101.622
Convergence		00 01 13.09234
Scale Factor		0.999950143

Geoid Height Computation
GEOID96 Interpolation
GEOID Program
Version 3.00

Computation #: 1 Region: GEOID96SC (NGS)

Station Name: TEST

Latitude	Longitude	Geoid Height (meters)
33 33 33.33333	88 47 47.77777	-27.926

Deflection Computation
Deflec96 Interpolation
DEFLEC Program
Version 3.00

Computation #: 1 Region: DEFLC96SCU (NGS)

Station Name: TEST

Latitude	Longitude	Xi Deflec. (arc sec)	Eta Deflec. (arc sec)	Hor. Laplace (arc sec)
33 33 33.33330	88 47 47.77770	-2.69	1.21	-.80

28. Sample data from CORPSCON, GEOID96, and DEFLEC96 PC programs

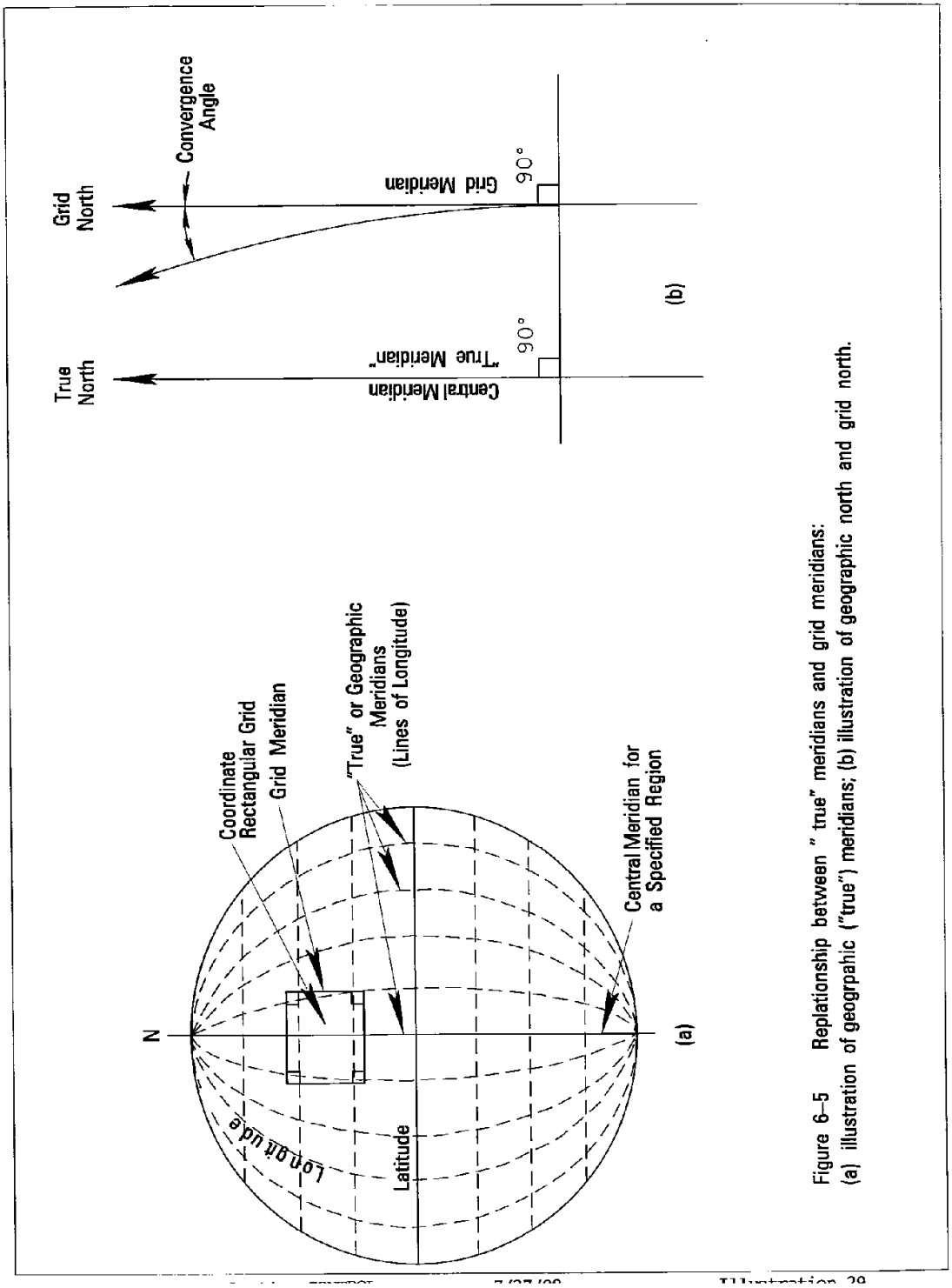


Figure 6–5 Replationship between " true" meridians and grid meridians:
(a) illustration of geogrpahic ("true") meridians; (b) illustration of geographic north and grid north.

29. Sketch showing relationship of grid and geodetic meridians

SPCS-GLO CORNER – TIE

CO:_____ N S E W ¼ CORNER SEC___ T____ __ R ____ __ _____ P.M.

NAD 27 POS Y___ ,___ .___ X___ ,___ .___ H___ .___ N = 0 h = H

NAD 83 (93) N___ ,___ .___ E___ ,___ .___ H___ .___ N - ___ .___ h___ .___

N___ ,___ .___ E___ ,___ .___ H___ .___ N - ___ .___ h___ .___

GAMMA + - ___ ' ___ " hF__ ._____ SF __ ._____ CGF__ ._____

SURVEY DATE: ___ - ___ - ___ TYPE: GPS-CONVENTIONAL LINK-LOOP-SPUR (NC-C)

ORIENTATION: POLARIS – SOLAR – AZ MK - RM#___ - _____

TIE STATIONS:_____

EST MAX POS ERROR OF _____ FT – M RELATIVE TO NEAREST TIE STATION _____

FOUND MONUMENT, EVIDENCE, AND REFERENCES:_____

_____

_____

_____

NEW MONUMENT AND / OR REFERENCES: _____

_____

_____

_____

This data is summitted with no guarantee
And is not to be used without other data
Being available to verify these results.

LS: _____ LS#: _____

PHONE: _____ - _____ - _____

FAX:_____ - _____ - _____
EMAIL: _____

ADDRESS: _____

_____

_____

(Sketch of survey on back of this form)

SKETCH

N

30. Form for recording data from a SPCS-GLO corner tie

****** NOTES *****

COORDINATES DERIVED FROM GPS SURVEY TIED TO:
NAD' 83 (93) MS West Zone

CONTROL STATION	NORTH	EAST
WATER VALLEY 2	516.061.068	763.030.160
RIVER	508.187.757	760.998.099
BRUCE	511.886.263	777.206.315

All azimuths and distances are
NAD' 83 (93) MS West Zone GRID values

	BOP	EOP
Ground to Grid Factor	0.9999912	0.9999918
Grid to Ground Correction	+8.8 ppm	+8.2 ppm
Grid to Geodetic Azimuth	+23' 22"	+23' 30"

31. Typical SPCS notes that should appear on plans and ROW plats

PRENTISS PROJECT ANALYSIS

An analysis of each project will be made by the District Surveyor to determine if single or multiple elevation, scale, or grid factors will be required.

The Prentiss project will be used as an example of this analysis. The project which is reported as 7.98 kilometers in length is first plotted on USGS 7.5 minute quad sheets. From its location on the quad sheets, the elevation varies from 350 to 490 feet for a total change of 140 feet with a geoid height of -27 meters. The project is located about 31 miles east of the central meridian of the Mississippi West Zone. Based on scaled coordinates of the BOP and EOP, the project extends 24,700 feet in the E-W direction and only 10,500 feet in the N-S direction.

Based on the scaled coordinates, the Scale Factor varies from 0.9999765 at the west end to 0.9999856 at the east end. Subtracting these two factors and expressing the difference in parts per million (ppm) produces a variation in scale factor of 9.1 ppm through the project. Using the average of the two scale factors (0.9999811) throughout the project will produce a maximum error of 4.6 ppm (half the total difference) or 1:220,000. The surveying error will far exceed this amount therefore one factor should be acceptable.

The geoid height of -27 meters must be applied to the orthometric height (elevation) to obtain the ellipsoidal height and then the ellipsoidal factor. The lowest elevation results in an EF of 0.9999874 and the highest elevation results in an EF of 0.9999808. Subtracting the two factors and expressing the difference in ppm produces a variation of 6.6 ppm. Using the average factor of 0.9999841 throughout the project will produce a maximum error of 3.3 ppm or 1:300,000 which should be acceptable.

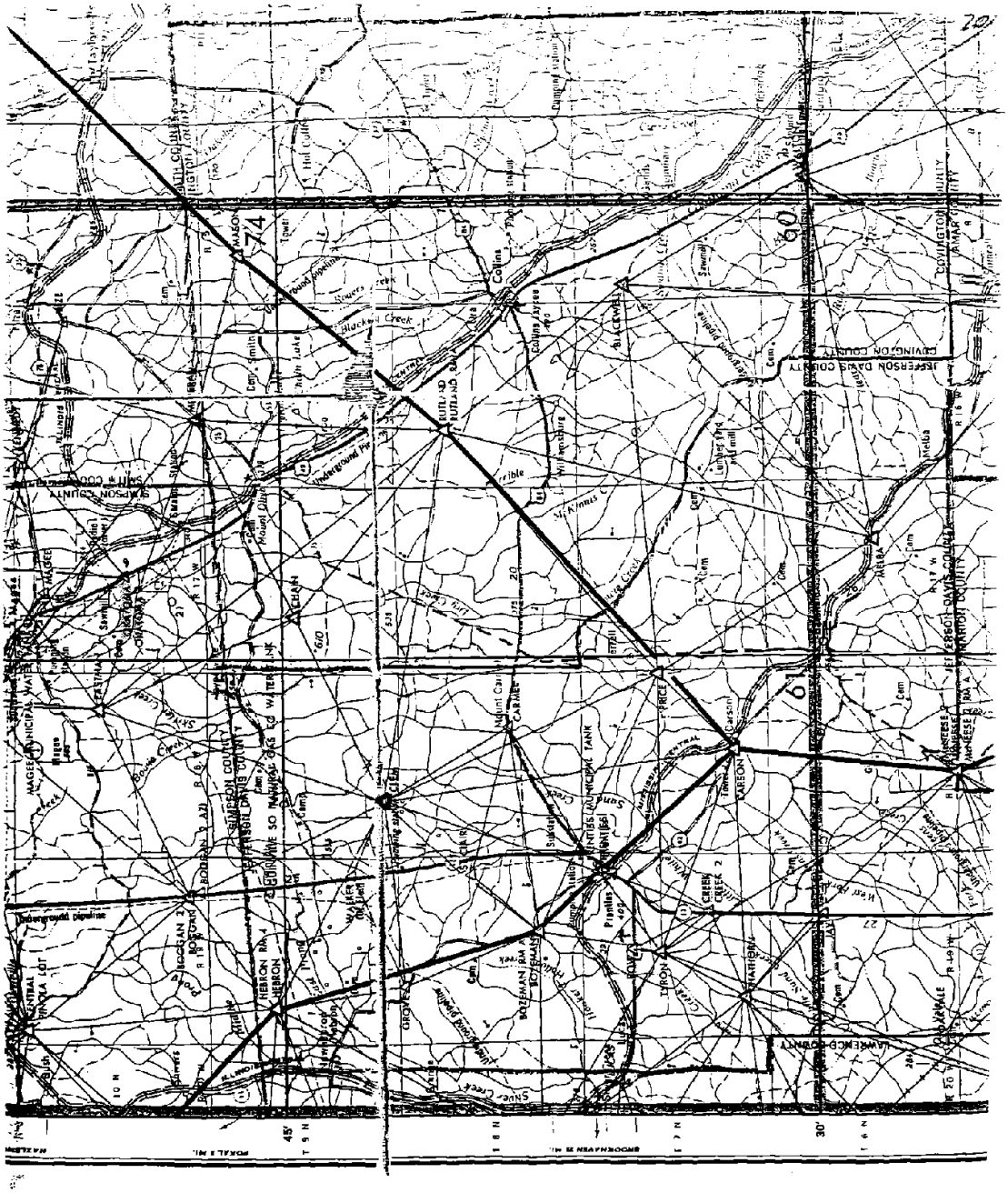
If single scale and elevation factors are to be used throughout the project, the two factors should be combined into a single combined GRID FACTOR to reduce the work involved. The resulting error (7.9 ppm or 1:130,000) will be the sum of the individual errors of 4.6 and 3.3 ppm and will amount to only 0.8 mm error at 100 meters. Using NO factor at all (assuming that grid is equal to ground distances) would produce an error of 35 ppm or 1:29,000 which is 3.5 mm at 100 meters. This would be acceptable in rough stakeout work.

The convergence angle (angle between the grid and geodetic or true meridian) increases with an increase in distance from the central meridian. The value for the Prentiss project varies from 15'21.4" at the west end to 17'52.3" at the east end, a total change of 2'30.9". Grid values which are given or obtained by inversing between coordinates will usually be the value needed. In the few cases where a geodetic value is needed, individual values for each location should be calculated as ME'seconds. M for the Prentiss project is 0.019904 and E' is E - 700,000m, the distance from the central meridian.

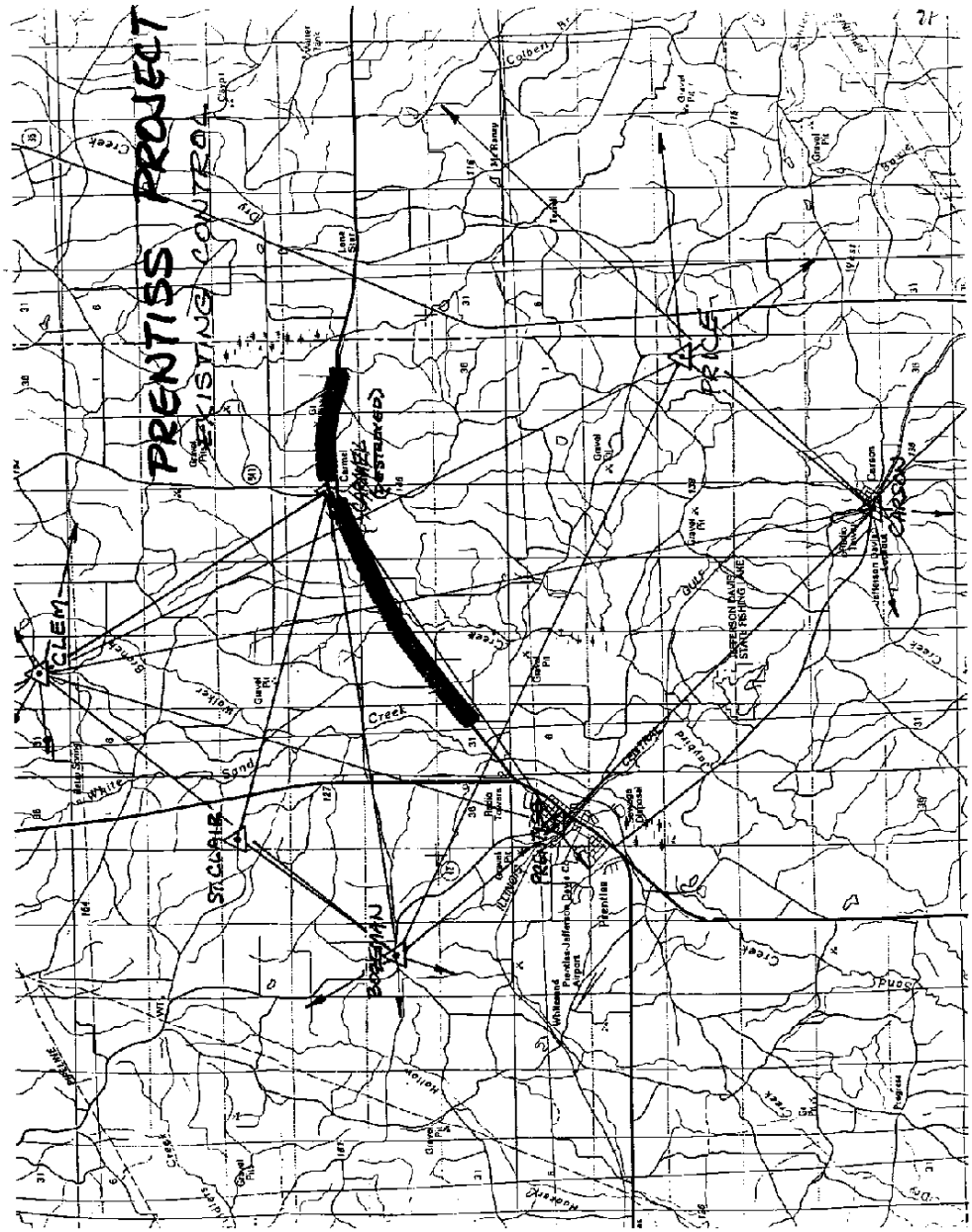
The formulae given below will allow for any conversion needed.

GRID DISTANCE = GROUND DISTANCE X 0.9999652
GROUND DISTANCE = GRID DISTANCE / 0.9999652
GROUND DISTANCE = GRID DISTANCE + 34.8 PPM
GEODETIC AZIMUTH = GRID AZIMUTH + 0.019904 (E-700,000m)

32. Explanation of Prentiss project analysis



33. NGS geodetic control diagram for Prentiss project area

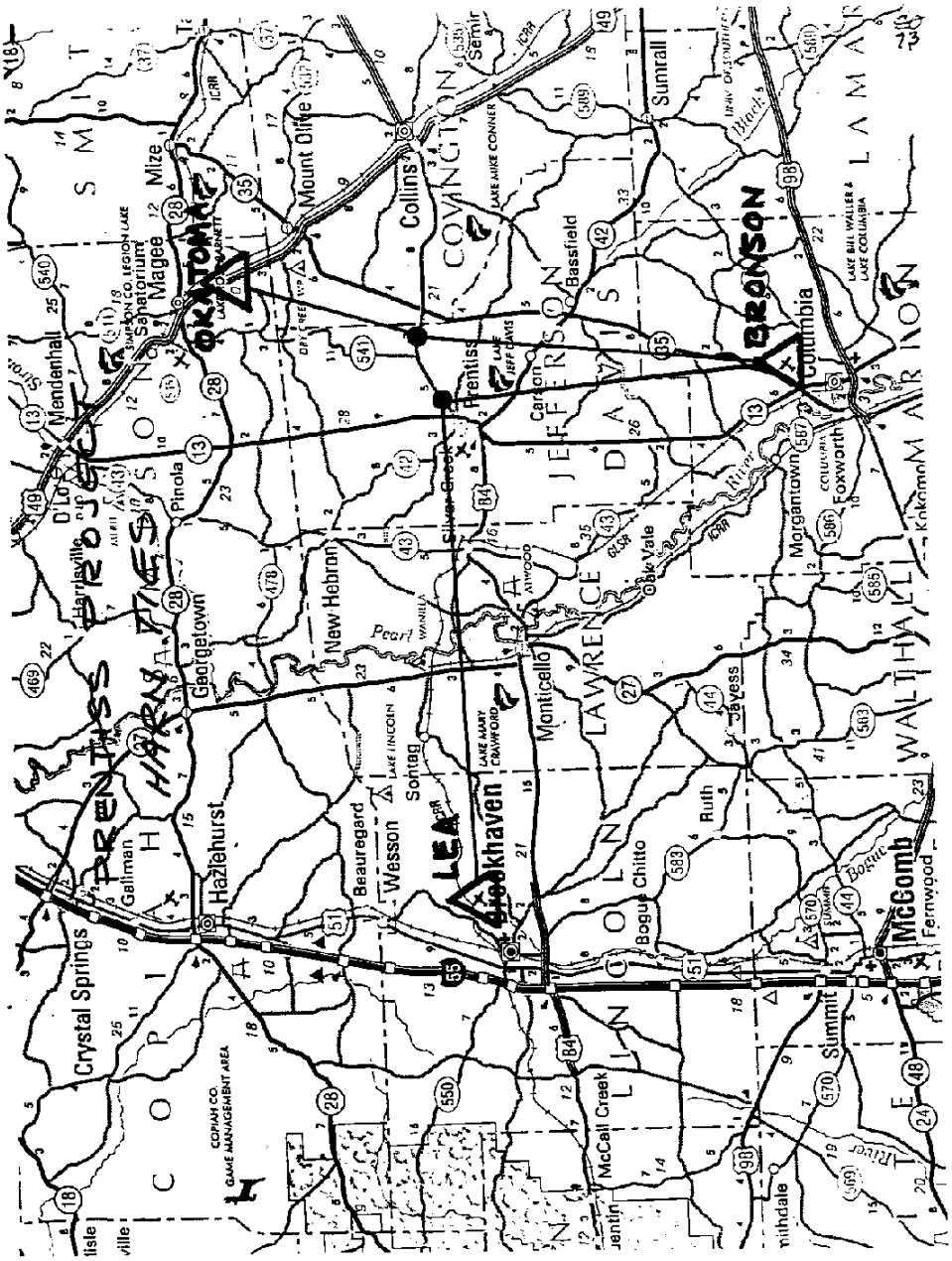


34. Existing control net for Prentiss project on 30x60 USGS map

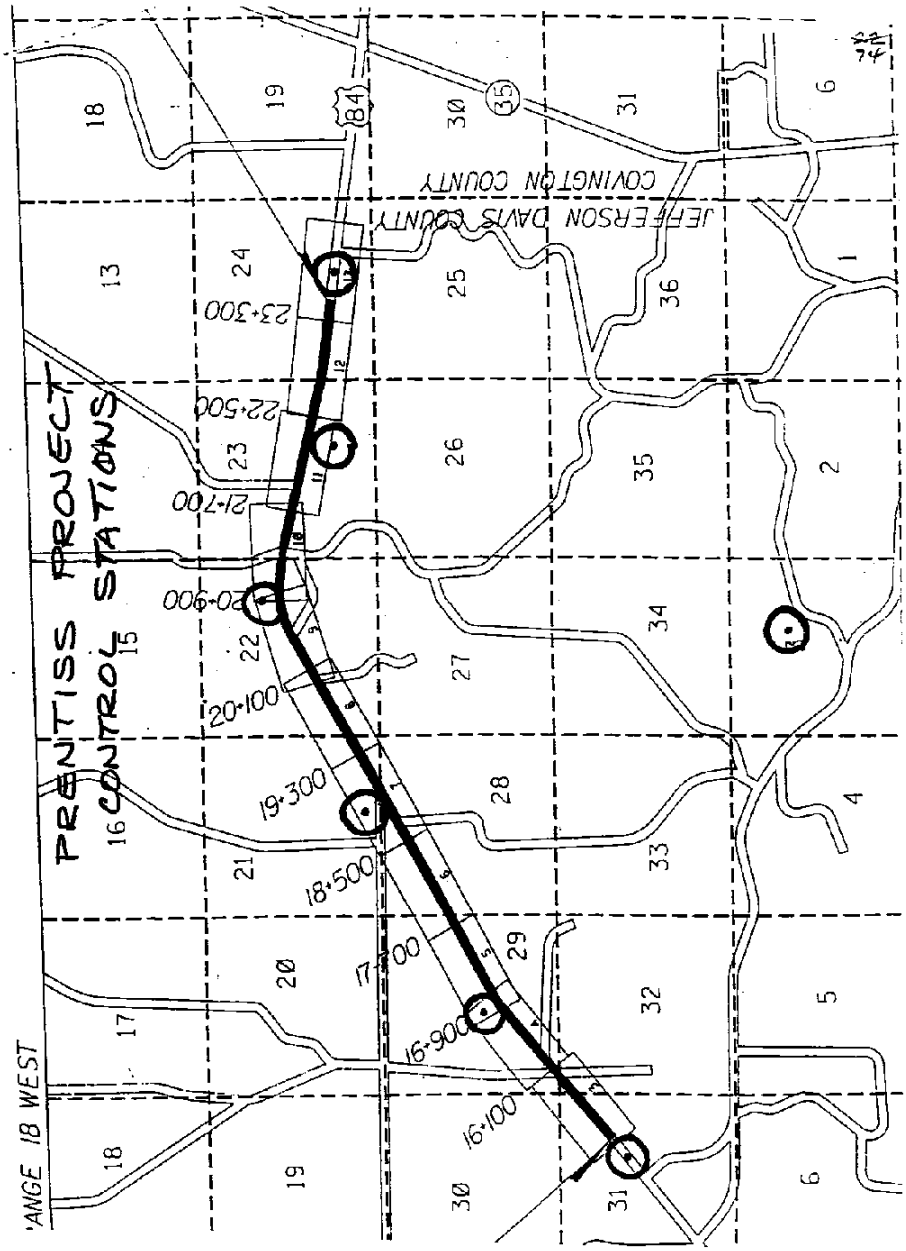
National Geodetic Survey, Retrieval Date = FEBRUARY 26, 1997

```
BV1727 ***********************************************************************************************************
BV1727  DESIGNATION   – CLEM RESET
BV1727  PID           - BV1727
BV1727  STATE/COUNTY  - MS/JEFFERSON DAVIS
BV1727  USGS QUAD     - MOUNT CARMEL (1982)
BV1727
BV1727                                  * CURRENT SURVEY CONTROL
BV1727
BV1727  ___________________________________________________________________________________________________
BV1727* NAD 83 (1993)  - 31 42 17.13200 (N)    089 49 50.30365 (W)                    ADJUSTED
BV1727* NAVD 88        -      163.    (meters)      535.      (feet)                  SCALED
BV1727  ___________________________________________________________________________________________________
BV1727  LAPLACE CORR-      0.31     (seconds)                                         DEFLEC96
BV1727  GEOID HEIGHT -    -25.86    (meters)                                          GEOID96
BV1727
BV1727  HORZ ORDER    - FIRST
BV1727
BV1727  The horizontal coordinates were established by classical geodetic method
BV1727. and adjusted by the National Geodetic Survey in May 1994.
BV1727
BV1727. The orthometric height was scaled from a topographic map.
BV1727
BV1727. The Laplace correction was computed from DEFLEC96 derived deflections.
BV1727
BV1727. The geoid height was determined by GEOID96.
BV1727
BV1727;                    North          East      Units      Scale        Converg.
BV1727;  SPC  MS  W    - 244,523.212   747,650.554   MT    0.99997799    + 0 15 15.1
BV1727;  SPC  MS  E    - 244,845.779   205,463.220   MT    1.00006019    - 0 31 27.0
BV1727;  UTM    16     - 3,511,195.642 231,728.526   MT    1.00048772    - 1 29 18.6
BV1727
BV1727:                    Primary Azimuth Mark                          Grid  Az
BV1727:  SPC  MS  W    -  CARMEL                                       148 49 46.1
BV1727:  SPC  MS  E    -  CARMEL                                       149 37 04.2
BV1727:  UTM    16     -  CARMEL                                       150 24 55.8
BV1727
BV1727 |_____________________________________________________________________________|
BV1727 |  PID     Reference Object                Distance              Geod. Az     |
BV1727 |                                                                dddmmss.s    |
BV1727 |          CLEM RM 5                       20.321 METERS        01259        |
BV1727 |          CLEM AZ MK RESET                                     1004347.0    |
BV1727 |          CLEM AZ MK                                           1022805.0    |
BV1727 |          CLEM RM 1                       41.605 METERS        14340        |
BV1727 |          CLEM RM 3                       25.802 METERS        14837        |
BV1727 |  BV1728 CARMEL                           APPROX. 7.6 KM       1490537.2    |
BV1727 |  BV1672 BASSFIELD MUNICIPAL TANK         APPROX. 24.5 KM      1600803.5    |
BV1727 |          CLEM RM 6                       14.880 METERS        19259        |
BV1727 |  BV1731 PRENTISS MUNICIPAL TANK          APPROX. 11.9 KM      1980544.8    |
BV1727 |          CLEM RM 4                       27.166 METERS        23228        |
BV1727 |          CLEM RM 2                       48.963 METERS        24036        |
BV1727 |_____________________________________________________________________________|
BV1727
BV1727                                  SUPERSEDED SURVEY CONTROL
BV1727
BV1727  NAD 83 (1986)  - 31 42 17.14607 (N)      089 49 50.30120 (W)          ADJUSTED
BV1727  NAD 27         - 31 42 16.55100 (N)      089 49 50.02500 (W)          ADJUSTED
BV1727
BV1727  .Superseded values are not recommended for survey control.
BV1727  .NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
```

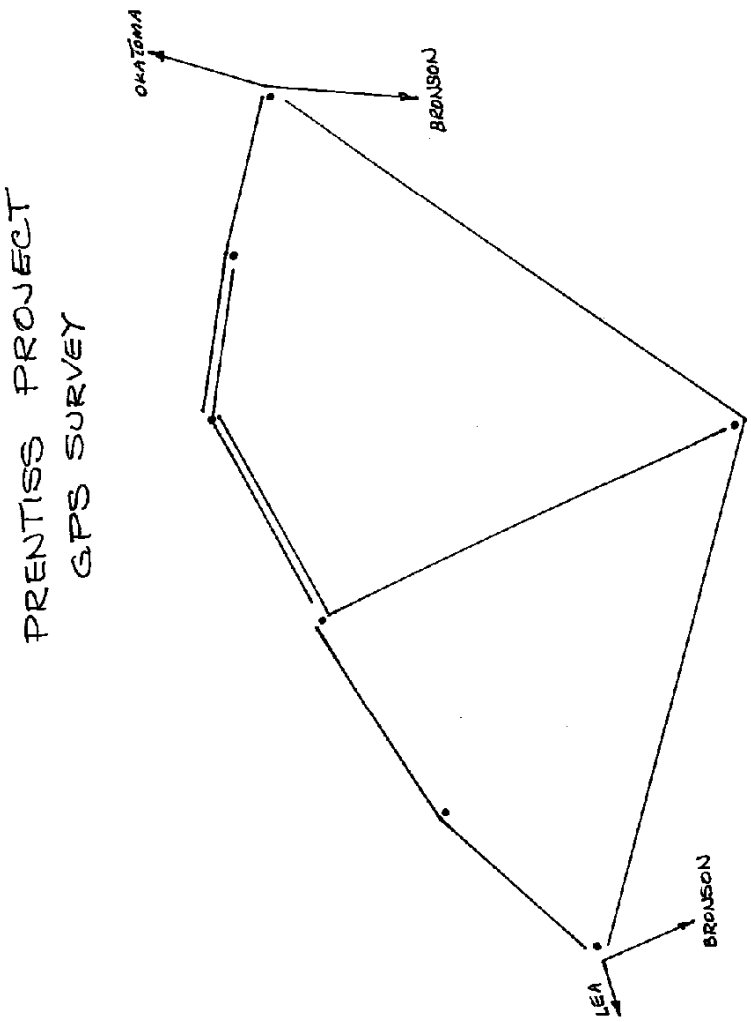
35. First page of the new data sheet for station CLEM on Prentiss project



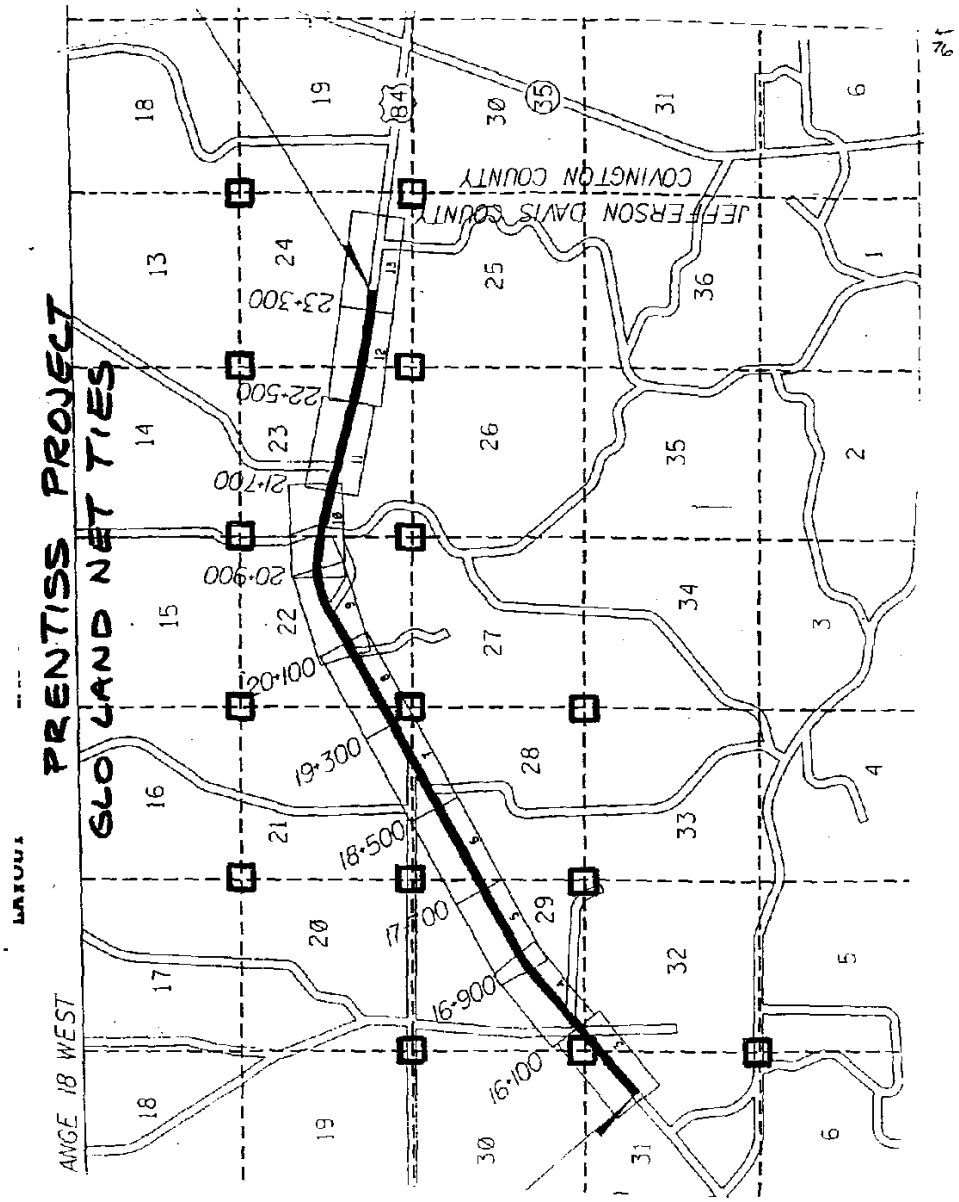
36. Three HARN station ties for Prentiss project



37. Horizontal control station location for Prentiss project



38. GPS survey independent vectors for Prentiss project



39. General Land Office (USPLS) land net ties for Prentiss project

Field Data Collection

PRELIMINARY SURVEYS

Mississippi DOT 6/1/04

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Contact Jeff Fracchia or Keith Boteler of Roadway Design if you find errors in it. (601-359-7287)

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GENERAL

INTRODUCTION

This chapter details the various activities involved in the preliminary survey process, including data requirements and procedures for gathering and presenting the data. Data can be collected with any equipment that will give you the accuracy's set forth in this manual in a timely manner. The required end product will be a complete survey in electronic format, certain check plots and required notes and documentation submitted as stated in this chapter.

This manual, and in the case of surveys performed by consultant firms, the contract, will define requirements for each separate project. A Survey Checklist (Form RWD-200, Located on Roadway Design's Web Site http://rwdweb/ Resources -> Forms). has been developed to insure completeness. It must be executed and submitted with the survey.

HORIZONTAL & VERTICAL CONTROL

The District Control crew will normally set the **Primary Control** for a project. These will be monuments at each end of the project and at intervals of 0.5 to 2.0 kilometers. 1st order Horizontal State Plane Coordinates will be present on these monuments. Second order elevations will also be provided on the Primary Control monuments nearest the project. These monuments will be submitted to the person in charge of the Preliminary Survey in a design file called Control.dgn and labeled in this file as PCM (Primary Control Markers). A detailed description of establishing the Primary Control is discussed in the Project Control chapter. The **Intermediate Control** will be monuments located between the Primary control at 250 to 300 meters or as needed and as described below. The accuracies required for this control is listed in the Accuracies and Precision section below.

HVCM – Horizontal & Vertical Control Point which contains Northing & Easting coordinate & Elevation.

HCM – Horizontal Control Point which contains Northing & Easting coordinate with no Elevation.

BM – Bench Mark or Vertical Control Point which contains Elevation only.

ACCURACIES & PRECISION

Accuracy

All horizontal control traverses will be run to a minimum of 2nd Order Class II (1:20,000) specifications. Bench Mark or Vertical Control elevations must be correct to a minimum of Third Order Accuracy. This requires the closure to be within 12.0 mm x square root of the distance in km (0.05 feet x square root of the distance in Miles). Cross-section notes (Conventional and Electronic) must carry the established job elevation datum.

Precision:

MDOT Measurement Precision		
Measurement Item	**Precision**	
	Metric (m)	**English (ft)**
Horizontal Distance, except cross-sections	0.001	0.01
Elevations: Benchmarks	0.001	0.001
Elevations: Centerline Pavements	0.001	0.01
Elevations: Centerline Subgrades	0.005	0.01
Cross-sections: Distances	0.1	1.0
Cross-Sections: Ground Elevations	0.05	0.1
Cross-Sections: Pavement Elevations	0.005	0.01

PROPOSED ROADWAY ALIGNMENT

Establishing the Proposed Roadway Alignment is discussed in the Project Control chapter.

COLLECTION METHODS

OVERVIEW

Collection of existing data (preliminary survey) for a project will begin once Project Control has been established by the District Control crew and alignment location is approved. The preliminary survey will be collected by the Project Office survey crew, a consultant, Photogrammetry section, or a combination of any of those just mentioned.

The control (X,Y, & Z)(State Plane Coordinates) established by the District Control crew shall be maintained and used throughout the life of the project. This control will be presented to the Project Office in a 2d Design file called CONTROL.DGN (See the section on Control Submittal in the CONTROL chapter). When the survey data is transferred to CADD the X,Y,Z values of the data must be maintained. Grid Distances and Grid Bearings shall be shown in this drawing with Scale Factors and Convergence Angles present.

Different types of survey equipment and different collection methods can be used to perform a preliminary survey. Only the more practical and automated are discussed below. Although collection methods used can vary, the accuracies discussed in this manual shall be attained and the survey completed in a timely manner.

COLLECTION METHODS

HORIZONTAL & VERTICAL COMBINED

I. With Total Station, Data Collector and Prism

Horizontal and Vertical data can be collected separately or combined. Ideally, when you are performing the preliminary survey, all horizontal and vertical data can be collected at the same time, with an end product a 2d DESIGN file (TOPO.DGN) showing all the topo and a 3d design file (3DG*.DGN) with spot shots and breaklines plus other files as described in the sections below.

Regardless of how the survey is collected, if a data collector is used, the Point descriptions described in this chapter shall be used if the survey is made and processed to CADD by DOT personnel. By using these PCODES, data can be loaded with GeoPak Survey to CADD with much of the drawing completed with Roadway Design's symbology automatically set. If a consultant collects the data and processes it to CADD, the consultant can use any method he wants as long as the accuracy's required are obtained, the survey is completed in a timely manner, and submitted as described in this manual.

Horizontal & Vertical (N,E,ELEV) are collected at same time using breaklines and ground shots to define vertical project information. This type of survey is split into two phases with one being shots only on existing ground and the second phase with shots taken on existing structures (bridges) that have a void (air) space between the structure and the existing ground.

If this option is used, three design files (TOPO.DGN, 3DG.DGN, & 3DA.DGN) should be submitted along with several other files which are discussed below.

Steps and files which should be submitted.

a) Ground and all topo shots are collected except for bridge shots.

b) This data is loaded in a 3D design file called 3DG*.DGN

c) This data is cleaned up and then file fenced to a 2D design file TOPO.DGN

d) TOPO.DGN is cleaned

e) 3DG.DGN - Make sure that no shots are present if they were not taken on existing ground.

f) Go to GeoPak DTM and Extract the Breaklines and Spot shots from this file. This step creates a file called *.DAT (where * is the name of the primary route.)

g) From GeoPak DTM dialog Build the triangles. This step looks at the DAT file created in the step above and creates a *.TIN file.

h) Cross-sections should be cut from this TIN file using Geopak's Ground Cross-sections from DTM to check the validity of the TIN. These cross-sections should be placed in a file called XS*.DGN (where * is the name of the route the cross-sections were taken about.) Cross Sections should be cut from a TIN at the same increment and locations as discussed in the (WHAT SHOULD BE SUBMITTED -> VERTICAL(EXISTING GROUND) -> Coverage) section.

I) The same data as listed above, except pertaining to only one bridge surface (instead of existing ground) shown in 3DA*.DGN.

DESCRIBING SHOTS IN THE FIELD

The following page is a list of PCODES (Point Codes) which shall be used in the field for a given point.

The DOT provides use of either numeric or alphabetic pcodes, so either can be used, based on what you prefer. These Pcodes shouldn't be mixed in one set of data though, so either use the numeric or the alphbetic, not a combination of both. The Pcodes are contained in two PCODE GeoPak Survey databases:

1) RWDSVY.SMD - Contains the Alphabetic character pcodes listed below in the second column.

2) RWDSVY-NO.SMD - Contains the numeric pcodes listed below in the 1st column.

Also, L (Begin Line) ,EL (End Line) ,C (Curve) ,EC (End Curve) should be used as another field if a line or curve should be drawn from one point to the next. By entering L on a description, a line will be drawn from this point to the next point with the same description. This will go on for each point with this description until EL is placed by this description signifying an End Line.

When using alphabetic codes, if different lines of a given description need to be open at the same time you can add a numeric value to the end of the descriptions shown below (i.e. PEL1, PEL2,) which ensures lines will not be drawn from PEL1 to PEL2.

When using numeric codes, if different lines of a given description need to be open at the same time you can add a alphabetic value to the end of the descriptions shown below (i.e. 8A, 8B) which ensures lines will not be drawn from 8A to 8B.

MDOT PCODES

Transportation

1	BOC	Back of Curb
2	BOHC	Back of Header Curb
3	BRN	Bridge End
4	CD	Concrete Drive
	CL	CenterLine of Ex. Road
5	DD	Dirt Drive
	EP	Edge of Pavement
16	FOCB	Face of Curb Bottom
	FOCT	Face of Curb Top
	FOHCB	Face of Header Curb Bottom
	FOHCT	Face of Header Curb Top
6	GD	Gravel Drive
7	PD	Paved Drive
8	PEL	Left Pavement Edge
9	PER	Right Pavement Edge
10	POC	Point on Curve
11	POT	Point on Tangent
12	PS	Secondary Road (Paved)
14	RW	Retaining Wall
19	SH	Shoulder
	SHP	Shoulder (Paved)
15	US	Secondary Road (UnPaved)
17	SH	Shoulder

Railroad

13	RR	Railroad
27	RRSIGN	RR Sign
28	RRFS	RR Sign (w/ Flashing Signal)
29	RRFSG	RR Sign (Flash. Sig. W/ Gate)
30	RRCFS	RR Sign (Cantilever Flashing)
31	RRCFSG	RR Sign (Cantilever Flash w/ Gate)
32	RRDEV	RR Device
33	RRMP	RR Mile Post
34	RRSW	RR Switch
35	RRC	RR Control Box

Non-Transportation

50	BBRD	Billboard
61	BUSH	Bush
62	CEM	Cemetary
69	FLAG	Flag Pole
70	GBM	Bench Mark
	GP	Gas Pump
	GRAV	Grave Headstone
71	HEDGE	Hedge
72	PARK	Parking Lot
73	POND	Pond
74	RRW	Residential Retaining Wall
75	SDISH	Satellite Dish
	STANK	Septic Tank
76	SW	Side Walk
77	TANK	Tank
78	TREE	Tree
79	TREEL	Tree Line
80	UTANK	Underground Tank
81	WELL	Well
82	VAC	Commercial Vacum
83	PK	Parking Meter
84	SPRINK	Sprinkler
85	PTANK	Propane Tank
86	SIGN	Sign
87	CPAD	Concrete Pad

Buildings

51	1SBLK	One Story Block
52	1SB	One Story Brick
53	1SF	One Story Frame
54	1SM	One Story Metal
55	2SBLK	Two Story Block
56	2SB	Two Story Brick
57	2SF	Two Story Frame
58	2SM	Two Story Metal
59	BARN	Barn
	CPY	Canopy
60	SHED	Shed

Fences

63	FENB	Fences – Barbed Wire
64	FENBR	Fences – Brick
65	FENCH	Fences – Chain Link
66	FENM	Fences – Metal
67	FENS	Fences – Stone
68	FENW	Fences – Wood
	GATE	GATE POST

Safety Devices

100	GRR	Guard Rail Right
101	GRL	Guard Rail Left

Rural Drainage

110	BOX	Box Culvert
111	CMP	Corrugated Metal Pipe
112	CMP12	12"
113	CMP15	15"
114	CMP18	18"
115	CMP24	24"
116	CMP30	30"
117	CMP36	36"
118	CMP42	42"
119	CMP48	48"
120	CMP54	54"
121	CMP60	60"
122	CMP22x13	22"x13"
123	CMP29x18	29"x18"
124	CMP36x23	36"x23"
125	CMP44x27	44"x27"
126	CMP51x31	51"x31"
127	CMP58x36	58"x36"
128	CMP65x40	65"x40"
129	CMP73x45	73"x45"
130	DITCH	Ditches,Stream,Rivers
	DI	Drop Inlet
131	MI	Median Inlet (EL. At Top of Grate)
	MIFL	Median Inlet Flowline
132	PDCH	Paved Ditch
133	PVC	Plastic Pipe
134	RCP	Concrete Pipe
135	RCP12	12" Concrete Pipe
136	RCP15	15" Concrete Pipe
137	RCP18	18" Concrete Pipe
138	RCP24	24" Concrete Pipe
139	RCP30	30" Concrete Pipe
140	RCP36	36" Concrete Pipe
141	RCP42	42" Concrete Pipe
142	RCP48	48" Concrete Pipe
143	RCP54	54" Concrete Pipe
144	RCP60	60" Concrete Pipe
145	RCP	22"x13" Concrete Pipe
146	RCP	29"x18" Concrete Pipe
147	RCP	36"x23" Concrete Pipe
148	RCP	44"x27" Concrete Pipe
149	RCP	51"x31" Concrete Pipe
150	RCP	58"x36" Concrete Pipe
151	RCP	65"x40" Concrete Pipe
152	RCP	73"x45" Concrete Pipe
153	CPP	Corrugated Plastic Pipe
154	INLET	Inlet (At Top of Grate)
	INLETFL	Inlet Flowline
155	WW	Wing Wall

Urban Drainage

175	CI	Curb Inlet
176	S	Storm Sewer
177	SMH	Storm Sewer Manhole (At Top)
	SMHFL	Storm Sewer Manhole Flowline

Properties

200	XROW	Ex. R.O.W. Marker
201	CITY	City Limits
202	CNTYLN	County Line
	FENCOR	Fence Corner
203	FIP	Found Iron Pin
204	FC	Found Corner (Desc.Req'd.)
	PC	Property Corner
205	PL	Property Line
206	STATE	State Boundary
	SIP	Set Iron Pin
	GLO	Section Corner

Utilities

Cable_TV

225	UTVC	Underground Television Cable
261	CBOX	Cable Box

Electric

226	EMH	Electric Manhole
227	LP	Existing Light Pole
228	LP/PED	Existing Light Pole w/ Pedestal
229	LUMP	Existing Luminar Pole
230	PP	Existing Power Pole
231	PP/PED	Existing Power Pole w/ Pedestal
232	UPC	Underground Electric Cable
262	TRNFMR	Transformer
	PBOX	Pull Box

Gas

233	GAS	Gas Line
234	GM	Gas Meter
235	GMH	Gas ManHole
236	GV	Gas Valve

Sewer

237	SS	Sanitary Sewer
238	SSMH	Sanitary Sewer Manhole

Telephone

250	TELEL	Telephone Line
251	TP	Existing Telephone Pole
252	TPED	Existing Telephon Pedestal
253	TP/PED	Existing Telephone Pole w/ Pedestal
254	TMH	Telephone Manhole
255	UTC	Underground Telephone Water
263	TBOOTH	Telephone Booth

Water

256	FH	Fire Hydrant
257	WATER	Water Line
258	WMH	Water Manhole
259	WM	Water Meter
260	WV	Water Valve

Signal

264	TSC	Traffic Signal Control Box
265	TSP	Traffic Signal Pole

X-Sections

276	LT	Left X-Section Shots
277	RT	Right X-Section Shots
278	L	Left X-Section Shots
279	R	Right X-Section Shots
285	BL	Break Line
280	BRL	Break Line
281	BR	Break Line
282	TB	Top Bank
283	DCH	Ditch FLow Line
284	SPOT	Spot Shot

CONTROL POINTS

300	PCM	Primary Control Mark
301	HVCM	Control with N,E,ELEV.
302	HCM	Control with N,E Only
303	BM	Vertical Control Point
304	TRNP	Turning Point
305	TRP	Traverse Point

The following is an example of how the points were processed with GeoPak based on alphabetic descriptions used in the field.

TOPO11.COR

```
1,  10000.000,  10000.000, *,    GBM
2,  11717.891,  9333.301,  *,    GD,    L
3,  11707.857,  9351.256,  *,    GD,    L
4,  11716.100,  9386.778,  *,    GD,    EL
5,  11725.150,  9372.634,  *,    GAS,   L
6,  11718.898,  9361.487,  *,    XROW,  L
7,  11718.900,  9361.750,  *,    PP,    L
8,  11702.914,  9387.802,  *,    GD,    L
9,  11689.874,  9358.367,  *,    GD,    L
10, 11667.839,  9349.933,  *,    GD,    EL
11, 11712.130,  9356.299,  *,    RCP,   L,   18"
12, 11688.697,  9363.814,  *,    RCP,   EL
13, 11706.997,  9325.356,  *,    PEL,   L
14, 11699.454,  9302.571,  *,    PER,   L
15, 11688.118,  9265.711,  *,    XROW1, L
16, 11686.648,  9261.011,  *,    WATER, L
17, 11566.305,  9410.565,  *,    PP,    L
18, 11402.726,  9360.821,  *,    XROW1, EL
19, 11400.391,  9356.913,  *,    WATER, EL
20, 11370.105,  9411.517,  *,    PER,   EL
21, 11376.637,  9434.961,  *,    PEL,   EL
22, 11434.134,  9455.706,  *,    XROW,  EL
23, 11417.972,  9431.583,  *,    GD,    L
24, 11386.862,  9442.453,  *,    GD1,   L
25, 11417.184,  9447.194,  *,    GD,    L
26, 11402.767,  9459.585,  *,    GD1,   L
27, 11434.482,  9494.195,  *,    GD,    EL
28, 11419.368,  9499.661,  *,    GD1,   EL
29, 11401.100,  9465.659,  *,    PP,    EL
30, 11398.485,  9478.710,  *,    GAS,   EL
31, 11421.241,  9450.685,  *,    RCP,   L,   18"
32, 11397.946,  9458.151,  *,    RCP,   EL
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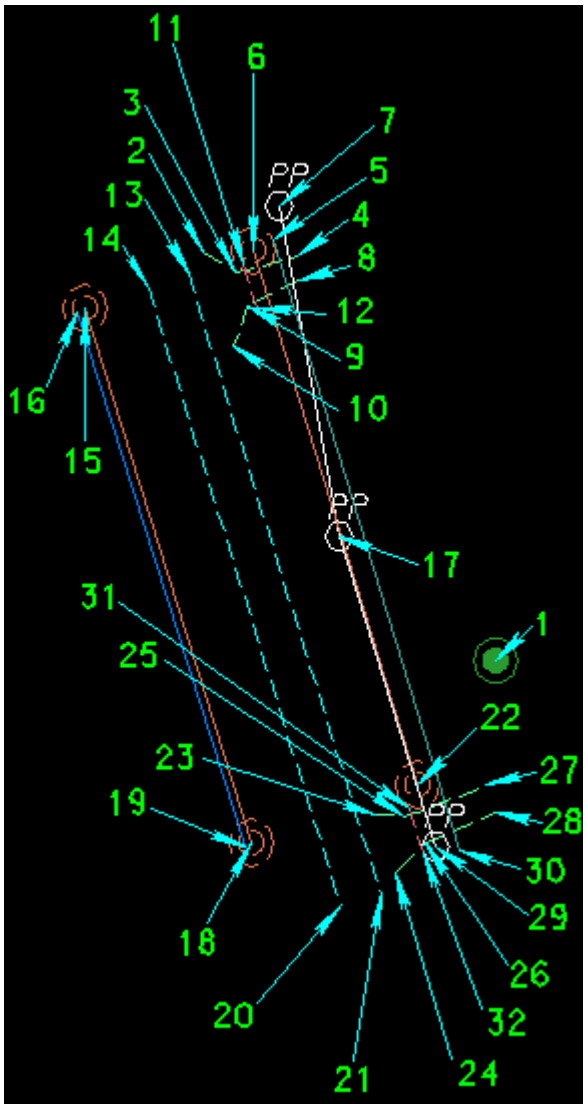

The following is an example of how the points were processed with GeoPak based on numeric descriptions used in the field.

TOPO11.COR

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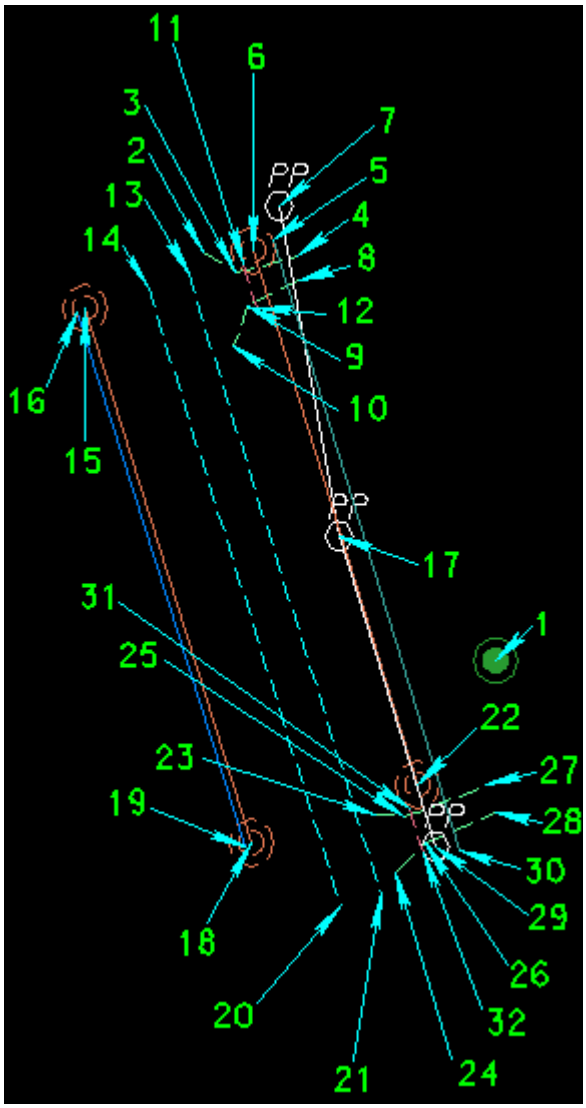
1,  10000.000,  10000.000, *,    303
2,  11717.891,  9333.301,  *,    6,    L
3,  11707.857,  9351.256,  *,    6,    L
4,  11716.100,  9386.778,  *,    6,    EL
5,  11725.150,  9372.634,  *,    233,   L
6,  11718.898,  9361.487,  *,    200,  L
7,  11718.900,  9361.750,  *,    230,    L
8,  11702.914,  9387.802,  *,    6,    L
9,  11689.874,  9358.367,  *,    6,    L
10, 11667.839,  9349.933,  *,    6,    EL
11, 11712.130,  9356.299,  *,    137,   L,   18"
12, 11688.697,  9363.814,  *,    137,   EL
13, 11706.997,  9325.356,  *,    8,   L
14, 11699.454,  9302.571,  *,    9,   L
15, 11688.118,  9265.711,  *,    200A, L
16, 11686.648,  9261.011,  *,    257, L
17, 11566.305,  9410.565,  *,    230,    L
18, 11402.726,  9360.821,  *,    200A, EL
19, 11400.391,  9356.913,  *,    257, EL
20, 11370.105,  9411.517,  *,    9,   EL
21, 11376.637,  9434.961,  *,    8,   EL
22, 11434.134,  9455.706,  *,    200,  EL
23, 11417.972,  9431.583,  *,    6,    L
24, 11386.862,  9442.453,  *,    6A,   L
25, 11417.184,  9447.194,  *,    6,    L
26, 11402.767,  9459.585,  *,    6A,   L
27, 11434.482,  9494.195,  *,    6,    EL
28, 11419.368,  9499.661,  *,    6A,   EL
29, 11401.100,  9465.659,  *,    230,    EL
30, 11398.485,  9478.710,  *,    233,   EL
31, 11421.241,  9450.685,  *,    137,   L,   18"
32, 11397.946,  9458.151,  *,    137,   EL
```



II. HORIZONTAL & VERTICAL SEPARATE

With this method, the horizontal data could be collected as stated above except you could leave off the elevation and gather the vertical ground information as cross-sections and profiles about staked baselines.

WHAT SHOULD BE SUBMITTED

OVERVIEW

This section describes what should be submitted to Roadway Design Division in regards to Preliminary Surveys. All survey data should be submitted with form RWD-200 located on Roadway Design's Web Page http://rwdweb for DOT employees. Horizontal data shall be submitted electronically. Cross-sections & Profiles can be submitted in Field Note Books, but electronic submittal is preferred. Microstation is the electronic drafting package the data should be submitted in.

The electronic data should be submitted through Email to bjames@mdot.state.ms.us, over the network, or on 3 ½" floppy disks or CD. Roadway Design's Survey Submittal form (RWD-200) should be submitted with the electronic and bound notes. This form is available through Roadway Design's Intranet Site (http://rwdweb Resources -> Forms). The plotted data and/or notes shall be bound together and also submitted with this form (you can save the form and print it) to Roadway Design with the following label:

TO: ROADWAY DESIGN DIVISION (83-01)

INITIAL PRELIMINARY SURVEY or ADDITIONAL SURVEY

DISTRICT:

PROJECT NUMBER:

The completed survey shall consist, at a minimum, of the items listed and summarized below. Each is described in detail on the following pages.

1) VERTICAL DATA (EXISTING GROUND) - ELECTRONIC or NOTES (As described in detail in the VERTICAL (EXISTING GROUND) section below.)

Summary: A) Baseline tied data:

Existing ground cross-sections taken 90 degrees from staked baseline stations can be submitted in cross-section books, as an XYZ ASCII text file, or in a Microstation design file after being processed with GeoPak.

Existing ground profiles taken about a staked baseline, shall either be submitted in field books or plotted on the profile part of a plan/profile sheet with the corresponding baseline shown in the plan part of this sheet either electronically or plotted on paper.

B) DTM - Digital Terrain Model

Existing ground data collected with random XYZ spot shots and breaklines shall be processed with GeoPak. A GeoPak TIN shall be created and cross-sections shall be extracted about all proposed and/or existing alignments. All cross-section design files shall be submitted along with the TIN file,3D design file showing spot shots and breaklines, and the GPK file.

2) HORIZONTAL DATA - ELECTRONIC

All topo must be submitted electronically in a 2D Microstation design file called TOPO.DGN. Additional topographic survey should be submitted in a design file called Tdate.DGN where date is the date of submittal.

3) DRAINAGE DATA - PLOTTED (For Drainage Areas 400 hectares (1000 acres) or greater)

Drainage data for drainage areas 400 hectares or greater or for drainage areas less than this, but involving a bridge, shall be placed on plan/profile sheets and submitted as paper plots. Associated Microstation files shall also be submitted.

VERTICAL (EXISTING GROUND)

Vertical data (existing ground) can be submitted by one of the following methods depending on how the data was collected.

COLLECTION METHOD	SUBMITTAL TYPE
I) Level, Rod, & Tape (90^ to baseline)	Notes (Cross-section books) or GeoPak Working Cross-section design file
II) Total Station, Data Collector, & Prism (90^ to baseline)	XYZ ASCII text file or GeoPak Working Cross-section design file
III) Total Station, Data Collector, & Prism (Random Spot Shot Breakline Survey)	GeoPak Working X-Section design file, *.DAT, *.TIN

NOTE: 1. If a GeoPak Working X-Section file is submitted, GeoPak's Coordinate Geometry database file (JOB*.GPK) shall also be submitted.
2. It is critical to clearly state the name or description of the alignment cross-sections are taken about in the cross-section book or at the top of the xyz ASCII text file.
3. Existing ground elevations will be tied to the project's established vertical datum.

COVERAGE

Cross-sections shall be taken at 100 feet intervals for rural projects and 50 feet intervals for urban projects. These intervals may also be appropriate on 3R projects, depending on the variability of earthwork along the project. Other factors that may influence the frequency of cross-sections include the presence of intersections, extent of driveway and turnout construction or reconstruction, ADA related work, drainage improvements, etc. Where a cross-section is not required at property ramps or driveways, a perpendicular profile is required at the centerline of the ramp/driveway in order to design the new property ramp or driveway. Enough coverage shall be taken so as to ensure that the proposed embankment will fit on the cross-sections. It is the responsibility of the Project Engineer to determine the limits needed but the following table provides normal coverage values. Vertical Ground data shall be collected along all proposed roadway alignments, alignments established for existing roadways. Vertical ground data for waterways, as described in the DRAINAGE section, and for Railroads crossing the proposed alignment, as described in the TOPO section, is also required.

C.L. to C.L. Spacing of Lines	Location of C.L. Survey	Distance Left	Distance Right
18 – 38m (60-125 feet)	C.L. of Median	50m (150 feet) Outside C.L. of Left Lane (Min.)	50m (150 feet) Outside C.L. of Right Land (Min.)

Note: 1. For undivided sections (five lane and transitional areas), the sections shall extend 50m (150 feet) left and right of the centerline.
2. If vertical ground data is collected by option III shown above, the same amount of area should be covered as if you were taking traditional cross-sections.

The following describes in detail how vertical ground data should be submitted.

I) Level, Rod, & Tape (90 degrees to baseline)

A) Cross-Section Books

NOTE: The example cross-section notes shown below are in English units.

1. Rod-readings or elevations may be used in the field books, but it usually is desirable to leave all shots in rod-readings.

2. All notes of a single location, i.e. ramps, pits or roadways, should be grouped together in sequence. Do not mix types and locations, i.e. originals and finals, roadways and ramps.

3. All cross-section notes should be labeled as to type, location, and **termini**.

4. Encircle in red pencil and mark “omit” or “do not punch” any cross-section or extraneous data that are not to be included in the earthwork computations. Pipe, culvert, skew and partial sections and any other extraneous data should be easily distinguishable from other notes.

5. Reference additional cross-section information to the same centerline or base line.

6. Check reference elevations before the cross-section notes are submitted for computation. Check the addition and subtraction of all rod-readings used to compute reference elevations. If cross-sections are taken as directly read from the level, then heights of instruments, bench marks, and turning point are considered as reference elevations.

7. The reference elevations should be repeated at the top of each page in the note books even though it may not have changed for several cross-sections.

8. If more than one height of instrument (reference elevation) is required for a section, the proper shot sequence should be maintained across the station in the notes. Do not scatter data about in the notes.

9. All points must be labeled as to station and must appear on the proper side of the centerline. Where there is insufficient room on one line, shots may be continued on the next line. Regardless of the sequence in which the shots were taken, the first shot encountered in the notes would be the left-most shot.

10. When recording rod-readings or elevations, it is recommended that decimal points not be used to represent fractional units. Instead, use a superscript digit and underline it, e.g., $11^{\underline{6}}$ The same procedure should be used to list distances, when it becomes necessary record them to a tenth of a foot.

11. Rod-readings are normally considered to be negative. Where plus (+) readings are required, bracket the plus shot, e.g. ($+1^{\underline{6}}$).

12. To avoid confusion, never use a zero (0^0) rod-reading or elevation with the centerline or base line distance of (0^0). Use at least one tenth (0^1 or $+ 0^1$) of a foot. At distances other than zero, a zero rod-reading or elevation is permissible.

13. Never substitute NG (natural ground), TB (top of bank) TS (top of a slope) for rod-readings.

14. Sections with eight (8) or less shots on either side should utilize the bound cross-section books with the centerlines pre-printed. This would usually include overlays and two-lane roadways.

Example (1)

DATE 1-1-70	ROD _____	WEATHER _____	I.D. _____
	ROD _____	TYPE SECTION Original	COL.24
NOTES _____	TAPE _____		

B.M.	+		H.I.		-		ELEV.		DESCRIPTION								
	6.50		305.10				298.60										
				9^{9}	10^{7}	10^{0}	8^{9}	8^{5}	8^{0}	7^{6}	7^{1}	8^{2}	8^{9}				
13+25				79	64	38	21	9	0	6	22	43	66				

15. Sections containing more than eight shots on either side should use the following procedure:

    a. If cross-sections are to be made from the centerline out, estimate the number of shots to the left of centerline and reserve this many spaces from the centerline to the left, striking out the printed centerline in the book. Continue the section from left to right until completed.

    b. With the aid of two or three tapes put together, begin taking shots to the left of the centerline and record shots from left to right striking out the printed zero (0). This procedure may be reversed as long as the recorded shots are in sequential order from left to right.

The following examples may be used when either or both sides of a cross-section contain more than eight (8) shots:

Example (2) Beginning at left and continuing to right side

DATE 1-1-70 ROD _____ WEATHER _____ I.D. _____
ROD _____ TYPE SECTION Original COL.24___
NOTES _____ TAPE _____

B.M.	+		H.I.		-		ELEV.		DESCRIPTION								
	2.20		314.60				312.40										
26+33	4^{9}	5^{5}	6^{2}	5^{3}	6^{8}	4^{8}	4^{5}	5^{3}	4^{4}	4^{3}	5^{9}	6^{3}	7^{2}	7^{9}	8^{2}	8^{8}	7^{5}
Lt.	241	230	219	201	189	176	152	133	117 ~~0~~	103	83	69	47	33	28	20	13
26+33	7^{0}	6^{2}	7^{1}	8^{3}	8^{5}	9^{0}	9^{7}	10^{4}	10^{7}	11^{1}	11^{9}	12^{3}	10^{1}	8^{7}	8^{5}	7^{7}	6^{9}
Lt. & Rt.	8	4	0	12	28	47	63	88	102 ~~0~~	131	147	160	184	200	218	213	240
26+33	6^{3}	4^{1}	6^{0}														
Rt.	263	284	300														

Example (3) Beginning at left and separating left side from right side

26+33	4^{9}	5^{5}	6^{2}	5^{3}	6^{8}	4^{8}	4^{5}	5^{3}	4^{4}	4^{3}	5^{9}	6^{3}	7^{2}	7^{9}	8^{2}	8^{8}	7^{5}
Lt.	241	230	219	201	189	176	152	133	117 ~~0~~	103	83	69	47	33	28	20	13
26+33	7^{0}	6^{2}	7^{1}														
Lt.	8	4	0														
26+33	8^{3}	8^{5}	9^{0}	9^{7}	10^{4}	10^{7}	11^{1}	11^{9}	12^{3}	10^{1}	8^{7}	8^{5}	7^{7}	6^{9}	6^{3}	4^{1}	6^{0}
									160								

Rt.	12	28	47	63	88	102	131	147	0	184	200	218	231	240	263	284	300
									/								

Example (4) Beginning at right of right side and left of left side

DATE 1-1-70 ROD _____ WEATHER _____ I.D. _____
ROD _____ TYPE SECTION Original _____ COL.24___
NOTES _____ TAPE _____
B.M. + H.I. - ELEV. DESCRIPTION

	2.20		314.60				312.40										
26+75	5^{8}	5^{0}	4^{6}	5^{3}	6^{1}	6^{5}	6^{8}	7^{2}	7^{3}	7^{9}	7^{0}						
Lt.	176	154	133	115	99	84	71	50	35 ~~0~~	8	0						
26+75																	
26+75							7^{7}	8^{2}	8^{6}	9^{0}	8^{5}	9^{2}	9^{7}	10^{3}	10^{9}	11^{2}	12^{0}
Rt.							9	17	42 ~~0~~	69	88	109	130	151	173	190	214

Example (5) Beginning at right and separating left from right side

			314.60														
27+00															4^{0}	5^{5}	6^{2}
Lt.															241	230	219
27+00	5^{3}	6^{8}	4^{8}	4^{5}	5^{3}	4^{4}	4^{3}	5^{9}	6^{3}	7^{2}	7^{9}	8^{2}	8^{8}	7^{5}	7^{0}	6^{2}	4^{1}
Lt.	201	189	176	152	133	117	108	83	75 ~~0~~	69	47	33	28	20	13	8	4
27+00																7^{1}	3^{3}
Rt.																0	6
27+00	8^{3}	8^{5}	9^{0}	9^{7}	10^{4}	10^{7}	11^{1}	11^{9}	12^{3}	10^{1}	8^{7}	8^{5}	7^{7}	6^{9}	6^{3}	4^{1}	6^{0}
Rt.	12	28	47	63	88	102	131	147	160 ~~0~~	184	200	218	231	240	263	284	300

Example (6) Beginning at right and continuing of left side.

DATE 1-1-70 ROD _____ WEATHER _____ I.D. _____
ROD _____ TYPE SECTION Original _____ COL.24___
NOTES _____ TAPE _____
B.M. + H.I. - ELEV. DESCRIPTION

	4.50		311.00				306.50										
27+00													4^{9}	5^{5}	6^{2}	5^{3}	6^{8}
Lt.													241	230	219	201	189
27+00	4^{8}	5^{4}	5^{3}	4^{4}	5^{9}	6^{3}	7^{2}	7^{9}	8^{2}	8^{8}	7^{5}	7^{0}	6^{2}	4^{1}	7^{1}	6^{3}	3^{5}
Lt. & Rt.	176	152	133	117	108	83	75	69	47 Ø	33	28	20	13	8	4	0	6
27+00	4^{8}	5^{4}	5^{3}	4^{4}	4^{3}	5^{9}	6^{3}	7^{2}	7^{9}	8^{2}	8^{8}	7^{5}	7^{0}	6^{2}	6^{3}	4^{1}	6^{0}
	12	28	47	63	88	102	131	147	160 Ø	184	200	218	231	240	263	284	300

Example (7) Beginning at centerline.

			311.00														
29+00						9^{2}	8^{7}	8^{0}	7^{6}	7^{7}	7^{1}	6^{6}	6^{5}	5^{9}	6^{4}	5^{8}	6^{2}
Lt.						270	250	235	201 Ø	180	151	126	104	73	48	22	0
29+00	6^{4}	5^{8}	5^{3}	6^{1}	6^{8}	7^{2}	7^{9}	8^{5}	9^{2}	9^{9}	10^{4}	11^{3}	11^{9}				
Rt.	12	35	58	73	98	120	148	170	189 Ø	205	235	250					

B) GeoPak Working Cross-Section Design File

Cross-sections can be processed with GeoPak and submitted in a design file. Steps from the X-Section chapter of Roadway Design's GeoPak User's Guide should be followed**.** All files created in these steps should be submitted. Naming conventions described in this manual and also Roadway Design's CADD manual should be used while processing these sections.

II) Total Station, Data Collector, & Prism (90 degrees to the baseline)

Vertical data collected with this method can be submitted as an ASCII text file in the format as described below or processed with GeoPak and submitted in a design file.

A) XYZ ASCII Text File

The ASCII text file(s) submitted should be named XS*.COR where * is the name of the baseline the cross-sections were taken about. (i.e. XS49.COR, XSLRWEST.COR, etc.)

An example of the format is shown below.

NOTE: It is critical that the survey baseline the cross-sections were taken about is identified at the top of this ASCII text file, and that the columns of data are identified as to what each represents (i.e. PNUM, N, E, ELEV, etc.), as shown below.

X-Sections for Hwy 49
POINT NUMBER, NORTHING COORD, EASTING COORD, ELEVATION, DESCRIPTION

```
500,570155.69982000,733291.65462000,73.929,tp
501,569793.03090000,733361.02800000,76.773,CL8+275.000
502,569790.51288000,733353.01379000,76.550,LT8+275.000
503,569788.90288000,733346.96199000,76.476,LT8+275.000
504,569786.78962000,733340.03627000,76.384,LT8+275.000
505,569785.14653000,733333.68831000,76.309,LT8+275.000
506,569784.59460000,733332.47066000,76.440,LT8+275.000
507,569782.43075000,733325.77248000,76.531,LT8+275.000
508,569794.15875000,733364.36214000,76.741,RT8+275.000
509,569794.42502000,733365.52070000,76.460,RT8+275.000
510,569795.00734000,733367.43856000,75.660,RT8+275.000
511,569796.02438000,733369.87337000,75.622,RT8+275.000
```

B) GeoPak Working Cross-Section Design File

Cross-sections can be processed with GeoPak and submitted in a design file. Steps from the X-Section chapter of Roadway Design's GeoPak User's Guide should be followed**.** All files created in these steps should be submitted. Naming conventions described in this User's Guide and also Roadway Design's CADD manual should be used while processing these sections.

III) Total Station, Data Collector, & Prism (Random Spot Shot - Breakline)

DEFINITIONS - The following definitions apply to all other discussions within this manual.

a. Digital Terrain Model (DTM) - a set of three dimensional random points and breaklines used to model the surface of the earth both horizontally and vertically.
b. Triangular Irregular Network (TIN) - Another name for a DTM
c. Breakline - Also known as a fault line, is defined as a discontinuity in the earth's surface such as the edge of pavement or shoulder. Other examples are the top of a sharply defined stream channel or the bottom of a man-made ditch. Breaklines are generally indicated by a sharply defined line on the ground surface rather than a smooth or rolling appearance.
d. Random Spot Shot - Those points which are not connected with any breakline but stand alone. (X, Y, & Z information is known.)
e. Link Lines - Also known as triangle lines are the imaginary lines stored internally in a computer connecting the points used to interpolate information about the ground surface where no actual point exists.

A DTM is interpreted by the computer as a set of points connected by a series of link lines. The algorithms used to create the lines connect points to their nearest neighbor. However, in some instances the nearest point may not be the proper link connection. For example, the nearest point to a point on the top of a ditch cut may be a point on the opposite top. The proper link is in the bottom of the ditch, though, hence the need for breaklines. The computer algorithm will not allow a link line to cross a breakline. So a breakline in the bottom of the ditch forces the links into the bottom instead of short circuiting across the top.

It is pointed out that breaklines may be required even when the ground shows no obvious discontinuity. The surveyor shall show adequate random points and breaklines to insure that the DTM accurately reflects the surface of the earth. Great care should be taken in the development of breaklines in the area of bridges or other structures, in a stream, under bridges, etc.

Random points are generally collected in a gridded manner with a nominal spacing of about ten to twenty meters. This spacing can vary widely, however, from both much smaller or much larger, depending on the regularity of the surface being modeled. The spacing and placement of random points shall be such as to insure the accuracy of the DTM.

Any TIN created by DOT personnel shall be created by GeoPak and cross-sections extracted and checked for validity of the TIN. Consultants who use GeoPak, must follow the guidelines established in this manual.

Consultants not using GeoPak software must provide the TIN as graphics (3d Triangle shapes) in a 3D design file and cross-sections for each Survey Baseline in a DGN file. Cross-sections shall be taken at 100 feet intervals for rural projects and 50 feet intervals for urban projects. These intervals may also be appropriate on 3R projects, depending on the variability of earthwork along the project. Other factors that may influence the frequency of cross-sections include the presence of intersections, extent of driveway and turnout construction or reconstruction, ADA related work, drainage improvements, etc. Where a cross-section is not required at property ramps or driveways, a perpendicular profile is required at the centerline of the ramp/driveway in order to design the new property ramp or driveway.

The following is a summary of how this type of survey shall be submitted.

A) GeoPak Working Cross-Section Design File

Using GeoPak, a DTM (Digital Terrain Model) (TIN) shall be created of the existing ground as described in the DTM chapter of Roadway Design's GeoPak User's Guide. Cross-sections shall then be extracted from this TIN using GeoPak and instructions in the X-Section chapter of Roadway Design's GeoPak User's Guide for each centerline of proposed construction or centerline of existing route involved if proposed is not known. Cross-Sections shall be extracted at 25m (100') increments. These sections shall be visually checked for errors and re-processed if needed. All files created in these steps and described in the instructions mentioned should be submitted but they are shown below for convenience.

1) 3DG*.DGN - 3D design file showing spot shots and breaklines of the existing ground.
2) 3DA*.DGN - 3D design file showing spot shots and breaklines of structures which elevation data is needed, such as a bridge.
3) 3DG*.DAT
   3DA*.DAT
4) 3DA*.TIN
   3DA*.TIN
5) JOB*.GPK.
6) XS**.DGN

** Name of primary route*
*** Name of baseline cross-sections created about*

HORIZONTAL (TOPO)

OVERVIEW

All topo data, regardless of the collection method, should be submitted in a 2D Microstation design file called **TOPO.DGN**. TOPO.DGN shall consist of a single long map with State Plane coordinate integrity maintained. Additional survey (Survey submitted after the initial survey submittal.) submitted in Tdate.DGN should also be on the same coordinate system. All aspects of this design file should adhere to Roadway Design's CADD standards including Microstation Design file working units, level symbology, line styles, cell libraries, text styles, etc. Roadway Design provides the following directories of files to aid you in meeting the CADD standards mentioned above. RWD\

GROUP\ < English Microstation seed design files, cell libraries, custom menus, etc.
HELP\ < CADD & GEOPAK Online HELP files explaining CADD standards and procedures
INPUT\ < English MDOT GeoPak files
MGROUP\ < Metric Microstation seed design files, cell libraries, custom, menus, etc.
MINPUT\ < Metric MDOT GeoPak file

These files are downloadable from Roadway Design's FTP Site located at ftp:\\rwdss.

Two items which should help specifically when loading or working with topo in a design file include:
RWD-SVY.SMD - This is MDOT's GeoPak Survey Database containing P(oint)CODES which should be used in the field to describe the type of data a shot represents. These PCODES are tied with Microstation cell libraries and custom line styles and topo is automatically drawn.

DZINE Bar Menu - Microstation menu which provides an easy way to set proper existing symbology.

It is important that all topography likely to be affected by, or that will affect, the proposed road be accurately located.

WHAT SHOULD BE SUBMITTED

The following section describes in detail what should be submitted to Roadway Design Division.

TOPO.DGN should include:

1. Horizontal and Vertical Control with appropriate labels. Cell's have been created in RWD.CEL and are listed below. Mathematical and Descriptive location shall be provided on these labels.

   HVC – Horizontal & Vertical Control Point which contains Northing & Easting coordinate & Elevation.

   HC – Horizontal Control Point which contains Northing & Easting coordinate with no Elevation.

   BM – Vertical Control Point which contains Elevation only.

2. Alignment information of the Centerline Construction of all proposed alignments. This includes tangent bearings, Curve and Spiral Data, and Stationing. Alignments should also be stored and submitted in GeoPak's Coordinate Geometry database file (JOB*.GPK) if GeoPak software is used.

NOTES: a) The arc definition for horizontal curves will be used entirely in highway location.

b) All survey stationing will be done from south to north and west to east.

c) Stationing should always begin with a station large enough to avoid any minus stations if the survey is extended for additional information. When tying to an existing road, the survey should extend far enough past the proposed beginning of the project to provide information necessary for the designer to make a good vertical and horizontal tie.

d) Check tangent bearings against curve tangent bearings to assure there are no kinks at the PC & PT of curves.

3. Location of existing roads. This includes edge of pavement and existing centerline information including tangent bearings, curve and spiral data, stationing, and ties to the Centerline Construction of the primary route. Topo should be collected 200m in each direction from the Existing Road – MainlineConstruction intersection.

NOTE: a) Do not send in numerous connected shots (PI's) on the existing centerlines. For example: If an existing alignment has one curve, and two tangents on each side of the curve, three elements should be used in Microstation to show this alignment; one line representing the back tangent, one arc representing the curve, and one line representing the forward tangent.

4. Alignment information of Survey Baseline if cross-sections taken about a baseline other than the CL Construction or Existing Alignments, except for Drainage Alignments (See Drainage section below.)

5. Railroad Crossings

a. General - A 90 degree crossing is desirable and in no case should tracks be intersected at an angle of less than 70 degrees.

b. Field Data Required

(1) Profile of the top of rail 200 m each direction; both rails if they are superelevated.
(2) Vertical Ground Data should be collected 60 m in each direction along the tracks within the railroad R.O.W. If the road coverage extends beyond 60m, the limits of the vertical data along the railroad should extend to it.
(3) Plus and bearing of each set of rails.
(4) Alignment of all tracks, 200 m each direction with curve information (if any) computed.
(5) Topography within the railroad R.O.W. for 200 m each direction, including switching devices, signal devices, control boxes, and utilities (especially fiber optic cables).
(6) Name of the railroad.
(7) Present railroad R.O.W. The term "Charter R.O.W." does not indicate that the railroad owns the property and charter R.O.W. should not be shown. Railroad R.O.W. should include only the property owned by deed or being used and maintained.
(8) Distance and direction to the nearest mile post and description of same.
(9) Size, type, invert elevation and condition (if required) of existing drainage structures with the direction of flow in field drains and channels indicated by arrows.

6. Existing driveways horizontal location & type.

7. Existing Property data including existing property line monumentation, fences, property lines, Land Owners, and existing ROW markers. These don't have to be related to any baseline, the XY coordinates in the design file explain their location. (See Property Data & Existing ROW section in this chapter for a detailed explanation of what property data should be collected and how it should be submitted.)

8. Existing buildings with description: 1SF - Residence, One Story Frame, names and types of businesses.

9. Existing Storm Drains - a) Inside diameter of pipe

b) Type pipe

c) Length

d) Direction of Flow

e) Upstream & Downstream Flowline Elevation

10. LAND CHARACTER - The land character of rural areas such as pasture, second growth, cultivated, swampy, etc., should be noted.
    a. Stock and Equipment Passes - It is the responsibility of survey parties to recommend locations where stock and/or equipment passes should be placed for proposed highways. The primary indicator for a stock pass is the dividing of a large area specifically used for pasture. Therefore, all pasture lands should be carefully noted. Also, field personnel should be cautioned against discussing possible locations with property owners. The assurance that a stock and/or equipment pass will be considered during the design process is usually the best response.
    b. Trees - Trees showing significant age or historical value which may be affected by construction should be shown with the size and type. The edges of wooded areas should also be identified.

11. Waters/Wetlands -
    a. Wetland areas should be outlined and identified as WETLAND with the classification. The Routine Wetland Determination Data Form from the Corps of Engineers Wetlands Delineation Manual should be completed for each Wetland Site. This form is also available through Roadway Design's Intranet Site http://rwdweb -> Resources -> Forms.
    b. All ponds, streams, rivers, etc. should be identified horizontally by the top banks, as waters of the US.

12. Utilities
    a. All existing utilities within the project area should be shown.
    b. Owners - The owner of each utility should be shown. Include name, address, contact person and phone number.
    c. Limits - When more than one utility company supplies the same service, the limits of each owner's service area should be indicated.
    d. Location and Profile - The location and depth of underground utilities should be determined as best possible. Profiles on gas lines and gravity-flow sewer lines are especially critical. However, gas lines should never be sounded with a steel rod.
    e. All underground utilities which may be affected by roadway or structure construction will be shown in the topo design file.
    f. Overhead - Overhead utility lines between poles will <u>not</u> be shown on present layout plots. The direction of the lines will be indicated by a short line through the cell representing the pole. Signals - At signalized intersections, the signal heads, span wires, poles and controller should be recorded and shown.
    h. The pole or tower number should be recorded, if available, for major transmission lines.
    i. Type of Utility - The type of service for each underground line and for each utility pole should be noted using Roadway Design's symbology.
    j. Storm Sewers and Sanitary Sewers - Elevations should be taken on the top and bottom of each manhole or catch basin and on the invert at each end of every pipe, including pipes that terminate in manholes. This information may be taken during development of the DTM or as part of a separate level run. It is advisable to develop a table of elevations and numbering system for the pipes of a sewer system.
    k. Septic Tanks and Drain Fields - In areas where there are no municipally owned sewer and water systems, information shall be shown on all developed property regarding sewage disposal and water supply. All septic tanks and field lines near the proposed roadway should also be located. However, a note indicating the location of facilities a considerable distance from the proposed roadway (or behind a building) will suffice.
    l. Wells - Any drilled wells (gas, oil, or water) that will be inside the proposed roadway or that will be abandoned should be shown. The name and address of the driller and name of the property owner at the time the well was drilled should also be noted. If this information is available, it should be listed in the planimetrics file adjacent to the well site.
    m. Location for Pay Item Purpose - Responsibility for payment (Utility Co. or State) to relocate a utility is determined by its location within or without of present R.O.W. When utilities are close to the present R.O.W. or user's line, care should be taken when developing the planimetrics file to indicate whether the utility is inside or outside of the present R.O.W.
    n. Occasionally problems are encountered in the coordinating of the location of underground utilities. Any such problems should be recorded in the project field book.

13. UNDERGROUND PETROLEUM STORAGE TANKS - The disposition of property containing underground petroleum storage tanks is of utmost importance. Environmental requirements call for expensive procedures to insure that leakage does not occur during any activity affecting the property. Because of the expense involved, the M.D.O.T. must carefully consider such property when planning or constructing a roadway project. The ideal solution would be to avoid such property. This, however, is not always possible.
    a. An attempt will be made to locate and identify all such property during the Location Review. Proposed alignments will then be located so that the property can be avoided if possible.
    b. In the event that such property is unavoidable, all tanks should be located as accurately as possible and recorded in the topo file. Accurate location of the underground tanks is often difficult. However, all possible sources of information should be investigated (conversation with tenants, request for plans from owners, etc.).
    c. Occasionally property with tanks not identified in the Location Committee report will be encountered. This is more likely when the tanks are not in use. The property and existing tanks should be brought to the attention of the District Engineer for consideration of moving the survey line to avoid the property. If this is not possible, the property and tanks should be located as discussed above.

DRAINAGE

Drainage data will be submitted in different ways depending on the size of the drainage areas. The information below describes what should be collected and how it should be submitted.

DRAINAGE MAP

METHODS - A drainage map will be prepared for every project that has drainage crossing the survey centerline, unless instructed otherwise. Large areas may be run on quad sheets or aerial mapping. Smaller areas should be surveyed in the field and shown in TOPO.DGN. Any drainage structures which control flow into or away from the immediate project area (where flow crosses the centerline) should be located and their size noted.
The following information should be provided:

1. An outline of the drainage area with numerical area provided.
2. The location where the drainage crosses the survey centerline (provide station).

HYDRAULIC INFORMATION BRIDGE DIVISION

(Drainage Areas 400 hectares (1000 acres) or Greater)

> ALL DATA MUST BE IN PLOTTED FORM ON PLAN/PROFILE SHEETS

For Structure Replacement on the Present Line:

1. A typical (representative) flood-plain profile including the channel section and the location thereof with references to the baseline.
2. A profile along the present highway giving the finish grade.
3. A ground-line profile along proposed detour if the location of the detour is known.
4. A stream-traverse 150m (500ft) upstream and 150m (500ft) downstream for typical crossings.
5. Typical Channel Sections (at least one upstream and downstream). Please show elevations and corresponding horizontal dimensions from the traverse baseline.
6. A stream profile (taken at the deepest part of the stream) extending 150m (500ft) upstream and downstream. The notes should reference this to the traverse baseline
7. The water-surface elevation at both ends of the stream profile and at the bridge with date.
8. Drainage data as available as follows:
    a. High-Water: Give elevations, approximate dates, and sources of information for floods of significance.
    b. The location of high-water should be clearly designated relative to the centerline of the proposed route. Both upstream and downstream high-water marks are desired.
    c. Drainage area at the site.
    d. Comment on drift and bank stability.
9. Data on Existing Bridges:
    a. Profile beneath the bridge with additional detail of any scour holes.

    b. Bottom elevation of the low stringers.

c. Type of bridge and span lengths.

NOTE: This information is also needed at other highways, County roads and railroads in the vicinity along with a profile down the centerline roadway.

10. Description and elevation of benchmarks nearest the existing bridge or proposed channel crossing and origin of datum.

Electronic files shall be submitted with the survey also, if they are available. As stated in Roadway Design's CADD manual, All Drainage Alignments shall be placed in a file called DRNALI.DGN, all drainage Plan/Profile sheets shall be named and submitted as discussed under the filename WK***[a,b,c].dgn.

For Determination of Structures on a Relocated Line:

The ten items listed above will be required except Item 2 may be omitted in a situation where the new line is not in the vicinity of the old line.

Also in such a situation, note that oftentimes, the centerline profile will suffice for Item 1.

Also where twin bridges are proposed, a ground line profile is needed along the centerline of both lanes.

HYDRAULIC INFORMATION FOR ROADWAY DESIGN DIVISION

(Drainage Areas from 80-400 hectares (200-1000 acres))

ITEMS Required

1. Profile of present highway presenting the finish grade (Include Stream Channel)
2. Ground line profile along proposed detour
3. A stream traverse 150m (500ft) upstream and downstream
4. A steam profile (taken at the deepest part of the stream, 60-90m (200-300') upstream and downstream) related to the traverse
5. Typical channel sections normal to the channel (at least one upstream and one downstream) related to the traverse
6. Water-Surface elevation at both ends of the stream profile
7. High-Water Marks Upstream and Downstream
8. Drainage Area
9. Comment on drift and bank stability
10. Size, Length, Skew, Material Type, and Upstream & Downstream Flowlines, of Existing Drainage Structures. Cross-Sections are also required at each existing drainage structure location. If structure is skewed a cross-section is required for the upstream and downstream end.
11. Descriptive information of existing culverts serving the same drainage area under nearby highways and railroads that will possibly effect MDOT structures

If a DTM is created, items 1,2,3,4,5 of the information shall be extracted from the DTM by the Project Office. The remainder of the data should be submitted as notes or in TOPO.DGN except for Item 10 which shall be submitted in TOPO.DGN. See DTM section for submittal type if XYZ Spot Shot/Breakline survey collected.

If the vertical ground data is collected as cross-sections, items 1 and 2 can be extracted by Roadway Design, Item's 3, 8, and 10 should be submitted in TOPO.DGN. Item 5 can be submitted as described in the Vertical Ground section of this chapter. Item 10 shall be submitted in TOPO.DGN. The rest can be submitted as notes or in TOPO.DGN

HYDRAULIC INFORMATION FOR ROADWAY DESIGN DIVISION

(Drainage areas less than 80 hectares (200 acres))

1. High-Water Marks Upstream and Downstream (TOPO.DGN or Notes)
2. Drainage Area (TOPO.DGN)
3. Descriptive information of existing culverts serving the same drainage area under nearby highways and railroads (TOPO.DGN)
4. Sufficient channel flowline profile to establish the natural channel slope, 60-90m (200-300') upstream and downstream with a stationed traverse line.
5. Typical channel sections upstream and downstream normal to the channel with location identified on traverse line mentioned in item 4.
6. Size, Length, Skew, Material Type, and Upstream & Downstream Flowlines, of Existing Drainage Structures (TOPO.DGN). Cross-Sections are also required at each existing drainage structure location. If structure is skewed a cross-section is required for the upstream and downstream end.

PROPERTY DATA & EXISTING R.O.W.

SUBMITTAL

The finished ROW survey shall be shown in TOPO.DGN on the same coordinate system as established as the control monuments. The property information which should be shown in this file includes all existing property information (found corners with description of corner, property owners, property lines) and GLO ties (section/quarter section corner ties). Grid distances and Bearings shall be shown. Found Property corners will be shown as cells FIP or FC (description). All property lines shall be shown. If corners of a property line are located in the field and deemed valid, the corners shall be connected with a property line. If no or only one corner is found for a property line, the property line location shall be computed from deeds or old plans and then located from other field tied corners or tied in the field to the apparent property line (i.e. fence). No ROW markers or property corners shall be shown unless the corner is located in the field. The ends of property lines with no FIP or FC cell will designate corners which were calculated from deed or plan research.

All property corners found shall be referenced to the centerline either by coordinates or by station/offset. Where the corners are located by coordinates only, the resulting station/offset shall be calculated with reference to the centerline of the project. The project engineer shall verify these calculated values and shall be responsible for correcting any discrepancies.

INTITIAL RESEARCH – LAND RECORDS

Property records shall be researched to determine the current ownership of the property at the time of the survey. The property map which is produced and submitted to Right of Way in accordance with SOP (number here) shall be used as an aid in obtaining these records. Existing Right of Way maps shall be located in the records at the District Office, Project Office, or the main Right of Way office to aid in determining the existing Right of Way on the current project. This information shall be used to locate existing property corners, property lines, section corners, existing rights of way, and existing highway centerlines during the topo survey phase.

TIES TO EXISTING PROJECTS

In cases where the new project is overlapping the old project, research should be done on the old as-built plans and in the field to tie the new survey alignment to the survey alignment which the existing ROW was purchased about. Angular & Station ties need to be made.

BRIDGE SURVEYS

On a multiple bridge project, the sites shall be tied together by either a traverse or by independent GLO corner ties.

EXISTING ROW CONSIDERATIONS

In projects where there is no record of acquisition of rights of way in the records at the district, the central office in Jackson, or in the courthouse, the survey should include information which shows the limits of the existing maintenance limits. This information shall include fence lines, back of ditches, edge of mowing limits, or center of ditch. The determination of the limits shall be at the discretion of the project engineer.

ROUNDING OF ANGLES AND BEARINGS

When showing deflection angles and bearings on maps, show the actual angles used in the calculations. (greater error is produced by rounding of angles)

CONSULTANTS

If a consultant collects the data and processes it to CADD, the consultant can use any method he wants to perform the survey as long as the accuracy's required are obtained, the survey is completed in a timely manner, and submitted as described in this manual.

Consultants who use GeoPak shall provide the survey as stated in this manual.

Consultants who do not use GeoPak shall provide the survey to the designer as stated in this chapter except for the following exceptions:

1. DTM's should be submitted as 3d triangle shapes in a Microstation 3d design file.

PRELIMINARY PLANS

DESIGN PLANS

Cover sheets for all plans showing Grid Distance shall have a note similar to the one below. This note should be submitted in CONTROL.DGN along with the survey:

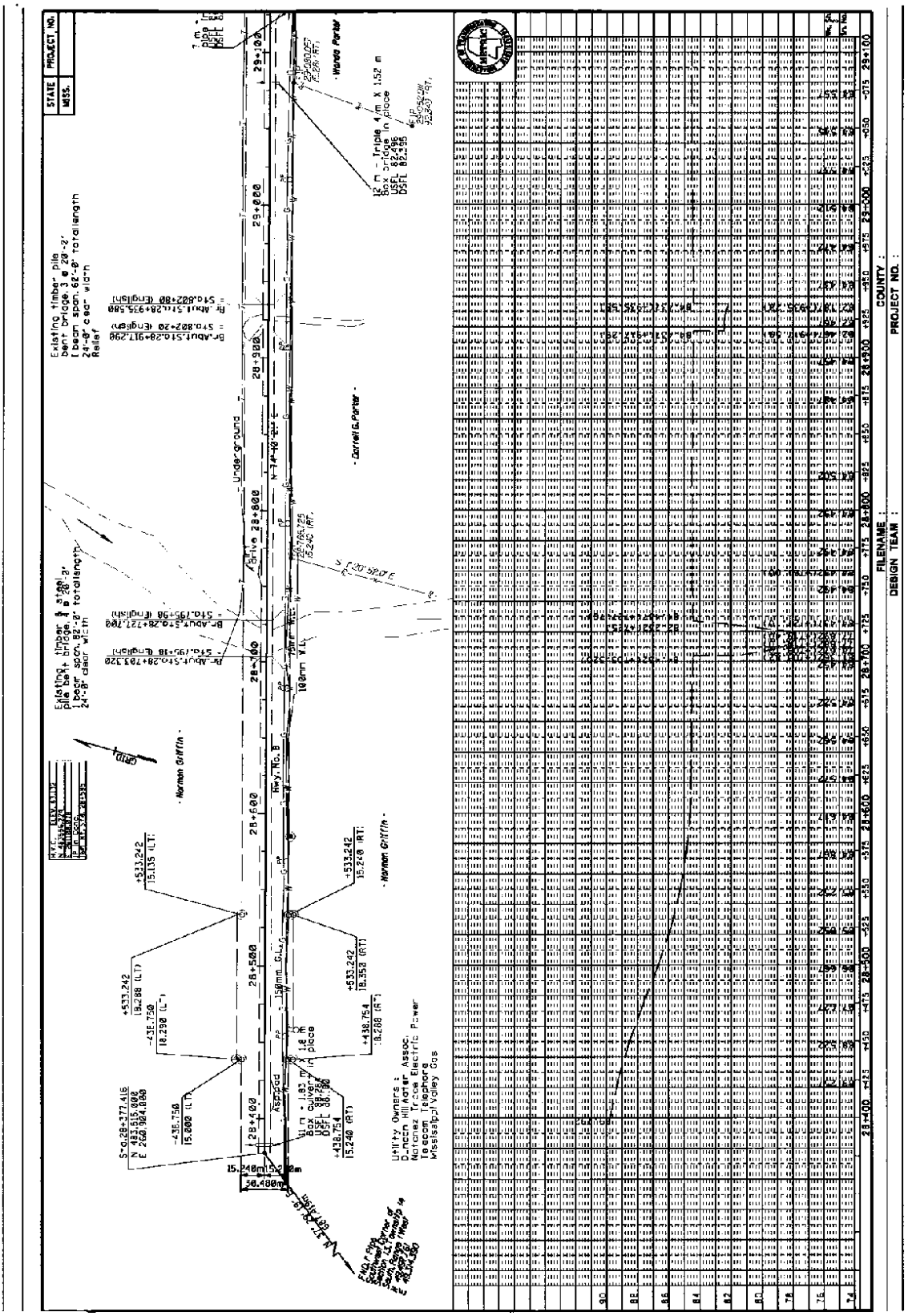
```
********************* NOTES ***********************
*  COORDINATES DERIVED FROM GPS SURVEY TIED TO:   *
*                      NAD'83(93) MS EAST ZONE    *
*  Control Station        NORTH         EAST      *
*  HAMILTON RESET      479,613.202   263,734.492  *
*  GAULEY              488,337.249   249,893.239  *
*  REID                498,191.845   266,835.895  *
*                                                 *
*          All azimuths and distances are         *
```

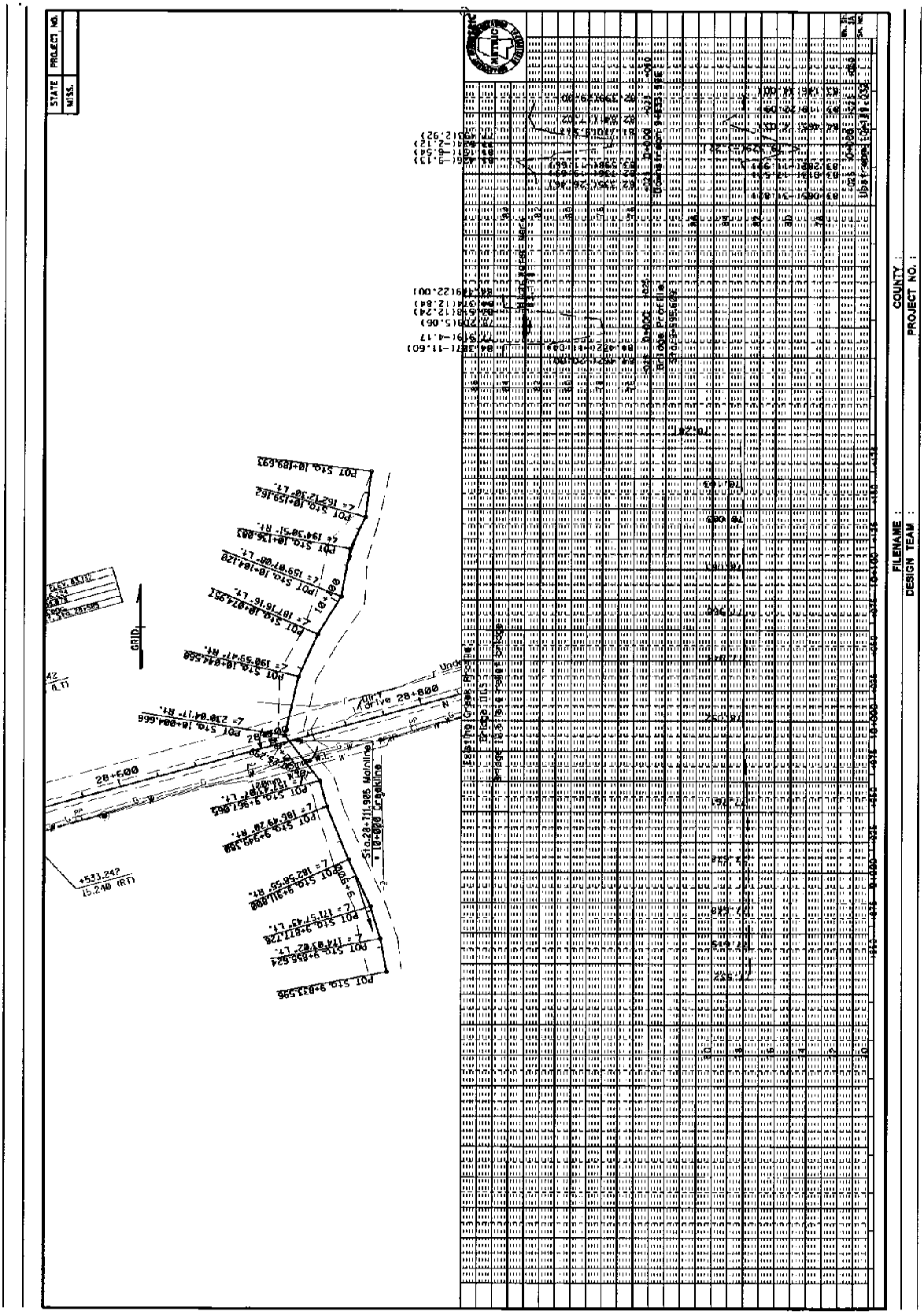
```
*       NAD'83(93) MS East Zone GRID values       *
*                                                 *
* CONVERSION VALUES              BOP        EOP   *
* Ground to Grid Factor      0.9999590  0.9999588 *
* Grid to Ground Correction  +41.0 ppm  +41.2 ppm *
* Grid to Geodetic Azimuth   -14'07.5"  -13'48.2" *
***************************************************
```

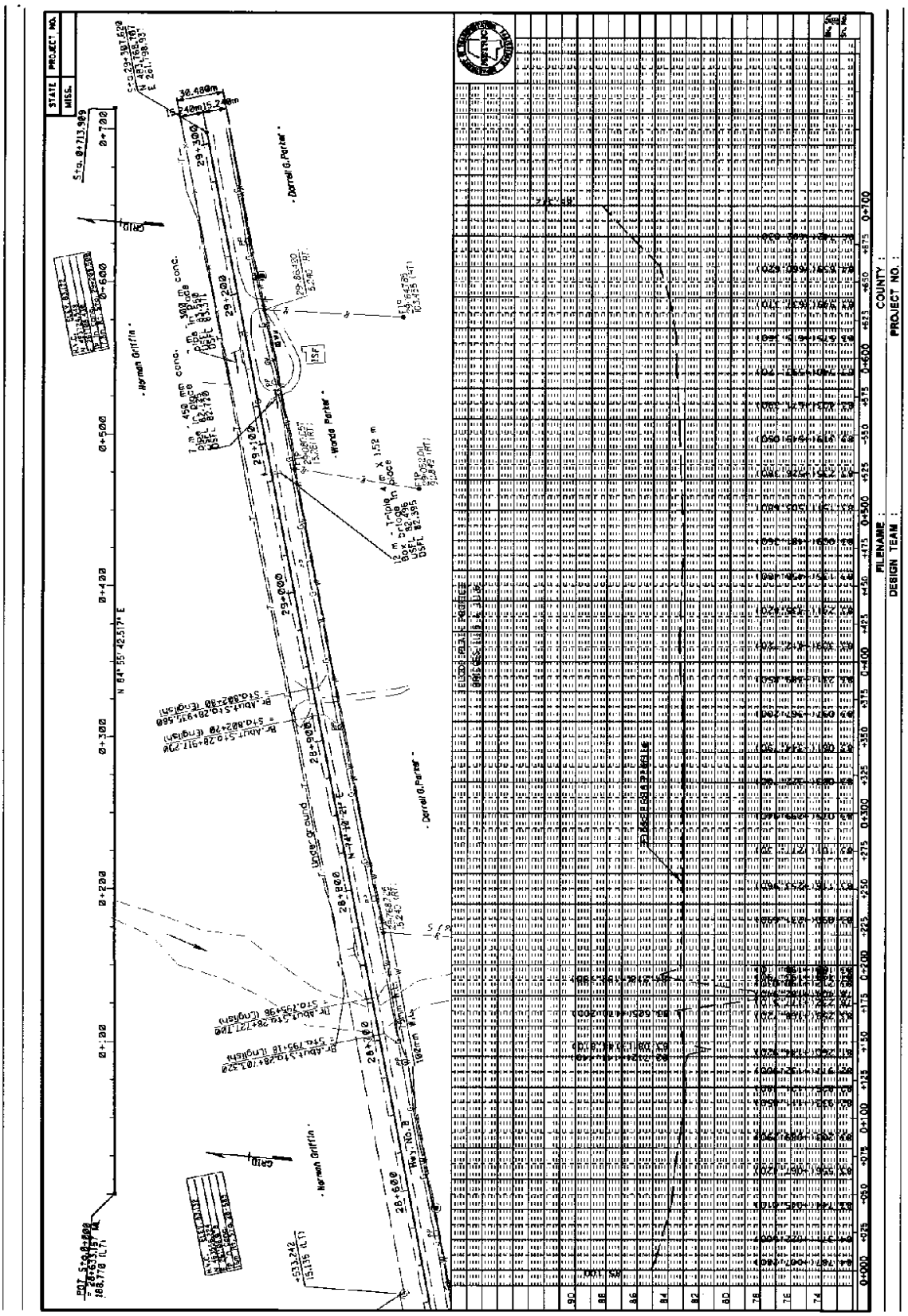
Coordinate Integrity must be maintained for the project in all design files. Final Contract plans will be made available to the department through Roadway Design’s FTP site.

EXAMPLE SURVEY

The examples on the following pages represent a sample survey. The only info not shown is the cross-section notes for the mainline.


STATE
PROJECT NO.
MISS.
Existing timber pile bent bridge, 3 @ 20'-0" I beam span, 62'-0" total length 24'-0" clear width Relief
Existing timber & steel pile bent bridge, 4 @ 20'-0" I beam span, 82'-0" total length 24'-0" clear width
Underground
Drive 28+800
N 74°48'24" E
Hwy. No. 8
Norman Griffin
Darrell G. Porter
Wanda Porter
Utility Owners:
Duncan Hill Water Assoc.
Montanez Trace Electric Power
Telecom Telephone
Mississippi Valley Gas
FILENAME :
DESIGN TEAM :
COUNTY :
PROJECT NO. :


STATE
MISS.
PROJECT NO.
COUNTY :
PROJECT NO. :
FILENAME :
DESIGN TEAM :
GRID
Sta.28+111.905 Mainline
= 10+000 Centerline
28+00
+533.242
15.240 (RT)


STATE
PROJECT NO.
MISC.
COUNTY :
PROJECT NO. :
FILENAME :
DESIGN TEAM :
Norman Griffin
Darrell G. Parker
Wanda Parker
Hwy. No. 2
Grid
N 84° 55' 42.51" E
N 74° 10' 21" E
Br. Abut. Sta. 28+917.706
= Sta. 0+713.989
Sta. 0+713.989
Sta. 29+387.520
N 261,768.767
E 261,198.93
30.480m
15.240m
15.240m
29+300
29+200
29+100
29+000
28+900
28+800
28+700
28+600
0+700
0+600
0+500
0+400
0+300
0+200
0+100
0+000
0+100
0+200
0+300
0+400
0+500
0+600
0+700
0+800
0+900
1+000
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1+300
1+400
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1+600
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1+800
1+900
2+000
2+100
2+200
2+300
2+400
2+500
2+600
2+700
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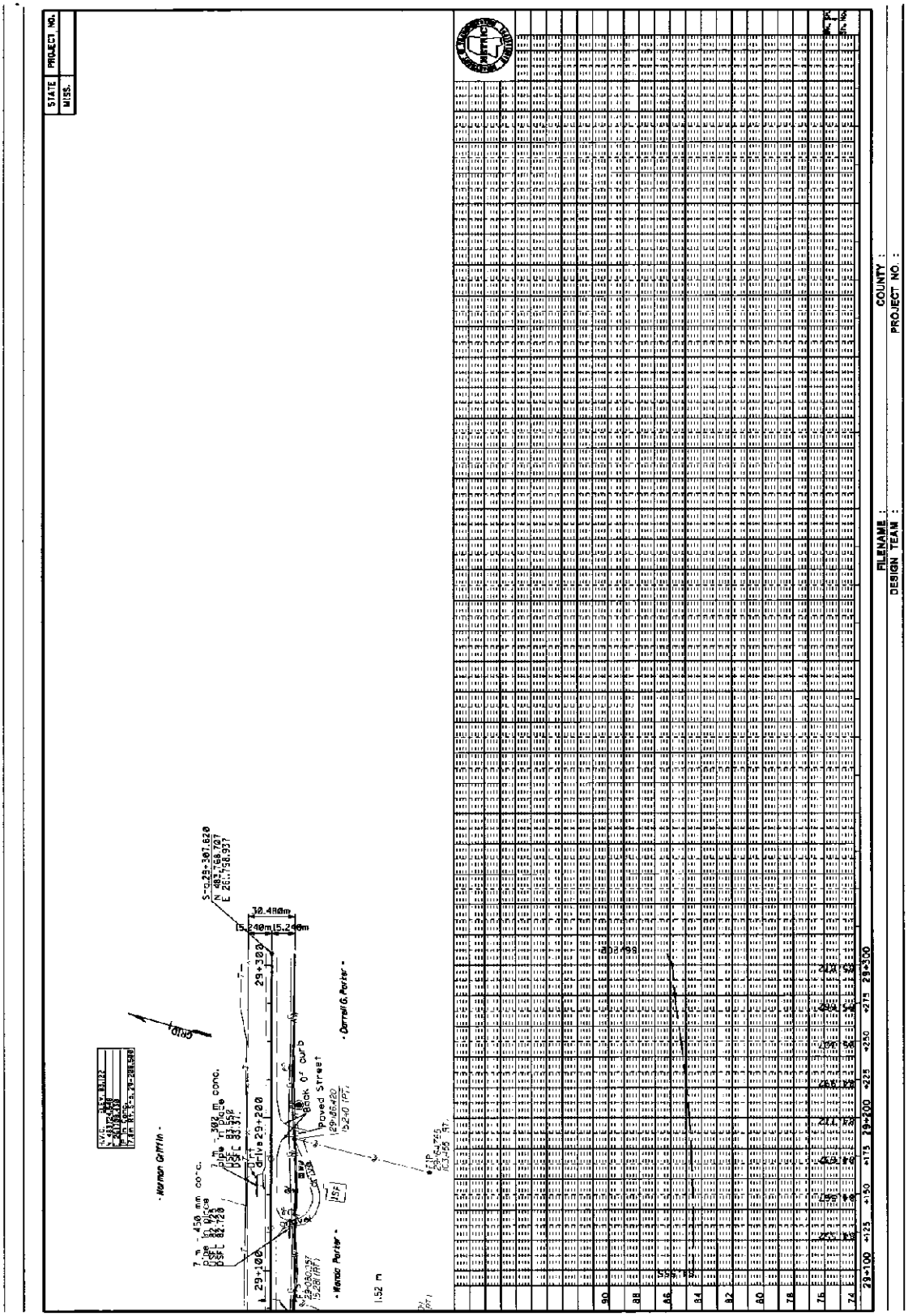
3+400
3+500
3+600
3+700
3+800
3+900


STATE
MISS.
PROJECT NO.
FILENAME :
DESIGN TEAM :
COUNTY :
PROJECT NO. :
Norman Griffin
Darrell G. Porter
Paved Street
Back of curb
Drive 29+200
30.480m
15.240m
15.240m
29+300
29+100
29+100
+125
+150
+175
29+200
+225
+250
+275
29+300
90
88
86
84
82
80
78
76
74
1.52 m

REFERENCES

1. Wyoming Department of Transportation Survey Manual
2. Florida Department of Transportation Survey Manual
3. Tennessee Department of Transportation Survey Manual

Field Data Collection

CONSTRUCTION SURVEYING

Mississippi DOT 6/1/2004

This manual was produced using *Doc-To-Help*®, by WexTech Systems, Inc.
Contact Jeff Fracchia or Keith Boteler of Roadway Design if you find errors in it. (601-359-7287)

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INTRODUCTION

Overview

This chapter details the various surveying activities involved in the construction survey process which includes construction staking, measuring final pay quantities and the As-Built R.O.W. plat survey.

The sections within this chapter provide various methods for accomplishing the surveys necessary for construction. The method used should be the one that does the job most economically, with the least amount of intermediate steps, and with the results having the accuracies described in this chapter.

There is generally a long time lapse and often radical crew changes between the time the original control was established and use of that control for construction staking. The Resident Engineer should thoroughly review items such as design plans, horizontal and vertical control listings, and all other design output that could aid in planning of the survey. A field review and re-flagging of control points should also be conducted. Office preparation of staking notes whenever possible saves costly field-crew time and often prevents field calculation blunders. Prior to preparing staking notes, all computer listings should be thoroughly reviewed and verified to assure that the output is based on the same design as shown on the printed contract plans.

Construction staking establishes basic line and grade control, delineates working areas, and serves as a base for verification of location and quantities of completed work. The Department provides the essential control to accomplish establishment of lines and grades with this control normally being the control established by the District Control crew prior to the preliminary survey. Supplemental stakes for the contractor's convenience, method of operation, or equipment are set by his forces. In some cases, such as large structures, etc. special contract provisions may limit the amount of control that will be set by State forces.

Preserving High Accuracy Control Monuments

It is the responsibility of the Project Engineer to preserve NGS, USGS, and HARN monuments. The Project Engineer shall contact the District Control crew to transfer existing monument information to temporary and then to new monuments for those existing monuments that will be destroyed by Construction. Disks shall be placed in all new bridge structures. The name associated with the disk will be "routeVyear-#" , where route is the name of the primary route, year is the year the monument was established, and # is the number (1,2,3, etc.) placed during each project. The Project Control crew will maintain a listing of these disks.

STAKING

Overview

Construction staking shall be in accordance with Construction division's Standard Operating Procedures.

Many staking reports can be generated using the Microstation and GeoPak files created during design for a given project and available through Roadway Design's WebSite (HTTP://MDOTISSRV006/ROADWAY/PROJECTS) . It is recommended that staking reports be generated from these files. Instructions are in the Reports chapter of Roadway Design's GeoPak User's Guide also available through Roadway Design's Web Page. Slope Stake, Clearing and Grubbing, Finished Grade Reports, etc. can be generated this way. Some projects will not have the cross-sections in GeoPak format (This could happen if a consultant created the CADD files and GeoPak was not used), but the Station, Offset, Elevation ASCII files of the existing ground surface and proposed ground surfaces are available for all projects and can be re-generated for each baseline of a given project.

Right of Way

Right-of-Way Markers constitute the monumentation of a given highway property. As such, they are used by others to make legal ties to the highway. All surveyors have the obligation to either accept the monumentation as a legal boundary or to reject it and re-establish the described boundary in accordance with their findings. Therefore, it is extremely important that right-of-way markers be staked to the tolerances specified below, and that markers conform to the positions described by contract plans. **The primary or intermediate control established shall be used as the reference points for setup and backsight locations when staking right-of-way markers. (Primary control is control established prior to the preliminary survey by the District Control crew. Secondary control is control established from this primary control.)**

After the R.O.W. markers are set, an As-Built R.O.W. plat will be generated to show the final location of these markers and other pertinent as-built information.

Temporary Staking

Temporary stakes shall be set by the DOT or a consultant of the DOT at each proposed R.O.W. marker location. The intent of this stake is to aid in the relocation of utilities and identify the DOT's proposed acquisition so that adjacent property owners will not be encroached upon during construction. The type of monument set can range from a flat stake to a tacked 50mm x 50mm hub. The temporary stake shall be set in accordance with the right of way plans prepared by Roadway Design division. Electronic files are available through Roadway Design's Intranet Page. The Right Of Way is to be marked with a standard flat stake showing the station number on the face side with the notation R-W and the distance from the centerline on the reverse side as shown in Figure R/W-1.

Right of Way Markers

Right of Way Markers shall be placed by the contractor in accordance with the departments Standard Specifications and the contract plans as soon as grading operations allow. The center of the marker shall be placed within 20mm (1/4 ") of the location specified in the contract plans. This will be verified by the department through the As-Built R.O.W. survey which follows completed construction. Markers not meeting this tolerance shall be re-set by the party who set the original monument. The location of these markers will have to be determined by survey. The temporary markers staked earlier in the job can not be assumed to be within the final tolerance of the proposed Right of Way Marker.

As-Built Right of Way Plat

After construction is complete and the ROW Markers are in place, the department or its consultant shall perform an As-Built Right of Way survey with the survey meeting Class "C" requirements. This plat is to be presented in the form of a certified drawing on 609mm x 914mm (24" x 36") paper at a scale of 1:1000 (1"=100') and will be filed in the District Office. This survey shall be placed in Microstation in one long continuous run with State Plane Coordinate values maintained. The name of this file shall be RWprojectnumber.DGN. Design files containing the sheets shall be named after the sheet number.

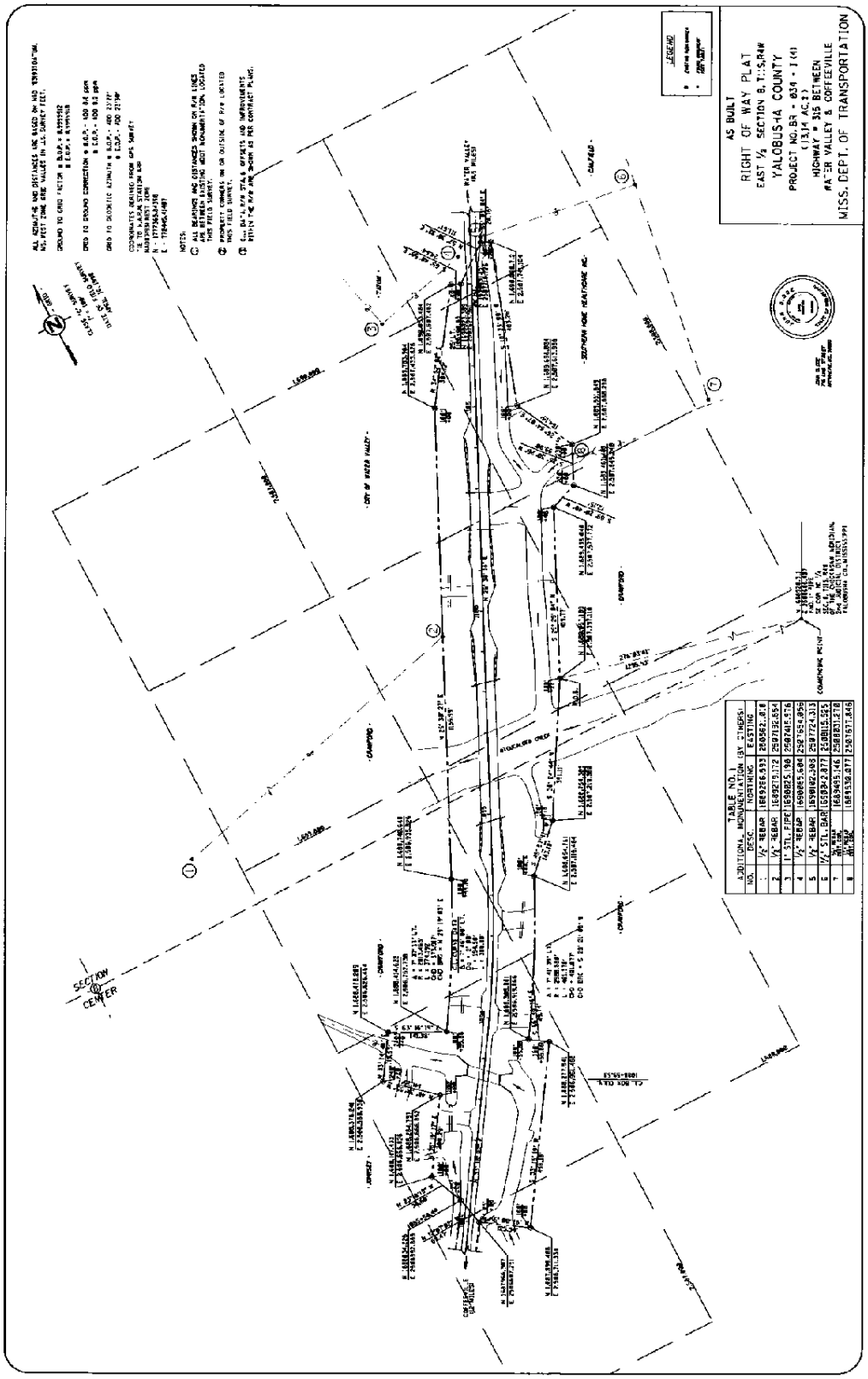
The Surveyor responsible for this survey, shall certify this drawing as a Right of Way plat which meets the Minimum Technical Standards for a Class “C” survey set forth by the Mississippi State Board of Registration for Professional Engineers and Land Surveyors.

These drawings shall show as-monumented (field tied) right of way markers with their location identified by State Plane Coordinates, map scale, completed title blocks, and Grid to Ground conversion factors. These drawings should also show the following Items from Construction or As-Built plans (if the AsBuilt information differs from the construction plans):

North arrows, section, township and range information, name of cities, top of banks of waterways, boundary monumentation, existing property and owners, project control (State Plane Coordinate data), complete centerline alignment data including beginning of survey station, source of bearing, all curve data, bearings on all tangent lines along the centerline, and end of survey station.

Distances and bearings must be identified as grid. All control points shall be identified as to type of material set at each respective point. All section lines and quarter section lines must be shown with state plane coordinates shown on any corners found or set. Type of corner and its size, either found or set, shall be spelled out or identified by a legend. **Electronic files for the project should be available through** HTTP://MDOTISSRV006/ROADWAY **-> PROJECTS -> FTP SITE.**

The following figure is an example of what the as-built right of way plat should look like.


AS BUILT
RIGHT OF WAY PLAT
EAST ½ SECTION 8, T.15.R4W
YALOBUSHA COUNTY
PROJECT NO. BR - 039 - 1 (4)
(1314 AC.)
HIGHWAY # 315 BETWEEN
WATER VALLEY & COFFEEVILLE
MISS. DEPT. OF TRANSPORTATION
LEGEND
NOTES:
ADDITIONAL MONUMENTATION (BY OTHERS)
TABLE NO. 1
NO. DESC. NORTHING EASTING
SECTION CENTER
CITY OF WATER VALLEY
STOCKADE CREEK
CONTRACTOR'S YARD

QUANTITY MEASUREMENTS & CALCULATIONS

Introduction

Overview

Preparing and submitting the final estimate involves computing and recording all the final quantities, and then assembling all the required supporting data. This guide will show all acceptable methods and formats needed to submit final estimate to Contract Administration Division (Final Plans Section).

Measurement- Documentation - Payment

Measurement, documentation, and other preparations for final estimates are begun early in the projects and continue throughout the project periods. Indeed the time to start work on the final estimate coincides with the time the first activity is performed. Even payment is begun early on, as contractors are paid monthly for the work performed to date.

Measurement

All measurements and base of payment are to be in strict accord with the Standard Specifications unless superseded by a contract document higher in the order of precedence. The prevailing order of the contract documents is spelled out in Subsection 105.04 of the specifications.

Documentation

Final estimates documentation is recorded on computer printouts (Don Karolyi Programs), Project Diary, Tickets, Geopak Printouts, Final Plans Excel Programs, Final Plans, and sometime statements or invoices. The Mississippi Department of Transportation Construction Manual stipulates where to document the work done on a project.

Payment

The whole point of measuring all the contract items so carefully, and documenting all the measurements and other data thoroughly, is to have a solid basis on which to pay the contractor. Always remember these key words; complete, accurate and legible. Your goal in documenting the work is to communicate information to others .If that information is incomplete, hard to decipher, or full of errors it will slow payment to the contractor.

Preparation and Submission of Final Data

Final computations and supporting data should be submitted as soon as possible after **RELEASE OF MAINTENANCE** to the Contract Administration Division (Final Plans Section) for checking. Early submission is vital in that Bill No. 1829, as enacted by the 1972 Legislature, provides that full and final payment on construction contracts must be made within forty-five (**45**) calendar days after the date **ACCEPTED BY THE DIRECTOR.** Failure to meet this deadline requires interest being paid by the Department to the Contractor for delinquent payment of monies due. It should be kept in mind that within the **45-**day period, not only must final pay computations be checked but also the Final Estimate must be prepared, submitted for checking, and approved by the Transportation Commission.

Supporting Data to be Submitted

(A.) Final Plans of Completed Work (Reduced Blue Line) ---------- 1 Set

(B.) Geopak files for earthwork volume (as indicated this chapter Final Cross-Section Manual) (Printout Signed by the Appropriate Personnel

And place in a Binder by order of pay items) (Appropriate Geopak Files

For Checking Earthwork shall be send on disk or Sent to Final Plans File

Server) ---------- 1 Set

(C.) All Original Tickets with (Don Karolyi Programs printout wrap around

for that day's work) (disk with Don printout) ---------- 1 Set

(D.) All Approval Final Plans Excel Programs (Must be indicated in Final Plans

Programs Index Sheet) printout signed by the appropriate personnel (place

In a Binder by order of pay items) with Programs Files on disk or sent to

Final Plans File Server ---------- ---------- 1 Set

(E.) Any other Computations not supported by Microstation, Geopak (as indicated

in Roadway Design D&C Manager Manual) and Approval Excel Programs

(Must be indicated in Final Plans Programs Index Sheet) must be submitted on

a 8 1/2 x 11 sheet that is clearly, complete, accurate and legible sheet and signed

by appropriate personnel.(place in a Binder by order of pay items) ---------- 1 Set

(F.) All charts, reports (Distributor chart, etc,) (place in Binder by order of pay

items) ---------- 1 Set

(G.) Final Report (CSD-200) (Shall be first sheet in Binder) ---------- 2 Copies

(H.) Project Diary w/ Completed General Data Sheet (1 Copy for each Contract) - 1 Set

(I.) Project Engineer's Affidavit (Each Copy signed and notarized) ---------- 3 Copies

(K.) All Bridge Item Computations, copies of all supplemental agreements, change orders,

Reports or Related items shall be placed in a separate Binder. ---------- 1 Set

Final Plans Check List for Preparation and Assembling of Final Data

1. Complete computations must be shown. **DO NOT** merely list dimensions (weights, etc.) and then an answer; show the actual combination of figures and mathematical procedure used to derive the answer furnished.(If Contract Administration Excel Programs is used just fill in blanks.)
2. All drawings shall be in a Microstation format with Roadway Design color table and symbology (These files shall contain only information about only one pay-item per file.) (Files shall use Roadway Design nomenclature.) (See Roadway Design manual for more information)
3. Decimals used in computations and quantities as recorded in the CSD-200 shall conform to precisely as set forth in CSD-50-17-50-000 (also same as indicated in Roadway Design manual)
4. ALL Original Tickets run on Don Karolyi Programs printout shall be wrap around for that days work. An overall summary printout is signed by appropriate personnel. A copy of the summary shall be place on a disk or sent to Contract Administration File Server.(All information send to Server shall be placed in same directory as final X-Sections for that Project)
5. All Traffic Stripping and Traffic Control quantities shall be in a Microstation format (same as indicated in Step 2) Quantities shall be run in Geopak with D & C Manager. Printout is to be Signed by appropriate personnel. A copy of all Files and Dgns used shall be placed on disks or sent to Contract Administration File Server.(same as indicated in step 2)

Approval Methods for Computation

1. Don Karolyi Programs
2. Contract Administration Approval Excel Programs
3. Geopak with Microstation

4. Microstation Dgns
5. Keith Purvis End Area Program

YOU MAY USE ANY OF THE ABOVE METHODS FOR FINAL QUANTITIES

Submitting Excel Program to Final Plan Index List for Approval Programs

Send E-mail or letter with copy of program (unprotected) with examples and directions or sent program to Contract Administration File Server (CAFP2). Also include your name, company, phone number.

Final Earthwork

Introduction

Project Offices shall use Geopak to process Cross-section Notes and Final Earthwork. This guide shows acceptable collection methods and formats needed to process with Geopak as well as detailed steps of collecting cross-sections, processing them with Geopak, calculating Final Earthwork, and delivering files to Contract Administration (Final Plans).

CREATED FILES

1) Several CADD files will be created while going through the processing steps. These files will be shown (in this manual) to the right of the steps that create them (in bold, underlined, and with a larger font). The naming convention shown should be followed as closely as possible.
2) These files that are created (in bold, underlined, and with a larger font) should be sent to Contract Administration (Final Plans) along with a printed copy of the earthwork totals.

NOTE: Earthwork totals should be approved and signed by the Project Engineer prior to being sent.

NOTE: All files in this manual that begin with orig (origrampc.cor) are shown for example purposes only. The actual files that you create should begin with o*.* (ie. orampc.cor)

NOTE: All files in this manual that begin with final (finalrampc.cor) are shown for example purposes only. The actual files that you create should begin with f*.* (ie. frampc.cor)

Overview of Cross-Sections for Final Pay

The basic concept of collecting x-sections has not changed. All x-sections shall be based off of a staked baseline. However, electronic (with total station) x-sections are now acceptable.

ACCEPTABLE COLLECTION METHODS

I. CONVENTIONAL CROSS-SECTIONS (Level, Tape, & Rod)

1) Type of data collected:
Station, H.I., Offset, Rod Reading

II. ELECTRONIC CROSS-SECTIONS (Using Total Station, Data Collector, & Prism)

NOTE: Electronic collection of data is acceptable only if the methods and steps listed in this chapter are adhered to.

1) Type of data collected:

A) X,Y,Z Coordinate Dependent (Preferred Electronic Method)
With a total station using the Project's existing Coordinate Control System which all baselines are tied to.

B) X,Y,Z Coordinate Independent (Alternative Electronic Method)
With a total station using a Coordinate System independent of the baseline. All shots for a given station need to be on the same coordinate system. The coordinate system may vary from station to station.

USING GEOPAK TO PROCESS

A detailed description of the steps to process cross-sections and earthwork with Geopak is provided on the following pages, but the general steps are:

1. Store your baseline as a CHAIN in Coordinate Geometry.
2. Process the original cross-sections.
3. Process the final cross-sections.
4. Run a closure report to make sure the final cross-sections tie to the original cross-sections.
5. Process Earthwork.

WHAT TO SUBMIT TO CONTRACT ADMINISTRATION

1. FORM FE-1.XLS (Excel worksheet found on \\rwdsrv\geopak\finalxs\forms)
2. FORM FE-2.XLS (Excel worksheet found on \\rwdsrv\geopak\finalxs\forms)
3. Printed copies of Earthwork totals.
4. Files created during steps of processing earthwork.
   Send these files to \\CAFP2\PROJECTS\"route number"
   (NOTE: Make a directory to put your route in. Name it what your "route number" is.)
5. Cross-Section books if Conventional cross-sections taken.

Collection of Data

General (Conventional and Electronic)

Cross-section notes (Conventional and Electronic) must carry the established job elevation datum. Bench Mark or Control Point elevations must be correct to Third Order Accuracy. This requires the closure to be within 12.0 mm x square root of the distance in km (0.05 feet x square root of the distance in Miles). Precision:

MDOT Measurement Precision	
Measurement Item	**Precision (Meters)**
Horizontal Distance, except cross-sections	0.001
Elevations: Benchmarks	0.001
Elevations: Centerline Pavements	0.001
Elevations: Centerline Grades	0.005
Cross-sections: Distances	0.1
Cross-Sections: Ground Elevations	0.05
Cross-Sections: Pavement Elevations	0.005

As stated earlier, cross-sections will be based off of a staked baseline. Cross-sections will be taken at intervals of a maximum of 25 m (100 feet) along the baseline and at right angles to it unless otherwise directed. Additional cross-sections must be taken at significant break points. Shots shall be taken at all significant breaks along the cross-section with maximum intervals of 7.5 m to 15 m (25 feet to 50 feet) along the cross-section. Final cross-sections shall be taken at the same stations as original cross-sections and at significant horizontal and vertical breaks (ie. Beginning and end of lane tapers, top & bottom of spill-throughs, etc.)

Conventional (Level, Tape, & Rod)

Specific instructions related to conventional cross-sections:

Existing S.O.P. NO. CSD-50-19-58-000 shall be followed except for the 99.9 feature, which will no longer be used. Geopak has a closure routine to tie the final section to the original section.

Also, as stated earlier, The Project Offices will be responsible for keying in these notes and shall use Geopak to process cross-sections and final earthwork. See *Chapter 11* for Key-in format required.

Electronic (Total Station, Data Collector, & Prism)

Specific instructions related to electronic cross-sections:

1. Length of sight should be limited to 90 m to 150 m (300 ft to 450 ft) using shorter lengths of sight if severe heat or other adverse conditions occur.

2. The format required:

POINT NUMBER, NORTHING COORD, EASTING COORD, ELEVATION, DESCRIPTION

ie. 1,120673.235, 10,928.384,50.780,CP3

2,12083.782,10892.287,50.612,CL10+000

3,12082.927,10885.415,50.600,L10+000

3. The only descriptions which should be used while collecting original & final x-section information should be:

Clstation - Centerline shot at the given station.

Lstation - Shot left of the centerline shot at the given station

Rstation - Shot right of the centerline shot at the given station

CP* - X,Y,Z control point

TP* - Turning Point which carries only Elevation

TRP* - Traverse Point which carries X,Y,Z

BMCHK* - Bench Mark

NOTE: * above represents additional description to detail the location or other data for the point.

4) The Centerline shot must be the first shot taken at each cross-section, then take all shots to the left & then all shots to the right. NOTE: You can take the shots in the field in any manner and edit the ASCII file in the office and arrange the notes CL, LT, RT if you wish, but if this is done, be sure to designate CL,LT, or RT on each shot while in the field.

5) Do not modify the X,Y,Z file created by your data collector. This file (OorFchainname.ASC) should be copied to OorFchainname.COR for further processing.

6) The RAW data file (OorFchainname.RAW), the unedited X,Y,Z file (OorFchainname.ASC), and the copied X,Y,Z file (OorFchainame.COR) must be submitted to Contract Administration.

ORAMPC.RAW
ORAMPC.ASC

ORAMPC.COR

Note: if you have more than one file for each baseline add -1,-2,-3,etc. To the filename.

ie. Orampc-1.RAW Orampc-2.RAW etc.

Orampc-1.ASC Orampc-2.ASC etc.

Orampc-1.COR Orampc-2.COR etc.

7) For X,Y,Z Independent you can process the OorF*.COR file as is with the TRANSFER.EXE PROGRAM mentioned in the XYZ Coordinate Independent section of the PROCESSING X-Sections chapter.

OR

7) For X,Y,Z Dependent edit the Oorf*.COR file and take out all lines that do not have CL,L,or R as a part of the description. Also take out CL,L,R out of these files leaving a format shown in section XYZ Coordinate Dependent of the Processing X-Sections Chapter.

Coordinate Geometry

Overview

A chain (baseline) has to be stored before the x-sections can be processed. There are two ways that this can be done:

1) Coordinate Geometry
2) Store Graphics (*Applications>Geopak Road>Other components>Store Graphics*)

For the steps involved, see **Roadway Design's Geopak Users Guide** or **On-Line Help Files.**

JOB#.GPK

AL*.DGN

Processing of Original and Final X-sections

XYZ Coordinate Dependent

FORMAT Required

This is an example of the format that is required by GeoPak:

Easting	Northing	Elevation	Station	Region Number
158758.602	66123.086	259.64999	0+000.00	
158762.6435	66124.71747	259.65105	0+000.00	
158765.2897	66125.78568	259.65142	0+000.00	
158766.1725	66126.14208	259.65968	0+000.00	
158777.516	66130.72121	259.68059	0+000.00	
158778.5085	66131.1219	259.68132	0+000.00	
158779.8666	66131.6701	259.68601	0+000.00	
158781.2585	66132.23202	259.76804	0+000.00	

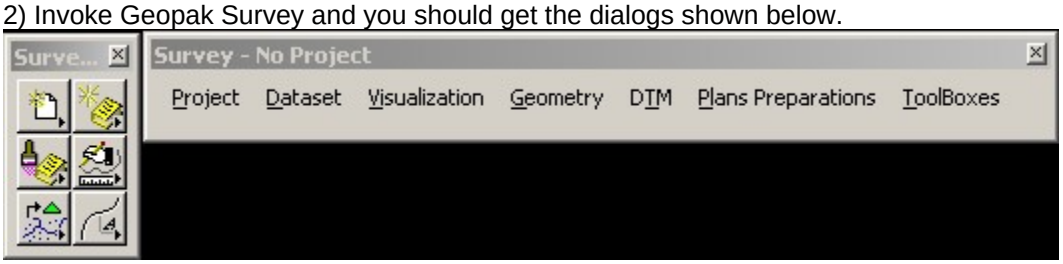
NOTE: 1. These columns can be in any order.
2. Notice that no TP,BM,etc. shots are present and that CL,L,& R have been taken out of the x-section station description.
3. Region Numbers are only required for stations that are on a chain twice or more as the result of an equation. If you have this case you need to edit the *.COR file and enter Region #'s as another field. Enter 1,2,3,etc. depending on the stations region number.

Note: Region Numbers define the region of a chain before & after an equation.
If you have 1 equation, you have 2 regions, Region 1 before the equation, Region 2 after it.
If you have 2 equations, you have 3 regions, Region 1 before the 1st equation, Region 2 between

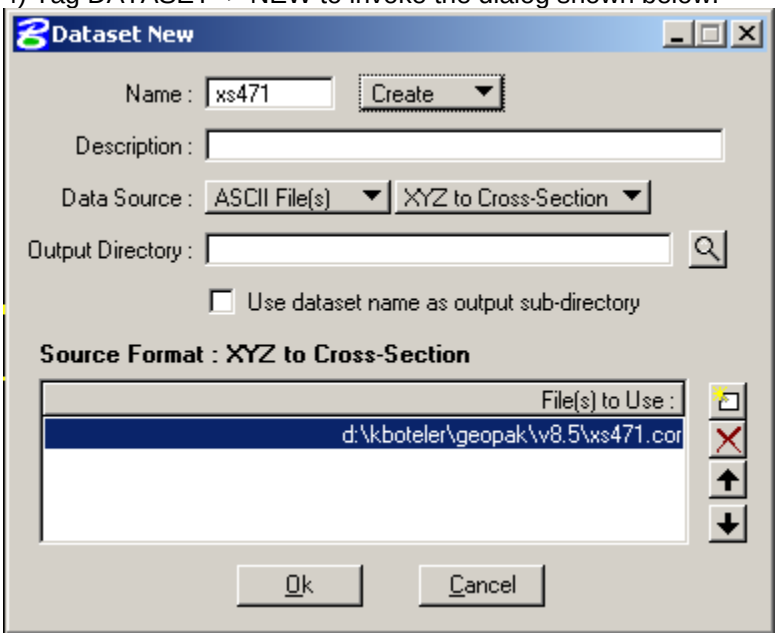
Ochainname.COR
Fchainname.COR

STEPS For Processing Original X-sections

1) Before you start create a x-section design file. The name should be **xschainname.dgn** (ie. xsrampc.dgn).
NOTE: Use XSSEED.DGN file as your Seed file.
Enter this design file that you just created.
2) Invoke Geopak Survey and you should get the dialogs shown below.



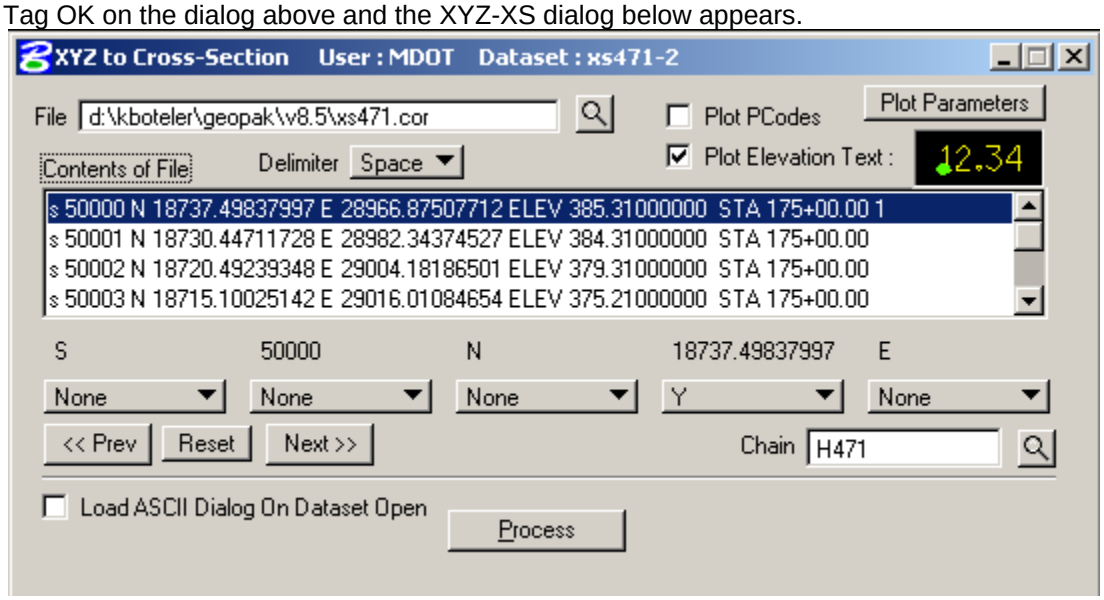
3) Tag PROJECT -> OPEN and open the project if you have already created a Project. If you have not already created GeoPak project, Tag Project NEW and enter a project name (i.e. 471) and select your job number.
4) Tag DATASET -> NEW to invoke the dialog shown below.



5) Enter a Dataset NAME (i.e. xs471) and set the DATA SOURCE to ASCII FILE(s), XYZ to CROSS-SECTION

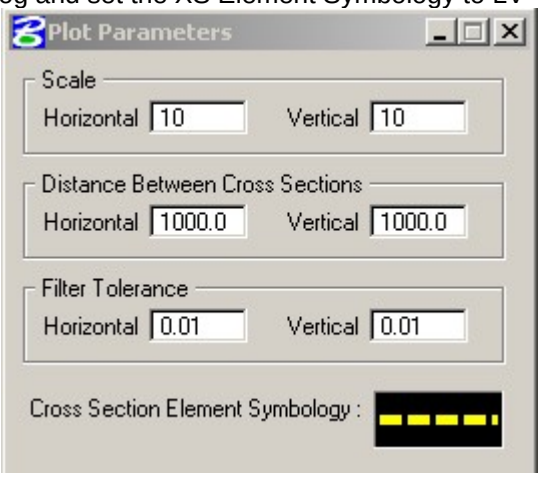
6) Tag the DATASET ADD SOURCE FILES TO LIST button, choose the .COR file, tag ADD, and then DONE.

7) Tag OK on the dialog above and the XYZ-XS dialog below appears.



8) Tag *CHAIN* to select the chain that your x-sections were taken about.
9) Set the **Delimiter** to whatever separates each field (ie. SPACE).
10) Tag on the first line of your **Contents of File**.
11) Define each element on the line selected with the toggle bars at the bottom of the dialog.

12) Tag Plot Parameters to invoke the dialog below. Double click the black area at the bottom right of the dialog and set the XS Element Symbology to LV=1,CO=2,LC=3,WT=4. Return to the main dialog (XYZ->XS)



13)Tag the **PROCESS** button. X-sections will be added to your design file. You can now use Geopak's X-section Labeling to scroll through your X-sections to check for errors. Errors found can be a bust in the survey or key in errors. These errors can be corrected in the design file or they can be reprocessed.

STEPS For Processing Final X-sections

NOTE: All Final x-sections should be at the same stations as the originals. If they are not at the same stations, go to the section on DTM for instructions.

1) Remain in the design file where you processed your original x-sections
2) Go through the same steps as shown above except use your final x-section notes. Change the names of the Dataset created to Fxschainame (i.e. Fxs471.dgn)
Also set your *Cross Section Element Symbology to LV=31, CO = 1, WT = 4, LC = 0* here for final x-sections.

XYZ Coordinate Independent

FORMAT Required

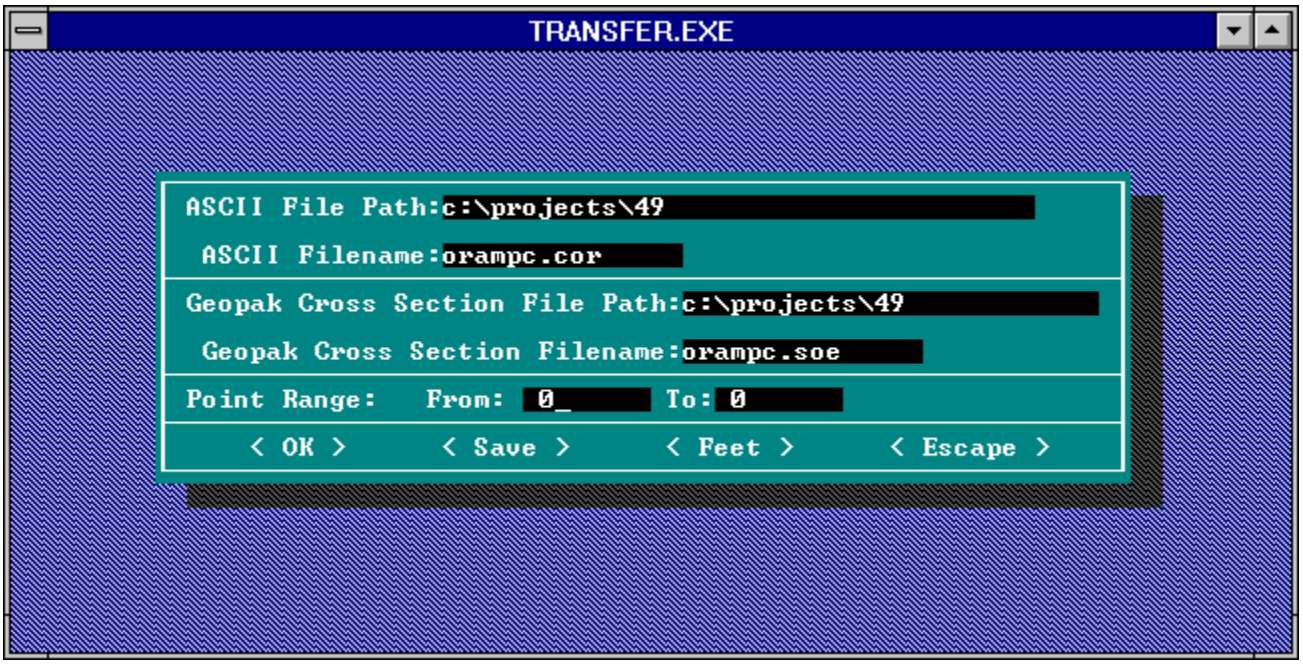
This is an example of the format that is required by an in house transfer program (Transfer.exe) that was written to convert XYZ to SOE.

```
500,570155.69982000,733291.65462000,73.929,tp
501,569793.03090000,733361.02800000,76.773,CL8+275.000
502,569790.51288000,733353.01379000,76.550,LT8+275.000
503,569788.90288000,733346.96199000,76.476,LT8+275.000
504,569786.78962000,733340.03627000,76.384,LT8+275.000
```

```
505,569785.14653000,733333.68831000,76.309,LT8+275.000
506,569784.59460000,733332.47066000,76.440,LT8+275.000
507,569782.43075000,733325.77248000,76.531,LT8+275.000
508,569794.15875000,733364.36214000,76.741,RT8+275.000
509,569794.42502000,733365.52070000,76.460,RT8+275.000
510,569795.00734000,733367.43856000,75.660,RT8+275.000
511,569796.02438000,733369.87337000,75.622,RT8+275.000
```

Use the Transfer.exe program if the cross-section coordinate system is independent of the baseline coordinate system. This file is located on \\rwdsrv\geopak\finalxs\transfer. You need to copy the files **Transfer.exe and Transfer.ini** to your working directory and double click on Transfer.exe to invoke the program.

Fill in the fields as shown below:



Tag **OK** and the program will create the *.SOE file. Below is an example of the SOE file.

```
8+275.000 -36.799  76.531
8+275.000 -29.706  76.44
8+275.000 -28.426  76.309
8+275.000 -21.833  76.384
8+275.000 -14.656  76.476
8+275.000 -8.382   76.55
8+275.000  0       76.773
8+275.000  3.577   76.741
8+275.000  4.724   76.46
8+275.000  6.741   75.66
8+275.000  9.368   75.622
```

Go to the steps in **XYZ Dependent**. Note that in **step 7** you will choose the **Data Source SOE=>XS** instead of XYZ=>XS. Also note that you will assign the fields as **Station, Offset, Elevation** instead of X, Y, Elevation, Station.

Station, H.I., Rod Reading, and Offset

FORMAT Required

This form of x-section data is usually typed in a text file with a .soe extension (ie. orampc.soe) from the x-section field books.

Ochainname.SOE
Fchainname.SOE

NOTE: If you try to create a file with a long file name, MS DOS editors will not work. If you use a DOS editor to create this file, use a short filename and you can come back later and rename it to match our naming convention.

It should be typed in the following format:

```
set plus 3 (Key this in for metric surveys only)
GROUND CHAIN NAME 1000 out FILENAME.cor
HI 93.624
GL 10+000.000 2.34 30.00 2.00 15.20 1.639 3.60 1.572 0 1.638 3.60 1.71 5.00 2.51
9.55 1.50 14.30 1.23 22.30 1.00 30.00
GL 10+020.000 2.41 30.00 1.99 13.90 1.703 3.60 1.658 0 1.717 3.60 1.85 5.70 2.44
8.30 2.46 9.20 2.72 10.20 2.01 13.90 1.82 23.70 1.80 30.00
GL 10+040.000 2.66 30.00 2.58 23.00 2.26 12.30 2.06 9.10 1.790 3.65 1.740 0 1.80
3.60 1.92 5.40 2.47 7.90 2.55 9.60 2.65 10.35 2.47 11.80 2.40 26.0 2.30 30.00
GL 10+060.000 3.06 35.00 2.83 25.20 2.45 15.50 2.07 6.00 1.887 3.58 1.830 0 1.890
3.60 2.12 6.10 2.39 8.24 2.61 10.20 2.76 10.97 2.59 11.75 2.53 21.70 2.47 30.00
HI 92.923
GL 10+080.000 2.58 30.00 2.48 19.90 2.00 16.70 1.41 6.70 1.290 3.56 1.237 0 1.299
3.62 1.35 5.00 1.93 7.93 1.90 9.72 2.27 11.18 1.82 12.95 1.88 25.60 1.75 30.00
GL 10+100.000 3.24 30.00 2.96 16.70 2.66 10.10 1.44 5.00 1.360 3.57 1.304 0 1.373
3.60 1.46 5.80 2.03 8.30 2.00 9.30 2.11 9.40 2.55 11.57 1.92 13.10 1.94 33.00
GL 10+120.000 3.20 30.00 3.19 11.83 1.53 5.00 1.442 3.59 1.390 0 1.449 3.62 1.56
5.00 2.15 8.05 2.16 10.23 2.68 11.00 2.67 12.60 2.25 13.40 2.07 14.14 1.98 30.00
GL 10+140.000 3.28 30.00 3.09 11.00 1.62 5.00 1.500 3.59 1.449 0 1.522 3.58 1.55
5.00 2.30 10.30 2.65 11.00 2.74 12.50 2.18 13.20 1.85 30.00
GL 10+160.000 3.33 30.00 3.19 11.40 1.64 5.00 1.536 3.59 1.482 0 1.549 3.60 1.60
5.00 2.32 8.20 2.36 10.20 2.93 11.05 2.94 12.00 2.31 13.10 2.21 13.90 1.85 24.20
1.54 31.00
END GROUND
```

NOTE: 1) GL Station RR Offset for each station should appear on one line.
HI should appear on its own line.
2) CHAIN NAME is the baseline that the x-sections were taken about.
FILENAME.cor is the name of the file that will be written once the text file is batched in. (ie. orampc.cor)
3) Negative (-) signs are <u>not</u> required for offsets to the left of the Baseline if a "0" offset shot was taken at that station.
4) Negative rod readings should be keyed in as negative rod readings.
5) Region Numbers (R 1, R 2, etc.) should be placed behind the station for stations that are on the chain twice as the result of an equation. (ie. 10+000.000 R 2)

STEPS For Processing Original or Final X-sections

There are two options to batch in the text file that you just created:

OPTION 1

1) Rename the *.soe text file that you created to FILENAMEJOB#.iOC (Where FILENAME is the file you want to call your x-sections, JOB# is the job number for the project, I is the extension for input, and OC is the operator code for the project)(ie. xs471471.icr)
2) Go into a design file. Get into Coordinate Geometry. **Load** the file that you renamed in step 1 of this option. (ie LOAD xs471)
3) **Read** the file. (Type READ)
4) Type **OUT FILE filename** (ie. OUT FILE xs471) This creates a file called FILENAMEJOB#.oOC (ie. xs471471.ocr). Using a text editor edit this file & search for errors. If any errors are present, fix them in FILENAMEJOB#.iOC file and go back to step 2 in this option.
5) Repeat steps 2-4 until no errors are present.
6) The *.cor file that you specified in the GROUND STATEMENT of the *.soe file, should have been created in your working directory.
7) This *.cor file, is the file that you will use to process your x-sections. (Go to **XYZ Coordinate Dependent** section of this chapter for processing the *.COR file.

DTM

Overview and Steps

Overview

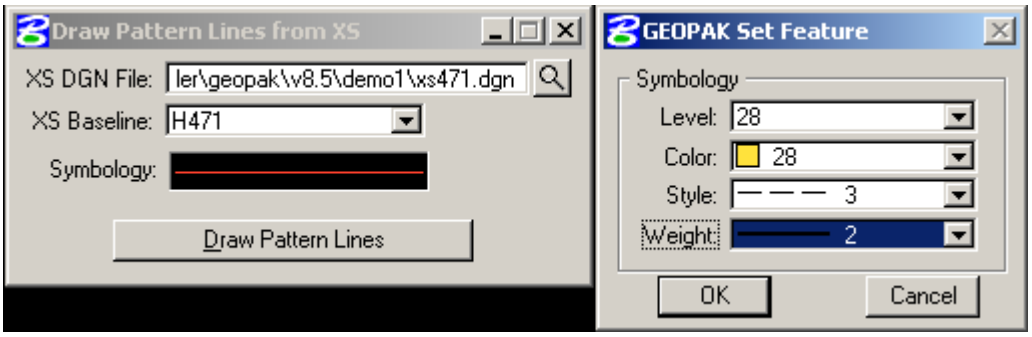
If you have final x-sections taken where there were no originals, you need to create a DTM (Digital Terrain Model) from your original sections and extract original x-sections at the stations of the finals. This will interpolate between the two adjacent x-sections. Steps are also provided below to easily determine the stations you have finals where there are no originals.

Steps for determining Final X-Section stations where there are no Originals

NOTE: If you already know where you have finals with no originals go to **Steps for creating a DTM of Original X-sections.**

1) Create a design file called XSFchainame.DGN (XSF471.DGN) and enter this design file. (Note: Use XSSEED.DGN as the seed design file.)
2) Process your Final X-sections by one of the methods described in the preceding sections.
3) Create a design file called PATchainame.dgn (PAT471.DGN) and enter this design file. (Note: Use SEED.DGN as the seed design file.
4) Invoke GeoPak's **DRAW PATTERN --> FROM CROSS-SECTIONS** dialog.
5) In this step you are going to create pattern lines from your original x-sections. Pattern Lines are just a plan view look of your x-sections which basically show where you have x-sections and the width of each section.

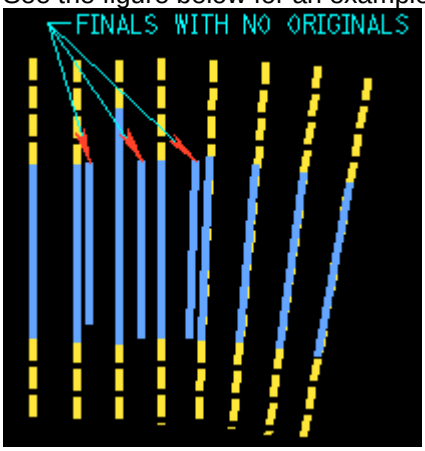
Fill in the dialog as shown below.



Note: The XS Dgn is the design file that contains your original x-sections.
6) Tag Apply and Pattern lines of your Original X-Sections are created.
7) In this step you are going to create pattern lines from your Final x-sections.
Set the dialog shown above settings to:
LV=28,CO=29,WT=3,LC=0, Xs Dgn = The design file containing your Final X-sections.
8) Tag Apply and Pattern Lines of your Final X-Sections are created.

Most of the Final Pattern lines (CO=29,LC=0) will be at the same location as the Original Pattern lines(CO=28,LC=30). For those that are not this is where you have Final X-Sections with no Originals.

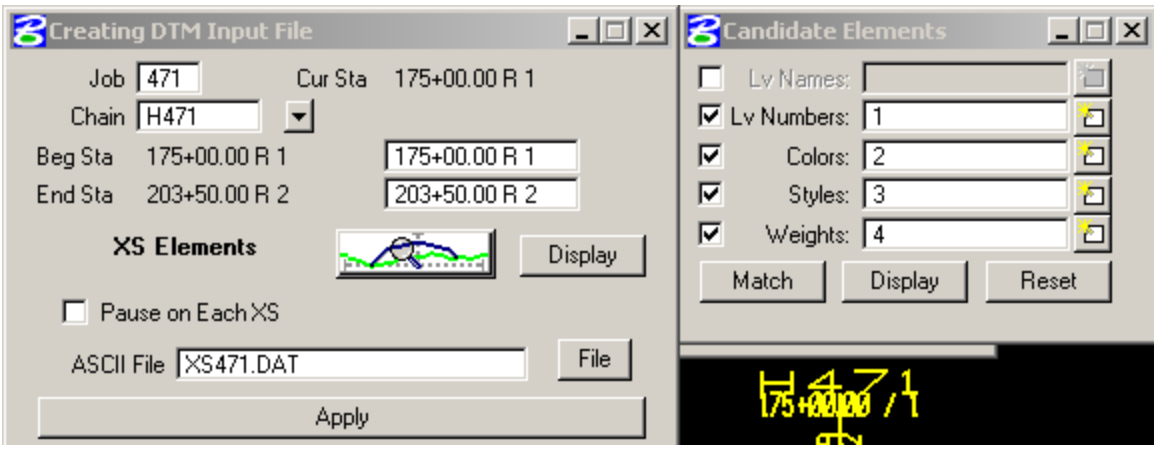
See the figure below for an example.



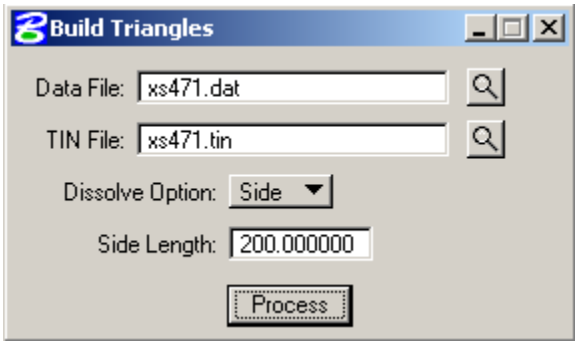
9) Change the Level of these line to Level 29

Steps for creating a DTM of Original X-sections

1) Go to Geopak's **XS Report** dialog. Tag on **DTM Input.** Fill in the fields with the information that meets your job requirements. Tag **Apply** when you have completed the information. This will create the file *.dat which will contain the XYZ coordinates of each shot of the x-sections.


Creating DTM Input File
Job 471
Cur Sta 175+00.00 R 1
Chain H471
Beg Sta 175+00.00 R 1
175+00.00 R 1
End Sta 203+50.00 R 2
203+50.00 R 2
XS Elements
Display
Pause on Each XS
ASCII File XS471.DAT
File
Apply
Candidate Elements
Lv Names:
Lv Numbers: 1
Colors: 2
Styles: 3
Weights: 4
Match
Display
Reset

2) Invoke Geopak's **DTM** application. *(Applications>Geopak Road>other components>DTM)* Tag on *Build>Triangles.*
   a) Fill in the *Data File* field with the *.dat file that was created in Step 1. (ie. orampc.dat)
   b) Fill in the *TIN File* field with the name of the *.tin file that you want Geopak to create. (ie orampc.tin)
   c) Make sure the *Dissolve Option* is set to **Side.**
   d) For the *Side Length* enter 2 X's normal distance b/t cross sections (ie. 2 X 25 = 50)
   e) Tag **Process** to build the triangles and create the *tin file.



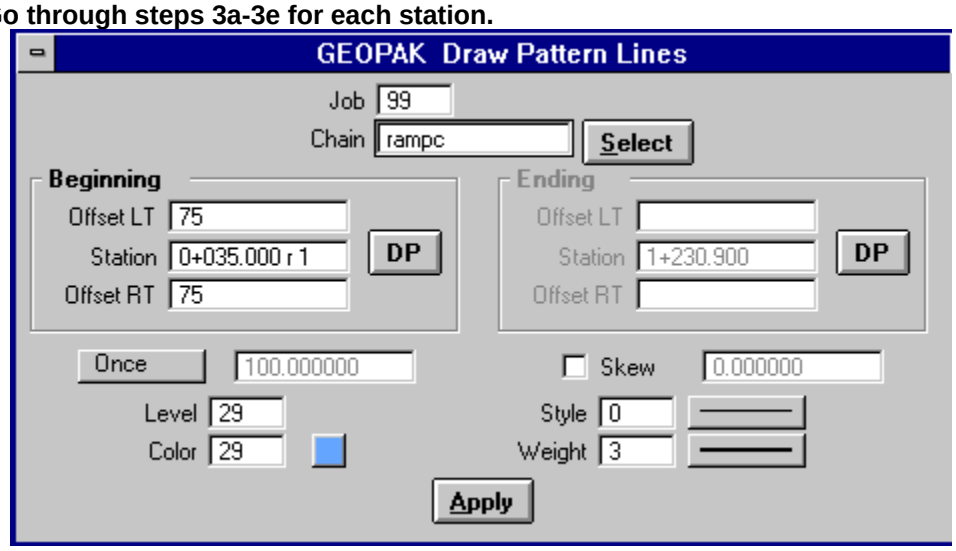
<u>NOTE: Skip Step 3 if you have already drawn Pattern Lines</u>.

3) Create a 2D design file (patrampc.dgn) and invoke Geopak's **Draw Pattern Lines** dialog (*Applications>Geopak Road>other components>Draw Patterns>by Station Range)*

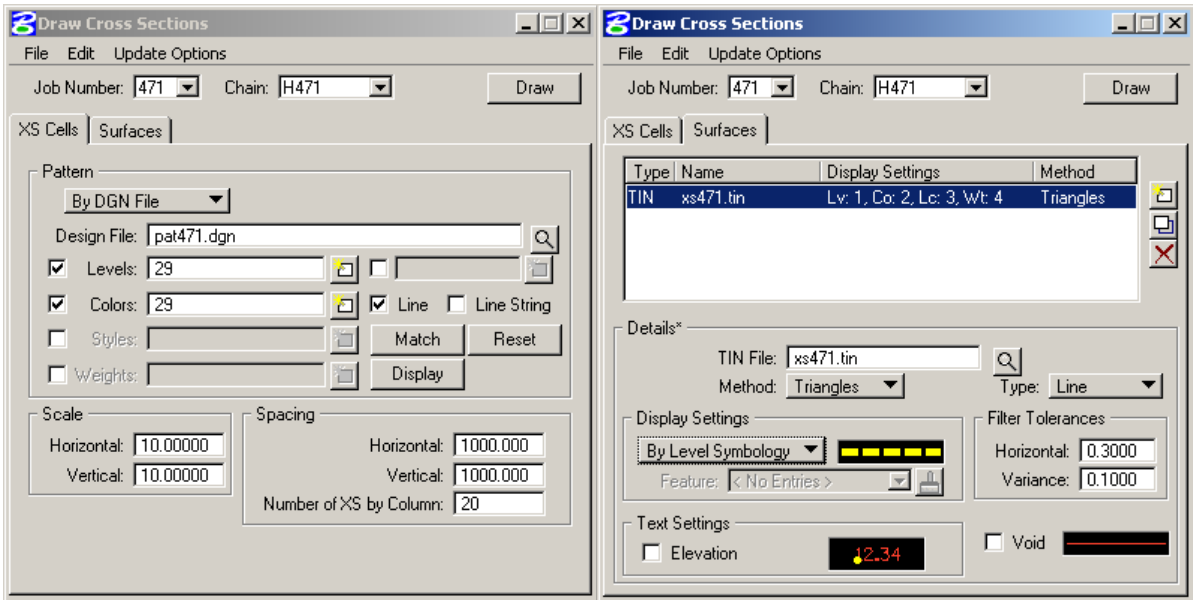
<u>PATchainname.DGN</u>

   a) Set the toggle in the lower left to **Once.**
   b) Fill in the station where you want the pattern line drawn.
   c) Fill in the offsets (LT. & RT.) (Offsets should approximately be the same as your original x-section offsets)
   d) Set your symbology to the setting as shown on the next page.
   e) Tag **Apply** and a pattern line will be created at the station you specified.

NOTE: For each final x-section station where there is not an original, you will need to create a pattern line. Go through steps 3a-3e for each station.



4) Get into your x-section design file XSRAMPC.DGN and invoke Geopak's **DRAW X-SECTIONS FROM SURFACES** (Under Road -> X-Sections). Fill in the fields to meet your job requirements. Set the toggles to match the example shown below:



5) Tag **DRAW**. This will draw original x-sections at stations you created the pattern lines earlier (STEP 3).
6) You should now have an original x-section for every final x-section. Go back to the section on Processing of Original and Final X-sections to process the final x-sections.

Closure

Overview and Steps

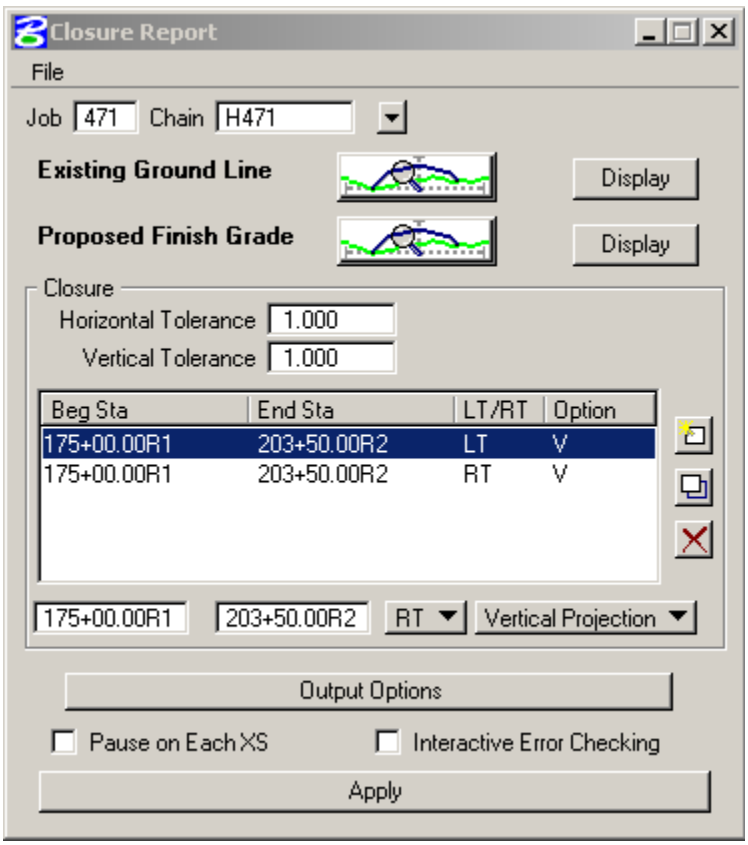
Overview

The Closure option on the x-section report dialog provides the user a method by which to tie or close a set of x-section elements to another. (ie. final to original) This closure application will tie the final elements to the original elements with a vertical line. The acceptable tolerance between the final and the original at the location that they are suppose to tie is 0.3 m (1 ft). If the tie is outside the tolerance, the error should be investigated and possibly corrected in the field and reprocessed.

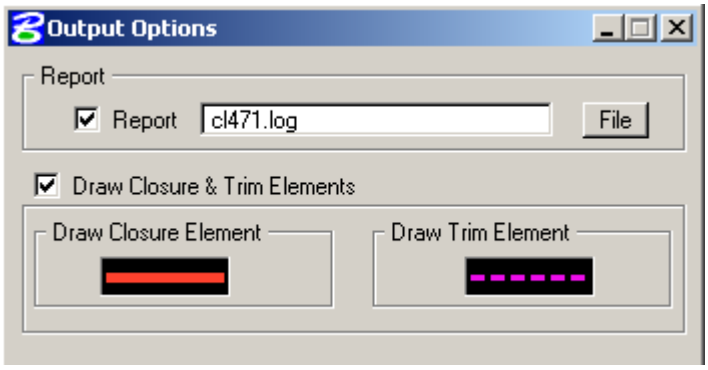
Steps

1) Invoke **Geopak's Cross Section Reports** dialog. Tag **Closure.**
2) Tag User -> Preferences and set the Tolerance on the invoked dialog (Report Header) to 0.001

3) Set the dialog as shown below:



3) Tag **Output Options** and fill out the fields to meet your job requirements.
An example is shown below: (Closure Symb. -> LV=31,co=1,wt=4,lc=0) (Trim Symb. -> LV=33,co=5,lc=2,wt=2).



4) Go back to the **Closure Report** dialog box and tag **Apply.**

5) After the closure has run, edit the *.log file that it created. (ie. cl471.log)
This file will show you the difference in elevation of the final and original at the tie location. If the tolerance is exceeded, Geopak will put an asterisk by the closure. This shot will have to be investigated further and possibly corrected in the field and reprocessed.
NOTE: This application will close all finals with originals even if the tolerance is exceeded.

Below is an example of a *.log file:

```
STATION              LEFT CLOSURE                    RIGHT CLOSURE
                   VERT           HORIZ           VERT            HORIZ
0+000.00R1        0.000           0.000          0.000            0.000
0+020.00R1        0.264           0.000         TRIMMED          TRIMMED
0+040.00R1      *-0.499           0.000         -0.139            0.000
0+060.00R1        0.119           0.000         -0.142            0.000
0+080.00R1       TRIMMED         TRIMMED        TRIMMED          TRIMMED
0+100.00R1        0.000           0.000          0.000            0.000
```

Earthwork

Overview And Steps

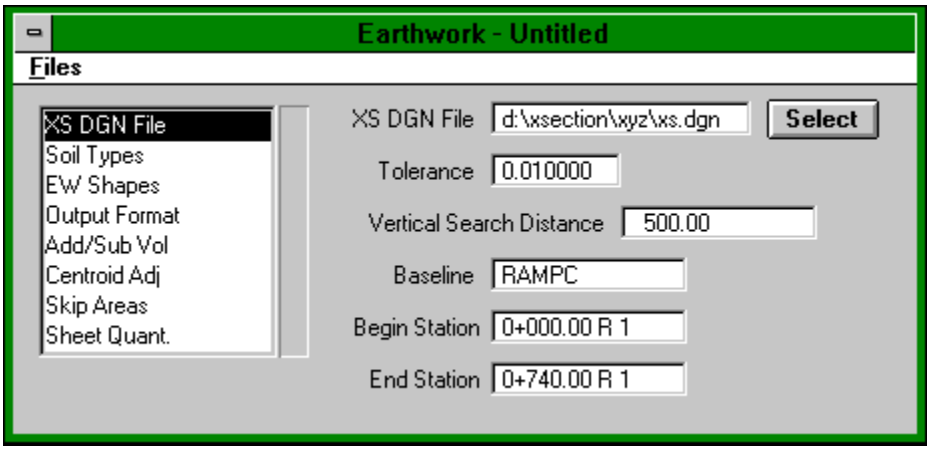
Overview

In Order for Geopak to calculate earthwork correctly, you **must** insure:

a) The final ties to the original (see chapter on Closure)
b) You don't have duplicate lines of the same symbology on top of each other.
c) The final doesn't tie to the exterior limits of the original. If this is the case Geopak will calculate the end area as double of what it should be. You can extend the Original some to overcome this problem.

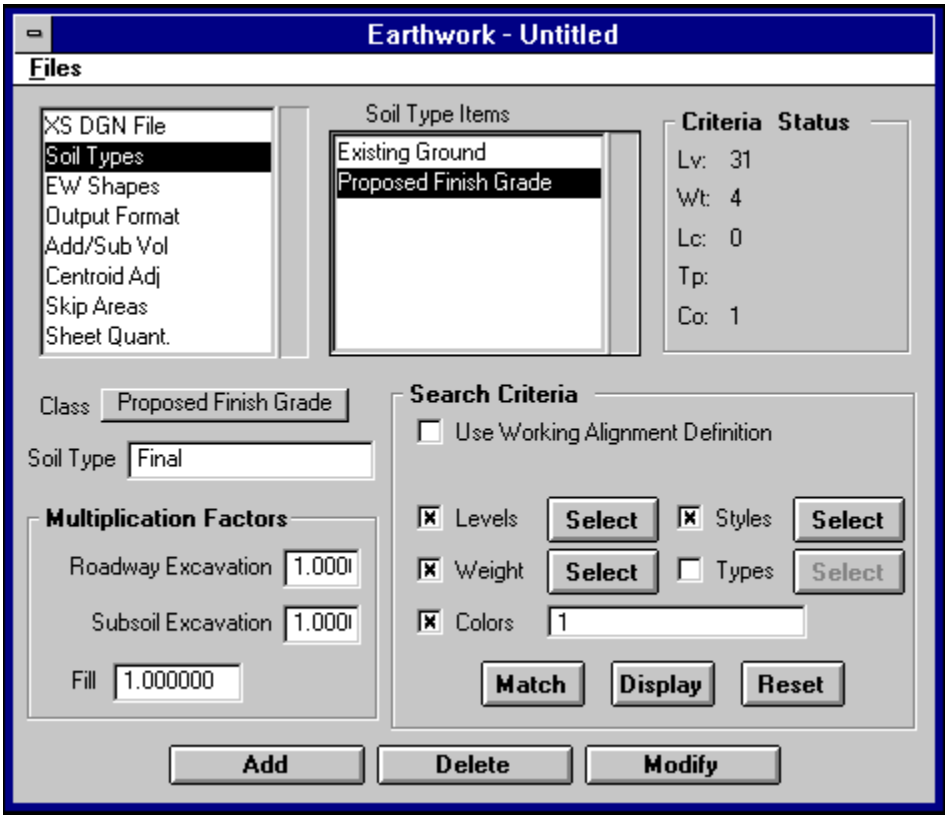
Steps for Processing

1) Invoke the **Earthwork** dialog from Geopak's **Road Project** main dialog.
2) Tag on **XS DGN File** in the dialog box and fill out the fields to meet your job specifications. An example is shown below:

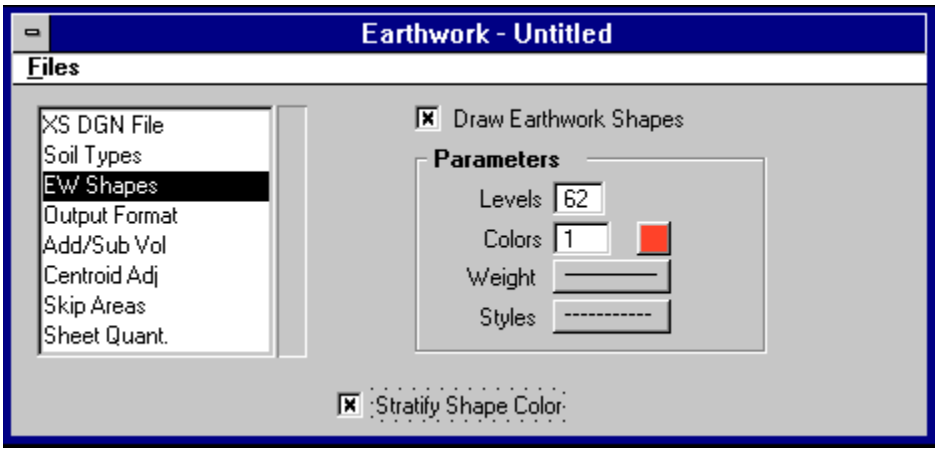


3) Tag on **Soil Type** in the dialog box.
   a) Set the *CLASS* to **Existing Ground** and enter **Original** next to *SOIL TYPE*
   b) Set all *Multiplication Factors* to **1.000**
   c) Under the *Search Criteria* set your levels, weights, colors, etc. to match your original. (ie. LV=1, WT=4, LC=3, CO=2)
   d) Tag **Add** to add this soil type to the *Soil Type Items* field.

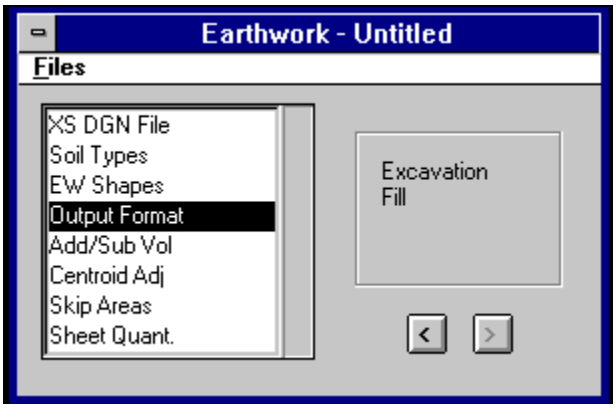
4) Tag on **Soil Type** in the dialog box.
   a) Set the *CLASS* to **Proposed Finish Grade** and enter **Final** next to *SOIL TYPE*
   b) Set all *Multiplication Factors* to **1.000**
   c) Under the *Search Criteria* set your levels, weights, colors, etc. to match your existing. (ie. LV=1, WT=4, LC=3, CO=2)
   d) Tag **Add** to add this soil type to the *Soil Type Items* field.



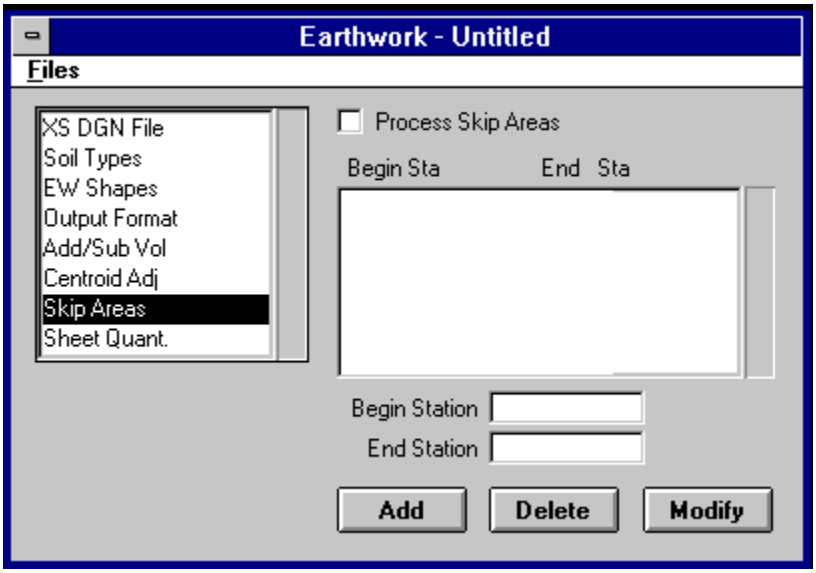
5) Tag on **EW Shapes** and fill in the fields similar to the one shown below:



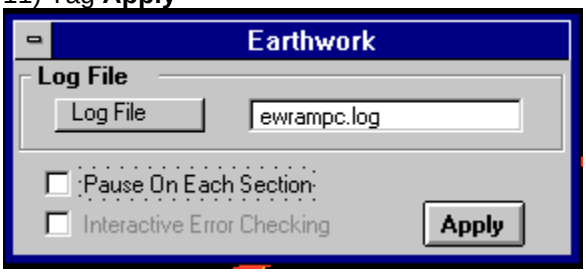
6) Tag on **Output Format**. Click on the arrows, until it appears like the example below:



7) Tag on **Skip Areas** only if you have station ranges that you do not need the earthwork values calculated. (ie. Bridge stations) Key in the beginning station that you want to skip. Then key in the ending station that you want to skip. Tag **Add** and make sure that the *Process Skip Areas* has been turned on.
NOTE: YOU MUST SKIP FROM AND TO STATIONS THAT HAVE A FINAL & AN ORIGINAL SECTION



8) Tag **Files>Save Settings** to save the settings.
9) Tag **Files>Run** to process your earthwork.
10) This will pop up the **Earthwork** dialog box. Under *Log File* set the toggle to **Log File** and enter the name of the file you want it to create. (ie. ewrampc.log)
11) Tag **Apply**



EWchainname.LOG

12) Below is an example of the *.log file created by Geopak.

Station	Material Name	End Areas (square meters)	Unadjusted Volumes (cubic meters)	Adjusted Volumes (cubic meters)	Mult Factor	Mass Ordinate
0+000.00	ORIGINAL					
	Excavation	0.95	0	0	1.00	
	Fill	0.00	0	0	1.00	0
	FINAL					
	Excavation	0.00	0	0	1.00	
	Fill	9.93	0	0	1.00	0
0+020.00	ORIGINAL					
	Excavation	2.27	32	32	1.00	
	Fill	0.00	0	0	1.00	32
	FINAL					
	Excavation	0.00	0	0	1.00	
	Fill	6.85	168	168	1.00	-136
0+040.00	ORIGINAL					
	Excavation	1.63	39	39	1.00	
	Fill	0.00	0	0	1.00	-97
	FINAL					
	Excavation	0.00	0	0	1.00	
	Fill	1.16	80	80	1.00	-177
0+060.00	ORIGINAL					
	Excavation	1.94	36	36	1.00	
	Fill	0.00	0	0	1.00	-141
	FINAL					
	Excavation	0.00	0	0	1.00	
	Fill	0.28	14	14	1.00	-155
0+080.00	ORIGINAL					
	Excavation	2.51	44	44	1.00	
	Fill	0.00	0	0	1.00	-111
	FINAL					
	Excavation	0.00	0	0	1.00	
	Fill	0.03	3	3	1.00	-114
0+100.00	ORIGINAL					
	Excavation	2.58	51	51	1.00	
	Fill	0.00	0	0	1.00	-63
	FINAL					
	Excavation	0.00	0	0	1.00	
	Fill	0.01	0	0	1.00	-63

G R A N D S U M M A R Y T O T A L S

Material Name		Unadjusted Volumes (cubic meters)	Adjusted Volumes (cubic meters)	Mult Factor
ORIGINAL				
	Excavation	202	202	1.00
	Fill	0	0	1.00
FINAL				
	Excavation	0	0	1.00
	Fill	265	265	1.00

NOTE: The Project Engineer must sign here.

Forms

Forms To Turn In

On the following pages is a copy of the forms that will be turned into Contract Administration. These are Excel files **(Fe-1.xls, Fe-2.xls)** that will be available in the RWD directory.. These forms can be printed out and filled in by hand. Examples of these forms are shown on the following pages.

MISSISSIPPI DOT			
CONTRACT ADMINISTRATION DIVISION			
FINAL EARTHWORK SUBMITTAL (FE-1)			
PROJECT NO.			
ROUTE:			
COUNTY:			
DATE:			
DISTRICT & PROJECT OFFICE			
CADD OPERATOR:			
PHONE:			
FILES SUBMITTED FOR BASELINE			
BASELINE DESCRIPTION			
ORIGINAL - METHOD OF COLLECTION	__ - X,Y,Z Dep.	__ - XYZ Indep.	__ - SOE
ORIGINAL RAW DATA FILE			
ORIGINAL COORD. FILE (UNEDITED)			
ORIGINAL COORDINATE FILE			
ORIGINAL SOE			
ALIGNMENT DESIGN FILE			
GPK FILE			
XS DESIGN FILE			
FINAL - METHOD OF COLLECTION	__ - X,Y,Z Dep.	__ - XYZ Indep.	__ - SOE
FINAL RAW DATA FILE			
FINAL COORD. FILE (UNEDITED)			
FINAL COORDINATE FILE			
FINAL SOE			
DTM (Digital Terrain Model)			
ORIGINAL DTM CREATED	__ YES	___NO	
ORIGINAL .DAT FILE		XXXXX	
ORIGINAL .TIN FILE		XXXXX	
PATTERN DESIGN FILE			
CLOSURE REPORT FILE			
EARTHWORK OUTPUT FILE			

CAD FE-2

MISSISSIPPI DEPARTMENT OF TRANSPORTATION
CONTRACT ADMINISTRATION DIVISION

FINAL EARTHWORK SUBMITTAL

PAY ITEM NUMBER	BASE LINE NAMES															GRAND TOTAL CUBIC METER
203-A																0
203-B																0
203-D																0
203-E																0
203-EX																0
203-F																0
203-G																0
203-H																0
																0
																0
																0
																0
																0
																0
																0
															UNITS	CUBIC METER
																0

PROJECT NO: _____ PROJECT ENGINEER: _____
ROUTE: _____
COUNTY: _____
DATE: _____
CADD OPERATOR: _____ PROJECT ENGINEER

MISSISSIPPI DOT

CONTRACT ADMINISTRATION DIVISION

FINAL EARTHWORK SUBMITTAL (FE-1)

PROJECT NO.	GAI-9371(4)A		
ROUTE:	HWY 49		
COUNTY:	HARRISON		
DATE:	9/30/97		
DISTRICT & PROJECT OFFICE	16-15		
CADD OPERATOR:	SAM WHITE		
PHONE:	635-9786		
FILES SUBMITTED FOR BASELINE			
BASELINE DESCRIPTION	RAMPC		
ORIGINAL - METHOD OF COLLECTION	**__ - X,Y,Z Dep.**	**__ - XYZ Indep.**	**_x_ - SOE**
ORIGINAL RAW DATA FILE			
ORIGINAL COORD. FILE (UNEDITED)			
ORIGINAL COORDINATE FILE			
ORIGINAL SOE	ORAMPC.SOE,ORAMPC.COR		
ALIGNMENT DESIGN FILE	ALI49.DGN		
GPK FILE	JOB49.GPK		
XS DESIGN FILE	XS49.DGN		
FINAL - METHOD OF COLLECTION	**_x_ - X,Y,Z Dep.**	**__ - XYZ Indep.**	**__ - SOE**
FINAL RAW DATA FILE	FRAMPC*.RAW		
FINAL COORD. FILE (UNEDITED)	FRAMPC*.ASC		
FINAL COORDINATE FILE	FRAMPC*.COR		
FINAL SOE			
DTM (Digital Terrain Model)			
ORIGINAL DTM CREATED	**_x_ YES**	**___NO**	
ORIGINAL .DAT FILE	ORAMPC.DAT	**XXXXX**	
ORIGINAL .TIN FILE	ORAMPC.TIN	**XXXXX**	
PATTERN DESIGN FILE	PATRAMPC.DGN		
CLOSURE REPORT FILE	CLRAMPC.LOG		
EARTHWORK OUTPUT FILE	EWRAMPC.LOG		

CAD FE-2

MISSISSIPPI DEPARTMENT OF TRANSPORTATION
CONTRACT ADMINISTRATION DIVISION

FINAL EARTHWORK SUBMITTAL

PAY ITEM NUMBER	BASE LINE NAMES															GRAND TOTAL CUBIC METER
	Hwy 49	West St.	Main St.	James St												
203-A	3038	735	387	675												4835
203-B																0
203-D																0
203-E																0
203-EX	5478	256	508	355												6597
203-F																0
203-G																0
203-H																0
																0
																0
																0
																0
																0
																0
																0
															UNITS	CUBIC METER

PROJECT NO: GAI-9371(4)A
ROUTE: HWY. 49
COUNTY: HARRISON
DATE: 9/30/97
CADD OPERATOR: SAM WHITE

PROJECT ENGINEER:

PUT SIGNATURE HERE
PROJECT ENGINEER