NGS/CALTRANS

San Diego

GPS-Derived Orthometric Height

Cooperative Project

National Geodetic Survey

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Introduction

In July 1992, the National Geodetic Survey (NGS), in cooperation with the California Department of Transportation (CALTRANS), undertook a cooperative project to estimate GPS-derived orthometric heights in San Diego County, California, that are accurate to +/- 5 cm. The project included the analysis of existing GPS, gravity, and leveling data; the determination of requirements for additional data of the three types listed above; the training of CALTRANS personnel to observe the required data; and the computation of an improved regional geoid model of the county using the proper combination of existing and new data. These activities resulted in recommended procedures, which improved CALTRANS' ability to determine more accurate GPS-derived orthometric heights to meet many of their vertical requirements for transportation improvement projects. The project was performed under existing cooperative NGS/CALTRANS agreement No. 53-P587, as an extension of the effort described in Section VI, Item 12 of the agreement. Appendix A contains a copy of the cooperative agreement.

NGS and CALTRANS personnel involved in the project are listed below:

National Geodetic Survey - Dave Zilkoski, Don D'Onofrio, Rudy Fury, Robert Moose, Dennis Milbert, Vic Richmond, Bruce Ward, Emery Balazs, Kathy Koepsell

CALTRANS - Tony Nothdurft, Wes Parks, Tim Dickey, Mike Wright,

NGS is investigating and documenting methods for implementing GPS-derived orthometric heights in the surveying community. Results of analyses performed by NGS indicate that with the use of appropriate planning, proper strategy when estimating and evaluating geoid height differences, and correct use and analysis of adjustment results, it is possible to compute GPS-derived orthometric heights that meet a wide range of engineering and land surveying requirements for vertical control.

Mainly due to atmospheric effects on GPS data, the vertical component determined by GPS is typically less accurate than the horizontal component. In addition, due to uncertainties in the estimation of geoid height differences, GPS-derived orthometric heights are typically less accurate than leveling-derived orthometric heights. NGS is currently working on algorithms and models to improve the estimation of geoid heights and geoid height differences, as well as investigating the use of better atmospheric models and modeling techniques in the reduction of GPS data. The factors discussed above make it impossible to state unequivocally the accuracy of GPS-derived orthometric heights. The minimum steps required when estimating GPS-derived orthometric heights and how to use the results obtained during the minimum step procedure are discussed in this report.

Heights and Height Differences

Orthometric heights (H) are referenced to an equipotential surface, e.g., the geoid, which approximates the mean sea level. The orthometric height of a point on the Earth's surface is the distance from the geoid to the point, measured along the plumb line normal to the geoid. Ellipsoid heights (h) are referenced to a reference ellipsoid. The ellipsoid height of a point is the distance from the reference ellipsoid to the point, measured along the line which is normal to the ellipsoid. At a point, the difference between the ellipsoid height and the orthometric height is defined as the geoid height (N).

An orthometric height can be computed (to a sufficient approximation) from an ellipsoid height by subtracting the geoid height, i.e., $H = h - N$. Similarly, an orthometric height difference (dH) can be obtained from an ellipsoid height difference (dh) by subtracting the geoid height difference (dN), i.e., $dH = dh - dN$. (See figure 1.)

When high-accuracy leveling field procedures are used, orthometric height differences can be computed from measurements of precise leveling with an uncertainty of less than 0.5 cm over a 15-kilometer distance. Less accurate results are achieved when third-order single-run leveling methods are employed, i.e., 1.5 cm over a 15-kilometer distance and 0.8 cm over a 4-kilometer distance. Depending on the accuracy requirements and distance between control points, GPS surveys and high-resolution geoid models can be employed as an alternative to classical geodetic leveling methods.

NGS has computed a high-resolution geoid model for the continental United States. The latest version is called GEOID93. GEOID93 is reported to have a typical uncertainty of 10 cm over 100 km distances. It appears to be much better over distances less than 10 km, typically 1 to 3 cm.

Steps Required When Estimating GPS-Derived Orthometric Heights

The problem of implementing GPS-derived orthometric heights into the surveying and mapping community is two-fold. First, users must accept and use orthometric height differences which have relative uncertainties between 3 and 6 cm (0.1 and 0.2 feet). Secondly, users must be able to reliably determine and document the accuracy estimates of their projects' final adjusted GPS-derived orthometric heights. Some relative height differences will appear to be better than 3 cm, while others may indicate that they are only good to 6 cm. The accuracy of adjusted GPS-derived orthometric height values depends on the accuracy of GPS-derived ellipsoid height differences, the accuracy of geoid height differences, and the accuracy of the leveling-derived orthometric heights used as vertical control.

There is not a GPS specification or procedure that by itself can account for inaccuracies in published orthometric heights and/or geoid models. This makes it difficult to prepare GPS specifications and procedures to establish GPS-derived orthometric heights. Draft FGCS specifications and procedures have been developed to estimate GPS-derived ellipsoid heights. These specifications include occupying with GPS equipment a minimum number of stations which have leveling-derived orthometric heights, i.e., bench marks.

This specification only assures that a long-wavelength systematic error, if present in the survey, can be detected and removed from the data. Local effects due to errors in the GPS data, distortions in the orthometric heights used as vertical control, or inaccuracies in the geoid model cannot be detected and removed unless additional bench marks are occupied by GPS.

Determining where orthometric height information is required in a GPS project is not an exact science. There are procedures which are performed during the planning stages of the project that assist users in determining where known vertical control information is required. These procedures will be discussed in more detail later in this report.

Anyone that has been involved with estimating GPS-derived orthometric heights would probably agree with the following three statements: (1) computing worthwhile GPS-derived orthometric heights on a project-by-project basis is relatively simple, (2) incorporating new GPS-derived orthometric heights into a network which is based on the results of other GPS projects is more difficult, and (3) making meaningful categorical statements about the accuracy of GPS-derived orthometric heights is premature.

NGS is developing a plan to facilitate the transition from a leveling-derived orthometric height system, i.e., the current National Geodetic Reference System (NGRS), to a combined leveling-derived and GPS-derived orthometric height system. (Appendix B contains a copy of a paper titled "A Strategy for an Orderly Transition from Leveling-Derived Orthometric Heights to GPS-Derived Orthometric Heights." Appendix C contains an outline of the Vertical Network Branch's (VNB) gravity plan in support of the implementation of GPS-derived orthometric heights.)

From a user's perspective, an accurate, consistent, and constant set of orthometric heights is very important. This may be difficult to maintain during the transition period. During the transition period, specifications and procedures will be modified to account for the use of more accurate geoid models, improvements in estimating GPS-derived ellipsoid heights, and the establishment of additional precise leveling-derived orthometric heights and GPS-derived ellipsoid heights. Other countries are also investigating how to make the transition (Mitchell 1990). NGS is in contact with these other agencies.

This report presents procedures which users can follow to estimate GPS-derived orthometric heights for a particular project. Combining results of many projects into a network, however, will be necessary for the implementation of GPS-derived orthometric heights into the surveying and mapping community. Procedures for estimating GPS-derived orthometric heights which are consistent with the NGRS National Geodetic Vertical Control Network are presented.

To assist in estimating the accuracy of GPS-derived orthometric heights, a prescribed set of steps should be followed. The results obtained during the analyses are used to estimate and document the expected accuracy of the project's GPS-derived orthometric heights.

The <u>minimum</u> steps required when computing GPS-derived orthometric heights are listed below:

1. During the project's <u>planning</u> stage, perform a detailed analysis of the geoid in the area of the survey in order to determine if additional gravity and/or leveling data are required to adequately estimate the slope of the geoid and changes in slope.

    a. Perform a detailed study of the density and distribution of observed gravity values and plot free-air and Bouguer anomalies to determine where <u>changes</u> in slope of the geoid may exist.

2. During the project's planning stage, perform a detailed study of the leveling network in the area, i.e., plot all leveling lines, note the age of leveling data, determine if bench marks can be occupied by GPS receivers, etc.

a. Perform a history check on monuments to determine if they are stable bench marks and if they are referenced to the same vertical datum.

3. After gathering the GPS data, analyze the GPS data by computing loop misclosures, comparing repeat base line results, and performing a 3-D minimum constraint least squares adjustment of the GPS data.

a. Compare GPS-derived coordinates with results of higher-order surveys to determine if coordinates (latitude, longitude, and ellipsoid height) estimated from higher-order surveys can be used to control remaining errors in the project.

b. Compute loop and repeat base line misclosures and check the results against allowable tolerances.

4. Using the best available geoid heights, compare adjusted GPS-derived orthometric height differences obtained from step 3 with leveling-derived orthometric height differences.

5. Detect and remove all data outliers determined in steps 3 and 4.

6. Analyze the local geoid in detail.

a. Plot the geoid heights in the area.

b. Plot the GPS stations in the area on gravity-related informational plots.

7. Estimate GPS-derived orthometric heights and local systematic differences between the geoid, orthometric, and ellipsoid heights systems by solving for trend parameters.

a. Plot the estimated slope of the geoid using differences between GPS-derived ellipsoid height differences and leveling-derived orthometric height differences ($dN = dh - dH$) obtained in step 4.

b. Estimate the local uncertainties in the geoid model for the area.

8. Compare adjusted GPS-derived orthometric height differences from step 7 with leveling-derived orthometric height differences to determine appropriate trend parameters.

a. Determine if there is enough valid information to reliably estimate trend parameters. Large differences between GPS-derived orthometric heights and leveling-derived orthometric heights may be due to "bad" information. Bad information includes, but is not limited to, the following: bench marks which have moved since their heights were last determined, misidentified stations, inconsistent vertical datums, incorrect ellipsoid heights, and inaccuracies in the geoid model.

9. Compute GPS-derived orthometric heights by performing a 3-dimensional least squares adjustment holding fixed all appropriate orthometric height values of published bench marks (and appropriate GPS-derived coordinates (latitude, longitude, and ellipsoid height) computed from higher-order surveys) and solving for (or applying) appropriate trend parameters.

10. Use the results from steps 1 through 9 to document the estimated accuracy of the GPS-derived orthometric heights.

Of course, it must be understood that each project is different and, therefore, the procedures used to compute GPS-derived orthometric heights will be slightly different for each project. There is not a simple "cookbook" method that works well all the time everywhere. The results from all steps and comparisons with known values must be considered before determining final GPS-derived heights.

Plan Outline

As previously stated, the accuracy of GPS-derived orthometric heights depends on the accuracy of GPS-derived ellipsoid height differences, the accuracy of geoid height differences, and the accuracy of leveling-derived orthometric heights used as vertical control. Therefore, the activities outlined below were addressed for this project.

Gravity Activities

- o Determine gravity data requirements
- o Obtain new gravity data
- o Process new gravity data
- o Load new gravity data into NGS gravity data base (NGS_GRAVITY)
- o Compute new geoid model
- o Compare new and old geoid models

Leveling Activities

- o Determine leveling data requirements
- o Determine status of NAVD 88 heights in NGS' Integrated Data Base (NGSIDB)
- o Incorporate 1978 Southern California Releveling Program (SCRP) data into NAVD 88
- o Obtain new height difference observations between bench marks with NAVD 88 heights and San Diego County GPS Network stations using either leveling procedures and/or "specially-designed" trigonometric leveling procedures
- o Process new height difference observations
- o Load new height difference observations into NGSIDB
- o Compute NAVD 88 heights for San Diego County GPS network stations

GPS Activities

- o Determine "internal" relative accuracy of GPS-derived ellipsoid heights for the San Diego County GPS network

GPS-Derived Orthometric Height Activities

- o Compare GPS-derived orthometric heights obtained from minimum constraint least squares adjustment with NAVD 88 heights
  - o Use GEOID93 and special geoid model computed for San Diego GPS project (GEOID93S)

- o Compute and compare GPS-derived orthometric heights using three different adjustment techniques
  - o Scale and Rotation Method
  - o Trend Removal Method
  - o Height Distribution Method

<u>Procedures to Follow When Estimating GPS-derived Orthometric Heights in San Diego County</u>

- o Provide brief description of procedures to be followed to meet CALTRANS project requirements

<u>Sample Project - City of San Diego GPS Project</u>

- o Provide brief description of GPS project
- o Describe how procedures mentioned in previous sections were followed
- o Compare GPS-derived orthometric heights with NAVD 88 values

<u>Conclusions</u>

- o Indicate future activities which need to be performed

Gravity Data Analysis

Step 1, performing detailed analysis of the geoid in the area of the survey, is probably the most important planning step when estimating GPS-derived orthometric heights. It is critical to determine which bench marks need to be occupied with GPS to adequately evaluate the slope and changes in slope of the geoid. Plotting a contour map of geoid heights estimated using a high-resolution geoid model is the first task, but by no means is it the only task. The plot may indicate a smooth, gently sloping geoid, but this could be because there wasn't enough gravity information in the area to adequately define changes in the shape of the geoid.

Analyzing gravity density plots and modeled geoid height values, as well as contour plots of free-air anomalies and Bouguer anomalies, are practical ways for users to determine which bench marks in the project need to be occupied by GPS or where additional gravity observations are required. The analysis may indicate that precise leveling may need to be performed to establish an orthometric height of a GPS monument in an area where no vertical control or gravity observations exist, or that additional gravity observations need to be collected.

Interpreting gravity-related informational plots can be kept to a minimum and still be helpful. The basic concept is that a high-resolution geoid model is only as good as the data and theory used to generate it. Therefore, you need to check the accuracy of the model where the plots indicate that there may be a change in the shape of the geoid or where there are insufficient gravity data to adequately define changes in the shape of the geoid. Users can think of these plots as similar to elevation contour lines on a topographic map. The closer the lines are together, the steeper the slope of the geoid. Where lines get close together and then farther apart, the slope of the geoid has changed.

Ideally, a GPS station with a leveling-derived orthometric height is required whenever there is a change in the slope of the geoid and/or wherever there is an area of sparse gravity data. Figure 2 is a sample contour plot of the geoid. A '$' on the plot indicates where GPS stations with known orthometric heights should be located to verify that the change in the shape of the modeled geoid is real.

Gravity density plots can be used to indicate where bench marks are required because of the lack of gravity data. Of course, the alternative to this is to obtain more gravity data and recompute the geoid model. At this time, this task is not practical for the average user, but NGS plans to improve GEOID93 using additional gravity data and comparisons of geoid height estimations using precise GPS and leveling data. For this project, additional gravity observations were obtained and a high-resolution geoid model was recomputed. For now, in other areas, GPS users can occupy known vertical control with GPS in areas where there is sparse gravity data. Figure 3 depicts an area of sparse gravity data. A '$' on the plot indicates where GPS stations with known orthometric heights should be established because of lack of gravity data.

It should be noted that these added stations may not be required if the geologic makeup of the area is known. The user can then make some assumptions based on gravity data, Bouguer and free-air anomaly plots, and geologic data of the area. This would depend on the accuracy of the available geologic data. In some areas it may be easier and more reliable to collect additional gravity data to assist in determining the accuracy of the geologic data. This is outside the scope of this project, but may be addressed in future projects.

Bouguer anomaly plots can be used to indicate where there are apparent changes in densities of material beneath the Earth's surface which could cause changes in the shape of the geoid. The shape of the geoid will vary depending upon changes in densities in material beneath the surface of the Earth. The user should have a GPS station which has a known leveling-derived orthometric height wherever the spacing between contour lines changes. Figure 4 is a plot of Bouguer anomalies. Once again, a '$' on the plot indicates where a known orthometric height is required to assist in determining if the change in slope of the geoid is real or an artifact of some error in the gravity data.

It should be apparent by now that only a contour plot of geoid heights in the vicinity of the GPS project may not provide enough information to enable a user to strategically locate stations with known orthometric heights within the project's areal extent. It should also be apparent by now that determining where to place GPS stations with known orthometric heights is not a difficult task, but it is not an exact science either. Performing this task during the planning stage of the project can save time later. The gravity density plots and contour plots of modeled geoid heights are probably the easiest for users to use and probably the best indicators of where it is necessary to have known vertical control occupied with GPS.

Demonstration of Minimum Steps

Various aspects of each step outlined in the introduction are described in more detail in other reports (Zilkoski and Hothem 1989, Zilkoski 1990a, and Zilkoski 1990b). These reports indicate several references which may be useful to GPS users. The steps will be used to estimate GPS-derived orthometric heights for the San Diego County high precision GPS project.

Step 1

The first step is to analyze the geoid in the area. Figures 5 through 13 are plots which depict geoid and gravity information in the area of the project. Figure 5, a contour plot of GEOID93 values, indicates a significant tilt from both the east and west sides of the project towards the center of the project area. The network should consist of bench marks occupied with GPS in such a manner to be able to confirm that these two different slopes are real.

Figure 6 is a plot of Bouguer anomalies in the area before any new gravity data were collected. It indicates large variations in structure which need to be checked. Note that, as expected, this is similar to the geoid plot depicted in figure 5. Figure 7 is a plot of free-air anomalies in the area. It also indicates that a significant tilt may be present. This is not surprising, because the terrain in the area is fairly mountainous. Bench marks located evenly throughout the project should be occupied with GPS to check the geoid model.

Figures 8a-8e indicate that the distribution of gravity data surrounding the area is probably not adequate and some voids should be filled in with gravity observations or bench marks should be occupied with GPS. The problem in this area is that the areas of sparse gravity data are in the mountainous regions of the county, so it is probably not feasible to level to many stations. It was decided that it would be easier and cheaper to obtain additional gravity data to check the geoid model. It should also be noted that this project is near the Pacific Ocean coastline where there is a lack of gravity data in the water.

Gravity void plots of the San Diego County region (32° 30′ N - 33° 30′ N, 116° 0′ W - 118° 0′ W) were generated and used to determine where additional gravity observations were required. The void plots indicated on a 2′ by 2′ (3 km x 3 km) grid where additional data were required. These plots, along with a computer diskette, were sent to Mr. Gerard (Tony) A. Nothdurf, CALTRANS, District 11, San Diego, California. (See appendix D.) Bouguer anomaly, free-air anomaly, and gravity data density plots were also generated to assist in the planning phase of the project.

USGS personnel in Sacramento, California, were contacted to obtain any existing gravity data collected by other agencies. It was determined that all available data were already in NGS' gravity data base.

Gravity void plots provide tabulated "gap" codes indicating the distribution of observed gravity data in a geographic area. The sizes of gaps are denoted by numerical codes for convenience in interpretation.

The method of analysis for the determination of data gaps (voids) is based on a circular pattern. The neighborhood of a point is subdivided into seven regions (rings) by concentric circles. The widths of rings are equal. It is determined through data searches which of the seven regions around the innermost circle, or cell, contain data. When there is an observed value in the cell itself, the gap code is set to zero, indicating that no new observation is required in this cell. When there is an observed value in the first ring but not in the cell, the gap code of the cell is set to one as an indicator of the closest observed value. If the first ring is also void of data, the search continues into subsequent rings outward until an observation is located, and the gap code is set according to the ring number, indicating the distance of the closest observation to the cell. The largest gap code value searched for is 8.

The search for gaps in the distribution of observed gravity based on the circular ring pattern is very simple conceptually. However, it would require a somewhat complex search and tabulation process to produce the void plot file. Therefore, a simplification in search strategy is achieved by laying a grid pattern of variable, but predefined, granularity, i.e., grid spacing, over the geographic area of which quadrangles designate the cells. Gap codes are then determined via data searches in the neighboring cells. Since these grid cells are rectangular, in contrast to the circular cells of the original ring pattern, the finer the grid's granularity the better the approximation to the original ring pattern. The most frequently used two-arc-minute granularity provides a good approximation to the ring search. Zero gap codes are shown as dots on the void plots to enhance readability. Figure 9a is a sample gravity void plot.

Figures 9b-9f are gravity void plots of the San Diego County area. Looking at figs. 9b-9f it is obvious that many areas needed additional gravity observations. A gravity observation program for the project was developed with CALTRANS personnel.

Descriptions and plots of the gravity base stations were generated and sent to CALTRANS. CALTRANS performed the reconnaissance to determine which stations were useable.

Robert E. Moose, Vertical Network Branch, NGS, traveled to San Diego to instruct CALTRANS personnel on how to conduct gravity surveys. Four CALTRANS field personnel were trained in making gravity observations, conducting gravity surveys, and using the HP 95XL gravity data logger program. During Mr. Moose's training the following gravity tasks were completed: 1) local calibration of the gravity meters, 2) establishment of seven base stations, and 3) observation of the first two areas needing densification (27 stations). Appendices E through G contain information related to the gravity observation program.

CALTRANS personnel plotted gravity void information on large-scale maps to assist in survey planning. Proposed stations which filled the void areas were plotted on these maps. Sites which were reasonable to reach by vehicle were labeled as drive stations and others were labeled as helicopter stations. The goal was to obtain gravity observations throughout the county at a 3 km by 3 km spacing. Since there was a limited budget allocated to this project, discussions with USGS personnel were used to establish priorities.

A total of 333 gravity data sites were observed and "field" processed by CALTRANS personnel. These data were "office" processed and loaded in NGS' gravity data base by NGS personnel. The new data were then used to generate new Bouguer anomaly, free-air anomaly, and gravity density plots. Figures 10a-10d depict the locations of the new gravity observations. Figures 11a-11e depict the location of all gravity observations now in the NGS gravity data base (NGS_GRAVITY). Figure 12 depicts the Bouguer anomaly plot which includes the newly observed gravity data. Comparing figure 6 with 12 indicates that where the new data were added there were some slight changes in the apparent structure of the earth's subsurface.

After the new gravity observations were loaded into NGS' gravity data base, a new geoid model, denoted in this report as GEOID93S, was computed. The differences between GEOID93S and the latest national geoid model, GEOID93, were compared. Figure 13 depicts contours of the new geoid. Figure 14 is a plot of the <u>differences</u> between GEOID93 and the new geoid model GEOID93S. Notice that some differences reach 4 cm in areas where new data were observed. These differences are significant when the goal is to estimate GPS-derived orthometric heights accurate to 3 to 5 cm. This will addressed in more detail later in this report.

A more detailed analysis of the geoid height model developed during this project is currently be prepared by Wes Parks, CALTRANS, and Dennis Milbert, NGS, and will be published as a separate report.

Leveling Data Section

Step 2 is to determine and evaluate the existing vertical control in the area. There are several NGS first-order leveling lines that were leveled between 1987 and 1989 in support of the new adjustment of the North American Vertical Datum of 1988 (NAVD 88) which are located in the eastern, western, and southern portions of the project. Figure 15 depicts the location of bench marks with NAVD 88 values in Southern California. As expected, there wasn't any vertical control with NAVD 88 heights located inside the project area. (See figures 16a.)

Bench mark movement is an error source that many analysts ignore, or do not have enough information to evaluate properly. The Federal Geodetic Control Subcommittee (FGCS) vertical control procedure to check the stability of bench marks is to perform check leveling between two or more bench marks and compare the results with published values. This is the recommended procedure. A less reliable method, but certainly a reasonable method which can be used when employing GPS equipment, that probably would be less expensive is to occupy two nearby bench marks (e.g., 2-3 km apart) using GPS.

The errors in geoid height differences using GEOID93 over lines 2-3 km long in most regions of the United States should be small enough that GPS-derived orthometric height differences can be compared with published orthometric height differences to check the stability of bench marks to at least the 2-to-4 centimeter level. The analyst must also ensure that all bench mark values are referenced to the same vertical reference system, e.g., NAVD 88, and that published values do not contain inconsistencies due to inconsistent previous adjustment constraints (Zilkoski, Richards, and Young, 1992).

None of the stations selected by San Diego County were bench marks with NAVD 88 values. Two stations, SD GPS 03 and YUNG, were leveled to by Metropolitan Water District of Southern California (MWDSC) in September 1992 during one of their projects. Bench marks in the San Diego County area which have NAVD 88 heights in NGS' NGSIDB were retrieved and plotted with the location of the GPS stations. (See figure 16a.) Eight GPS stations were located near bench marks which had NAVD 88 height values: Ocotillo, SD GPS 31, CA 11 02, Junction AZ, SD GPS 33, CA 11 01, SD GPS 24, and SD GPS 01. (See figs. 16b and 16c.)

Bench marks in the San Diego County area which did not have NAVD

88 heights, but were leveled to after 1977 were retrieved and plotted. This network consisted basically of leveling lines observed in 1978 during the Southern California Releveling Program (SCRP). (See figure 17.) These SCRP data were incorporated into NAVD 88. The NAVD 88 height of one GPS station, 11 AAR, was established by this adjustment.

Other agencies were contacted to determine if they had leveling data which would help generate a more consistent network. Due to the age of the data, network design, and because the data were not in computer-readable form, it was decided that it was not feasible to include any additional data from other agencies for this project.

After the SCRP data were incorporated into NAVD 88, the San Diego County GPS stations were plotted with bench marks that had NAVD 88 height values. Three more GPS stations were located near bench marks involved in the SCRP network adjustment: SD GPS 32, SD GPS 15, and SD GPS 35, and ,as previously stated, the height of one GPS station was computed in the SCRP adjustment: 11 AAR. (See figure 18.)

It was not feasible to perform precise leveling procedures to tie the San Diego County GPS stations to bench marks with NAVD 88 heights. CALTRANS personnel could, however, perform precise trigonometric procedures to some of the stations. Therefore, NGS and CALTRANS developed draft specifications and procedures to perform precise trigonometric height differences for short leveling runs. NGS personnel performed several precise leveling ties to San Diego County GPS stations and CALTRANS performed the special trigonometric procedures over the same lines. The special trigonometric procedures seemed to work well and it was decided to use the trig procedures, if the line lengths were limited to 10 km.

Leveling and/or trigonometric leveling ties were made to as many stations as feasible. A total of 14 out of the 34 GPS stations were tied to NAVD 88 using short leveling and/or trigonometric leveling ties. One of the 14 stations, SD GPS 34, was tied to a 1970 leveling line. A special NAVD 88 height value was estimated for this tie station. This special NAVD 88 height value will not be published as an official NAVD 88 height.

Most of the GPS stations were located too far from leveling lines to make it feasible to perform a tie for this project. However, some of the San Diego GPS stations may be tied to the system in the future as other projects are undertaken.

It should be noted that it was not possible to obtain leveling-derived orthometric heights on GPS stations where the new geoid model showed significant changes. Most of the areas where gravity data were obtained were in areas where there is very little leveling activity. Helicopters were used in many cases because it was impossible to drive to the sites. Some of the drive stations may be tied in the future using the new trigonometric specifications and procedures. This was understood and agreed upon in the beginning of this project.

Appendix H contains the leveling/trigonometric height differences used to estimate NAVD 88 orthometric height values for the San Diego GPS stations. Appendix I contains the draft specifications and procedures used to perform the specially designed trigonometric leveling. Table 1 lists the values of these stations and the procedures used to estimate their height values. The following list summarizes the procedures used to estimate the NAVD 88 heights for the 17 GPS stations:

Level(1) - NAVD 88 height estimated by incorporating 1978 Southern California Releveling Project (SCRP) leveling data into NAVD 88,

Level(2) - NAVD 88 height estimated by using a short one-mark leveling tie from a station which had a published NAVD 88 height,

Level(3) - NAVD 88 height estimated using a new leveling line (1992) which was incorporated into NAVD 88,

Level(4) - NAVD 88 height estimated by using a short one-mark leveling tie from a NAVD 88 SCRP (1978) adjusted height,

Trig(1) - NAVD 88 height estimated from a height difference obtained using specially designed trigonometric procedures. A one-mark tie was from a bench mark which had published NAVD 88 height value,

Trig(2) - NAVD 88 height estimated from a height difference obtained using specially designed trigonometric procedures. One-mark ties were connected to bench marks which had NAVD 88 height values obtained when the SCRP network was incorporated into NAVD 88,

Trig(3) - NAVD 88 height estimated from a height difference obtained using specially-designed trigonometric procedures. A one-mark tie was from a bench mark which was last leveled to in 1970. A NAVD 88 height value was estimated for the tie bench mark using the 1970 data.

GPS Data Analysis

Steps 3, 4, and 5

The next phase to design, observe, and process the GPS data. This portion of the project was already completed by San Diego County and submitted to NGS in 1991 for incorporation into NAD 83. The processed GPS vectors were retrieved from NGSIDB and used in this project. Figure 19 is a plot of the GPS stations and vectors. The San Diego County GPS project, denoted GPS430 in NGSIDB, was classified as meeting FGCS GPS B-order specifications and procedures, i.e., 8 mm + 1:1,000,000. There were 34 stations occupied simultaneously over a 3 day period. Data were gathered during each session for a duration of 7 hours. These data were then reduced using one reference station for each day. On days 1 and 2, station Monument Peak was used as the reference station, and on Day 3, San Diego GPS 12 was used as the reference station. The correlation coefficient matrix was computed for each set of observations.

Steps 3, 4, and 5 are interwoven. First, a 3-dimensional minimum constraint least squares adjustment of the data was performed. Figure 20 is the residual plot of the GPS "up" component, du, from a minimum-constraint least squares adjustment. The residuals ranged between +/- 5.7 cm, with a RMS value of 1.8 cm. Appendix J contains the results of the minimum-constraint least squares adjustment.

Notice that a few residuals exceeded 5 cm, although most are between +/- 3 cm. These observations were investigated because of their large residuals. If the goal is to obtain GPS-derived orthometric heights with uncertainties between 3 and 5 cm, then these data must be considered potential data outliers. Also, notice that the spread of the residuals does not seem to increase as the line length increases. Dual-frequency GPS receivers and long observing duration times were used, which help to decrease errors significantly.

GPS results can also be evaluated by analyzing network loop misclosures and repeat base line differences. These analyses tools are very <u>effective</u> when the network consists of small loops, triangles, braced quadrilaterals, and repeat base lines. Classical techniques of establishing horizontal and vertical control used networks which consisted of many loops, triangles, and braced quadrilaterals. This design helped in detecting data outliers. GPS can provide absolute and relative positioning information much easier, faster, and more precise than some classical techniques, but the wrong station can still be occupied, the height of antenna can be measured wrong or incorrectly entered during the base line reduction processing phase, the receiver can malfunction, an abnormal atmospheric condition can cause large errors in the height component, or some "unknown Gremlin" can be causing an error source not yet detected. Occupying all stations at least twice helps to detect, reduce, and/or minimize some of these errors.

Loops were not analyzed in this project because all stations were occupied simultaneously and all sessions were reduced using one reference station. Since there were only three sessions, the height component residuals for each vector for each session were plotted. Figure 21 depicts the residuals in the height component from the minimum constraint least squares adjustment for each "TO" station for each session. For example, the three values at station SD GPS 35, -0.9, 2.7, and -1.4, are the du residuals in cm for vector Monument Peak to SD GPS 35 on day 1 (-0.9 cm), Monument Peak to SD GPS 35 on day 2 (2.7 cm), and SD GPS 12 to SD GPS 35 on day 3 (-1.4 cm). Stations SD GPS 07 and CA 11 09 only have two values because they were not observed on day 1 of the project due to unavoidable logistical problems.

To evaluate how good the GPS-derived ellipsoid heights were estimated, seven minimum-constraint least squares adjustments were performed using the following different sets of data:

1) all data,
2) only day 1 data,
3) only day 2 data,
4) only day 3 data,
5) days 1 and 2 data,
6) days 1 and 3 data,
7) days 2 and 3 data.

The GPS-derived ellipsoid heights from the adjustments were tabulated and compared with each other. Tables 2 and 3 present the differences in ellipsoid height estimated using the seven different sets of adjustment results.

Day 1 seems to disagree with day 2 and day 3, more than day 2 disagreed with day 3. (Compare columns 10 and 11 with column 12 in table 2.) There is a 10 cm spread at several stations between day 1 and day 2 results. However, when day 1 and day 2 are combined and compared with the results using all data, the differences are typically between +/- 2 cm. (See column 7 in table 3.) Comparing any two-day combination with the all-data solution indicates the differences are between +/- 3 cm. (See columns 7, 8, and 9 in table 3.)

It should be pointed out here that the published ellipsoid heights from NGSIDB for project GPS430 were not used for this study because of differences in ellipsoid height differences between California High Precision GPS Network (CAHPGN) stations, which were established in project GPS412, and San Diego County GPS stations. Ten CAHPGN stations were in common with the San Diego GPS network.

A comparison of the 10 CAHPGN final ellipsoid heights resulting from the HPGN final adjustment with ellipsoid heights resulting from a minimum constraint adjustment of the HPGN project indicated relatively small changes in heights due to constraints imposed in the final adjustment of the HPGN. However, even though most of the differences were only a few millimeters, two height differences were greater than 2.5 cm and the largest relative difference was 8 cm.

Using these heights along with the horizontal coordinates from the CAHPGN final adjustment as constraints in the San Diego GPS network adjustment could enter a distortion in the ellipsoid heights at the few cm level.

A comparison of ellipsoid heights obtained from a minimum constraint solution of GPS430 with their published ellipsoid heights indicate several relative differences greater than 10 cm. These differences were at stations which were part of the CAHPGN. (See table 4.)

These differences could be looked at in two ways. Either the coordinates from the CAHPGN stations are more accurate than the San Diego GPS data and they should be constrained in an adjustment to help control remaining errors or constraining the HPGN values will distort the final set of San Diego GPS-derived ellipsoid heights.

CAHPGN stations were established according to FGCS B-order specifications and procedures. They were occupied at least twice for about 4 hours for each occupation. Their base line lengths were approximately 50 km. The San Diego County stations were occupied three times for 7 hours each occupation. All 34 stations in the San Diego GPS network were occupied simultaneously over 3 separate days. The San Diego project residuals in the vertical component were typically between +/- 3 cm, with a mean value of 1.8 cm. The CAHPGN GPS residuals in the vertical component were typically between +/- 10 cm, with a mean value of 3.2 cm.

As stated previously, CAHPGN (GPS412) established the heights of 10 stations which were common with the San Diego GPS network (GPS430). The data from GPS430 which were common to these ten stations were used in GPS412. These same data were then used in GPS430 again. The differences between a minimum-constraint least squares adjustment of GPS430 data and the solution loaded into NGSIDB indicate a few relative differences exceeding 10 cm. The adjusted values from the minimum-constraint solution of GPS430 data were used rather than the NGSIDB values because it could not easily be determined which values were better.

Although using the same data twice, unless there are unusual circumstances or if some special processing techniques are used, never appears to be the correct procedure to follow, for all practical purposes it may not have made any difference in the heights if GPS430 would have been re-reduced excluding the data already used in GPS412. Since the influence to the height values could not be determined without re-reducing the data, it was decided to use the results from the minimum-constraint solution of GPS430 data retrieved from NGSIDB. The set of adjusted heights and their standard errors are included in table 5.

Ellipsoid heights from the San Diego County GPS project were also compared with the ellipsoid heights from the Landers Earthquake project performed in 1993. GPS-derived ellipsoid heights estimated from minimum constraint least squares adjustments agreed to within +/- 4 cm after a trend was removed. Figure 22 is a plot of the differences with and without a trend removed. Table 6 contains the differences and trend-removal information.

GPS-Derived Orthometric Height Analysis

The next phase of the analysis is to compare adjusted GPS-derived orthometric heights obtained from a minimum-constraint solution with leveling-derived orthometric heights. Figure 23 is a comparison of the GPS-derived orthometric heights estimated using GEOID93S with NAVD 88 height values.

The results presented in figure 23 do not indicate any obvious problems. The relative differences between closely spaced GPS stations are all less than 5 cm. There appears, however, to be an apparent tilt in both the north-south and east-west directions. This could be due to errors in the GPS data, NAVD 88 orthometric heights, or modeled geoid height values. There is not enough information to separate the tilts into separate components due to different error sources.

However, local systematic differences in the system can be removed by solving for scale and rotation parameters (by holding the latitude and longitude values of two horizontal control stations and the height value of at least three vertical control stations fixed) in the adjustment when estimating the coordinates in a least squares adjustment; or the local systematic differences can be estimating using all the vertical control information and solving for trend parameters (east-west, north-south, and bias shift). This will be discussed in more detail later in this report.

Step 6

Step 6 is to analyze the local geoid in more detail. Figures 5 through 9 presented plots which provided geoid and gravity information that were used during the planning phase of the project. After GPS data are collected, processed, and preliminary adjustment results are analyzed, a more detailed analysis of the geoid in the area of the project is performed.

The location of the stations occupied by GPS in the project are shown with gravity-related informational plots on figures 24 through 29. The San Diego GPS stations and spot gravity site locations were plotted together. Figures 24 through 26 depict the location of GPS stations relative to gravity observations. Three separate plots were generated: 1) GPS stations and spot gravity site locations prior to CALTRANS observations (figure 24), 2) GPS stations and spot gravity site locations collected by

CALTRANS personnel (figure 25), and 3) GPS stations and spot gravity site locations after CALTRANS gravity was loaded into NGS' gravity data base (figure 26).

The project area is basically surrounded by vertical control. A total of 17 of the 34 stations have NAVD 88 heights. No vertical control exists in several portions of the county because of the mountainous terrain. This is, however, where the users want to eventually establish vertical control using GPS. Figure 27 depicts the location of the control on a contour plot of Bouguer anomaly values. There are many areas which are missing gravity observations and the differences in Bouguer anomaly values appear to be different significantly throughout the area. From the western side of the project to the center of the project area, the difference in Bouguer anomaly values is about -60 mgals; from the center of the project to the eastern side, the Bouguer anomaly difference is about 40 mgals; and it is about 20 mgals from the top of the project area to the bottom.

A question which needs to be answered is, what is the expected change in a geoid height for a certain amount of change in a Bouguer anomaly value? This question does not have a simple answer because gravity anomalies surrounding the area of interest are influencing the geoid height values inside the project area. Therefore, you cannot just look at a relative Bouguer anomaly difference and determine what the geoid height difference should be. It should be noted that the purpose of these plots is not to estimate a change in geoid height, they are used to determine a priori if there are areas in the project where the modeled geoid height values need to be verified.

Figure 28 is a plot of the modeled geoid height using the special geoid model developed for this project. It indicates that there is a tilt in the geoid similar to the Bouguer anomaly tilt indicated on figure 27. This is not unusual. The geoid height differences are 3 meters from the sides of the project to the center. From one side to the other side the difference is close to zero. It looks like two separate planes which meet in the middle of the project. That is, the geoid height at station CA 11 07 is -34.12 and the geoid height at station SD GPS 15 is -31.40, and the geoid height at stations OCOTILLO is -34.04. The project area is approximately 200 km across. From each edge to the center is approximately 100 km; therefore, the geoid slope is approximately 1:30,000 or this is 3 cm change in geoid height per kilometer in distance. A 10 percent error in the slope of the modeled geoid would result in 3 mm per kilometer error. In 10 kilometers the error would be 3 cm. This possible error needs to be checked and, if present, reduced and/or eliminated when estimating GPS-derived orthometric heights at the 3 to 5 cm level.

Figure 29 is a plot of the differences between GEOID93 and GEOID93S. Some differences approach 4 cm. As expected, these differences occur where the new data were collected. Once again, these differences are important when estimating GPS-derived orthometric heights at the 3 to 5 cm level.

Step 7 and 8

Step 7 is to estimate GPS-derived orthometric heights and local systematic differences between the three height systems by solving for trend parameters. Step 8 is to analyze the results.

Figure 30 presents the comparison of adjusted GPS-derived orthometric heights obtained from a minimum constraint least squares adjustment with NAVD 88 height values. While there appears to be only a few anomalous values, there is a very obvious trend between the two sets of heights.

Figure 31 is a plot of the differences after a simple trend (plane) was used to remove some of the discrepancy between the two sets of heights. Table 7 lists these differences. The coefficient-of-correlation value was only 71 percent, but the relative differences between closely spaced stations seem to improve. The overall differences between stations located in the southwest corner and the stations located in the northeast corner improved significantly, i.e., from stations SD GPS 24 and 11 AAR the difference was 17.6 cm before a trend was removed and -0.1 cm after a trend was removed.

Trend removal procedures include analyzing the results to determine if there are data outliers. These outliers may be due to bench mark movement, ellipsoid height errors, and/or inaccuracies in the geoid height model. After several iterations of rejecting data outliers, a new set of trend parameters were estimated. These values are depicted in figure 32 and table 8. The procedure used to select data outliers was to reject the largest data outlier which was greater than 5 cm and then recompute the trend parameters without the data outlier. This process was repeated until no residual value was greater than +/- 5 cm.

There were four stations rejected: three of the four stations (CA 11 07, GPS 21, and GPS 34) indicated large differences in GPS-derived ellipsoid heights (greater than 10 cm) between day 1 and day 2 observations. (See table 2, column 10.) The fourth station rejected, OCOTILLO, is hanging out by itself outside the county. All stations were connected to NAVD 88 bench marks using one-mark, short leveling/trig ties. Two stations were connected to older leveling data, GPS 21 was tied to 1978 leveling data and GPS 34 was connected to 1970 leveling data. After removing a trend the differences (not included rejected stations) ranged between -4.4 cm and 2.6 cm and the coefficient of relation was 88 percent.

Even at the rejected stations, the differences between GPS-derived orthometric heights and leveling-derived orthometric heights were only between -6.9 cm and 5.4 cm. This is over a distance of approximately 80 km. Most relative differences for stations 20 to 25 km apart are less than 5 cm.

Most of the differences between the system using all data and the system with rejections are less than a few centimeters. (See table 9, column 15.) The RMS value is lower and the coefficient-of-correlation value is better, but the evidence for rejection of these stations is weak at best. More will be said about this later in the report. The results using GEOID93 are also presented and showed similar results. (See figure 33 and tables 7, 8, and 9.)

During the transition from a leveling-derived orthometric height system to a combined GPS-derived and leveling-derived orthometric height system there will be different methods used to estimate a consistent set of GPS-derived orthometric heights for a project. NGS ultimately envisions implementing a system where GPS data, gravity/geoid heights, and leveling-derived orthometric heights are adjusted together and a single, homogenous set of adjusted ellipsoid heights, geoid heights, and orthometric heights are generated. It is not difficult to perform an adjustment like this, but the results are not meaningful unless the relative weighting scheme is correct. NGS has used the integrated geodesy approach for computing geoid models for special projects (Milbert and Dewhurst 1992).

Kearsley et al. (1992) performed a study to develop and test numerical methods needed for combining GPS-derived ellipsoid heights and gravimetrically-derived geoid heights into an existing leveling network. As expected, they concluded that realistic estimates of accuracy and precision of the observed data and derived quantities are needed. NGS will continue to perform studies to estimate appropriate, realistic standard errors of GPS-derived ellipsoid heights, geoid heights, and orthometric heights.

<u>During the transition period, NGS will recommend a single method that all users should use for consistency and traceability</u>. However, this report is meant to be a guide for others and one of

its purposes is to generate discussion to determine the best method of estimating GPS-derived orthometric heights.

Through discussions with users there appears to be three methods which are typically employed today to estimate GPS-derived orthometric heights for projects. Method 1 is called the scale and rotation method because scale and rotation parameters are solved for, along with the adjusted coordinates. Method 2 is called the trend removal method because trend parameters are used to apply rotation parameters to GPS vectors to account for the differences between the three height systems. Method 3 is called the height distribution method because differences between the three height systems are distributed into the unconstrained horizontal (latitude and longitude) and vertical coordinates (ellipsoid heights). These three methods are demonstrated using the San Diego GPS project and the results are compared.

Selection of Constraints and Removal of Trends

Method 1: Scale and Rotation Method

The first method, denoted as the scale and rotation method, is described in detail in Vincenty (1987) and demonstrated in Zilkoski and Hothem (1987). This method removes differences between the three height systems by solving for scale and rotation parameters along with the adjusted heights using two known latitude and longitude values and all known orthometric height values as constraints. The adjusted heights are provided in table 10, column 2.

When solving for scale and rotation parameters, the selection of constraints is important to the final set of heights. Most of the GPS adjustment software available today make it easy for users to constrain coordinates (latitude, longitude, and height) of individual stations and solve for scale and rotation parameters. When making the selection of constraints, if the analyst uses the procedures outlined in this report, the final set of heights should not be distorted very much.

It was previously stated that appropriate GPS-derived coordinates (latitude, longitude, and ellipsoid heights) computed from higher-order surveys could be used to control the lower-order network adjustment. The analyst must be careful that horizontal coordinates (latitude and longitude) which are less accurate than the GPS survey are not held fixed. These constraints will force errors into ellipsoid heights of nearby stations. See Zilkoski (1991) for more details. These GPS-derived coordinates can only help to control errors if they are of higher accuracy than the

GPS data being adjusted. The analyst must avoid the urge to fix all known control in one adjustment to obtain one set of latitude, longitude, and ellipsoid heights.

Method 2: Trend Removal Method

A second method, denoted in this report as the trend removal method, basically best fits a plane through the differences between the GPS-derived orthometric heights obtained from a minimum constraint adjustment and the NAVD 88 orthometric height values. Using this method, all appropriate differences between the height systems are used to solve for trend parameters which best describe the differences between the three systems. The trend parameters are then used to rotate the GPS vectors in the new system.

The height differences shown on figure 23 and table 7 were used to demonstrate how the trend removal method was implemented in this project. Once again, the differences on figure 23 are from the comparison of adjusted GPS-derived orthometric heights obtained from a minimum constraint least squares adjustment with published NAVD 88 values. Figure 31 depicts the results when all values were used to estimate the trend parameters and figure 32 depicts the results when the anomalous values were removed. The project's GPS-derived orthometric heights using the trend removal method with rejected stations are provided in table 10, column 3.

Using this method, the ellipsoid heights will be consistent with each other, the GPS-derived orthometric heights will be consistent with the published values, and the remaining errors in the ellipsoid heights will be distributed in the GPS network. Of course, it is still important that all data outliers are removed. Errors in ellipsoid heights and/or orthometric heights should not be forced into the local trend removal model. If the bench mark moved, the GPS-derived orthometric height would supersede the old published height value and the difference would not be used in determining the trend model. Similarly, if the difference is shown to be due to an error in the ellipsoid height, then the difference should not be used to estimate the trend parameters. For this project, stations CA 1107, Ocotillo, SD GPS 21, and SD GPS 34 were not used to estimate the trend parameters, but their NAVD 88 height values were constrained in the adjustment.

A potential problem with this method is allowing an error in an ellipsoid height or an orthometric height or a geoid height to contaminate the local trend removal model. Some incorrect decisions may be made due to insufficient data. Although, if the analyst follows the steps outlined in this report and the network contains enough redundant observations, the size of these errors should be relatively small. The analyst may recommend obtaining new data, i.e, GPS data, leveling observations, and/or gravity data, to help verify the results of the survey.

A major problem with this method is that the local height differences between the height systems which are being removed using local trend parameters must be documented and saved for future surveys. GPS surveys occupying different bench marks in the same area will probably obtain slightly different parameter values. Until NGS publishes a high resolution geoid model with uncertainties less than 1 cm over 10-15 km distances, these differences would have to be coordinated. After several neighboring projects are incorporated into the system, a combined readjustment may be necessary. These readjustments cannot be avoided during the transition period. However, if each project is surrounded by published leveling-derived orthometric heights, the distortions between small county-size GPS projects should be relatively small and easily handled. This is not the easiest method to implement at the National level.

Height Distribution Method

The height distribution method is probably the easiest method to use. In the height distribution method, the orthometric heights of all published height values are constrained to their published values. The project's GPS-derived orthometric heights using the constrained height method are provided in table 10, column 4.

This method can be used to account for the differences between the height systems by constraining all published height values and forcing the differences into all three components of the unconstrained stations and into the two horizontal components of the vertically-constrained stations. Some users do not like this method because it forces non-GPS errors into GPS vectors. This is why method 1, or some variation of method 1 such as the trend removal method, is used by some analysts. However, if the differences are small, this method will not distort the remaining GPS-derived orthometric heights very much. It does have a major advantage of being much simpler to implement because trend parameter values do not have to be modeled or disseminated.

A disadvantage of this method is that good GPS-derived heights may get distorted,.although if surveys are properly planned, i.e., short line lengths, small loop lengths, repeat occupations, and a lot of bench marks occupied, it should be possible to reduce the amount of distortion distributed throughout the network. Specifications and procedures will be developed such that large non-GPS errors will not be forced into GPS vectors. In addition, implementation of this system may require counties and states to establish state-wide high accuracy reference networks (HARNs) and county-wide GPS networks similar to this one in San Diego County.

As mentioned above, constraining all published height values does remove the differences between the three height systems. This method is feasible today because of the development of the high-resolution geoid model, GEOID93. The user, however, must be extremely careful using this method because errors in all three height systems are forced into the final set of GPS-derived orthometric heights.

A Discussion About Estimating the Final Set of Adjusted Heights for a Project

Accounting for Systematic Differences Between the Three Height Systems During the Transition Period

One of the things to remember about establishing and maintaining a vertical control network is preserving consistency. A network consisting of many inconsistent local networks is relatively useless to many users. When the orthometric height of a station is superseded because of adjustment constraints and not because the monument's physical location has changed, the stations near this monument must be made consistent with its new value. Of course, forcing excessive distortions into the network also makes a network less useful.

In the previous section, three methods were presented for estimating GPS-derived orthometric heights <u>for a project</u>. This section will present the differences between the three methods.

Steps 9 and 10

The last two steps of the project are to compute GPS-derived orthometric heights by performing a 3-dimensional least squares adjustment holding fixed all <u>appropriate</u> orthometric height values of published bench marks (and <u>appropriate</u> GPS-derived coordinates (latitude, longitude, and ellipsoid height) computed form higher-order surveys, removing systematic differences between the height systems, and using the results from all the steps to document the estimated accuracy of the GPS-derived orthometric heights. Notice the key word underlined above, appropriate. Steps 1 through 8 are performed to help determine what <u>appropriate</u> means and to assist in documenting "how good" the GPS-derived orthometric heights really are.

This report has described three method of establishing GPS-derived orthometric heights for a project and for accounting for the systematic differences between the three height systems. These methods should be used for each project and the results compared.

Comparison of Three Methods

Notice that all three methods provided similar results. (See table 10.) However, there are several large relative differences between the height distribution method (method 3) and the other two methods. Figure 34 depicts these differences. For example, the height of station SD GPS 23 using method 3 differed by -8.5 cm from method 1 and by -9.1 for method 2. These results do not ensure that all three methods will work the same way everywhere. It does indicate that during the transition period, all three methods should be performed for a project and if there are not significant differences between the results, then the constrained height method should be used to estimate the GPS-derived orthometric heights.

The constrained height method is the easiest to maintain consistency on a National level and the recommended procedure were possible, but users must ensure that "large distortions" have not been forced into surrounding heights. If the San Diego GPS network GPS-derived orthometric heights are estimated using methods 1 or 2, then local surveys will probably be able to use method 3 when properly connecting to the San Diego GPS network.

A simple procedure which can be used to determine the effect of forcing differences between the three height systems into surrounding height is to compare residuals in the height component obtained from the overly-constrained adjustment with height component residuals obtained from a minimally-constrained adjustment. Figure 35 is a plot of the residuals in the height component from a minimum constraint least squares adjustment. Figure 36 is a plot of the residuals in the GPS up component from the adjustment using the scale and rotation method, figure 37 is a plot of residuals in the GPS up component from the trend removal method, and figure 38 is a plot of residuals in the GPS up component using the height distribution method. Table 11 lists the differences in height component residuals between each method and the minimum-constraint solution for each vector of the GPS project. Notice that most differences are less than 3 cm for methods 1 and 2. This is good because it indicates that the height constraints did not force any large distortions into the unconstrained heights. However, the many of the differences using method 3 exceed 5 cm. (See table 11, column 8.) This indicates that the height constraints did force some large distortions into the unconstrained heights. Figures 39 through 41 depict the differences in graphic form.

Since the residual plots look the best for the scale and rotation method, this method was used to establish the final set of GPS-derived orthometric heights in the San Diego GPS project. Appendix K contains the results of this adjustment. See table 10, column 2 for a list of the final set of adjusted heights.

Procedures To Follow When Estimating GPS-Derived Orthometric Heights in San Diego County

GPS-derived orthometric heights will eventually be routinely used in place of leveling-derived orthometric heights, probably sooner in Southern California than in other places in the United States because of the difficulty in maintaining a leveling network due to crustal movement. GPS will make it easier and cheaper to maintain a 3-dimensional system. Education is an important factor in the implementation of GPS-derived orthometric heights because users must accept and utilize orthometric height differences which have relative uncertainties that are typically greater than they are used to, i.e., between 3 and 6 cm for bench marks that are 10 km apart, and they must be able to determine and document how good the final adjusted GPS-derived orthometric heights really are.

The list of steps presented in this report are not meant to be complete. They are only a minimum set of steps which should be performed for all projects. The factors discussed in this report show how it is impossible to make categorical statements about the accuracy of GPS-derived orthometric heights. It is important that GPS users perform a prescribed set of steps. The results obtained during the analyses can be used to estimate the accuracy of GPS-derived orthometric heights. Every GPS project should perform the steps described in this report. The amount of detail will depend on the areal extent of the project.

Basic control and procedural requirements for estimating GPS-derived orthometric heights in San Diego County include:

1) Surround the project with bench marks which have NAVD 88 height values (minimum of six bench marks required).

a) At least three leveling-derived orthometric heights.
b) Stations with known orthometric heights need to be evenly distributed throughout the project.
c) All San Diego GPS network stations which are inside and at the edges of the project's areal extent must be occupied.

2) Hold one station's published height, latitude, and longitude values fixed. Compare the results with all published values.

3) Hold all published height values which were determined to be valid vertical control stations. Trend parameters should not have to be solved for in the San Diego County area if the above procedures are followed and the areal extent is relatively small.

Sample Project

City of San Diego GPS Network

The City of San Diego GPS network was used to help evaluate the final set of GPS-derived orthometric heights estimated for this project. Gregory A. Helmer, an employee of Robert Bein, William Frost and Associates, San Diego, California, was provided GPS-derived orthometric heights for seven San Diego GPS network control stations which were common to the City of San Diego GPS network. The GPS project tied into all San Diego GPS stations which were inside and at the edges of the project's areal extent. Nine bench marks with NAVD 88 heights were also occupied inside the City of San Diego project area. Figure 42 shows the areal extent of the city GPS network relative to the county GPS network.

Mr. Helmer performed a special adjustment fixing the GPS-derived orthometric heights of the San Diego stations established in this project. A comparison of the GPS-derived orthometric heights estimated from the special adjustment with the nine stations which had NAVD 88 height values indicated differences between -2.7 cm and 6.3 cm. Relative differences from a station to its closest neighbor was typically less than 2.5 cm. (See figure 43.)

The largest difference, 6.3 cm, was at station C 58 Reset. The elevation of this stations is 869 meters. The relative difference between M 1411 and C 58 Reset is -7.1 cm. The elevation difference between the two stations is 664 meters. Station C 58 Reset, which is hanging off the edge of the project, was observed twice, but both times which were on the same day was from station M 1411, i.e., a GPS spur observation. The length of the line is approximately 47 km. Additional analysis would need to be performed to determine if the ellipsoid height or orthometric height or geoid height has a several-centimeter error associated with it.

Excluding station C 58 Reset, the comparison of the GPS-derived orthometric heights estimated from the special adjustment with the eight other stations that had NAVD 88 height values indicated differences between -2.7 cm and 1.3 cm.

This project indicates that the San Diego County GPS-derived orthometric height system computed for the project can be used to implement GPS-derived orthometric heights in the area at the 3 to 5 cm level.

Conclusions

Using GPS to estimate an accurate orthometric height at a station is not as straightforward as using GPS to estimate accurate latitude and longitude. Establishing accurate vertical control requires shorter line lengths, more occupations, and occupation of more known vertical control than when establishing horizontal control. Therefore, when establishing accurate vertical control using GPS the horizontal control results may appear to be an overkill.

Several steps outlined in this report could be combined and, as a matter of fact, during the discussion some of them were combined. The intent of the list of steps was to point out that each step must be addressed. Many users skip the minimum constraint adjustment step and proceed directly to holding all vertical control fixed and analyzing residuals. This is not a recommended procedure because it could allow large errors to be forced into horizontal components and unconstrained vertical components, and these errors may go undetected. In addition, the error estimate of the unknown vertical control is almost impossible to determine this way.

Even though a high-resolution geoid has been developed for the continental United States, performing a detailed analysis of the geoid in the area of the survey is still one of the most important steps in computing GPS-derived orthometric heights at the 3 to 5 cm level. It is critical to determine which bench marks need to be occupied with GPS to adequately evaluate the geoid model or where additional gravity observations are required.

In the future, when high resolution geoid height values have meaningful error estimates associated with them, surveyors will be able to use the error estimates to help determine the accuracy of their GPS-derived orthometric heights. This would facilitate the implementation of GPS-derived orthometric heights into the surveying and mapping community. NGS is working on this task.

Even if geoid heights were known exactly, when the project's GPS-derived ellipsoid heights have large uncertainties, the GPS-derived orthometric heights will have large uncertainties. The current FGCS specifications and procedures contain <u>minimum</u> requirements to estimate GPS-derived ellipsoid heights. As previously stated, due mainly to atmospheric effects, the height component of GPS is less reliable than the horizontal components.

There are procedures which can be followed to assist in determining the relative precision of the GPS-derived ellipsoid heights. These procedures include occupying a station twice and comparing heights estimated from different vectors, comparison of repeat base line observations obtained over different days and conditions, checking loop misclosures against allowable tolerances, plotting residuals of height components (du) from least squares adjustments of GPS data, and comparison of GPS-derived orthometric heights with known orthometric heights. The list of steps provided in this report should assist users in computing usable GPS-derived orthometric heights for projects today.

The primary purpose of this report was to provide CALTRANS with a system for computing GPS-derived orthometric heights which meet their engineering/transportation surveying requirements. This report is also meant to be a first cut at a guide for users to estimate GPS-derived orthometric heights and document the results. It can be used to assist surveyors during the transition from a leveling-derived orthometric height system to a combined leveling-derived and GPS-derived orthometric height system.

This is a first attempt to document the procedures required to estimate accurate GPS-derived orthometric heights in the real world. It is recognized that this version requires a lot of improvement before it will be useful to the average surveyor or mapper. The intent of distributing this document now is to obtain comments and suggestions from GPS users and other reviewers in order to develop and document an official guidebook and Federal specifications and procedures to compute accurate GPS-derived orthometric heights which meet Federal Geodetic Control Subcommittee (FGCS) vertical control standards. New products will be developed to assist users, i.e., new-minus-old tables and gravity density plots.

Please send all comments and suggestions to:

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The next step in the process of implementing this system into the surveying and mapping community of San Diego County is to 1) perform a pilot project in a mountainous region of the county to evaluate the system, 2) develop procedures for disseminating new geoid information and GPS-derived orthometric heights for evaluating GPS projects performed in the area, and 3) establish a memorandum of understanding with CALTRANS, San Diego County, and NGS which addresses a plan for implementing GPS-derived orthometric heights in the county.

The plan will include publication of NAVD 88 GPS-derived orthometric heights, procedures for handling crustal movement at county stations, and procedures for users to perform leveling between GPS stations tied to the county network.

References

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Zilkoski, D. B. 1990a, Establishing Vertical Control Using GPS Satellite Surveys: Proceeding of the 19th International Federation of Surveying Congress (FIG), Commission 5, pp. 282-294.

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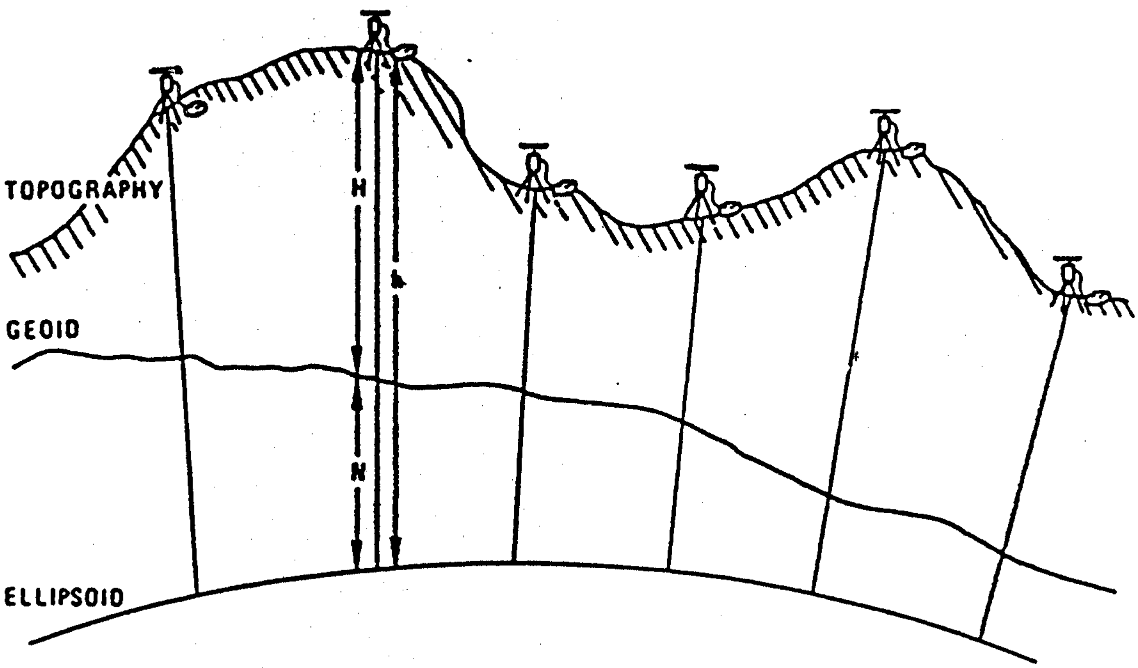
Zilkoski, D. B., Richards, J. R. and Young, G. M. 1992, Results of the General Adjustment of the North American Vertical Datum of 1988: Surveying and Land Information Systems, Vol. 52, No. 3, 1992, pp. 133-149.

List of Figures

Fig. 1

ORTHOMETRIC HEIGHT DIFFERENCES USING GPS RELATIVE POSITIONING



- BETWEEN TWO STATIONS SURVEYED BY GPS, WE CAN COMPUTE:

  Δh - ELLIPSOID HEIGHT DIFFERENCE

- IF FROM ASTROGRAVIMETRIC PREDICTION METHODS WE CAN COMPUTE:

  ΔN - GEOIDAL HEIGHT DIFFERENCE

- THEN,

  $\Delta H = \Delta h - \Delta N$, WHERE ΔH IS THE ORTHOMETRIC HEIGHT DIFFERENCE

Fig. 2

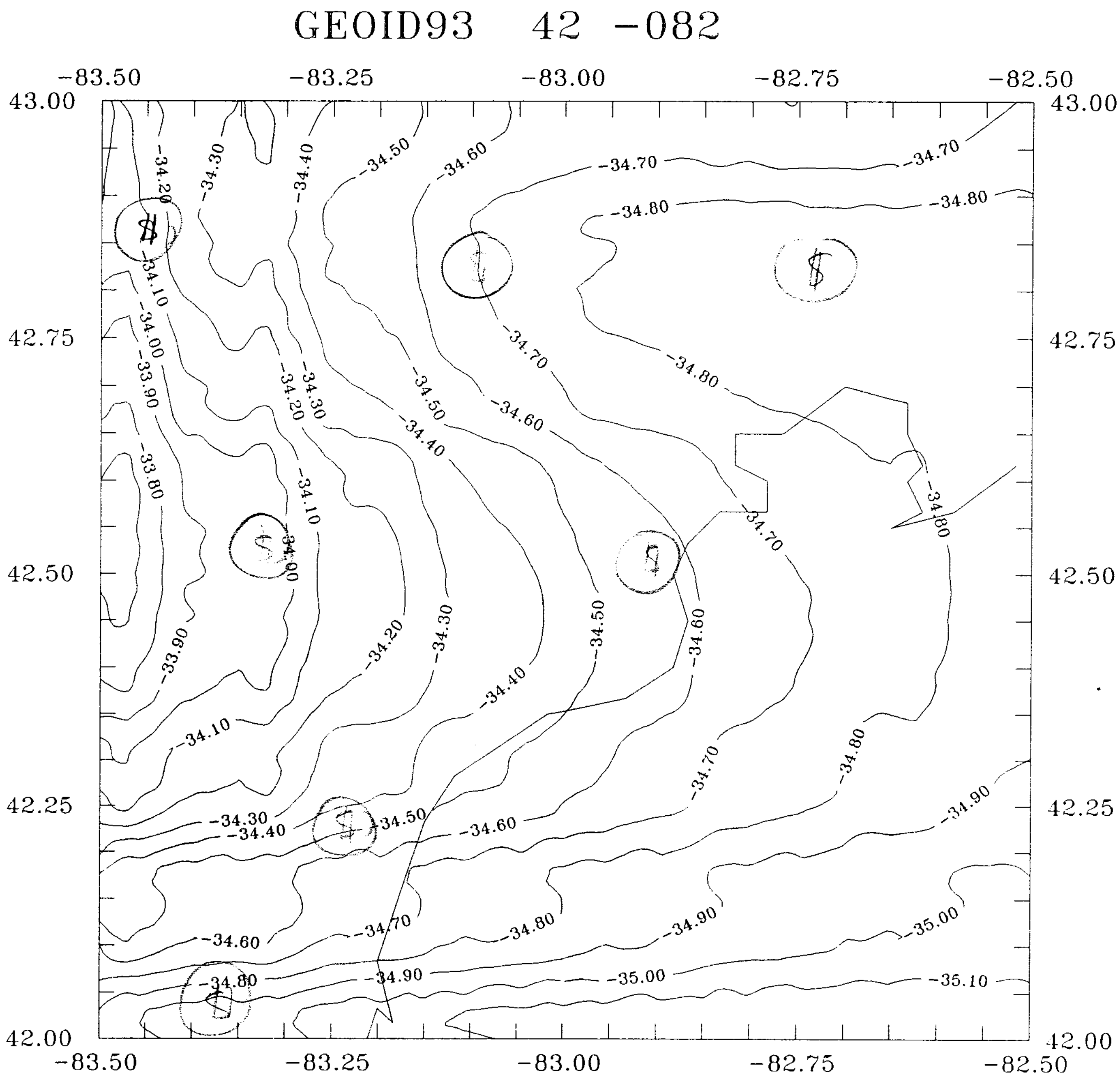

GEOID93 42 -082
-83.50
-83.25
-83.00
-82.75
-82.50
43.00
42.75
42.50
42.25
42.00
-34.20
-34.30
-34.40
-34.50
-34.60
-34.70
-34.80
-34.10
-34.00
-33.90
-33.80
-34.90
-35.00
-35.10

Fig. 3

Surface Gravity Density 42 -082

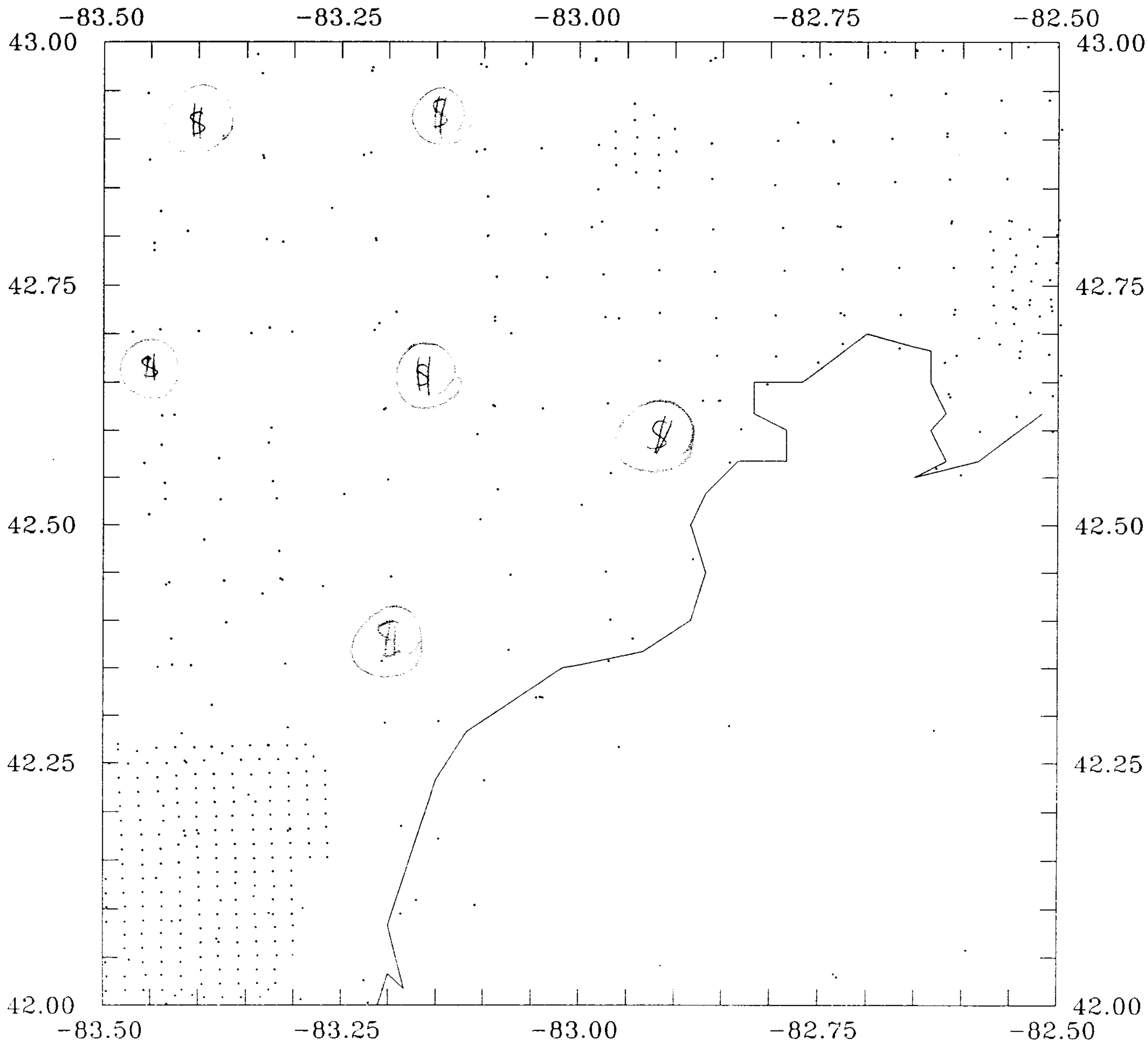


Fig. 4

Bouguer Anomalies 42 -082

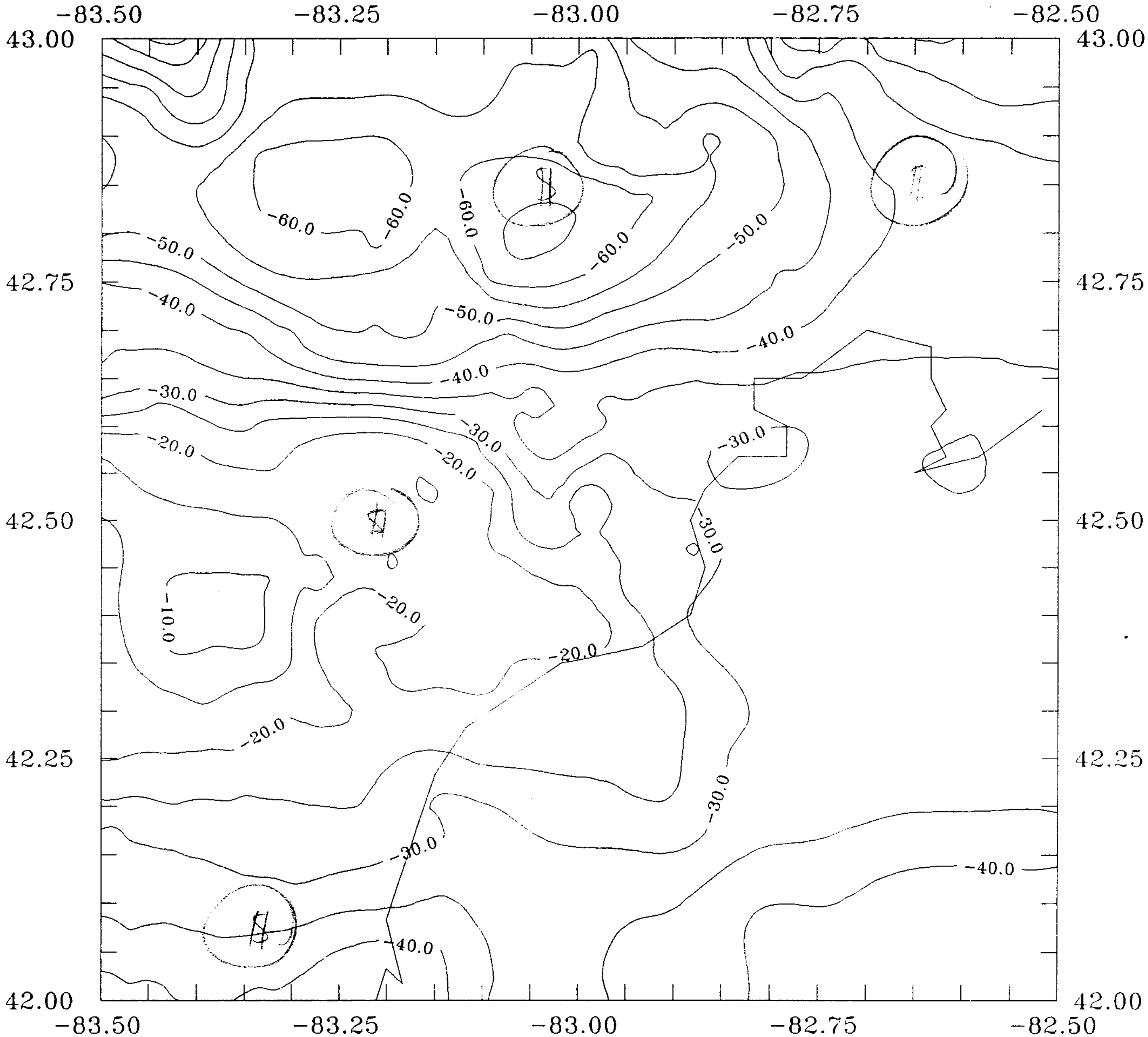


Fig. 5

units = meters

GEOID93 - San Diego area

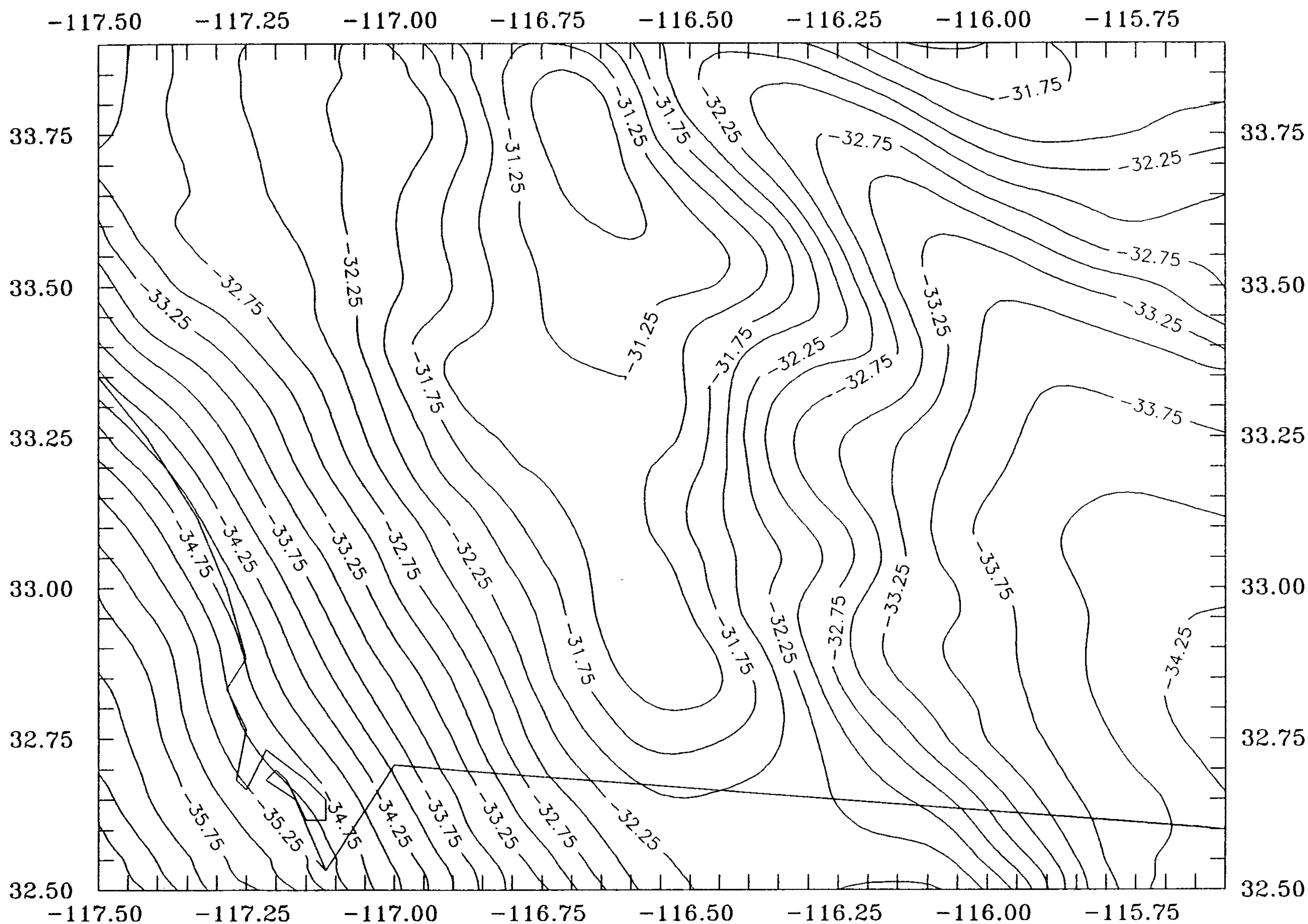
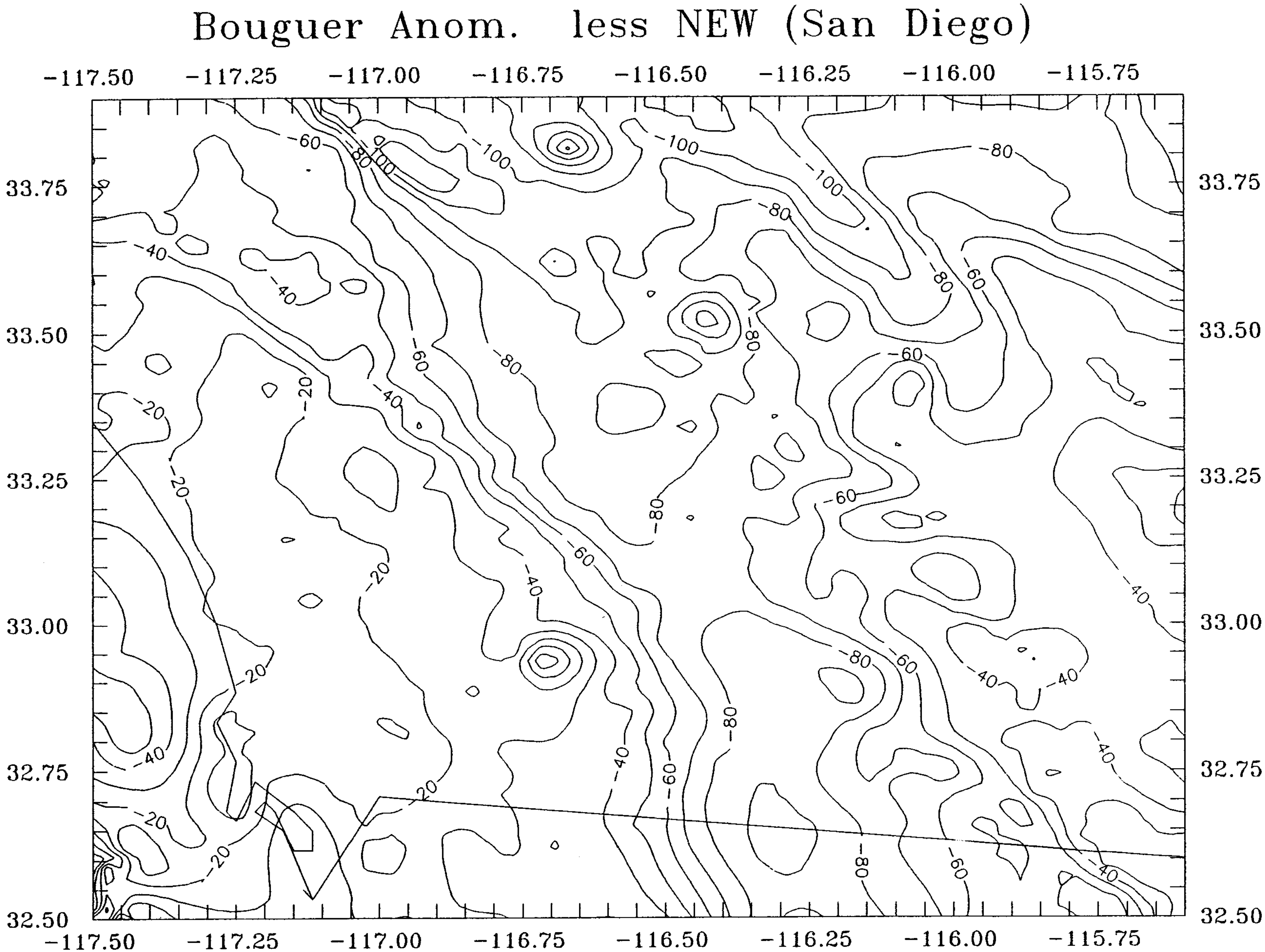


Fig. 6



Bouguer Anom. less NEW (San Diego)
-117.50
-117.25
-117.00
-116.75
-116.50
-116.25
-116.00
-115.75
33.75
33.50
33.25
33.00
32.75
32.50
-100
-80
-60
-40
-20

Fig. 7

Free Air Anom. less NEW (San Diego)

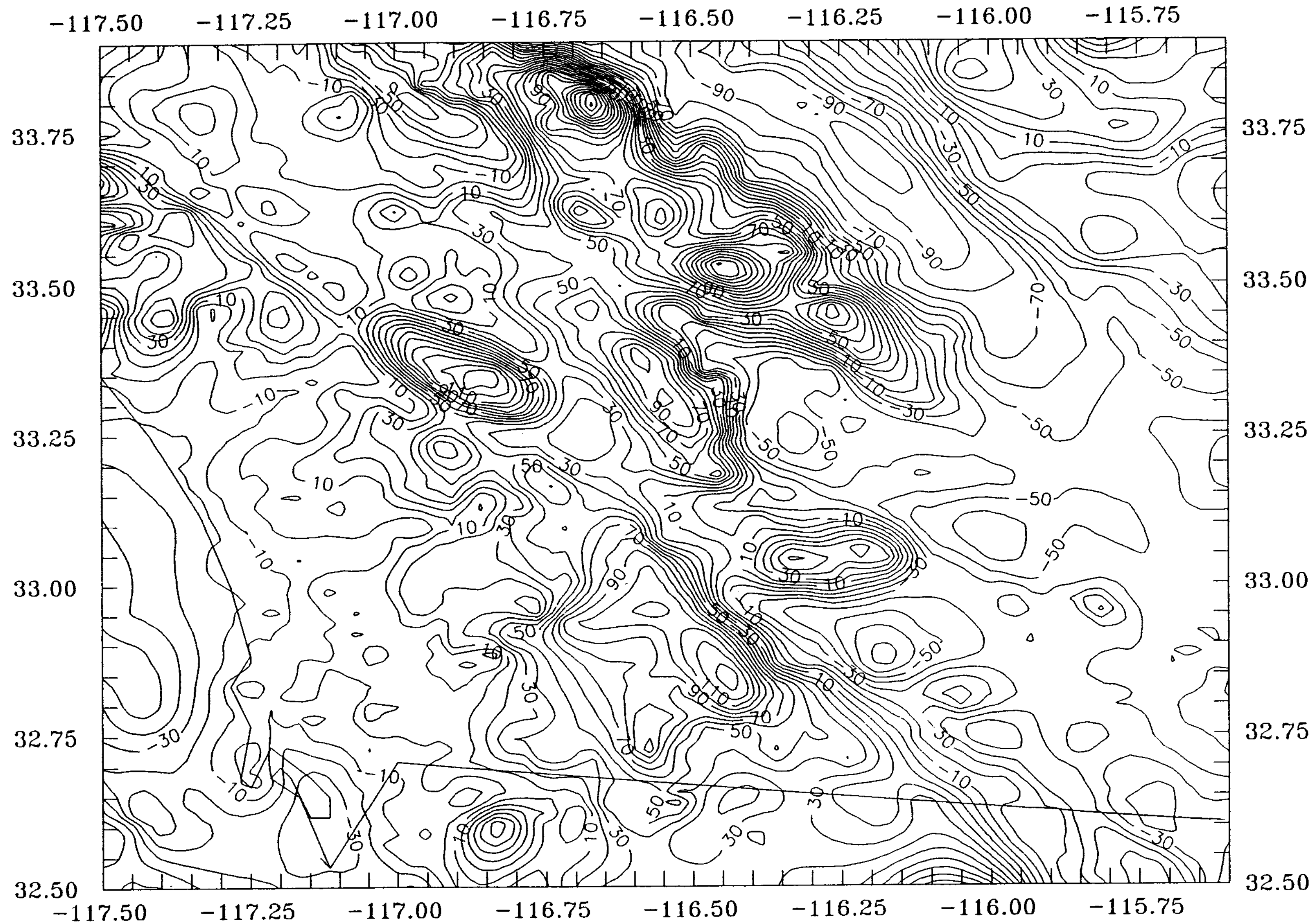


Fig 8a

Surface Gravity Density less New

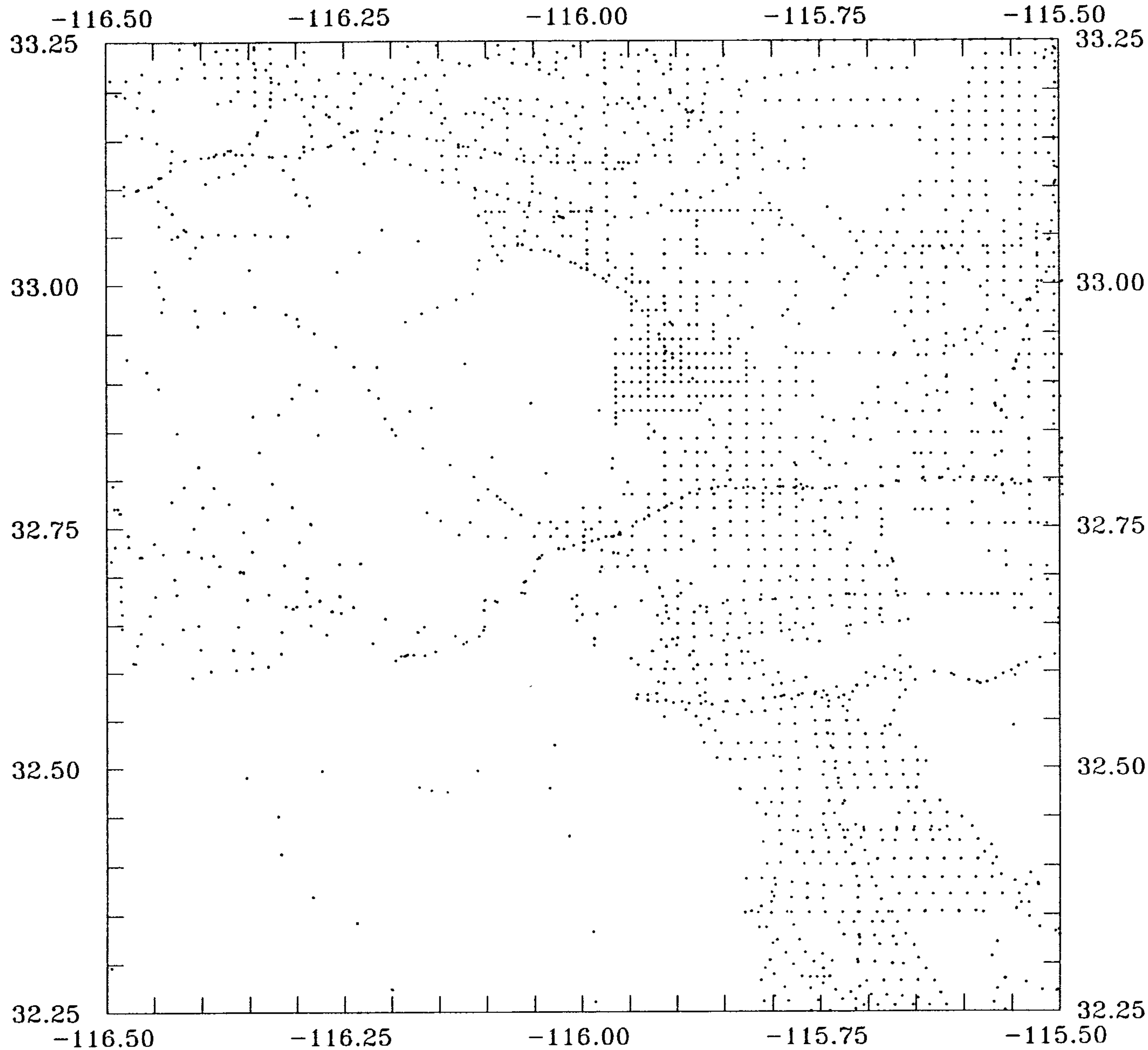


Fig. 8b

Surface Gravity Density less New

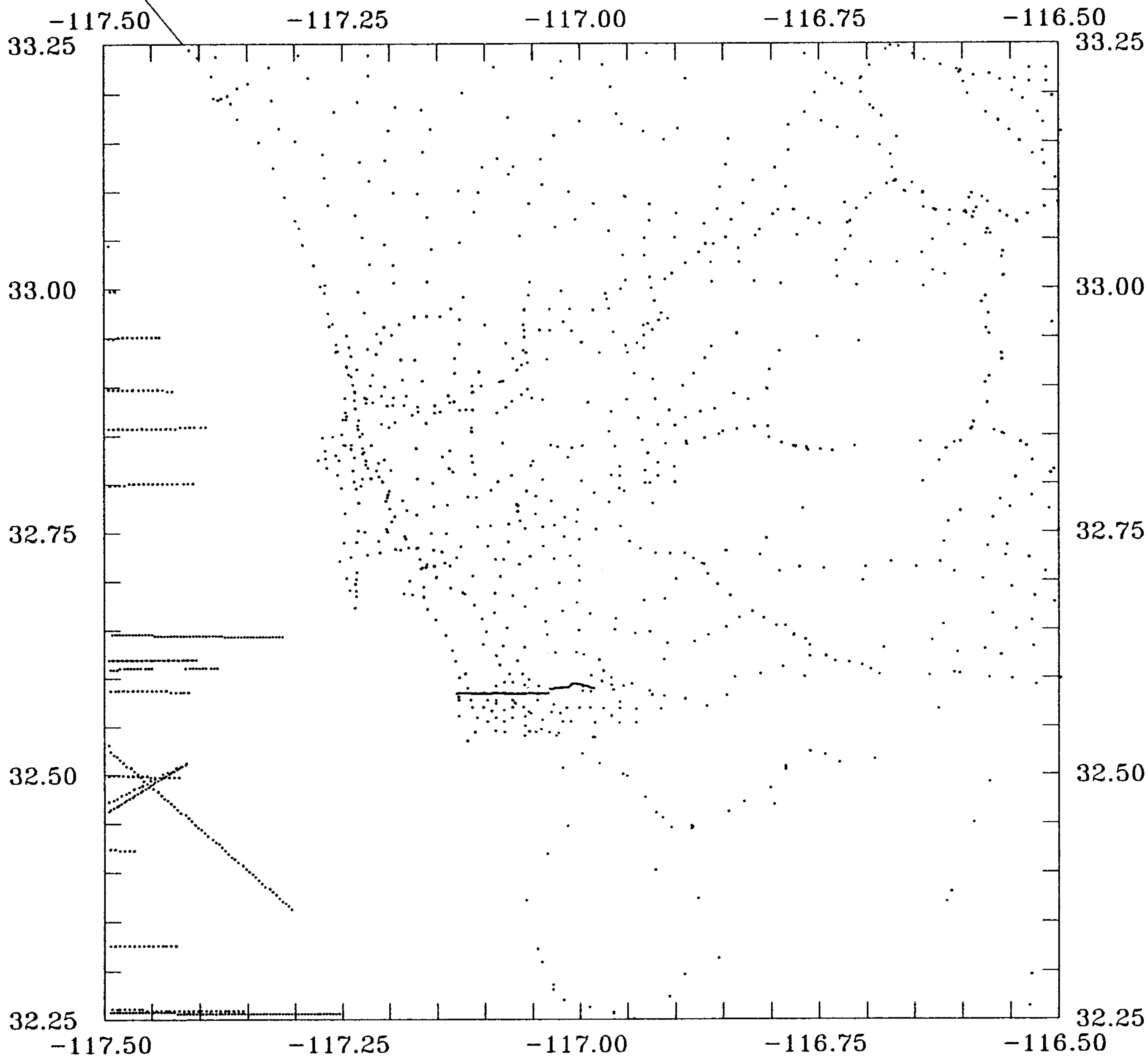


Fig. 8c

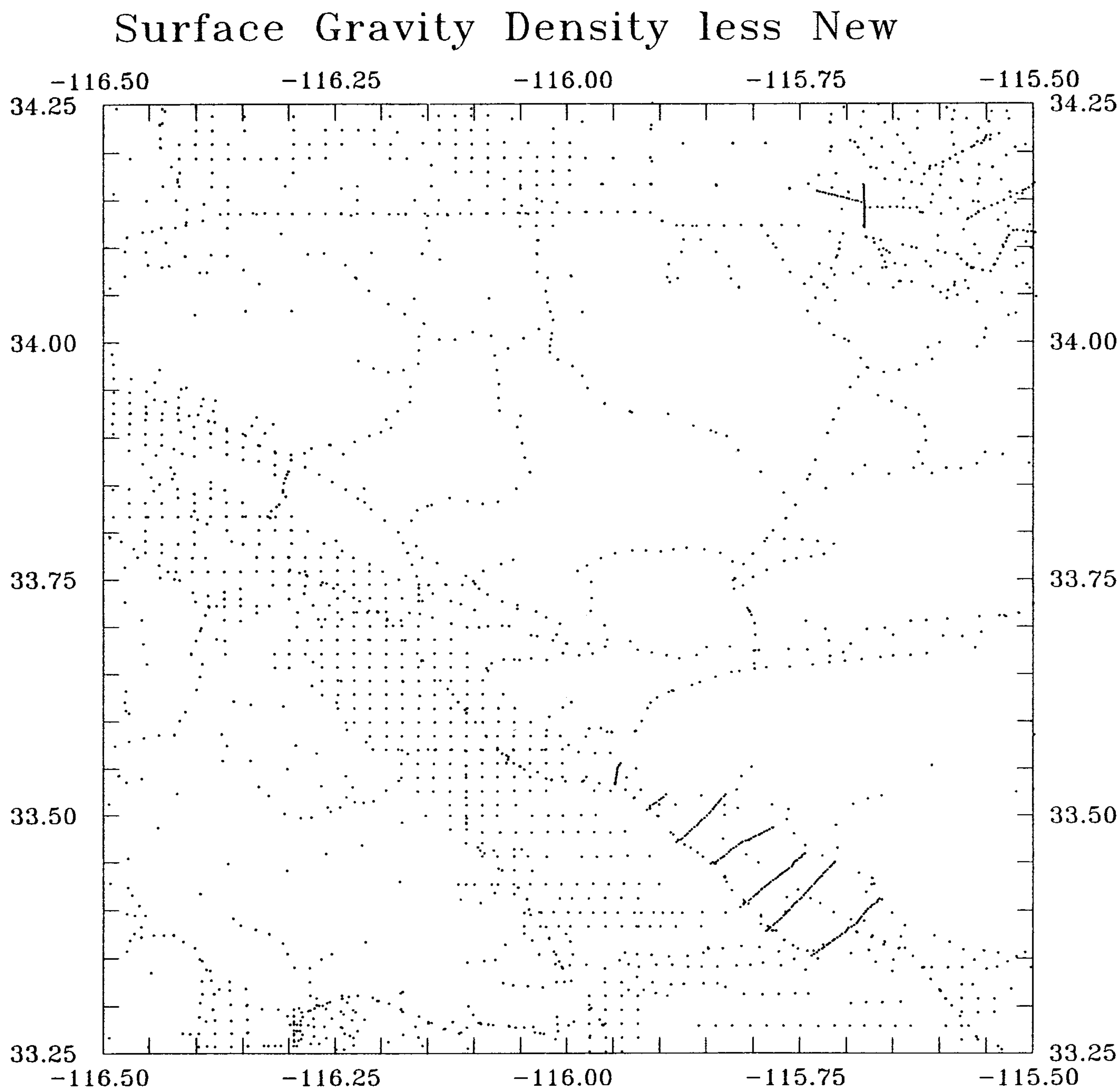

Surface Gravity Density less New
−116.50
−116.25
−116.00
−115.75
−115.50
34.25
34.00
33.75
33.50
33.25

Fig. 8d

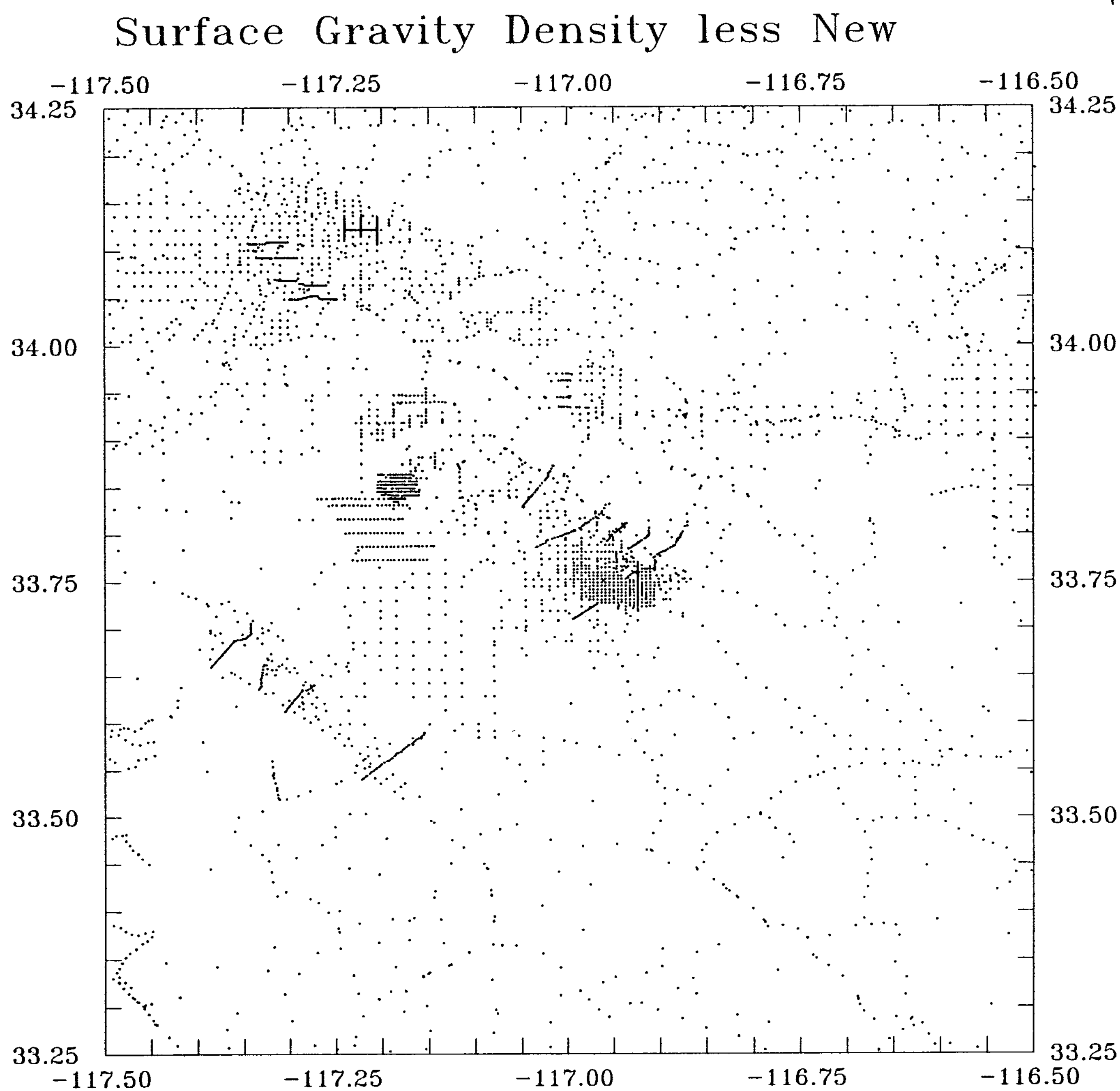

Surface Gravity Density less New
−117.50
−117.25
−117.00
−116.75
−116.50
34.25
34.00
33.75
33.50
33.25

Fig. 8e

Surface Gravity less NEW (San Diego)

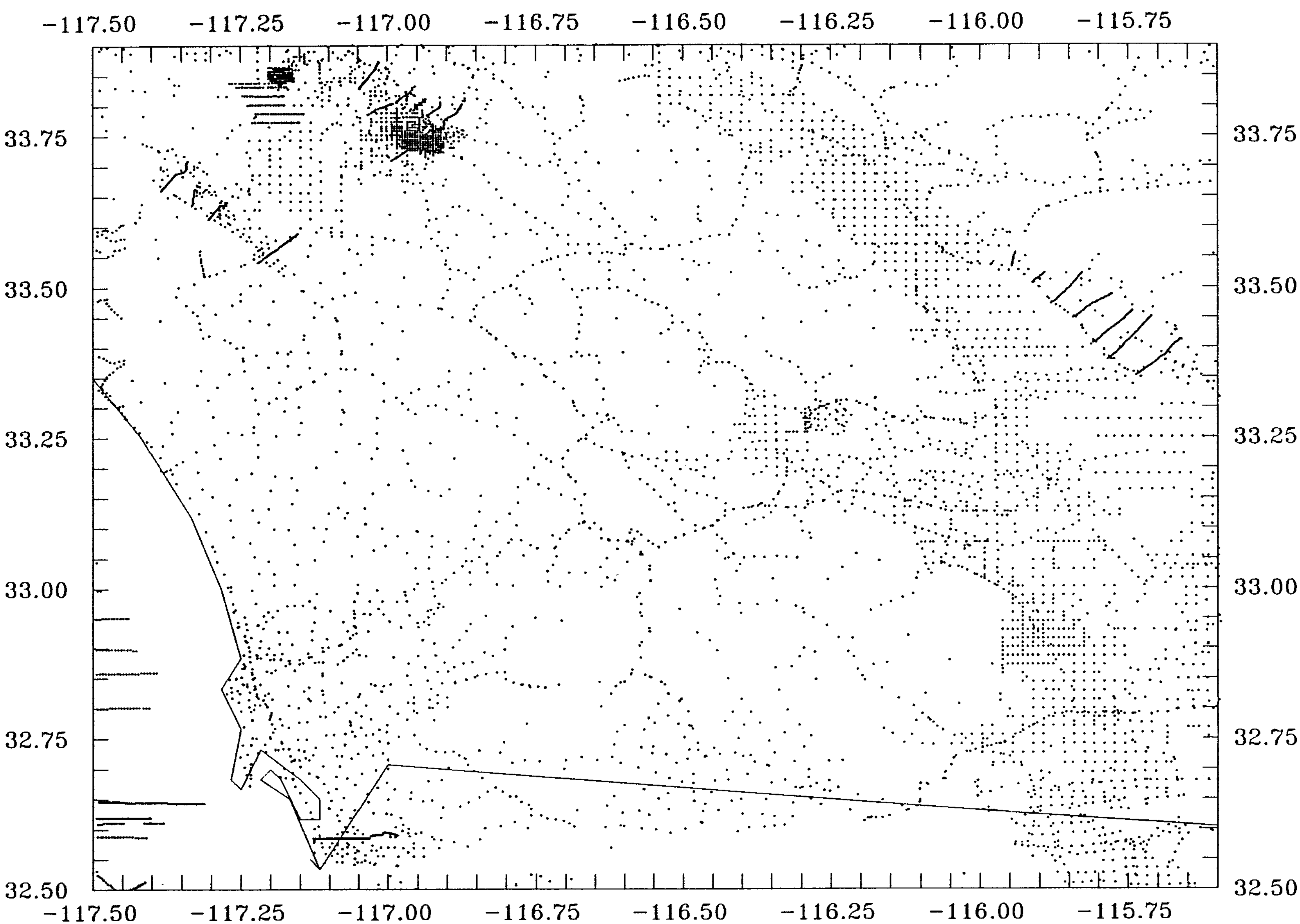


Fig 9a

Gravity Void Codes

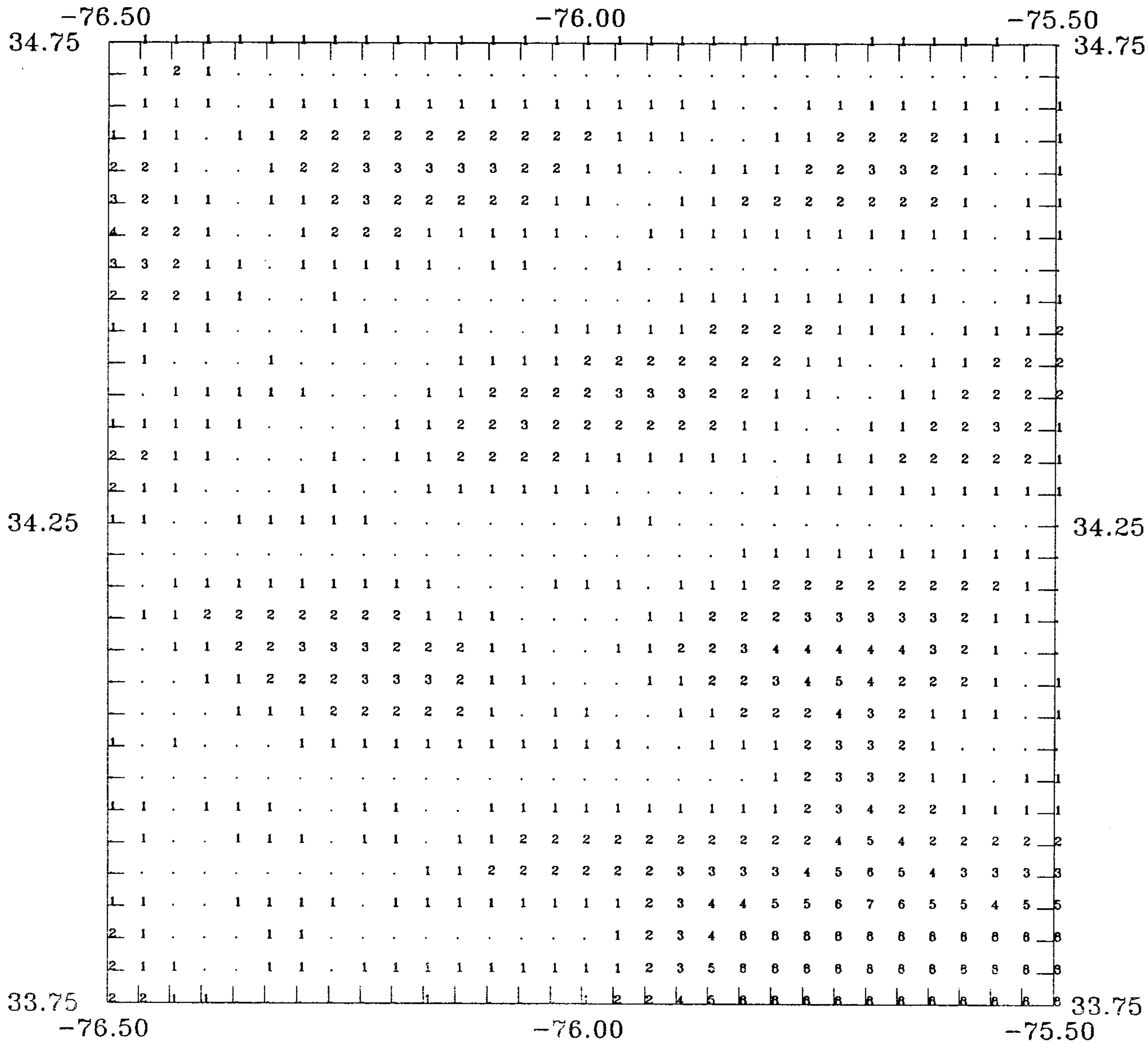
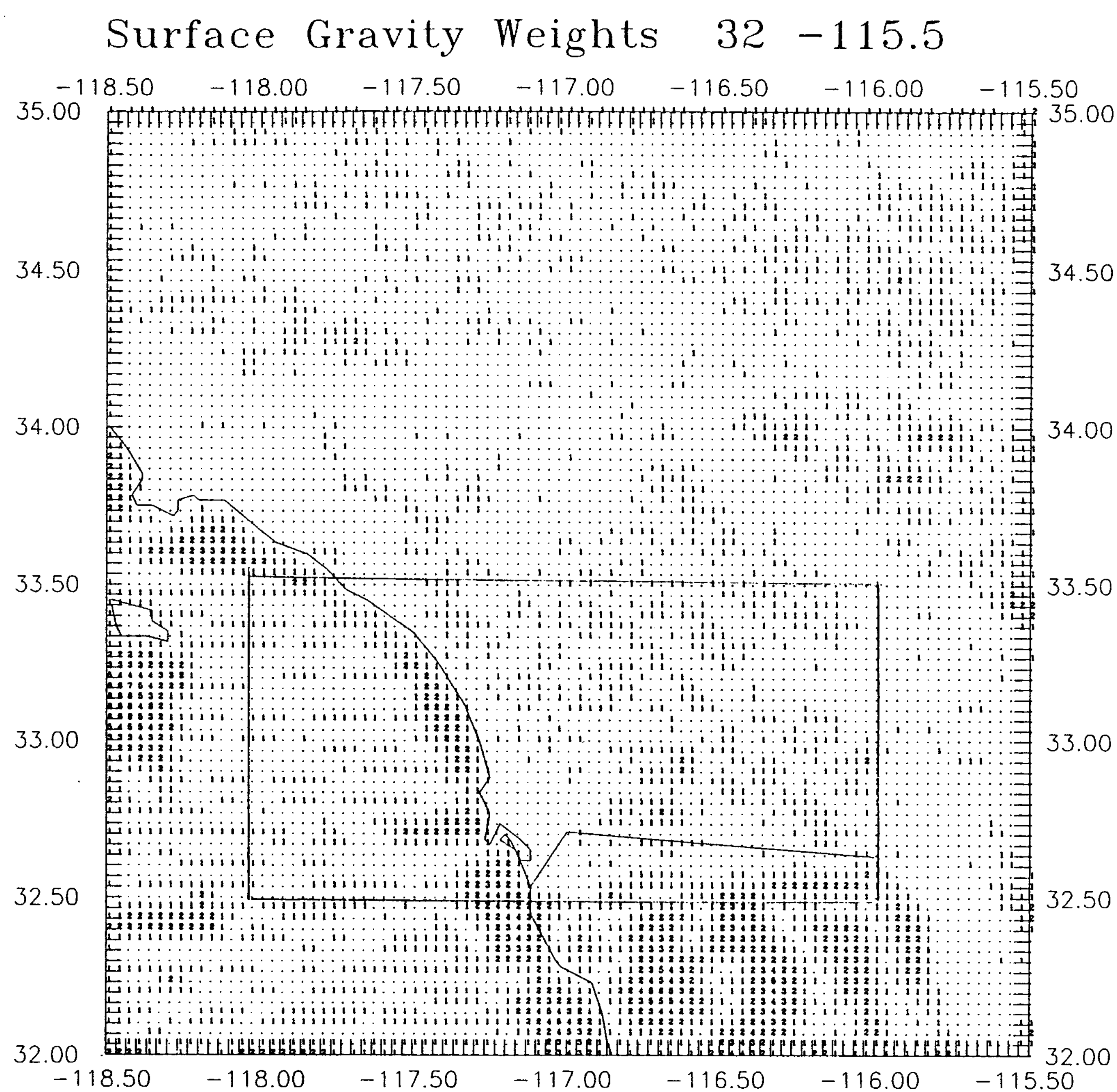


Fig 9b



Surface Gravity Weights 32 -115.5
-118.50
-118.00
-117.50
-117.00
-116.50
-116.00
-115.50
35.00
34.50
34.00
33.50
33.00
32.50
32.00

Fig. 9c

Gravity Voids – San Diego

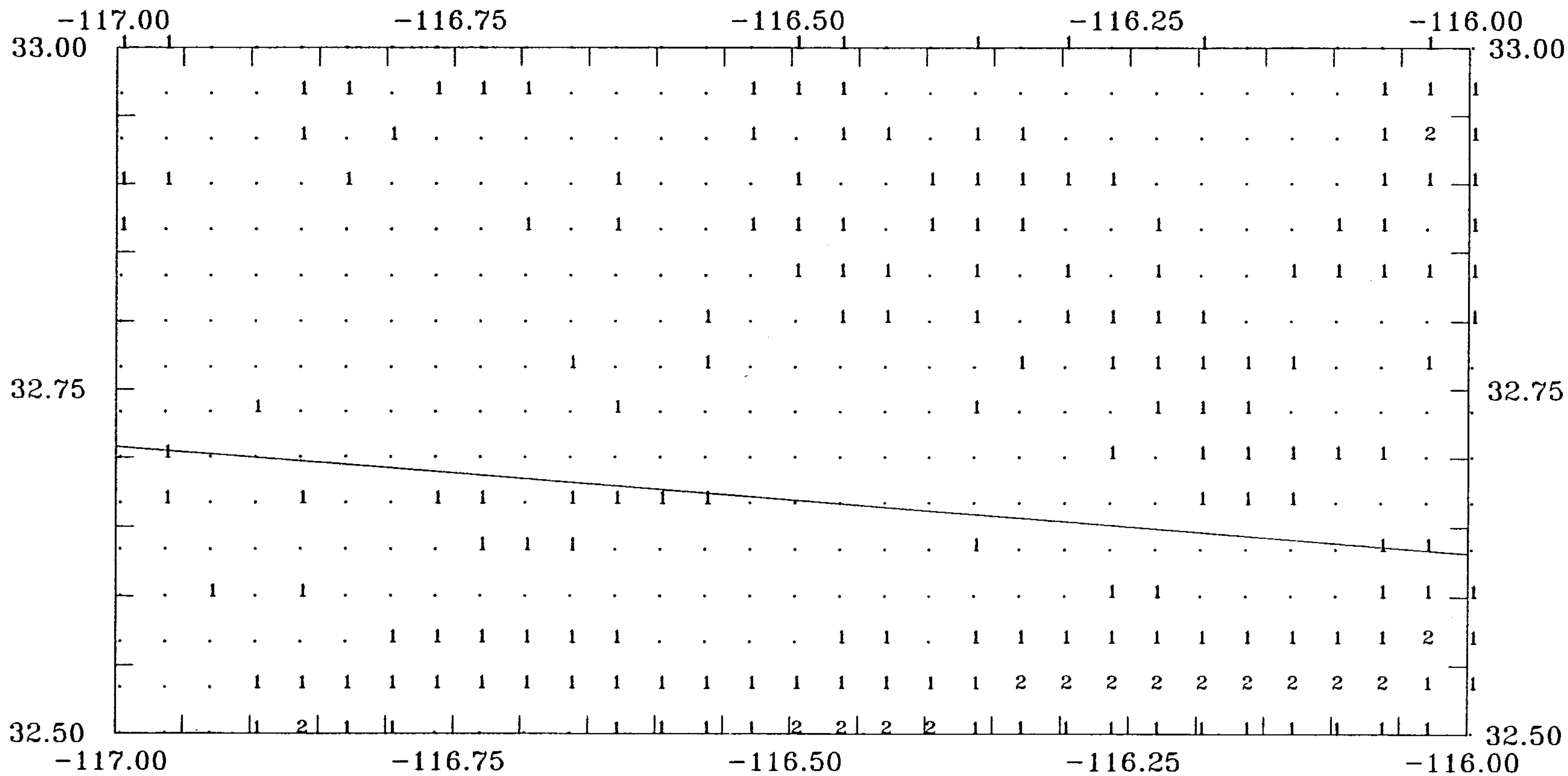


Fig. 9d

Gravity Voids - San Diego

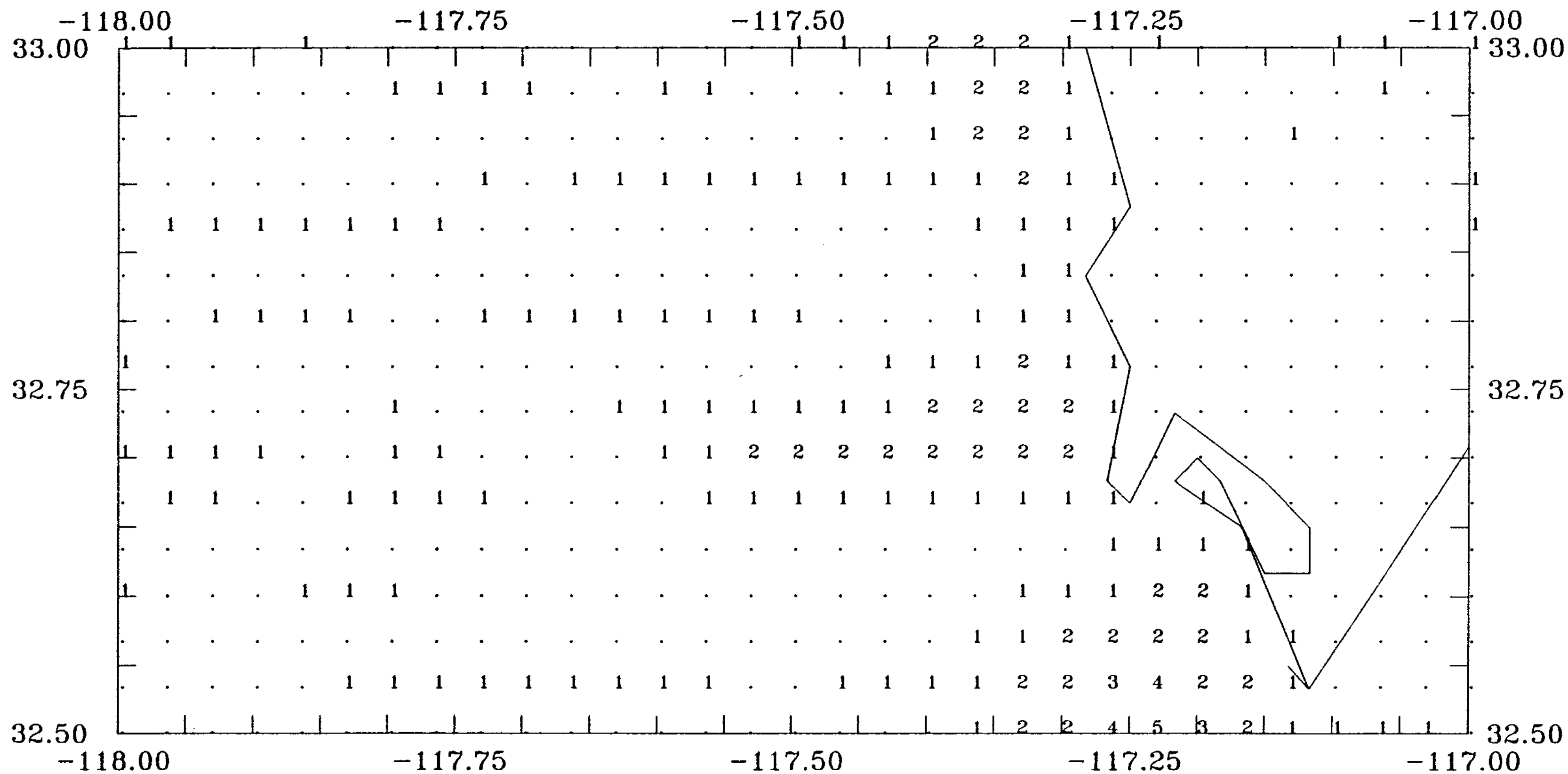


Fig. 9e

Gravity Voids – San Diego

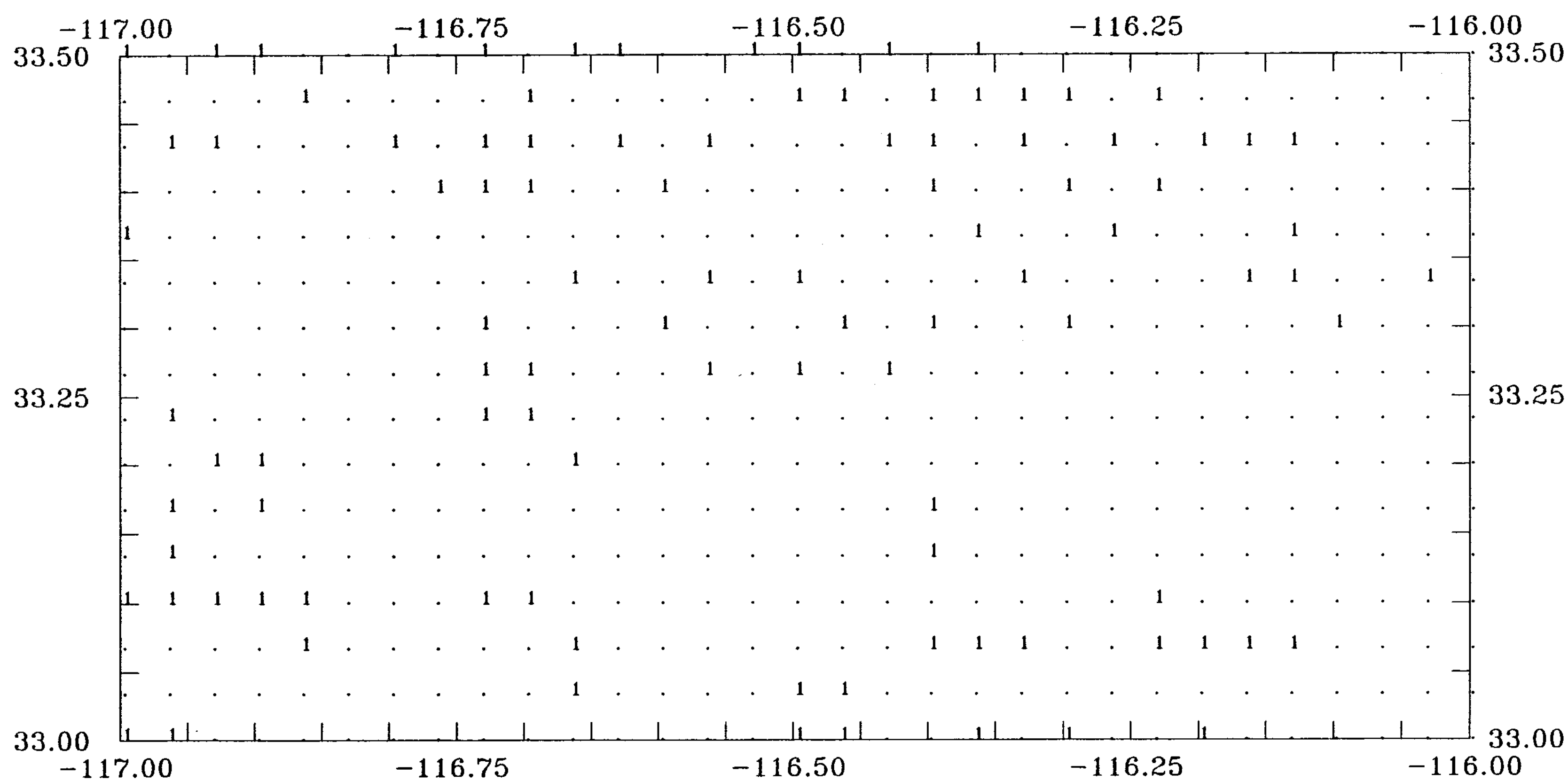


Fig. 9f

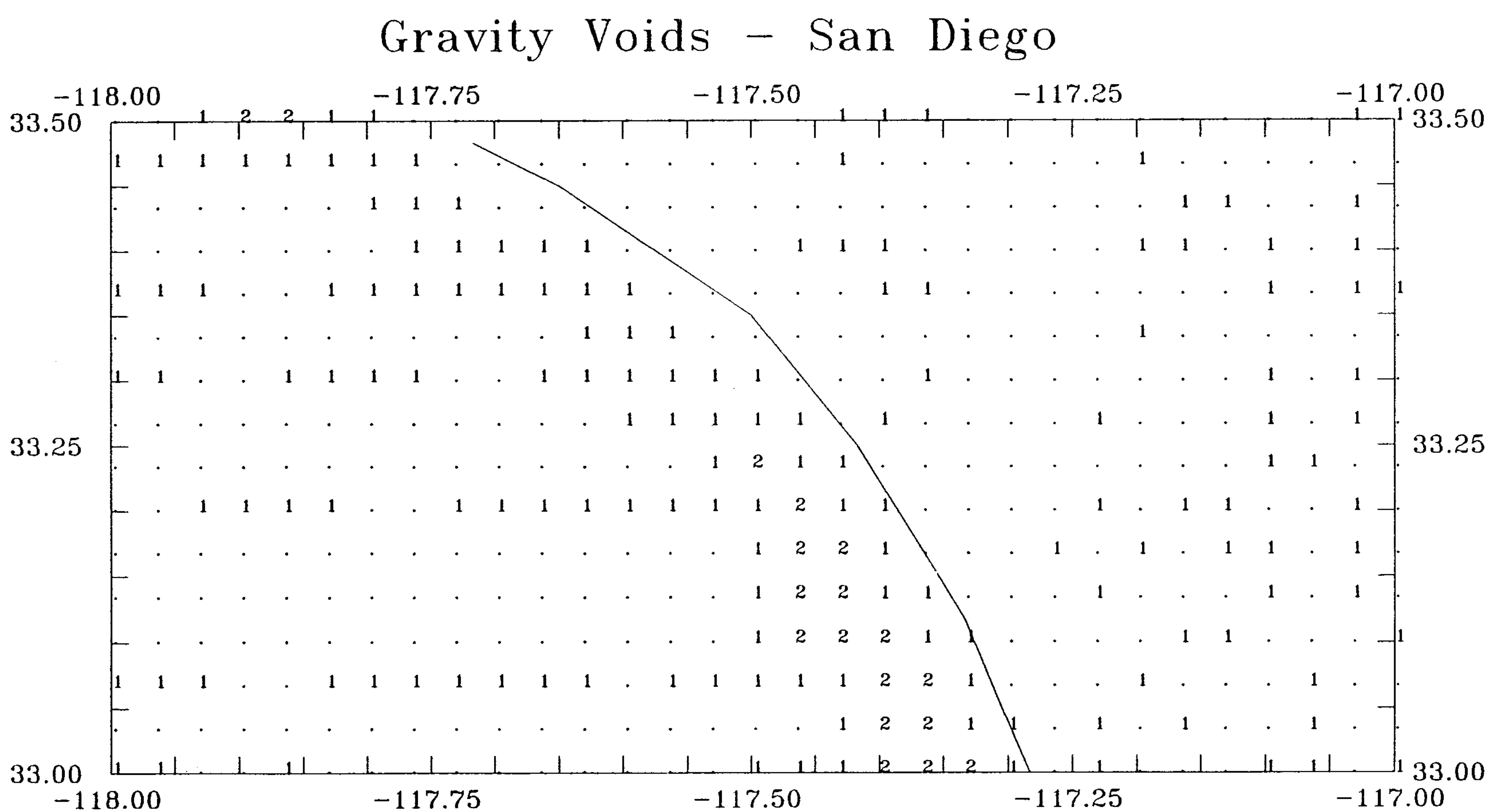

Gravity Voids - San Diego
-118.00
-117.75
-117.50
-117.25
-117.00
33.50
33.25
33.00

Fig 10a

Surface Gravity Added (San Diego)

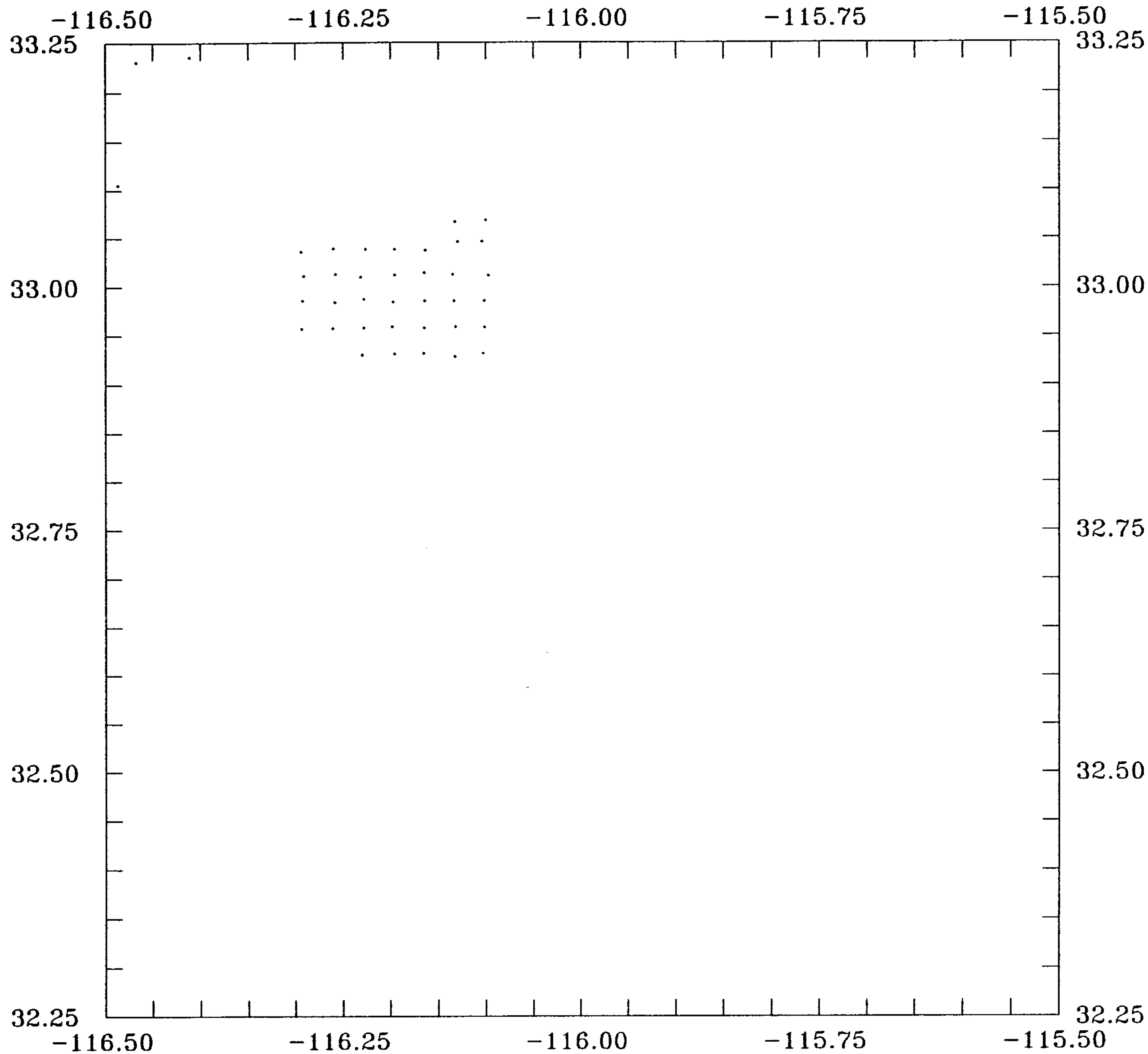


Fig 10b

Surface Gravity Added (San Diego)

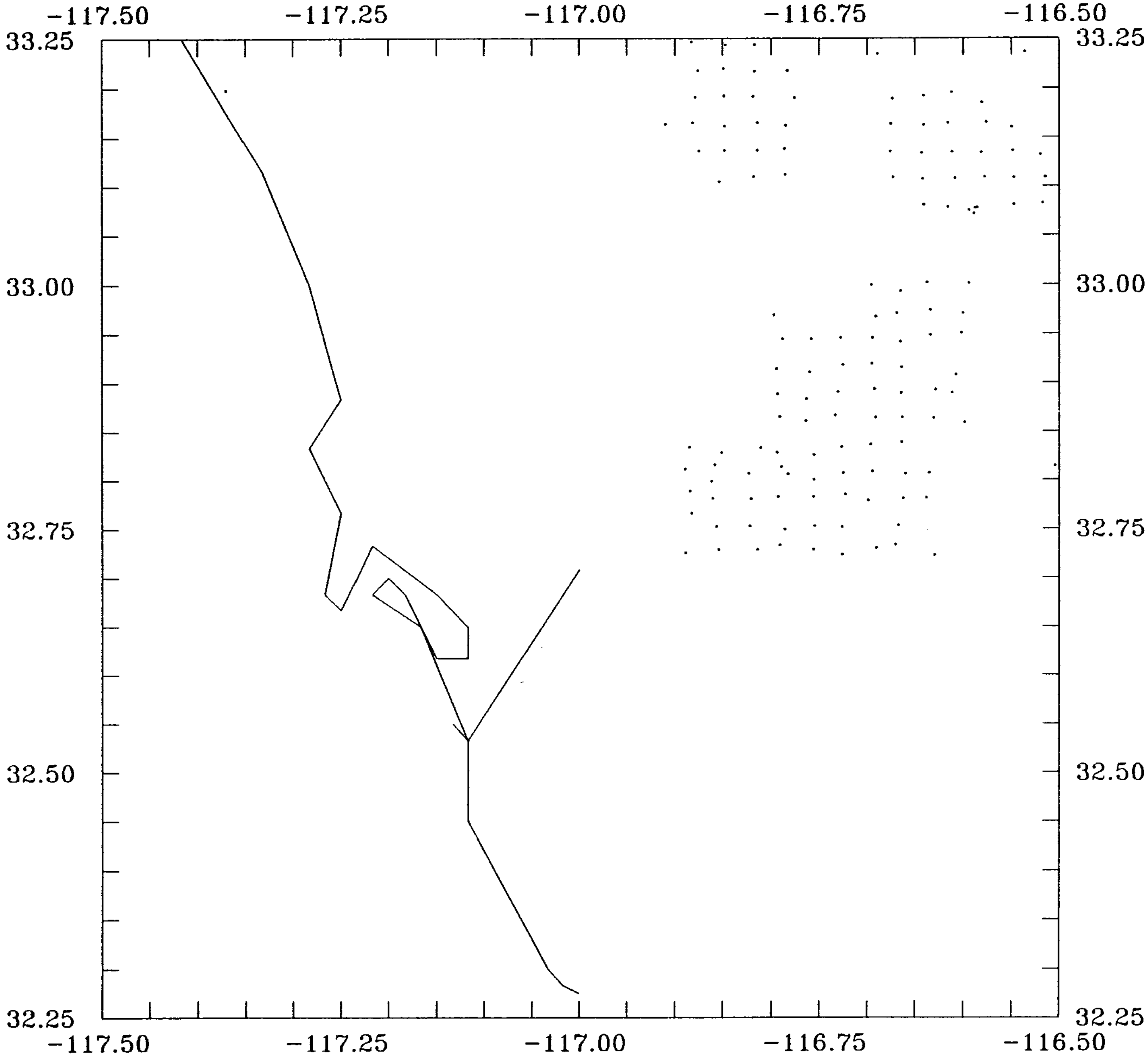


Fig. 10c

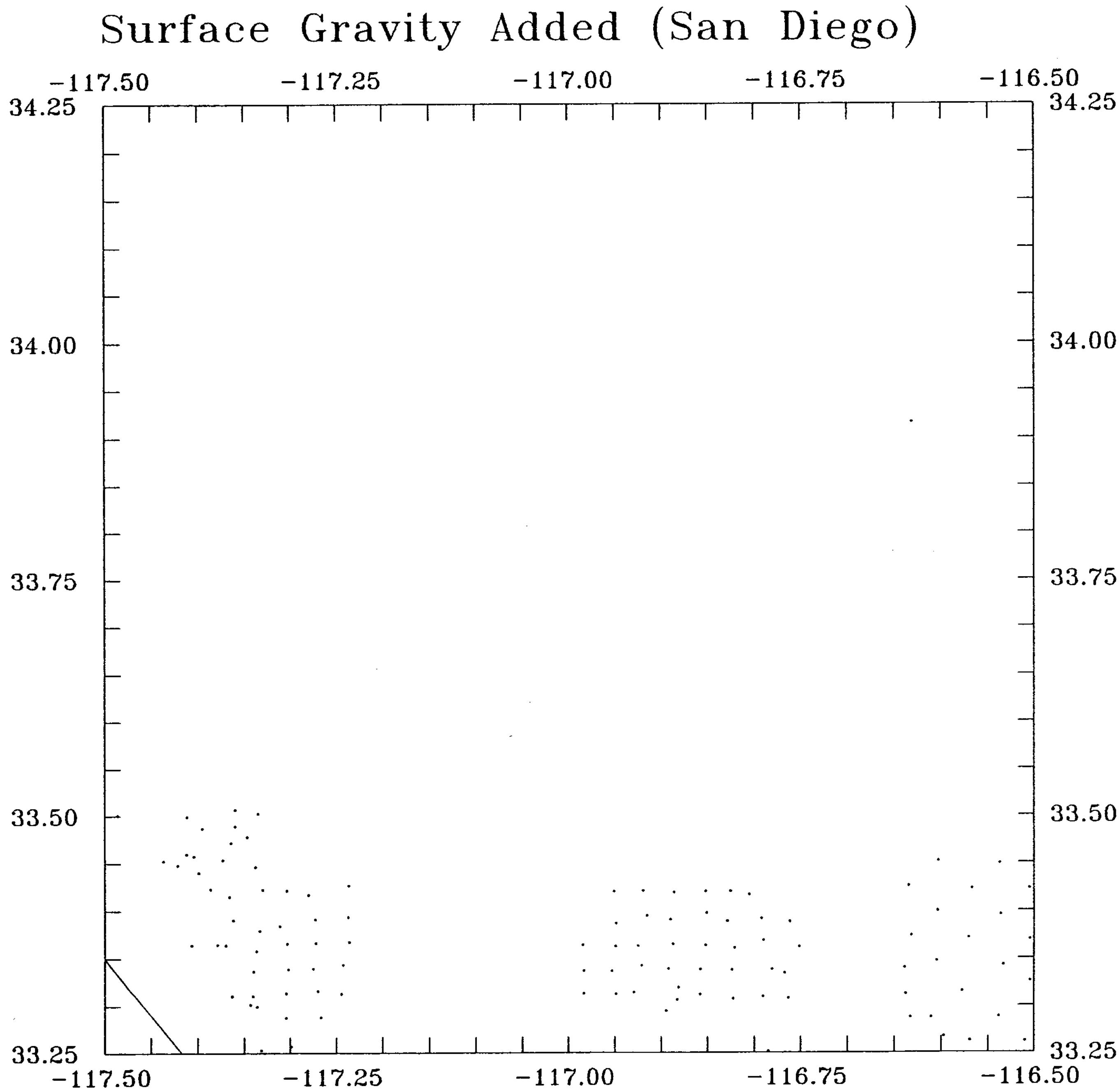

Surface Gravity Added (San Diego)
−117.50
−117.25
−117.00
−116.75
−116.50
34.25
34.00
33.75
33.50
33.25

Fig. 10d

Surface Gravity Added (San Diego)

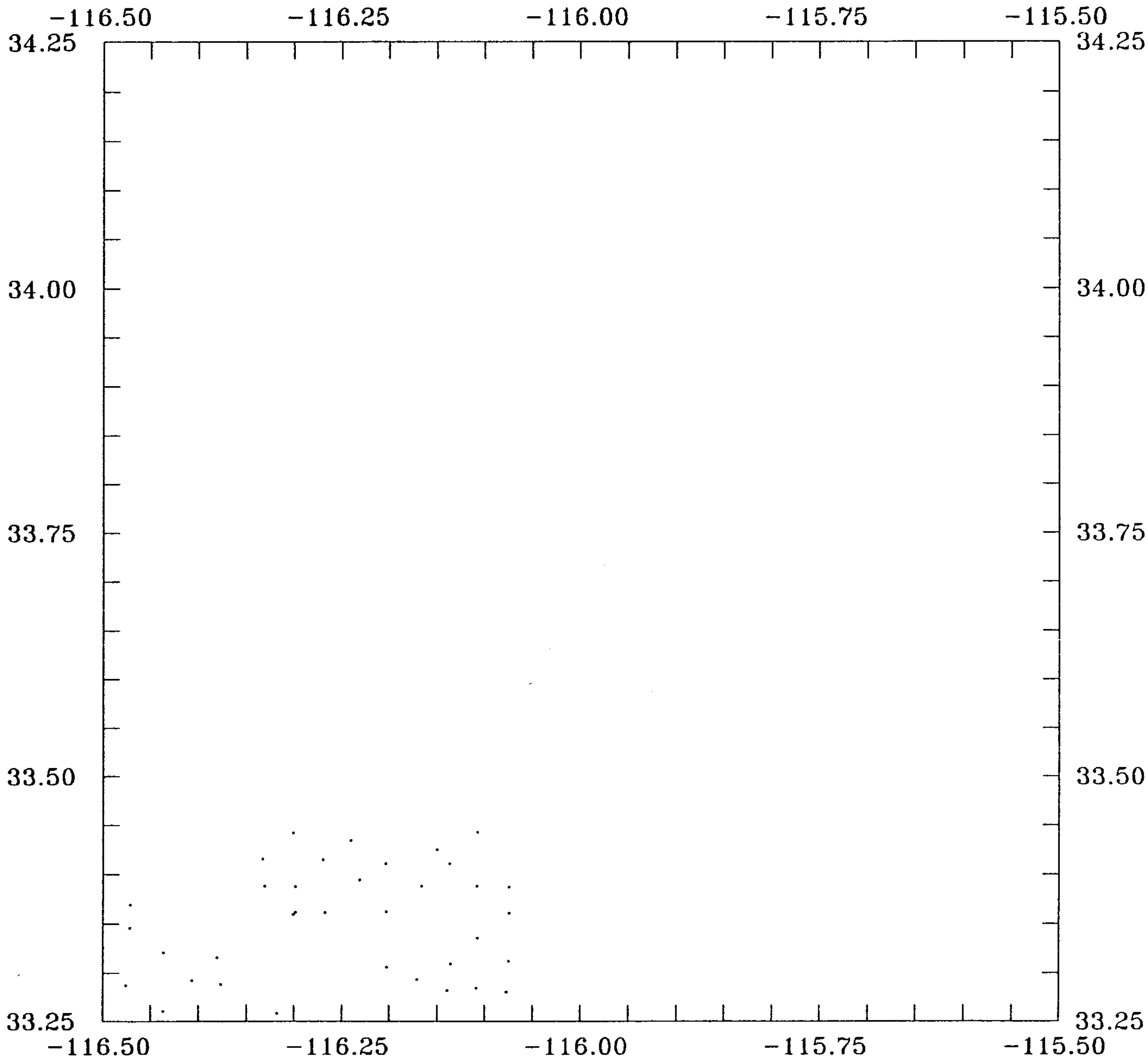


Fig. 11a

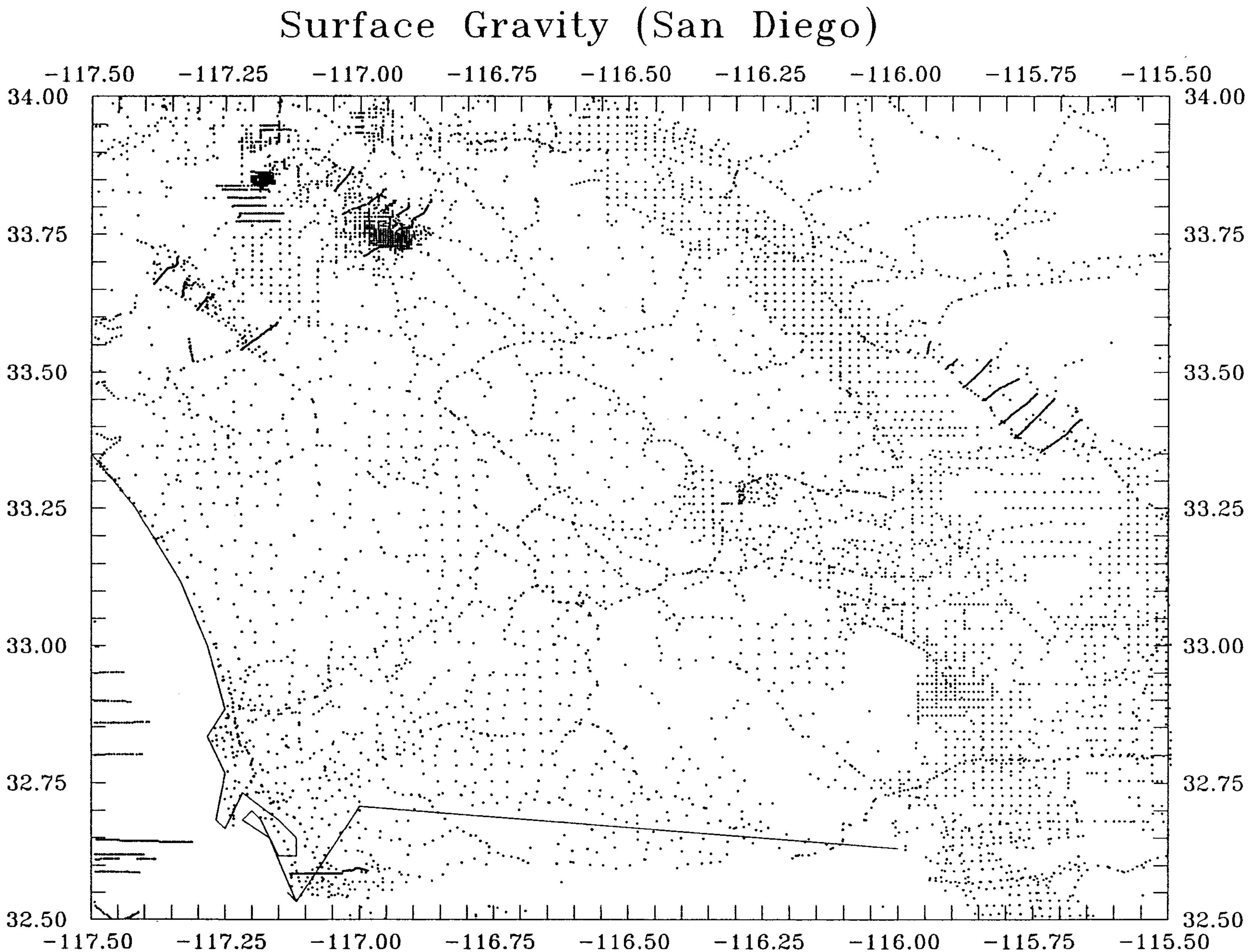

Surface Gravity (San Diego)
-117.50
-117.25
-117.00
-116.75
-116.50
-116.25
-116.00
-115.75
-115.50
34.00
33.75
33.50
33.25
33.00
32.75
32.50

Fig 11b

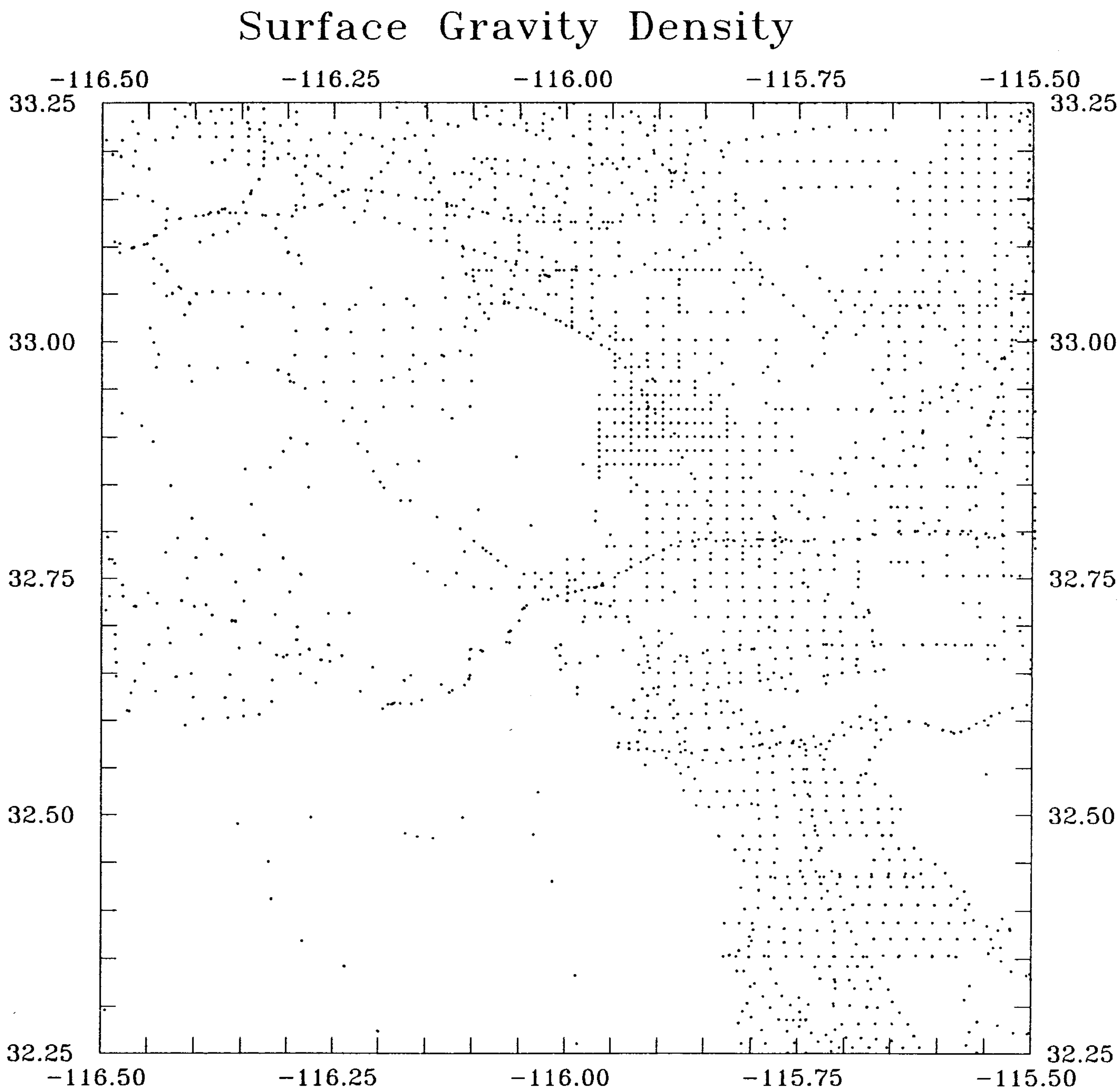

Surface Gravity Density
−116.50
−116.25
−116.00
−115.75
−115.50
33.25
33.00
32.75
32.50
32.25

Fig. 11c

Surface Gravity Density

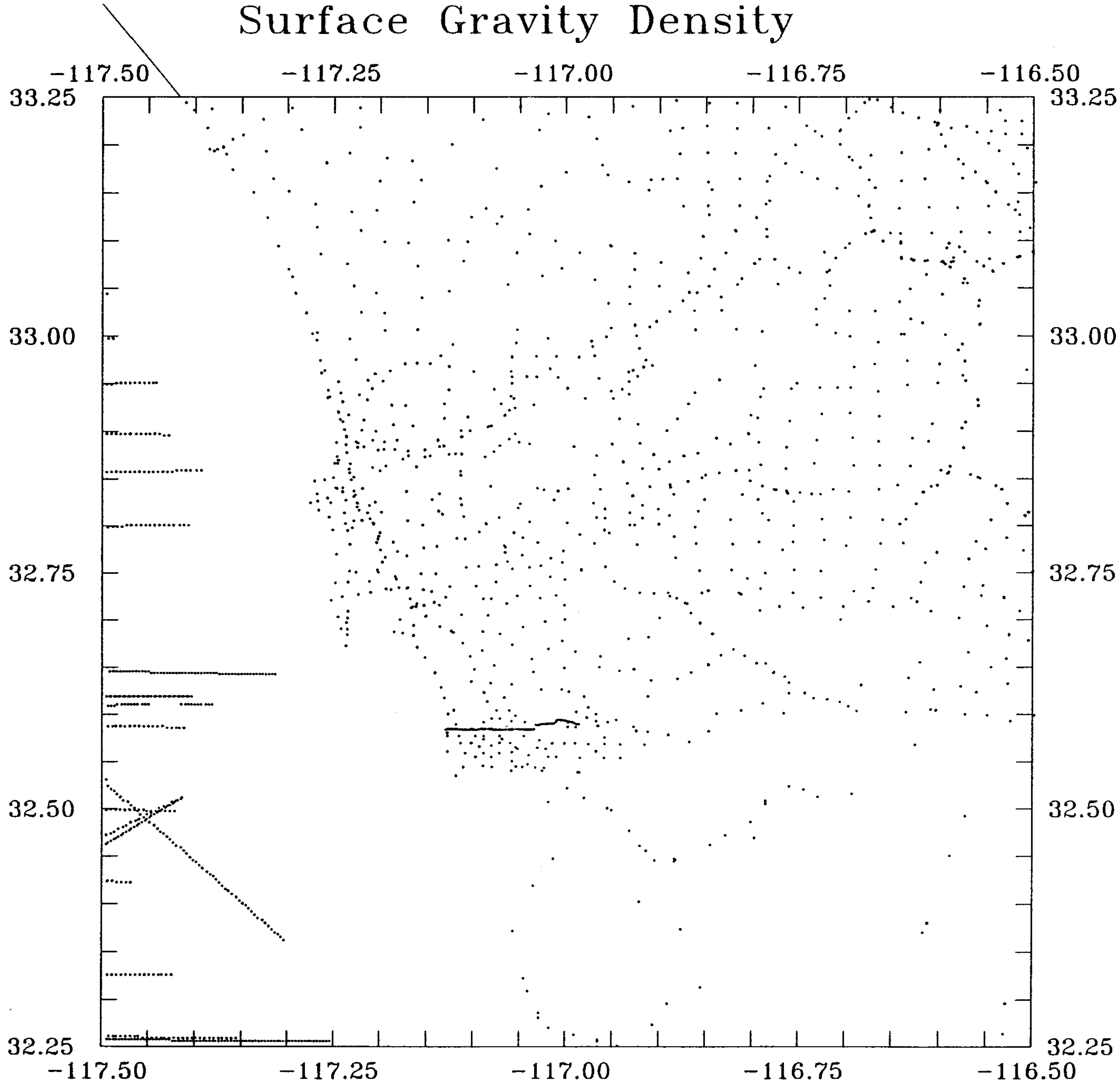
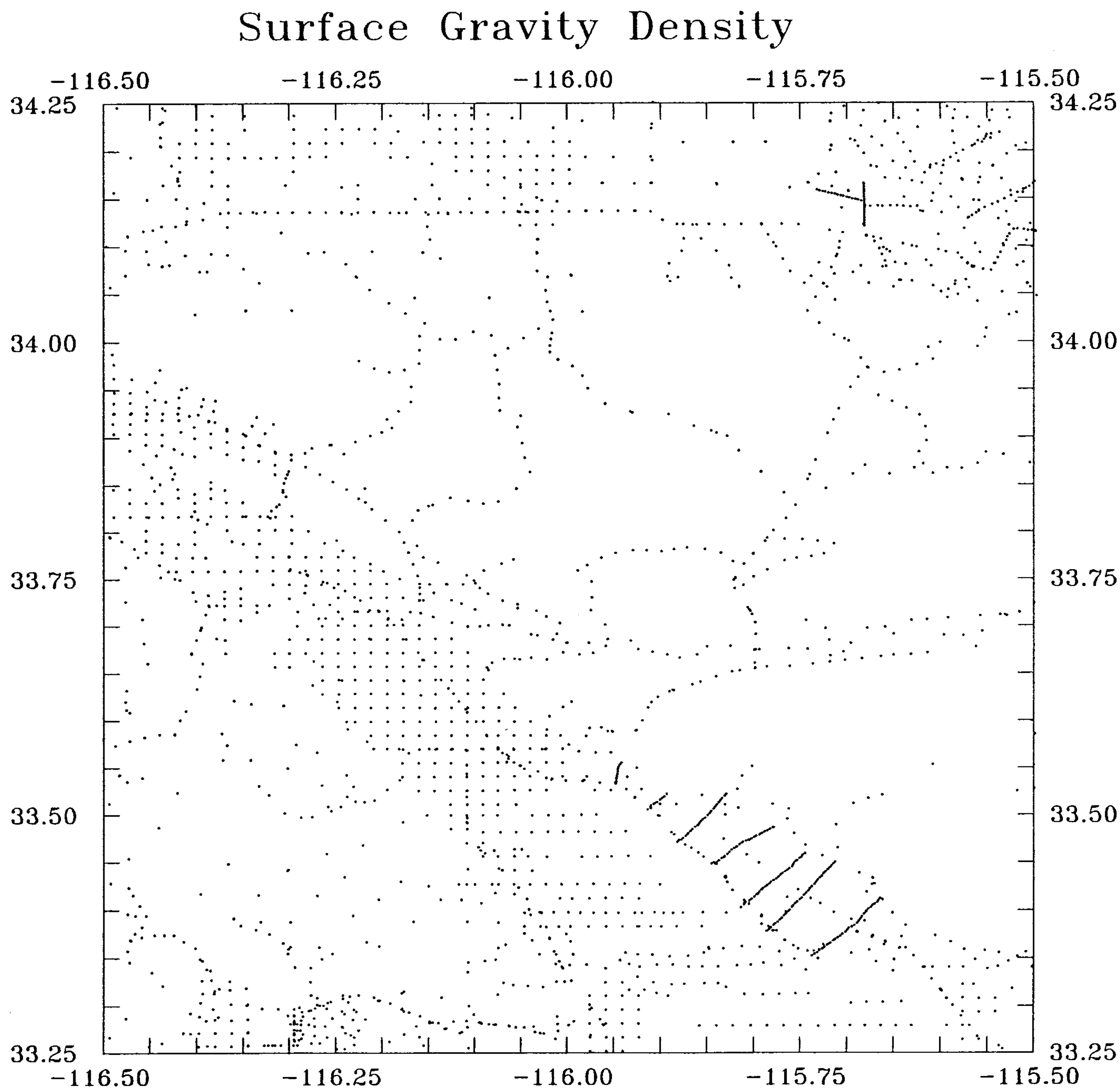


Fig 11d



Surface Gravity Density
-116.50
-116.25
-116.00
-115.75
-115.50
34.25
34.00
33.75
33.50
33.25

Fig. 11e

Surface Gravity Density

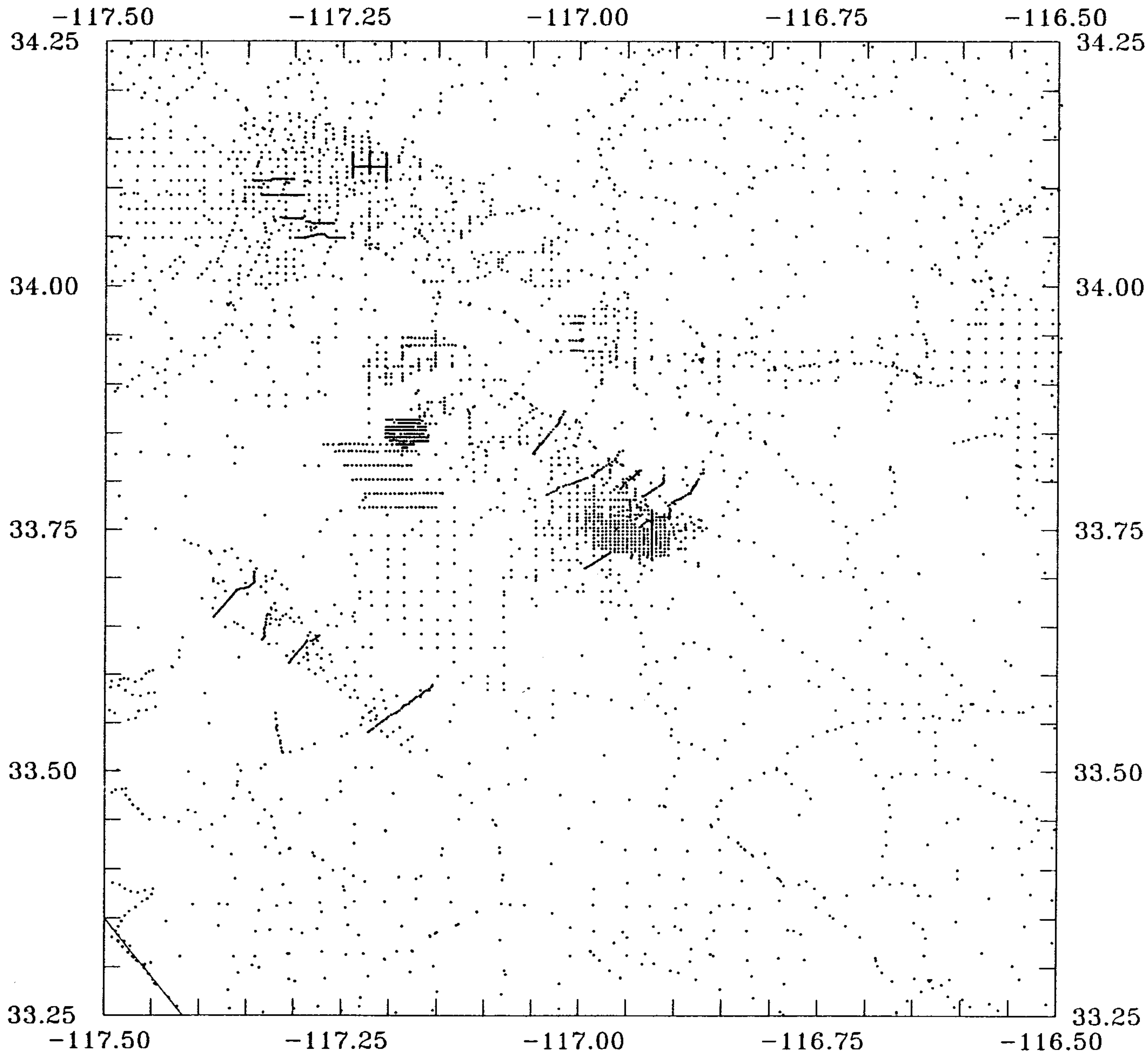
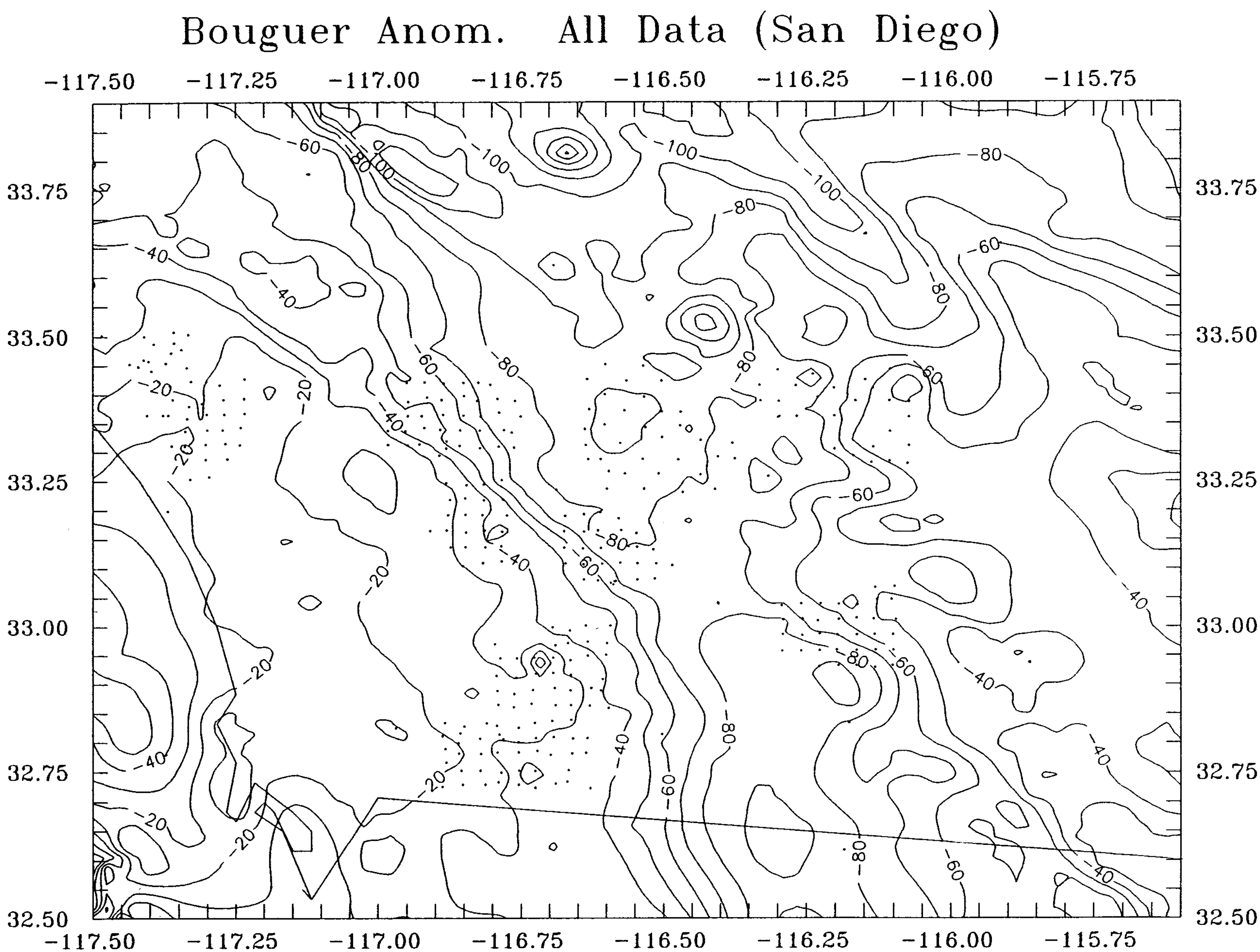


Fig. 12


Bouguer Anom. All Data (San Diego)
-117.50
-117.25
-117.00
-116.75
-116.50
-116.25
-116.00
-115.75
33.75
33.50
33.25
33.00
32.75
32.50
-20
-40
-60
-80
-100

units = meters

Fig. 13

LOCAL GEOID - San Diego area

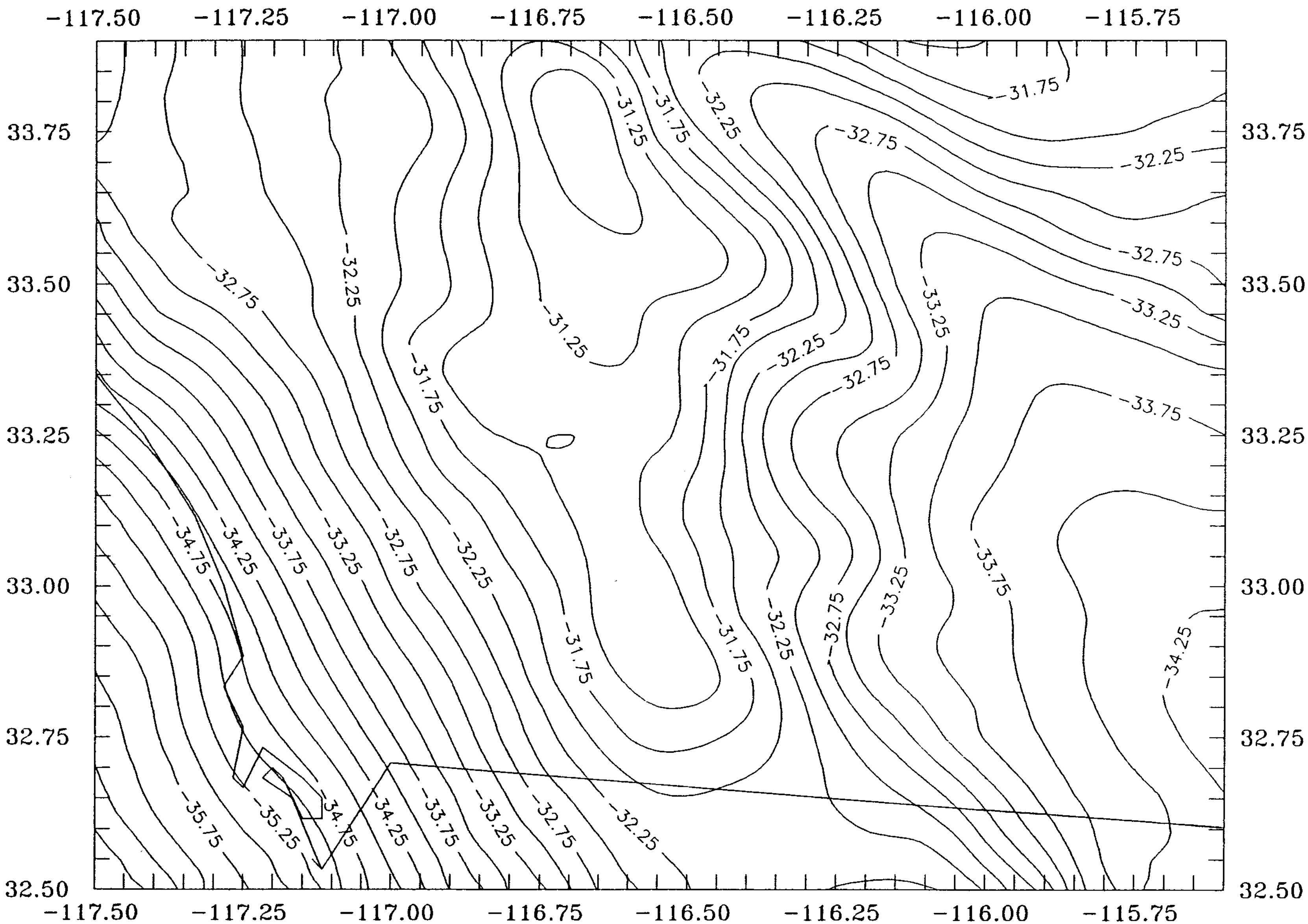


Fig. 14

Units = meters

GEOID93 – LOCAL GEOID; San Diego area

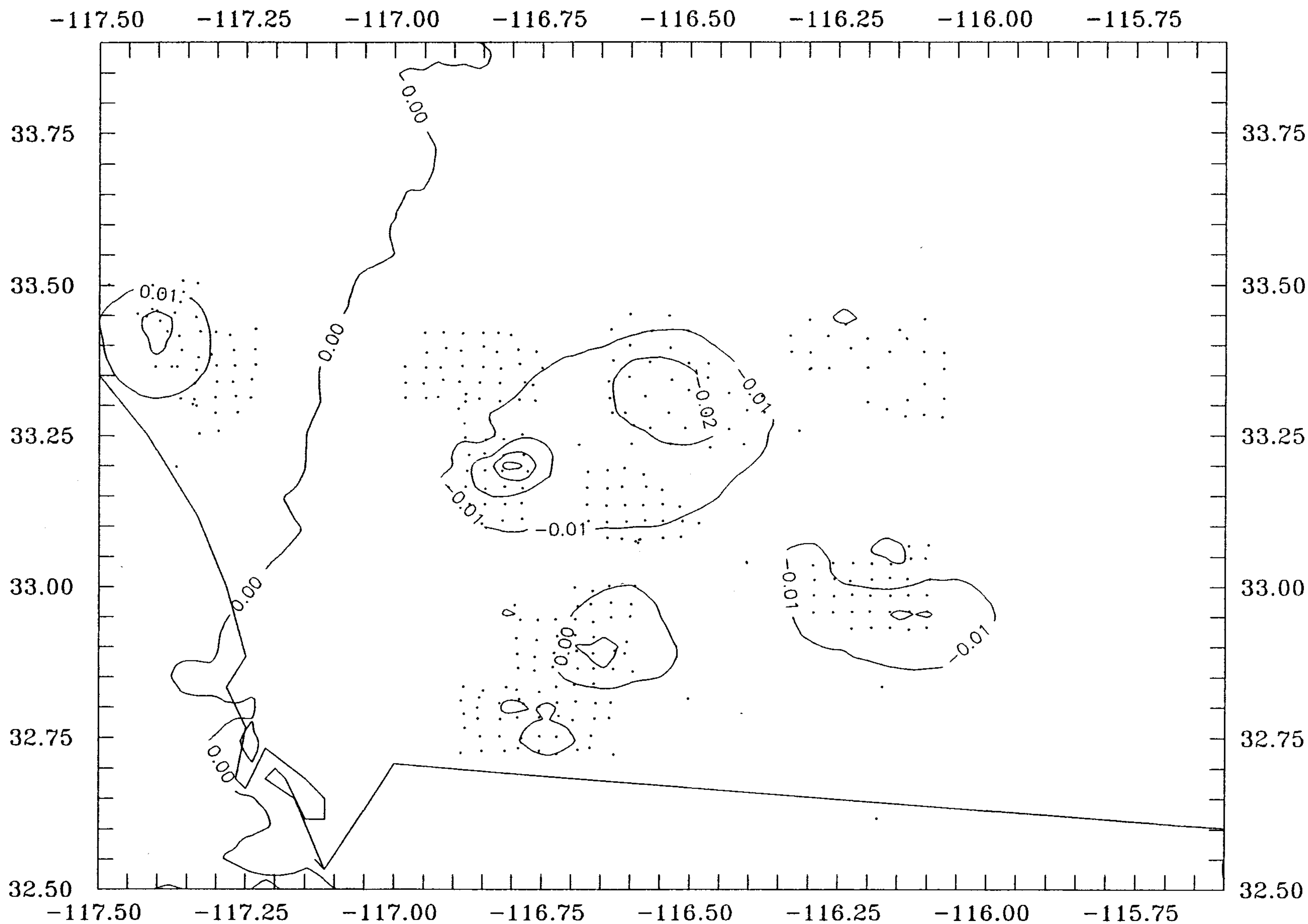


Fig. 15

NAVD 88 Bench Marks in NGSIDB (3/2/93)

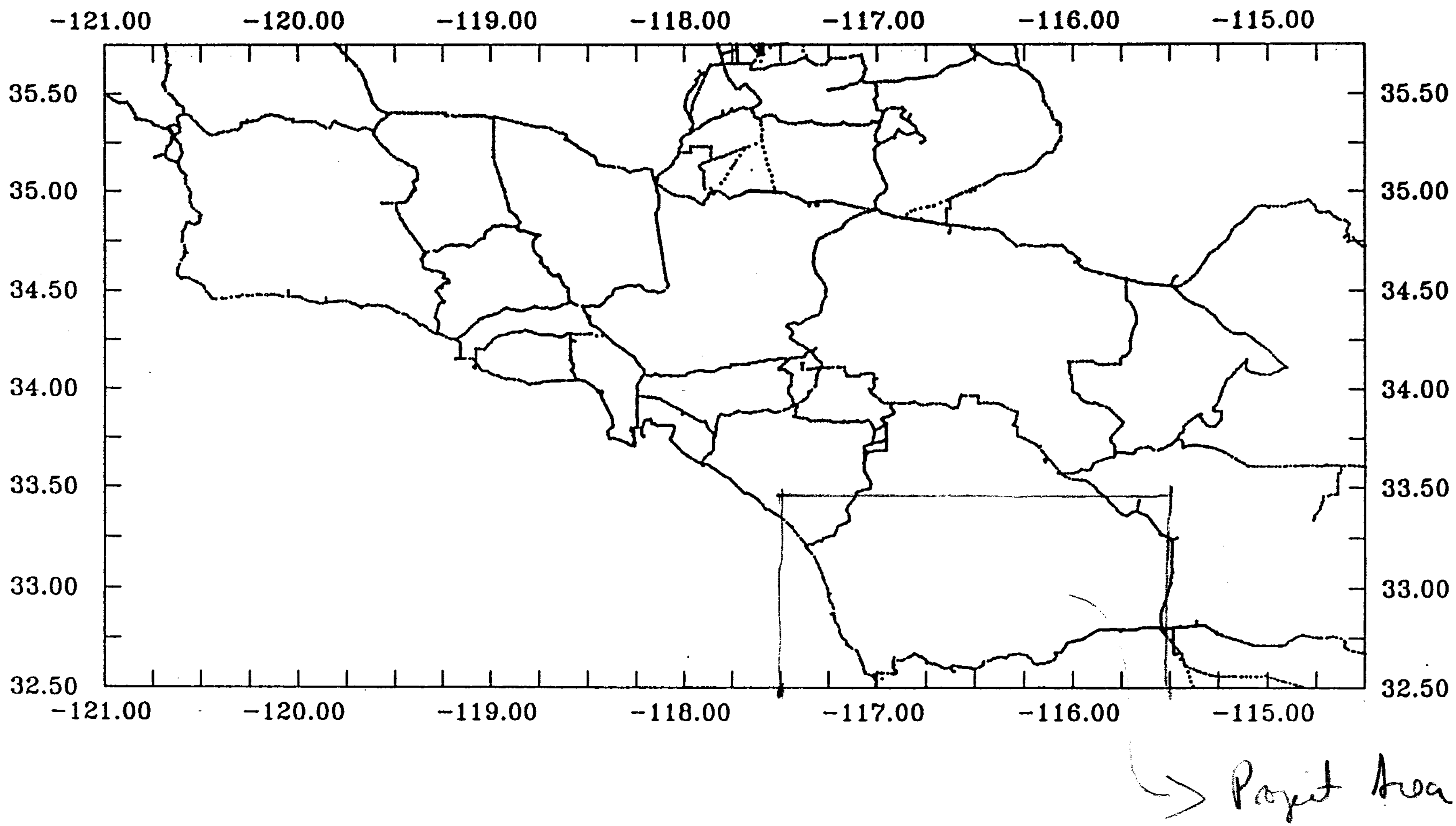


Fig. 16a

NAVD 88 and San Diego GPS Network (o–GPS/BM)

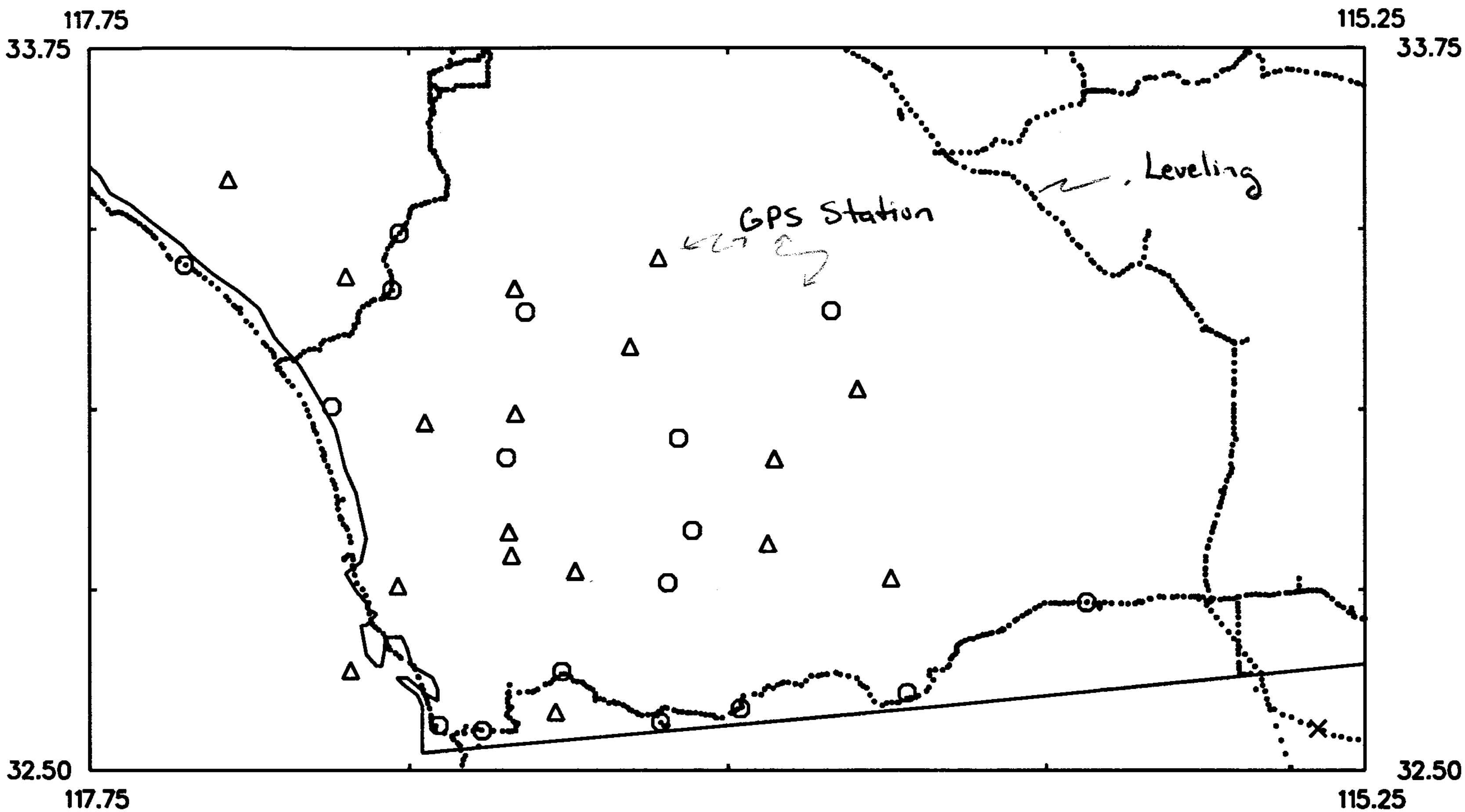
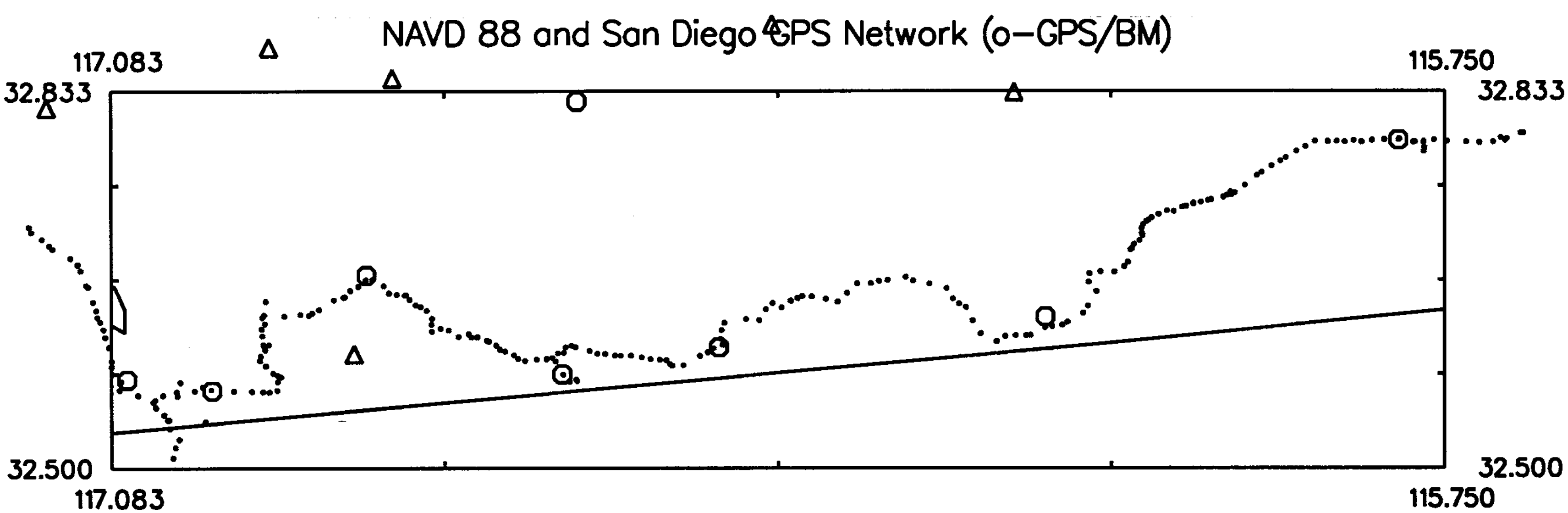


Fig. 16b


NAVD 88 and San Diego GPS Network (o–GPS/BM)
117.083
32.833
115.750
32.833
32.500
117.083
32.500
115.750

NAVD 88 and San Diego GPS Network (o–GPS/BM)

Fig. 16c

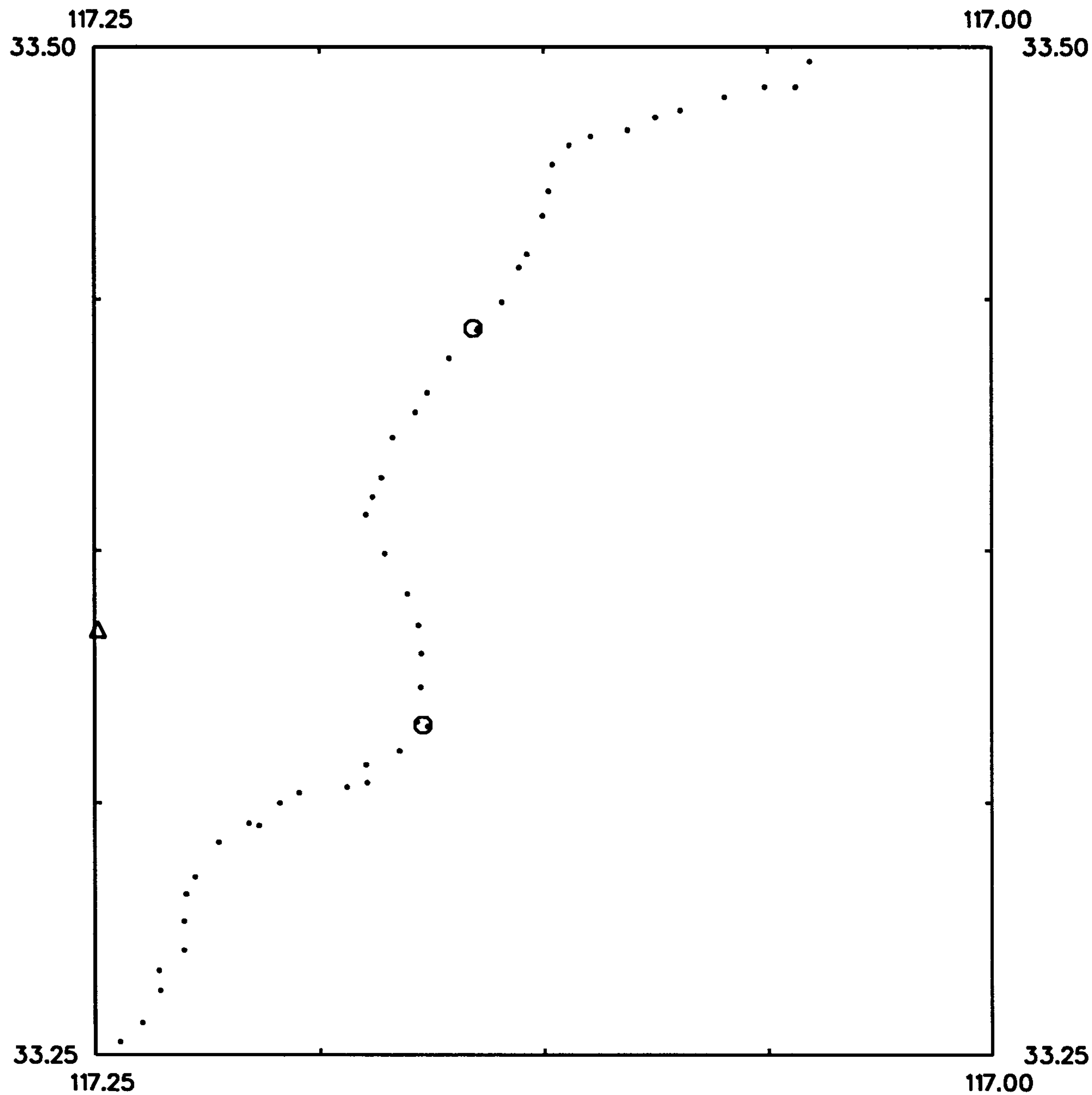
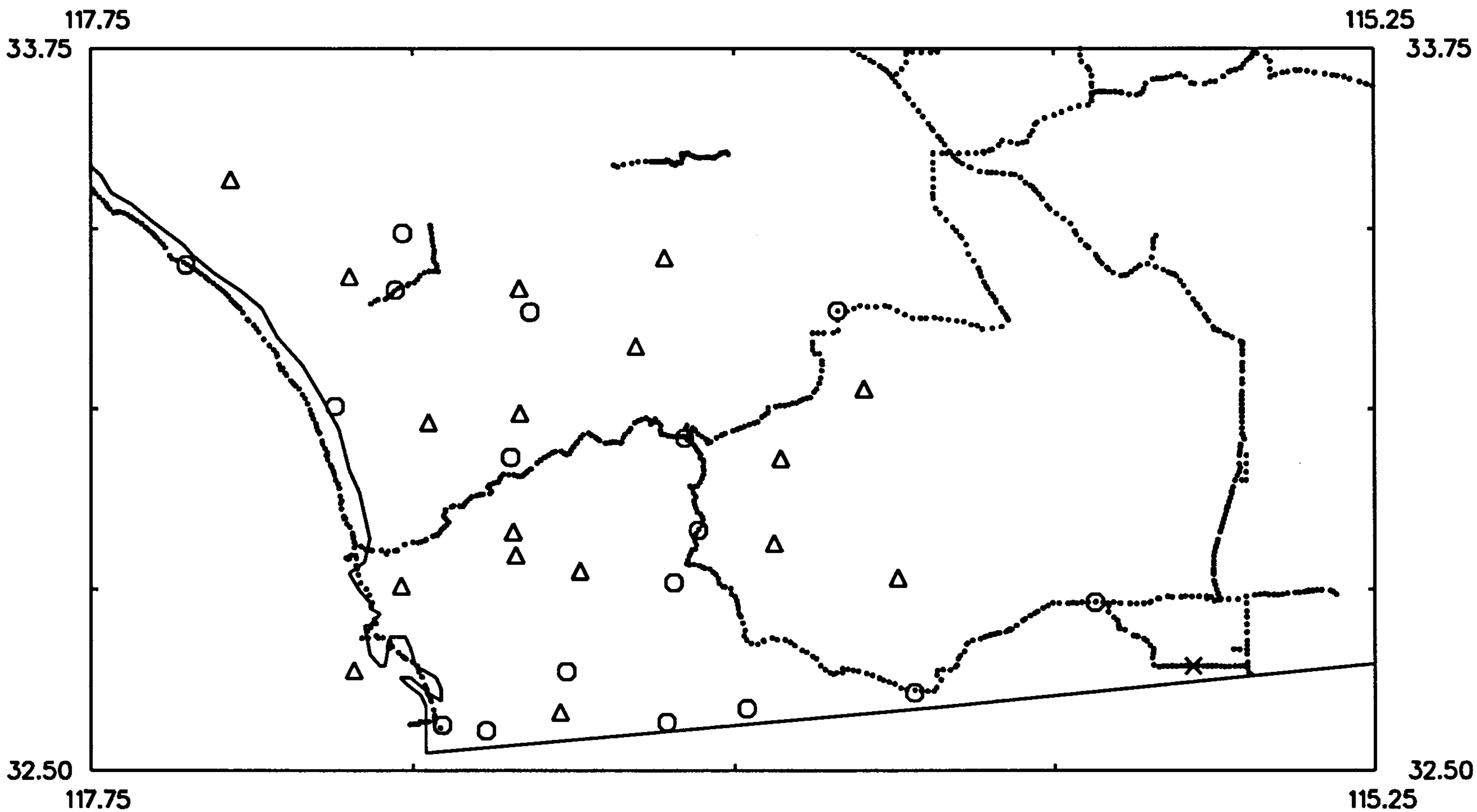


Fig. 17

NAVD 88/SCRP and SD GPS Network (0–GPS/BM)



\laser:scrp

Fig 18

NAVD 88 (Post Project) and SD GPS Network (o-GPS/BM)

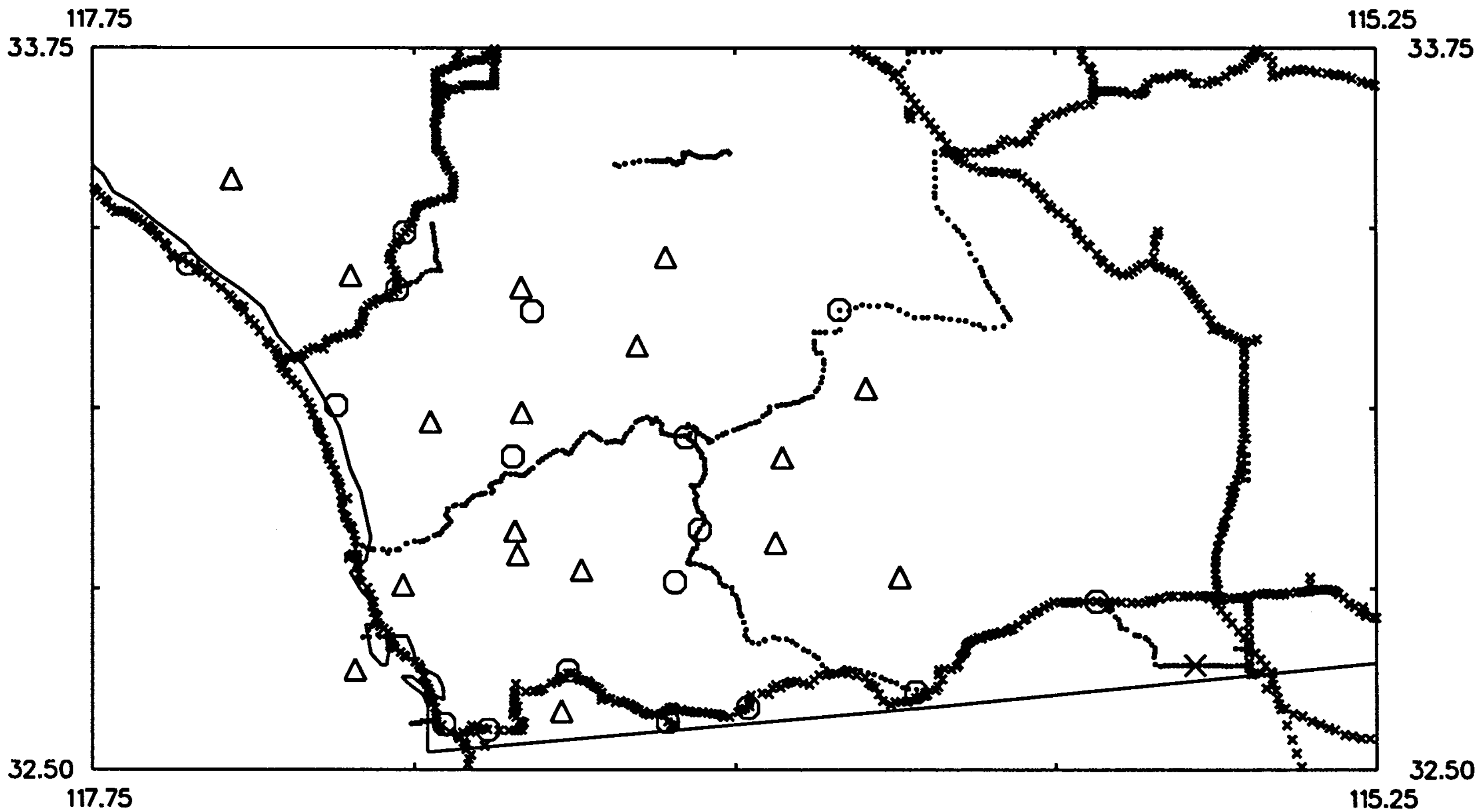


Table 1

San Diego GPS-Derived Orthometric Height Project

STATION	NAVD 88	
11AAR	188.052	LEVEL(1)
CA1101	156.771	TRIG(1)
CA1102	798.485	TRIG(1)
CA1107	94.902	LEVEL(2)
JUNCAZ	562.793	TRIG(1)
OCOT	-1.778	LEVEL(2)
SDGPS01	29.528	LEVEL(2)
SDGPS03	93.958	LEVEL(3)
SDGPS15	1281.509	TRIG(2)
SDGPS21	1096.931	LEVEL(4)
SDGPS24	46.494	LEVEL(2)
SDGPS31	926.012	TRIG(1)
SDGPS32	418.536	TRIG(2)
SDGPS33	222.523	TRIG(1)
SDGPS34	823.437	TRIG(3)
SDGPS35	1234.762	TRIG(2)
YUNG	352.094	LEVEL(3)

LEVEL(1) - NAVD 88 HEIGHT ESTIMATED IN SCRP POSTED ADJUSTMENT
LEVEL(2) - NAVD 88 HEIGHT ESTIMATED USING SHORT LEVELING TIE AND NAVD88 G.A. BENCH MARK
LEVEL(3) - NAVD 88 HEIGHT ESTIMATED USING NEW LEVELING LINE AND NAVD 88 G.A (NGSIDB)
LEVEL(4) - NAVD 88 HEIGHT ESTIMATED USING SHORT LEVELING TIE AND SCRP POSTED NAVD 88 HEIGHT

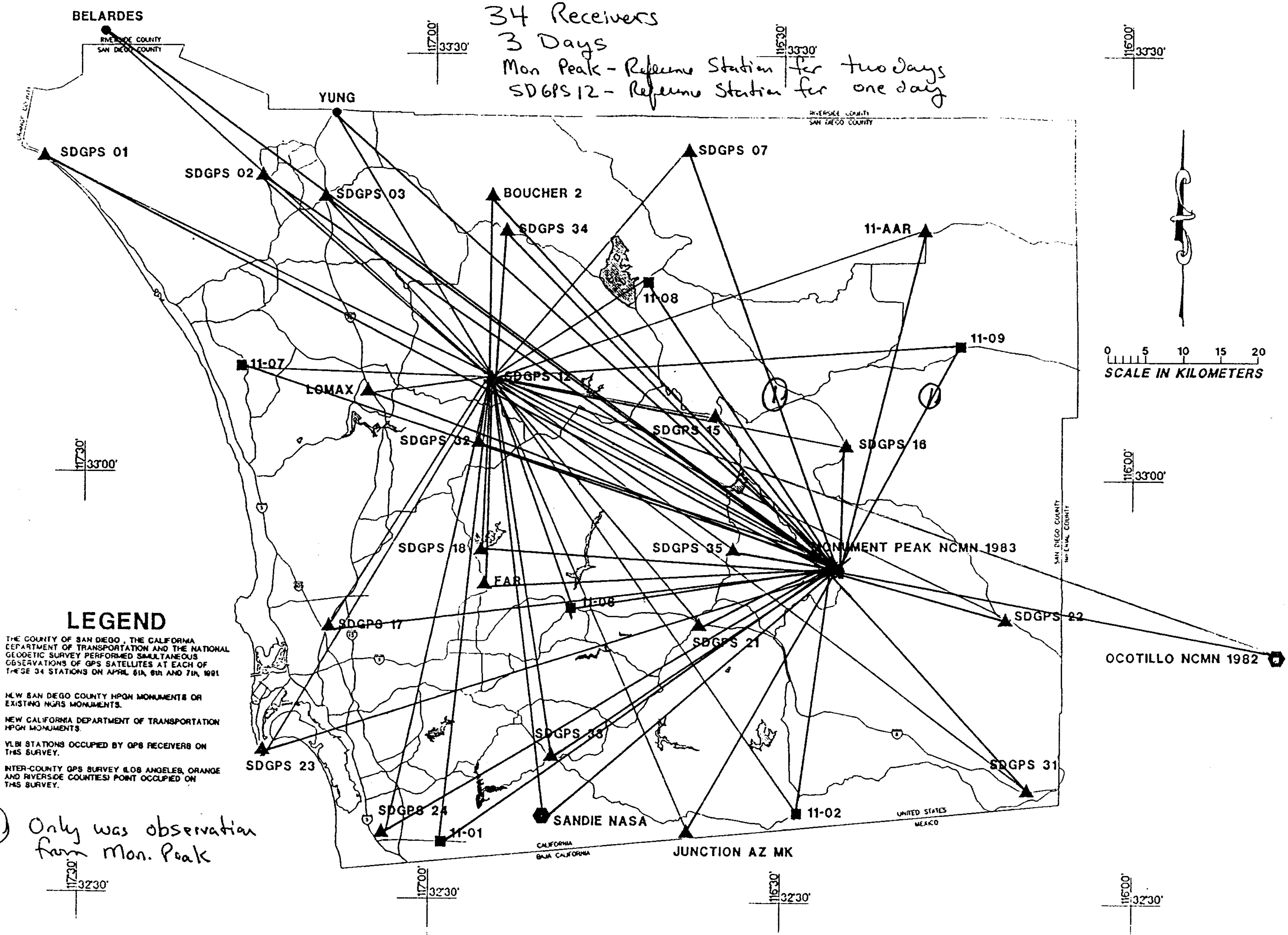
TRIG(1) - NAVD 88 ESTIMATED USING SHORT TRIG TIE AND NAVD 88
TRIG(2) - NAVD 88 ESTIMATED USING SHORT TRIG TIE AND SCRP POSTED HEIGHTS
TRIG(3) - NAVD 88 ESTIMATED USING SHORT TRIG TIE AND 1970 POSTED HEIGHTS

Du Residuals

Fig. 19

SAN DIEGO COUNTY HIGH PRECISION GEODETIC NETWORK

34 Receivers
3 Days
Mon Peak - Reference Station for two days
SDGPS 12 - Reference Station for one day



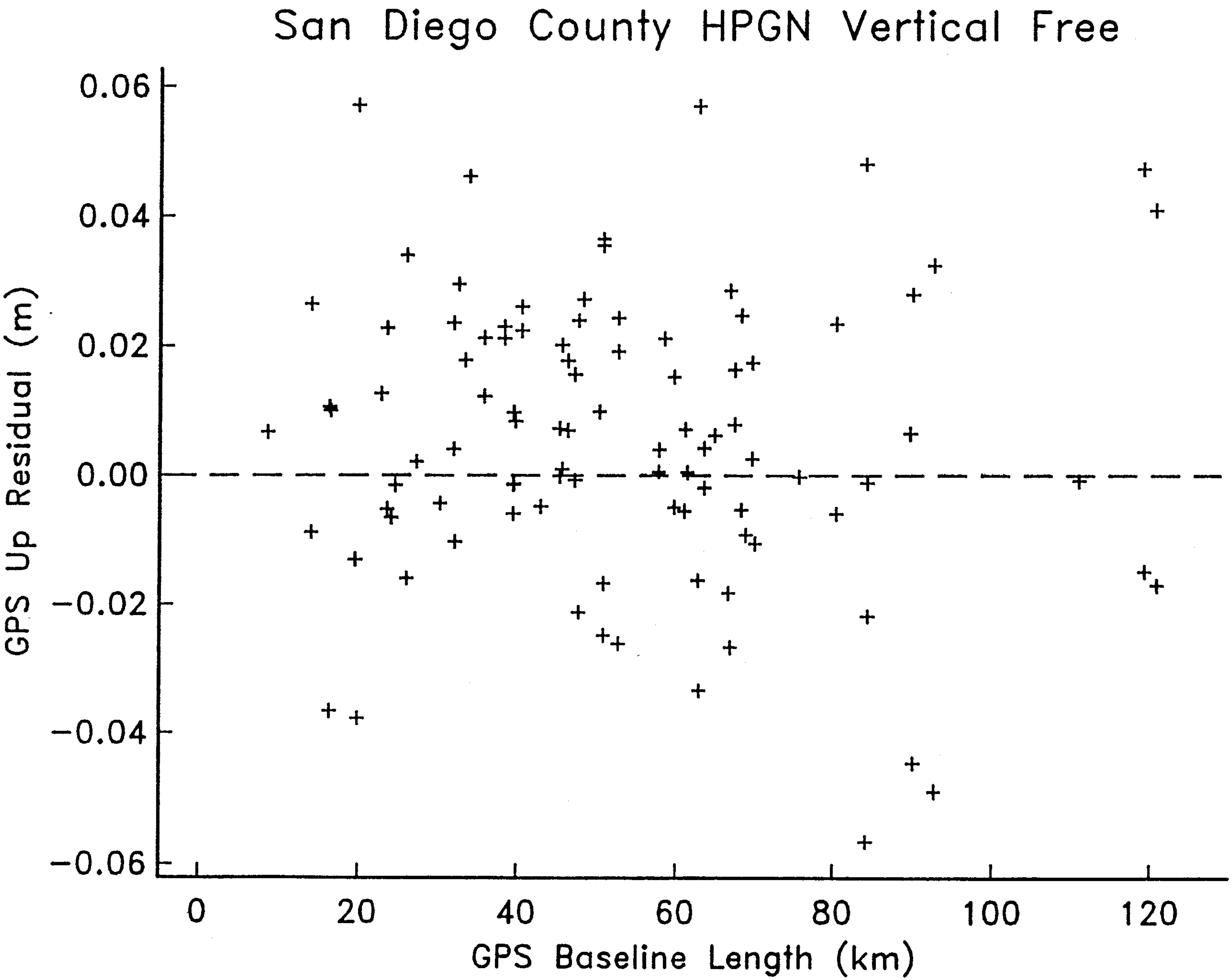
LEGEND

THE COUNTY OF SAN DIEGO, THE CALIFORNIA DEPARTMENT OF TRANSPORTATION AND THE NATIONAL GEODETIC SURVEY PERFORMED SIMULTANEOUS OBSERVATIONS OF GPS SATELLITES AT EACH OF THESE 34 STATIONS ON APRIL 5th, 6th AND 7th, 1991

- ▲ NEW SAN DIEGO COUNTY HPGN MONUMENTS OR EXISTING NGRS MONUMENTS.
- ■ NEW CALIFORNIA DEPARTMENT OF TRANSPORTATION HPGN MONUMENTS.
- ⬢ VLBI STATIONS OCCUPIED BY GPS RECEIVERS ON THIS SURVEY.
- ● INTER-COUNTY GPS SURVEY (LOS ANGELES, ORANGE AND RIVERSIDE COUNTIES) POINT OCCUPIED ON THIS SURVEY.

(1) Only was observation from Mon. Peak

Fig. 20



Adjustment of Aug 4 1992 at 13:33
Mean value is 0.018 meters

dU Residuals from Minimum Constraint Least Squares Adjustment
(Units = cm)

Fig. 21

SAN DIEGO COUNTY HIGH PRECISION GEODETIC NETWORK

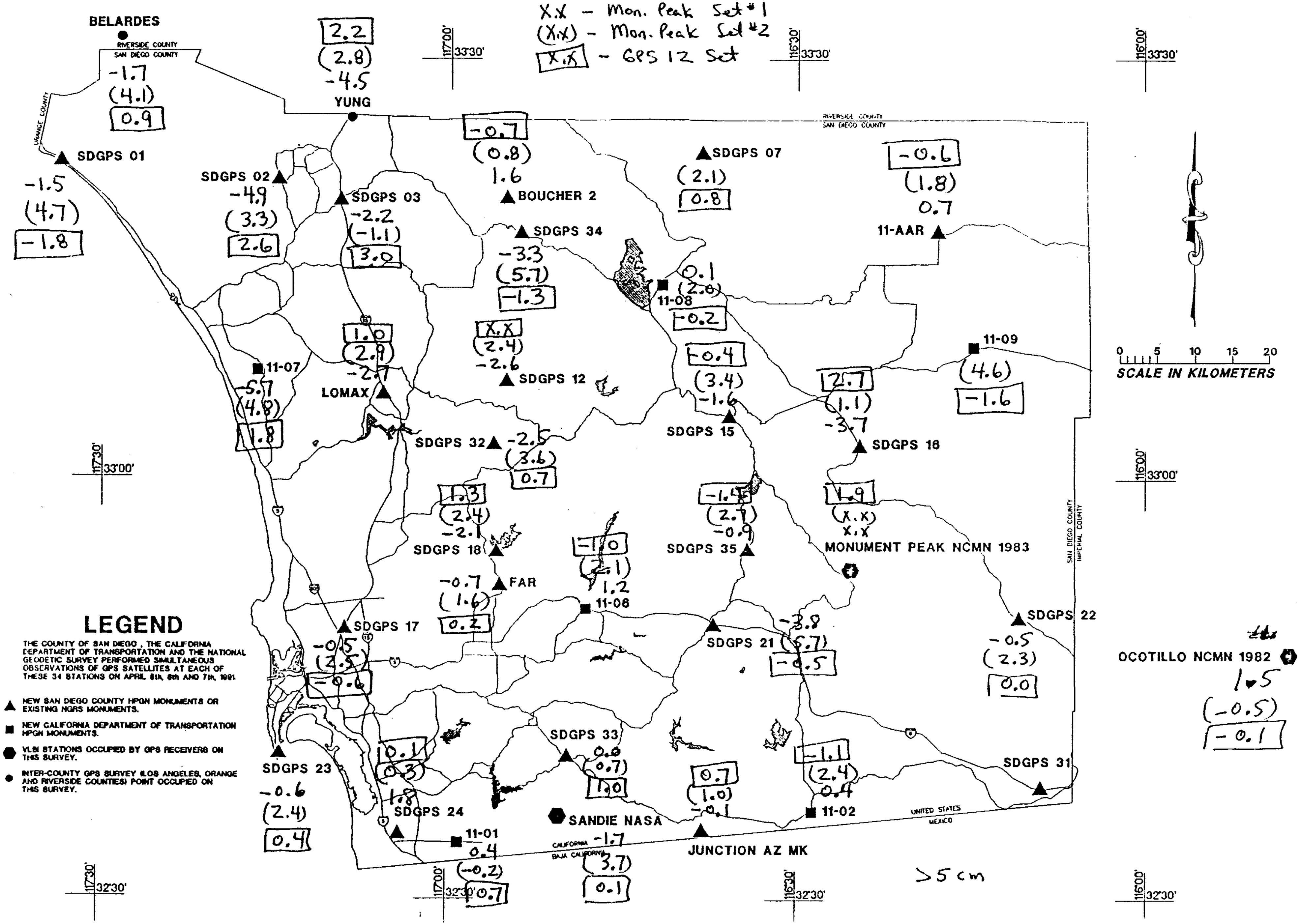


Table 2

Differences in ellipsoid heights using different occupations

NUMBER	NAME	Ellipsoid Heights OCC(MON 1) (m)	OCC(MON 2) (m)	OCC(GPS 12) (m)	OCC(ALL DATA) (m)	Differences in Ellipsoid Heights MON 1-ALL (cm)	MON 2-ALL (cm)	GPS 12-ALL (cm)	MON 1-MON 2 (cm)	MON 1-GPS12 (cm)	MON 2-GPS12 (cm)
1	11 AAR	155.487	155.461	155.482	155.476	1.1	-1.5	0.6	2.6	0.5	-2.1
2	BELARDES	671.897	671.824	671.872	671.863	3.4	-3.9	0.9	7.3 *	2.5	-4.8
3	BOUCHER 2	1629.220	1629.214	1629.226	1629.219	0.1	-0.5	0.7	0.6	-0.6	-1.2
4	FAR	174.448	174.417	174.428	174.430	1.8	-1.3	-0.2	3.1	2.0	-1.1
5	HPGN CA 11 01	122.483	122.474	122.463	122.469	1.4	0.5	-0.6	0.9	2.0	1.1
6	HPGN CA 11 02	766.430	766.395	766.428	766.416	1.4	-2.1	1.2	3.5	0.2	-3.3
7	HPGN CA 11 06	391.482	391.459	391.488	391.477	0.5	-1.8	1.1	2.3	-0.6	-2.9
8	HPGN CA 11 07	60.847	60.727	60.755	60.773	7.4 *	-4.6	-1.8	12.0 *	9.2 *	-2.8
9	HPGN CA 11 08	842.131	842.096	842.116	842.114	1.7	-1.8	0.2	3.5	1.5	-2.0
10	HPGN CA 11 09	201.637	201.566	201.626	201.609	2.8	-4.3	1.7	7.1 *	1.1	-6.0 *
11	JUNCTION AZ MK	530.407	530.381	530.382	530.388	1.9	-0.7	-0.6	2.6	2.5	-0.1
12	LOMAX	254.714	254.643	254.660	254.670	4.4	-2.7	-1.0	7.1 *	5.4 *	-1.7
13	MON PEAK	1839.895	1839.880	1839.859	1839.878	1.7	0.2	-1.9	1.5	3.6	2.1
14	OCOTILLO	-35.729	-35.724	-35.730	-35.731	0.2	0.7	0.1	-0.5	0.1	0.6
15	SD GPS 01	-4.903	-4.981	-4.917	-4.936	3.3	-4.5	1.9	7.8 *	1.4	-6.4 *
16	SD GPS 02	185.487	185.391	185.395	185.421	6.6 *	-3.0	-2.6	9.6 *	9.2 *	-0.4
17	SD GPS 03	61.151	61.115	61.082	61.111	4.0	0.4	-2.9	3.6	6.9 *	3.3
18	SD GPS 07	1421.898	1421.849	1421.860	1421.868	3.0	-1.9	-0.8	4.9	3.8	-1.1
19	SD GPS 12	592.007	591.941	591.964	591.963	4.4	-2.2	0.1	6.6 *	4.3	-2.3
20	SD GPS 15	1250.262	1250.198	1250.234	1250.229	3.3	-3.1	0.5	6.4 *	2.8	-3.6
21	SD GPS 16	757.767	757.705	757.686	757.713	5.4 *	-0.8	-2.7	6.2 *	8.1 *	1.9
22	SD GPS 17	91.244	91.199	91.227	91.221	2.3	-2.2	0.6	4.5	1.7	-2.8
23	SD GPS 18	210.145	210.085	210.094	210.106	3.9	-2.1	-1.2	6.0 *	5.1 *	-0.9
24	SD GPS 21	1065.512	1065.402	1065.462	1065.457	5.5 *	-5.5 *	0.5	11.0 *	5.0 *	-6.0 *
25	SD GPS 22	295.558	295.515	295.536	295.535	2.3	-2.0	0.1	4.3	2.2	-2.1
26	SD GPS 23	90.679	90.635	90.652	90.656	2.3	-2.1	-0.4	4.4	2.7	-1.7
27	SD GPS 24	11.729	11.729	11.729	11.729	0.0	0.0	0.0	0.0	0.0	0.0
28	SD GPS 31	893.667	893.650	893.664	893.670	-0.3	-2.0	-0.6	1.7	0.3	-1.4
29	SD GPS 32	386.059	385.983	386.010	386.016	4.3	-3.3	-0.6	7.6 *	4.9	-2.7
30	SD GPS 33	189.455	189.433	189.428	189.438	1.7	-0.5	-1.0	2.2	2.7	0.5
31	SD GPS 34	792.046	791.941	792.009	791.995	5.1 *	-5.4 *	1.4	10.5 *	3.7	-6.8 *
32	SD GPS 35	1203.595	1203.544	1203.570	1203.568	2.7	-2.4	0.2	5.1 *	2.5	-2.6
33	SANDIE	989.674	989.606	989.640	989.640	3.4	-3.4	0.0	6.8 *	3.4	-3.4
34	YUNG	319.708	319.621	319.624	319.646	6.2 *	-2.5	-2.2	8.7 *	8.4 *	-0.3
					AVE	2.9	-2.1	-0.3	5.0	3.2	-1.9
					MIN	-0.3	-5.5	-2.9	-0.5	-0.6	-6.8
					MAX	7.4	0.7	1.9	12.0	9.2	3.3

* - Absolute value greater than or equal to 5 cm

MON 1 - FIRST SET OF VECTORS FROM MONUMENT PEAK USED TO ESTIMATE HEIGHTS
MON 2 - SECOND SET OF VECTORS FROM MONUMENT PEAK USED TO ESTIMATE HEIGHTS
GPS 12 - VECTORS FROM SD GPS 12 USED TO ESTIMATE HEIGHTS
ALL - ALL DATA USED TO ESTIMATE HEIGHTS

Tabl 3

Differences in ellipsoid heights using different occupations

NUMBER	NAME	Ellipsoid Heights: MON 1+MON 2 (m)	MON 1+GPS12 (m)	MON 2+GPS12 (m)	OCC(ALL DATA) (m)	Differences in Ellipsoid Heights: MON(1+2)-ALL (cm)	MON1+12-ALL (cm)	MON2+12-ALL (cm)	(1+2)-(1+12) (cm)	(1+2)-(2+12) (cm)	(1+12)-(2+12) (cm)
1	11 AAR	155.473	155.484	155.472	155.476	-0.3	0.8	-0.4	-1.1	0.1	1.2
2	BELARDES	671.858	671.884	671.847	671.863	-0.5	2.1	-1.6	-2.6	1.1	3.7
3	BOUCHER 2	1629.214	1629.225	1629.217	1629.219	-0.5	0.6	-0.2	-1.1	-0.3	0.8
4	FAR	174.431	174.438	174.422	174.430	0.1	0.8	-0.8	-0.7	0.9	1.6
5	HPGN CA 11 01	122.474	122.471	122.466	122.469	0.5	0.2	-0.3	0.3	0.8	0.5
6	HPGN CA 11 02	766.411	766.428	766.411	766.416	-0.5	1.2	-0.5	-1.7	0.0	1.7
7	HPGN CA 11 06	391.471	391.488	391.473	391.477	-0.6	1.1	-0.4	-1.7	-0.2	1.5
8	HPGN CA 11 07	60.782	60.799	60.741	60.773	0.9	2.6	-3.2	-1.7	4.1	5.8 *
9	HPGN CA 11 08	842.112	842.123	842.107	842.114	-0.2	0.9	-0.7	-1.1	0.5	1.6
10	HPGN CA 11 09	201.588	201.641	201.597	201.609	-2.1	3.2	-1.2	-5.3 *	-0.9	4.4
11	JUNCTION AZ MK	530.392	530.393	530.380	530.388	0.4	0.5	-0.8	-0.1	1.2	1.3
12	LOMAX	254.676	254.685	254.650	254.670	0.6	1.5	-2.0	-0.9	2.6	3.5
13	MON PEAK	1839.887	1839.872	1839.874	1839.878	0.9	-0.6	-0.4	1.5	1.3	-0.2
14	OCOTILLO	-35.731	-35.73	-35.730	-35.731	0.0	0.1	0.1	-0.1	-0.1	0.0
15	SD GPS 01	-4.945	-4.911	-4.950	-4.936	-0.9	2.5	-1.4	-3.4	0.5	3.9
16	SD GPS 02	185.435	185.438	185.392	185.421	1.4	1.7	-2.9	-0.3	4.3	4.6
17	SD GPS 03	61.130	61.113	61.095	61.111	1.9	0.2	-1.6	1.7	3.5	1.8
18	SD GPS 07	1421.873	1421.875	1421.854	1421.868	0.5	0.7	-1.4	-0.2	1.9	2.1
19	SD GPS 12	591.972	591.978	591.946	591.963	0.9	1.5	-1.7	-0.6	2.6	3.2
20	SD GPS 15	1250.227	1250.247	1250.215	1250.229	-0.2	1.8	-1.4	-2.0	1.2	3.2
21	SD GPS 16	757.730	757.717	757.694	757.713	1.7	0.4	-1.9	1.3	3.6	2.3
22	SD GPS 17	91.219	91.235	91.211	91.221	-0.2	1.4	-1.0	-1.6	0.8	2.4
23	SD GPS 18	210.112	210.119	210.089	210.106	0.6	1.3	-1.7	-0.7	2.3	3.0
24	SD GPS 21	1065.453	1065.487	1065.431	1065.457	-0.4	3.0	-2.6	-3.4	2.2	5.6 *
25	SD GPS 22	295.534	295.547	295.525	295.535	-0.1	1.2	-1.0	-1.3	0.9	2.2
26	SD GPS 23	90.657	90.668	90.642	90.656	0.1	1.2	-1.4	-1.1	1.5	2.6
27	SD GPS 24	11.729	11.729	11.729	11.729	0.0	0.0	0.0	0.0	0.0	0.0
28	SD GPS 31	893.667	893.684	893.657	893.670	-0.3	1.4	-1.3	-1.7	1.0	2.7
29	SD GPS 32	386.019	386.035	385.996	386.016	0.3	1.9	-2.0	-1.6	2.3	3.9
30	SD GPS 33	189.443	189.441	189.430	189.438	0.5	0.3	-0.8	0.2	1.3	1.1
31	SD GPS 34	791.989	792.027	791.973	791.995	-0.6	3.2	-2.2	-3.8	1.6	5.4 *
32	SD GPS 35	1203.567	1203.582	1203.557	1203.568	-0.1	1.4	-1.1	-1.5	1.0	2.5
33	SANDIE	989.638	989.66	989.622	989.640	-0.2	2.0	-1.8	-2.2	1.6	3.8
34	YUNG	319.659	319.662	319.621	319.646	1.3	1.6	-2.5	-0.3	3.8	4.1
					AVE	0.1	1.3	-1.3	-1.1	1.4	2.6
					MIN	-2.1	-0.6	-3.2	-5.3	-0.9	-0.2
					MAX	1.9	3.2	0.1	1.7	4.3	5.8

* - Absolute value greater than or equal to 5 cm

MON 1 - FIRST SET OF VECTORS FROM MONUMENT PEAK USED TO ESTIMATE HEIGHTS
MON 2 - SECOND SET OF VECTORS FROM MONUMENT PEAK USED TO ESTIMATE HEIGHTS
GPS 12 - VECTORS FROM SD GPS 12 USED TO ESTIMATE HEIGHTS
ALL - ALL DATA USED TO ESTIMATE HEIGHTS

Table 4

San Diego GPS-Derived Orthometric Height Project

Station	GPS(h) min. constraint adjustment (m)	GPS(h) from NGSIDB (m)	Difference (cm)
11AAR	155.292	155.288	0.4
CA1101	122.285	122.281	0.4
CA1102	766.232	766.193	3.9
CA1107	60.589	60.658	-6.9
JUNCAZ	530.204	530.200	0.4
OCOT	-35.916	-35.967	5.1
SDGPS01	-5.12	-5.118	-0.2
SDGPS03	60.927	60.930	-0.3
SDGPS15	1250.045	1250.041	0.4
SDGPS21	1065.272	1065.268	0.4
SDGPS24	11.545	11.545	0.0
SDGPS31	893.486	893.473	1.3
SDGPS32	385.832	385.829	0.3
SDGPS33	189.253	189.253	0.0
SDGPS34	791.811	791.811	0.0
SDGPS35	1203.384	1203.381	0.3
YUNG	319.462	319.465	-0.3
	Datum Point SD GPS 24		

Table 5

2s

STATION NAME	GPS (h) Min. Constraint adjustment (M)	GPS (h) Standard Error (cm)
11 AAR	155.476	3.0
BELARDES	671.863	3.0
BOUCHER 2	1629.219	3.3
FAR	174.43	3.0
CA 11 01	122.469	3.1
CA 11 02	766.416	3.0
CA 11 06	391.477	3.1
CA 11 07	60.773	3.0
CA 11 08	842.114	3.0
CA 11 09	201.609	3.4
JUNCTION AZ MK	530.388	3.0
LOMAX	254.67	3.0
MON PEAK NCMN 7274	1839.878	3.1
OCOTILLO NCMN 7270	-35.731	3.0
SD GPS 01	-4.936	3.0
SD GPS 02	185.421	3.0
SD GPS 03	61.111	3.1
SD GPS 07	1421.868	3.3
SD GPS 12	591.963	3.0
SD GPS 15	1250.229	3.0
SD GPS 16	757.713	3.1
SD GPS 17	91.221	3.0
SD GPS 18	210.106	3.0
SD GPS 21	1065.457	3.0
SD GPS 22	295.535	3.0
SD GPS 23	90.656	3.1
SD GPS 24	* 11.729	0.0
SD GPS 31	893.67	3.1
SD GPS 32	386.016	3.0
SD GPS 33	189.438	3.0
SD GPS 34	791.995	3.0
SD GPS 35	1203.568	3.1
SANDIE NASA	989.64	3.0
YUNG	319.646	3.0

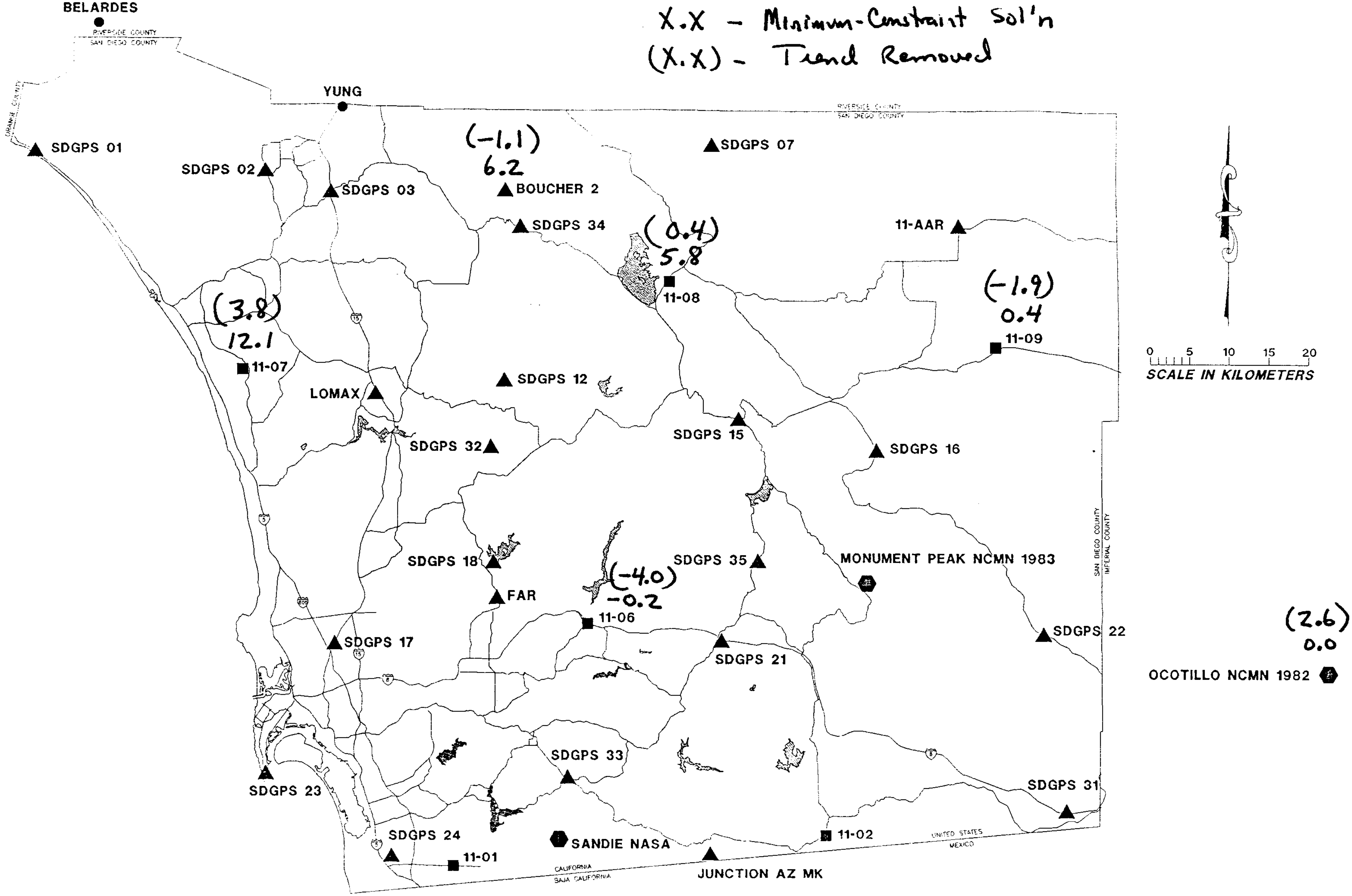
* CONSTRAINED HEIGHT IN ADJUSTMENT
Standard errors are a posteriori values

Fig 22

$h_{Landers} - h_{SDGPS}$ (units=cm)

SAN DIEGO COUNTY HIGH PRECISION GEODETIC NETWORK

X.X - Minimum-Constraint Sol'n
(X.X) - Trend Removed



Tab 6

STATION NAME	GPS(h) Min. Constraint adjustment Landers (M)	GPS(h) Min. Constraint adjustment SD GPS (M)	Differences (cm)	Differences Trend Removed (cm)
BOUCHER 2	1629.281	1629.219	6.2	-1.1
CA 11 06	391.475	391.477	-0.2	-4.0
CA 11 07	60.894	60.773	12.1	3.8
CA 11 08	842.172	842.114	5.8	0.4
CA 11 09	201.613	201.609	0.4	-1.9
OCOTILLO NCMN 7270	-35.731	-35.731	0.0	2.6

Shift (cm)	3.339
tilts	
e-w	-0.129
n-s	0.123
RMS (cm)	2.916
r value	0.64

$H_{GPS} - H_{88}$ (UNITS = cm)

Fig. 23

SAN DIEGO COUNTY HIGH PRECISION GEODETIC NETWORK

Minimum-Constraint Solution (Geoid 93S)

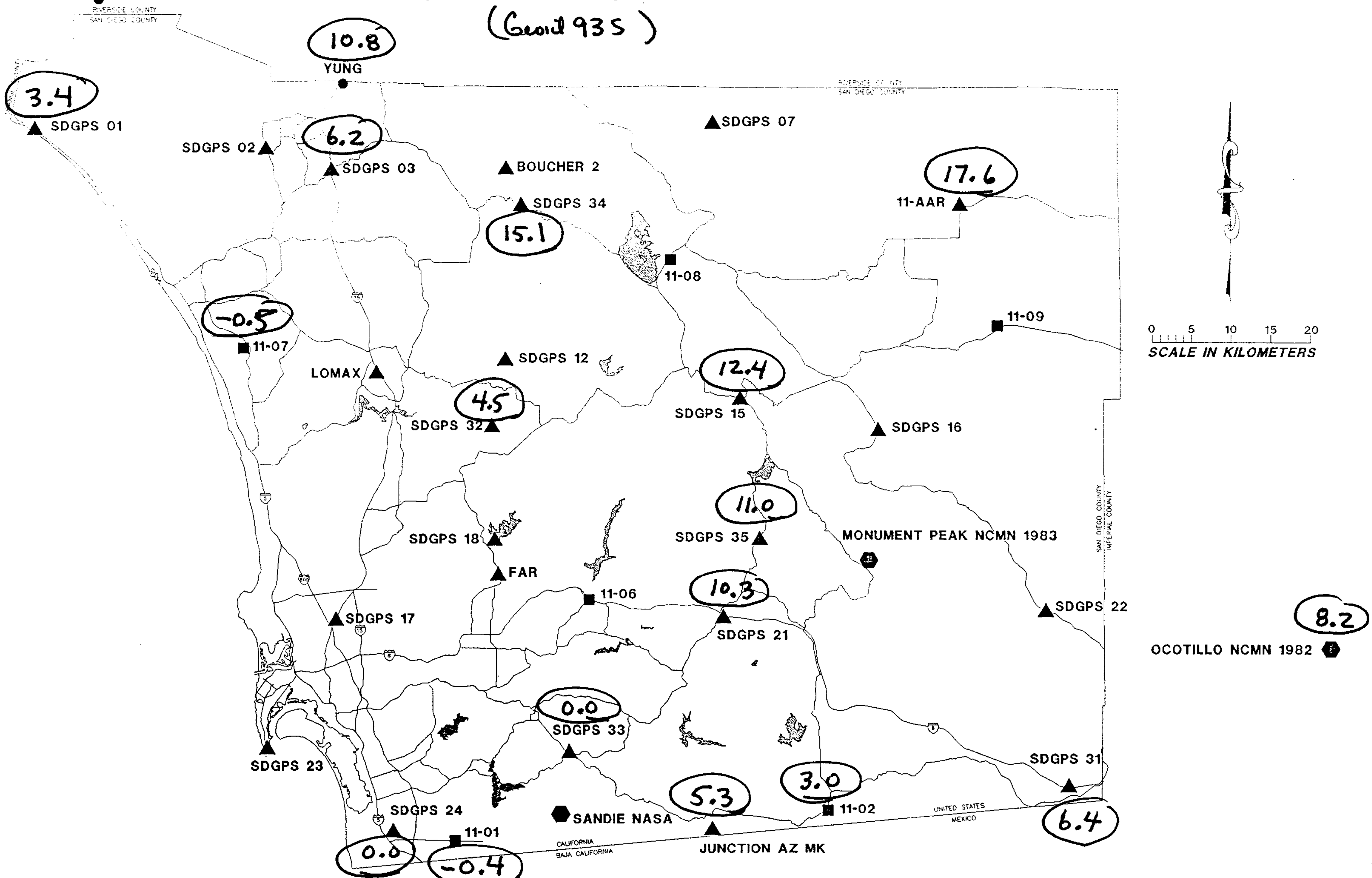


Fig 24 before

Surface Gravity Density - San Diego (2)

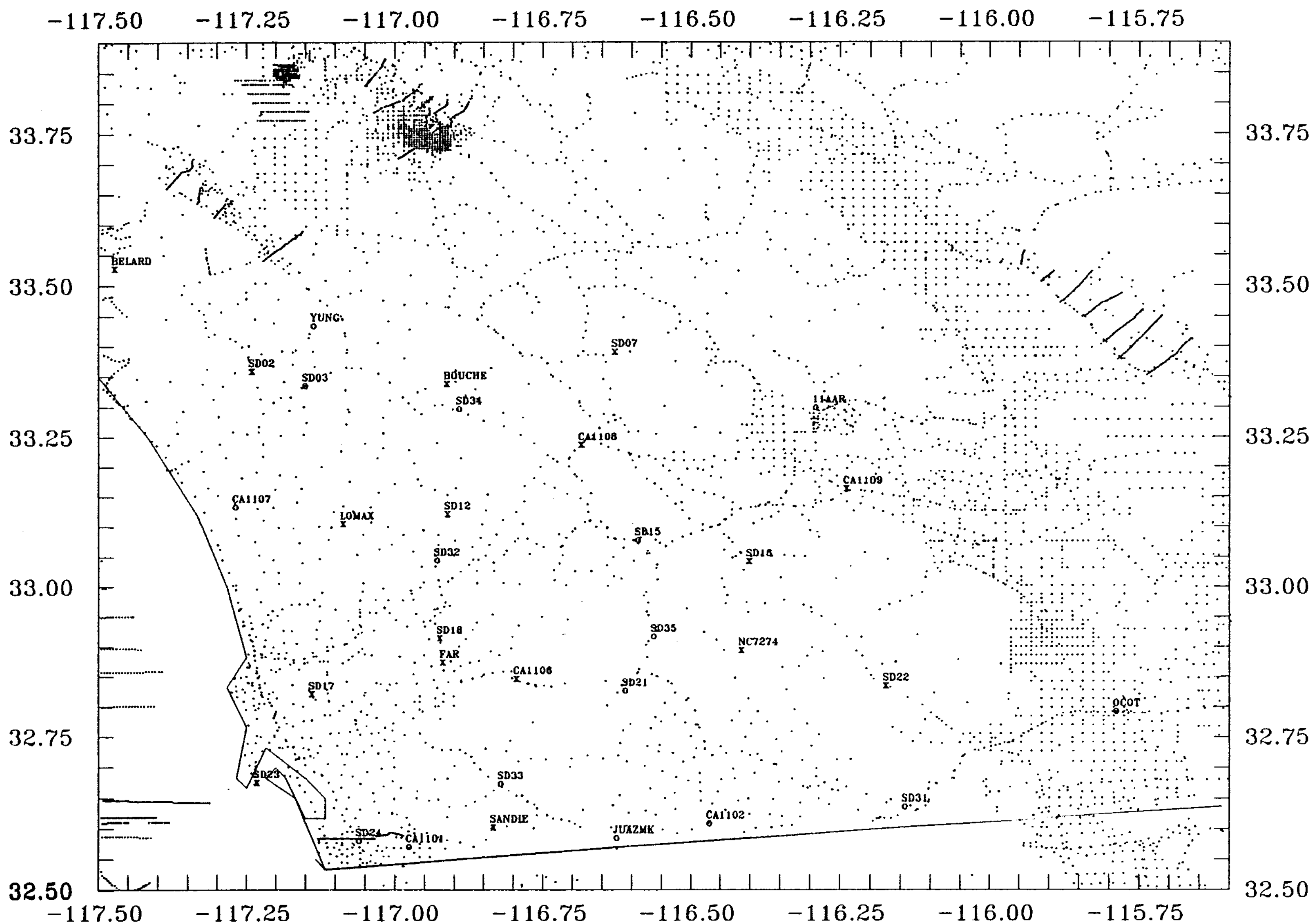


Fig. 25

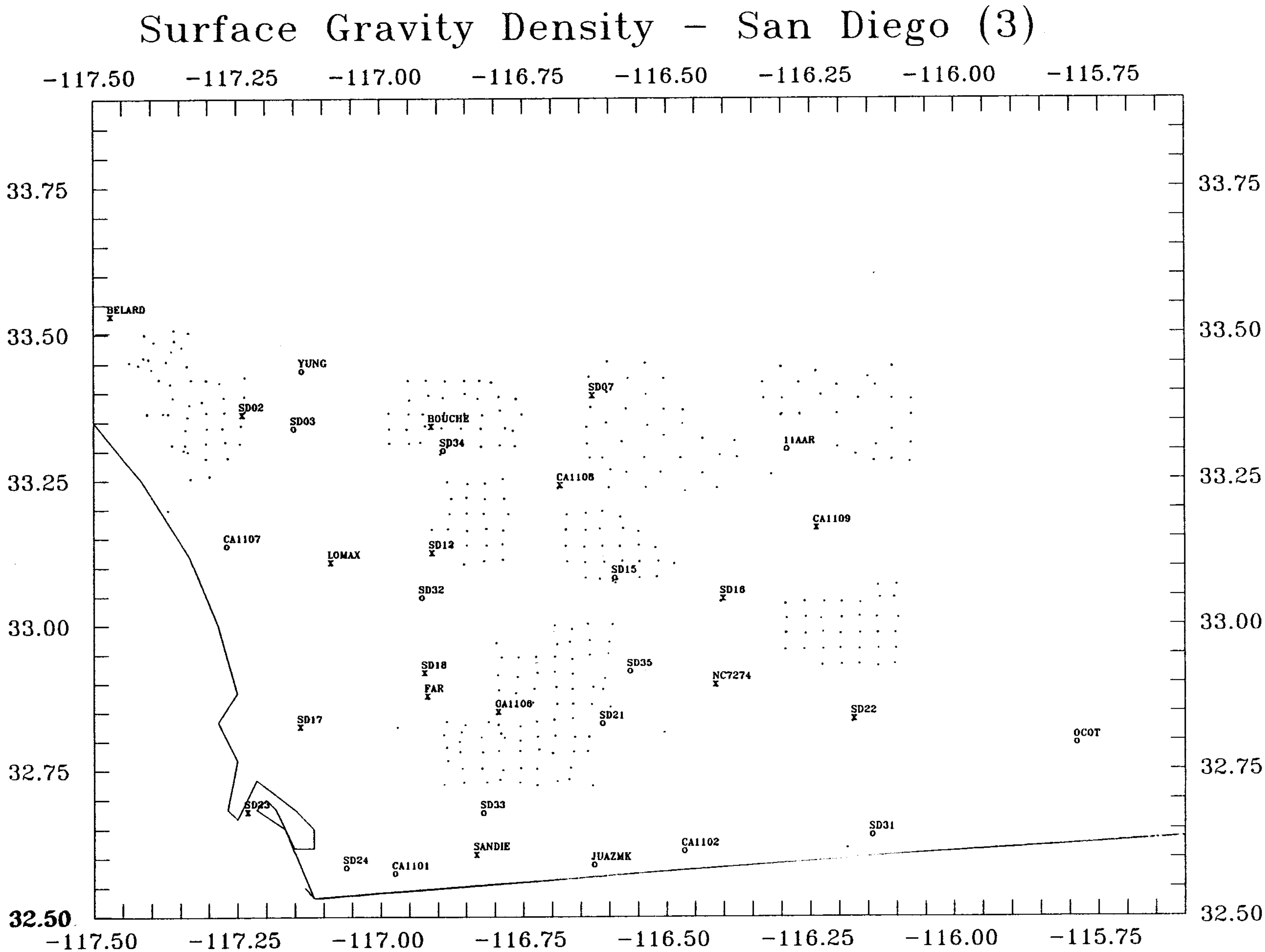

Surface Gravity Density - San Diego (3)
-117.50
-117.25
-117.00
-116.75
-116.50
-116.25
-116.00
-115.75
33.75
33.50
33.25
33.00
32.75
32.50
BELARD
YUNG
SD02
SD03
BOUCHE
SD34
SDQ7
11AAR
CA1108
CA1109
CA1107
LOMAX
SD12
SD15
SD32
SD16
SD18
SD35
NC7274
FAR
CA1106
SD21
SD22
SD17
OCOT
SD23
SD33
SD31
SANDIE
CA1102
SD24
CA1101
JUAZMK

Fig. 26

Surface Gravity Density – San Diego

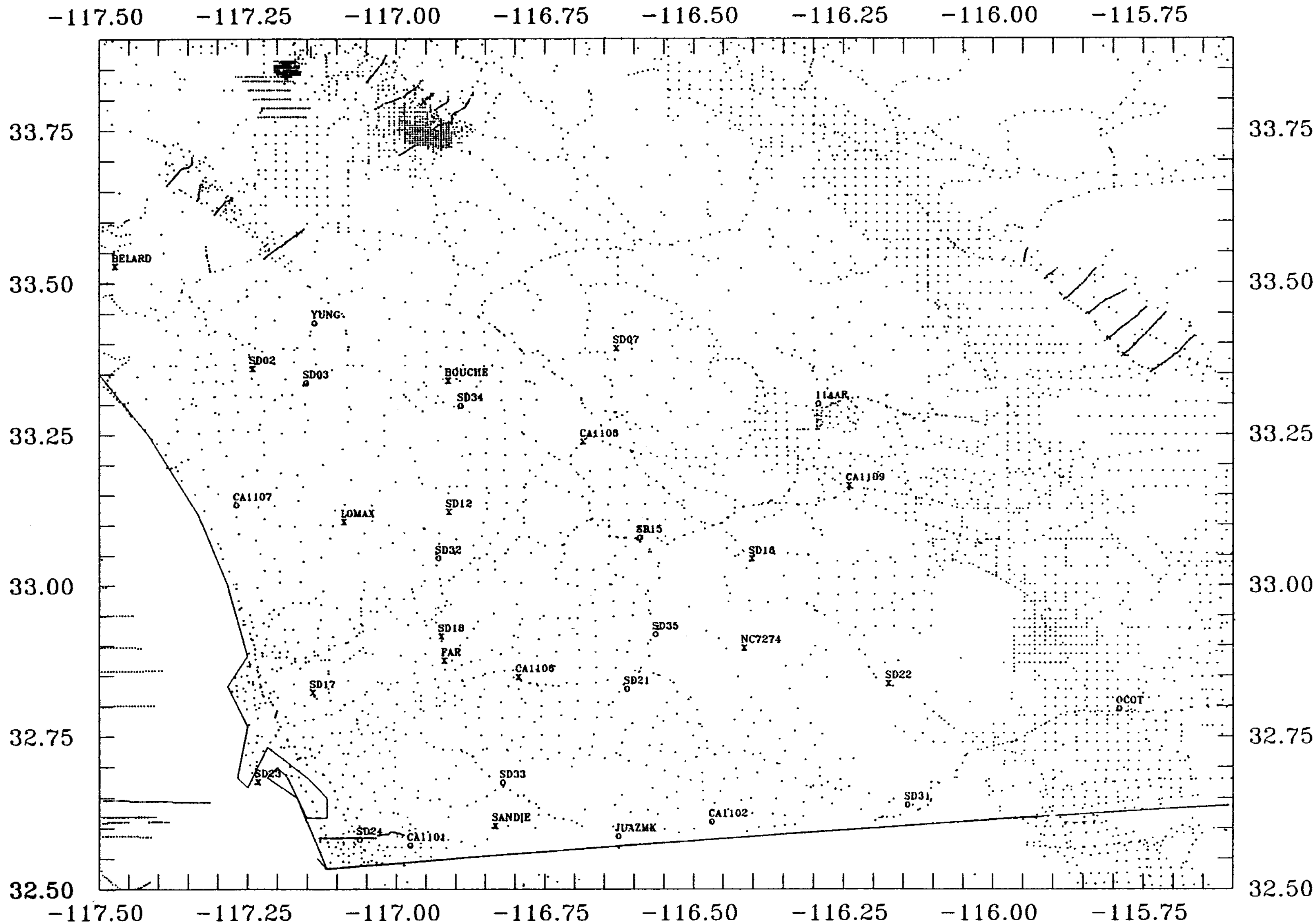


Fig 27

Bouguer Anomalies - San Diego

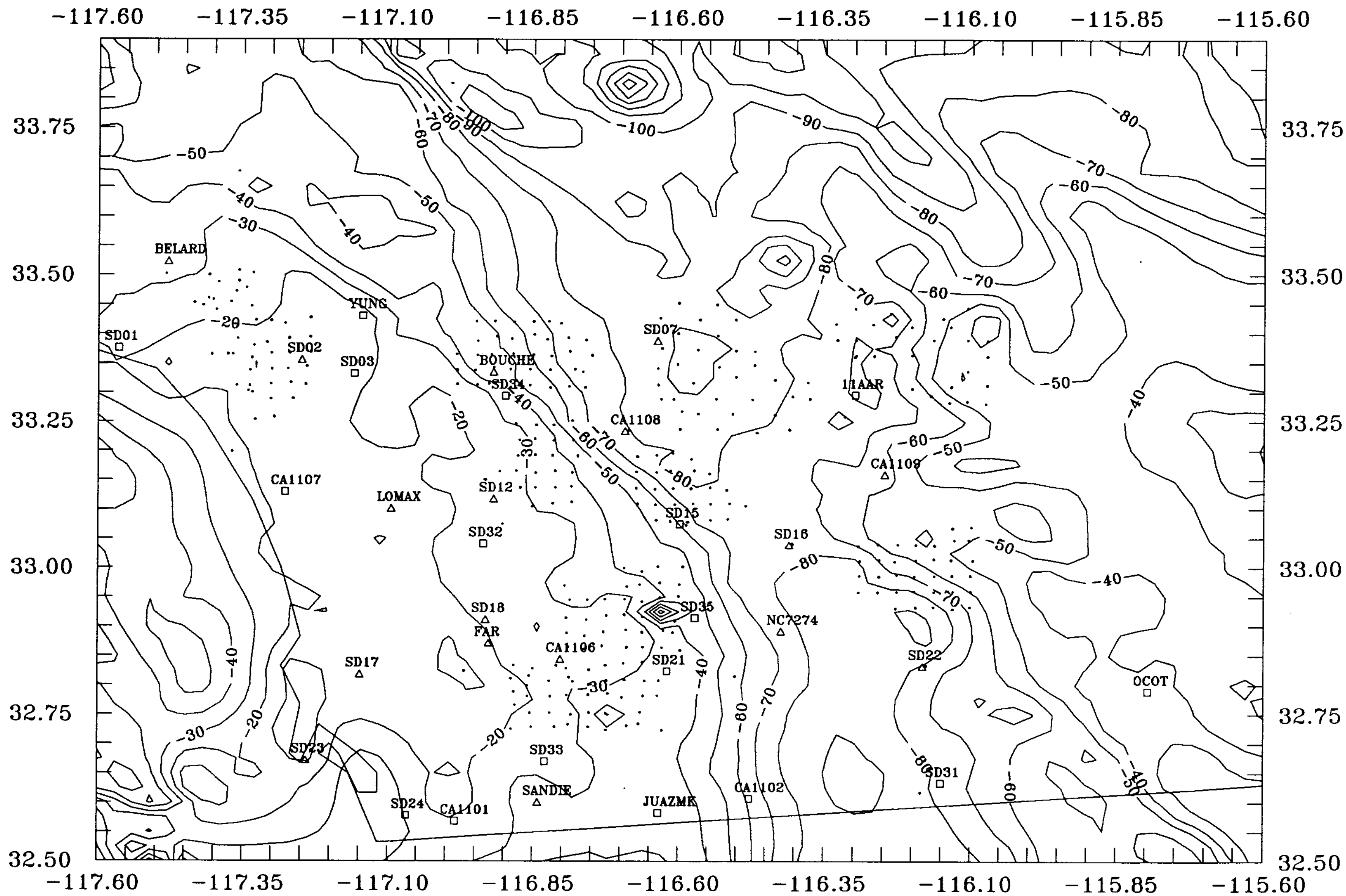


Fig. 28

LOCAL GEOID (m); San Diego Co.

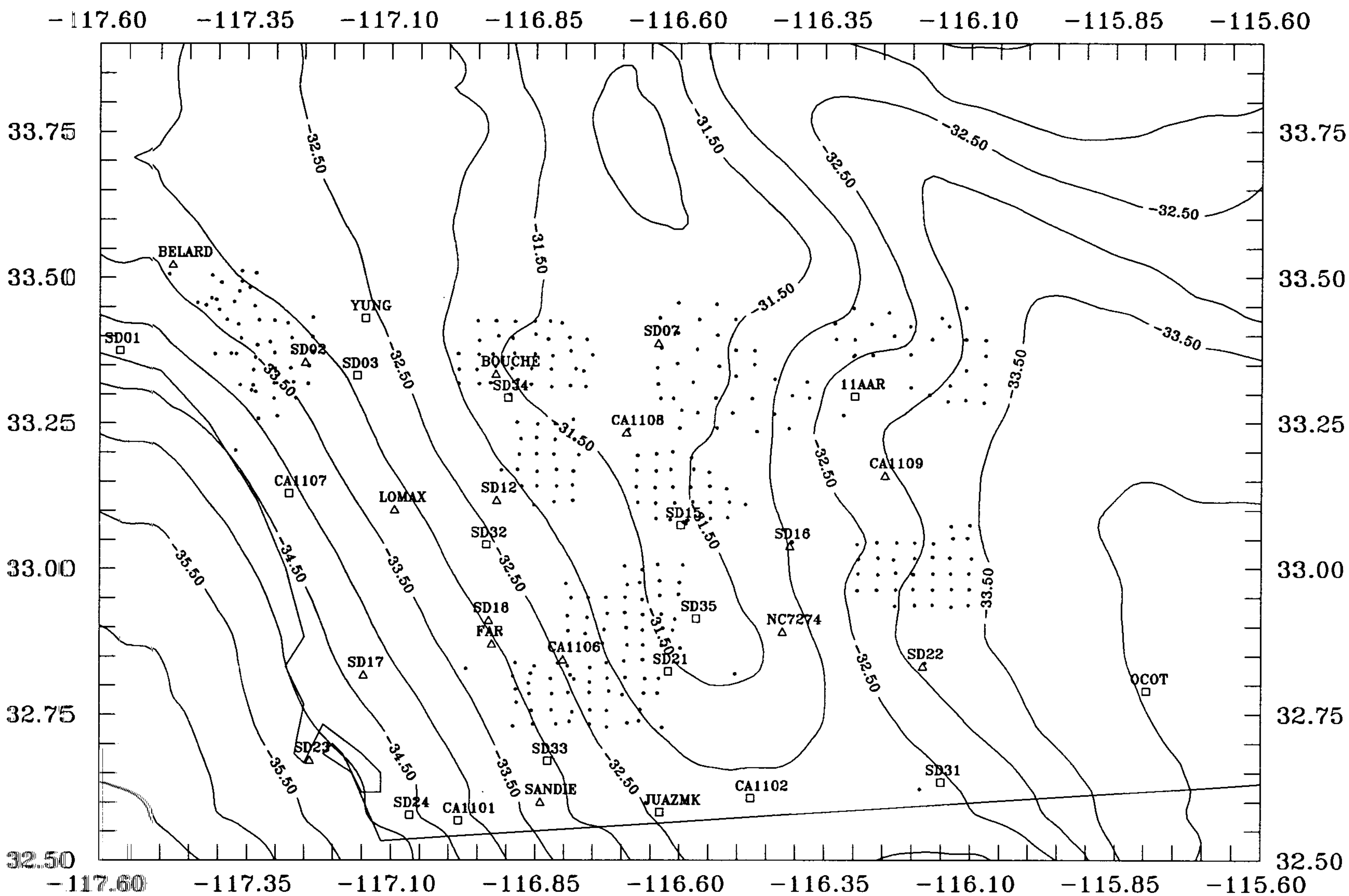


Fig. 29

LOCAL Geoid - GEOID93 (cm); San Diego Co.

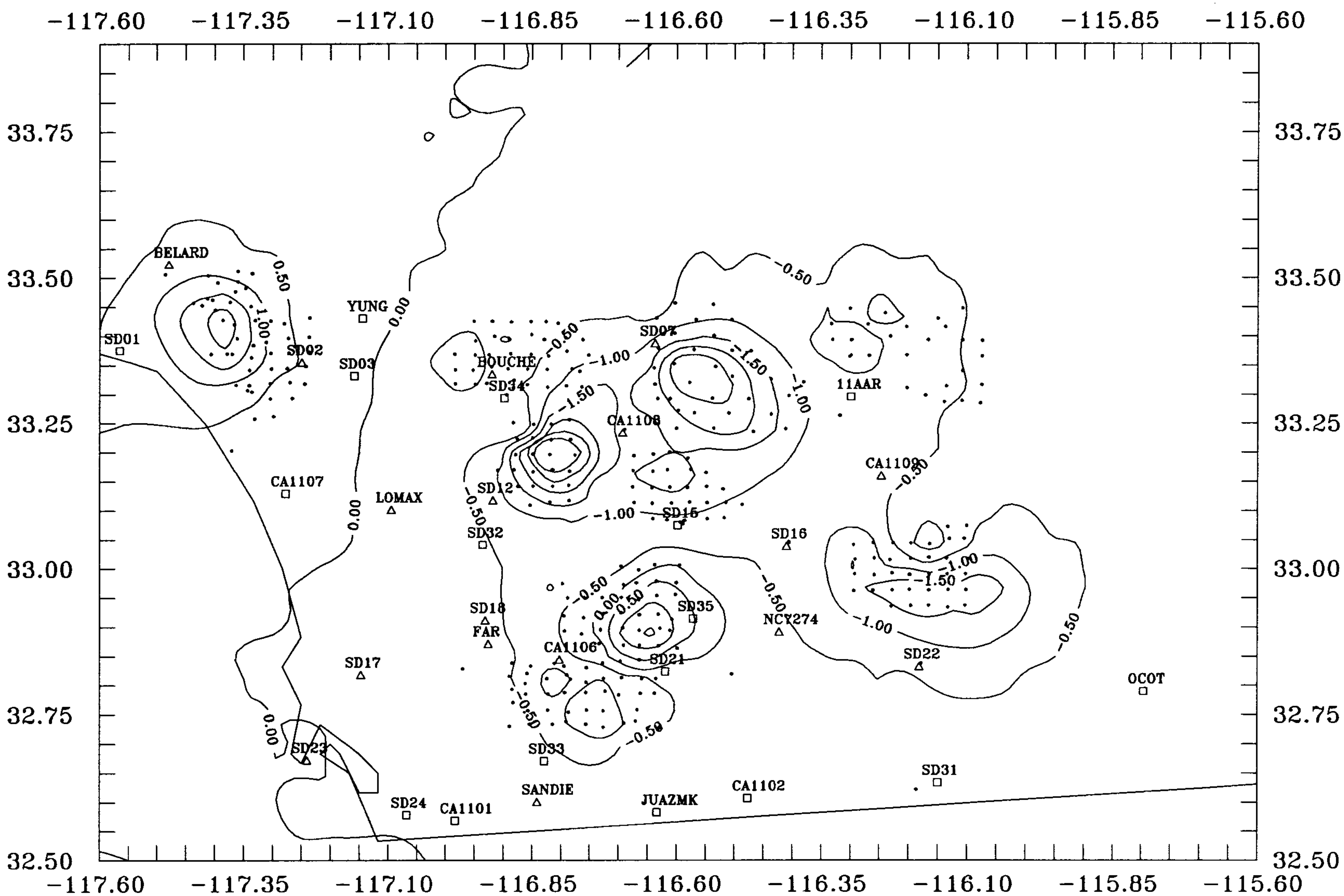


Fig. 30

GPS(H) – NAVD88(H) (cm); 17 Sta.– San Diego Co.

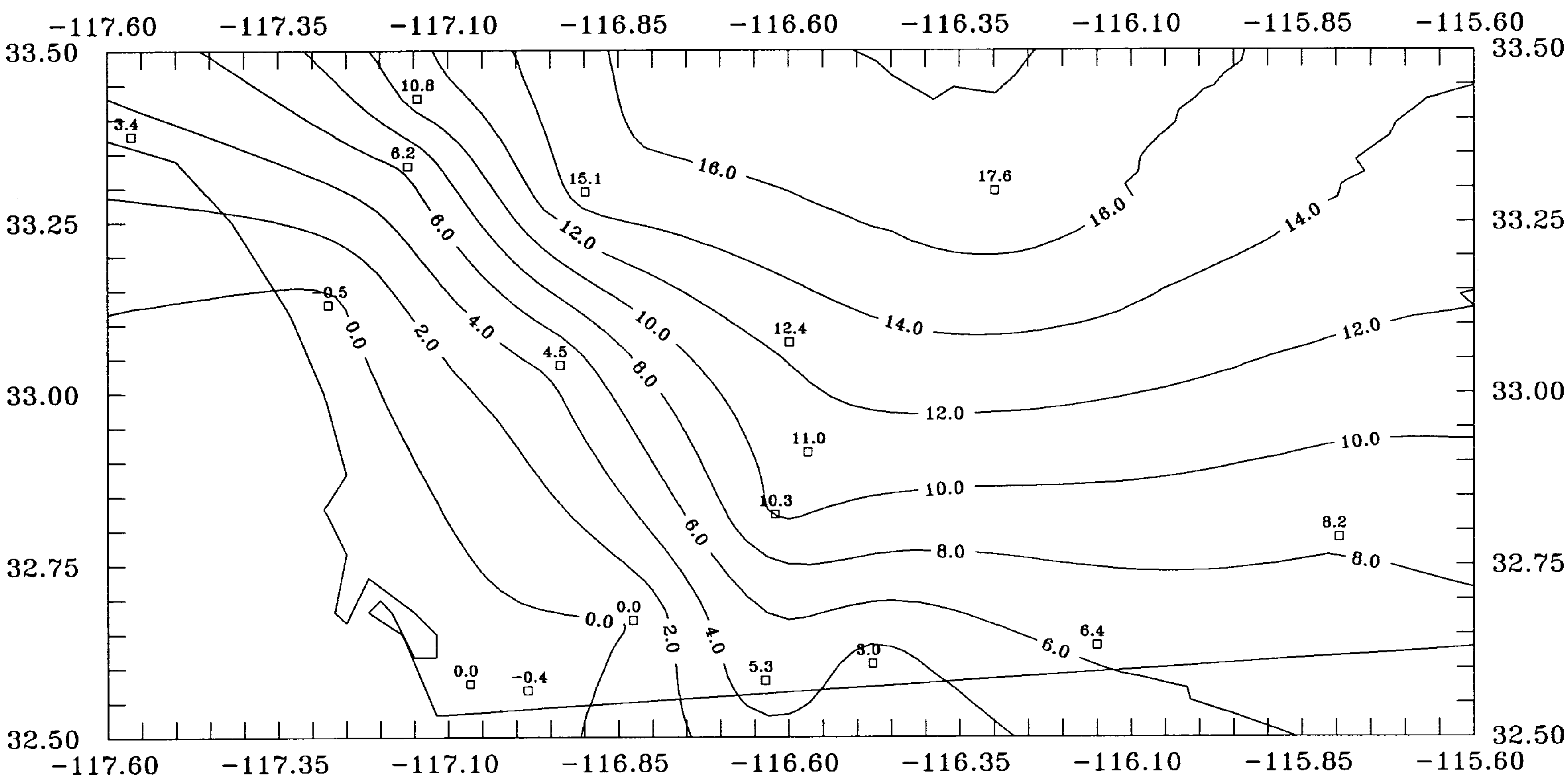
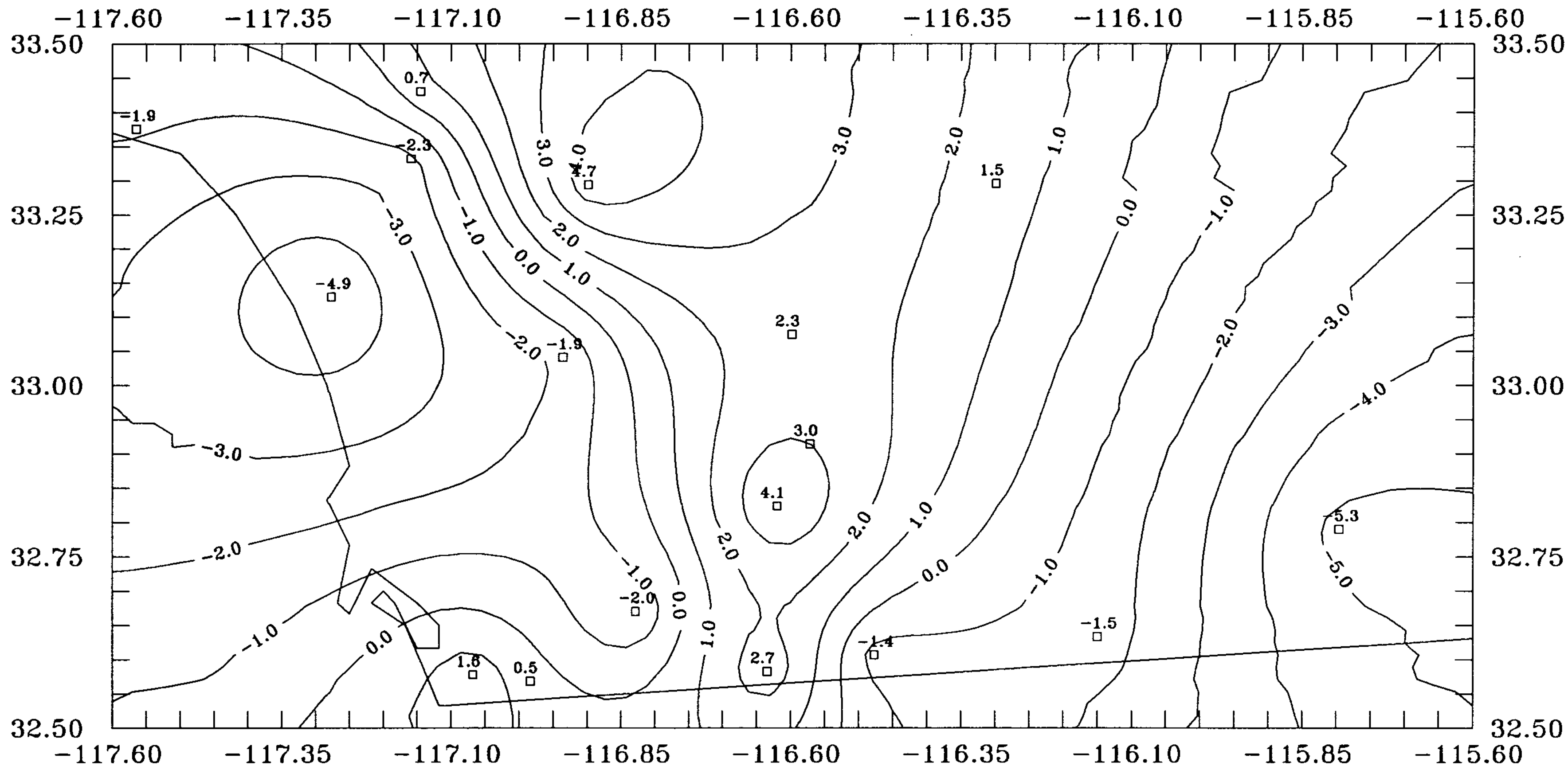


Fig. 31

GPS(H)-NAVD88(H) 17 Sta. trend removed-San Diego



Tab 7

San Diego GPS-Derived Orthometric Height Project

STATION Station	GEOID93S (m)	GEOID93 (m)	GPS(H) GEOID93S (m)	GPS(H) GEOID93 (m)	NAVD 88 (m)		GPSH(93S) - NAVD (cm)	GPSH(G93) - NAVD (cm)	GPSH(93S) - NAVD trend (cm)	GPSH(G93) - NAVD (no rejects) (cm)
11AAR	-32.752	-32.745	188.228	188.221	188.052	LEVEL(1)	17.6	16.9	1.5	1.2
CA1101	-34.299	-34.298	156.768	156.767	156.771	TRIG(1)	-0.4	-0.4	0.5	0.5
CA1102	-32.099	-32.097	798.515	798.513	798.485	TRIG(1)	3.0	2.8	-1.4	-1.4
CA1107	-34.124	-34.125	94.897	94.898	94.902	LEVEL(2)	-0.5	-0.4	-4.9	-4.9
JUNCAZ	-32.458	-32.456	562.846	562.844	562.793	TRIG(1)	5.3	5.1	2.7	2.7
OCOT	-34.036	-34.034	-1.696	-1.698	-1.778	LEVEL(2)	8.2	8.0	-5.3	-4.9
SDGPS01	-34.499	-34.505	29.563	29.569	29.528	LEVEL(2)	3.4	4.0	-1.9	-1.4
SDGPS03	-32.909	-32.910	94.020	94.021	93.958	LEVEL(3)	6.2	6.3	-2.3	-2.2
SDGPS15	-31.404	-31.395	1281.633	1281.624	1281.509	TRIG(2)	12.4	11.5	2.3	1.7
SDGPS21	-31.578	-31.575	1097.034	1097.031	1096.931	LEVEL(4)	10.3	10.0	4.1	4.0
SDGPS24	-34.765	-34.765	46.494	46.494	46.494	LEVEL(2)	0.0	0.0	1.6	1.6
SDGPS31	-32.406	-32.403	926.076	926.073	926.012	TRIG(1)	6.4	6.1	-1.5	-1.4
SDGPS32	-32.565	-32.560	418.581	418.576	418.536	TRIG(2)	4.5	4.0	-1.9	-2.3
SDGPS33	-33.086	-33.083	222.523	222.520	222.523	TRIG(1)	-0.0	-0.3	-2.0	-2.2
SDGPS34	-31.593	-31.589	823.588	823.584	823.437	TRIG(3)	15.1	14.7	4.7	4.5
SDGPS35	-31.304	-31.308	1234.872	1234.876	1234.762	TRIG(2)	11.0	11.4	3.0	3.7
YUNG	-32.556	-32.557	352.202	352.203	352.094	LEVEL(3)	10.8	10.9	0.7	0.9
						Ave	6.7	6.5	0.0	-0.0
						Min	-0.5	-0.4	-5.3	-4.9
						Max	17.6	16.9	4.7	4.5
								Shift (cm)	8.187	7.979
								tilts	sec	sec
								e-w	0.203	0.193
								n-s	0.312	0.309
								RMS (cm)	2.953	2.883
								r value	0.72	0.72

Fig. 32

GPS(H) - NAVD88(H) (cm); 13 Sta.- San Diego CO.

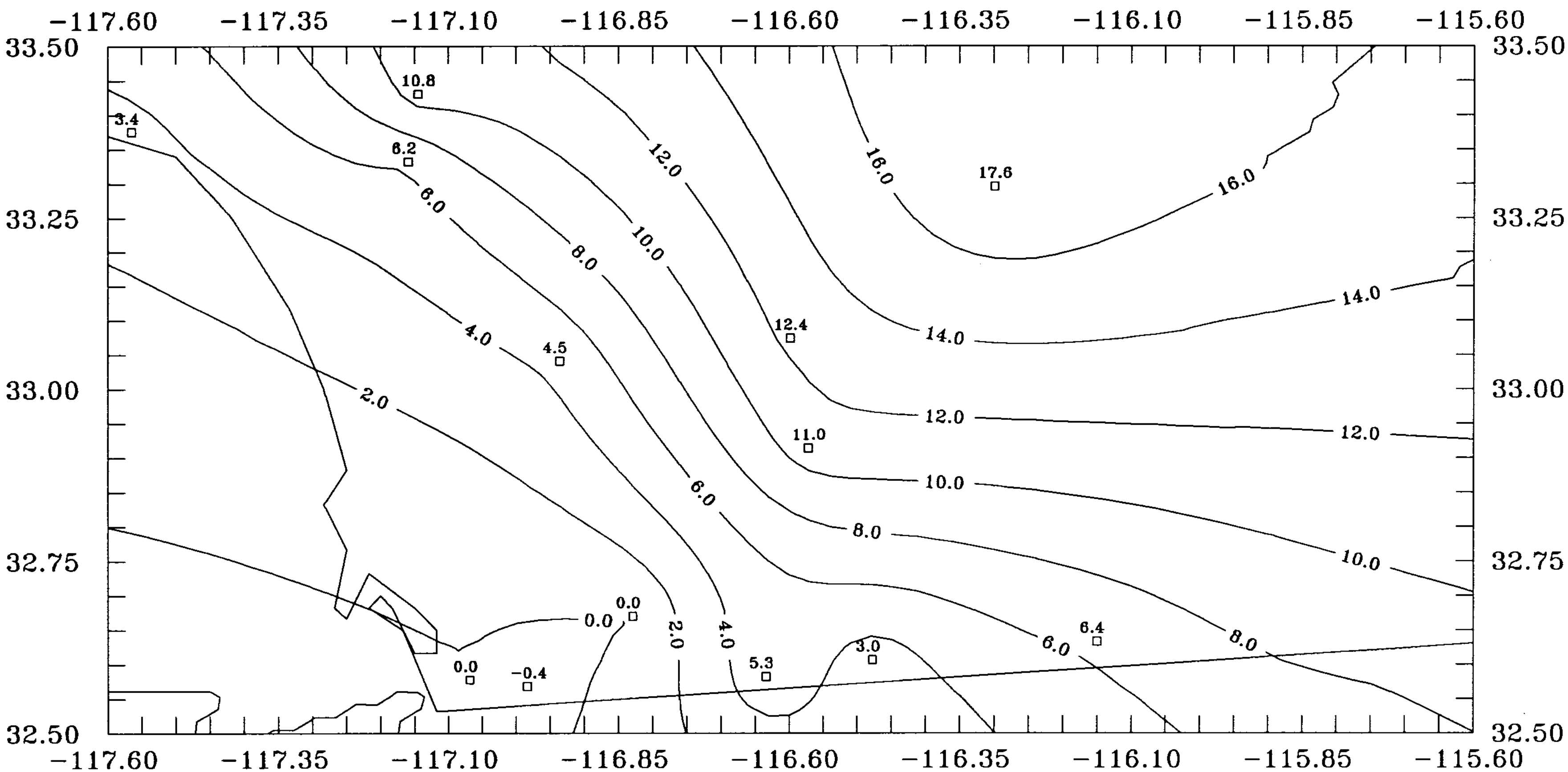


Fig. 33

GPS(H)−NAVD88(H) 13 Sta. trend removed−San Diego

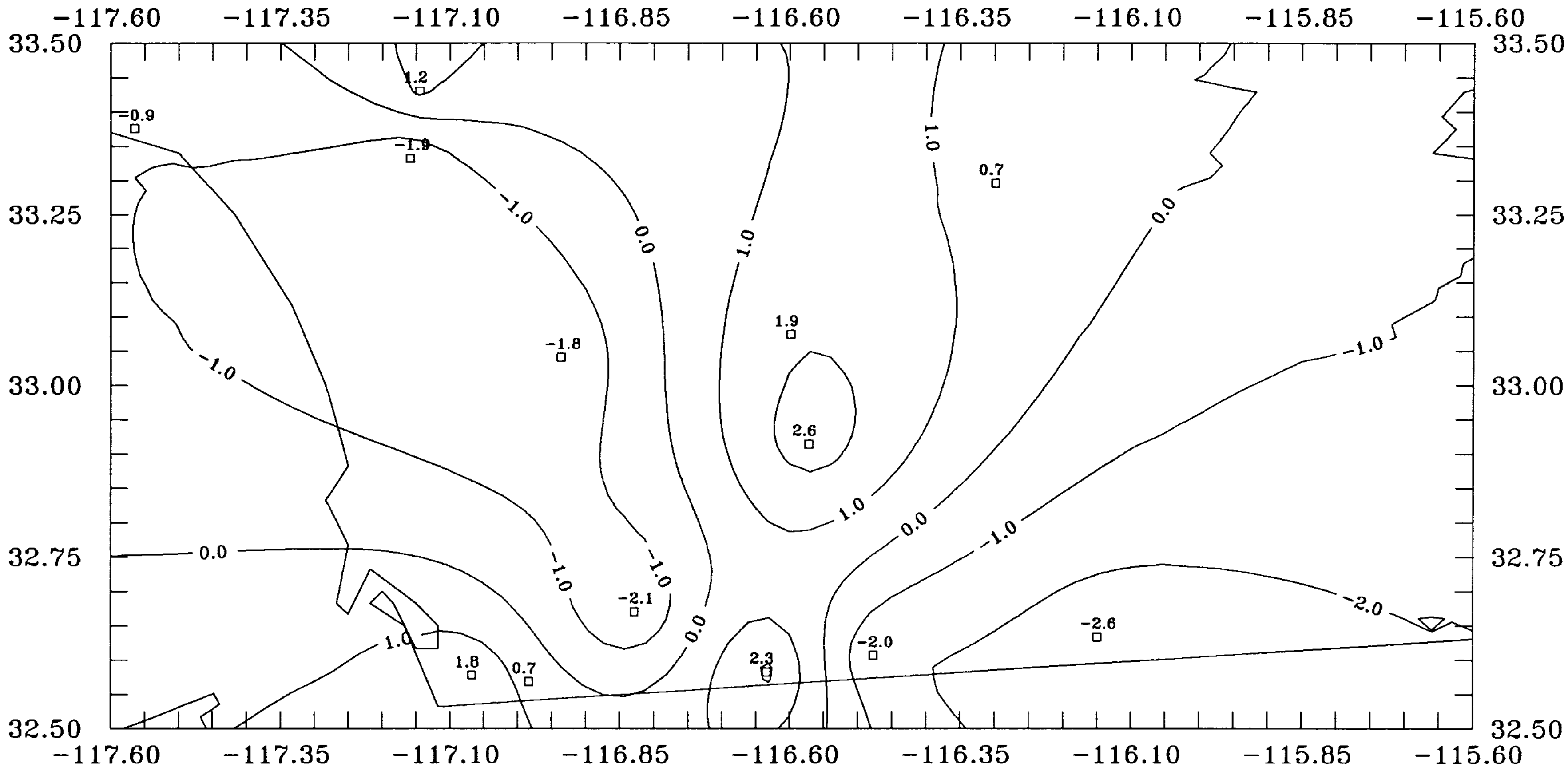


Table 8

San Diego GPS-Derived Orthometric Height Project

Station	GEOID93S (m)	GEOID93 (m)	GPS(H) GEOID93S (m)	GPS(H) GEOID93 (m)	NAVD 88 (m)		GPSH(93S) - NAVD (cm)	GPSH(G93) - NAVD (cm)	GPSH(93S) - NAVD trend (cm)	GPSH(G93) - NAVD removed (cm)	(includes rejections)
11AAR	-32.752	-32.745	188.228	188.221	188.052	LEVEL(1)	17.6	16.9	0.7	1.2	
CA1101	-34.299	-34.298	156.768	156.767	156.771	TRIG(1)	-0.4	-0.4	0.7	0.7	
CA1102	-32.099	-32.097	798.515	798.513	798.485	TRIG(1)	3.0	2.8	-2.0	-1.5	
CA1107	-34.124	-34.125	94.897	94.898	94.902	LEVEL(2)	-0.5	-0.4	-4.4	-4.3	Rej in G93 and 93S trend removal analysis
JUNCAZ	-32.458	-32.456	562.846	562.844	562.793	TRIG(1)	5.3	5.1	2.3	2.7	
OCOT	-34.036	-34.034	-1.696	-1.698	-1.778	LEVEL(2)	8.2	8.0	-6.9	-5.5	Rej in G93 and 93S trend removal analysis
SDGPS01	-34.499	-34.505	29.563	29.569	29.528	LEVEL(2)	3.4	4.0	-0.9	-0.6	
SDGPS03	-32.909	-32.910	94.020	94.021	93.958	LEVEL(3)	6.2	6.3	-1.9	-1.6	
SDGPS15	-31.404	-31.395	1281.633	1281.624	1281.509	TRIG(2)	12.4	11.5	2.0	1.8	
SDGPS21	-31.578	-31.575	1097.034	1097.031	1096.931	LEVEL(4)	10.3	10.0	3.7	4.0	Rej in G93 and 93S trend removal analysis
SDGPS24	-34.765	-34.765	46.494	46.494	46.494	LEVEL(2)	0.0	0.0	1.9	1.8	
SDGPS31	-32.406	-32.403	926.076	926.073	926.012	TRIG(1)	6.4	6.1	-2.6	-1.8	
SDGPS32	-32.565	-32.560	418.581	418.576	418.536	TRIG(2)	4.5	4.0	-1.8	-2.0	
SDGPS33	-33.086	-33.083	222.523	222.520	222.523	TRIG(1)	-0.0	-0.3	-2.1	-2.1	
SDGPS34	-31.593	-31.589	823.588	823.584	823.437	TRIG(3)	15.1	14.7	4.8	4.8	Rej in G93 and 93S trend removal analysis
SDGPS35	-31.304	-31.308	1234.872	1234.876	1234.762	TRIG(2)	11.0	11.4	2.6	3.7	Rej in G93 trend analysis
YUNG	-32.556	-32.557	352.202	352.203	352.094	LEVEL(3)	10.8	10.9	1.2	1.5	
						Ave	6.7	6.5	0.0	0.0	Ave, Min, and Max values for trend
						Min	-0.5	-0.4	-2.6	-2.1	removal analysis do not include
						Max	17.6	16.9	2.6	2.7	rejections.

Shift(cm)	6.540	6.156	
tilts	sec	sec	
e-w	0.234	0.208	Ave, Min, and Max values for trend
n-s	0.311	0.303	removal analysis do not include
RMS (cm)	1.914	1.762	rejections.
r value	0.88	0.89	

Tabl 9

San Diego GPS-Derived Orthometric Height Project

Station	GEOID93S (m)	GEOID93 (m)	GPS(H) GEOID93S (m)	GPS(H) GEOID93 (m)	NAVD 88 (m)		GPSH(93S) - NAVD trend removed (rej) (cm)	GPSH(G93) - NAVD trend removed (rej) (cm)	GPSH(93S) - NAVD trend removed (no rej) (cm)	GPSH(G93) - NAVD trend removed (no rej) (cm)	Differences rej minus no rej 93S (cm)	Differences rej minus no rej 93 (cm)
11AAR	-32.752	-32.745	188.228	188.221	188.052	LEVEL(1)	0.69	1.17	1.49	1.20	-0.80	-0.03
CA1101	-34.299	-34.298	156.768	156.767	156.771	TRIG(1)	0.67	0.74	0.54	0.50	0.13	0.24
CA1102	-32.099	-32.097	798.515	798.513	798.485	TRIG(1)	-2.00	-1.50	-1.41	-1.40	-0.59	-0.10
CA1107	-34.124	-34.125	94.897	94.898	94.902	LEVEL(2)	-4.35	-4.33	-4.93	-4.90	0.58	0.57
JUNCAZ	-32.458	-32.456	562.846	562.844	562.793	TRIG(1)	2.30	2.66	2.72	2.70	-0.42	-0.04
OCOT	-34.036	-34.034	-1.696	-1.698	-1.778	LEVEL(2)	-6.87	-5.46	-5.32	-4.90	-1.55	-0.56
SDGPS01	-34.499	-34.505	29.563	29.569	29.528	LEVEL(2)	-0.87	-0.61	-1.88	-1.40	1.01	0.79
SDGPS03	-32.909	-32.910	94.020	94.021	93.958	LEVEL(3)	-1.86	-1.63	-2.29	-2.20	0.43	0.57
SDGPS15	-31.404	-31.395	1281.633	1281.624	1281.509	TRIG(2)	1.95	1.78	2.34	1.70	-0.39	0.08
SDGPS21	-31.578	-31.575	1097.034	1097.031	1096.931	LEVEL(4)	3.70	4.00	4.08	3.99	-0.38	0.01
SDGPS24	-34.765	-34.765	46.494	46.494	46.494	LEVEL(2)	1.85	1.83	1.60	1.55	0.25	0.28
SDGPS31	-32.406	-32.403	926.076	926.073	926.012	TRIG(1)	-2.55	-1.80	-1.50	-1.40	-1.05	-0.40
SDGPS32	-32.565	-32.560	418.581	418.576	418.536	TRIG(2)	-1.78	-1.98	-1.88	-2.28	0.10	0.30
SDGPS33	-33.086	-33.083	222.523	222.520	222.523	TRIG(1)	-2.09	-2.09	-2.01	-2.23	-0.08	0.14
SDGPS34	-31.593	-31.589	823.588	823.584	823.437	TRIG(3)	4.75	4.80	4.70	4.45	0.05	0.35
SDGPS35	-31.304	-31.308	1234.872	1234.876	1234.762	TRIG(2)	2.57	3.68	3.01	3.66	-0.44	0.02
YUNG	-32.556	-32.557	352.202	352.203	352.094	LEVEL(3)	1.16	1.45	0.74	0.90	0.42	0.55
						Ave	-0.14	0.14	0.00	-0.06		
						Min	-6.87	-5.46	-5.32	-4.90		
						Max	4.75	4.80	4.70	4.45		
						r value	0.88	0.89	0.72	0.72		

LEVEL(1) - NAVD 88 HEIGHT ESTIMATED IN SCRP POSTED ADJUSTMENT
LEVEL(2) - NAVD 88 HEIGHT ESTIMATED USING SHORT LEVELING TIE AND NAVD88
LEVEL(3) - NAVD 88 HEIGHT ESTIMATED USING NEW LEVELING LINE AND NAVD 88
LEVEL(4) - NAVD 88 HEIGHT ESTIMATED USING SHORT LEVELING TIE AND SCRP PO

TRIG(1) - NAVD 88 ESTIMATED USING SHORT TRIG TIE AND NAVD 88
TRIG(2) - NAVD 88 ESTIMATED USING SHORT TRIG TIE AND SCRP POSTED HEIGHTS
TRIG(3) - NAVD 88 ESTIMATED USING SHORT TRIG TIE AND 1970 POSTED HEIGHTS

$H_{GPS} - H_{88}$

(UNIT=cm)

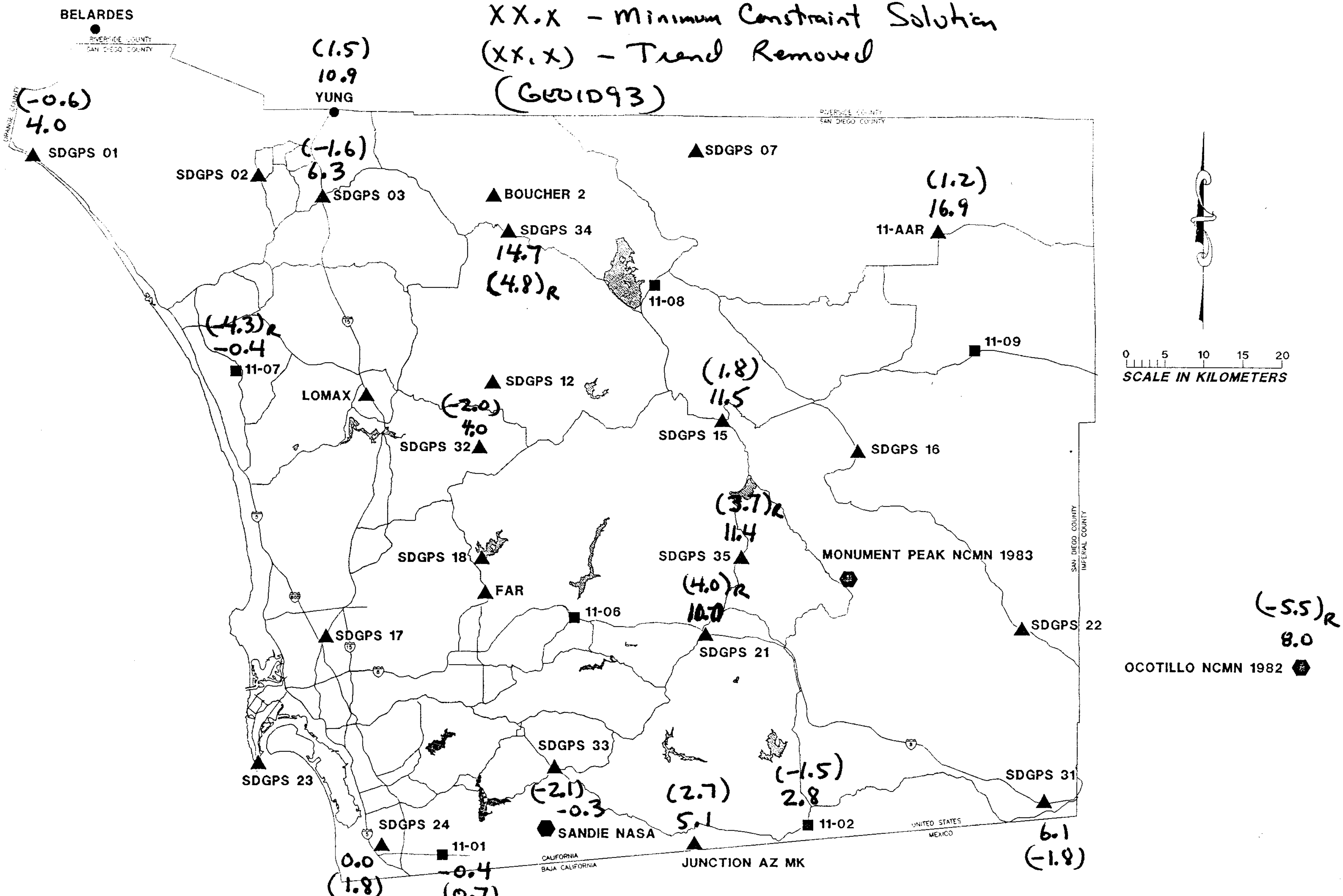
Fig. 33

SAN DIEGO COUNTY HIGH PRECISION GEODETIC NETWORK

XX.X - Minimum Constraint Solution

(XX.X) - Trend Removed

(GEOID93)



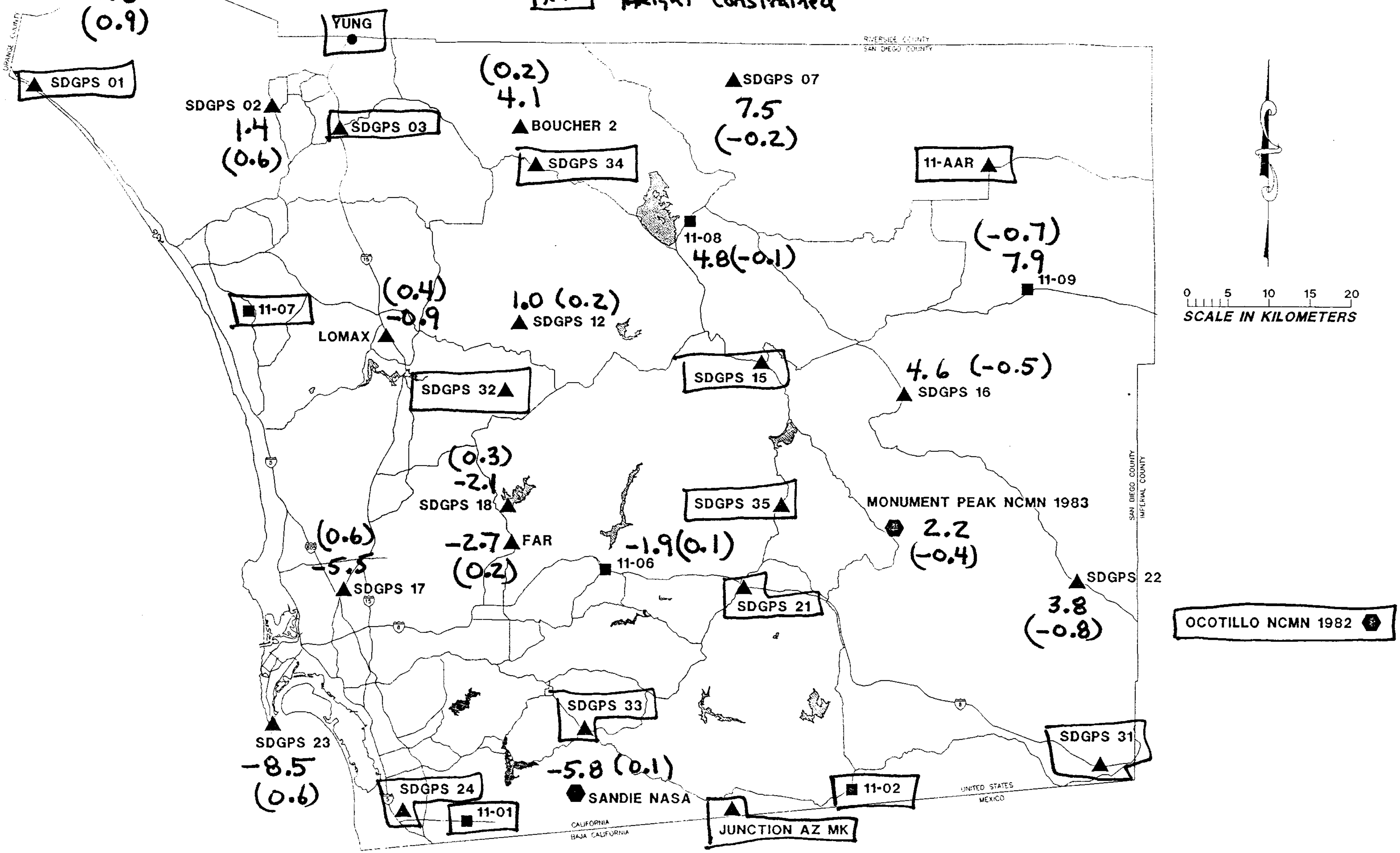
Comparison of Adjusted Heights
(units = cm)

Fig. 34

SAN DIEGO COUNTY HIGH PRECISION GEODETIC NETWORK

$H_{method 3} - H_{method 1}$ ($H_{method 2} - H_{method 1}$)

[XXXX] - Height Constrained

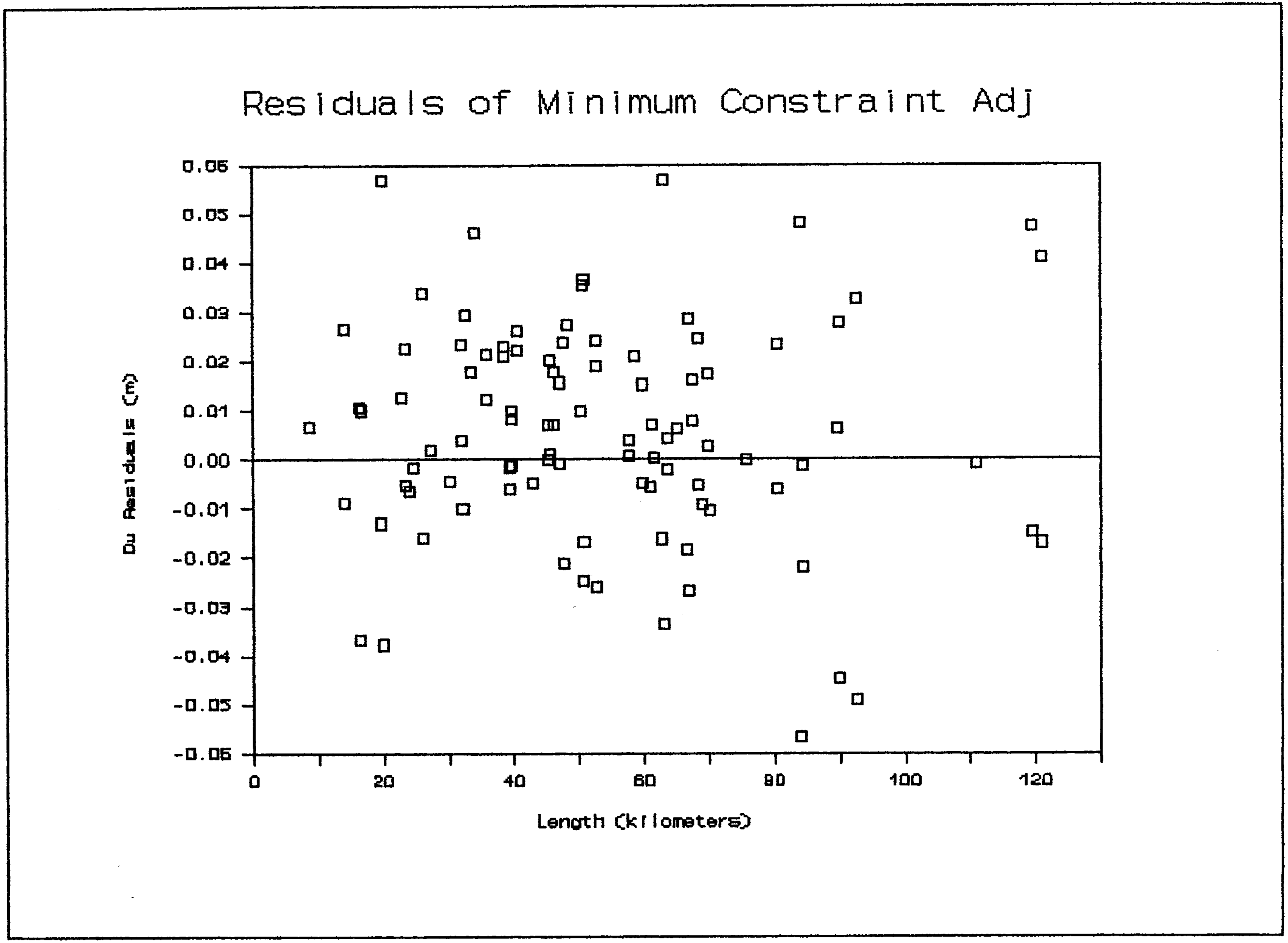


Tab6 10

STATION NAME	NAVD 88 METHOD 1 (M)	NAVD 88 METHOD 2 (M)	NAVD 88 METHOD 3 (M)		METHOD 2 MINUS METHOD 1 (CM)	METHOD 3 MINUS METHOD 1 (CM)	METHOD 3 MINUS METHOD 2 (CM)
11 AAR	188.052	188.052	188.052	*	0.0	0.0	0.0
BELARDES	705.225	705.234	705.241		0.9	1.6	0.7
BOUCHER 2	1660.657	1660.659	1660.698		0.2	4.1	3.9
FAR	207.444	207.446	207.417		0.2	-2.7	-2.9
CA 11 01	156.771	156.771	156.771	*	0.0	0.0	0.0
CA 11 02	798.485	798.485	798.485	*	0.0	0.0	0.0
CA 11 06	423.876	423.877	423.857		0.1	-1.9	-2.0
CA 11 07	94.902	94.902	94.902	*	0.0	0.0	0.0
CA 11 08	873.503	873.502	873.551		-0.1	4.8	4.9
CA 11 09	234.399	234.392	234.478		-0.7	7.9	8.6
JUNCTION AZ MK	562.793	562.793	562.793	*	0.0	0.0	0.0
LOMAX	287.819	287.823	287.81		0.4	-0.9	-1.3
MON PEAK NCMN 7274	1871.476	1871.472	1871.498		-0.4	2.2	2.6
OCOTILLO NCMN 7270	-1.778	-1.778	-1.778	*	0.0	0.0	0.0
SD GPS 01	29.528	29.528	29.528	*	0.0	0.0	0.0
SD GPS 02	218.555	218.561	218.569		0.6	1.4	0.8
SD GPS 03	93.958	93.958	93.958	*	0.0	0.0	0.0
SD GPS 07	1452.931	1452.929	1453.006		-0.2	7.5	7.7
SD GPS 12	624.162	624.164	624.172		0.2	1.0	0.8
SD GPS 15	1281.509	1281.509	1281.509	*	0.0	0.0	0.0
SD GPS 16	789.651	789.646	789.697		-0.5	4.6	5.1
SD GPS 17	125.532	125.538	125.477		0.6	-5.5	-6.1
SD GPS 18	243.006	243.009	242.985		0.3	-2.1	-2.4
SD GPS 21	1096.931	1096.931	1096.931	*	0.0	0.0	0.0
SD GPS 22	328.531	328.523	328.569		-0.8	3.8	4.6
SD GPS 23	125.888	125.894	125.803		0.6	-8.5	-9.1
SD GPS 24	46.494	46.494	46.494	*	0.0	0.0	0.0
SD GPS 31	926.012	926.012	926.012	*	0.0	0.0	0.0
SD GPS 32	418.536	418.536	418.536	*	0.0	0.0	0.0
SD GPS 33	222.523	222.523	222.523	*	0.0	0.0	0.0
SD GPS 34	823.437	823.437	823.437	*	0.0	0.0	0.0
SD GPS 35	1234.762	1234.762	1234.762	*	0.0	0.0	0.0
SANDIE NASA	1022.944	1022.945	1022.886		0.1	-5.8	-5.9
YUNG	352.094	352.094	352.094	*	0.0	0.0	0.0

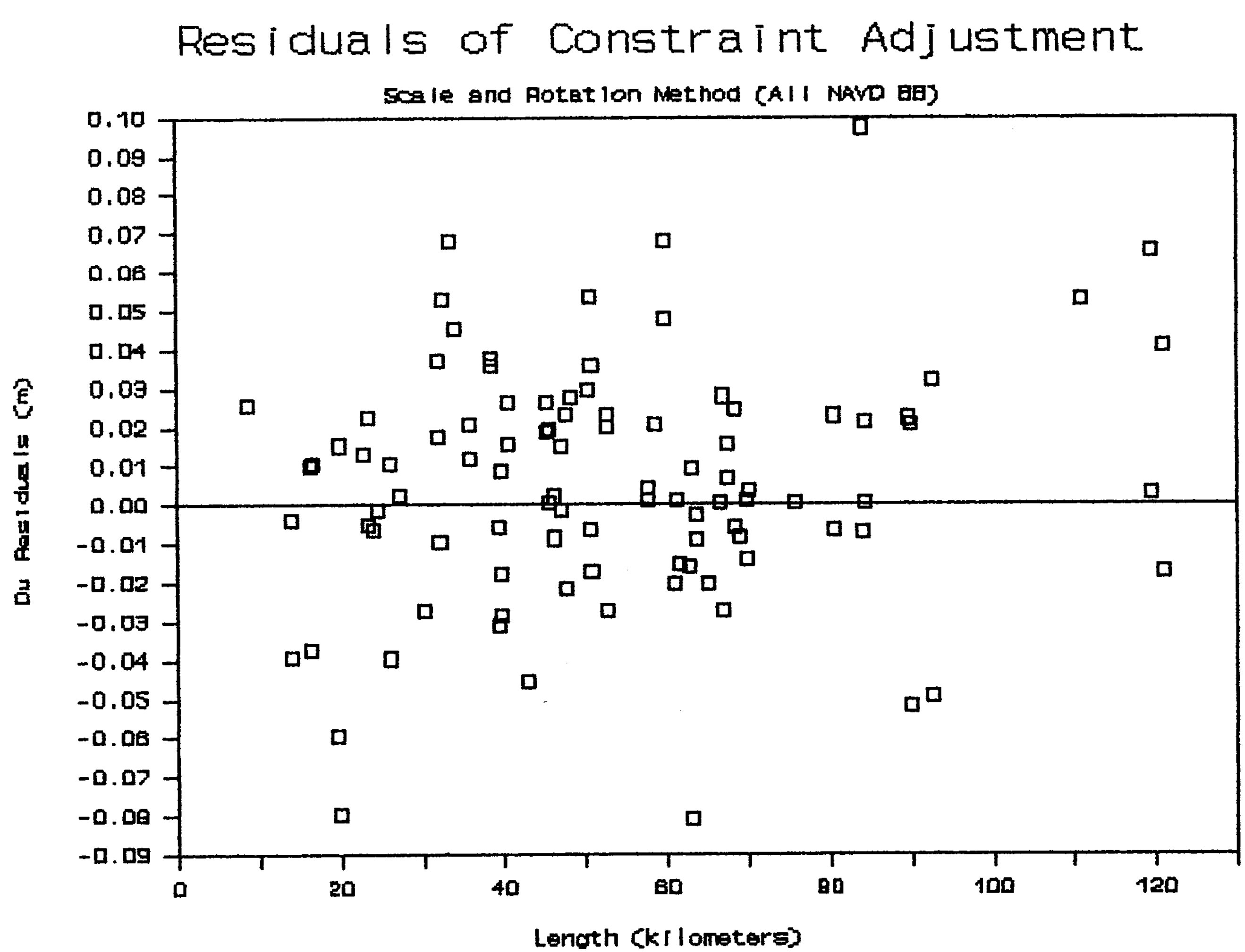
* CONSTRAINED HEIGHT IN ADJUSTMENT
METHOD 1 - Scale and Rotation Method
METHOD 2 - Trend Removal Method
METHOD 3 - Height Distribution Method

Fig. 35



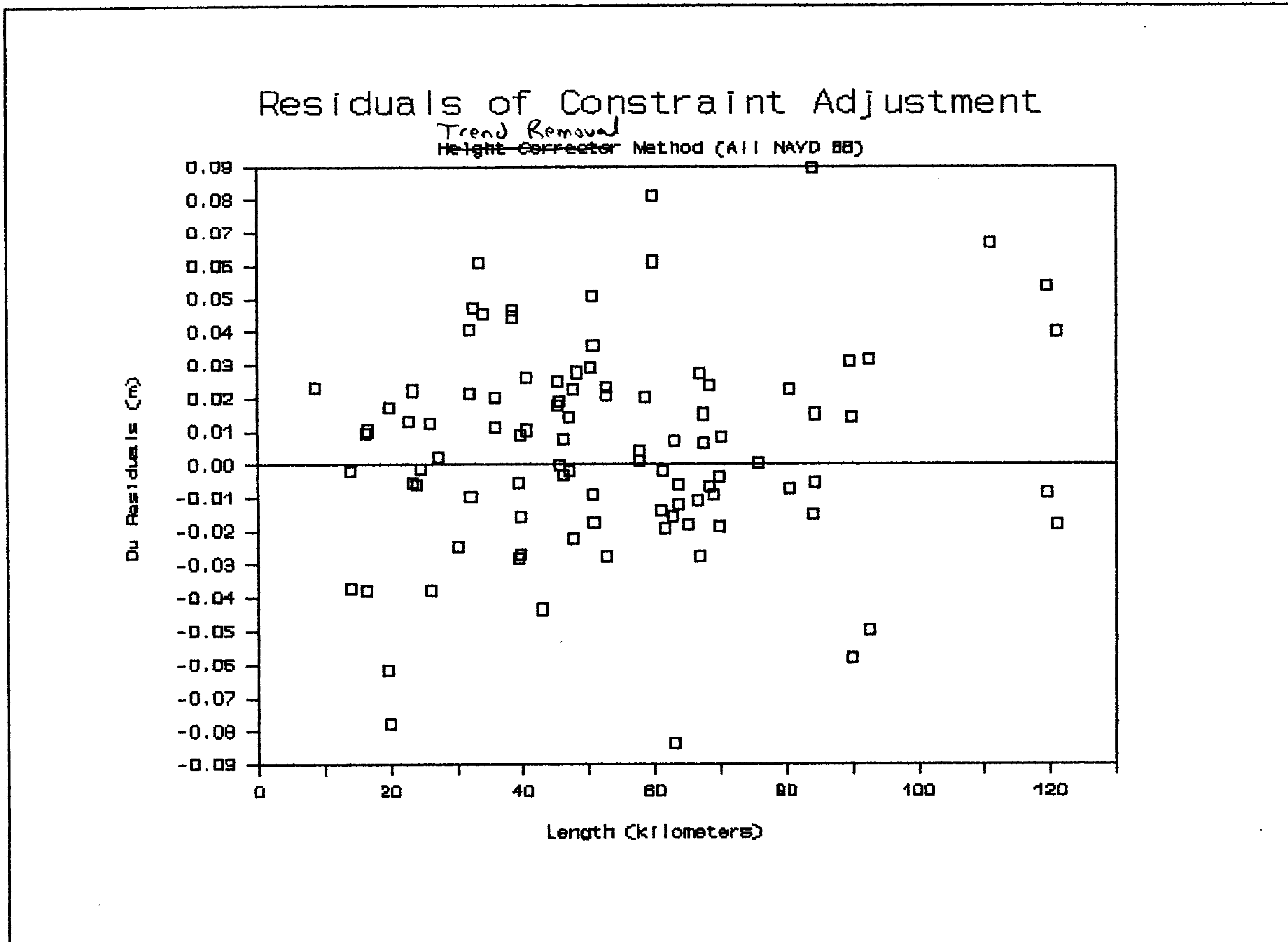
Residuals of Minimum Constraint Adj
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
Du Residuals (m)
0
20
40
60
80
100
120
Length (kilometers)

Fig. 36



Residuals of Constraint Adjustment
Scale and Rotation Method (All NAVD 88)
Du Residuals (m)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
0
20
40
60
80
100
120
Length (kilometers)

Fig. 37



Residuals of Constraint Adjustment
Trend Removal
~~Height Corrector~~ Method (All NAVD 88)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
Du Residuals (m)
0
20
40
60
80
100
120
Length (kilometers)

Fig. 38

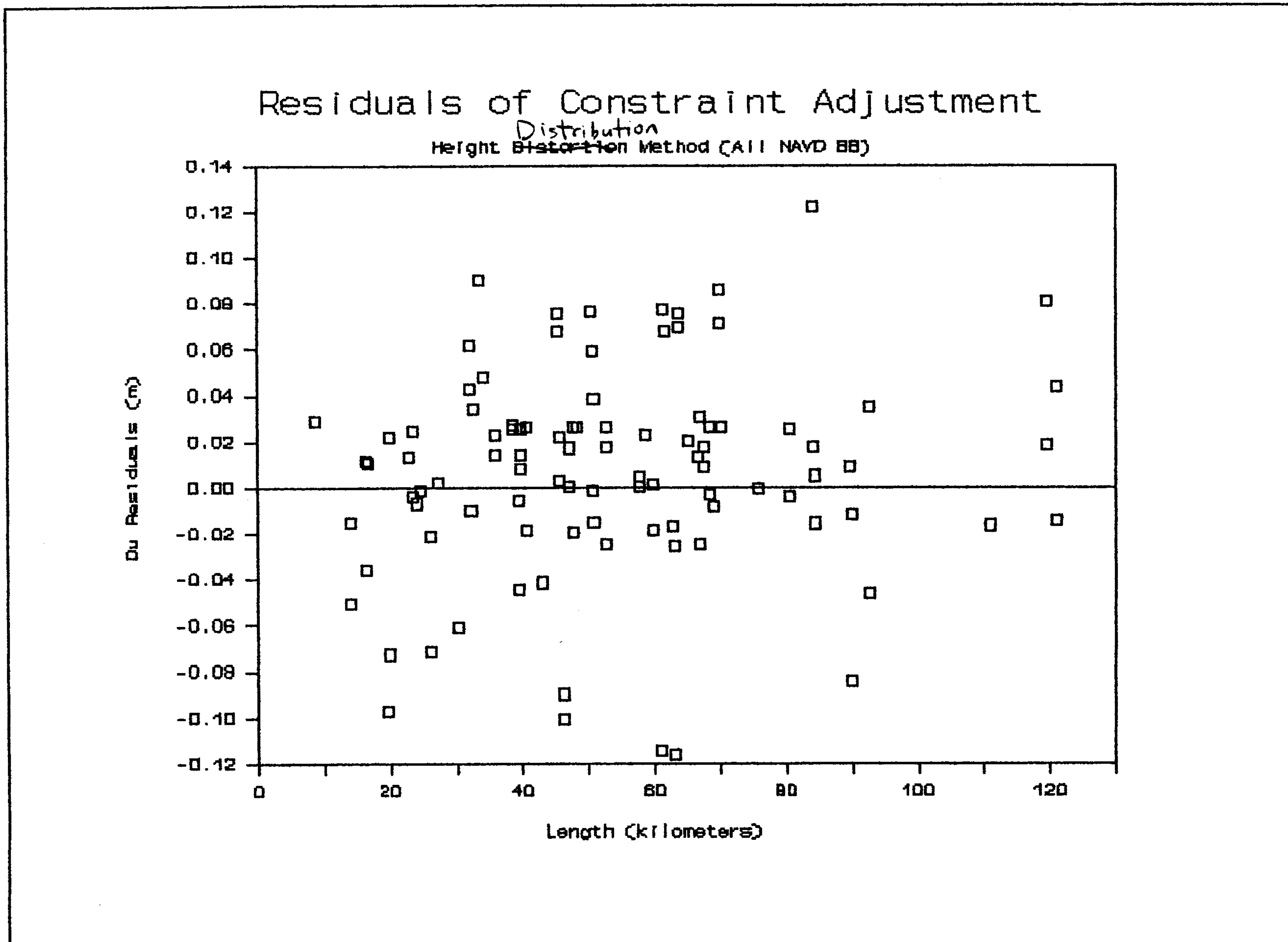

Residuals of Constraint Adjustment
Height ~~Distortion~~ Distribution Method (All NAVD 88)
Du Residuals (m)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
0
20
40
60
80
100
120
Length (kilometers)

Table 11

Final Set of du residuals

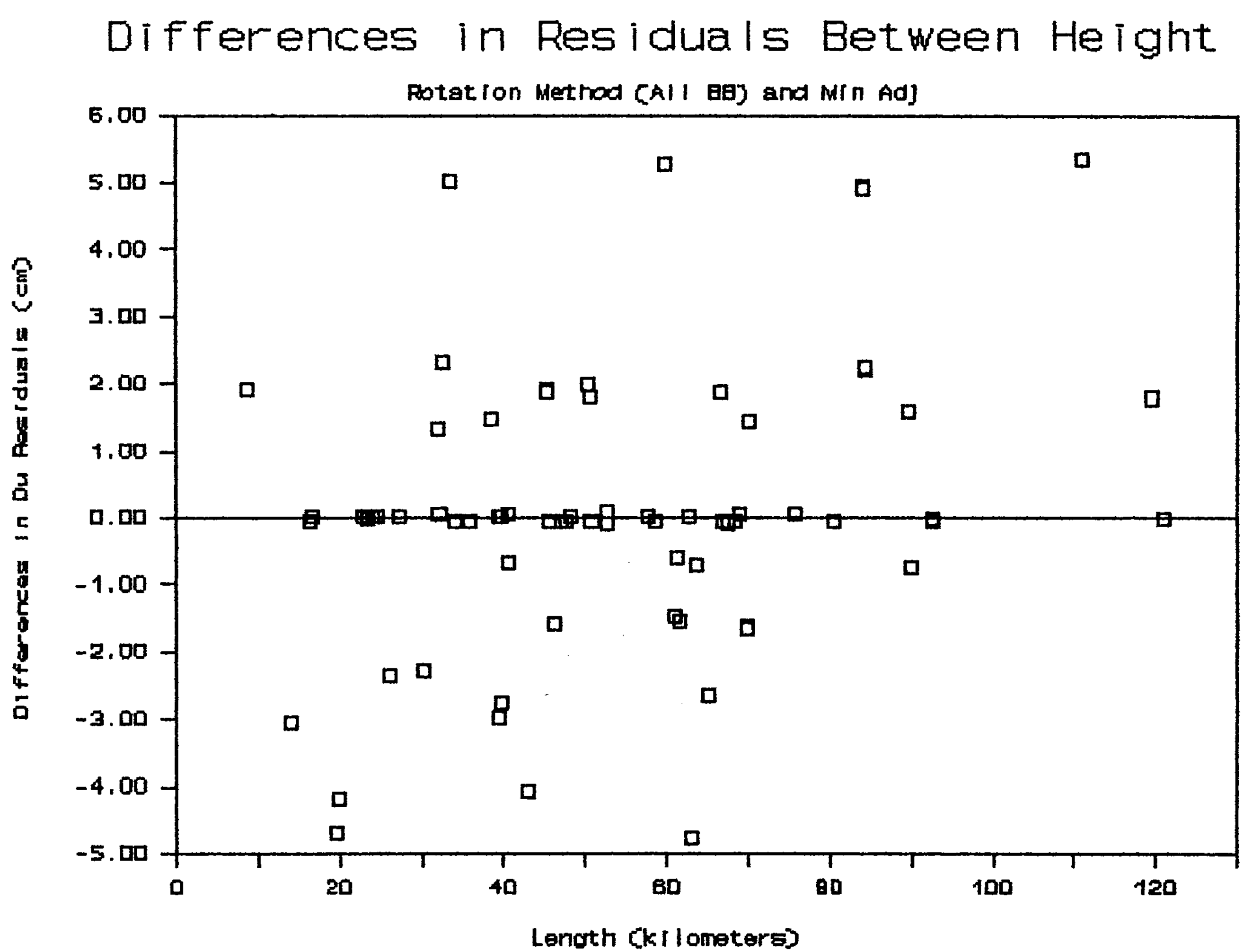
Min. Constraint Adjustment GEOID93S du (m)	length (m)	Method 1 du (m)	Method 2 du (m)	Method 3 du (m)	Method 1 - Free (cm)	Method 2 - Free (cm)	Method 3 - Free (cm)
0.0042	63631.23	-0.0028	-0.0060	0.0758	-0.7	-1.0	7.2 *
0.0041	32046.04	0.0176	0.0215	0.0424	1.4	1.7	3.8
0.0123	35917.70	0.0118	0.0115	0.0139	-0.1	-0.1	0.2
-0.0565	84087.15	-0.0072	-0.0148	0.0174	4.9	4.2	7.4 *
0.0010	45594.17	0.0004	-0.0001	0.0028	-0.1	-0.1	0.2
0.0164	67549.26	0.0156	0.0152	0.0178	-0.1	-0.1	0.1
0.0153	59776.54	0.0682	0.0814	0.0015	5.3 *	6.6 *	-1.4
-0.0167	50778.71	-0.0172	-0.0176	-0.0151	-0.1	-0.1	0.2
-0.0148	119353.22	0.0031	-0.0087	0.0186	1.8	0.6	3.3
-0.0489	92713.84	-0.0493	-0.0499	-0.0465	-0.0	-0.1	0.2
-0.0218	84292.65	0.0005	-0.0055	-0.0155	2.2	1.6	0.6
-0.0261	52668.17	-0.0270	-0.0275	-0.0244	-0.1	-0.1	0.2
-0.0159	26050.15	-0.0395	-0.0376	-0.0711	-2.4	-2.2	-5.5 *
-0.0366	16420.02	-0.0373	-0.0376	-0.0356	-0.1	-0.1	0.1
-0.0053	68384.27	-0.0059	-0.0064	-0.0035	-0.1	-0.1	0.2
-0.0212	47662.85	-0.0218	-0.0223	-0.0191	-0.1	-0.1	0.2
-0.0377	19884.59	-0.0794	-0.0777	-0.0726	-4.2	-4.0	-3.5
-0.0052	23595.43	-0.0055	-0.0057	-0.0036	-0.0	-0.1	0.2
-0.0059	80413.30	-0.0065	-0.0071	-0.0038	-0.1	-0.1	0.2
0.0175	69788.08	0.0011	-0.0034	0.0863	-1.6	-2.1	6.9 *
0.0212	38396.61	0.0361	0.0445	0.0257	1.5	2.3	0.5
-0.0001	45288.67	0.0189	0.0177	0.068	1.9	1.8	6.8 *
-0.0248	50773.83	-0.0066	-0.0093	-0.0012	1.8	1.6	2.4
-0.0334	62935.33	-0.0810	-0.0834	-0.116	-4.8	-5.0 *	-8.3 *
-0.0088	14116.66	-0.0394	-0.0370	-0.0504	-3.1	-2.8	-4.2
-0.0013	39589.33	-0.0287	-0.0270	0.0146	-2.7	-2.6	1.6
-0.0267	66979.51	-0.0273	-0.0278	-0.0247	-0.1	-0.1	0.2
-0.0007	47191.30	-0.0014	-0.0019	0.0008	-0.1	-0.1	0.2
0.0070	46313.00	-0.0087	-0.0028	-0.1005	-1.6	-1.0	-10.8 *
-0.0170	120921.02	-0.0173	-0.0179	-0.0145	-0.0	-0.1	0.3
-0.0446	90028.95	-0.0520	-0.0580	-0.0838	-0.7	-1.3	-3.9
-0.0019	63631.23	-0.0089	-0.0121	0.0697	-0.7	-1.0	7.2 *
0.0236	32046.04	0.0371	0.0409	0.0619	1.4	1.7	3.8
0.0213	35917.70	0.0208	0.0205	0.023	-0.1	-0.1	0.2
0.0481	84087.15	0.0973	0.0897	0.1219	4.9	4.2	7.4 *
0.0202	45594.17	0.0196	0.0191	0.0221	-0.1	-0.1	0.2
0.0462	34008.38	0.0456	0.0453	0.0475	-0.1	-0.1	0.1
0.0079	67549.26	0.0071	0.0067	0.0093	-0.1	-0.1	0.1
-0.0049	59776.54	0.0479	0.0612	-0.0187	5.3 *	6.6 *	-1.4
0.0365	50778.71	0.0359	0.0356	0.038	-0.1	-0.1	0.2
0.0474	119353.22	0.0653	0.0536	0.0808	1.8	0.6	3.3
0.0325	92713.84	0.0322	0.0315	0.0349	-0.0	-0.1	0.2
-0.0011	84292.65	0.0213	0.0152	0.0052	2.2	1.6	0.6
0.0212	58548.82	0.0205	0.0201	0.0225	-0.1	-0.1	0.1
0.0244	52668.17	0.0235	0.0231	0.0262	-0.1	-0.1	0.2
0.0340	26050.15	0.0104	0.0123	-0.0212	-2.4	-2.2	-5.5 *
0.0107	16420.02	0.0100	0.0097	0.0117	-0.1	-0.1	0.1
0.0248	68384.27	0.0242	0.0238	0.0267	-0.1	-0.1	0.2
0.0240	47662.85	0.0234	0.0229	0.0261	-0.1	-0.1	0.2
0.0571	19884.59	0.0154	0.0171	0.0222	-4.2	-4.0	-3.5
0.0228	23595.43	0.0226	0.0223	0.0244	-0.0	-0.1	0.2
0.0235	80413.30	0.0229	0.0224	0.0256	-0.1	-0.1	0.2
0.0026	69788.08	-0.0139	-0.0184	0.0713	-1.7	-2.1	6.9 *
0.0230	38396.61	0.0379	0.0463	0.0275	1.5	2.3	0.5
0.0073	45288.67	0.0262	0.0251	0.0754	1.9	1.8	6.8 *
0.0355	50773.83	0.0537	0.0510	0.0591	1.8	1.6	2.4

Table 11 (con't)

0.0570	62935.33	0.0095	0.0071	-0.0255	-4.8	-5.0 *	-8.3 *
0.0265	14116.66	-0.0041	-0.0018	-0.0151	-3.1	-2.8	-4.2
0.0098	39589.33	-0.0176	-0.0159	0.0256	-2.7	-2.6	1.6
0.0286	66979.51	0.0280	0.0275	0.0307	-0.1	-0.1	0.2
0.0157	47191.30	0.0150	0.0146	0.0173	-0.1	-0.1	0.2
0.0178	46313.00	0.0021	0.0080	-0.0897	-1.6	-1.0	-10.8 *
0.0410	120921.02	0.0407	0.0400	0.0435	-0.0	-0.1	0.2
0.0280	90028.95	0.0205	0.0146	-0.0113	-0.8	-1.3	-3.9
0.0071	61209.23	0.0010	-0.0018	0.0769	-0.6	-0.9	7.0 *
-0.0105	70140.43	0.0039	0.0082	0.026	1.4	1.9	3.7
-0.0102	32192.56	-0.0098	-0.0097	-0.0103	0.0	0.1	-0.0
0.0179	33503.82	0.0681	0.0609	0.09	5.0 *	4.3	7.2 *
-0.0015	24626.55	-0.0012	-0.0012	-0.0014	0.0	0.0	0.0
-0.0162	62815.16	-0.0159	-0.0158	-0.0166	0.0	0.0	-0.0
-0.0065	24106.03	-0.0064	-0.0063	-0.0069	0.0	0.0	-0.0
0.0192	52668.17	0.0201	0.0206	0.0175	0.1	0.1	-0.2
-0.0008	111034.29	0.0529	0.0666	-0.0164	5.4 *	6.7 *	-1.6
0.0006	57787.03	0.0009	0.0010	0.0003	0.0	0.0	-0.0
-0.0182	66718.95	0.0006	-0.0106	0.0135	1.9	0.8	3.2
0.0261	40578.83	0.0266	0.0265	0.0267	0.0	0.0	0.1
0.0296	32665.93	0.0529	0.0473	0.0342	2.3	1.8	0.5
0.0084	39809.74	0.0086	0.0087	0.0079	0.0	0.0	-0.0
-0.0043	30301.62	-0.0270	-0.0245	-0.0613	-2.3	-2.0	-5.7 *
0.0273	48281.03	0.0274	0.0277	0.0265	0.0	0.0	-0.1
-0.0059	39519.81	-0.0056	-0.0055	-0.0058	0.0	0.0	0.0
0.0127	22859.13	0.0130	0.0129	0.013	0.0	0.0	0.0
-0.0048	42932.82	-0.0456	-0.0434	-0.0414	-4.1	-3.9	-3.7
-0.0002	75811.61	0.0004	0.0006	-0.0004	0.1	0.1	-0.0
0.0040	57874.46	0.0043	0.0043	0.0044	0.0	0.0	0.0
0.0005	61462.93	-0.0151	-0.0190	0.0675	-1.6	-2.0	6.7 *
0.0065	89737.94	0.0223	0.0312	0.0093	1.6	2.5	0.3
0.0099	50303.84	0.0298	0.0292	0.0763	2.0	1.9	6.6 *
0.0067	8661.07	0.0258	0.0235	0.0285	1.9	1.7	2.2
-0.0130	19605.96	-0.0597	-0.0616	-0.0974	-4.7	-4.9	-8.4 *
-0.0014	39507.95	-0.0311	-0.0283	-0.0447	-3.0	-2.7	-4.3
0.0062	65020.84	-0.0203	-0.0181	0.0203	-2.7	-2.4	1.4
0.0101	16560.72	0.0104	0.0104	0.0104	0.0	0.0	0.0
0.0021	27307.39	0.0023	0.0025	0.0019	0.0	0.0	-0.0
-0.0055	61069.09	-0.0203	-0.0139	-0.1148	-1.5	-0.8	-10.9 *
-0.0092	68975.86	-0.0086	-0.0088	-0.0084	0.1	0.0	0.1
0.0224	40583.71	0.0158	0.0104	-0.0186	-0.7	-1.2	-4.1

* Absolute value greater than or equal to 5 cm

Fig. 39



Differences in Residuals Between Height
Rotation Method (All BB) and Min Adj
Differences in Du Residuals (cm)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
0
20
40
60
80
100
120
Length (kilometers)

Fig. 40

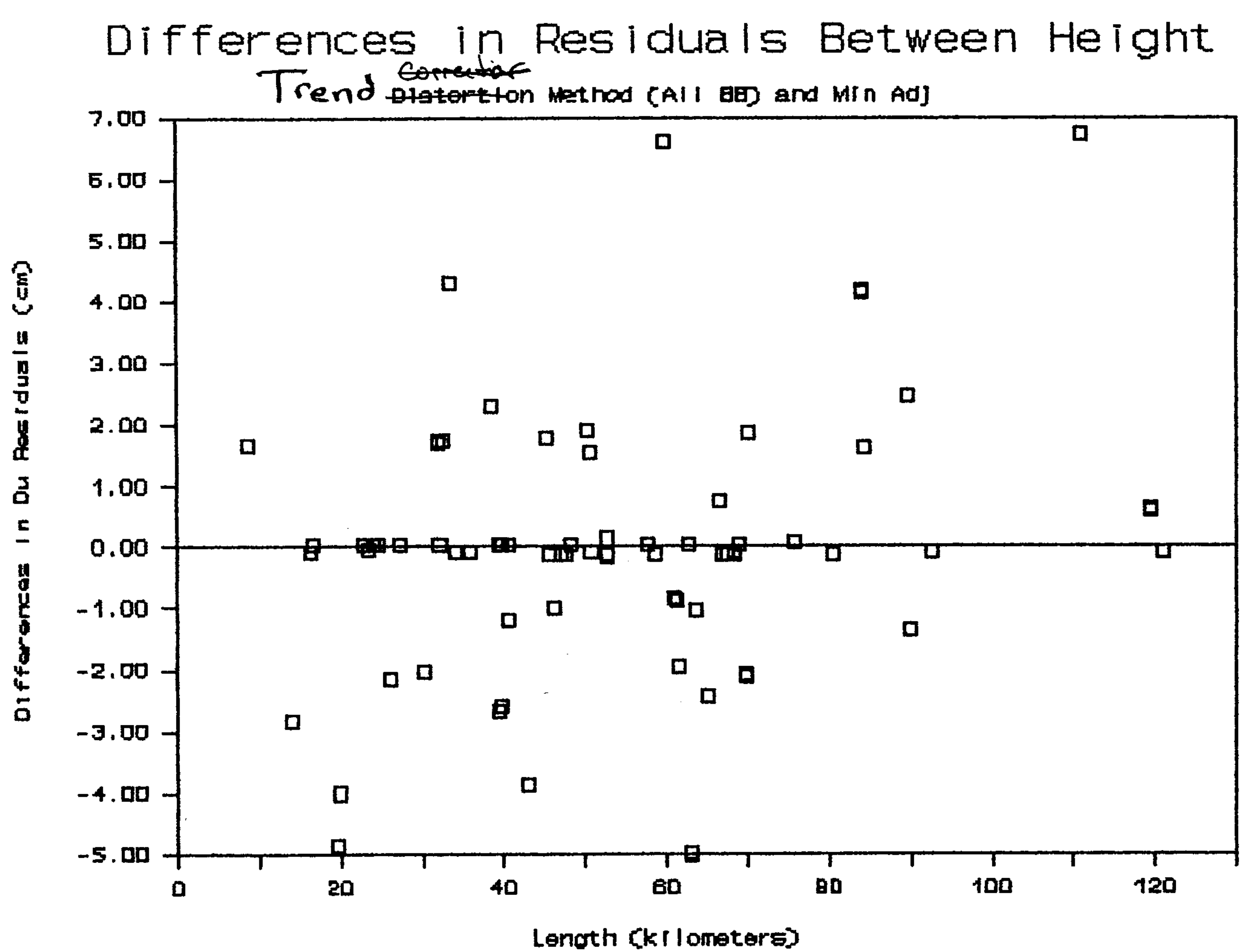

Differences in Residuals Between Height
Trend ~~Distortion~~ Correction Method (All BB) and Min Adj
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
0
20
40
60
80
100
120
Differences in Du Residuals (cm)
Length (kilometers)

Fig. 41

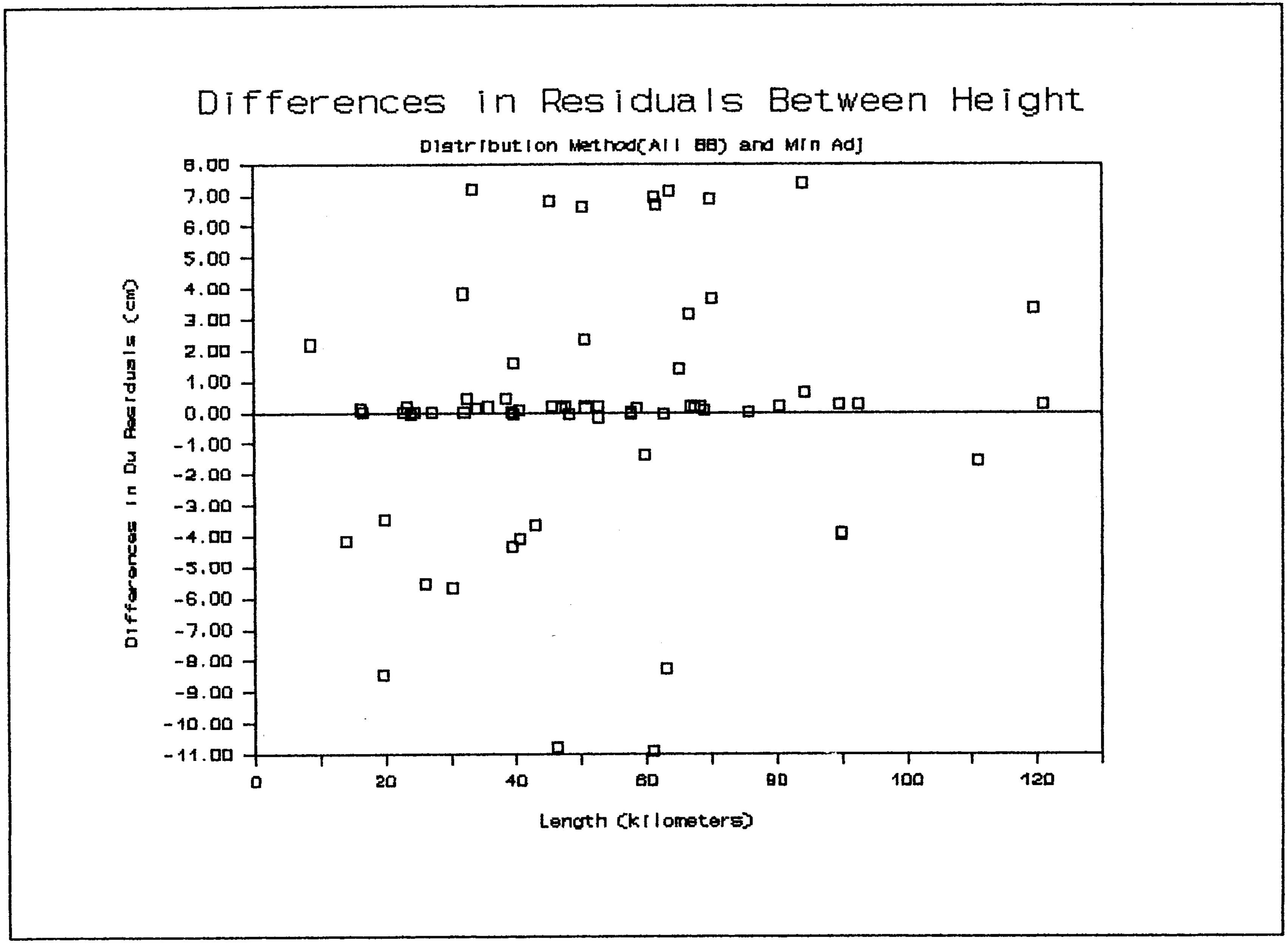

Differences in Residuals Between Height
Distribution Method(All BB) and Min Adj
Differences in Du Residuals (cm)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
-9.00
-10.00
-11.00
0
20
40
60
80
100
120
Length (kilometers)

Fig. 42

City of San Diego GPS Project

SAN DIEGO COUNTY HIGH PRECISION GEODETIC NETWORK

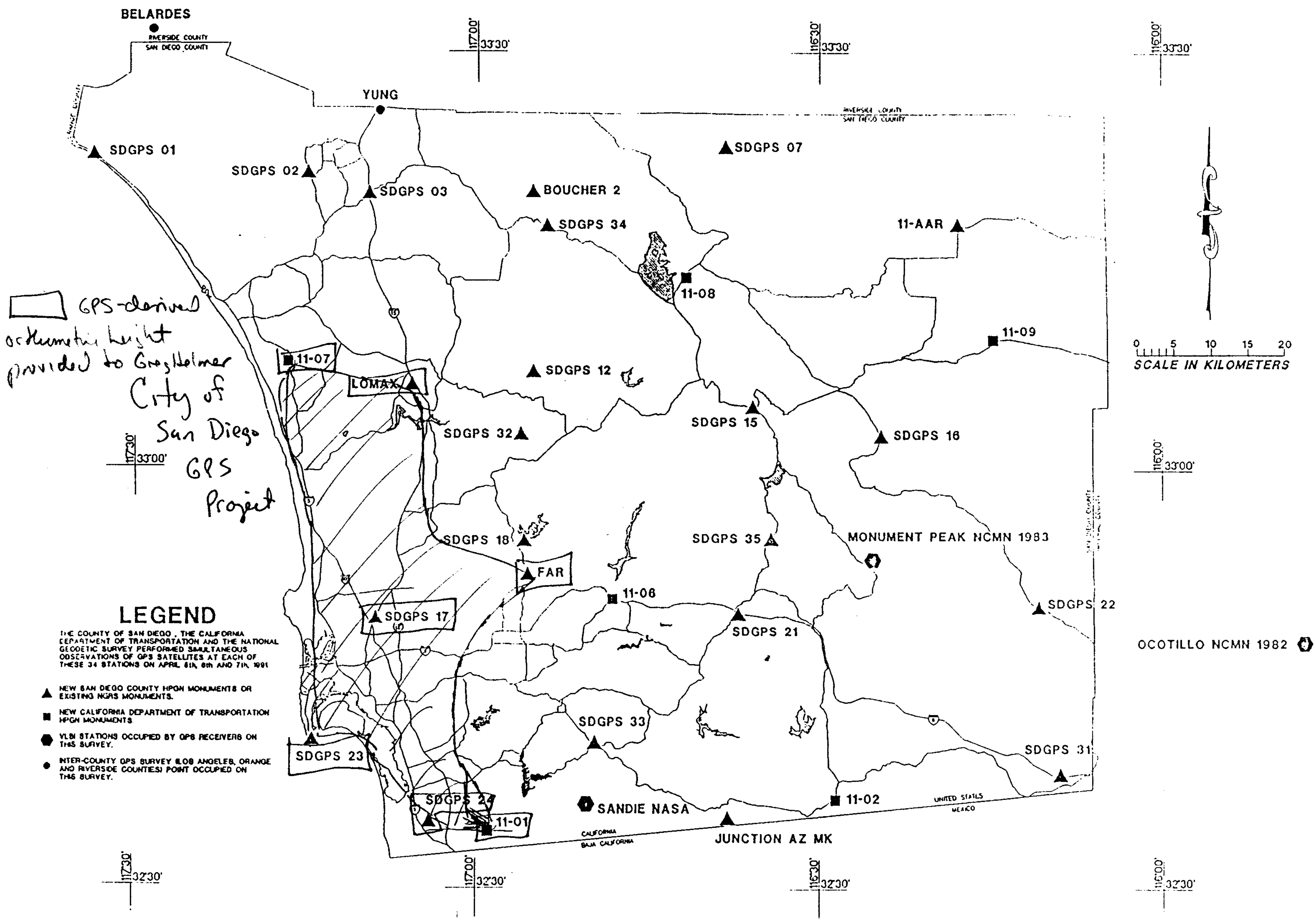
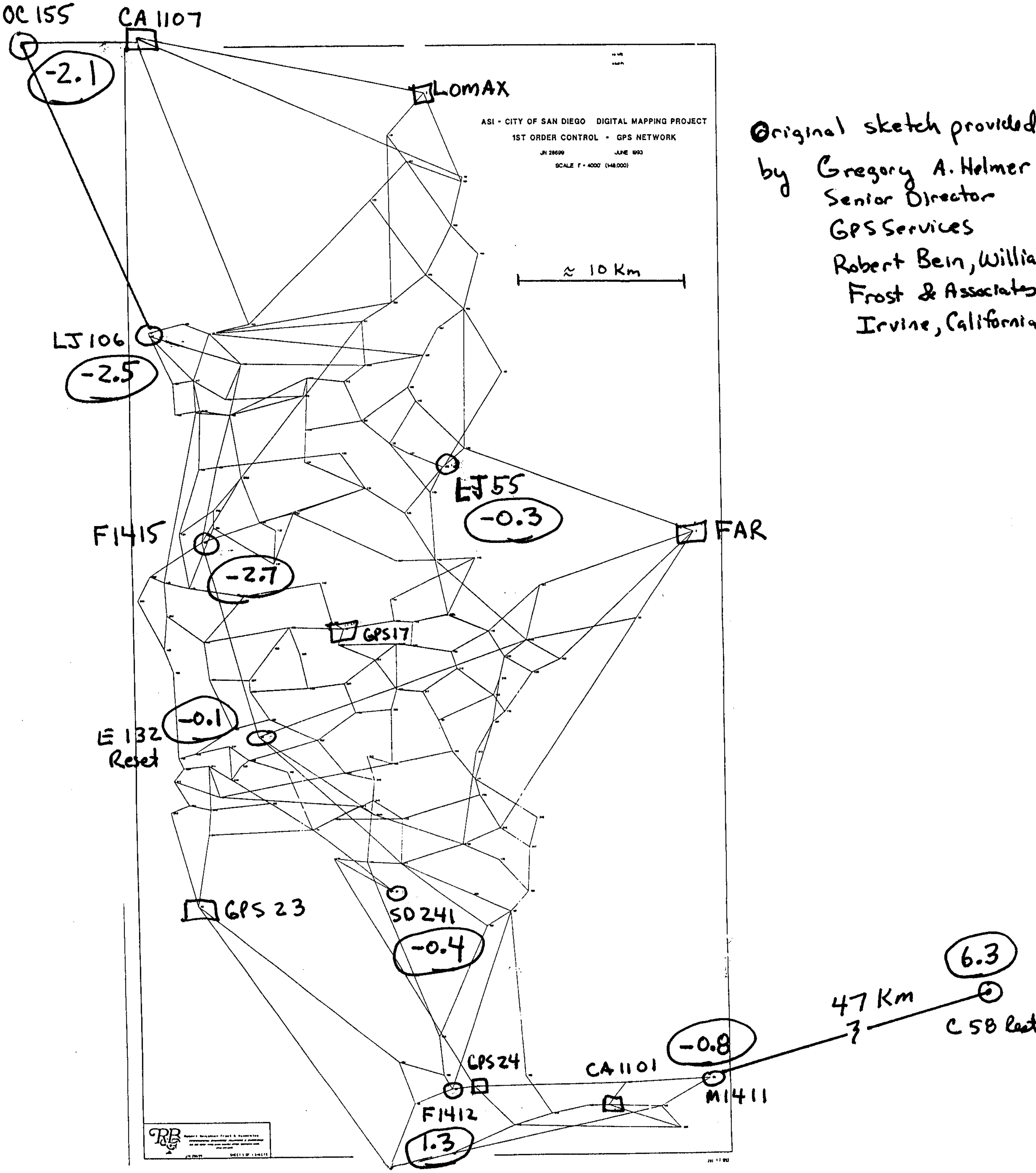


Fig. 43

$H_{GPS} - H_{88}$

units = cm



Original sketch provided by Gregory A. Helmer Senior Director GPS Services Robert Bein, William Frost & Associates Irvine, California

Appendices

Appendix A: Cooperative Agreement

FROM: GEO TO: 3014438701 AUG 10, 1992 11:31AM #382 P.2

RK6D1H GV

STATE OF CALIFORNIA

STANDARD AGREEMENT— APPROVED BY THE ATTORNEY GENERAL

STD. 2 (REV.5-91)

CONTRACT NUMBER 63P587 | AM. NO. 2

TAXPAYER'S FEDERAL EMPLOYER IDENTIFICATION NUMBER 53-030 56

THIS AGREEMENT, made and entered into this 18th day of June, 19 92, in the State of California, by and between State of California, through its duly elected or appointed, qualified and acting

TITLE OF OFFICER ACTING FOR STATE: Director | AGENCY: Department of Transportation, hereafter called the State, and

CONTRACTOR'S NAME: National Oceanic & Atmospheric Administration, National Ocean Service, hereafter called the Contractor

WITNESSETH: That the Contractor for and in consideration of the covenants, conditions, agreements, and stipulations of the State hereinafter expressed, does hereby agree to furnish to the State services and materials as follows: *(Set forth service to be rendered by Contractor, amount to be paid Contractor, time for performance or completion, and attach plans and specifications, if any.)*

See Sheets 2 and 3 of 3 for text of amendment.

CONTINUED ON 2 SHEETS, EACH BEARING NAME OF CONTRACTOR AND CONTRACT NUMBER.

The provisions on the reverse side hereof constitute a part of this agreement.

IN WITNESS WHEREOF, this agreement has been executed by the parties hereto, upon the date first above written.

STATE OF CALIFORNIA	CONTRACTOR
AGENCY: Department of Transportation	CONTRACTOR (If other than an individual, state whether a corporation, partnership, etc.): National Oceanic & Atmoshperic Admin National Ocean Servic
BY (AUTHORIZED SIGNATURE): ▷ [signature]	BY (AUTHORIZED SIGNATURE): ▷ [signature] 7/18/92
PRINTED NAME OF PERSON SIGNING: KELLY JONES HEADQUARTERS CONTRACT OFFICER	PRINTED NAME AND TITLE OF PERSON SIGNING: Rear Admiral J. Austin Yeager Director, Coast and Geodetic Survey
TITLE: Departmental Contract Officer	ADDRESS: 11400 Rockville Pike Rockville, Maryland 20852

AMOUNT ENCUMBERED BY THIS DOCUMENT $ 64,000.00	PROGRAM/CATEGORY (CODE AND TITLE): Transportation		FUND TITLE: State Hwy Acct	Department of General Services Use Only
PRIOR AMOUNT ENCUMBERED FOR THIS CONTRACT $ 178,000.00	(OPTIONAL USE)			
	ITEM: 2660-001-042-20,40	CHAPTER:	STATUTE: 92	FISCAL YEAR: 92/93
TOTAL AMOUNT ENCUMBERED TO DATE $ 242,000.00	OBJECT OF EXPENDITURE (CODE AND TITLE): 53302 - 908160 - 6132			Exempt from Dept. of General Services
I hereby certify upon my own personal knowledge that budgeted funds are available for the period and purpose of the expenditure stated above.	T.B.A. NO.	B.R. NO.		
SIGNATURE OF ACCOUNTING OFFICER: ▷ [signature]		DATE: 6/22/92		

☐ CONTRACTOR ☐ STATE AGENCY ☐ DEPT. OF GEN. SER. ☐ CONTROLLER ☐

AMENDMENT 2 TO COOPERATIVE AGREEMENT NO. 53-P587
BETWEEN THE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
AND THE
CALIFORNIA DEPARTMENT OF TRANSPORTATION

This amendment is made and entered into by and between the U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service, hereinafter referred to as NOS, and the California Department of Transportation, hereinafter referred to as CALTRANS.

The National Geodetic Survey (NGS), in cooperation with the California Department of Transportation (CALTRANS), will perform research to develop procedures to determine GPS-derived orthometric heights. The research will be done under the existing cooperative NGS/CALTRANS agreement No. 53-P587 as an extension of the effort described in Section VI, Item 12 of said existing agreement.

This research is required for two primary reasons. The vertical (up) component of GPS positional calculations is generally the weakest component of the three positional components (east, north, and up). Also the difference between the datum reference ellipsoid (which is the mathematical basis for GPS vertical positions) and the geoid (which is the basis for elevations of engineering works) is not precisely known for any given point.

NGS agrees to:

A. Research and analyze existing data (GPS, gravimetric and vertical) from NGS and other sources in the San Diego county test area.

B. Determine requirements for additional observational data (GPS, gravimetric, or vertical) in the San Diego county test area.

C. Provide for training CALTRANS personnel to perform additional measurements as determined in B, above.

D. Provide support for field activities (data acquisition through data submission) to selected CALTRANS personnel.

E. Analyze combined existing and new data to determine an improved regional geoid model in the test area.

F. Suggest recommendations for procedures to be used to improve the capability of determining more accurate GPS-derived orthometric heights required for transportation improvement projects, including procedural statements regarding (a) data/information required, (b) expected precision of results, and (c) limitations/precautions.

G. Provide results of the study within twelve months of initiation of the project.

CALTRANS agrees to:

A. Provide personnel for training and to assist NGS in obtaining additional field data to support improved GPS orthometric height determination.

B. Provide funding on an equal cost sharing basis (CALTRANS share not to exceed $64,000) with NGS in the data acquisition and analysis phases of the research project.

COST ESTIMATES

Research and analyze data		$40,000
Determine additional data requirements		5,000
Perform field observations		
GPS measurements	30,000	
Vertical control measurements	28,000	
Gravity observations	10,000	
		68,000
Analyze final data and prepare recommendations		15,000
Total		$128,000

The NOS and CALTRANS mutually agree that:

1. The term of Agreement No. 53-P587 is extended until June 30, 1993.

2. Additional gravity observations, data analysis and special equipment purchase are needed to continue the development of the high precision geodetic network for California. These activities will be accomplish on a cooperative basis.

3. CALTRANS will provide reimbursement of funds expended on this project of up to $64,000 for the period ending on June 30, 1993.

Except as hereby amended, modified or changed, all other scope of services, terms, funding, and conditions of the original amendment shall remain in full force and effect.

Appendix B: Paper titled "A Strategy for an Orderly Transition from Leveling-Derived Orthometric Heights to GPS-Derived Orthometric Heights"

A Strategy for an Orderly Transition from Leveling-Derived Orthometric Heights to GPS-Derived Orthometric Heights

David B. Zilkoski
Vertical Network Branch
National Geodetic Survey
Coast and Geodetic Survey
Rockville, Maryland 20852

ABSTRACT

The accuracy of adjusted GPS-derived orthometric height values depends on the accuracy of GPS-derived ellipsoid height differences, the accuracy of geoid height differences, and the accuracy of the leveling-derived orthometric heights used as vertical control. There is not a single GPS specification or procedure that by itself can account for inaccuracies in published orthometric heights and geoid models. Therefore, preparation of GPS specifications and procedures to establish GPS-derived orthometric heights is a difficult task.

Over the last several years, NGS has performed several investigations in support of implementation of GPS-derived orthometric heights. The results of these investigations were used to: (1) develop and document preliminary procedures to be followed when computing GPS-derived orthometric heights, (2) develop a high-resolution geoid model for the conterminous United States, (3) present workshops on computing GPS-derived orthometric heights, and (4) assist other agencies in computing GPS-derived orthometric heights which met their project requirements.

NGS is developing a plan to facilitate an orderly transition from leveling-derived orthometric heights to GPS-derived orthometric heights. The plan will consider consistency, distortions, and long-term Federal programs. During the transition period, users must accept and use GPS-derived orthometric height differences which have typical relative uncertainties which are larger than leveling-derived orthometric height differences over short lines, i.e., between 3 and 6 cm (0.1 and 0.2 feet) for GPS-derived differences over 5 km.

INTRODUCTION

Most surveyors who have been involved in computing GPS-derived orthometric heights would probably agree with the following three statements: (1) computing worthwhile GPS-derived orthometric heights on a project-by-project basis is relatively simple, (2) incorporating new GPS-derived orthometric heights into a network which is based on the results of other GPS projects is more difficult, and (3) at this time, making meaningful categorical statements about the absolute accuracy of GPS-derived orthometric heights is premature.

***

Presented at the 1993 Spring ACSM/ASPRS Annual Convention held in New Orleans, Louisiana, on February 14-18, 1993.

The difficulty of implementing GPS-derived orthometric heights into the surveying and mapping community is two-fold. First, during the transition period users must accept and use GPS-derived orthometric height differences which have typical relative uncertainties larger than leveling-derived orthometric height differences over short lines, i.e., between 3 and 6 cm (0.1 and 0.2 feet) for GPS-derived differences over 5 km. Second, users must be able to reliably determine and document the accuracy estimates for their project's final adjusted GPS-derived orthometric heights. The accuracy of adjusted GPS-derived orthometric height values depends on the accuracy of (1) GPS-derived ellipsoid height differences, (2) geoid height differences, and (3) the leveling-derived orthometric heights used as vertical control.

There is not a single GPS specification or procedure that by itself can account for inaccuracies in published orthometric heights and geoid models. This makes it difficult to prepare GPS specifications and procedures to establish GPS-derived orthometric heights. Draft specifications and procedures have been developed by the Federal Geodetic Control Subcommittee (FGCS) to estimate GPS-derived ellipsoid heights. The specifications include GPS occupation of a minimum number of stations which have leveling-derived orthometric heights, i.e., bench marks. This specification only assures that a long-wavelength systematic discrepancy can be detected and removed from the data. Local effects due to errors in the GPS data, distortions in the orthometric heights used as vertical control, or inaccuracies in the geoid model cannot be detected and removed unless additional bench marks are occupied by GPS. Local differences between the three height systems will be unique to each GPS project.

NGS is developing a plan to facilitate the transition from a leveling-derived orthometric height system, i.e., the vertical control portion of the current NGRS, to a combined leveling- and GPS-derived orthometric height system. From a user's perspective, an accurate, consistent, and constant set of orthometric heights is very important. This may be difficult to maintain during the transition period. During the transition period, specifications and procedures will be modified to account for the use of more accurate geoid models, improvements in estimating GPS-derived ellipsoid heights, and better a priori estimates of geoid, ellipsoid, and orthometric height values.

TASKS WHICH SHOULD BE PERFORMED FOR PROPER IMPLEMENTATION

The tasks listed below should be performed, or at least considered, before GPS-derived orthometric heights can be fully implemented into the surveying and mapping community. The tasks are grouped by function. Some of the tasks are currently underway, but most will be performed during the next 5 to 10 years. Many of the tasks will be performed concurrently. The sequence of tasks does not indicate order or priority. The list will be modified as new tasks are identified. The list will also be modified if it is determined that certain tasks do not need to be performed or that they should be combined with other tasks. A final list of tasks will be documented in a plan developed by NGS.

Tasks Associated with Geoid Modeling
Evaluate NGS gravity data base holdings and GEOID90 model (or its successor) to determine where additional gravity data are required.
Obtain additional gravity data where required by collecting existing data and by observing new data. New gravity data will be observed primarily by State and local agencies with assistance from NGS such as loaning of gravimeters and consulting advice as to data requirements and processing.
Improve accuracy of GEOID90 (or its successor) model. a) Use additional gravity data obtained from above. b) Use more accurate and higher resolution digital terrain models.
Develop a realistic error model for GEOID90 (or its successor). If possible, develop an interim error model which can be used for pilot projects.
Develop mechanism for distributing updated national high-resolution geoid models periodically.

Tasks Associated with Specifications and Procedures
Develop and document specifications and procedures for estimating GPS-derived ellipsoid heights. Investigate and document methods of improving the accuracy of GPS-derived ellipsoid heights. a) Evaluate accuracy attainable using different observing and reduction methods. b) Evaluate effects of improved orbits. c) Develop improved tropospheric refraction models. Develop and document procedures for estimating the accuracy of GPS-derived orthometric heights for a project. Develop and document specifications and procedures for computing GPS-derived orthometric heights. Develop routines and new products to provide surveyors with information necessary for planning GPS surveys. a) Gravity density and anomaly plots. b) NAVD 88 height information.

Tasks Associated with Establishing a Three-Dimensional National Geodetic Reference Network

Establish a nationwide high-precision three-dimensional network.

a) Use existing A-Order and VLBI networks.
b) Estimate a consistent set of precise ellipsoid heights.
c) Tie as many stations to NAVD 88 as possible.

Use nationwide high-precision three-dimensional network to control state-wide high-precision three-dimensional networks.

a) Estimate a consistent set of precise ellipsoid heights for the state-wide three-dimensional networks.
b) Tie as many stations to NAVD 88 as possible.

Use the state-wide three-dimensional network to control county-wide high-precision three-dimensional networks. County-wide is used here to mean a relatively small areal extent. It may not actually have to be limited to a county.

a) Estimate a consistent set of precise ellipsoid heights for the county-wide three-dimensional networks.
b) Tie as many stations to NAVD 88 as possible.

Tasks Associated with Evaluating Discrepancies between the Three Height Systems

Evaluate the comparison of NAVD 88 with GPS-derived orthometric heights computed using GEOID90 (or its successor) and the best estimate of ellipsoid heights from the nationwide three-dimensional network.

If necessary, remove long-wavelength discrepancies between ellipsoid, geoid, and orthometric height systems.

Evaluate the comparison of NAVD 88 with GPS-derived orthometric heights computed using GEOID90 (or its successor) and the best estimate of ellipsoid heights from state-wide GPS networks.

If necessary, remove medium-wavelength discrepancies between ellipsoid, geoid, and orthometric height systems.

Evaluate the comparison of NAVD 88 with GPS-derived orthometric computed using GEOID90 (or its successor) and the best estimate of ellipsoid heights from county-wide GPS projects.

If necessary and the data are accurate enough, remove short-wavelength discrepancies between ellipsoid, geoid, and orthometric height systems.

Tasks Associated with Disseminating GPS-Derived Orthometric Heights
Undertake pilot projects to develop and evaluate procedures necessary to handle discrepancies between the three height systems. Publish GPS-derived orthometric heights for pilot projects. Develop and document procedures necessary for <u>States/Counties to implement</u> GPS-derived orthometric heights at the local level. Educate users on procedures for computing GPS-derived orthometric heights. a) Publish a guidebook on computing GPS-derived orthometric heights. b) Publicize procedures with presentations at FGCS, ACSM, ASCE, etc. c) Assist others in converting from NGVD 29 to NAVD 88. d) Work with State and County agencies to develop GPS networks that are accurate enough to obtain GPS-derived orthometric heights which are better than 3 cm.

DISCUSSION ON IMPLEMENTATION OF GPS-DERIVED ORTHOMETRIC HEIGHTS

An important consideration to remember about establishing and maintaining a national vertical control network is to preserve consistency. A network consisting of many inconsistent local networks is relatively useless to users. When orthometric heights of stations are superseded because of adjustment constraints and not because the monument's physical location has changed, the rest of the network must be made consistent with the new values. Of course, forcing distortions into a network also makes the network less useful.

To decrease the number of station heights superseded, it has been recommended that standard errors be published with each GPS-derived orthometric height value, i.e., 5 cm. A published height value would be superseded when the change in its value exceeded its standard error. Unfortunately, this puts the burden on the user to determine if two closely spaced first-order stations meet first-order specifications. In the past, users did not have to be concerned about this because they were putting in lower-order control where higher-order control already existed. The FGCS specifications and procedures usually ensured that two first-order stations would have relative accuracies two to three times better than expected. In the past, the national network was generated by agencies with an overall network design in mind. The Federal government responsibility was to establish the primary and secondary control networks, while state and local government responsibilities were the lower-order networks.

On a project-by-project basis, estimating GPS-derived orthometric heights is not a difficult task. However, publishing GPS-derived orthometric heights which are usable for multipurpose is not as easy. The published heights should be compatible with the National Geodetic Vertical Reference System, i.e., NAVD 88. Establishing lower-order standards is not the solution. It is true that lower-order standards will have to be established and new specifications and procedures will have to be developed. While not absolutely necessary for computing local GPS-derived orthometric heights, establishing a high-precision three-dimensional National Geodetic Reference Network will help facilitate the implementation of GPS-derived orthometric heights.

The design of the national network should include sufficient redundancy such that the precision of the final adjusted ellipsoid heights is beyond question. Once a nationwide high-precision three-dimensional network is in place and analyzed, the latest geoid model could be evaluated using the ellipsoid heights and published NAVD 88 orthometric height values. This network would consist of stations spaced approximately 100 kilometers apart and established to A-order standards. Long-wavelength discrepancies between the geoid model and the ellipsoid and orthometric height systems could be removed using these high-precision ellipsoid heights.

NGS has already started a nationwide GPS network. The three-dimensional nationwide control network would then be used by each state to establish a state-wide high-precision three-dimensional control network. Many states have already established state-wide high precision GPS networks. It should be noted that these GPS networks were established with horizontal accuracy in mind and do not necessarily provide adequate vertical accuracy. If necessary, and if accurate enough, the state-wide three-dimensional control network could be used to remove medium-wavelength discrepancies between the height systems. This network would consist of stations spaced approximately 40 kilometers apart and established to B-order standards.

The state-wide control networks should then be used by each county when establishing a county-wide high-precision three-dimensional control network. The ellipsoid heights from the county-wide GPS survey should be used to implement GPS-derived orthometric heights in that county. County projects need to be designed in such a manner that accurate ellipsoid heights are generated, i.e., standard errors less than 2 cm. Discrepancies between the height systems must also be addressed at this level. This may be as simple as fixing all published NAVD 88 height values which were occupied in the county-wide high-precision GPS network or publishing realistic standard error values on the GPS- and leveling-derived orthometric heights.

Pilot projects must be used to determine the best method to implement the system. The goal should be to minimize the amount of distortion forced into the network. As stated previously, forcing too much distortion into a network can make the network worthless.

Of course a complete new network will take several years to be fully implemented. Some states would be completed sooner than others. Obviously, this is a long-term plan. There will have to be interim products. The products would include improvements to GEOID 90, i.e., removal of regional and local tilts, and GPS-derived orthometric height pilot projects. There are three pilot projects currently underway: San Diego County, California, Orange

County, Florida, and Nassau County, New York. The California and Florida projects are tied to state-wide three-dimensional high-precision GPS networks and all three projects have established a county-wide precise three-dimensional GPS network.

This plan is not much different than the plan used to establish the original NGRS. First-order networks, both horizontally and vertically, were established to support second-order networks, and these second-order networks were used to establish third-order networks. These third-order networks were used to make maps, build the national and local highway systems, and relate most mapping products to each other.

Interim products were produced during the development of the national networks. That is, there were several horizontal and vertical network adjustments performed from the late 1800s to the early 1900s. There were vertical network adjustments published in 1900, 1903, 1907, 1912, and 1929 and horizontal network adjustments were performed in 1901 and 1927.

NGRS was developed over time in response to the needs of users. For example, the U.S. Geological Survey (USGS) was tasked to map the United States and U.S. Army Corps of Engineers (COE) was tasked to maintain and monitor the navigable waterways of the United States. These tasks required geodetic control to be established throughout the United States. USGS, COE, state DOT's, and county agencies established most of the lower-order control. The cost of developing NGRS was shared by all users. Today, the costs associated with the implementation of GPS-derived orthometric heights should also be shared by all users and, in fact, this is what is happening. NGS is establishing an A-order three-dimensional nationwide GPS network, State agencies are establishing a B-order three-dimensional state-wide GPS network, and several counties have already established first-order three-dimensional county-wide GPS networks.

CONCLUSION

Over the last several years, NGS has performed several investigations in support of implementation of GPS-derived orthometric heights. The results of these investigations were used to develop and document preliminary procedures to be followed when computing GPS-derived orthometric heights, as well as develop a high-resolution geoid model for the conterminous United States, present workshops on computing GPS-derived orthometric heights, and assist other agencies in computing GPS-derived orthometric heights which met their project requirements.

NGS realizes that there are several remaining tasks to perform before GPS-derived orthometric heights can be fully implemented into NGRS. The tasks include: (1) continue to educate users on the procedures for computing GPS-derived orthometric heights, (2) publish a guidebook on computing GPS-derived orthometric heights, (3) improve the accuracy of GEOID 90, (4) develop a meaningful error model for GEOID 90 (or its successor), (5) assist others in converting their NGVD 29 heights to NAVD 88 heights, and (6) work with state and county agencies to develop GPS networks that consist of stations that are spaced close enough (and positioned accurately enough) to obtain GPS-derived orthometric heights which are better than 3 cm.

As part of an overall plan to modernize the National Geodetic Reference System, NGS is developing a plan to facilitate an orderly transition from leveling-derived orthometric heights to GPS-derived orthometric heights. The plan will consider consistency, distortions, and long-term Federal programs. Designing a high precision three-dimensional national reference network is not an unreasonably difficult task, but will require long-term coordination and assistance from all users.

Appendix C: VNB's gravity plan in support of the implementation of GPS-derived orthometric heights

VNB's Gravity Plan in Support of the
Implementation of GPS-Derived Orthometric Heights
(May 1992)

- Determine regions of the country where additional gravity data are required through data distribution and gravity field variability (correlations) analyses.

- Borrow gravity meters from DMA.

- Obtain existing gravity data collected by other agencies.

- Establish cooperative agreements with agencies interested in collecting additional new data or improving the accuracy of GEOID90.

  - NGS' responsibilities include gravity survey planning and analyses of data collected by other agencies.

    - Types of data include gravity, leveling, and GPS.
    - Types of data analyses include gravity survey adjustments, leveling data reduction and adjustments, and GPS network adjustments.

- For areas where additional data are required, determine specific sites where observations are to be taken.

  In the area selected:

  - Plot bench marks
  - Plot IGSN stations
  - Plot existing gravity sites
  - Plot "2-minute grid points" where additional data are required
  - Take appropriate action on "0" coded gravity data in NGSIDB (Quality control unedited gravity data)
  - Plot and quality control data collected from other agencies.

- Schedule date for data acquisition.

- Calibrate gravity meters.

- Train other agencies' personnel in the appropriate procedures for data acquisition.

  - Data collection
  - Data processing
  - Data coding
  - Data submission.

- These trained field personnel perform gravity measurements at a nearby test site.

- NGS evaluates test set of data for correctness and completeness.

- The trained personnel then perform gravity measurements at sites selected by the Vertical Network Branch (VNB).

VNB's Gravity Plan in Support of the
Implementation of GPS-Derived Orthometric Heights
(May 1992)

- VNB personnel analyze and load new gravity data into NGSIDB.
- VNB evaluates the impact and adequacy of new gravity data through local geoid computations and analysis.
- VNB cooperates with Advanced Geodetic Science Branch (AGSB) to develop improved geoid model.
- VNB and AGSB evaluate new geoid model using GPS/leveling data.
- VNB and AGSB document results of new model.
- If significant GPS/leveling data exist in the area of the new model, VNB publishes a special report which includes GPS-derived orthometric height values estimated using the new geoid model, along with procedures for implementing GPS-derived orthometric heights in the area.

VNB's Gravity Plan in Support of the
Implementation of GPS-Derived Orthometric Heights
(August 1992)

For each gravity project undertaken:

- Obtain existing gravity data collected by other agencies.
  - Contact geophysical exploration companies
  - Attend technical meetings, e.g., SEG Meetings
  - Contact USGS and Universities

- Establish cooperative agreements with agencies interested in collecting additional new data.
  - NGS' responsibilities include gravity survey planning and analyses of data collected by other agencies.
    - Types of data include gravity, leveling, and GPS.
    - Types of data analyses include gravity survey adjustments, leveling data reduction and adjustments, and GPS network adjustments.

- For areas where additional data are required, determine specific sites where observations are to be taken.

  In the area selected:
  - Plot bench marks
  - Plot IGSN stations
  - Plot existing gravity sites
  - Plot "2-minute grid points" where additional data are required
  - Take appropriate action on "0" coded gravity data in NGSIDB
  - Plot and quality control data collected from other agencies.

- Schedule date for data acquisition.

- Calibrate gravity meters.

- Train other agencies' personnel in the appropriate procedures for data acquisition.

  On-site training consists of:
  - Data collection
  - Data processing
  - Data coding
  - Data submission.

  NOTE: These trained field personnel perform gravity measurements at a nearby test site. NGS evaluates test set of data for correctness and completeness.

- The trained personnel then perform gravity measurements at sites selected by the Vertical Network Branch (VNB) and submit data to NGS.

- VNB personnel analyze and load new gravity data into NGSIDB.

VNB's Gravity Plan in Support of the
Implementation of GPS-Derived Orthometric Heights
(August 1992)

For each gravity project undertaken (continued):

- VNB cooperates with Advanced Geodetic Science Branch (AGSB) to develop improved geoid model by:
  - providing gravity data
  - analyzing suspect gravity data detected by AGSB
  - pursuing ways to obtain additional gravity data in areas suggested by AGSB.

- VNB cooperates with AGSB to evaluate new geoid model by:
  - comparing GPS-derived orthometric heights to precisely leveled values
  - identifying areas where the geoid model and leveling do not agree.

Appendix D: Gravity void information to CALTRANS

June 3, 1992

Mr. Gerard A. Nothdurf
Dept. of Transportation, Dist. 11
2819 Guan St., P.O. Box 85406
San Diego, California 92186-5406

Dear Mr. Nothdurf,

As a follow-up to your discussion with Mr. David Zilkoski about observed gravity densities, I am enclosing a short note delineating the strategy we use in encoding the sizes (weights) of voids and a floppy disc containing the requested data.

The four files on the floppy are:

N3211601.dat
N3211701.dat
N3311602.dat
N3311702.dat

The files include data for 1/2°(lat.) x 1°(lon.) geographic areas which coincide with 1/4th of the areal coverage of 1:250,000 USGS/NOS topo. sheets, or with the full areal coverage of 1:100,000 topo. sheets. Files are identified by the 1/2°x 1/2° south-east starting block of area covered. We use the following encoding system for easy identification:

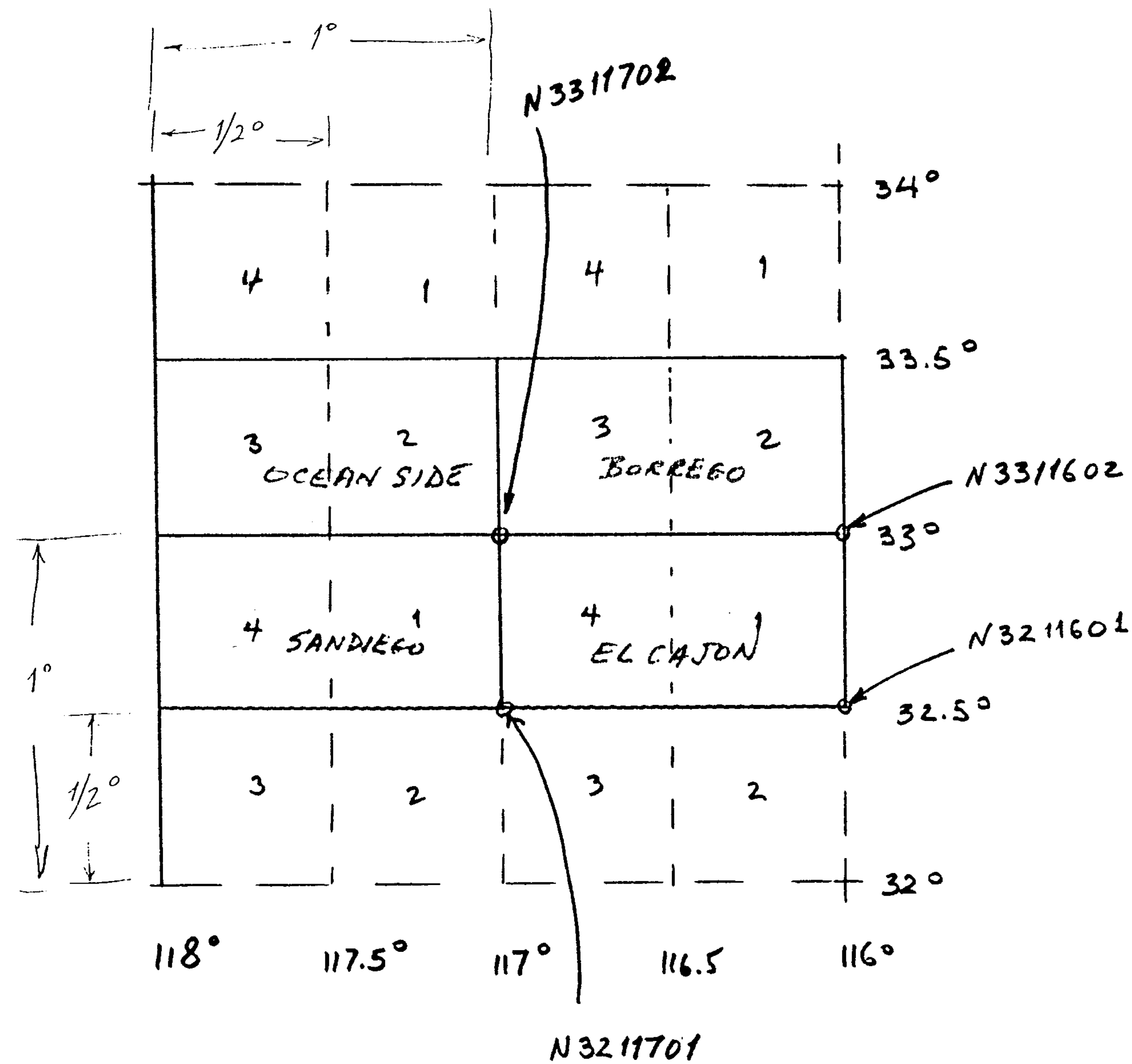
N indicates northern hemisphere
32 or 33 are the latitude of the south-east corner of area
116 or 117 are the longitude of the south-east corner of area
01 or 02 are the 1/2° x 1/2° starting block identifiers
[Block identifiers are numbered from 01 starting from the north-east, continuing clockwise 02 for the south-east, 03 for south-west and 04 to the north-west 1/2° block]

The files have free formats in which the data fields are separated by commas. Data items are latitude, longitude (negative to west) and symbol (void weight) to be plotted.

Please call me on 301-443-8657 number if you incur any problem with the files.

Sincerely yours,

Rudolf J. Fury
Geodesist



1°
1/2°
N3311702
34°
33.5°
33°
32.5°
32°
4
1
3
2
OCEAN SIDE
BORREGO
N3311602
SANDIEGO
EL CAJON
N3211601
1°
1/2°
118°
117.5°
117°
116.5
116°
N3211701

June 1, 1992

STRATEGY IN ASSIGNING WEIGHTS FOR GAPS IN GRAVITY OBSERVATION DISTRIBUTIONS

The algorithm locates voids in the observed gravity data distribution in a selected geographic area. The selected area is overlaid with a grid for voids analysis. This grid may be assigned various granularity (i.e., 1, 2, 3 ... arc minutes spacing). The search algorithm assigns ZERO weights to those grid quadrangles where there is at least one observation. If a quadrangle is void of observed gravity, then neighbouring quadrangles are tested.

The neighbourhood of the central quadrangle is partitioned into zones according to the template below. A weight of ONE is assigned to an empty quadrangle if at least one observation is located in any connecting quadrangle. If these quadrangles are also void of data, the search continues further outward from the central quadrangle. In the course of this search, a "void weight" is then determined depending in which of the neighbouring quadrangles (i.e., zones) was an observation located. Consequently, the higher the weight number the greater the void of observed gravity around a quadrangle. ZERO weights are represented by dots in the graphical representation of voids for better visual interpretation (see attached sample).

8	8	8	8	8	8	8	8	8	8	8
8	7	6	5	5	4	5	5	6	7	8
8	6	5	4	3	3	3	4	5	6	8
8	5	4	2	2	2	2	2	4	5	8
8	5	3	2	1	1	1	2	3	5	8
8	4	3	2	1	0	1	2	3	4	8
8	5	3	2	1	1	1	2	3	5	8
8	5	4	2	2	2	2	2	4	5	8
8	6	5	4	3	3	3	4	5	6	8
8	7	6	5	5	4	5	5	6	7	8
8	8	8	8	8	8	8	8	8	8	8

Appendix E: Gravity observation program - workshop outline

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
Coast and Geodetic Survey
Rockville, Maryland 20852

September 4, 1992

MEMORANDUM FOR: Edward J. McKay
Chief, Vertical Network Branch

FROM: Robert E. Moose *REM*
Vertical Network Branch, NGS

SUBJECT: Two Week Temporary Duty on CALTRANS/NGS Cooperative Gravity Collection Project

From August 17 to August 28 I was in San Diego, California, to instruct personnel of the California Department of Transportation (CALTRANS) in conducting gravity surveys. This is the second deployment of the DMA gravity meters on loan to NGS for the purpose of improvement of geoid determination. The first deployment was to the Minnesota State Advisor.

A formal presentation, lasting about an hour, of why NGS needs more gravity data was made on the 17th (see attachment 1). About 15 people, including NGS State Advisor to California, Joseph D. D'Onofrio, were in attendance.

Subsequent discussions were held with the office personnel concerning the desired density of gravity observations and the design of a gravity survey.

Four CALTRANS field personnel were trained in making gravity observations, conducting gravity surveys, and using the HP 95XL gravity data logger program (see attachment 2).

Gravity tasks completed include: 1) local calibration of the gravity meters, 2) establishment of seven base stations, and 3) the observation of the first two areas needing densification (27 stations).

Present CALTRANS plans are to observe gravity in San Diego County at 250 new stations reachable by using 4-wheel-drive vehicles and 150 stations reachable only by helicopter. All new stations will be positioned by GPS observations using the "rapid-static" method.

Attachments

cc: N/CG1x2 - W. Strange
N/CG1x7 - G. Tuell
N/CG1x9 - D. D'Onofrio
N/CG13 - R. Fury
G. Young
D. Zilkoski
N/CG18 - D. Milbert

Attachment 1

Outline - Gravity Observation Densification Programs

A. Gravity's Place in Geodesy
   The gravity connection between observations of angles and distances and:
   1. the ellipsoid
   2. the geoid

B. The Uses of Gravity

C. The Physics of Gravity
   a. Gravitational force - the dyne
   b. Gravitational acceleration - the gal
   c. Rotational force
   d. Gravity gradient

D. The Gravity Meter

E. Gravity Anomalies
   1. Normal gravity
   2. Free air anomaly
   3. Bouguer anomaly
   4. Terrain corrected anomaly

F. The Gravity Observation Error Budget
   a. Instrumental error
   b. Horizontal position error
   c. Latitude error
   d. Observation time error
   e. Vertical position error

G. Where More Gravity Observations Are Needed

H. Gravity Surveys
   a. Ladder sequence loop
   b. Modified ladder sequence loop
   c. Line sequence loop

I. Blue Book Gravity Record Formats
   a. Gravity Survey Information Records
   b. Gravity Survey Equipment Records
   c. Gravity Observation Records
   d. Gravity Station Designation Records

Attachment 2

Daily Log - CALTRANS/NGS Cooperative Gravity Collection Project

August 10
LaCoste & Romburg gravimeters G809 and G811 (on loan from DMA) were shipped to the California Department of Transportation (CALTRANS) office in San Diego, California.

August 16
Traveled to San Diego, California, by commercial air carrier.

August 17
A gravity workshop was held at the Kerney Mesa office of CALTRANS. The workshop consisted of about 1 hour of lecture and 1 hour of "hands-on" familiarization with the LaCoste & Romburg model G gravity meter. There were eight CALTRANS employees in attendance. Also attending were three employees from the local office of the U.S. Geological Survey and the NGS State Advisor to California, D. D'Onofrio.

August 18
Instruction was given to three CALTRANS employees in taking gravity readings, conducting gravity surveys, and using the HP 95LX gravity observation recording program. This instruction was conducted at Presidio Park in San Diego, where there is an approximately 500 ft difference in elevation.

August 19
The local scale factor was determined by observing between IGSN71 stations Montgomery Airport (USC&GS R896) and Jacumba (USC&GS R58) and back to Montgomery Airport. This is a range of (979,513.57 - 979,282.62) 231 mgals. The distance between these stations is 70 miles.

Gravity measurements were also made at two intermediate USC&GS bench mark stations: N570, S1312, and at USC&GS triangulation station MESH 1935. These intermediate USC&GS stations were observed to ascertain how well these stations, which are on several lines of an existing, extensive bench mark/gravity station network in the area, agree with the IGSN71 datum. If the agreement is good then it is planned to include these stations in those available as gravity base stations for the planned densification surveys.

Also, the previously determined gravity value at station MESH is 979,206.77 mgals. This station may be used to extend the range of the scale factor determination to (979,513.57 - 979,206.77) 307 mgals.

August 20
"Reconn" for future gravity base stations was conducted in the Palomar Mountain and Anza-Borrego Desert areas. Generally, existing stations of the California High Precision Geodetic Network (HGPN) were selected. GPS setups and gravity observations were made at several stations to determine a workable procedure.

August 21
There was no field crew activity due to their 4-day workweek schedule. To respond to the concern of CALTRANS personnel about the detection of tares in the gravity observations, I wrote a program for the HP 41CX calculator that makes a running error analysis of the gravity meter observations.

August 24
Five gravity base stations were established in the north-central (Palomar Mtn.) region of the county. These station occupations included GPS setups for practice.

August 25
Three gravity base stations were established in the south-central (Anza-Borrego Desert) region of the county.

August 26
The first area (vicinity of Alpine) needing densification was observed. Three Trimble GPS receivers, each monitored by a CALTRANS employee, were setup as static receivers on the periphery of the area. The "rover" Trimble receiver in "rapid static mode" accompanied the gravity party. There were eleven stations in the area. Station sites had been "reconned" and marked by CALTRANS personnel (Tim Dicky).

The primary criteria for densification is if the existing point density is less than one station per two arc minute square. The secondary criteria is the variability of the terrain. The gravity party was provided with a brief "to-reach" for the stations which made for efficiency.

Station occupation commenced with the setup of the GPS receiver. The gravity observation would begin beside the GPS tripod often before the GPS antenna was in place. Gravity observations with the two meters were generally accomplished within 10 minutes. Usually, a 15-minute station occupation was achieved. The observations were completed in less than 8 hours, which included about one and a half hours travel time to and from the area.

August 27
The second densification area (Lyons Valley), containing 16 stations, was observed in a similar manner. The observations were completed in less than 10 hours.

August 28
A fourth CALTRANS person (Tony Nothdurft) was instructed in making gravity observations.

Comments:
The tare detector program is quite useful. Upon entry of the first meter's reading at a station by the recorder, the program predicts the second meter's reading. The recorder then relays to the observer the whole number of the prediction to facilitate the setting of the second meter. After the null is found on the second meter, it is compared to the predicted reading. If the difference is greater than 3 sigma (1 sigma = 0.015 mgals), a tare is suspected. The procedure is then to repeat the setup and reading of both gravity meters. If the difference between the actual and predicted readings with the second meter still differ by more than 3 sigma, a tare has occurred and it is necessary to return to the previous station and repeat the gravity observations there.

There is a minor problem in the gravity data logging program. When a non-numeric entry is erroneously made at a numeric prompt, the program errors off and the system writes an end of file to the sequential data file. The program is not able to re-open this data file.

Gravity party operations on a daily schedule would be facilitated with an allotment of three batteries for each gravity meter.

The gravity party presently uses two vehicles and consists of three individuals: one to operate the GPS receiver, one to make the gravity observations, and one to record the gravity observations. After sufficient experience has been gained, operations could probably be conducted out of one vehicle by two individuals and would be less costly.

Present CALTRANS plans are to observe gravity in San Diego County at 150 helicopter stations (45 by the Marines on Camp Pendeleton) and 250 drive stations (27 completed).

Appendix F: Gravity observation program - instructions

MAKING A GRAVITY OBSERVATION

The gravity meter is carefully removed from its carrying case and gently set over the station mark. The Lacoste & Romberg model G gravity meter can be read optically or electronically.

A. Optical Reading

1. Level the gravity meter.

   Leveling is performed using the left front and the right leveling screws only, so as to maintain a constant instrument height from one occupation of the same station to the next.

   Leveling is an iterative procedure. The meter is approximately leveled using the fluid levels, cross level first, then the long level. To move the cross level up, turn the lower left leveling screw counter-clockwise. To move the long level left, turn the right leveling screw counter-clockwise. Refine the leveling by repeating the level adjustments; cross level first, then long level.

2. After the meter has been accurately leveled, unclamp the beam (turn the clamping knob counter-clockwise).

3. Turn on the internal light to illuminate the crosshair and the reading reticule. The toggle switch for the internal light is on the top cover of the meter, on the right front.

4. Looking into the eyepiece, locate the shadow of the crosshair. To null the meter, the left edge of the crosshair shadow is aligned with the right edge of the reading line (e.g., the reading line for G81 is at 2.50).

   Nulling is done in one direction only, going upscale, i.e., from left to right, by turning the measuring dial in small increments in a clockwise direction. The crosshair is moved to the right by turning the measuring dial clockwise. To move the crosshair to the left, the measuring dial is turned counter-clockwise.

   The gravity measurement system is highly damped, requiring as much as 10-15 seconds to respond to a change in setting of the reading dial.

   If the crosshair should come to rest to the right of the reading line, the measuring dial must be turned down scale (counter-clockwise) about one-half revolution and the null attempted again.

5. Nulling the gravity meter is also an iterative procedure. First the levels are checked and adjusted if needed. Then looking into the eyepiece, the crosshair is brought to the null position by small increments in the clockwise direction of the measuring dial. These two operations are iterated until the measuring dial position is found that nulls the meter while both levels are centered.

   When the null position has been found, it is tested by first noting the measuring dial reading, then turning the measuring dial about one-half revolution down scale (counter-clockwise), and then resetting it to the reading. A good measuring dial setting has been achieved when the crosshair returns to the reading line two or three times in succession, while the levels remain centered.

6. The concatenation of the numbers on the reading counters and this measuring dial setting is the reading recorded on the gravity observation form as the gravity meter reading at this station.

   Note that the rightmost reading counter is the same number as the whole divisions on the reading dial. Do not include one of these duplicate numbers.

7. Note the time of the observation and record it. This will be used for the subsequent gravitational tide correction.

8. <u>Clamp the beam</u> (turn the clamping knob clockwise).

9. Measure the height of the gravity meter (from the base of the meter to the station mark) and record the height on the gravity observation form.

B. Electronic Reading

1. Level the gravity meter (see section A1 above).

2. Unclamp the beam (see section A2 above).

3. The nulling of the meter can be done using the zero line on the galvanometer dial (see sections A4 and A5 above for the similar optical nulling procedure). The zero line of the galvanometer has previously been aligned with the optical method reading line.

4. Record the gravity observation (see section A6 above).

5. Note the time of the observation and record it.

6. Clamp the beam (turn the clamping knob clockwise).

7. Measure the height of the gravity meter and record it on the gravity observation form.

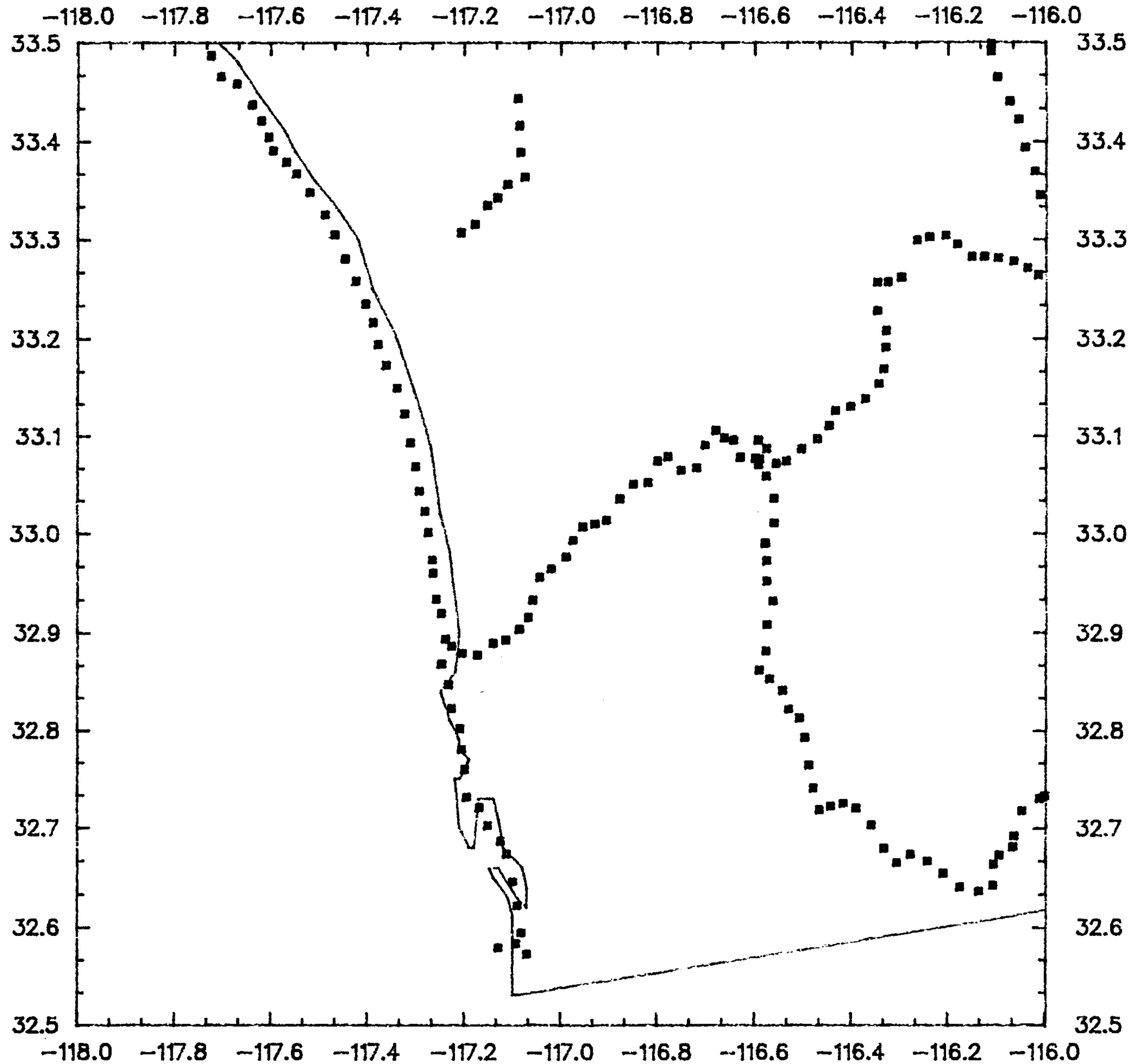
Carefully return the gravity meter to its carrying case.

Robert E. Moose
Vertical Network Branch, NGS
June 1992

Appendix G: Gravity observation program - monumented stations with gravity observations

Gravity on monumented stations.

Surface Gravity Density 32.5 116.0



Appendix H: NAVD 88 height values for GPS stations

Level(1) - NAVD 88 height estimated by incorporating 1978 Southern California Releveling Project (SCRP) leveling data into NAVD 88,

Level(2) - NAVD 88 height estimated by using a short one-mark leveling tie from a station which had a published NAVD 88 height,

Level(3) - NAVD 88 height estimated using a new leveling line (1992) which was incorporated into NAVD 88,

Level(4) - NAVD 88 height estimated by using a short one-mark leveling tie from a NAVD 88 SCRP (1978) adjusted height,

Trig(1) - NAVD 88 height estimated from a height difference obtained using specially designed trigonometric procedures. A one-mark tie was from a bench mark which had published NAVD 88 height value,

Trig(2) - NAVD 88 height estimated from a height difference obtained using specially designed trigonometric procedures. One-mark ties were connected to bench marks which had NAVD 88 height values obtained when the SCRP network was incorporated into NAVD 88,

Trig(3) - NAVD 88 height estimated from a height difference obtained using specially-designed trigonometric procedures. A one-mark tie was from a bench mark which was last leveled to in 1970. A NAVD 88 height value was estimated for the tie bench mark using the 1970 data.

Leveling Data Section - NAVD 88 Height Values

Station 11 AAR

Level(1) - NAVD 88 height estimated by incorporating 1978 Southern California Releveling Project (SCRP) leveling data into NAVD 88.

```
 Queued by NGVD3Z in project VERTICAL on NGSA
Job opened in print queue.
File is 1 disk record

****
****
**** N   N  GGG  V   V DDDD   333  ZZZZZ
**** NN  N G   G V   V D   D 3   3     Z
**** N N N G     V   V D   D     3    Z
**** N N N G     V   V D   D   33    Z
**** N N N G  GG V   V D   D     3  Z
**** N  NN G   G  V V  D   D 3   3 Z
**** N   N  GGGG   V   DDDD   333  ZZZZZ
****
****
****  SSS   CCC  RRRR  PPPP         1   1   AAA   AAA  RRRR
**** S   S C   C R   R P   P       11  11  A   A A   A R   R
**** S     C     R   R P   P        1   1  A   A A   A R   R
****  SSS  C     RRRR  PPPP  -----  1   1  AAAAA AAAAA RRRR
****     S C     R R   P            1   1  A   A A   A R R
**** S   S C   C R  R  P            1   1  A   A A   A R  R
****  SSS   CCC  R   R P          111 111  A   A A   A R   R
****
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**** Queued on 19 Oct 93 08:50:52 Tuesday
**** Options: -ACCOUNTING -AT PR1 -COPYFILE -FORM        -NO_FORMAT -OPENED -PARALLEL -PRIORITY 5 -SUSPENDABLE
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**** Copy 2 of 2 began printing 19 Oct 93 08:52:16 Tuesday by PR5 rev 5.4 on NGSA
****
****
****
****  CCC   OOO  PPPP  Y   Y         222          OOO  FFFFF         222
**** C   C O   O P   P  Y Y         2   2        O   O F            2   2
**** C     O   O P   P   Y Y            2        O   O F                2
**** C     O   O PPPP     Y            2         O   O FFFF            2
**** C     O   O P        Y           2          O   O F              2
**** C   C O   O P        Y          2           O   O F             2
****  CCC   OOO  P        Y         22222         OOO  F            22222
****
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409110230087DX047111 AAR 331744N1161752W 188.05156A979.4848 3.8

Leveling Data Section - NAVD 88 Height Values

Stations CA 11 07
OCOTILLO
SD GPS 01
SD GPS 24

Level(2) - NAVD 88 height estimated by using a short one mark leveling tie from a station which had a published NAVD 88 height.

PROJECT MARK ID	ACRN	DESIGNATION	ELEVATION	ADJ CODE	GEOPOTENTIAL NUMBER
1	DC0326	JM 168	219.4976	A	214.99382
2	DC0409	B 736	1057.0347	A	1035.20999
3	DC0413	M 570	1086.1713	A	1063.73724
4	DC0412	CY 59	1080.4101	A	1058.10090
5	DC0104	K 741	158.0658	A	154.82367
6	DC1363	P 1312	1237.9545	A	1212.36119
7	DC0008	CA 3	757.3540	A	741.71669
8	DB0790	DIXIE	-1.3250	A	-1.29785
9	DC0162	G 91 RESET	894.9322	A	876.42558
10	DX0310	RA 154	420.3722	A	411.74590
11	DX1452	W 282	24.3189	A	23.82220
12	DX0194	4219 T	1287.2625	A	1260.64006
13	DX0501	PMT 75	834.0951	A	816.93081
14	DX3438	T 1307	14.8902	A	14.58576
16	DC2029	JUNCTION CADH AZ MK 1974	562.7931	A	551.20969
17	DC1396	R 1411	561.5758	A	550.01757
18	DC1421	D 1412	21.4558	A	21.01582
19	DB1234	OCOTILLO NCMN 7270	-1.7777	A	-1.74126
20	DC2125	HPGN CA 11 01	156.7713	A	153.55555
21	DC2126	HPGN CA 11 02	798.4855	A	781.99696
22	DX5291	HPGN CA 11 07	94.9020	A	92.96167
24	DX5295	HPGN CA SDGPS 01	29.5284	A	28.92530
25	DX5300	SAN DIEGO GPS 15	1281.5093	A	1255.00052
26	DC2131	HPGN CA SDGPS 21	1096.9305	A	1074.27542
27	DC2134	HPGN CA SDGPS 24	46.4938	A	45.54062
28	DC2135	SAN DIEGO GPS 31	926.0116	A	906.86551
29	DX5302	SAN DIEGO GPS 32	418.5361	A	409.94746
30	DC2136	SAN DIEGO GPS 33	222.5232	A	217.95727
31	DX5303	SAN DIEGO GPS 34	823.4371	A	806.49024
32	DC2137	SAN DIEGO GPS 35	1234.7616	A	1209.23497

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THE FOLLOWING COMMANDS WERE USED IN THIS ADJUSTMENT
 TITLE 'SPECIAL ADJ OF TRIG DATA IN SUPPORT OF CALTRANS HGPS PROJECT'
 *
 *  POST ONE TRIG LINE BECAUSE NO NAVD 88 HEIGHTS AVAILABLE
 *   THE ONLY TIE IS TO A VERY OLD LEVEL LINE - L15872 (1956)
 *
 POST LINE TG1/12
 *
 *  CONSTRAIN NAVD 88 FROM GENERAL ADJUSTMENT
 *
 CONSTRAIN BM DC0326  219.49760 0.01                                        0000002
 CONSTRAIN BM DC0104  158.06580 0.01                                        0000002
 CONSTRAIN BM DC0008  757.35400 0.01                                        0000002
 CONSTRAIN BM DC0162  894.93220 0.01                                        0000002
 CONSTRAIN BM DX3438   14.89020 0.01                                        0000002
 CONSTRAIN BM DC1396  561.57580 0.01                                        0000002
 *
 *   CONSTRAIN NAVD 88 HEIGHTS FROM SCARP ADJUSTMENT
 *
 CONSTRAIN BM DC0412 1080.41006 0.01
 CONSTRAIN BM DX0310 420.37222 0.01
 CONSTRAIN BM DC1363 1237.95455 0.01
 CONSTRAIN BM DX0194 1287.26248 0.01
 *
 *   CONSTRAIN NAVD 88 HEIGHT ESTIMATED USING L21532 (1968-70)
 *   L21532 TIED TO L25016 AT ONE END AND L24301/18 AT THE OTHER
 *   DX0501 PMT 75 SD CO - 834.0951
 *
 CONSTRAIN BM DX0501 834.0951 0.01
 *
 *
 *   CONSTRAIN OTHER NAVD 88 FROM GENERAL ADJUSTMENT FOR LEVEL LINES
 *
 CONSTRAIN BM DB0790   -1.32500 0.01                                        0000002
 CONSTRAIN BM DX1452   24.31890 0.01                                        0000002
 CONSTRAIN BM DC1421   21.45580 0.01                                        0000002

THE FOLLOWING OPTIONS WERE REQUESTED BY THE USER
 corrections applied: ortho; level; rod; temp; astro; ref; mag;
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File is 8 disk records, last modified 02 Sep 93 08:08:04 Thursday

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**** NN  N G   G V   V D   D 3   3     Z
**** N N N G     V   V D   D     3    Z
**** N N N G     V   V D   D   33    Z
**** N N N G  GG V   V D   D     3  Z
**** N  NN G   G  V V  D   D 3   3 Z
**** N   N  GGGG   V   DDDD   333  ZZZZZ
****
****
****  AAA  DDDD     JJJ     CCC   OOO  M   M  OOO
**** A   A D   D     J     C   C O   O MM MM O   O
**** A   A D   D     J     C     O   O M M M O   O
**** AAAAA D   D     J     C     O   O M   M O   O
**** A   A D   D J   J     C     O   O M   M O   O
**** A   A D   D J   J  .. C   C O   O M   M O   O
**** A   A DDDD   JJ    ..  CCC   OOO  M   M  OOO
****
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****
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Job 0 ADJ.COMO in queue A01 on NGSA
Queued on 19 Oct 93 08:11:24 Tuesday
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Copy began printing 19 Oct 93 08:11:24 Tuesday by PR5 rev 5.4 on NGSA

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02 Sep 93 08:07:36 Thursday
OK 08:07:39  2.712  2.121
08:07:39 (      3.12)  <LGROUP ver 1.007>
08:07:40 (      3.26)  Alternate adjustment project:  NAVD$
08:07:40 (      3.95)  Begin mark scan
08:07:41 (      4.30)  Begin observation scan
08:07:42 (      4.80)      14 groups in the adjustment
08:07:42 (      4.81)  Begin singular class scan
08:07:42 (      4.91)  Begin second observation scan
```

Group 1 contains 2 marks:

DC0326/JM 168	DC2136/SAN DIEGO GPS 33

Lines:
TG1/8

Group 2 contains 8 marks:

DC0412/CY 59	DC0413/M 570	$T0006/TBM 13
DC0409/B 736	$T0007/TBM 12	$T0008/TBM 11
$T0009/TBM 10	DC2131/HPGN CA SDGPS 21	

Lines:
GPS430/5 TG1/5

Group 3 contains 2 marks:

DC0104/K 741	DC2125/HPGN CA 11 01

Lines:
TG1/14

Group 4 contains 2 marks:

DC1363/P 1312	DC2137/SAN DIEGO GPS 35

Lines:
TG1/9

Group 5 contains 2 marks:

DC0008/CA 3	DC2126/HPGN CA 11 02

Lines:
TG1/13

Group 6 contains 2 marks:

DB0790/DIXIE	DB1234/OCOTILLO NCMN 7270

Lines:
GPS430/6

Group 7 contains 2 marks:

DC0162/G 91 RESET	DC2135/SAN DIEGO GPS 31

Lines:
TG1/10

Group 8 contains 6 marks:

DX0310/RA 154	$T0010/TBM 14	$T0011/TBM 15
$T0012/TBM 16	$T0013/TBM 17	DX5302/SAN DIEGO GPS 32

```
Lines:
  TG1/6
------------------------------------------------------------------------------
Group     9 contains      2 marks:

  DX1452/W 282                          DX5295/HPGN CA SDGPS 01

Lines:
  GPS430/4
------------------------------------------------------------------------------
Group    10 contains      2 marks:

  DX0194/4219 T                         DX5300/SAN DIEGO GPS 15

Lines:
  TG1/7
------------------------------------------------------------------------------
Group    11 contains      2 marks:

  DX0501/PMT 75                         DX5303/SAN DIEGO GPS 34

Lines:
  TG1/11
------------------------------------------------------------------------------
Group    12 contains      7 marks:

  DX3438/T 1307                         $T0001/TBM 9                      $T0002/TBM 8
  $T0003/TBM 7                          $T0004/TBM 6                      $T0005/TBM 5
  DX5291/HPGN CA 11 07

Lines:
  GPS430/3       TG1/3
------------------------------------------------------------------------------
Group    13 contains      2 marks:

  DC1396/R 1411                         DC2029/JUNCTION CADH AZ MK 1974

Lines:
  TG1/15
------------------------------------------------------------------------------
Group    14 contains      2 marks:

  DC1421/D 1412                         DC2134/HPGN CA SDGPS 24

Lines:
  GPS430/1
------------------------------------------------------------------------------

08:07:44 (      6.66)  End LGROUP
08:07:44 (      6.87)  <VLSQ ver 1.028>
08:07:44 (      6.96)  Alternate adjustment project:  NAVD$
08:07:45 (      7.98)  bm scan complete
08:07:46 (      8.71)  reordering complete
08:07:46 (      8.98)  normal equation setup complete
08:07:49 (     11.17)  normal equations formed
08:07:49 (     11.24)  normal equations solved

          Summary:
          Singularities ..................      0
```

```
Constraints .....................     14
Benchmarks and TBMs adjusted ....     43
Sections ........................     41
Runnings ........................     53
Variance of unit weight .........   0.45
VTPV...................0.535328364D+01
Degrees of Freedom...........      12

08:07:53 (     14.69)  end VLSQ
```

```
ANY OBSERVATIONS WITH A RESIDUAL EXCEEDING  10.0 WILL BE FLAGGED
ANY OBSERVATIONS WITH A NORMALIZED RESIDUAL EXCEEDING   2.0 WILL BE FLAGGED
THE ALPHA FACTOR FOR COMPUTING THE MAXIMUM ALLOWABLE TAU IS 0.050
TAU WILL NOT BE COMPUTED
ALL OBSERVATIONS WILL BE LISTED
THE ADJUSTED ELEVATIONS WILL BE LISTED
```

```
THE FOLLOWING COMMANDS WERE USED IN THIS ADJUSTMENT
 TITLE 'SPECIAL ADJ OF TRIG DATA IN SUPPORT OF CALTRANS HGPS PROJECT'
 *
 *  POST ONE TRIG LINE BECAUSE NO NAVD 88 HEIGHTS AVAILABLE
 *   THE ONLY TIE IS TO A VERY OLD LEVEL LINE - L15872 (1956)
 *
 POST LINE TG1/12
 *
 *  CONSTRAIN NAVD 88 FROM GENERAL ADJUSTMENT
 *
 CONSTRAIN BM DC0326  219.49760 0.01                                     0000002
 CONSTRAIN BM DC0104  158.06580 0.01                                     0000002
 CONSTRAIN BM DC0008  757.35400 0 01                                     0000002
 CONSTRAIN BM DC0162  894.93220 0.01                                     0000002
 CONSTRAIN BM DX3438   14.89020 0.01                                     0000002
 CONSTRAIN BM DC1396  561.57580 0 01                                     0000002
 *
 *   CONSTRAIN NAVD 88 HEIGHTS FROM SCARP ADJUSTMENT
 *
 CONSTRAIN BM DC0412 1080.41006 0.01
 CONSTRAIN BM DX0310 420.37222 0.01
 CONSTRAIN BM DC1363 1237.95455 0.01
 CONSTRAIN BM DX0194 1287.26248 0.01
 *
 *   CONSTRAIN NAVD 88 HEIGHT ESTIMATED USING L21532 (1968-70)
 *   L21532 TIED TO L25016 AT ONE END AND L24301/18 AT THE OTHER
 *   DX0501 PMT 75 SD CO - 834.0951
 *
 CONSTRAIN BM DX0501 834.0951 0.01
 *
 *
 *   CONSTRAIN OTHER NAVD 88 FROM GENERAL ADJUSTMENT FOR LEVEL LINES
 *
 CONSTRAIN BM DB0790   -1.32500 0.01                                     0000002
 CONSTRAIN BM DX1452   24.31890 0.01                                     0000002
 CONSTRAIN BM DC1421   21.45580 0.01                                     0000002

THE FOLLOWING OPTIONS WERE REQUESTED BY THE USER
 corrections applied: ortho; level; rod; temp; astro; ref; mag;
```

PROJECT MARK ID	ACRN	DESIGNATION	ELEVATION	ADJ CODE	GEOPOTENTIAL NUMBER
1	DC0326	JM 168	219.4976	A	214.99362
2	DC0409	B 736	1057.0347	A	1035.20999
3	DC0413	M 570	1086.1713	A	1063.73724
4	DC0412	CY 59	1080.4101	A	1058.10090
5	DC0104	K 741	158.0658	A	154.82367
6	DC1363	P 1312	1237.9545	A	1212.36119
7	DC0008	CA 3	757.3540	A	741.71669
8	DB0790	DIXIE	-1.3250	A	-1.29785
9	DC0162	G 91 RESET	894.9322	A	876.42558
10	DX0310	RA 154	420.3722	A	411.74590
11	DX1452	W 282	24.3189	A	23.82220
12	DX0194	4219 T	1287.2625	A	1260.64006
13	DX0501	PMT 75	834.0951	A	816.93081
14	DX3438	T 1307	14.8902	A	14.58576
16	DC2029	JUNCTION CADH AZ MK 1974	562.7931	A	551.20969
17	DC1396	R 1411	561.5758	A	550.01757
18	DC1421	D 1412	21.4558	A	21.01582
19	DB1234	OCOTILLO NCMN 7270	-1.7777	A	-1.74126
20	DC2125	HPGN CA 11 01	156.7713	A	153.55555
21	DC2126	HPGN CA 11 02	798.4855	A	781.99696
22	DX5291	HPGN CA 11 07	94.9020	A	92.96167
24	DX5295	HPGN CA SDGPS 01	29.5284	A	28.92530
25	DX5300	SAN DIEGO GPS 15	1281.5093	A	1255.00052
26	DC2131	HPGN CA SDGPS 21	1096.9305	A	1074.27542
27	DC2134	HPGN CA SDGPS 24	46.4938	A	45.54062
28	DC2135	SAN DIEGO GPS 31	926.0116	A	906.86551
29	DX5302	SAN DIEGO GPS 32	418.5361	A	409.94746
30	DC2136	SAN DIEGO GPS 33	222.5232	A	217.95727
31	DX5303	SAN DIEGO GPS 34	823.4371	A	806.49024
32	DC2137	SAN DIEGO GPS 35	1234.7616	A	1209.23497

MARK_ID FROM	MARK_ID TO	LINE/PART	YR	SPSNS FROM	SPSNS TO	RUNS	DIST	GEOPOTENTIAL OBSERVED	GEOPOTENTIAL PRIOR	GEOPOTENTIAL POST	RESIDUALS "V"	RESIDUALS NORMAL	RESIDUALS TAU	O/C	FLAGS
18	27	GPS430/1	93	4*	5	1	1.98	24.5248	1.4	0.0	0.00*	0.00	0.00	12	
37	22	GPS430/3	93	14	13	1	0.54	1.2786	0.7	0.0	-0.21	0.29	0.00	12	
36	37	GPS430/3	93	15	14	1	0.75	32.8260	0.9	0.0	-0.03	0.04	0.00	12	
35	36	GPS430/3	93	17	15	1	1.29	25.8265	1.1	0.0	-0.02	0.02	0.00	12	
34	35	GPS430/3	93	18	17	1	0.93	7.5485	0.9	0.0	-0.11	0.12	0.00	12	
33	34	GPS430/3	93	19	18	1	1.08	-3.3102	1.0	0.0	-0.45	0.44	0.00	12	
14	33	GPS430/3	93	20*	19	1	1.34	14.2074	1.1	0.0	-0.07	0.06	0.00	12	
11	24	GPS430/4	93	22*	21	1	0.23	5.1031	0.5	0.0	0.00*	0.00	0.00	12	
41	26	GPS430/5	93	24	23	1	0.14	19.3577	0.4	0.0	-0.02	0.05	0.00	12	
40	41	GPS430/5	93	25	24	1	0.86	43.6067	0.9	0.0	-0.13	0.14	0.00	12	
39	40	GPS430/5	93	26	25	1	0.97	9.7545	1.0	0.0	-0.14	0.15	0.00	12	
2	39	GPS430/5	93	27	26	1	1.49	-33.6535	1.2	0.0	0.26	0.22	0.00	12	
38	2	GPS430/5	93	28	27	1	1.47	-28.3159	1.2	0.0	-0.02	0.02	0.00	12	
4	38	GPS430/5	93	29*	28	1	0.60	5.4247	0.8	0.0	0.29	0.38	0.00	12	
4	3	GPS430/5	93	29*	30	1	0.15	5.6363	0.4	0.0	0.00*	0.00	0.00	12	
8	19	GPS430/6	93	31*	32	1	0.10	-0.4434	0.3	0.0	0.00*	0.00	0.00	12	
9	28	TG1/10	93	13*	14	1	1.57	30.4399	5.2	0.0	0.00*	0.00	0.00	30	
13	31	TG1/11	93	15*	16	1	0.68	-10.4406	3.4	0.0	0.00*	0.00	0.00	30	
7	21	TG1/13	93	19*	20	1	0.58	40.2803	3.1	0.0	0.00*	0.00	0.00	30	
5	20	TG1/14	93	21*	22	1	0.29	-1.2681	2.2	0.0	0.00*	0.00	0.00	30	
17	16	TG1/15	93	23*	24	1	0.05	1.1921	1.3	0.0	0.00*	0.00	0.00	30	
37	22	TG1/3	93	14	13	2	0.57	1.2765	2.2	0.0	1.89	0.86	0.00	30	
36	37	TG1/3	93	15	14	2	0.76	32.8256	2.5	0.0	0.33	0.13	0.00	30	
35	36	TG1/3	93	17	15	2	1.31	25.8263	3.3	0.0	0.10	0.03	0.00	30	
34	35	TG1/3	93	18	17	2	0.94	7.5474	2.8	0.0	1.05	0.37	0.00	30	
33	34	TG1/3	93	19	18	2	1.10	-3.3147	3.1	0.0	4.04	1.32	0.00	30	
14	33	TG1/3	93	20*	19	2	1.33	14.2067	3.4	0.0	0.59	0.18	0.00	30	
41	26	TG1/5	93	24	23	2	0.15	19.3575	1.1	0.0	0.18	0.16	0.00	30	
40	41	TG1/5	93	25	24	2	0.88	43.6054	2.7	0.0	1.20	0.44	0.00	30	
39	40	TG1/5	93	26	25	2	1.00	9.7532	2.9	0.0	1.21	0.42	0.00	30	
2	39	TG1/5	93	27	26	2	1.51	-33.6510	3.6	0.0	-2.30	0.64	0.00	30	
38	2	TG1/5	93	28	27	2	1.50	-28.3160	3.6	0.0	0.17	0.05	0.00	30	
4	38	TG1/5	93	29*	28	2	0.63	5.4276	2.3	0.0	-2.66	1.15	0.00	30	
10	42	TG1/6	93	1*	2	1	1.35	12.4325	4.8	0.0	0.00*	0.00	0.00	30	
42	43	TG1/6	93	2	3	1	1.10	-1.1303	4.3	0.0	0.00*	0.00	0.00	30	
43	44	TG1/6	93	3	4	1	1.10	-11.8448	4.3	0.0	0.00*	0.00	0.00	30	
44	45	TG1/6	93	4	5	1	1.08	-3.0740	4.3	0.0	0.00*	0.00	0.00	30	
45	29	TG1/6	93	5	6	1	1.26	1.8183	4.6	0.0	0.00*	0.00	0.00	30	
12	25	TG1/7	93	7*	8	1	0.38	-5.6395	2.5	0.0	0.00*	0.00	0.00	30	
1	30	TG1/8	93	9*	10	1	0.64	2.9637	3.3	0.0	0.00*	0.00	0.00	30	
6	32	TG1/9	93	11*	12	1	0.14	-3.1262	1.6	0.0	0.00*	0.00	0.00	30	

BMS	=	30
TBMS	=	13
TOTAL OBSERVATIONS	=	41
NON SPUR OBSERVATIONS	=	41
DROPPED MARKS	=	0
POSTED MARKS	=	2
FLOATED MARKS	=	0
MAX FLAGS	=	0
NORMAL FLAGS	=	0
TAU FLAGS	=	0
CRITICAL VALUE OF TAU	=	0.00

```
  SUCCESSFUL RUN
09/02/93.08:08:00.Thu
OK, Batch_Event -END 'Normal Termination.'
Event 'NORMAL TERMINATION.' posted.

NGVD3Z (user 154) logged out Thursday, 02 Sep 93 08:08:04.
Time used: 00h 00m connect, 00m 21s CPU, 00m 04s I/O.
Goodbye NGVD3Z.
```

```
 Queued by NGVD3Z in project VERTICAL on NGSA
<B04>NGVD3Z>CALTRANS.HGPS>GPS.H88>TRIG_LEVEL>FINAL>COMMANDS on NGSA
File is 1 disk record, last modified 01 Sep 93 14:55:08 Wednesday

****
****
**** N   N  GGG  V   V DDDD   333  ZZZZZ
**** NN  N G   G V   V D   D 3   3     Z
**** N N N G     V   V D   D     3    Z
**** N N N G     V   V D   D   33    Z
**** N N N G  GG V   V D   D     3  Z
**** N  NN G   G  V V  D   D 3   3 Z
**** N   N  GGGG   V   DDDD   333  ZZZZZ
****
****
****  CCC   OOO  M   M M   M  AAA  N   N DDDD   SSS
**** C   C O   O MM MM MM MM A   A NN  N D   D S   S
**** C     O   O M M M M M M A   A N N N D   D S
**** C     O   O M M M M M M AAAAA N N N D   D  SSS
**** C     O   O M   M M   M A   A N N N D   D     S
**** C   C O   O M   M M   M A   A N  NN D   D S   S
****  CCC   OOO  M   M M   M A   A N   N DDDD   SSS
****
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****
**** Job 0 COMMANDS in queue A01 on NGSA
**** Queued on 19 Oct 93 08:11:56 Tuesday
**** Options: -ACCOUNTING -AT PR1 -COPYFILE -FORM        -NO_FORMAT -PARALLEL -PRIORITY 5 -SUSPENDABLE
****
**** Copy began printing 19 Oct 93 08:12:00 Tuesday by PR5 rev 5.4 on NGSA
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```
TITLE 'SPECIAL ADJ OF TRIG DATA IN SUPPORT OF CALTRANS HGPS PROJECT'
*
*  POST ONE TRIG LINE BECAUSE NO NAVD 88 HEIGHTS AVAILABLE
*   THE ONLY TIE IS TO A VERY OLD LEVEL LINE - L15872 (1956)
*
POST LINE TG1/12
*
*  CONSTRAIN NAVD 88 FROM GENERAL ADJUSTMENT
*
CONSTRAIN BM DC0326  219.49760 0.01                                  00000025 A
CONSTRAIN BM DC0104  158.06580 0.01                                  00000025 A
CONSTRAIN BM DC0008  757.35400 0.01                                  00000025 A
CONSTRAIN BM DC0162  894.93220 0.01                                  00000025 A
CONSTRAIN BM DX3438   14.89020 0.01                                  00000025 A
CONSTRAIN BM DC1396  561.57580 0.01                                  00000025 A
*
*   CONSTRAIN NAVD 88 HEIGHTS FROM SCARP ADJUSTMENT
*
CONSTRAIN BM DC0412 1080.41006 0.01
CONSTRAIN BM DX0310 420.37222 0.01
CONSTRAIN BM DC1363 1237.95455 0.01
CONSTRAIN BM DX0194 1287.26248 0.01
*
*   CONSTRAIN NAVD 88 HEIGHT ESTIMATED USING L21532 (1968-70)
*   L21532 TIED TO L25016 AT ONE END AND L24301/18 AT THE OTHER
*   DX0501 PMT 75 SD CO - 834.0951
*
CONSTRAIN BM DX0501 834.0951 0.01
*
*
*   CONSTRAIN OTHER NAVD 88 FROM GENERAL ADJUSTMENT FOR LEVEL LINES
*
CONSTRAIN BM DB0790   -1.32500 0.01                                  00000025 A
CONSTRAIN BM DX1452   24.31890 0.01                                  00000025 A
CONSTRAIN BM DC1421   21.45580 0.01                                  00000025 A
```

Leveling Data Section - NAVD 88 Height Values

Stations SD GPS 03
YUNG

Level(3) - NAVD 88 height estimated using a new leveling line (1992) which was incorporated into NAVD 88.

```
 Queued by NGVD3Z in project VERTICAL on NGSA
<B04>NGVD3Z>CALTRANS.HGPS>GPS.H88>TRIG_LEVEL>YUNG_03>IDB on NGSA
File is 5 disk records, last modified 19 Oct 93 09:34:04 Tuesday

****
****
**** N   N  GGG  V   V DDDD   333  ZZZZZ
**** NN  N G   G V   V D   D 3   3     Z
**** N N N G     V   V D   D     3    Z
**** N N N G     V   V D   D   33    Z
**** N N N G  GG V   V D   D     3  Z
**** N  NN G   G  V V  D   D 3   3 Z
**** N   N  GGGG   V   DDDD   333  ZZZZZ
****
****
**** III DDDD  BBBB
****  I  D   D B   B
****  I  D   D B   B
****  I  D   D BBBB
****  I  D   D B   B
****  I  D   D B   B
**** III DDDD  BBBB
****
****
****
**** Job 0 IDB in queue A01 on NGSA
**** Queued on 19 Oct 93 09:34:36 Tuesday
**** Options: -ACCOUNTING -AT PR1 -COPYFILE -FORM        -NO_FORMAT -PARALLEL -PRIORITY 5 -SUSPENDABLE
****
**** Copy began printing 19 Oct 93 09:34:40 Tuesday by PR5 rev 5.4 on NGSA
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```
> mkinfo dx5297
username = NGVD3Z  usernumber = 81
1) OPEN NGSIDB
2) @PAGESIZE 500
CRT page size set to 500
3) START MKINFO ('DX5297');
```

UID	POINT_AVAIL	DESIGNATION	ACRN	SET_CLASS	MONUMENT	STABILITY	MAGNETIC_MK	YR_SET	SET_BY
11499875		SDGPS 03	DX5297	31	DD	D	N	1991	CADT

AST_REC	REC_BY	COND	STATE	COUNTY	QID	QSN	LAT_APPROX	LON_APPROX
9921006	MWDSC	G	CA	073	0331172		0	0

1 row affected

PSEUDONYM
NE 15/76 1980

1 row affected

STAMPED
SDGPS 03 1991

1 row affected

D_CODE	TEXT
H	P000019921006
S	31SIDEWALK
O	CADT
K	THE STATION IS LOCATED 6.0 MI (9.7 KM) SOUTHEAST OF THE TOWN OF
K	FALLBROOK, 12.0 MI (19.3 KM) SOUTH OF TEMECULA, AT THE JUNCTION OF
K	INTERSTATE 15 AND STATE HIGHWAY 76.
K	TO REACH THE STATION FROM THE JUNCTION OF INTERSTATE 15 AND STATE
K	HIGHWAY 78 IN ESCONDIDO, GO NORTH ON INTERSTATE 15 FOR 15.0 MI
K	(24.1 KM) TO THE JUNCTION OF HIGHWAY 76 AT POST MILE 46.5 ON I-15,
K	AND THE STATION IN THE NORTHEAST CORNER OF THE BRIDGE OVER I-15.
K	THE STATION MARK IS IN THE EAST ABUTMENT OF THE BRIDGE AT THE
K	NORTHEAST CORNER IN THE SIDEWALK, 2.5 FT (0.8 M) EAST OF THE
K	EXPANSION JOINT AT THE BEGINING OF THE BRIDGE DECK, 2.5 FT (0.8 M)
K	NORTH OF THE TOP OF THE CURB, 33.5 FT (10.2 M) WEST OF THE EAST END OF
K	THE BRIDGE SIDEWALK.
R	19921006GMWDSC
T	PALA MESA, AT THE INTERSECTION OF INTERSTATE 15 AND STATE HWY 76, AT
T	THE NORTHEAST CORNER OF THE BRIDGE OVER THE FREEWAY. FOUND A 2 INCH
T	CADT DISK SET W/EPOXY IN NORTH CONCRETE ABUTMENT IN THE NORTHEAST
T	CORNER OF BRIDGE, DISK IS SET IN CONCRETE SIDEWALK AREA 2.5 FEET (0.8
T	M) EASTERLY OF EXPANSION JOINT FOR BRIDGE AND 2.5 FEET (0.8 M) BACK
T	OF TOP FACE OF CONCRETE CURB ABUTMENT ADDITIONAL STAMPING SDGPS 03
T	1991 TO THIS DISK BY SAN DIEGO COUNTY SURVEYORS.

23 rows affected

HEIGHT	DATUM	ADJ_ID	OBS_DATE	ELEV_SOURCE	ELEV_QUALITY	ELEV_TECH
93.2368	29	L253537	1992	F		

93.90	88	GPS430		H		G
93.9584	88	00000052		A		

3 rows affected

LATITUDE	LONGITUDE	DATUM	ADJ_ID	POS_SOURCE	POS_QUALITY	POS_TECH
N331953.	W1170927.	27		S	4	
N331954.31129	W1170931.67229	83	GPS430	A	B	G

2 rows affected
1) EXIT
> mkinfo dx5304
username = NGVD3Z usernumber = 81
1) OPEN NGSIDB
2) @PAGESIZE 500
CRT page size set to 500
3) START MKINFO ('DX5304');

```
|--------|-----------|--------------------------------------------------|------|----------|--------|---------|-----------|------|------|
-------|------|----|-----|------|----------|----|-------------|--------------|
|UID     |POINT_AVAIL|DESIGNATION                                       |ACRN  |SET_CLASS|MONUMENT|STABILITY|MAGNETIC_MK|YR_SET|SET_BY|
AST_REC|REC_BY|COND|STATE|COUNTY|QID       |QSN |   LAT_APPROX|    LON_APPROX|
|--------|-----------|--------------------------------------------------|------|----------|--------|---------|-----------|------|------|
-------|------|----|-----|------|----------|----|-------------|--------------|
|11499891|           |YUNG                                              |DX5304|59        |F       |A        |I          |1990  |CA-073|
9920828|MWDSC |G   |CA   |073   |0331172   |    |            0|             0|
|--------|-----------|--------------------------------------------------|------|----------|--------|---------|-----------|------|------|
-------|------|----|-----|------|----------|----|-------------|--------------|
```

1 row affected

PSEUDONYM

1 row affected

STAMPED
YUNG

1 row affected

D_CODE	TEXT
H	P000019920828
S	59STAINLESS STEEL ROD IN SLEEVE
O	CA-073
T	THE STATION IS LOCATED 0.2 MILE SOUTH OF THE INTERSECTION OF RTE 15
T	AND THE RIVERSIDE/SAN DIEGO COUNTY LINE.
T	TO REACH THE STATION FROM THE THE COUNTY LINE, GO SOUTH ALONG RTE 15
T	0.2 MILE TO THE INTERSECTION OF RAINBOW VALLEY BLVD. GO EAST ON
T	RAINBOW VALLEY BLVD. OVER BRIDGE AND TURN LEFT ONTO NORTH BOUND ON
T	RAMP AND THE STATION ON THE LEFT.
T	THE STATION IS A STANDARD 3 DIMENSIONAL GPS MONUMENT CONSISTING OF A
T	STAINLESS STEEL ROD DRIVEN TO REFUSAL, NO STAMPING. LOCATED IN THE
T	NORTHEAST QUADRANT OF RTE 15 AND RAINBOW VALLEY BLVD BETWEEN THE RAMP
T	AND MAIN LANES. WEST OF RAMP AND NORTH OF RAINBOW VALLEY BLVD AND 29
T	FEET NNW OF AN ELECTROLIER.
P	RMR5 3 1
R	19920828GMWDSC

16 rows affected

HEIGHT	DATUM	ADJ_ID	OBS_DATE	ELEV_SOURCE	ELEV_QUALITY	ELEV_TECH
351.3642	29	L253537	1992	F		
352.07	88	GPS430		H		G
352.0941	88	00000052		A		

3 rows affected

LATITUDE	LONGITUDE	DATUM	ADJ_ID	POS_SOURCE	POS_QUALITY	POS_TECH
N332547.	W1170837.	27		S	4	
N332548.75296	W1170840.74024	83	GPS430	A	B	G

2 rows affected
1) EXIT
> como -end

Leveling Data Section - NAVD 88 Height Values

Station SD GPS 24

Level(4) - NAVD 88 height estimated by using a short one-mark leveling tie from a NAVD 88 SCRP (1978) adjusted height.

PROJECT MARK ID	ACRN	DESIGNATION	ELEVATION	ADJ CODE	GEOPOTENTIAL NUMBER
1	DC0326	JM 168	219.4976	A	214.99362
2	DC0409	B 736	1057.0347	A	1035.20999
3	DC0413	M 570	1086.1713	A	1063.73724
4	DC0412	CY 59	1080.4101	A	1058.10090
5	DC0104	K 741	158.0658	A	154.82367
6	DC1363	P 1312	1237.9545	A	1212.36119
7	DC0008	CA 3	757.3540	A	741.71669
8	DB0790	DIXIE	-1.3250	A	-1.29785
9	DC0162	G 91 RESET	894.9322	A	876.42558
10	DX0310	RA 154	420.3722	A	411.74590
11	DX1452	W 282	24.3189	A	23.82220
12	DX0194	4219 T	1287.2625	A	1260.64006
13	DX0501	PMT 75	834.0951	A	816.93081
14	DX3438	T 1307	14.8902	A	14.58576
16	DC2029	JUNCTION CADH AZ MK 1974	562.7931	A	551.20969
17	DC1396	R 1411	561.5758	A	550.01757
18	DC1421	D 1412	21.4556	A	21.01582
19	DB1234	OCOTILLO NCMN 7270	-1.7777	A	-1.74126
20	DC2125	HPGN CA 11 01	156.7713	A	153.55555
21	DC2126	HPGN CA 11 02	798.4855	A	781.99696
22	DX5291	HPGN CA 11 07	94.9020	A	92.96167
24	DX5295	HPGN CA SDGPS 01	29.5284	A	28.92530
25	DX5300	SAN DIEGO GPS 15	1281.5093	A	1255.00052
26	DC2131	HPGN CA SDGPS 21	1096.9305	A	1074.27542
27	DC2134	HPGN CA SDGPS 24	46.4938	A	45.54062
28	DC2135	SAN DIEGO GPS 31	926.0116	A	906.86551
29	DX5302	SAN DIEGO GPS 32	418.5361	A	409.94746
30	DC2136	SAN DIEGO GPS 33	222.5232	A	217.95727
31	DX5303	SAN DIEGO GPS 34	823.4371	A	806.49074
32	DC2137	SAN DIEGO GPS 35	1234.7616	A	1209.23497

```
THE FOLLOWING COMMANDS WERE USED IN THIS ADJUSTMENT
 TITLE 'SPECIAL ADJ OF TRIG DATA IN SUPPORT OF CALTRANS HGPS PROJECT'
 *
 *  POST ONE TRIG LINE BECAUSE NO NAVD 88 HEIGHTS AVAILABLE
 *   THE ONLY TIE IS TO A VERY OLD LEVEL LINE   L15872 (1956)
 *
 POST LINE TG1/12
 *
 *  CONSTRAIN NAVD 88 FROM GENERAL ADJUSTMENT
 *
 CONSTRAIN BM DC0326  219.49760 0.01                                      0000002
 CONSTRAIN BM DC0104  158.06580 0.01                                      0000002
 CONSTRAIN BM DC0008  757.35400 0.01                                      0000002
 CONSTRAIN BM DC0162  894.93220 0.01                                      0000002
 CONSTRAIN BM DX3438   14.89020 0.01                                      0000002
 CONSTRAIN BM DC1396  561.57580 0.01                                      0000002
 *
 *   CONSTRAIN NAVD 88 HEIGHTS FROM SCARP ADJUSTMENT
 *
 CONSTRAIN BM DC0412 1080.41006 0.01
 CONSTRAIN BM DX0310 420.37222 0.01
 CONSTRAIN BM DC1363 1237.95455 0.01
 CONSTRAIN BM DX0194 1287.26248 0.01
 *
 *   CONSTRAIN NAVD 88 HEIGHT ESTIMATED USING L21532 (1968-70)
 *   L21532 TIED TO L25016 AT ONE END AND L24301/18 AT THE OTHER
 *   DX0501 PMT 75 SD CO - 834.0951
 *
 CONSTRAIN BM DX0501 834.0951 0.01
 *
 *
 *   CONSTRAIN OTHER NAVD 88 FROM GENERAL ADJUSTMENT FOR LEVEL LINES
 *
 CONSTRAIN BM DB0790   -1.32500 0.01                                      0000002
 CONSTRAIN BM DX1452   24.31890 0.01                                      0000002
 CONSTRAIN BM DC1421   21.45580 0.01                                      0000002

THE FOLLOWING OPTIONS WERE REQUESTED BY THE USER
 corrections applied: ortho; level; rod; temp; astro; ref; mag;
```

Leveling Data Section - NAVD 88 Height Values

Stations CA 11 01
CA 11 02
Junction AZ MK
SD GPS 31
SD GPS 33

Trig(1) - NAVD 88 height estimated from a height difference obtained using specially designed trigonometric procedures. A one-mark tie was from a bench mark which had published NAVD 88 height.

PROJECT MARK ID	ACRN	DESIGNATION	ELEVATION	ADJ CODE	GEOPOTENTIAL NUMBER
1	DC0326	JM 168	219.4976	A	214.99362
2	DC0409	B 736	1057.0347	A	1035.20999
3	DC0413	M 570	1086.1713	A	1063.73724
4	DC0412	CY 59	1080.4101	A	1058.10090
5	DC0104	K 741	158.0658	A	154.82367
6	DC1363	P 1312	1237.9545	A	1212.36119
7	DC0008	CA 3	757.3540	A	741.71669
8	DB0790	DIXIE	-1.3250	A	-1.29785
9	DC0162	G 91 RESET	894.9322	A	876.42558
10	DX0310	RA 154	420.3722	A	411.74590
11	DX1452	W 282	24.3189	A	23.82220
12	DX0194	4219 T	1287.2625	A	1260.64006
13	DX0501	PMT 75	834.0951	A	816.93081
14	DX3438	T 1307	14.8902	A	14.58576
16	DC2029	JUNCTION CADH AZ MK 1974	562.7931	A	551.20969
17	DC1396	R 1411	561.5758	A	550.01757
18	DC1421	D 1412	21.4556	A	21.01582
19	DB1234	OCOTILLO NCMN 7270	-1.7777	A	-1.74126
20	DC2125	HPGN CA 11 01	156.7713	A	153.55555
21	DC2126	HPGN CA 11 02	798.4855	A	781.99696
22	DX5291	HPGN CA 11 07	94.9020	A	92.96167
24	DX5295	HPGN CA SDGPS 01	29.5284	A	28.92530
25	DX5300	SAN DIEGO GPS 15	1281.5093	A	1255.00052
26	DC2131	HPGN CA SDGPS 21	1096.9305	A	1074.27542
27	DC2134	HPGN CA SDGPS 24	46.4938	A	45.54062
28	DC2135	SAN DIEGO GPS 31	926.0116	A	906.86551
29	DX5302	SAN DIEGO GPS 32	418.5361	A	409.94746
30	DC2136	SAN DIEGO GPS 33	222.5232	A	217.95727
31	DX5303	SAN DIEGO GPS 34	823.4371	A	806.49024
32	DC2137	SAN DIEGO GPS 35	1234.7616	A	1209.23497

```
THE FOLLOWING COMMANDS WERE USED IN THIS ADJUSTMENT
 TITLE 'SPECIAL ADJ OF TRIG DATA IN SUPPORT OF CALTRANS HGPS PROJECT'
 *
 *  POST ONE TRIG LINE BECAUSE NO NAVD 88 HEIGHTS AVAILABLE
 *   THE ONLY TIE IS TO A VERY OLD LEVEL LINE - L15872 (1956)
 *
 POST LINE TG1/12
 *
 *  CONSTRAIN NAVD 88 FROM GENERAL ADJUSTMENT
 *
 CONSTRAIN BM DC0326  219.49760 0.01                                              0000002
 CONSTRAIN BM DC0104  158.06580 0.01                                              0000002
 CONSTRAIN BM DC0008  757.35400 0.01                                              0000002
 CONSTRAIN BM DC0162  894.93220 0.01                                              0000002
 CONSTRAIN BM DX3438   14.89020 0.01                                              0000002
 CONSTRAIN BM DC1396  561.57580 0.01                                              0000002
 *
 *   CONSTRAIN NAVD 88 HEIGHTS FROM SCARP ADJUSTMENT
 *
 CONSTRAIN BM DC0412 1080.41006 0.01
 CONSTRAIN BM DX0310 420.37222 0.01
 CONSTRAIN BM DC1363 1237.95455 0.01
 CONSTRAIN BM DX0194 1287.26248 0.01
 *
 *   CONSTRAIN NAVD 88 HEIGHT ESTIMATED USING L21532 (1968-70)
 *   L21532 TIED TO L25016 AT ONE END AND L24301/18 AT THE OTHER
 *   DX0501 PMT 75 SD CO - 834.0951
 *
 CONSTRAIN BM DX0501 834.0951 0.01
 *
 *
 *   CONSTRAIN OTHER NAVD 88 FROM GENERAL ADJUSTMENT FOR LEVEL LINES
 *
 CONSTRAIN BM DB0790   -1.32500 0.01                                              0000002
 CONSTRAIN BM DX1452   24.31890 0.01                                              0000002
 CONSTRAIN BM DC1421   21.45580 0.01                                              0000002

THE FOLLOWING OPTIONS WERE REQUESTED BY THE USER
 corrections applied: ortho; level; rod; temp; astro; ref; mag;
```

Leveling Data Section - NAVD 88 Height Values

Stations SD GPS 15
SD GPS 32
SD GPS 35

Trig(2) - NAVD 88 height estimated from a height difference obtained using specially designed trigonometric procedures. One-mark ties were connected to bench marks which had NAVD 88 height values obtained when the SCRP network was incorporated into NAVD 88.

PROJECT MARK ID	ACRN	DESIGNATION	ELEVATION	ADJ CODE	GEOPOTENTIAL NUMBER
1	DC0326	JM 168	219.4976	A	214.99362
2	DC0409	B 736	1057.0347	A	1035.20999
3	DC0413	M 570	1086.1713	A	1063.73724
4	DC0412	CY 59	1080.4101	A	1058.10090
5	DC0104	K 741	158.0658	A	154.82367
6	DC1363	P 1312	1237.9545	A	1212.36119
7	DC0008	CA 3	757.3540	A	741.71669
8	DB0790	DIXIE	-1.3250	A	-1.29785
9	DC0162	G 91 RESET	894.9322	A	876.42558
10	DX0310	RA 154	420.3722	A	411.74590
11	DX1452	W 282	24.3189	A	23.82220
12	DX0194	4219 T	1287.2625	A	1260.64006
13	DX0501	PMT 75	834.0951	A	816.93081
14	DX3438	T 1307	14.8902	A	14.58576
16	DC2029	JUNCTION CADH AZ MK 1974	562.7931	A	551.20969
17	DC1396	R 1411	561.5758	A	550.01757
18	DC1421	D 1412	21.4558	A	21.01582
19	DB1234	OCOTILLO NCMN 7270	-1.7777	A	-1.74126
20	DC2125	HPGN CA 11 01	156.7713	A	153.55555
21	DC2126	HPGN CA 11 02	798.4855	A	781.99696
22	DX5291	HPGN CA 11 07	94.9020	A	92.96167
24	DX5295	HPGN CA SDGPS 01	29.5284	A	28.92530
25	DX5300	SAN DIEGO GPS 15	1281.5093	A	1255.00052
26	DC2131	HPGN CA SDGPS 21	1096.9305	A	1074.27542
27	DC2134	HPGN CA SDGPS 24	46.4938	A	45.54062
28	DC2135	SAN DIEGO GPS 31	926.0116	A	906.86551
29	DX5302	SAN DIEGO GPS 32	418.5361	A	409.94746
30	DC2136	SAN DIEGO GPS 33	222.5232	A	217.95727
31	DX5303	SAN DIEGO GPS 34	823.4371	A	806.49024
32	DC2137	SAN DIEGO GPS 35	1234.7616	A	1209.23497

```
THE FOLLOWING COMMANDS WERE USED IN THIS ADJUSTMENT
 TITLE 'SPECIAL ADJ OF TRIG DATA IN SUPPORT OF CALTRANS HGPS PROJECT'
 *
 *  POST ONE TRIG LINE BECAUSE NO NAVD 88 HEIGHTS AVAILABLE
 *   THE ONLY TIE IS TO A VERY OLD LEVEL LINE - L15872 (1956)
 *
 POST LINE TG1/12
 *
 *  CONSTRAIN NAVD 88 FROM GENERAL ADJUSTMENT
 *
 CONSTRAIN BM DC0326  219.49760 0.01                                                        0000002
 CONSTRAIN BM DC0104  158.06580 0.01                                                        0000002
 CONSTRAIN BM DC0008  757.35400 0.01                                                        0000002
 CONSTRAIN BM DC0162  894.93220 0.01                                                        0000002
 CONSTRAIN BM DX3438   14.89020 0.01                                                        0000002
 CONSTRAIN BM DC1396  561.57580 0.01                                                        0000002
 *
 *   CONSTRAIN NAVD 88 HEIGHTS FROM SCARP ADJUSTMENT
 *
 CONSTRAIN BM DC0412 1080.41006 0.01
 CONSTRAIN BM DX0310 420.37222 0.01
 CONSTRAIN BM DC1363 1237.95455 0.01
 CONSTRAIN BM DX0194 1287.26248 0.01
 *
 *   CONSTRAIN NAVD 88 HEIGHT ESTIMATED USING L21532 (1968-70)
 *   L21532 TIED TO L25016 AT ONE END AND L24301/18 AT THE OTHER
 *   DX0501 PMT 75 SD CO - 834.0951
 *
 CONSTRAIN BM DX0501 834.0951 0.01
 *
 *
 *   CONSTRAIN OTHER NAVD 88 FROM GENERAL ADJUSTMENT FOR LEVEL LINES
 *
 CONSTRAIN BM DB0790   -1.32500 0.01                                                        0000002
 CONSTRAIN BM DX1452   24.31890 0.01                                                        0000002
 CONSTRAIN BM DC1421   21.45580 0.01                                                        0000002

THE FOLLOWING OPTIONS WERE REQUESTED BY THE USER
 corrections applied: ortho; level; rod; temp; astro; ref; mag;
```

Leveling Data Section - NAVD 88 Height Values

Stations SD GPS 34

Trig(3) - NAVD 88 height estimated from a height difference obtained using specially-designed trigonometric procedures. A one-mark tie was from a bench mark which was last leveled to in 1970. A NAVD 88 height value was estimated for the tie bench mark using the 1970 data.

PROJECT MARK ID	ACRN	DESIGNATION	ELEVATION	ADJ CODE	GEOPOTENTIAL NUMBER
1	DC0326	JM 168	219.4976	A	214.99362
2	DC0409	B 736	1057.0347	A	1035.20999
3	DC0413	M 570	1086.1713	A	1063.73724
4	DC0412	CY 59	1080.4101	A	1058.10090
5	DC0104	K 741	158.0658	A	154.82367
6	DC1363	P 1312	1237.9545	A	1212.36119
7	DC0008	CA 3	757.3540	A	741.71669
8	DB0790	DIXIE	-1.3250	A	-1.29785
9	DC0162	G 91 RESET	894.9322	A	876.42558
10	DX0310	RA 154	420.3722	A	411.74590
11	DX1452	W 282	24.3189	A	23.82220
12	DX0194	4219 T	1287.2625	A	1260.64006
13	DX0501	PMT 75	834.0951	A	816.93081
14	DX3438	T 1307	14.8902	A	14.58576
16	DC2029	JUNCTION CADH AZ MK 1974	562.7931	A	551.20969
17	DC1396	R 1411	561.5758	A	550.01757
18	DC1421	D 1412	21.4558	A	21.01582
19	DB1234	OCOTILLO NCMN 7270	-1.7777	A	-1.74126
20	DC2125	HPGN CA 11 01	156.7713	A	153.55555
21	DC2126	HPGN CA 11 02	798.4855	A	781.99696
22	DX5291	HPGN CA 11 07	94.9020	A	92.96167
24	DX5295	HPGN CA SDGPS 01	29.5284	A	28.92530
25	DX5300	SAN DIEGO GPS 15	1281.5093	A	1255.00052
26	DC2131	HPGN CA SDGPS 21	1096.9305	A	1074.27542
27	DC2134	HPGN CA SDGPS 24	46.4938	A	45.54062
28	DC2135	SAN DIEGO GPS 31	926.0116	A	906.86551
29	DX5302	SAN DIEGO GPS 32	418.5361	A	409.94746
30	DC2136	SAN DIEGO GPS 33	222.5232	A	217.95727
31	DX5303	SAN DIEGO GPS 34	823.4371	A	806.49024
32	DC2137	SAN DIEGO GPS 35	1234.7616	A	1209.23497

```
THE FOLLOWING COMMANDS WERE USED IN THIS ADJUSTMENT
 TITLE 'SPECIAL ADJ OF TRIG DATA IN SUPPORT OF CALTRANS HGPS PROJECT'
 *
 *  POST ONE TRIG LINE BECAUSE NO NAVD 88 HEIGHTS AVAILABLE
 *   THE ONLY TIE IS TO A VERY OLD LEVEL LINE - L15872 (1956)
 *
 POST LINE TGi/12
 *
 *  CONSTRAIN NAVD 88 FROM GENERAL ADJUSTMENT
 *
 CONSTRAIN BM DC0326  219.49760 0.01                                    0000002
 CONSTRAIN BM DC0104  158.06580 0.01                                    0000002
 CONSTRAIN BM DC0008  757.35400 0.01                                    0000002
 CONSTRAIN BM DC0162  894.93220 0.01                                    0000002
 CONSTRAIN BM DX3438   14.89020 0.01                                    0000002
 CONSTRAIN BM DC1396  561.57580 0 01                                    0000002
 *
 *   CONSTRAIN NAVD 88 HEIGHTS FROM SCARP ADJUSTMENT
 *
 CONSTRAIN BM DC0412 1080.41006 0.01
 CONSTRAIN BM DX0310 420.37222 0.01
 CONSTRAIN BM DC1363 1237.95455 0.01
 CONSTRAIN BM DX0194 1287.26248 0.01
 *
 *   CONSTRAIN NAVD 88 HEIGHT ESTIMATED USING L21532 (1968-70)
 *   L21532 TIED TO L25016 AT ONE END AND L24301/18 AT THE OTHER
 *   DX0501 PMT 75 SD CO - 834.0951
 *
 CONSTRAIN BM DX0501 834.0951 0.01
 *
 *
 *   CONSTRAIN OTHER NAVD 88 FROM GENERAL ADJUSTMENT FOR LEVEL LINES
 *
 CONSTRAIN BM DB0790   -1.32500 0.01                                    0000002
 CONSTRAIN BM DX1452   24.31890 0.01                                    0000002
 CONSTRAIN BM DC1421   21.45580 0.01                                    0000002
THE FOLLOWING OPTIONS WERE REQUESTED BY THE USER
 corrections applied: ortho; level; rod; temp; astro; ref; mag;
```

Appendix I: Draft specially designed trigonometric procedures

INTERIM SPECIFICATIONS FOR TRIGONOMETRIC LEVELING
Second Order, Class II

(NGS-CADOT COOPERATIVE EFFORT)

- **NETWORK GEOMETRY**

  Same as in Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee, 1984, page 3-6.

- **INSTRUMENTATION**

  Electronic Theodolite

  Zenith Distance - standard deviation ± 0.5 seconds (Wild T2000 equivalent or better).

  Electronic Distance Measuring Instrument

  Distance - standard deviation ± 5 mm +3 ppm or better.

  Targets

  Must be designed so that the zenith distance and EDMI slope distance are measured to or can be reduced to the same point.

  Must have a well defined pointing area for zenith distance, preferably, a wedge shaped light background between two dark areas.

  Target Poles

  Each set of poles should be constructed of the same material.

  Must be one piece with a durable flat footplate and provide a target attachment device that does not alter height between footplate and target.

  Should be 2 meters to 2.5 meters in length.

  Each set should be the same length to within 1 mm.

  Must have a leveling bubble of 20 minute sensitivity or better.

  Must have braces to provide good stability.

  Should have a pointing device capable of keeping the target face perpendicular to the line of sight to the instrument.

Barometer

Accurate to ± 0.5 inches.

Thermometer

Accurate to ± 5.0 degrees Centigrade.

Turning Points

A turning point consisting of a steel turning pin with a driving cap should be utilized. If a steel pin cannot be driven, then a turning plate ("turtle") weighing at least 7 kg should be substituted. In situations allowing neither turning pins nor turning plates (sandy or marshy soils), a long wooden stake with double-headed nail should be driven to a firm depth.

Tripod

Fixed legs that will provide good stability.

- **CALIBRATION**

EDMI

Should be calibrated, at least annually, over an established calibration base line.

Electronic Theodolite

Vertical Index Error to be checked once each day.

Circular instrument leveling bubble (bullseye) to be kept in good adjustment.

Targets and Poles

Leveling rod bubble verticality maintained to within 10'.

Leveling rod bubbles to be checked daily or at any time a problem may be suspected.

Each target set should be checked, at least annually, for reflector offset constants. Reflector offset constants should be as close to equal as possible. If they are not equal, then data collector software should be able to distinguish between them and apply the correct offset to the slope distance for the respective target.

Barometers and thermometers should be checked annually against a known standard.

- **FIELD PROCEDURES**

Minimal Observation Method

Backsight - circle left (BSCL)
Foresight - circle left (FSCL)
Foresight - circle right (FSCR)
Backsight - circle right (BSCR)

Backsight - circle left (BSCL)
Foresight - circle left (FSCL)
Foresight - circle right (FSCR)
Backsight - circle right (BSCR)

Uncorrected zenith distance (ZD) and slope distance measured at each pointing. Corrected ZDs will be computed and slope distances will be corrected for refractive index and offsets. A standard curvature and refraction correction will be applied to each instrument to target difference of elevation (d.e.) prior to computing setup d.e. Computations will result in two independent d.e.s for each setup. The mean of these will be the final setup d.e. Section length will be computed from the sum of the corrected slope distances.

Section Running

Double Run (DR) or a Single Run Modified Double Simultaneous (SRMDS) where two independent differences of elevation are determined at each setup.

May single run using SRMDS, if line length between network control points is less than 10 km.

At the minimum must use SRMDS; must double run spur lines; must double run 10 per cent of all single run leveling.

Difference of Backward and Forward Sight Lengths

Difference of backward and forward sight lengths never to exceed 10 meters per setup and 10 meters per section.

Maximum Sight Length

Maximum sight length never to exceed 70 meters.

Minimum Ground Clearance

Lines of sight to backsight and foresight should be kept as parallel to ground as possible so as to parallel isothermal layers. Minimum ground clearance of line of sight 1.0 meter.

Even Number of Setups

An even number of setups will assure that the same target will be observed at both the starting and ending benchmarks. Any difference in height of target poles affecting section d.e. will be eliminated.

Maximum Section Misclosure

Second Order Class II - $8mm\sqrt{D}$ where D is the shortest length of section (one way) in km.

Maximum Loop Misclosure

Second Order Class II - $8mm\sqrt{E}$ where E is the perimeter of the loop in km.

Single-run Methods

Reverse direction of single runs every other day.

Trigonometric Leveling

A precision check will be performed between the two setup differences of elevations computed from the observations.

The difference between the two d.e.s for one setup not to exceed 1.4 mm.

Double run leveling may always be used, but SRMDS may be used only where it can be evaluated by loop closures or new-old comparisons. Rods must be leap-frogged between setups (alternate setup method).

Auxiliary Trigonometric Leveling Data

The date, beginning and ending times, cloud coverage, air temperature (to nearest degree), temperature scale, barometric pressure (to ± 0.5 inches Hg), pressure units, and average wind speed should be recorded for each section, plus any changes in the date, instrumentation, observer, or time zone.

- **OFFICE PROCEDURES**

Second Order, Class II

Section Misclosures

(backward and forward) Algebraic sum of all corrected section misclosures of a leveling line not to exceed $8mm\sqrt{D}$.

Section misclosure not to exceed 8mm$\sqrt{E}$.

Loop Misclosures

Algebraic sum of all corrected misclosures not to exceed 8mm$\sqrt{F}$.

Loop misclosure not to exceed 8mm$\sqrt{F}$.

(D -- shortest length of section (one way) in km)
(E -- shortest one-way length of section in km)
(F -- length of loop in km)

The normalized residuals from a minimally constrained least squares adjustment will be checked for blunders. The observation weights will be checked by inspecting the post adjustment estimate of the variance of unit weight. Elevation difference standard errors computed by error propagation in a correctly weighted least squares adjustment will indicate the provisional accuracy classification. A survey variance factor ratio will be computed to check for systematic error. The least squares adjustment will use models that account for:

gravity effect or orthometric correction
earth tides and magnetic field
crustal motion

refraction -- although a standard refraction is presently being applied to the trig-leveling observations, further analysis of refraction effects may yield a more specific correction to be applied after more data is available.

Appendix J: Results of minimum constraint least square adjustment

davez

adj.g93s.free.f

venus

Job: adj.g93s.free.final
Date: Tue Oct 19 09:28:44 1993

Minimum-Constraint Least Square Adjustment

```
ENTER INPUT BLUE BOOK FILENAME (DEFAULT='BBOOK'):

bbk.g93s
 ENTER ADJUSTMENT FILE FILENAME
 (DEFAULT='AFILE', IF THERE ISNT ONE, ENTER: 'NOAFILE'):

afile.free.final
 ENTER GPS FILE FILENAME
 (DEFAULT='GFILE', IF THERE ISNT ONE, ENTER: 'NOGFILE'):

gfile
 ENTER DOPPLER FILE FILENAME
 (DEFAULT='DFILE', IF THERE ISNT ONE, ENTER: 'NODFILE'):

DFILE
1                                                 NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                     ADJUSTMENT PROGRAM                                    PAGE    1
                                                      VERSION   4.00


0SYSTEM TIME IS Tue Oct 19 09:14:24 1993
0********************************* A-FILE CONTENTS *********************************

     CC       5324                                 32344082082N117040407350W  46494
     II  9999999
     MM3Y
     PP22
0********************************** END OF A-FILE *********************************
1                                                 NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                     ADJUSTMENT PROGRAM                                    PAGE    2
                                                      VERSION   4.00


 ***************** ADJUSTMENT FILE OPTIONS **********

 ELLIPSOID SEMI-MAJOR AXIS = 6378137.000 METERS
 ELLIPSOID SQUARE FLATTENING =0.006694380022903416
 DEFAULT MEAN SEA LEVEL =    0.000 METERS
 DEFAULT GEOID HEIGHT =   0.000 METERS
 ADJUST ORTHOMETRIC ELEVATIONS
 SCALE SIGMAS BY A-POSTERIORI SIGMA OF UNIT WEIGHT
 ABORT IF SINGULARITIES
 DO NOT UPDATE *80* RECORDS
 DO NOT UPDATE BLUE BOOK AND ADJUSTMENT FILE AT THE END OF EACH ITERATION
 COMPUTE A 3-DIMENSIONAL ADJUSTMENT
 COMPUTE NO MORE THAN    5 ITERATIONS
 DO NOT DISPLAY STATISTICS IF SOLUTION SLOWLY CONVERGES
 ABORT IF MISCLOSURE EXCEEDS 0.1E+21 SIGMA
 PRINT WHEN MISCLOSURES EXCEED 0.1E+21 SIGMA
 CONVERGE IF RMS SUM OF SHIFTS BELOW   0.003 METERS
 COMPUTE NORMALIZED RESIDUALS AND INVERSE
 ECHO LARGE BLUE BOOK MISCLOSURES ONLY
 ECHO GPS DATA TRANSFER FILE
 ECHO LARGE G-FORMAT MISCLOSURES ONLY
 ECHO DOPPLER DATA TRANSFER FILE
 DISPLAY CONSTRAINTS
 DISPLAY ALL RESIDUALS/SD GREATER OR EQUAL TO  0.0
 DISPLAY DIRECTION RESIDUALS
 DISPLAY ANGLE RESIDUALS
 DISPLAY ZENITH DISTANCE RESIDUALS
 DISPLAY DISTANCE RESIDUALS
 DISPLAY ASTRO-AZIMUTH RESIDUALS
 DISPLAY GPS RESIDUALS
 DISPLAY DOPPLER RESIDUALS
 DISPLAY CONSTRAINED RESIDUALS
 DISPLAY RESIDUALS GROUPED AROUND INTERSECTION STAS
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 DISPLAY POSITION SHIFTS
 DISPLAY POSITION GOOGE NUMBERS
0ERROR - NO DFILE FOUND IN SUBROUTINE FIRST

 MINUTES SINCE START OF PROGRAM IS    0.0
1                                          NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                              ADJUSTMENT PROGRAM                    PAGE   3
                                               VERSION   4.00


 ******** CONSTRAINTS *************
0 OBS #

      3   CC        5324                    32344082082N117040407350W  46494
0************ END OF CONSTRAINTS ************
1                                          NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                              ADJUSTMENT PROGRAM                    PAGE   4
                                               VERSION   4.00


 ************ BLUE BOOK ************
0 OBS #

 ******** END OF BLUE BOOK ********
1                                          NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                              ADJUSTMENT PROGRAM                    PAGE   5
                                               VERSION   4.00


 ******** GPS OBSERVATIONS *************

0*********** END OF GPS OBSERVATIONS *********

 MINUTES TO READ BBOOK, GFILE, AND DFILE    0.1

 MINUTES TO REORDER    0.0

 THE NUMBER OF NON-TRIVIAL COMPONENTS IS  1.
1                                          NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                              ADJUSTMENT PROGRAM                    PAGE   6
                                               VERSION   4.00


0*** OBSERVATIONAL SUMMARY ***
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SSN	CMP	STATION NAME	DIR FRM	DIR TO	ANG FRM	ANG TO	AZI FRM	AZI TO	DIS FRM	DIS TO	ZD FRM	ZD TO	GPS FRM	GPS TO	DOP
5652	1	11 AAR	0	0	0	0	0	0	0	0	0	0	0	3	0
5744	1	BELARDES	0	0	0	0	0	0	0	0	0	0	0	3	0
10	1	BOUCHER 2	0	0	0	0	0	0	0	0	0	0	0	3	0
5555	1	FAR	0	0	0	0	0	0	0	0	0	0	0	3	0
151	1	HPGN CA 11 01	0	0	0	0	0	0	0	0	0	0	0	3	0
152	1	HPGN CA 11 02	0	0	0	0	0	0	0	0	0	0	0	3	0
156	1	HPGN CA 11 06	0	0	0	0	0	0	0	0	0	0	0	3	0
157	1	HPGN CA 11 07	0	0	0	0	0	0	0	0	0	0	0	3	0
158	1	HPGN CA 11 08	0	0	0	0	0	0	0	0	0	0	0	3	0
159	1	HPGN CA 11 09	0	0	0	0	0	0	0	0	0	0	0	2	0
5529	1	JUNCTION CADH AZ MK 1974	0	0	0	0	0	0	0	0	0	0	0	3	0
5554	1	LOMAX	0	0	0	0	0	0	0	0	0	0	0	3	0
189	1	MONUMENT PEAK NCMN 7274	0	0	0	0	0	0	0	0	0	0	64	1	0
198	1	OCOTILLO NCMN 7270	0	0	0	0	0	0	0	0	0	0	0	3	0
5301	1	SAN DIEGO GPS 01	0	0	0	0	0	0	0	0	0	0	0	3	0
5302	1	SAN DIEGO GPS 02	0	0	0	0	0	0	0	0	0	0	0	3	0
5303	1	SAN DIEGO GPS 03	0	0	0	0	0	0	0	0	0	0	0	3	0
5307	1	SAN DIEGO GPS 07	0	0	0	0	0	0	0	0	0	0	0	2	0

5312	1	SAN DIEGO GPS 12	0	0	0	0	0	0	0	0	0	0	33	2	0
5315	1	SAN DIEGO GPS 15	0	0	0	0	0	0	0	0	0	0	0	3	0
5316	1	SAN DIEGO GPS 16	0	0	0	0	0	0	0	0	0	0	0	3	0
5317	1	SAN DIEGO GPS 17	0	0	0	0	0	0	0	0	0	0	0	3	0
5318	1	SAN DIEGO GPS 18	0	0	0	0	0	0	0	0	0	0	0	3	0
5321	1	SAN DIEGO GPS 21	0	0	0	0	0	0	0	0	0	0	0	3	0
5322	1	SAN DIEGO GPS 22	0	0	0	0	0	0	0	0	0	0	0	3	0
5323	1	SAN DIEGO GPS 23	0	0	0	0	0	0	0	0	0	0	0	3	0
5324C	1	SAN DIEGO GPS 24	0	0	0	0	0	0	0	0	0	0	0	3	0
5331	1	SAN DIEGO GPS 31	0	0	0	0	0	0	0	0	0	0	0	3	0
5359	1	SAN DIEGO GPS 32	0	0	0	0	0	0	0	0	0	0	0	3	0
5358	1	SAN DIEGO GPS 33	0	0	0	0	0	0	0	0	0	0	0	3	0
5361	1	SAN DIEGO GPS 34	0	0	0	0	0	0	0	0	0	0	0	3	0
5363	1	SAN DIEGO GPS 35	0	0	0	0	0	0	0	0	0	0	0	3	0
220	1	SANDIE NASA 1976	0	0	0	0	0	0	0	0	0	0	0	3	0
5745	1	YUNG	0	0	0	0	0	0	0	0	0	0	0	3	0

TOTAL MINUTES TO COMMENCMENT OF ADJUSTMENT 0.2

0*********** COMMENCING ADJUSTMENT ***********

THE AVERAGE BAND WIDTH FOR THE 3 DIM. ADJUSTMENT OF 34 STATIONS AND RANK 102 IS 104.9%. D.P. WORDS NEEDED= 5458
0ITERATION # 0 THE RMS CORRECTION IS 438.256 METERS --- VTPV= 3079.978 DF= 192 VARIANCE= 16.04
0 MAXIMUM SHIFT - STATION: MONUMENT PEAK NCMN 7274 VERTICAL SHIFT= 1871.567 METERS

MINUTES NEEDED FOR ITERATION 0 = 0.1
0ITERATION # 1 THE RMS CORRECTION IS 0.000 METERS --- VTPV= 3079.978 DF= 192 VARIANCE= 16.04
0 MAXIMUM SHIFT - STATION: MONUMENT PEAK NCMN 7274 LONGITUDE SHIFT= 0.000 METERS

MINUTES NEEDED FOR ITERATION 1 = 0.1
0*********** ADJUSTMENT CONVERGED *************

THE FOLLOWING UNKNOWNS HAVE GOOGE NUMBERS LESS THAN 1.00D-03

MINUTES TO INVERT 0.0

0*** JOB STATISTICS ***

0A.) BLUE-BOOK STATISTICS

NO. *80* CONTROL RECORDS	34
NO. *84* GEOID HT. RECORDS	0
NO. *85* DEFLECTION RECORDS	0
NO. *86* ELEVATION RECORDS	34
NO. DIRECTIONS	0
NO. ANGLES	0
NO. GPS VECTORS	97
NO. DOPPLER OBS.	0
NO. ZENITH DISTANCES	0
NO. DISTANCES	0
NO. AZIMUTHS	0
B.) NO. CONSTRAINTS	3
C.) NO. ACCURACIES	0
D.) NO. REJECTED OBS.	0

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	V=C-O METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION / TO STATION(S)
1	LA	32 34 40.82082N	32 34 40.82082N	0.00000	0.000	0.00	0.00	0.0000	0.00	SAN DIEGO GPS 24
2	LO	117 4 4.07350W	117 4 4.07350W	0.00000	0.000	0.00	0.00	0.0000	0.00	SAN DIEGO GPS 24
3	EH	11.729	11.729		0.000	0.00	0.00	0.0000	0.00	SAN DIEGO GPS 24
4	DX	-54996.4855	-54996.4760		-0.0095	0.00	-2.20	0.0047		MONUMENT PEAK NCMN 7274
5	DY	7577.7812	7577.7790		0.0022	0.01	0.24	0.0067		HPGN CA 11 01
6	DZ	-31094.9688	-31094.9730		0.0042	0.01	0.69	0.0058		
	DN	-35859.8934	-35859.8957		0.0023	0.01				
	DE	-52536.1697	-52536.1802		-0.0094	0.00				
	DU	-1717.5813	-1717.5855		0.0042	-0.01				
7	DX	-11750.1520	-11750.1490		-0.0030	0.00	-0.71	0.0046		MONUMENT PEAK NCMN 7274
8	DY	-12254.4603	-12254.4590		-0.0013	0.01	-0.15	0.0065		HPGN CA 11 02
9	DZ	-27179.2363	-27179.2400		0.0037	0.01	0.60	0.0055		
	DN	-31625.5214	-31625.5232		0.0017	0.01				
	DE	-5061.9006	-5061.8985		-0.0021	0.00				
	DU	-1073.4588	-1073.4629		0.0041	-0.01				
10	DX	-32472.9696	-32472.9690		-0.0006	0.00	-0.13	0.0060		MONUMENT PEAK NCMN 7274
11	DY	14441.5555	14441.5630		-0.0075	0.01	-0.76	0.0074		HPGN CA 11 06
12	DZ	-5198.9551	-5198.9670		0.0119	0.01	1.73	0.0059		
	DN	-5253.9317	-5253.9378		0.0062	0.01				
	DE	-35501.8271	-35501.8300		0.0028	0.00				
	DU	-1448.4078	-1448.4201		0.0123	-0.01				
13	DX	-64057.8384	-64057.8550		0.0166	0.00	3.82	0.0045		MONUMENT PEAK NCMN 7274
14	DY	50201.5515	50201.5000		0.0515	0.01	5.64	0.0063		HPGN CA 11 07
15	DZ	21143.4726	21143.4940		-0.0214	0.01	-3.40	0.0057		
	DN	26369.3290	26369.3179		0.0112	0.01				
	DE	-79825.7067	-79825.6983		-0.0084	0.00				
	DU	-1778.7319	-1778.6754		-0.0565	-0.01				
16	DX	-12973.8355	-12973.8350		-0.0005	0.00	-0.13	0.0045		MONUMENT PEAK NCMN 7274
17	DY	30559.2201	30559.2180		0.0021	0.01	0.23	0.0065		HPGN CA 11 08
18	DZ	31251.2763	31251.2720		0.0043	0.01	0.69	0.0058		
	DN	37938.9006	37938.8961		0.0045	0.01				
	DE	-25268.0234	-25268.0220		-0.0014	0.00				
	DU	-997.7099	-997.7109		0.0010	-0.01				
19	DX	-29287.4193	-29287.4230		0.0037	0.00	0.80	0.0065		MONUMENT PEAK NCMN 7274
20	DY	44950.1370	44950.1460		-0.0090	0.01	-0.93	0.0082		BOUCHER 2
21	DZ	41044.2992	41044.2790		0.0202	0.01	3.06	0.0064		
	DN	49139.9638	49139.9503		0.0135	0.01				
	DE	-46347.8362	-46347.8435		0.0073	0.00				
	DU	-210.4471	-210.4635		0.0164	-0.01				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	V=C-O METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION / TO STATION(S)
22	DX	50688.3106	50688.3190		-0.0084	0.00	-1.98	0.0049		MONUMENT PEAK NCMN 7274
23	DY	-29897.5439	-29897.5360		-0.0079	0.01	-0.87	0.0068		OCOTILLO NCMN 7270
24	DZ	-10491.2905	-10491.3020		0.0115	0.01	1.83	0.0056		
	DN	-11276.2832	-11276.2870		0.0038	0.01				
	DE	58673.3538	58673.3579		-0.0041	0.00				
	DU	-1875.6654	-1875.6807		0.0153	-0.01				
25	DX	-42536.5334	-42536.5420		0.0086	0.00	2.03	0.0047		MONUMENT PEAK NCMN 7274
26	DY	2596.0712	2596.0590		0.0122	0.01	1.33	0.0065		SANDIE NASA 1976
27	DZ	-27611.2589	-27611.2510		-0.0079	0.01	-1.28	0.0055		
	DN	-32281.6849	-32281.6862		0.0013	0.01				
	DE	-39187.3403	-39187.3425		0.0022	0.00				
	DU	-850.3283	-850.3116		-0.0167	-0.01				
28	DX	-80985.8278	-80985.8360		0.0082	0.00	1.85	0.0046		MONUMENT PEAK NCMN 7274

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION / TO STATION(S)
29	DY	75886.6026	75886.5850		0.0176	0.01	1.93	0.0064		SAN DIEGO GPS 01
30	DZ	43905.6996	43905.6970		0.0026	0.01	0.42	0.0057		
	DN	53634.3499	53634.3370		0.0128	0.01				
	DE	-106607.4537	-106607.4530		-0.0007	0.00				
	DU	-1843.5158	-1843.5009		-0.0148	-0.01				
31	DX	-55504.5322	-55504.5480		0.0158	0.00	3.62	0.0046		MONUMENT PEAK NCMN 7274
32	DY	61129.7029	61129.6560		0.0469	0.01	5.14	0.0064		SAN DIEGO GPS 02
33	DZ	42169.4486	42169.4630		-0.0144	0.01	-2.30	0.0057		
	DN	51431.0260	51431.0114		0.0146	0.01				
	DE	-77123.0871	-77123.0800		-0.0071	0.00				
	DU	-1653.8037	-1653.7549		-0.0489	-0.01				
34	DX	-48640.4267	-48640.4340		0.0073	0.00	1.69	0.0047		MONUMENT PEAK NCMN 7274
35	DY	56095.6375	56095.6100		0.0275	0.01	3.04	0.0065		SAN DIEGO GPS 03
36	DZ	39907.8797	39907.8770		0.0027	0.01	0.44	0.0058		
	DN	48804.8920	48804.8745		0.0175	0.01				
	DE	-68703.4992	-68703.4933		-0.0059	0.00				
	DU	-1778.2691	-1778.2472		-0.0218	-0.01				
37	DX	-34789.2864	-34789.2980		0.0116	0.00	2.73	0.0045		MONUMENT PEAK NCMN 7274
38	DY	33916.7190	33916.6940		0.0250	0.01	2.74	0.0064		SAN DIEGO GPS 12
39	DZ	20329.7215	20329.7270		-0.0055	0.01	-0.89	0.0057		
	DN	25052.1747	25052.1643		0.0104	0.01				
	DE	-46311.6335	-46311.6326		-0.0009	0.00				
	DU	-1247.7972	-1247.7710		-0.0261	-0.01				
40	DX	-9508.7610	-9508.7700		0.0090	0.00	2.07	0.0044		MONUMENT PEAK NCMN 7274
41	DY	17617.1133	17617.0980		0.0153	0.01	1.68	0.0061		SAN DIEGO GPS 15
42	DZ	16668.2590	16668.2610		-0.0020	0.01	-0.32	0.0053		
	DN	20253.4701	20253.4621		0.0080	0.01				
	DE	-16372.5182	-16372.5195		0.0013	0.00				
	DU	-589.6369	-589.6209		-0.0159	-0.01				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION / TO STATION(S)
43	DX	5452.2566	5452.2440		0.0126	0.01	2.45	0.0050		MONUMENT PEAK NCMN 7274
44	DY	8232.3309	8232.2920		0.0389	0.01	3.58	0.0077		SAN DIEGO GPS 16
45	DZ	13119.3991	13119.4040		-0.0049	0.01	-0.67	0.0068		
	DN	16338.7989	16338.7810		0.0179	0.01				
	DE	1220.4828	1220.4889		-0.0060	0.00				
	DU	-1082.1642	-1082.1276		-0.0366	-0.01				
46	DX	-61919.9197	-61919.9170		-0.0027	0.00	-0.62	0.0049		MONUMENT PEAK NCMN 7274
47	DY	27960.2081	27960.1990		0.0091	0.01	0.99	0.0068		SAN DIEGO GPS 17
48	DZ	-7781.9172	-7781.9180		0.0008	0.01	0.13	0.0058		
	DN	-8134.3418	-8134.3462		0.0044	0.01				
	DE	-67876.2288	-67876.2223		-0.0065	0.00				
	DU	-1748.7060	-1748.7006		-0.0053	-0.01				
49	DX	-41360.6598	-41360.6710		0.0112	0.00	2.58	0.0045		MONUMENT PEAK NCMN 7274
50	DY	23665.9167	23665.8990		0.0177	0.01	1.94	0.0064		SAN DIEGO GPS 18
51	DZ	983.4632	983.4700		-0.0068	0.01	-1.10	0.0056		
	DN	2225.7484	2225.7428		0.0056	0.01				
	DE	-47582.9481	-47582.9502		0.0021	0.00				
	DU	-1629.7503	-1629.7290		-0.0212	-0.01				
52	DX	-17986.9205	-17986.9270		0.0065	0.00	1.49	0.0046		MONUMENT PEAK NCMN 7274
53	DY	5140.4358	5140.3990		0.0368	0.01	4.04	0.0064		SAN DIEGO GPS 21
54	DZ	-6741.1759	-6741.1620		-0.0139	0.01	-2.26	0.0055		
	DN	-7524.8350	-7524.8427		0.0077	0.01				
	DE	-18389.5070	-18389.4964		-0.0106	0.00				
	DU	-774.4251	-774.3874		-0.0377	-0.01				
55	DX	19255.1497	19255.1540		-0.0043	0.00	-1.01	0.0045		MONUMENT PEAK NCMN 7274
56	DY	-12057.6986	-12057.7100		0.0114	0.01	1.25	0.0065		SAN DIEGO GPS 22
57	DZ	-6371.4547	-6371.4580		0.0033	0.01	0.53	0.0055		
	DN	-6587.6190	-6587.6263		0.0073	0.01				
	DE	22604.4816	22604.4905		-0.0089	0.00				

	DU	-1544.3468	-1544.3416	-0.0052	-0.01				
58	DX	-73656.0299	-73656.0280	-0.0019	0.00	-0.39	0.0049		MONUMENT PEAK NCMN 7274
59	DY	24130.1762	24130.1680	0.0082	0.01	0.81	0.0074		SAN DIEGO GPS 23
60	DZ	-21420.1590	-21420.1580	-0.0010	0.01	-0.14	0.0064		
	DN	-24351.1620	-24351.1647	0.0027	0.01				
	DE	-76617.6195	-76617.6141	-0.0054	0.00				
	DU	-1749.4694	-1749.4634	-0.0059	-0.01				
61	DX	-61772.4985	-61772.4830	-0.0155	0.00	-3.57	0.0045		MONUMENT PEAK NCMN 7274
62	DY	11779.0481	11779.0570	-0.0089	0.01	-0.97	0.0064		SAN DIEGO GPS 24
63	DZ	-30261.9878	-30261.9970	0.0092	0.01	1.49	0.0055		
	DN	-34800.1993	-34800.1990	-0.0003	0.01				
	DE	-60464.6892	-60464.6793	-0.0099	0.00				
	DU	-1828.3713	-1828.3888	0.0175	-0.01				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
64	DX	16434.4381	16434.4370		0.0011	0.00	0.22	0.0072		MONUMENT PEAK NCMN 7274
65	DY	-24501.0651	-24501.0410		-0.0241	0.01	-2.32	0.0098		SAN DIEGO GPS 31
66	DZ	-24574.5127	-24574.5190		0.0063	0.01	0.97	0.0063		
	DN	-28614.4831	-28614.4770		-0.0061	0.01				
	DE	25585.4569	25585.4453		0.0116	0.00				
	DU	-946.2396	-946.2608		0.0212	-0.01				
67	DX	-39324.4462	-39324.4470		0.0008	0.00	0.18	0.0044		MONUMENT PEAK NCMN 7274
68	DY	6397.3687	6397.3670		0.0017	0.01	0.19	0.0062		SAN DIEGO GPS 33
69	DZ	-21534.2722	-21534.2750		0.0028	0.01	0.45	0.0054		
	DN	-24550.4081	-24550.4115		0.0034	0.01				
	DE	-38021.2649	-38021.2649		-0.0001	0.00				
	DU	-1650.4994	-1650.4993		-0.0001	-0.01				
70	DX	-38279.4330	-38279.4440		0.0110	0.00	2.58	0.0046		MONUMENT PEAK NCMN 7274
71	DY	30679.0681	30679.0460		0.0221	0.01	2.41	0.0064		SAN DIEGO GPS 32
72	DZ	13094.3444	13094.3520		-0.0076	0.01	-1.23	0.0056		
	DN	16550.1470	16550.1400		0.0070	0.01				
	DE	-47978.7582	-47978.7581		-0.0001	0.00				
	DU	-1453.7744	-1453.7496		-0.0248	-0.01				
73	DX	-28382.8365	-28382.8590		0.0225	0.00	5.16	0.0044		MONUMENT PEAK NCMN 7274
74	DY	42464.3822	42464.3550		0.0272	0.01	2.97	0.0061		SAN DIEGO GPS 34
75	DZ	36770.1795	36770.1880		-0.0085	0.01	-1.36	0.0055		
	DN	44572.3602	44572.3486		0.0116	0.01				
	DE	-44419.1658	-44419.1738		0.0079	0.00				
	DU	-1047.6956	-1047.6621		-0.0334	-0.01				
76	DX	-11569.0969	-11569.1010		0.0041	0.00	0.86	0.0045		MONUMENT PEAK NCMN 7274
77	DY	7893.3668	7893.3530		0.0138	0.01	1.40	0.0064		SAN DIEGO GPS 35
78	DZ	1769.3818	1769.3760		0.0058	0.01	0.86	0.0056		
	DN	2519.1298	2519.1173		0.0125	0.01				
	DE	-13875.4839	-13875.4813		-0.0025	0.00				
	DU	-636.3080	-636.2992		-0.0088	-0.01				
79	DX	-25482.2431	-25482.2370		-0.0061	0.00	-1.41	0.0045		MONUMENT PEAK NCMN 7274
80	DY	-6761.3123	-6761.3180		0.0057	0.01	0.62	0.0064		JUNCTION CADH AZ MK 1974
81	DZ	-29533.9568	-29533.9580		0.0012	0.01	0.20	0.0055		
	DN	-34269.1315	-34269.1338		0.0023	0.01				
	DE	-19779.4457	-19779.4377		-0.0080	0.00				
	DU	-1309.5091	-1309.5078		-0.0013	-0.01				
82	DX	-49772.4557	-49772.4610		0.0053	0.00	1.22	0.0045		MONUMENT PEAK NCMN 7274
83	DY	40764.1892	40764.1610		0.0282	0.01	3.09	0.0064		LOMAX
84	DZ	18634.3334	18634.3400		-0.0066	0.01	-1.06	0.0056		
	DN	23247.2048	23247.1953		0.0095	0.01				
	DE	-62795.7807	-62795.7728		-0.0079	0.00				
	DU	-1585.0041	-1584.9774		-0.0267	-0.01				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
85	DX	-42014.1673	-42014.1670		-0.0003	0.00	-0.07	0.0044		MONUMENT PEAK NCMN 7274
86	DY	21308.3247	21308.3250		-0.0003	0.01	-0.04	0.0061		FAR
87	DZ	-2790.0360	-2790.0340		-0.0020	0.01	-0.33	0.0053		
	DN	-2245.6181	-2245.6162		-0.0019	0.01				
	DE	-47108.4148	-47108.4147		-0.0001	0.00				
	DU	-1665.4462	-1665.4454		-0.0007	-0.01				
88	DX	21884.1390	21884.1450		-0.0060	0.00	-1.40	0.0045		MONUMENT PEAK NCMN 7274
89	DY	18033.1046	18033.1050		-0.0004	0.01	-0.05	0.0063		11 AAR
90	DZ	36616.7361	36616.7280		0.0081	0.01	1.31	0.0055		
	DN	44804.7103	44804.7052		0.0051	0.01				
	DE	11601.4897	11601.4949		-0.0052	0.00				
	DU	-1684.3799	-1684.3869		0.0070	-0.01				
91	DX	-70030.5734	-70030.5840		0.0106	0.00	2.43	0.0045		MONUMENT PEAK NCMN 7274
92	DY	79735.7482	79735.7290		0.0192	0.01	2.10	0.0064		BELARDES
93	DZ	57963.9745	57963.9720		0.0025	0.01	0.39	0.0057		
	DN	70041.0949	70041.0808		0.0141	0.01				
	DE	-98563.5691	-98563.5699		0.0007	0.00				
	DU	-1166.6038	-1166.5867		-0.0170	-0.01				
94	DX	-44825.6408	-44825.6560		0.0152	0.00	3.49	0.0045		MONUMENT PEAK NCMN 7274
95	DY	60648.9936	60648.9490		0.0446	0.01	4.89	0.0065		YUNG
96	DZ	49168.8330	49168.8430		-0.0100	0.01	-1.62	0.0056	65.72	
	DN	59727.4705	59727.4534		0.0172	0.01				
	DE	-67346.3626	-67346.3560		-0.0066	0.00				
	DU	-1519.6552	-1519.6106		-0.0446	-0.01				
97	DX	-54996.4855	-54996.4870		0.0015	0.00	0.36	0.0046		MONUMENT PEAK NCMN 7274
98	DY	7577.7812	7577.7800		0.0012	0.01	0.13	0.0065		HPGN CA 11 01
99	DZ	-31094.9688	-31094.9680		-0.0008	0.01	-0.13	0.0057		
	DN	-35859.8934	-35859.8937		0.0003	0.01				
	DE	-52536.1897	-52536.1905		0.0008	0.00				
	DU	-1717.5813	-1717.5794		-0.0019	-0.01				
100	DX	-11750.1520	-11750.1390		-0.0130	0.00	-3.34	0.0044		MONUMENT PEAK NCMN 7274
101	DY	-12254.4603	-12254.4410		-0.0193	0.01	-2.37	0.0063		HPGN CA 11 02
102	DZ	-27179.2363	-27179.2440		0.0077	0.01	1.38	0.0052		
	DN	-31625.5214	-31625.5154		-0.0060	0.01				
	DE	-5061.9006	-5061.8976		-0.0030	0.00				
	DU	-1073.4588	-1073.4824		0.0236	0.00				
103	DX	-32472.9696	-32472.9650		-0.0046	0.00	-1.20	0.0046		MONUMENT PEAK NCMN 7274
104	DY	14441.5555	14441.5730		-0.0175	0.01	-2.17	0.0063		HPGN CA 11 06
105	DZ	-5198.9551	-5198.9670		0.0119	0.01	2.15	0.0053		
	DN	-5253.9317	-5253.9320		0.0003	0.01				
	DE	-35501.8271	-35501.8309		0.0037	0.00				
	DU	-1448.4078	-1448.4292		0.0213	0.00				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
106	DX	-64057.8384	-64057.8190		-0.0194	0.00	-5.00	0.0044		MONUMENT PEAK NCMN 7274
107	DY	50201.5515	50201.5880		-0.0365	0.01	-4.48	0.0061		HPGN CA 11 07
108	DZ	21143.4726	21143.4480		0.0246	0.01	4.42	0.0054		
	DN	26369.3290	26369.3309		-0.0019	0.01				
	DE	-79825.7067	-79825.7060		-0.0008	0.00				
	DU	-1778.7319	-1778.7799		0.0481	0.00				
109	DX	-12973.8355	-12973.8180		-0.0175	0.00	-4.51	0.0044		MONUMENT PEAK NCMN 7274
110	DY	30559.2201	30559.2330		-0.0129	0.01	-1.58	0.0063		HPGN CA 11 08
111	DZ	31251.2763	31251.2690		0.0073	0.01	1.30	0.0055		
	DN	37938.9006	37938.9051		-0.0045	0.01				

	DE	-25268.0234	-25268.0135	-0.0099	0.00			
	DU	-997.7099	-997.7301	0.0202	0.00			
112	DX	22519.7725	22519.7960	-0.0235	0.00	-6.41	0.0051	MONUMENT PEAK NCMN 7274
113	DY	8467.1937	8467.2300	-0.0363	0.01	-4.75	0.0071	HPGN CA 11 09
114	DZ	24036.1457	24036.1270	0.0187	0.01	3.57	0.0059	
	DN	29733.1385	29733.1463	-0.0078	0.01			
	DE	16426.3947	16426.3996	-0.0049	0.00			
	DU	-1638.2472	-1638.2933	0.0462	0.00			
115	DX	-29287.4193	-29287.4140	-0.0053	0.00	-1.12	0.0065	MONUMENT PEAK NCMN 7274
116	DY	44950.1370	44950.1520	-0.0150	0.01	-1.58	0.0079	BOUCHER 2
117	DZ	41044.2992	41044.3090	-0.0098	0.01	-1.48	0.0062	
	DN	49139.9638	49139.9806	-0.0168	0.01			
	DE	-46347.8362	-46347.8382	0.0020	0.00			
	DU	-210.4471	-210.4550	0.0079	-0.01			
118	DX	50688.3106	50688.3000	0.0106	0.00	2.71	0.0047	MONUMENT PEAK NCMN 7274
119	DY	-29897.5439	-29897.5420	-0.0019	0.01	-0.23	0.0066	OCOTILLO NCMN 7270
120	DZ	-10491.2905	-10491.2860	-0.0045	0.01	-0.81	0.0053	
	DN	-11276.2832	-11276.2811	-0.0022	0.01			
	DE	58673.3538	58673.3435	0.0103	0.00			
	DU	-1875.6654	-1875.6604	-0.0049	0.00			
121	DX	-42536.5334	-42536.5210	-0.0124	0.00	-3.19	0.0044	MONUMENT PEAK NCMN 7274
122	DY	2596.0712	2596.0990	-0.0278	0.01	-3.41	0.0063	SANDIE NASA 1976
123	DZ	-27611.2589	-27611.2790	0.0201	0.01	3.59	0.0053	
	DN	-32281.6849	-32281.6853	0.0004	0.01			
	DE	-39187.3403	-39187.3417	0.0014	0.00			
	DU	-850.3283	-850.3647	0.0365	0.00			
124	DX	-80985.8278	-80985.8070	-0.0208	0.00	-5.25	0.0045	MONUMENT PEAK NCMN 7274
125	DY	75886.6026	75886.6390	-0.0364	0.01	-4.46	0.0062	SAN DIEGO GPS 01
126	DZ	43905.6996	43905.6770	0.0226	0.01	4.07	0.0054	
	DN	53634.3499	53634.3538	-0.0039	0.01			
	DE	-106607.4537	-106607.4517	-0.0020	0.00			
	DU	-1843.5158	-1843.5632	0.0474	0.00			

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	V=C-O METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
127	DX	-55504.5322	-55504.5140		-0.0182	0.00	-4.72	0.0044		MONUMENT PEAK NCMN 7274
128	DY	61129.7029	61129.7280		-0.0251	0.01	-3.08	0.0062		SAN DIEGO GPS 02
129	DZ	42169.4486	42169.4360		0.0126	0.01	2.26	0.0054		
	DN	51431.0260	51431.0323		-0.0062	0.01				
	DE	-77123.0871	-77123.0821		-0.0049	0.00				
	DU	-1653.8037	-1653.8363		0.0325	0.00				
130	DX	-48640.4267	-48640.4250		-0.0017	0.00	-0.40	0.0046		MONUMENT PEAK NCMN 7274
131	DY	56095.6375	56095.6390		-0.0015	0.01	-0.16	0.0063		SAN DIEGO GPS 03
132	DZ	39907.8797	39907.8850		-0.0053	0.01	-0.84	0.0055		
	DN	48804.8920	48804.8975		-0.0055	0.01				
	DE	-68703.4992	-68703.4984		-0.0009	0.00				
	DU	-1778.2691	-1778.2679		-0.0011	0.00				
133	DX	-4312.3890	-4312.3750		-0.0140	0.00	-3.83	0.0049		MONUMENT PEAK NCMN 7274
134	DY	36163.3469	36163.3640		-0.0171	0.01	-2.22	0.0069		SAN DIEGO GPS 07
135	DZ	45842.9878	45842.9820		0.0058	0.01	1.10	0.0060		
	DN	55021.2590	55021.2659		-0.0069	0.01				
	DE	-20011.2531	-20011.2482		-0.0049	0.00				
	DU	-417.9647	-417.9859		0.0212	0.00				
136	DX	-34789.2864	-34789.2750		-0.0114	0.00	-2.92	0.0044		MONUMENT PEAK NCMN 7274
137	DY	33916.7190	33916.7390		-0.0200	0.01	-2.44	0.0062		SAN DIEGO GPS 12
138	DZ	20329.7215	20329.7120		0.0095	0.01	1.69	0.0054		
	DN	25052.1747	25052.1793		-0.0046	0.01				
	DE	-46311.6335	-46311.6323		-0.0012	0.00				
	DU	-1247.7972	-1247.8216		0.0244	0.00				
139	DX	-9508.7610	-9508.7430		-0.0180	0.00	-4.63	0.0044		MONUMENT PEAK NCMN 7274
140	DY	17617.1133	17617.1380		-0.0247	0.01	-3.03	0.0061		SAN DIEGO GPS 15

141	DZ	16668.2590	16668.2430	0.0160	0.01	2.88	0.0053	
	DN	20253.4701	20253.4730	-0.0030	0.01			
	DE	-16372.5182	-16372.5132	-0.0050	0.00			
	DU	-589.6369	-589.6708	0.0340	0.00			
142	DX	5452.2566	5452.2610	-0.0044	0.00	-1.16	0.0046	MONUMENT PEAK NCMN 7274
143	DY	8232.3309	8232.3400	-0.0091	0.01	-1.13	0.0065	SAN DIEGO GPS 16
144	DZ	13119.3991	13119.3950	0.0041	0.01	0.76	0.0056	
	DN	16338.7989	16338.8009	-0.0020	0.01			
	DE	1220.4828	1220.4827	0.0001	0.00			
	DU	-1082.1642	-1082.1749	0.0107	0.00			
145	DX	-61919.9197	-61919.9100	-0.0097	0.00	-2.44	0.0047	MONUMENT PEAK NCMN 7274
146	DY	27960.2081	27960.2270	-0.0189	0.01	-2.32	0.0064	SAN DIEGO GPS 17
147	DZ	-7781.9172	-7781.9300	0.0128	0.01	2.29	0.0055	
	DN	-8134.3418	-8134.3410	-0.0008	0.01			
	DE	-67876.2288	-67876.2287	-0.0001	0.00			
	DU	-1748.7060	-1748.7308	0.0248	0.00			

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
148	DX	-41360.6598	-41360.6480		-0.0118	0.00	-3.04	0.0044		MONUMENT PEAK NCMN 7274
149	DY	23665.9167	23665.9340		-0.0173	0.01	-2.12	0.0061		SAN DIEGO GPS 18
150	DZ	983.4632	983.4510		0.0122	0.01	2.19	0.0054		
	DN	2225.7484	2225.7494		-0.0010	0.01				
	DE	-47582.9481	-47582.9453		-0.0028	0.00				
	DU	-1629.7503	-1629.7743		0.0240	0.00				
151	DX	-17986.9205	-17986.8990		-0.0215	0.00	-5.54	0.0044		MONUMENT PEAK NCMN 7274
152	DY	5140.4358	5140.4830		-0.0472	0.01	-5.79	0.0062		SAN DIEGO GPS 21
153	DZ	-6741.1759	-6741.2010		0.0251	0.01	4.50	0.0053		
	DN	-7524.8350	-7524.8279		-0.0071	0.01				
	DE	-18389.5070	-18389.5088		0.0018	0.00				
	DU	-774.4251	-774.4822		0.0571	0.00				
154	DX	19255.1497	19255.1570		-0.0073	0.00	-1.93	0.0044		MONUMENT PEAK NCMN 7274
155	DY	-12057.6986	-12057.6800		-0.0186	0.01	-2.28	0.0063		SAN DIEGO GPS 22
156	DZ	-6371.4547	-6371.4660		0.0113	0.01	2.02	0.0053		
	DN	-6587.6190	-6587.6177		-0.0013	0.01				
	DE	22604.4816	22604.4799		0.0017	0.00				
	DU	-1544.3468	-1544.3697		0.0228	0.00				
157	DX	-73656.0299	-73656.0190		-0.0109	0.00	-2.84	0.0045		MONUMENT PEAK NCMN 7274
158	DY	24130.1762	24130.1940		-0.0178	0.01	-2.21	0.0064		SAN DIEGO GPS 23
159	DZ	-21420.1590	-21420.1700		0.0110	0.01	1.99	0.0055		
	DN	-24351.1620	-24351.1600		-0.0020	0.01				
	DE	-76617.6195	-76617.6178		-0.0017	0.00				
	DU	-1749.4694	-1749.4928		0.0235	0.00				
160	DX	-61772.4985	-61772.5000		0.0015	0.00	0.38	0.0044		MONUMENT PEAK NCMN 7274
161	DY	11779.0481	11779.0500		-0.0019	0.01	-0.23	0.0062		SAN DIEGO GPS 24
162	DZ	-30261.9878	-30261.9910		0.0032	0.01	0.58	0.0053		
	DN	-34800.1993	-34800.2015		0.0022	0.01				
	DE	-60464.6892	-60464.6913		0.0021	0.00				
	DU	-1828.3713	-1828.3739		0.0026	0.00				
163	DX	16434.4381	16434.4450		-0.0069	0.00	-1.85	0.0047		MONUMENT PEAK NCMN 7274
164	DY	-24501.0651	-24501.0440		-0.0211	0.01	-2.60	0.0068		SAN DIEGO GPS 31
165	DZ	-24574.5127	-24574.5210		0.0083	0.01	1.50	0.0054		
	DN	-28614.4831	-28614.4782		-0.0049	0.01				
	DE	25585.4569	25585.4538		0.0031	0.00				
	DU	-946.2396	-946.2626		0.0230	0.00				
166	DX	-39324.4462	-39324.4440		-0.0022	0.00	-0.57	0.0043		MONUMENT PEAK NCMN 7274
167	DY	6397.3687	6397.3760		-0.0073	0.01	-0.89	0.0061		SAN DIEGO GPS 33
168	DZ	-21534.2722	-21534.2740		0.0018	0.01	0.32	0.0052		
	DN	-24550.4081	-24550.4056		-0.0025	0.01				
	DE	-38021.2649	-38021.2662		0.0013	0.00				
	DU	-1650.4994	-1650.5067		0.0073	0.00				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
169	DX	-38279.4330	-38279.4190		-0.0140	0.00	-3.61	0.0043		MONUMENT PEAK NCMN 7274
170	DY	30679.0681	30679.0950		-0.0269	0.01	-3.30	0.0061		SAN DIEGO GPS 32
171	DZ	13094.3444	13094.3260		0.0184	0.01	3.29	0.0053		
	DN	16550.1470	16550.1481		-0.0011	0.01				
	DE	-47978.7582	-47978.7578		-0.0005	0.00				
	DU	-1453.7744	-1453.8099		0.0355	0.00				
172	DX	-28382.8365	-28382.8060		-0.0305	0.00	-7.87	0.0043		MONUMENT PEAK NCMN 7274
173	DY	42464.3822	42464.4230		-0.0408	0.01	-5.00	0.0060		SAN DIEGO GPS 34
174	DZ	36770.1795	36770.1520		0.0275	0.01	4.94	0.0052		
	DN	44572.3602	44572.3646		-0.0044	0.01				
	DE	-44419.1658	-44419.1569		-0.0089	0.00				
	DU	-1047.6956	-1047.7526		0.0570	0.00				
175	DX	-11569.0969	-11569.0820		-0.0149	0.00	-3.88	0.0044		MONUMENT PEAK NCMN 7274
176	DY	7893.3668	7893.3890		-0.0222	0.01	-2.74	0.0061		SAN DIEGO GPS 35
177	DZ	1769.3818	1769.3740		0.0078	0.01	1.41	0.0053		
	DN	2519.1298	2519.1377		-0.0079	0.01				
	DE	-13875.4839	-13875.4804		-0.0035	0.00				
	DU	-636.3080	-636.3344		0.0265	0.00				
178	DX	-25482.2431	-25482.2350		-0.0081	0.00	-2.10	0.0044		MONUMENT PEAK NCMN 7274
179	DY	-6761.3123	-6761.3050		-0.0073	0.01	-0.90	0.0062		JUNCTION CADH AZ MK 1974
180	DZ	-29533.9568	-29533.9590		0.0022	0.01	0.40	0.0053		
	DN	-34269.1315	-34269.1279		-0.0036	0.01				
	DE	-19779.4457	-19779.4417		-0.0040	0.00				
	DU	-1309.5091	-1309.5189		0.0098	0.00				
181	DX	-49772.4557	-49772.4400		-0.0157	0.00	-4.05	0.0044		MONUMENT PEAK NCMN 7274
182	DY	40764.1892	40764.2090		-0.0198	0.01	-2.43	0.0062		LOMAX
183	DZ	18634.3334	18634.3190		0.0144	0.01	2.59	0.0053		
	DN	23247.2048	23247.2062		-0.0014	0.01				
	DE	-62795.7807	-62795.7756		-0.0051	0.00				
	DU	-1585.0041	-1585.0327		0.0286	0.00				
184	DX	-42014.1673	-42014.1630		-0.0043	0.00	-1.11	0.0043		MONUMENT PEAK NCMN 7274
185	DY	21308.3247	21308.3370		-0.0123	0.01	-1.51	0.0061		FAR
186	DZ	-2790.0360	-2790.0450		0.0090	0.01	1.61	0.0052		
	DN	-2245.6181	-2245.6186		0.0005	0.01				
	DE	-47108.4148	-47108.4165		0.0017	0.00				
	DU	-1665.4462	-1665.4619		0.0157	0.00				
187	DX	21884.1390	21884.1480		-0.0090	0.00	-2.30	0.0044		MONUMENT PEAK NCMN 7274
188	DY	18033.1046	18033.1150		-0.0104	0.01	-1.28	0.0062		11 AAR
189	DZ	36616.7361	36616.7240		0.0121	0.01	2.18	0.0052		
	DN	44804.7103	44804.7074		0.0029	0.01				
	DE	11601.4897	11601.4932		-0.0034	0.00				
	DU	-1684.3799	-1684.3977		0.0178	0.00				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
190	DX	-70030.5734	-70030.5540		-0.0194	0.00	-5.02	0.0044		MONUMENT PEAK NCMN 7274
191	DY	79735.7482	79735.7790		-0.0308	0.01	-3.77	0.0062		BELARDES
192	DZ	57963.9745	57963.9550		0.0195	0.01	3.43	0.0055		
	DN	70041.0949	70041.0984		-0.0036	0.01				
	DE	-98563.5691	-98563.5658		-0.0033	0.00				
	DU	-1166.6038	-1166.6447		0.0410	0.00				
193	DX	-44825.6408	-44825.6240		-0.0168	0.00	-4.34	0.0044		MONUMENT PEAK NCMN 7274
194	DY	60648.9936	60649.0160		-0.0224	0.01	-2.74	0.0063		YUNG

195	DZ	49168.8330	49168.8240	0.0090	0.01	1.58	0.0055	63.28	
	DN	59727.4705	59727.4781	-0.0075	0.01				
	DE	-67346.3626	-67346.3576	-0.0049	0.00				
	DU	-1519.6552	-1519.6832	0.0280	0.00				
196	DX	-20207.1991	-20207.2020	0.0029	0.00	0.74	0.0045		SAN DIEGO GPS 12
197	DY	-26338.9378	-26338.9310	-0.0068	0.01	-0.84	0.0064		HPGN CA 11 01
198	DZ	-51424.6903	-51424.6960	0.0057	0.01	1.03	0.0056		
	DN	-60905.1811	-60905.1834	0.0022	0.01				
	DE	-6075.1792	-6075.1849	0.0057	0.00				
	DU	-469.4888	-469.4959	0.0071	0.00				
199	DX	23039.1344	23039.1260	0.0084	0.00	2.15	0.0044		SAN DIEGO GPS 12
200	DY	-46171.1794	-46171.1900	0.0106	0.01	1.30	0.0063		HPGN CA 11 02
201	DZ	-47508.9578	-47508.9590	0.0012	0.01	0.22	0.0052		
	DN	-56672.2879	-56672.2962	0.0082	0.01				
	DE	41326.7709	41326.7682	0.0027	0.00				
	DU	174.2624	174.2728	-0.0105	0.00				
202	DX	2316.3168	2316.3180	-0.0012	0.00	-0.31	0.0046		SAN DIEGO GPS 12
203	DY	-19475.1636	-19475.1730	0.0094	0.01	1.17	0.0063		HPGN CA 11 06
204	DZ	-25528.6766	-25528.6700	-0.0066	0.01	-1.20	0.0053		
	DN	-30302.7987	-30302.7974	-0.0013	0.01				
	DE	10865.5807	10865.5861	-0.0054	0.00				
	DU	-200.4919	-200.4817	-0.0102	0.00				
205	DX	-29268.5520	-29268.5500	-0.0020	0.00	-0.49	0.0044		SAN DIEGO GPS 12
206	DY	16284.8324	16284.8510	-0.0186	0.01	-2.26	0.0062		HPGN CA 11 07
207	DZ	813.7511	813.7450	0.0061	0.01	1.10	0.0055		
	DN	1318.2366	1318.2410	-0.0044	0.01				
	DE	-33473.6641	-33473.6708	0.0067	0.00				
	DU	-531.1855	-531.2035	0.0179	0.00				
208	DX	21815.4508	21815.4410	0.0098	0.00	2.53	0.0044		SAN DIEGO GPS 12
209	DY	-3357.4989	-3357.4980	-0.0009	0.01	-0.11	0.0063		HPGN CA 11 08
210	DZ	10921.5548	10921.5520	0.0028	0.01	0.50	0.0056		
	DN	12884.9564	12884.9521	0.0043	0.01				
	DE	20985.2894	20985.2802	0.0092	0.00				
	DU	250.1617	250.1632	-0.0015	0.00				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	V=C-O METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
211	DX	57309.0589	57309.0480		0.0109	0.00	3.00	0.0051		SAN DIEGO GPS 12
212	DY	-25449.5253	-25449.5380		0.0127	0.01	1.65	0.0071		HPGN CA 11 09
213	DZ	3706.4242	3706.4290		-0.0048	0.01	-0.92	0.0059		
	DN	4681.1937	4681.1888		0.0048	0.01				
	DE	62639.2707	62639.2666		0.0041	0.00				
	DU	-390.3125	-390.2963		-0.0162	0.00				
214	DX	5501.8671	5501.8720		-0.0049	0.00	-1.16	0.0064		SAN DIEGO GPS 12
215	DY	11033.4180	11033.4040		0.0140	0.01	1.61	0.0079		BOUCHER 2
216	DZ	20714.5778	20714.5740		0.0038	0.01	0.62	0.0062		
	DN	24083.5359	24083.5271		0.0088	0.01				
	DE	-89.3901	-89.3793		-0.0107	0.00				
	DU	1037.2535	1037.2600		-0.0065	0.00				
217	DX	34789.2864	34789.2940		-0.0076	0.00	-1.95	0.0044		SAN DIEGO GPS 12
218	DY	-33916.7190	-33916.7070		-0.0120	0.01	-1.47	0.0062		MONUMENT PEAK NCMN 7274
219	DZ	-20329.7215	-20329.7350		0.0135	0.01	2.42	0.0053		
	DN	-25052.1747	-25052.1783		0.0036	0.01				
	DE	46311.6335	46311.6349		-0.0014	0.00				
	DU	1247.7972	1247.7779		0.0192	0.00				
220	DX	85477.5970	85477.6040		-0.0070	0.00	-1.81	0.0046		SAN DIEGO GPS 12
221	DY	-63814.2629	-63814.2690		0.0061	0.01	0.74	0.0066		OCOTILLO NCMN 7270
222	DZ	-30821.0120	-30821.0140		0.0020	0.01	0.36	0.0053		
	DN	-36323.2325	-36323.2355		0.0030	0.01				
	DE	104923.0305	104923.0395		-0.0090	0.00				

	DU	-628.4649	-628.4640	-0.0008	0.00				
223	DX	-7747.2470	-7747.2430	-0.0040	0.00	-1.00	0.0044		SAN DIEGO GPS 12
224	DY	-31320.6479	-31320.6510	0.0031	0.01	0.38	0.0063		SANDIE NASA 1976
225	DZ	-47940.9804	-47940.9830	0.0026	0.01	0.46	0.0053		
	DN	-57329.0024	-57329.0051	0.0027	0.01				
	DE	7250.3633	7250.3683	-0.0050	0.00				
	DU	397.6700	397.6695	0.0006	0.00				
226	DX	-46196.5414	-46196.5480	0.0066	0.00	1.66	0.0045		SAN DIEGO GPS 12
227	DY	41969.8836	41969.8720	0.0116	0.01	1.43	0.0062		SAN DIEGO GPS 01
228	DZ	23575.9782	23575.9910	-0.0128	0.01	-2.29	0.0055		
	DN	28581.2863	28581.2897	-0.0034	0.01				
	DE	-60284.0970	-60284.0976	0.0006	0.00				
	DU	-596.6824	-596.6642	-0.0182	0.00				
229	DX	-20715.2458	-20715.2440	-0.0018	0.00	-0.46	0.0044		SAN DIEGO GPS 12
230	DY	27212.9839	27213.0090	-0.0251	0.01	-3.06	0.0062		SAN DIEGO GPS 02
231	DZ	21839.7271	21839.7150	0.0121	0.01	2.16	0.0054		
	DN	26377.4782	26377.4809	-0.0026	0.01				
	DE	-30833.5043	-30833.5141	0.0098	0.00				
	DU	-406.4902	-406.5163	0.0261	0.00				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	V=C-O METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
232	DX	-13851.1403	-13851.1320		-0.0083	0.00	-2.12	0.0045		SAN DIEGO GPS 12
233	DY	22178.9185	22178.9450		-0.0265	0.01	-3.32	0.0061		SAN DIEGO GPS 03
234	DZ	19578.1583	19578.1460		0.0123	0.01	2.23	0.0053		
	DN	23751.7475	23751.7522		-0.0047	0.01				
	DE	-22419.5342	-22419.5388		0.0046	0.00				
	DU	-530.8264	-530.8560		0.0296	0.00				
235	DX	30476.8974	30476.8950		0.0024	0.00	0.65	0.0049		SAN DIEGO GPS 12
236	DY	2246.6279	2246.6350		-0.0071	0.01	-0.92	0.0069		SAN DIEGO GPS 07
237	DZ	25513.2663	25513.2590		0.0073	0.01	1.39	0.0060		
	DN	29964.5631	29964.5598		0.0032	0.01				
	DE	26196.4029	26196.3976		0.0053	0.00				
	DU	829.9411	829.9328		0.0084	0.00				
238	DX	25280.5254	25280.5220		0.0034	0.00	0.88	0.0044		SAN DIEGO GPS 12
239	DY	-16299.6057	-16299.6080		0.0023	0.01	0.28	0.0061		SAN DIEGO GPS 15
240	DZ	-3661.4624	-3661.4600		-0.0024	0.01	-0.44	0.0052		
	DN	-4799.5991	-4799.5990		-0.0001	0.01				
	DE	29911.8533	29911.8513		0.0020	0.00				
	DU	658.2553	658.2596		-0.0043	0.00				
241	DX	40241.5430	40241.5520		-0.0090	0.00	-2.36	0.0046		SAN DIEGO GPS 12
242	DY	-25684.3881	-25684.3640		-0.0241	0.01	-2.99	0.0065		SAN DIEGO GPS 16
243	DZ	-7210.3223	-7210.3330		0.0107	0.01	1.94	0.0056		
	DN	-8712.9065	-8712.9015		-0.0050	0.01				
	DE	47488.0629	47488.0602		0.0028	0.00				
	DU	165.7090	165.6818		0.0273	0.00				
244	DX	-27130.6333	-27130.6390		0.0057	0.00	1.44	0.0046		SAN DIEGO GPS 12
245	DY	-5956.5110	-5956.5140		0.0030	0.01	0.37	0.0064		SAN DIEGO GPS 17
246	DZ	-28111.6387	-28111.6360		-0.0027	0.01	-0.48	0.0056		
	DN	-33182.3380	-33182.3387		0.0006	0.01				
	DE	-21459.1982	-21459.2019		0.0037	0.00				
	DU	-500.7697	-500.7638		-0.0059	0.00				
247	DX	-6571.3734	-6571.3680		-0.0054	0.00	-1.35	0.0044		SAN DIEGO GPS 12
248	DY	-10250.8023	-10250.7930		-0.0093	0.01	-1.13	0.0062		SAN DIEGO GPS 18
249	DZ	-19346.2583	-19346.2650		0.0067	0.01	1.20	0.0054		
	DN	-22823.4976	-22823.4975		-0.0002	0.01				
	DE	-1217.2697	-1217.2691		-0.0006	0.00				
	DU	-381.8563	-381.8690		0.0127	0.00				
250	DX	16802.3659	16802.3580		0.0079	0.00	2.03	0.0044		SAN DIEGO GPS 12
251	DY	-28776.2832	-28776.2860		0.0028	0.01	0.34	0.0062		SAN DIEGO GPS 21
252	DZ	-27070.8974	-27070.8980		0.0006	0.01	0.11	0.0052		

	DN	-32574.7696	-32574.7734	0.0038	0.01				
	DE	27962.2549	27962.2491	0.0058	0.00				
	DU	473.4408	473.4456	-0.0048	0.00				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
253	DX	54044.4361	54044.4320		0.0041	0.00	1.04	0.0044		SAN DIEGO GPS 12
254	DY	-45974.4176	-45974.4150		-0.0026	0.01	-0.32	0.0064		SAN DIEGO GPS 22
255	DZ	-26701.1762	-26701.1750		-0.0012	0.01	-0.22	0.0054		
	DN	-31635.9736	-31635.9724		-0.0013	0.01				
	DE	68894.6883	68894.6835		0.0048	0.00				
	DU	-296.7212	-296.7210		-0.0002	0.00				
256	DX	-38866.7435	-38866.7470		0.0035	0.00	0.89	0.0045		SAN DIEGO GPS 12
257	DY	-9786.5429	-9786.5390		-0.0039	0.01	-0.48	0.0064		SAN DIEGO GPS 23
258	DZ	-41749.8804	-41749.8850		0.0046	0.01	0.83	0.0055		
	DN	-49397.5846	-49397.5875		0.0028	0.01				
	DE	-30150.9523	-30150.9572		0.0049	0.00				
	DU	-501.3892	-501.3932		0.0040	0.00				
259	DX	-26983.2121	-26983.2170		0.0049	0.00	1.22	0.0044		SAN DIEGO GPS 12
260	DY	-22137.6709	-22137.6690		-0.0019	0.01	-0.23	0.0063		SAN DIEGO GPS 24
261	DZ	-50591.7092	-50591.7110		0.0018	0.01	0.32	0.0054		
	DN	-59845.4008	-59845.4025		0.0018	0.01				
	DE	-13995.8056	-13995.8108		0.0052	0.00				
	DU	-580.2466	-580.2471		0.0005	0.00				
262	DX	51223.7244	51223.7300		-0.0056	0.00	-1.44	0.0047		SAN DIEGO GPS 12
263	DY	-58417.7841	-58417.7860		0.0019	0.01	0.24	0.0068		SAN DIEGO GPS 31
264	DZ	-44904.2341	-44904.2450		0.0109	0.01	1.95	0.0054		
	DN	-53661.6033	-53661.6120		0.0087	0.01				
	DE	71925.2343	71925.2401		-0.0058	0.00				
	DU	301.1524	301.1459		0.0065	0.00				
265	DX	-4535.1598	-4535.1540		-0.0058	0.00	-1.45	0.0043		SAN DIEGO GPS 12
266	DY	-27519.3503	-27519.3460		-0.0043	0.01	-0.52	0.0061		SAN DIEGO GPS 33
267	DZ	-41863.9937	-41864.0020		0.0083	0.01	1.51	0.0052		
	DN	-49596.9360	-49596.9395		0.0035	0.01				
	DE	8393.9378	8393.9410		-0.0032	0.00				
	DU	-402.5270	-402.5370		0.0099	0.00				
268	DX	-3490.1467	-3490.1430		-0.0037	0.00	-0.91	0.0044		SAN DIEGO GPS 12
269	DY	-3237.6510	-3237.6460		-0.0050	0.01	-0.61	0.0061		SAN DIEGO GPS 32
270	DZ	-7235.3771	-7235.3800		0.0029	0.01	0.52	0.0052		
	DN	-8500.8170	-8500.8162		-0.0009	0.01				
	DE	-1645.5651	-1645.5641		-0.0010	0.00				
	DU	-205.9470	-205.9537		0.0067	0.00				
271	DX	6406.4499	6406.4450		0.0049	0.00	1.23	0.0043		SAN DIEGO GPS 12
272	DY	8547.6631	8547.6540		0.0091	0.01	1.13	0.0060		SAN DIEGO GPS 34
273	DZ	16440.4580	16440.4660		-0.0080	0.01	-1.43	0.0052		
	DN	19517.9862	19517.9872		-0.0010	0.01				
	DE	1844.4530	1844.4527		0.0002	0.00				
	DU	200.0319	200.0449		-0.0130	0.00				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
274	DX	23220.1895	23220.1850		0.0045	0.00	1.15	0.0043		SAN DIEGO GPS 12
275	DY	-26023.3522	-26023.3520		-0.0002	0.01	-0.02	0.0061		SAN DIEGO GPS 35
276	DZ	-18560.3397	-18560.3400		0.0003	0.01	0.05	0.0053		
	DN	-22532.0845	-22532.0857		0.0012	0.01				
	DE	32447.0251	32447.0210		0.0041	0.00				

	DU	611.5552	611.5565	-0.0014	0.00			
277	DX	9307.0432	9307.0360	0.0072	0.00	1.81	0.0044	SAN DIEGO GPS 12
278	DY	-40678.0313	-40678.0250	-0.0063	0.01	-0.77	0.0062	JUNCTION CADH AZ MK 1974
279	DZ	-49863.6782	-49863.6860	0.0078	0.01	1.38	0.0053	
	DN	-59315.2403	-59315.2456	0.0052	0.01			
	DE	26634.7171	26634.7078	0.0093	0.00			
	DU	-61.6539	-61.6601	0.0062	0.00			
280	DX	-14983.1693	-14983.1740	0.0047	0.00	1.18	0.0044	SAN DIEGO GPS 12
281	DY	6847.4702	6847.4840	-0.0138	0.01	-1.69	0.0062	LOMAX
282	DZ	-1695.3880	-1695.3910	0.0030	0.01	0.53	0.0054	
	DN	-1804.0747	-1804.0716	-0.0031	0.01			
	DE	-16458.7089	-16458.7193	0.0105	0.00			
	DU	-337.2944	-337.3045	0.0101	0.00			
283	DX	-7224.8809	-7224.8780	-0.0029	0.00	-0.73	0.0043	SAN DIEGO GPS 12
284	DY	-12608.3943	-12608.3970	0.0027	0.01	0.32	0.0060	FAR
285	DZ	-23119.7575	-23119.7630	0.0055	0.01	0.98	0.0051	
	DN	-27294.3590	-27294.3642	0.0052	0.01			
	DE	-733.0278	-733.0240	-0.0038	0.00			
	DU	-417.5319	-417.5340	0.0021	0.00			
286	DX	56673.4254	56673.4190	0.0064	0.00	1.64	0.0044	SAN DIEGO GPS 12
287	DY	-15883.6145	-15883.6140	-0.0005	0.01	-0.06	0.0061	11 AAR
288	DZ	16287.0147	16287.0210	-0.0063	0.01	-1.13	0.0052	
	DN	19751.3691	19751.3731	-0.0040	0.01			
	DE	57785.1730	57785.1671	0.0059	0.00			
	DU	-436.3497	-436.3442	-0.0055	0.00			
289	DX	-35241.2870	-35241.2900	0.0030	0.00	0.75	0.0044	SAN DIEGO GPS 12
290	DY	45819.0292	45819.0250	0.0042	0.01	0.52	0.0062	BELARDES
291	DZ	37634.2530	37634.2620	-0.0090	0.01	-1.61	0.0055	
	DN	44985.2695	44985.2742	-0.0047	0.01			
	DE	-52287.5497	-52287.5504	0.0007	0.00			
	DU	80.1444	80.1536	-0.0092	0.00			
292	DX	-10036.3544	-10036.3530	-0.0014	0.00	-0.35	0.0044	SAN DIEGO GPS 12
293	DY	26732.2746	26732.2970	-0.0224	0.01	-2.76	0.0063	YUNG
294	DZ	28839.1115	28839.1020	0.0095	0.01	1.70	0.0055 63.00	
	DN	34672.8618	34672.8651	-0.0033	0.01			
	DE	-21089.2339	-21089.2428	0.0089	0.00			
	DU	-272.2856	-272.3081	0.0224	0.00			

0RESIDUAL STATISTICS

OBSERVATION NUMBERS OF 20 GREATEST STANDARDIZED RESIDUALS (V/SD)

172 112 152 14 151 124 73 32 190 106 173 174 95 113 127 139 109 153 107 125

TOTAL=	294	NO-CHECK=	3
MAX V=	5.1D-02	MAX V/SD=	1.407
MIN V=	-4.7D-02	MIN V/SD=	-1.964
MEAN V=	-3.8D-04	MEAN V/SD=	0.005

	N	VTPV	RMS VTPV	RN	VTPV/RN	MEAN ABS RESIDUAL
DELTA X	97	480.9	2.23	64.00	7.51	0.008 (METERS)
DELTA Y	97	1636.1	4.11	64.00	25.56	0.015 (METERS)
DELTA Z	97	963.0	3.15	64.00	15.05	0.008 (METERS)
DOPPLER X	0	0.0	0.00	0.00	0.00	0.000 (METERS)
DOPPLER Y	0	0.0	0.00	0.00	0.00	0.000 (METERS)
DOPPLER Z	0	0.0	0.00	0.00	0.00	0.000 (METERS)
DIRECTION	0	0.0	0.00	0.00	0.00	0.000 (SECONDS)
H ANGLE	0	0.0	0.00	0.00	0.00	0.000 (SECONDS)
ZEN DIST	0	0.0	0.00	0.00	0.00	0.000 (SECONDS)
DISTANCE	0	0.0	0.00	0.00	0.00	0.000 (METERS)

```
 AZIMUTH         0       0.0      0.00      0.00          0.00       0.000 (SECONDS)
 OTHER           3       0.0      0.00      0.00          0.00       0.000
 TOTAL         294    3080.0      3.24    192.00         16.04

               N          RMS                                        MEAN ABS
          CONTRIB.     RESIDUAL                                      RESIDUAL
 NORTH        97         0.007                                       0.005 (METERS)
 EAST         97         0.005                                       0.004 (METERS)
 UP           97         0.023                                       0.018 (METERS)

0DEGREES OF FREEDOM       =              192
 VARIANCE SUM             =             3080.0
 STD.DEV.OF UNIT WEIGHT   =                4.01
 VARIANCE OF UNIT WEIGHT  =               16.04

 MINUTES TO LIST RESIDUALS     9.3
1                                                 NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                     ADJUSTMENT PROGRAM                                 PAGE  24
                                                      VERSION    4.00


0ADJUSTED POSITIONS

        SSN NAME                              LATITUDE        LONGITUDE       M.S.L.    G. HT.    E. HT.
0     1 5652 11 AAR                        33 17 44.46849N  116 17 54.77298W  188.228  -32.752  155.476
                               SHIFTS (M.)       0.009N           0.011E                      188.228 AZ= 52 HOR=  0.0 TOT=188.2
                        SCALED SIGMAS (M.)       0.004            0.004                         0.030
                               GOOGES            8.4D-01          7.6D-01                       7.4D-01
0     2 5744 BELARDES                      33 31 23.41400N  117 28 47.24628W  705.308  -33.445  671.863
                               SHIFTS (M.)       0.013N           0.008W                      705.308 AZ=329 HOR=  0.0 TOT=705.3
                        SCALED SIGMAS (M.)       0.005            0.004                         0.030
                               GOOGES            7.9D-01          7.3D-01                       7.0D-01
0     3   10 BOUCHER 2                     33 20  4.98352N  116 55  9.32091W 1660.766  -31.547 1629.219
                               SHIFTS (M.)       0.006N           0.012E                     1660.766 AZ= 64 HOR=  0.0 TOT=*****
                        SCALED SIGMAS (M.)       0.005            0.005                         0.033
                               GOOGES            1.0D+00          9.7D-01                       9.3D-01
0     4 5555 FAR                           32 52 17.45443N  116 55 34.10348W  207.484  -33.054  174.430
                               SHIFTS (M.)       0.003N           0.002E                      207.484 AZ= 29 HOR=  0.0 TOT=207.5
                        SCALED SIGMAS (M.)       0.004            0.004                         0.030
                               GOOGES            8.5D-01          8.4D-01                       7.7D-01
0     5  151 HPGN CA 11 01                 32 34  6.43647N  116 58 59.47379W  156.768  -34.299  122.469
                               SHIFTS (M.)       0.005N           0.014W                      156.768 AZ=290 HOR=  0.0 TOT=156.8
                        SCALED SIGMAS (M.)       0.004            0.004                         0.031
                               GOOGES            1.0D+00          9.7D-01                       8.8D-01
0     6  152 HPGN CA 11 02                 32 36 23.92982N  116 28 36.49840W  798.515  -32.099  766.416
                               SHIFTS (M.)       0.006S           0.009E                      798.515 AZ=127 HOR=  0.0 TOT=798.5
                        SCALED SIGMAS (M.)       0.004            0.004                         0.030
                               GOOGES            1.0D+00          9.8D-01                       8.9D-01
0     7  156 HPGN CA 11 06                 32 50 39.81943N  116 48  7.42646W  423.924  -32.447  391.477
                               SHIFTS (M.)       0.001N           0.013E                      423.924 AZ=  0 HOR=  0.0 TOT=423.9
                        SCALED SIGMAS (M.)       0.004            0.004                         0.031
                               GOOGES            1.0D+00          9.8D-01                       9.0D-01
0     8  157 HPGN CA 11 07                 33  7 46.17503N  117 16 37.07880W   94.897  -34.124   60.773
                               SHIFTS (M.)       0.025N           0.027W                       94.897 AZ=313 HOR=  0.0 TOT= 94.9
                        SCALED SIGMAS (M.)       0.004            0.004                         0.030
                               GOOGES            1.0D+00          9.7D-01                       8.7D-01
0     9  158 HPGN CA 11 08                 33 14  1.57932N  116 41 35.95577W  873.618  -31.504  842.114
                               SHIFTS (M.)       0.018N           0.003E                      873.618 AZ=  9 HOR=  0.0 TOT=873.6
                        SCALED SIGMAS (M.)       0.004            0.004                         0.030
                               GOOGES            1.0D+00          9.7D-01                       8.5D-01
1                                                 NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                     ADJUSTMENT PROGRAM                                 PAGE  25
                                                      VERSION    4.00


0ADJUSTED POSITIONS
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      SSN NAME                                   LATITUDE       LONGITUDE        M.S.L.    G. HT.     E. HT.
0  10  159 HPGN CA 11 09                      33  9 35.32882N  116 14 49.22981W  234.545   -32.936   201.609
                             SHIFTS (M.)            0.007N             0.027E                        234.545 AZ= 75 HOR=  0.0 TOT=234.5
                      SCALED SIGMAS (M.)            0.005              0.004                           0.034
                             GOOGES                 7.2D-01            6.9D-01                         6.5D-01
0  11 5529 JUNCTION CADH AZ MK 1974           32 34 58.10786N  116 38  1.65308W  562.846   -32.458   530.388
                             SHIFTS (M.)            0.001S             0.007E                        562.846 AZ=  0 HOR=  0.0 TOT=562.8
                      SCALED SIGMAS (M.)            0.004              0.004                           0.030
                             GOOGES                 8.7D-01            8.7D-01                         8.2D-01
0  12 5554 LOMAX                              33  6  4.83150N  117  5 40.63403W  287.877   -33.207   254.670
                             SHIFTS (M.)            0.006N             0.001W                        287.877 AZ=  0 HOR=  0.0 TOT=287.9
                      SCALED SIGMAS (M.)            0.004              0.004                           0.030
                             GOOGES                 9.0D-01            8.7D-01                         7.8D-01
0  13  189 MONUMENT PEAK NCMN 7274            32 53 30.33783N  116 25 22.09142W 1871.567   -31.689  1839.878
                             SHIFTS (M.)            0.003S             0.023E                       1871.567 AZ= 99 HOR=  0.0 TOT=*****
                      SCALED SIGMAS (M.)            0.004              0.004                           0.031
                             GOOGES                 1.0D+00            9.7D-01                         8.7D-01
0  14  198 OCOTILLO NCMN 7270                 32 47 24.34686N  115 47 46.22577W   -1.695   -34.036   -35.731
                             SHIFTS (M.)            0.007S             0.036E                         -1.695 AZ=101 HOR=  0.0 TOT=  1.7
                      SCALED SIGMAS (M.)            0.004              0.004                           0.030
                             GOOGES                 9.9D-01            9.6D-01                         9.1D-01
0  15 5301 SAN DIEGO GPS 01                   33 22 31.07248N  117 33 54.53710W   29.563   -34.499    -4.936
                             SHIFTS (M.)            0.010N             0.009W                         29.563 AZ=319 HOR=  0.0 TOT= 29.6
                      SCALED SIGMAS (M.)            0.004              0.004                           0.030
                             GOOGES                 9.9D-01            9.5D-01                         8.8D-01
0  16 5302 SAN DIEGO GPS 02                   33 21 19.52708N  117 14 56.75528W  218.635   -33.214   185.421
                             SHIFTS (M.)            0.010N             0.004W                        218.635 AZ=340 HOR=  0.0 TOT=218.6
                      SCALED SIGMAS (M.)            0.004              0.004                           0.030
                             GOOGES                 9.8D-01            9.5D-01                         8.5D-01
0  17 5303 SAN DIEGO GPS 03                   33 19 54.31161N  117  9 31.67238W   94.020   -32.909    61.111
                             SHIFTS (M.)            0.010N             0.002W                         94.020 AZ=347 HOR=  0.0 TOT= 94.0
                      SCALED SIGMAS (M.)            0.004              0.004                           0.031
                             GOOGES                 9.8D-01            9.5D-01                         8.8D-01
0  18 5307 SAN DIEGO GPS 07                   33 23 15.85654N  116 38 13.99384W 1453.074   -31.206  1421.868
                             SHIFTS (M.)            0.011N             0.006E                       1453.074 AZ= 30 HOR=  0.0 TOT=*****
                      SCALED SIGMAS (M.)            0.005              0.004                           0.033
                             GOOGES                 5.5D-01            5.7D-01                         5.3D-01
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0ADJUSTED POSITIONS

      SSN NAME                                   LATITUDE       LONGITUDE        M.S.L.    G. HT.     E. HT.
0  19 5312 SAN DIEGO GPS 12                   33  7  3.38752N  116 55  5.86919W  624.239   -32.276   591.963
                             SHIFTS (M.)            0.006N             0.002E                        624.239 AZ= 19 HOR=  0.0 TOT=624.2
                      SCALED SIGMAS (M.)            0.004              0.004                           0.030
                             GOOGES                 9.8D-01            9.5D-01                         8.4D-01
0  20 5315 SAN DIEGO GPS 15                   33  4 27.61550N  116 35 52.52064W 1281.633   -31.404  1250.229
                             SHIFTS (M.)            0.006N             0.007E                       1281.633 AZ= 49 HOR=  0.0 TOT=*****
                      SCALED SIGMAS (M.)            0.004              0.004                           0.030
                             GOOGES                 9.8D-01            9.5D-01                         8.5D-01
0  21 5316 SAN DIEGO GPS 16                   33  2 20.59604N  116 24 35.10390W  789.765   -32.052   757.713
                             SHIFTS (M.)            0.005N             0.010E                        789.765 AZ= 63 HOR=  0.0 TOT=789.8
                      SCALED SIGMAS (M.)            0.004              0.004                           0.031
                             GOOGES                 9.8D-01            9.5D-01                         8.6D-01
0  22 5317 SAN DIEGO GPS 17                   32 49  6.32700N  117  8 52.18052W  125.544   -34.323    91.221
                             SHIFTS (M.)            0.003N             0.001W                        125.544 AZ=338 HOR=  0.0 TOT=125.5
                      SCALED SIGMAS (M.)            0.004              0.004                           0.030
                             GOOGES                 9.8D-01            9.5D-01                         8.8D-01
0  23 5318 SAN DIEGO GPS 18                   32 54 42.57639N  116 55 52.76571W  243.052   -32.946   210.106
                             SHIFTS (M.)            0.004N             0.002E                        243.052 AZ= 26 HOR=  0.0 TOT=243.1
                      SCALED SIGMAS (M.)            0.004              0.004                           0.030
                             GOOGES                 9.7D-01            9.4D-01                         8.6D-01
```

```
0    24 5321 SAN DIEGO GPS 21                    32 49 26.12905N  116 37  9.19865W  1097.035   -31.578  1065.457
                                 SHIFTS (M.)            0.002N              0.007E                      1097.035 AZ= 70 HOR=   0.0 TOT=*****
                          SCALED SIGMAS (M.)            0.004               0.004                         0.030
                                 GOOGES                 9.7D-01             9.4D-01                       8.5D-01
0    25 5322 SAN DIEGO GPS 22                    32 49 56.53237N  116 10 52.81761W   328.636   -33.101   295.535
                                 SHIFTS (M.)            0.002N              0.013E                       328.636 AZ= 80 HOR=   0.0 TOT=328.6
                          SCALED SIGMAS (M.)            0.004               0.004                         0.030
                                 GOOGES                 9.6D-01             9.2D-01                       8.4D-01
0    26 5323 SAN DIEGO GPS 23                    32 40 19.97679N  117 14 25.91772W   125.870   -35.214    90.656
                                 SHIFTS (M.)            0.002N              0.003W                       125.870 AZ=305 HOR=   0.0 TOT=125.9
                          SCALED SIGMAS (M.)            0.004               0.004                         0.031
                                 GOOGES                 9.6D-01             9.3D-01                       8.3D-01
0    27 5324 SAN DIEGO GPS 24                    32 34 40.82082N  117  4  4.07350W    46.494   -34.765    11.729
                                 SHIFTS (M.)            0.000N              0.000E                        46.494 AZ=  0 HOR=   0.0 TOT= 46.5
                          SCALED SIGMAS (M.)            0.000               0.000                         0.000
                                 GOOGES                 1.0D+00             1.0D+00                       1.0D+00
1                                                          NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                              ADJUSTMENT PROGRAM                                              PAGE  27
                                                               VERSION    4.00


0ADJUSTED POSITIONS

        SSN NAME                                   LATITUDE          LONGITUDE         M.S.L.    G. HT.     E. HT.
0    28 5331 SAN DIEGO GPS 31                    32 38  1.66402N  116  8 59.31868W   926.076   -32.406   893.670
                                 SHIFTS (M.)            0.002S              0.014E                       926.076 AZ= 97 HOR=   0.0 TOT=926.1
                          SCALED SIGMAS (M.)            0.004               0.004                         0.031
                                 GOOGES                 9.4D-01             9.2D-01                       8.3D-01
0    29 5359 SAN DIEGO GPS 32                    33  2 27.47255N  116 56  9.31153W   418.581   -32.565   386.016
                                 SHIFTS (M.)            0.006N              0.002E                       418.581 AZ= 17 HOR=   0.0 TOT=418.6
                          SCALED SIGMAS (M.)            0.004               0.004                         0.030
                                 GOOGES                 9.4D-01             9.2D-01                       8.2D-01
0    30 5358 SAN DIEGO GPS 33                    32 40 13.51994N  116 49 42.92117W   222.524   -33.086   189.438
                                 SHIFTS (M.)            0.001N              0.003E                       222.524 AZ=  0 HOR=   0.0 TOT=222.5
                          SCALED SIGMAS (M.)            0.004               0.004                         0.030
                                 GOOGES                 9.3D-01             9.2D-01                       8.3D-01
0    31 5361 SAN DIEGO GPS 34                    33 17 36.85896N  116 53 54.65927W   823.588   -31.593   791.995
                                 SHIFTS (M.)            0.009N              0.002E                       823.588 AZ= 12 HOR=   0.0 TOT=823.6
                          SCALED SIGMAS (M.)            0.004               0.004                         0.030
                                 GOOGES                 9.3D-01             9.1D-01                       8.3D-01
0    32 5363 SAN DIEGO GPS 35                    32 54 52.09145N  116 34 15.89225W  1234.872   -31.304  1203.568
                                 SHIFTS (M.)            0.004N              0.007E                      1234.872 AZ= 64 HOR=   0.0 TOT=*****
                          SCALED SIGMAS (M.)            0.004               0.004                         0.031
                                 GOOGES                 9.2D-01             8.8D-01                       8.2D-01
0    33  220 SANDIE NASA 1976                    32 36  2.64994N  116 50 27.04492W  1022.953   -33.313   989.640
                                 SHIFTS (M.)            0.007S              0.006W                      1022.953 AZ=220 HOR=   0.0 TOT=*****
                          SCALED SIGMAS (M.)            0.004               0.004                         0.030
                                 GOOGES                 9.8D-01             9.7D-01                       8.8D-01
0    34 5745 YUNG                                33 25 48.75331N  117  8 40.74031W   352.202   -32.556   319.646
                                 SHIFTS (M.)            0.011N              0.002W                       352.202 AZ=351 HOR=   0.0 TOT=352.2
                          SCALED SIGMAS (M.)            0.004               0.004                         0.030
                                 GOOGES                 7.2D-01             6.9D-01                       6.5D-01

 MINUTES TO LIST ADJUSTED POSITIONS     0.0
0END OF ADJUST PROCESSING
 SYSTEM TIME IS Tue Oct 19 09:24:05 1993
 HAVE A NICE DAY!
```

Appendix K: Results of final constrained least square adjustment (scale and rotation method)

davez

adj.g93s.final

venus

Job: adj.g93s.final
Date: Tue Oct 19 09:00:14 1993

Final Constrained Least Square Adjustment

```
 ENTER INPUT BLUE BOOK FILENAME (DEFAULT='BBOOK'):

bbk.g93s
 ENTER ADJUSTMENT FILE FILENAME
 (DEFAULT='AFILE', IF THERE ISNT ONE, ENTER: 'NOAFILE'):

afile.final
 ENTER GPS FILE FILENAME
 (DEFAULT='GFILE', IF THERE ISNT ONE, ENTER: 'NOGFILE'):

gfile
 ENTER DOPPLER FILE FILENAME
 (DEFAULT='DFILE', IF THERE ISNT ONE, ENTER: 'NODFILE'):

DFILE
1                                                    NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                         ADJUSTMENT PROGRAM                                             PAGE    1
                                                          VERSION    4.00


0SYSTEM TIME IS Wed Sep  8 07:47:05 1993
0******************************** A-FILE CONTENTS *********************************

     CC         5652                                                                     188052
     CC         0151                                                                     156771
     CC         0152                                                                     798485
     CC         0157                                                                      94902
     CC         5529                                                                     562793
     CC         0198                                                                      -1778
     CC         5301                                                                      29528
     CC         5303                                                                      93958
     CC         5315                                                                    1281509
     CC         5321                                                                    1096931
     CC         5324                                                                      46494
     CC         5331                                                                     926012
     CC         5359                                                                     418536
     CC         5358                                                                     222523
     CC         5361                                                                     823437
     CC         5363                                                                    1234762
     CC         5745                                                                     352094
     CC         5324                                         32344082082N117040407350W
     CC         0159                                         33093533055N116144923165W
     II   9999999
     MM3Y
     PP22
     RR
     SS25
0********************************** END OF A-FILE *********************************
1                                                    NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                         ADJUSTMENT PROGRAM                                             PAGE    2
                                                          VERSION    4.00


 ***************** ADJUSTMENT FILE OPTIONS **********

 ELLIPSOID SEMI-MAJOR AXIS = 6378137.000 METERS
 ELLIPSOID SQUARE FLATTENING =0.00669438002290341б
 DEFAULT MEAN SEA LEVEL =    0.000 METERS
 DEFAULT GEOID HEIGHT =    0.000 METERS
 ADJUST ORTHOMETRIC ELEVATIONS
 SCALE SIGMAS BY A-POSTERIORI SIGMA OF UNIT WEIGHT
 ABORT IF SINGULARITIES
 DO NOT UPDATE *80* RECORDS
 DO NOT UPDATE BLUE BOOK AND ADJUSTMENT FILE AT THE END OF EACH ITERATION
 COMPUTE A 3-DIMENSIONAL ADJUSTMENT
 COMPUTE NO MORE THAN     5 ITERATIONS
```

```
 DO NOT DISPLAY STATISTICS IF SOLUTION SLOWLY CONVERGES
 ABORT IF MISCLOSURE EXCEEDS 0.1E+21 SIGMA
 PRINT WHEN MISCLOSURES EXCEED 0.1E+21 SIGMA
 CONVERGE IF RMS SUM OF SHIFTS BELOW   0.003 METERS
 COMPUTE NORMALIZED RESIDUALS AND INVERSE
 ECHO LARGE BLUE BOOK MISCLOSURES ONLY
 ECHO GPS DATA TRANSFER FILE
 ECHO LARGE G-FORMAT MISCLOSURES ONLY
 ECHO DOPPLER DATA TRANSFER FILE
 DISPLAY CONSTRAINTS
 DISPLAY ALL RESIDUALS/SD GREATER OR EQUAL TO  0.0
 DISPLAY DIRECTION RESIDUALS
 DISPLAY ANGLE RESIDUALS
 DISPLAY ZENITH DISTANCE RESIDUALS
 DISPLAY DISTANCE RESIDUALS
 DISPLAY ASTRO-AZIMUTH RESIDUALS
 DISPLAY GPS RESIDUALS
 DISPLAY DOPPLER RESIDUALS
 DISPLAY CONSTRAINED RESIDUALS
 DISPLAY RESIDUALS GROUPED AROUND INTERSECTION STAS
 DISPLAY POSITION SHIFTS
 DISPLAY POSITION GOOGE NUMBERS
0ERROR - NO DFILE FOUND IN SUBROUTINE FIRST

 MINUTES SINCE START OF PROGRAM IS     0.0
1                                                 NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                      ADJUSTMENT PROGRAM                                   PAGE   3
                                                       VERSION   4.00


 ******** CONSTRAINTS *************
0 OBS #

      1   CC        5652                                                                188052
      2   CC        0151                                                                156771
      3   CC        0152                                                                798485
      4   CC        0157                                                                 94902
      5   CC        5529                                                                562793
      6   CC        0198                                                                 -1778
      7   CC        5301                                                                 29528
      8   CC        5303                                                                 93958
      9   CC        5315                                                               1281509
     10   CC        5321                                                               1096931
     11   CC        5324                                                                 46494
     12   CC        5331                                                                926012
     13   CC        5359                                                                418536
     14   CC        5358                                                                222523
     15   CC        5361                                                                823437
     16   CC        5363                                                               1234762
     17   CC        5745                                                                352094
     19   CC        5324                              32344082082N117040407350W
     21   CC        0159                              33093533055N116144923165W
0************ END OF CONSTRAINTS *************
1                                                 NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                      ADJUSTMENT PROGRAM                                   PAGE   4
                                                       VERSION   4.00


 ************ BLUE BOOK ************
0 OBS #

 ******** END OF BLUE BOOK ********
1                                                 NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                      ADJUSTMENT PROGRAM                                   PAGE   5
                                                       VERSION   4.00
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******** GPS OBSERVATIONS *************

0*********** END OF GPS OBSERVATIONS *********

 MINUTES TO READ BBOOK, GFILE, AND DFILE     0.1

 MINUTES TO REORDER     0.0

 THE NUMBER OF NON-TRIVIAL COMPONENTS IS  1.
1
 PROGRAM ADJUST                              NATIONAL GEODETIC SURVEY                                PAGE    6
                                               ADJUSTMENT PROGRAM
                                                 VERSION    4.00
```

0*** OBSERVATIONAL SUMMARY ***

SSN	CMP	STATION NAME	DIR FRM	DIR TO	ANG FRM	ANG TO	AZI FRM	AZI TO	DIS FRM	DIS TO	ZD FRM	ZD TO	GPS FRM	GPS TO	DOP
5652	1	11 AAR	0	0	0	0	0	0	0	0	0	0	0	3	0
5744	1	BELARDES	0	0	0	0	0	0	0	0	0	0	0	3	0
10	1	BOUCHER 2	0	0	0	0	0	0	0	0	0	0	0	3	0
5555	1	FAR	0	0	0	0	0	0	0	0	0	0	0	3	0
151	1	HPGN CA 11 01	0	0	0	0	0	0	0	0	0	0	0	3	0
152	1	HPGN CA 11 02	0	0	0	0	0	0	0	0	0	0	0	3	0
156	1	HPGN CA 11 06	0	0	0	0	0	0	0	0	0	0	0	3	0
157	1	HPGN CA 11 07	0	0	0	0	0	0	0	0	0	0	0	3	0
158	1	HPGN CA 11 08	0	0	0	0	0	0	0	0	0	0	0	3	0
159	1	HPGN CA 11 09	0	0	0	0	0	0	0	0	0	0	0	2	0
5529	1	JUNCTION CADH AZ MK 1974	0	0	0	0	0	0	0	0	0	0	0	3	0
5554	1	LOMAX	0	0	0	0	0	0	0	0	0	0	0	3	0
189	1	MONUMENT PEAK NCMN 7274	0	0	0	0	0	0	0	0	0	0	64	1	0
198	1	OCOTILLO NCMN 7270	0	0	0	0	0	0	0	0	0	0	0	3	0
5301	1	SAN DIEGO GPS 01	0	0	0	0	0	0	0	0	0	0	0	3	0
5302	1	SAN DIEGO GPS 02	0	0	0	0	0	0	0	0	0	0	0	3	0
5303	1	SAN DIEGO GPS 03	0	0	0	0	0	0	0	0	0	0	0	3	0
5307	1	SAN DIEGO GPS 07	0	0	0	0	0	0	0	0	0	0	0	2	0
5312	1	SAN DIEGO GPS 12	0	0	0	0	0	0	0	0	0	0	33	2	0
5315	1	SAN DIEGO GPS 15	0	0	0	0	0	0	0	0	0	0	0	3	0
5316	1	SAN DIEGO GPS 16	0	0	0	0	0	0	0	0	0	0	0	3	0
5317	1	SAN DIEGO GPS 17	0	0	0	0	0	0	0	0	0	0	0	3	0
5318	1	SAN DIEGO GPS 18	0	0	0	0	0	0	0	0	0	0	0	3	0
5321	1	SAN DIEGO GPS 21	0	0	0	0	0	0	0	0	0	0	0	3	0
5322	1	SAN DIEGO GPS 22	0	0	0	0	0	0	0	0	0	0	0	3	0
5323	1	SAN DIEGO GPS 23	0	0	0	0	0	0	0	0	0	0	0	3	0
5324C	1	SAN DIEGO GPS 24	0	0	0	0	0	0	0	0	0	0	0	3	0
5331	1	SAN DIEGO GPS 31	0	0	0	0	0	0	0	0	0	0	0	3	0
5359	1	SAN DIEGO GPS 32	0	0	0	0	0	0	0	0	0	0	0	3	0
5358	1	SAN DIEGO GPS 33	0	0	0	0	0	0	0	0	0	0	0	3	0
5361	1	SAN DIEGO GPS 34	0	0	0	0	0	0	0	0	0	0	0	3	0
5363	1	SAN DIEGO GPS 35	0	0	0	0	0	0	0	0	0	0	0	3	0
220	1	SANDIE NASA 1976	0	0	0	0	0	0	0	0	0	0	0	3	0
5745	1	YUNG	0	0	0	0	0	0	0	0	0	0	0	3	0

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 TOTAL MINUTES TO COMMENCMENT OF ADJUSTMENT     0.1
1
 PROGRAM ADJUST                              NATIONAL GEODETIC SURVEY                                PAGE    7
                                               ADJUSTMENT PROGRAM
                                                 VERSION    4.00

0*********** COMMENCING ADJUSTMENT ***********

 THE AVERAGE BAND WIDTH FOR THE 3 DIM. ADJUSTMENT OF    34 STATIONS AND RANK    106 IS 104.7%.   D.P. WORDS NEEDED=     5884
0ITERATION # 0 THE RMS CORRECTION IS    438.217 METERS --- VTPV=        3567.869  DF=    206  VARIANCE=            17.32
0 MAXIMUM SHIFT - STATION: MONUMENT PEAK NCMN 7274              VERTICAL SHIFT=   1871.476 METERS
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 MINUTES NEEDED FOR ITERATION  0 =     0.1
0ITERATION # 1 THE RMS CORRECTION IS      0.001 METERS --- VTPV=       3567.423  DF=   206  VARIANCE=          17.32
0 MAXIMUM SHIFT - STATION: MONUMENT PEAK NCMN 7274                LATITUDE SHIFT=      0.002 METERS

 MINUTES NEEDED FOR ITERATION  1 =     0.1
0*********** ADJUSTMENT CONVERGED *************


 THE FOLLOWING UNKNOWNS HAVE GOOGE NUMBERS LESS THAN 1.00D-03

 MINUTES TO INVERT     0.0
1                                                  NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                       ADJUSTMENT PROGRAM                                       PAGE   8
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0*** JOB STATISTICS ***

0A.) BLUE-BOOK STATISTICS
         NO. *80* CONTROL RECORDS        34
         NO. *84* GEOID HT. RECORDS       0
         NO. *85* DEFLECTION RECORDS      0
         NO. *86* ELEVATION RECORDS      34
         NO. DIRECTIONS                   0
         NO. ANGLES                       0
         NO. GPS VECTORS                 97
         NO. DOPPLER OBS.                 0
         NO. ZENITH DISTANCES             0
         NO. DISTANCES                    0
         NO. AZIMUTHS                     0
 B.) NO. CONSTRAINTS                     21
 C.) NO. ACCURACIES                       0
 D.) NO. REJECTED OBS.                    0
1                                                  NATIONAL GEODETIC SURVEY
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0NORMALIZED RESIDUALS
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	COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
1 EH	155.300	155.300		0.000	0.00	0.00	0.0193	0.00	11 AAR
2 EH	122.472	122.472		0.000	0.00	0.00	0.0189	0.00	HPGN CA 11 01
3 EH	766.386	766.386		0.000	0.00	0.00	0.0173	0.00	HPGN CA 11 02
4 EH	60.778	60.778		0.000	0.00	0.00	0.0172	0.00	HPGN CA 11 07
5 EH	530.335	530.335		0.000	0.00	0.00	0.0173	0.00	JUNCTION CADH AZ MK 1974
6 EH	-35.814	-35.814		0.000	0.00	0.00	0.0204	0.00	OCOTILLO NCMN 7270
7 EH	-4.971	-4.971		0.000	0.00	0.00	0.0190	0.00	SAN DIEGO GPS 01
8 EH	61.049	61.049		0.000	0.00	0.00	0.0182	0.00	SAN DIEGO GPS 03
9 EH	1250.105	1250.105		0.000	0.00	0.00	0.0169	0.00	SAN DIEGO GPS 15
10 EH	1065.353	1065.353		0.000	0.00	0.00	0.0168	0.00	SAN DIEGO GPS 21
11 EH	11.729	11.729		0.000	0.00	0.00	0.0186	0.00	SAN DIEGO GPS 24
12 EH	893.606	893.606		0.000	0.00	0.00	0.0181	0.00	SAN DIEGO GPS 31

13	EH	385.971	385.971		0.000	0.00	0.00	0.0166	0.00	SAN DIEGO GPS 32
14	EH	189.437	189.437		0.000	0.00	0.00	0.0170	0.00	SAN DIEGO GPS 33
15	EH	791.844	791.844		0.000	0.00	0.00	0.0172	0.00	SAN DIEGO GPS 34
16	EH	1203.458	1203.458		0.000	0.00	0.00	0.0171	0.00	SAN DIEGO GPS 35
17	EH	319.538	319.538		0.000	0.00	0.00	0.0180	0.00	YUNG
18	LA	32 34 40.82082N	32 34 40.82082N	0.00000	0.000	0.00	0.00	1.8972	0.00	SAN DIEGO GPS 24
19	LO	117 4 4.07350W	117 4 4.07350W	0.00000	0.000	0.00	0.00	1.6034	0.00	SAN DIEGO GPS 24
20	LA	33 9 35.33055N	33 9 35.33055N	0.00000	0.000	0.00	0.00	1.9149	0.00	HPGN CA 11 09
21	LO	116 14 49.23165W	116 14 49.23165W	0.00000	0.000	0.00	0.00	1.5930	0.00	HPGN CA 11 09

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
22	DX	-54996.4830	-54996.4760		-0.0070	0.00	-1.49	0.0047		MONUMENT PEAK NCMN 7274
23	DY	7577.7866	7577.7790		0.0076	0.01	0.77	0.0067		HPGN CA 11 01
24	DZ	-31094.9724	-31094.9730		0.0006	0.01	0.09	0.0058		
	DN	-35859.8933	-35859.8958		0.0025	0.01				
	DE	-52536.1898	-52536.1802		-0.0096	0.00				
	DU	-1717.5883	-1717.5855		-0.0028	-0.01				
25	DX	-11750.1567	-11750.1490		-0.0077	0.00	-1.68	0.0046		MONUMENT PEAK NCMN 7274
26	DY	-12254.4708	-12254.4590		-0.0118	0.01	-1.19	0.0065		HPGN CA 11 02
27	DZ	-27179.2293	-27179.2400		0.0107	0.01	1.60	0.0055		
	DN	-31625.5218	-31625.5232		0.0014	0.01				
	DE	-5061.9001	-5061.8985		-0.0017	0.00				
	DU	-1073.4455	-1073.4631		0.0176	-0.01				
28	DX	-32472.9694	-32472.9690		-0.0004	0.00	-0.09	0.0060		MONUMENT PEAK NCMN 7274
29	DY	14441.5559	14441.5630		-0.0071	0.01	-0.72	0.0074		HPGN CA 11 06
30	DZ	-5198.9554	-5198.9670		0.0116	0.01	1.69	0.0059		
	DN	-5253.9317	-5253.9379		0.0061	0.01				
	DE	-35501.8271	-35501.8300		0.0028	0.00				
	DU	-1448.4082	-1448.4200		0.0118	-0.01				
31	DX	-64057.8562	-64057.8550		-0.0012	0.00	-0.25	0.0045		MONUMENT PEAK NCMN 7274
32	DY	50201.5133	50201.5000		0.0133	0.01	1.35	0.0063		HPGN CA 11 07
33	DZ	21143.4984	21143.4940		0.0044	0.01	0.64	0.0057		
	DN	26369.3275	26369.3176		0.0099	0.01				
	DE	-79825.7055	-79825.6984		-0.0071	0.00				
	DU	-1778.6821	-1778.6749		-0.0071	-0.01				
34	DX	-12973.8353	-12973.8350		-0.0003	0.00	-0.08	0.0045		MONUMENT PEAK NCMN 7274
35	DY	30559.2206	30559.2180		0.0026	0.01	0.28	0.0065		HPGN CA 11 08
36	DZ	31251.2759	31251.2720		0.0039	0.01	0.64	0.0058		
	DN	37938.9005	37938.8960		0.0045	0.01				
	DE	-25268.0236	-25268.0221		-0.0014	0.00				
	DU	-997.7102	-997.7105		0.0004	-0.01				
37	DX	-29287.4190	-29287.4230		0.0040	0.00	0.86	0.0065		MONUMENT PEAK NCMN 7274
38	DY	44950.1376	44950.1460		-0.0084	0.01	-0.86	0.0082		BOUCHER 2
39	DZ	41044.2988	41044.2790		0.0198	0.01	3.00	0.0064		
	DN	49139.9636	49139.9501		0.0135	0.01				
	DE	-46347.8364	-46347.8437		0.0073	0.00				
	DU	-210.4474	-210.4630		0.0156	-0.01				
40	DX	50688.2924	50688.3190		-0.0266	0.00	-5.91	0.0049		MONUMENT PEAK NCMN 7274
41	DY	-29897.5852	-29897.5360		-0.0492	0.01	-5.07	0.0068		OCOTILLO NCMN 7270
42	DZ	-10491.2628	-10491.3020		0.0392	0.01	5.88	0.0056		
	DN	-11276.2843	-11276.2869		0.0026	0.01				
	DE	58673.3557	58673.3580		-0.0023	0.00				

	DU	-1875.6127	-1875.6810		0.0683	-0.01				

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0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
43	DX	-42536.5332	-42536.5420		0.0088	0.00	2.07	0.0047		MONUMENT PEAK NCMN 7274
44	DY	2596.0716	2596.0590		0.0126	0.01	1.38	0.0065		SANDIE NASA 1976
45	DZ	-27611.2592	-27611.2510		-0.0082	0.01	-1.33	0.0055		
	DN	-32281.6850	-32281.6863		0.0013	0.01				
	DE	-39187.3402	-39187.3425		0.0022	0.00				
	DU	-850.3289	-850.3117		-0.0172	-0.01				
46	DX	-80985.8343	-80985.8360		0.0017	0.00	0.35	0.0046		MONUMENT PEAK NCMN 7274
47	DY	75886.5889	75886.5850		0.0039	0.01	0.40	0.0064		SAN DIEGO GPS 01
48	DZ	43905.7090	43905.6970		0.0120	0.01	1.79	0.0057		
	DN	53634.3489	53634.3366		0.0123	0.01				
	DE	-106607.4535	-106607.4533		-0.0003	0.00				
	DU	-1843.4972	-1843.5002		0.0030	-0.01				
49	DX	-55504.5321	-55504.5480		0.0159	0.00	3.65	0.0046		MONUMENT PEAK NCMN 7274
50	DY	61129.7032	61129.6560		0.0472	0.01	5.17	0.0064		SAN DIEGO GPS 02
51	DZ	42169.4483	42169.4630		-0.0147	0.01	-2.33	0.0057		
	DN	51431.0257	51431.0110		0.0146	0.01				
	DE	-77123.0873	-77123.0802		-0.0071	0.00				
	DU	-1653.8035	-1653.7542		-0.0493	-0.01				
52	DX	-48640.4348	-48640.4340		-0.0008	0.00	-0.18	0.0047		MONUMENT PEAK NCMN 7274
53	DY	56095.6203	56095.6100		0.0103	0.01	1.04	0.0065		SAN DIEGO GPS 03
54	DZ	39907.8916	39907.8770		0.0146	0.01	2.15	0.0058		
	DN	48804.8912	48804.8742		0.0170	0.01				
	DE	-68703.4989	-68703.4935		-0.0054	0.00				
	DU	-1778.2460	-1778.2467		0.0006	-0.01				
55	DX	-34789.2861	-34789.2980		0.0119	0.00	2.78	0.0045		MONUMENT PEAK NCMN 7274
56	DY	33916.7197	33916.6940		0.0257	0.01	2.81	0.0064		SAN DIEGO GPS 12
57	DZ	20329.7210	20329.7270		-0.0060	0.01	-0.97	0.0057		
	DN	25052.1746	25052.1642		0.0104	0.01				
	DE	-46311.6337	-46311.6327		-0.0010	0.00				
	DU	-1247.7977	-1247.7707		-0.0270	-0.01				
58	DX	-9508.7526	-9508.7700		0.0174	0.00	3.68	0.0044		MONUMENT PEAK NCMN 7274
59	DY	17617.1317	17617.0980		0.0337	0.01	3.39	0.0061		SAN DIEGO GPS 15
60	DZ	16668.2467	16668.2610		-0.0143	0.01	-2.13	0.0053		
	DN	20253.4706	20253.4620		0.0086	0.01				
	DE	-16372.5190	-16372.5196		0.0005	0.00				
	DU	-589.6603	-589.6207		-0.0396	-0.01				
61	DX	5452.2568	5452.2440		0.0128	0.01	2.50	0.0050		MONUMENT PEAK NCMN 7274
62	DY	8232.3315	8232.2920		0.0395	0.01	3.63	0.0077		SAN DIEGO GPS 16
63	DZ	13119.3987	13119.4040		-0.0053	0.01	-0.72	0.0068		
	DN	16338.7989	16338.7810		0.0179	0.01				
	DE	1220.4828	1220.4888		-0.0061	0.00				
	DU	-1082.1648	-1082.1275		-0.0373	-0.01				

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0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
64	DX	-61919.9195	-61919.9170		-0.0025	0.00	-0.57	0.0049		MONUMENT PEAK NCMN 7274
65	DY	27960.2085	27960.1990		0.0095	0.01	1.04	0.0068		SAN DIEGO GPS 17
66	DZ	-7781.9175	-7781.9180		0.0005	0.01	0.08	0.0058		
	DN	-8134.3419	-8134.3463		0.0044	0.01				
	DE	-67876.2288	-67876.2223		-0.0065	0.00				
	DU	-1748.7064	-1748.7004		-0.0059	-0.01				
67	DX	-41360.6596	-41360.6710		0.0114	0.00	2.62	0.0045		MONUMENT PEAK NCMN 7274

68	DY	23665.9172	23665.8990	0.0182	0.01	1.99	0.0064	SAN DIEGO GPS 18
69	DZ	983.4629	983.4700	-0.0071	0.01	-1.15	0.0056	
	DN	2225.7483	2225.7427	0.0056	0.01			
	DE	-47582.9481	-47582.9502	0.0021	0.00			
	DU	-1629.7507	-1629.7288	-0.0218	-0.01			
70	DX	-17986.9057	-17986.9270	0.0213	0.00	4.51	0.0046	MONUMENT PEAK NCMN 7274
71	DY	5140.4683	5140.3990	0.0693	0.01	6.96	0.0063	SAN DIEGO GPS 21
72	DZ	-6741.1977	-6741.1620	-0.0357	0.01	-5.29	0.0055	
	DN	-7524.8339	-7524.8427	0.0089	0.01			
	DE	-18389.5082	-18389.4963	-0.0119	0.00			
	DU	-774.4668	-774.3874	-0.0795	-0.01			
73	DX	19255.1498	19255.1540	-0.0042	0.00	-0.98	0.0045	MONUMENT PEAK NCMN 7274
74	DY	-12057.6984	-12057.7100	0.0116	0.01	1.27	0.0065	SAN DIEGO GPS 22
75	DZ	-6371.4548	-6371.4560	0.0032	0.01	0.51	0.0055	
	DN	-6587.6189	-6587.6262	0.0073	0.01			
	DE	22604.4816	22604.4905	-0.0089	0.00			
	DU	-1544.3472	-1544.3417	-0.0055	-0.01			
76	DX	-73656.0297	-73656.0280	-0.0017	0.00	-0.35	0.0049	MONUMENT PEAK NCMN 7274
77	DY	24130.1766	24130.1680	0.0086	0.01	0.85	0.0074	SAN DIEGO GPS 23
78	DZ	-21420.1593	-21420.1580	-0.0013	0.01	-0.19	0.0064	
	DN	-24351.1621	-24351.1648	0.0027	0.01			
	DE	-76617.6195	-76617.6141	-0.0054	0.00			
	DU	-1749.4698	-1749.4633	-0.0065	-0.01			
79	DX	-61772.4926	-61772.4830	-0.0096	0.00	-2.06	0.0045	MONUMENT PEAK NCMN 7274
80	DY	11779.0609	11779.0570	0.0039	0.01	0.40	0.0064	SAN DIEGO GPS 24
81	DZ	-30261.9962	-30261.9970	0.0008	0.01	0.12	0.0055	
	DN	-34800.1989	-34800.1991	0.0002	0.01			
	DE	-60464.6896	-60464.6793	-0.0103	0.00			
	DU	-1828.3877	-1828.3888	0.0011	-0.01			
82	DX	16434.4330	16434.4370	-0.0040	0.01	-0.78	0.0071	MONUMENT PEAK NCMN 7274
83	DY	-24501.0768	-24501.0410	-0.0358	0.01	-3.23	0.0098	SAN DIEGO GPS 31
84	DZ	-24574.5050	-24574.5190	0.0140	0.01	1.99	0.0062	
	DN	-28614.4835	-28614.4769	-0.0066	0.01			
	DE	25585.4576	25585.4454	0.0122	0.00			
	DU	-946.2251	-946.2611	0.0360	-0.01			

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
85	DX	-39324.4531	-39324.4470		-0.0061	0.00	-1.29	0.0044		MONUMENT PEAK NCMN 7274
86	DY	6397.3539	6397.3670		-0.0131	0.01	-1.32	0.0062		SAN DIEGO GPS 33
87	DZ	-21534.2624	-21534.2750		0.0126	0.01	1.88	0.0054		
	DN	-24550.4088	-24550.4116		0.0028	0.01				
	DE	-38021.2644	-38021.2648		0.0004	0.00				
	DU	-1650.4804	-1650.4994		0.0190	-0.01				
88	DX	-38279.4396	-38279.4440		0.0044	0.00	0.96	0.0045		MONUMENT PEAK NCMN 7274
89	DY	30679.0539	30679.0460		0.0079	0.01	0.79	0.0064		SAN DIEGO GPS 32
90	DZ	13094.3539	13094.3520		0.0019	0.01	0.28	0.0056		
	DN	16550.1464	16550.1399		0.0065	0.01				
	DE	-47978.7577	-47978.7581		0.0004	0.00				
	DU	-1453.7558	-1453.7493		-0.0065	-0.01				
91	DX	-28382.8194	-28382.8590		0.0396	0.00	8.41	0.0044		MONUMENT PEAK NCMN 7274
92	DY	42464.4188	42464.3550		0.0638	0.01	6.44	0.0061		SAN DIEGO GPS 34
93	DZ	36770.1544	36770.1880		-0.0336	0.01	-4.93	0.0055		
	DN	44572.3611	44572.3484		0.0127	0.01				
	DE	-44419.1672	-44419.1740		0.0068	0.00				
	DU	-1047.7427	-1047.6616		-0.0810	-0.01				
94	DX	-11569.0860	-11569.1010		0.0150	0.01	2.96	0.0045		MONUMENT PEAK NCMN 7274
95	DY	7893.3907	7893.3530		0.0377	0.01	3.51	0.0064		SAN DIEGO GPS 35
96	DZ	1769.3657	1769.3760		-0.0103	0.01	-1.41	0.0056		
	DN	2519.1306	2519.1172		0.0133	0.01				
	DE	-13875.4848	-13875.4813		-0.0034	0.00				

	DU	-636.3386	-636.2991		-0.0395	-0.01				
97	DX	-25482.2333	-25482.2370		0.0037	0.00	0.78	0.0045		MONUMENT PEAK NCMN 7274
98	DY	-6761.2910	-6761.3180		0.0270	0.01	2.72	0.0064		JUNCTION CADH AZ MK 1974
99	DZ	-29533.9709	-29533.9580		-0.0129	0.01	-1.93	0.0055		
	DN	-34269.1308	-34269.1338		0.0030	0.01				
	DE	-19779.4464	-19779.4376		-0.0088	0.00				
	DU	-1309.5366	-1309.5080		-0.0287	-0.01				
100	DX	-49772.4555	-49772.4610		0.0055	0.00	1.27	0.0045		MONUMENT PEAK NCMN 7274
101	DY	40764.1896	40764.1610		0.0286	0.01	3.14	0.0064		LOMAX
102	DZ	18634.3331	18634.3400		-0.0069	0.01	-1.11	0.0056		
	DN	23247.2046	23247.1951		0.0095	0.01				
	DE	-62795.7808	-62795.7729		-0.0080	0.00				
	DU	-1585.0043	-1584.9770		-0.0273	-0.01				
103	DX	-42014.1670	-42014.1670		0.0000	0.00	-0.01	0.0044		MONUMENT PEAK NCMN 7274
104	DY	21308.3252	21308.3250		0.0002	0.01	0.02	0.0061		FAR
105	DZ	-2790.0364	-2790.0340		-0.0024	0.01	-0.39	0.0053		
	DN	-2245.6182	-2245.6163		-0.0019	0.01				
	DE	-47108.4148	-47108.4147		-0.0001	0.00				
	DU	-1665.4467	-1665.4453		-0.0014	-0.01				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION / TO STATION(S)
106	DX	21884.1444	21884.1450		-0.0006	0.00	-0.12	0.0045		MONUMENT PEAK NCMN 7274
107	DY	18033.1167	18033.1050		0.0117	0.01	1.19	0.0063		11 AAR
108	DZ	36616.7280	36616.7280		0.0000	0.01	-0.01	0.0055		
	DN	44804.7107	44804.7052		0.0055	0.01				
	DE	11601.4890	11601.4947		-0.0057	0.00				
	DU	-1684.3952	-1684.3866		-0.0086	-0.01				
109	DX	-70030.5733	-70030.5840		0.0107	0.00	2.46	0.0045		MONUMENT PEAK NCMN 7274
110	DY	79735.7485	79735.7290		0.0195	0.01	2.13	0.0064		BELARDES
111	DZ	57963.9743	57963.9720		0.0023	0.01	0.36	0.0057		
	DN	70041.0943	70041.0803		0.0141	0.01				
	DE	-98563.5695	-98563.5702		0.0007	0.00				
	DU	-1166.6032	-1166.5859		-0.0173	-0.01				
112	DX	-44825.6381	-44825.6560		0.0179	0.00	3.82	0.0045		MONUMENT PEAK NCMN 7274
113	DY	60648.9994	60648.9490		0.0504	0.01	5.12	0.0065		YUNG
114	DZ	49168.8290	49168.8430		-0.0140	0.01	-2.10	0.0056	69.96	
	DN	59727.4704	59727.4531		0.0173	0.01				
	DE	-67346.3630	-67346.3563		-0.0067	0.00				
	DU	-1519.6620	-1519.6100		-0.0520	-0.01				
115	DX	-54996.4830	-54996.4870		0.0040	0.00	0.87	0.0046		MONUMENT PEAK NCMN 7274
116	DY	7577.7866	7577.7800		0.0066	0.01	0.67	0.0065		HPGN CA 11 01
117	DZ	-31094.9724	-31094.9680		-0.0044	0.01	-0.66	0.0057		
	DN	-35859.8933	-35859.8937		0.0005	0.01				
	DE	-52536.1898	-52536.1905		0.0006	0.00				
	DU	-1717.5883	-1717.5794		-0.0089	-0.01				
118	DX	-11750.1567	-11750.1390		-0.0177	0.00	-4.15	0.0044		MONUMENT PEAK NCMN 7274
119	DY	-12254.4708	-12254.4410		-0.0298	0.01	-3.31	0.0062		HPGN CA 11 02
120	DZ	-27179.2293	-27179.2440		0.0147	0.01	2.39	0.0052		
	DN	-31625.5218	-31625.5154		-0.0064	0.01				
	DE	-5061.9001	-5061.8975		-0.0026	0.00				
	DU	-1073.4455	-1073.4826		0.0370	-0.01				
121	DX	-32472.9694	-32472.9650		-0.0044	0.00	-1.15	0.0046		MONUMENT PEAK NCMN 7274
122	DY	14441.5559	14441.5730		-0.0171	0.01	-2.12	0.0063		HPGN CA 11 06
123	DZ	-5198.9554	-5198.9670		0.0116	0.01	2.10	0.0053		
	DN	-5253.9317	-5253.9321		0.0003	0.01				
	DE	-35501.8271	-35501.8309		0.0037	0.00				
	DU	-1448.4082	-1448.4291		0.0208	0.00				
124	DX	-64057.8562	-64057.8190		-0.0372	0.00	-8.73	0.0044		MONUMENT PEAK NCMN 7274
125	DY	50201.5133	50201.5880		-0.0747	0.01	-8.30	0.0061		HPGN CA 11 07

126	DZ	21143.4984	21143.4480		0.0504	0.01	8.22	0.0054	
	DN	26369.3275	26369.3307		-0.0032	0.01			
	DE	-79825.7055	-79825.7061		0.0006	0.00			
	DU	-1778.6821	-1778.7795		0.0974	-0.01			

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
127	DX	-12973.8353	-12973.8180		-0.0173	0.00	-4.45	0.0044		MONUMENT PEAK NCMN 7274
128	DY	30559.2206	30559.2330		-0.0124	0.01	-1.53	0.0063		HPGN CA 11 08
129	DZ	31251.2759	31251.2690		0.0069	0.01	1.25	0.0055		
	DN	37938.9005	37938.9050		-0.0045	0.01				
	DE	-25268.0236	-25268.0136		-0.0099	0.00				
	DU	-997.7102	-997.7298		0.0196	0.00				
130	DX	22519.7728	22519.7960		-0.0232	0.00	-6.34	0.0051		MONUMENT PEAK NCMN 7274
131	DY	8467.1941	8467.2300		-0.0359	0.01	-4.69	0.0071		HPGN CA 11 09
132	DZ	24036.1453	24036.1270		0.0183	0.01	3.51	0.0059		
	DN	29733.1386	29733.1463		-0.0077	0.01				
	DE	16426.3946	16426.3995		-0.0049	0.00				
	DU	-1638.2476	-1638.2932		0.0456	0.00				
133	DX	-29287.4190	-29287.4140		-0.0050	0.00	-1.06	0.0065		MONUMENT PEAK NCMN 7274
134	DY	44950.1376	44950.1520		-0.0144	0.01	-1.52	0.0079		BOUCHER 2
135	DZ	41044.2988	41044.3090		-0.0102	0.01	-1.55	0.0062		
	DN	49139.9636	49139.9804		-0.0168	0.01				
	DE	-46347.8364	-46347.8384		0.0020	0.00				
	DU	-210.4474	-210.4545		0.0071	-0.01				
136	DX	50688.2924	50688.3000		-0.0076	0.00	-1.84	0.0047		MONUMENT PEAK NCMN 7274
137	DY	-29897.5852	-29897.5420		-0.0432	0.01	-4.91	0.0066		OCOTILLO NCMN 7270
138	DZ	-10491.2628	-10491.2860		0.0232	0.01	3.88	0.0053		
	DN	-11276.2843	-11276.2809		-0.0034	0.01				
	DE	58673.3557	58673.3435		0.0122	0.00				
	DU	-1875.6127	-1875.6607		0.0480	0.00				
139	DX	-42536.5332	-42536.5210		-0.0122	0.00	-3.14	0.0044		MONUMENT PEAK NCMN 7274
140	DY	2596.0716	2596.0990		-0.0274	0.01	-3.36	0.0063		SANDIE NASA 1976
141	DZ	-27611.2592	-27611.2790		0.0198	0.01	3.54	0.0053		
	DN	-32281.6850	-32281.6854		0.0004	0.01				
	DE	-39187.3402	-39187.3416		0.0014	0.00				
	DU	-850.3289	-850.3648		0.0359	0.00				
142	DX	-80985.8343	-80985.8070		-0.0273	0.00	-6.38	0.0045		MONUMENT PEAK NCMN 7274
143	DY	75886.5889	75886.6390		-0.0501	0.01	-5.66	0.0062		SAN DIEGO GPS 01
144	DZ	43905.7090	43905.6770		0.0320	0.01	5.30	0.0054		
	DN	53634.3489	53634.3533		-0.0044	0.01				
	DE	-106607.4535	-106607.4519		-0.0016	0.00				
	DU	-1843.4972	-1843.5624		0.0653	0.00				
145	DX	-55504.5321	-55504.5140		-0.0181	0.00	-4.68	0.0044		MONUMENT PEAK NCMN 7274
146	DY	61129.7032	61129.7280		-0.0248	0.01	-3.05	0.0062		SAN DIEGO GPS 02
147	DZ	42169.4483	42169.4360		0.0123	0.01	2.22	0.0054		
	DN	51431.0257	51431.0319		-0.0062	0.01				
	DE	-77123.0873	-77123.0824		-0.0049	0.00				
	DU	-1653.8035	-1653.8356		0.0322	0.00				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
148	DX	-48640.4348	-48640.4250		-0.0098	0.00	-2.09	0.0046		MONUMENT PEAK NCMN 7274
149	DY	56095.6203	56095.6390		-0.0187	0.01	-1.92	0.0063		SAN DIEGO GPS 03
150	DZ	39907.8916	39907.8850		0.0066	0.01	0.97	0.0055		
	DN	48804.8912	48804.8972		-0.0060	0.01				

	DE	-68703.4989	-68703.4986	-0.0003	0.00			
	DU	-1778.2460	-1778.2674	0.0213	-0.01			
151	DX	-4312.3887	-4312.3750	-0.0137	0.00	-3.75	0.0049	MONUMENT PEAK NCMN 7274
152	DY	36163.3475	36163.3640	-0.0165	0.01	-2.15	0.0069	SAN DIEGO GPS 07
153	DZ	45842.9874	45842.9820	0.0054	0.01	1.03	0.0060	
	DN	55021.2589	55021.2658	-0.0069	0.01			
	DE	-20011.2534	-20011.2485	-0.0049	0.00			
	DU	-417.9650	-417.9855	0.0205	0.00			
154	DX	-34789.2861	-34789.2750	-0.0111	0.00	-2.86	0.0044	MONUMENT PEAK NCMN 7274
155	DY	33916.7197	33916.7390	-0.0193	0.01	-2.36	0.0062	SAN DIEGO GPS 12
156	DZ	20329.7210	20329.7120	0.0090	0.01	1.61	0.0054	
	DN	25052.1746	25052.1791	-0.0046	0.01			
	DE	-46311.6337	-46311.6324	-0.0013	0.00			
	DU	-1247.7977	-1247.8212	0.0235	0.00			
157	DX	-9508.7526	-9508.7430	-0.0096	0.00	-2.24	0.0044	MONUMENT PEAK NCMN 7274
158	DY	17617.1317	17617.1380	-0.0063	0.01	-0.70	0.0061	SAN DIEGO GPS 15
159	DZ	16668.2467	16668.2430	0.0037	0.01	0.59	0.0052	
	DN	20253.4706	20253.4730	-0.0023	0.01			
	DE	-16372.5190	-16372.5133	-0.0058	0.00			
	DU	-589.6603	-589.6706	0.0103	-0.01			
160	DX	5452.2568	5452.2610	-0.0042	0.00	-1.09	0.0046	MONUMENT PEAK NCMN 7274
161	DY	8232.3315	8232.3400	-0.0085	0.01	-1.07	0.0065	SAN DIEGO GPS 16
162	DZ	13119.3987	13119.3950	0.0037	0.01	0.68	0.0056	
	DN	16338.7989	16338.8010	-0.0020	0.01			
	DE	1220.4828	1220.4827	0.0001	0.00			
	DU	-1082.1648	-1082.1748	0.0100	0.00			
163	DX	-61919.9195	-61919.9100	-0.0095	0.00	-2.39	0.0047	MONUMENT PEAK NCMN 7274
164	DY	27960.2085	27960.2270	-0.0185	0.01	-2.27	0.0064	SAN DIEGO GPS 17
165	DZ	-7781.9175	-7781.9300	0.0125	0.01	2.24	0.0055	
	DN	-8134.3419	-8134.3411	-0.0008	0.01			
	DE	-67876.2288	-67876.2287	-0.0001	0.00			
	DU	-1748.7064	-1748.7306	0.0242	0.00			
166	DX	-41360.6596	-41360.6480	-0.0116	0.00	-2.99	0.0044	MONUMENT PEAK NCMN 7274
167	DY	23665.9172	23665.9340	-0.0168	0.01	-2.06	0.0061	SAN DIEGO GPS 18
168	DZ	983.4629	983.4510	0.0119	0.01	2.13	0.0054	
	DN	2225.7483	2225.7493	-0.0010	0.01			
	DE	-47582.9481	-47582.9453	-0.0028	0.00			
	DU	-1629.7507	-1629.7741	0.0234	0.00			

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
169	DX	-17986.9057	-17986.8990		-0.0067	0.00	-1.55	0.0044		MONUMENT PEAK NCMN 7274
170	DY	5140.4683	5140.4830		-0.0147	0.01	-1.62	0.0061		SAN DIEGO GPS 21
171	DZ	-6741.1977	-6741.2010		0.0033	0.01	0.54	0.0053		
	DN	-7524.8339	-7524.8279		-0.0059	0.01				
	DE	-18389.5082	-18389.5088		0.0006	0.00				
	DU	-774.4668	-774.4822		0.0153	-0.01				
172	DX	19255.1498	19255.1570		-0.0072	0.00	-1.90	0.0044		MONUMENT PEAK NCMN 7274
173	DY	-12057.6984	-12057.6800		-0.0184	0.01	-2.26	0.0063		SAN DIEGO GPS 22
174	DZ	-6371.4548	-6371.4660		0.0112	0.01	2.00	0.0053		
	DN	-6587.6189	-6587.6176		-0.0013	0.01				
	DE	22604.4816	22604.4799		0.0017	0.00				
	DU	-1544.3472	-1544.3698		0.0226	0.00				
175	DX	-73656.0297	-73656.0190		-0.0107	0.00	-2.79	0.0045		MONUMENT PEAK NCMN 7274
176	DY	24130.1766	24130.1940		-0.0174	0.01	-2.16	0.0064		SAN DIEGO GPS 23
177	DZ	-21420.1593	-21420.1700		0.0107	0.01	1.94	0.0055		
	DN	-24351.1621	-24351.1601		-0.0020	0.01				
	DE	-76617.6195	-76617.6178		-0.0017	0.00				
	DU	-1749.4698	-1749.4927		0.0229	0.00				
178	DX	-61772.4926	-61772.5000		0.0074	0.00	1.76	0.0044		MONUMENT PEAK NCMN 7274
179	DY	11779.0609	11779.0500		0.0109	0.01	1.23	0.0062		SAN DIEGO GPS 24

180	DZ	-30261.9962	-30261.9910	-0.0052	0.01	-0.86	0.0053		
	DN	-34800.1989	-34800.2016	0.0027	0.01				
	DE	-60464.6896	-60464.6913	0.0017	0.00				
	DU	-1828.3877	-1828.3739	-0.0138	0.00				
181	DX	16434.4330	16434.4450	-0.0120	0.00	-2.91	0.0047		MONUMENT PEAK NCMN 7274
182	DY	-24501.0768	-24501.0440	-0.0328	0.01	-3.66	0.0067		SAN DIEGO GPS 31
183	DZ	-24574.5050	-24574.5210	0.0160	0.01	2.61	0.0054		
	DN	-28614.4835	-28614.4781	-0.0054	0.01				
	DE	25585.4576	25585.4539	0.0037	0.00				
	DU	-946.2251	-946.2629	0.0378	0.00				
184	DX	-39324.4531	-39324.4440	-0.0091	0.00	-2.13	0.0043		MONUMENT PEAK NCMN 7274
185	DY	6397.3539	6397.3760	-0.0221	0.01	-2.45	0.0060		SAN DIEGO GPS 33
186	DZ	-21534.2624	-21534.2740	0.0116	0.01	1.89	0.0052		
	DN	-24550.4088	-24550.4056	-0.0032	0.01				
	DE	-38021.2644	-38021.2662	0.0018	0.00				
	DU	-1650.4804	-1650.5067	0.0263	-0.01				
187	DX	-38279.4396	-38279.4190	-0.0206	0.00	-4.78	0.0043		MONUMENT PEAK NCMN 7274
188	DY	30679.0539	30679.0950	-0.0411	0.01	-4.53	0.0061		SAN DIEGO GPS 32
189	DZ	13094.3539	13094.3260	0.0279	0.01	4.51	0.0053		
	DN	16550.1464	16550.1480	-0.0016	0.01				
	DE	-47978.7577	-47978.7578	0.0001	0.00				
	DU	-1453.7558	-1453.8096	0.0538	-0.01				

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
190	DX	-28382.8194	-28382.8060		-0.0134	0.00	-3.13	0.0043		MONUMENT PEAK NCMN 7274
191	DY	42464.4188	42464.4230		-0.0042	0.01	-0.46	0.0060		SAN DIEGO GPS 34
192	DZ	36770.1544	36770.1520		0.0024	0.01	0.39	0.0052		
	DN	44572.3611	44572.3644		-0.0033	0.01				
	DE	-44419.1672	-44419.1571		-0.0101	0.00				
	DU	-1047.7427	-1047.7521		0.0095	-0.01				
193	DX	-11569.0860	-11569.0820		-0.0040	0.00	-0.94	0.0044		MONUMENT PEAK NCMN 7274
194	DY	7893.3907	7893.3890		0.0017	0.01	0.19	0.0061		SAN DIEGO GPS 35
195	DZ	1769.3657	1769.3740		-0.0083	0.01	-1.34	0.0053		
	DN	2519.1306	2519.1377		-0.0071	0.01				
	DE	-13875.4848	-13875.4804		-0.0044	0.00				
	DU	-636.3386	-636.3344		-0.0042	-0.01				
196	DX	-25482.2333	-25482.2350		0.0017	0.00	0.39	0.0044		MONUMENT PEAK NCMN 7274
197	DY	-6761.2910	-6761.3050		0.0140	0.01	1.55	0.0061		JUNCTION CADH AZ MK 1974
198	DZ	-29533.9709	-29533.9590		-0.0119	0.01	-1.95	0.0053		
	DN	-34269.1308	-34269.1279		-0.0029	0.01				
	DE	-19779.4464	-19779.4417		-0.0048	0.00				
	DU	-1309.5366	-1309.5191		-0.0176	-0.01				
199	DX	-49772.4555	-49772.4400		-0.0155	0.00	-4.00	0.0044		MONUMENT PEAK NCMN 7274
200	DY	40764.1896	40764.2090		-0.0194	0.01	-2.37	0.0062		LOMAX
201	DZ	18634.3331	18634.3190		0.0141	0.01	2.53	0.0053		
	DN	23247.2046	23247.2060		-0.0014	0.01				
	DE	-62795.7808	-62795.7757		-0.0051	0.00				
	DU	-1585.0043	-1585.0323		0.0280	0.00				
202	DX	-42014.1670	-42014.1630		-0.0040	0.00	-1.04	0.0043		MONUMENT PEAK NCMN 7274
203	DY	21308.3252	21308.3370		-0.0118	0.01	-1.45	0.0061		FAR
204	DZ	-2790.0364	-2790.0450		0.0086	0.01	1.54	0.0052		
	DN	-2245.6182	-2245.6187		0.0005	0.01				
	DE	-47108.4148	-47108.4165		0.0017	0.00				
	DU	-1665.4467	-1665.4618		0.0150	0.00				
205	DX	21884.1444	21884.1480		-0.0036	0.00	-0.85	0.0044		MONUMENT PEAK NCMN 7274
206	DY	18033.1167	18033.1150		0.0017	0.01	0.19	0.0061		11 AAR
207	DZ	36616.7280	36616.7240		0.0040	0.01	0.65	0.0052		
	DN	44804.7107	44804.7075		0.0033	0.01				
	DE	11601.4890	11601.4930		-0.0039	0.00				
	DU	-1684.3952	-1684.3975		0.0022	0.00				

No.	Comp.	Computed	Observed	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	Station
208	DX	-70030.5733	-70030.5540		-0.0193	0.00	-4.99	0.0044		MONUMENT PEAK NCMN 7274
209	DY	79735.7485	79735.7790		-0.0305	0.01	-3.74	0.0062		BELARDES
210	DZ	57963.9743	57963.9550		0.0193	0.01	3.40	0.0055		
	DN	70041.0943	70041.0979		-0.0036	0.01				
	DE	-98563.5695	-98563.5661		-0.0034	0.00				
	DU	-1166.6032	-1166.6439		0.0407	0.00				

0NORMALIZED RESIDUALS

No.	Comp.	COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION / TO STATION(S)
211	DX	-44825.6381	-44825.6240		-0.0141	0.00	-3.34	0.0044		MONUMENT PEAK NCMN 7274
212	DY	60648.9994	60649.0160		-0.0166	0.01	-1.86	0.0063		YUNG
213	DZ	49168.8290	49168.8240		0.0050	0.01	0.81	0.0055	68.15	
	DN	59727.4704	59727.4778		-0.0074	0.01				
	DE	-67346.3630	-67346.3579		-0.0051	0.00				
	DU	-1519.6620	-1519.6825		0.0205	0.00				
214	DX	-20207.1968	-20207.2020		0.0052	0.00	1.20	0.0045		SAN DIEGO GPS 12
215	DY	-26338.9331	-26338.9310		-0.0021	0.01	-0.24	0.0064		HPGN CA 11 01
216	DZ	-51424.6934	-51424.6960		0.0026	0.01	0.43	0.0056		
	DN	-60905.1809	-60905.1834		0.0024	0.01				
	DE	-6075.1792	-6075.1848		0.0056	0.00				
	DU	-469.4949	-469.4959		0.0010	-0.01				
217	DX	23039.1294	23039.1260		0.0034	0.00	0.80	0.0044		SAN DIEGO GPS 12
218	DY	-46171.1906	-46171.1900		-0.0006	0.01	-0.06	0.0062		HPGN CA 11 02
219	DZ	-47508.9503	-47508.9590		0.0087	0.01	1.41	0.0052		
	DN	-56672.2882	-56672.2961		0.0079	0.01				
	DE	41326.7717	41326.7684		0.0033	0.00				
	DU	174.2763	174.2725		0.0039	-0.01				
220	DX	2316.3167	2316.3180		-0.0013	0.00	-0.32	0.0046		SAN DIEGO GPS 12
221	DY	-19475.1639	-19475.1730		0.0091	0.01	1.13	0.0063		HPGN CA 11 06
222	DZ	-25528.6764	-25528.6700		-0.0064	0.01	-1.16	0.0053		
	DN	-30302.7986	-30302.7974		-0.0013	0.01				
	DE	10865.5809	10865.5862		-0.0053	0.00				
	DU	-200.4917	-200.4818		-0.0098	0.00				
223	DX	-29268.5700	-29268.5500		-0.0200	0.00	-4.58	0.0044		SAN DIEGO GPS 12
224	DY	16284.7936	16284.8510		-0.0574	0.01	-6.34	0.0062		HPGN CA 11 07
225	DZ	813.7774	813.7450		0.0324	0.01	5.26	0.0054		
	DN	1318.2350	1318.2408		-0.0058	0.01				
	DE	-33473.6625	-33473.6708		0.0083	0.00				
	DU	-531.1351	-531.2032		0.0681	-0.01				
226	DX	21815.4508	21815.4410		0.0098	0.00	2.52	0.0044		SAN DIEGO GPS 12
227	DY	-3357.4992	-3357.4980		-0.0012	0.01	-0.14	0.0063		HPGN CA 11 08
228	DZ	10921.5550	10921.5520		0.0030	0.01	0.53	0.0056		
	DN	12884.9565	12884.9522		0.0043	0.01				
	DE	20985.2894	20985.2801		0.0093	0.00				
	DU	250.1619	250.1631		-0.0012	0.00				
229	DX	57309.0589	57309.0480		0.0109	0.00	3.00	0.0051		SAN DIEGO GPS 12
230	DY	-25449.5256	-25449.5380		0.0124	0.01	1.62	0.0071		HPGN CA 11 09
231	DZ	3706.4244	3706.4290		-0.0046	0.01	-0.89	0.0059		
	DN	4681.1940	4681.1891		0.0049	0.01				
	DE	62639.2708	62639.2666		0.0042	0.00				
	DU	-390.3127	-390.2967		-0.0159	0.00				

0NORMALIZED RESIDUALS

No.	Comp.	COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION / TO STATION(S)
232	DX	5501.8671	5501.8720		-0.0049	0.00	-1.15	0.0064		SAN DIEGO GPS 12

233	DY	11033.4179	11033.4040	0.0139	0.01	1.60	0.0079	BOUCHER 2
234	DZ	20714.5778	20714.5740	0.0038	0.01	0.63	0.0062	
	DN	24083.5359	24083.5271	0.0088	0.01			
	DE	-89.3901	-89.3795	-0.0107	0.00			
	DU	1037.2536	1037.2600	-0.0064	0.00			
235	DX	34789.2861	34789.2940	-0.0079	0.00	-2.02	0.0044	SAN DIEGO GPS 12
236	DY	-33916.7197	-33916.7070	-0.0127	0.01	-1.56	0.0062	MONUMENT PEAK NCMN 7274
237	DZ	-20329.7210	-20329.7350	0.0140	0.01	2.51	0.0053	
	DN	-25052.1746	-25052.1782	0.0036	0.01			
	DE	46311.6337	46311.6350	-0.0013	0.00			
	DU	1247.7977	1247.7776	0.0201	0.00			
238	DX	85477.5785	85477.6040	-0.0255	0.00	-6.15	0.0046	SAN DIEGO GPS 12
239	DY	-63814.3050	-63814.2690	-0.0360	0.01	-4.08	0.0066	OCOTILLO NCMN 7270
240	DZ	-30820.9838	-30821.0140	0.0302	0.01	5.04	0.0053	
	DN	-36323.2334	-36323.2351	0.0017	0.01			
	DE	104923.0327	104923.0396	-0.0069	0.00			
	DU	-628.4118	-628.4648	0.0530	0.00			
241	DX	-7747.2470	-7747.2430	-0.0040	0.00	-1.02	0.0044	SAN DIEGO GPS 12
242	DY	-31320.6482	-31320.6510	0.0028	0.01	0.35	0.0063	SANDIE NASA 1976
243	DZ	-47940.9802	-47940.9830	0.0028	0.01	0.50	0.0053	
	DN	-57329.0023	-57329.0051	0.0027	0.01			
	DE	7250.3636	7250.3685	-0.0049	0.00			
	DU	397.6702	397.6693	0.0009	0.00			
244	DX	-46196.5482	-46196.5480	-0.0002	0.00	-0.04	0.0045	SAN DIEGO GPS 12
245	DY	41969.8691	41969.8720	-0.0029	0.01	-0.32	0.0062	SAN DIEGO GPS 01
246	DZ	23575.9880	23575.9910	-0.0030	0.01	-0.49	0.0055	
	DN	28581.2855	28581.2894	-0.0039	0.01			
	DE	-60284.0966	-60284.0978	0.0011	0.00			
	DU	-596.6632	-596.6638	0.0006	0.00			
247	DX	-20715.2460	-20715.2440	-0.0020	0.00	-0.49	0.0044	SAN DIEGO GPS 12
248	DY	27212.9834	27213.0090	-0.0256	0.01	-3.11	0.0062	SAN DIEGO GPS 02
249	DZ	21839.7274	21839.7150	0.0124	0.01	2.21	0.0054	
	DN	26377.4781	26377.4807	-0.0026	0.01			
	DE	-30833.5044	-30833.5143	0.0099	0.00			
	DU	-406.4895	-406.5160	0.0266	0.00			
250	DX	-13851.1487	-13851.1320	-0.0167	0.00	-3.83	0.0045	SAN DIEGO GPS 12
251	DY	22178.9005	22178.9450	-0.0445	0.01	-4.98	0.0061	SAN DIEGO GPS 03
252	DZ	19578.1706	19578.1460	0.0246	0.01	4.00	0.0053	
	DN	23751.7468	23751.7521	-0.0053	0.01			
	DE	-22419.5336	-22419.5389	0.0053	0.00			
	DU	-530.8029	-530.8558	0.0530	0.00			

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
253	DX	30476.8974	30476.8950		0.0024	0.00	0.66	0.0049		SAN DIEGO GPS 12
254	DY	2246.6277	2246.6350		-0.0073	0.01	-0.94	0.0069		SAN DIEGO GPS 07
255	DZ	25513.2664	25513.2590		0.0074	0.01	1.41	0.0060		
	DN	29964.5632	29964.5600		0.0032	0.01				
	DE	26196.4029	26196.3975		0.0054	0.00				
	DU	829.9412	829.9326		0.0086	0.00				
256	DX	25280.5336	25280.5220		0.0116	0.00	2.70	0.0044		SAN DIEGO GPS 12
257	DY	-16299.5880	-16299.6080		0.0200	0.01	2.19	0.0061		SAN DIEGO GPS 15
258	DZ	-3661.4743	-3661.4600		-0.0143	0.01	-2.31	0.0052		
	DN	-4799.5983	-4799.5988		0.0006	0.01				
	DE	29911.8526	29911.8513		0.0013	0.00				
	DU	658.2323	658.2594		-0.0271	-0.01				
259	DX	40241.5430	40241.5520		-0.0090	0.00	-2.36	0.0046		SAN DIEGO GPS 12
260	DY	-25684.3883	-25684.3640		-0.0243	0.01	-3.02	0.0065		SAN DIEGO GPS 16
261	DZ	-7210.3222	-7210.3330		0.0108	0.01	1.95	0.0056		
	DN	-8712.9063	-8712.9013		-0.0050	0.01				
	DE	47488.0631	47488.0602		0.0028	0.00				

	DU	165.7089	165.6814	0.0274	0.00			
262	DX	-27130.6333	-27130.6390	0.0057	0.00	1.43	0.0046	SAN DIEGO GPS 12
263	DY	-5956.5112	-5956.5140	0.0028	0.01	0.34	0.0064	SAN DIEGO GPS 17
264	DZ	-28111.6385	-28111.6360	-0.0025	0.01	-0.45	0.0056	
	DN	-33182.3381	-33182.3387	0.0006	0.01			
	DE	-21459.1980	-21459.2018	0.0038	0.00			
	DU	-500.7693	-500.7637	-0.0056	0.00			
265	DX	-6571.3734	-6571.3680	-0.0054	0.00	-1.36	0.0044	SAN DIEGO GPS 12
266	DY	-10250.8025	-10250.7930	-0.0095	0.01	-1.16	0.0062	SAN DIEGO GPS 18
267	DZ	-19346.2581	-19346.2650	0.0069	0.01	1.23	0.0054	
	DN	-22823.4977	-22823.4975	-0.0002	0.01			
	DE	-1217.2695	-1217.2690	-0.0005	0.00			
	DU	-381.8561	-381.8690	0.0130	0.00			
268	DX	16802.3805	16802.3580	0.0225	0.00	5.24	0.0043	SAN DIEGO GPS 12
269	DY	-28776.2514	-28776.2860	0.0346	0.01	3.79	0.0062	SAN DIEGO GPS 21
270	DZ	-27070.9186	-27070.8980	-0.0206	0.01	-3.33	0.0052	
	DN	-32574.7683	-32574.7733	0.0050	0.01			
	DE	27962.2537	27962.2493	0.0045	0.00			
	DU	473.3997	473.4453	-0.0456	-0.01			
271	DX	54044.4360	54044.4320	0.0040	0.00	1.01	0.0044	SAN DIEGO GPS 12
272	DY	-45974.4181	-45974.4150	-0.0031	0.01	-0.38	0.0064	SAN DIEGO GPS 22
273	DZ	-26701.1758	-26701.1750	-0.0008	0.01	-0.15	0.0054	
	DN	-31635.9734	-31635.9721	-0.0013	0.01			
	DE	68894.6886	68894.6836	0.0049	0.00			
	DU	-296.7211	-296.7215	0.0004	0.00			

0NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION TO STATION(S)
274	DX	-38866.7435	-38866.7470		0.0035	0.00	0.88	0.0045		SAN DIEGO GPS 12
275	DY	-9786.5431	-9786.5390		-0.0041	0.01	-0.51	0.0064		SAN DIEGO GPS 23
276	DZ	-41749.8802	-41749.8850		0.0048	0.01	0.86	0.0055		
	DN	-49397.5847	-49397.5876		0.0028	0.01				
	DE	-30150.9521	-30150.9571		0.0050	0.00				
	DU	-501.3888	-501.3931		0.0043	0.00				
277	DX	-26983.2065	-26983.2170		0.0105	0.00	2.44	0.0044		SAN DIEGO GPS 12
278	DY	-22137.6588	-22137.6690		0.0102	0.01	1.14	0.0062		SAN DIEGO GPS 24
279	DZ	-50591.7172	-50591.7110		-0.0062	0.01	-1.03	0.0054		
	DN	-59845.4002	-59845.4026		0.0023	0.01				
	DE	-13995.8059	-13995.8107		0.0048	0.00				
	DU	-580.2621	-580.2471		-0.0150	-0.01				
280	DX	51223.7191	51223.7300		-0.0109	0.00	-2.57	0.0047		SAN DIEGO GPS 12
281	DY	-58417.7965	-58417.7860		-0.0105	0.01	-1.17	0.0067		SAN DIEGO GPS 31
282	DZ	-44904.2260	-44904.2450		0.0190	0.01	3.10	0.0054		
	DN	-53661.6037	-53661.6119		0.0082	0.01				
	DE	71925.2352	71925.2402		-0.0050	0.00				
	DU	301.1676	301.1453		0.0223	-0.01				
283	DX	-4535.1669	-4535.1540		-0.0129	0.00	-2.96	0.0043		SAN DIEGO GPS 12
284	DY	-27519.3659	-27519.3460		-0.0199	0.01	-2.19	0.0061		SAN DIEGO GPS 33
285	DZ	-41863.9834	-41864.0020		0.0186	0.01	3.07	0.0052		
	DN	-49596.9367	-49596.9395		0.0028	0.01				
	DE	8393.9386	8393.9411		-0.0026	0.00				
	DU	-402.5072	-402.5371		0.0299	-0.01				
286	DX	-3490.1534	-3490.1430		-0.0104	0.00	-2.37	0.0044		SAN DIEGO GPS 12
287	DY	-3237.6659	-3237.6460		-0.0199	0.01	-2.18	0.0060		SAN DIEGO GPS 32
288	DZ	-7235.3671	-7235.3800		0.0129	0.01	2.08	0.0052		
	DN	-8500.8176	-8500.8162		-0.0014	0.01				
	DE	-1645.5644	-1645.5641		-0.0003	0.00				
	DU	-205.9279	-205.9537		0.0258	-0.01				
289	DX	6406.4668	6406.4450		0.0218	0.00	4.98	0.0043		SAN DIEGO GPS 12
290	DY	8547.6991	8547.6540		0.0451	0.01	5.04	0.0060		SAN DIEGO GPS 34
291	DZ	16440.4334	16440.4660		-0.0326	0.01	-5.28	0.0052		

		COMPUTED	OBSERVED	V (METER)	SDV	V/SDV	MDE	RN	STATIONS
	DN	19517.9874	19517.9872	0.0002	0.01				
	DE	1844.4516	1844.4526	-0.0010	0.00				
	DU	199.9852	200.0449	-0.0597	0.00				
292	DX	23220.2001	23220.1850	0.0151	0.00	3.52	0.0043		SAN DIEGO GPS 12
293	DY	-26023.3290	-26023.3520	0.0230	0.01	2.52	0.0061		SAN DIEGO GPS 35
294	DZ	-18560.3552	-18560.3400	-0.0152	0.01	-2.46	0.0052		
	DN	-22532.0835	-22532.0856	0.0021	0.01				
	DE	32447.0243	32447.0211	0.0032	0.00				
	DU	611.5251	611.5563	-0.0312	-0.01				

ONORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O SEC	METER	SDV	V/SDV	MDE 3-SIGMA	RN	FROM STATION / TO STATION(S)
295	DX	9307.0528	9307.0360		0.0168	0.00	3.85	0.0044		SAN DIEGO GPS 12
296	DY	-40678.0108	-40678.0250		0.0142	0.01	1.57	0.0061		JUNCTION CADH AZ MK 1974
297	DZ	-49863.6919	-49863.6860		-0.0059	0.01	-0.96	0.0053		
	DN	-59315.2395	-59315.2455		0.0060	0.01				
	DE	26634.7165	26634.7079		0.0086	0.00				
	DU	-61.6806	-61.6604		-0.0203	-0.01				
298	DX	-14983.1693	-14983.1740		0.0047	0.00	1.17	0.0044		SAN DIEGO GPS 12
299	DY	6847.4699	6847.4840		-0.0141	0.01	-1.72	0.0062		LOMAX
300	DZ	-1695.3879	-1695.3910		0.0031	0.01	0.56	0.0054		
	DN	-1804.0747	-1804.0717		-0.0031	0.01				
	DE	-16458.7088	-16458.7193		0.0106	0.00				
	DU	-337.2940	-337.3044		0.0104	0.00				
301	DX	-7224.8809	-7224.8780		-0.0029	0.00	-0.72	0.0043		SAN DIEGO GPS 12
302	DY	-12608.3945	-12608.3970		0.0025	0.01	0.30	0.0060		FAR
303	DZ	-23119.7574	-23119.7630		0.0056	0.01	1.00	0.0051		
	DN	-27294.3590	-27294.3642		0.0052	0.01				
	DE	-733.0276	-733.0239		-0.0037	0.00				
	DU	-417.5317	-417.5340		0.0023	0.00				
304	DX	56673.4306	56673.4190		0.0116	0.00	2.77	0.0043		SAN DIEGO GPS 12
305	DY	-15883.6031	-15883.6140		0.0109	0.01	1.23	0.0061		11 AAR
306	DZ	16287.0070	16287.0210		-0.0140	0.01	-2.32	0.0052		
	DN	19751.3698	19751.3734		-0.0036	0.01				
	DE	57785.1724	57785.1670		0.0055	0.00				
	DU	-436.3648	-436.3446		-0.0202	0.00				
307	DX	-35241.2872	-35241.2900		0.0028	0.00	0.71	0.0044		SAN DIEGO GPS 12
308	DY	45819.0287	45819.0250		0.0037	0.01	0.46	0.0062		BELARDES
309	DZ	37634.2533	37634.2620		-0.0087	0.01	-1.56	0.0055		
	DN	44985.2692	44985.2739		-0.0047	0.01				
	DE	-52287.5499	-52287.5507		0.0008	0.00				
	DU	80.1453	80.1540		-0.0086	0.00				
310	DX	-10036.3520	-10036.3530		0.0010	0.00	0.24	0.0044		SAN DIEGO GPS 12
311	DY	26732.2797	26732.2970		-0.0173	0.01	-1.95	0.0062		YUNG
312	DZ	28839.1080	28839.1020		0.0060	0.01	0.99	0.0055	67.88	
	DN	34672.8618	34672.8650		-0.0032	0.01				
	DE	-21089.2342	-21089.2430		0.0088	0.00				
	DU	-272.2920	-272.3079		0.0158	0.00				

ORESIDUAL STATISTICS

OBSERVATION NUMBERS OF 20 GREATEST STANDARDIZED RESIDUALS (V/SD)

124 91 125 126 71 92 142 224 130 238 40 42 143 144 72 291 225 268 50 113

TOTAL= 312 NO-CHECK= 4
MAX V= 6.9D-02 MAX V/SD= 2.021

```
 MIN V= -7.5D-02    MIN V/SD=    -2.099
MEAN V= -3.1D-04   MEAN V/SD=     0.059
```

	N	VTPV	RMS VTPV	RN	VTPV/RN	MEAN ABS RESIDUAL
DELTA X	97	914.7	3.07	65.89	13.88	0.010 (METERS)
DELTA Y	97	1687.4	4.17	72.14	23.39	0.020 (METERS)
DELTA Z	97	965.2	3.15	67.96	14.20	0.011 (METERS)
DOPPLER X	0	0.0	0.00	0.00	0.00	0.000 (METERS)
DOPPLER Y	0	0.0	0.00	0.00	0.00	0.000 (METERS)
DOPPLER Z	0	0.0	0.00	0.00	0.00	0.000 (METERS)
DIRECTION	0	0.0	0.00	0.00	0.00	0.000 (SECONDS)
H ANGLE	0	0.0	0.00	0.00	0.00	0.000 (SECONDS)
ZEN DIST	0	0.0	0.00	0.00	0.00	0.000 (SECONDS)
DISTANCE	0	0.0	0.00	0.00	0.00	0.000 (METERS)
AZIMUTH	0	0.0	0.00	0.00	0.00	0.000 (SECONDS)
OTHER	21	0.2	0.09	0.00	35.00	0.000
TOTAL	312	3567.4	3.38	206.00	17.32	

	N CONTRIB.	RMS RESIDUAL	MEAN ABS RESIDUAL
NORTH	97	0.007	0.005 (METERS)
EAST	97	0.005	0.004 (METERS)
UP	97	0.031	0.023 (METERS)

```
0DEGREES OF FREEDOM       =          206
 VARIANCE SUM            =        3567.4
 STD.DEV.OF UNIT WEIGHT  =          4.16
 VARIANCE OF UNIT WEIGHT =         17.32

 MINUTES TO LIST RESIDUALS     9.9
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0ADJUSTED AUXILIARY PARAMETERS

 NUM                               VALUE
0#     1 AUXILIARY PARAMETER IS  -3.99D-08
                  SCALED SIGMA =  4.86D-08        VAL/SD=    -0.8
                        GOOGE =  9.78D-01

 MINUTES TO LIST AUXILIARY PARAMETERS    0.0
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0ADJUSTED AUXILIARY GPS AND DOPPLER ROTATION PARAMETERS

 ROTATION ORIGIN IS  32 47 42.61610N    116 47 54.08854W

 NUM                X ROTATION             Y ROTATION            Z ROTATION
0#  1        VALUE =  2.08D-01            -2.71D-01              1.49D-01    (ARC SECONDS)
      SCALED SIGMA =  3.11D-02             3.62D-02              8.90D-03
            VAL/SD =     6.7                -7.5                  16.8
             GOOGE =  9.30D-01             8.81D-01              9.05D-01

 MINUTES TO LIST ROTATION PARAMETERS    0.0
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0ADJUSTED POSITIONS

      SSN NAME                                          LATITUDE          LONGITUDE         M.S.L.    G. HT.      E. HT.
0     1 5652 11 AAR                                 33 17 44.47011N  116 17 54.77526W   188.052   -32.752    155.300
                             SHIFTS (M.)                 0.059N              0.048W                          188.052 AZ=321 HOR=  0.1 TOT=188.1
                      SCALED SIGMAS (M.)                 0.005               0.004                             0.000
                             GOOGES                      6.8D-01             6.4D-01                           1.0D+00
0     2 5744 BELARDES                               33 31 23.41298N  117 28 47.24916W   705.225   -33.445    671.780
                             SHIFTS (M.)                 0.019S              0.082W                          705.225 AZ=258 HOR=  0.1 TOT=705.2
                      SCALED SIGMAS (M.)                 0.006               0.006                             0.025
                             GOOGES                      5.7D-01             5.1D-01                           7.0D-01
0     3   10 BOUCHER 2                              33 20  4.98381N  116 55  9.32320W  1660.657   -31.547   1629.110
                             SHIFTS (M.)                 0.015N              0.047W                         1660.657 AZ=288 HOR=  0.0 TOT=*****
                      SCALED SIGMAS (M.)                 0.005               0.005                             0.028
                             GOOGES                      9.9D-01             9.6D-01                           9.0D-01
0     4 5555 FAR                                    32 52 17.45470N  116 55 34.10438W   207.444   -33.054    174.390
                             SHIFTS (M.)                 0.011N              0.022W                          207.444 AZ=298 HOR=  0.0 TOT=207.4
                      SCALED SIGMAS (M.)                 0.004               0.003                             0.023
                             GOOGES                      8.0D-01             7.7D-01                           8.5D-01
0     5  151 HPGN CA 11 01                          32 34  6.43665N  116 58 59.47376W   156.771   -34.299    122.472
                             SHIFTS (M.)                 0.010N              0.013W                          156.771 AZ=309 HOR=  0.0 TOT=156.8
                      SCALED SIGMAS (M.)                 0.004               0.004                             0.000
                             GOOGES                      1.0D+00             9.7D-01                           1.0D+00
0     6  152 HPGN CA 11 02                          32 36 23.93112N  116 28 36.49850W   798.485   -32.099    766.386
                             SHIFTS (M.)                 0.033N              0.006E                          798.485 AZ= 11 HOR=  0.0 TOT=798.5
                      SCALED SIGMAS (M.)                 0.004               0.004                             0.000
                             GOOGES                      9.7D-01             9.4D-01                           1.0D+00
0     7  156 HPGN CA 11 06                          32 50 39.81998N  116 48  7.42728W   423.876   -32.447    391.429
                             SHIFTS (M.)                 0.017N              0.009W                          423.876 AZ=334 HOR=  0.0 TOT=423.9
                      SCALED SIGMAS (M.)                 0.004               0.004                             0.024
                             GOOGES                      9.9D-01             9.7D-01                           9.0D-01
0     8  157 HPGN CA 11 07                          33  7 46.17443N  117 16 37.08040W    94.902   -34.124     60.778
                             SHIFTS (M.)                 0.006N              0.069W                           94.902 AZ=276 HOR=  0.1 TOT= 94.9
                      SCALED SIGMAS (M.)                 0.005               0.004                             0.000
                             GOOGES                      9.7D-01             9.6D-01                           1.0D+00
0     9  158 HPGN CA 11 08                          33 14  1.58009N  116 41 35.95779W   873.503   -31.504    841.999
                             SHIFTS (M.)                 0.042N              0.050W                          873.503 AZ=310 HOR=  0.1 TOT=873.5
                      SCALED SIGMAS (M.)                 0.005               0.004                             0.024
                             GOOGES                      9.9D-01             9.5D-01                           8.3D-01
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0ADJUSTED POSITIONS

      SSN NAME                                          LATITUDE          LONGITUDE         M.S.L.    G. HT.      E. HT.
0    10  159 HPGN CA 11 09                          33  9 35.33055N  116 14 49.23165W   234.399   -32.936    201.463
                             SHIFTS (M.)                 0.061N              0.021W                          234.399 AZ=342 HOR=  0.1 TOT=234.4
                      SCALED SIGMAS (M.)                 0.000               0.000                             0.029
                             GOOGES                      9.9D-01             9.9D-01                           8.4D-01
0    11 5529 JUNCTION CADH AZ MK 1974               32 34 58.10884N  116 38  1.65314W   562.793   -32.458    530.335
                             SHIFTS (M.)                 0.029N              0.005E                          562.793 AZ= 10 HOR=  0.0 TOT=562.8
                      SCALED SIGMAS (M.)                 0.004               0.003                             0.000
                             GOOGES                      7.6D-01             7.1D-01                           1.0D+00
0    12 5554 LOMAX                                  33  6  4.83137N  117  5 40.63562W   287.819   -33.207    254.612
                             SHIFTS (M.)                 0.002N              0.042W                          287.819 AZ=274 HOR=  0.0 TOT=287.8
                      SCALED SIGMAS (M.)                 0.004               0.004                             0.023
                             GOOGES                      8.8D-01             8.6D-01                           8.4D-01
0    13  189 MONUMENT PEAK NCMN 7274                32 53 30.33927N  116 25 22.09237W  1871.476   -31.689   1839.787
                             SHIFTS (M.)                 0.041N              0.002W                         1871.476 AZ=358 HOR=  0.0 TOT=*****
                      SCALED SIGMAS (M.)                 0.004               0.004                             0.024
                             GOOGES                      1.0D+00             9.7D-01                           8.7D-01
0    14  198 OCOTILLO NCMN 7270                     32 47 24.34954N  115 47 46.22646W    -1.778   -34.036    -35.814
                             SHIFTS (M.)                 0.076N              0.018E                           -1.778 AZ= 14 HOR=  0.1 TOT=  1.8
                      SCALED SIGMAS (M.)                 0.005               0.005                             0.000
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                                      GOOGES            8.6D-01             9.1D-01                          1.0D+00
0    15 5301 SAN DIEGO GPS 01                    33 22 31.07123N   117 33 54.53950W    29.528   -34.499     -4.971
                                      SHIFTS (M.)       0.028S              0.071W                           29.528 AZ=249 HOR=  0.1 TOT= 29.5
                               SCALED SIGMAS (M.)       0.006               0.006                            0.000
                                      GOOGES            9.0D-01             9.1D-01                          1.0D+00
0    16 5302 SAN DIEGO GPS 02                    33 21 19.52658N   117 14 56.75766W   218.555   -33.214     185.341
                                      SHIFTS (M.)       0.006S              0.065W                           218.555 AZ=266 HOR=  0.1 TOT=218.6
                               SCALED SIGMAS (M.)       0.005               0.005                            0.024
                                      GOOGES            9.4D-01             9.1D-01                          8.0D-01
0    17 5303 SAN DIEGO GPS 03                    33 19 54.31129N   117  9 31.67468W    93.958   -32.909     61.049
                                      SHIFTS (M.)       0.000S              0.062W                           93.958 AZ=  0 HOR=  0.1 TOT= 94.0
                               SCALED SIGMAS (M.)       0.005               0.005                            0.000
                                      GOOGES            9.4D-01             9.1D-01                          1.0D+00
0    18 5307 SAN DIEGO GPS 07                    33 23 15.85745N   116 38 13.99632W  1452.931   -31.206    1421.725
                                      SHIFTS (M.)       0.039N              0.058W                          1452.931 AZ=304 HOR=  0.1 TOT=*****
                               SCALED SIGMAS (M.)       0.005               0.005                            0.029
                                      GOOGES            4.8D-01             4.4D-01                          7.6D-01
1                                                         NATIONAL GEODETIC SURVEY
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0ADJUSTED POSITIONS

       SSN NAME                                    LATITUDE          LONGITUDE          M.S.L.    G. HT.     E. HT.
0    19 5312 SAN DIEGO GPS 12                    33  7  3.38779N   116 55  5.67084W   624.162   -32.276     591.886
                                      SHIFTS (M.)       0.015N              0.041W                           624.162 AZ=291 HOR=  0.0 TOT=624.2
                               SCALED SIGMAS (M.)       0.004               0.004                            0.023
                                      GOOGES            9.8D-01             9.5D-01                          8.5D-01
0    20 5315 SAN DIEGO GPS 15                    33  4 27.61654N   116 35 52.52219W  1281.509   -31.404    1250.105
                                      SHIFTS (M.)       0.038N              0.033W                          1281.509 AZ=319 HOR=  0.1 TOT=*****
                               SCALED SIGMAS (M.)       0.004               0.004                            0.000
                                      GOOGES            9.7D-01             9.4D-01                          1.0D+00
0    21 5316 SAN DIEGO GPS 16                    33  2 20.59745N   116 24 35.10534W   789.651   -32.052     757.599
                                      SHIFTS (M.)       0.048N              0.028W                           789.651 AZ=331 HOR=  0.1 TOT=789.7
                               SCALED SIGMAS (M.)       0.004               0.004                            0.025
                                      GOOGES            9.6D-01             9.4D-01                          8.4D-01
0    22 5317 SAN DIEGO GPS 17                    32 49  6.32678N   117  8 52.18123W   125.532   -34.323     91.209
                                      SHIFTS (M.)       0.003S              0.020W                           125.532 AZ=261 HOR=  0.0 TOT=125.5
                               SCALED SIGMAS (M.)       0.004               0.004                            0.024
                                      GOOGES            9.5D-01             9.3D-01                          8.5D-01
0    23 5318 SAN DIEGO GPS 18                    32 54 42.57664N   116 55 52.76673W   243.006   -32.946     210.060
                                      SHIFTS (M.)       0.012N              0.025W                           243.006 AZ=296 HOR=  0.0 TOT=243.0
                               SCALED SIGMAS (M.)       0.004               0.004                            0.023
                                      GOOGES            9.7D-01             9.4D-01                          8.6D-01
0    24 5321 SAN DIEGO GPS 21                    32 49 26.13007N   116 37  9.19944W  1096.931   -31.578    1065.353
                                      SHIFTS (M.)       0.034N              0.014W                          1096.931 AZ=338 HOR=  0.0 TOT=*****
                               SCALED SIGMAS (M.)       0.004               0.003                            0.000
                                      GOOGES            9.6D-01             9.3D-01                          1.0D+00
0    25 5322 SAN DIEGO GPS 22                    32 49 56.53427N   116 10 52.81845W   328.531   -33.101     295.430
                                      SHIFTS (M.)       0.061N              0.009W                           328.531 AZ=352 HOR=  0.1 TOT=328.5
                               SCALED SIGMAS (M.)       0.004               0.004                            0.024
                                      GOOGES            8.8D-01             8.7D-01                          7.8D-01
0    26 5323 SAN DIEGO GPS 23                    32 40 19.97638N   117 14 25.91796W   125.888   -35.214     90.674
                                      SHIFTS (M.)       0.011S              0.009W                           125.888 AZ=220 HOR=  0.0 TOT=125.9
                               SCALED SIGMAS (M.)       0.005               0.004                            0.026
                                      GOOGES            8.9D-01             8.6D-01                          7.4D-01
0    27 5324 SAN DIEGO GPS 24                    32 34 40.82082N   117  4  4.07350W    46.494   -34.765     11.729
                                      SHIFTS (M.)       0.000N              0.000E                           46.494 AZ=  0 HOR=  0.0 TOT= 46.5
                               SCALED SIGMAS (M.)       0.000               0.000                            0.000
                                      GOOGES            1.0D+00             1.0D+00                          1.0D+00
1                                                         NATIONAL GEODETIC SURVEY
 PROGRAM ADJUST                                             ADJUSTMENT PROGRAM                                                   PAGE  30
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0ADJUSTED POSITIONS

      SSN NAME                                    LATITUDE          LONGITUDE          M.S.L.     G. HT.     E. HT.
0   28 5331 SAN DIEGO GPS 31                  32 38  1.66601N   116  8 59.31888W    926.012    -32.406    893.606
                             SHIFTS (M.)            0.060N                0.009E                         926.012 AZ=  9 HOR=  0.1 TOT=926.0
                      SCALED SIGMAS (M.)            0.005                 0.004                            0.000
                             GOOGES                 8.1D-01               8.2D-01                          1.0D+00
0   29 5359 SAN DIEGO GPS 32                  33  2 27.47277N   116 56  9.31292W    418.536    -32.565    385.971
                             SHIFTS (M )            0 012N                0 034W                         418 536 AZ=290 HOR=  0 0 TOT=418 5
                      SCALED SIGMAS (M.)            0.004                 0.004                            0.000
                             GOOGES                 9.4D-01               9.1D-01                          1.0D+00
0   30 5358 SAN DIEGO GPS 33                  32 40 13.52042N   116 49 42.92143W    222.523    -33.086    189.437
                             SHIFTS (M.)            0.016N                0.003W                         222.523 AZ=348 HOR=  0.0 TOT=222.5
                      SCALED SIGMAS (M.)            0.004                 0.003                            0.000
                             GOOGES                 8.9D-01               8.4D-01                          1.0D+00
0   31 5361 SAN DIEGO GPS 34                  33 17 36.85931N   116 53 54.66151W    823.437    -31.593    791.844
                             SHIFTS (M.)            0.020N                0.056W                         823.437 AZ=290 HOR=  0.1 TOT=823.4
                      SCALED SIGMAS (M.)            0.004                 0.004                            0.000
                             GOOGES                 9.2D-01               8.8D-01                          1.0D+00
0   32 5363 SAN DIEGO GPS 35                  32 54 52.09255N   116 34 15.89331W   1234.762    -31.304   1203.458
                             SHIFTS (M.)            0.038N                0.020W                        1234.762 AZ=332 HOR=  0.0 TOT=*****
                      SCALED SIGMAS (M.)            0.004                 0.003                            0.000
                             GOOGES                 8.8D-01               8.5D-01                          1.0D+00
0   33  220 SANDIE NASA 1976                  32 36  2.65046N   116 50 27.04496W   1022.944    -33.313    989.631
                             SHIFTS (M.)            0.009N                0.007W                        1022.944 AZ=320 HOR=  0.0 TOT=*****
                      SCALED SIGMAS (M.)            0.004                 0.004                            0.024
                             GOOGES                 9.6D-01               9.2D-01                          8.3D-01
0   34 5745 YUNG                              33 25 48.75304N   117  8 40.74294W    352.094    -32.556    319.538
                             SHIFTS (M.)            0.002N                0.070W                         352.094 AZ=272 HOR=  0.1 TOT=352.1
                      SCALED SIGMAS (M.)            0.005                 0.005                            0.000
                             GOOGES                 5.2D-01               4.5D-01                          1.0D+00

 MINUTES TO LIST ADJUSTED POSITIONS    0.0
0END OF ADJUST PROCESSING
 SYSTEM TIME IS Wed Sep  8 07:57:22 1993
 HAVE A NICE DAY!
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Summary

Computing Accurate NAVD 88 GPS-Derived Orthometric Heights in San Diego County

During April 5-7, 1991, San Diego County held a GPS-A-THON. An article titled "Precisely San Diego" was published in the April 1992 issue of GPS World to describe this GPS project in detail. The goal of the GPS-A-THON was to get precise coordinates for San Diego County's 4,300 square miles. To accomplish this surveyors simultaneously occupied 34 stations with GPS receivers from 12:30 p.m. to 7:30 p.m. each day for 3 days. The San Diego County network was incorporated into NAD 83 (1992) using California High Precision GPS Network (CAHPGN) coordinates as constraints. These coordinates meet the horizontal control requirements of all county activities, but the accurate GPS-derived vertical values are GPS-derived <u>ellipsoid</u> heights. Engineering and mapping projects, however, use <u>orthometric</u> height differences for establishing vertical control. (See GPS World February 1993.) When appropriate steps are followed and a high-resolution geoid model is used, it is possible to compute GPS-derived orthometric heights that meet a wide range of engineering and mapping vertical control requirements.

In July 1992, the National Geodetic Survey (NGS), in cooperation with the California Department of Transportation (CALTRANS), undertook a cooperative project to estimate GPS-derived orthometric heights in San Diego County, California, that are accurate to +/- 5 cm. The project included the analysis of existing GPS, gravity, and leveling data; the determination of requirements for additional data of the three types listed above; the training of CALTRANS personnel to observe the required data; and the computation of an improved regional geoid model of the county using the proper combination of existing and new data. These activities resulted in recommended procedures which improved CALTRANS' ability to determine more accurate GPS-derived orthometric heights to meet many of their vertical requirements for transportation improvement projects.

Heights and Height Differences

Orthometric heights (H) are referenced to an equipotential surface, e.g., the geoid, which approximates the mean sea level. The orthometric height of a point on the Earth's surface is the distance from the geoid to the point, measured along the plumb line normal to the geoid. Ellipsoid heights (h) are referenced to a reference ellipsoid. The ellipsoid height of a point is the distance from the reference ellipsoid to the point, measured along the line which is normal to the ellipsoid. At a point, the difference between the ellipsoid height and the orthometric height is defined as the geoid height (N).

An orthometric height can be computed (to a sufficient approximation) from an ellipsoid height by subtracting the geoid height, i.e., H = h - N. Similarly, an orthometric height difference (dH) can be obtained from an ellipsoid height difference (dh) by subtracting the geoid height difference (dN), i.e., dH = dh - dN. (See figure 1.)

Plan Outline

The accuracy of GPS-derived orthometric heights depends on the accuracy of GPS-derived ellipsoid height differences, the accuracy of geoid height differences, and the accuracy of leveling-derived orthometric heights used as vertical control. Therefore, the activities outlined below were addressed for this project.

Gravity Activities

- o Determine gravity data requirements
- o Obtain new gravity data
- o Process new gravity data
- o Load new gravity data into NGS gravity data base
- o Compute new geoid model
- o Compare new and old geoid models

Leveling Activities

- o Determine leveling data requirements
- o Determine status of NAVD 88 heights in NGS' Integrated Data Base (NGSIDB)
- o Incorporate 1978 Southern California Releveling Program (SCRP) data into NAVD 88
- o Obtain new height difference observations between bench marks with NAVD 88 heights and San Diego County GPS Network stations using either leveling procedures and/or "specially-designed" trigonometric leveling procedures
- o Process new height difference observations
- o Load new height difference observations into NGSIDB
- o Compute NAVD 88 heights for San Diego County GPS network stations

GPS Activities

- o Determine "internal" relative accuracy of GPS-derived ellipsoid heights for the San Diego County GPS network

GPS-Derived Orthometric Height Activities

- Compare GPS-derived orthometric heights obtained from minimum constraint least squares adjustment with NAVD 88 heights
- Use GEOID93 and special geoid model computed for San Diego GPS project (GEOID93S)
- Compute and compare GPS-derived orthometric heights

Procedures to Follow When Estimating GPS-Derived Orthometric Heights in San Diego County

- Provide brief description of procedures to be followed to meet CALTRANS project requirements

Sample Project - City of San Diego GPS Project

- Provide brief description of GPS project
- Describe how procedures mentioned in previous sections were followed
- Compare GPS-derived orthometric heights with NAVD 88 values

Gravity Data Analysis

Performing detailed analysis of the geoid in the area of the survey is probably the most important planning step when estimating GPS-derived orthometric heights. It is critical to determine which bench marks need to be occupied with GPS to adequately evaluate the slope and changes in slope of the geoid. Plotting a contour map of geoid heights estimated using a high-resolution geoid model is the first task, but by no means is it the only task. The plot may indicate a smooth, gently sloping geoid, but this could be because there wasn't enough gravity information in the area to adequately define changes in the shape of the geoid.

Analyzing gravity density plots and modeled geoid height values, as well as contour plots of free-air anomalies and Bouguer anomalies, are practical ways for users to determine which bench marks in the project need to be occupied by GPS or where additional gravity observations are required. The analysis may indicate that precise leveling may need to be performed to establish an orthometric height of a GPS monument in an area where no vertical control or gravity observations exist, or that additional gravity observations need to be collected.

Gravity density plots of the San Diego County region (32° 30′ N - 33° 30′ N, 116° 0′ W - 118° 0′ W) were generated and used to determine where additional gravity observations were required. (See figure 2.) The density plots indicated on a 2′ by 2′ (3 km x 3 km) grid where additional data were required. Bouguer anomaly, free-air anomaly, and gravity void plots (plots which depict numerically which areas are void of gravity data) were also generated to assist in the planning phase of the project.

The gravity plots indicate that the distribution of gravity data surrounding the area is probably not adequate and some voids should be filled in with gravity observations or bench marks should be occupied with GPS. The problem in this area is that the areas of sparse gravity data are in the mountainous regions of the county, so it is probably not feasible to level to many stations. It was decided that it would be easier and more economical to obtain additional gravity data to check the geoid model.

A gravity observation program for the project was developed by NGS and CALTRANS personnel. Descriptions and plots of the gravity base stations were generated by NGS and provided to CALTRANS. CALTRANS performed the reconnaissance to determine which stations were useable.

A NGS employee traveled to San Diego to instruct CALTRANS personnel on how to conduct gravity surveys. Four CALTRANS field personnel were trained in making gravity observations, conducting gravity surveys, and using the HP 95XL gravity data logger program. During the training phase the following gravity tasks were completed: 1) local calibration of the gravity meters, 2) establishment of seven base stations, and 3) observation of the first two areas needing densification (27 stations).

CALTRANS personnel plotted gravity void information on large-scale maps to assist in survey planning. Proposed stations which filled the void areas were plotted on these maps. Sites which were reasonable to reach by vehicle were labeled as drive stations and others were labeled as helicopter stations. The goal was to obtain gravity observations throughout the county at a 3 km by 3 km spacing.

A total of 333 gravity data sites were observed and "field" processed by CALTRANS personnel. These data were "office" processed and loaded into NGS' gravity data base by NGS personnel. The new data were then used to generate new Bouguer anomaly, free-air anomaly, and gravity density plots.

After the new gravity observations were loaded into NGS' gravity data base, a new geoid model, denoted in this article as

GEOID93S, was computed. The differences between GEOID93S and the latest national geoid model, GEOID93, were compared. Figure 3 depicts contours of the new geoid. Figure 4 is a plot of the differences between GEOID93 and the new geoid model GEOID93S. Figure 4 also depicts the location of the new gravity observations. Notice that some differences reach 4 cm in areas where new data were observed. These differences are significant when the goal is to estimate GPS-derived orthometric heights accurate to 3 to 5 cm.

Leveling Data Section

Another phase of the project was to determine and evaluate the existing vertical control in the area. There are several NGS first-order leveling lines that were leveled between 1987 and 1989 in support of the new adjustment of the North American Vertical Datum of 1988 (NAVD 88) which are located in the eastern, western, and southern portions of the project. As expected, there wasn't any vertical control with NAVD 88 heights located inside the project area.

None of the stations selected by San Diego County were bench marks with NAVD 88 values. Two stations, SD GPS 03 and YUNG, were leveled to by Metropolitan Water District of Southern California (MWDSC) in September 1992 during one of their projects. Bench marks in the San Diego County area which have NAVD 88 heights in NGS' NGSIDB were retrieved and plotted with the location of the GPS stations. Eight GPS stations were located near bench marks which had NAVD 88 height values: Ocotillo, SD GPS 31, CA 11 02, Junction AZ, SD GPS 33, CA 11 01, SD GPS 24, and SD GPS 01.

Bench marks in the San Diego County area which did not have NAVD 88 heights, but were leveled to after 1977 were retrieved and plotted. This network consisted basically of leveling lines observed in 1978 during the Southern California Releveling Program (SCRP). These SCRP data were incorporated into NAVD 88. The NAVD 88 height of one GPS station, 11 AAR, was established by this adjustment.

Other agencies were contacted to determine if they had leveling data which would help generate a more consistent network. Due to the age of the data, network design, and because the data were not in computer-readable form, it was decided that it was not feasible to include any additional data from other agencies for this project.

After the SCRP data were incorporated into NAVD 88, the San Diego County GPS stations were plotted with bench marks that had NAVD

88 height values. Three more GPS stations were located near bench marks involved in the SCRP network adjustment: SD GPS 32, SD GPS 15, and SD GPS 35, and, as previously stated, the height of one GPS station was computed in the SCRP adjustment: 11 AAR. (See figure 5.)

It was not feasible to perform precise leveling procedures to tie the San Diego County GPS stations to bench marks with NAVD 88 heights. CALTRANS personnel could, however, perform precise trigonometric procedures to some of the stations. Therefore, NGS and CALTRANS developed draft specifications and procedures to perform precise trigonometric height differences for short leveling runs. NGS personnel performed several precise leveling ties to San Diego County GPS stations and CALTRANS performed the special trigonometric procedures over the same lines. The special trigonometric procedures seemed to work well and it was decided to use the trig procedures, if the line lengths were limited to no more than 10 km.

Leveling and/or trigonometric leveling ties were made to as many stations as feasible. A total of 14 of the 34 GPS stations were tied to NAVD 88 using short leveling and/or trigonometric leveling ties. One of the 14 stations, SD GPS 34, was tied to a 1970 leveling line.

It should be noted that it was not possible to obtain leveling-derived orthometric heights on GPS stations where the new geoid model showed significant changes. Most of the areas where gravity data were obtained were in areas where there is very little leveling. Helicopters were used in many cases because it was impossible to drive to the sites. Some of the drive stations may be tied in the future using the new trigonometric specifications and procedures. This was understood and agreed upon in the beginning of this project.

Table 1 lists the values of these stations and the procedures used to estimate their height values. The following list summarizes the procedures used to estimate the NAVD 88 heights for the 17 GPS stations:

Level(1) - NAVD 88 height estimated by incorporating 1978 Southern California Releveling Project (SCRP) leveling data into NAVD 88,

Level(2) - NAVD 88 height estimated by using a short one-mark leveling tie from a station which had a published NAVD 88 height,

Level(3) - NAVD 88 height estimated using a new leveling line (1992) which was incorporated into NAVD 88, Level(4) - NAVD 88 height estimated by using a short one-mark leveling tie from a NAVD 88 SCRP (1978) adjusted height,

Trig(1) - NAVD 88 height estimated from a height difference obtained using specially designed trigonometric procedures. A one-mark tie was from a bench mark which had published NAVD 88 height value,

Trig(2) - NAVD 88 height estimated from a height difference obtained using specially designed trigonometric procedures. One-mark ties were connected to bench marks which had NAVD 88 height values obtained when the SCRP network was incorporated into NAVD 88,

Trig(3) - NAVD 88 height estimated from a height difference obtained using specially-designed trigonometric procedures. A one-mark tie was from a bench mark which was last leveled to in 1970. A NAVD 88 height value was estimated for the tie bench mark using the 1970 data.

GPS Data Analysis

In 1991 San Diego County designed, observed, and processed the GPS data. The data and results were submitted to NGS in 1991 for incorporation into NAD 83. For this project, the processed GPS vectors were retrieved from NGS' Integrated Data Base (NGSIDB) and used in this project. Figure 6 is a plot of the GPS stations and vectors.

There were 34 stations occupied simultaneously over a 3 day period. Data were gathered during each session for a duration of 7 hours. These data were then reduced using one reference station for each day. On days 1 and 2, station Monument Peak was used as the reference station, and on Day 3, San Diego GPS 12 was used as the reference station. The correlation coefficient matrix was computed for each set of observations.

An analysis of the GPS data was performed by county personnel at the Scripps facility under the guidance for Scripps geophysicist Yehuda Bock and reported in the April 1992 issue of GPS World. The article provided a diagram which depicted the estimated accuracy of the GPS-derived ellipsoid heights.

A more detailed analysis was performed for this project because the goal of the project was to compute GPS-derived orthometric heights accurate to 3 to 5 cm. Therefore, residuals in the GPS "up" component greater than 3 cm needed to be investigated and, more importantly, these stations involved with higher residuals needed to be analyzed when the GPS network results and leveling network results were combined.

First, a 3-dimensional minimum-constraint least squares adjustment of the data was performed.. Figure 7 is the residual plot of the GPS up component, du, from a minimum-constraint least squares adjustment. The residuals ranged between +/- 5.7 cm, with a RMS value of 1.8 cm.

GPS results can also be evaluated by analyzing network loop misclosures and repeat base line differences. These analyses tools are <u>very effective</u> when the network consists of small loops, triangles, braced quadrilaterals, and repeat base lines. Classical techniques of establishing horizontal and vertical control used networks which consisted of many loops, triangles, and braced quadrilaterals. This design helped in detecting data outliers.

GPS can provide absolute and relative positioning information much easier, faster, and more precise than some classical techniques, but the wrong station can still be occupied, the height of antenna can be measured wrong or incorrectly entered during the base line reduction processing phase, the receiver can malfunction, an abnormal atmospheric condition can cause large errors in the height component, or some unknown "Gremlin" can be causing an error source not yet detected. Occupying all stations at least twice helps to detect, reduce, and/or minimize some of these errors.

Loops were not analyzed in this project because all stations were occupied simultaneously and each day's session was reduced using one reference station. Since there were only three sessions, to evaluate how good the GPS-derived ellipsoid heights were estimated, seven minimum-constraint least squares adjustments were performed using the following different sets of data:

1) all data,
2) only day 1 data,
3) only day 2 data,
4) only day 3 data,
5) days 1 and 2 data,
6) days 1 and 3 data, and
7) days 2 and 3 data.

The GPS-derived ellipsoid heights from the adjustments were tabulated and compared with each other. Tables 2 and 3 present the differences in ellipsoid height estimated using the seven different sets of adjustment results.

Day 1 seems to disagree with day 2 and day 3, more than day 2 disagreed with day 3. (Compare columns 10 and 11 with column 12 in table 2.) There is a 10 cm spread at several stations between day 1 and day 2 results. However, when day 1 and day 2 are combined and compared with the results using all data, the differences are typically between +/-.2 cm. (See column 7 in table 3.) Comparing any two-day combination with the all-data solution indicates the differences are between +/- 3 cm. (See columns 7, 8, and 9 in table 3.)

GPS-Derived Orthometric Height Analysis

The next phase of the analysis is to compare adjusted GPS-derived orthometric heights obtained from a minimum-constraint solution with leveling-derived orthometric heights. Figure 8 is a comparison of the GPS-derived orthometric heights estimated using GEOID93S with NAVD 88 height values.

The results presented in figure 8 do not indicate any obvious problems. While there appears to be only a few anomalous values, there is a very obvious trend between the two sets of heights. This could be due to errors in the GPS data, NAVD 88 orthometric heights, or modeled geoid height values. There is not enough information to separate the tilts into separate components due to different error sources.

However, <u>local systematic differences in the system</u> can be removed by solving for scale and rotation parameters (by holding the latitude and longitude values of two horizontal control stations and the height value of at least three vertical control stations fixed) in the adjustment when estimating the coordinates in a least squares adjustment; or the local systematic differences can be estimating using all the vertical control information and solving for trend parameters (east-west, north-south, and bias shift).

Figure 9 is a plot of the differences after a simple trend (plane) was used to remove some of the discrepancy between the two sets of heights. Table 4 lists these differences. The coefficient-of-correlation value was only 71 percent, but the relative differences between closely spaced stations seem to improve. The overall differences between stations located in the southwest corner and the stations located in the northeast corner improved significantly, i.e., from stations SD GPS 24 and 11 AAR the difference was 17.6 cm before a trend was removed and -0.1 cm after a trend was removed.

Accounting for Systematic Differences Between the Three Height Systems During the Transition Period

One of the things to remember about establishing and maintaining a vertical control network is preserving consistency. A network consisting of many inconsistent local networks is relatively useless to many users. When the orthometric height of a station is superseded because of adjustment constraints and not because the monument's physical location has changed, the stations near this monument must be made consistent with its new value. Of course, forcing excessive distortions into the network also makes a network less useful.

The last step of the project is to compute GPS-derived orthometric heights by performing a 3-dimensional least squares adjustment holding fixed all <u>appropriate</u> orthometric height values of published bench marks and <u>appropriate</u> GPS-derived coordinates (latitude, longitude, and ellipsoid height) computed form higher-order surveys, removing systematic differences between the height systems, and using the results from all the steps to document the estimated accuracy of the GPS-derived orthometric heights. Notice the key word underlined above, appropriate.

Through discussions with users there appears to be three methods which are typically employed today to estimate GPS-derived orthometric heights for projects. Method 1 is called the scale and rotation method because scale and rotation parameters are solved for, along with the adjusted coordinates. Method 2 is called the trend removal method because trend parameters are used to apply rotation parameters to GPS vectors to account for the differences between the three height systems. Method 3 is called the height distribution method because differences between the three height systems are distributed into the unconstrained horizontal (latitude and longitude) and vertical coordinates (ellipsoid heights). These were the three methods used in the San Diego GPS project.

Comparison of Three Methods

Notice that all three methods provided similar results. (See table 5.) However, there are several large relative differences between the height distribution method (method 3) and the other two methods. For example, the height of station SD GPS 23 using method 3 differed by -8.5 cm from method 1 and by -9.1 for method 2. These results do not ensure that all three methods will work the same way everywhere. It does indicate that during the transition period, all three methods should be performed for comparison purposes for a project.

The constrained height method is the easiest to maintain consistency on a National level, but <u>users must ensure that</u>

"large distortions" have not been forced into surrounding heights. If the San Diego GPS network GPS-derived orthometric heights are estimated using methods 1 or 2, then local surveys will probably be able to use method 3 when properly connecting to the San Diego GPS network.

A simple procedure which can be used to determine the effect of forcing differences between the three height systems into surrounding heights is to compare residuals in the height component obtained from the overly-constrained adjustment with height component residuals obtained from a minimally-constrained adjustment. The differences in height component residuals between each method and the minimum-constraint solution for each vector of the GPS project were analyzed. Most differences were less than 3 cm for methods 1 and 2. This is good because it indicates that the height constraints did not force any large distortions into the unconstrained heights. However, many of the differences using method 3 exceed 5 cm. This indicates that the height constraints did force some large distortions into the unconstrained heights.

Since the residual plots look the best for method 1, the scale and rotation method, this method was used to establish the final set of GPS-derived orthometric heights in the San Diego GPS project. See table 5, column 2 for a list of the final set of adjusted heights.

Sample Project
City of San Diego GPS Network

The City of San Diego GPS network was used to help evaluate the final set of GPS-derived orthometric heights estimated for this project. Gregory A. Helmer, an employee of Robert Bein, William Frost and Associates, San Diego, California, was provided GPS-derived orthometric heights for seven San Diego GPS network control stations which were common to the City of San Diego GPS network. The GPS project tied into all San Diego GPS stations which were inside and at the edges of the project's areal extent. Nine bench marks with NAVD 88 heights were also occupied inside the City of San Diego project area. The typical spacing between GPS stations was less than 5 km.

A special adjustment fixing the GPS-derived orthometric heights of the San Diego stations established in this project was performed. A comparison of the GPS-derived orthometric heights from the special adjustment with the nine stations which had NAVD 88 height values indicated differences ranging from -2.7 cm to 6.3 cm. Relative differences from a station to its closest neighbor was typically less than 2.5 cm. (See figure 10.)

The largest difference, 6.3 cm, was at station C 58 Reset. The elevation of this stations is 869 meters. The relative difference between M 1411 and C 58 Reset is -7.1 cm. The elevation difference between the two stations is 664 meters. Station C 58 Reset, which is hanging off the edge of the City's project, was observed twice, but both times, which were on the same day, was from station M 1411, i.e., a GPS spur observation. The length of the line is approximately 47 km. Additional analysis would need to be performed to determine if it is the ellipsoid height, orthometric height, or geoid height which has a several-centimeter error.

Excluding station C 58 Reset, the comparison of the GPS-derived orthometric heights estimated from the special adjustment with the eight other stations that had NAVD 88 height values indicated differences between -2.7 cm and 1.3 cm.

This project indicates that the San Diego County GPS-derived orthometric height system computed for the project can be used to implement GPS-derived orthometric heights in the area at the 3 to 5 cm level.

Conclusions

Using GPS to estimate an accurate orthometric height at a station is not as straightforward as using GPS to estimate accurate latitude and longitude. Establishing accurate vertical control requires shorter line lengths, more occupations, and occupation of more known vertical control than when establishing horizontal control. Therefore, when establishing accurate vertical control using GPS, the horizontal control results may appear to be an overkill.

Even though a high-resolution geoid has been developed for the continental United States, performing a detailed analysis of the geoid in the area of the survey is still one of the most important steps in computing GPS-derived orthometric heights at the 3 to 5 cm level. It is critical to determine which bench marks need to be occupied with GPS to adequately evaluate the geoid model or where additional gravity observations are required.

In the future, when high resolution geoid height values have meaningful error estimates associated with them, surveyors will be able to use the error estimates to help determine the accuracy of their GPS-derived orthometric heights. This would facilitate the implementation of GPS-derived orthometric heights into the surveying and mapping community. NGS is working on this task.

Even if geoid heights were known exactly, when the project's GPS-derived ellipsoid heights have large uncertainties, the GPS-derived orthometric heights will have large uncertainties. The current FGCS specifications and procedures contain minimum requirements to estimate GPS-derived ellipsoid heights. There are procedures which can be followed to assist in determining the relative precision of the GPS-derived ellipsoid heights. These procedures include occupying a station twice and comparing heights estimated from different vectors, comparison of repeat base line observations obtained over different days and conditions, checking loop misclosures against allowable tolerances, plotting residuals of height components (du) from least squares adjustments of GPS data, and comparison of GPS-derived orthometric heights with known orthometric heights.

The next step in the process of implementing this system into the surveying and mapping community of San Diego County is to 1) perform a pilot project in a mountainous region of the county to evaluate the system, 2) develop procedures for disseminating new geoid information and GPS-derived orthometric heights for evaluating GPS projects performed in the area, and 3) establish a memorandum of understanding with CALTRANS, San Diego County, and NGS which addresses a plan for implementing GPS-derived orthometric heights in the county.

This internal NGS project report which provides the final results and details of each phase of the project is available from NGS. A more detailed analysis of the geoid height model developed during this project is currently being prepared by CALTRANS and NGS personnel and will be published as a separate report.

For more information about the project, please contact:

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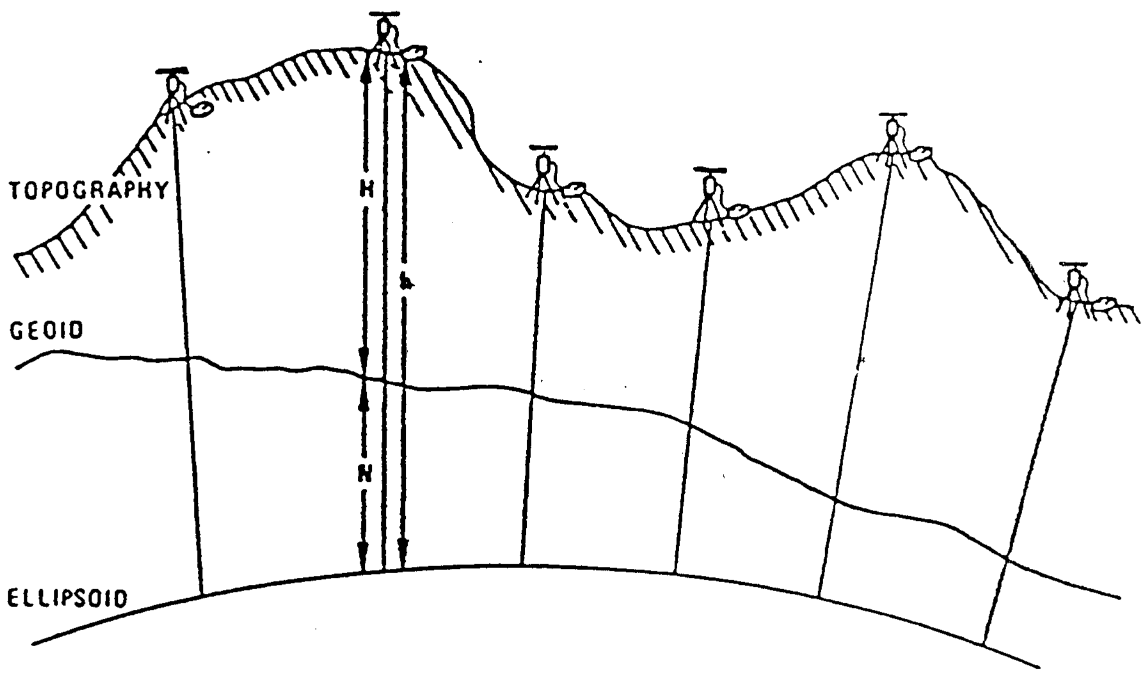
Fig. 1s

ORTHOMETRIC HEIGHT DIFFERENCES USING GPS RELATIVE POSITIONING



- BETWEEN TWO STATIONS SURVEYED BY GPS, WE CAN COMPUTE:

  Δh - ELLIPSOID HEIGHT DIFFERENCE

- IF FROM ASTROGRAVIMETRIC PREDICTION METHODS WE CAN COMPUTE:

  ΔN - GEOIDAL HEIGHT DIFFERENCE

- THEN,

  $\Delta H = \Delta h - \Delta N$, WHERE ΔH IS THE ORTHOMETRIC HEIGHT DIFFERENCE

Fig. 2s

Surface Gravity Density - San Diego (2)

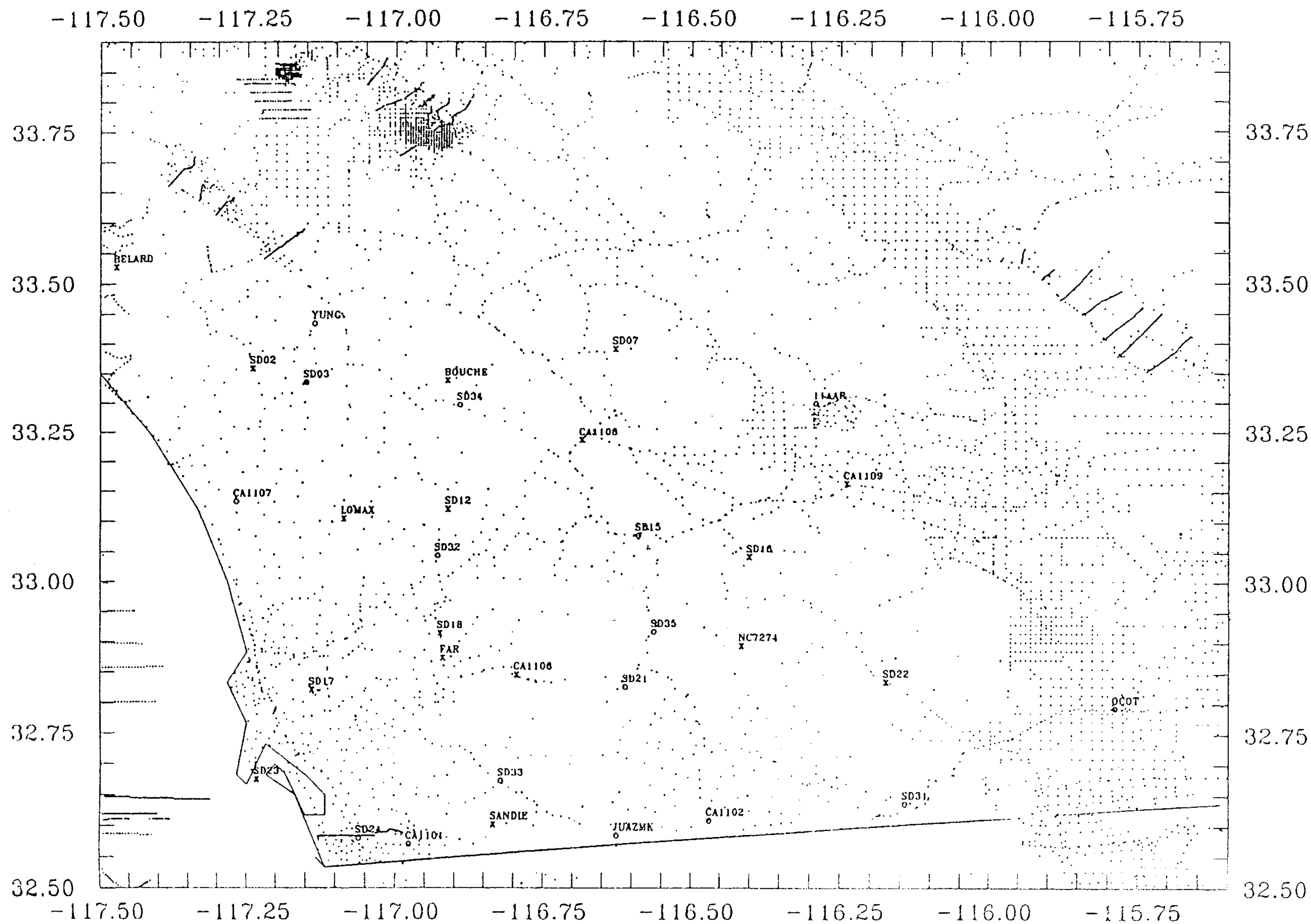


Fig. 3s

units = meters

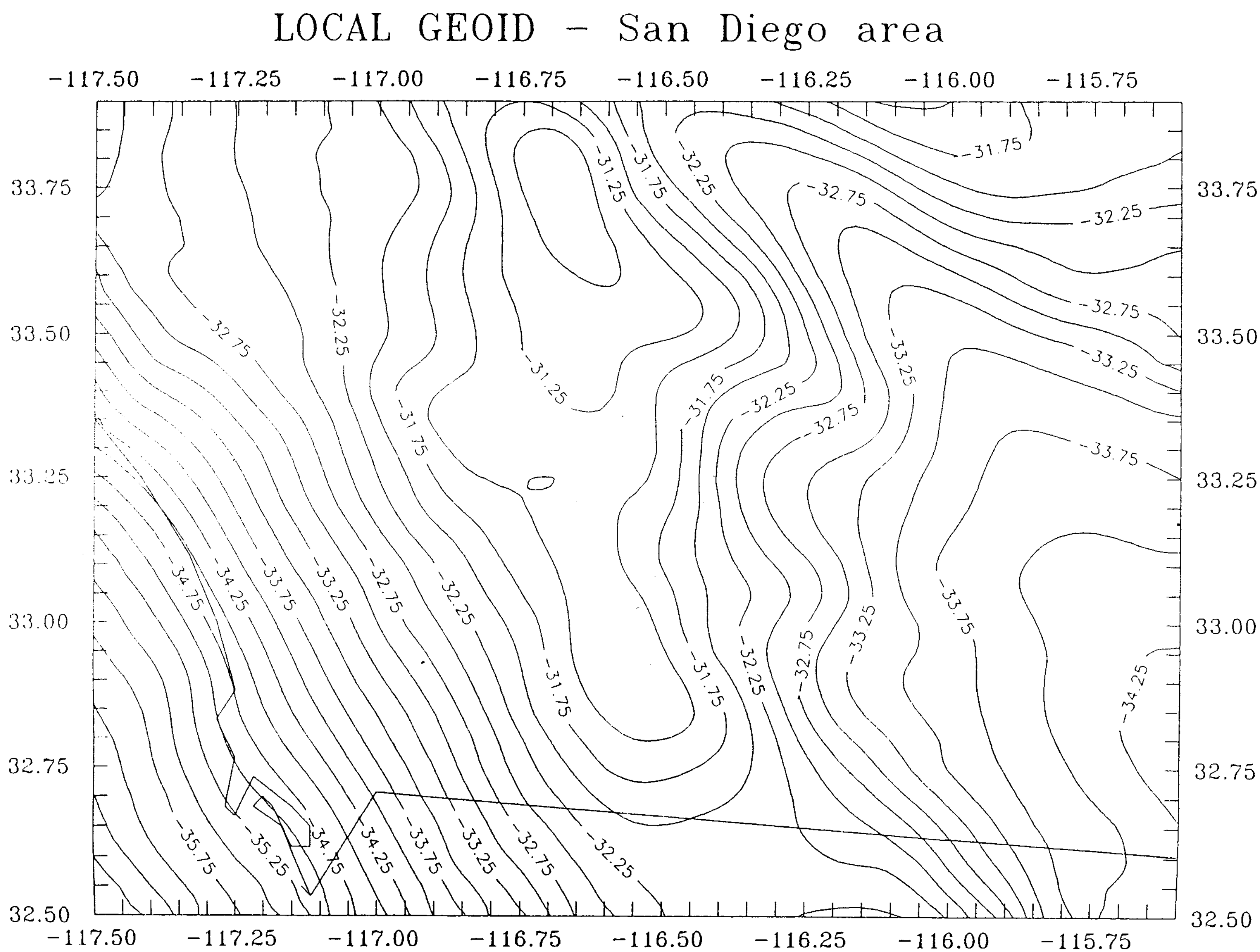


Fig. 4s

Units = meters

GEOID93 - LOCAL GEOID; San Diego area

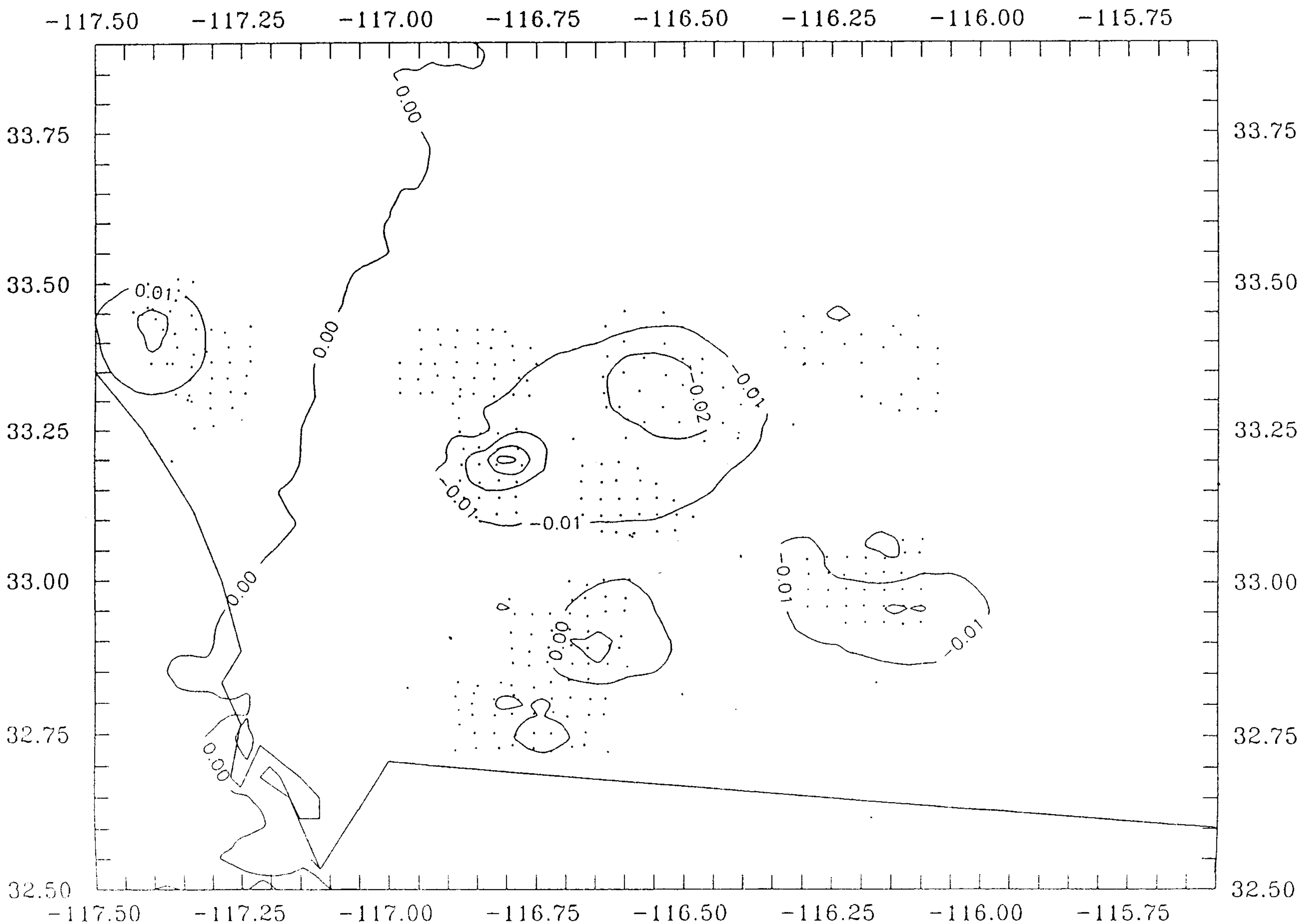
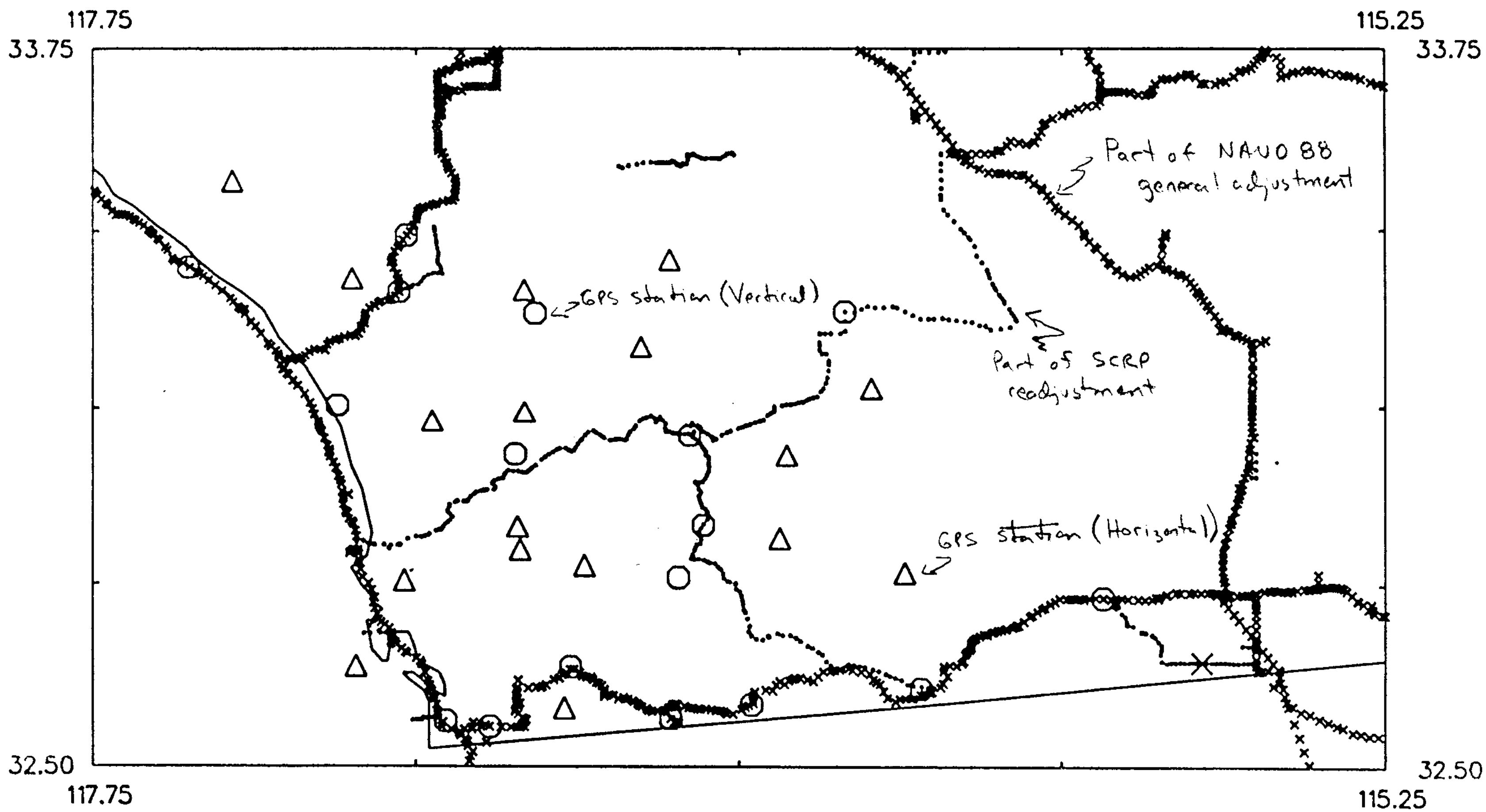


Fig 5s

NAVD 88 (Post Project) and SD GPS Network (o–GPS/BM)



Tab6 1s

San Diego GPS-Derived Orthometric Height Project

STATION	NAVD 88	
11AAR	188.052	LEVEL(1)
CA1101	156.771	TRIG(1)
CA1102	798.485	TRIG(1)
CA1107	94.902	LEVEL(2)
JUNCAZ	562.793	TRIG(1)
OCOT	-1.778	LEVEL(2)
SDGPS01	29.528	LEVEL(2)
SDGPS03	93.958	LEVEL(3)
SDGPS15	1281.509	TRIG(2)
SDGPS21	1096.931	LEVEL(4)
SDGPS24	46.494	LEVEL(2)
SDGPS31	926.012	TRIG(1)
SDGPS32	418.536	TRIG(2)
SDGPS33	222.523	TRIG(1)
SDGPS34	823.437	TRIG(3)
SDGPS35	1234.762	TRIG(2)
YUNG	352.094	LEVEL(3)

LEVEL(1) - NAVD 88 HEIGHT ESTIMATED IN SCRP POSTED ADJUSTMENT
LEVEL(2) - NAVD 88 HEIGHT ESTIMATED USING SHORT LEVELING TIE AND NAVD88 G.A. BENCH MARK
LEVEL(3) - NAVD 88 HEIGHT ESTIMATED USING NEW LEVELING LINE AND NAVD 88 G.A (NGSIDB)
LEVEL(4) - NAVD 88 HEIGHT ESTIMATED USING SHORT LEVELING TIE AND SCRP POSTED NAVD 88 HEIGHT

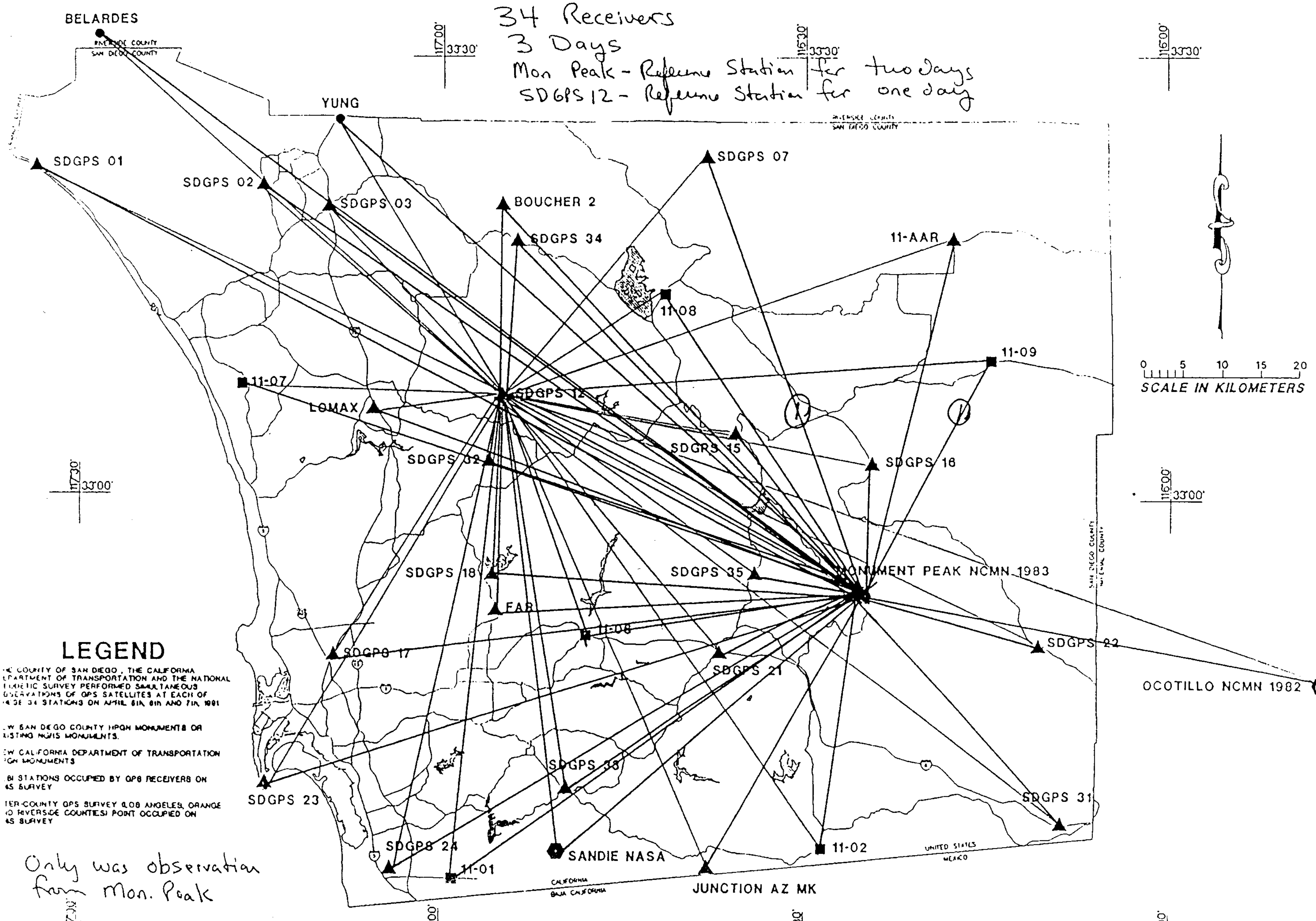
TRIG(1) - NAVD 88 ESTIMATED USING SHORT TRIG TIE AND NAVD 88
TRIG(2) - NAVD 88 ESTIMATED USING SHORT TRIG TIE AND SCRP POSTED HEIGHTS
TRIG(3) - NAVD 88 ESTIMATED USING SHORT TRIG TIE AND 1970 POSTED HEIGHTS

Du Residuals

Fig. 6s

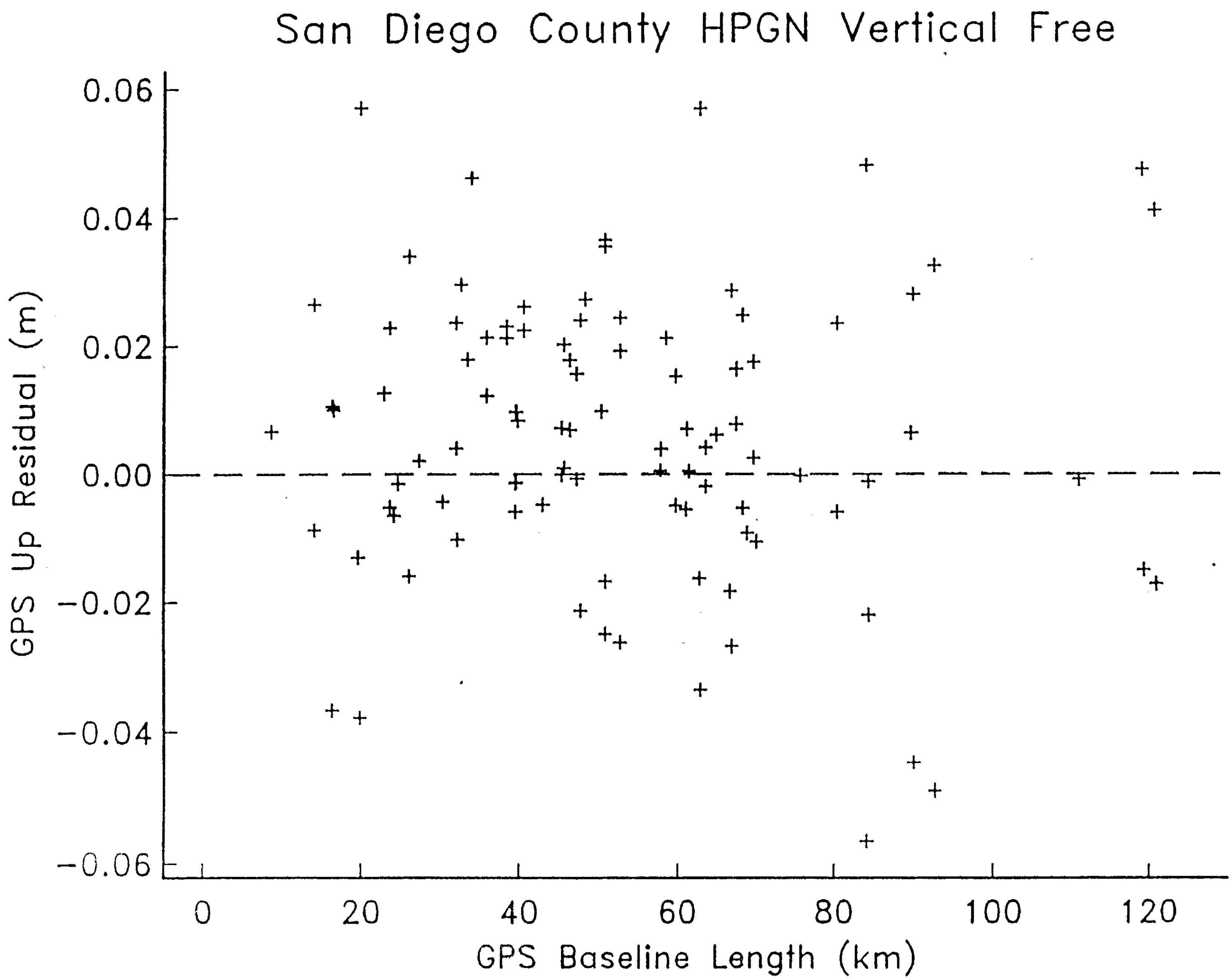
SAN DIEGO COUNTY HIGH PRECISION GEODETIC NETWORK

34 Receivers
3 Days
Mon Peak - Reference Station for two days
SDGPS12 - Reference Station for one day



Only was observation from Mon. Peak

Fig 7s



Adjustment of Aug 4 1992 at 13:33
Mean value is 0.018 meters

Tab6 2s

Differences in ellipsoid heights using different occupations

NUMBER	NAME	Ellipsoid Heights OCC(MON 1) (m)	OCC(MON 2) (m)	OCC(GPS 12) (m)	OCC(ALL DATA) (m)	Differences in Ellipsoid Heights MON 1-ALL (cm)	MON 2-ALL (cm)	GPS 12-ALL (cm)	MON 1-MON 2 (cm)	MON 1-GPS12 (cm)	MON 2-GPS12 (cm)
1	11 AAR	155.487	155.461	155.482	155.476	1.1	-1.5	0.6	2.6	0.5	-2.1
2	BELARDES	671.897	671.824	671.872	671.863	3.4	-3.9	0.9	7.3 *	2.5	-4.8
3	BOUCHER 2	1629.220	1629.214	1629.226	1629.219	0.1	-0.5	0.7	0.6	-0.6	-1.2
4	FAR	174.448	174.417	174.428	174.430	1.8	-1.3	-0.2	3.1	2.0	-1.1
5	HPGN CA 11 01	122.483	122.474	122.463	122.469	1.4	0.5	-0.6	0.9	2.0	1.1
6	HPGN CA 11 02	766.430	766.395	766.428	766.416	1.4	-2.1	1.2	3.5	0.2	-3.3
7	HPGN CA 11 06	391.482	391.459	391.488	391.477	0.5	-1.8	1.1	2.3	-0.6	-2.9
8	HPGN CA 11 07	60.847	60.727	60.755	60.773	7.4 *	-4.6	-1.8	12.0 *	9.2 *	-2.8
9	HPGN CA 11 08	842.131	842.096	842.116	842.114	1.7	-1.8	0.2	3.5	1.5	-2.0
10	HPGN CA 11 09	201.637	201.566	201.626	201.609	2.8	-4.3	1.7	7.1 *	1.1	-6.0 *
11	JUNCTION AZ MK	530.407	530.381	530.382	530.388	1.9	-0.7	-0.6	2.6	2.5	-0.1
12	LOMAX	254.714	254.643	254.660	254.670	4.4	-2.7	-1.0	7.1 *	5.4 *	-1.7
13	MON PEAK	1839.895	1839.880	1839.859	1839.878	1.7	0.2	-1.9	1.5	3.6	2.1
14	OCOTILLO	-35.729	-35.724	-35.730	-35.731	0.2	0.7	0.1	-0.5	0.1	0.6
15	SD GPS 01	-4.903	-4.981	-4.917	-4.936	3.3	-4.5	1.9	7.8 *	1.4	-6.4 *
16	SD GPS 02	185.487	185.391	185.395	185.421	6.6 *	-3.0	-2.6	9.6 *	9.2 *	-0.4
17	SD GPS 03	61.151	61.115	61.082	61.111	4.0	0.4	-2.9	3.6	6.9 *	3.3
18	SD GPS 07	1421.898	1421.849	1421.860	1421.868	3.0	-1.9	-0.8	4.9	3.8	-1.1
19	SD GPS 12	592.007	591.941	591.964	591.963	4.4	-2.2	0.1	6.6 *	4.3	-2.3
20	SD GPS 15	1250.262	1250.198	1250.234	1250.229	3.3	-3.1	0.5	6.4 *	2.8	-3.6
21	SD GPS 16	757.767	757.705	757.686	757.713	5.4 *	-0.8	-2.7	6.2 *	8.1 *	1.9
22	SD GPS 17	91.244	91.199	91.227	91.221	2.3	-2.2	0.6	4.5	1.7	-2.8
23	SD GPS 18	210.145	210.085	210.094	210.106	3.9	-2.1	-1.2	6.0 *	5.1 *	-0.9
24	SD GPS 21	1065.512	1065.402	1065.462	1065.457	5.5 *	-5.5 *	0.5	11.0 *	5.0 *	-6.0 *
25	SD GPS 22	295.558	295.515	295.536	295.535	2.3	-2.0	0.1	4.3	2.2	-2.1
26	SD GPS 23	90.679	90.635	90.652	90.656	2.3	-2.1	-0.4	4.4	2.7	-1.7
27	SD GPS 24	11.729	11.729	11.729	11.729	0.0	0.0	0.0	0.0	0.0	0.0
28	SD GPS 31	893.667	893.650	893.664	893.670	-0.3	-2.0	-0.6	1.7	0.3	-1.4
29	SD GPS 32	386.059	385.983	386.010	386.016	4.3	-3.3	-0.6	7.6 *	4.9	-2.7
30	SD GPS 33	189.455	189.433	189.428	189.438	1.7	-0.5	-1.0	2.2	2.7	0.5
31	SD GPS 34	792.046	791.941	792.009	791.995	5.1 *	-5.4 *	1.4	10.5 *	3.7	-6.8 *
32	SD GPS 35	1203.595	1203.544	1203.570	1203.568	2.7	-2.4	0.2	5.1 *	2.5	-2.6
33	SANDIE	989.674	989.606	989.640	989.640	3.4	-3.4	0.0	6.8 *	3.4	-3.4
34	YUNG	319.708	319.621	319.624	319.646	6.2 *	-2.5	-2.2	8.7 *	8.4 *	-0.3
					AVE	2.9	-2.1	-0.3	5.0	3.2	-1.9
					MIN	-0.3	-5.5	-2.9	-0.5	-0.6	-6.8
					MAX	7.4	0.7	1.9	12.0	9.2	3.3

* - Absolute value greater than or equal to 5 cm

MON 1 - FIRST SET OF VECTORS FROM MONUMENT PEAK USED TO ESTIMATE HEIGHTS
MON 2 - SECOND SET OF VECTORS FROM MONUMENT PEAK USED TO ESTIMATE HEIGHTS
GPS 12 - VECTORS FROM SD GPS 12 USED TO ESTIMATE HEIGHTS
ALL - ALL DATA USED TO ESTIMATE HEIGHTS

Tab6 2

Tab6 3s

Differences in ellipsoid heights using different occupations

NUMBER	NAME	Ellipsoid Heights: MON 1+MON 2 (m)	MON 1+GPS12 (m)	MON 2+GPS12 (m)	OCC(ALL DATA) (m)	Differences in Ellipsoid Heights: MON(1+2)-ALL (cm)	MON1+12-ALL (cm)	MON2+12-ALL (cm)	(1+2)-(1+12) (cm)	(1+2)-(2+12) (cm)	(1+12)-(2+12) (cm)
1	11 AAR	155.473	155.484	155.472	155.476	-0.3	0.8	-0.4	-1.1	0.1	1.2
2	BELARDES	671.858	671.884	671.847	671.863	-0.5	2.1	-1.6	-2.6	1.1	3.7
3	BOUCHER 2	1629.214	1629.225	1629.217	1629.219	-0.5	0.6	-0.2	-1.1	-0.3	0.8
4	FAR	174.431	174.438	174.422	174.430	0.1	0.8	-0.8	-0.7	0.9	1.6
5	HPGN CA 11 01	122.474	122.471	122.466	122.469	0.5	0.2	-0.3	0.3	0.8	0.5
6	HPGN CA 11 02	766.411	766.428	766.411	766.416	-0.5	1.2	-0.5	-1.7	0.0	1.7
7	HPGN CA 11 06	391.471	391.488	391.473	391.477	-0.6	1.1	-0.4	-1.7	-0.2	1.5
8	HPGN CA 11 07	60.782	60.799	60.741	60.773	0.9	2.6	-3.2	-1.7	4.1	5.8 *
9	HPGN CA 11 08	842.112	842.123	842.107	842.114	-0.2	0.9	-0.7	-1.1	0.5	1.6
10	HPGN CA 11 09	201.588	201.641	201.597	201.609	-2.1	3.2	-1.2	-5.3 *	-0.9	4.4
11	JUNCTION AZ MK	530.392	530.393	530.380	530.388	0.4	0.5	-0.8	-0.1	1.2	1.3
12	LOMAX	254.676	254.685	254.650	254.670	0.6	1.5	-2.0	-0.9	2.6	3.5
13	MON PEAK	1839.887	1839.872	1839.874	1839.878	0.9	-0.6	-0.4	1.5	1.3	-0.2
14	OCOTILLO	-35.731	-35.73	-35.730	-35.731	0.0	0.1	0.1	-0.1	-0.1	0.0
15	SD GPS 01	-4.945	-4.911	-4.950	-4.936	-0.9	2.5	-1.4	-3.4	0.5	3.9
16	SD GPS 02	185.435	185.438	185.392	185.421	1.4	1.7	-2.9	-0.3	4.3	4.6
17	SD GPS 03	61.130	61.113	61.095	61.111	1.9	0.2	-1.6	1.7	3.5	1.8
18	SD GPS 07	1421.873	1421.875	1421.854	1421.868	0.5	0.7	-1.4	-0.2	1.9	2.1
19	SD GPS 12	591.972	591.978	591.946	591.963	0.9	1.5	-1.7	-0.6	2.6	3.2
20	SD GPS 15	1250.227	1250.247	1250.215	1250.229	-0.2	1.8	-1.4	-2.0	1.2	3.2
21	SD GPS 16	757.730	757.717	757.694	757.713	1.7	0.4	-1.9	1.3	3.6	2.3
22	SD GPS 17	91.219	91.235	91.211	91.221	-0.2	1.4	-1.0	-1.6	0.8	2.4
23	SD GPS 18	210.112	210.119	210.089	210.106	0.6	1.3	-1.7	-0.7	2.3	3.0
24	SD GPS 21	1065.453	1065.487	1065.431	1065.457	-0.4	3.0	-2.6	-3.4	2.2	5.6 *
25	SD GPS 22	295.534	295.547	295.525	295.535	-0.1	1.2	-1.0	-1.3	0.9	2.2
26	SD GPS 23	90.657	90.668	90.642	90.656	0.1	1.2	-1.4	-1.1	1.5	2.6
27	SD GPS 24	11.729	11.729	11.729	11.729	0.0	0.0	0.0	0.0	0.0	0.0
28	SD GPS 31	893.667	893.684	893.657	893.670	-0.3	1.4	-1.3	-1.7	1.0	2.7
29	SD GPS 32	386.019	386.035	385.996	386.016	0.3	1.9	-2.0	-1.6	2.3	3.9
30	SD GPS 33	189.443	189.441	189.430	189.438	0.5	0.3	-0.8	0.2	1.3	1.1
31	SD GPS 34	791.989	792.027	791.973	791.995	-0.6	3.2	-2.2	-3.8	1.6	5.4 *
32	SD GPS 35	1203.567	1203.582	1203.557	1203.568	-0.1	1.4	-1.1	-1.5	1.0	2.5
33	SANDIE	989.638	989.66	989.622	989.640	-0.2	2.0	-1.8	-2.2	1.6	3.8
34	YUNG	319.659	319.662	319.621	319.646	1.3	1.6	-2.5	-0.3	3.8	4.1
					AVE	0.1	1.3	-1.3	-1.1	1.4	2.6
					MIN	-2.1	-0.6	-3.2	-5.3	-0.9	-0.2
					MAX	1.9	3.2	0.1	1.7	4.3	5.8

* - Absolute value greater than or equal to 5 cm

MON 1 - FIRST SET OF VECTORS FROM MONUMENT PEAK USED TO ESTIMATE HEIGHTS
MON 2 - SECOND SET OF VECTORS FROM MONUMENT PEAK USED TO ESTIMATE HEIGHTS
GPS 12 - VECTORS FROM SD GPS 12 USED TO ESTIMATE HEIGHTS
ALL - ALL DATA USED TO ESTIMATE HEIGHTS

Tab6 3

Fig. 8s

GPS(H) - NAVD88(H) (cm); 17 Sta.- San Diego Co.

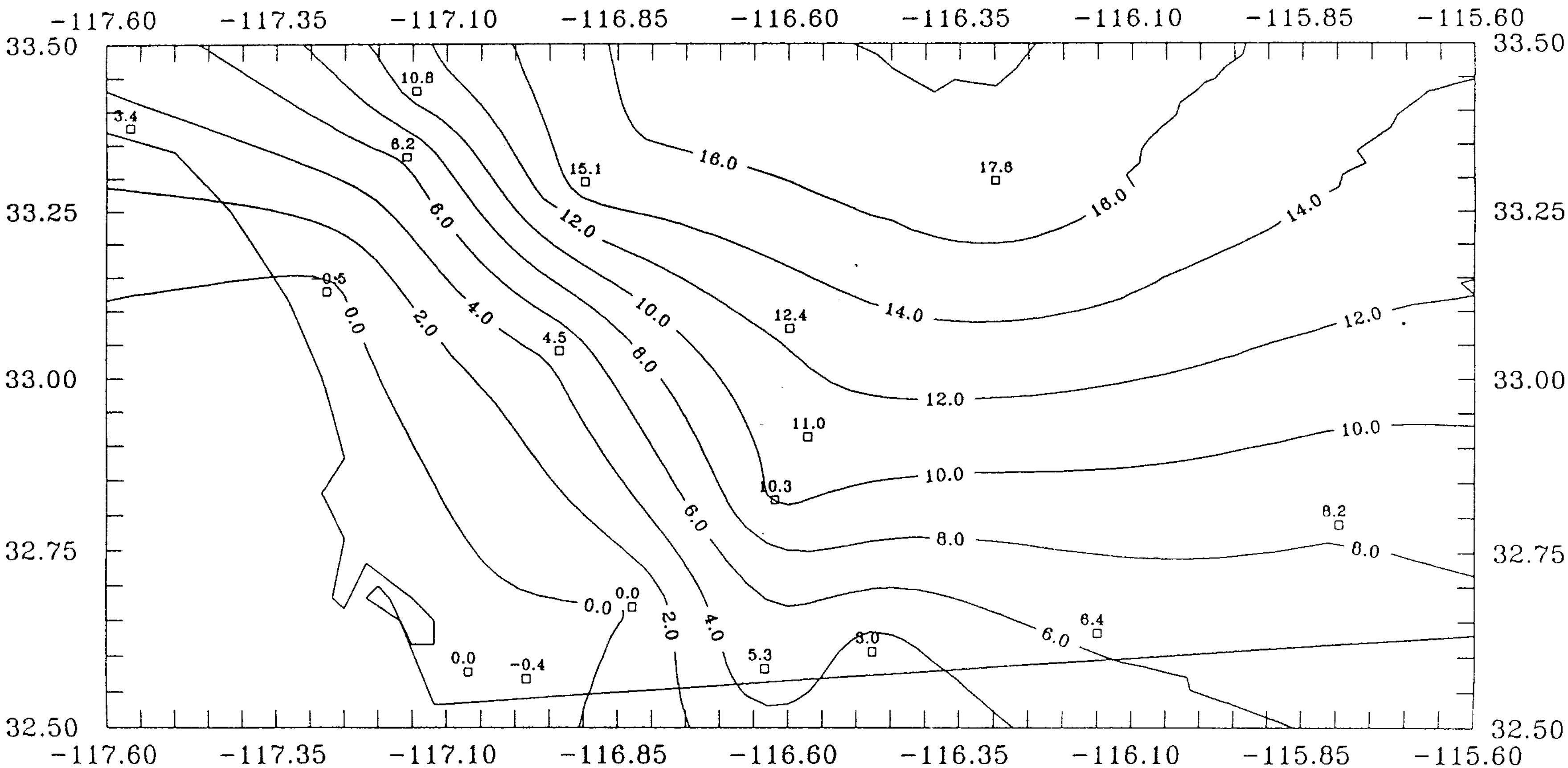


Fig. 9s

GPS(H)-NAVD88(H) 17 Sta. trend removed-San Diego

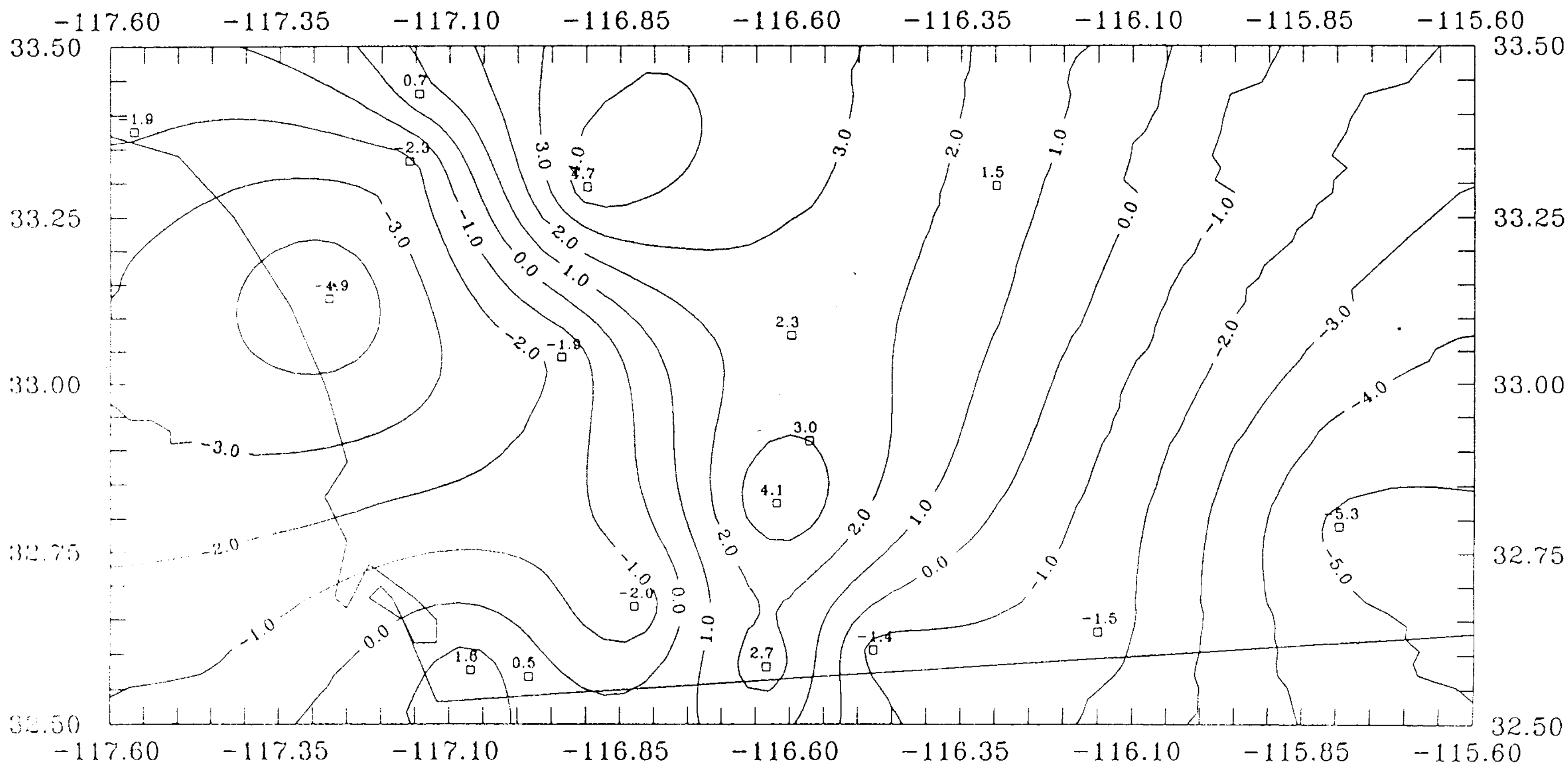


Table 4s

San Diego GPS-Derived Orthometric Height Project

STATION Station	GEOID93S (m)	GEOID93 (m)	GPS(H) GEOID93S (m)	GPS(H) GEOID93 (m)	NAVD 88 (m)		GPSH(93S) - NAVD (cm)	GPSH(G93) - NAVD (cm)	GPSH(93S) - NAVD trend (cm)	GPSH(G93) - NAVD (no rejects) (cm)
11AAR	-32.752	-32.745	188.228	188.221	188.052	LEVEL(1)	17.6	16.9	1.5	1.2
CA1101	-34.299	-34.298	156.768	156.767	156.771	TRIG(1)	-0.4	-0.4	0.5	0.5
CA1102	-32.099	-32.097	798.515	798.513	798.485	TRIG(1)	3.0	2.8	-1.4	-1.4
CA1107	-34.124	-34.125	94.897	94.898	94.902	LEVEL(2)	-0.5	-0.4	-4.9	-4.9
JUNCAZ	-32.458	-32.456	562.846	562.844	562.793	TRIG(1)	5.3	5.1	2.7	2.7
OCOT	-34.036	-34.034	-1.696	-1.698	-1.778	LEVEL(2)	8.2	8.0	-5.3	-4.9
SDGPS01	-34.499	-34.505	29.563	29.569	29.528	LEVEL(2)	3.4	4.0	-1.9	-1.4
SDGPS03	-32.909	-32.910	94.020	94.021	93.958	LEVEL(3)	6.2	6.3	-2.3	-2.2
SDGPS15	-31.404	-31.395	1281.633	1281.624	1281.509	TRIG(2)	12.4	11.5	2.3	1.7
SDGPS21	-31.578	-31.575	1097.034	1097.031	1096.931	LEVEL(4)	10.3	10.0	4.1	4.0
SDGPS24	-34.765	-34.765	46.494	46.494	46.494	LEVEL(2)	0.0	0.0	1.6	1.6
SDGPS31	-32.406	-32.403	926.076	926.073	926.012	TRIG(1)	6.4	6.1	-1.5	-1.4
SDGPS32	-32.565	-32.560	418.581	418.576	418.536	TRIG(2)	4.5	4.0	-1.9	-2.3
SDGPS33	-33.086	-33.083	222.523	222.520	222.523	TRIG(1)	-0.0	-0.3	-2.0	-2.2
SDGPS34	-31.593	-31.589	823.588	823.584	823.437	TRIG(3)	15.1	14.7	4.7	4.5
SDGPS35	-31.304	-31.308	1234.872	1234.876	1234.762	TRIG(2)	11.0	11.4	3.0	3.7
YUNG	-32.556	-32.557	352.202	352.203	352.094	LEVEL(3)	10.8	10.9	0.7	0.9
						Ave	6.7	6.5	0.0	-0.0
						Min	-0.5	-0.4	-5.3	-4.9
						Max	17.6	16.9	4.7	4.5
								Shift(cm)	8.187	7.979
								tilts	sec	sec
								e-w	0.203	0.193
								n-s	0.312	0.309
								RMS (cm)	2.953	2.883
								r value	0.72	0.72

Table 5s

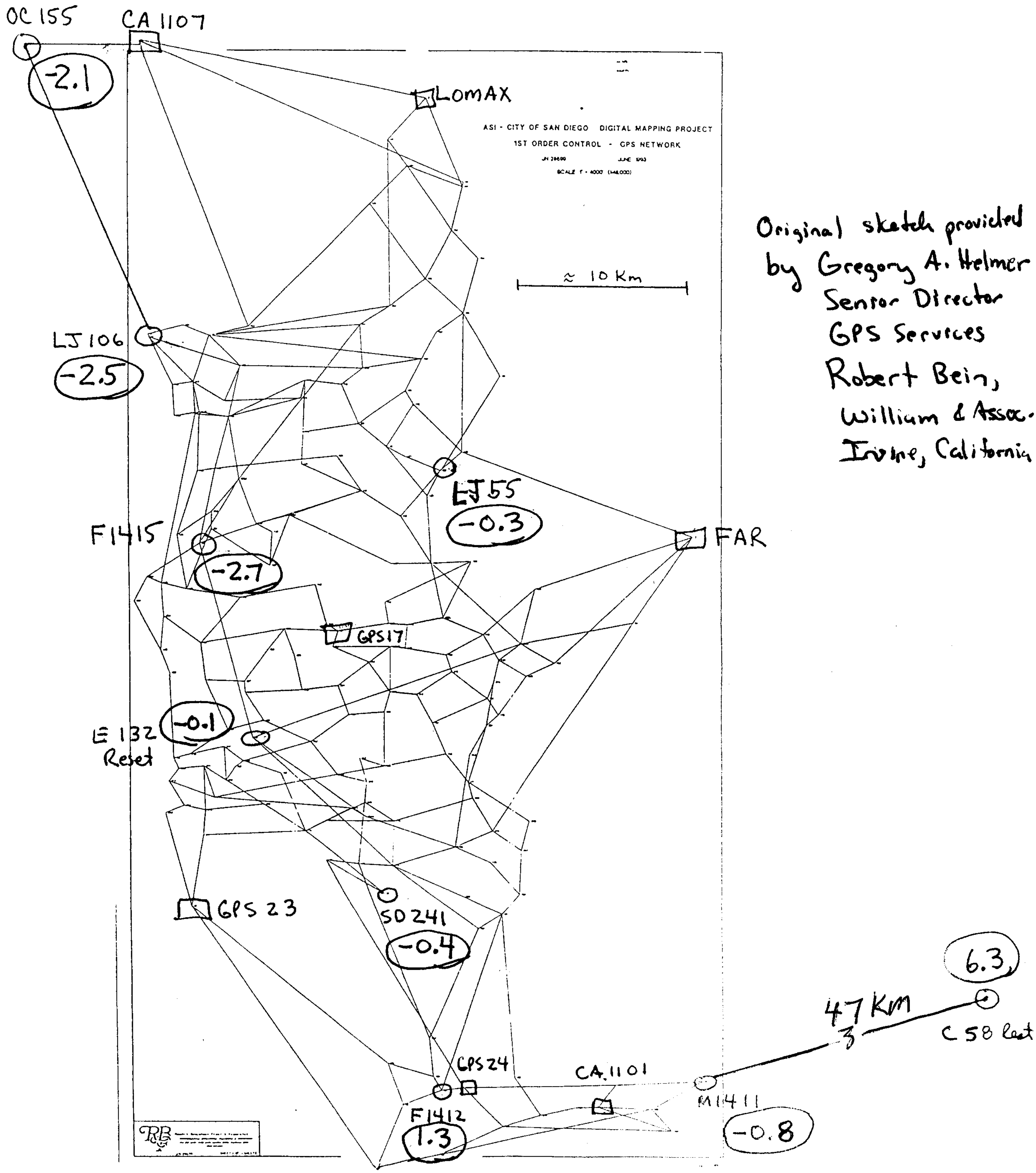
STATION NAME	NAVD 88 METHOD 1 (M)	NAVD 88 METHOD 2 (M)	NAVD 88 METHOD 3 (M)		METHOD 2 MINUS METHOD 1 (CM)	METHOD 3 MINUS METHOD 1 (CM)	METHOD 3 MINUS METHOD 2 (CM)
11 AAR	188.052	188.052	188.052	*	0.0	0.0	0.0
BELARDES	705.225	705.234	705.241		0.9	1.6	0.7
BOUCHER 2	1660.657	1660.659	1660.698		0.2	4.1	3.9
FAR	207.444	207.446	207.417		0.2	-2.7	-2.9
CA 11 01	156.771	156.771	156.771	*	0.0	0.0	0.0
CA 11 02	798.485	798.485	798.485	*	0.0	0.0	0.0
CA 11 06	423.876	423.877	423.857		0.1	-1.9	-2.0
CA 11 07	94.902	94.902	94.902	*	0.0	0.0	0.0
CA 11 08	873.503	873.502	873.551		-0.1	4.8	4.9
CA 11 09	234.399	234.392	234.478		-0.7	7.9	8.6
JUNCTION AZ MK	562.793	562.793	562.793	*	0.0	0.0	0.0
LOMAX	287.819	287.823	287.81		0.4	-0.9	-1.3
MON PEAK NCMN 7274	1871.476	1871.472	1871.498		-0.4	2.2	2.6
OCOTILLO NCMN 7270	-1.778	-1.778	-1.778	*	0.0	0.0	0.0
SD GPS 01	29.528	29.528	29.528	*	0.0	0.0	0.0
SD GPS 02	218.555	218.561	218.569		0.6	1.4	0.8
SD GPS 03	93.958	93.958	93.958	*	0.0	0.0	0.0
SD GPS 07	1452.931	1452.929	1453.006		-0.2	7.5	7.7
SD GPS 12	624.162	624.164	624.172		0.2	1.0	0.8
SD GPS 15	1281.509	1281.509	1281.509	*	0.0	0.0	0.0
SD GPS 16	789.651	789.646	789.697		-0.5	4.6	5.1
SD GPS 17	125.532	125.538	125.477		0.6	-5.5	-6.1
SD GPS 18	243.006	243.009	242.985		0.3	-2.1	-2.4
SD GPS 21	1096.931	1096.931	1096.931	*	0.0	0.0	0.0
SD GPS 22	328.531	328.523	328.569		-0.8	3.8	4.6
SD GPS 23	125.888	125.894	125.803		0.6	-8.5	-9.1
SD GPS 24	46.494	46.494	46.494	*	0.0	0.0	0.0
SD GPS 31	926.012	926.012	926.012	*	0.0	0.0	0.0
SD GPS 32	418.536	418.536	418.536	*	0.0	0.0	0.0
SD GPS 33	222.523	222.523	222.523	*	0.0	0.0	0.0
SD GPS 34	823.437	823.437	823.437	*	0.0	0.0	0.0
SD GPS 35	1234.762	1234.762	1234.762	*	0.0	0.0	0.0
SANDIE NASA	1022.944	1022.945	1022.886		0.1	-5.8	-5.9
YUNG	352.094	352.094	352.094	*	0.0	0.0	0.0

* CONSTRAINED HEIGHT IN ADJUSTMENT
METHOD 1 - Scale and Rotation Method
METHOD 2 - Trend Removal Method
METHOD 3 - Height Distribution Method

Fig 10s

$H_{GPS} - H_{88}$

units = cm



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