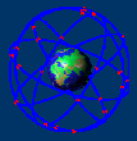
Geodetic Datums and Reference Frames



"Down to Earth"© with Datums

Realization - Recovery - Relationships

September 28, 2012 Ontario, CA
October 5, 2012 Sacramento, CA

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Handouts

- Datum-RefSyst 2012.74v1

Introduction

- The USAF declared the Global Positioning System (GPS) "operational" in 1994. This was the biggest game changer in the history of surveying.
- Presently we have GPS, Glonass, Galileo and Compass (Beidu) all referred to as the Global Navigation Satellite System (GNSS).
- GNSS is shrinking the world - It is more important than ever to adopt universal datums for integrating geo-spatial communities.

Introduction

- Common datums allow us to speak the same language, to easily share information and to build on the efforts of others.
- The challenge is knowing where to anchor our measurements; to know what datum should be used and why.
- As professionals, our duty is to advise our clients of what will best serve their needs. We are expected to know otherwise we risk practicing outside our area of competence. (Board Rule)

Introduction

- Obtaining accurate measurements with GNSS is overshadowed by the importance and consequences of the positions we publish.

TERMINOLOGY

- Datum: A mathematical model defined by parameters that determine its origin, scale, and orientation and used to describe the spatial relationship of points. A datum can be 1, 2, 3 or 4 dimensional.
- Reference Frame (Reference System): A datum is realized by establishing coordinates on points (monuments) in the world which provides access to the datum. The introduction of new measurements and adjustments is a new realization of the datum. New adjustments are used to improve the accuracy of points in an absolute sense relative to the datum, and locally relative to other points.
  - A set of station coordinates infers a particular realization of a reference frame for a datum.

TERMINOLOGY

1. Datum Recovery: The acquisition of a datum through measured connections to monuments referencing the datum, or applying a model or a transformation to move from one datum or realization to another.
   - A report containing a qualitative and quantitative analysis of the recovery is necessary so others can make an assessment and "follow in your footsteps".

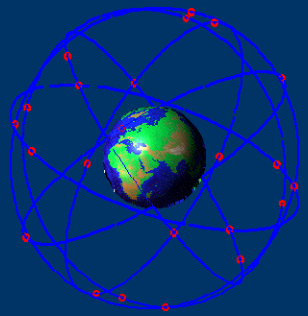
ACRONYMS

Acronyms

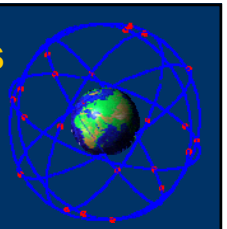
- **Datums**
- **GRS80: Geodetic Reference System 1980 (ellipsoid model adopted in 1980)**
- **ITRS: International Terrestrial Reference System (geocentric)**
- **NAD27: North American Datum 1927 (horizontal system)**
- **NAD83: North American Datum 1983 (not geocentric)**
- **NAVD88: North American Vertical Datum 1988**
- **NGVD29: National Geodetic Vertical Datum 1929**
- **WGS84: World Geodetic System 1984 (DoD) (equivalent to ITRF08)**
- **Reference Systems**
- **CSRN: California Spatial Reference Network (California's NSRS) (see PRC)**
- **HARN: High Accuracy Reference Network (state's)**
- **HPGN: High Precision Geodetic Network (CA's HARN, first GPS in 1991)**
- **HPGN-D: Densification of the High Precision Geodetic Network**
- **IGS: International GNSS Service**
- **ITRF: International Terrestrial Reference Frame**
- **NGRS: National Geodetic Reference System (old name)**
- **NSRS: National Spatial Reference System (new name for NGRS)**
- **VLBI: Very Long Baseline Interferometery (world network)**
- **Projections**
- **SPC: State Plane Coordinate System (Lambert or Mercator Projections)**
- **UTM: Universal Transverse Mercator (world coordinate system)**

Agenda: Geodetic Datums

- 1D: Vertical
  - Geoid
  - Tidal Datums
  - NGVD29
  - NAVD88
- 2D: Horizontal
  - NAD27
  - NAD83
- 3D: Geometric
  - NAD83
  - WGS84
  - ITRF/IGS (4D)



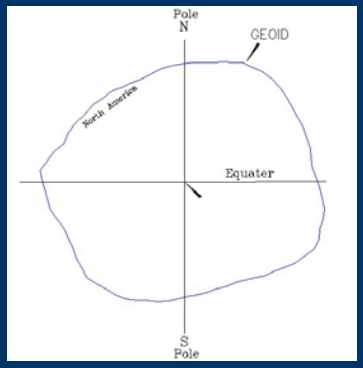
Vertical Datums



- **1D: Vertical**
  - **Geoid – Global Mean Sea Level Concept**
  - **Tidal Datums**
  - **NGVD29 - National Geodetic Vertical Datum of 1929**
  - **NAVD88 - North American Vertical Datum of 1988**

Geoid – An Elusive Datum

- The Geoid: An equal-potential surface approximating global mean sea level.



Geoid – An Elusive Surface

- Equal-Potential Surface is a surface where the force of gravity is everywhere equal. There are an infinite number of equal-potential surfaces. These surfaces are undulating due to the non-homogenous nature of the mass of the planet.
- The Geoid is defined as that particular equal-potential surface that represents global mean sea level, as if it were extended into the land masses and unaffected by exo-planetary gravitational forces (water does not flow).

Geoid – an analogy

- In a Galaxy far far away… you discover a world similar to the earth,
  - completely covered with water,
  - it doesn't rotate,
  - there is no sun and moon,
  - no tides, no currents,
  - the water is at rest, and then it suddenly freezes over.
- You setup your instrument on the ice surface and run levels, and every where you run across the planet you find the surface elevation to be the same. That undulating surface is an equal-potential surface
- Back on the Earth, the Geoid is a particular equal-potential surface defined as global mean sea level.

Geoid – An Elusive Surface

- Heights measured with trigonometric and differential leveling methods are Orthometric Heights.
- Orthometric Heights (elevations) are normal (perpendicular) to the geoid surface and represent the length of the gravity vector from a point on the surface of the earth to the geoid.
- The zero surface of NGVD29 and NAVD88 was intended to approximate the geoid.

Geoid

- Gravimetric measurements are used to define the surface of the geoid.
- Geoid surface varies (undulates) across the earth because of changing gravity forces due to the size and densities of the land masses.
- Difference between the geoid and an ellipsoidal surface is called the geoid separation (N).

ELLIPSOID - GEOID RELATIONSHIP

Orthometric Heights are modeled by applying geoid separations (N) to ellipsoid heights (h) to obtain orthometric heights (H).

H = Orthometric Height (NAVD88)
h = Ellipsoidal Height (NAD83)
N = Geoid Height

H = h – N

Geoid Model

- Geoid Models define the heights or separation between the geoid and ellipsoid surface at a given location.
- The geoid-ellipsoid separations are interpolated from a grid data base stored in binary and ascii files. Data for the present Geoid12A Model for California is contained in the file "g2012au5.bin" available at the NGS
  - http://www.ngs.noaa.gov/GEOID/GEOID12A/GEOID12A_CONUS.shtml
- Input is NAD83 latitude and longitude. Do not use NAD27 (300' difference).
- Geoid12A is the present hybrid geoid model release in July 2012 to estimate the NAVD88 surface relative to the NAD83(2011) ellipsoid surface.

Geoid Model

- Geoid12A was preceded by Geoid09, Geoid03, Geoid99, Geoid 96, Geoid 93, and Geoid 90.
- The GEOID12A model like 09, 03, 99, and 96 are hybrid models. The hybrid model is based on a gravity model; however, it is modified to best fit NAVD88 benchmarks with measured NAD83 ellipsoid heights.
- Geoid09 is the former hybrid geoid model developed by the NGS to estimate the NAVD88 surface relative to the NAD83(2007) ellipsoid surface.

Geoid Model (continued)

- GEOID09 model was based on the 2007 Adjustment of NAD83 which re-adjusted and harmonized the High Accuracy Reference Networks (HARN) in the 48 continental states. GEOID09 is to be used with NAD83 (2007.00) ellipsoid heights which are not the same as NAD83(2011) ellipsoid heights.
- Geoid09 has an estimated 2-3 cm accuracy (one sigma) in regions with GNSS measurements on NAVD88 Bench Marks. According to the NGS, a relative accuracy of about 1 to 2 part-per-million, or better is expected in areas with sparse coverage.

Example: EH's using Geoid09 & Geoid99

A look at the relationship h = H + N: Measured EH's v. Computed EH's get better with new adjustments and better geoid models

```
Pseudo-Ellipsoid: Add Geoid Height to NAVD88 Height to obtain an estimated EH
(h=H+N).  Use (H=h-N) to obtain an estimated Orthometric Height.

LV1180  DESIGNATION  -   ARP 1967
LV1180  PID          -   LV1180
LV1180  STATE/COUNTY -   CA/HUMBOLDT
LV1180  USGS QUAD    -   ARCATA SOUTH (1972)
LV1180
LV1180                    *CURRENT SURVEY CONTROL
LV1180
LV1180* NAD 83(1992) -   40 48 17.21986(N)   124 06 56.60986(W)   ADJUSTED
LV1180* NAVD 88      -        1.86   (meters)      6.1   (feet)   LEVELING
LV1180
LV1180  EPOCH DATE   -          1991.35
LV1180  X            -  -2,711,656.143  (meters)                    COMP
LV1180  Y            -  -4,002,732.600  (meters)                    COMP
LV1180  Z            -   4,146,018.930  (meters)                    COMP
LV1180  LAPLACE CORR-            9.32   (seconds)                DEFLEC99
LV1180  ELLIP HEIGHT-          -28.41   (meters)                 GPS OBS
LV1180  GEOID HEIGHT-          -30.21   (meters)                 GEOID99
*****************************************************************************

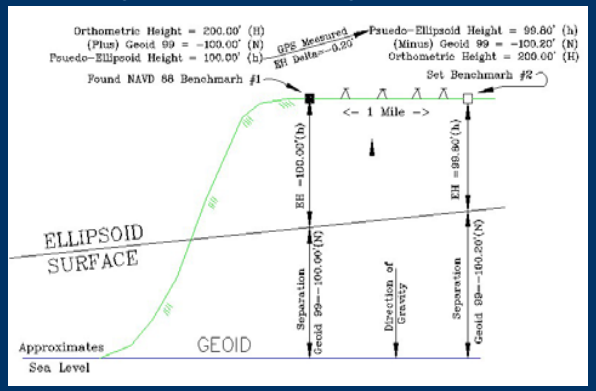
                    mtrs
(H) NAVD 88          1.86                  1.86
(N) GEOID HEIGHT   -30.21 Geoid99       -30.43 Geoid09
                   ------               ------
(h) P-ELLIPSOID HT -28.35               -28.57
(h) ELLIPSOID HT   -28.41 1991.35       -28.56 2007.00
```


Geoid: Recovery

- The NGS gravimetric geoid model USGG2012 used with ITRF, IGS or WGS84; and the GRS80 Ellipsoid provides the best estimate of the geoid.
- GEOID12A, a hybrid geoid model, estimates NAVD88 heights when referenced to the GRS80 Ellipsoid centered in NAD83(2011).
- The important advantage of geoid models is not so much in estimating the geoid or an NAVD88 height, but in applying the difference in the differences. The precision of the model is not in the absolute geoid height, but in the difference in heights at two locations. Combining the difference in the geoid heights with the difference in the measured ellipsoid heights between two points will approach leveling accuracies.

Example: Determine Orthometric Heights with a geoid model comparable to leveling

Use GNSS to measured between two points and applying **H = h – N** to check the leveling. This method should agree within centimeters



The Future Geoid

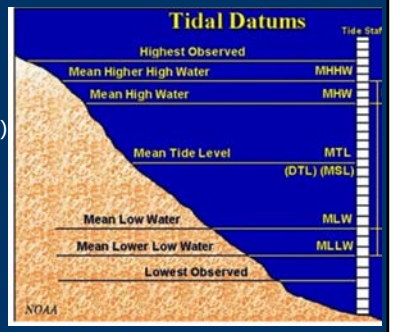
- The present NGS GRAV-D Program combines satellite and airborne gravity measurements with the intention of defining a geoid model with a relative precision of one centimeter. In the next ten years a new National Vertical Datum will replace NAVD88 facilitating the measurement of orthometric heights within 2 centimeters anywhere anytime (the combined error of the model + measured ellipsoid height).

Tidal Datums

Tides are the result of gravitational and meteorological forces interacting with the physical configuration of the shoreline and sea bed. Tidal heights will vary along the shoreline.

Tidal Datums are defined for:

Mean Higher High Water (MHHW)
Mean High Water (MHW)
Mean Sea Level (MSL)
Mean Tide Level (MTL)
Mean Low Water (MLW)
Mean Lower Low Water (MLLW)



Tidal Datums

- The National Ocean Survey (NOS) observes the tides at 26 primary and numerous secondary and tertiary tide stations around North America and offshore.
- Precise determination of the elevation of tidal datums at a specific location requires observations of the tide for 18.61 years (taken as 19 years to round out seasonal events).
- The water heights at these tide stations are published based on a 19 year epoch. The present National Tidal Datum Epoch is 1983-2001. (Previous 1960-1979).

Tidal Datums

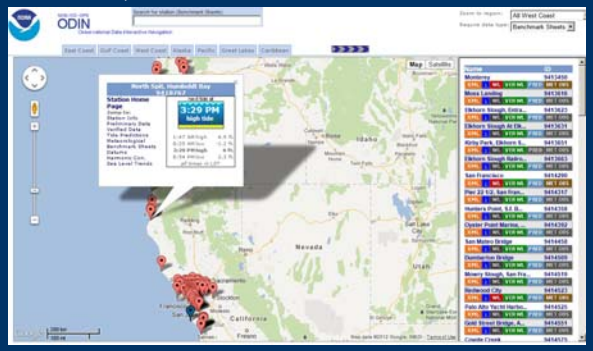
- Tide Stations are referenced by permanent monuments in their vicinity called Tidal Benchmarks. Benchmark descriptions and heights are available at the NOS.
- At each Tide Station, Mean Lower Low Water for a the particular 19 year epoch is taken as zero and is referenced to Tidal Benchmarks and available at the NOS.
- Tidal benchmarks were usually connected to the National Geodetic Vertical Datum of 1929 (NGVD 1929) in years past and presently to the North American Vertical Datum of 1988 (NAVD88).

Tidal Datum Recovery

- Tidal Datums can be recovered in the vicinity of a Tide Station by a direct measurement from the Tidal Benchmarks.
- Tidal Datums can be recovered indirectly by equating the desired datum i.e. MHW to NAVD88 and recovering NAVD88 Benchmarks.
- Relative to a Primary Tide Station, a local Tidal Datum can be determined by observing for
  - 13 months to yield an elevation within 0.1 feet
  - 30 days to yield an elevation within 0.2 feet

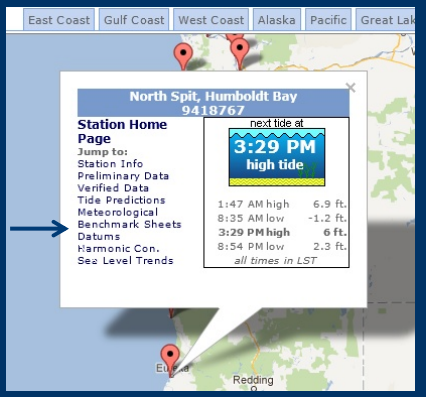
Tide Station Benchmarks

To access NOS Tide Station Data: Go to http://tidesandcurrents.noaa.gov/, click on the interactive map (below), choose the region, set the data type to "Benchmark Sheets", zoom in on the area of interest, and click on a station to see details.



Tide Station and Benchmarks

Click on "Benchmark Sheets" to see the Station Information, Tidal Benchmarks, and the Tidal Datums (following)



"Benchmark Sheet" page (top)


North Spit, Humboldt Bay, CA
Station ID: 9418767
North Spit, Humboldt Bay, CA:

Bench Mark Sheets

Map | Satellite

Bench mark positions only appear on the map if their coordinates in the CO-OPS database are at the precision of degrees/minutes/seconds/and tenths of seconds. If the coordinates are less precise, the mark will not appear.

Map Key: The large marker is the location of the water level sensor; the smaller red markers indicate the location of bench marks included in the published bench mark sheet below the map; blue markers indicate the location of newer bench marks not yet incorporated into the published bench mark sheet.

Click here for a printable version of the benchmark sheet.

"Benchmark Sheet" page (middle)


U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Datums Page Page 1 of 8

Station ID: 9418767
Name: NORTH SPIT, HUMBOLDT BAY CALIFORNIA
NOAA Chart: 18622
USGS Quad: EUREKA
PUBLICATION DATE: 10/06/2011
Latitude: 40° 46.0' N
Longitude: 124° 13.0' W

To reach the tidal bench marks from the U.S. Highway 101 in North Eureka, take Samoa exit from State Highway 255, and proceed NW on State Highway 255 for 2.9 KM (1.8 MI) to a T intersection, then turn south onto the Navy Base road and continue for about 6 KM (4 MI) to Humboldt Bay Coast Guard Station. The bench marks are on the Coast Guard Base property. The tide gauge is at the east end of the southern pier of two finger piers directly east of the 3-story Coast Guard station building.

TIDAL BENCH MARKS

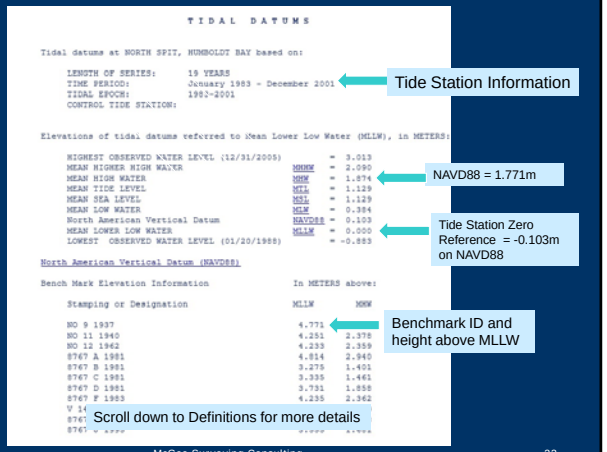
PRIMARY BENCH MARK STAMPING: NO 9 1937
DESIGNATION: 941 8767 TIDAL 9

MONUMENTATION: Tidal Station disk
AGENCY: US Coast and Geodetic Survey (USC&GS)
SETTING CLASSIFICATION: Concrete ramp
VM#: 1717
PID#: LV0361

The primary bench mark is a disk set in the SW corner of the concrete ramp at Humboldt Bay Coast Guard Station boat house, at the south end of the east doors of the boat house at the west end of the marine railway, 12.95 m (42.5 ft) NW of the SE edge of concrete apron, 1.45 m (4.8 ft) SW of southern-most rail, and 0.15 m (0.5 ft) SE of the cornerstone of the building which is inscribed "A.D. 1936".

BENCH MARK STAMPING: NO 11 1940

"Benchmark Sheet" page (bottom)



T I D A L D A T U M S

Tidal datums at NORTH SPIT, HUMBOLDT BAY based on:

LENGTH OF SERIES: 19 YEARS
TIME PERIOD: January 1983 - December 2001
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION:

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (12/31/2005)		= 3.013
MEAN HIGHER HIGH WATER	MHHW	= 2.090
MEAN HIGH WATER	MHW	= 1.874
MEAN TIDE LEVEL	MTL	= 1.129
MEAN SEA LEVEL	MSL	= 1.129
MEAN LOW WATER	MLW	= 0.384
North American Vertical Datum	NAVD88	= 0.103
MEAN LOWER LOW WATER	MLLW	= 0.000
LOWEST OBSERVED WATER LEVEL (01/20/1988)		= -0.883

North American Vertical Datum (NAVD88)

Bench Mark Elevation Information — In METERS above:

Stamping or Designation	MLLW	MHW
NO 9 1937	4.771	
NO 11 1940	4.251	2.378
NO 12 1962	4.233	2.359
8767 A 1981	4.814	2.940
8767 B 1981	3.275	1.401
8767 C 1981	3.335	1.461
8767 D 1981	3.731	1.858
8767 F 1983	4.235	2.362

Tide Station Information

NAVD88 = 1.771m

Tide Station Zero Reference = -0.103m on NAVD88

Benchmark ID and height above MLLW

Scroll down to Definitions for more details

Tidal BM NGS Data Sheet and Graph

National Geodetic Survey Data Sheet

Graph obtained at NGS Website
http://www.ngs.noaa.gov/newsys-cgi-bin/ngs_opsd.prl

```
      National Geodetic Survey,   Retrieval Date = FEBRUARY 24, 2012
HT0702 ***********************************************************************
HT0702  TIDAL BM   -  This is a Tidal Bench Mark.
HT0702  DESIGNATION -  941 4290 TIDAL 180
HT0702  PID        -  HT0702
HT0702  STATE/COUNTY-  CA/SAN FRANCISCO
HT0702  USGS QUAD  -  SAN FRANCISCO NORTH (1995)
HT0702                      *CURRENT SURVEY CONTROL
HT0702
HT0702* NAD 83(1986)-  37 48 19.28   (N)    122 28 00.38   (W)      HD_HELD1
HT0702* NAVD 88    -        1.996   (meters)      13.11   (feet)   ADJUSTED
HT0702 ___________________________________________________________________
HT0702  GEOID HEIGHT-         -32.55   (meters)                     GEOID09
HT0702  DYNAMIC HT  -           3.994 (meters)       13.10   (feet) COMP
HT0702  MODELED GRAV-     979,982.4   (mgal)                       NAVD 88
HT0702
HT0702  VERT ORDER  -  FIRST      CLASS I
HT0702
HT0702.The horizontal coordinates were established by differentially corrected
HT0702.hand held GPS obs and have an estimated accuracy of +/- 3 meters.
HT0702.
HT0702.The orthometric height was determined by differential leveling and
HT0702.adjusted in June 1991.
HT0702
HT0702.This Tidal Bench Mark is designated as VM 967
HT0702.by the CENTER FOR OPERATIONAL OCEANOGRAPHIC PRODUCTS AND SERVICES.
HT0702
HT0702                          SUPERSEDED SURVEY CONTROL
HT0702
HT0702  NGVD 29 (??/??/??)    3.169   (m)          10.40   (f) ADJUSTED    1 1
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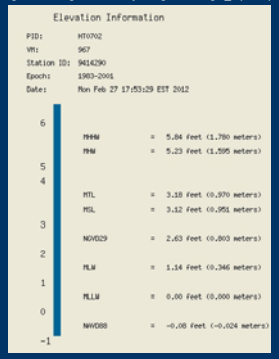


Tidal Datum Recovery (continued)

- Remote Locations: In location remote to Tide Stations where benchmarks are available, and assuming the Tidal Datum surface in linear, the Tidal Datums could be equated to NAVD88 Heights and interpolated between the nearest Tide Stations.
  - Note that the difference in the height of MLLW relative to NAVD88 between Eureka and Crescent City is 0.03' in 75 miles. The gradient (if assumed to be linear) between Santa Barbara and San Francisco is 0.002'/mile.

Tidal Datum Recovery

- The height of a Tidal Datum like Mean High Water can be determined by observing a predicted high tide that corresponds to the level of Mean High Water at a known tide station and simultaneously at a local site.
  - See "Survey Procedures for Determining Mean High Water" published in the Proceedings of the ACSM at Seattle Wash., September 30,1976 by Jack E. Guth, and "Water Boundaries" by George M. Cole, 1983. This procedure has been adopted by the Florida State Legislation.

Tidal Datum Recovery

- Build your own portable tide station shown here at Morro Bay by Robert Reese, PLS.

MHW Datum: a Riparian Boundaries

- In CA the tidal boundary between the state and an upland (riparian) owner is the ordinary high water mark in its last natural condition. (Civil Code Section 670 and 830)
- California courts in 1861 defined the ordinary high-water mark as the limit reached by the Neap Tides
- Neap Tides are the more moderate tides occurring during the first and third stages of the Moon.

MHW Datum: a Riparian Boundary

- The Federal Court in 1935 in *Borax Consolidated,Ltd. v. Los Angeles* (1935) 296 U.S. 10 , defined the Ordinary High Water Mark to be the Mean High Water Line based on the average of all high waters (higher high and lower high) occurring over a tidal epoch of 18.61 years.
- The Federal Rule has been followed in California for the practical reason that tidal data are published by the National Ocean Survey for all high tides over a 19-year period and information is not readily available to determine the height of Neap High Tide. The California State Lands Commission has followed the Federal Rule since 1938.

National Geodetic Vertical Datum 1929 (NGVD29)

- NGVD29 was the national vertical datum until superseded by NAVD88 in 1991.

The origin of zero was derived from an adjustment of the national leveling network constrained to Mean Sea Level at 26 tide stations along the east and west coasts of the US and Canada.

National Geodetic Vertical Datum 1929 (NGVD29)

- NGVD29 is an early attempt to model the geoid by constraining a continent of precise leveling measurements to mean sea level assuming it represented the geoid.
- Subsequently, over 60 years of "Supplemental Adjustments" were published conforming to the original adjustment and re-distributing inconsistencies.

North American Vertical Datum 1988 (NAVD88)

- NAVD88 superseded NGVD29 when it was published in 1991. The datum zero was intended to approximate a geoid surface. However, it is now known that a continental tilt of about a meter exists in NAVD88 (the elusive geoid).
- NAVD88 heights are "Helmert Orthometric Heights" which take in to account the affects of gravity in the reduction of observations.
- A new national First Order leveling network called the "A" Net was observed between about 1978 and 1991.
- Heights are based on a minimally constrained least squares adjustment of the "A" Net fixing a single benchmark on the Saint Lawrence Seaway in the northeastern US.

NAVD88

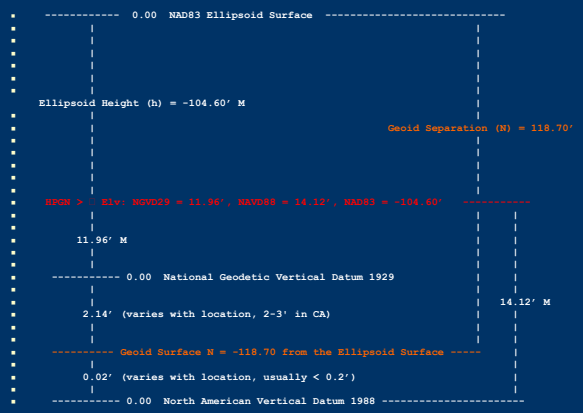
- Benchmarks in the "A" Net are so indicated by the term "ADJUSTED" shown on NGS Datasheets.
- Only about 25% of the 50,000 benchmarks in California were included in the "A" Net. The remaining were re-adjusted as follows.
- Some benchmarks heights were re-adjusted loops using old measurements constrained to the new "A" Net and are indicated by the term "POSTED" shown on DS's (amount of error distribution is listed).
- Other benchmarks not included in the A-Net had their NGVD29 elevations shifted to NAVD88 by applying the NGS VertCon program and are indicated by "VERTCON" shown on DS's.

NAVD88 verses NGVD29

- NAVD88 and NGVD29 are unrelated datums. They differ in their origins, definitions of height, measurements, adjustments, and constraints.
- There is no consistent relationship between the two systems. However, in a local are, it may be possible to determine a reliable shift given sufficient benchmarks in both datums.
- In California, NAVD88 heights will be a larger value than NGVD29 by 70-100 cm or 2-3 feet (telltale sign)

Example: Vertical Datum Relationships

- **Shown below are NGVD29, NAVD88 and NAD83 Ellipsoid Heights at Port Hueneme, California at HPGN-D Station "941 1065 TIDAL 6 RESET**



Recovery: NGVD29 & NAVD88

- NGVD29 & NAVD88 datums are referenced by benchmarks in the NSRS and described on NGS Datasheets.
  - Caveat: A mark's position may change due to the dynamic nature of the earth's crust; the coordinates of a mark can only be certain at the date of the field survey.
- Datasheets list:
  - NGVD29 benchmarks under "Superseded Survey Control"
  - NAVD88 benchmarks at the top ("ADJUSTED" is best)

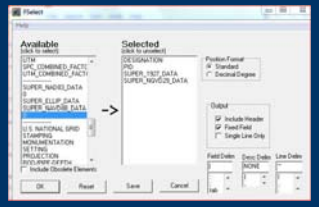
Note: Recovering one benchmark is not sufficient to recover the datum. At least two must be leveled and found in agreement.

Recovery: NGVD29 & NAVD88

- Access Datasheets at the NGS website: http://www.ngs.noaa.gov/cgi-bin/datasheet.prl Click on "DATASHEETS", "Radial Search", and enter coordinates for the search area. Set the "Data Type" to "Any Vertical Control".
- For NGVD29, look under "Vertical Source" for benchmarks with "29/..."
- For NAVD88, look under "Vertical Source" for benchmarks with "88/……".

Recovery: NGVD29 & NAVD88

The NGS utility DSWIN will read a text file containing Datasheets (downloaded from the NGS) and extract a list of stations by data types. For example, extract all benchmarks with NGVD29 heights by selecting "SUPER_NGVD29_DATA".



PID	SUPER_NGVD29_DATA	
DZ0929	NGVD 29	215.145 ADJ UNCH
EW5523	NGVD 29	946.231 ADJ UNCH
DZ0219	NGVD 29	288.412 ADJ UNCH
DZ0745	NGVD 29	8.758 ADJ UNCH
DZ0807	NGVD 29	26.029 ADJ UNCH
DZ0183	NGVD 29	95.931 ADJ UNCH
DZ0093	NGVD 29	25.700 ADJ UNCH
DZ0492	NGVD 29	34.966 ADJ UNCH
DZ0493	NGVD 29	7.914 ADJ UNCH
EW5357	NGVD 29	47.33 RESET

Instructions: Download the utility at http://www.ngs.noaa.gov/PC_PROD/DSWIN/

Run the program, specify a file containing Datasheets, choose FILE, SAVE AS, and specify a name for the new file, choose DSSELECT for Output Format, and select the data types.

Recovery: VertCon 88 ←→ 29 Model

- VertCon is a model based on benchmarks with heights common to both NGVD29 and NAVD88. VertCon computes the difference between the two datums given the latitude and longitude. (NGS accuracy claimed is 2 cm).
  - Caveat: The accuracy of recovering an NAVD88 height is dependent on the local availability and density of benchmarks common to both datums and the stability of the monument keeping in mind the NGVD29 field surveys occurred over many years prior to about 1978.
  - Suggestion for validating VertCon: Look for the nearest benchmarks with both datums and compare their differences with VertCon.

NAVD88 - Recovery

- Ellipsoid heights can be combined with a hybrid geoid model to obtain estimated NAVD88 Heights better than 10 cm.
  - (NAD83(2007) EH + Geoid09 ~ NAVD88)
  - (NAD83(2011) EH + Geoid12a ~ NAVD88)

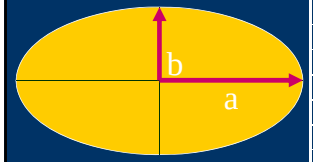
Graphic Apps for Researching Control

- Earth Survey has a collection of geodetic tools that run in Google Earth. NGSCS is a graphical front end for viewing NGS stations and Datasheets. QUADS and PLSGE provide access to data and images from the USGS and BLM. Seven other tools (DeflecGE, GeoidGE, MagDec, NADGE, SPCGE, VERGE, and XYZGE) are graphical front ends for programs in the NGS Geodetic Tool Kit. http://www.metzgerwillard.us/EarthSurvey.html
- Trial Version of the new NGS Map Tool available: http://beta.ngs.noaa.gov/googletest/NGSMap/NGSMap.shtml
- DSWORLD: third party program for accessing NGS control: http://www.ngs.noaa.gov/PC_PROD/PARTNERS/index.shtml

Horizontal Datums

- **2D: Horizontal**
  - **Ellipsoids**
  - **NAD27 - North American Datum 1927**
  - **NAD83 - North American Datum 1983**

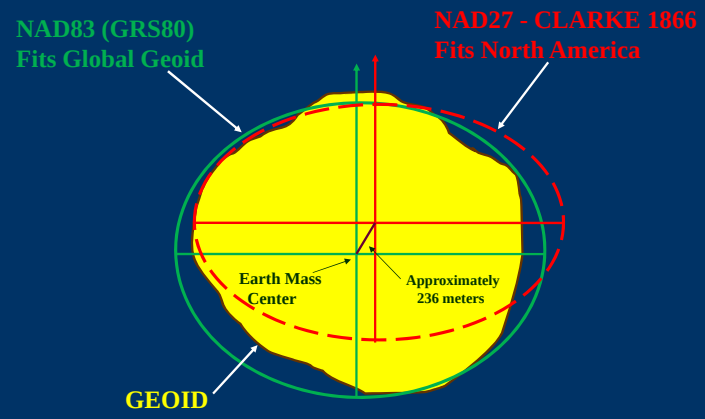
CONCEPTS: Ellipse and Ellipsoid Mathematical Model of the Earth



a = Semi major axis
b = Semi minor axis
f = a-b = Flattening
a

Ellipsoid	a (m)	1/f
AIRY 1830	6377563.396	299.3249646
BESSEL 1841	6377397.155	299.1528128
CLARKE 1858	6378293.645	294.26068
CLARKE 1866	6378206.4	294.9786982
CLARKE 1880	6378249.145	294.9786982
EVEREST 1830	6377276.345	300.8017
GRS 80	6378137	298.2572221
HOUGH 1956	6378270	297.0
INTERNATIONAL 1924	6378388	297.0
KRASSOVSKY 1938	6378245	298.3
PZ90	6378136	298.2578390
WGS 60	6378165	298.3
WGS 66	6378145	298.25
WGS 72	6378135	298.26
WGS 84	6378137	298.2572236

NAD27, NAD83 Ellipsoids and the Geoid

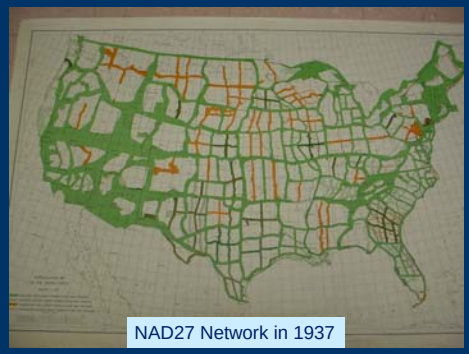


North American Datum 1927 (NAD27)

- Oldest Continental System established 1920's
- The origin is the best known latitude & longitude at station "Meads Ranch" in Kansas, orientated to station "Waldo".
- The Ellipsoid is Clark's Ellipsoid Of 1866, orientated to fit North America.
- The NAD27 ellipsoid surface is assumed to be at sea level therefore, NGVD29 elevations were used to compute the State Plane Coordinate (SPC) height reduction factor to develop the combined grid factor for SPC surveys.

NAD27

National adjustment of baselines and triangulation measurements established 25,000 stations, with an average precision of 1:100,000.



NAD27 Network in 1937

North American Datum 1983 (NAD83)

- Satellite geodesy and the introduction of laser distance measurement systems in the 60's and 70's exposed intolerable inconsistencies in the NAD27 Network.
- This spurred the NGS to develop the North America Datum of 1983.
- The NGS adopted the GRS80 Ellipsoid for NAD83 Datum because it best fit the global geoid.

VLBI Network – Reference Frame for NAD83

There existed at the time, a 3D global network called the Very Long Baseline Interferometry (VLBI) network which provided the primary reference frame for the realization of NAD83.

NAD83(86)

- High precision trans-continental EDM traverses were measured to strengthened the NAD27 triangulation networks and connect to the VLBI Network.
- NAD27 measurements were combined with new measurements in an adjustment to strengthen the network and remove inconsistencies.
- The NAD83 Adjustment established new positions on 250,000 stations with an average precision 1:300,000.
- NAD83 was introduced in 1986 and is commonly referred to by it datum tag NAD83(86).
- The adjustment epoch date is 1984.00.

NAD83(86) Verses NAD27

- NAD83 and NAD27 use different ellipsoids, different constraints, and are realized by adjustments of different sets of measurements, resulting in the realization of two datums on the same monuments.
- There is no consistent relationship between NAD83 and NAD27.
- The shift from NAD27 to NAD83 is about 20-30 feet in latitude and 300 feet in longitude in CA
- The scale and orientations are similar.

Recovery: NAD27 & NAD83(86)

- NAD27 & NAD83 are referenced by passive monuments in the NSRS and described on NGS Datasheets.
- Datasheets list NAD27 and NAD83(86) stations under "Superseded Survey Control".
- Stations that existed prior to about 1990 will have NAD83(86) positions because they preceded GPS and do not have ellipsoid heights
- Caveat: A mark's position may change due to the dynamic nature of the earth's crust; the coordinates of a mark can only be certain at the date of the field survey.

Recovery: NAD27 & NAD83(86)

- Access Datasheets at the NGS website http://www.ngs.noaa.gov/cgi-bin/datasheet.prl
  Click "DATASHEETS", "Radial Search", and enter coordinates for the search area, set the "Data Type" to "Any Horizontal Control"

  For NAD83, choose First Order or less stations (all horizontal stations that existed prior to about 1990 will have an NAD83(86) position).

  For NAD27, choose First Order or less stations, most will have NAD27 values. (use DSWIN to sort superceded values)

Definition

- Transformation: A mathematical process for moving points from one coordinate system to another by some combination of translations, rotations and scale.
- Conformal (Helmert) transformations are most appropriate for common survey applications. There is the 2D (4 parameter) and 3D (7 parameter) transformation
- Photogrammetrist often use an affine transformation because it solves for scale along individual axis.
- Trimble uses the term calibration, some use localization, but they meant transformation

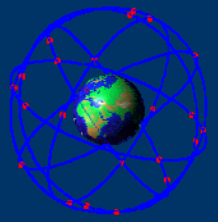
Recovery: NAD27 & NAD83(86)

- 2D Transformation - Best Method: Include a minimum of two stations in the survey with NAD27 SPC or NAD83(86) SPC values and compute a 2D conformal transformation.
  - If three or more stations are available then the residuals will be indicators of the success of recovery.
  - If only two stations are available then check the scale and rotation. If working in NAD83 SPC or transforming between NAD83 SPC and NAD27 SPC, expect a scale of one and a rotation of seconds.

Recovery: NAD27 & NAD83(86)

- The NGS program NADCON will convert between NAD83 and NAD27 with an accuracy of about ½'. (GIS)
- The NGS program "NADCON HPGN" will convert NAD83 HPGN positions to NAD83(86). (NGS stated accuracy is 5 cm).
- Corpscon v6 Software (find on Internet) includes VertCon, NadCon, NadCon HPGN and Geoid Models to perform conversions between datums and will convert graticule coordinates to grid and vica versa.

Geometric Datums



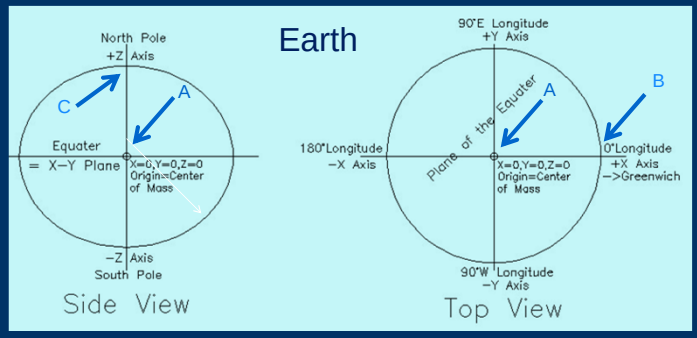
- **3D: Geometric**
  - **North American Datum 1983 (NAD83)**
  - **World Geodetic System 1984 (WGS84)**

North American Datum of 1983 (in 3D)

- NAD83(86) was short lived because the advent of GPS made its inconsistencies glaring apparent. Any surveyor with GPS was capable of making high precision measurements (not just the NGS).
- NAD83 already had the elements of a 3D system because it was based on the GRS80 Ellipsoid and was referenced by the 3D VLBI network.
- The center of the GRS80 Ellipsoid is the origin of a three dimensional XYZ cartesian coordinate system. The origin was intended to be at the Earth's center of mass.
- Positions measured with GPS are in XYZ Cartesian Coordinates. (XYZ are converted to latitude, longitude and ellipsoid heights and then to a grid)

Cartesian Coordinate System: Defines 3D Space

Origin (A) is 0,0,0 at the center of the GRS80 Ellipsoid intended to be at the center of mass; the X-Y Plane coincides with the equator with the +X axis pointing towards Greenwich (B); and, the Z Axis coincides with Earth's mean axis of rotation with +Z points pointing towards the N. Pole (C).

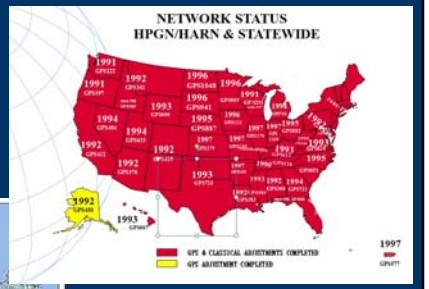


NAD83 in 3D – The Beginning

- In the late 1980's, the NGS began a program based solely on GPS to establish independent high accuracy 3D networks to improve the NSRS.
- These 3D network realizations of NAD83 were called High Accuracy Reference Networks (HARN)
- HARN's were surveyed and adjusted on a state by state basis between 1990 and 1997.

High Accuracy Reference Networks

In California, the HARN is referred to as the High Precision Geodetic Networks (HPGN).



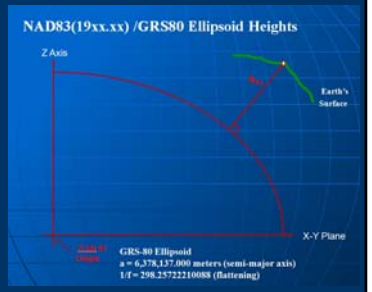
The CA HPGN adjustment was completed in 1992 and is referred to by a datum tag of NAD83(92).

North American Datum 1983 NAD83(92)

- The HPGN network was constrained to the original VLBI Network creating 3D coord's
  - The VLBI was an AA Order network (1:100,000,000)
  - The HPGN was a B Order network (1:1,000,000)
- The HPGN network introduced two new concepts to surveyors:
  - Epoch and Datum Tags
  - Ellipsoid Heights (a third dimension)

NAD83(92) Ellipsoid Heights

- Origin for EH's is zero at the surface of the GRS80 ellipsoid
- EH's are normal to the ellipsoid surface, unlike orthometric heights which are normal to the geoid
- The HPGN monuments provided access to ellipsoid heights for the first time because they not available with NAD83(86).



NAD83(92) – Ellipsoid vs Geoid

- Ellipsoid heights are interesting but surveyors prefer a gravity based height system where water flows downhill.
- The concept of a geoid height was introduced to the surveying community by the NGS with Geoid90.
- Geoid90 and Geoid93 were the first gravimetric geoid models.
- Surveyors were now able to use their GPS measured ellipsoid heights to estimate elevations. Better geoid models followed as discussed previously.

NAD83 Epochs

- NAD83 is fixed to the North American Plate (easterly of the San Andreas Fault). A large part of California in moving with respect to the North American Plate, and because of GPS, we can measure and report this.
- It necessary in California to state the epoch of surveys because the positions change as much as 5 centimeters per year relative to the North American Plate.
- Surveys that are referenced to monuments with NGS sanctioned NAD83 positions must state the Epoch being used. This is important since other surveyors before or after may use the same monument with a different epoch position.

NAD83 Epochs

- Furthermore, our surveys must be referenced to NGS or CSRC sanctioned epochs for uniformity and to give validity to the SPC's as required by the PRC.
- Previous NGS and CSRC sanctioned epochs are not invalid because they are superseded. The position is still valid for the particular epoch on a monument. Tools provided by the NGS (HTDP) and CSRC (SECTOR) can be used to change from one epoch to another.
- Some have used the CSRC SECTOR utility to obtain "day-of-observation positions" and argue that they satisfy the requirement for a sanctioned epoch; however, it that is not the intent of the PRC. The intent is to base surveys on a common sanctioned published epoch.

NAD83 (19xx.xx) Epochs

- An epoch date is assign to the coordinates (realization) based on the average date of the field observations.
- The original CA HPGN GPS survey is referred to as NAD83(1991.35) which is its Epoch Tag used in calculations relating different epochs.
- This nomenclature is required by the CA Public Resources Code Section 8815.1 and 8815.2. "CCS83(1991.35)" is the correct way to refer to State plane coordinates.
- NAD83(1991.35) is commonly referred to as NAD83(92) which is its Datum Tag. The NGS DS's will show both the datum tag and the epoch tag.

HPGN - NAD83(1991.35)

- The HPGN survey established about 240 “B” Order stations in California. Subsequently, the HPGN-D densification surveys established stations about every 10-20 kilometers along state highways constrained to the “B” Order Network.
- An NAD83(86) First Order triangulation stations was included in the HPGN survey in every 1 degree quad. These stations were later held fixed in a re-adjustment of conventional triangulation network measurements to upgrade their NAD83(86) positions to NAD83(1991.35) positions.
- The upgraded triangulation stations have the NAD83(92) datum tag, but do not have ellipsoid heights. They are not equivalent in precision to the HPGN. (better absolute accuracy, not relative)

NAD83 Adjustments Epochs by the NGS

Earthquakes and special projects required re-surveys and re-adjustments of regional areas in CA leading to multiple Epochs.

- 1984.00 NAD83(86) initial national adjustment creating NAD83
- 1991.35 NAD83(92) HPGN B-Order Network in CA, first time GPS and ellipsoid heights; followed by densification surveys
- 1992.88 Regional CA re-adjustment for Lander’s EQ
- 1995.00 Regional CA re-adjustment for Northridge EQ
- 1995.50, 1996.0, 1997.30 numerous adjustments occurring in CA
- 1998.50 A-Order Federal Base Network Stations

NAD83 Adjustments Epochs by the NGS

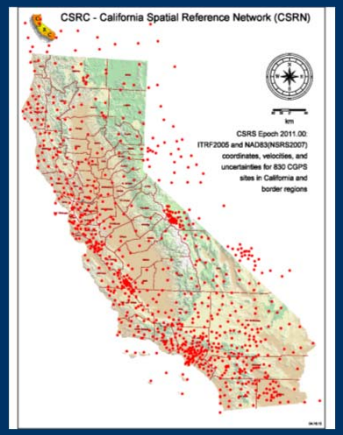
- 2002.00 NAD83(CORS96) The national CORS solution shown on DS’s up until July 2012
- 2007.00 NAD83(2007) National re-adjustment to harmonize state HARN’s. 700 CORS were fixed on the NAD83(CORS96) 2002.00 Epoch. In California the CORS were fixed on the 2007.00 Epoch. The NAD83(86) stations were not included.
- 2010.00 NAD83(2011) National re-adjustment of 1800+ CORS released in September 2011 followed in July 2012 by a re-adjustment of the passive HARN networks. Finally, we are all on the same epoch, but what about the the NAD83(86)/NAD83(92) passive monuments

2022? Proposed new geometric datum coinciding with ITRF/IGS?

CGPS: a California CORS Network

- SCIGN, PBO, and others have established permanent GPS reference stations over the last two decades. The California Spatial Reference Center (CSRC) http://csrc.ucsd.edu/ working with SOPAC at the University of San Diego has leveraged these systems to develop a CORS for California. These are referred to as the Continuous GPS (CGPS) stations and constitute the primary component of the California Spatial Reference Network (CSRN).

California Spatial Reference Network
830 CGPS Stations



CSRC NAD83 Adjustments of the CGPS

- The NGS and the CSRC have partnered for the last decade to provide geodetic services in CA. The coordinates published by the CSRC, can be found at http://csrc.ucsd.edu/ and are sanctioned by the Public Resources Code (PRC). (NGS?)
- CSRC published NAD83 positions on the CGPS Network for Epochs 2004.00, 2006.00, 2007.00, 2009.00 and 2011.00.
- The CSRC CGPS 2007.00 Epoch is consistent with the National NAD83(2007) Adjustment which is based on the CORS(96) 2002.00 Epoch. The CSRC 2009.00 and 2011.00 Epochs are based on 2007 Adjustment. The present CSRC adjustment of the CGPS is referred to as NAD83(2007) 2011.00 Epoch.
- Be Aware: The CSRC NAD83(2007) 2011.00 Epoch is not the same as the NGS NAD83(2011) Adjustment, which is on the 2010.00 Epoch. NAD83(2007) [CORS(96) 2002.00] and NAD83(2011) [CORS 2010.00] are two very different realizations of NAD83.

NGS NAD83(2011) 2010.00 vs. CSRC NAD83(2007) 2010.00 ADJUSTMENTS

	NGS NAD83(2011) EPOCH 2010.00	CSRC (SECTOR) NAD83 (2007) EPOCH 2010.00	Diff(m)
At CORS and CGPS Station P162			
Latitude	40-41-27.92827	40-41-27.92828	N 0.000
Longitude	124-14-13.27512	124-14-13.27544	E -0.008
Ellips. Ht	-6.043m	-6.045m	Up -0.002
At CORS and CGPS Station LORS			
Latitude	34 07 59.96493	34 07 59.96500	N 0.002
Longitude	117 45 14.60442	117 45 14.60445	E -0.001
Ellips. Ht	449.603m	449.597m	Up -0.006

NAD83(xxxx.xx) 3D - Recovery

- Referenced by passive monuments (the ones with ellipsoid hts) described on NGS Data Sheets (DS).
- DS's list the latest NAD83(xxxx.xx) epochpositions under "Current Control".
  - See "Superseded Control" for prior epochs.
- Access DS's at the NGS website:
  http://www.ngs.noaa.gov/cgi-bin/datasheet.prl
  Click "DATASHEETS", "Radial Search", enter the coordinates for the search area, set the "Data Type" to "GPS Sites Only". All stations with ellipsoid heights should be retrieved.

Example: NGS Data Sheet

```
GU2656  DESIGNATION -  FELIPE AZ MK
GU2656  PID         -  GU2656
GU2656  STATE/COUNTY-  CA/SANTA CLARA
GU2656  COUNTRY     -  US
GU2656  USGS QUAD   -  SAN FELIPE (1971)
GU2656
GU2656                        *CURRENT SURVEY CONTROL
GU2656* NAD 83(2007) POSITION- 36 57 40.54509(N) 121 23 55.49180(W)   ADJUSTED  < Datum Tag
GU2656* NAD 83(2007) ELLIP HT-   102.912 (meters)        (02/10/07)  ADJUSTED  < Datum Tag
GU2656* NAD 83(2007) EPOCH   -  2007.00                              < Adjustment Epoch Tag
GU2656* NAVD 88 ORTHO HEIGHT -  135.665  (meters)      445.09  (feet) ADJUSTED  < ADJUSTED, LEVELED, VERTCON?
GU2656
GU2656  NAD 83(2007) X  - -2,658,440.533 (meters)                    COMP      < XYZ ECEF Equivalent to L,L,EH
GU2656  NAD 83(2007) Y  - -4,355,438.792 (meters)                    COMP      < XYZ ECEF Equivalent to L,L,EH
GU2656  NAD 83(2007) Z  -  3,814,020.847 (meters)                    COMP      < XYZ ECEF Equivalent to L,L,EH
GU2656  LAPLACE CORR    -          3.93  (seconds)                   DEFLEC09  < Slope of geoid
GU2656  GEOID HEIGHT    -        -32.76  (meters)                    GEOID09
GU2656  DYNAMIC HEIGHT  -       135.558  (meters)      444.74  (feet) COMP
GU2656  MODELED GRAVITY -   979,843.9  (mgal)                       NAVD 88
GU2656
GU2656  VERT ORDER      -  FIRST     CLASS I
GU2656
GU2656  FGDC Geospatial Positioning Accuracy Standards (95% confidence, cm)
GU2656  Type                                           Horiz  Ellip  Dist(km)
GU2656  ----------------------------------------------------------------------
GU2656  NETWORK                                         0.79   3.47
GU2656  ----------------------------------------------------------------------
GU2656  MEDIAN LOCAL ACCURACY AND DIST (064 points)     1.21   4.96     89.10
GU2656  ----------------------------------------------------------------------
GU2656  NOTE: Click here for information on individual local accuracy
GU2656  values and other accuracy information.
GU2656
GU2656.The horizontal coordinates were established by GPS observations
GU2656.and adjusted by the National Geodetic Survey in February 2007. < Not the date of observation
GU2656.The horizontal coordinates are valid at the epoch date displayed above
GU2656.which is a decimal equivalence of Year/Month/Day. < The position is based on last observ. 1998.50 below
GU2656.The orthometric height was determined by differential leveling and
GU2656.adjusted in June 1991. < NAVD88 A Net leveled in 1980's +/-
GU2656.The X, Y, and Z were computed from the position and the ellipsoidal ht. < X,Y,Z equivalent to L,L,EH
GU2656.The Laplace correction was computed from DEFLEC09 derived deflections.
GU2656.The ellipsoidal height was determined by GPS observations
GU2656.and is referenced to NAD 83. < Height based on last observ.
GU2656.The geoid height was determined by GEOID09.
```


Example: NGS Data Sheet (cont'd)

```
GU2656;                      North          East       Units Scale Factor Converg.
GU2656;SPC CA 3      -   551,576.399 1,919,959.751   MT  1.00002345   -0 33 00.9
GU2656;SPC CA 3      - 1,809,630.24  6,299,067.95    sFT  1.00002345   -0 33 00.9
GU2656;UTM 10        - 4,091,772.992   642,550.561   MT  0.99985034   +0 57 46.6
GU2656!              -  Elev Factor  x  Scale Factor =   Combined Factor
GU2656!SPC CA 3      -    0.99998385  x   1.00002345  =   1.00000730
GU2656!UTM 10        -    0.99998385  x   0.99985034  =   0.99983419
GU2656
GU2656                          SUPERSEDED SURVEY CONTROL
GU2656  NAD 83(1998)-  36 57 40.54079(N)     121 23 55.48706(W) AD(1998.50) A   < 1998.50 obs. last?
GU2656  ELLIP H (04/06/00)  102.936  (m)                        GP(1998.50) 3 1 < 1998.50 obs. last?
GU2656  ELLIP H (11/17/92)  102.966  (m)                        GP(         ) 5 1
GU2656  NAD 83(1992)-  36 57 40.53740(N)     121 23 55.48206(W) AD(1991.35) B   < First GNSS obs.+EH
GU2656  ELLIP H (05/15/92)  102.966  (m)                        GP(1991.35) 4 2 < First GNSS obs.+EH
GU2656  NAD 83(1986)-  36 57 40.54034(N)     121 23 55.48079(W) AD(1984.00) 3   < NAD83 initial adj, no EH
GU2656  NAD 27       -  36 57 40.73358(N)     121 23 51.72782(W) AD(      ) 3   < NAD27 available
GU2656  NAVD 88 (05/15/92)  135.67   (m)          445.1    (f) LEVELING   3   < Leveled or NAVD88 1991 adjustment
GU2656  NGVD 29 (??/??/??)  134.783  (m)          442.20   (f) ADJUSTED   1 1 < NGVD29 available, VertCon?
GU2656
GU2656.See file dsdata.txt to determine how the superseded data were derived.  < See NGS dsdata.txt for more info
GU2656
GU2656_MARKER: DZ = AZIMUTH MARK DISK
GU2656_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
GU2656_SP SET: CONCRETE POST
GU2656_STAMPING: FELIPE 1962 < Probably date of original obs.
GU2656_MARK LOGO: CGS
GU2656_PROJECTION: FLUSH
GU2656_MAGNETIC: N = NO MAGNETIC MATERIAL
GU2656_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO              < Stability A-D
GU2656+STABILITY: SURFACE MOTION
GU2656_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
GU2656+SATELLITE: SATELLITE OBSERVATIONS - June 10, 2003                     < Probably good for GNSS
GU2656
GU2656  HISTORY     - Date      Condition        Report By
GU2656
GU2656                          STATION DESCRIPTION
GU2656  HISTORY     - Date      Condition        Report By
GU2656  HISTORY     - 1962      MONUMENTED       CGS
GU2656  HISTORY     - 1977      GOOD             NGS
```


NAD83 – Recovery via CGPS

- NAD83 is referenced by the CGPS at http://csrc.ucsd.edu/

Go to the link, identify the nearest stations, and download the coordinate files and static observation files (Rinex Files) that correspond to your static on-site observations. Process the static data and run a network adjustment to determine valid coordinates on your survey. (see CalSurveyor 2011 three part article)

NAD83 – Recovery via CRTN

NAD83 is referenced by the the California Real Time Network (CRTN) established and maintained by the CSRC. http://sopac.ucsd.edu/projects/realtime/

CRTN utilizes a subset of CGPS stations upgraded to real-time data telemetry to provide a single baseline solution.

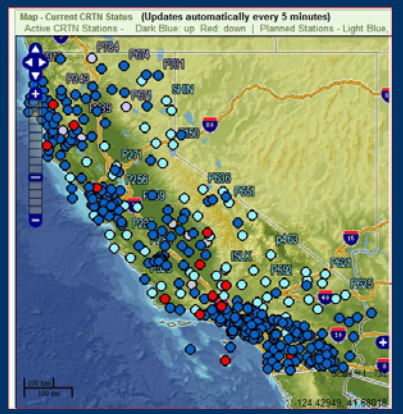
CRTN therefore, provides real time positioning via an internet connection based on measurements (vectors) from positions of the CGPS reference stations operating as CRTN stations.

California Real Time Network (CRTN)

303 CRTN Stations

CSRC CRTN Status

http://sopac.ucsd.edu/projects/realtime/

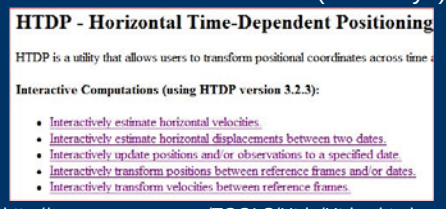


Advantages of Using CGPS/CRTN

- Active CGPS/CRTN stations have an advantage over passive monuments for the following reasons:
- Surveyors do not have to physically occupy monuments to reference their surveys to NAD83 coordinates
- Highest accuracy reference monuments available
- The CGPS are monitored daily, and if they move or are disturbed, it is detected within 24 hours. Whereas, the position of a passive station is only known at the time it was last measured. For the HPGN this dates back to 1991.
- Most important! Surveyor's have access, unlike private RTN's, to sanctioned NAD83 coordinates in Real Time with CRTN than can be published on a RS.

HTDP

Online HTDP (Horizontal Time-Dependent Positioning) Program will model the secular and episodic motions relative to the North American Plate (accuracy?)



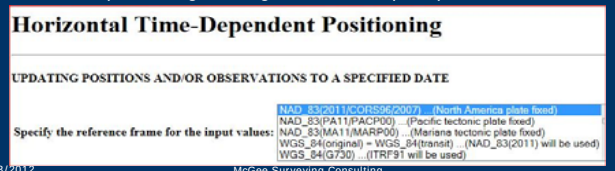
HTDP - Horizontal Time-Dependent Positioning

HTDP is a utility that allows users to transform positional coordinates across time

Interactive Computations (using HTDP version 3.2.3):

- Interactively estimate horizontal velocities.
- Interactively estimate horizontal displacements between two dates.
- Interactively update positions and/or observations to a specified date.
- Interactively transform positions between reference frames and/or dates.
- Interactively transform velocities between reference frames.

http://www.ngs.noaa.gov/TOOLS/Htdp/Htdp.shtml



Horizontal Time-Dependent Positioning

UPDATING POSITIONS AND/OR OBSERVATIONS TO A SPECIFIED DATE

Specify the reference frame for the input values:

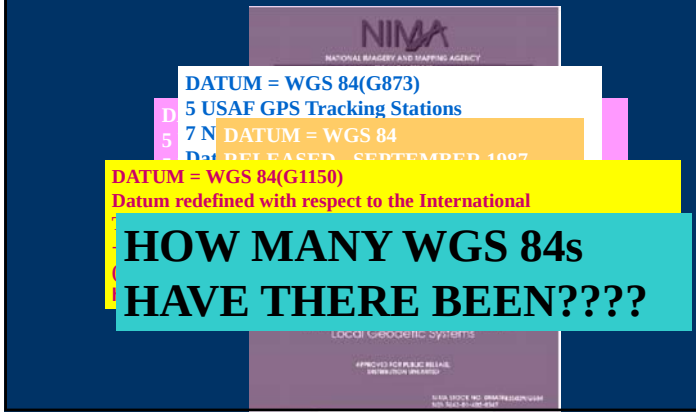
NAD_83(2011/CORS96(2007)) ...(North America plate fixed)
NAD_83(PA11/PACP00) ...(Pacific tectonic plate fixed)
NAD_83(MA11/MARP00) ...(Mariana tectonic plate fixed)
WGS_84(original) = WGS_84(transit) ...(NAD_83(2011) will be used)
WGS_84(G730) ...(ITRF91 will be used)

World Geodetic System 1984 (WGS84)

- WGS 84 is the 3D reference frame used for the Global Positioning System (GPS) maintained by the Air Force for the DOD.
- WGS 84 (G1674) is the latest realization of WGS84 in February 2012 by the National Geospatial Intelligence Agency (NGA) (formerly the National Imagery and Mapping Agency).
- G1674 refers to the GPS week when computed GPS Broadcast Orbits began using this frame. The original WGS84 frame was updated from a doppler satellite based frame to GPS based in 1994.

WORLD GEODETIC SYSTEM 1984

http://earth-info.nga.mil/GandG/publications/tr8350.2/wgs84.pdf



WGS84

- The WGS84(G1674) reference frame conforms to ITRF08 Epoch 2005.00. For more information see:
  - NATIONAL IMAGERY AND MAPPING AGENCY TECHNICAL REPORT 8350.2, Third Edition: Department of Defense World Geodetic System 1984, Its Definition and Relationships with Local Geodetic Systems (to be updated in 2013)
  - "A Refinement to the World Geodetic System 1984 Reference Frame" *by Merrigan, Swift, Wong, and Saffel* presented at the Institute of Navigation's GPS 2002 Portland Meeting.
  - "Recent Updates to the WGS84 Reference Frame" by *R. Wong, C. Rollins, National Geospatial Intelligence Agency* presented at the ION GNSS 2012, Session A3: Geodesy, Surveying & RTK for Civil Applications

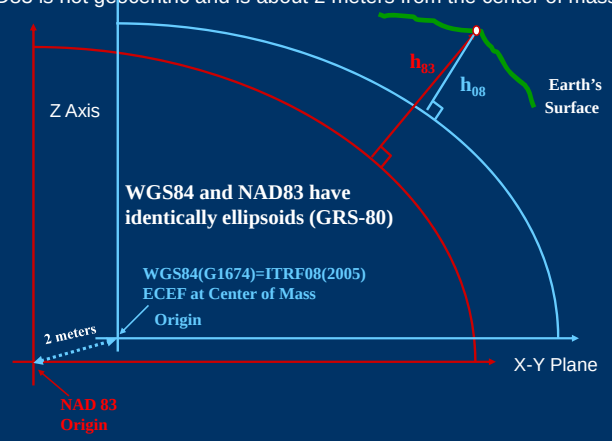
WGS84 GPS Positions

- It is a common misconception that the resultant position of a GPS survey is referenced to WGS84.
- This would be the case if we were using GPS in an absolute mode (no reference/base station).
- In the differential or relative positioning GPS mode, the geospatial coordinates will be in the datum the reference receiver is assigned.
- (NAD83 in -> NAD83 out) (WGS84 in -> WGS84 out)

WGS84 vs. NAD83 (What's the Difference?)

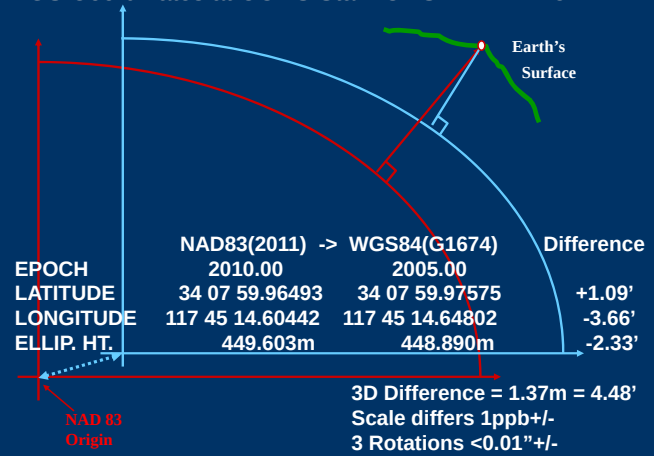
WGS84=ITRF08=IGS08 Geocentric Datums

NAD83 is not geocentric and is about 2 meters from the center of mass.



NAD83(2011) vs. WGS84(G1674)

NGS Coordinates at CORS Sta. LORS PID=DM7524



	NAD83(2011)	-> WGS84(G1674)	Difference
EPOCH	2010.00	2005.00	
LATITUDE	34 07 59.96493	34 07 59.97575	+1.09'
LONGITUDE	117 45 14.60442	117 45 14.64802	-3.66'
ELLIP. HT.	449.603m	448.890m	-2.33'

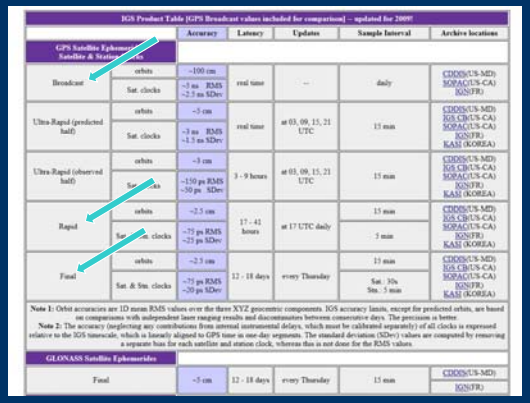
3D Difference = 1.37m = 4.48'

Scale differs 1ppb+/-

3 Rotations <0.01"+/-

Satellite Ephemeris

Orbit Errors & WGS84



IGS Product Table [GPS Broadcast values included for comparison] – updated for 2009!

		Accuracy	Latency	Updates	Sample Interval	Archive locations
GPS Satellite Ephemerides / Satellite & Station Clocks						
Broadcast	orbits	~100 cm	real time	--	daily	CDDIS(US-MD) SOPAC(US-CA) IGN(FR)
	Sat. clocks	~5 ns RMS ~2.5 ns SDev				
Ultra-Rapid (predicted half)	orbits	~5 cm	real time	at 03, 09, 15, 21 UTC	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. clocks	~3 ns RMS ~1.5 ns SDev				
Ultra-Rapid (observed half)	orbits	~3 cm	3 - 9 hours	at 03, 09, 15, 21 UTC	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. clocks	~150 ps RMS ~50 ps SDev				
Rapid	orbits	~2.5 cm	17 - 41 hours	at 17 UTC daily	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. clocks	~75 ps RMS ~25 ps SDev			5 min	
Final	orbits	~2.5 cm	12 - 18 days	every Thursday	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. & Stn. clocks	~75 ps RMS ~20 ps SDev			Sat.: 30s Stn.: 5 min	
GLONASS Satellite Ephemerides						
Final		~5 cm	12 - 18 days	every Thursday	15 min	CDDIS(US-MD) IGN(FR)

Note 1: Orbit accuracies are 1D mean RMS values over the three XYZ geocentric components. IGS accuracy limits, except for predicted orbits, are based on comparisons with independent laser ranging results and discontinuities between consecutive days. The precision is better.

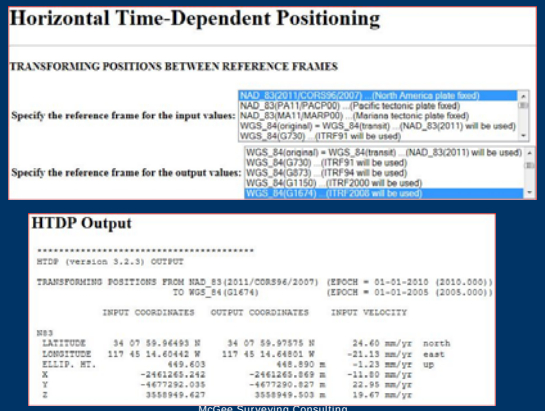
Note 2: The accuracy (neglecting any contributions from internal instrumental delays, which must be calibrated separately) of all clocks is expressed relative to the IGS timescale, which is linearly aligned to GPS time in one-day segments. The standard deviation (SDev) values are computed by removing a separate bias for each satellite and station clock, whereas this is not done for the RMS values.

WGS84 Recovery

- Measurements with GPS receivers result in WGS84 vectors between points, but the positions are in the datum of the reference receiver.
- Generally, monuments referencing WGS84 do not exist outside of military bases.
- ITRF/IGS positions are available for the CGPS, CRTN and CORS stations.
- The NGS Horizontal Time Dependant Positioning (HTDP) program will transform NAD83 positions to WGS84/ITRF.

HTDP

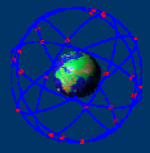
HTDP (Horizontal Time-Dependent Positioning) Program performs transformations between reference frames: NAD83, WGS84 and ITRF



Geometric + Time Datums

- **International Terrestrial Reference System (ITRS) is a dynamic coordinate system including time.**
- **High precision positions and velocities take into account the natural movement of the earth's surface to determine real time coordinates.**
- **NGS has adopted the International Terrestrial Reference Frame ITRF08 2005.00 Epoch as a Reference Frame and based the CORS NAD83(2011) adjustment on the IGS08 2005.00 Epoch**
- **For more information about ITRF coordinates see the ITRF readme file at the NGS web site.**

Final Thought



- "..... it is far more important to have a somewhat faulty measurement of the spot where the line truly exists than to have an extremely accurate measurement of the place where the line does not exist at all"

A.C Mulford, Boundaries and Landmarks, 1912

THE END

- Questions & Comments:
- Questionnaire: Three Questions for Participants
  - 1- Name one or more significant things that you learned here today:
  - 2- Name one or more significant things that you are still unsure about after today:
  - 3- Name one or more significant things that you would like to know more about:

Grid Projections
(Grid Coordinate Systems)

- SPC: State Plane Coordinate System (Lambert or Mercator)
- UTM: Universal Transverse Mercator

California State Plane Coordinate Zones & Scale Factors

- SPC defined in the Public Resources Code (PUC) Section 8813 etc. Zones include specific counties as shown.
- Grid Scale Factor <1:10,000 by design
- Lambert (conical) Projection in CA
- NAD83 absorbed Zone 7 in into Zone 5
- PRC requires SPC be based on First Order control determined by GPS
- NAD83 & NAD27 have similar Factors and Convergence for Zones 1-6

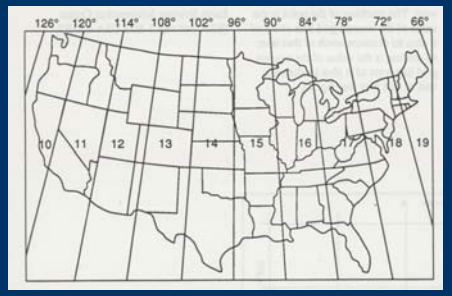
CALIFORNIA STATE PLANE COORDINATE SYSTEM Parameters

Note: Scale and Convergence Angles same for 27 & 83

NAD 83 Lambert Projection Sets Zones 1-6				NAD 27 Lambert projection sets Zones 1-7			
Name of projection set:	CA 0401 - NAD83			Name of projection set:	CA 0401 - NAD27		
False east:	2000000.0000		m	False east:	609601.2192		m
False north:	500000.0000		m	False north:	0.0000		m
Latitude of origin:	39	20 0.0000	N	Latitude of origin:	39	20 0.0000	N
Central meridian:	122	0 0.0000	W	Central meridian:	122	0 0.0000	W
Latitude first parallel:	40	0 0.0000	N	Latitude first parallel:	40	0 0.0000	N
Latitude second parallel:	41	40 0.0000	N	Latitude second parallel:	41	40 0.0000	N
Name of projection set:	CA 0402 - NAD83			Name of projection set:	CA 0402 - NAD27		
False east:	2000000.0000		m	False east:	609601.2192		m
False north:	500000.0000		m	False north:	0.0000		m
Latitude of origin:	37	40 0.0000	N	Latitude of origin:	37	40 0.0000	N
Central meridian:	122	0 0.0000	W	Central meridian:	122	0 0.0000	W
Latitude first parallel:	38	20 0.0000	N	Latitude first parallel:	38	20 0.0000	N
Latitude second parallel:	39	50 0.0000	N	Latitude second parallel:	39	50 0.0000	N
Name of projection set:	CA 0403 - NAD83			Name of projection set:	CA 0403 - NAD27		

Universal Transverse Mercator

- Based on the Mercator (cylindrical) Projection
- Zones are 6° wide N & S of Equator



GROUND LEVEL COORDINATES "IF YOU DO"

TRUNCATE COORDINATE VALUES

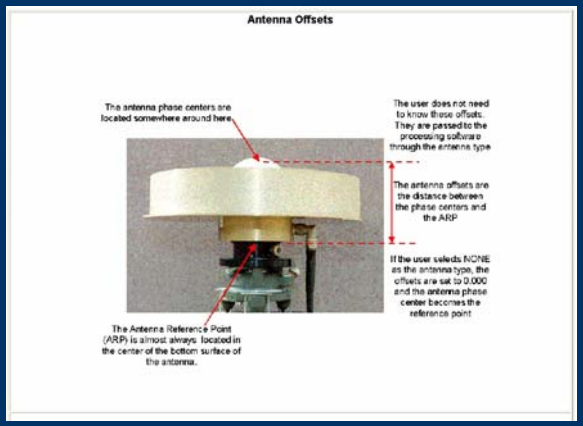
SUCH AS:

N = 1,750,260.07 ft becomes 50,260.07

E = 6,099,440.89 ft becomes 99,440.89

DOCUMENT DOCUMENT DOCUMENT !!

Antenna Models



Antenna Models

NGS's CORS group began using Absolute Antenna calibrations upon the release of the new CORS coordinates in IGS08 Epoch 2005.00 and NAD83(2011,MA11,PA11) Epoch 2010.00.

NGS Antenna Calibration page at http://www.ngs.noaa.gov/ANTCAL/

states Absolute Antenna Calibration values are now the default values on this page. These Absolute values should be used when processing data with CORS coordinates. These calibrations are different from previous Relative Antenna calibrations.

What does this mean to the users?

TERMINOLOGY

- Active Monuments: Reference points monitored in near real time and usually accessible via the internet, i.e CORS, CGPS, RTN
- Passive Monuments: In the ground points referencing the datum
- National Spatial Reference System (NSRS): A consistent coordinate system of that specifies Latitude , Longitude, Height, Scale, Gravity & Orientation; how these values change with time; and a high accuracy geographic reference framework throughout the United States. Formerly called the National Geodetic Reference System (NGRS).
- Transformation: A mathematical process for moving one coordinate system to another by some combination of translations, rotations and scale. A conformal (Helmert) 2D and 3D are most common. Photogrammetrist use an affine transformation (aka calibration by Trimble)

Statement regarding control used for the NAD 83(NSRS2007)

- **Control for the NAD 83(NSRS2007) adjustment was provided by the CORS. . For all states except AZ, CA, OR, WA, NV and AK, the values used were the NAD83 CORS(96) Epoch 2002.0 values currently published by NGS.**
- **In California, the NAD 83 values used for the California CORS and the National CORS were provided by the CSRC in epoch 2007. These values are currently published by CSRC and available from their website-**
- **For AZ, OR, WA, NV and AK, HTDP was used to convert the published NAD83 positions of the CORS(96) Epoch 2002.00 to Epoch 2007.00**
- **For all stations on the stable North American plate, no epoch date is shown – as has been the practice. For the other states, an epoch date of 2007.0 is shown. In those states, except CA, HTDP can be used with the currently published CORS to determine the proper value to use. In CA, the values as currently published on the CSRS website can be used with HTDP (if necessary).**

Datum Topics

- Geoid and Geoid Models
- Ellipsoid and Cartesian Coordinate System (XYZ)
- Reference Systems
- Grid Projections
- NGS Data Sheets
- Antenna Models and SV Orbits
- Reports and Adjustments (time?)

Datum ? What Datum ?

- **Where are you?**
- **Where do you want to be….**