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CHARLESTON PEAK GRAVITY CALIBRATION LOOP, NEVADA

by

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ABSTRACT

A mountain-type calibration loop has been established in southern Nevada to test the performance and check the calibration of gravity meters used in the Nevada Nuclear Waste Storage Investigations. The observed gravity values are on the IGSN 71 datum and range from about 979,265 mGal at Charleston Park (elevation 7,540 ft) to 979,541 mGal at Indian Springs (elevation 3,115 ft), a difference of 275 mGal. Five stations have been established between Indian Springs and Charleston Park at gravity intervals of about 50 mGal. Geomorphic evidence indicates the area is reasonably stable with regard to possible short-term (<50 years) gravity changes.

INTRODUCTION

A new gravity calibration loop has been established in southern Nevada in support of the U.S. Geological Survey's quality assurance responsibility for the NNWSI (Nevada Nuclear Waste Storage Investigations). The purpose of the loop is to provide accurately known observed gravity values over the gravity range found in southern Nevada, to periodically test the performance of gravity meters, and to check or adjust their calibration factors. Gravity stations making up the loop were chosen in June 1979 and were based on the following criteria: (1) permanency of station mark, (2) accessibility of station location, (3) ease of relocating a station, (4) a difference in observed gravity of about 50 mGal between stations, and (5) a minimum local terrain correction. Another consideration was the expected stability of gravity, that is, the freedom from possible effects that might change gravity, such as seasonal water table variations in highly porous media. Subsequent runs were made intermittently during the period from June 1979 to February 1980. Additional runs will be made with various meters as opportunity and necessity permit.

Prior to 1979, the calibration of gravity meters used in southern Nevada by the U.S. Geological Survey had to be tested on calibration loops at Mt. Hamilton, California, or Mt. Evans, Colorado (Barnes and others, 1969) (fig. 1). The gravity range of the Charleston Peak loop (marked "Ch. Peak" in fig. 1) is similar to the all-year (lower) section of the Mt. Evans loop, but is significantly less than that of the Mt. Hamilton loop (marked "Mt Ham." in fig. 1).

The Charleston Peak loop observed gravity values are on the IGSN 71 datum (Morelli, 1974) and are presently based on 4 runs with LaCoste and Romberg gravity meter G17B using a factor of 1.00252, and 6 runs with LaCoste and Romberg gravity meter G177 using a factor of 1.0003. There are 8 stations in the loop, including the base station at Mercury, Nevada, which is just within the NTS (Nevada Test Site).

ACKNOWLEDGMENTS

We appreciate the assistance of H. M. Van Buren in the initial planning, selection, and description of gravity stations and of J. D. Spielman, R. N. Harris, D. B. Snyder, R. W. Tang, and R. L. Morin who assisted in the establishment of the loop.

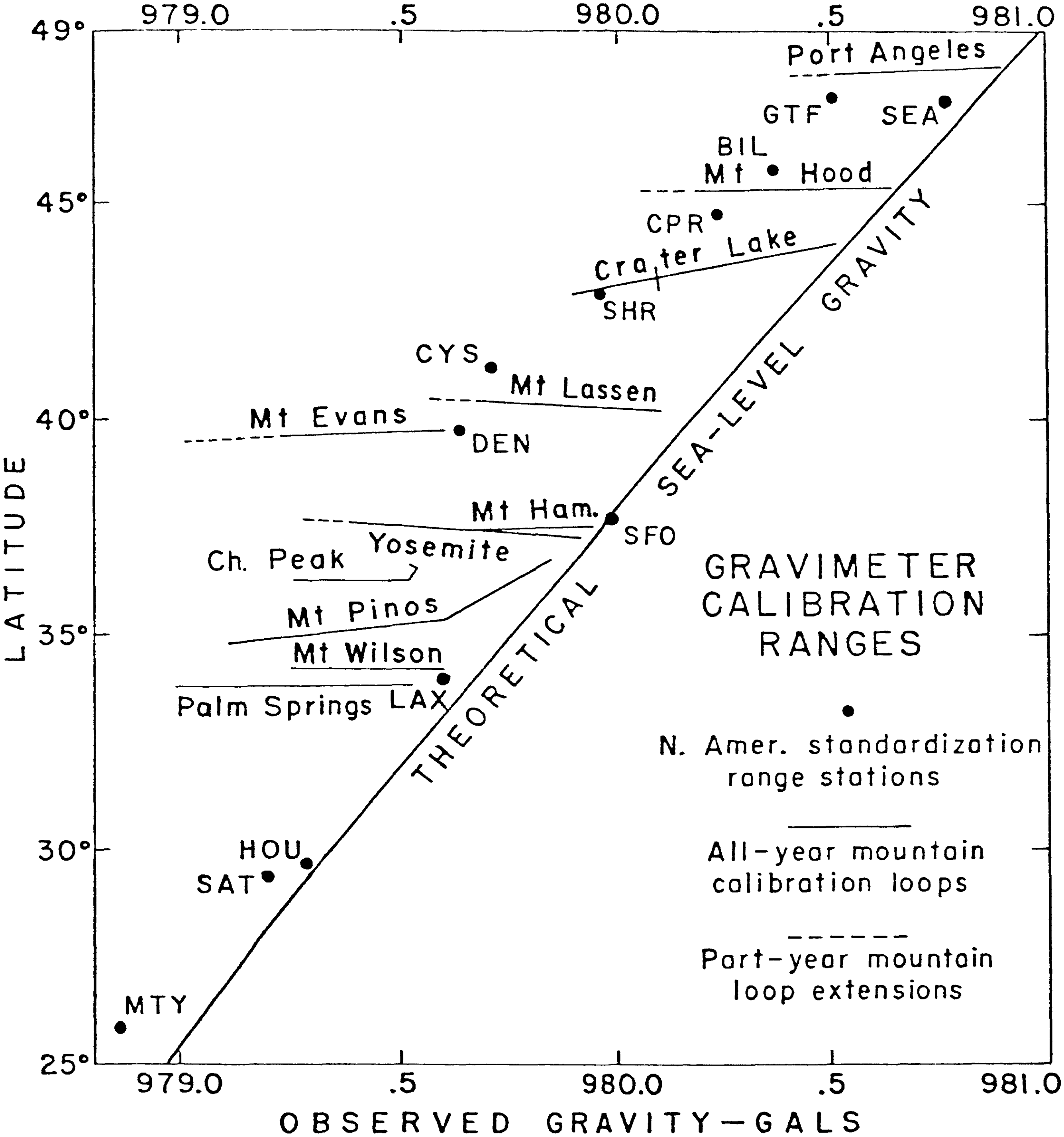

Figure 1. Latitude and gravity ranges of U.S. Geological Survey mountain calibration loops. After Barnes and others (1969).

GENERAL DESCRIPTION

The Charleston Peak calibration loop is very convenient for gravity work based in the Las Vegas-Nevada Test Site area. The loop begins in the U.S. Geological Survey Core Library Building at Mercury, about 70 mi (110 km) WNW. of Las Vegas. The loop continues southeastward for about 20 mi (30 km) of freeway driving on U.S. Highway 95 to the U.S. Air Force gravity base station at the Indian Springs Post Office. The loop then continues for 30 more mi (50 km) of freeway driving before starting the 20 mi (30 km) ascent along Nevada State Highway 157 to the Charleston Park Restaurant (fig. 2).

The loop takes 5 to 6 hours for a round trip from Mercury, including lunch at the Charleston Park Restaurant. The loop can be run all year round, although winter snow can make stations above the snow line difficult to locate. However, station CPF at the top can usually be reoccupied because it is located on a partially covered cement walkway.

The gravity range starts at 979,518.80 mGal at Mercury, increases 22.36 mGal to 979,541.16 mGal at Indian Springs Post Office, and then decreases 275.27 mGal to 979,265.89 mGal at the Charleston Park Restaurant. The increase in gravity between Mercury and Indian Springs is primarily due to the decrease in elevation of 665 feet. Gravity decreases 18.94 mGal between Indian Springs and station CPA in spite of the decrease in elevation because of the effect of low-density sediments in Las Vegas Valley (see Kane and others, 1979). Further decreases in gravity up Charleston Peak are consistent with corresponding elevation increases using an approximate factor of -60 mGal/1,000 ft (-60 mGal/300 m).

The gravity differences listed in table 1 are based on the average of 4 runs with LaCoste and Romberg meter G17B and 6 runs with LaCoste and Romberg meter G177 during 1979-80 and have computed standard errors of 0.01 to 0.02 mGal (Table 3). The total loop average from MERC to CPF is 252.91 mGal and from ISPO to CPF is 275.27 mGal. Since public access to the Nevada Test Site is not permitted, the loop may be alternately run using station ISPO or station CPA as the base. When operating out of Las Vegas, the use of CPA as the base station instead of ISPO saves 60 miles of driving with a loss of only about 19 mGal in the total gravity range.

Detailed descriptions and sketch maps of all eight stations are given in Appendix 1. Photographs of each station are also included in Appendix 1 as an aid in relocation and replication of the measurements. Gravity is probably more stable at stations located at higher elevations, on or near pre-Cenozoic bedrock in the Spring Mountains (CPD to CPF) than those located at lower elevations on thicker alluvial deposits (CPA to CPC). Little or no subsidence of the Mercury area has occurred due to the withdrawal of well water (G. Doty, oral commun., 1981). Water withdrawal from wells near Indian Springs may cause a slight decrease in gravity at station ISPO. However, repeat

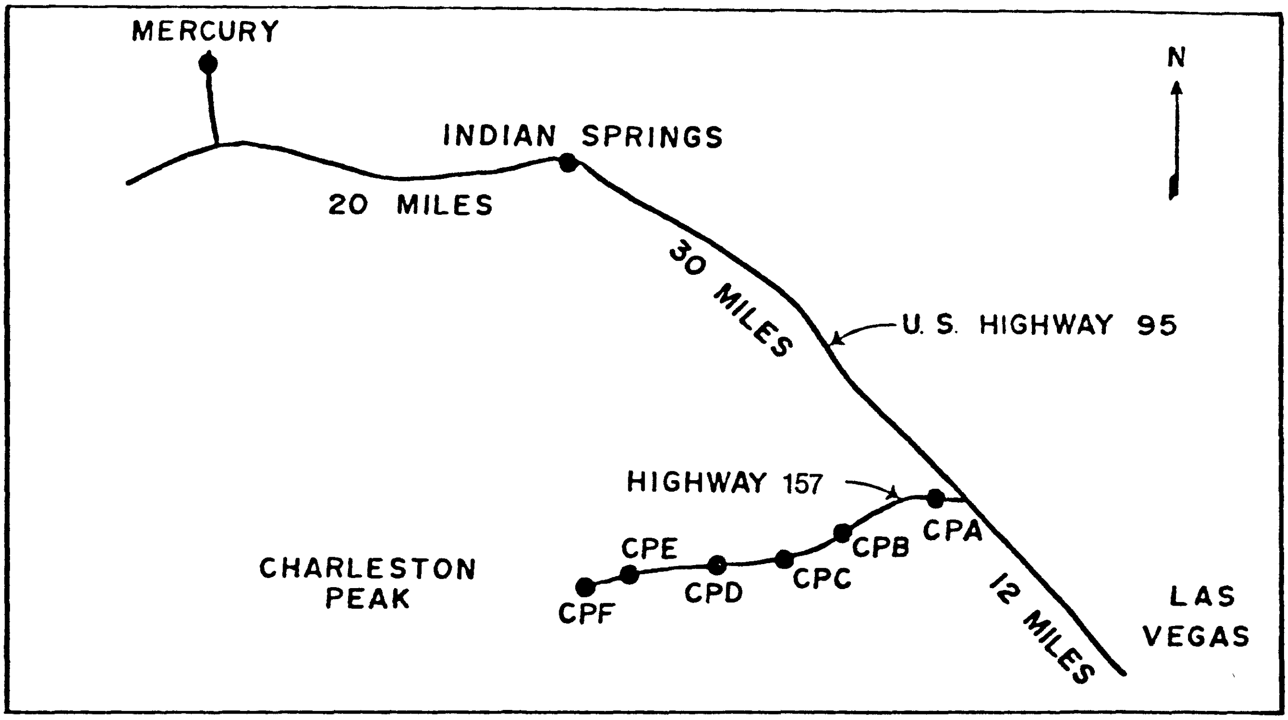

Figure 2. Sketch map of the Charleston Peak calibration loop.

Table 1. Principal facts for gravity stations on the Charleston Peak calibration loop.

Stat	Name	Latitude	Longitude	Elev[1] (feet)	Observed Gravity (mGal) IGSN 71	ΔG (mGal) IGSN 71
MERC	Mercury	36°39.35'	115°59.76'	3780.	979,518.80	n.a.[2]
ISPO	Indian Springs	36°34.60'	115°39.00'	3115.	979,541.163	+22.36
CPA	Hwy. Jct.	36°19.50'	115°20.00'	3023.	979,522.222	-18.94
CPB	Scott Blvd.	36°17.65'	115°25.76'	4104.	979,470.828	-51.39
CPC	Dirt Track	36°16.63'	115°28.82'	4910.	979,423.012	-47.82
CPD	Bridge	36°16.29'	115°32.56'	5920.	979,373.230	-49.78
CPE	Ranger station	36°15.80'	115°36.65'	7120.	979,302.758	-70.47
CPF	Charleston Park	36°15.48'	115°38.65'	7540.	979,265.890	-36.87
			Total loop difference		MERC-CPF	-252.91
					ISPO-CPF	-275.27
					CPA-CPF	-256.33

[1]Stations CPA and CPB are located on bench marks. Station ISPO is located on a USAF gravity base station. All other stations have approximate elevations determined from 7½ or 15' quadrangle maps.

[2]Not applicable

measurements between Las Vegas, Indian Springs, and Mercury have been made over a 20-year period since about 1960, and no significant gravity changes (>0.03 mGal) have been observed (D. L. Healey, oral commun., 1980).

Previous work indicates that it may be necessary to multiply factory calibration tables for gravity meters by a small correction factor if accuracies in gravity differences better than about 1 part in 1,000 are desired (Barnes and others, 1968; Oliver and others, 1981, table 7). In southern Nevada, the observed gravity range is about 979,000 mGal to 979,700 mGal, a difference of about 700 mGal (Kane and others, 1978; Snyder and others, 1980; Healey and others, 1981). Thus, to obtain a relative accuracy in gravity measurements of 0.05 mGal, a calibration of 5 parts in 70,000 is required or a little better than 1 part in 10,000. This accuracy is, of course, an order of magnitude better than required for normal exploration work and is obtainable by the determination of corrections or "calibration factors" to meters by means of measurements on local mountain loops.

CALCULATION OF OBSERVED GRAVITY VALUES

Several steps were involved in calculating the observed gravity values for the new calibration loop including: 1) rechecking or establishing a new calibration factor for each meter, 2) comparing the established observed gravity values on a known calibration loop to those calculated by each meter, 3) calculating the observed gravity values for each station on the new loop with each meter, and 4) combining the results of step (3) to obtain the final observed gravity values on the new calibration loop.

CALIBRATION FACTORS

Meter G17B

Eight runs on the Mt. Hamilton loop (California) were made with meter G17B between June 1979 and April 1980. Reduction of the data using a least squares method, which included a correction for G17B's circular error, yields a constrained factor of 1.00251 $\pm$ 0.00009(s.e.) and an unconstrained factor of 1.00252 $\pm$ 0.00008(s.e.). The constraint in the former option is that the line of best fit is forced to pass through the origin (Δg=0) at Menlo Park. The unconstrained result agrees perfectly with the previous factor of 1.00252 based on 4 runs in

1977 (R. C. Jachens, oral commun., 1980). The data suggest that the 309.31 mGal gravity difference between Menlo Park and the top of Mt. Hamilton has not changed perceptibly (±0.02 mGal) between 1977 and 1980.

Meter G177

Six Mt. Hamilton runs with meter G177 during 1979-1980 result in a constrained factor of 1.00037 ± 0.00007(s.e.) and an unconstrained factor of 1.00032 ± 0.00006(s.e.). To the nearest fourth decimal, the result is 1.0003 ± 0.0001 and is 1 part in 10,000 higher than the value for G177 of 1.0002 obtained by S. L. Robbins (oral commun., 1980) on the basis of 3 runs on Mt. Hamilton in 1968.

To confirm the reliability of the new factor, 1.0003 was used to calculate observed gravity values on the Mt. Hamilton calibration loop. These values were then compared to the established values on the Mt. Hamilton loop, which are based on approximately 50 runs. The results, presented in table 2, show that the new factor of 1.0003 generally meets calibration loop standards (gravity differences OG_e-OG_c reliable to 1 part in 10,000). There are slight problems with stations HC and HF which may need additional work, but stations HG and HH, which have the largest gravity differences, have acceptable precision.

Table 2. Comparison of established observed gravity values (OGe) and values based on runs with meter G177 with a factor of 1.0003 (OGc) for the Mount Hamilton calibration loop.

Station	OGe Woollard & Rose (1963) datum (mGal)	Average of 6 runs with G177 OG_c (mGal)	Standard error for OG_c (mGal)	OG_e - OG_c (mGal)
MP-A	979,958.74	n.a.[1]	n.a.	n.a.
HC	979,884.93	979,884.90	0.012	+0.03
HE	979,784.94	979,784.95	0.018	-0.01
HF	979,748.76	979,748.73	0.013	+0.03
HG	979,697.72	979,697.71	0.018	-0.01
HH	979,649.43	971,649.44	0.018	-0.01

[1]Not applicable

RELIABILITY OF THE CHARLESTON PEAK LOOP

The observed gravity values and the standard errors for the Charleston Peak gravity calibration loop are listed in table 3. The observed gravity values are relative to the value at MERC on the IGSN 71 datum of 979,518.80 mGal (see Morelli, 1974, and Oliver and others, 1981, for discussion of relation between IGSN 71 and Woollard and Rose (1963) gravity datums in the western United States). The standard errors for the observed gravity values based on 10 combined runs are less than 0.02 mGal and do not seem to be a function of gravity difference. The standard errors, of course, are inversely proportional to the square root of the number of runs, and these errors should decrease as the number of runs increases, provided the standard deviation remains constant. Hopefully, additional runs will decrease the standard errors of all stations to about 0.01 mGal.

Table 3. Observed gravity values (OG) for the Charleston Peak calibration loop based on 4 runs with G17B (1.00252) and 6 runs with G177 (1.0003)

Station	OG IGSN 71 Datum (mGal)	Standard Error (mGal)
MERC	(979,518.80)	n.a.[1]
ISPO	979,541.163	0.014
CPA	979,522.222	0.013
CPB	979,470.828	0.013
CPC	979,423.012	0.015
CPD	979,373.230	0.019
CPE	979,302.758	0.020
CPF	979,265.890	0.018

[1]Not applicable

APPLICATION TO TECTONIC STABILITY STUDIES AT THE NTS AND VICINITY

Now that the Charleston Peak gravity loop is accurately established, any subsequent changes in relative elevation greater than about 3 to 4 in (7 to 10 cm) at any of the 8 stations along the loop could be detected by measuring a corresponding gravity change of about 10 μGal (.01 mGal) or more. Changes in gravity can be caused by effects other than changes in elevation, such as the seasonal variation in the depth to the water table and mass changes at depth. However, the source of gravity changes can usually be determined by standard interpretive techniques (see Barnes, 1966; Oliver, 1975).

The general relation between gravity and elevation change is 5 to 8 μGal/in (2 to 3 μGal/cm) depending on the cause of the elevation change (Jachens, 1978). Thus, the present data for the Charleston Peak loop with a maximum standard error of ±20 μGal (Table 3) probably provide a data base accurate enough to detect elevation changes greater than about 3 to 4 in (7 to 10 cm). If additional data reduce the standard errors to 10 μGal, then the detection of relative elevation changes of 1 to 2 in (3 to 5 cm) by rapid gravity measurements may become possible.

In addition to the Charleston Peak loop, there are about 30 gravity base stations throughout southern Nevada that have been described by Healey and others (1978a; 1978b; 1981), and more recently by Snyder and others (1980), by Snyder and Oliver (1981), and by Ponce (1981). These gravity bases have been established by four or more ties and are not as accurate as stations on the Charleston Peak loop, but generally have standard errors of ±0.03 mGal. Thus repeat measurements on any of these bases should be able to delineate areas of gross tectonic instability where changes in elevation greater than about 4 to 6 in (10 to 15 cm) may occur.

Geomorphic studies indicate that Spring Mountains (in which Charleston Peak is the highest point) and Calico Hills (located 20 km west of Mercury, Fig. 2) have been rising for the last 10 million years (D. L. Hoover, oral commun., 1981), whereas there is no evidence for vertical movement of Yucca Mountain, a site west of Calico Hills that is being considered for the possible storage of high-level nuclear waste. Preliminary estimates of the average rates of uplift for the Spring Mountains and Calico Hills are about 2.3 ft/1,000 yr (0.7 m/1,000 yr) and about 0.7 ft/1,000 yr (0.2 m/1,000 yr), respectively (D. L. Hoover, written commun., 1981). Thus, at the Spring Mountains rate, it would take about 50 years to produce a detectable gravity change of about -10 μGal at station CPF at Charleston Park. Detectable gravity changes at Calico Hills would require an even larger data base unless the predicted gravity decrease (elevation increase) were to be episodic instead of continuous, which is possible.

The Mercury-Charleston Peak area can be regarded as stable, for the purpose of calibrating gravity meters and testing meter performance. However, should measurable gravity changes occur, they probably would be geographically related and of considerable interest to tectonic and ground water studies.

SUMMARY

The first mountain gravity-calibration loop in Nevada has been established between Mercury and Charleston Park. The loop has a range of about 275 mGal covering about the same gravity interval as the all-year part of the Mt. Evans loop in Colorado (979.2 to 979.5 Gal) and has a lower range than the Mt. Hamilton loop, California (979.6 to 979.9 Gal, fig. 1). The loop was established in support of the U.S. Geological Survey's quality assurance responsibility for the NNWSI and comprises 8 accurately known observed gravity stations, used periodically to check or adjust gravity meter calibration factors and test meter performance.

Since public access to the Nevada Test Site is not permitted, the loop may be alternately run with station ISPO at Indian Springs or station CPA about 20 mi (30 km) N. of Las Vegas as the primary base. When operating out of Las Vegas, the use of CPA as the base station saves 60 mi (100 km) of driving with only a 19 mGal decrease in the total gravity range.

The calculation of the observed gravity values for the Charleston Peak calibration loop involved: (1) a check of the 1.00252 factor for gravity meter G17B, (2) an adjustment of the factor for meter G177 from 1.0002 to 1.0003, and (3) combination of the 4 runs with meter G17B and 6 runs with G177 to obtain the final observed gravity values. The standard errors for the observed values on the 10 combined runs were 0.01 to 0.02 mGal, which meets present calibration loop standards.

Although geomorphic evidence indicates that the Spring Mountains, which include four stations on the upper part of the loop, have been rising at the average rate of about 2.3 ft/1,000 yr (0.7 m/1,000 yr), the rise is sufficiently slow that it would not cause a detectable decrease in gravity (0.01 mGal) within 50 years. If a more rapid episodic rise occurred, the associated gravity decrease could be geographically related to the mountain front. Gravity may also be expected to decrease slightly at Indian Springs due to ground water withdrawal.

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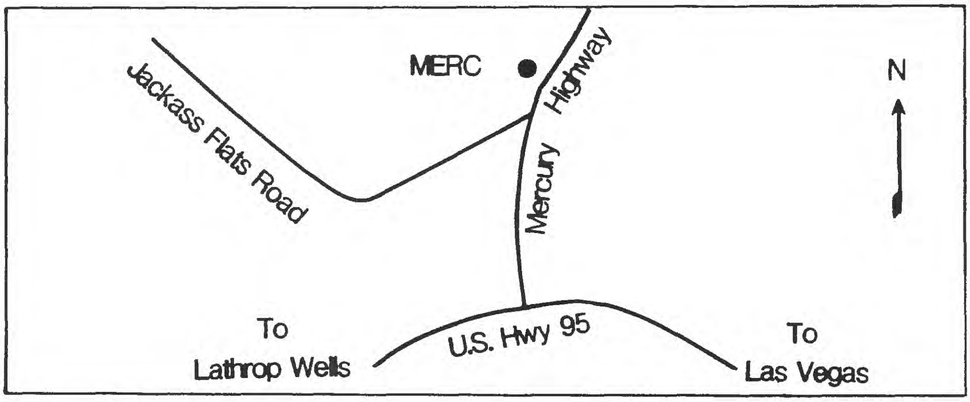
APPENDIX 1.

GRAVITY STATION DESCRIPTIONS

GRAVITY BASE STATION #	MERC
NAME Mercury	STATE Nevada
LATITUDE 36° 39.35'	LONGITUDE 115° 59.75'
ELEVATION 3780'	
OBSERVED GRAVITY 979,518.80 mGal	SBA

LOCATION DESCRIPTION:

The station is at Mercury, Nevada, about 70 miles northwest of Las Vegas along U.S. Highway 95. The station is in the southwest corner of the U.S. Geological Survey Core Library Building, in a rear storage room, by the geophysics workbench. Read the meter in the corner formed by two gray cabinets in the northwest corner of the room with the meter facing the corner.

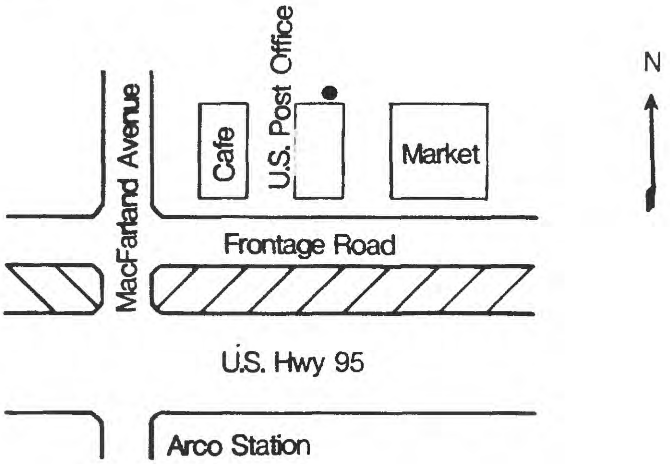


GRAVITY BASE STATION # ISPO

NAME Indian Springs	STATE Nevada
LATITUDE 36° 34.60'	LONGITUDE 115° 39.00'
ELEVATION 3115'	
OBSERVED GRAVITY 979,541.16 mGal	S B A

LOCATION DESCRIPTION:

The station is at Indian Springs, Nevada at the U.S. Post Office, on the southeast corner of the back (north) porch against the north wall of the post office and about 8 feet east of the back door. The station is marked with a standard U.S. Air Force gravity base station disc. Read over the disc with the meter facing the building.



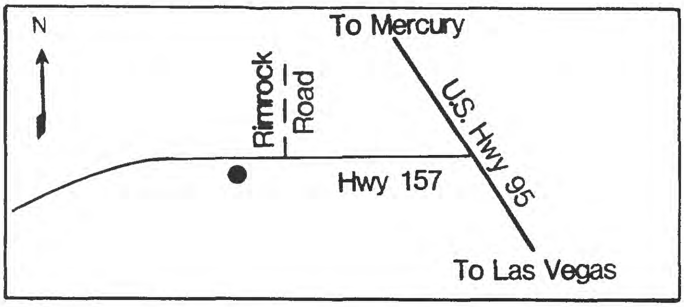
GRAVITY BASE STATION # CPA

NAME	Highway Junction	STATE	Nevada
LATITUDE	36° 19.50'	LONGITUDE	115° 20.00'
ELEVATION	3023'		
OBSERVED GRAVITY	979,522.22 mGal	SBA	

LOCATION DESCRIPTION:

The station is located on the east end of a concrete culvert headwall 30 feet south of the centerline of Nevada State Highway 157 and 1.2 miles west of the junction of State Highway 157 and U.S. Highway 95. The station is 0.35 mile west of the junction of a dirt track (called Rimrock Road) and Highway 157. A black and white Nevada Highway Department paddleboard about 3.5 feet in height partly painted red is adjacent to the station.

The station is marked by a standard tablet stamped "2 GWM 1951" with a USGS gravity disc adjacent to it. Read over the bench mark with the meter facing toward the highway.

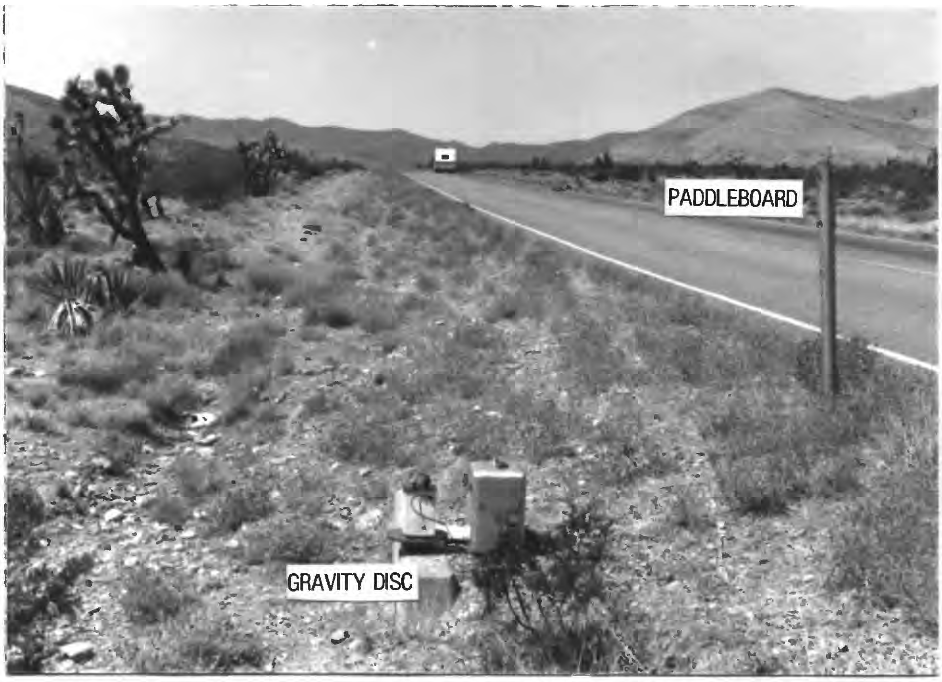


GRAVITY BASE STATION #	CPB
NAME Scott Blvd.	STATE Nevada
LATITUDE 36° 17.65'	LONGITUDE 115° 25.26'
ELEVATION 4104'	
OBSERVED GRAVITY 979,470.83 mGal	SBA

LOCATION DESCRIPTION:

The station is located on the east end of a concrete culvert headwall 30 feet south of the centerline of Nevada State Highway 157 and 6.6 miles west of the junction of State Highway 157 and U.S. Highway 95. The station is 0.60 mile west of the junction of Scott Blvd. and Highway 157, and is 5.4 miles west along Highway 157 from CPA. A black and white Nevada Highway Department paddle-board about 3.5 feet in height partly painted red is adjacent to the station.

The station is marked by a standard tablet stamped "5 GWM 1951" with a USGS gravity disc adjacent to it. Align the gravity base plate in the star-drilled holes painted red on the concrete headwall. Read over the bench mark with the meter facing the highway.



GRAVITY BASE STATION #	CPC
NAME Dirt Track	STATE Nevada
LATITUDE 36° 16.63'	LONGITUDE 115° 28.82'
ELEVATION 4910'	
OBSERVED GRAVITY 979,423.01 mGal	SBA

LOCATION DESCRIPTION:

The station is located on the east end of a concrete culvert headwall 30 feet south of the centerline of Nevada State Highway 157 and 10.3 miles west of the junction of State Highway 157 and U.S. Highway 95. The station is 0.60 mile west of the junction o of a dirt track leading north and Highway 157, and is 3.9 miles west along Highway 157 from CPB. A black and white Nevada Highway Department paddleboard about 3.5 feet in height partly painted red is adjacent to the station.

The station is marked by a USGS gravity disc. Align the gravity base plate in the star-drilled holes painted red on the concrete headwall. Read over the gravity disc with the meter facing the highway.

GRAVITY BASE STATION #	CPD
NAME Bridge	STATE Nevada
LATITUDE 36° 16.29'	LONGITUDE 115° 32.56'
ELEVATION 4820'	
OBSERVED GRAVITY 979,373.23 mGal	SBA

LOCATION DESCRIPTION:

The station is located on the west end of a concrete bridge headwall, behind a guardrail, 20 feet north of the centerline of Nevada State Highway 157 and 13.7 miles west of the junction of State Highway 157 and U.S. Highway 95. The station is 1.2 miles west of station CPC and is 40 feet east of a road sign "NO PARKING ON PAVEMENT" located on the north side of the highway. The guardrail has a red slash painted on each end.

The station is marked by a USGS gravity disc. Align the gravity base plate in the star-drilled holes painted red on the brigde headwall. Read over the gravity disc with the meter facing the highway.

GRAVITY BASE STATION # CPE	
NAME Kyle Canyon Ranger Station	STATE Nevada
LATITUDE 36° 15.80'	LONGITUDE 115° 36.65'
ELEVATION 7120'	
OBSERVED GRAVITY 979,302.76 mGal	S B A

LOCATION DESCRIPTION:

The station is located on the southeast corner of a stone bridge at the entrance to the Kyle Canyon Ranger Station, 165 feet south of the centerline of Nevada State Highway 157 and 18.0 miles west of the junction of State Highway 157 and U.S. Highway 95. The station is 4.3 miles west along Highway 157 from CPD. The entrance road to the Ranger Station and Visitor Center is marked by a sign "KYLE CANYON RANGER STATION".

The station is marked by a USGS gravity disc . Read over the disc with the meter facing Highway 157.

GRAVITY BASE STATION # CPF

NAME	Charleston Park	STATE	Nevada
LATITUDE	36° 15.48'	LONGITUDE	115° 38.65'
ELEVATION	7540'		
OBSERVED GRAVITY	979,265.89 mGal	S B A	

LOCATION DESCRIPTION:

The station is located near the southwest corner of the Charleston Park Restaurant and Lounge 20.9 miles west of the junction of Nevada State Highway 157 and U.S. Highway 95. The station is 2.8 miles west along State Highway 157 from CPE and is 0.2 mile east along a left branch of a Y-intersection in the Highway. The station is located on a concrete pad adjacent to a shed containing a water heater for the restaurant.

The station is marked by a USGS gravity disc. Align the gravity base plate in the star-drilled holes. Read over the gravity disc with the meter facing the restaurant.