Well Location Accuracy Assessment, Kanawha State Forest

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This report outlines the methodology and results of an accuracy assessment of gas well locations located in the Kanawha State Forest, located South of Charleston, West Virginia. Well locations obtained using differential corrected GPS were compared to coordinates in the West Virginia Department of Environmental Protection (WVDEP) database, and to locations from a commercial vendor.

The reference dataset was obtained by the author as part of a trail mapping project. The GPS receiver was a 12 channel Trimble Pro-XL. The data was differentially corrected using a permanent base station located approximately 15 miles from the study area. Though the Pro-XL is rated as a sub-meter accuracy receiver, extensive canopy cover and rugged terrain produced sub-optimal conditions for data collection. Data collection standards for the trail mapping project specified an HDOP reading of less than 3, so horizontal error approaching three meters could occur for some wells.

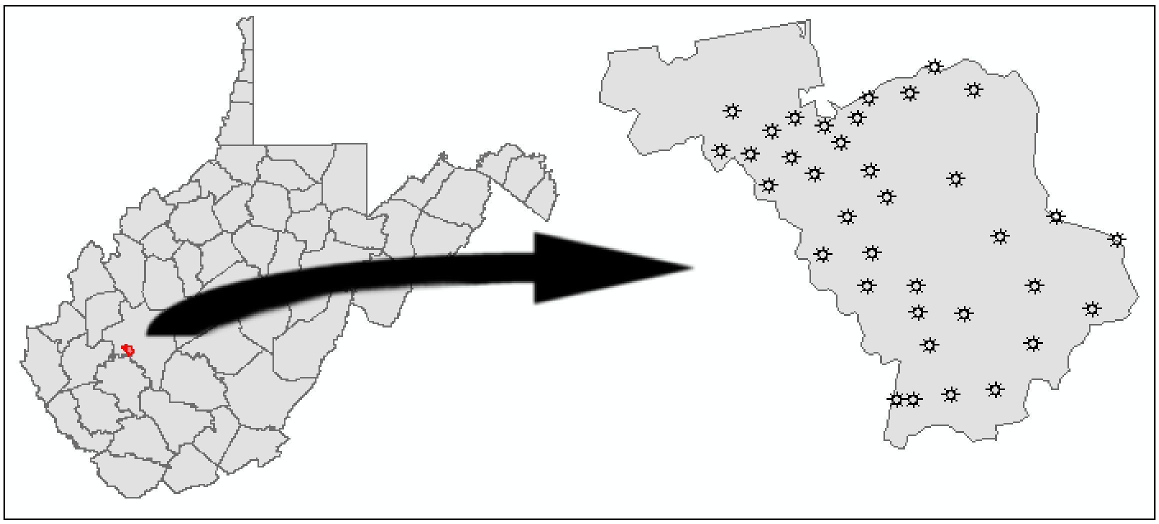

Figure 1. Study area.

State regulations are adept at insuring that well locations cannot be located with precision. Permit applications do not include the coordinates of the proposed well. Rather, well location is estimated using a mylar overlay that is designed to be placed on an appropriate USGS 7.5' topographic map (Figure 2). The upper right corner of the overlay is associated with a tic mark on the underlying map. When the corner of the overlay is aligned with the proper tic mark, the location of the well indicated on the overlay corresponds to the location on the underlying map. Thus, well locations can be recorded by using the overlay to manually mark well locations on a library of paper maps.

Alternatively, well locations can be calculated from the longitude/latitude of the tic mark and two offset vectors (to the south and west). The offsets are estimated manually by measuring the distance from the corner of the overlay and multiplying by the scale of the map. Planar coordinates of the well are then calculated by converting the longitude/latitude coordinate to UTM and subtracting the south/west vectors.

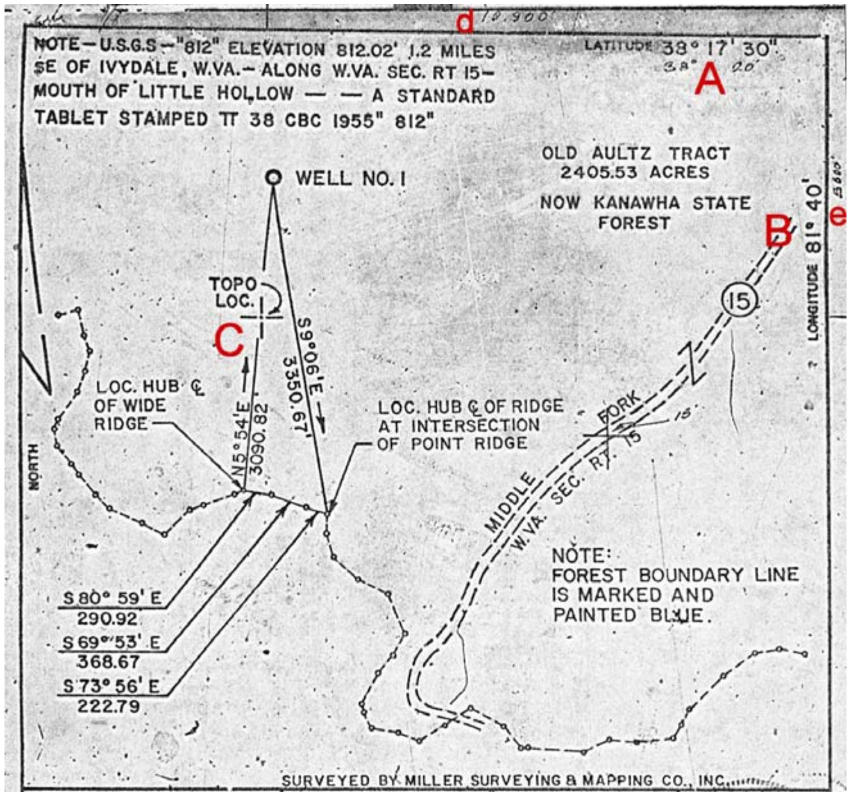

Figure 2. Well location diagram required by state regulation. The upper right corner is associated with a latitude and longitude, labeled at A and B. The proposed well is marked relative to this corner at C (identified by the "TOPO LOC." Label). All other features on this diagram are positionally unrelated to this mark. The WVDEP calculates the offset, in feet, to the South and West, which is written on the diagram at d and e.

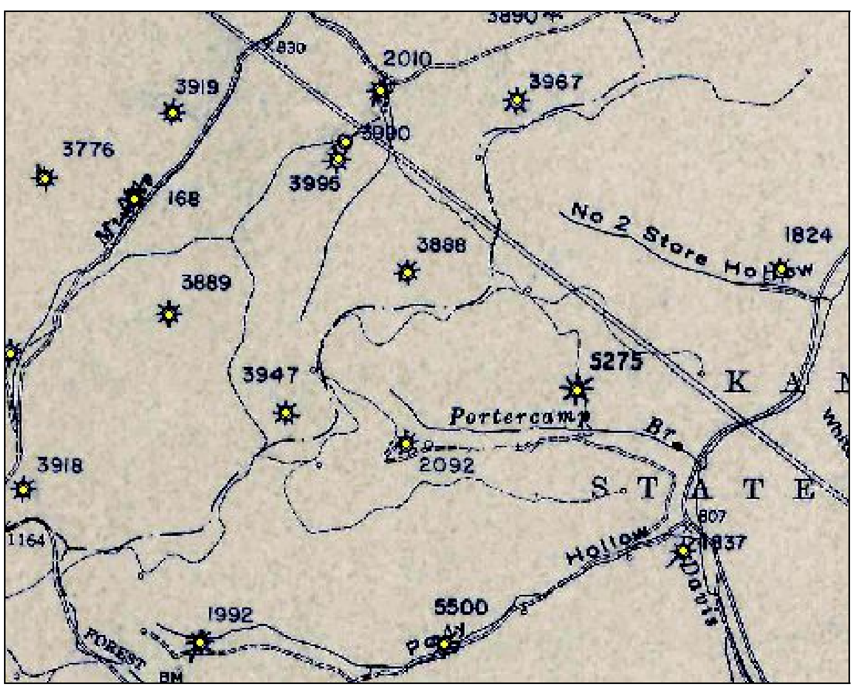

Figure 3. Portion of and Oil&Gas Information Service well location map. Digitized wells are shown in yellow.

Two sources of well locations were tested. The first source was the WVDEP database, which maintains data fields for longitude/latitude and offset values that are entered manually. The second source is a set of monochrome USGS 7.5 minute maps maintained by the Oil and Gas Information Service (OGIS) that have well locations annotated on them (figure 3).

Three of the OGIS maps were georeferenced, using a reference grid of 2.5' longitude/latitude tic marks. Twelve tie points were used for each map. Because the tie points offered consistent spacing and coverage throughout the scene, it was considered acceptable to use a second order transformation equation. This reduced the RMS error to less than 2.2 meters for each map. Well locations then were digitized on-screen at a display scale of 1:5,000.

Each test dataset contained 35 wells that matched the GPS well database. RMSE error and accuracy statistics at the 95% confidence interval were calculated based on the FGDC *Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data Accuracy.* Equations were adapted from Appendix 3-A:

$$\text{RMSE} = \text{sqrt}\left[\sum \left(\left(x_{test,\,i} - x_{GPS,\,i}\right)^{2} + \left(y_{test,\,i} - y_{GPS,\,i}\right)^{2}\right)/n\right]$$

where i identifies one of n corresponding wells in the test database and the GPS database. Accuracy at the 95% confidence interval is calculated as 1.7308 * RMSE, assuming a normally distributed (non-systematic) error pattern. Results of the calculations are shown in table 1.

	OGIS maps	WVDEP coordinates
RMSE Error	56.6 meters	1,355.9 meters
Accuracy (95%)	97.9 meters	2,346.8 meters
Standard Deviation	34.2 meters	1,269.8 meters

Table 1. well location errors associated with two databases, relative to GPS locations.

It is important to note that well locations in the test datasets are taken from permit applications, and as such represent the *intended* location of a well. Circumstances associated with site preparation can result in an actual well location that is shifted somewhat from the permitted location, perhaps by 10 meters or so. Eight of the wells in the OGIS dataset, better than 1 in 5, produced errors of less than 20 meters. Even so, the RMSE figure probably is somewhat higher than the best possible outcome. Given these results, the OGIS maps would not be considered a source of precision information, though they are valuable as a general indicator of well activity, or as a starting point for conducting a more accurate survey.

The coordinates calculated from the WVDEP database exhibited a large standard deviation, due to three wells with an error of greater than 4,000 meters. Many large errors in the WVDEP data are suspected to result from data entry errors. Each well requires eight data fields to identify its location—degrees, minutes, seconds, and an offset for each dimension, presenting multiple opportunities for mistakes. For example, one of the wells in this dataset has the same value for minutes and seconds of longitude—37, even though 0 and 30 are the only legitimate values.

For the other two wells with large errors, the original mylar overlay was obtained and compared to the database fields. Both contained multiple data entry errors—one offset was entered as 5,000 instead of 5,600, and a second offset was entered as 8,800 rather than 6,800. These errors probably resulted from misinterpreting the handwriting on the overlay. In addition, both wells used a latitude that did not represent the original value on the overlay, but referred to a second, hand written, latitude written below the original. Apparently this was meant as a correction, but was itself in error. Using the original latitude and the correct offset numbers brought the error for these two wells down to 13 meters and 35 meters, respectively.

In addition to data entry error, the process of measuring and calculating offsets on the overlay is a labor intensive and inexact exercise that is prone to adding error even when done correctly. It is also ironic to think that a surveyed well location first must be encrypted onto an overlay—a process that adds its own quantity of error—before being decrypted by the WVDEP.

The impact of this process on producing usable coordinates is illustrated by the fact that removing the four worst samples from the WVDEP dataset reduced the RMSE error to 125.2 meters, but still included 12 wells displaced by more then 100 meters. This indicates that other error sources still significantly impact coordinate accuracy.

Clearly the process for reporting the locations of new wells should be changed to require, or at least encourage, actual coordinates of the intended well during the permitting process. This will provide a foundation for accurate database development into the future. Additional sources of well locations also should be pursued from operators, particularly large ones, who maintain survey and/or GPS databases of their well locations.

Appendix A. Coordinate Data

API	X_GPS	Y_GPS	X_OGIS	Y_OGIS	X_WVDEP	Y_WVDEP	OGIS d2	OGIS err	WVDEP d2	WVDEP err
039-01018	444,468.9	4,234,712.0	444,447.0	4,234,713.3	444,492.6	4,234,619.0	482.1	22.0	9,219.3	96.0
039-01159	441,457.3	4,231,269.5	441,449.0	4,231,258.2	441,407.4	4,231,280.0	197.6	14.1	2,602.8	51.0
039-00043	442,724.3	4,232,868.1	442,707.0	4,232,846.5	442,503.2	4,232,920.0	766.7	27.7	51,585.2	227.1
039-01825	442,565.2	4,235,396.4	442,544.6	4,235,426.2	442,593.7	4,235,118.0	1,315.1	36.3	78,327.5	279.9
039-01826	442,912.3	4,237,063.8	442,991.8	4,237,065.5	442,915.6	4,237,017.0	6,322.6	79.5	2,197.1	46.9
039-01884	440,897.8	4,233,398.5	440,879.9	4,233,376.1	440,796.0	4,233,452.0	823.5	28.7	13,236.5	115.1
039-01912	441,773.6	4,231,277.5	441,763.4	4,231,266.8	441,682.7	4,231,150.0	217.8	14.8	24,507.8	156.5
039-01939	440,071.3	4,233,989.6	440,013.1	4,233,894.9	440,138.2	4,233,767.0	12,362.6	111.2	54,012.4	232.4
039-01963	442,496.6	4,231,352.4	442,502.5	4,231,350.8	442,358.4	4,231,247.0	37.2	6.1	30,229.3	173.9
039-01997	445,601.1	4,234,278.1	445,609.0	4,234,215.3	445,812.4	4,234,040.0	4,005.2	63.3	101,340.5	318.3
039-00042	443,309.1	4,231,444.0	443,262.2	4,231,527.4	443,227.4	4,231,440.0	9,159.5	95.7	6,695.7	81.8
039-02054	441,721.3	4,237,023.1	441,665.0	4,236,997.5	441,628.1	4,236,936.0	3,815.7	61.8	16,265.5	127.5
039-02048	444,038.2	4,232,322.1	444,039.1	4,232,301.0	443,887.3	4,232,341.0	447.6	21.2	23,121.8	152.1
039-02078	443,402.9	4,234,315.4	443,326.5	4,234,242.7	443,366.1	4,234,201.0	11,127.1	105.5	14,452.0	120.2
039-02815	441,846.8	4,233,394.3	441,951.5	4,233,302.1	0.0	0.0	19,465.2	139.5		
039-03346	442,078.0	4,232,303.0	442,040.8	4,232,238.1	442,105.3	4,232,225.0	5,600.4	74.8	6,824.9	82.6
039-03777	438,379.2	4,236,688.3	438,355.2	4,236,671.1	438,425.3	4,241,497.0	872.8	29.5	23,125,475.4	4,808.9
039-03776	439,131.5	4,236,294.3	439,115.2	4,236,301.7	439,179.7	4,240,338.0	319.4	17.9	16,354,051.9	4,044.0
039-03889	439,502.6	4,235,821.5	439,546.3	4,235,832.7	439,550.2	4,235,852.0	2,041.4	45.2	3,199.0	56.6
039-03919	439,560.6	4,236,554.3	439,559.0	4,236,527.6	439,565.5	4,236,538.0	715.5	26.7	288.8	17.0
039-03888	440,403.8	4,236,083.4	440,376.4	4,235,974.5	440,403.7	4,235,989.0	12,608.5	112.3	8,914.4	94.4
039-03890	440,927.4	4,236,914.7	440,886.6	4,236,887.7	440,906.6	4,236,934.0	2,394.8	48.9	803.7	28.3
039-03918	439,065.2	4,235,282.7	439,040.3	4,235,229.0	439,062.6	4,235,243.0	3,496.6	59.1	1,581.9	39.8
039-03947	439,936.3	4,235,508.2	439,954.8	4,235,491.1	440,838.0	4,236,950.0	635.6	25.2	2,891,760.3	1,700.5
039-03967	440,734.5	4,236,547.4	440,756.4	4,236,569.6	440,769.4	4,236,553.0	972.5	31.2	1,247.2	35.3
039-03995	440,117.5	4,236,385.4	440,135.5	4,236,366.2	440,144.6	4,236,398.0	692.6	26.3	889.5	29.8
039-03997	438,723.0	4,235,884.1	438,711.7	4,235,873.3	438,742.5	4,235,868.0	245.8	15.7	639.6	25.3
039-03998	438,154.0	4,235,949.1	438,146.9	4,235,903.2	438,178.6	4,235,944.0	2,160.2	46.5	629.2	25.1
039-05276	440,999.0	4,234,020.8	440,982.8	4,234,022.2	441,040.7	4,234,027.0	263.5	16.2	1,776.7	42.2
039-05275	440,982.0	4,235,557.6	440,968.0	4,235,571.7	441,007.2	4,235,557.0	395.9	19.9	633.3	25.2
039-05303	442,161.6	4,237,502.0	442,131.3	4,237,476.4	442,166.9	4,237,488.0	1,565.3	39.6	223.5	14.9
039-01837	441,286.4	4,235,056.6	441,340.2	4,235,014.8	441,264.8	4,234,893.0	4,634.8	68.1	27,245.5	165.1
039-02044	445,152.4	4,232,968.7	445,120.7	4,232,989.1	445,096.7	4,237,604.0	1,420.2	37.7	21,489,233.5	4,635.6
039-05500	440,527.4	4,234,691.7	440,508.3	4,234,694.6	440,580.5	4,234,709.0	371.7	19.3	3,120.6	55.9
039-05799	441,880.9	4,232,894.8	0.0	0.0	441,888.9	4,232,865.0			948.5	30.8
039-02047	444,061.7	4,233,398.0	444,063.4	4,233,489.7	443,951.6	4,233,484.0	8,421.7	91.8	19,515.1	139.7

	OGIS err	WVDEP err
RMSE	56.6 m	1,355.9 m
Accuracy (95%)	97.9 m	2,346.8 m
Std Dev	34.2 m	1,269.8 m
Average	48.0 m	522.2 m