



NEH Community Deep Mapping Institute

Georeferencing Historical Maps



Introduction

Georeferencing is the process of aligning imagery with real-world geographic coordinates. Essentially assigning a real-world geographical location to an image such as a historical map scan. Georeferencing involves identifying ground control points, which are locations that are known on the earth's surface. Georeferenced maps are one of the most important pieces of a deep map as they serve as the foundation for much of the data that is included in your deep map. A georeferenced map serves many different purposes and can be used as historical cartographic overlay maps in your deep Map, but as just important, it is used to digitize historical features such as building footprints, streets, and other important features on the historical landscape. Georeferenced historical maps can also be used to create historical geolocators (a subject of a future workshop module!). When georeferencing historical maps from different years, it allows you to visually show how the landscape has changed overtime.

In this module you will learn how to georeference a historical map scan. The tutorial will georeference and mosaic two Sanborn Fire Insurance Plan Sheets from the Library of Congress using Michigan Tech's instance of Map Warper online georeferencing software. Georeferencing is not limited to Sanborn Fire Insurance Plans! We encourage you to follow along using any historical map scan from your Deep Mapping project. Michigan Tech's Geospatial Research Facility hosts its own instance of MapWarper for the NEH Community Deep Mapping Institute. Map Warper is an open source image georeferencing tool which runs through a web interface. With Map Warper you can georeference historical map sheets and optionally create a mosaic of several georeferenced historical map sheets. A mosaic is when you have more than one historical map stitched together, such as adjacent Sanborn sheets. The advantage of a mosaic is that it uses several maps representing the same time period to depict an urban place in greater extent and details while still maintaining the historical perspective from the original cartographer (Lafreniere & Rivet, 2010). When a map is georeferenced in Map Warper it automatically produces and serves what is called a tile cache. A tile cache allows large map images to be displayed faster in your deep mapping application. It also produces a **tile url**, which allows for easy integration of your georeferenced maps into your deep mapping application and into GIS software such as ArcGIS Online, ArcGIS Pro, and QGIS.

Georeferencing and mosaicking can also be done using ArcGIS Pro or QGIS. If you are interested in using either of those platforms instead there are a couple of tutorials available for each platform listed below.

1. [Georeferencing a Historical Map in ArcGIS Pro](#) - Van Pelt and Opie Library
2. [Georeferencing in QGIS](#) - QGIS Training Manual

Considerations when Georeferencing

Map Scale

When georeferencing historical maps there are a few things to consider. First is the scale of the historical map. Maps such as Sanborn Fire Insurance Plans are larger scale maps (1 inch to 50 feet), meaning they show more detail in a smaller area such as buildings and individual roads. Maps like this typically consist of many sheets covering a smaller area such as a town or city. Smaller scale maps, which have less detail and show a large area will often cover entire counties, states, or countries in a single map sheet. Smaller scale maps cover a wider area and are going to require less control points to accurately georeference than larger scale maps.

Basemap

Another important consideration is the basemap you are georeferencing the historical imagery to. It is highly recommended to use a satellite (aerial imagery) basemap or a combination of streets and aerial imagery basemaps. If you are fortunate enough to have basemaps of historical aerial imagery of the area that would be the best option.

Control Point Location

Georeferencing historical maps can be difficult at times due to the changing landscape. What was once there 100 years ago may no longer exist at all today, making georeferencing all or a portion of the map difficult or impossible. The most common features to georeference a historical map to are things that typically don't change a lot over time and still may exist today. Good examples are street intersections or the

corners of old historical buildings such as courthouses, churches and rear lot lines (Lafreniere & Rivet, 2010).

File Format and Resolution

Additional considerations when georeferencing historical maps are the file format and resolution of the historical map image scans. Deep web mapping applications use tile caches of georeferenced maps which allow for deep zooming of the historical map scans. For deep zooming, maps scanned at a high resolution are required to clearly display map text and features at higher zoom levels. It is recommended that your historical map scans be at least 300 dpi. For maps covering a larger area, a dpi in the range of 600 is recommended. The Sanborn Fire Insurance plan map scans used in this tutorial from the Library of Congress are available at 300 dpi in TIFF format. Map Warper can accept images in JPEG, PNG, GIF, or TIFF file formats. Please note that you should not use PDF files in Map Warper.

Georeferencing using Map Warper

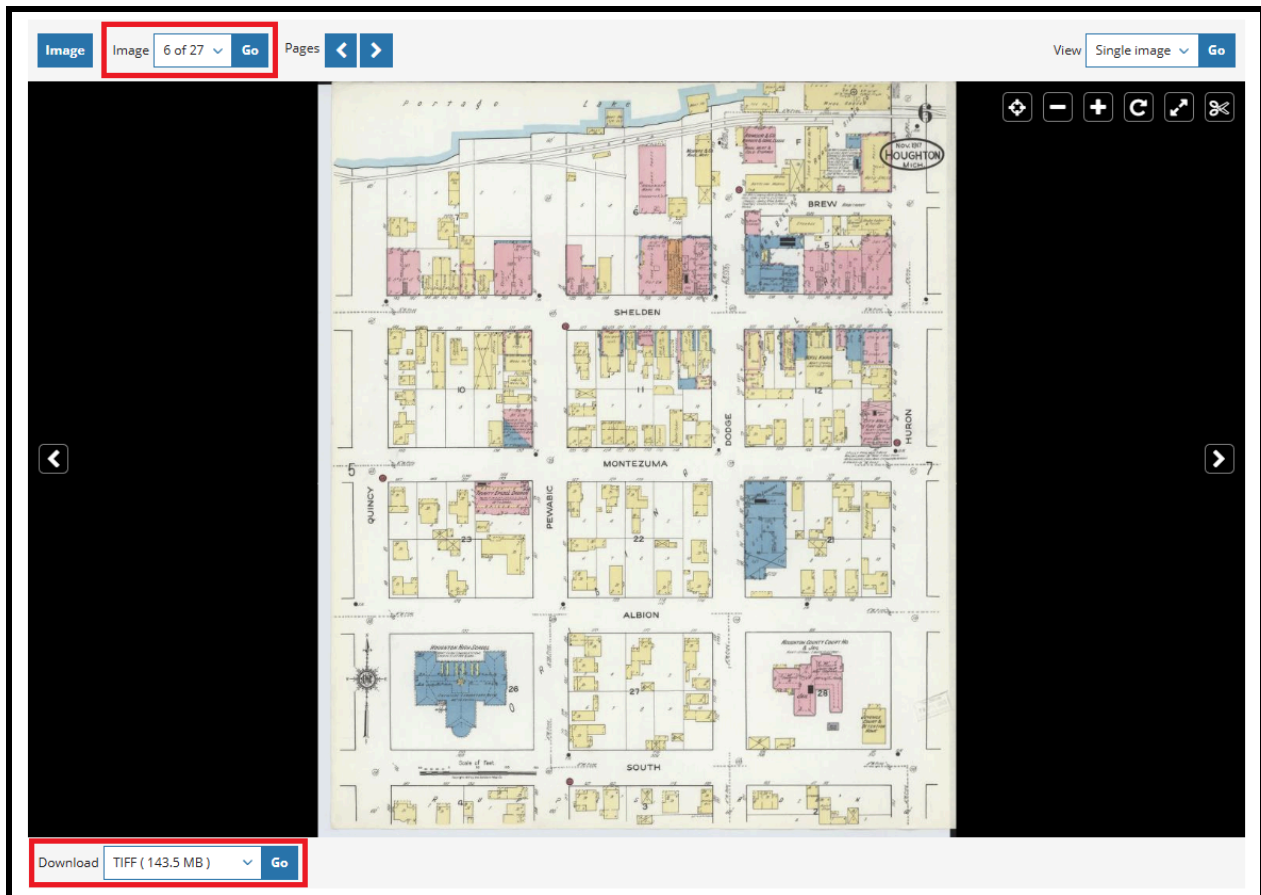
This section of the module will walk you through georeferencing a historical map scan in Map Warper. We will be using a Sanborn Fire Insurance Plan sheet from the Library of Congress but you can follow along using your own historical map.

Download Sanborn Fire Insurance Plans

If you are following along using the tutorial data. First you will download two Sanborn Fire Insurance Plan sheets from the Library of Congress. We will use sheets 6 and 7 from Houghton, Michigan for the year 1917.

1. Go to:
<https://www.loc.gov/resource/g4114hm.g040451917/?sp=1&st=image&r=-0.561,-0.001,2.122,1.315,0>
2. From the drop down menu select sheet 6 of 27 and press **Go**.

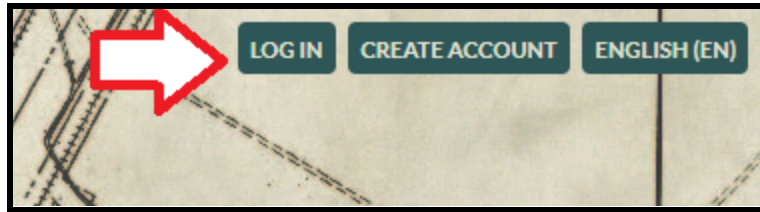
3. From the **Download** drop down select TIFF and Press **Go** to download the image.



4. Repeat this process for Image 7. You should now have Sanborn sheets 6 and 7 downloaded as .TIFF images for Houghton Michigan in 1917. Remember the location of these on your hard drive as we will use them later.

Logging into Map Warper

1. Go to The Geospatial Research Facility's instance of Map Warper at: <https://geomapwarper.sabu.mtu.edu/>
2. Click the **LOG IN** button. Sign in with the credentials you were provided in your email. Your team should have one login for the entire team to share.



- At the **sign in page** enter the credentials provided to your team and click **login**.

 A screenshot of the 'Log in' page. It has a white background with a black border. The title 'Log in' is at the top. Below it are two input fields: 'Email' with the text 'rcowling@mtu.edu' and 'Password' with masked characters. There is a 'Remember Me' checkbox and a 'LOG IN' button at the bottom.

- You are now logged into Map Warper. You are presented with an interface with several tabs and sections of previously uploaded maps. Please be aware that the maps shown here are from everyone using this instance of Map Warper, not only from your team.

 A screenshot of the MTU Map Warper dashboard. The header shows the 'MTU Map Warper' logo and a navigation bar with tabs: Home, Browse All Maps, Browse Rectified Maps, Find Maps by Location, Upload Map, Browse All Mosaics, Find Mosaics by Location, Add Mosaic, About, and Help. The main content area is divided into sections: 'Overview' with a description and an 'UPLOAD MAP!' button; 'What is it?' with a paragraph about the tool; 'Favourites' with a table of saved maps; and 'Last Rectified Maps' with a table of recently processed maps. The 'Last Rectified Maps' table includes columns for Map, Title, Year, Last Updated, and Status.

MAP	TITLE	YEAR	LAST UPDATED	STATUS
	Sanborn Fire Insurance Plan Sheet 7 of Houghton, Michigan 1917 <i>Sanborn Fire Insurance Plan Sheet 7 of Houghton, Michigan 1917 From the Library of Congress. (In 1 layer)</i> View Map Rectify Map Add Favourite Download KML	1917	1 day ago	3 control points

5. Let's look at some of the more important tabs and what they do. Navigate to each tab and briefly look at the page.

a. Browse All Maps

- i. Shows all uploaded maps from anyone using this instance of Map Warper.

b. Browse Rectified Maps

- i. Displays all georeference maps from anyone using this instance of Map Warper.

c. Find Maps by Location

- i. Allows for searching of georeferenced maps by spatial location or extent.

d. Upload Map

- i. This is where you upload your historical maps!

e. Browse All Mosaics

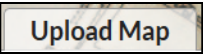
- i. View all historical mosaics made by anyone using this instance of Map Warper.

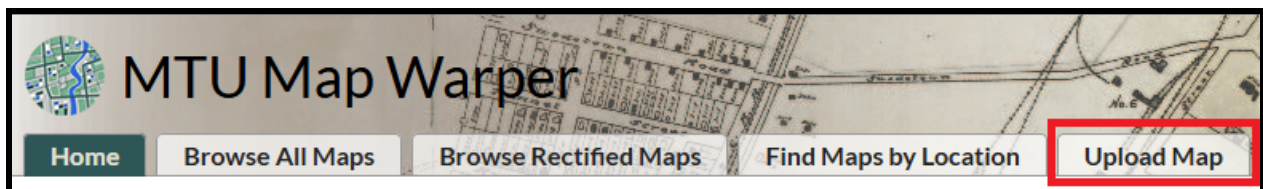
f. Find Mosaics by Location

- i. Locate mosaics based on their spatial location or extent.

g. Add Mosaic

- i. This is where you can create a mosaic from your georeferenced map sheets!

6. Click on the **Upload Map**  tab. This is where you will upload your map image and add metadata about the map. Click on the **Choose File** button under **Upload An Image File**. Select the Sanborn Fire Insurance Plan .TIFF for sheet 6 from where you saved it on your hard drive.



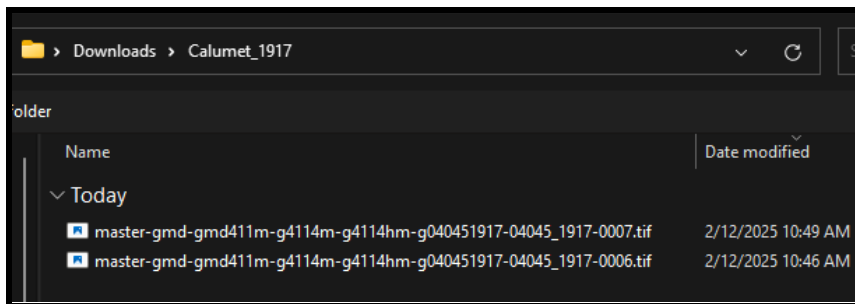
Upload An Image File:

No file chosen

OR

Upload from a URL:

Map visibility. Maps are by default visible to all users.



7. Next fill in metadata about your map. At a minimum the metadata should include
 - a. Title
 - b. Description
 - c. Tags
 - i. Optionally it would be good to include an Issue Year, Date Depicted, and a Source.
8. When you are finished press the **CREATE** button. Your map will now be uploaded. ***Depending on the size this could take a few minutes.***

Upload a new map

By uploading images to the website, you agree that you have permission to do so, and accept that anyone else can potentially view and use them, including changing control points.

Title

Description (max 255 chars)

 Source: Library of Congress.

Subject Area (optional)

Metadata Unique ID (optional)

Source / Bibliographic Ref URL (optional)

Call Number (optional)

Publisher (optional)

Place of Publication (optional)

Author(s) (optional)

Date Depicted (year, optional)

Published Date (optional)

Reprint Date (optional)

Scale (optional)

Metadata Projection (optional)

Metadata Locations (optional)
 Lat:
 Lon:

Upload An Image File:
 master-gmd...917-0006.tif
 OR
 Upload from a URL:

Map visibility. Maps are by default visible to all users.

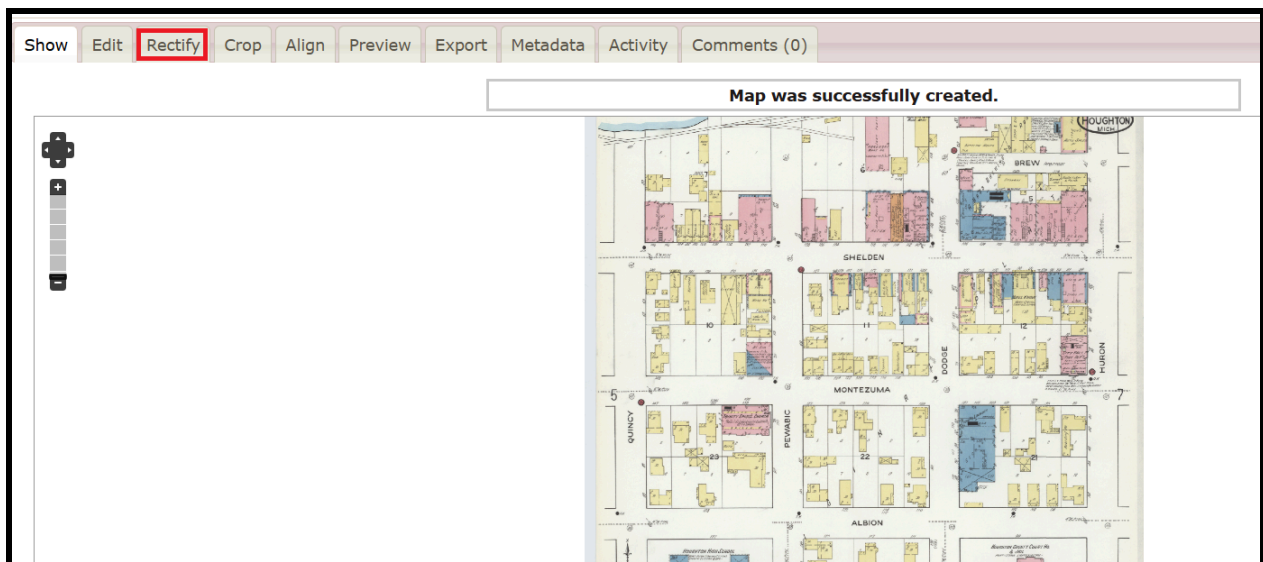
Issue Year (year, optional)

Used to display maps by year:

Tags (comma separated)

Is a map ☒

- You should now see your map displayed in a zoomable window. Next we will georeference the map. Click on the **Rectify** tab.



Georeferencing a historical map

On the **Rectify** Tab you will be presented with two side-by-side screens. The one on the left is your Sanborn Fire Insurance Plan .TIFF. The one on the right is a web map to which you will georeference your image. This will be done by adding **control points** on each of the two screens. First by selecting a location on the Sanborn Map, then by

selecting its real world location on the web mapping interface. The two interfaces have similar controls, let's look at what each one does before you begin.

Tool Overview

- The **Add Control Point** tool  allows you to add a control point on your uploaded map and on the web map.
- The **Move Control Point** tool  allows you to move an existing control point.
- The **Move Around Map** tool  allows you to pan around the map.
- The **Add Custom Basemap** tool  lets you use custom basemaps from a service URL.
- The **Map Selector** menu  allows you to change the basemap between streets and satellite.

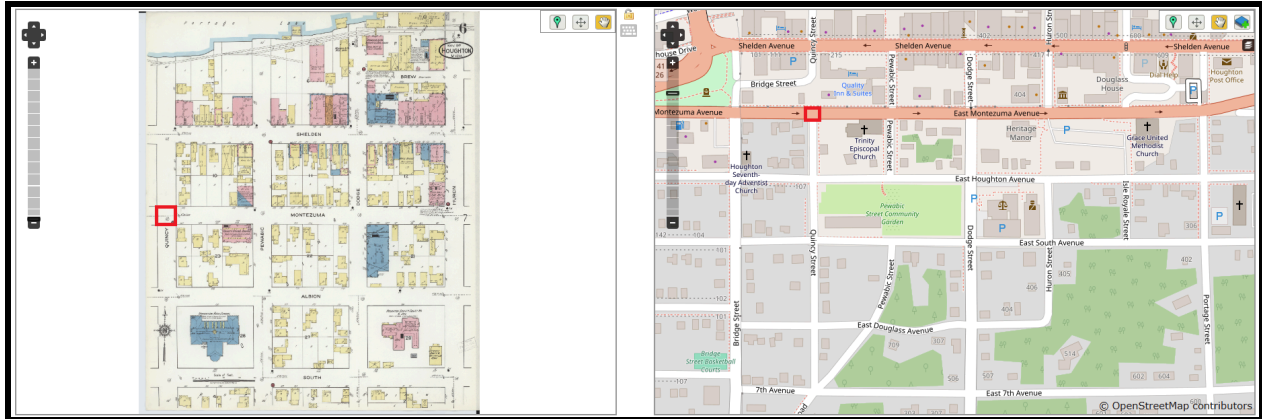
- The **Move Control**  provides another option to move the map or image right, left, up, down

- The **Zoom Slider Control**  provides another method of zooming in and out. You can also do this with your mouse wheel or trackpad.

1. On the Web mapping interface, zoom to the location that your historical map shows. In this tutorial we are going to zoom into the City of Houghton, Michigan. The easiest way to georeference Sanborn maps is by using street intersections. Street intersections typically don't change much over time. Looking at the Sanborn Fire Insurance Plan you can potentially locate intersections that still exist today and zoom the web map to that area as a starting point. Using the

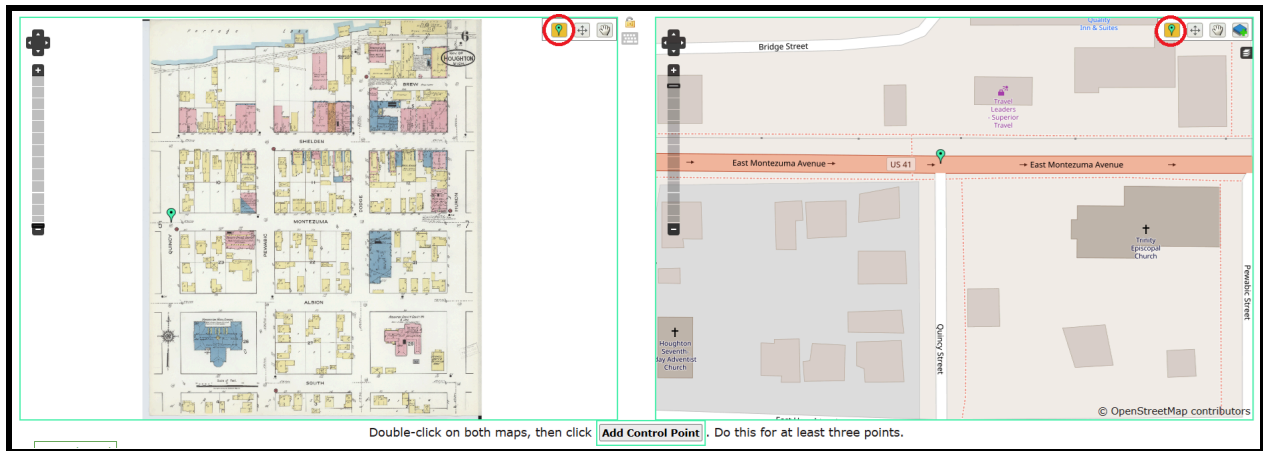
zoom slider control (or your mouse wheel) and the **Move Around Map**  tool, zoom and pan to the city of Houghton, Michigan.

2. One of the street intersections that can easily be identified is the intersection of Montezuma and Quincy Street. Use the zoom slider or your mouse wheel to zoom to the intersection on the Sanborn Map. Then zoom to the intersection on the web map.



3. When georeferencing it is a good practice to start with the historical map first and then the web map second. Click on the **Add Control Point**  tool and place a control point on the Sanborn map image at the intersection of Quincy and Montezuma streets by clicking on the location on the image at the intersection. The green marker will appear on the Sanborn Fire Insurance plan.
4. Next, on the web map interface click on the **Add Control Point** tool. Click on the intersection of Quincy and Montezuma on the web map and place the control point. Zooming and panning the map as needed. The green marker will appear at that location on the web map interface.
5. If at any point you need to adjust your control points, you can use the **Move**

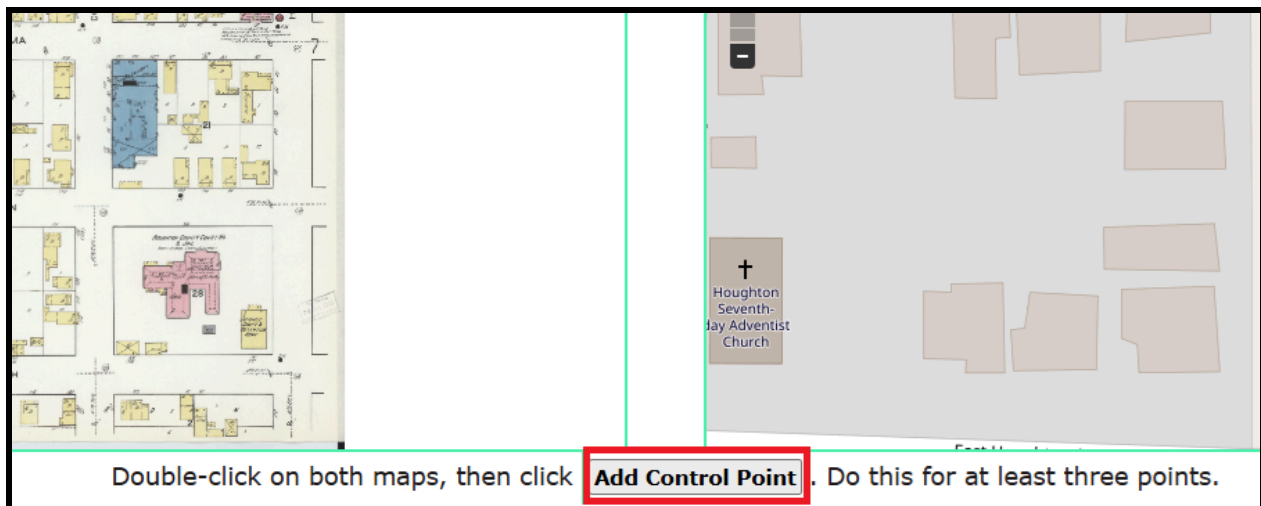
Control Point  tool to reposition the control point on either the image or the web map interface.



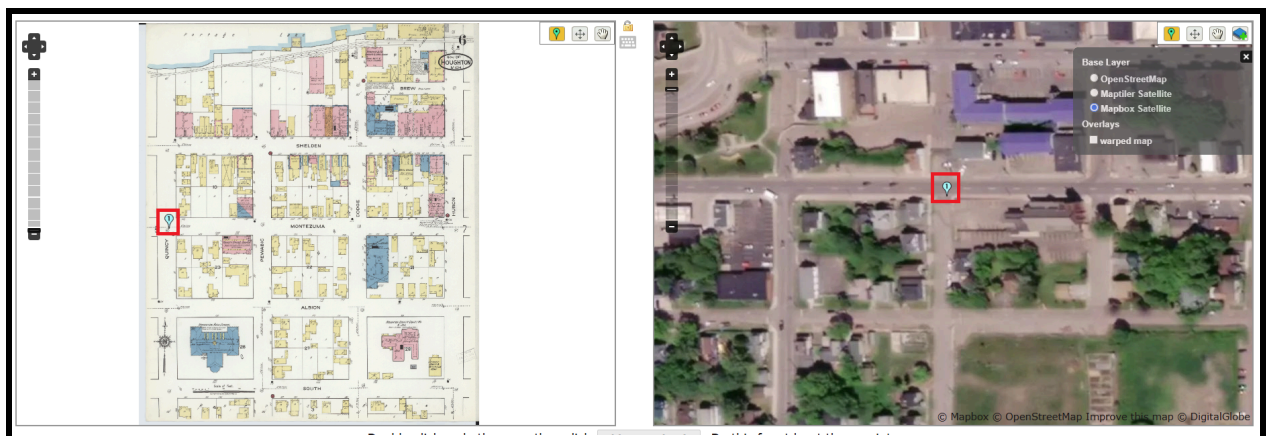
- You can also change the basemap to satellite making it easier to reference things such as buildings and see how your control points align with the street intersections. Simply Click on the **Map Selector Menu**  button and Select **Mapbox Satellite**.



- Now click on the **Add Control Point** button underneath the map interface.

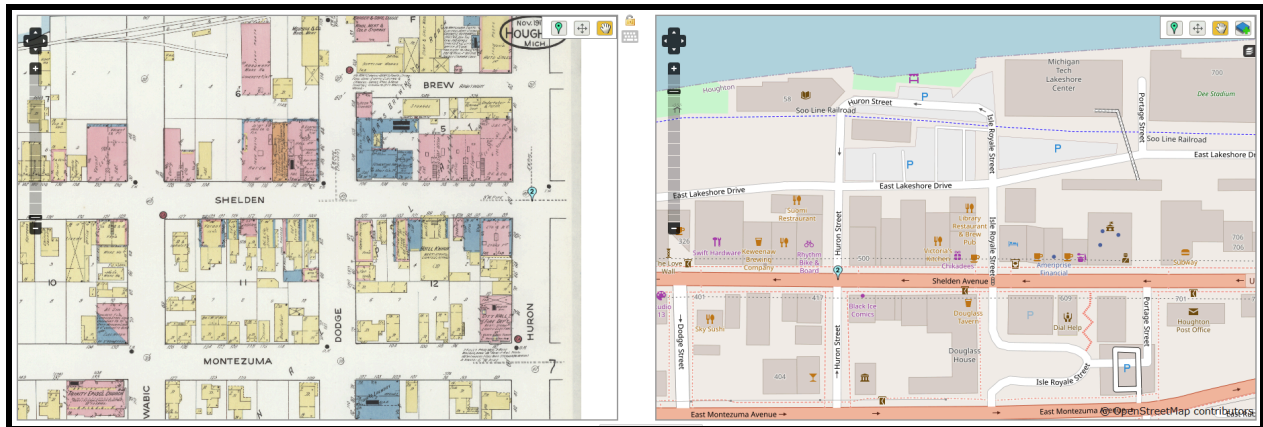


8. You will now notice both of your map markers have changed color and been assigned a number, 1. This is your first control point and this means that the numbered markers on both the Sanborn map and the web map correspond with each other.

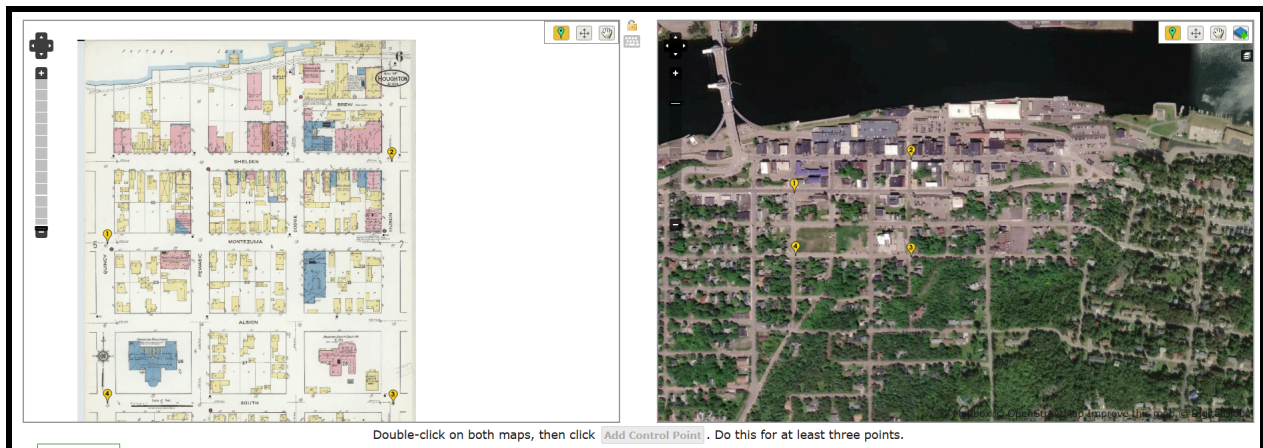


9. Now let's add another control point. Click on the **Map Selector** button and switch back to OpenStreetMap so that you can view the streets with text names. For best results your control points should be spread out as evenly as possible throughout the map. Another easily identifiable street intersection is the intersection of Shelden and Huron streets. Using the **Move Around Map tool** and zoom tools on the web map interface go to the intersection of Shelden and Huron Streets (it is about ¼ mile east of your first control point).
10. Using the window with your Sanborn Map image first, click the **Control Point tool** and click at the intersection of Shelden and Huron streets on the Sanborn Map. Repeat this process in the web map interface. Click the **Add**

Control Point button when finished. You will see this control point has been assigned a value of 2. You now have added two control points.



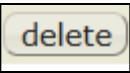
11. To reference a map in Map Warper, you need at least 3 control points. For this Sanborn Map sheet which covers a relatively small area, we will add two more control points. Find two more existing street intersections and repeat the steps, above adding two more control points. The image below shows control points at the intersections of East South Avenue and Hruon and East South Avenue and Quincy Streets. This adds a good number of control points at the corners of the map for accurate georeferencing.



12. You now have four control points. Check over your control point locations and make sure you are satisfied with the result. If adjustments need to be made to any control points, you can reposition them using the **Move Control Point Tool**

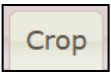


13. If you make a mistake when adding a control point and you want to delete the control point altogether, under the **Control Panel** click **Control Points**. The

Control Points table will appear. Press the **delete**  button to remove that control point.

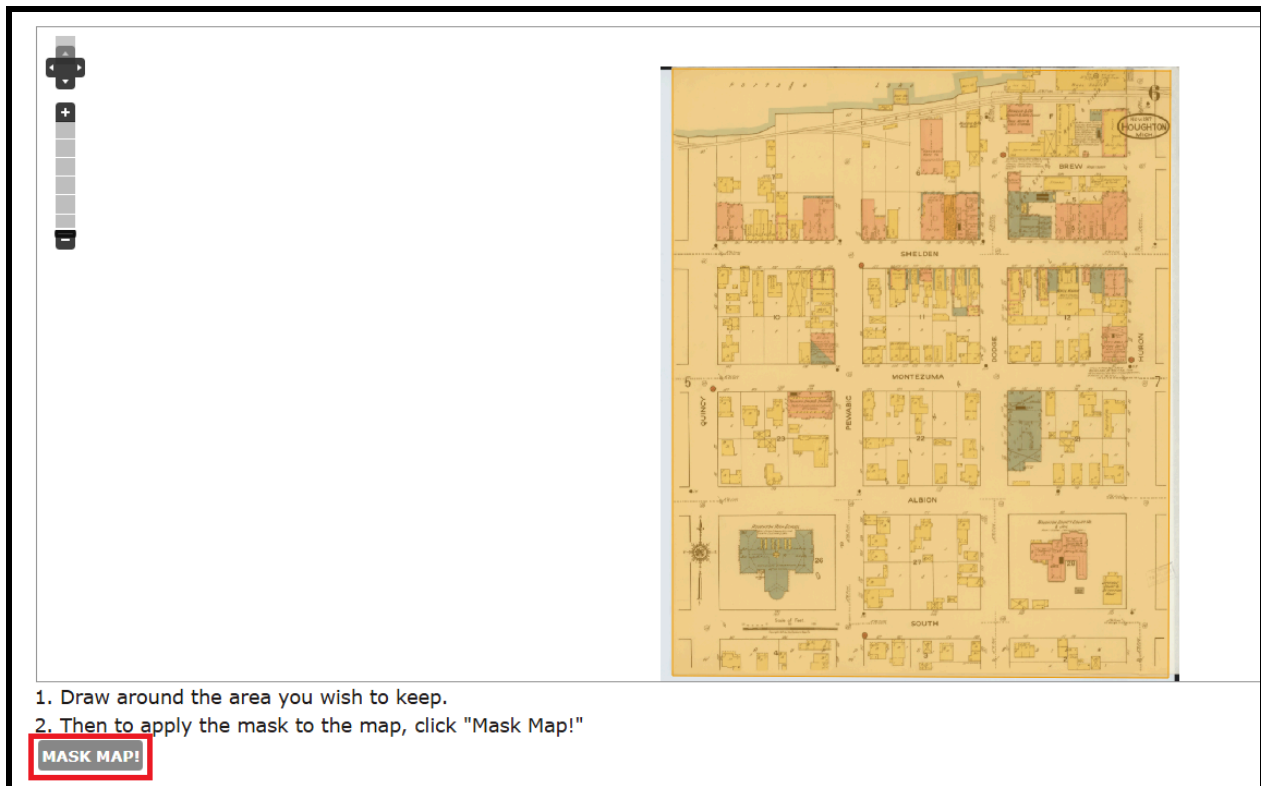
Control Panel						
Control Points						
Point	Image X	Image Y	Lon	Lat	Error(0.00)	
1	679.5775	2915.815	-88.5681322182	47.1218589397	0.00	
2	6035.9425	7450.1	-88.564395901	47.1197454483	0.00	
3	4430.3175	308.28	-88.5656082595	47.1230853833	0.00	

14. Now you are ready to warp the image but first you can apply a **clipping mask**. A clipping mask will remove the borders from the map. In this example the Sanborn Map sheet has borders we don't want on the left and right side.

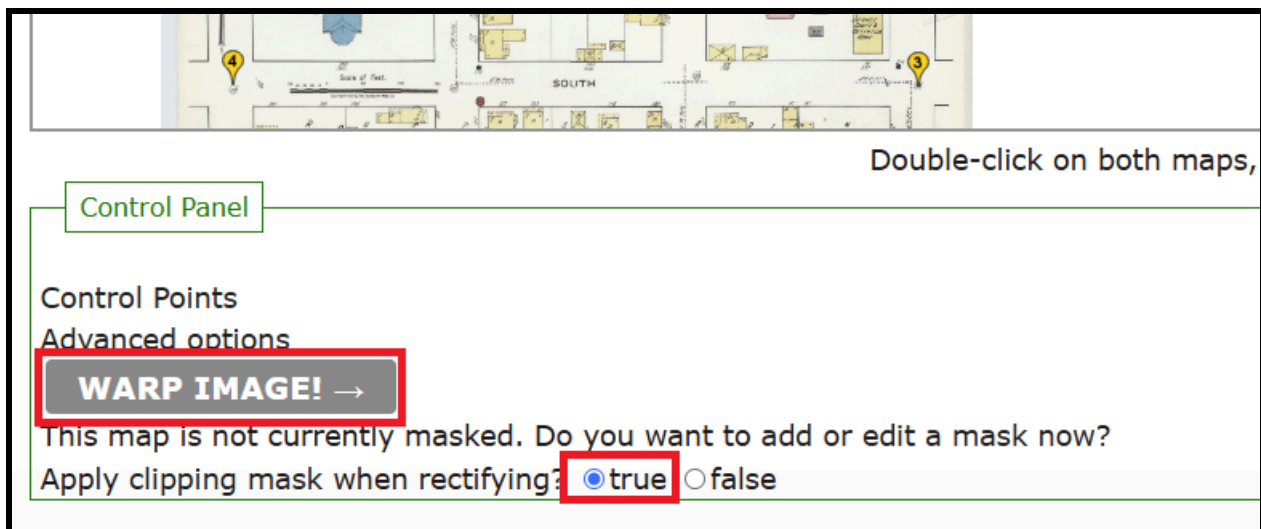
15. Click on the **Crop**  tab and follow the instructions below.

16. On the **Crop** tab you will see your map image and a series of tools on the right hand side.

- The **Hand** tool  allows you to move the map around.
 - The **Draw Polygon** tool  allows you to draw a clipping mask polygon.
 - The **Edit Polygon** tool  allows you to edit your clipping mask.
 - The **Delete Polygon** tool  will delete your clipping mask.
17. Click on the **Draw Polygon**  tool. You will use this tool to draw a masking polygon over your map. You will want to draw a polygon that will crop out unwanted sections of the map, such as a border or white space. Start on the right side of the map by clicking down on the upper right hand corner. You will see a blue dot appear along with a line. Drag the dot over to the upper left hand corner to where the actual map ends and click down to create a vertex. Now drag to the lower left corner and click down and create another vertex. Next drag over to the lower right hand corner and click down to create a vertex and finally up to the upper right hand corner and double click to finish. If you need to adjust the polygon or remove it, you can use the **Edit Polygon**  tool to adjust the polygon or the **Delete Polygon**  tool to start over.
18. When you are finished hit the **MASK MAP!** Button.



19. Return to the **Rectify** tab. Select the box for **Apply clipping mask when rectifying?** to true. Click the **WARP IMAGE!** Button.



20. The map will now be georeferenced. You can examine the georeferenced map now in the web map interface. Use the opacity slider on the bottom to adjust the opacity of your Sanborn Map. It is recommended you compare with the **Mapbox Satellite** layer. You can select it with the **Basemap Selector**  button. Compare the alignment of the streets and buildings on the Mapbox Satellite layer

with the georeferenced Sanborn map

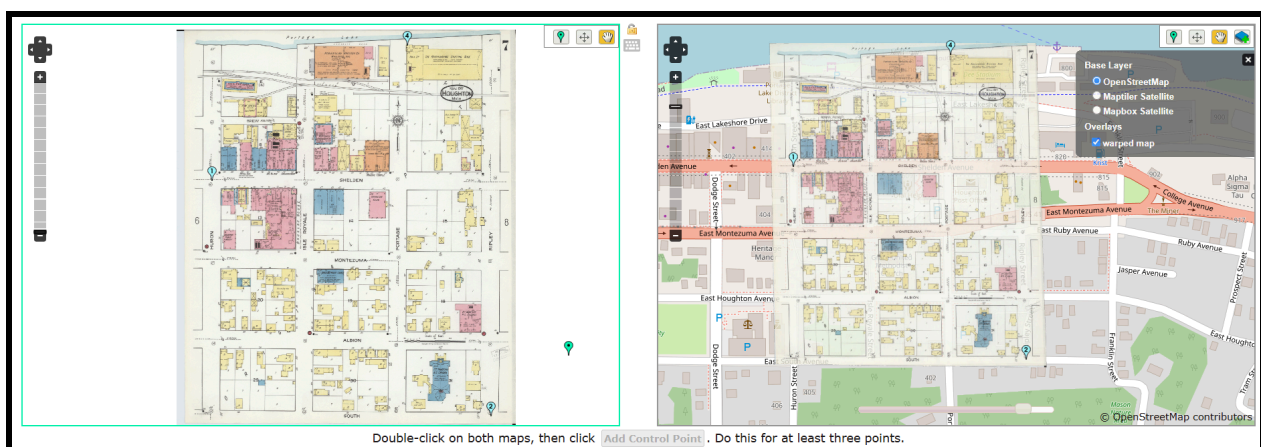


21. If corrections are needed use the **Move Control Point** tool to adjust one or more control points on both the Sanborn map image and the web map and hit the **WARP IMAGE!** Button again and the image will re-georeference. If you need to delete a control point, bring up the **Control Points table**, select and delete the control point and hit the **WARP IMAGE!** button again to see the result.



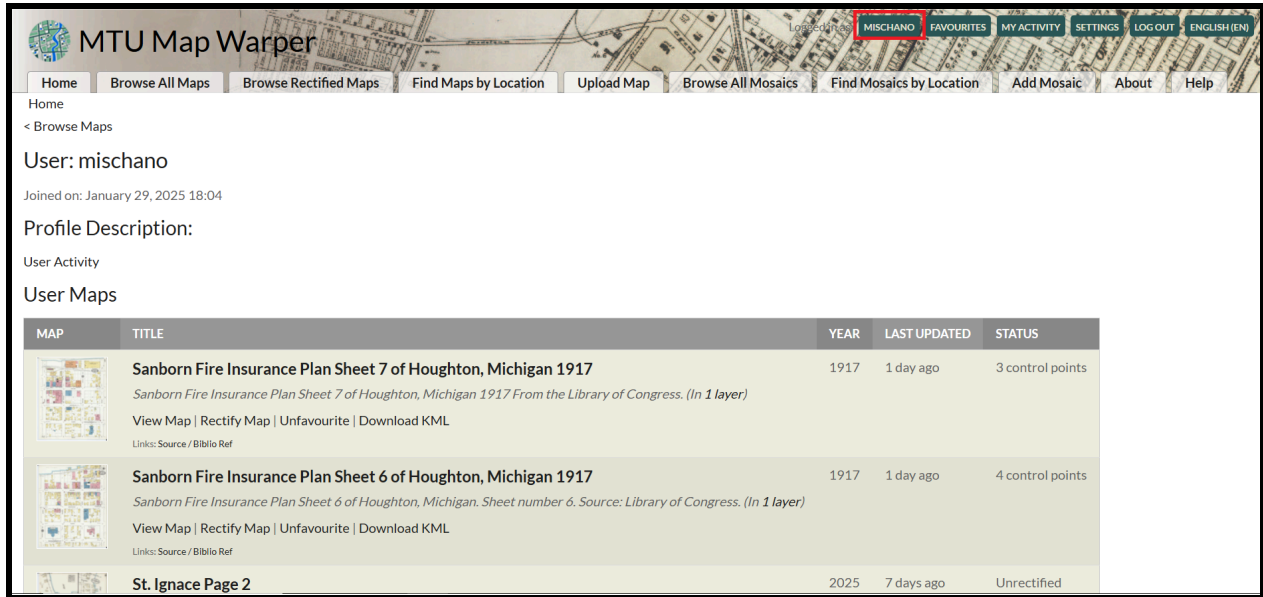
22. Now repeat this entire process using Sanborn Fire Insurance Plan Sheet 7. The geographic location of this sheet is adjacent to sheet 6. Be sure to write the appropriate metadata for the map. When you are finished you will have two fully referenced Sanborn map sheets and we will make a mosaic out of them!

The final warped map should look something like this:



Viewing your Georeferenced Maps

To view all of your uploaded and georeferenced maps you can simply click on your **username** on the **top navigation bar** and a list of your maps will be displayed.



The screenshot shows the MTU Map Warper user profile for 'mischano'. The top navigation bar includes links for Home, Browse All Maps, Browse Rectified Maps, Find Maps by Location, Upload Map, Browse All Mosaics, Find Mosaics by Location, Add Mosaic, About, and Help. The user's profile information is displayed, including their username, join date, and a description. Below this, a table lists the user's maps.

MAP	TITLE	YEAR	LAST UPDATED	STATUS
	Sanborn Fire Insurance Plan Sheet 7 of Houghton, Michigan 1917 <i>Sanborn Fire Insurance Plan Sheet 7 of Houghton, Michigan 1917 From the Library of Congress. (In 1 layer)</i> View Map Rectify Map Unfavourite Download KML Links: Source / Biblio Ref	1917	1 day ago	3 control points
	Sanborn Fire Insurance Plan Sheet 6 of Houghton, Michigan 1917 <i>Sanborn Fire Insurance Plan Sheet 6 of Houghton, Michigan. Sheet number 6. Source: Library of Congress. (In 1 layer)</i> View Map Rectify Map Unfavourite Download KML Links: Source / Biblio Ref	1917	1 day ago	4 control points
	St. Ignace Page 2	2025	7 days ago	Unrectified

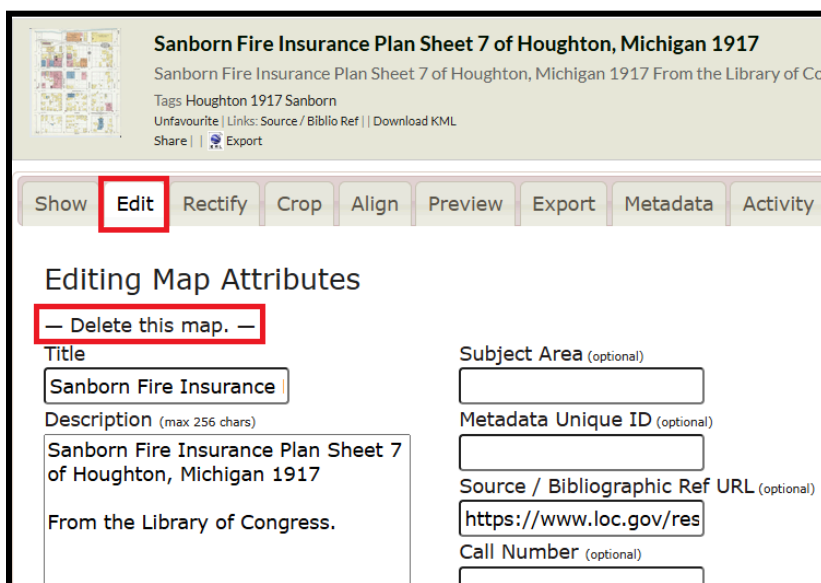
Exporting your Georeferenced Image

Once your map has been georeferenced, click on the **Export** tab. Here you can export it to a variety of different formats including Images and Map Services. You can export it as a GeoTiff or a PNG image. You can download KML files to use in Google Earth or Tiles to use in Web Mapping Applications. We will use these URLs in later modules including building mobile deep mapping applications.



Delete your Georeferenced Map or Image

In the event you would like to delete your georeferenced map or any image you uploaded that is not georeferenced, you can do so by clicking on the **Edit** tab on the item's page. Then Click on the – **Delete this Map.** – text.



Creating a Mosaic

Map Warper also has the capability of mosaicking multiple images together. Creating a mosaic is useful when you have maps that consist of more than one sheet. The Sanborn Fire Insurance plans georeferenced in this module are a perfect example. Sanborn maps consist of multiple sheets that can be stitched together to make up most of a city or town. Sanborn Map sheets will often have overlapping areas on adjacent sheets. This means that the edges of two adjacent sheets will show the same buildings or streets and you will have to decide which information to display from each one. The tricky part is cropping out this overlap or overlapping the sheets in such a way that it does not show the overlapping areas.

Now we are going to make a mosaic of the two Sanborn maps sheets that we georeferenced!

1. On the top navigation bar click on the **Add Mosaic Tab** .
2. Here you will see a list of maps that you have georeferenced and check boxes next to each. Check the box next to each map you want to mosaic. In this case check the box next to Sanborn Fire Insurance Plan sheets 6 and 7 for Houghton. You will also see some basic metadata fields for your mosaic. Enter at least a Name and Description here, display year is recommended. Click the **CREATE** button.

New Mosaic

Note: All Mosaics are public, you can add unlisted maps to them they won't be listed
 but they would be seen on the final map image.

Name

Description

Source / Bibliographic Ref URL

Depicts Year(year, optional)

Used to display layers by year.

Choose from your Favourites

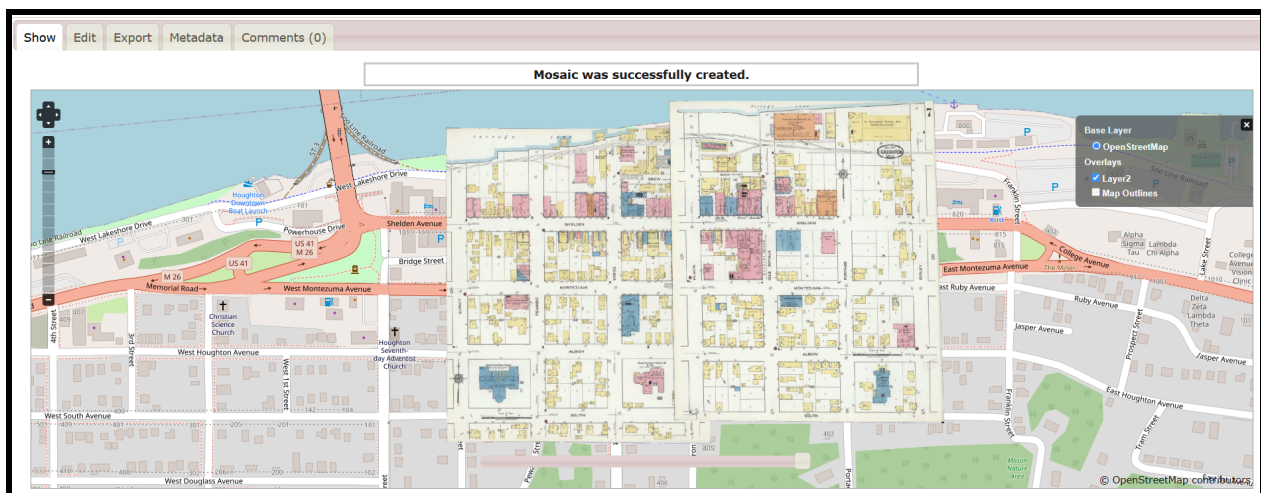
☐	TEST: Downtown Houghton <i>This is a test upload.</i> Depicts: 2025	detail
☐	St. Ignace Page 2 Depicts: 1882	detail
☐	St. Ignace Page 2 Depicts: 1888	detail
☐	St. Ignace Page 2 Depicts: 2025	detail
☒	Sanborn Fire Insurance Plan Sheet 6 of Houghton, Michigan 1917 <i>Sanborn Fire Insurance Plan Sheet 6 of Houghton, Michigan, Sheet number 6. Source: Library of...</i> Depicts: 1917	detail
☒	Sanborn Fire Insurance Plan Sheet 7 of Houghton, Michigan 1917 <i>Sanborn Fire Insurance Plan Sheet 7 of Houghton, Michigan 1917 From the Library of Congress.</i> Depicts: 1917	detail

CREATE

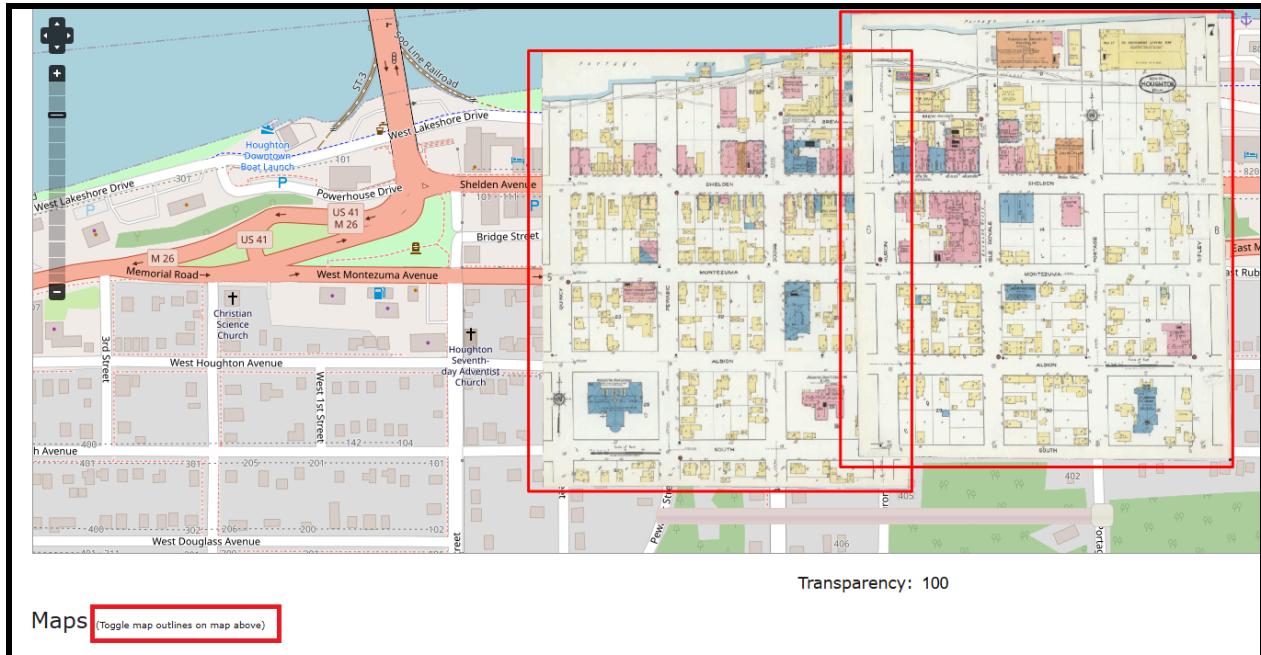
3. A mosaic has now been created and you can download it or use it as a service

just like a regular map by going to the **Export Tab** Export.

4. Depending on the specific map images that are mosaicked together, the order the maps were georeferenced, and your initial cropping, the mosaic may be usable in its current state or it may have unwanted overlap. In the case of these Sanborn Maps, they have unwanted overlap between sheets. To solve this problem we will have to adjust the clipping on one or both of the individual images.



- On the bottom of the mosaic under the Maps section, if you click on (**Toggle map outlines on map above**) you will see the outline of each map and the unwanted overlap.



- Underneath the web map under the **Maps** section click on Sanborn Fire Insurance Plan Sheet 7. This will bring you back to the individual map page for that map and we can adjust the cropping on that specific sheet.

Maps (Toggle map outlines on map above)

MAP	TITLE
	Sanborn Fire Insurance Plan Sheet 6 of Houghton, Michigan 1917 Sanborn Fire Insurance Plan Sheet 6 of Houghton, Michigan. Sheet number 6. Source: Library of Congress. (In 1 layer) View Map Rectify Map Unfavourite Download KML Links: Source / Biblio Ref
	Sanborn Fire Insurance Plan Sheet 7 of Houghton, Michigan 1917 Sanborn Fire Insurance Plan Sheet 7 of Houghton, Michigan 1917 From the Library of Congress. (In 1 layer) View Map Rectify Map Unfavourite Download KML Links: Source / Biblio Ref

- Click on the **Crop** tab and click on the **Edit Vertices** button . To adjust the map's cropping. Now click on the orange crop box over the map, it will turn blue and orange circles will appear on the 4 corners of the box. Click and drag them individually to adjust the chopping box. On the mosaic preview we could see that most of the overlap was in the western corner of the map along Huron Street. In

this case I will adjust the cropping box to go right down the center of Huron Street. The majority of the time with Sanborn Fire Insurance plan mosaics cropping the sheets between a specific street is the best method for display. When you are done, hit the **MASK MAP!** button and the mask will update.

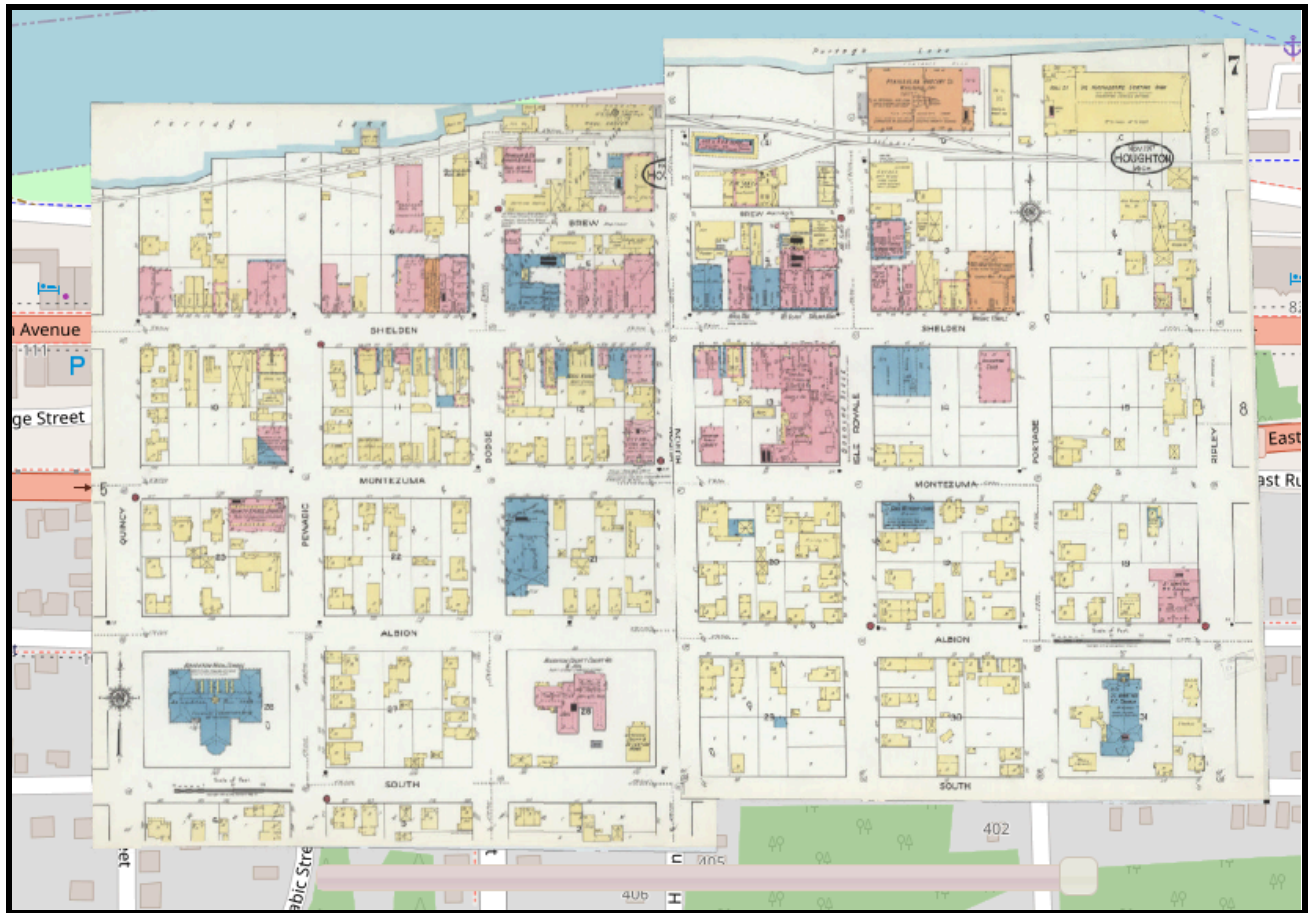


8. Return to the mosaic under the **Browse All Mosaics** tab



on the **top navigation bar**.

9. You can see in the preview that this mosaic is now much better looking and the overlap is gone. It could potentially take a few different adjustments on each map to get the desired result and mosaicing Sanborn Fire Insurance Plans is rarely a perfect process.



Using your Map or Mosaic in ArcGIS Portal

You can now use your georeferenced map or mosaic in GIS software such as ArcGIS Pro or QGIS using the **tiles url** from the **Export** tab on the Item page.

Show
Edit
Rectify
Crop
Align
Preview
Export
Metadata
Activity
Comments (0)

Export

Images

GeoTiff: Download rectified GeoTiff

PNG: Download rectified PNG (and associated .aux.xml file .aux.xml)

Map Services

KML: Download KML file (for use in Google Earth, etc)

WMS: WMS Capabilities URL (for JOSM OpenStreetMap Editor)

Tiles (Google/OSM scheme): <https://geomapwarper.sabu.mtu.edu/maps/tile/10/{z}/{x}/{y}.png>

Bibliographic Links:

Bibliographic



You can also use the **Tiles url** to add it as a new item or in a web map using the add **layer from URL option** in your own [ArcGIS Online](#) or [Michigan Tech's ArcGIS Enterprise Portal](#). Detailed instructions on how to do this will be available in the next module. In the next asynchronous module you will use these historical maps that you georeferenced and mosaicked to digitize historical features such as building footprints from them.



References

Lafreniere, D., and Rivet, D. 2010. Rescaling the Past through Mosaic Historical Cartography. *Journal of Maps*, Vol. 6, no. 1: 417-422.