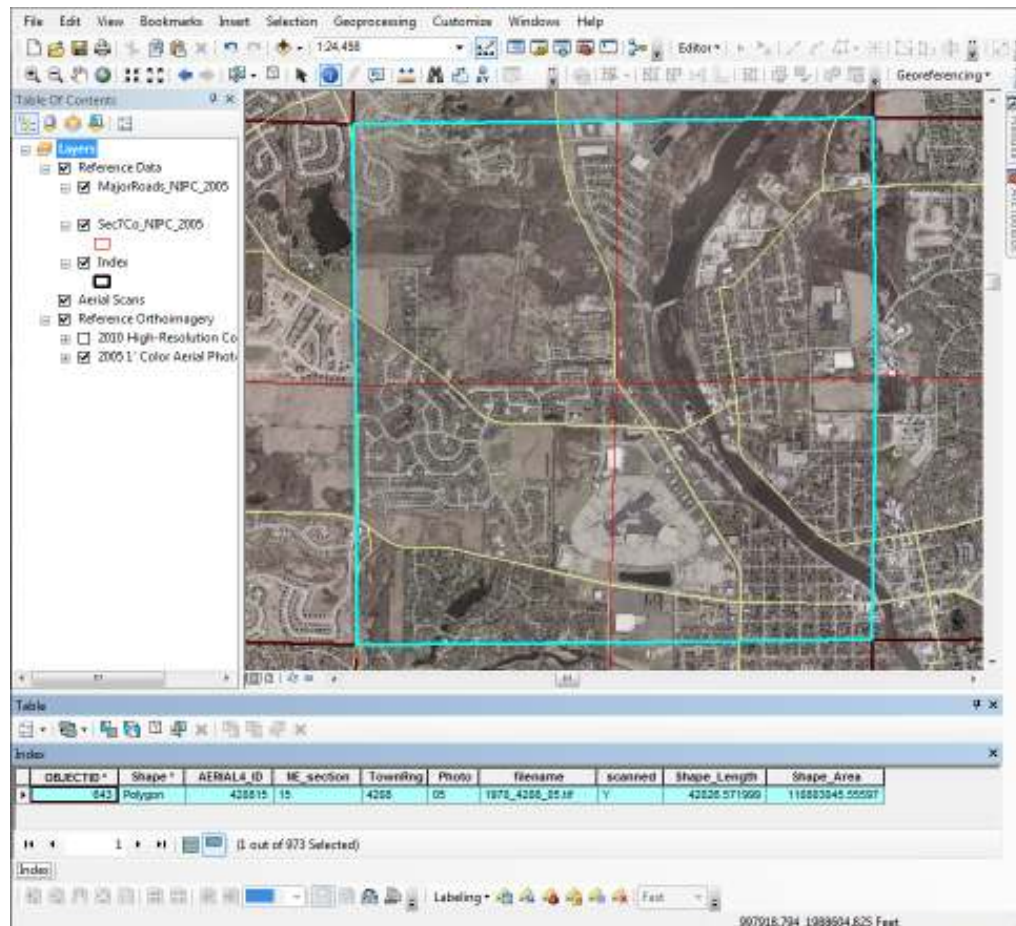# CMAP's Historical Aerial Photo Georeferencing Workflow
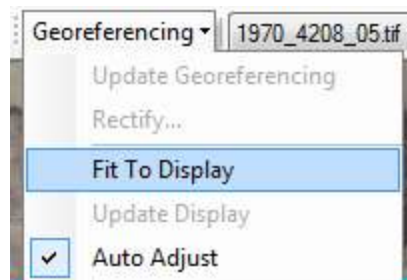
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After a set of historical aerial photos have been scanned into TIFF format, they must be georeferenced in order to be properly viewed in a GIS software package. This document describes the workflow used for such georeferencing at CMAP, using a scanned photo from 1970 as an example.
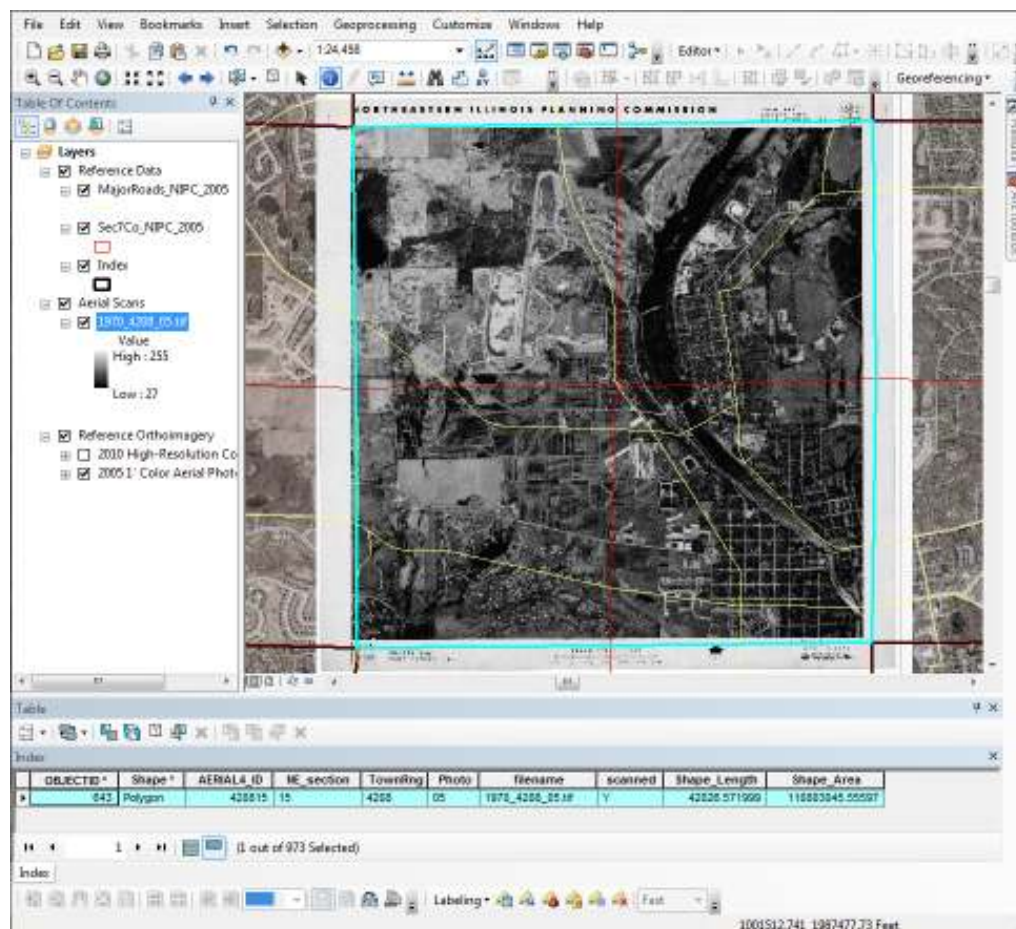
1. Open the georeferencing template ArcMap document, containing major roads, Public Land Survey (PLS) boundaries, and aerial imagery from 2005 as reference datasets.

2. This map document contains an "**Index**" polygon layer, which has 9 square features for each PLS township. Each of these squares corresponds to the approximate extent of a single scanned aerial photo (although the photos are always slightly larger).

   a. Open the **Index** attribute table and select the polygon corresponding to the scanned photo about to be referenced.

   b. Zoom to the selection. The ArcMap dataframe should now be centered on a single **Index** square.

3. Now the non-georeferenced TIFF can be added to the document, and it will be placed in roughly the correct location.

    a. Open the "Add Data" dialog window and navigate to the directory containing the scanned photos. Add the TIFF corresponding to the selected **Index** polygon. The image probably won't appear on the map yet.

    b. In the Georeferencing Toolbar, make sure that the newly-added image is selected in the drop-down menu, and then click "Georeferencing" --> "Fit To Display".

    c. As in the screenshot below, the scanned image will now be in nearly the correct place, but still needs some adjustments.

4. Control points can be added in places where features visible in the scanned photo can be accurately matched with other data layers in the map document. It is important that the control points be distributed quite evenly throughout the entire image, and not clustered in one or two smaller areas: this can lead to greater distortion in the areas

with few (or no) control points. Only a "1st Order Polynomial (Affine) Transformation" should be used, which requires a minimum of 3 control points. However, the more control points added, the better the georeferencing will be, since errors introduced by one control point will be mitigated by all of the others. Therefore, aim for a minimum of 6 evenly-distributed control points per image, and an ideal of 15-20.

a. To begin adding control points, click the "Add Control Points" button in the Georeferencing Toolbar.

b. For each control point, two clicks on the map are required: the first click is the control point's location on the non-georeferenced image; the second click is on the correct, georeferenced location (using the map document's other data layers). While clicking on control points, zoom/pan and turn data layers on/off as much as necessary to be absolutely confident in the locations you're clicking. When in doubt, pick another control point instead!

c. Once a suitable number of control points have been added, look at each one again: make sure it was specified as accurately as possible. Don't be afraid to delete control points and recreate them, or replace them with a better option.

d. A good general strategy is to define the first control points using the obvious street intersections, using the major roads data layer to identify the "true" locations. Major roads are less likely to have moved between the year of the scanned photo and the year of the reference data than other features like the corners of houses. Below is a set of 7 control points for the example photograph at major road intersections.

Once the display has updated based on these control points (which "Auto Adjust" mode does automatically), a final solution is usually close at hand.

e. However, because it can be challenging to accurately click the exact center of an intersection on the scanned photo, and because there is no guarantee that there will be six or more evenly-distributed intersections, these points should be supplemented or (ideally) replaced with control points corresponding to features that are clearly identifiable in both the scanned photo and the reference aerial photography (either the 2005 set, or the higher-resolution 2010 set). Once these other points have been added, the error-prone road intersection control points may be doing more harm than good, and their deletion should be strongly considered when a sufficient number of higher-accuracy options are available. For example, the corners of certain houses can be very distinct and easy to select with great confidence:

This will of course require the scanned photo layer to be repeatedly toggled off and on, so that the imagery behind it can be seen and the best candidates

control point candidates can be identified. Corners of tall buildings may appear far from their actual coordinates, depending on the angle of the camera taking the photos – use reference points as close to the ground as possible.
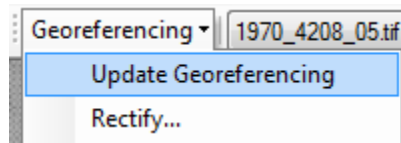
f. The Link Table is tremendously useful for identifying problematic control points, as the points can be sorted by "Residual" (i.e. the distance between the source and map locations for each control point). The points with the highest residual are likely to be the ones causing the biggest errors. Individual control points can be turned on and off to see their effect on the "Total RMS Error": the smaller this number – while still maintaining a healthy number of evenly distributed and accurately defined control points – the better.

Link

Total RMS Error: Forward: 16.1114

	Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	<Residual>
✓	4	27.755885	18.390236	998726.727207	1983110.267013	12.6213	18.5023	22.3972
✓	5	27.878668	27.339294	998761.501513	1986792.665740	-8.11357	-19.8267	21.4226
✓	2	16.674642	17.352242	994106.081229	1982705.094126	-10.8224	12.7106	16.6939
✓	7	23.210205	6.970544	996820.924694	1978345.357235	-1.72239	-11.2333	11.3646
✓	1	16.809738	26.971886	994182.076599	1986700.684403	4.21323	8.77441	9.73353
✓	6	6.666940	19.841520	989970.650818	1983747.618721	3.82384	-8.92727	9.71174
☐	3	14.780860	6.538608	993277.990951	1978159.989959	0	0	0
☐	8	8.669319	8.860223	990712.431417	1979168.012601	0	0	0
☐	9	9.173407	27.116355	991026.355028	1986738.498712	0	0	0

For the test image, seven control points were used in the end. Six of these are building corners. They were distributed quite evenly, although no reliable control points could be established in the southwestern quadrant.

g. When the control points are satisfactory, save the georeferenced image by selecting "Georeferencing" --> "Update Georeferencing" from the Georeferencing Toolbar.

Georeferencing ▾	1970_4208_05.tif
Update Georeferencing	
Rectify...	

This will create a .tfwx file with the same name as the TIFF being georeferenced, in the same directory – in the example case, the file produced is 1970_4208_05.tfwx. This is simply a "world file" containing 6 numeric parameters that define the transformation, and is what allows a TIFF to be displayed in the correct location in a GIS package. The corresponding .tif.aux.xml file will also be updated with information about the coordinate system and control points used to define the transformation. Needless to say, these files are important – don't delete them!