Using Differential GPS at the Boise Hydrogeophysical Research Site to Determine Installation and Boundary Locations

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ABSTRACT

Since 2009 several new installations have been placed at the Boise Hydrogeophysical Research Site and, with these new installations, updated elevations were needed to accurately integrate new measuring points with previously surveyed positions. A Differential Global Positioning System (DGPS) survey was designed to obtain position data for the new installations and to verify (or update) previously surveyed positions, which could then be converted from old coordinates into the more common UTM format and datum that will be more useful locally and globally. The details of this DGPS survey are outlined within this report and the most current installation positions are presented here as well. The main purpose of this report is to serve as a reference for quickly locating installation positions at the Boise Hydrogeophysical Research Site.

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LIST OF ACRONYMS

GPS	Global Positioning System	Satellite navigation system providing location and time anywhere on Earth
DGPS	Differential Global Positioning System	Use of fixed, ground-based reference stations to improve GPS location
NGS	National Geodetic Survey	Supports all positioning activities in the US
OPUS	Online Positioning User Service	Provides high-accuracy reference coordinates (operated by NGS)
NSRS	National Spatial Reference System	Coordinate solution provided by OPUS
NetRS	Type of GPS receiver	Used in stationary or long-term installations
CORS	Continuously Operating Reference Station	Long-term installations that serve as reference coordinates
IDTD	Idaho Transportation Department	Code for the CORS in Boise, ID
Trimble R7	Type of GPS receiver	Used in kinematic surveys
GNSS	Global Navigation Satellite System	Systems of satellites that provide geo-spatial positioning
TBC	Trimble Business Center	Program used to process GPS data
PPK	Post Processed Kinematic	A type of kinematic survey
NAD83	North American Datum of 1983	Geodetic reference system
RINEX	Receiver Independent Exchange Format	Data format for raw satellite navigation system data

INTRODUCTION

DGPS Overview

The Global Positioning System (GPS) is a constellation of satellites orbiting approximately 20,200 km above the Earth's surface. GPS is a passive system meaning that it is always available and anyone can access the signal with the proper instruments. The core components needed to collect GPS satellite data are an antenna and a receiver. The antenna collects the signal from the satellite and the receiver stores the signal and can perform certain pre-processing tasks (i.e. bandpass filtering, pseudo-ranging, etc.) as designated by the receiver program settings (Van Sickle, 2001). The basic concept of GPS is a simple triangulation; three or more GPS satellites transmit a signal that is picked up by an antenna/receiver and the travel time from all satellites is calculated to high accuracy to determine the absolute position of the antenna.

Differential GPS (DGPS) also referred to as relative positioning, uses two GPS receivers at differential locations that track the same satellites. One of the receivers is placed at a location where the absolute position is known, such as a previously surveyed position or NGS benchmark, while the other is placed at a point where the position is to be determined. A baseline (a straight line vector between the two receivers) can be calculated between the known point (base station) to the unknown point (roving station) to find the coordinates of the roving station (El-Rabbany, 2006). Accuracy of DGPS is much greater than standard GPS and can be on the order of millimeters, compared to the typical meter level accuracy of standard GPS. Accuracy is improved because both the base station and roving station are tracking the same satellites and record the same errors, drifts, and biases contained in the incoming satellite signal (Langley, 1993) and, in post-processing, the errors from the satellite signal can be removed. Spatially-correlated errors can be further reduced thereby decreasing errors in the distance between the two receivers (El-Rabbany, 2006).

Field setup for DGPS requires that at least two receivers are collecting data for the same time period. These should consist of at least one base station that is located at a known point, and one or more roving stations located at unknown points. Generally, the base station will stay at the same point for the duration of the survey and the other receivers will be moved between measured positions. The accuracy of the roving station is dependent on the length of time it stays at the same position (occupation time) as this will increase the resolution of the baseline vector calculated between two points. Multiple base stations can be used to provide greater accuracy with shorter occupation times.

Boise Hydrogeophysical Research Site Overview

The Boise Hydrogeophysical Research Site (BHRS) is located 15 km southeast of downtown Boise, Idaho on a fluvial gravel bar adjacent to the Boise River (figure 1). The gravel bar is composed of coarse, braided stream deposits of unconsolidated cobble, gravel, and sand that are Quaternary to Recent in age (Reboulet and Barrash, 2003). The aquifer is unconfined and ~18 m thick and is underlain by a continuous clay and basalt layer (Barrash et al., 2006; Barrash and Clemo, 2002). The BHRS has been the site of numerous hydrologic and geophysical investigations and over the years there have been several installations emplaced for monitoring of both the saturated and unsaturated zones (figure 1); these include wells, piezometers, tensiometer nests, neutron access tubes, and river edge reference positions. Data collected for the wells used static survey methodology and relative positioning while the river edge data were collected using kinematic GPS surveying. Obtaining accurate locations of these installations was the motivation of this report as previous surveying left some ambiguity in positioning.

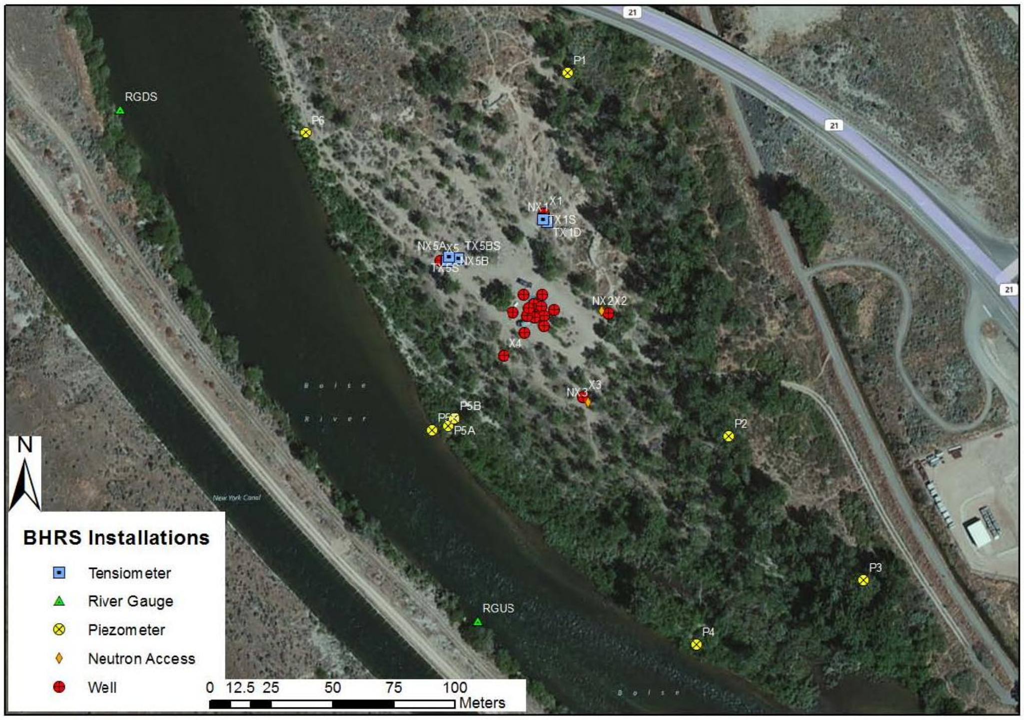

Figure 1: Satellite image of the BHRS with installations as determined by DGPS

METHODS

The methodology presented here includes both field operation of DGPS receivers and processing of DGPS data. A more detailed operating procedure for receiver setup, data collection and processing can be found in the appendix.

Survey Data Background

The National Geodetic Survey (NGS) has provided surveyed benchmarks across the United States for use in local surveying projects. The surveyed NGS benchmarks closest to the BHRS are shown in figure 2. The "NGS Data Point" location was used as a base station for many of the DGPS surveys at the BHRS. For the NGS points located near the BHRS, second order vertical resolution (sub-centimeter) was not practical, as it may be in other areas. So to make up for this lack of resolution of the base station, a long term data acquisition occupation was conducted at the NGS site and data were corrected using the continuously operating reference station network (CORS; http://www.ngs.noaa.gov/CORS) with the OPUS processor (Online Positioning User

Service; http://www.ngs.noaa.gov/OPUS). This, along with additional post-processing, provided an accurate absolute position of the NGS base station with sub-centimeter accuracy. All BHRS installation positioning is referenced with the OPUS-calculated base station and baselines processed from this known position.

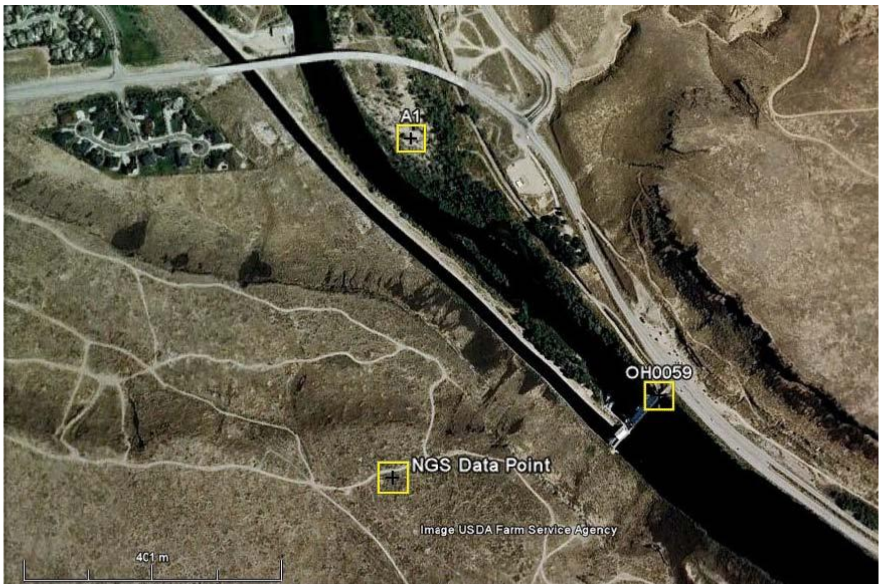

Figure 2: Aerial photograph of the BHRS and surrounding area showing the NGS benchmarks.

DGPS requires that two antenna/receiver units (NetRS units) are collecting data from the same satellites during the same time period. One of these units should be positioned as the base station and remain there for the entirety of the survey; the other unit (roving station) can be moved to different positions to obtain the relative position between roving unit and base station. Equipment for each position includes an antenna, receiver, tripod, and power source (figure 3). The tripod is placed directly over the point to be measured and leveled. The distance from the top of the tripod to the desired position (e.g. land surface or measuring point) is measured and recorded. This distance between the antenna center and top of tripod should also be measured but most processing programs have built-in antenna offsets for popular antenna. The receiver connects directly to the antenna and for the BHRS surveys was powered by a 12 volt DC battery.

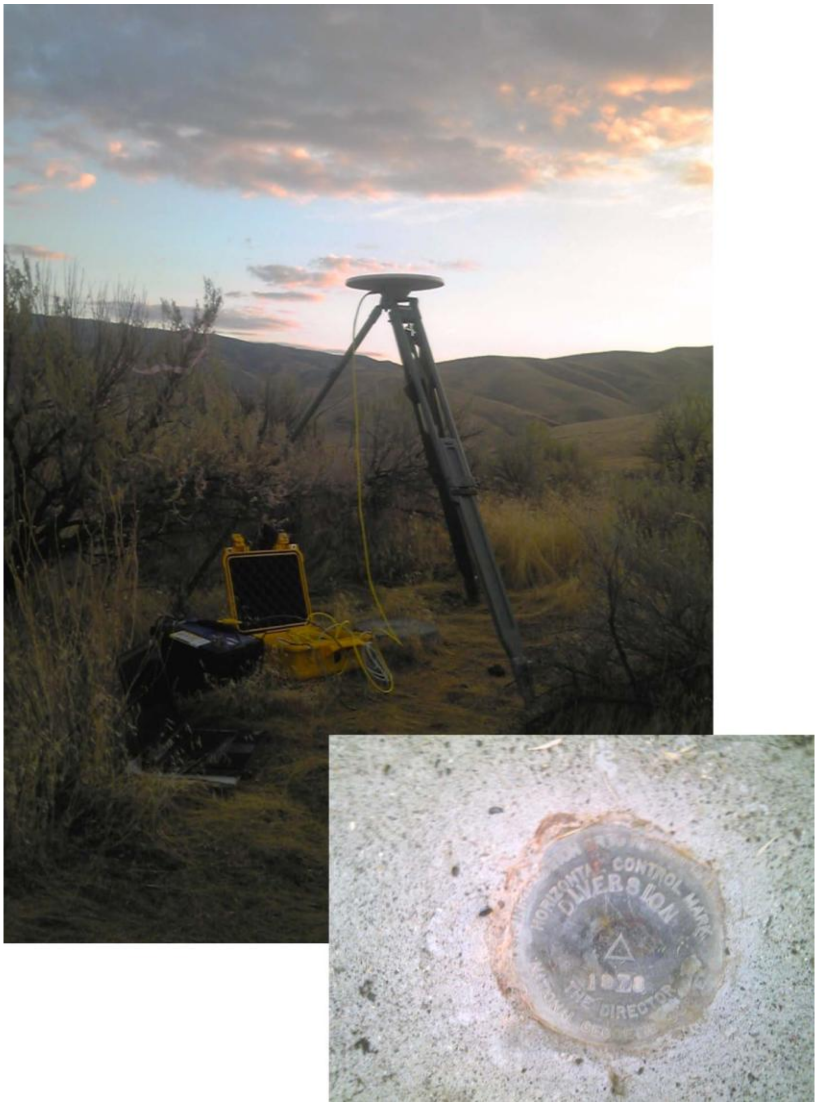

Figure 3: Photograph of NetRS and Trimble antenna data acquisition at the Diversion Benchmark (inset). NetRS receiver is housed in the yellow case and powered by a car battery

Field Operation – Static Surveying

Static surveys (where continuous local base station data are available) have been approximately 1.5 hours in length for most of the BHRS installations. This occupation time along with relatively clear positioning (no blocking structures), resulted in differential vertical positioning errors of < 1 cm. This accuracy has also been achieved with acquisition periods as short as 10 minutes but testing times were extended to insure appropriate accuracy when collecting data. Longer collection periods help offset the chance of patchy satellite coverage or dropped satellites, as well as ambiguities arising from surrounding vegetation or other obstructions. One installation (P3) was located under dense vegetation and accurate positioning could not be resolved through DGPS. P3 was therefore surveyed using a Trimble Total Station from known points produced from the DGPS surveys. Point surveys can also provide absolute positioning with high accuracy without a NetRS receiver located at a base station, but the data acquisition period should be lengthened to a period greater than four hours.

Survey data are processed through OPUS but accuracy obtained varies considerably depending on satellite reception and proximity to regional CORS sites. CORS commonly available through the OPUS processor are located at distances between 19 km and 165 km from the BHRS (note: the Boise CORS (IDTD) was down for much of the acquisition period thus increasing required occupation time). Longer, continuous occupation time reduces the uncertainty in calculating positions from CORS at this distance.

Field Operation – Kinematic Surveying

Kinematic surveys are designed to acquire less accurate but more rapid position data and were used to obtain elevation profiles at specific locations across the BHRS as well as synoptic river edge position. Kinematic surveys use the Trimble R7 GNSS receiver paired with a Trimble handheld unit that runs the Controller software. A portable tripod can be used with this survey that allows the operator to temporarily stop at points during the kinematic survey and collect point data with greater accuracy. Accuracy for this type of survey varies considerably with the occupation time but typically, RMS errors less than 5 cm can be obtained with one minute occupation times if the data are processed using another local receiver (base station). A fast static solution can also be obtained using the Trimble R7 GNSS receiver where data acquisition takes approximately eight minutes per location but results in RMS error < 3 cm. This level of resolution is ideal for elevation profiles where total relief is more than 100 times the resolution (e.g. at the BHRS) or where vertical accuracy is compromised for lateral resolution (river edge position).

PROCESSING DATA

Trimble Business Center software was used to process all baselines between the base station and the roving station points. Raw data files were uploaded into the software where corrections were made for antenna height and were automatically differentially corrected based on overlapping time codes in the raw receiver data. Baselines can be processed between all overlapping data and vectors can be drawn between the base station and roving station points. In the baseline processing report output by the Trimble software, accuracies are reported for each of the vectors in XYZ format along with local coordinate measures in a system and geoid provided by the user. The data in this report were processed using the system specifications shown in table 1.

Table 1: Project information and coordinate system information for new positioning using differential GPS

Name:	UTM
Datum:	NAD 1983 (Conus) CORS96
Zone:	11 North
Geoid:	GEOID09 (Conus)

RESULTS

Static Survey

The Diversion Benchmark (OH1220 in figure 3) was used as the base station for most DGPS collections at the BHRS. To obtain high accuracy positioning for this point, a static survey was conducted and differentially corrected using OPUS static processor and an additional local antenna and receiver. First order horizontal position described by the NGS information was confirmed with the static survey and derived data were used for the base station position (table 2) in baseline processing (this point was used as the projection for the majority of baselines during GPS surveying at the BHRS with a calculated horizontal and vertical accuracy of +/− 0.002 m and 0.006 m, respectively). Satellite data were collected at each position listed in table 3 while simultaneously collecting data at the Diversion Benchmark for use in differential corrections. Positions were determined by processing vector baselines (between 440 m and 660 m in length) from the benchmark to the measuring points at each installation using Trimble Business Center software. Criteria for successful position rendering include a vertical precision of less than 1 cm at

95% confidence level. For comparison, table 4 shows the final DGPS-derived XYZ locations form table 3 along with the original surveyed elevations. In general, differences in elevations were between 0.5 and 0.8 m which may reflect increased land surface/geoid elevations since the original survey was conducted in 1998.

Other BHRS positions were determined using multiple NetRS units for extended occupations (greater than 2 hours). Surveys conducted using this method required longer occupation time, but allowed for all new point collection without re-occupying the known NGS data point. Previously surveyed positions served as known points (base stations) and additional surveys were used as QA/QC for previous work. Given adequate time and satellite reception, all re-occupations returned positive checks for previous positioning with absolute location being within the precision listed in table 3

Table 2: Coordinates for the diversion benchmark (NGS OH1220) from OPUS using the static processor and local baseline processing.

Diversion Benchmark NGS OH1220	
Easting [m]	572846.219
Northing [m]	4820888.090
Elevation [m AMSL]	957.904
Ellipsoid Height [m]	941.976

Table 3: Global coordinates (based on projection outlined in table 1) of the specific BHRS installation measuring points for all GPS surveyed points at the BHRS

Point	Easting [m]	Northing [m]	Elevation [m]	Horz. Precision [m]	Vert. Precision [m]
A1	572891.740	4821441.441	850.846	0.003	0.005
X1	572895.463	4821481.441	851.016	0.002	0.004
X2	572921.732	4821440.641	850.895	0.002	0.004
X3	572911.504	4821406.577	850.477	0.002	0.003
X4	572878.909	4821423.456	850.013	0.003	0.004
X5	572853.159	4821461.926	850.547	0.002	0.007
P1	572905.318	4821538.888	850.268	0.002	0.003
P2	572970.873	4821390.535	850.267	0.002	0.006
P4	572957.814	4821305.237	849.309	0.003	0.006
P5	572854.626	4821396.839	849.361	0.003	0.004
P6	572798.025	4821514.412	849.398	0.003	0.004
RGDS	572722.599	4821524.175	849.359	0.003	0.004
RGUS	572868.182	4821314.827	849.431	0.003	0.005
Diversion	572846.219	4820888.090	957.904		

Table 4: Comparison of old and new measuring point elevations for selected installations at the BHRS.

Well	Old Z [m AMSL]	DGPS Z [m AMSL]	ΔZ [m]
A1	850.22	850.846	0.626
X1	850.40	851.016	0.616
X2	850.27	850.895	0.625
X3	849.80	850.477	0.677
X4	849.39	850.013	0.623
X5	849.93	850.547	0.617
P1	849.481	850.268	0.787
P2	849.690	850.267	0.577
P4	848.781	849.309	0.528
P5	848.791	849.361	0.570
P6	848.518	849.398	0.880
RGDS	848.615	849.359	0.744
RGUS	848.75	849.431	0.681

Kinematic Survey

The relative position of the river edge has been monitored at the BHRS biweekly from 2010 through July 2013 as lateral distance from a known location to the river edge. For much of that time, three locations (P4, P5, and P6) were used to define the river boundary and track changes in river edge position (Thoma and Barrash, 2012). This provided a good set of the change in river edge position but was limited to these three permanent installations. A continuous river edge was therefore defined on November 3, 2011 using the Trimble R7 GNSS receiver to walk the river boundary (figure 5). The roving unit allows the user to continuously collect XYZ data while walking. Accuracy can be increased by collecting stationary point data for a longer occupation time along the line with horizontal accuracy typically < 10 cm for these points. These data were not collected regularly but are an example of how DGPS can be used to quickly obtain accurate data in a dynamic system.

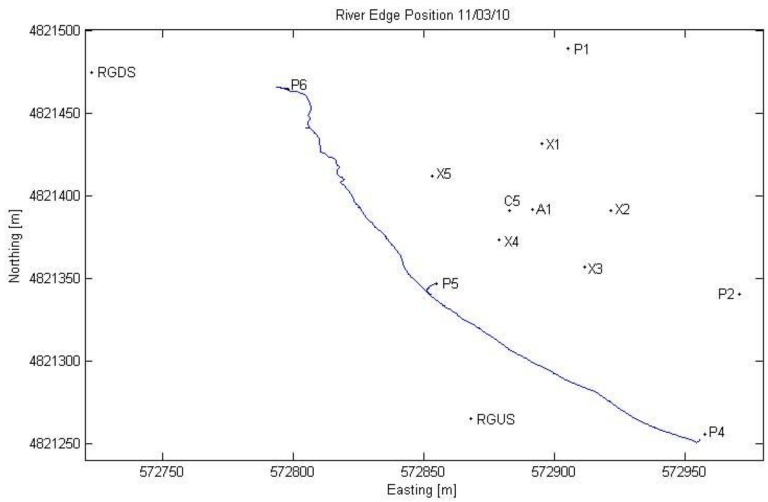

Figure 4: River edge boundary of the Boise River (outlined in blue) on 11/03/11 as determined with Trimble R7 GNSS receiver through a kinematic survey.

SUMMARY AND CONCLUSIONS

Global positions reported in this report and in the appendix are given in UTM 11N using NAD1983 as the horizontal control datum. All elevations are reported in relation to the GEOID09 vertical datum (http://www.ngs.noaa.gov/GEOID/GEOID09/). A local coordinate system was also defined at the BHRS using well A1 as the origin (0,0) and XY coordinates based on NAD1983 horizontal control and elevations on the local grid are reported as absolute elevations (not relative to A1 MP). After collecting point data for a selection of the inner wells, it was observed that the relative vertical positions to A1 were similar to that recorded from previous surveys but with a consistent offset. Henceforth a uniform offset of 0.626 m was applied (presumably the difference in vertical datum between the two surveys) to the originally-surveyed elevations to correct them to the newest survey. This offset was verified on two separate occasions using NetRS receivers. Based on this finding, it was decided to use only data from the NetRS receivers and use previous survey differences to determine elevations for the inner well field positions.

The differential GPS campaign described in this report was used to determine the position of recent installations (2009 – 2011) at the BHRS that were completed after the initial survey (1998) of the well field. Instead of applying new positions to the old survey data (which were based on the local state plane coordinate system), new global and local positions were derived that would eliminate any errors inherent in the conversion of positional data between different projections. This research also puts forth a database populated with accurate and consistent installation positions processed at one time with the same coordinate system, equipment, and software, and thus provides more reliable relative positions. The database created can be updated as needed with future installations using the already established coordinate system and collection procedures outlined herein.

ACKNOWLEDGMENTS

This work is supported in part by the U.S. Army RDECOM ARL Army Research Office under grant W911NF-09-1-0534. Special thanks are due to HP Marshall for the use of DGPS equipment and for providing instruction for its use.

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APPENDIX

Summary of BHRS Positions

Local Grid			Global Coordinates		
MP	**X [m]**	**Y [m]**	**Easting [m]**	**Northing [m]**	**MP Z [m AMSL]**
A1	0.000	0.000	572891.740	4821441.441	850.846
B1	-0.140	2.850	572891.600	4821444.291	850.916
B2	3.050	1.760	572894.790	4821443.201	850.876
B3	3.550	-2.100	572895.290	4821439.341	850.826
B4	0.020	-2.610	572891.760	4821438.831	850.746
B5	-3.190	-1.770	572888.550	4821439.671	850.736
B6	-2.300	1.390	572889.440	4821442.831	850.836
C1	3.209	6.636	572894.949	4821448.077	850.956
C2	8.059	0.648	572899.799	4821442.089	850.866
C3	3.901	-5.905	572895.641	4821435.536	850.786
C4	-4.157	-8.803	572887.583	4821432.638	850.556
C5	-9.076	-0.389	572882.664	4821441.052	850.636
C6	-4.601	6.943	572887.139	4821448.384	850.786
X1	3.723	40.000	572895.463	4821481.441	851.016
X2	29.992	-0.800	572921.732	4821440.641	850.895
X3	19.764	-34.864	572911.504	4821406.577	850.477
X4	-12.831	-17.985	572878.909	4821423.456	850.013
X5	-38.581	20.485	572853.159	4821461.926	850.547
P1	13.578	97.447	572905.318	4821538.888	850.268
P2	79.133	-50.906	572970.873	4821390.535	850.267
P3	126.741	-121.922	573018.481	4821319.519	849.360
P4	66.074	-136.204	572957.814	4821305.237	849.309
P5	-37.114	-44.602	572854.626	4821396.839	849.361
P6	-93.715	72.971	572798.025	4821514.412	849.398
P5RI	-42.233	-48.389	572849.507	4821393.052	848.493
P5RO	-42.233	-48.389	572849.507	4821393.052	848.493
P5AD	-35.582	-46.811	572856.158	4821394.630	849.333
P5AM	-35.582	-46.811	572856.158	4821394.630	849.340
P5AS	-35.582	-46.811	572856.158	4821394.630	849.341
P5BD	-33.120	-43.726	572858.620	4821397.715	849.373
P5BM	-33.120	-43.726	572858.620	4821397.715	849.352
P5BS	-33.120	-43.726	572858.620	4821397.715	849.343
RGDS	-169.141	82.734	572722.599	4821524.175	849.359
RGUS	-23.558	-126.614	572868.182	4821314.827	849.431
NX1	5.250	38.385	572896.990	4821479.826	850.237
NX2	27.239	0.056	572918.979	4821441.497	850.183
NX3	21.734	-37.108	572913.474	4821404.333	849.715
NX5	-37.431	22.815	572854.309	4821464.256	849.857
NX5B	-33.390	23.584	572858.350	4821465.025	849.815
TX1D	5.111	36.632	572896.851	4821478.073	850.387
TX1S	3.325	37.499	572895.065	4821478.940	850.294
TX5D	-35.935	20.708	572855.805	4821462.149	849.960
TX5S	-35.325	22.488	572856.415	4821463.929	850.009
TX5BD	-31.730	21.885	572860.010	4821463.326	850.028
TX5BS	-30.782	21.854	572860.958	4821463.295	850.112

Trimble GPS Overview

This is a tutorial on downloading data from the Trimble NetRS and the preprocessing needed to use Trimble Business Center.

- Materials Needed
  - Computer with Ethernet port
  - Cat-5 Ethernet cable (located with each receiver, in the Pelican case) Note: While it might not be absolutely necessary, connection via Ethernet cable has worked better when the connected computer has a static IP address set. If you experience problems connecting, try setting a static IP and disabling any wireless communications
- Plug Ethernet cable from power connection on receiver to computer (Figure A-1)

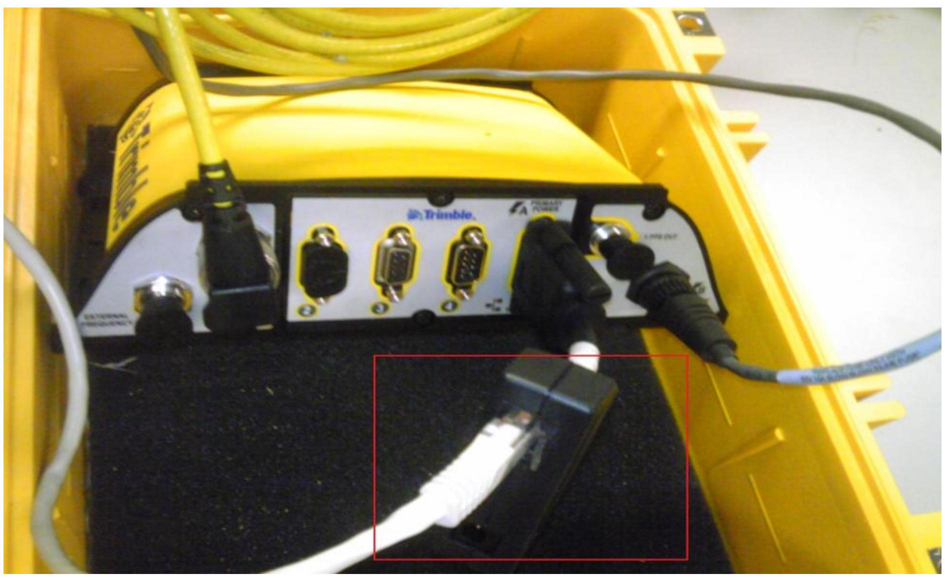

Figure A-1: Connection panel for Trimble receiver. Connection can be made through Ethernet cable (preferred) or serial cable

- Open an Internet browser and navigate to http://192.168.1.10
  - If the Trimble home screen does not open, close the browser, wait a minute, and repeat the previous step
  - When connected, the home screen (Figure A-2) will provide the receiver details
    - The serial number on the home screen should match the receiver. The default system name for all receivers is the serial number
  - The left hand menu provides details about the receiver configuration and allows the user to view real-time satellite information when connected to an antenna

- Click ‘Satellites’ to display the current configuration of satellites and to view the satellites that are currently sending information to the antenna
  - Reviewing this information during field setup is important to ensuring your location has a clear sky view
    - Note: 8-10 satellites are common for relatively open spaces. Sub-centimeter accuracy has been difficult to obtain with less 6 satellites

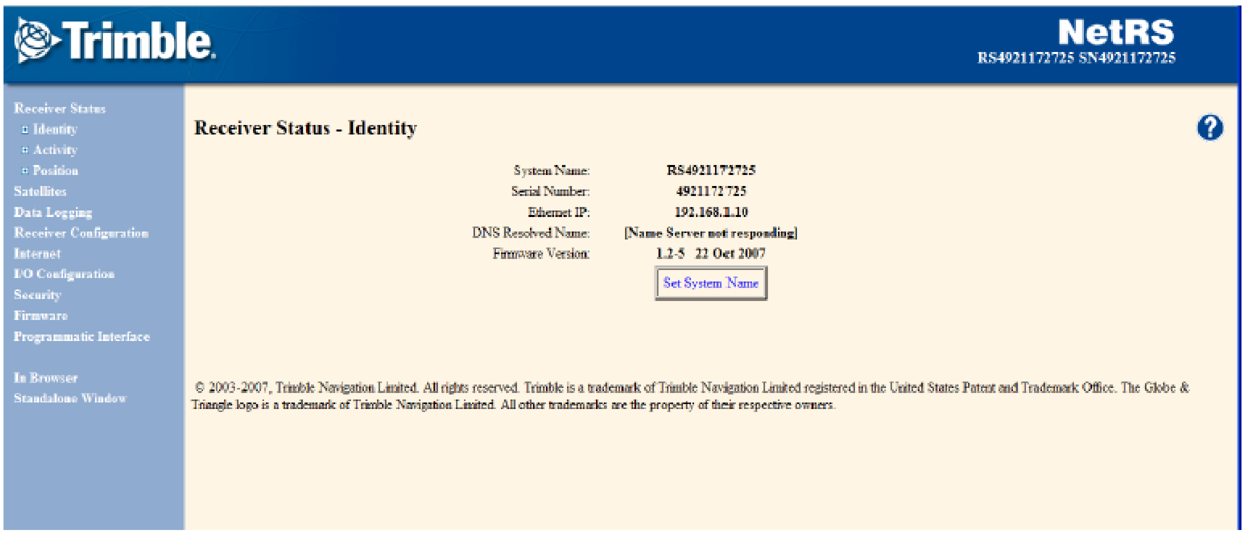

Figure A-2: Screenshot of the Trimble home screen displaying receiver details

- Click ‘Data Logging’ to view your current recording session
  - Powering up the receiver will usually start the last logging program loaded to the receiver but clicking through this at setup will ensure the correct configuration file is running and data files are being saved
  - The ‘Session Name’ shows the current test (configuration file) that is running
  - Click the test name to view the specifics
    - Current default is set for longer deployments with continuous collection of satellite information but with data files saved at 10 min intervals. Minimal pre-processing options are applied at the receiver but can be applied using Trimble Business Center processing software
    - If you wish to make changes to this file, make sure to save the new file using a different name so other configuration files are not overwritten
- Under ‘Data Logging’ on the left hand menu, click ‘Data Files’ to view the receiver

memory

- Folders are created for each month with a sub folder for each day. Click through to the current day and time to ensure your data are being recorded and files are being created.

- An example file path is shown in figure A-3. Default file names include the receiver name (RS4921172725), date (20101006; October 06, 2010) and time (13:50 UTC)

- Data can also be downloaded directly from the 'Logged Date Files' screen. If you don't have many files to download, the easiest way to get the files is to right-click the file name and save the file to your computer

    - For larger sets of data, FTP can be used to automate the downloading process

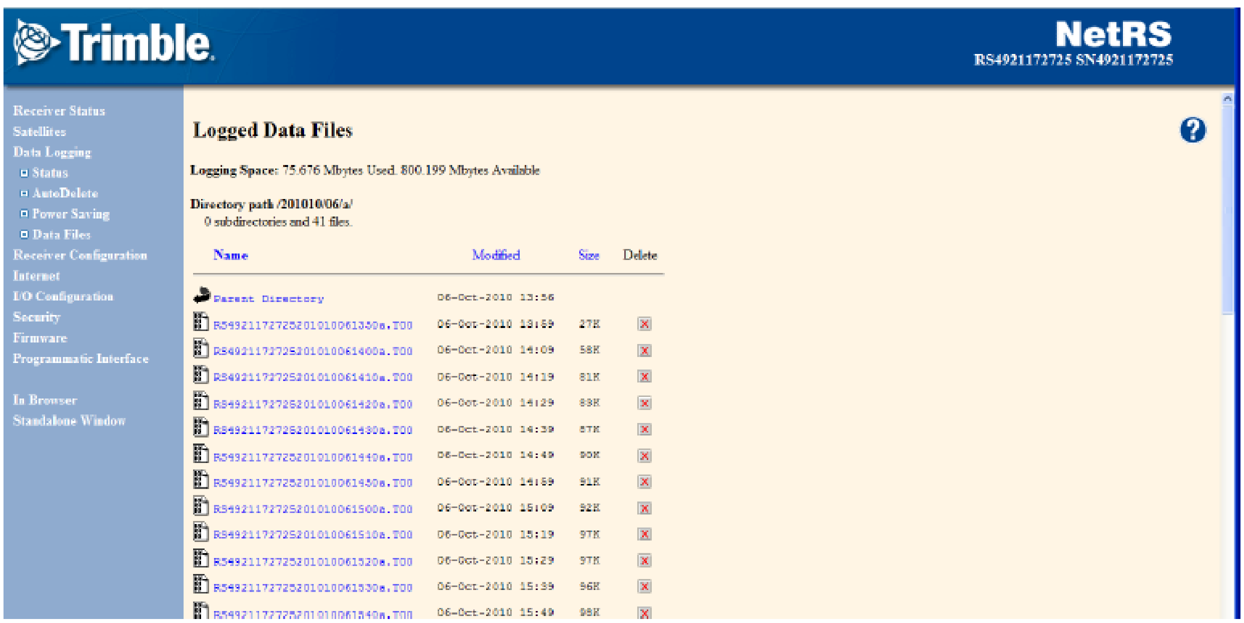

Figure A-3: Screenshot of the Trimble home screen displaying receiver details. Files can be saved directly from this screen

Creating files to upload to OPUS

Overview

Introduction text from: http://www.ngs.noaa.gov/OPUS/about.html

This Online Positioning User Service (OPUS) provides you with simplified access to high-accuracy National Spatial Reference System (NSRS) coordinates: all you need is a clear view of the sky and a survey-grade Global Positioning System (GPS) receiver. OPUS processes your GPS data files with the same models and tools which help manage the nation's Continuously Operating Reference Station (CORS) network, resulting in coordinates which are both highly accurate and highly consistent with other users. Your computed NSRS position is sent privately via email and, if you choose, can also be shared publicly via the NGS database.

- Materials Needed
  - Computer
  - Trimble Data files (filename.T00)
  - RINEX conversion software
    - http://www.trimble.com/trimblerinex_ts.asp
  - Dat2Rin software (including rinmerge.exe)
    - http://www.trimble.com/support_trl.asp?Nav=Collection-3621

Convert to RINEX

- Open Convert to RINEX Program
  - Under ‘File,’ select ‘Open.’ Select all files from station
  - The files will be scanned and you will be able to view data associated with each file
    - The file name can be changed by clicking to the right of the ‘RINEX file name w/o extension’ field. A shorter or more descriptive name can be helpful in merging the file as that process is DOS based
    - Under ‘File.’ select ‘Convert Files’
  - The files are now in RINEX form and could be uploaded to OPUS if they were of appropriate length
    - OPUS uses two processors for computing absolute position
      - Rapid Static requires single data files between 15 min and 2 hr
      - Static requires data greater than 2 hr
- Merging Data Files
- Place rinmerge.exe in the folder containing the raw data files
- Open a DOS prompt and navigate to the RINEX files (we’ll be using .10o files)
  - To combine 3 files into 1 file (mergedfile.10o) type the following command (spacing is important)
    - rinmerge _lename1.10o+_lename2.10o+_lename3.10o merged_le.10o
  - Warnings may appear in the DOS window pertaining to Unexpected Leap Seconds or unrecognized records in headers but should be followed by a ‘File merge successful’ output.
    - Tip: The program has a tendency to crash when combining numerous files (7+). With 10 minute data files, it is recommended to merge the files into hourly files, then combine hourly files into a daily file for upload to the Static OPUS processor.
  - The new file (with your given filename) should be in your folder and ready for upload to OPUS

Upload to OPUS

- Navigate to http://www.ngs.noaa.gov/OPUS/index.jsp (figure A-4)
  - The 'View' and 'About' tabs have a wealth of knowledge and links about how OPUS works and links to other sources of information about processing and creating files for upload
  - Enter the email address to where you want your solution sent
    - Note: OPUS may not recognize @u.boisestate.edu accounts. Just use another email if you get an 'unrecognized email' error
  - Upload your merged .10o file
    - You can upload multiple .10o files through a single .zip (must be .zip). Doing this will not join .10o files. Each one will be processed separately and you will receive individual reports for each file in the .zip
  - Select the TRM41249.00 Trimble Zephyr Geodetic with GP. This will include the offsets listed on the antenna in elevation calculations
  - Add the antenna height based on the measurement you made in the field. The antenna height is the distance between your measuring point and the base of the antenna (or top of the tripod mount)
  - Select a processor to use based on the length of your record and an email will be sent within a few minutes
    - The options button allows you to select specific CORS to use (default option will pick the nearest operating stations) along with some specific projection objects. Most useful of the options is the ability to receive an .xml file of the results. TBC allows for the direct upload of .xml files which can serve as checks (or absolute positions) for baseline calculations

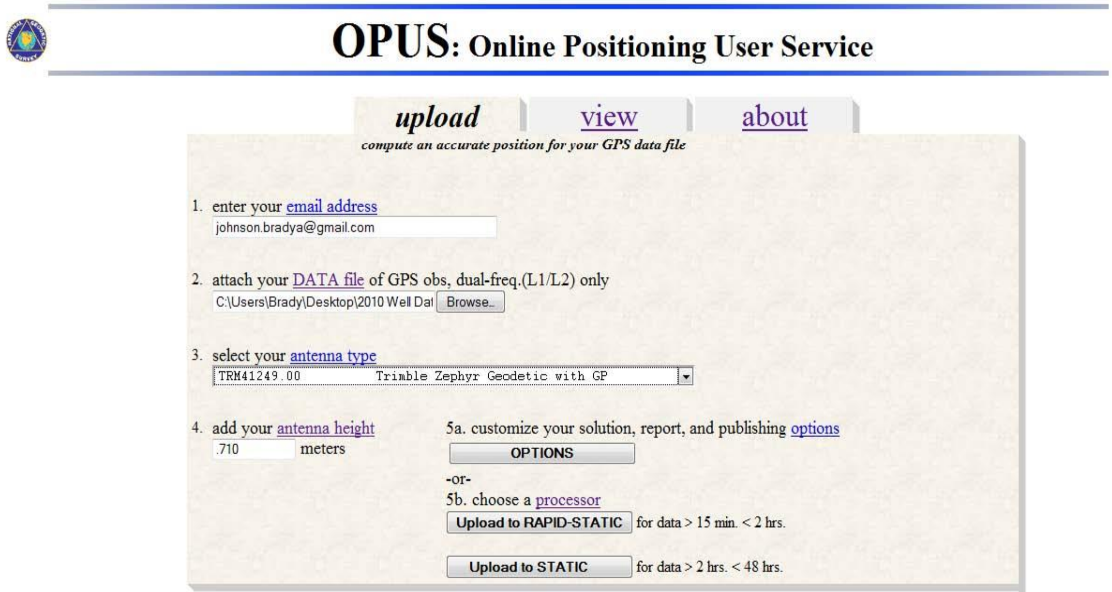

Figure A-4: Upload screen for OPUS