Documentation for VDatum (and the Datum Tutorial)
Vertical Datum Transformation Software Version 1.06 , Updated 30 October 2004
NOAA National Ocean Service

1.0   INTRODUCTION

VDatum is a tool for transformation of height data expressed in different vertical datums. Such transformations are frequently necessary when data from diverse sources need to be combined or intercompared. Informally, a datum can be considered as the "coordinate system" of geospatial data. It can immediately be appreciated that artificial steps or discontinuities can appear in maps and charts if they are built from data based on inconsistent datums. More background on vertical datums can be found in the "DATUMS" section of this document.

VDatum operates in two modes: batch mode and interactive mode.   As the names imply, the interactive mode allows the transformation of one elevation at a time, and the batch mode allows transformation of files of points from one vertical datum to another. VDatum is written in Java 2, and is distributed in both source code form and in Java bytecode form imbedded in a Java Archive (JAR) file. Running VDatum requires installation of the Java Runtime Environment (JRE) or installation of a Java development package, such as the Java Software Development Kit (JDK). A copy of the JRE for Microsoft Windows is included with VDatum. Users who do not have Windows will need to obtain a JRE or a JDK for their computer platform.

VDatum is built as a technology demonstration project. It is implemented primarily for the region of Tampa Bay, Florida, as part of this demonstration. The source code and algorithms are open, and if this project is successful, then the vertical datum transformation methodologies could conceivably be incorporated into various commercial Geographic Information System (GIS) packages.

2.0   INSTALLATION

As discussed in the introduction, running VDatum requires installation of the Java Runtime Environment (JRE) or installation of a Java development package, such as the Java Software Development Kit (JDK). For the remainder of this section, it is assumed that the user does have a Microsoft Windows system, does not have Java software development package, and does need to install the JRE. A copy of the JRE for Microsoft Windows is included with VDatum. Users will need to obtain a JRE or a JDK for other computer platforms.

Installation of VDatum consists of two steps:
         Installation of the VDatum folder
         Installation of the Java Runtime Environment (JRE)

Installation of the VDatum folder
VDatum may be obtained from the Internet of from a CD-ROM. On your computer you will need to create a folder (or subdirectory) to hold VDatum and the working files. The folder may have any name, but you may want to consider naming the folder as "VDatum". Copy the following files from the Internet or the CD-ROM into that folder:

```
VDatum.bat      Batch file to execute VDatum
VDatum.jar      VDatum Java archive  (contains Java bytecodes)
DTL.GTX         Datum transformation grid, dynamic tide level
G99.GTX         Datum transformation grid, GEOID99
MHHW.GTX        Datum transformation grid, mean higher high water
MHW.GTX         Datum transformation grid, mean high water
MLLW.GTX        Datum transformation grid, mean lower low water
MLW.GTX         Datum transformation grid, mean low water
MTL.GTX         Datum transformation grid, mean tide level
```

```
NCLA.GTX         Datum transformation grid, NADCON latitude shifts
NCLO.GTX         Datum transformation grid, NADCON longitude shifts
SST.GTX          Datum transformation grid, sea surface topography
VCN.GTX          Datum transformation grid, VERTCON 2.0
```

Upper or lower case can be used for the filenames of any of the datum transformation grids ("GTX" files). But, the upper and lower case for VDatum.jar MUST be exactly "VDatum.jar".

Optional files and folders

```
VDatum.doc       Documentation for VDatum (this is what you are reading)

Sample           Folder containing sample height data
  datain.txt     Sample height data, input

Source           Folder containing Java source code
  VDatum.java    Java source code for VDatum

Progrmmr         Folder containing useful programmer files
  DOIT.BAT       Batch file to compile and execute VDatum (must have SDK)
  MAKJAR.BAT     Batch file to make a Java archive (JAR) for VDatum
  MANIFEST.TMP   Command file to make the Java archive (JAR) for VDatum
```

Installation of the Java Runtime Environment (JRE)
The instructions shown here for the installation of the Java Runtime Environment (JRE) are adapted from the installation instructions found at http://www.javasoft.com/j2se/1.3/jre/install-windows.html . Please note that the instructions found at www.javasoft.com are to be considered authoritative, and can correct or supercede any instructions in the VDatum documentation. It may be possible to run VDatum with other versions of the JRE. The site, www.javasoft.com, has the latest versions of the JRE as well as the Java Software Development Kit (SDK).

Installation of the Java Runtime Environment (JRE) involves three steps:
        Copy the JRE archive to a temporary directory on the computer
        Execute the self-extracting archive to perform the installation
        (Optional: delete the JRE archive to recover disk space)

Copy the JRE archive to a temporary directory on the computer:

```
j2re1_3_0-win.exe   Self-extracting archive, JRE 1.3 for Windows
```

Execute the self-expanding archive to perform the installation. This is most easily done by locating the file j2re1_3_0-win.exe on your computer with your file Explorer, and double clicking on that file. After installation of the JRE, you may delete j2re1_3_0-win.exe if you so choose. If there are difficulties with installation of the JRE, we request you check with the instructions at www.javasoft.com.

3.0   OPERATION

Locate the batch file, VDatum.bat, on your computer with your file Explorer, and double click on that file. The batch file will create an MS-DOS command window which will, in turn, launch the VDatum application window. No interaction takes place in the MS-DOS command window. All activity is done with the VDatum application window.

When launched, VDatum opens in the interactive mode, and will appear as:
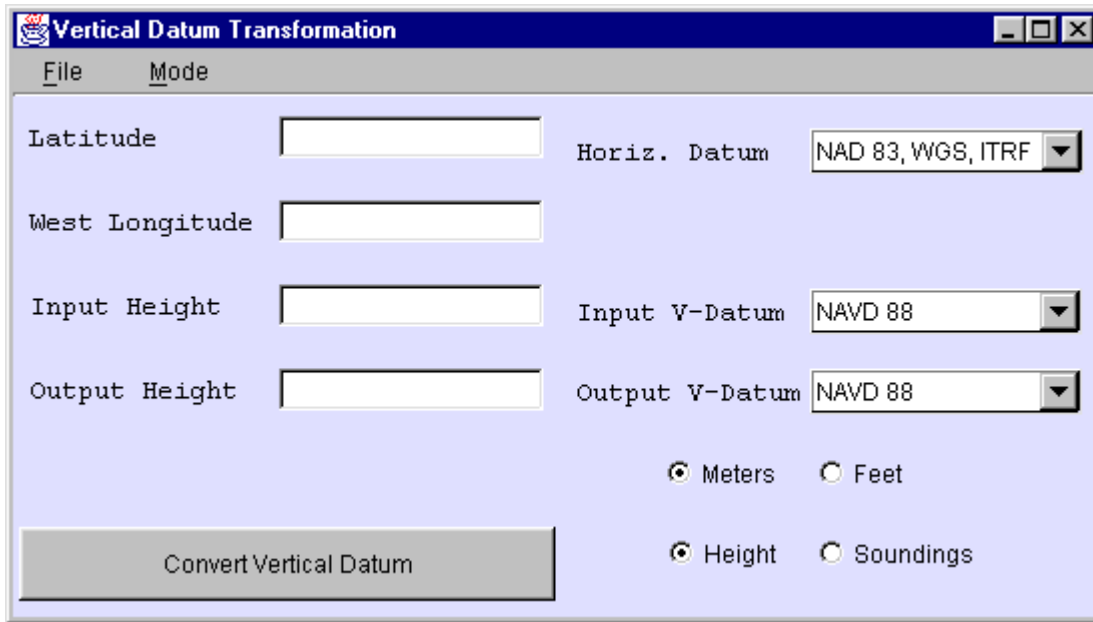
To check operation, let's do a quick datum transformation in Tampa Bay:

> Click in the "Latitude" box and enter 27.7
> Click in the "Longitude" box and enter 82.5
> Click in the "Input Height" box and enter 10
> Click on the "Output V-Datum" menu and select NGVD 29 (from 28 different choices)
> Don't adjust the other controls at this time
> Click on the "Convert Vertical Datum" button

You will immediately see the result, 10.2880, in the "Output Height" box. Congratulations! It's just that simple! A point 10.0 meters above the NAVD 88 reference is seen to be 10.288 meters above NGVD 29.

To switch to the batch mode, click on the "Mode" on the menu bar (or use the alt-m shortcut). One can then select "Interactive" or "Batch". Go ahead and select "Batch". You will notice the VDatum Graphic User Interface (GUI) has changed slightly to reflect the batch mode:
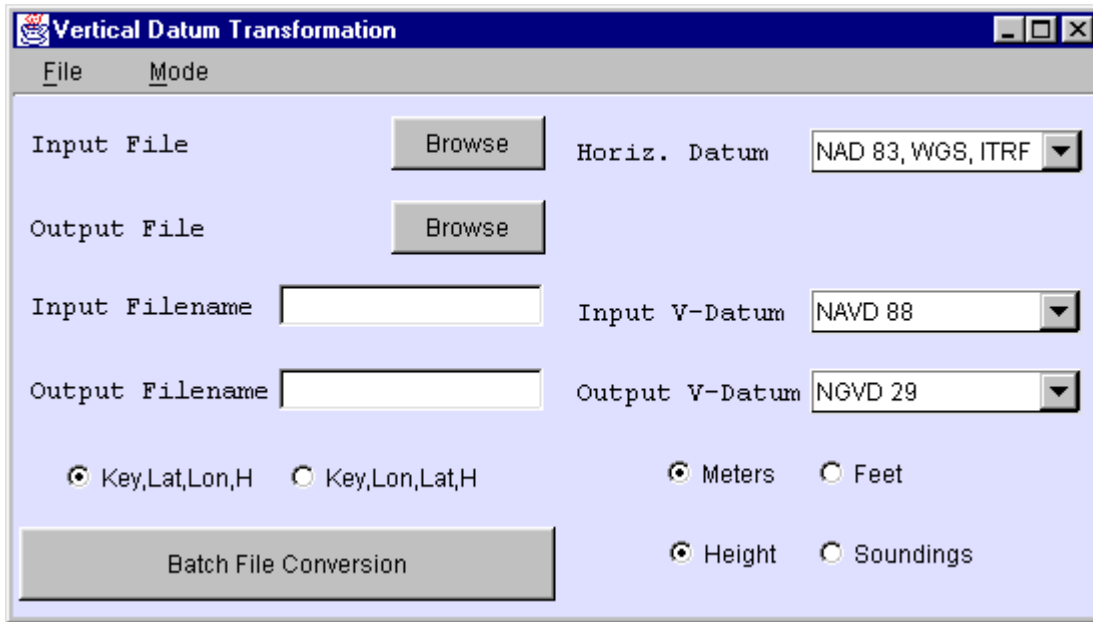
You can use the "Browse" buttons to search your files for input and output data sets.

Warning: if you select or manually type an existing filename as an output file, that file will be overwritten. Be careful.

You can use the browse window to easily maneuver around your directories, and you can type a new output file name in the "File name" box of the browse window. Practice by selecting the "datain.txt" file, that was an optional download in the Sample folder, as an input file. And, indicate that "dataout.txt" should be created in the same folder (Sample). Keep the datum conversion as: from NAVD 88 into NGVD 29. Then, press the "Batch File Conversion" button.

You should shortly see a message box indicating the successful transformation of 10 data points, corresponding to the 10 lines in the input file, datain.txt. Inspect both the input and output files by double clicking on them in your file Explorer, or by opening them with your favorite text processor.

You can close VDatum in two different ways. Either select "File" on the menu bar, and then select "Exit", or click on the "go away box", the box with the "x" in the upper right hand corner of the VDatum window. The MS-DOS window that launched VDatum does not automatically close, so you will need to click on that "go away box" to get rid of it.

4.0   DETAILED DESCRIPTION OF THE VDatum WINDOWS

Menu Bar
==================================
  File Menu
          About …   Display information box and version number
          Exit   Exit the application

  Mode Menu
          Interactive   Select interactive mode
          Batch   Select batch mode

Interactive Mode Window
==

Latitude
Input, geodetic latitude, positive north, in 3 formats:

Decimal degrees	(e.g. 27.614889)	
Degrees, decimal minutes	(e.g. 27 36.89334)	separate with blanks
Degrees, minutes, decimal seconds	(e.g. 27 36 53.60)	separate with blanks

West Longitude
Input, geodetic longitude, positive west, 3 formats:

Decimal degrees	(e.g. 82.72805)	
Degrees, decimal minutes	(e.g. 82 43.683)	separate with blanks
Degrees, minutes, decimal seconds	(e.g. 82 43 40.98)	separate with blanks

Input Height
Input, height or sounding, feet or meters, decimal format, no imbedded blanks.

Output Height
Output, identical sense and units as input height (height/sounding, feet/meters)

Horizontal Datum
Select, horizontal datum of the latitude and longitudes. Modern maps and data sources should use the "NAD 83, WGS, ITRF" selection. Only use the "NAD 27" selection if the source data horizontal positions are believed to be georeferenced in NAD 27. Note: selection of the horizontal datum has negligible effects in Tampa Bay. However, it could be important in the West Coast of the U.S.

Input V-Datum
Select, vertical datum of the input height or sounding. For more guidance, please see the DATUMS section of this document.

Output V-Datum
Select, vertical datum of the input height or sounding. For more guidance, please see the DATUMS section of this document.

Meters/Feet button pair
Select, units of the heights or soundings. Identical units are used for both input and output. Internally, the software uses a conversion factor of 3937.0/1200.0 (multiply to convert meters to feet).

Height/Soundings button pair
Select, sense of the input and output data. Heights are positive upward from the reference datum. Soundings are positive downward from the reference datum.

Convert Vertical Datum button
Click to interactively convert the vertical datum.

Batch Mode Window
==

Input File Browse button
Press this button to display a browse window. Left clicking (and double clicking) on the folders, arrows, buttons, and folders allow movement through the directory trees. Click on an input file, and it's name will be copied to the file name box in the browse window. One can also manually type the file name in that box. Be sure the input file name is a validly formatted file for VDatum. Close the browse window by pressing the "Open" button. The path and file name will be automatically transferred to the "Input Filename" box in theVDatum window.

Output File Browse button
Press this button to display a browse window. Left clicking (and double clicking) on the folders, arrows, buttons, and folders allow movement through the directory trees. If you click on a file, it's name will be copied to the file name box in the browse window.

Warning: if you select an existing file, that file will be overwritten by VDatum.

Instead, use the browse window controls to move through the directory trees, until you get to the desired directory. Then, manually type a new file name in the "File name" box. Be sure the output file does not have the same name as an existing file. Close the browse window by pressing the "Open" button. The path and file name will be automatically transferred to the "Output Filename" box in theVDatum window.

Input Filename
Location of the input file. If a simple file name is used, VDatum will search the directory where the VDatum.jar application is stored. Full paths and the file name can be entered in this field. The field is scrollable by means of the arrow keys. No default file names are used; there must be a file name in this field before you press the "Batch File Conversion" button. File names can be any valid file name. They do not have to end in ".txt". However, input files must be simple ASCII text, irregardless of the file name. For more detail, refer to the section BATCH FILE FORMATS AND EXAMPLES.

Output Filename
Location of the output file. If a simple file name is used, VDatum will place the file in the directory where the VDatum.jar application is stored. Full paths and the file name can be entered in this field. The field is scrollable by means of the arrow keys. . No default file names are used; there must be a file name in this field before you press the "Batch File Conversion" button. . File names can be any valid file name. They do not have to end in ".txt". Output files will be simple ASCII text, irregardless of the file name. For more detail, refer to the section BATCH FILE FORMATS AND EXAMPLES.

Warning: if you type the name of an existing file, that file will be overwritten by VDatum.

Key,Lat,Lon,H/Key,Lon,Lat,H button pair
Select, indicate the ordering of latitude vs. longitude in the input and output files. For more detail, refer to the section BATCH FILE FORMATS AND EXAMPLES.

Horizontal Datum
Select, horizontal datum of the latitude and longitudes. Modern maps and data sources should use the "NAD 83, WGS, ITRF" selection. Only use the "NAD 27" selection if the source data horizontal positions are believed to be georeferenced in NAD 27. Note: selection of the horizontal datum has negligible effects in Tampa Bay. However, it could be important in the West Coast of the U.S.

Input V-Datum
Select, vertical datum of the input height or sounding. For more guidance, please see the DATUMS section of this document.

Output V-Datum
Select, vertical datum of the input height or sounding. For more guidance, please see the DATUMS section of this document.

Meters/Feet button pair
Select, units of the heights or soundings. Identical units are used for both input and output. Internally, the software uses a conversion factor of 3937.0/1200.0 (multiply to convert meters to feet).

Height/Soundings button pair
Select, sense of the input and output data. Heights are positive upward from the reference datum. Soundings are positive downward from the reference datum.

Batch File Conversion button
Click to interactively convert the vertical datum.

Upon completion of the batch mode processing, a report window, "Batch Processing Report", will be displayed. It will report the number of input records, the modes of height/sounding and feet/meters, and the number of records that had non-fatal problems. Press of the "OK" button to dismiss the report window. If a record had a problem, typically due to being outside a valid region, a null value of -999999.0000 will be used as the output height.

5.0   BATCH FILE FORMATS AND EXAMPLES
Input files for VDatum batch mode processing are simple ASCII 4-column text files, with one record per line. Each record indicates one height/sounding. All data in an input file must have the same characteristics. That is, all the records must be in feet or meters, be heights or soundings, and, be in a common horizontal and vertical datum. Data sets of mixed characteristics must be broken into subsets with common characteristics prior to processing with VDatum.

Each record consists of four fields, in the order:
         Key
         Latitude
         Longitude
         Height
when the "Key,Lat,Lon,H" button is selected.

Note that it is possible to process data with a different ordering of latitude and longitude:
         Key
         Longitude
         Latitude
         Height
by selection of the "Key,Lon,Lat,H" button.

Note, also, that soundings can be used in the fourth field instead of heights by selection of the "Soundings" button.

The fields in each record can be delimited in a number of ways. Valid delimiters are: space, tab, newline, carriage-return, form-feed, comma, semicolon, and colon.

Key Field
This is a simple ASCII key of any length. You may not imbed any of the field delimiters (space, tab, newline, carriage-return, form-feed, comma, semicolon, and colon) in the key field. The key field is present to allow extraction of data from a data base or GIS, conversion through VDatum, and updating of the data base or GIS with the transformed heights. While key fields may be unique, VDatum does not check any key fields.

Latitude Field
Decimal degrees, positive North. Use the "Horizontal Datum" selection to indicate NAD 83 or NAD 27 horizontal datum.

Longitude Field
Decimal degrees, positive West. Use the "Horizontal Datum" selection to indicate NAD 83 or NAD 27 horizontal datum. Special note: to support some GIS conventions, VDatum will detect when a longitude field is positive East. This is done by sensing the presence of a leading minus sign (e.g. -82.56583). One should not use lead minus signs if performing 3-D transformations outside the Western hemisphere.

Height/Sounding Field

Decimal value. Units are feet or meters, depending upon the setting of the "Meters/Feet" button pair. The sense of the sign of the data are heights or soundings, depending upon the setting of the "Height/Soundings" button pair. All data must be in the same horizontal and vertical datum. Use the "Horizontal Datum" selection to indicate NAD 83 or NAD 27 horizontal datum. Use the "Input V-Datum" selection to indicate the vertical datum. Data sets of mixed characteristics must be broken into subsets with common characteristics prior to processing with VDatum.

Example input file (For Tampa Bay)

```
=================================
aaba 27.57083   82.57305   11.1
baba 27.74305   82.70666   12.0
vaba 27.68666   82.51972   13.5
zaba 27.72277   82.47305   14.1
maba 27.80583   82.40916   15.7
ZYXW 27.91666   82.83000   16.2
out1 27.52444   82.43000   17.1
yaba 27.96638   82.56583   18.3
daba 27.94638   82.40194   19.0
dooo 27.87388   82.85166   99.8
```

The example output file was generated from the example input file with the following VDatum settings:

Horizontal Datum:	NAD83
Input V-Datum:	NAD 83(86)
Output V-Datum:	MLLW
Units:	Feet
Sense:	Height
Format:	Key,Lat,Lon,H

Example output file (For Tampa Bay)

```
=================================
aaba 27.57083   82.57305   91.8088
baba 27.74305   82.70666   92.3050
vaba 27.68666   82.51972   94.6037
zaba 27.72277   82.47305   95.5899
maba 27.80583   82.40916   97.8207
ZYXW 27.91666   82.83000   97.0520
out1 27.52444   82.43000   -999999.0000
yaba 27.96638   82.56583   100.4350
daba 27.94638   82.40194   101.7175
dooo 27.87388   82.85166   180.2016
```

Note that "out1" was outside the defining region for the tidal datums, and was assigned an error value indicator of -999999.0000.

6.0   ERROR MESSAGES

The following error is non-fatal. The message may be displayed on the right hand side of the VDatum window when in interactive mode.

`Grid Boundary Error`
Category: Non-fatal error
Action: Proceed with transforming other points. If subsequent points are in a valid transformation region, the message will be cleared. Note that a default output value of -999999.0000 is generated when this error occurs. This value, -999999.0000, is not valid; it should not be used under any circumstances.

The following errors are fatal. Please take the indicated action.

`Input batch file could not be opened`
Category: Fatal error
Action: Restart VDatum and provide a valid input filename before batch file conversion

`Output batch file could not be opened`
Category: Fatal error
Action: Restart VDatum and provide a valid output filename before batch file conversion

`File ncla.gtx could not be opened.`
`File nclo.gtx could not be opened.`
`File g99.gtx could not be opened.`
`File vcn.gtx could not be opened.`
`File sst.gtx could not be opened.`
`File mllw.gtx could not be opened.`
`File mlw.gtx could not be opened.`
`File mhw.gtx could not be opened.`
`File mhhw.gtx could not be opened.`
`File mtl.gtx could not be opened.`
`File dtl.gtx could not be opened.`
Category: Fatal error
Action: Insure missing files are in same folder/subdirectory as VDatum.jar

`Batch file input format error 1.`
`Batch file input format error 2.`
Category: Fatal error
Action: Format error in the input batch file. Review section BATCH FILE FORMATS AND EXAMPLES and correct the input batch file. For example, "`Batch file input format error 2.`" will be generated if an input record does not have 4 columns.

`Batch file output error 1.`
`Batch file newLine output error`
`Error closing files`
Category: Fatal error
Action: System failed in writing output. Check disk space and write protection settings.

`<filename> header input error.`
`<filename> header format error.`
`<filename> grid input error.`
`<filename> grid format error.`
Category: Fatal error
Action: The transformation grid file "<filename>" has become corrupted. Recopy the file from the CD or Internet.

The following errors should never be encountered. These messages are generated by internal programming safeguards to prevent erroneous behaviors and/or results. Contact the programming team.

```
LookAndFeel error 1
LookAndFeel error 2
LookAndFeel error 3
LookAndFeel error 4
mode error: ButtonHandler
mode error: RadioButtonHandler
mode error: ItemHandler
illegal datum code <integer>
group error 1: ipI= <integer>
group error 2: opI= <integer>
group error 3: opI= <integer>
group error 4: ipI= <integer>
index error: inI,outI= <integer> <integer>
index error: ila=      <integer>
index error: ila,nla=  <integer> <integer>
index error: ilo=      <integer>
index error: ilo,nlo=  <integer> <integer>
blterpG error1: ix= <integer>
blterpG error2: jy= <integer>
blterpG error3: ix= <integer>
blterpG error4: jy= <integer>
bqterpG error1: ix= <integer>
bqterpG error2: jy= <integer>
bqterpG error3: ix= <integer>
bqterpG error4: jy= <integer>
bqterpG error5: x= <float>
bqterpG error6: y= <float>
```
Category: Fatal error
Action: Contact the programming team.

7.0   A TUTORIAL ON DATUMS

As a general definition, a datum is any quantity or set of quantities that may serve as a referent or basis for calculation of other quantities. This broad characterization, in turn, leads to two related definitions of a geodetic datum.

> A geodetic datum is a set of constants specifying the coordinate system used for geodetic control.

> A geodetic datum is as defined above, together with the coordinate system and the set of all points and lines whose coordinates, lengths, and directions have been determined by measurement and calculation.

The first definition is realized, for example, by specification of an ellipsoid and associated origin and orientation information. The second definition, which is prevalent in mapping and charting, is realized, for example, by specification of ellipsoid, origin, and orientation in combination with a self-consistent set of observed reference coordinates. The first definition represents an *idealization* of a geodetic datum, and the second definition expresses the *realization* of a geodetic datum.

Before the advent of manmade satellites, geodetic positions in surveying were determined separately, either horizontally in two-dimensions as latitudes and longitudes or vertically in the third dimension as heights or depths.

Horizontal datums have been defined using a reference ellipsoid and six topocentric parameters expressing origin, and orientation. One example North American Datum (NAD) 1927. Due to the constraints and requirements of the times, horizontal datums were non-geocentric in definition.

Vertical datums are expressed in some form of orthometric height, and can be clustered into two categories: those generally based on Mean Sea Level (MSL), and those based on some tidally-derived surface of an averaged high or low water. Examples of the former is the North American Vertical Datum (NAVD) 1988, and an example of the latter is Mean Lower Low Water (MLLW). Vertical datums depend upon two elements, the approximation or realization of Mean Sea Level, and the approximation or realization of orthometric height.

Three dimensional datums are defined using a reference ellipsoid and six geocentric parameters expressing origin, and orientation. Unlike a horizontal datum, a three dimensional datum provides the foundation for accurate determination of ellipsoid heights. Examples of three dimensional datums are North American Datum (NAD) 1983 and World Geodetic System (WGS) 1984.

The North American Datum 1983 (NAD 83) was affirmed as the official horizontal datum for the United States by a notice in the Federal Register (Vol. 54, No. 113 page 25318) on June 14, 1989.

The North American Vertical Datum 1988 (NAVD 88) was affirmed as the official vertical datum for the United States by a notice in the Federal Register (Vol. 58, No. 120 page 34245) on June 24, 1993.

Geodetic Reference Systems and Reference Frames
Using the satellites orbiting around the Earth, the determination of geodetic positions became three-dimensional, either as rectangular (X, Y, Z) coordinates or converted to geodetic (latitude, longitude, ellipsoidal height) coordinates using an Earth-centered ellipsoid. Because of this methodology, it became possible to establish positions of high accuracy in a rectangular reference frame without specification of an ellipsoid. An example of such a reference frame is the International Terrestrial Reference Frame (ITRF) 2000. A geodetic reference system is the combination of a reference frame and an ellipsoid. As seen above, a geodetic reference system is a synonym for a three dimensional datum. Examples of geodetic reference system are North American Datum 1983 and World Geodetic System 1984. When the International Terrestrial Reference Frame (ITRF) is specified in combination with a geocentric ellipsoid, such as the Geodetic Reference System (GRS) 1980 ellipsoid, then it is also a geodetic reference system.

The geodetic reference system used by unaugmented GPS is the WGS 84. The most recent WGS 84 (G1150) reference frame and the ITRF2000 system are in agreement to better than one centimeter.

The geodetic reference system used by deployed GPS augmentations (the Maritime Differential GPS and the Nationwide Differential GPS (NDGPS)) is the NAD 83. The DGPS corrections provided by these augmentations are referenced to NAD 83, thus allowing DGPS receivers to easily provide NAD 83 coordinates. The National Continuously Operating Reference Station (National CORS) system includes coordinate data bases in both the NAD 83 geodetic reference system, and in the ITRF2000 reference frame combined with the Geodetic Reference System (GRS) 1980 ellipsoid.

Geoid
The geoid is a specified equipotential surface, defined in the Earth's gravity field, which best fits, in a least squares sense, global mean sea level. It should be noted that due to effects such as atmospheric pressure, temperature, prevailing winds and currents, and salinity variations, MSL can depart from an equipotential surface by a meter or more.

The geoid is a complex, physically based surface, and can vary by up to 100 meters in height from a geocentric ellipsoid. Thus, national and regional vertical datums around the world, which are locally tied to MSL, are significantly different from one another when considered on a global basis. In addition, due to the realization and orthometric height approximations of various vertical datums, other departures at the meter level or more will be found when comparing elevations to a global geoid reference.

For the United States, the GEOID99 geoid model as been developed to directly relate ellipsoid heights from the NAD 83 three dimensional datum to the NAVD 88 vertical datum. Comparisons with GPS ellipsoid heights on leveled benchmarks show this conversion can generally be accomplished in the conterminous United States to about 2.5 cm (one sigma).

On a global basis, the Earth Gravitational Model (EGM) 1996 was developed to provide an improved WGS 84 spherical harmonic model of the Earth's gravitational potential. EGM 96 is quoted as accurate to better than one meter in gravity surveyed areas.

Land Maps
As discussed earlier the NAD 83 and the NGVD 88 datums were adopted by Congress as datums for the United States. Depending upon the scale of mapping and the spacing of contour intervals, the older NAD 27 and NGVD 29 datums may be adequate to represent the National Spatial Data Accuracy Standard. Except for the largest map scales, the horizontal components of WGS 84 and NAD 83 may be considered equivalent. Datum transformations are available which relate the NAD 27 and NAD 83 datums, and which relate the NGVD 29 and NAVD 88 datums.

Nautical Charts
As discussed earlier, the NAD 83 and the NGVD 88 datums were adopted by Congress as datums for the United States. On a global basis, the International Hydrographic Organization (IHO) designated the use of the World Geodetic System as the universal datum. Since then, the horizontal features have been based on WGS 84 or in other geodetic reference systems which are compatible, such as NAD 83 or the ITRF combined with the GRS80 ellipsoid.

All vertical features and depths are still defined with respect to tidal surfaces, which may differ in definition from chart to chart. Typically, a low waterline, rather than mean sea level, is adopted as the vertical reference for a chart. Representing depths relative to a low waterline is a conservative approach, since depths below a ship's keel are so important.

Aeronautical Charts
As discussed earlier the NAD 83 and the NGVD 88 datums were adopted by Congress as datums for the United States. On a global basis, the International Civil Aviation Organization (ICAO) designated the use of the WGS 84 as the universal datum. Since then, the horizontal features have been based on WGS 84 or in other geodetic reference systems which are compatible, such as NAD 83 or the ITRF combined with the GRS80 ellipsoid.

All vertical features and elevations are still determined relative to the local vertical datums, which may vary by a meter or more from a global geoid reference.

Vertical Datums (and the vertical part of 3-D datums)
As discussed in the introduction, vertical datums come in two categories: those based on a form of Mean Sea Level (MSL), which we will call *Orthometric Datums*, and those based on tidally-derived surfaces of high or low water, which we will call *Tidal Datums*. In addition, there is a distinct category of 3-dimensional datums, that are typically realized through space-based systems, such as GPS. We will consider the vertical component of 3-D datums as another type of vertical datum, and refer to these *as 3-D Datums*.

VDatum converts between 28 different vertical datums. There are many other datums used globally, but these are not addressed in this document. The general categories of datums are:

Orthometric Datums

NAVD 88   North American Vertical Datum 1988
NGVD 29   North American Geodetic Vertical Datum 1929

Tidal Datums

```
MLLW           Mean Lower Low Water
MLW            Mean Low Water
LMSL           Local Mean Sea Level
MTL            Mean Tide Level
DTL            Diurnal Tide Level
MHW            Mean High Water
MHHW           Mean Higher High Water
```
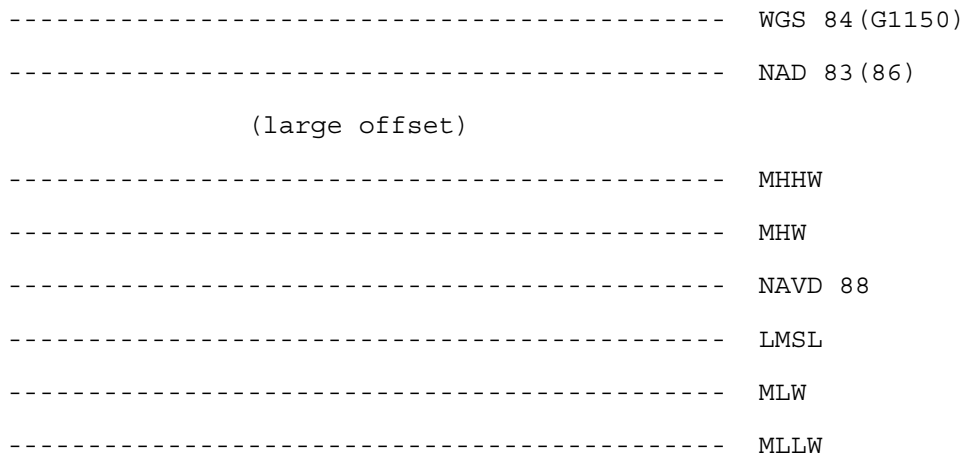
3-D Datums

```
NAD 83 (86)    North American Datum 1983 (1986)
WGS 84(G1150)  World Geodetic System 1984 (G1150)
WGS 84(G873)   World Geodetic System 1984 (G873)
WGS 84(G730)   World Geodetic System 1984 (G730)
WGS 84(orig)   World Geodetic System 1984 (original system -- 1984)
WGS 72         World Geodetic System 1972
ITRF2000       International Terrestrial Reference Frame 2000
ITRF97         International Terrestrial Reference Frame 1997
ITRF96         International Terrestrial Reference Frame 1996
ITRF94         International Terrestrial Reference Frame 1994
ITRF93         International Terrestrial Reference Frame 1993
ITRF92         International Terrestrial Reference Frame 1992
ITRF91         International Terrestrial Reference Frame 1991
ITRF90         International Terrestrial Reference Frame 1990
ITRF89         International Terrestrial Reference Frame 1989
ITRF88         International Terrestrial Reference Frame 1988
SIO/MIT 92     Scripps Institution of Oceanography/Massachusetts Institute of Technology 1992
NEOS 90        National Earth Orientation Service 1990
PNEOS 90       Preliminary National Earth Orientation Service 1990
```

In practice, a user will only have to transform between a few datums. The 28 varieties of tidal and 3-D datums supported by VDatum are supplied merely to be complete.

Schematic of Selected Vertical Datum Reference Surfaces at Tampa Bay (Approximate – not to scale)

```
-------------------------------------------- WGS 84(G1150)

-------------------------------------------- NAD 83(86)

             (large offset)

-------------------------------------------- MHHW

-------------------------------------------- MHW

-------------------------------------------- NAVD 88

-------------------------------------------- LMSL

-------------------------------------------- MLW

-------------------------------------------- MLLW
```

The separations between the tidal surfaces and the NAD 83 (and other 3-D datums) are in excess of 24 meters. The relation NAD 83 to NAVD 88 is the GEOID99 geoid height model. The relation of NAVD 88 to LMSL is calibrated from tide model comparisons with leveled, tidal benchmarks, and is expressed as a constant 0.163 meters in the Tampa Bay region (SST.GTX).

WGS 84, WGS 84 (G730), WGS 84 (G873), WGS 84 (G1150), and NAD 83 (86)

It is not well known that there is more than one WGS 84 reference frame. To date, there have been four WGS 84 reference frames: WGS 84, WGS 84 (G730), WGS 84 (G873), and WGS 84 (G1150).   In this document, the original WGS 84 frame is denoted WGS 84 (orig.). The dates of these reference frames are:

WGS 84 (G1150)-- Broadcast GPS orbit from January 20, 2002 to present.
WGS 84 (G873) -- Broadcast GPS orbit from January 29, 1997 to January 19, 2002.
WGS 84 (G730) -- Broadcast GPS orbit from June 29, 1994 to January 28, 1997.
WGS 84 (orig.)   -- Broadcast GPS orbit from January 23, 1987 to June 28, 1994.

The WGS 84 frames were updated to conform with the best available scientific reference frames. One can establish an association:

WGS 84 (G1150)-- Equivalent to ITRF2000(1997.0) at the one centimeter level.
WGS 84 (G873) -- Equivalent to ITRF94(1997.0) at the few centimeter level.
WGS 84 (G730) -- Equivalent to ITRF92(1994.0) at the few centimeter level.
WGS 84 (orig.)   -- Equivalent to NAD 83 (86) within the conterminous US.

The shifts between WGS 84 (orig.) and WGS 84 (G730) [and for NAD 83 (86) to ITRF92(1994.0)] are a little over 2 meters. The shifts between WGS 84 (G730), WGS 84 (G873), and WGS 84 (G1150)) [and for ITRF92(1994.0), ITRF94(1997.0), and ITRF2000(1997.0)] are just a few centimeters.

The original NAD 83 (86) reference frame has been retained throughout the years, even though that frame is not geocentric by about 2 meters.

This has lead to two seemingly contradictory statements found in literature:

> WGS 84 is identical to NAD 83
> WGS 84 differs from NAD 83 by about 2 meters.

As seen from above, the problem arises because the full datum names have not been used. To be exact:

> WGS 84 (original) is identical to NAD 83 (86) (within the conterminous US)
> WGS 84 (G1150) differs from NAD 83 (86) by about 2 meters.

We can not close this section without emphasizing one final point. It is unlikely that most users will detect differences between WGS 84 (G1150) and NAD 83 (86) without rigorous processing. This is due to how one obtains WGS 84 (G1150) coordinates, and how one obtains NAD 83 (86) coordinates. There is no readily accessible network of WGS 84 (G1150) control stations, as compared to the National Spatial Reference System (NSRS) of NAD 83 (86) control stations. So, generally, one uses autonomous GPS (point positioning) methods with code pseudoranges to establish a point in WGS 84 (G1150). Broadcast orbits are currently accurate to about 3 meters RMS. An individual code range is generally accurate from a few decimeters to several meters or more, depending upon multipath. With SA off, with atmospheric models, and with nominal atmospheric conditions, pseudorange horizontal accuracy (conterminous US) is about 5 meters (2D -- 95%). So, one can see the *realization* of the WGS 84 (G1150) datum is usually at a few meter level, even though the *idealized* WGS 84 (G1150) datum is defined at a one centimeter level. By contrast, the NAD 83 system is both *defined* and *realized* at a 5 centimeter level. Such precise realizations are performed with differential carrier phase, not with pseudoranges.

(Additional discussion, including Differential GPS (DGPS) positioning, can be found in the section: "WHAT DATUM IS MY DATA IN? WHAT DATUM DO I WANT?")

8.0   WHAT DATUM IS MY DATA IN? WHAT DATUM DO I WANT?

These are the key questions that need to be answered. A supplier of geospatial data should provide the appropriate metadata, in this case datum identification, to allow its use. If you generate new data, you should provide the datum identification along with those new data.

When dealing with paper maps and charts, the datums are typically provided. Topographic maps (from USGS, for example) will have elevations referenced to either NAVD 88 or to the older NGVD 29. The NAVD 88 was affirmed as the official vertical datum for the United States by a notice in the Federal Register (Vol. 58, No. 120 page 34245) on June 24, 1993. Also, note that maps have a horizontal datum. Even if the features are horizontally referenced to NAD 83, this does not mean the vertical datum is a 3-D vertical datum.

Nautical charts will have depths referred to different tidal surfaces, which may vary from chart to chart. In the United States, MLLW and MLW are the typical low water reference surfaces. Note: to support harbor and river navigation, bridge clearances are typically referenced to a high water, MHW or MHHW; not to a low water. Also note that charts (like maps) have a horizontal datum. Even if the features are horizontally referenced to NAD 83, this does not mean the vertical datum is a 3-D vertical datum.

As discussed above, when collecting data georeferenced with autonomous GPS, then you are in the WGS 84 (G1150) datum. Note, however, that data collection systems may provide the option of output in different datums. If you selected such an option, then your data will probably be in the selected datum.

If however, you are collecting data georeferenced by augmented GPS, then you are probably in NAD 83 (86). If the augmentation was one of the U.S. Coast Guard Maritime Differential GPS or National Differential GPS (NDGPS) base stations, then those broadcast pseudorange correctors are established using NAD 83 (86) coordinates, and your output coordinates will be in NAD 83 (86). If you are using National CORS data for carrier phase postprocessing, and if you are processing with ITRF2000 coordinates, then your output coordinates will be in ITRF2000. Note that there is a whopping 1.5 meter vertical datum difference between NAD 83 (86) and WGS 84 (G1150) in the Tampa Bay region (and only about a 1.5 millimeter difference between ITRF97 and WGS 84 (G873) in the Tampa Bay region). As above, augmented GPS data collection systems may provide the option of output in different datums. If you selected such an option, then your data will probably be in the selected datum.

Details on Orthometric Datums
The North American Vertical Datum (NAVD) 1988 is based on an adopted elevation at Point Rimouski (Father's Point). It uses Helmert orthometric heights as an approximation to true orthometric heights. By contrast, the National Geodetic Vertical Datum (NGVD) 1929 was fixed to a set of reference tide gauges, without correction for local sea surface topography departures, and it used normal orthometric heights as an approximation to true orthometric heights. The discrepancies between these two datums is not a simple offset and tilt, but a complex surface that is related to gravity field variations of the Earth. Neither NAVD 88 nor NGVD 29 are in conformance with mean sea level, nor with the geopotential surface that best fits the Earth's mean sea surface (idealized global geoid). NAVD 88 is a better realization of an orthometric datum based on a geopotential surface; however that geopotential is not the ideal global geoid. In addition, one will have average local departures from global mean sea level due to prevailing winds, currents, atmospheric pressure, temperature, and salinity effects. All of these effects are absorbed into an offset between NAVD 88 and mean sea level as established by the Tampa Bay hydrodynamic model. This relation of NAVD 88 to LMSL is calibrated from tide model comparisons with leveled, tidal benchmarks, and is expressed as a constant 0.163 meters in Tampa Bay.

Details on Tidal Datums
Tidal datums are referenced to stages of the tide at a particular point. At a point we have tidal datums such a Mean Low Water (MLW) and a Mean Lower Low Water (MLLW). Both are referencing a low water, but are computed differently due to the definitions of MLW and MLLW. There are dozens of different definitions of high, low, and mean waters used around the world.

In addition, due to the spatial variability of tidal dynamics, a given low water definition will differ from mean sea level by varying amounts from place to place. The spatial variation of tide dynamics is complex, and depends upon location on the Earth, the 2-D shape of the coast, the bottom hydrography of a bay or harbor, and other effects such as wind, salinity, and river discharge. Establishment of tide zones during the process of data capture and chart compilation addresses tidal spatial variation. The most comprehensive approach to this problem (which was done for Tampa Bay) is to establish tidal datum grids derived from suitable numerical circulation models.

Lower low water --	The lower of the two low waters of any tidal day. The single low water occurring daily during periods when the tide is diurnal is considered to be a lower low water.
Low water --	Minimum height reached by a falling tide.
Higher high water --	The higher of the two high waters of any tidal day. The single high water occurring daily during periods when the tide is diurnal is considered to be a higher high water.
High water --	Maximum height reached by a rising tide.
Diurnal tide level --	The average of mean lower low water and mean higher high water.
Mean tide level --	The average of mean low water and mean high water.
Mean sea level --	Average height of the surface of the sea for all stages of the tide over a 19 year period, usually determined from hourly height readings.

By these definitions, one can envision that mean sea level, mean tide level, and diurnal tide level are all close to one another, that mean lower low water is lower than mean low water, and that mean higher high water is higher than mean high water. The magnitudes of the high and low waters vary from place to place depending upon the range of the tide, that the local mean sea level at a point will vary due to physical effects, and that the entire set of tidal datums will vary relative to an ellipsoid due to geoidal undulations.

Details on 3-D Datums
As discussed above, all 3-D datums (reference system) represent a reference frame (origin, orientation, and scale) combined with an ellipsoid. The GRS80 ellipsoid is used in VDatum for all 3-D datums. The GRS80 ellipsoid parameters are:

Semi-major axis = 6378137 meters   (exact)
Flattening = 1/298.257222101   (derived)
Semi-minor axis = 6356752.3141 meters   (derived)

The WGS 84 ellipsoid is slightly different in flattening:

Semi-major axis = 6378137 meters (exact)
Flattening = 1/298.257223563   (derived)
Semi-minor axis = 6356752.3142 meters   (derived)

The difference in flattening between these two ellipsoids causes a maximal departure of 0.1 millimeter in ellipsoidal height at the Earth's poles. This difference is considered negligible for VDatum.

The majority of 3-D datums supported by VDatum will not be encountered in practice. They are provided for completeness. ITRF2000, for example, is customarily realized through post-processed GPS carrier phase from a National CORS station using an ITRF2000 coordinate for that CORS. Most likely, GPS-based georeferencing will be in the NAD 83 (86) datum. Data may be in the WGS 84 (G1150) datum if the data were collected through autonomous GPS.

Rigorous nomenclature for 3-D datums requires specification of an epoch date for any ITRFxx coordinate. This is because the ITRF datums include models for plate tectonic motion. Thus, an ITRF2000 coordinate for a station at one epoch will differ from the ITRF2000 coordinate for the same station at a different epoch. This variation is (generally) avoided with NAD 83 (86) coordinates, since those are anchored to the North American Plate. Exceptions occur with active tectonic areas, such as Southern California, or along the Pacific Coast. Since plate motion is generally horizontal, epoch date differences between measurement and datum reference epochs are neglected.

List of details and epoch dates

NAD 83 (86)   -- Date tag 1986.0. Published by NGS from 1986 to present. Datum is anchored to North
                   American Plate, so epochs only used in crustal motion software.
                    (note: numerous realizations are indicated by date tags, but all retain original 3-D frame.)
WGS 84 (G1150)-- Reference epoch 2001.0. Broadcast GPS orbit from January 20, 2002 to present.
WGS 84 (G873) -- Reference epoch 1997.0. Broadcast GPS orbit from Jan. 29, 1997 to January 19, 2002.
WGS 84 (G730) -- Reference epoch 1994.0. Broadcast GPS orbit, June 29, 1994 to January 28, 1997.
WGS 84 (orig.) -- Broadcast GPS orbit from January 23, 1987 to June 28, 1994.
WGS 72   -- Broadcast GPS orbit from start of GPS operations to January 22, 1987.
ITRF2000   -- Reference epoch 1997.0. Used in NGS from December 2, 2001 to present.
ITRF97   -- Reference epoch 1997.0. Used in NGS from August 1, 1999 to December 1, 2001.
                    (note: negligible alteration in coordinate realization adopted June 3, 2000.)
ITRF96   -- Reference epoch 1997.0. Used in NGS from March 1, 1998 to July 31, 1999.
ITRF94   -- Reference epoch 1996.0. Used in NGS from June 30, 1996 to February 28, 1998.
ITRF93   -- Reference epoch 1995.0. Used in NGS from January 1, 1995 to June 29, 1996.
ITRF92   -- Reference epoch 1994.0. Used in NGS from January 9, 1994 to December 31, 1994.
ITRF91   -- Reference epoch 1992.6. Used in NGS from December 1, 1993 to January 8, 1994.
ITRF91   -- Reference epoch 1988.0. Used in NGS from August 16, 1992 to December 19, 1992.
ITRF90   -- Reference epoch 1988.0. Not used by NGS.
ITRF89   -- Reference epoch 1988.0. Not used by NGS.
ITRF88   -- Reference epoch 1988.0. Not used by NGS.
SIO/MIT 92   -- Reference epoch 1992.57. Used in NGS, December 20, 1992 to November 30, 1993.
NEOS 90   -- Reference epoch 1988.0. Used in NGS from October 20, 1991 to August 15, 1992.
PNEOS 90   -- Not used by NGS.

9.0   PROGRAMMING DETAILS

VDatum is programmed in Java 2 using the Swing Graphics User Interface (GUI) Component Package. The bytecode was compiled with the Java Software Development Kit (JDK) version 1.3, and packaged into a Java archive (VDatum.jar). VDatum is currently distributed as a Java application, to be run locally on a user platform.

The datum transformation algorithms can be considered as traversing a minimal spanning tree, whose nodes represent individual datums. The datums are conceptually grouped into three subsets: 3-D datums, orthometric datums, and tidal datums. Each subset has a principal member: NAD83 for 3-D datums, NAVD 88 for orthometric datums, and Local Mean Sea Level (LMSL) for tidal datums. The logic begins with the source and target datums, extracts their categories, encodes the traversal path through the principal members, and also applies the transformations to go between the source and target datums and their associated principal members.

THE VDatum ROADMAP

```
WGS 84(G1150)------>|
WGS 84(G873) ------>|
WGS 84(G730) ------>|
WGS 84(orig) ------>|
WGS 72       ------>|
ITRF2000     ------>|
ITRF97       ------>|
ITRF96       ------>|
ITRF94       ------>| -------> NAD 83 (86)
ITRF93       ------>|                |
ITRF92       ------>|                |
ITRF91       ------>|                |
ITRF90       ------>|                |
ITRF89       ------>|                |
ITRF88       ------>|                |
SIO/MIT 92   ------>|                |
NEOS 90      ------>|                |
PNEOS 90     ------>|                |
                                     |
                          NAVD 88  --------->  NGVD 29
                                     |
                                     |        |-------> MHHW
                                     |        |-------> MHW
                          LMSL --->  |-------> MTL
                                              |-------> DTL
                                              |-------> MLW
                                              |-------> MLLW
```

For example, the transformation from WGS84(G1150) to MLLW proceeds: WGS84(G1150) to NAD 83 (86) to NAVD 88 to LMSL to MLLW.

The transformations between the 3-D datums are provided by 7 parameter Helmert transformations (3 translations, 3 rotations, and a scale change), calibrated through global networks of satellite and extra-terrestrial measurements. The equations and coefficients implemented in VDatum are approximations to the more rigorous forms used by geodesists. The more rigorous forms are time dependent. However, users of VDatum will typically not have metadata regarding reference times used to establish positioning. And, more importantly, the time dependent part of the more rigorous equations are, for the most part, horizontal. Given the microscopic effect on the vertical, the significant complication of end-user tracking of datum reference times, and the general error budgets of the user's data, the simplified forms were judged to be most appropriate. More detail on the 3-D transformations and their rigorous forms can be found in HTDP.

Transformations between NAD 83 (86) and NAVD 88 are performed by interpolation of the GEOID99 geoid height grid, g99.gtx. More detail on the GEOID99 model can be found by following the links in section 10 (Contacts and Resources).

Transformations between NAVD 88 and NGVD 29 are performed by interpolation of the VERTCON 2.0 vertical datum grid. More detail on the VERTCON model can be found by following the links in section 10 (Contacts and Resources).

Transformations between NAVD 88 and LMSL are performed by interpolation of a sea surface topography grid. This grid in Tampa Bay is currently taken to be a single constant, and was estimated by comparison of measured tidal values, NAVD 88 datum values, and tidal model predictions at tide benchmarks throughout the region. The Tampa Bay estimate is 0.163 meters.

Transformations between the tidal datums are performed by interpolation of grids computed from hydrodynamic models of Tampa Bay (Hess 1994).

Format for the Datum Grid Files
The datum transformation grid files are simple ASCII text files, and are named with a suffix ".GTX". Each file contains a header record followed by one or more grid element records. Only one data value is provided in each grid element record.

The header record consists of six fields, in the order:
> Lower left hand latitude
> Lower left hand longitude
> Delta latitude
> Delta longitude
> Number of rows (# of latitudes)
> Number of columns (# of longitudes)

The fields may be expressed in free format, with one or more blanks separating each field.

Lower left hand latitude Field
Decimal degrees, positive North, origin from equator. Field is the geodetic latitude of the lower left hand grid element.

Lower left hand longitude Field
Decimal degrees, positive East, origin from Greenwich. Field is the geodetic longitude of the lower left hand grid element.

Delta latitude Field
Decimal degrees, non-zero, positive. Field is the latitude spacing between the rows of the grid.

Delta longitude Field
Decimal degrees, non-zero, positive. Field is the longitude spacing between the columns of the grid.

Number of rows (# of latitudes) Field
Non-zero, positive integer. Field is the number of rows comprising the grid.

Number of columns (# of longitudes) Field
Non-zero, positive integer. Field is the number of columns comprising the grid.

Grid element Field
Decimal value. Units are meters (with exception of the VERTCON transformation grid). Null values are expressed by -88.8888 irrespective of the nature of the grid. Null values enable encoding of irregular datum transformation fields, such as those for tidal datums.

The Ordering of the Grid Elements
The grid elements can be considered as arranged in a 2-D array. The first element is in the lower left hand, Southwest, corner of the grid. Thus the first element corresponds to the latitude and longitude fields in the grid header record. Elements are read from East to West. The rows are read from South to North. This scheme is often known as row-major order.

An example of the grid element order for a 4 x 4 grid is:

```
13  14  15  16          North
 9  10  11  12            ^
 5   6   7   8            |
 1   2   3   4            |
```

The Registration of the Grid Elements
Each grid element is located exactly at the latitude and longitude computed through the header record:

```
latitude  = llh_latitude  + (latitude_index  -1)* delta_latitude
longitude = llh_longitude + (longitude_index -1)* delta_longitude
```

The notion of cells, or cell corners is not used. It should be noted that this scheme can be used to hold both averaged or mean datum transformation values, as well as fields derived from point values of datum transformations.

All grids are registered in the NAD 83 datum. Given the accuracy and granularity of these grids, any WGS84 or ITRF georeferenced grid can be considered identical to NAD 83. If source datum transformation data are georeferenced in NAD 27, then they must be horizontally transformed into NAD 83 or an equivalent prior to grid generation.

Example of a Datum Transformation Grid (beginning of G99.GTX)

```
27.45  277.1  0.01666666666666667  0.01666666666666667 40 34
 -23.91976
 -23.94055
 -23.96038
 -23.97931
```

   … and so on, for a total of 1360 (40 x 34) grid element records.

Interpolation Method
VDatum includes three interpolation methods.   Two methods are used when a point is surrounded by grid values, and the third method is used when the point is not surrounded by grid values. When the point to be interpolated is surrounded, then either bilinear or biquadratic interpolation is used. Biquadratic interpolation is used to interpolate the NADCON horizontal datum transformations (NCLA.GTX, NCLA.GTX), the VERTCON datum transformation (VCN.GTX), the GEOID99 datum transformation (G99.GTX), and the sea surface topography datum transformations (SST.GTX). Bilinear interpolation is used as the primary method for the tidal datum transformations. When the point to be interpolated is not surrounded on four sides, as indicated by the presence of grid null values, then Shepard's method (quadratic distance weighting, nearest 1 to 3 points only) is used instead.

Description of Datum Transformation Grid Contents
        (units of meters unless otherwise noted)

DTL.GTX
Tidal model. Location of DTL relative to LMSL. This surface is "near" LMSL.

G99.GTX
GEOID99 model. Location of NAVD 88 relative to NAD 83 ellipsoid. Values are also known as geoid height. Values are negative throughout the conterminous U.S.

MHHW.GTX
Tidal model. Location of MHHW relative to LMSL. Values are always positive.

MHW.GTX
Tidal model. Location of MHW relative to LMSL. Values are always positive. MHW is closer to LMSL than MHHW.

MLLW.GTX
Tidal model. Location of MLLW relative to LMSL. Values are always negative.

MLW.GTX
Tidal model. Location of MLW relative to LMSL. Values are always negative. MLW is closer to LMSL than MLLW.

MTL.GTX
Tidal model. Location of MTL relative to LMSL. This surface is "near" LMSL.

NCLA.GTX
NADCON latitude model. Horizontal location of NAD 83 relative to NAD 27. North shift, units of arc-seconds.

NCLO.GTX
NADCON longitude model. Horizontal location of NAD 83 relative to NAD 27. West shift, units of arc-seconds.

SST.GTX
Inverse sea-surface topography. Location of NAVD 88 relative to LMSL. A value calibrated by fitting tide model results to tidal benchmarks leveled in NAVD 88. Grid accomodates the local variations between a LMSL surface, and the NAVD 88 geopotential surface. A positive value indicates that the NAVD 88 reference surface is further from the center of the Earth than the local mean sea level surface.

VCN.GTX
VERTCON 2.0 model. Location of NAVD 88 relative to NGVD 29. This grid is in units of millimeters.

DISCLAIMER: Although many of the vertical datum transformations between the North American Vertical Datum of 1988 (NAVD 88) and mean sea level, and between mean sea level and the other tidal datums, are based on tidal values from the present National Tidal Datum Epoch (NTDE, 1983 to 2001), some are based on data from older tidal epochs. NOS is in the process of updating the data in VDatum to conform to the latest NTDE. In the meantime, care should be used when applying these transformations.

REFER TO NOTES FOR EACH VDATUM AREA.

RESOURCES

Geoid Models: National Geodetic Survey
http://www.ngs.noaa.gov/GEOID/

The VERTCON PC Software: National Geodetic Survey
http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml#VERTCON
ftp://ftp.ngs.noaa.gov/pub/pcsoft/vertcon/README.TXT
http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html

Reference Frame Transformations (incorporated in HTDP): National Geodetic Survey
http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml#HTDP
http://www.ngs.noaa.gov/TOOLS/Htdp/Htdp.html

Water Level observations and analysis:
Center for Operational Oceanographic Products and Services
http://co-ops.nos.noaa.gov/index.html

CONTACTS

> Tidal Modeling Questions
> Edward Myers, Ph.D. (Edward.Myers@noaa.gov)
> Coast Survey Development Laboratory
> NOAA National Ocean Service
>
> Geoid and VDatum Tool Questions
> Jason Woolard (Jason.Woolard@noaa.gov)
> National Geodetic Survey
> NOAA National Ocean Service
>
> Bathymetry Questions
> Michael Brown (Mike.Brown@noaa.gov)
> Coast Survey Development Laboratory
> NOAA National Ocean Service
>
> Topography and Merged Data Questions
> Stephen White (Stephen.A.White@noaa.gov)
> National Geodetic Survey
> NOAA National Ocean Service

SOFTWARE VERSION
VDatum 1.06
16 September 2002, Updated 30 October 2004

The program/software is upgraded to version 1.06.

It is critical that software version 1.05 or later be used
when transforming data from 3-D (ellipsoidal) datums
into tidal datums. The bug did not affect transformations
in the opposite direction.

Version 1.06 also indicates that VDatum now supports
28 datums, including the recent ITRF2000(1997.0) and the
equivalent WGS84(G1150)

VDatum will now accept "NULL" values in the sst.gtx datum
transformation grid.

Please refer to the VDatum.DOC or VDatum.PDF for installation
and operation instructions.

Note, also, the batch mode expects 4 column input data.
"Format Error Type 2" indicates an incorrect number of columns.

VDATUM SOFTWARE HISTORY
22 November 2002

1.06
Added the WGS84(G1150) frame, total of 28 vertical datums.

1.05
Fixed error in the transformation between 3-D datums and the
tidal datums. Note: the transformation in the other direction
was correct. The error was a sign error in NAVD 88 to LMSL
datums, but did not appear when transforming from NAVD 88 to
LMSL. It only occurred when the starting datum was a 3-D
datum. All existing grids were OK.

1.04
Added the ITRF 2000(1997.0) frame, total of 27 vertical datums.

1.03
Switched to bilinear interpolation for the NAVD 88 <--> LMSL
transformations. This allows placement of null values in the
SST.GTX grids.

1.02
Added ability to create files in the file chooser code that
is invoked in batch mode.

1.01
Fixed sign error in the application of the tide datums.