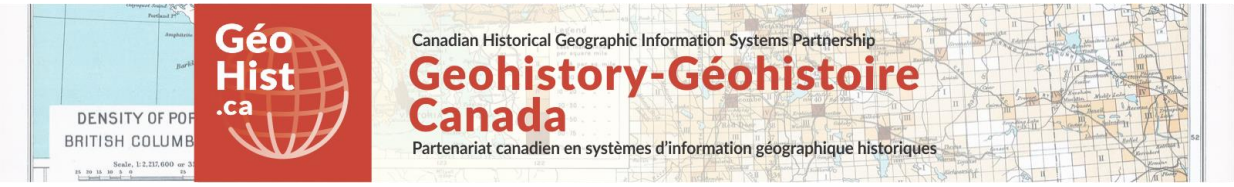


Development document for:
Historical Atlas of Canada Population by Census Divisions 1851-1961 web-map
Using: ArcGIS Online (AGOL) and hosted data, published to Canadian HGIS Portal
Link to webmaps: The **ArcGIS Online versions can be found on the Geohistory-Géohistoire Canada Development Portal** hosted online by our partners at Esri Canada, at: HACOLP Population Apps Gallery.
http://hgisportal.esri.ca/portal/home/item.html?id=f7e6329dd6b3494b9b689e1750cf6781
The "Gallery" contains 4 apps: Population Density (in 3 different versions) and Population Growth.

GOAL: Historical Atlas of Canada (HAC) Time series maps of Population by Census Division (CD), improved from HAC Online Learning project chapter: Summary of Population Growth, 1851-1961.
http://www.historicalatlas.ca/website/hacolp/national_perspectives/population/UNIT_25/index.htm

REQUIREMENTS: The original website has three interactive maps of population by Census Division: Population Density (choropleth), Population Growth (graduated circles) and Population Distribution (dot density) for 11 census years, 1851-1961, using old ArcIMS technology. These maps should be reproduced but updated to current webmap standards, improving performance and visualization, and using a Time-slider to click through the time period, replacing the Checkbox interface originally used. The project is also an appropriate one to use to explore the web-mapping software's capacity for legend design flexibility, and map projections other than the standard Web Mercator.

Credits: Historical Atlas of Canada Online Learning Project, Canadian Historical GIS Partnership Development project, GIS and Cartography Office Dept of Geography University of Toronto

Note: The ArcGIS Online documentation is extensive and comprehensive. Therefore many details will only be referenced to that documentation rather than explained in full here.

Approach: Decision made to use ArcGIS Pro for map generation and publishing to the HGIS Portal, and ArcGIS Online Time Aware App as the basis for building the app.

Functionality
Mapping functionality: ArcGIS Pro shared to ArcGIS Online Web Map, with Time-Aware layer
Interface functionality: ArcGIS Online App Template: Time Aware
Projection functionality: ArcGIS Online hosted map image layer used as Base Map

Map Data:
Overlay Mapping data: 1851-1961 Census Divisions polygons merged - AGOL Feature layers (hosted)
1851-1961 Census Divisions boundaries Merged - AGOL Feature layers (hosted)
1851-1961 Provinces/Territories Polygons Merged - AGOL Feature layers (hosted)
Background Mapping data: Modern Cities, Modern Provincial Boundaries - AGOL hosted feat. layers
Base map: Esri World Light Gray Canvas Base (Suitable for thematic overlay mapping)

Note re: Historical Atlas of Canada Data
These data are available publicly through the Historical Atlas of Canada Online Learning project, by email request. http://www.historicalatlas.ca
Census Divisions are also available through the Scholars Geoportal http://geo1.scholarsportal.info/

PRODUCTION NOTES

OVERLAY MAPPING DATA

ArcGIS Desktop / ArcGIS Pro

Individual shapefiles for each year 1851 through 1961 were provided by the HACOLP and used as the basis for the project. For comparison's sake, both ArcMap and ArcGIS Pro were used to create the merged data layers necessary to create a coded, time-enabled layer suitable for making Time-enabled in ArcGIS Pro and for use in the Time-Aware app. Comparable tools were found for all required Geoprocessing in each environment - so it is mostly a matter of choice and familiarity which to work in. For example, the original data sets were named by Year, but had only a Text field specifying census year. The "Convert time field" tool was used to generate a date field for time-enabling. The tool was available both in the ArcGIS Pro Data Management toolbox
http://pro.arcgis.com/en/pro-app/tool-reference/data-management/convert-time-field.htm
and in the ArcGIS Desktop Toolbox:
http://desktop.arcgis.com/en/arcmap/10.3/tools/data-management-toolbox/convert-time-field.htm

FEATURES AND SYMBOLIZATION

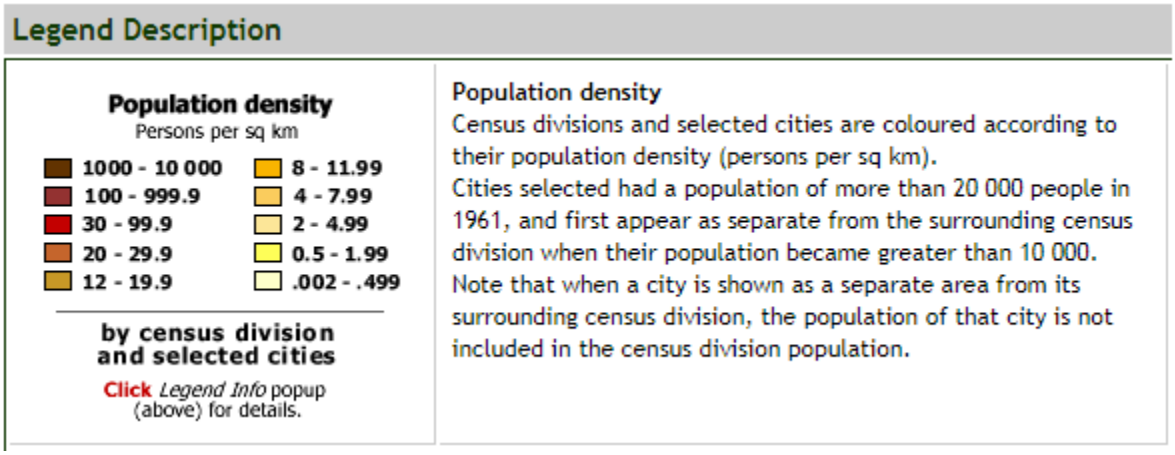
Overlay Layers

1851-1961 Census Divisions polygons Merged
Population Density field used for choropleth map
Population field used for graduated and proportional symbol maps
1851-1961 Census Divisions boundaries Merged - Single line symbol for CD outlines
1851-1961 Provinces/Territories Polygons Merged - Single line symbol for outlines, and labels for changing province/territory names over time

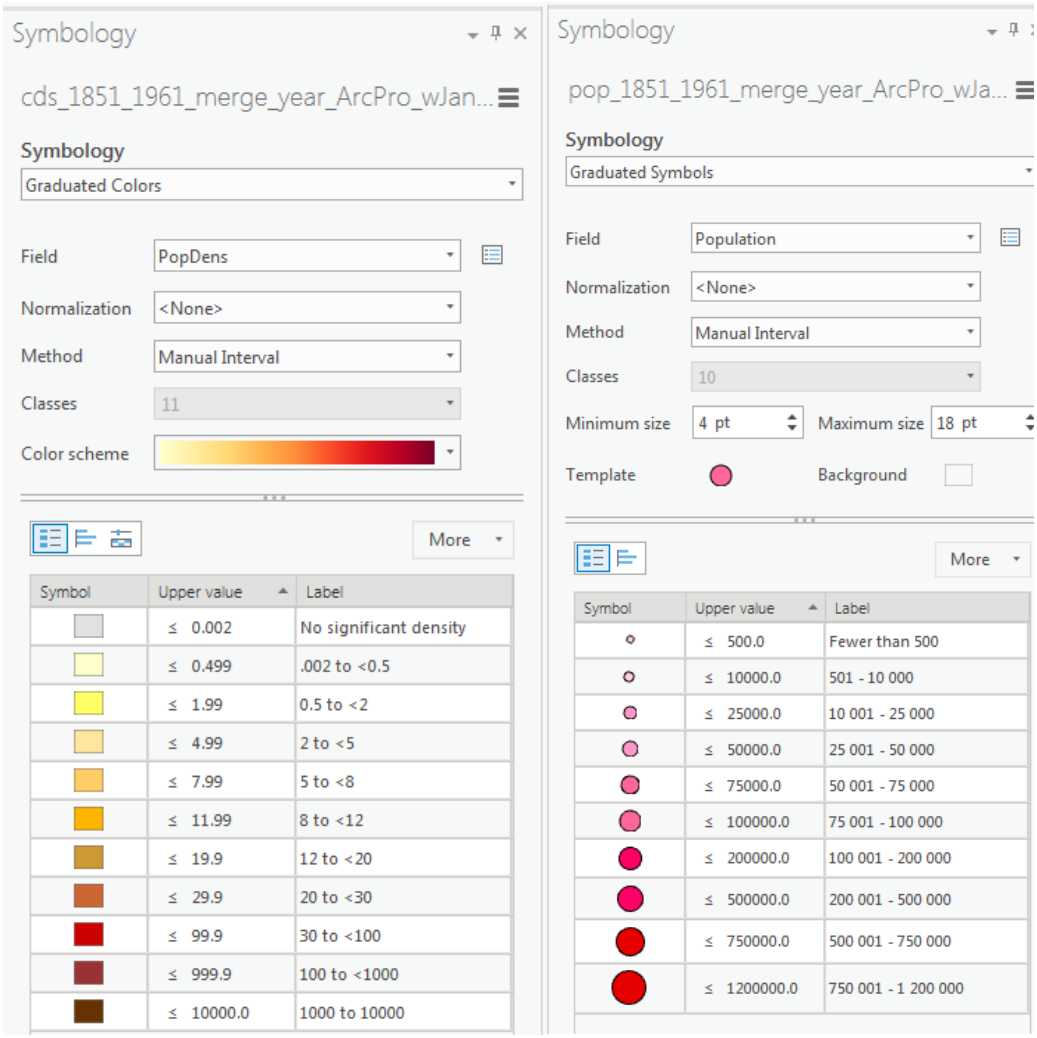
Each of these three sets of shapefiles were merged to create layers containing features for all years, using Merge tool. Raw population values, area and population density already existed in files. Year was converted to Date field using "Convert time field" tool. Field formatted as: 1/1/YYYY 12:00:00 by default. See discussion below under "ISSUES with DATE FIELD AND TIMELINE".

Colour and Symbol design

Since the goal of this project was to reproduce the design of the HACOLP webmaps, colours and symbol were based on those inherited from those webmaps. So for example, the HACOLP legend for population density is reproduced below:



In ArcGIS Pro using the Symbology interface, this is easily reproduced, basing colours on values acquired from the original ArcMap document, or using a "Colour picker" tool, grabbed from the online screen display. The same method can be used to reproduce the Graduated Symbols "Population Growth" map.



The Legend information set up for the ArcGIS Pro document is carried over to the Feature Layers and Webmap in the HGIS Portal, when Share -> Web Map is used to publish the layers.

Attributes for polygon features (Census Divisions)
The attribute fields used for population mapping and Pop-up display are:
CDNAME: Census Division name
PROVNAME: Province name
CDAREASQKM: Area of Census Division in square km
CDPOPDENS: Calculated density in persons per sq km
Population: Number of persons in Census Division
YEAR: Text field holding Census Year value 1851, 1861.... 1961

The attribute fields used for the Time Aware properties on the layer are formatted as “Date” field.:
YEAR_CON - Result of Convert Time tool - Set for all in format 1/1/YYYY (see **ISSUES** note below)
MID_YEAR - Calculated to set for all in format 6/1/YYYY - except for one as explained in **ISSUES** below

ISSUES with DATE FIELD AND TIMELINE

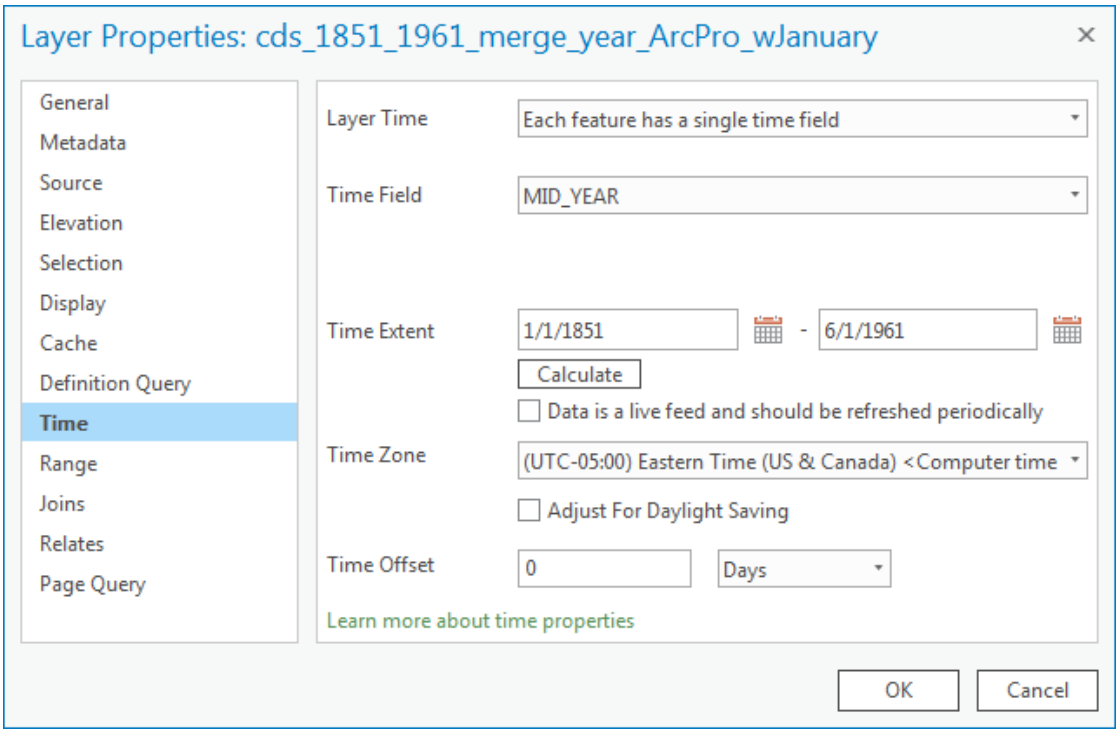
To make a layer time aware, the relevant fields must be defined as type: DATE. When a field containing an integer or text YEAR value is converted to type DATE, it is formatted as 1/1/YYYY.

However, when Time is enabled on layers containing Date fields, the earliest and latest values determine the maximum range of the Time Extent, and therefore the beginning and end of any Time Slider. When intervals are set up on the timeline, they are based on equal divisions of the timeline, and they are inclusive. So for example the interval 1/1/1851 - 1/1/1861 would include features dated with values of January 1, 1851 AND January 1, 1861. This means when this interval is highlighted, TWO sets of features are being drawn, and when the user clicks on a polygon, TWO sets of polygons are popped up - 1851 and 1861. This may be very confusing for the user.

We tried various methods or work-arounds to fix this issue. The first involved creating a new field, MID_YEAR, and calculating the dates in it to the middle of the year - June 1, YYYY instead of January (Field calculation syntax: MID_YEAR = DateAdd ("d", 151, [YEAR_FIELD])). This assumed that when the time-slider's interval was set to "Decade" it would assume a start date of January 1, YYYY. This was not successful, as the decade was just counted from the first value of MID_YEAR.

Therefore it appeared that the data needed to include a fictional or spurious date earlier than the actual start date, to extend the time-slider's nominal extent. To this end we added a small spurious polygon to each time enabled layer, up around the North Pole. The value of MID_YEAR for this feature was calculated to be January 1, 1851 (Field calculation syntax: MID_YEAR = DateSerial(1851,1,1)).

This work-around managed to extend the maximum Time Extent of the layer. Each merged data layer in the ArcGIS Pro document must be made Time Aware to work with the Time Slider. Time settings on Layer Properties are shown below. These are carried over to the pubished Feature Service.



For Time Settings used in the ArcGIS Online Web Map, see **PUBLISHING FROM ARCGIS PRO TO WEB MAP** below.

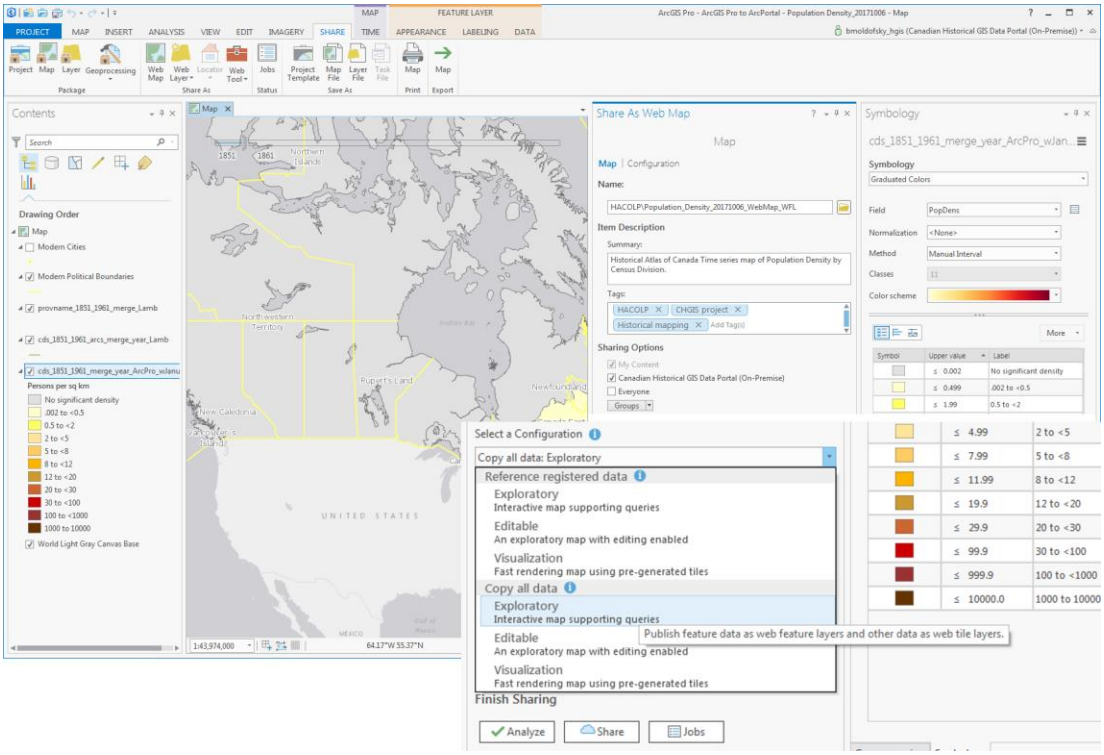
Background Mapping data:

Modern Cities, Modern Provincial Boundaries - AGOL hosted feature layers
Colour coding: Yellow symbolization with label halos seen as most unobtrusive while providing modern geographic reference information. This follows the design set in the original HACOLP web maps.
A common alternative is to use the Reference Base map (or one of the other pre-loaded base map options such as Esri World Topo) for modern geography, by setting a transparency on the thematic overlay layers. This may affect map interpretation when using colour-sensitive representation methods such as choropleth, and also raises issues in matching legend colours with on-map appearance. Using "Modern" overlay layers also allows reference layers to be appear on the alternative projection demonstrated here (Lambert projection version) where no Web Mercator "Base" layers are available to be included.

BASE MAPS
Reference Base Map: Esri World Light Gray Canvas Base (Suitable for thematic overlay mapping)
Selected Esri World Light Gray Canvas Base as the most useful option to provide a neutral base map as a geographic reference background for colour-based thematic mapping such as choropleth and graduated symbol representation.

PUBLISHING FROM ARCGIS PRO TO WEB MAP

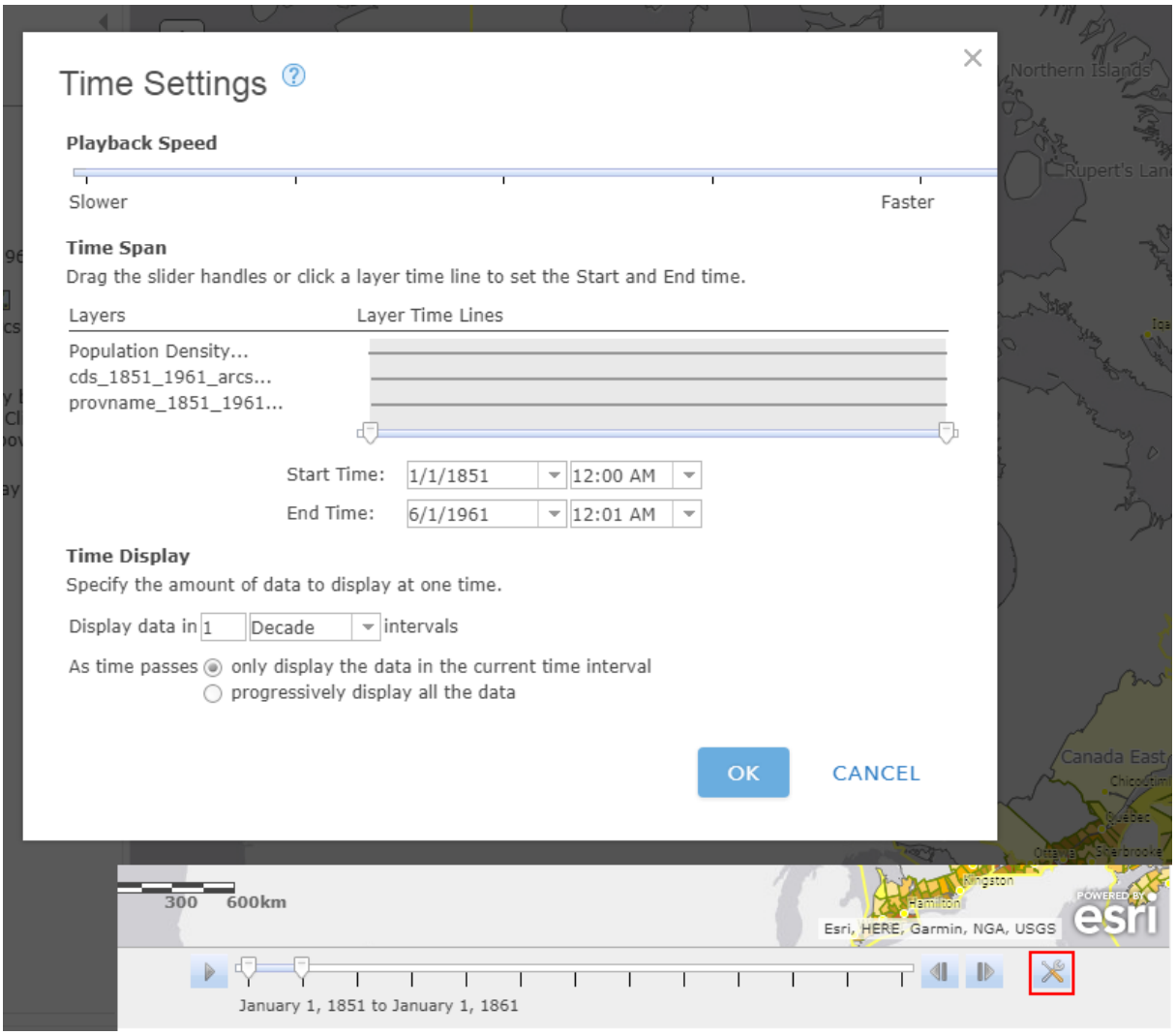
The method for publishing from ArcGIS Pro to a Arcgis Online or Arcgis Portal web map is well documented at: http://pro.arcgis.com/en/pro-app/help/sharing/overview/share-a-web-map.htm
For this project, on the ArcGIS Pro "Share" tab, we selected "Web Map". In the dropdown for "Configuration", we selected "Copy all data" (to portal) and "Exploratory - interactive map supporting queries." See image below.



Sharing the map using this configuration resulted in the creation of a set of hosted feature layers on the HGIS portal, as well as the map reproduced as a web map in the portal. In an attempt to improve speed and performance, another version of the web map was made using the "Reference registered data - Exploratory" configuration. For details see **ISSUE: PERFORMANCE/SPEED** on p. 13 below.

The web map inherited most of the settings of the ArcGIS Pro map layers: symbolization, labelling, time-aware settings, etc. However, these can be edited or re-set in ArcGIS portal. This is a very easy, intuitive and flexible method of publishing web maps.

The exception was the time-line settings, which had to be re-configured for the web map. As described above, these required some unexpected manipulation because of the use of the two-handled range slider, and the bracketing of both start and end dates - leading us to add the January 1, 1851 polygon. After that, configuration of the time-line was straightforward. See image below.



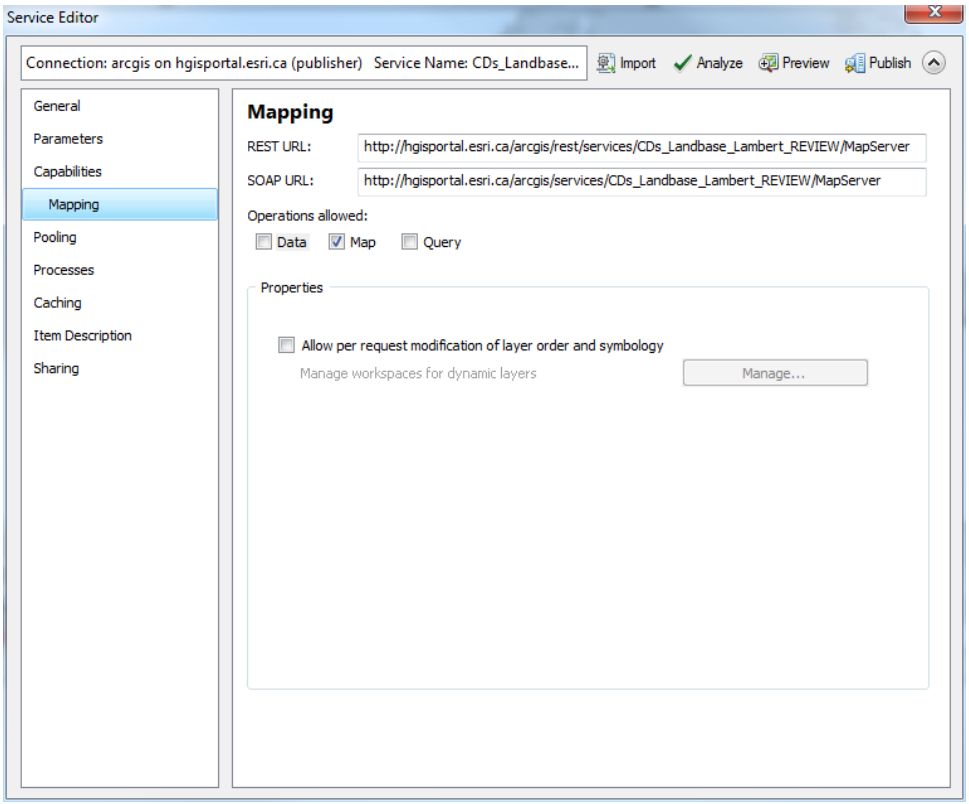
The timeline configuration is accessed by clicking the tool icon as outlined in red bottom right, then clicking on "Advanced settings". The image depicts the settings arrived at for our synchronized population and other reference overlay layers.

PUBLISHING WEB MAP USING PROJECTION OTHER THAN WEB MERCATOR

One of the issues that came up a number of times in our web-mapping user survey last year was the desire to be able to use map projections other than the standard "Web Mercator" projection that Google popularized and that tiled "slippy map" technology has made ubiquitous online. This projection is especially inappropriate for large region/small scale maps such as the map of all of Canada, where the distortion of shape and enlargement of area progressively as one moves northward on the map is extremely misleading. This is especially true for a polygon-based representation method like choropleth mapping. The Historical Atlas Online used a Lambert Conic Conformal projection (hereafter shortened to "Lambert") which is also the standard used for printed maps and online maps from the Atlas of Canada. http://www.nrcan.gc.ca/earth-sciences/geography/atlas-canada

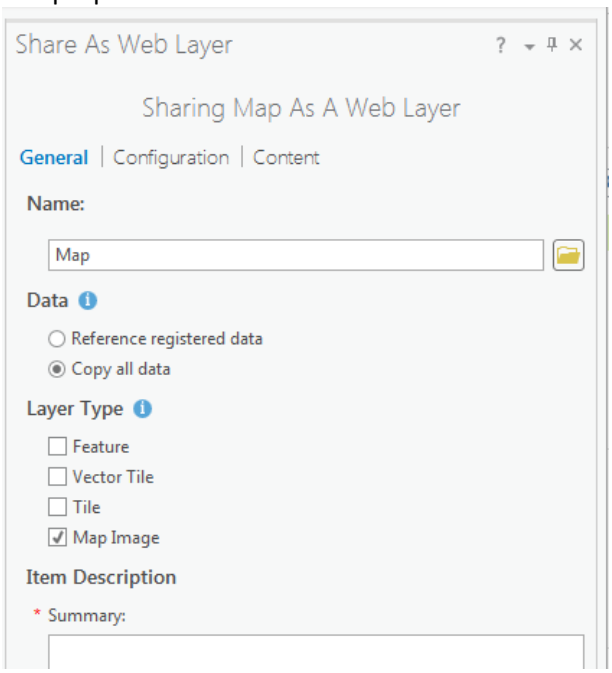
Therefore the Historical Atlas of Canada population maps were a good candidate to test ArcGIS Online's capability for mapping with this projection. The method for choosing a custom base map from an online web service is outlined in ArcGIS Online documentation at: http://doc.arcgis.com/en/arcgis-online/create-maps/choose-basemap.htm .

In our case we wanted to create our own base map and load it into the HGIS Portal as a web service, to then use as a custom base map. We imported our base map feature shape files from the Historical Atlas of Canada data sets, and created an ArcMap document symbolizing a neutral grey base map in Lambert. From ArcMap we signed in to the HGIS Portal, and using Share as -> Service, published a map service for the Lambert base layer. We tried various configurations to do this, as the requirements seem unclear from the documentation. We believe the critical point in this process is to publish the Service with only Mapping capabilities (NOT Feature Access) and with Caching -> Dynamically from the data (NOT Using tiles from a cache. The image illustrates the Mapping form under Capabilities in the Service Editor:

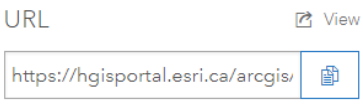


This process results in a "Map Image Layer" map service in the portal. This is the only type capable of being used as a projected base map.

We also tested using ArcGIS Pro to publish this map service. Under the "Share" tab, select Web Layer -> Publish Web Layer. This will bring up the Share Map as Web Layer interface pictured below. Again the critical point is to publish the map as **Layer type: Map Image**. The other Layer Types will not work. For example "Tile" converted the web layer into tiles in the Web Mercator projection, so was not useful for this purpose.

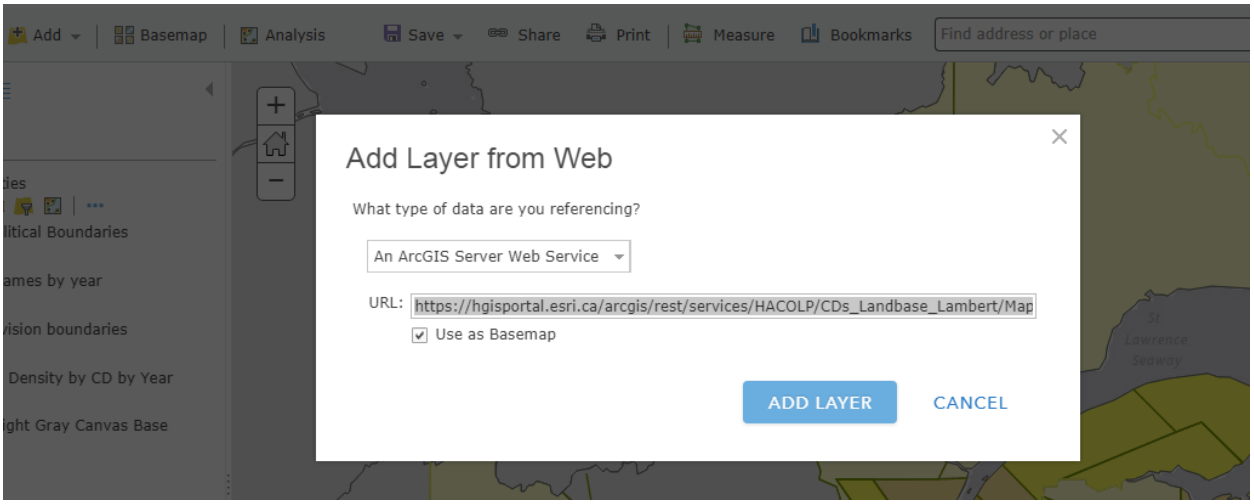


Once created, the Map Image web service cannot be directly selected as a base map layer. If it is brought into a blank or pre-existing web map it will be converted to Web Mercator by default. To use it as a base map, it must be added as a "Layer from the Web." Therefore get the URL for the Map Image Layer from the Item details page for the map service. This is in the bottom right corner of the page.



The Lambert base map we used can be found here, as an example:
http://hgisportal.esri.ca/portal/home/item.html?id=0e529350e2f74d85877d2e0a2b75433c

Copy the URL for the service. Then open the Web Map which you wish to convert to Lambert projection - in our case it was a copy of the HACOLP Population Density web map - in Map Viewer. Then use the Add Item -> Add Layer from Web dropdown to bring up the Add Layer from Web input form. Paste the URL in accordingly, and check the box for "Use as Basemap." See image below as an example.



This effectively replaces the ArcGIS Online base map with our own Lambert projected base. The web map demonstrating this is at:
http://hgisportal.esri.ca/portal/apps/TimeAware/index.html?appid=3b4e5a44a79342db9de8ec1e9e6c9d4b

It would be useful to have the ArcGIS Online standard base maps available in different projections. At the moment, as soon as the Lambert layer is included as the base map, no other base map data is visible. This is an artifact of the Tile base mapping technology currently used. However, Vector tiles are now becoming the standard technology, for base maps, which should open the door to much more flexibility in base map design, including the option of re-projection. For more information on the current capbilities, see: https://www.arcgis.com/home/group.html?id=30de8da907d240a0bccd5ad3ff25ef4a#overview

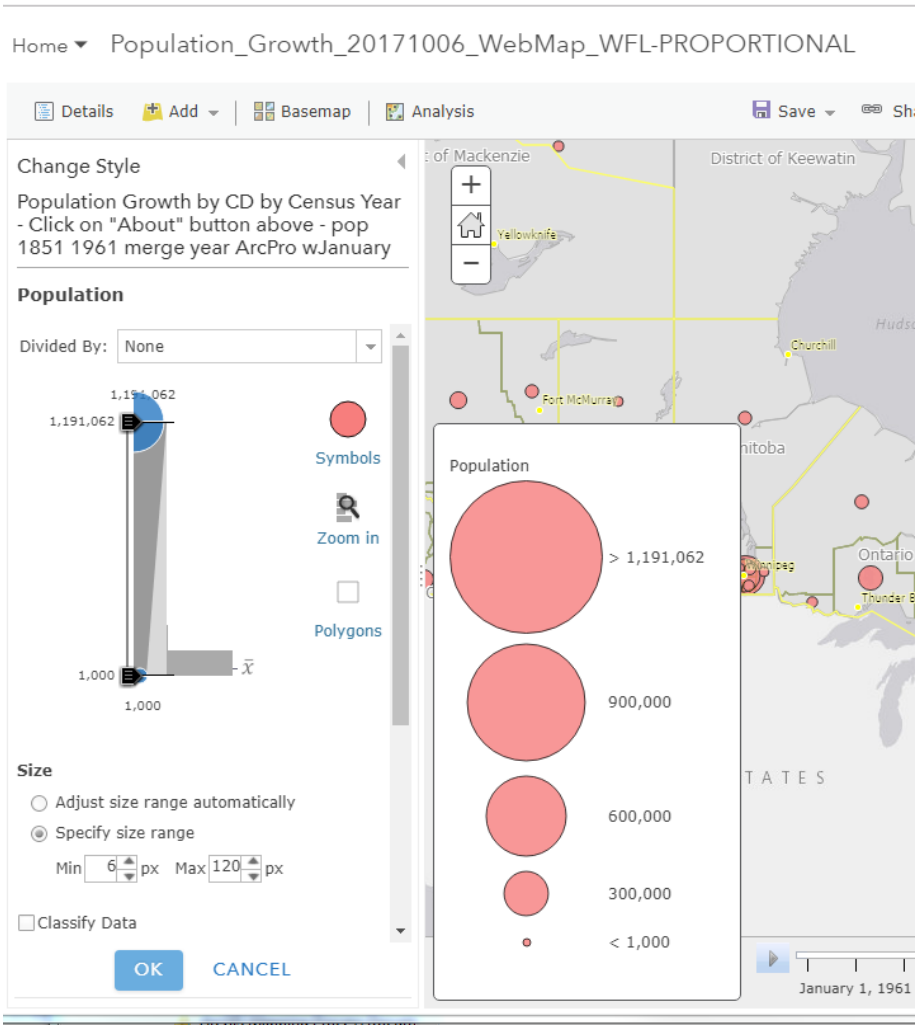
ISSUES: Web map alternative symbolizations: Dot density distribution (and Proportional symbols)

Currently ArcGIS Pro does not support Dot density representation, which was one of the symbolizations used for the Population distribution map in the original HACOLP web maps. Attempts were made to work around this constraint: ArcMap was used to create dot density maps, but attempts to share these as Web Map services to the HGIS portal were unsuccessful - the symbolization is not supported currently in ArcGIS Online.

As a follow-up, there are a number of sophisticated symbolizations available in ArcGIS Pro which are NOT supported online. These symbolizations are "downgraded" to a simpler alternative when maps are shared:
http://pro.arcgis.com/en/pro-app/help/sharing/analyzer-warning-messages/24082-layer-s-symbol-will-be-downgraded.htm

However, the use of Proportional symbols IS supported in ArcGIS online, as an alternative to Graduated symbols which represent interval classes by size. We were able to make a copy of the Population Growth web map, and re-symbolize the Graduated symbols using ArcGIS Online's "Style" editing tools (see image below.) The proportional sizing interface includes some useful options, that are missing from many such tools - especially the ability to specify a minimum value and circle size, below which threshold all symbols are held constant - and to ignore features with zero or null values. However, although not docuumented, the sizing calculations appear to interpolate linearly between minimum and maximum declared diameter sizes, rather than allowing use of the AREA of the circle or other more

sophisticated sizing methods such as Flannery's constant (Appearance Compensation in Arcmap - see http://desktop.arcgis.com/en/arcmap/10.3/map/working-with-layers/using-proportional-symbols.htm).



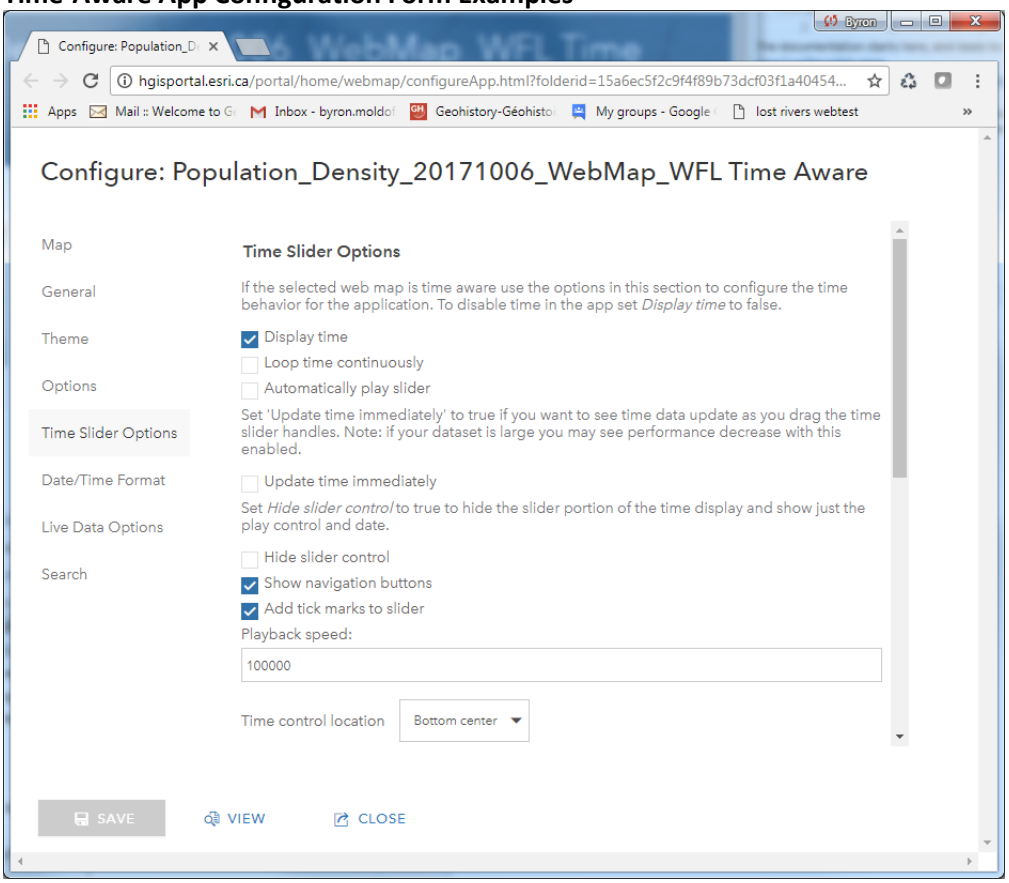
The resultant web app was not included in the HACOLP Population App Gallery, but those interested can view it here:
http://hgisportal.esri.ca/portal/apps/TimeAware/index.html?appid=bf0f9d30527846ad9abed337f954d8f4

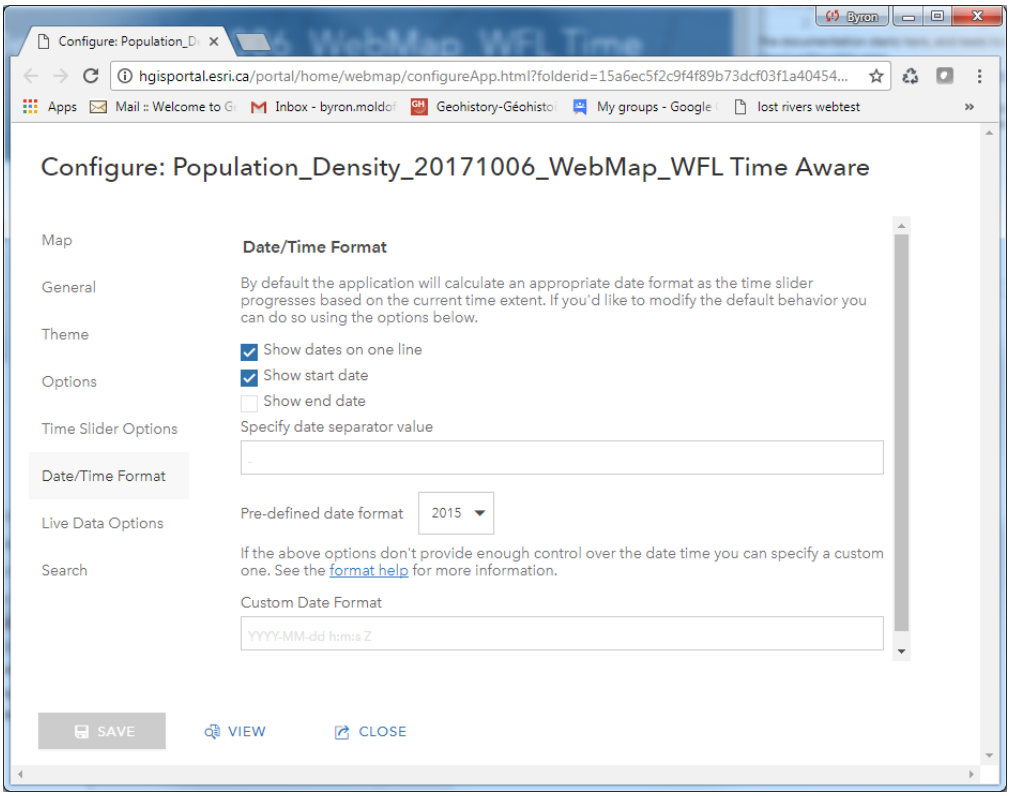
GENERATING TIME-AWARE APP FROM WEB MAP

Esri tools have simplified the work flow for generating an App from any of the pre-configured templates provided, such as the Time-Aware app. The documentation starts at the link below, and leads on to very extensive instructions: http://www.esri.com/software/configurable-apps
Specifically from Portal, from here: http://server.arcgis.com/en/portal/latest/use/create-map-apps.htm

The configuration of the Time- Aware App is accomplished by filling out a series of customized forms. The examples below, for the "General" and "Date-Time Format" forms, illustrate some of the settings used for our Time-Aware app. See images below.

Time-Aware App Configuration Form Examples



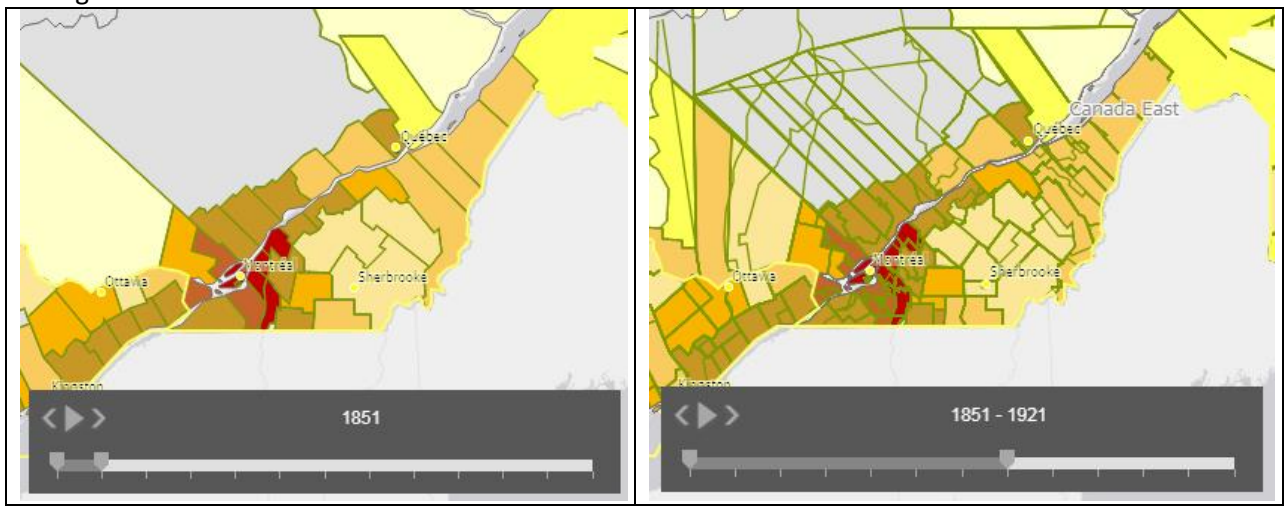


ISSUES IN INTERFACE FUNCTIONALITY AND DESIGN

ISSUE: Time slider functionality in Time-Aware app

Time slider requirements were: to show Census Division population measures (Population, Density, Distribution) symbolized in different ways, by census year over time, using an easy-to-understand slider, and to display the date of any point on the slider by YYYY year only. Since the requirement is to show the census population changing over time, having a one-handled slider showing a specific census date, i.e. a snapshot in time, rather than a two-handled slider showing an adjustable date range, would make the tool easier to understand. However, this is not available in the Time-Aware app, without customization. It was decided to use the two-handled "range" slider as a demonstration of the problem embedded in this template, rather than customize it. The method of customization using the Web App Builder Developers edition is described in our other pilot web-mapping project, Lost Rivers of Toronto Disappearing Rivers, for which documentation can be found here: http://geohist.ca/wp-content/uploads/2017/10/LostRivers_Disappearing_Rivers_Devt_AGOL.pdf

The problem is illustrated below. On the left is the Time-slider is set to 1851, and shows one census year of data. On the right, the Time-slider is set to the range of 1851-1921, and show overlays 7 census years of data. Only the "top" layer of polygons (1921) are visible, but the line overlay shows all 7 sets of CD boundaries, and performance is affected by the re-drawing of multiple polygon layers in the background.



As a result, instructions to the reader are included in the "About" panel to avoid using the slider in this way, but this is obviously not ideal. The fix is to customize either the Time-aware app or a Web App Builder app, however this takes significant effort and resources, and an independent web server.

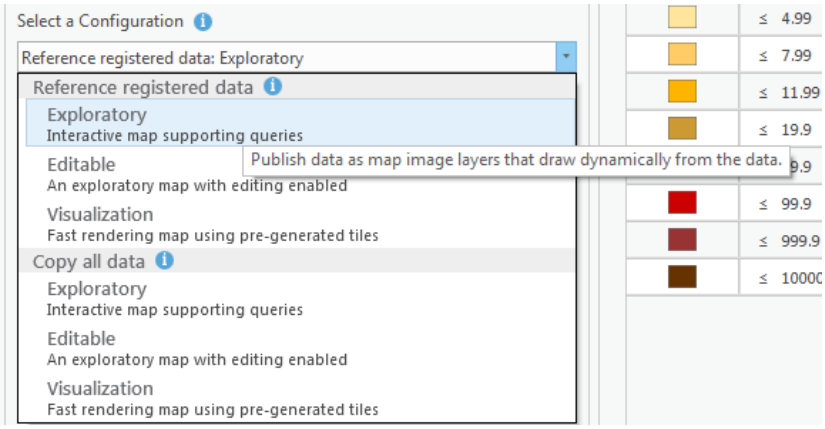
We would encourage Esri to create a configurable option in the Time-aware app to make it easy to implement the "show time as an instant" visualization. This would be a much needed and appreciated improvement in future versions of the template.

ISSUE: PERFORMANCE/SPEED - Attempts to use Vector tiles, Tiled map services, Registered data

The speed of drawing of the time-aware layers in the AGOL web app is not immediate, and on sub-optimal connections will make the app difficult to use. This also makes the "Play animation" capability of the time slider non-functional, as the map will not redraw fast enough to show change over time continuously. Performance will obviously vary depending on the number and complexity of the features within the data layers. The Census Divisions file merged for all years 1851-1961 contains 2570 polygons. The CD boundaries for the same set contains about 5800 arcs. These were generalized for the purposes of the HACOLP, but still represents a large amount of coordinate data that needs to be redrawn as the time-slider is moved, when drawn from feature layers.

Attempts were made to improve performance by using Tiled map services (using pre-generated tiles), and Vector tiled map services. Neither of these were able to retain the multiple overlapping layers of polygons and support time-awareness that is necessary for this application. In the future, Vector tile technology holds promise for significantly enhancing performance of vector-based data by chunking it into pieces the way image tiling does, only serving up the parts and resolution necessary for any particular map view. Vector tiling is supported by ArcGIS Online, but its current implementation appears to be designed and usable for base map purposes only.

Our partners at Esri Canada suggested publishing the Web maps from ArcGIS Pro using the **"Reference registered data -- Exploratory"** option instead of "Copy all data -- Exploratory". (see image below.)



In this configuration, the data is still copied to the portal, but the benefit is that the polygon layers will be served as tiles instead of as SVG polygons - this should greatly improve the drawing speed. The time slider would continue to work with the "Exploratory" option in this case, since the tiles are generated on-the-fly by the server as each new map extent or time extent is requested (as opposed to the "Visualization" option, where the tiles are cached ahead of time).

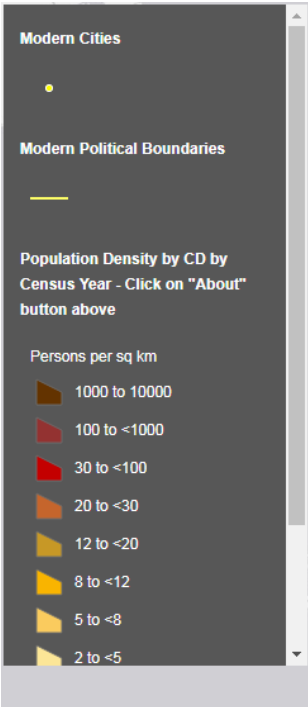
NOTE: The "Reference registered data" options are only available when publishing to an ArcGIS Enterprise portal, not with ArcGIS Online. The map services are served from the ArcGIS Server instance (https://hgisportal.esri.ca/arcgis) associated with the portal.

A version of the web map and app was made using this configuration: Population Density by Census Division 1851-1961 Time Aware - Registered data. It is viewable from the gallery, or by clicking here: http://hgisportal.esri.ca/portal/apps/TimeAware/index.html?appid=47cd6db7dc3c44019b72e52db6703ea6

The app seems to take about the same time for initial loading, or re-loading at different scales or views - however, once the tiles are loaded and in the browser cache, the maps redraw quickly. It is probably the best option for production purposes, but both versions are included in the Portal for comparison.

ArcGIS Online documentation does recommend **"Optimizing" hosted feature layers** for complex polygons at small scales, which exactly the case for our CD map of Canada (see: http://doc.arcgis.com/en/arcgis-online/share-maps/manage-hosted-feature-layers.htm#ESRI_SECTION1_736A1F3329BB46069CF1B62393705C4C
This procedure is available in the ArcGIS Online environment, but not in the ArcGIS Portal platform. We tested this method as well, by creating a version of the web map and app in the University of Toronto ArcGIS Online account, and "Optimizing" the layers. You can compare performance by viewing it here: http://utoronto.maps.arcgis.com/apps/TimeAware/index.html?appid=71c6126dc11a4834961aab44e1f40b3b

ISSUE: Legend design



Legend design in the Time-Aware App, like all the AGOL configurable apps, seems pretty much cast in stone. Legends are inherited from the settings used in the Web Map that the App takes as its source. Labelling of legend entries is modifiable, as edited in the Web Map. However, other design modifications appear to be difficult or impossible to implement, such as:

Order of Layers listed in legend
Good legend design principles suggests that the placing of symbols in the legend symbols should reflect their order of importance on the map. They may also be grouped according to symbol type (linear features together) or other similarities (historical features together.) The order of layers listed in the AGOL legend is the drawing order as specified in the Web Map. This often causes less important information to be listed first - as in our web map, where "Modern" information is positioned on top.

Shape of polygon symbols in legend
Customizability of legend polygon symbols was explored for ArcGIS Online and the HGIS Portal. The current default polygon shape is a trapezoid. There are currently no options provided in the web map to customize the shape of the polygon display. This is possible only by changing the drawing path of the Scalable Vector Graphics <svg> element used for the polygon symbol. However, custom code would need to be written in order for a Web app to modify the existing <svg> element automatically, and to do this whenever the map legend is drawn or updated. This does not seem to be a feasible solution, unless the app is downloaded and hosted on an independent server.

Spacing of layers listed in legend
Again, no flexibility without downloading, customization of code and serving locally.