Using RTK GPS for Water Surface Elevation Correction "RTK Tides" using HYPACK as an Example.

It is quite common for confusion to arise about the process used during a hydrographic survey when GPS-derived water surface elevation is incorporated into the data as an RTK Tide correction. This article explains a little about the process.

What we are discussing here might be a tide-related correction to a chart datum for coastal surveying – maybe to update navigational charts, or it might be nothing to do with tides at all. For example, surveying a river with the need to express bathymetry results as a bottom elevation on the desired vertical datum – not simply as "depth" results. Whether it is anything to do with tidal forces or not, the term "RTK Tide" is ubiquitous in hydrographic-speak to refer to vertical corrections of echo sounding data using RTK GPS.

Although there is some confusing terminology, it's a simple idea so let's try to keep it that way. First keep in mind any GPS receiver will give the user basically two things in terms of vertical positioning: height above the GPS reference ellipsoid surface and height above Mean Sea Level (MSL) where ever he or she is on the Earth. How is MSL defined? Well, a geoid surface is a measure of the strength of gravity which in turn mostly controls the height of the sea; it is logical to say that MSL height equals the geoid height and vice versa. Using RTK techniques to obtain tide information is a logical extension of this basic principle. We are measuring the GPS receiver height above a geoid.

MSL and the Geoid

Most people (and maps) refer heights to mean sea level (MSL). MSL depends on the gravity field at the observer's location. The gravity field varies around the earth depending on the density of the earth's crust. A model of gravity variations around the earth is known as a 'geoid' model. In the surveying world, it is more usual to refer to a specific geoid model rather than to MSL. And for good measure, we can define a 'geoid model' as a table of geographic points with assigned geoid values located around the earth based on measurements of the gravity field, MSL observations and extrapolation. Geoid models vary in quality, some have geoid values on a 10-mile grid, others have much denser grids. All GPS receivers have a geoid model loaded inside, to allow them to output an approximate elevation anywhere in the world – such as the EGM96 model. This large-scale geoid is inadequate for surveying purposes, so local higher resolution geoids are always used during the survey and applied to the GPS receiver output instead. This may be in hydrographic software or a GNSS data collector. Without a good geoid model, a surveyor might find a river flowing uphill!

Shape of the Earth

The surface of the Earth is described as near as possible by a spheroid, i.e. a 3D shape. To all intents and purposes for this discussion of using RTK for tide correction we consider just the one ellipsoid (meridian) on the Earth's surface where the User is located. The ellipsoid is a single "ring" whereas the spheroid is the 3D shape. Both the spheroid and the thus the ellipsoid(s) are defined mathematically and can be used for calculations. As the thickness of the Earth's crust varies the gravity field strength varies considerably and irregularly so that the geoid is not suitable as a simple mathematical reference surface like the ellipsoid. The WGS 84 ellipsoid is the fundamental reference surface for GPS receivers.

If the GPS receiver is located stationary on land the 3D position does not vary too much. However, floating on water in an area subject to tide the 3D position will change. Assuming the vessel is secured alongside a jetty the vessel will rise and fall with the tide and thus the height above the ellipsoid will follow the tide movement. Relating the rise and fall data to the local vertical reference datum is the tricky bit about the RTK tide correction.

Data Output by the Receiver

Two things the surveyor must know to use RTK for tide corrections are, One: the height of his GPS antenna above the water level. Two: the local geoid value. A GPS receiver measures the GPS antenna height above the ellipsoid. The height above the ellipsoid is presented to the surveyor as two values. These two values are given in fields 9 and 11 of the NMEA GGA message which is the most commonly referenced GPS receiver output message containing latitude, longitude, satellite number and quality information, plus height data:

$GPGGA,172814.0,3723.46587704,N,12202.26957864,W,2,6,1.2,**18.8**,M,**-25.6**,M,2.0

Field 9 gives the orthometric height above the geoid model loaded into the receiver at the specific geographic location of the antenna. This value is the best approximation to MSL given by the geoid model in the receiver. Field 9 is calculated from the measured height above the GPS reference ellipsoid by applying the separation between the ellipsoid and the geoid (MSL) at the measured position. The separation is shown in field 11.

Ellipsoid height (not shown in GGA message) = MSL (Field 9) + Separation (Field 11)

Thus, the ellipsoid height may be back-calculated from the GGA output by adding the separation and the MSL height. At this point, don't forget that the receiver will output the height of the antenna so the offset from the antenna to the water surface must be considered. Usually, what we need from the GPS receiver is the ellipsoid height and we don't really care about this MSL value. That is because we will apply a better geoid later, to get an accurate MSL.

So why do we require RTK for tides?

All GPS equipment operating without RTK corrections is not able to output elevation accurately enough to meet typical specifications for tide corrections or surveying in general. It would not be useful to gather soundings with an echo sounder at a 1cm accuracy and then apply an elevation correction that might be 0.5m in error! Typically, better than 10cm (4") or so is specified for a tide correction. So, to conduct bathymetry measurements where the water surface elevation changes during the survey, for a completely satellite-derived solution (ie no tide gauge or manual level measurements) – RTK quality positioning MUST be used.

Now for the Process

So how does the surveyor use the height information being given by the GPS receiver? First it should be said again that the geoid model loaded in his receiver is probably not very accurate. Many governmental authorities have created their own geoid models of much higher quality, valid over certain limited geographical zones. These improved geoid models are typically used.

To state the obvious, having accurately measured the height of the antenna above the water line and used RTK to accurately measure the antenna height above the ellipsoid we must accept that the quality (accuracy) of our tide data directly depends on the quality of the geoid model being used.

Most professional surveyors will have access to information about local height datums (and related information) and will be using hydrographic survey software packages which contain various software tools as well as having requisite geoid models. Where available the surveyor chooses the geoid model that is most appropriate to his survey. The software substitutes this geoid model for the one in the GNSS receiver (remember this geoid is applied to the ellipsoid height calculated from the GPS receiver output). The difference between an ellipsoid and a geoid is the separation and usually designated "N". The difference between a geoid and a chart datum is usually designated as a 'K' value.

The surveyor may be required to reduce his sounding to a different datum than to the geoid in use. He may be given the relationship of the required chart datum to the geoid value, i.e. the 'K' value. In other words, his survey soundings will be 'reduced' to a different level (datum) than the geoid. Lowest astronomical tide (LAT) is the usual datum used for hydrographic charts. If surveying on a lake or river with no further reductions to LAT to worry about, "RTK Tide" height will be the same as the newly calculated geoid height.

As an example of the facilities provided by a high quality hydrographic software program we'll use HYPACK®. To best illustrate the principle of what may be known and how it may be used for calculation tide data the following HYPACK table shows how HYPACK presents the options:

TABLE 1. Configuring your Geodesy for RTK Tide Corrections

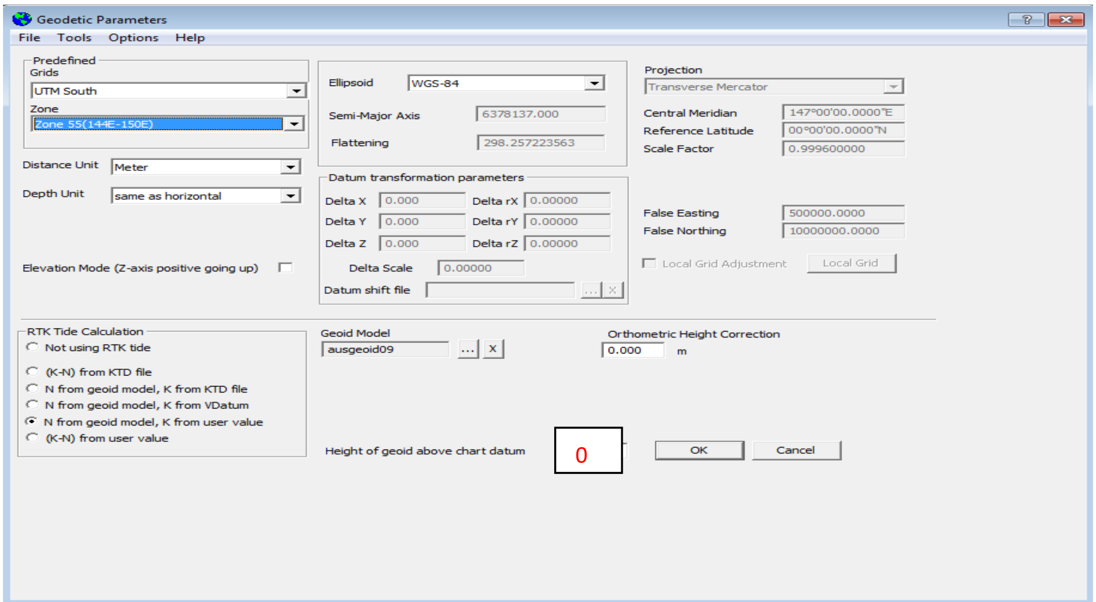
Area Description	RTK Selection	Enter Geoid?	KTD File?	Enter Chart Datum[a]?
• US Coastal Waters	N from Geoid[b], K from VDatum[c]	Yes	No	Chart Datum
• **Geoid** Present • **Constant Separation** of Geoid - Chart Datum	N from Geoid, K from user value	Yes	No	Height of Geoid above Chart Datum
• **Geoid** Present • **Changing Separation** of Geoid - Chart Datum	N from Geoid, K from KTD	Yes	Yes Geoid above Chart Datum values	No
• **No Geoid** Present • **Constant Separation** of Reference Ellipsoid-Chart Datum	(K-N) from user value	No	No	Height of Ellipsoid above Chart Datum
• **No Geoid** Present • **Changing Separation** of Reference Ellipsoid-Chart Datum	(K-N) from KTD	No	Yes Ellipsoid above Chart Datum values	No

a. These fields are enabled and disabled according to the RTK selection.

b. If you use the 2012 Geoid, you must also use the 2012 VDatum files. Otherwise, use the previous version of VDatum with Geoid 2009.

c. When using the VDatum database, you *must* use one of the pre-defined chart datums. If you enter a user-defined chart datum level, the VDatum database is ignored.The Vertical Datum field is written to the header of your file, but HYPACK® doesn't use it for anything else.

Here are the geodesy-related options in HYPACK:



For surveys with no reduction to LAT, the RTK Tide selection as shown in the HYPACK “Geodetic Parameters” example is commonly used. The geoid model in HYPACK is applied in place of the one used to generate MSL height inside the receiver. The geoid heights may be shifted up or down equally across the whole survey area using the orthometric height correction. The height of the geoid above chart datum in this case will be zero.

KTD files are created during surveys and log the result of K (height of geoid above chart datum) minus N (height of geoid above ellipsoid). This result will change over the survey area and so a KTD file allows a variable correction to the chart datum based on the surveyor’s position. One thing to remember about KTD files is that if you are surveying on the geoid datum for RTK Tide elevation results then you can ignore the VDatum or KTD options completely.

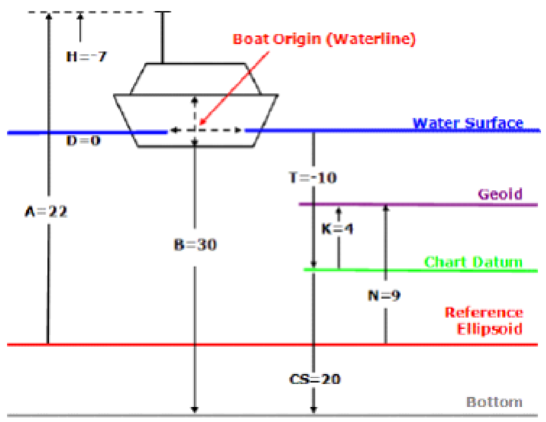
Note that HYPACK (very sensibly) provide an entry field for an orthometric height correction. This allows the computed tide correction to be further referenced to a local datum where an offset remains.

HYPACK give the following diagram to illustrate how the various known fixed and varying parameters are related.

RTK Methodology

The following figure shows all of the components needed to compute the Chart Sounding (CS = the distance of the bottom below the Chart Datum).

Obtaining Real Time Water Levels



In this scenario, a conventional survey using a tide gauge would have a tide reading of +10 metres. Applying this tide reading to the measured depth (i.e. water line to bottom) i.e. applying -10m to the measured sounding would give a chart sounding of 20 metres.

The corresponding equation when using RTK is:

Tr = -(-H) – A – (K – N) = -H – A – (K + N)

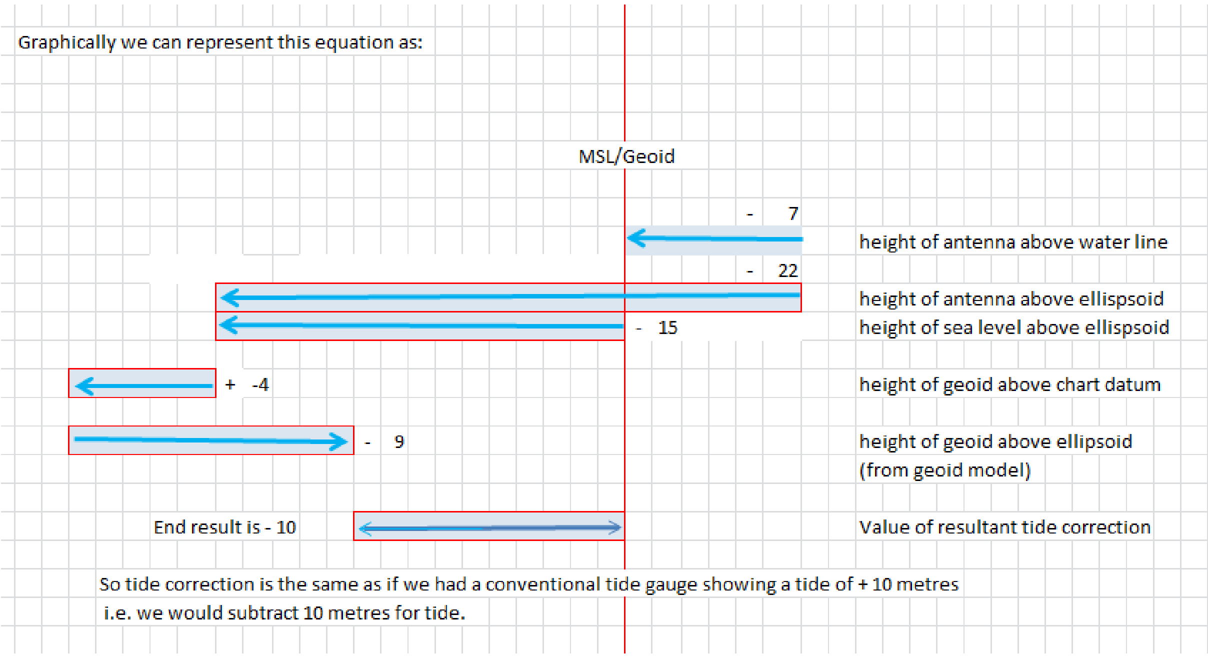
Tr is the RTK tide correction. All measurements are in the metres.

H is the antenna height above sea level, i.e. the water line of the boat, i.e. the sea surface, i.e. the geoid & MSL

A (+22) is the height of the antenna above the ellipsoid.

N-9 is the height of the ellipsoid above geoid. (in other words the ellipsoid is below the geoid)

-4 is height of chart datum above geoid. (in other words the chart datum is below geoid)



If the chart datum was MSL the tide reduction would be 6 metres, i.e. 'K' would be zero.

There is potential for difficulties when working with RTK because of quality of the geoid models and because of the reliance on good quality corrections from the RTK Base station. Waves & swell can cause short term variations in height not attributable to tide therefore it is normal to 'average' RTK heights over a period of 2 or 3 minutes (A tool for this is available in HYPACK). Variable draft is not of concern for tide data because as boat draft increases antenna height decreases