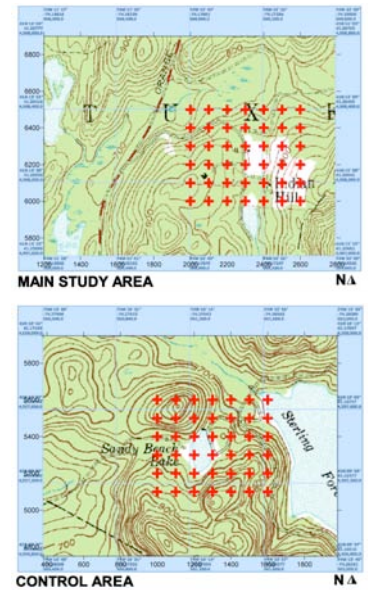


Establishing Longitudinal Wildlife Census Quadrangles in Sterling Forest State Park, Sterling Forest, New York



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PROJECT INTENT

Establish two 500 m x 600 m longitudinal wildlife census quadrangles (a Main Study Site and a Control Study Site) in Sterling Forest State Park, New York using laser survey techniques to mark every 100 m interval within each site. Laser surveying was selected over differentially corrected GPS (DGPS), because DGPS could not be used in most parts of the study areas due to dense tree canopy. The longitudinal wildlife census quadrangles will be used by Ithaca College biology professor John Confer in his study of Golden-Winged Warbler habitats and used by any researcher that can benefit from the quadrangles.

METHOD

The center of each survey area was selected based on estimated locations of the survey regions and on local features to facilitate establishing several survey points from the center location (called the primary site datum, PSD). Using a laser transit (called a total station) survey points were set-out in 100 m intervals in all directions from the PSD where line of site permitted. The survey grids were aligned roughly on grid north using local features and aerial photographs to guide the alignment.

Due to limited line of site from trees, shrubs, topography, and buildings temporary points were often placed at a distance of 50 m from the total station. The total station was moved to the temporary point, reoriented on the grid by backsighting to the last location, and then new points were set-out from the temporary location. Where possible the temporary location was chosen in the middle of a quadrangle to facilitate setting-out corner locations (Fig. 1a). When this method was not possible the total station was moved along a transect (Fig. 1b).

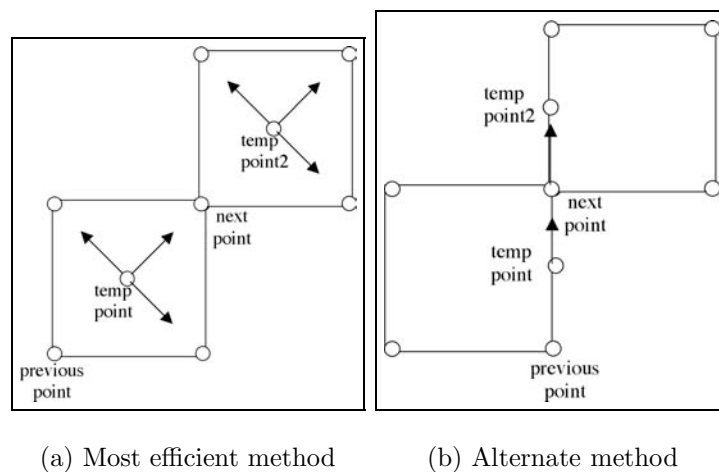


Figure 1: Method of moving the total station to efficiently set out points.

In some areas more than one temporary point was used before setting out the desired corner point. Throughout the multi-weekend project standard survey techniques were followed. When possible the transect was closed (i.e. following a path that ends with a final reading taken at the starting location) and the locations of points established on previous survey days giving measures of error in the set-out points. It is important to note that both total station operators (Professor Rogers and physics student Kevin Faehndrich) did not spend a lot of time ensuring that each survey instrument was directly over each survey point. To precisely align the instrument over the survey point takes time and in all cases we were within 5 centimeters of the survey point. All other aspects of precision surveying were rigorously followed. We chose to accept this error to reduce instrument set-up time, and 5-centimeter errors along 100-meter transects is acceptable.

EQUIPMENT

Sokkia SET6E Total Station with tripod, 2 prisms, and 2-15 foot rods (Fig. 2).
Leica TCR1105 Total station with tripod, 2 prisms, and 2-12 foot rods. Several 2-way Motorola radios. Many 1-foot-long pvc stakes, blaze orange pin flags, and large, metal fencing stakes.



(a) Physics Student Kevin Faehndrich using the Sokkia Total Station

(b) Volunteer Martin Rogers holding a Prism and Rod

Figure 2: Laser Surveying Equipment.

ERROR

Analysis of location checks (Table 1 and Table 2) and a nearly closed transect on 13-Mar-04 indicates a conservative error of ± 3 m in the location of each point. This error is larger than expected due to a few outlying points. A more realistic error is ± 1.0 m. Note that the error analysis obtained from the check shot to point C2 (Table 2) was done after moving the total station 6 times over an approximate 600 meter distance.

Table 1: Examples of Evaluation of error in the Control Site data

Local X-Coord (m)	Local Y-Coord (m)	Local Elev (m)	Comment	Diff in X-Coord (m)	Diff in Y-Coord (m)	Diff in Elev (m)
1599.990	5098.942	996.772	Setout N6			
1599.677	5099.411	996.411	Check Near N6	-0.313	0.469	0.063
1299.978	5298.899	1002.903	P4			
1302.975	5299.568	1003.688	Check to P4 From T200	-2.997	-0.669	-0.785
1302.924	5299.596	1003.591	Check to P4 From T201	-2.946	-0.697	-0.688
1499.152	5301.729	1014.433	P6			
1498.748	5301.888	1014.223	Check to near P6	0.404	-0.159	0.210
1409.372	5190.7	1041.3	T202			
1409.22	5190.631	1041.248	Check to T202	0.020	-0.094	0.074
1571.513	5092.93	1001.682	T208			
1571.151	5092.841	1001.589	Check to T208	0.362	0.089	0.093

Table 2: Examples of Evaluation of error in the Main Site data

Local X-Coord (m)	Local Y-Coord (m)	Local Elev (m)	Comment	Diff in X-Coord (m)	Diff in Y-Coord (m)	Diff in Elev (m)
2000.537	6099.493	1020.258	B1			
200.515	6099.485	1020.223	Check to B1	0.022	0.008	0.035
2298.405	6099.922	998.850	B4			
2298.336	6099.921	998.552	Check to B4	0.069	0.063	0.298
2100.738	6199.068	1012.498	C2			
2100.974	6198.971	1011.823	Check to C2	-0.236	0.097	0.675
2399.691	6201.440	997.560	C5			
2399.687	6201.458	995.455	Check to C5	-0.004	0.018	-2.105
2500.106	6199.313	1010.966	C6			
2499.845	6199.403	1010.863	Check to C6	0.261	-0.090	0.103
2199.820	6400.330	989.947	E3			
2200.053	6400.247	989.946	Check near E3	-0.233	0.083	0.001
2103.951	6499.781	971.029	F2			
2104.241	6500.026	970.928	Check to F2	-0.290	-0.245	0.091

CONVERTING LOCAL COORDINATES TO STATE PLANE COORDINATES

The census quadrangles were aligned roughly on grid north based on a visual inspection of USGS 7.5' Topographic maps (Monroe Quadrangle and Sloatsburg Quadrangle) and a handheld compass. A precise alignment with grid north was not necessary for the scope of the project nor practical. Instead the census quadrangles were aligned on local features (roads, gaps in trees, and ponds) to make it easier to establish the grid, and easier to conduct wildlife census surveys.

The grid was established using the following grid establishment procedures. Primary site datum (PSD) locations were chosen at the main site (point C4) and control site (point Q4) and marked with a survey stake. Point C4 was assigned the local coordinates of 2300 m, 6200 m due to its proximity in the middle of the area of interest. The southwest most corner has coordinates 2000 m, 6000 m. It is common practice to not assign 0 m, 0 m to the PSD and instead assign large positive numbers to avoid dealing with negative coordinates. Negative coordinates have the potential to introduce unnecessary confusion due to misspoken or incorrectly written coordinates. It is easy to forget to write or read the minus sign.

Abandoning the use of 0 m, 0 m for the PSD many scientists choose 100 m, 100 m or 500 m, 500 m or some larger, equal coordinates for the PSD based on the size of the study area. This method is only clear if one always attaches an E (for easting) and a N (for northing) to every coordinate. This problem is compounded by the fact that in the United States it is convention to report Latitude (the y-coordinate) and then Longitude (the x-coordinate). This is backwards from graphing convention. Most scientists outside of the United States report their easting (longitude or x-coordinate) before their northing. In the author's convention the northing is always the larger of the two numbers. This convention adds additional information to minimize communication errors.

When two sites are being worked on during the same project the author's grid establishing conventions also assign different values to the PSDs to further clarify to which site the coordinates are associated with. While establishing the census quadrangles the control site's PSD (point Q4) was assigned the coordinates 1300 m, 5400 m and the main site's PSD (point C4) was assigned 2300 m, 6200 m.

Using a local grid system makes it easier to establish the grid, but these coordinates need to be transformed into a universal coordinate system such as latitude and longitude or Universal Transverse Mercator (UTM) coordinates so that the coordinates can be understood by anyone. The UTM coordinates and State Plane coordinates of a few survey points were obtained using a hand held Garmin Global Positioning System (GPS) unit and a Trimble GPS unit. Without differential corrections the UTM / State Plane coordinates obtained have an accuracy ranging from 4 meters to 9 meters. A minimum of 2 UTM or State Plane coordinates are necessary to translate the local grid coordinates into UTM or State Plane coordinates. Additional UTM / State Plane coordinates obtained using the GPS provide a check of the transformation.

Because the local grid system and the State Plane system do not share the same origin (Fig. 3) the coordinates need to be translated so that the two systems share the same origin (0 m, 0 m point). This translation is done by picking one survey point that has both a known local coordinate and a State Plane coordinate (obtained using a GPS unit). For the main site point C4 (the primary site datum) was chosen with local coordinates of (2300 m, 6200 m) and State Plane coordinates of (1482319.213 ft, 468704.236 ft). Equation 1 was used to translate all of the local points and equation 2 was used to translate the State Plane coordinates so that the two coordinate systems share the same origin.

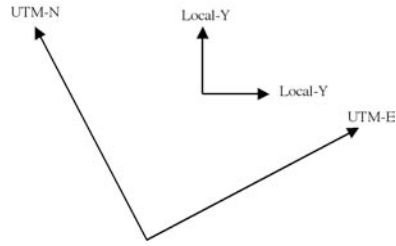


Figure 3: Example of two coordinate system that do not share the same origin.

$$\begin{aligned} LocalX' &= LocalX - 2300 \text{ m} \\ LocalY' &= LocalY - 6200 \text{ m} \end{aligned} \quad (1)$$

$$\begin{aligned} StatePlaneX' &= StatePlaneX - 1482319.213 \text{ ft} \\ StatePlaneY' &= StatePlaneY - 468704.236 \text{ ft} \end{aligned} \quad (2)$$

The next step is to rotate the points in the local coordinate system so that they align with the State Plane coordinate system. This is done using standard rotation equations (Eq. 3 and Eq. 4).

$$StatePlaneX'' = LocalX' \cdot \cos(\theta) + LocalY' \cdot \sin(\theta) \quad (3)$$

$$StatePlaneY'' = -LocalX' \cdot \sin(\theta) + LocalY' \cdot \cos(\theta) \quad (4)$$

Equations 3 and 4 are easy to use if the angle between the two coordinate systems is known; which in this case the angle is not known. Equations 3 and 4 can be solved for the angle using a survey point whose coordinates are known in both of the coordinate systems.

First, solve equation 4 for $\cos(\theta)$.

$$\cos(\theta) = \frac{StatePlaneY'' + LocalX' \cdot \sin(\theta)}{LocalY'} \quad (5)$$

Second, substitute 5 into equation 3

$$StatePlaneX'' = LocalX' \cdot \left[\frac{StatePlaneY'' + LocalX' \cdot \sin(\theta)}{LocalY'} \right] + LocalY' \cdot \sin(\theta) \quad (6)$$

Simplify equation 6

$$StatePlaneX'' = \frac{LocalX' \cdot StatePlaneY''}{LocalY'} + \frac{LocalX'^2 \cdot \sin(\theta)}{LocalY'} + LocalY' \cdot \sin(\theta) \quad (7)$$

Gather terms containing $\sin(\theta)$ after multiplying $LocalY' \cdot \sin(\theta)$ by $LocalY'/LocalY'$

$$StatePlaneX'' = \frac{LocalX' \cdot StatePlaneY''}{LocalY'} + \frac{LocalX'^2 \cdot \sin(\theta) + LocalY'^2 \cdot \sin(\theta)}{LocalY'} \quad (8)$$

Simplify further and solve for $\sin(\theta)$

$$\sin(\theta) = \frac{\left[StatePlaneX'' - \frac{LocalX' \cdot StatePlaneY''}{LocalY'} \right]}{\left[\frac{LocalX'^2 + LocalY'^2}{LocalY'} \right]} \quad (9)$$

Simplify the numerator

$$\sin(\theta) = \frac{\left[\frac{LocalX' \cdot StatePlaneX'' - LocalX' \cdot StatePlaneY''}{LocalY'} \right]}{\left[\frac{LocalX'^2 + LocalY'^2}{LocalY'} \right]} \quad (10)$$

The $LocalY'$ terms cancel resulting in

$$\sin(\theta) = \frac{LocalX' \cdot StatePlaneX'' - LocalX' \cdot StatePlaneY''}{LocalX'^2 + LocalY'^2} \quad (11)$$

The final step is to solve for θ

$$\theta = \arcsin \left(\frac{LocalX' \cdot StatePlaneX'' - LocalX' \cdot StatePlaneY''}{LocalX'^2 + LocalY'^2} \right) \quad (12)$$

The State Plane coordinates of 6 points at the main site were determined using a Trimble GPS with differential correction which gives positions to an accuracy of ± 3 ft (1 m). The local and state plane coordinates of these six points were translated to share the same origin using point C4. Additionally, the local coordinates were converted from meters to feet (multiply by 2.81 ft / m) to share the same units as the desired state plane coordinates. The results of these translations are shown in tables 3 and 4.

Table 3: Linear transformation of the local grid points.

Point ID	Local X-Coord (m)	Local Y-Coord (m)	LocalX' (m)	LocalY' (m)	LocalX' (ft)	LocalY' (ft)
D5	2400.802	6301.012	100.802	101.012	330.7145281	331.403503
C4	2300	6200	0	0	0	0
B4	2298.405	6099.984	-1.595	-100.016	-5.232928635	-328.1357933
E3	2199.82	6400.33	-100.18	200.33	-328.6738499	657.2492749
E2	2100.762	6400.22	-199.238	200.22	-653.6666053	656.8883833
B2	2100.722	6101.858	-199.278	-98.142	-653.7978386	-321.9875123

Table 4: Linear transformation of the state plane grid points.

Point ID	State Plane E (ft)	State Plane N (ft)	StatePlaneX' (ft)	StatePlaneY' (ft)
D5	1482670.25	469023.299	351.037	319.063
C4	1482319.213	468704.236	0	0
B4	1482300.18	468373.092	-19.033	-331.144
E3	1482026.33	469379.534	-292.883	675.298
E2	1481694.327	469388.359	-624.886	684.123
B2	1481655.405	468409.112	-663.808	-295.124

The angle of rotation is obtained by using the linearly translated data. To account for errors in the coordinates the angle of rotation was calculated for 5 of the 6 data points (C4 cannot be used for determining the angle of rotation because C4 becomes the origin after the linear transformation). Table 5 shows the results of using equation 12 to obtain the rotation angle.

The final steps are to use the average rotation angle of 2.610 degrees and the rotation equations 3 and 4 to transform all of the local grid coordinates into State Plane coordinates. Once the data are rotated they need to be linearly transformed back to the original origin of the State Plane coordinate system by adding on the amount we subtracted (Eqn. 13).

Table 5: Determining the rotation angle between the two coordinate systems using the linearly transformed data.

Point ID	LocalX' (ft)	LocalY' (ft)	StatePlaneX'' (ft)	StatePlaneY'' (ft)	angle (degrees)
D5	330.7145281	331.403503	351.037	319.063	2.828
C4	0	0	0	0	
B4	-5.232928635	-328.1357933	-19.033	-331.144	2.401
E3	-328.6738499	657.2492749	-292.883	675.298	3.127
E2	-653.6666053	656.8883833	-624.886	684.123	2.449
B2	-653.7978386	-321.9875123	-663.808	-295.124	2.243
				Average	2.610

$$\begin{aligned} \text{StatePlane}X''' &= \text{StatePlane}X'' + 1482319.213 \text{ ft} \\ \text{StatePlane}Y''' &= \text{StatePlane}Y'' + 468704.236 \text{ ft} \end{aligned} \tag{13}$$

The same method was used to also translate the local grid coordinates to UTM coordinates. It is not possible to translate the local coordinates to state plane coordinates for the control unit due to a lack of GPS gathered state plane coordinates for a few survey markers. If a few diagnostic state plane coordinates are gathered by the wildlife census researchers all coordinates can easily be translated into state plane using the method outlined above. Figure 4 and figure 5 show the location of the wildlife census markers and contour plots overlaid on aerial photographs obtained from www.terraserver.microsoft.com. Tables 6 and 7 display the translation of the local coordinates from both sites to UTM coordinates.

CONCLUSIONS

The two wildlife census quadrangles were successfully established over the course of several weekends. The accuracy of the grid positions is sufficient for their intended use. Not all of the grid points were successfully placed at the desired 100-meter intervals due to obstacles and difficulty in surveying under the field conditions. Even though these points are not at the desired 100-meter interval their locations are known to an accuracy of 1 meter or less.

To facilitate using the quadrangle I suggest that each metal survey pole marking a grid corner be marked with the State Plane coordinates in some easy to read fashion. I also recommend that pink surveyors tape be used to mark visible way points along each transect (pink is more readily seen in all seasons versus orange and other colors that are hard to see in the fall). When conducting a wildlife census the surveyor should start at the stake marking the beginning of the first transect. After recording their starting location by reading the State Plane coordinates off of the stake they begin walking the first transect. They should see pink flagging tape from the first grid point. As they proceed toward the pink flagging tape they should see the next flagging tape. In this manner they can stay on their transect until they reach the metal stake marking the 100-meter-distance along the transect.

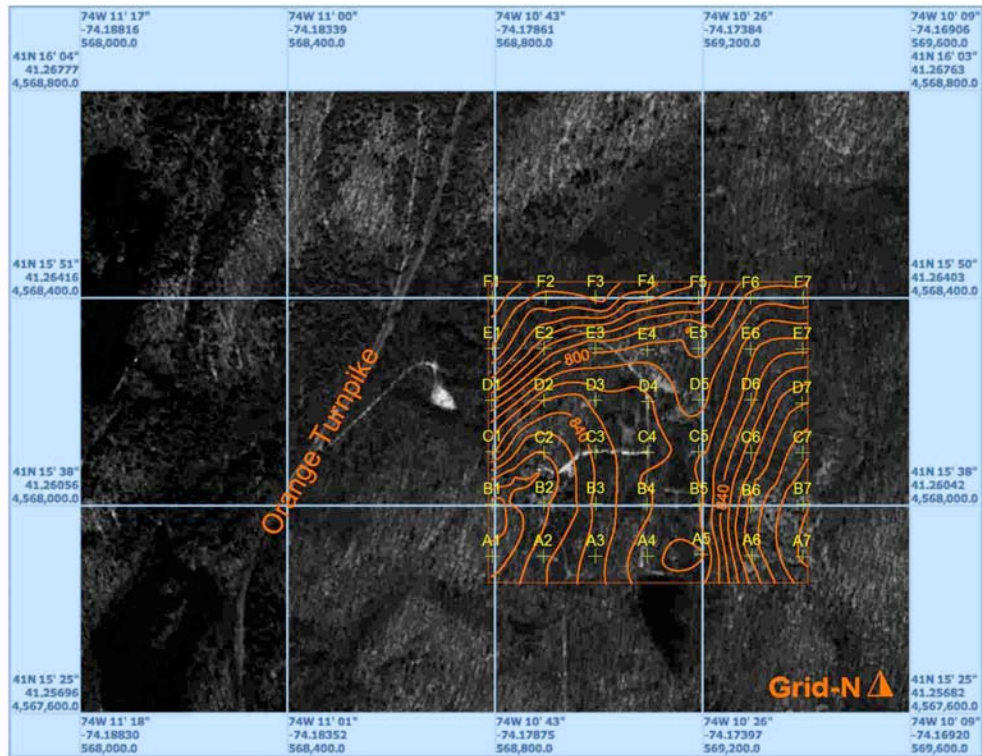


Figure 4: Main study area showing quadrangle points with a contour plot showing topographic changes (10 m intervals).

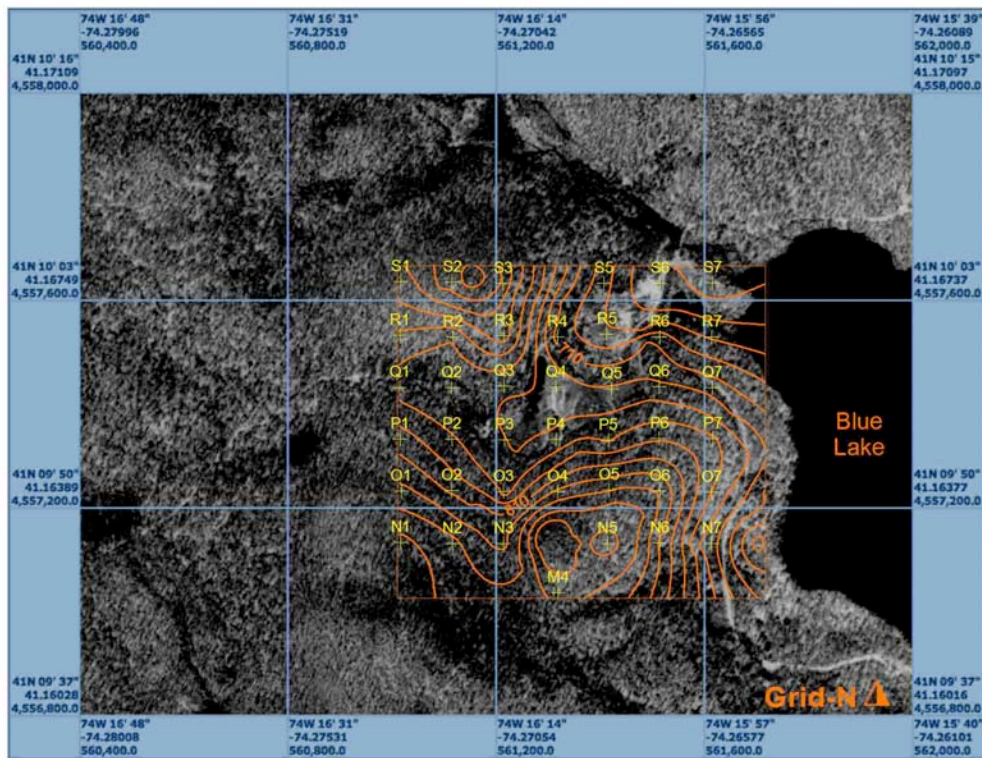


Figure 5: Main study area showing quadrangle points with a contour plot showing topographic changes (10 m intervals).

Table 6: Local and Universal Transverse Mercator (UTM) coordinates of points marking the corners of the census quadrangles at the Main site.

Local X-Coord (m)	Local Y-Coord (m)	Local Elev (m)	Local Elev (ft)	Point ID	UTM N (m)	UTM E (m)	Elev above sea level (ft)
1999.8	5999.7	1018.5	2862.1	A1	4567900.2	568794.9	877.4
2099.4	5999.2	1009.8	2837.4	A2	4567899.7	568894.5	852.8
2200.2	5999.7	1003.3	2819.3	A3	4567900.2	568995.3	834.7
2299.9	6000.1	995.7	2798.0	A4	4567900.5	569095.1	813.4
2405.2	6002.9	993.8	2792.5	A5	4567903.4	569200.3	807.8
2502.1	6001.2	1017.1	2858.0	A6	4567901.7	569297.3	873.3
2599.7	5999.1	1027.3	2886.7	A7	4567899.5	569394.8	902.1
2000.5	6099.5	1020.3	2866.9	B1	4568000.0	568795.7	882.3
2100.7	6101.9	1013.1	2846.7	B2	4568002.3	568895.9	862.0
2200.8	6100.6	1004.1	2821.4	B3	4568001.1	568996.0	836.8
2298.4	6100.0	998.9	2806.8	B4	4568000.5	569093.6	822.1
2400.1	6099.6	997.3	2802.5	B5	4568000.1	569195.3	817.9
2500.6	6097.1	1017.2	2858.3	B6	4567997.6	569295.8	873.7
2600.4	6099.8	1025.9	2882.8	B7	4568000.3	569395.5	898.2
2001.1	6201.0	1000.7	2811.9	C1	4568101.5	568796.3	827.3
2100.7	6199.1	1012.5	2845.1	C2	4568099.5	568895.9	860.5
2199.9	6200.0	1004.3	2822.1	C3	4568100.5	568995.0	837.4
2300.0	6200.0	1000.0	2810.0	C4	4568100.5	569095.2	825.4
2399.7	6201.4	997.6	2803.1	C5	4568101.9	569194.8	818.5
2500.1	6199.3	1011.0	2840.8	C6	4568099.8	569295.3	856.2
2599.9	6199.2	1022.0	2871.7	C7	4568099.7	569395.1	887.1
1999.5	6300.2	987.5	2774.8	D1	4568200.7	568794.7	790.2
2100.4	6300.9	1001.7	2814.9	D2	4568201.3	568895.6	830.3
2199.7	6299.9	999.4	2808.3	D3	4568200.4	568994.8	823.6
2302.6	6298.3	998.6	2806.0	D4	4568198.8	569097.7	821.4
2400.8	6301.0	993.3	2791.1	D5	4568201.5	569196.0	806.5
2500.3	6301.0	1004.1	2821.5	D6	4568201.5	569295.4	836.8
2599.1	6295.1	1015.6	2854.0	D7	4568195.6	569394.3	869.3
2000.9	6400.1	969.6	2724.6	E1	4568300.6	568796.1	740.0
2100.8	6400.2	984.6	2766.7	E2	4568300.7	568895.9	782.1
2199.8	6400.3	989.9	2781.8	E3	4568300.8	568995.0	797.1
2300.0	6398.8	992.5	2788.9	E4	4568299.3	569095.2	804.2
2398.8	6400.2	989.5	2780.6	E5	4568300.7	569193.9	795.9
2499.6	6399.1	1000.7	2812.1	E6	4568299.5	569294.7	827.4
2599.8	6399.5	1004.3	2822.1	E7	4568300.0	569395.0	837.5
1999.8	6499.5	962.5	2704.6	F1	4568400.0	568795.0	720.0
2104.0	6499.8	971.0	2728.6	F2	4568400.3	568899.1	743.9
2200.2	6500.0	968.8	2722.3	F3	4568400.5	568995.4	737.7
2299.0	6500.4	974.2	2737.5	F4	4568400.9	569094.2	752.8
2398.9	6499.1	978.1	2748.5	F5	4568399.6	569194.0	763.8
2499.4	6497.9	992.6	2789.3	F6	4568398.4	569294.5	804.7
2600.6	6499.1	992.0	2787.6	F7	4568399.5	569395.7	802.9

Table 7: Local and Universal Transverse Mercator (UTM) coordinates of points marking the corners of the census quadrangles at the Control site.

Local X-Coord (m)	Local Y-Coord (m)	Local Elev (m)	Local Elev (ft)	Point ID	UTM N (m)	UTM E (m)	Elev above sea level (ft)
1304.2	5005.0	1045.8	2938.7	M4	561319.1	4557037.7	875.7
1001.3	5101.6	1045.9	2938.9	N1	561016.2	4557134.3	875.9
1100.7	5098.8	1039.2	2920.1	N2	561115.7	4557131.6	857.1
1199.3	5098.8	1027.9	2888.4	N3	561214.2	4557131.5	825.5
1399.2	5099.8	1053.7	2960.9	N5	561414.1	4557132.5	898.0
1500.1	5100.3	1028.1	2889.0	N6	561515.0	4557133.0	826.0
1600.0	5098.9	996.8	2800.9	N7	561614.9	4557131.7	738.0
1002.0	5200.6	1031.6	2898.8	O1	561016.9	4557233.3	835.9
1099.3	5201.0	1020.8	2868.5	O2	561114.2	4557233.7	805.5
1198.8	5199.8	1003.9	2821.1	O3	561213.7	4557232.5	758.1
1303.4	5199.6	1030.9	2896.9	O4	561318.3	4557232.3	834.0
1402.6	5203.1	1035.3	2909.3	O5	561417.5	4557235.8	846.4
1499.8	5200.2	1036.1	2911.4	O6	561514.8	4557233.0	848.4
1599.5	5198.7	1008.1	2832.6	O7	561614.4	4557231.4	769.7
999.8	5300.8	1019.2	2864.0	P1	561014.7	4557333.5	801.1
1099.6	5300.1	1009.3	2836.2	P2	561114.6	4557332.8	773.3
1200.6	5299.4	1001.3	2813.6	P3	561215.5	4557332.1	750.7
1300.0	5298.9	1002.9	2818.2	P4	561314.9	4557331.6	755.2
1400.8	5297.9	1007.4	2830.9	P5	561415.7	4557330.6	768.0
1499.2	5301.7	1014.4	2850.6	P6	561514.1	4557334.4	787.6
1601.9	5301.4	1009.4	2836.5	P7	561616.9	4557334.1	773.6
999.3	5399.9	1005.2	2824.5	Q1	561014.2	4557432.6	761.6
1098.9	5399.9	1002.3	2816.6	Q2	561113.9	4557432.6	753.6
1200.5	5402.1	1002.1	2816.0	Q3	561215.5	4557434.9	753.1
1300.0	5400.0	1000.0	2810.0	Q4	561314.9	4557432.7	747.1
1407.5	5397.2			Q5	561422.4	4557430.0	
1498.7	5401.3	995.2	2796.5	Q6	561513.6	4557434.0	733.5
1600.5	5399.6	991.2	2785.3	Q7	561615.4	4557432.3	722.4
1000.0	5500.2		0.0	R1	561014.9	4557532.9	
1101.8	5497.5	1009.0	2835.3	R2	561116.8	4557530.2	772.3
1200.0	5499.2	1025.9	2882.8	R3	561214.9	4557531.9	819.8
1303.2	5496.7	983.7	2764.3	R4	561318.1	4557529.5	701.4
1398.1	5502.5	973.8	2736.4	R5	561413.0	4557535.3	673.4
1500.0	5497.4		0.0	R6	561514.9	4557530.2	
1600.0	5497.4	971.6	2730.3	R7	561615.0	4557530.1	667.4
1001.3	5603.8	1025.8	2882.5	S1	561016.2	4557636.5	819.6
1100.7	5603.1	1037.9	2916.6	S2	561115.6	4557635.8	853.7
1198.3	5600.8	1034.7	2907.6	S3	561213.2	4557633.5	844.7
1392.4	5600.9	975.3	2740.6	S5	561407.3	4557633.6	677.7
1500.1	5600.0	959.5	2696.2	S6	561515.1	4557632.8	633.2
1601.1	5602.1	953.8	2680.2	S7	561616.0	4557634.8	617.3