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Appendix A: NGS Data Sheets/Velocities & HTDP Output

Appendix B: Reference Documents

R1: Report & version 2 of coordinate table 1, *California Spatial Reference System, CSRS epoch 2017.50 (NAD83)*, January 4, 2018

R2: City of Santa Barbara Survey Benchmarks 2008 Height Modernization Project, on file in the Office of the Santa Barbara County Surveyor

R3: Santa Barbara Control Network, Record of Survey Book 147 Pages 70 through 74, inclusive, Santa Barbara County Recorder's Office

R4: *GNSS Surveying Standards And Specifications, 1.1*, a joint publication of the California Land Surveyor's Association (CLSA) & the California Spatial Reference Center (CSRC), dated December 10, 2011

Appendix C: Raw Vector Data (Post-Processed Covariance Matrix Format)

Appendix D: Star*Net Adjustment Outputs

Appendix E: Record of Survey

Surveyor's Statement:

This report was prepared by me at the request of the County of Santa Barbara.



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The following is intended to be a supplement to the Record of Survey establishing the 2018 Montecito High Precision Geodetic Control Network, documenting the data analysis and procedures thereof. Refer to the Record of Survey for station coordinates, accuracies, descriptions, and additional notes.

Adjustment Overview

The field campaign was performed in June, July, and August of 2018. The Global Navigation Satellite System (GNSS) was used to determine positions based on the North American Datum of 1983 (NAD83). This survey is referenced to five (COPR, P519, RCA2, P548, & CSST) continuously operating Global Positioning Stations (cGPS) and their published coordinates per that certain report and version 2 ("table 1, version 2") of coordinates thereof prepared by the California Spatial Reference Center (CSRC), University of California San Diego, titled "California Spatial Reference System, CSRS epoch 2017.50 (NAD83)" dated January 4, 2018 (known henceforth as "R1", see Appendix B). Two of said CGPS stations (COPR & CSST) are also part of National Geodetic Survey's (NGS) Continuously Operating Reference Station (CORS) network. For network redundancy and to include a third station that is included in the CORS network to offer more flexibility in forward compatibility and analysis checks; NGS CORS station CASN (NGS PID: DP2483) was included in all adjustments described below (coordinates solved for, not held fixed). *It should be noted the most current published NGS epoch via data sheets is 2010.00 while the most current epoch via the CSRC is 2017.50 per R1.*

As an additional check throughout the data analysis phase (all adjustments) of this survey a NAD83(2011), epoch 2017.50 (epoch and NAD83 realization as per R1 and this survey) coordinate was computed for station CASN based on applying NGS published velocities to the NGS data sheet published NAD83(2011), epoch 2010.00 coordinate via NGS's Horizontal Time Dependent Positioning (HTDP) software version 3.2.5.

A privately managed active GNSS station was included herein (station 8 of this survey) for further network redundancy. See "Station 8 (PSSB) Geodetic Coordinate Establishment" below for further detail. Neither CASN or station 8 have published coordinates per R1.

Equipment & Procedures

Field data was collected using a combination of Trimble R-10, Trimble R-8 model 2, and Trimble R-8 model 4 receivers collecting static data at a 5 second epoch interval with a 10-degree horizon mask.

Field procedures strictly followed those recommendations for a survey with anticipated data results having a spatial accuracy classification of "Vertical, 0.5 centimeters to 2.0 centimeters" at the 95 percent confidence interval as outlined per "GNSS Surveying Standards and Specifications, 1.1," a joint publication of the California Land Surveyor's Association (CLSA) & the California Spatial Reference Center (CSRC), dated December 10, 2011 (see Appendix B). As specified therein; all stations were occupied with a minimum of two sessions each with a minimum occupation time of 30 minutes each while 50 percent of stations were occupied with a third session, all having a minimum two-hour sidereal time displacement. Due to station specific sky obstructions some station occupation durations were increased by up to two hours to improve final coordinate spatial accuracy. Establishment of orthometric heights at all stations is described below in Master Adjustments 3A, 3B, 4A, and 4B. The planetary K-index as published by the National Oceanic and Atmospheric Administration (NOAA) did not exceed 4 at

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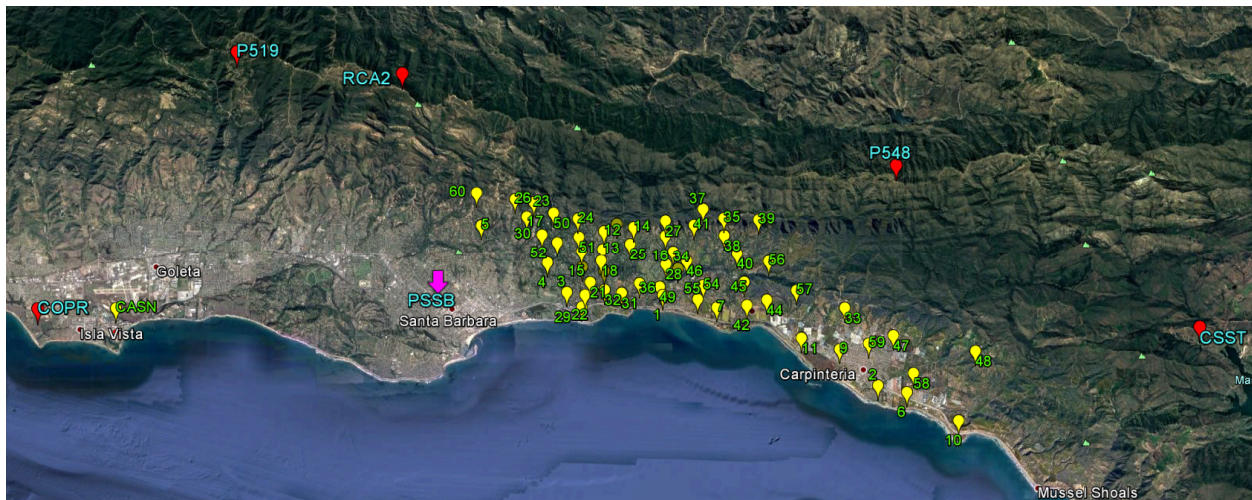
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any time during data collection. Rapid or precise ephemeris obtained from the International GNSS Service (IGS) was utilized in all post-processing of data. Field data was post-processed using Trimble Business Center version 4.10; vector analysis and adjustments were performed using MicroSurvey Star*Net version 9.1.3.7548.

Adjustments

A narrative of the data adjustments, analysis, and establishment of final coordinates to be perpetuated via the Record of Survey are outlined below. Residual values listed in the tables below are based on the resultant geodetic coordinates (latitude, longitude, ellipsoid height) being projected as the California Coordinate System of 1983 (CCS83), Zone 5.



Station 8 ("PSSB") Geodetic Coordinate Establishment

Station 8 ("PSSB") is an active station included in the privately managed CalVRS/AzGPS Real Time Network, privately managed by Arizona based AzGPS, LLC, and is known within said real-time network as "PSSB" and/or "SBPS". Said station is not included in aforementioned report. The geodetic coordinates established by this survey at said station are based on three 24-hour static occupations collected with a Trimble R-10 receiver, post-processed and adjusted independent of the remaining station adjustments. The final geodetic coordinates for station 8 are based on a fully constrained adjustment per "Station 8 Adjustment 2A" described below, holding fixed the R1 geodetic coordinates at said five cGPS stations. Station 8 was then incorporated as a 6th fixed station in the "Master Adjustments" described herein for all remaining stations to offer both additional network geometry strength in vector redundancy as well as significantly shorter baseline lengths from all stations in the westerly direction.

(all values in U.S. Survey Feet unless otherwise noted)

**dZ comparison based on ellipsoid height (modelled with Geoid 12B when applicable) when noted with asterisk*

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Station 8 Adjustment 1A – Minimally Constrained Adjustment

This adjustment is a minimally constrained adjustment, RCA2 being fixed at the geodetic position per R1; the closures at other stations follow:

Station	dN	dE	dZ
CASN	0.000405	-0.004144	-0.013063*
COPR	0.050108	0.001455	-0.032703*
CSST	-0.002483	0.009524	0.016126*
P519	0.002422	-0.006078	-0.011255*
P548	0.004171	0.001406	-0.003717*
RCA2	-0.000000	-0.000000	-0.000000* FIXED

Station 8 Adjustment 1B – Free Weighted Adjustment

A free weighted constrained adjustment, setting all stations to a weight of 1 meter while letting the HTDP position of CASN float while solving for rotations and scale results in the following closures and solved transformations:

Station	dN	dE	dZ
CASN	-0.021975	-0.001808	0.016737* FREE
COPR	0.025740	0.004014	0.000155*
CSST	0.002435	0.009601	0.006617*
P519	-0.016477	-0.009654	-0.000864*
P548	0.002476	-0.000827	-0.011392*
RCA2	-0.014174	-0.003135	0.005485*

Scale Factor 1.000000022311 : -0.022311 PPM (Solved)

Rotation Around North Axis : -0.060032 Sec (Solved)

Rotation Around East Axis : 0.089602 Sec (Solved)

Rotation Around Vert Axis : -0.038817 Sec (Solved)

Station 8 Adjustment 2A – Fully Constrained Adjustment

A fully constrained adjustment fixing all five primary stations to their published coordinates per R1 while letting the HTDP position of CASN float:

Station	dN	dE	dZ
CASN	-0.007970	-0.004250	-0.004544* FREE
COPR	-0.000000	-0.000000	-0.000000* FIXED
CSST	-0.000000	-0.000000	-0.000000* FIXED
P519	-0.000000	-0.000000	-0.000000* FIXED
P548	-0.000000	-0.000000	-0.000000* FIXED
RCA2	-0.000000	-0.000000	-0.000000* FIXED

(all values in U.S. Survey Feet unless otherwise noted)

*dZ comparison based on ellipsoid height (modelled with Geoid 12B when applicable) when noted with asterisk

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Station 8 Adjustment 2B – Fully Constrained Adjustment (solving for scale & rotations)

For further analysis below are the transformation results of Station 8 Adjustment 2A above while solving for rotations and scale:

Scale Factor 1.000000034818 : -0.034818 PPM (Solved)
Rotation Around North Axis : -0.102798 Sec (Solved)
Rotation Around East Axis : 0.435568 Sec (Solved)
Rotation Around Vert Axis : -0.031307 Sec (Solved)

Master Adjustment (Geodetic Positions) Stations 1 through 60 (except 8)

Master Adjustment 1A – Minimally Constrained Adjustment

This adjustment is a minimally constrained adjustment, RCA2 being fixed at the geodetic position per R1; the closures at other stations follow:

Station	dN	dE	dZ
8	0.002426	0.009060	-0.062941*
CASN	0.001271	-0.000907	-0.031701* HTDP
COPR	0.049555	0.004479	-0.023620*
CSST	-0.000052	0.007989	0.047506*
P519	-0.001672	-0.006311	-0.027652*
P548	0.005646	0.000041	-0.020621*
RCA2	-0.000000	-0.000000	-0.000000* FIXED

Master Adjustment 1B – Free Weighted Adjustment

A free weighted constrained adjustment, setting all stations, including the Station 8 Adjustment 2A final geodetic position at station 8 described above to a weight of 1 meter while letting the HTDP position of CASN float, and solving for rotations and scale results in the following closures and solved transformations:

Station	dN	dE	dZ
8	-0.003841	0.002496	-0.011292*
CASN	-0.009395	-0.006724	0.048790* HTDP FREE
COPR	0.037717	-0.001255	0.063175*
CSST	0.004707	0.001887	0.047642*
P519	-0.007998	-0.014249	0.006615*
P548	0.009629	-0.006186	-0.020590*
RCA2	-0.002710	-0.007059	0.024708*

Scale Factor 1.000000005681 : -0.005681 PPM (Solved)
Rotation Around North Axis : -0.123870 Sec (Solved)
Rotation Around East Axis : 0.225117 Sec (Solved)
Rotation Around Vert Axis : -0.021425 Sec (Solved)

(all values in U.S. Survey Feet unless otherwise noted)

*dZ comparison based on ellipsoid height (modelled with Geoid 12B when applicable) when noted with asterisk

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Master Adjustment 2A – Fully Constrained Adjustment

A fully constrained adjustment fixing all five primary stations to their published coordinates per R1 and including the Station 8 Adjustment 2A final geodetic position at station 8 described above while letting the HTDP position of CASN float:

Station	dN	dE	dZ
8	-0.000000	-0.000000	-0.000000* FIXED (Station 8 Adjustment 2A)
CASN	-0.009943	-0.002973	-0.013220* FREE
COPR	-0.000000	-0.000000	-0.000000* FIXED
CSST	-0.000000	-0.000000	-0.000000* FIXED
P519	-0.000000	-0.000000	-0.000000* FIXED
P548	-0.000000	-0.000000	-0.000000* FIXED
RCA2	-0.000000	-0.000000	-0.000000* FIXED

The 3D closure residual seen at the HTDP derived 2017.50 position of station CASN above is a further check for our procedure and data quality.

Master Adjustment 2B – Fully Constrained Adjustment (solving for scale & rotations)

For further analysis below are the transformation results of Master Adjustment 2A above while solving for rotations and scale:

Scale Factor 0.999999990226 : 0.009774 PPM (Solved)
Rotation Around North Axis : -0.096545 Sec (Solved)
Rotation Around East Axis : 0.195981 Sec (Solved)
Rotation Around Vert Axis : -0.032929 Sec (Solved)

Master Adjustment (Orthometric Heights)

All Stations

Note: The orthometric heights established by this survey are based on static observations of five existing passive monuments having published North American Vertical Datum of 1988 (NAVD88) orthometric heights (NGS: June 1991 adjustment) per NGS data sheets (stations 2, 6, & 9) or 2nd order levelled elevations from NGS benchmarks per the City of Santa Barbara Survey Benchmarks 2008 Height Modernization Project on file in the Office of the Santa Barbara County Surveyor (R2) (stations 3 & 5). No field levelling was performed as part of this survey. As noted below, station 9 (NGS PID: EW9491) was found to be vertically inconsistent with the remaining four passive stations and thus was set free in the fully constrained adjustment (Master Adjustment 4A) from which the orthometric heights for all stations in this survey were derived.

Master Adjustment 3A (Orthometric Height) – Minimally Constrained

(all values in U.S. Survey Feet unless otherwise noted)

*dZ comparison based on ellipsoid height (modelled with Geoid 12B when applicable) when noted with asterisk

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This adjustment produced a minimally constrained adjustment fixing (arbitrarily) stations COPR and CSST for horizontal, and station 6's published NAVD88 orthometric height (per NGS data sheet) and setting other known stations free. The "Geoid 12B" geoid model was applied to ellipsoid heights. Analysis of the height closures seen below verify the integrity of the control identifying station 9 as an outlier. In-depth analysis of said geoid model was not a part of this survey; however, this adjustment serves as evidence for the real-world validity of said model within the network area:

Station	dZ
2	-0.061025
3	0.032497
5	-0.008963
6	-0.000000 FIXED
9	-0.283385

Master Adjustment 3B (Orthometric Height) – Free Weighted Adjustment

This adjustment produced a minimally constrained adjustment fixing (arbitrarily) stations COPR and CSST for horizontal, and assigning all stations' published orthometric heights a weight of 10 feet. Said geoid model was applied while solving for rotations (not for scale). Analysis of the results verify the integrity of the control identifying station 9 as an outlier. Note the results below:

Station	dZ
2	0.111458
3	0.104063
5	0.163879
6	0.179637
9	-0.048257

Scale Factor 1.000000000000 : 0.000000 PPM (None) – FIXED
Rotation Around North Axis : 2.006430 Sec (Solved)
Rotation Around East Axis : -4.811804 Sec (Solved)
Rotation Around Vert Axis : -0.085342 Sec (Solved)

The rotations shown above around the North and East axis are due to the inclusion of outlier station 9 as well as the linear nature of the geometry of the five benchmarks.

Master Adjustment 4A (Orthometric Height) – Fully Constrained Adjustment

This adjustment produced a minimally constrained adjustment again fixing (arbitrarily) stations COPR and CSST for horizontal, and fixing stations 2, 3, 5, and 6 published orthometric heights while allowing the published height at station 9 to float. Said geoid model was applied to the network to establish modeled orthometric heights at the remaining network stations. The table below shows the 95% confidence region for the orthometric height values computed in this adjustment at the following stations. (This is not inclusive of the inherent error within the geoid model itself.)

(all values in U.S. Survey Feet unless otherwise noted)

*dZ comparison based on ellipsoid height (modelled with Geoid 12B when applicable) when noted with asterisk

1	0.043965	23	0.035877	45	0.065767
2	0.000000 (FIXED)	24	0.042977	46	0.058008
3	0.000000 (FIXED)	25	0.048377	47	0.058132
4	0.048136	26	0.045644	48	0.034057
5	0.000000 (FIXED)	27	0.053182	49	0.035033
6	0.000000 (FIXED)	28	0.053871	50	0.055688
7	0.047060	29	0.036125	51	0.037393
8	0.024680	30	0.051869	52	0.046589
9	0.042587	31	0.049239	53	0.043972
10	0.051166	32	0.043199	54	0.043599
11	0.057449	33	0.053840	55	0.035490
12	0.049797	34	0.026417	56	0.040291
13	0.041799	35	0.034413	57	0.055096
14	0.058956	36	0.044977	58	0.038551
15	0.061025	37	0.046344	59	0.055639
16	0.046012	38	0.049319	60	0.043777
17	0.038950	39	0.051618	CASN	0.023581
18	0.051075	40	0.047213	COPR	0.026283
19	0.052972	41	0.046855	CSST	0.026933
20	0.061612	42	0.039023	P519	0.025369
21	0.051262	43	0.048987	P548	0.023771
22	0.029458	44	0.050207	RCA2	0.024831

Master Adjustment 4B (Orthometric Height) – Fully Constrained Adjustment (Solving for rotations)

The following results are derived from holding all the identical parameters as Master Adjustment 4A while also solving for rotations. The following transformations were computed therefrom:

Scale Factor 1.000000000000 : 0.000000 PPM (None) FIXED
Rotation Around North Axis : 1.041921 Sec (Solved)
Rotation Around East Axis : -2.402093 Sec (Solved)
Rotation Around Vert Axis : -0.075830 Sec (Solved)

Similarly to Master Adjustment 3B above, the rotations around the North and East axis having such high values are due to the linear nature of the geometry of the five benchmarks.

Final Coordinates

Final geodetic coordinates for station 8 (PSSB) were obtained from “Station 8 Adjustment 2A.” Final geodetic coordinates for all other stations are those established by “Master Adjustment 2A.” Plane coordinates (northings & eastings) were established via projecting said final geodetic coordinates as CCS83, Zone 5. Orthometric heights for all stations including: 8, CASN, and all cGPS control stations, are based on “Master Adjustment 4A (Orthometric Height).”