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Systematic Approach To A GIS Concluding With An Accuracy Analysis

Authors Note

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DATA COLLECTION OF NATIONAL GEODETIC SURVEY MONUMENTS USING BAD ELF'S BLUETOOTH GPS TO DETERMINE IF THE DEVICE PRODUCES CONSISTENT RESULTS AT ONE METER CEP

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Contents

Introduction

This white paper is intended for professionals looking to start a GIS for data collection using ESRI Collector in conjunction with Bad Elf's Bluetooth GPS receiver. This paper will provide a systematic guide to:

- Setting up a Geodatabase
- Starting a GIS
- Publishing to ArcGIS Online
- Using ESRI Collector
- Accuracy Analysis
- Cartographic Representation
- Final Results

Required Apparatus

Supplied by the Geospatial Technologies department at Mesa Community College, https://www.mesacc.edu/departments/cultural-science/geographic-information-systems, were an ESRI ArcGIS Online account which is required, licensing to ArcGIS Desktop and the ESRI Collector App. Bad Elf, LLC supplied their handheld Bluetooth GPS receiver https://bad-elf.com/ in correlation with the Bad Elf App for this study.

Procedure

There are three ESRI products necessary for preparation in using Bad Elf's handheld Bluetooth GPS receiver for data collection in concurrence with ESRI Collector. First, using ArcCatalog to create a geodatabase, domains, feature datasets and feature classes. Second, the feature classes must be prepared for publishing to ArcGIS Online using ArcMap. Third, once published online the project then must be shared for viewing in ESRI Collector. Fourth, the ESRI Collector app can be downloaded on a smartphone or tablet for data collection in the field.

The goal of this project is to determine if Bad Elf's handheld Bluetooth GPS receiver can produce consistent results at 1 meter CEP. To follow through with this task, using known and documented point locations are necessary. The location points used are National Geodetic Survey monuments researched at http://www.ngs.noaa.gov/.

There are two tasks involved for field collection. First, to survey at least 15 to 20 monuments using ESRI Collector. To supply at least 20 surveys, 40 monuments were chosen to allow for destroyed or unlocated marks. Second, to provide a minimum of 15 minute raw logs of those monuments using the Bad Elf app.

Finally, two simple delta positional errors have been calculated using horizontal accuracy between NGS monuments and Bad Elf's Bluetooth GPS surveys, along with the

computation of the raw logs to those monuments. A gradational point model using size to represent distance of the delta differences have been published as a final product in ArcGIS Online. The final cartographic map representation can be viewed at https://bad-elf.com/pages/bad-elf-accuracy-study.

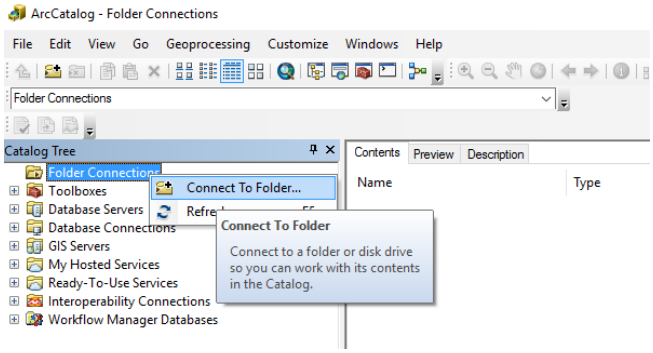
Constructing the Geodatabase

Constructing a geodatabase can be accomplished in ArcMap, though the use of ArcCatalog through ArcMap has limited functionality. Therefore, the following procedures will be completed directly in ArcCatalog.

Geodatabase

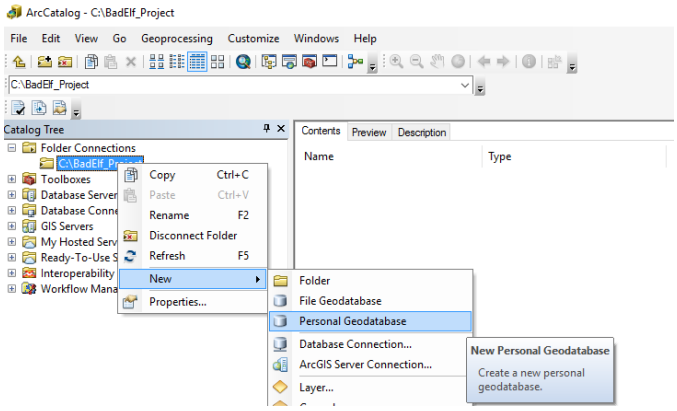
Setting up a geodatabase provides a central location for GIS data storage. Within a geodatabase, domains are used to make dropdown menus for adding consistent naming conventions in a data field. Also datasets are useful for organization and keeping consistent geographic coordinates and projections between feature classes and shapefiles.

Steps to create a new geodatabase are as followed:



First, connect to the project folder. Right click on [Folder Connections] and select [Connect to Folder]. In the window that follows, browse to the intended project folder and click [OK].

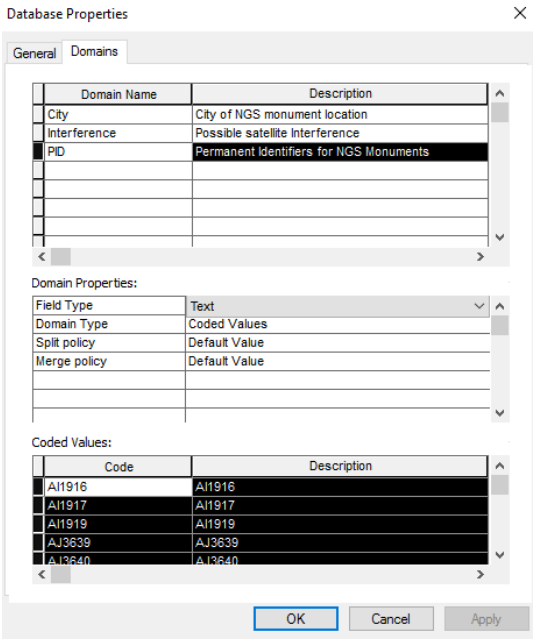
Second, right click on the project folder and select [New Personal Geodatabase] and give the geodatabase a name. There is also the option to connect to an already existing database.



Domains

Domains are important for assigning attributes and keeping a consistent labeling scheme within feature class fields. When adding or editing data, if a domain is applied to the feature class, a dropdown menu will be provided for uniformity. Domains are created

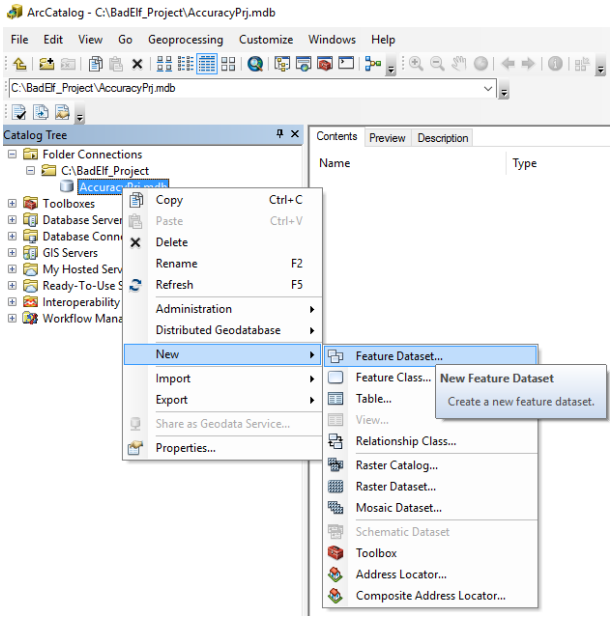
within the properties of the geodatabase. Once the [Database Properties] window is open click on the [Domains] tab.



Add fields that have been predetermined to contain a dropdown list. In this project, there are six domains that will be applied to different fields in the feature classes. Once [Domain Name] and [Description] are added, the [Field Type] must be designated. The [Field Type] is the data type of the domain and it is essential that it matches the feature class field type when created. Next [Coded Values] must be added. Since the [Field Type] is [Text], alphanumeric codes can be assigned. The [Code] and [Description] are required to be entered simultaneously before moving on to the next code.

Feature Datasets

Feature Datasets within a geodatabase are very useful for grouping feature classes that share the same spatial reference. However, while editing, the dataset is locked to multiple users so only one person can implement edits at a time. Three separate datasets were constructed in this project; the Bad Elf data collection, the National Geodetic Survey data, and an accuracy analysis dataset.



To add a feature dataset to the geodatabase right click on the geodatabase and select [New]. In the dropdown menu select [Feature Dataset]. When the [New Feature Dataset] window appears, enter a name for the dataset. In the following window select the coordinate system that will be specific to the project. In this case the projected coordinate system NAD_1983_HARN_UTM_Zone_12N was chosen. No vertical coordinate system was used in the following window. Finally select XY, Z and M tolerances or leave the default values provided.

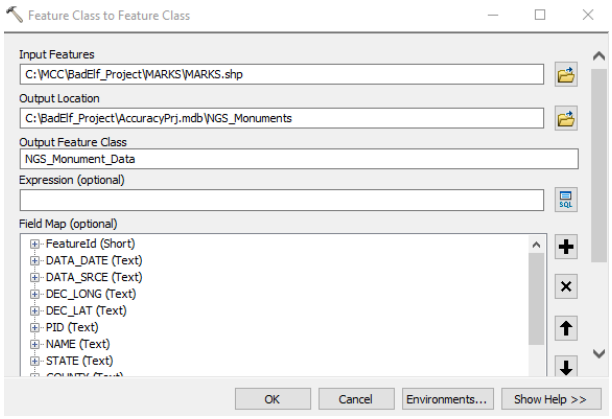
Feature Classes

In the initial stages of this project, feature classes are added to two of the three feature datasets. The accuracy analysis dataset will be used in conjunction with the field data to determine whether the handheld Bad Elf Bluetooth GPS receiver produces consistent results at 1 meter CEP.

National Geodetic Survey Monuments

The NGS monuments dataset can be used to import the National Geodetic Survey shapefile acquired from http://www.ngs.noaa.gov/ into its own feature class. If there are any differences in the spatial reference for the shapefile, the data will automatically be converted to the spatial reference designated for the feature dataset. Alternatively, ArcToolbox can be used to change the datum manually. To import the NGS monument data, right click on the feature dataset and select [Import] then [Feature Class].

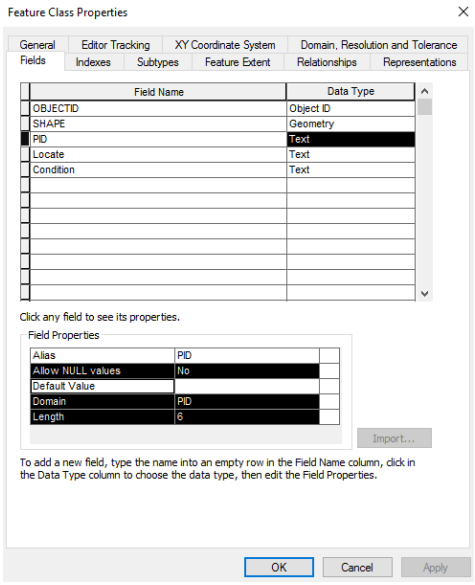
Within the [Feature Class to Feature Class] window click on the folder icon located next to [Input Features]. Click on the [Connect to Folder] icon and browse to the NGS shapfile for importation. Verify the [Output Location] is correct and assign a name to the feature class under [Output Feature Class]. A review of the NGS Monument metadata shows much of the data is not necessary for this project.



New NGS Feature Class

Since the monuments are located within eight different cities of the eastern suburbs of Phoenix Arizona, a simple way to locate the monuments and add a few attributes within ESRI Collector will be helpful. To do this, a new feature class is required. This feature class will also contain fields to identify whether the monument is located, accessible or destroyed and if the condition of each monument that is located happens to be good or poor. The most important field to be added to all the feature classes is the permanent identifier field or PID. The PID will be the primary key and the only way to join the data for analysis. These fields will be designated domains created in the geodatabase.

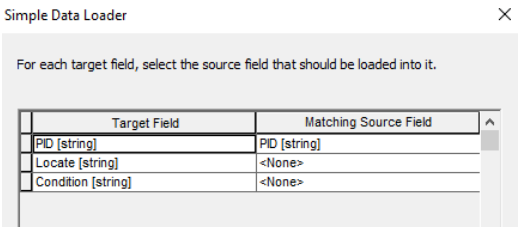
To create the new feature class right click on the feature dataset and navigate to [New] then [Feature Class]. In the [New Feature Class] window name the feature class and select [Point Features] under [Type of features stored in this feature class] since the NGS monuments are point data.



In the following window within the [Fields] tab enter the [Field Name] and [Data Type] for each field within the feature class. The [Field Properties] box is where null values are allowed, a domain is added if necessary, and the length of the text within the field is designated.

Next the NGS metadata must be loaded to this new feature class. The coordinates are assigned to the point data when PID is loaded. Right click on the new feature class and navigate to [Load] then [Load Data]. Within the [Simple Data Loader] window click the folder icon for [Input data] and browse to the initial feature class loaded in the dataset. Add this to the [List of source data to load].

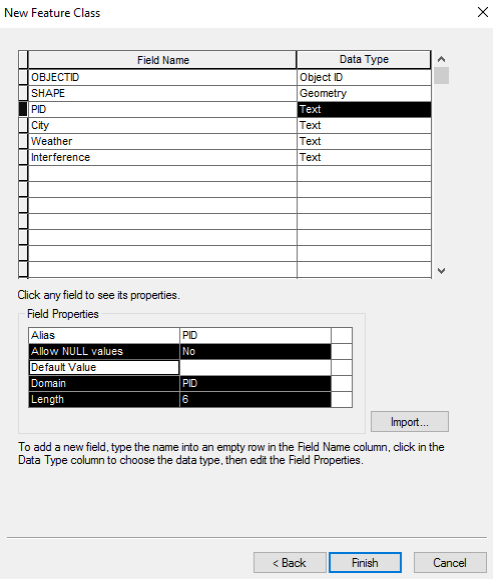
When [Target Field] and [Matching Source Field] are displayed, the common field in both feature classes is PID (Permanent Identifiers). This will be the connection between both feature classes so the NGS metadata will be loaded to the new feature class. The fields [Locate] and [Condition] should be [Null] for each of the monument PID's. These fields will be edited and updated through ESRI Collector.



Bad Elf Data Collection Feature Class

The second feature dataset is for the Bad Elf data feature classes. There will be two feature classes in this dataset but the second feature class won't be loaded till after the field collection. The second feature class will contain the RINEX output derived from the 15 minute raw logs with Bad Elf's handheld Bluetooth GPS receiver at each monument where accessible to do so.

The first feature class will contain fields loaded from a utility that must be inserted into ArcToolbox along with some additional descriptive fields.

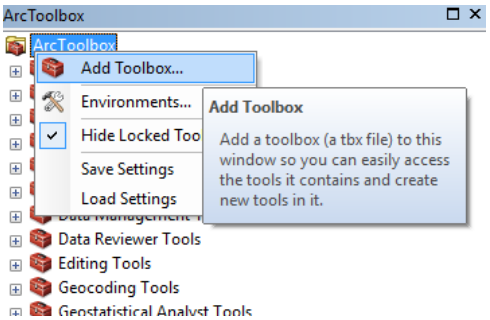


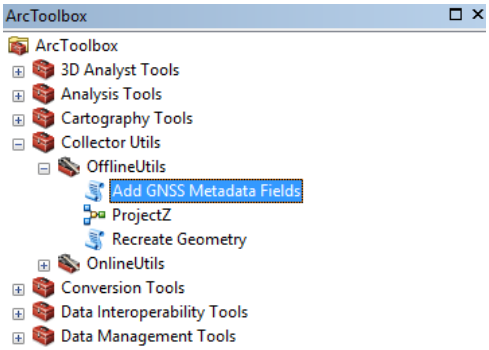
Initially a new feature class must be added to the dataset. This feature class will also contain point features and will designate fields with domains assigned for PID, City, Weather, and Interference. Once the feature class is created the utility that will be inserted to ArcToolbox will load the fields required to import data directly from the GPS receiver. For more information on loading feature classes, refer to New NGS Feature Class above.

ArcToolbox

The utility to be loaded into ArcToolbox is designed for all GPS receivers and is compatible in conjunction with ESRI Collector. To open ArcToolbox click the icon with the red toolbox on the menu bar.

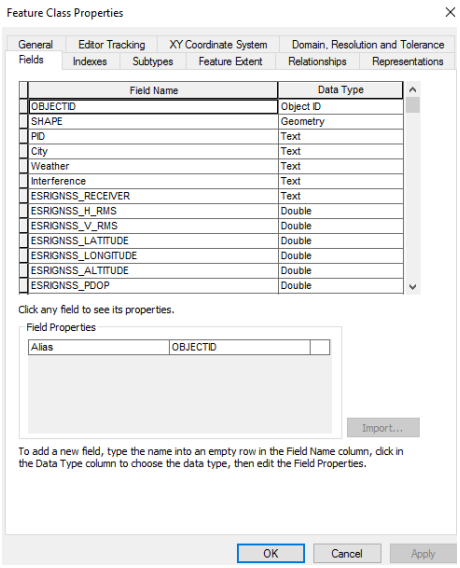
The toolbox can be loaded by right clicking in the [ArcToolbox] window and selecting [Add Toolbox]. Navigate to the location of the toolbox called CollectorUtils.tbx and select to add the utility.





To complete the Bad Elf data collection feature class open ArcToolbox. Navigate to [Add GNSS Metadata Fields] and browse to the Bad Elf feature class within the geodatabase Bad Elf feature dataset.

Once complete verify no errors occurred and the fields were added to the feature class as shown in the image to the right.



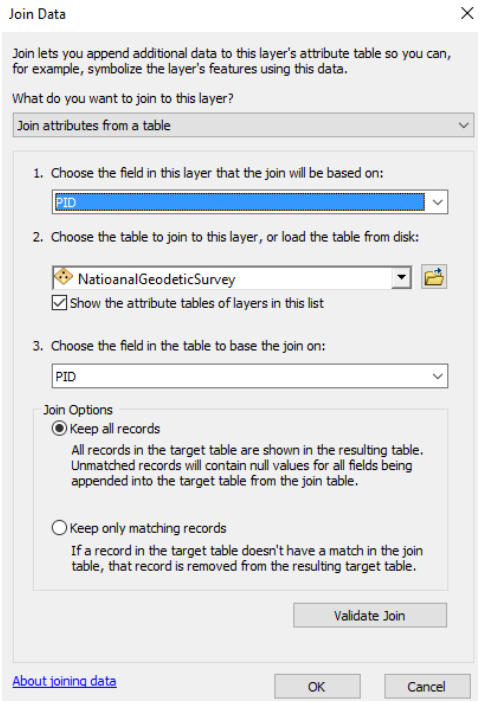
Constructing a Map for Publication

To publish feature classes to ArcGIS Online, the layers must be modified and templates must be created. Also, the property extents of the main layer must be altered after adjusting the scale range of the feature classes. This is accomplished in ArcMap.

After adding the Bad Elf data collection feature class and the NGS feature class to ArcMap, it is helpful to add a bookmark of the project location. If the map goes blank from accidental panning away from the project area, a bookmark can easily zoom back to the geographic location. To add bookmarks simply go to the [Bookmarks] shortcut menu at the top of ArcMap.

Joining Feature Classes

Since the NGS feature class has no data other than [PID] and [NULL] values in the other two fields, joining this feature class to the original National Geodetic Survey feature class will add all the data to the attribute table. Then create a new feature class with all the data joined and finally remove any fields not needed for the project.

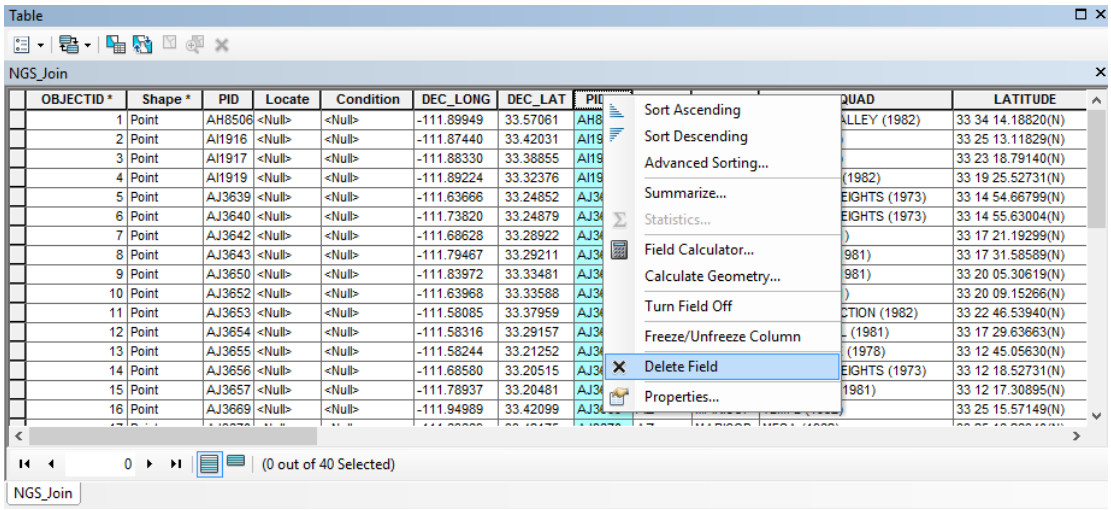


In the NGS collection feature class shortcut menu under [Joins and Relate] select [Join]. In the [Join Data] window select [Join attributes from a table]. In step one under [Choose the field in this layer that the join will be based on], choose [PID] since this field is the common identifier between both feature classes. Select the National Geodetic Survey feature class to join with in step two and in step three select the common identifier of the feature class to be joined. Again, in this case the field of commonality is [PID]. In the [Join Options] box check [Keep all records] then validate before completing the join. Index the join field if requested.

Once the feature classes are joined, in the short cut menu of the NGS collection feature class under [Data] select [Export Data]. Keep all default properties except the [Output feature

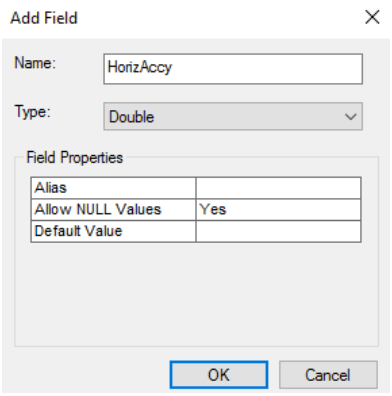
class]. Select the browse icon and in the popup window [Saving Data], change the [Save as type] option to [File and Personal Geodatabase feature classes]. Navigate to the project geodatabase and save in the appropriate feature data set. Add the layer to the map when prompted. Remove the National Geodetic Survey and NGS collection feature classes from the map which are no longer required.

Open the attribute table in the new feature class' shortcut menu and delete any unnecessary fields by selecting [Delete Field] in the field name shortcut menu.



Adding Fields from a Table

The accuracy analysis will be based on horizontal accuracy. The horizontal accuracy is not an attribute in the National Geodetic Survey feature class but can be found in the NGS datasheets from http://www.ngs.noaa.gov/. By researching through each Permanent Identifier's datasheet an FGDC 95% confidence horizontal accuracy is obtained. Tabulate each horizontal accuracy with the PID in excel and save as a csv file. Add the csv file to ArcMap.



Open the attribute table in the feature class short cut menu. Within the table options short cut menu select [Add Field]. In the [Add Field] window, enter the name for the field, the data type which is [Double] and allow null values.

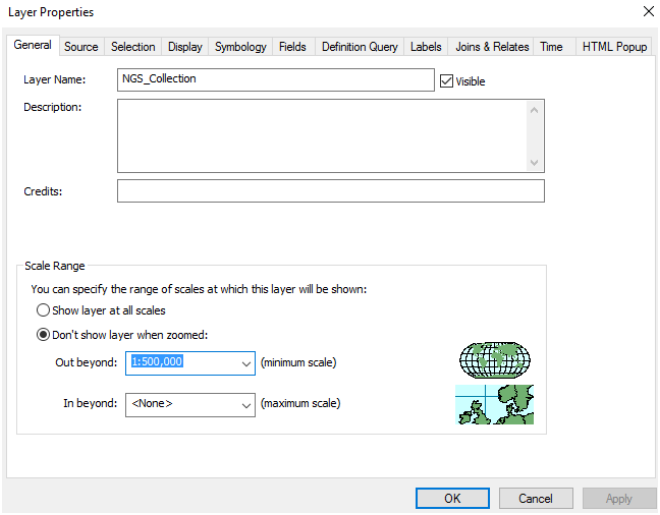
This field will be used to calculate the horizontal accuracy from the csv file.

Join the NGS feature class to the csv table using PID to link the table to the feature class. Open the attribute table and in the dropdown menu of the horizontal accuracy field, open the [Field Calculator]. In the [Fields] box of the [Field Calculator] window, scroll down to find the horizontal accuracy field from the table and double click to add the field to the

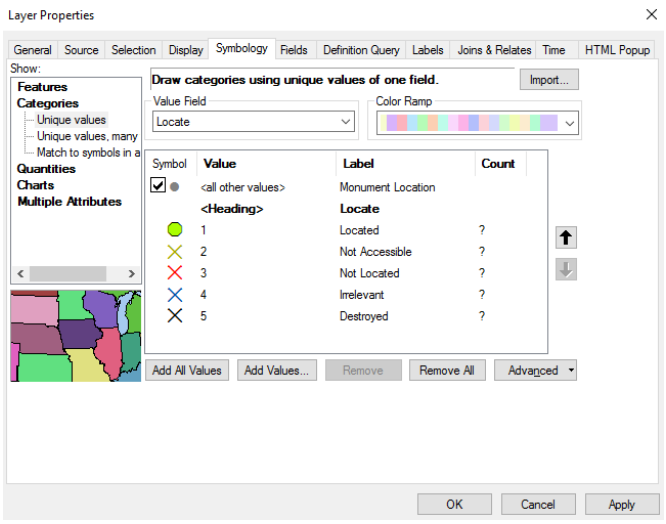
calculation box. Once applied the column will be populated with the data from the table. Remove all joins when complete.

Feature Class Properties

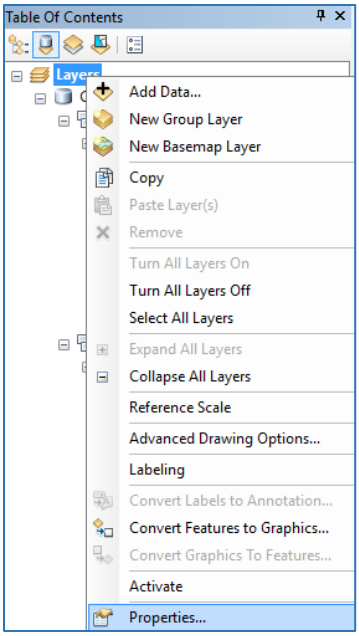
The properties can be found in the menu of each feature class. Once the [Layer Properties] window is open select the [General] tab. The [Out beyond] scale range must be added to prevent errors when publishing. To enter the [Out beyond] scale range verify the option [Don't show layer when zoomed] is checked.



Next, select the [Symbology] tab in the [Layer Properties] window. Within the [Show] box, under the [Categories] drop down menu highlight [Unique values]. In the neighboring box choose a [Value Field]. For this project the value field chosen for the NGS feature class is [Locate] and the Bad Elf feature class is [Interference]. The templates for both feature classes will be assigned from these fields. Once the [Value Field] is assigned click on the [Add All Values] box to add all the values assigned to the field from the domain.



Furthermore, within symbology is where the cartographic design of the symbols are allocated. To do this, double click on the symbol to edit.

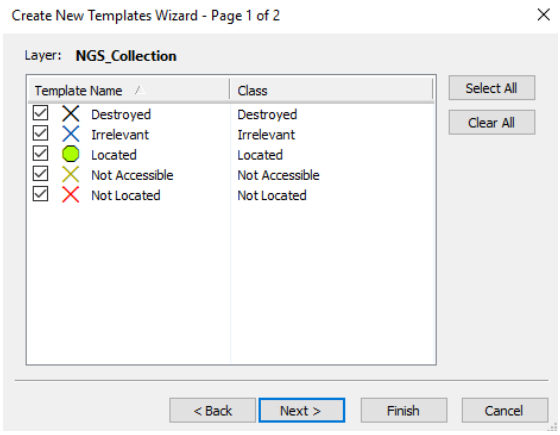


Layer Properties

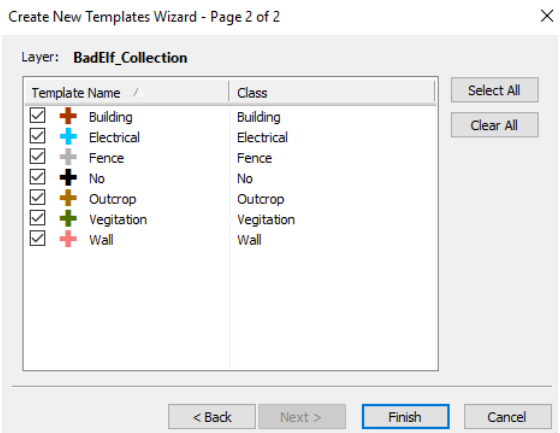
To prevent an error during publishing, the layer extent needs to be modified. Open the main [Layers] property window and select the [Data Frame] tab. Within the [Extent Used By Full Extent Command] box, check [Other] and open [Specify Extent]. In the [Full Extent] window check [Current Visible Extent] to set the Extent.

When selecting the [Current Visible Extent] option, it is important to verify the whole project area is visible in the [Data View] window. Otherwise a portion of the project will be discarded when published online.

Feature Templates

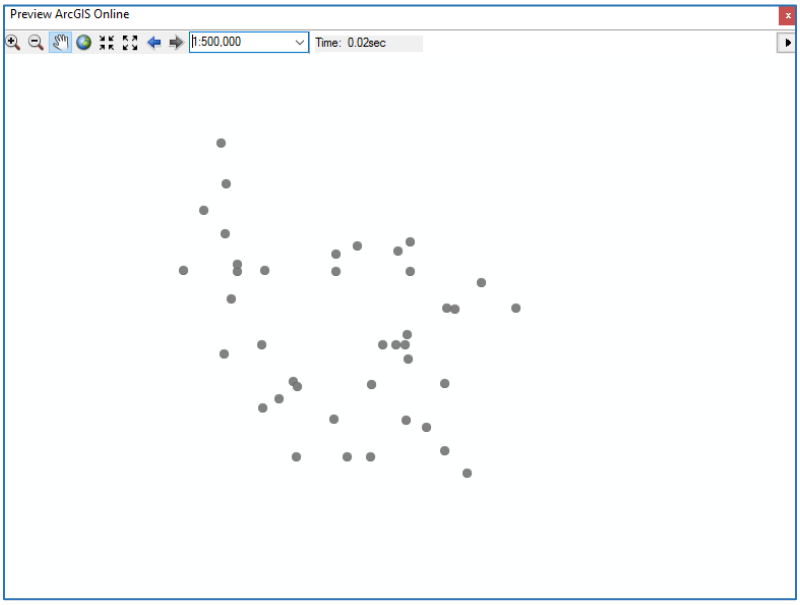


Feature templates are critical for generating features and are necessary for publication online. All feature classes must have an associated template. To add a template to a feature class, within the feature class menu under [Edit Features], open [Organize Feature Templates]. In the [Organize Feature Templates] window, select [New Template] then click [Select Visible Layers]. Verify the templates are assigned properly before closing.



Publishing to ArcGIS Online

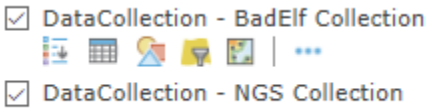
To publish the map to ArcGIS Online, signing into an online account is essential. In the main menu bar under [File], select [Sign In]. Once signed into an online account the project must be shared as a service. This is also found in the [File] dropdown menu, under [Share As] and [Service]. In the [Share as Service] window, check [Publish a service] and provide a [Service name]. Once the [Service Editor] window appears, display the [Feature Access] options and check the [Create], [Delete], [Query], [Sync] and [Update] boxes. Next display [Item Description]. The [Summary] and [Tags] are required to be completed for publication. Finally display the [Sharing] options to share with the public or an organization. Once completed, it is best to [Analyze] and [Preview] the map in the [Service Editor] window to verify there are no errors prior to publication.



Constructing a Map for ESRI Collector

Publishing a service to ArcGIS Online yields a [Feature Layer] and [Service Definition] within [My Content] of an account. Viewing the item details of the feature layer displays an overview of the published layers and is where the details of the layers can be edited. This is also where the data can be viewed to verify the layers loaded properly, settings can be adjusted, and layer property attributes can be changed.

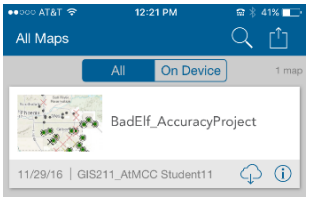
Open the project in [Map Viewer] after reviewing the feature layer. It may be necessary to zoom in to see the locations of the National Geodetic Survey points on the map. Under each layer name there are icons to display the legend, attribute table, change the style of the legend, filter, perform analysis, and an options dropdown menu as shown in the image to the right.

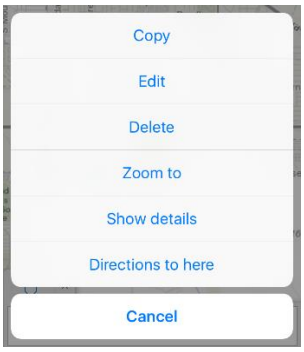


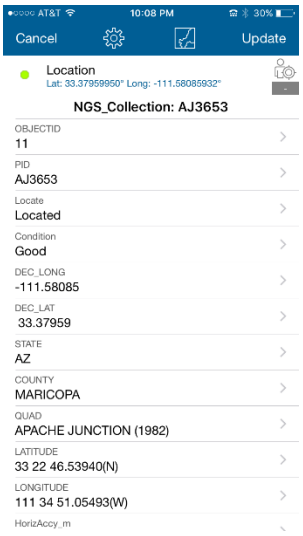
Once the map and features are satisfactory, save the map. Enter the map title, tags, and summary. After the map is saved it is important to share the map either publicly or with a group account. As soon as the map is shared it is ready to be viewed in ESRI Collector.

ESRI Collector

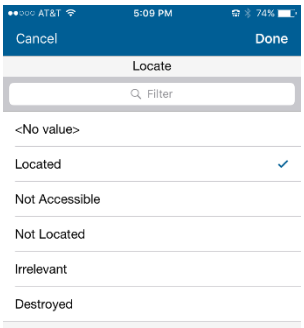
ESRI Collector was used with an iPhone and Bad Elf's handheld Bluetooth GPS. Open the app and sign into an account to select the project. The two layers published from ArcMap are now ready to receive data. The National Geodetic Survey data collection layer is used to easily locate and drive to each monument and enter data by using the edit feature. Select a monument point and a popup window displaying the NGS data collection layer will appear. On the right of the window there is an icon of a box with an arrow pointing up. Select this icon to open the menu and select [Edit].





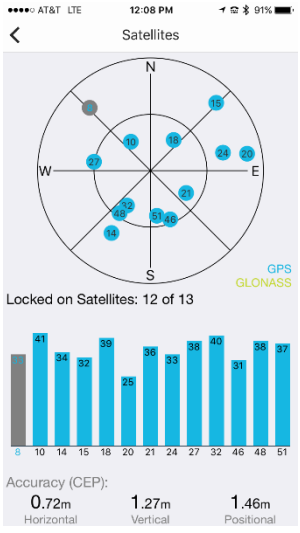


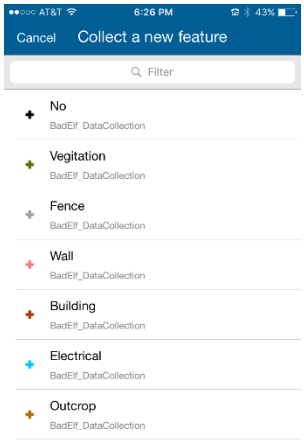
Next enter [Location] and [Condition] by tapping on the fields and selecting the appropriate options from the dropdown menus. These dropdown menus are the same attributes that were created when adding the domains from the geodatabase to the feature classes prior to publication. Select [Update] when complete.



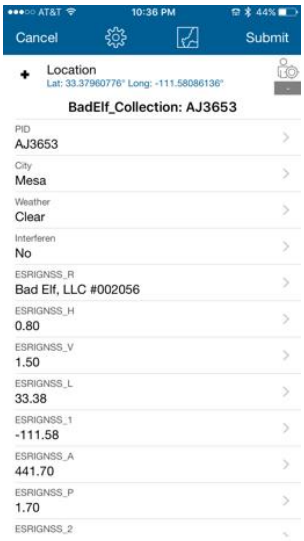
When the layer is updated, the new feature point will be displayed on the map and can be viewed by those who have access.

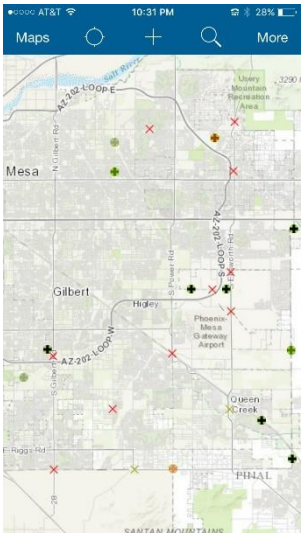
Since ESRI Collector is connected to the Bad Elf Bluetooth GPS through the iPhone, data can easily be added to the Bad Elf collection layer. After placing the GPS on the monument, allow the satellite reading to stabilize for a minute to acquire a better positional accuracy. Satellite coverage can be viewed in the Bad Elf app.





The [+] symbol in the menu bar of ESRI Collector opens the attribute window to start the process of recording the location. A list from all template attributes become available. Select the appropriate option for the [Interference] field of the Bad Elf data collection layer. Next enter the [PID] from the menu. Refer to the NGS layer to select the accurate PID label. Likewise, select the appropriate attributes for the [City] and [Weather] fields. The remainder of the fields are automatically populated from ESRI Collector in relation to the Bad Elf GPS connection. Hence the necessity for importing the GNSS metadata fields to the feature class from [ArcToolbox] prior to publication.

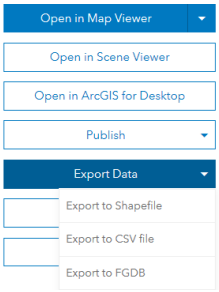




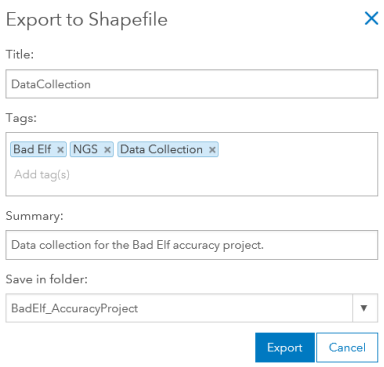
After striving to survey 40 National Geodetic Survey monuments; 23 were located, one was visibly pulled out of the ground and destroyed near a construction site and the remainder were either inaccessible or no longer viable.

Preparation for Analysis

Recall that the goal of this GIS is to determine if Bad Elf's handheld Bluetooth GPS receiver can produce consistent results at 1 meter CEP. Now that all the data is collected and noted for possible interference, a simple analysis can be completed in ArcMap. For the analysis, two feature classes will be added into the accuracy analysis dataset within the geodatabase. The second feature class will be based on the postprocessed data with the accuracy analysis identical to the Bad Elf data collection feature class analysis. The analysis is simply to calculate the delta difference between the NGS and Bad Elf horizontal accuracy and then visually display the results.



The data from each layer must be exported as shapefiles so manipulation of the attribute tables in ArcMap can be permitted. Export each layer from the [View item details] page of the feature layer found within [My Content] of the ESRI Online account. Select the [Export Data] dropdown menu and [Export to Shapefile]. In the [View item details] of the shapefile select [Download]. Save the zipped file in the project folder and extract the zipped data in preparation for ArcMap.



Open ArcMap and add both shapefiles with all the data collected to a new project. In the dropdown menu of each shapefile select [Data] then [Export Data]. Using the browse icon, save as a [File and Personal Geodatabase feature classes] and navigate to the appropriate dataset to save. Add the exported data to the map as a layer for each feature class and remove the shapefiles.

Next, join the attribute table of the Bad Elf data to the NGS feature class. Under the dropdown menu of the NGS layer select [Joins and Relates] and [Join]. Again, the [PID] field is the common identifier of both feature classes to join properly. Index the join field if requested.

Export the joined attribute data as a new feature class in the accuracy analysis dataset the same way the shapefiles were exported into the geodatabase. Be sure to save as a feature class and add the layer to the map. Remove the join and the Bad Elf feature class when finished.

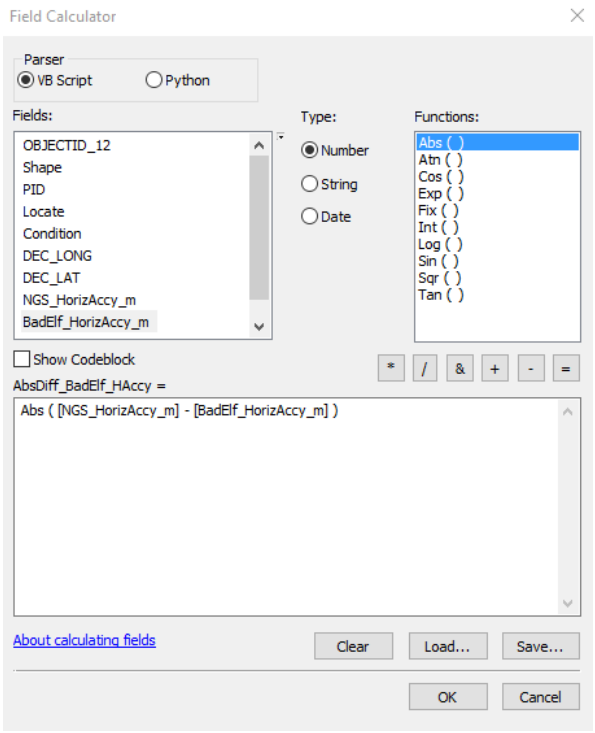
Accuracy Analysis Calculation

Open the attribute table to the new accuracy analysis feature class and remove all unnecessary fields. Other than permanent fields, at a minimum, the fields required are [PID], [HorizAccy_m] and [ESRIGNSS_H]. Once complete add three new fields to better identify each horizontal accuracy and for the calculation of the absolute difference.

To add the fields, under [Table Options] select [Add Field]. The first field will be labeled to identify the NGS horizontal accuracy. Likewise, the second field is will be used for identifying the Bad Elf horizontal accuracy. The final field is for the absolute difference between the horizontal accuracies of NGS and Bad Elf surveys. Make sure each new field contains a [Double] data type.

HorizAccy_m	ESRIGNSS_H	NGS_HorizAccy_m	BadElf_HorizAccy_m	AbsDiff_BadElf_HAccy
0.0048	0.790253	<Null>	<Null>	<Null>
0.0058	<Null>	<Null>	<Null>	<Null>
0.005	<Null>	<Null>	<Null>	<Null>
0.0059	0.886172	<Null>	<Null>	<Null>
0.0087	<Null>	<Null>	<Null>	<Null>

Next select the new NGS horizontal accuracy field and open the [Field Calculator]. In the [Fields] box double click on the [HorizAccy_m] field to add to the calculation box. Run the program when ready. The same process is used for the Bad Elf horizontal accuracy populated from the [ESRIGNSS_H] field. Once both fields are calculated, delete the originals.

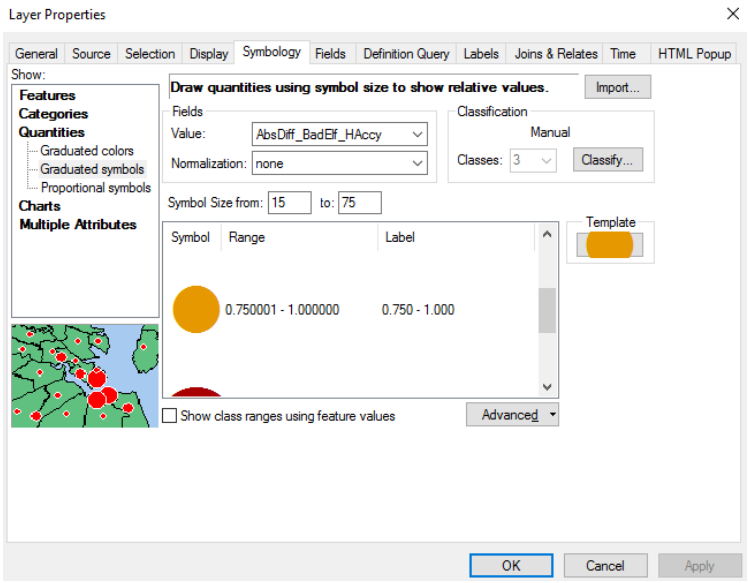


To calculate the absolute difference in the remaining field, open the [Field Calculator] and within the [Functions] box, double click [Abs()] to add to the calculation box. Next, within the [Fields] box input the [NGS_HorizAccy_m] within the parenthesis of the absolute value function. Select the [-] icon then add the [BadElf_HorizAccy_m] field. Run the procedure when finished.

Cartographic Design

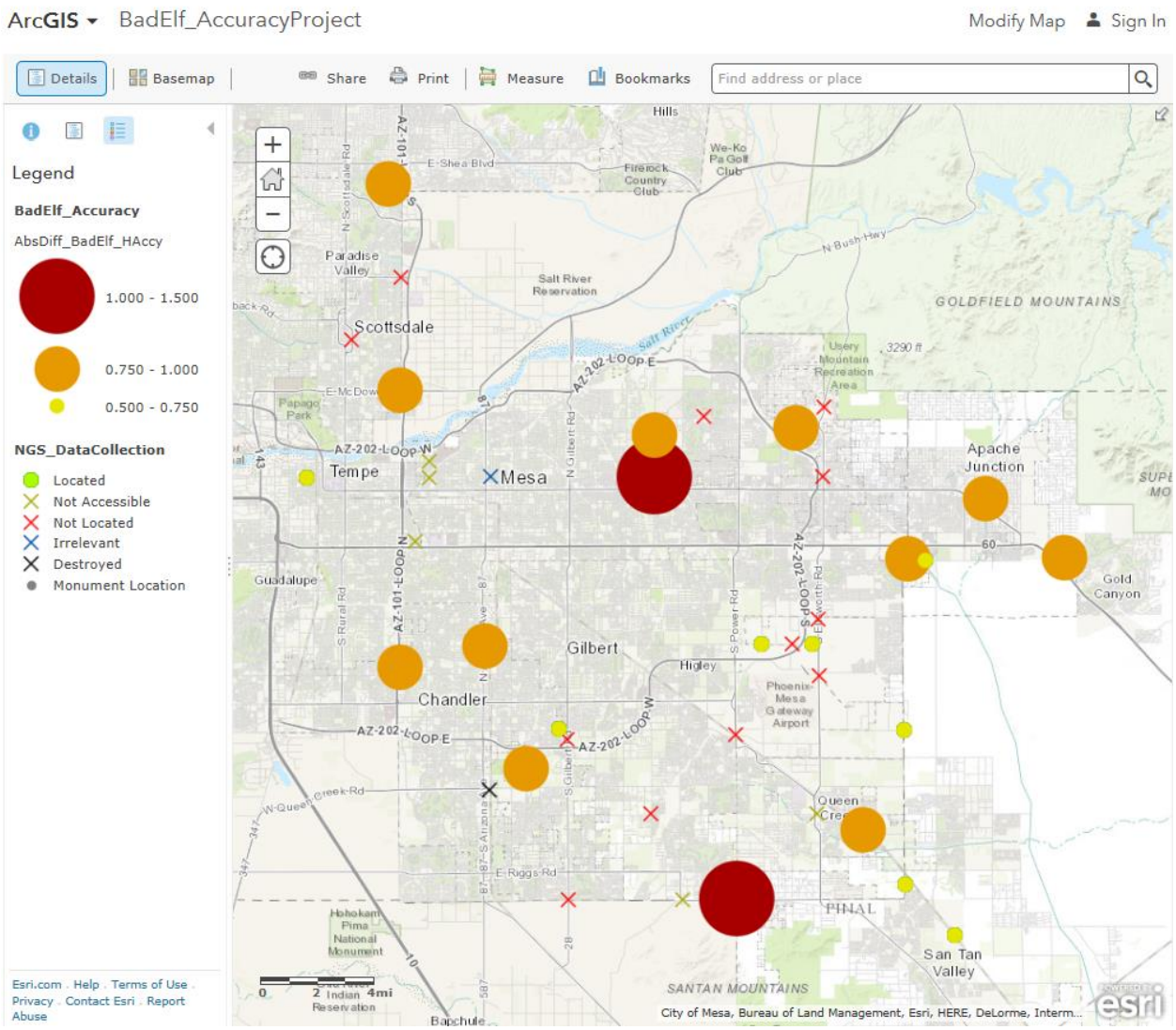
After all fields are calculated, a cartographic representation of the delta difference field is pertinent. This is accomplished within the [Symbology] window of the feature class properties. An easy way to visualize the delta difference of the horizontal accuracy is to use a gradational point model using size to represent distance of the delta differences.

In the [Symbology] window within the [Show] box under [Quantities] select [Graduated symbols]. Select the calculated absolute difference horizontal accuracy field from the dropdown menu for [Value] within the [Fields] box. Under [Classification], enter the number of [Classes] for the quantity of symbols desired. For this cartographic representation 3 ranges are used to display the data. The intervals for each symbol can be changed by selecting the values under [Range] and [Label]. Instead of using the [Range] default values, to be more intelligently pleasing and help answer the question of consistent results less than one meter CEP, intervals were chosen at 0.50, 0.75, and greater than 1.00 meter. Finally Enter the [Symbol Size from] range and double click on each symbol to change style and color.



Once the cartographic design is complete, publish the results online. To publish the results, all feature classes must be designated a template, scale range and an extent to the layers property. Then share as a service for publishing. Review publishing the data collection feature class for more details.

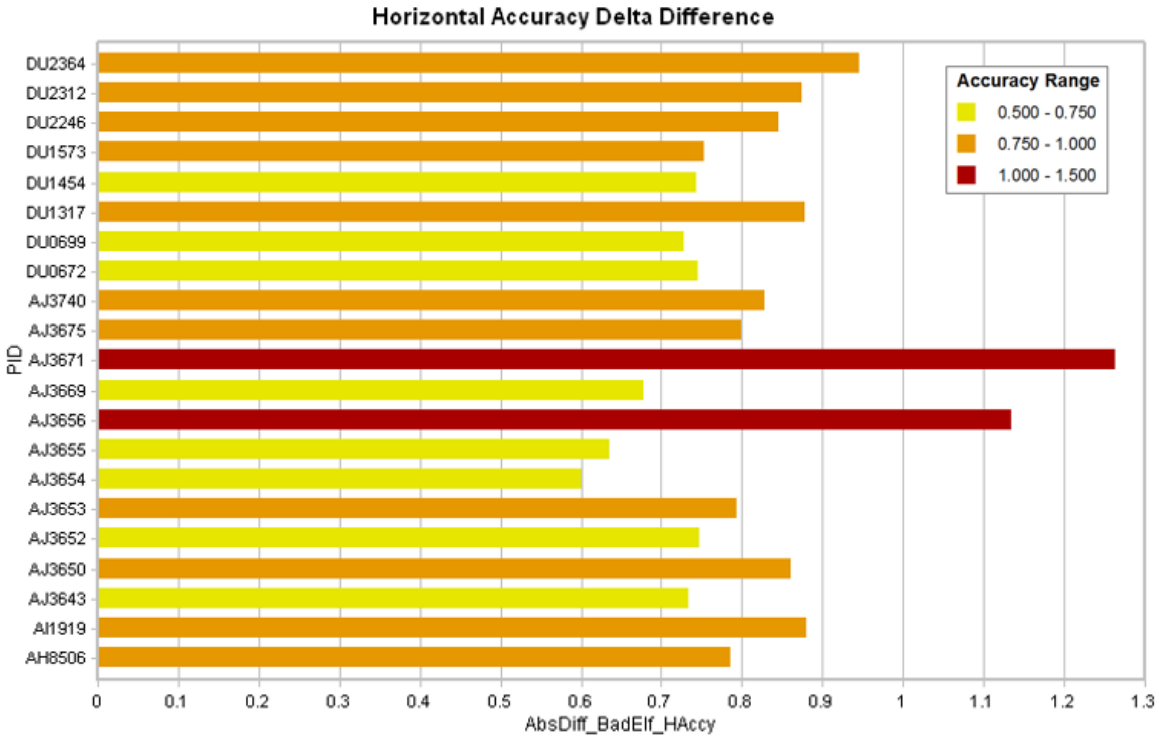
Lastly, after publishing, add the new accuracy feature layer to the online map for completion.



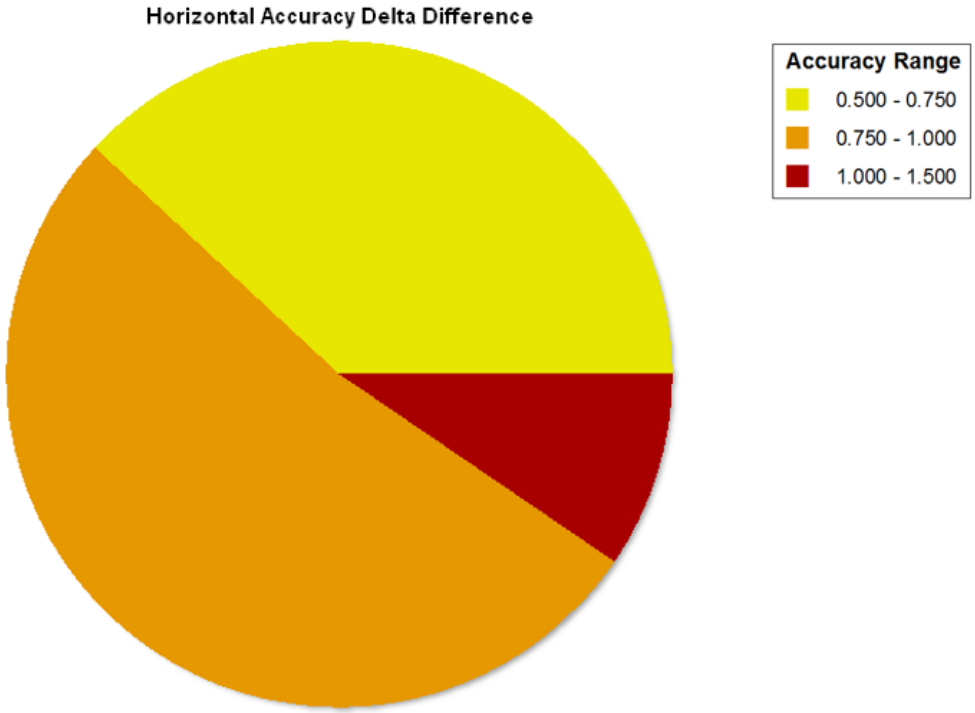
Results of Analysis

Overall, Bad Elf's handheld Bluetooth GPS receiver was consistent with results less than 1 meter CEP. Although the analysis resulted in two locations having a horizontal accuracy greater than 1 meter CEP, this can be explained due to very high interference. The delta difference of these two monuments, AJ3656 and AJ3671, ranged between 1.13 and 1.26 meters respectively. Furthermore, AJ3656 was located within about two feet of a 6 foot block wall and AJ3671 was directly under a large tree with several other large trees within a few meter proximity. Do to the results of the study it would be beneficial to add a field containing an interference scale that would portray the severity of potential satellite hindrance.

Appendix 1 - Bad Elf Accuracy Data

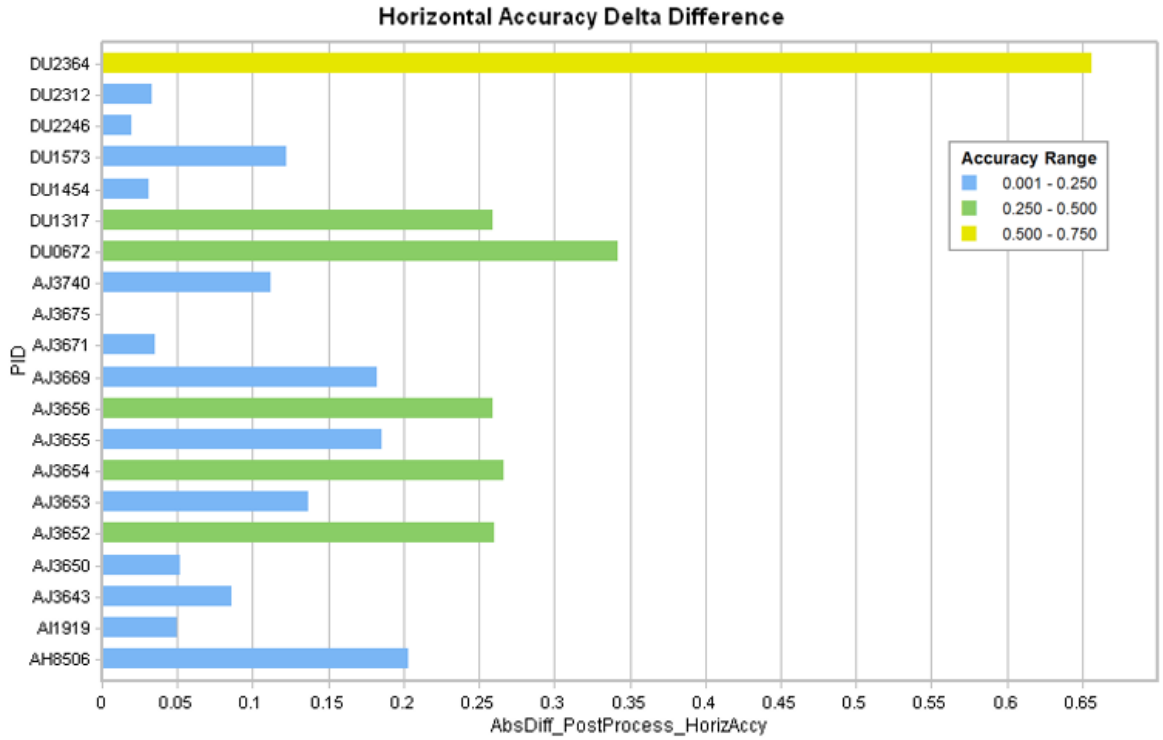


Two results are greater than 1 meter CEP which can be explained by very high satellite interference.

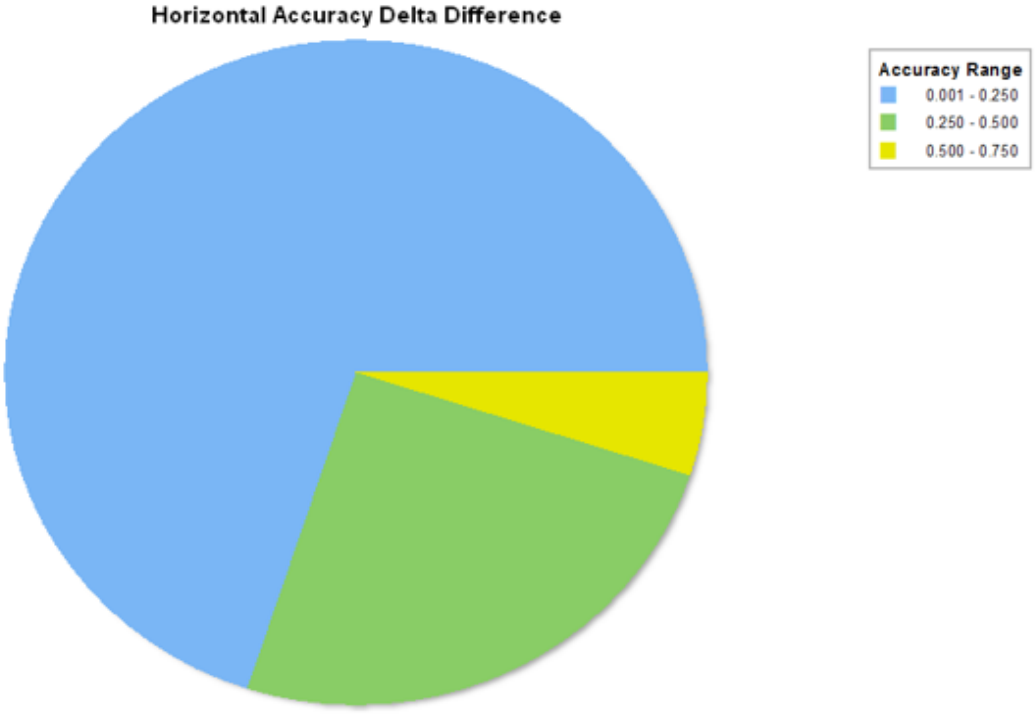


Results of the absolute value of the horizontal accuracy between NGS monuments and Bad Elf Bluetooth data collection.

Appendix 2 - Postprocessed Accuracy Data



Results of the absolute value of the horizontal accuracy between NGS monuments and the postprocessed data.



Results of the absolute value of the horizontal accuracy between NGS monuments and the postprocessed data.