

**SURVEY REPORT**  
of  
**2008 HEIGHT MODERNIZATION GPS SURVEY**  
for the  
**CITY OF SANTA BARBARA**  
by  
**MCGEE SURVEYING CONSULTING**  
Santa Barbara, California

**PROJECT OVERVIEW:** The City of Santa Barbara, Department of Public Works, Engineering (the City) with the assistance of Michael McGee, PLS of McGee Surveying Consulting performed a Height Modernization Survey to upgrade the Santa Barbara City Control Network (SBCN). The results of the 2008 Second Order Leveling Network Survey (see separate Report) were combined with the 2008 high accuracy GPS measurements to determine a refined geoid model and facilitate the use of GPS technology to establish accurate orthometric heights within the City.

**PROJECT DATUMS & REFERENCE SYSTEMS:** Positions are based on the North American Datum of 1983 (NAD 83), 1991.35 Epoch adjustment of the High Precision Geodetic Network (HPGN) as published by the National Geodetic Survey (NGS). The 1991.35 Adjustment of NAD 83 resulted from a state wide B-Order GPS Survey by the NGS which superseded the 1986 introductory adjustment of the NAD 83 Datum. NGS stations HPGN0501, HPGN0502 and HPGN0504 in the National Spatial Reference System (NSRS) were used in 1995 to establish a primary City GPS control network of 36 points. This network, known as the Santa Barbara Control Network (SBCN), is recorded in Book 147 of Records of Survey at Page 70-74, Santa Barbara County Records. In 1996, point 0006 was destroyed and reset nearby as shown in Book 149 of Records of Survey at Page 16-17. In 1997, a convention was adopted by the City to add the number 10000 to the SBCN point numbers to avoid leading zero's; therefore, 0004 is referred to as 10004 and 0031 is likewise 10031 or SBCN10031. Subsequently, additional points have been set to densify the original Network. Numbers in the range of 9001 to 9999 have been reserved for this purpose.

Orthometric heights, commonly referred to as elevations, are based on the North American Vertical Datum of 1988 (NAVD 88). The NAVD 88 Datum superseded the old NAVD 29 vertical datum in 1991. Orthometric heights established by the City in the 2008 Second Order Leveling Network Survey serve as the vertical basis for this network upgrade.

**STATE PLANE COORDINATE PARAMETERS:** Grid coordinates are NAD83-1991.35 California State Plane Coordinates Zone Five. The average Grid Scale Factor is 0.99993783. The Height Reduction Factor, based on the average ellipsoid heights is 0.99999479. The average Combined Grid Factor is 0.99993262. Multiply the Combined Factor times ground distances to obtain grid distances. Grid bearings should be rotated by a Convergence Angle to obtain geodetic bearings. The convergence angle varies across the City between -0°56' on the east and -1°00' on the west and averages -0°58.

**FIELD SURVEYS/NETWORK:** The GPS field campaign took place between June 18 and June 25 with additional observations collected on July 3, August 23 and September 19, 2008. The procedure was for one unit to be operated as a reference base station while one to two units occupied assigned points for 30 minutes. On a different hour of the day and/or on a different day the process was repeated with the reference base receiver occupying a different point. Descriptions and details of the points used in this survey are available at the City Department of Public Works, Engineering. See the Appendix for a map showing the locations of points. Nearby continuously operated GPS stations known as CGPS in California were included in the processing. A CGPS station is similar to a CORS (Continuously Operated Reference Station) except the term CORS is reserved for those published nationally by the NGS.

**PROJECT ADJUSTMENTS:** A separate transformation and adjustment was computed as described below.

**TRANSFORMATION:** A transformation was processed to validate the record 1995 horizontal coordinates of the SBCN points included in this survey, and to determine the rotations to apply to Geoid03 to best fit the local geoid.

A transformation, with no scale change, was computed using least squares to best fit the measurements of 21 SBCN points to the 1995 record horizontal positions. The differences from the record positions to the computed positions in feet are listed below under dN and dE. The north and east differences at 9027=K1215, COPR and UCSB represent the shifts from NAD 83, 2007.0 Epoch (derived from the national re-adjustment of the NSRS in February 2008) to the NAD 83, 1991.35 Epoch established for the City.

The transformation also computed a best fit to the new orthometric heights established by the 2008 Second Order Leveling Network Survey on 27 points including 18 of the SBCN points. These Orthometric heights represent the local geoid. Ellipsoid height differences measured with GPS were combined with the NGS Geoid03 Model and rotations were solved to compute a best fit surface through the 27 points listed below under dZ. The differences from the leveled orthometric heights to the computed best fit orthometric heights based on GPS measurements are shown in feet. The rotations that were applied to obtain this best fit solution are listed below.

Rotation Around North Axis: -0.5536 Seconds (Solved)  
 Rotation Around East Axis : 0.7101 Seconds (Solved)  
 Rotation Around Vert Axis : -0.3366 Seconds (Solved)

Station	dN(ft)	dE(ft)	dZ(ft)	Comments
9002	n/a	n/a	-0.002	
9027	-1.650	1.697	-0.002	= K1215 HARN Station (NAD 83, 2007)
9031	n/a	n/a	0.018	
9034	n/a	n/a	0.028	= Tidal-3
9035	n/a	n/a	0.014	
9036	n/a	n/a	0.001	
9037	n/a	n/a	-0.006	
9038	n/a	n/a	0.016	
9039	n/a	n/a	<del>0.038</del>	(not used in vertical solution) (used 9002 nearby)
10002	-0.006	-0.042	-0.019	
10003	0.016	-0.027	0.030	
10005	-0.010	-0.021	-0.014	
10006R	0.015	-0.009	<del>-0.041</del>	(not used in vertical solution)(poor vertical GPS)
10007	0.018	0.004	-0.021	
10009	0.017	-0.015	0.007	
10011	0.014	-0.012	<del>0.067</del>	(not used in vertical solution)(no good elevation)
10012	0.002	-0.013	-0.010	
10015	-0.039	-0.011	0.019	
10020	0.009	0.008	<del>-0.076</del>	(not used in vertical solution) (poor vertical GPS)
10021	0.001	0.001	-0.021	
10022	0.011	-0.014	-0.031	
10023	0.000	0.017	0.024	
10026	-0.020	0.025	-0.026	
10027	-0.015	0.014	0.018	
10029	0.000	-0.006	<del>0.080</del>	(not used in vertical solution, anomaly in Geoid03)
10030	0.014	0.005	0.017	
10031	0.000	0.021	0.010	
10033	-0.015	0.010	-0.025	
10034	0.010	0.027	-0.008	
10035	-0.020	0.039	-0.027	
COPR	1.768	1.581	<del>0.012</del>	= CGPS (not used in vertical solution)
UCSB	-1.740	1.608		= CGPS (no good elevation)
W1042_BOLT	n/a	n/a	0.007	

## ANALYSIS and COMMENTS:

Analysis of the above north and east differences (dN and dE) between the record and the computed positions at the 21 SBCN points follow (does not include 9027, COPR and UCSB):

Ranges are between -0.039 to +0.018 feet in the north, and -0.042 to +0.039 feet in the east component  
Averages of the absolute values are 0.012 feet in the north and 0.016 feet in the east component  
Standard Deviations are 0.015 feet in north and of 0.020 feet in the east

The computed positions are based on precision 2008 GPS measurements and represent a higher relative accuracy for these SBCN points; however, the differences are deemed insignificant and acceptable at the accuracy levels required for the City. The record values were accepted, rather than cast uncertainty on the considerable number of prior surveys based on the record position of the SBCN.

Analysis of the height differences (dZ), between the new leveled orthometric heights and those computed based on a best fit transformation follow (except those noted above as "not used in vertical solution"):

Ranges are between -0.031 to +0.030 feet  
Average of the absolute values of the differences is 0.016 feet  
Standard Deviation of 0.018 feet

The results of this analysis indicates that orthometric heights accurate to 0.03 feet can be determined using GPS technology within the City (see APPLICATION below for information).

**ADJUSTMENT:** A minimally constrained adjustment was processed to develop ellipsoid heights. Point 9027=K1215 (NGS B-Order Station) was fixed at its NAD 83, 2007 Epoch position to establish NAD 83, 2007 latitude, longitude and ellipsoid heights on the points included in this survey. Closures on the NAD 83, 2007 record positions of the CGPS stations COPR and UCSB are shown below as a matter of information. Units are feet.

Point	Latitude	Longitude	E.H.	Description
9027	34-24-41.84597	119-41-56.07706	-85.702	K1215, NAD83(2007) Fixed Position
Station	dN	dE	dZ	
9027	0.000	0.000	0.000	Fixed
COPR	-0.029	-0.113	-0.041	
UCSB	-0.019	-0.087	-0.051	

Ellipsoid heights were not published on the 1995 Record of Survey but are necessary for collecting and processing GPS measurements. The 2007 ellipsoid heights are backward compatible with the horizontal NAD83, 1991.35 Epoch positions used for the City in 1995. See the attached 2008 Height Modernization Survey Coordinate List for the results of this adjustment. Positions are published on the 2007 Epoch and the 1991.35 Epoch (1995 record horizontal combined with 2007 ellipsoid heights). The positions on the CGPS stations COPR, UCSB and RCA2 are the results of this minimally constrained adjustment relative to 9027=K1215. Note, the NAD83, 2007 Epoch positions on the City control points are provided for information to relate the City control to the 2007 national re-adjustment and are not intended to supersede the 1991.35 Epoch used for the City.

**LOCAL GEOID HEIGHTS:** Listed below are the following: NAD 83 ellipsoid heights (Ellipsoid Ht.) determined in the above Adjustment, the NAVD 88 Orthometric Heights determined by the 2008 Leveling, and their differences known as the Local Geoid Height (Local GH). The Local Geoid Height is the measured geoid height and is compared with the estimated geoid height computed with the Geoid03 Model. The differences between the Local GH (LGH) and the Geoid03 are listed as a matter of information in column six. Units are feet.

Point	Ellipsoid Ht.	Orthometric Ht.	Local GH	Geoid03 GH	LGH-Gd03
9002	-48.772	68.816	-117.588	-117.449	-0.140
9027	-85.702	31.343	-117.045	-116.933	-0.112
9031	556.101	671.838	-115.738	-115.693	-0.044
9035	52.047	168.824	-116.777	-116.670	-0.107
9036	-94.720	21.905	-116.625	-116.543	-0.081
9037	33.581	150.413	-116.833	-116.706	-0.126
9038	112.855	229.168	-116.313	-116.228	-0.085
10002	521.985	637.646	-115.661	-115.569	-0.093
10003	198.288	314.265	-115.977	-115.922	-0.055
10005	480.293	595.990	-115.697	-115.626	-0.070
10007	73.532	190.025	-116.493	-116.359	-0.135
10009	196.437	312.658	-116.222	-116.142	-0.080
10012	40.720	157.267	-116.547	-116.439	-0.108
10015	-36.889	79.495	-116.384	-116.332	-0.052
10021	-68.050	48.681	-116.731	-116.613	-0.118
10022	112.795	229.398	-116.603	-116.462	-0.140
10023	55.144	172.251	-117.107	-117.008	-0.099
10026	-102.029	14.695	-116.724	-116.619	-0.105
10027	-98.760	17.701	-116.461	-116.413	-0.047
10030	63.539	181.017	-117.478	-117.350	-0.127
10031	345.077	462.413	-117.336	-117.213	-0.123
10033	-105.655	11.329	-116.984	-116.859	-0.126
10034	19.769	137.407	-117.639	-117.484	-0.155
10035	-107.325	9.965	-117.290	-117.145	-0.145
W1042_BOLT	9.775	126.456	-116.681	-116.560	-0.121

**APPLICATION:** The results of this survey can be applied in several ways to obtain reliable orthometric heights in the City with GPS measured ellipsoid heights. Methods, procedures and site requirements to obtain accurate ellipsoid height differences between points are addressed in the Appendix. To establish orthometric heights, include the nearest two or more (minimum of two for a check) SBCN or 9000 numbered points listed above in a GPS survey and apply one of the following three procedures.

1- Single EH Difference: Using GPS measured ellipsoid height differences between two points, apply the Local GH from column four in the above table using the formula:  $H_u = H_k + N_k + (h_u - h_k) - N_u$

In this formula "k" refers to the point with the known orthometric height, "u" refers to the point with the unknown orthometric height, H= Orthometric Height, N=Local Geoid Height, and h=Ellipsoid Height. The Local Geoid Heights should be interpolated as necessary.

2- Local Transformation: Use GPS measured ellipsoid height differences combined with a geoid model and include four or more of the nearest points (minimum of three required) with leveled orthometric heights to solve for a local transformation as was done in the Transformation described on Page 2. Note, the geometry of the points is important.

3- Do Nothing: Use GPS measured ellipsoid height differences and use Geoid03. The loss of accuracy may be acceptable and can be estimated by comparing the Local Geoid Heights and the Geoid03 Heights. Given that the spacing between SBCN points is about 4000 feet on average, then most surveys will be within 2000 feet of a point with a known height.

**ACCURACY:** After removing 22 GPS vectors with excessive residuals, the two dimensional residuals range between 0.00 and 0.08 feet and average 0.02 feet with a standard deviation of 0.014 feet. The vertical residuals range between -0.05 and +0.04 feet and average 0.015 feet with a standard deviation of 0.019 feet. Points were re-observed as necessary to obtain vertical residuals in agreement within 0.05 feet. The horizontal coordinates are estimated to have a standard deviation of 0.02 feet in north and east as discussed following the Transformation results on page 2.

NAVD 88 orthometric heights are derived from the GPS measured ellipsoid heights combined with the Geoid 03 model and constrained to points with known orthometric heights. An accuracy of better than 0.05 feet in the ellipsoid heights is obtainable when measured at unobstructed sites with repeat observations. The relative accuracy of the heights modeled from GPS measurements and a refined geoid are expected to be better than 0.05 feet. The results of the Transformation discussed on page 2, column dZ demonstrates this survey attained accuracies better than 0.03 feet.

**EQUIPMENT, DATA COLLECTION & POST PROCESSING OF DATA:** Geodetic grade dual frequency P-code receivers were utilized to collect satellite signal data as follows: one Leica System 300 (SR399 with internal antenna) and two Leica System 530 (with AT502 antennas). The receivers were operated by the City survey crews. Phase measurements were collected for the carrier on the L1 & L2 frequencies, C/A Code on L1 and the P-Code on L1 & L2 every 10 seconds. The criteria for data collection was to observe 6 or more satellites above 15° with an average GDOP of 5 or less. The length of the observation times was 30 minutes and points were occupied multiple times as necessary to obtain vertical residuals less than 0.05 feet. The vectors were processed with Leica Geo Office v6.0 at a cutoff angle of 15° above the horizon using a rapid ephemeris. GPS vectors are measured in the military World Geodetic System of 1984 (WGS 84) and constrained to NAD 83 geodetic positions and ellipsoid heights with "Starnet-Pro" v6.0 GPS network adjustment software.

Attachments: 2008 Height Modernization Coordinate List

**SURVEYOR'S STATEMENT:** This report on the criteria and procedures used on this GPS Survey was prepared by me on November 27, 2008 at the request of the City of Santa Barbara.

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Michael R. McGee, PLS 3945

## APPENDIX

Methods and procedures to obtain accurate ellipsoid heights: Trees and plants will block or attenuate satellite signals passing through the foliage degrading accuracies. To obtain the best possible accuracies, available satellite obstruction diagrams should be used to estimate the best time for observing points. Upon arriving at a point to be observed, a dual frequency receiver is set up and the location of each satellite in the sky is estimated with a compass and abney/clinometer. Satellites obstructed by foliage and trees are turned off. If 5 or more unobstructed satellites with a PDOP of 4 or less or a GDOP of 5 or less are available then the measurement is taken for 15-30 minutes of data collection. The observation of the point is repeated at a time of the day differing by at least 2 hours and preferably on a different day. To be acceptable, the difference of the two observations should approach the desired vertical accuracy for the survey.

### 2008 Height Modernization GPS Control Points



			Santa Barbara Control Network						
			2008 Height Modernization Survey Coordinate List (Feet)						
11/13/2008	NAD83, 2007 Epoch			NAD83, 1991.35 Epoch					NAVD88
Point ID	Latitude	Longitude	Ellipsoid Ht	Latitude	Longitude	Ellipsoid Ht	SPC North	SPC East	Height
9002	34-23-46.31024	119-42-35.34552	-48.77	34-23-46.29416	119-42-35.32493	-48.77	1970950.95	6045897.68	68.82
9027	34-24-41.84597	119-41-56.07706	-85.70	34-24-41.82993	119-41-56.05647	-85.70	1976508.40	6049282.64	31.34
9031	34-26-43.97486	119-41-34.67555	556.10	34-26-43.95884	119-41-34.65501	556.10	1988822.30	6051283.35	671.84
9034	34-24-36.38310	119-41-29.54948	-106.60	34-24-36.36707	119-41-29.52890	-106.60	1975918.77	6051495.54	10.43
9035	34-25-43.61570	119-44-28.53044	52.05	34-25-43.59959	119-44-28.50985	52.05	1982970.26	6036620.00	168.82
9036	34-25-15.14826	119-40-38.49679	-94.72	34-25-15.13224	119-40-38.47626	-94.72	1979765.28	6055837.64	21.91
9037	34-25-34.09553	119-44-07.01111	33.58	34-25-34.07945	119-44-06.99060	33.58	1981976.85	6038405.65	150.41
9038	34-26-25.76131	119-44-02.42392	112.86	34-26-25.74523	119-44-02.40339	112.86	1987192.29	6038879.94	229.17
9039	34-23-44.28465	119-42-33.95538	-51.33	34-23-44.26859	119-42-33.93481	-51.33	1970744.23	6046010.67	66.27
10002	34-27-24.29082	119-43-37.73179	521.98	34-27-24.27473	119-43-37.71099	521.98	1993072.52	6041049.33	637.65
10003	34-26-48.88964	119-43-28.72070	198.29	34-26-48.87334	119-43-28.70002	198.29	1989481.39	6041742.35	314.26
10005	34-26-44.85695	119-41-07.47686	480.29	34-26-44.84109	119-41-07.45625	480.29	1988873.20	6053562.33	595.99
10006R	34-26-28.37427	119-45-36.61149	57.00	34-26-28.35781	119-45-36.59098	57.00	1987593.46	6030997.37	173.60
10007	34-26-25.61337	119-44-56.13088	73.53	34-26-25.59693	119-44-56.11052	73.53	1987255.23	6034382.28	190.03
10009	34-26-16.57643	119-42-44.61042	196.44	34-26-16.56017	119-42-44.58982	196.44	1986152.20	6045380.19	312.66
10011	34-25-58.50759	119-44-47.06569	45.21	34-25-58.49120	119-44-47.04509	45.21	1984502.35	6035093.81	
10012	34-25-46.23409	119-42-46.33028	40.72	34-25-46.21798	119-42-46.30966	40.72	1983087.84	6045183.90	157.27
10015	34-25-35.19014	119-40-22.36319	-36.89	34-25-35.17462	119-40-22.34258	-36.89	1981768.54	6057222.71	79.50
10020	34-25-04.57660	119-42-28.61392	-57.53	34-25-04.56044	119-42-28.59346	-57.53	1978852.07	6046596.10	59.44
10021	34-25-17.85514	119-41-57.52969	-68.05	34-25-17.83909	119-41-57.50919	-68.05	1980150.07	6049222.49	48.68
10022	34-25-59.98587	119-44-00.75029	112.80	34-25-59.96957	119-44-00.72967	112.80	1984584.62	6038975.16	229.40
10023	34-24-43.38466	119-42-55.95484	55.14	34-24-43.36855	119-42-55.93445	55.14	1976749.12	6044269.39	172.25
10026	34-25-02.25079	119-40-03.20476	-102.03	34-25-02.23510	119-40-03.18452	-102.03	1978412.51	6058772.04	14.70
10027	34-25-17.03591	119-39-22.53093	-98.76	34-25-17.02022	119-39-22.51059	-98.76	1979850.59	6062203.67	17.70
10029	34-24-18.84908	119-44-21.65690	-88.10	34-24-18.83285	119-44-21.63620	-88.10	1974392.59	6037047.41	29.33
10030	34-24-12.51460	119-43-47.08916	63.54	34-24-12.49829	119-43-47.06857	63.54	1973702.36	6039932.28	181.02
10031	34-24-18.88868	119-42-54.32557	345.08	34-24-18.87258	119-42-54.30517	345.08	1974270.88	6044363.62	462.41
10033	34-24-46.11663	119-41-18.68528	-105.66	34-24-46.10079	119-41-18.66483	-105.66	1976887.30	6052422.15	11.33
10034	34-23-48.88775	119-43-14.29681	19.77	34-23-48.87151	119-43-14.27643	19.77	1971267.14	6042638.62	137.41
10035	34-24-15.31513	119-41-41.53329	-107.32	34-24-15.29931	119-41-41.51312	-107.32	1973806.26	6050455.70	9.96
COPR	34-24-53.65236	119-52-46.24080	-72.86	34-24-53.63606	119-52-46.22023	-72.86	1978671.21	5994842.32	
RCA2	34-29-59.91741	119-43-11.93664	3871.17	34-29-59.90148	119-43-11.91609	3871.17	2008765.41	6043478.14	
UCSB	34-24-47.88819	119-50-37.68055	-29.39	34-24-47.87194	119-50-37.65997	-29.39	1977889.15	6005600.25	
W1042_BOLT	34-26-25.42172	119-46-09.80638	9.77	34-26-25.40559	119-46-09.78583	9.77	1987343.88	6028212.44	126.46

**2008 NAVD 88 BENCHMARK LIST**  
**2008 Second Order Leveling Network**  
**Orthometric Heights (Feet)**

for the  
**City Of Santa Barbara**  
 by the  
**City Of Santa Barbara**  
**& McGee Surveying Consulting**  
 10/28/2008

POINT ID	ELEVATION	DESCRIPTION
<b>A1044</b>	<b>36.142</b>	3-3/4" brass disk stamped "USC&GS A-1044 1960", approximately 0.1 mile east of Olive Mill Rd railroad crossing, in top of north end of the west sandstone block abutment on wooden bridge.
<b>A609</b>	<b>29.946</b>	3-5/8" brass disk stamped "USC&GS A-609 1942", southeast corner of concrete wingwall, railroad overpass, US 101 northbound off-ramp to Los Patos Way.
<b>BAT1900</b>	<b>109.531</b>	Bolt of Standard City Monument, westerly corner of intersection of Bath St and Pedregosa St.
<b>BAT1935</b>	<b>118.196</b>	2" brass disk stamped "SB CITY MON", inside wheelchair ramp of southerly corner of intersection of Bath St and Mission St.
<b>BM801</b>	<b>232.363</b>	"PK" nail in top of sandstone bridge wall, westerly side and southerly end of bridge, 70' northerly of centerline of Stanwood Dr and Sycamore Canyon Rd.
<b>BM803</b>	<b>428.976</b>	"PK" nail in top of sandstone bridge wall, northerly side of bridge, 30' westerly of easterly end of wall, 35' westerly of gate center at entrance to Parma Park.
<b>BM804</b>	<b>639.454</b>	"Survey Mark" spike in pavement, southerly side of Stanwood Dr, 70' easterly of centerline of Stanwood Dr and El Cielito Rd, 36' westerly of fire hydrant and 2' from berm flowline, in view of tennis court on Stanwood Dr near El Cielito Rd.
<b>BM805</b>	<b>543.496</b>	"Survey Mark" spike in sandstone boulder on northerly side of Foothill Rd, approximately 325' westerly of centerline of Foothill Ln.
<b>BM806</b>	<b>453.561</b>	"PK" nail in top of sandstone bridge wall, northerly side of Foothill Rd, 20' easterly of westerly end of wall, 0.1 mile east of SB County Fire Station 15, opposite Mission Oaks Ln.
<b>BM807</b>	<b>456.986</b>	2" brass disk stamped "CalTrans PM 3.255", in driveway to SB County Fire Station 15, 2491 Foothill Rd.
<b>BM808</b>	<b>454.833</b>	2" brass disk stamped "CalTrans PM 3.25", in boulder in front of wall of SB County Fire Station 15, 2491 Foothill Rd.
<b>BM809</b>	<b>404.831</b>	"PK" nail in concrete headwall, northerly side of Foothill Rd, 50' westerly of centerline of Mission Canyon Rd .

<b>BM810</b>	<b>341.663</b>	3-1/2" brass disk stamped "Corps of Engineers – US Army", on the easterly side of Mission Canyon Rd, across from entrance to St. Mary's Retreat House.
<b>BM811</b>	<b>180.137</b>	2" brass disk stamped "SB CITY MON", westerly corner, Anacapa St and Pedregosa St.
<b>BM812</b>	<b>120.617</b>	"PK" nail in top of curb, easterly return, southerly corner, Castillo St and Padre St.
<b>BM813</b>	<b>364.257</b>	"PK" nail in top of curb, westerly side of San Roque Rd, southerly end of curb and gutter.
<b>BM814</b>	<b>378.645</b>	"PK" nail in top of curb, westerly side of San Roque Rd, 3' southerly of driveway to 825 San Roque Rd.
<b>BM815</b>	<b>61.010</b>	"PK" nail in chiseled "X" in top of curb of traffic island nose at Las Positas Rd and Jerry Harwin Parkway.
<b>BM816</b>	<b>94.079</b>	Chiseled square on back of curb, easterly return, northeasterly corner, Shoreline Dr and Santa Cruz Blvd.
<b>BM817</b>	<b>53.899</b>	Chiseled square on back of curb, easterly return, northeasterly corner, Shoreline Dr and Las Ondas.
<b>BM819</b>	<b>182.965</b>	Chiseled square in top of curb, westerly return, southwesterly corner, Cliff Dr and Cooper Rd.
<b>BM820</b>	<b>120.481</b>	Chiseled square on top of curb, southerly side of W. Padre St, 40' westerly of return, in front of front door to 403 W. Padre St.
<b>C658</b>	<b>154.173</b>	3-5/8" brass disk stamped "USC&GS C-658 1948", northeast corner of concrete wingwall, railroad culvert, 200' easterly of centerline of intersection of Modoc Rd and Veronica Springs Rd.
<b>CAB13</b>	<b>11.587</b>	Chiseled square in top of curb, westerly end of wheelchair ramp, southerly side of Cabrillo Blvd, 95' westerly of intersection of Cabrillo Blvd and Milpas St.
<b>CAL4010</b>	<b>194.283</b>	Chiseled square in top of curb, northerly side of Calle Real, easterly side of entrance to 4010 Calle Real Shopping Center, 25' westerly of guardrail and 300' easterly of Wye Rd.
<b>CAN00</b>	<b>49.353</b>	Chiseled square in top of curb, southerly end of wheelchair ramp, westerly corner of intersection of Canon Perdido St and Anacapa St.
<b>CAR1005W</b>	<b>176.469</b>	Chiseled square in back of curb, westerly side of Carrillo St, 57' southerly of centerline of a 6'-wide concrete walkway and 200' northerly of centerline of Vista Del Pueblo, across from driveway at 1005 W. Carrillo St.
<b>CAR1030W</b>	<b>224.451</b>	Chiseled square in back of curb, westerly side of Carrillo St, 580' northerly of centerline of Miramonte Dr and 300' southerly of centerline of Vista Del Pueblo.
<b>CAR400W</b>	<b>53.971</b>	Chiseled square in top of curb, westerly return, southerly corner of intersection of Carrillo St and Castillo St.
<b>CAR606W</b>	<b>63.738</b>	Chiseled square in back of curb, westerly end of driveway entrance to 606 W. Carrillo St, across from San Pascual St.
<b>CAR953W</b>	<b>144.256</b>	Chiseled square in back of curb, westerly side of Carrillo St, 45' northerly of a catch basin and 6' northerly of power pole #1665157E,

		across from 953 W. Carrillo St.
<b>CARP1133</b>	<b>36.652</b>	Chiseled square in back of curb, southerly return, westerly corner of intersection of Carpinteria St and Soledad St.
<b>CLI1900</b>	<b>200.703</b>	Chiseled square in top of curb, westerly return, southwesterly corner of intersection of Cliff Dr and Meigs Rd.
<b>CLI2109</b>	<b>190.831</b>	Chiseled square in top of curb, easterly return, southeasterly corner of intersection of Cliff Dr and Oliver Rd.
<b>CLI2309</b>	<b>188.052</b>	Chiseled square in top of curb, westerly return, southwesterly corner of intersection of Cliff Dr and Mohawk Rd.
<b>CLI2346</b>	<b>177.767</b>	Chiseled square in top of curb, westerly return, southwesterly corner of intersection of Cliff Dr and Mesa Ln, across from 2346 Cliff Dr.
<b>GAR1900</b>	<b>216.686</b>	Bolt of Standard City Monument, westerly corner of intersection of Garden St and Pedregosa St.
<b>GAR2000</b>	<b>231.966</b>	Bolt of Standard City Monument, westerly corner of intersection of Garden St and Mission St.
<b>GPS9002</b>	<b>68.816</b>	Lead and Tag, "CITY ENGR 9002", set in concrete catch basin on southerly side of Shoreline Dr, opposite centerline of San Rafael Ave.
<b>GPS9009</b>	<b>526.419</b>	Rebar in pavement, centerline of San Roque Rd, 55.5' southerly of unmarked power pole, 9.5' off westerly lip, ~125' northerly of northerly entrance to Cater Water Treatment Plant at 1150 San Roque Rd.
<b>GPS9016</b>	<b>10.569</b>	1-1/2" brass disk stamped "LADO SB90 1984," on southerly side of Cabrillo Blvd, opposite Bath St.
<b>GPS9017</b>	<b>10.884</b>	Lead and Tag stamped "CITY ENG", in east-bound concrete beach bike lane (in sand), opposite 216 W. Cabrillo Blvd (Sambo's), ~375' easterly of centerline of Bath St.
<b>GPS9018</b>	<b>10.529</b>	Monument "J" – 3" brass disk stamped "City of Santa Barbara Harbor Survey," on southerly side of Cabrillo Blvd, ~215' westerly of Chapala St centerline.
<b>GPS9019</b>	<b>11.037</b>	Lead and Tag stamped "CITY ENG", in west-bound concrete beach bike lane (in sand), opposite 28 W. Cabrillo Blvd (Harbor View Inn).
<b>GPS9022CAB17</b>	<b>11.761</b>	CAB 17 – 2" brass disk stamped "CALTRANS 116+10.41," southerly side of Cabrillo Blvd, 10' westerly of centerline of Calle Caesar Chavez.
<b>GPS9023CAB14</b>	<b>12.050</b>	CAB 14 – 2" brass disk stamped "CALTRANS 101+75.89," southerly side of Cabrillo Blvd, 120' westerly of centerline of Calle Puerto Vallarta.
<b>GPS9030</b>	<b>162.532</b>	Lead and Tag stamped "LS 4997", northwesterly corner, State St and Pedregosa St.
<b>GPS9031</b>	<b>671.838</b>	3" brass disk marked "City of Santa Barbara Benchmark" with punch, stamped "9031", in the most southwesterly concrete pad of reservoir vault access, inside circular shepherd's hook fence at Sheffield Reservoir park.

<b>GPS9033</b>	<b>211.401</b>	"MAG" nail and shiner, westerly side of Sycamore Canyon Rd, northerly side of CalTrans road closure, opposite 1750 Sycamore Canyon Rd driveway, ~20' E'ly of fire hydrant.
<b>GPS9034TIDAL3</b>	<b>10.433</b>	TIDAL 3 – 3-5/8" brass disk stamped "USC&GS BM 3 1973", southerly side of Cabrillo Blvd, top of a catch basin, ~500' westerly of the centerline point-of-intersection of Chapala St and Cabrillo Blvd, opposite the Hotel Oceana, 202 W. Cabrillo Blvd.
<b>GPS9035MOD3601</b>	<b>168.824</b>	Chiseled square in back of curb, westerly return, southwesterly corner of Modoc Rd and Veronica Springs Ro, marked MOD 3601.
<b>GPS9036</b>	<b>21.905</b>	"PK" nail in most northeasterly crosswalk at Milpas St Roundabout, at centerline of Carpinteria Ave.
<b>GPS9037</b>	<b>150.413</b>	Steel rod capped with a nut, with concrete collar, at south nose of traffic island at the southwest side of the intersection of Las Positas Rd and Modoc Rd.
<b>GPS9038</b>	<b>229.168</b>	"PK" nail in catch basin, northerly side of State St, northeasterly corner of State St at Las Positas Rd.
<b>GPS9039</b>	<b>66.238</b>	Steel rod near sea cliff at Shoreline Park, near whale tail bench and opposite GPS9002.
<b>J324</b>	<b>44.241</b>	3" NGS brass disk stamped "J324 1934" set in concrete base of flagpole in De La Guerra Plaza.
<b>K1215</b>	<b>31.343</b>	3" NGS brass disk stamped " K1215 1970" – 0.4 miles southwest along the Union Pacific Railroad from Railroad Depot, and ~2500' southwest along the Union Pacific Railroad from the intersection of Montecito St and the Union Pacific railroad tracks, in the top and 0.5' northeast of the southwest end of the southeast concrete curb of railroad overpass over Castillo St, 12.8' southeast of the southeast rail of the southeast track, 0.8' southwest of the northeast end of a steel guard rail and about level with the track.
<b>LAS1102</b>	<b>78.183</b>	3-1/2" brass disk stamped "Corps of Engineers", top of concrete headwall, easterly side of Las Positas Rd, 50' southerly of Portesuello Ave.
<b>LAS1402</b>	<b>92.462</b>	Chiseled square in southeasterly corner of headwall on southerly side of Las Positas Pl, at intersection of Las Positas Rd and Las Positas Pl.
<b>LAS2400</b>	<b>185.263</b>	Chiseled square in top of bridge wall, northeasterly corner of US 101 overpass, 100' southerly of Calle Real.
<b>LAS2900</b>	<b>253.283</b>	Lead and tack, southeasterly corner of intersection of Las Positas Rd and Stanley Dr.
<b>LAS3061</b>	<b>250.099</b>	Chiseled square in top of curb, northerly return, northwesterly corner of intersection of Las Positas Rd and McCaw Ave.
<b>LOS340</b>	<b>297.514</b>	Bolt of Standard City Monument, southerly corner of intersection of Los Olivos St and Laguna St.
<b>LOS505</b>	<b>338.472</b>	2" brass cap stamped "Survey Monument of the Caroline Hazard Property", most southerly of two identical monuments, by sandstone pillar between two driveways at 505 E. Los Olivos St.
<b>MEI500</b>	<b>221.560</b>	Chiseled square in top of curb, southerly return, southeasterly corner of intersection of Meigs Rd and Dolores Dr.

<b>MEI606</b>	<b>249.223</b>	Chiseled square in back of curb, northerly return, northeasterly corner of intersection of Meigs Rd and Ricardo Ave.
<b>MEI630</b>	<b>303.861</b>	Chiseled square in top of curb, southerly return, southeasterly corner of intersection of Meigs Rd and Aurora Ave.
<b>MEI800</b>	<b>373.335</b>	1-3/8" brass disk stamped "100", center of sidewalk on easterly side of Meigs Rd, 50' southerly of intersection of Meigs Rd and La Coronilla Dr.
<b>MOD2000</b>	<b>110.193</b>	Chiseled square in back of curb, westerly return, northerly corner of intersection of Modoc Rd and Mission St.
<b>MOD2109</b>	<b>116.833</b>	Chiseled square in top of curb, easterly return, southerly corner of intersection of Modoc Rd and Eucalyptus Ave.
<b>MOD2220</b>	<b>121.936</b>	Chiseled square in top of curb, westerly return, southwesterly corner of intersection of Modoc Rd and Portesuello Ave.
<b>MOD2303</b>	<b>123.190</b>	Chiseled square in back of curb, westerly return, northwesterly corner of intersection of Modoc Rd and Vista Madera.
<b>MOD2414</b>	<b>122.050</b>	Chiseled square in top of curb, southerly side of Modoc Rd, 2' northerly of telephone pole #S26391Y.
<b>MOD2505</b>	<b>132.602</b>	Chiseled square in back of curb, southerly side of Modoc Rd, westerly side of westerly driveway entrance to Fire Station No. 5 at 2505 Modoc Rd.
<b>MOD2541</b>	<b>141.003</b>	Chiseled square in top of curb, southerly return, southeasterly corner of intersection of Modoc Rd and Hacienda Dr.
<b>MOD3523</b>	<b>118.591</b>	Chiseled square in top of westerly end of catch basin, northerly side of Modoc Rd, across from 3523 Modoc Rd.
<b>MOD3558</b>	<b>126.055</b>	Chiseled square in top of curb, easterly return, northeasterly corner of driveway entrance to Arroyo Verde Condominiums, 1300 westerly of Las Positas Rd.
<b>MOD3659</b>	<b>168.412</b>	Chiseled square in top of curb, easterly return, southeasterly corner of intersection of Modoc Rd and Palermo Dr.
<b>MOD3721</b>	<b>151.808</b>	Chiseled square in top of curb, 8' southerly of southerly return, southeasterly corner of intersection of Modoc Rd and Ferrara Way.
<b>MOD3831</b>	<b>159.531</b>	Chiseled square in top of curb, 50' southerly of southerly return, southeasterly corner of Modoc Rd and Calle De Los Amigos, between light standard and fire plug #1828.
<b>PED100W</b>	<b>144.795</b>	Square bolt of Standard City Monument, westerly corner of intersection of Pedregosa St and Chapala St.
<b>PED130</b>	<b>204.211</b>	Bolt of Standard City Monument, westerly corner of intersection of Pedregosa St and Santa Barbara St.
<b>PM0.88</b>	<b>64.789</b>	2" brass disk stamped "PM0.88", top of curb of most northerly traffic island, 5-Points Roundabout, centerline of Sycamore Canyon Rd.
<b>PM1.10</b>	<b>95.947</b>	1" IP with cap stamped "CalTrans", easterly side of Sycamore Canyon Rd, 0.2 miles north of 5-Points Roundabout.
<b>PM1.63</b>	<b>160.471</b>	1" IP with cap stamped "CalTrans", westerly side of Sycamore Canyon Rd, 0.7 miles north of 5-Points Roundabout.

<b>PM1.78</b>	<b>183.444</b>	1" IP with cap stamped "CalTrans", westerly side of Sycamore Canyon Rd, 0.9 miles north of 5-Points Roundabout.
<b>PM16.53</b>	<b>181.336</b>	2" brass disk stamped "P4 Reset 1984", in concrete sidewalk, easterly side of bridge at Las Positas Rd and Highway 101.
<b>PM2.42</b>	<b>316.274</b>	Chiseled square in top of curb, easterly side of Alamar Ave, 25' northerly of northerly return, northeasterly corner, Alamar Ave and Foothill Rd.
<b>PM2.51</b>	<b>313.219</b>	Chiseled square in top of curb, northerly return, northwesterly corner, Glen Albyn Dr and Foothill Rd.
<b>PM3.84</b>	<b>569.494</b>	Chiseled square in top of curb, southerly side of Mountain Drive, opposite Foothill Rd.
<b>PM4.19</b>	<b>654.981</b>	Chiseled square in catch basin, northerly side of Mountain Dr, 170' westerly of El Rancho Hacienda Rd.
<b>PM4.28</b>	<b>666.208</b>	2" brass disk stamped "CalTrans", in top of curb on northerly side of Mission Ridge Rd, in front of Sheffield Reservoir, 100' easterly of Mission Ridge Rd and Mountain Dr.
<b>S1441</b>	<b>113.392</b>	3" NGS brass disk stamped "S-1441 1989", east end, southerly side of Union Pacific Railroad over-crossing at Mission St, 40' easterly of centerline of Mission St.
<b>SAL2S</b>	<b>88.088</b>	Chiseled square in top of curb at mid-point of return, southerly corner of intersection of Salinas St and Salinas Pl.
<b>SAN1000</b>	<b>67.788</b>	Chiseled square, top of curb, 2' easterly of traffic signal on easterly side of traffic island at intersection of San Andres St and Carrillo St.
<b>SBCN10002</b>	<b>637.646</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, 20' easterly of San Roque Rd, 21' westerly of chain link fence around Laurel Canyon Dam, 0.23 miles northerly of Cater Treatment Plant at 1150 San Roque Rd.
<b>SBCN10003</b>	<b>314.265</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near centerline of Alamar Ave, 45' northerly of centerline of Foothill Rd.
<b>SBCN10005</b>	<b>595.990</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, center of the cul-de-sac at the northerly end of Orizaba Rd, northerly of Stanwood Dr.
<b>SBCN10006R</b>	<b>173.600</b>	4-1/2" brass disk stamped "X 1042 Reset 1996", in concrete sidewalk along west side of Route 154 bridge over Highway 101, directly over the center median strip of Highway 101.
<b>SBCN10007</b>	<b>190.025</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near centerline of intersection of State St and Plaza Ave, in front of the Peppertree Inn.
<b>SBCN10009</b>	<b>312.658</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, 2' westerly of the easterly edge of pavement of Los Olivos St, opposite the main door of the Old Mission.

<b>SBCN10012</b>	<b>157.267</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, in painted median strip near the centerline of State St, midway between Islay St and Pedregosa St, in front of 1819 State St.
<b>SBCN10015</b>	<b>79.495</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near the intersection of the centerline of Clifton St with the southerly curb face line of Salinas St.
<b>SBCN10020</b>	<b>59.436</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near the centerline of Figueroa St, 140' northerly of the end of the cul-de-sac and 110' southerly of the centerline of Castillo St, in front of 406 and 407 Figueroa St.
<b>SBCN10021</b>	<b>48.681</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with sidewalk surface, easterly corner of the intersection of Canon Perdido St and Anacapa St.
<b>SBCN10022</b>	<b>229.398</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near the intersection of the centerline of Alegria Rd with the easterly curb face line of Las Positas Rd, across from the Municipal Golf Course.
<b>SBCN10023</b>	<b>172.251</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near the centerline intersection of Belmonte Drive and Plaza Del Monte.
<b>SBCN10026</b>	<b>14.695</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near the centerline intersection of Cabrillo Blvd and Ninos Dr, near East Beach parking lot entrance.
<b>SBCN10027</b>	<b>17.701</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near the intersection of the centerline of Channel Dr with the easterly curb face line of Cabrillo Blvd.
<b>SBCN10029</b>	<b>29.334</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, in the center of a triangular concrete curb traffic island, at the northwesterly corner of the intersection of Las Positas Rd and Cliff Dr.
<b>SBCN10030</b>	<b>181.017</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near the nose of the painted median strip at the easterly side of the intersection of Cliff Dr and Flora Vista Dr, 35' easterly of the centerline of Flora Vista Dr.
<b>SBCN10031</b>	<b>462.413</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, in a turnaround area on the northerly side of the Vic Trace Reservoir.
<b>SBCN10033</b>	<b>11.329</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, in the nose of a painted median strip, near the centerline of Cabrillo Blvd, 36' northeasterly of the centerline of Helena Ave, in front of 29 E. Cabrillo Blvd.
<b>SBCN10034</b>	<b>137.407</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, near the centerline of Shoreline Dr, in a painted median strip, 150' westerly of Lighthouse Pl, in front of Washington School playground.
<b>SBCN10035</b>	<b>9.965</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, 2'

		southerly of the nose of a concrete median strip at the northerly side of the intersection of Cabrillo Blvd and Harbor Way, opposite La Playa Stadium.
<b>SBCN10036</b>	<b>51.339</b>	2" iron pipe with 2-1/2" brass disk stamped Santa Barbara Control Network 1995, in 6" monument well flush with ground surface, in grass median strip, 15' from the easterly nose of median on the westerly side of the intersection of Coast Village Rd and Butterfly Ln.
<b>SBCO</b>	<b>271.959</b>	"PK" nail and tag stamped "Evans", set in "Cachuma Water" manhole, easterly side of Stanwood Dr, 250' northerly of Conejo Rd.
<b>STA1300</b>	<b>90.624</b>	Chiseled square in top of curb, southerly return, westerly corner of intersection of State St and Victoria St.
<b>T1441</b>	<b>60.810</b>	3-5/8" NGS brass disk stamped "T-1441 1989", east end, southerly side of Union Pacific Railroad over-crossing at Carrillo St, 45' easterly of centerline of Carrillo St.
<b>T28</b>	<b>39.224</b>	3-5/8" USC&GS brass disk stamped "T-28 1920", west end, southerly side of Union Pacific Railroad over-crossing at Cabrillo Blvd, 30' westerly of centerline of Cabrillo Blvd, 21' southerly of railroad tracks.
<b>TIDAL1</b>	<b>16.145</b>	3-5/8" brass disk stamped "USC&GS BM 1 1930", southerly side of Cabrillo Blvd, set in easterly post of concrete guardrail over Mission Creek, 312' northeasterly of the centerline of the intersection of Cabrillo Blvd and State St.
<b>TIDAL2</b>	<b>12.838</b>	3-5/8" brass disk stamped "USC&GS BM 2 1930", southerly side of Cabrillo Blvd, set in the top of the southwest end of a concrete sea wall, 147' northeasterly of the centerline of the intersection of Cabrillo Boulevard and Castillo Street.
<b>TIDAL3</b>	<b>10.433</b>	3-5/8" brass disk stamped "USC&GS NO 3 1973", southerly side of Cabrillo Blvd, top of a catch basin, ~500' westerly of the centerline point-of-intersection of Chapala St and Cabrillo Blvd, opposite the Hotel Oceana, 202 W. Cabrillo Blvd. (aka GPS9034)
<b>W1042</b>	<b>126.393</b>	3-5/8" USC&GS brass disk stamped "W1042 1960", west end, southerly side of Union Pacific Railroad over-crossing at Hollister Ave, 7' southerly of the southerly rail.
<b>W1042_BOLT</b>	<b>126.456</b>	Located 1/2' northwesterly of W1042 (NGS brass cap), bolt is about 3/8" wide x 1" high, set in concrete and is used for a strap down for a 6" conduit running over W1042.

**SURVEY REPORT**  
of the  
**City Of Santa Barbara**  
**2008 SECOND ORDER LEVELING NETWORK SURVEY**  
prepared by  
**McGee Surveying Consulting**  
Santa Barbara, California

**PROJECT OVERVIEW:** The City of Santa Barbara, Department of Public Works, Engineering (the City) performed a Height Modernization Survey Project between May 2007 and June 2008. The purpose was to upgrade the City from the superseded National Geodetic Vertical Datum of 1929 (NGVD 29) to the North American Vertical Datum of 1988 (NAVD 88), to establish a vertical reference network known as the 2008 Second Order Leveling Network and to support the utilization of GPS technology for establishing elevations within the City. Previously, the City and the public have relied on estimates of the relationship between the old and new datum. This survey provides an assessment of the National Geodetic Survey (NGS) NAVD 88 benchmarks in the City and their relationship to the old NGVD 29 City Benchmarks.

New elevations resulting from this leveling survey supersede the NGVD 29 Datum elevations. New elevations of specific points in the City's GPS network known as the Santa Barbara Control Network (SBCN) also supersede those shown on the 1995 Record of Survey recorded in Book 147 of Records of Surveys at Page 70-74 and Book 149 of Records of Surveys at Page 16-17. A leveling network was established across the City connected to NGS Benchmarks (permanent monuments with published elevations). Points in the SBCN were included for the purpose of determining the conversion from ellipsoid heights measured with GPS to NAVD 88 elevations. See the 2008 Height Modernization GPS Survey Report for additional information.

**PROJECT DATUMS, REFERENCE SYSTEMS and HISTORY:** Orthometric heights (elevations) published by this survey are based on the North American Vertical Datum of 1988 (NAVD 88) established by the National Geodetic Survey (NGS) as referenced to monuments in the National Spatial Reference System. NGVD 29 was established by the NGS, formerly the United States Coast & Geodetic Survey about 1930. In years past, the NGS and its predecessor have established benchmarks within the Railroad Right-of-Way and along the waterfront. The results of national leveling surveys through these benchmarks in the late seventies were published as the last Adjustment of NGVD 29. The City of Santa Barbara under the direction of Archie Macomber, a former surveyor for the City, conducted leveling surveys in 1978 establishing benchmarks throughout much of the City based on the NGVD 29 Datum. In 1989, the NGS benchmarks were re-leveled as part of a national leveling survey to upgrade to the new NAVD 88 Datum. In 1991, the NGVD 29 Datum was superseded when the NGS published the new NAVD 88 elevations. Since 1991, NAVD 88 elevations within the City were usually approximated by shifting NGVD 29 benchmark elevations +2.65 feet. The actual difference from NGVD 29 to NAVD 88 varies throughout the City between +2.5 and +2.7 feet.

**EQUIPMENT, DATA COLLECTION & POST PROCESSING OF DATA:** The measurements were collected and recorded with second order electronic digital levels and bar code rods. A Topcon DL-102C was used during Phase One and Two, and a Leica DNA10 was used during Phase Three. The FGCS Specifications and Procedures (ver. 4.0) for Second Order Class I Geodetic Leveling were followed. The instrument was calibrated before commencing each field day of leveling and the rods were calibrated periodically. The field survey procedures follow: the instrument was set up at locations intended to balance the backsights (BS) and foresights (FS), three measurements were averaged for each sighting and were taken in the sequence BS-FS-FS-BS, with two rods moving in a leap frog manner. McGee Surveying Consulting processed the measurements, analyzed network closures and residuals using Starplus Starnet Software v6.0, computed final adjustments and reported the results.

**SURVEY NETWORK:** The Leveling Network was planned and surveyed in three phases described below. Thirty-four miles of inter-connected loops were measured to form a backbone network for the City. All points were connected with independent measurements and closed loops. The naming convention for the points follows: the NGS benchmark names were used and cross referenced to their PID as shown below; new benchmarks are preceded by "BM" and begin with 801 (i.e BM801); control points established with GPS are preceded by "GPS" and begin with 9001 (i.e GPS9035) and are consistent with the horizontal accuracy of the primary Santa Barbara Control Network; points preceded by PM are Caltrans control points utilized in this survey; Santa Barbara Control Network (SBCN) point numbers are preceded by SBCN with 10000 added to the numbers shown on the Book 147 of Records of Surveys at Page 70-74 (i.e SBCN10001); and the old City benchmarks take their original names (i.e MOD3601). In a few cases old City benchmarks were used for GPS control and the names are combined (i.e GPS9035MOD3601).

The leveling loops are shown on an attached map and are described as follows: Phase One, completed in April 2007, began 1/2 mile west of Highway 154 and proceeded easterly adjacent to Highway 101 along the Union Pacific Railroad, Castillo Street, Cabrillo Boulevard to Hot Springs Road and east along the Railroad for a total of 9 miles. Phase One connected eleven NGS NAVD 88 Benchmarks used to recover the NAVD 88 Datum. Phase Two, completed in January 2008, began on Phase One at Santa Barbara Control Network (SBCN) 10026 and proceeded northerly along Milpas Street, Carpinteria Street and Sycamore Canyon Road to Stanwood Drive, then westerly along Stanwood Drive, Mission Ridge Road, Mountain Drive, Foothill Road to Mission Canyon Road, then southerly to and along Mission Street to Highway 101, connecting to Phase One at the Railroad for a total of 9 miles. Phase Three, completed in July 2008, consisted of several loops for a total of 16 miles. The first loop began at Mission Canyon Road and Foothill Road (at Phase Two) and ran westerly along Foothill Road to San Roque Road and southerly along San Roque Road and Las Positas Road to Highway 101 connecting to Phase One at the Railroad. The second loop began at Las Positas Road and Highway 101 and ran southerly along Las Positas Road to Cliff Drive, then easterly to and along Shoreline Drive to Cabrillo Boulevard connecting to Phase One. Several smaller loops were run as shown on the attached diagram.

**PROJECT ADJUSTMENTS:** A Minimally Constrained Adjustment was processed first to analyze the record elevations of eleven recovered NGS benchmarks, compute loop closures and validate the integrity of the survey measurements.

The adjustment contained 351 measured vertical differences after removing measurements that did not meet the Second Order Class I tolerance of (6mm\* $\sqrt{\text{kilometers}}$ ). The average absolute value of the residuals is 0.002' with a standard deviation of 0.003'. The range is -0.014 to +0.014' with nine residuals equal to or greater than 0.010'. There are five large loops and multiple smaller loops. The loop closures are generally 0.01' with the exception of 0.06' on the largest loop from Mission Street and Highway 101, easterly to Cabrillo Boulevard and to Milpas Street, then northerly to Stanwood Drive and westerly over Mountain Drive and Foothill Road back to Highway 101 at Mission Street. All loop closures meet First Order tolerances except the last which met Second Order Class I.

NGS benchmark C658 was fixed for this analysis at its published NAVD 88 elevation of 154.173 feet. The differences in feet from the NGS record elevations of the benchmarks to the calculated elevations, determined in this minimally constrained adjustment, are listed below and arranged from west to east.

NGS Benchmarks		
ID	Diff.	Comment
W1042	0.057	
C658	0.000	Fixed
S1441	-0.000	
T1441	0.025	
K1215	0.041	aka GPS9027
TIDAL2	-0.035	
TIDAL3	0.014	
TIDAL1	0.017	
A609	-0.064	
T28	-0.075	
A1044	-0.098	

Fixing C658 finds three benchmarks to the southeast in good agreement at First Order vertical tolerances as listed below.

S1441 1.1 miles southeasterly of C658 at 0.000'

TIDAL3 1.9 miles southeasterly of S1441 at -0.014'

TIDAL1 0.3 miles northeasterly of TIDAL3 at -0.017'

Note, the relative accuracy of TIDAL3 and TIDAL1 is 0.003'.

In the final Constrained Adjustment, the above 4 benchmarks were fixed at their NGS published NAVD 88 elevations. The final elevations and differences from record to computed are listed below in alphabetical order in feet.

ID	NGS Designation	NGS Benchmarks		Diff.	Comments
		NGS PID	Final Elev.		
A1044	A 1044	EW3734	36.142	-0.114	
A609	A 609	EW3736	29.946	-0.080	
C658	C 658	EW3758	154.173	0.000	Fixed
K1215	K 1215	EW3749	31.343	0.031	
S1441	S 1441	EW9489	113.392	0.000	Fixed
T1441	T 1441	EW9490	60.810	0.019	
T28	T 28	EW3735	39.224	-0.090	
TIDAL1	941 1340 TIDAL 1	EW3742	16.145	0.000	Fixed
TIDAL2	941 1340 TIDAL 2	EW3741	12.838	-0.049	
TIDAL3	941 1340 TIDAL 3	EW7026	10.433	0.000	Fixed
W1042	W 1042	EW3766	126.393	0.057	

NGS Data Sheets for the above benchmarks are attached for reference and are listed in order of their NGS PID. One additional NGS benchmark J324 did not have an NAVD 88 elevation and is listed below with the summary of old City benchmarks included in this survey.

Listed below are the computed shifts from NGVD 29 to NAVD 88 at 51 City Benchmarks and the NGS Benchmark J324. The shifts vary between 2.52' and 2.71' and average 2.61'. The shifts at CAR953W of -0.42' and at CLI2346 of 2.38' are outliers and indicate the original NGVD 29 elevation is incorrect.

#### City Benchmarks

ID	Diff.	ID	Diff.
(1)ANA00	2.529	LAS3061	2.653
BAT1900	2.614	LOS340	2.631
BAT1935	2.626	LOS505	2.664
CAB13	2.557	MEI500	2.536
CAB23	2.523	MEI606	2.575
CAL4010	2.521	MEI630	2.585
CAN00	2.631	MEI800	2.611
CAR1005W	2.576	MOD2000	2.589
CAR1030W	2.637	MOD2109	2.621
CAR400W	2.647	MOD2220	2.678
CAR606W	2.620	MOD2303	2.658
CAR953W	-0.423	-MOD2414	2.650
CARP1133	2.593	MOD2505	2.643
CLI1900	2.574	MOD2541	2.668
CLI2109	2.566	MOD3523	2.630
CLI2309	2.562	MOD3558	2.683
CLI2346	2.384	MOD3601	2.663
GAR1900	2.663	MOD3659	2.675
GAR2000	2.671	MOD3721	2.655
GPS9022CAB17	2.571	MOD3831	2.658
GPS9023CAB14	2.552	PED100W	2.621
J324	2.541	PED130	2.677
LAS1102	2.546	SAL2S	2.713
LAS1402	2.652	SAN1000	2.558
LAS2400	2.647	STA1300	2.642
LAS2900	2.638	STA3800	2.547

(1)ANA00 was destroyed after the survey and because it is a City block corner it was replaced but not used for elevation.

Listed below are the computed shifts from the NAVD 88 elevations published in 1995 on 22 of the 36 Santa Barbara Control Network (SBCN) points.

<u>Santa Barbara Control Network</u>			
ID	Diff.	ID	Diff.
SBCN10002	-0.050	SBCN10023	-0.039
SBCN10003	0.125	SBCN10025	-0.100
SBCN10005	0.130	SBCN10026	0.015
SBCN10006R	0.090	SBCN10027	0.034
SBCN10007	0.032	SBCN10029	-0.096
SBCN10009	0.028	SBCN10030	-0.113
SBCN10012	0.007	SBCN10031	0.022
SBCN10015	0.094	SBCN10033	-0.009
SBCN10020	-0.184	SBCN10034	-0.053
SBCN10021	0.007	SBCN10035	-0.051
SBCN10022	-0.012	SBCN10036	0.039

Note: SBNC10025 was destroyed in 2004 and was included by a tie to a reference point set before construction. The elevation of SBNC10025 is computed to have been 119.657 feet.

OTHER CITY LEVELING SURVEYS: The City performed leveling surveys in 2000 to connect SBCN10002 to control points #9006 to 9010 at the Cater Plant. This survey found SBCN10002 to differ 0.05' from the record; however, GPS9009 at the Plant was found to be at 526.419' verses 526.41 in June 2000. The 2000 survey results are compatible with this survey; however, SBCN10002 located north of the Plant appears to have settled 0.05'. In 2001, the City performed leveling surveys to connect NGS Benchmark TIDAL-1 to SBCN10033, GPS9015, GPS9025 (destroyed) and TIDAL-2. TIDAL-1 was fixed and SBCN10033 was found in good agreement. TIDAL-2 was found 0.044 feet lower than the published elevation at 12.843 feet in 2001. This survey finds TIDAL-2 at 12.838 feet (final). The 2001 survey results are compatible with this survey.

GPS SURVEYS: At completion of the leveling, a precision GPS survey observed a select set of SBCN points and new control points that were included in the Leveling Network Survey. These measurements provide a basis for using GPS technology to model orthometric heights (elevations) at the level of one centimeter (0.03") across the City. Combining the leveled elevations of SBCN points with GPS measurements provides the means to utilize GPS as a replacement tool for conventional leveling to establish NAVD 88 elevations. The benefit will result in costs savings and improved accuracy for City projects and the private sector when relying on City elevations for project control. See the 2008 Height Modernization GPS Survey Report for additional information.

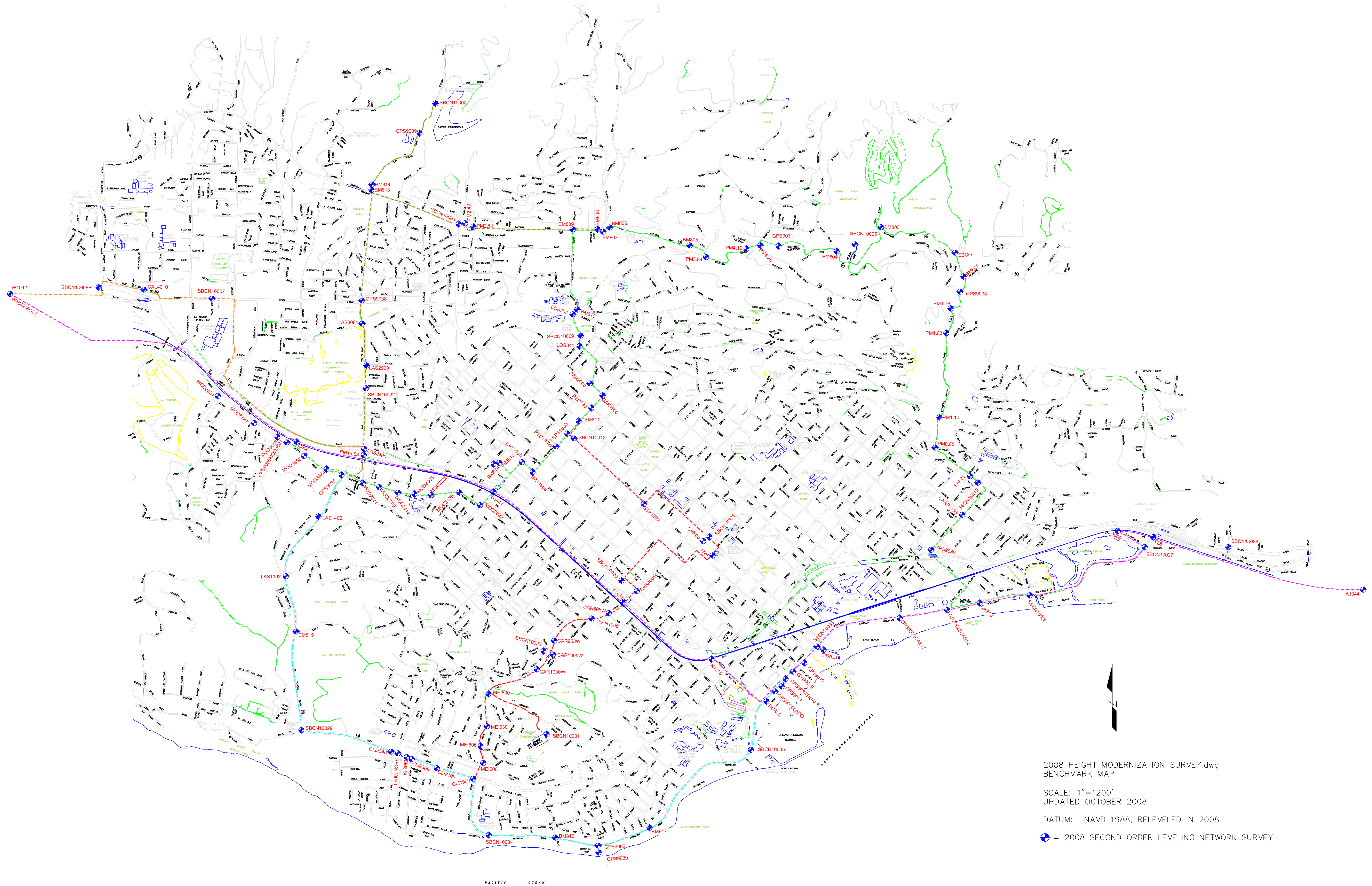
ACCURACY: The relative accuracy of the leveled heights are expected to be better than 0.01 feet. The absolute accuracy of these heights is dependent on the values provided for the NGS benchmarks.

Attachments: Elevation List, NGS Reference Data

SURVEYOR'S STATEMENT: This report on the criteria and procedures used on the Differential Leveling Survey was prepared by me on November 11, 2008 at the request of the City of Santa Barbara.

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Michael R. McGee, PLS 3945



2008 HEIGHT MODERNIZATION SURVEY.dwg  
BENCHMARK MAP

SCALE: 1"=1200'  
UPDATED OCTOBER 2008

DATUM: NAVD 1988, RELEVELED IN 2008

● = 2008 SECOND ORDER LEVELING NETWORK SURVEY