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## **ONLINE MAPPING APPLICATION DEVELOPMENT FOR THE SCHOOL OF FOREST RESOURCES AND ENVIRONMENTAL SCIENCE GEOSPATIAL DATA**

Aysen Sozen  
*Michigan Technological University, asozen@mtu.edu*

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ONLINE MAPPING APPLICATION DEVELOPMENT  
FOR THE SCHOOL OF FOREST RESOURCES AND ENVIRONMENTAL  
SCIENCE GEOSPATIAL DATA

By  
Aysen Sozen

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF GEOGRAPHIC INFORMATION SCIENCE

MICHIGAN TECHNOLOGICAL UNIVERSITY

2017

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This thesis has been approved in partial fulfillment of requirements for the Degree of  
MASTER OF GEOGRAPHIC INFORMATION SCIENCE.

School of Forest Resources and Environmental Science

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## Abbreviations

<i>API</i>	Application programming interface
<i>CDL</i>	Cropland data layer
<i>CHM</i>	Canopy height model
<i>CSS</i>	Cascading style sheets
<i>DBMS</i>	Database management system
<i>DEM</i>	Digital elevation models
<i>ESRI</i>	Environmental systems research institute
<i>GCP</i>	Ground control points
<i>GDB</i>	Geodatabase
<i>GIS</i>	Geographic information system
<i>HTML</i>	Hypertext markup language
<i>MDO</i>	Multi-directional oblique weighted
<i>REST</i>	Representational state transfer
<i>SDK</i>	Software development kit
<i>SFRES</i>	School of forest resources and environmental science
<i>SQL</i>	Structured Query Language
<i>URL</i>	Uniform resource locator

## **Abstract**

This thesis emphasizes current Web GIS technologies with emphasis on architectures, particularly web applications. The goal of the study is based on data sharing and improving the efficiency of students, professionals and researchers utilizing data from the School of Forest Resources and Environmental Science (SFRES) geospatial data.

This paper is an overview of the MTU geospatial web page and using ArcGIS JavaScript API to develop a web application. The development of the application was based on open source software tools such as Map Server and Feature Server for the GIS functions, HTML, and JavaScript as programming languages and CSS as a markup language.

## **1. Chapter - Introduction**

### **1.1. Importance of GIS**

A Geographic Information System (GIS) is a computer-based technology designed for analyzing, managing, storing, and displaying geospatial data (Chang 2014). GIS allows us to view, understand, question, interpret, and visualize our world in ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. Geographic analysis is the core strength of GIS. Depending on the project, there are many different analysis approaches to choose from. GIS modeling tools make it relatively easy to conduct simple or complex analyses and create new output.

As Chang (2014) mentioned, GIS has the capability to store, manipulate and display geospatial data on computer systems. Once the data is collected, edited and referenced to a projected coordinate system, the next step is to make the data readily available to users for making maps, assisting in fieldwork and conducting spatial analyses. The main goal of this research was to develop an application programming interface (API) to facilitate access to the geospatial data found on the School of Forest Resources and Environmental Sciences (SFRES) GIS server. The mapping application enables students and researchers to access the data from anywhere and anytime without having direct access to the GIS server. The web application uses the National Map Viewer format and includes a scale bar, north arrow, legend, title and map author. The created map view can be downloaded and/or printed for field use and other applications.

## 1.2. Web GIS Technology

Web GIS, the integration product of Web Technologies and GIS, is different from traditional GIS in that it masks the differences among various types of databases, networks, hardware and software (Lu, et al. 2010). It is a platform for delivering GIS capabilities and many organizations shares and collaborates GIS resources over the internet to access easily and use geographic information in recent years (Law 2013). Therefore, Web GIS provides accessible, manageable and sharable global geographic information data indiscriminatingly (Liu, et al. 2009).

Geospatial data can be acquired via web GIS from the internet (Peng and Tsou 2003). According to the research by Menno-Jan (2004), although Web GIS offers GIS functionality in a web environment, Web GIS is used in limited access situations for mapping applications to solve geospatial analysis problems (Kraak 2004). The interactive and dynamic appearance of maps will guide and assist users as a future trend in solving geospatial analysis problems (Kraak 2004).

Web GIS Applications are created and designed using a wide variety of resources. A web GIS includes at least a server and a client (ESRI, Developers ArcGIS, Create Web Apps 2017). The client is a mobile application, desktop application or web browser and the server is a GIS server (ESRI, Developers ArcGIS, Create Web Apps 2017). The foundation for all ArcGIS web APIs is the ArcGIS Server REST (REpresentational State Transfer) API and a web application based on ArcGIS technology is built by ArcGIS API for Flex, ArcGIS API for Silverlight, ArcGIS API for JavaScript and others (Rubalcava, ArcGIS Web Development 2015). ArcGIS API for Silverlight and ArcGIS API for Flex use Microsoft Silverlight to build applications, and provide fluid and interactive applications. The Flex API based on the Flex software development kit (SDK) and this API was released in 2014 (Svensson 2014). ArcGIS API for Silverlight and ArcGIS API for Flex were supported through 2016, and followed by ESRI leading customers to explore web solutions based on ArcGIS API for JavaScript (Hansen and Zwaap 2015).

ArcGIS JavaScript API is the only API that does not require a browser plug-in and supports the following browsers:

- Chrome
- Firefox
- Safari
- Microsoft Edge
- Internet Explorer 11+ (Rubalcava, ArcGIS Web Development 2015).

Consequently, the API developed for accessing the SFRES GIS server is built with ArcGIS API for JavaScript. This program is a client-server side scripting language and provides interactive applications. JavaScript facilitates web page functionality and minimizes differences between any browsers.

### **1.3. Database Design and Construction**

Designing a geodatabase (GDB) is based upon a common set of fundamental GIS design steps and requires forethought and planning. Consideration must be given to users' needs and their level of expertise in accessing and manipulating geospatial data as well as how to present the results to various users. Geospatial data stored in a GDB is managed in a standardized Data Base Management System (DBMS) tables using SQL data types, which allows SQL statements to search the GDB (Arctur and Zeiler 2004). There are geographical and topological relationships for all GDB spatial entities. To manage data within the GIS database, PostgreSQL is generally used, and it is an open source Database software (Xulin , Wenfang and Guohong 2008).

ArcGIS Server is used to publish services for visualization, spatial data management and spatial analysis (Esri, ArcGIS for Developers, ArcGIS Server services overview 2017). The REST API offers additional information on using ArcGIS Server Services successfully (ESRI, Developers ArcGIS, Web App Builder for ArcGIS (Developer

Edition) 2017). This API includes several sections to work with different components of the ArcGIS system (Esri, ArcGIS Resources, The ArcGIS REST API 2017). ArcGIS REST API can utilize ArcGIS Online services hosted by Esri and services (Esri, ArcGIS Resources, The ArcGIS REST API 2017). By using the ArcGIS REST API, web services can be published and items can be created, and shared on ArcGIS Online or an in house portal (Esri, ArcGIS Resources, The ArcGIS REST API 2017).

ArcGIS Server site can be operated with a single machine (Figure 1.1), or multiple machines (Figure 1.2). The single ArcGIS Server machine is configured with using a local account or the domain account designate as the ArcGIS Server account (ESRI, ArcGIS Enterprise, Installation Guides, Single-machine deployment 2017, ESRI, ArcGIS Server, The ArcGIS Server Account 2017). More than one ArcGIS Server machines can be administered and used as a single logical unit in multiple machine (ESRI, ArcGIS Enterprise, Installation Guides, Multiple-machine deployment with ArcGIS Web Adaptor 2017).

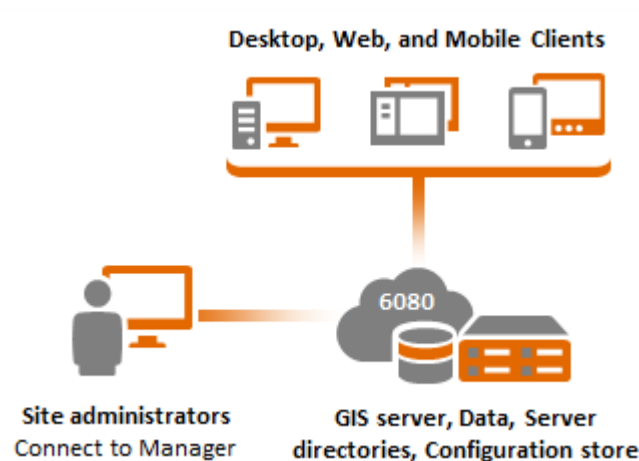


Figure 1.1. Architecture of A Single ArcGIS Server Machine © 2017 Esri (ESRI, ArcGIS Enterprise, Installation Guides, Single-machine deployment 2017).

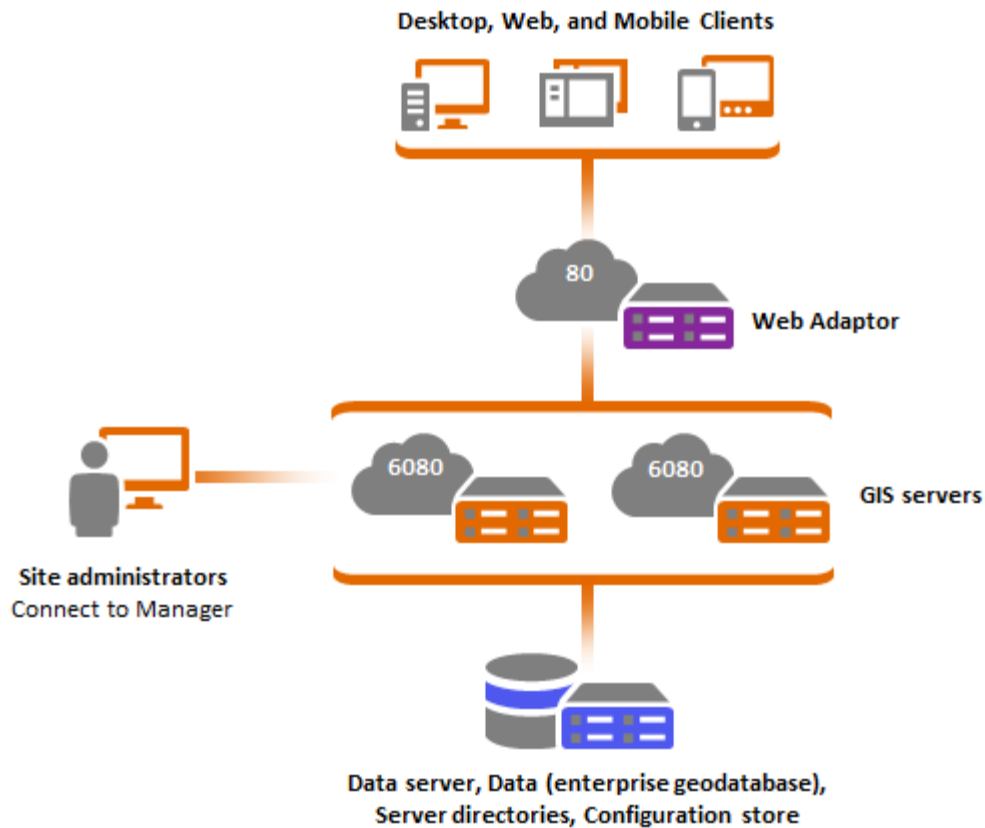


Figure 1.2. Architecture of Multiple ArcGIS Servers in Multiple-Machine © 2017 Esri (ESRI, ArcGIS Enterprise, Installation Guides, Multiple-machine deployment with ArcGIS Web Adaptor 2017).

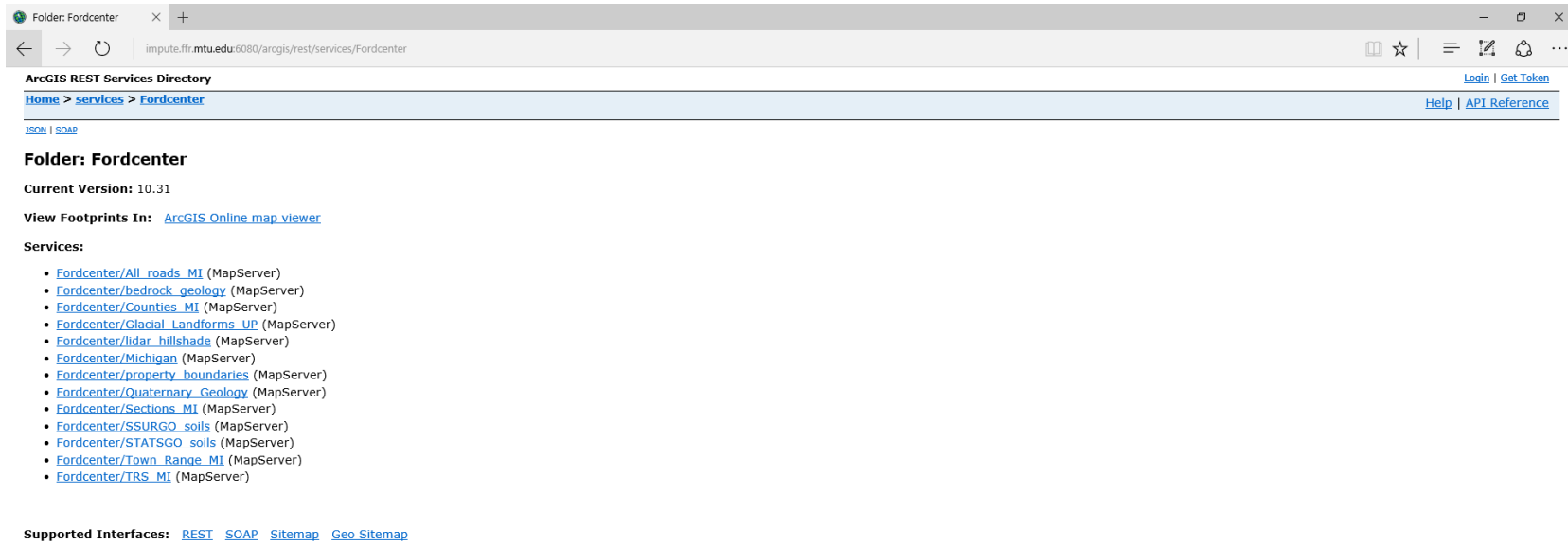
ArcGIS Server uses port 6080 to communicate with machines on the internet, and the firewall must be allowed HTTP communication through this port (ESRI, ArcGIS Enterprise, Installation Guides, Ports used by ArcGIS Server 2017). Also after installing ArcGIS for Server, it can be administered it by making web service requests and connecting immediately through port 6080 (Law, Understanding architecture, deployment, and workflows 2013). As shown on Figure 1.2, ArcGIS Server clients connect to the Web Adaptor before connecting the ArcGIS Servers. This makes the overall site more resilient to failures and provides security features (ESRI, ArcGIS



Enterprise, Installation Guides, Multiple-machine deployment with ArcGIS Web Adaptor 2017).

In this research, a single ArcGIS Server machine was used because it permits high performance and is straightforward to install, maintain and upgrade. Additionally, additional components are not needed. The ArcGIS Server site provides GIS resources as a web service that create a link via REST-based architecture (Law, Understanding architecture, deployment, and workflows 2013). All SFRES Geospatial data are available from the website (Figure 1.3).

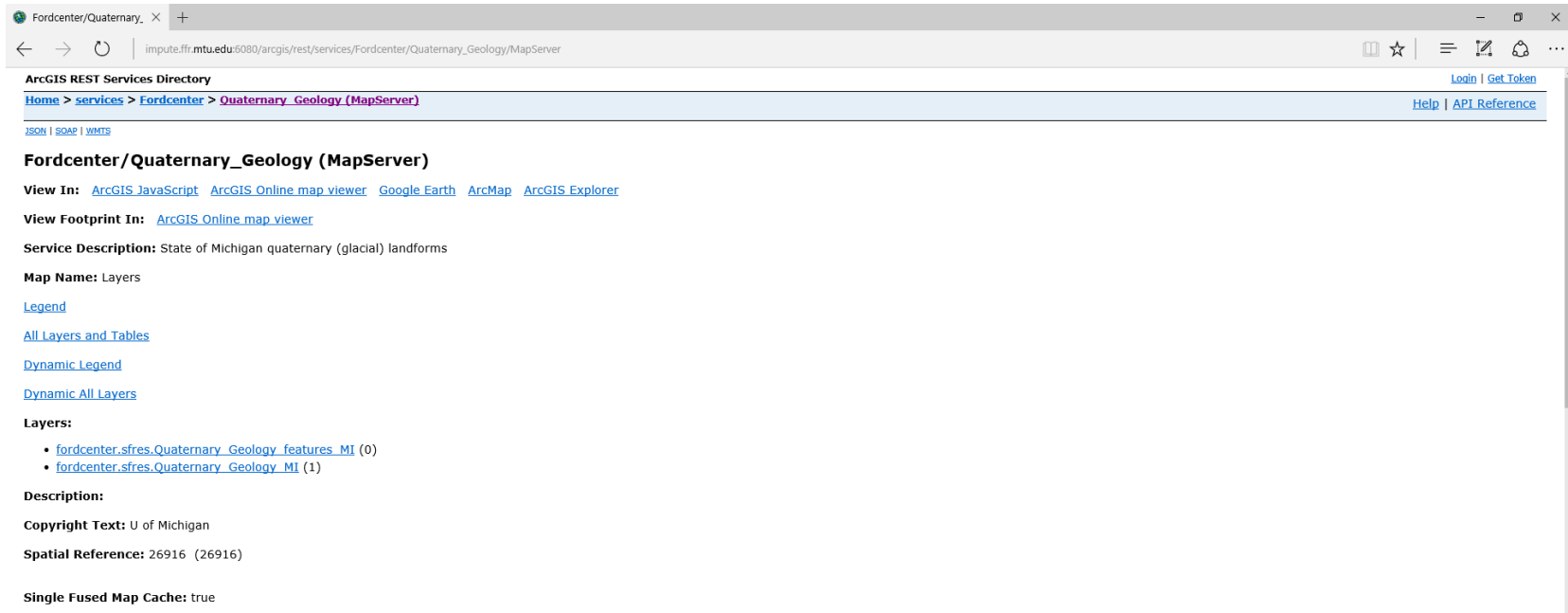
Here is the link: *<<http://impute.ffr.mtu.edu:6080/arcgis/rest/services/Fordcenter>>*



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Figure 1.3. SFRES Geospatial Data - ArcGIS for Server main access point (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

As shown in Figure 1.3, SFRES geospatial data display in the Ford Center folder on site. Figure 1.4 shows the selection of, “*Fordcenter > Quaternary\_Geology (MapServer)*” was selected and these is metadata which includes information about the data (Figure 1.4). The layer can be viewed in ArcGIS JavaScript (Figure 1.5) and ArcGIS Online map viewer (Figure 1.6). The layer can be downloaded as a *.kmz* file by clicking Google Earth, as a *.lyr* file by clicking ArcMap and as a *.nmf* file by clicking ArcGIS Explorer. The layer also can be viewed in the ArcGIS Online map viewer and the tag shows the center of the area (Figure 1.7).



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Figure 1.4. SFRES Geospatial data (Fordcenter > Quaternary\_Geology (MapServer)) (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

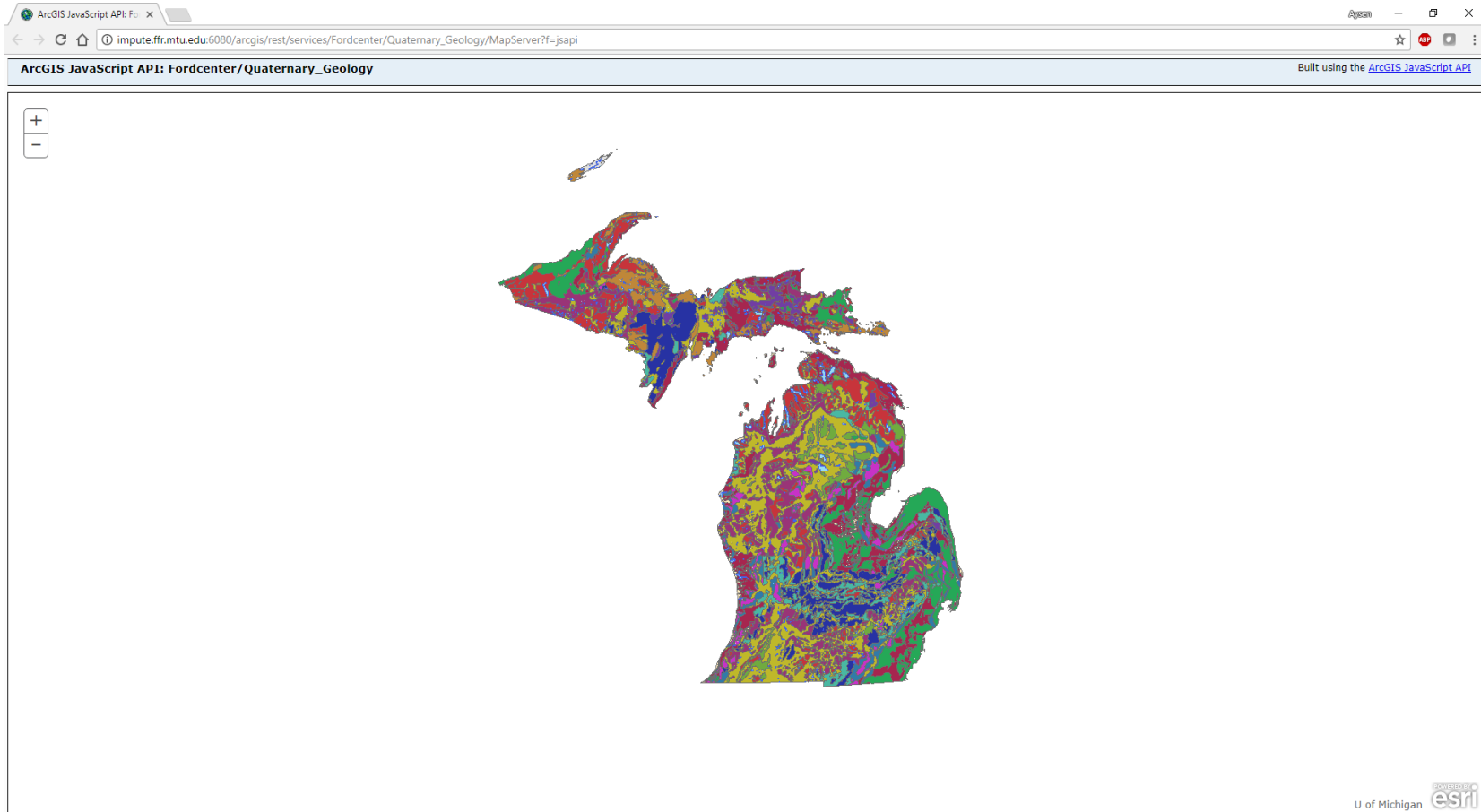


Figure 1.5. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) - shown with ArcGIS JavaScript (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

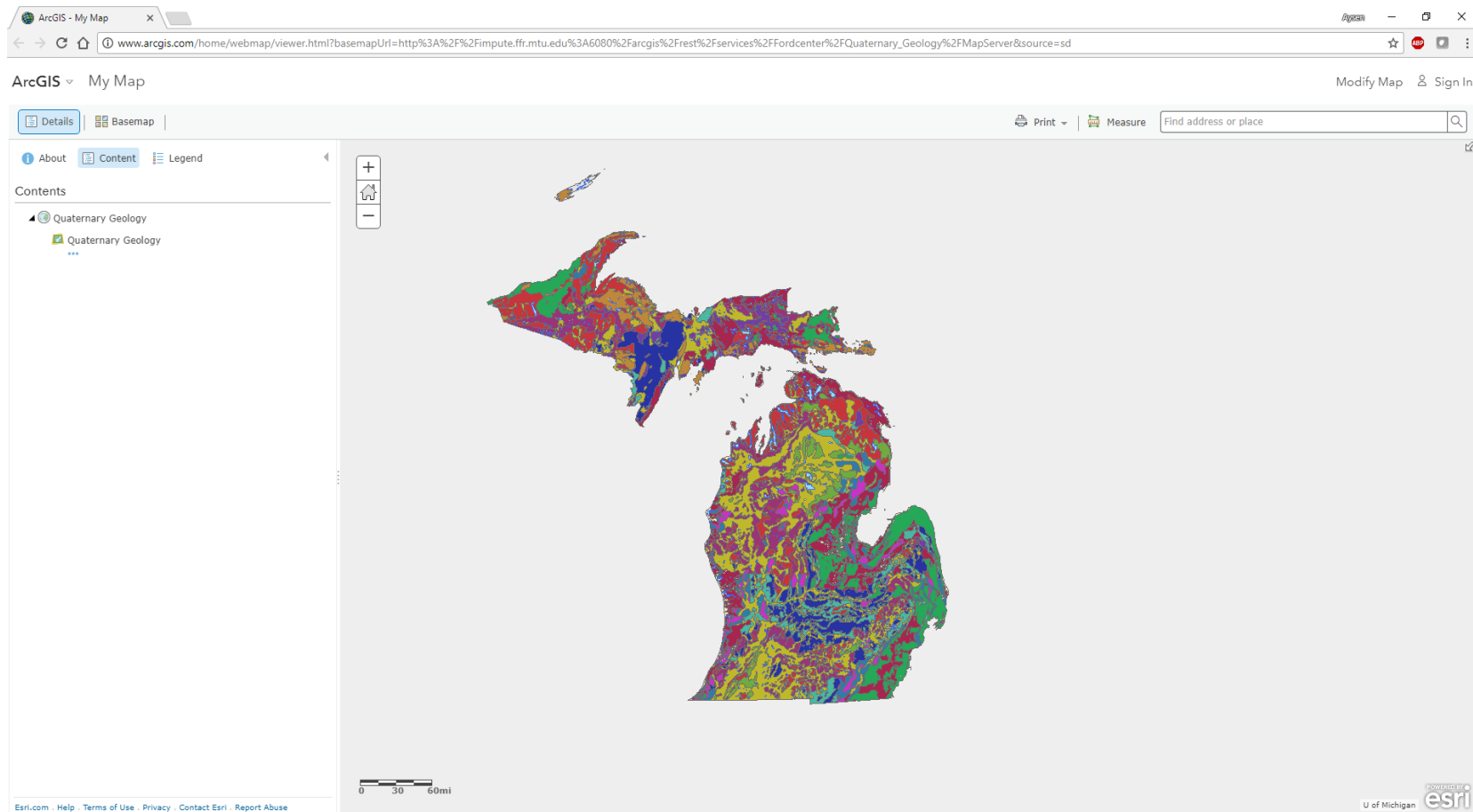


Figure 1.6. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) - viewed in the ArcGIS Online map viewer (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

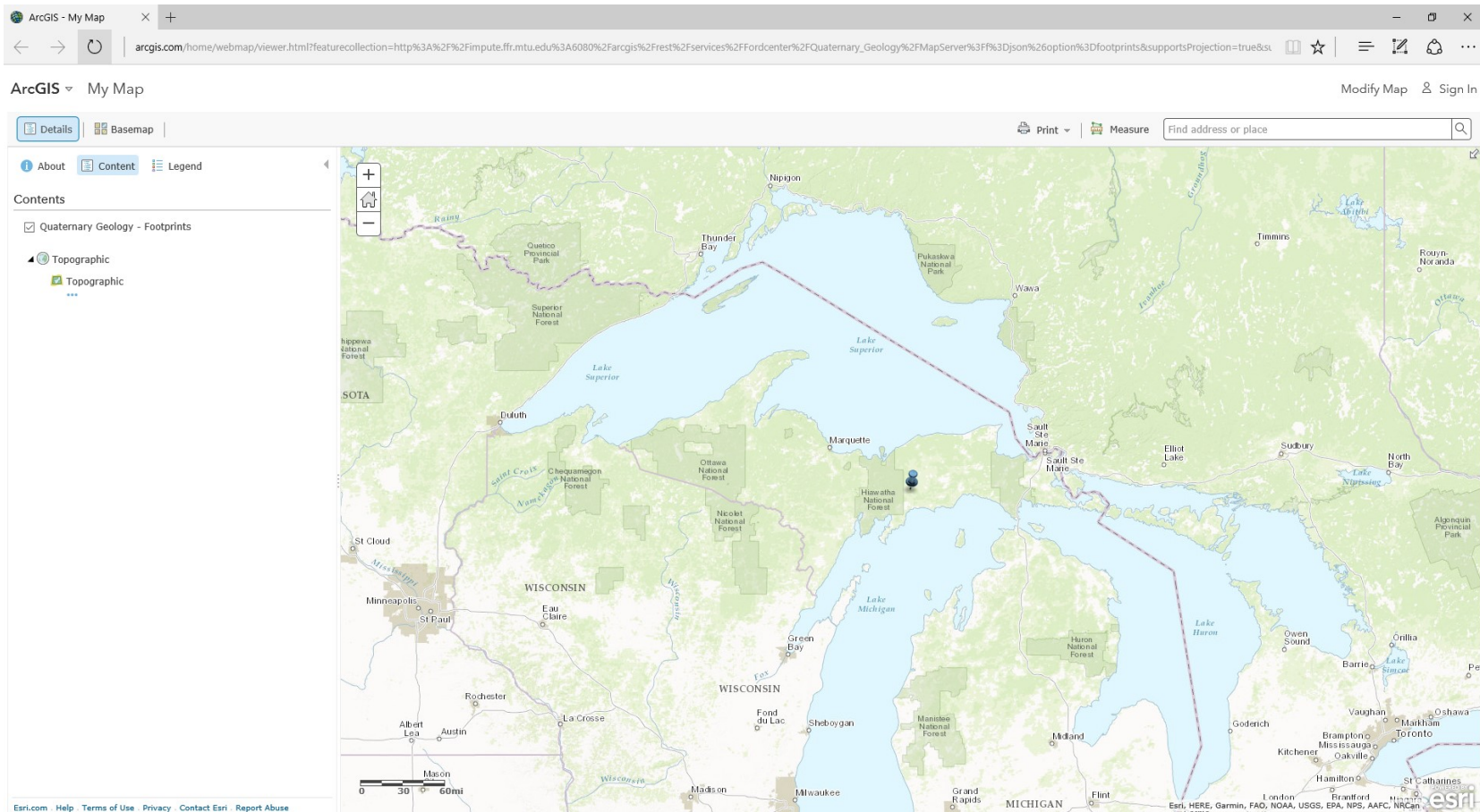
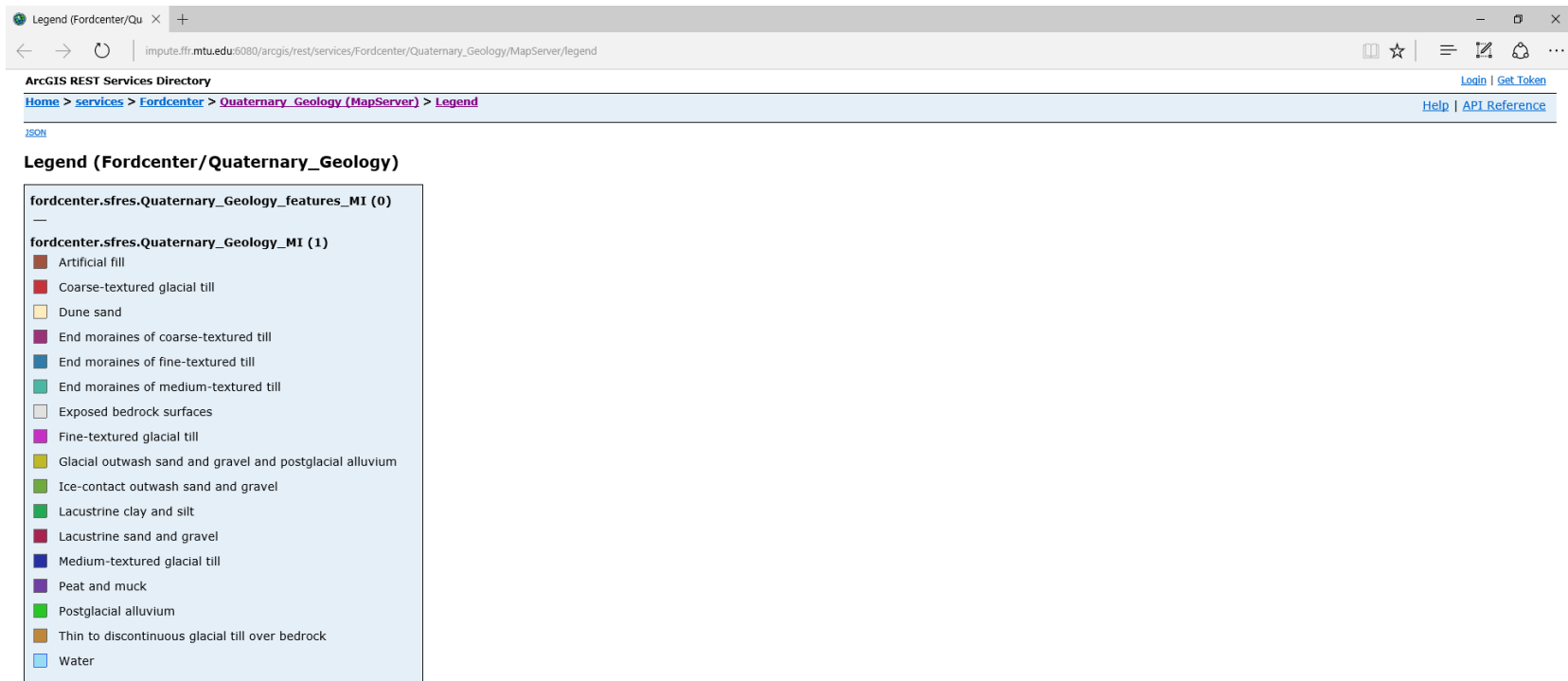


Figure 1.7. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) - viewed footprint in ArcGIS online map viewer (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

Legend of the layer can be displayed by clicking “*Legend*” button on the site (Figure 1.8). It can be seen all information about layers and tables by clicking the “*All Layers and Tables*” button (Figure 1.9. and Figure 1.10.). “*Dynamic Legend*” and/or “*Dynamic All Layers*” represent layers and/or tables of a map service published the server and they based on an existing map service layer (ESRI, ArcGIS-Resources-Dynamic Layer/ Table n.d.) (Figures 1.11 and 1.12). It includes initial and full extent (xmin, ymin, xmax, ymax, spatial reference), and document information.





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Figure 1.8. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) – Legend (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

The screenshot displays a web browser window with the URL `impute.fri.mtu.edu:6080/arcgis/rest/services/Fordcenter/Quaternary_Geology/MapServer/layers`. The page title is "All Layers and Tables (Fordcenter/Quaternary\_Geology)". The breadcrumb navigation shows: Home > services > Fordcenter > Quaternary\_Geology (MapServer) > All Layers and Tables. There are links for "Login | Get Token" and "Help | API Reference".

**All Layers and Tables (Fordcenter/Quaternary\_Geology)**

**Layers:**

- Layer:** [fordcenter\\_sfres\\_Quaternary\\_Geology\\_features\\_MI \(0\)](#)
- Name:** fordcenter.sfres.Quaternary\_Geology\_features\_MI
- Display Field:** features
- Type:** Feature Layer
- Geometry Type:** esriGeometryPolyline
- Description:** Shows the quaternary geology for the state of Michigan
- Definition Expression:** N/A
- Copyright Text:** FC staff, Michigan Technological University, SFRES Staff
- Default Visibility:** true
- MaxRecordCount:** 1000
- Supported Query Formats:** JSON, AMF
- Min Scale:** 1000000
- Max Scale:** 0
- Supports Advanced Queries:** true
- Supports Statistics:** true
- Has Labels:** true
- Can Modify Layer:** true
- Can Scale Symbols:** false
- Use Standardized Queries:** true
- Extent:**
  - XMin: 245001.7817
  - YMin: 4621077.6362
  - XMax: 872945.3219
  - YMax: 5257735.8017
  - Spatial Reference: 26916 (26916)

Figure 1.9. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) - All Layers and Tables - 1(ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

All Layers and Tables (F...)

impute.fir.mtu.edu:6080/arcgis/rest/services/Fordcenter/Quaternary\_Geology/MapServer/layers

**Drawing Info:**

*Renderer:*

*Simple Renderer:*

*Symbol:*

Style: esriSLSSolid

Color: [0, 0, 0, 255]

Width: 0

*Label:*

*Description:*

Transparency: 0

*Labeling Info:*

Label Placement: esriServerLinePlacementAboveAlong

Label Expression: [features]

Use Coded Values: true

*Symbol:*

Color: [0, 0, 0, 255]

Background Color: N/A

Outline Color: N/A

Vertical Alignment: bottom

Horizontal Alignment: center

Right to Left: false

Angle: 0

XOffset: 0

YOffset: 0

Size: 7

Font Family: Arial

Font Style: normal

Font Weight: normal

Font Decoration: none

Min. Scale: 250000.0

Max. Scale: 0.0

**Advanced Query Capabilities:**

Supports Statistics: true

Supports OrderBy: true

Supports Distinct: true

Supports Pagination: true

Supports TrueCurve: true

**HasZ: false**

**HasM: false**

**Has Attachments: false**

**HTML Popup Type:** esriServerHTMLPopupTypeAsHTMLText

**Type ID Field:** null

**Fields:**

- objectid ( type: esriFieldTypeOID , alias: objectid )
- length ( type: esriFieldTypeDouble , alias: LENGTH )
- features ( type: esriFieldTypeString , alias: FEATURES , length: 25 )
- shape ( type: esriFieldTypeGeometry , alias: shape )
- st\_length(shape) ( type: esriFieldTypeDouble , alias: st\_length(shape) )

Figure 1.10. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) - All Layers and Tables – 2 (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

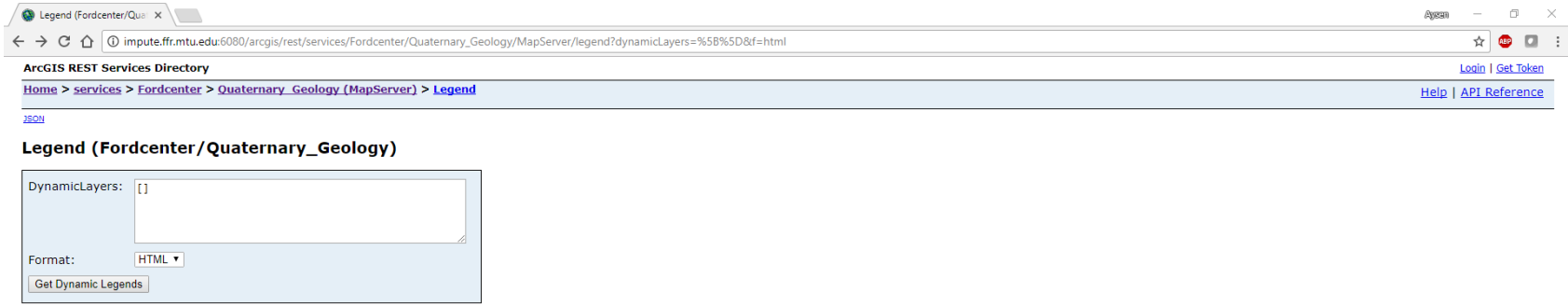


Figure 1.11. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) - Dynamic legend (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

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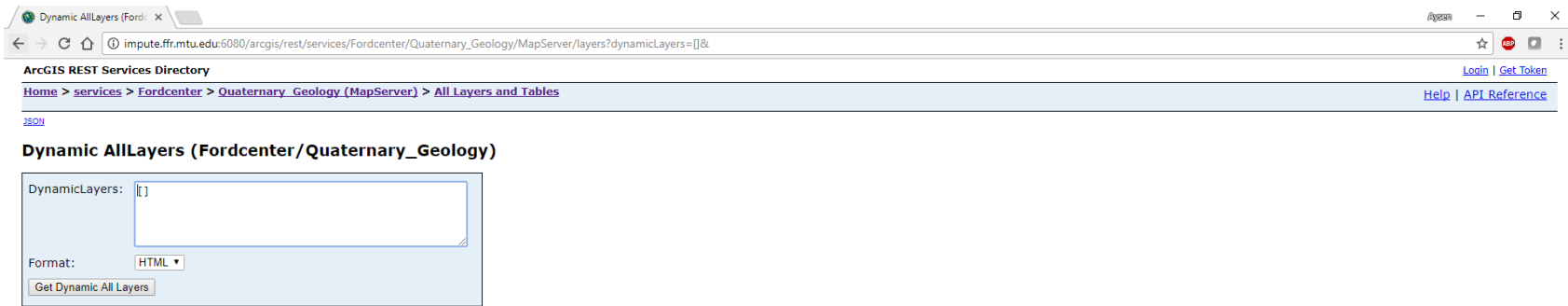


Figure 1.12. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) - Dynamic all layers (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

Fordcenter/Quaternary. X +  
impute.fir.mtu.edu:6080/arcgis/rest/services/Fordcenter/Quaternary\_Geology/MapServer

**Tile Info:**

- **Height:** 256
- **Width:** 256
- **DPI:** 96
- **Levels of Detail:** 7
  - **Level ID:** 0 [ [Start Tile](#), [End Tile](#) ]
    - Resolution: 2116.670900008467
    - Scale: 8000000
  - **Level ID:** 1 [ [Start Tile](#), [End Tile](#) ]
    - Resolution: 1058.3354500042335
    - Scale: 4000000
  - **Level ID:** 2 [ [Start Tile](#), [End Tile](#) ]
    - Resolution: 529.1677250021168
    - Scale: 2000000
  - **Level ID:** 3 [ [Start Tile](#), [End Tile](#) ]
    - Resolution: 264.5838625010584
    - Scale: 1000000
  - **Level ID:** 4 [ [Start Tile](#), [End Tile](#) ]
    - Resolution: 132.2919312505292
    - Scale: 500000
  - **Level ID:** 5 [ [Start Tile](#), [End Tile](#) ]
    - Resolution: 66.1459656252646
    - Scale: 250000
  - **Level ID:** 6 [ [Start Tile](#), [End Tile](#) ]
    - Resolution: 33.0729828126323
    - Scale: 125000
- **Format:** PNG
- **Compression Quality:** 0.0
- **Origin:** X: -5120900.0  
Y: 9998100.0
- **Spatial Reference:** 26916 (26916)

Figure 1.13. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) - Description 1 (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

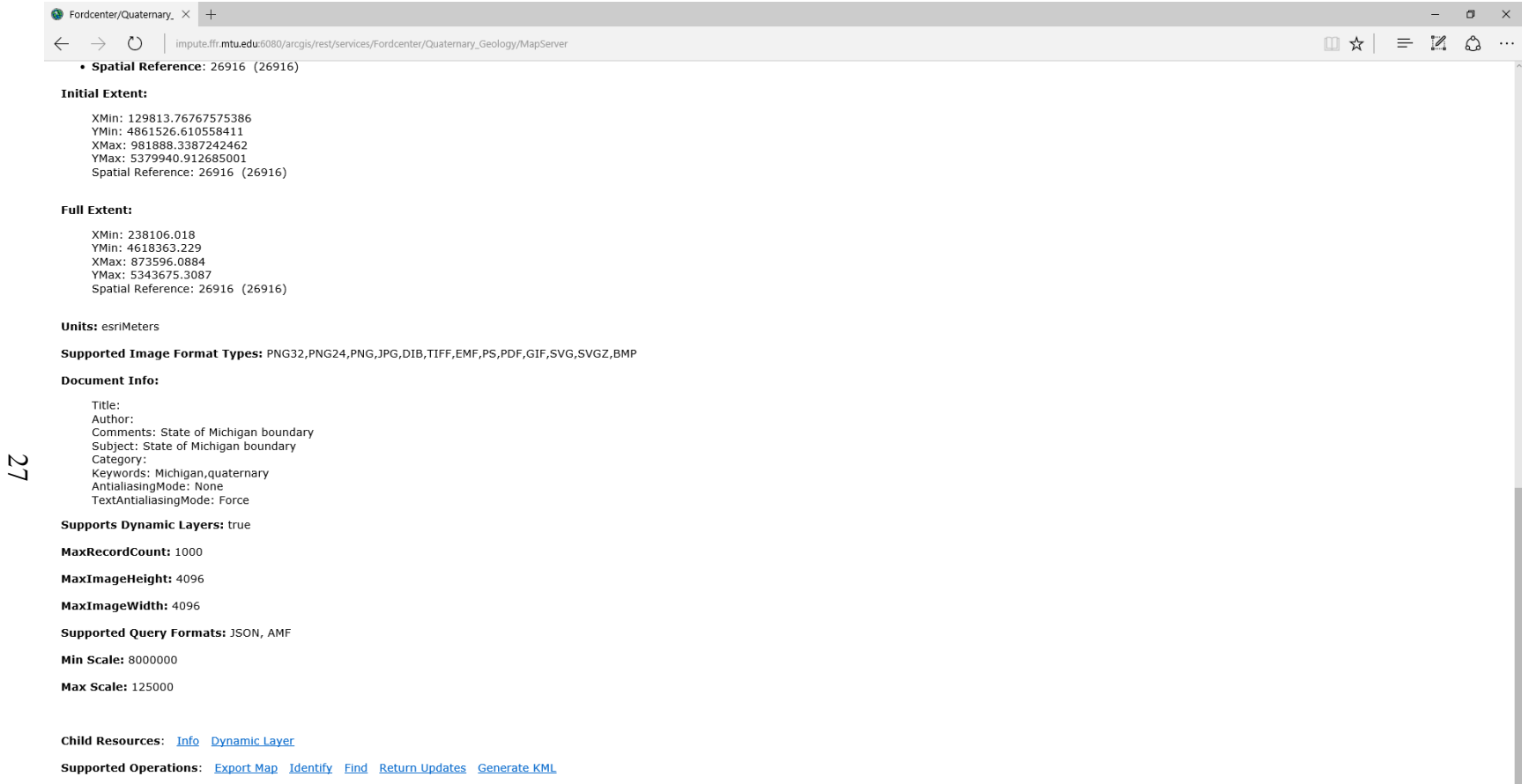


Figure 1.14. SFRES geospatial data (Fordcenter/Quaternary\_Geology (MapServer)) - Description 2 (ArcGIS REST Services Directory Interface of The SFRES Geospatial Data).

After adding a single machine to the site when working with ArcGIS 10.31 for Server, and adding all SFRES geospatial data to the site, information can be requested by structuring a request URLs (Uniform Resource Locator), which is in a defined format from the server to display on web application (Law 2013). The URL returns a web page, an image, or another form of data (Rubalcava, ArcGIS Web Development 2015). Observe the URL bar to perceive how different URLs are used to recover data through REST while navigating the Service Directory (Law, Understanding architecture, deployment, and workflows 2013).

## **2. Chapter – Software and Data**

One of the most important steps involved in creating a web application is deciding how it will be organized and what content will be included. (Winkelman 2004).

Web applications consist of three components:

- The database
- The “server” is a web application server at remote location anywhere in the world. It scripts before the HTML is loaded. That will process web requests and send pages to the client and the action takes place on a web server (Segue 2013).
- The client runs in a web browser like Explorer, or Google Chrome and process requests without call - backs to the server (Wodehouse 2015).

The purpose of this work ensures a powerful and efficient application. Therefore, the web application can be in interaction with the user via ArcGIS API for JavaScript, the HTML viewer developed for the user interface and the CSS formatted the HTML document. The client-side of the system runs JavaScript beside HTML (Basu and Paul 2016). It is for displaying the map and implementing the processing in the server-side, then regaining the results (Basu and Paul 2016).

### **2.1. Data Set**

The data is stored and managed in a PostgreSQL object-relational database, and the data served out via ArcGIS REST services such as the Map Server and Feature Server services. There are three basic geospatial data types (tables, feature classes, and raster datasets) inside the GDB. The geographic dataset is designed as a logical data model within the GDB structure. The SFRES GDB utilizes the map model developed for the National Map Viewer and includes elevation, hydrography, boundaries, transportation, structures, land cover, etc (Table 2.1.).



Table 2.1. Data residing on the SFRES geospatial data server.

<b>Data Type</b>	<b>Name</b>
SDE Feature Class	Boundaries/City
SDE Feature Class	Boundaries/County
SDE Feature Class	Boundaries/First Division
SDE Feature Class	Boundaries/Special Survey
SDE Feature Class	Boundaries/Townships
SDE Feature Class	Boundaries/School Properties
SDE Feature Class	Boundaries/State Outlines
SDE Feature Class	Boundaries/Topo Grid
SDE Feature Class	Boundaries/Upper Peninsula
SDE Feature Class	Boundaries/Village
SDE Feature Class	Control Points
SDE Feature Class	Control Points/GCP (Ground Control Points)Section Corners
SDE Feature Class	Control Points/Lidar Control Polygon
SDE Feature Class	Geomorphology/Bedrock Geology
SDE Feature Class	Geomorphology/Michigan Soils
SDE Feature Class	Geomorphology/Quaternary Geology Features MI
SDE Feature Class	Geomorphology/Quaternary Glacial Landforms UP
SDE Feature Class	Geomorphology/Quaternary Glacial Landforms UP1
SDE Feature Class	Geomorphology/Western UP Contours 50M
SDE Feature Class	Hydrography/Lakes and Ponds
SDE Feature Class	Hydrography/Rivers and Streams
SDE Feature Class	Hydrography/Watersheds UP
SDE Feature Class	Hydrography/Wells
SDE Feature Class	Infrastructure/All Buildings
SDE Feature Class	Land Use/Michigan 1800 Land use
SDE Feature Class	Roads Trails/Alb Town roads
SDE Feature Class	Roads Trails/All roads

SDE Feature Class	Roads Trails/St roads
SDE Feature Class	Roads Trails/Trails
SDE Feature Class	SSurgo Soils/Soils
SDE Raster	CDL2013 (Cropland Data Layer)
SDE Raster	Ford Lands Aspect
SDE Raster	Ford Lands MDOW (Multi-Directional Oblique Weighted) Hillshade
SDE Raster	Ford Lands Slope
SDE Raster	Keweenaw Imagery
SDE Raster	Lidar CHM (Canopy Height Model)
SDE Raster	Lidar CHM Hillshade
SDE Raster	Lidar DEM (Digital Elevation Models)
SDE Raster	Lidar Hillshade
SDE Raster	Western UP DEM 30M

## 2.2. Cascading Style Sheet

Web site developers and users can gain control over a browser's display pages by a Cascading Style Sheet that defines how different page elements appear in the viewer (Paulson 2005). There are three levels of style sheets: external style sheets, internal style sheets, inline sheets and inline style.

External style sheets are in separate files and can be applied to any document. They are capable of changing the look of an entire website. A <link> tag is used to specify that the browser needs to fetch and use a particular external style sheet file as noted in the following example.

```
<link rel = "stylesheet" type = "text/css" href = "externalfile.css"> </link>
```

The “rel” is required for the <link> tag to specify the relationship between the current, and the linked document and “stylesheet” is the value of the “rel” attribute. The “type” attribute specifies the text/css type of the linked document. The “href” attribute is the location of the .css document.

The <style> element defines style information and internal style sheets are used for a single page which has a unique style.

```
<style type = "text/css" > .... </style>
```

Inline style is specified for a specific occurrence of a tag and appears in the opening tag. It applies only to the content of that tag.

```
style = "... "
```

### **2.3. JavaScript**

JavaScript is a Hyper Text Markup Language (HTML) programming language used to support web sites and web applications. There are three major parts of JavaScript. The first one is Core JavaScript that consists of the basic JavaScript language, operators, expressions, and statements. The second one is Client Side JavaScript that are statements inserted in an HTML page, and interpreted by the web browser which respond to user events like page navigation.

The last one is Server Side JavaScript that are statements also embedded in an HTML page, and Server Side JavaScript also contains the core JavaScript elements (Oracle 1999). A web application or a web app, client-server software application, uses a combination of client-side scripts to present information to users and server-side scripts to store the information and retrieval of the information (Ndegwa 2016).

## 2.4. ArcGIS JavaScript API

ArcGIS JavaScript API, a well-stocked JavaScript library, is designed to maximize productivity to build mapping applications (Rubalcava, ArcGIS Web Development 2015). This API is a simple way to insert the GIS maps such as displaying an interactive map of the data, and an ArcGIS Server is needed to deploy applications built with this API (Aly and Labib 2013). Generating hi-performing apps and decent imaging of data requires this API that compounds new web technology and powerful geospatial abilities (APIs 2017).

The ArcGIS JavaScript API combines modern web technology, and it is designed to develop productivity for the best-enhanced web mapping applications and smarter data visualization. The API also combines powerful geospatial abilities enabling us to generate hi-performing apps (ESRI, Developers ArcGIS 2017). ArcGIS API for JavaScript make it easy to interact with ArcGIS Server to provide data-rich web map applications and (Rubalcava, ArcGIS Web Development 2015) (Figure 2.1.).

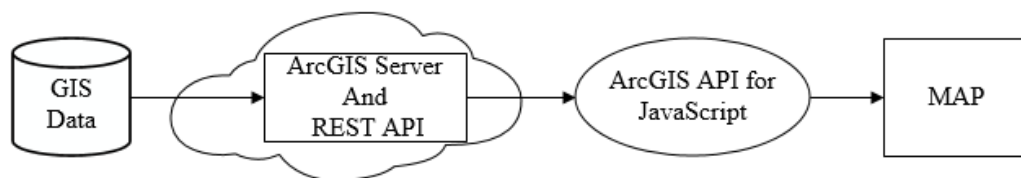


Figure 2.1. Producing maps with ArcGIS API for JavaScript © 2005 by Manning Publications Co (Rubalcava, ArcGIS Web Development 2015).

This application consists of the following items:

### 1 – Map viewer

- Build map viewer for displaying vector maps, ArcGIS JavaScript API used.
- Set base map (e.g. Streets map, Topographic map, ...)
- Navigation toolbar (Zoom in, Zoom out)
- Search toolbar (the ability to search any city, country, etc.)
- Legend widget (to display legend with focusing in layer)

- Export map (.pdf, .png32, .png8, .jpg, .gif, .eps, .svg, .svgz file format)

## 2 – Downloading data

- Downloadable data (.lyr file format)

GIS data is generally stored in a GDB on a server and is not directly accessible via the web. ArcGIS server is the gateway for both storing ArcGIS data and viewing GIS it in external clients like a web browser. The ArcGIS API for JavaScript displays map services in the browser (Rubalcava, ArcGIS Web Development 2015). The ArcGIS API for JavaScript is based on Dojo, and the Dojo Toolkit offers many tools for writing JavaScript. Therefore, this application was created with using version 4.3 of the ArcGIS API for JavaScript, and the Dojo toolkit.

### 2.4.1. ESRI

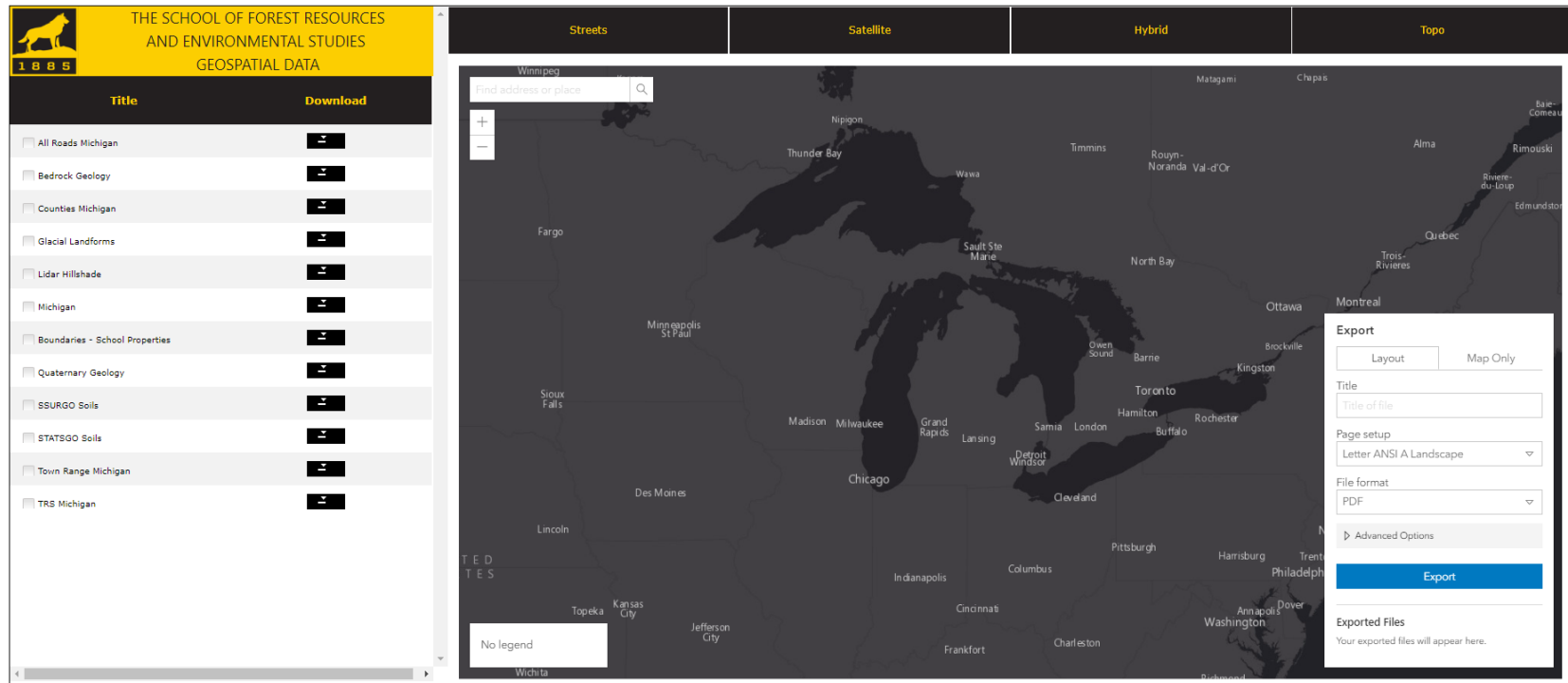
ESRI is the global market leader in GIS and its next generation JavaScript API is the 4.3 series of the ArcGIS API for JavaScript and is used for the SFRES web based mapping application. The following sections provide an overview of some key capabilities of this web application.

#### ➤ **Map Application**

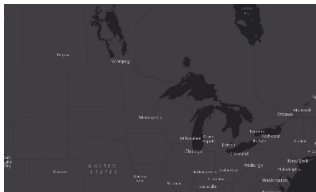
The map application provides mapping contexts where users can change the base maps or background maps. Options include topographic, satellite imagery, streets and hybrid maps based on ESRI Base Map geospatial data. The differences between these base maps are shown in Figure 2.2.

```
require([
    "esri/Map"],
function(Map) {
    /* code goes here */
}); (ESRI, ArcGIS Developers- ArcGIS API for JavaScript - ESRI - Map 2017)
```

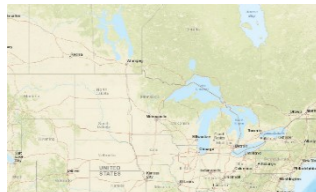
The “require” tag imports resource, is “esri/Map”, into the web application.



Base map



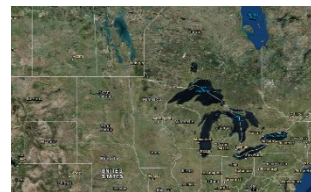
Streets



Satellite



Hybrid



Topo

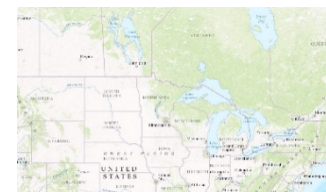


Figure 2.2. ArcGIS Server provides access to GIS data such as different base maps (Interface of the application created by author).

## ➤ Layers

Layer has no constructor and the base class for all layers can be added to a map (ESRI, ArcGIS for Developers - ArcGIS API for JavaScript - Api Reference-Layer 2017). Different types of GIS layers, such as map image layer, feature layer, etc., can be added to the map using the add method statement.

```
map.add(Layer);
```

- **Map Image Layer**

A MapImageLayer represents a resource and it allows the map display to be analyzed dynamically (ESRI, Developers ArcGIS, MapView, Map Image Layer 2017). A map image layer was added with using this tag (Figure 2.3)

```
require([  
    "esri/layers/MapImageLayer "],  
function(MapImageLayer) {  
    var mapimagelayer = new MapImageLayer({ url: MapImageURL });  
}); (ESRI, Developers ArcGIS, MapView, Map Image Layer 2017)
```

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**Title** **Download**

- All Roads Michigan
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- Glacial Landforms
- Lidar Hillshade
- Michigan
- Boundaries - School Properties
- Quaternary Geology
- Sections Michigan
- SSURGO Soils
- STATSGO Soils
- Town Range Michigan
- TRS Michigan

Streets Satellite Hybrid Topo

Find address or place

lidar\_hills  
fordcenter.mdh.lidar\_h  
s  
High : 254  
Low : 0

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Figure 2.3. Adding a hillshade (Interface of the application created by author).



- **Feature Layer**

The Feature Layer gets information from a server, which requires ArcGIS Server 10 or above (ESRI, Developers ArcGIS, Feature Layer 2017).

With feature layer tag, feature layer was added to the map (Figure 2.4).

```
require([
    "esri/layers/FeatureLayer", ...
], function(FeatureLayer, ... ) {
    var featureLayer = new FeatureLayer("url" );
    /* code goes here */
}); (ESRI, Developers ArcGIS, Feature Layer 2017)
```

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<input type="checkbox"/> Michigan	[Download Icon]
<input type="checkbox"/> Boundaries - School Properties	[Download Icon]
<input type="checkbox"/> Quaternary Geology	[Download Icon]
<input type="checkbox"/> SSURGO Soils	[Download Icon]
<input type="checkbox"/> STATSGO Soils	[Download Icon]
<input checked="" type="checkbox"/> Town Range Michigan	[Download Icon]
<input type="checkbox"/> TRS Michigan	[Download Icon]

Streets Satellite Hybrid Topo

Find address or place

Town\_Range

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Figure 2.4. Adding Feature Layer (Interface of the application created by author).

➤ **Views**

- **Map View**

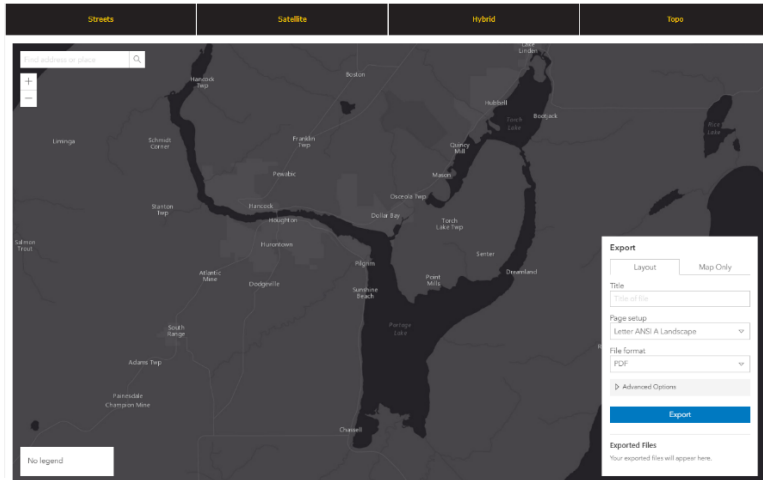
A MapView represents a 2D view of a location using center, scale and rotation. Summarize of the code displays on Table 2.2.

```
require([  
    "esri/view/MapView"],  
    function(MapView) {  
        var mview = new MapView({  
            center: [-118.2438934, 34.058481],  
            container: "viewDiv",  
            map: map,  
            scale: 100000 });  
    }); (ESRI, Developers ArcGIS, Map View 2017)
```

Table 2.2. Property overview (ESRI, Developers ArcGIS, Map View 2017).

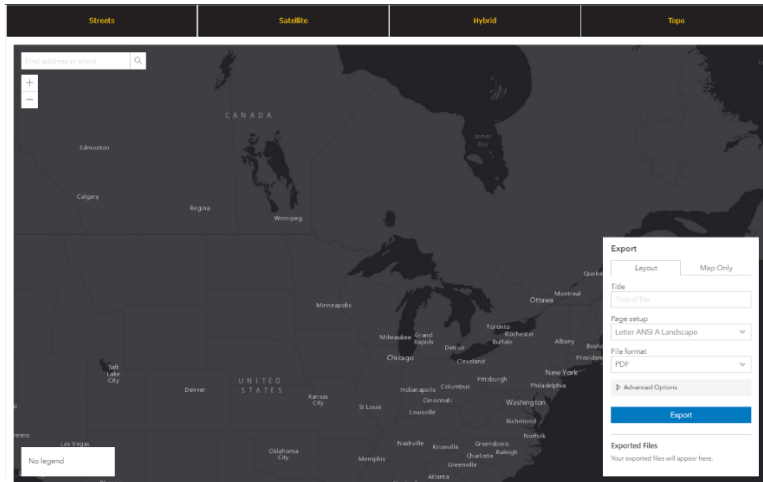
Name	Description
center	The view's center point is represented.
container	The ID or node that holds the view.
map	An example of a Map object to presents in the view.
scale	Stands for the map scale at the view center.
padding	Making the center and extent.

The differences between different scales with the same center point are illustrated in Figure 2.5 and Figure 2.6. When scale number increases, percent of zooming increases.



Set the scale: 100.000 and center: [-88.5, 47.1].

Figure 2.5. Map View Example1 (Interface of the application created by author).






Set the scale: 10.000.000 and center: [-88.5, 47.1].

Figure 2.6. Map View Example2(Interface of the application created by author).

➤ **Widget**

- **Search**

Operations can be query such as locator service(s), map/feature service feature layer(s) with using the Search widget (ESRI, Developers ArcGIS, Search Widget 2017). As is seen on Figure 2.7, there is a textbox and search is accessed through the textbox. Search widget displays appropriate data and it can be clicked on a search result item name, or used search options  button on the search window to focus on a place. It can also be deleted with close  button (on Figure 2.8). After searching any place with the search widget, as is seen in figure 2.9, it gives a point of the location, which is sought out with  **Zoom to** button and it makes to zoom to the location more.

```
require([
    "esri/widgets/Search"
], function(Search) {
    /* code goes here */
}); (ESRI, Developer ArcGIS, Search Widget 2017)
```

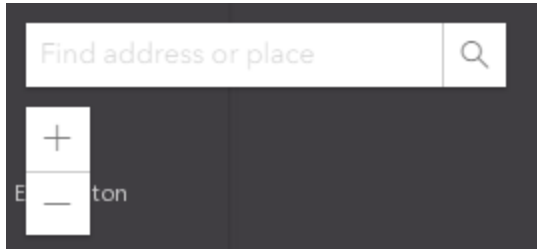


Figure 2.7. Search, zoom in and zoom out widget (Interface of the application created by author).

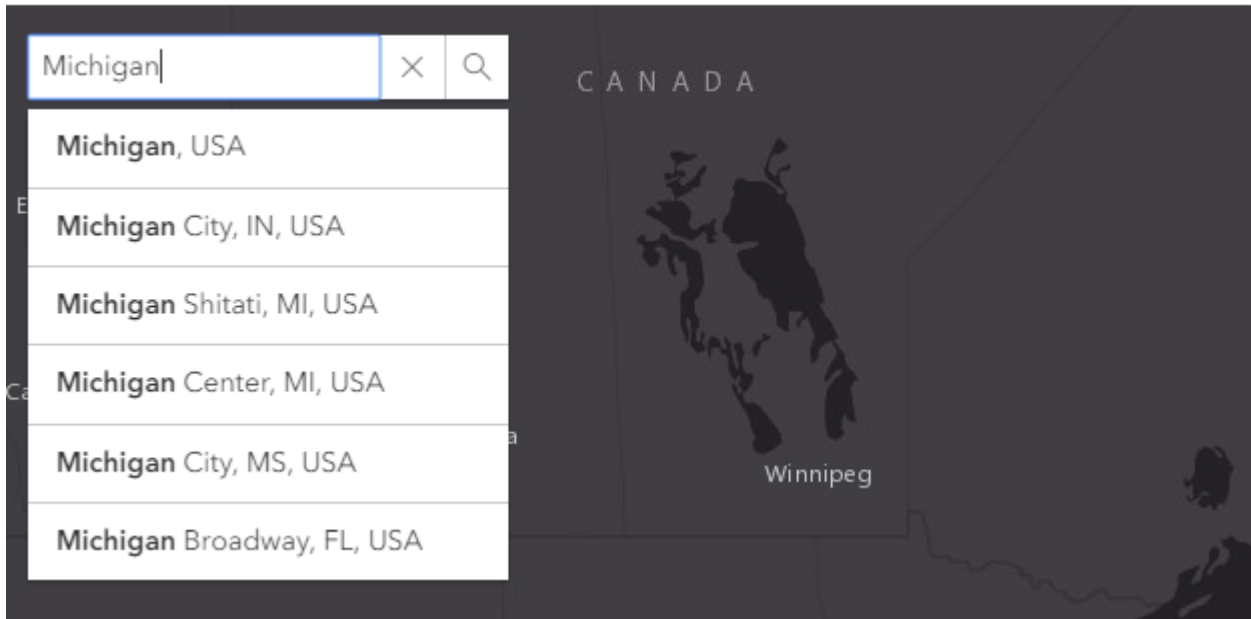
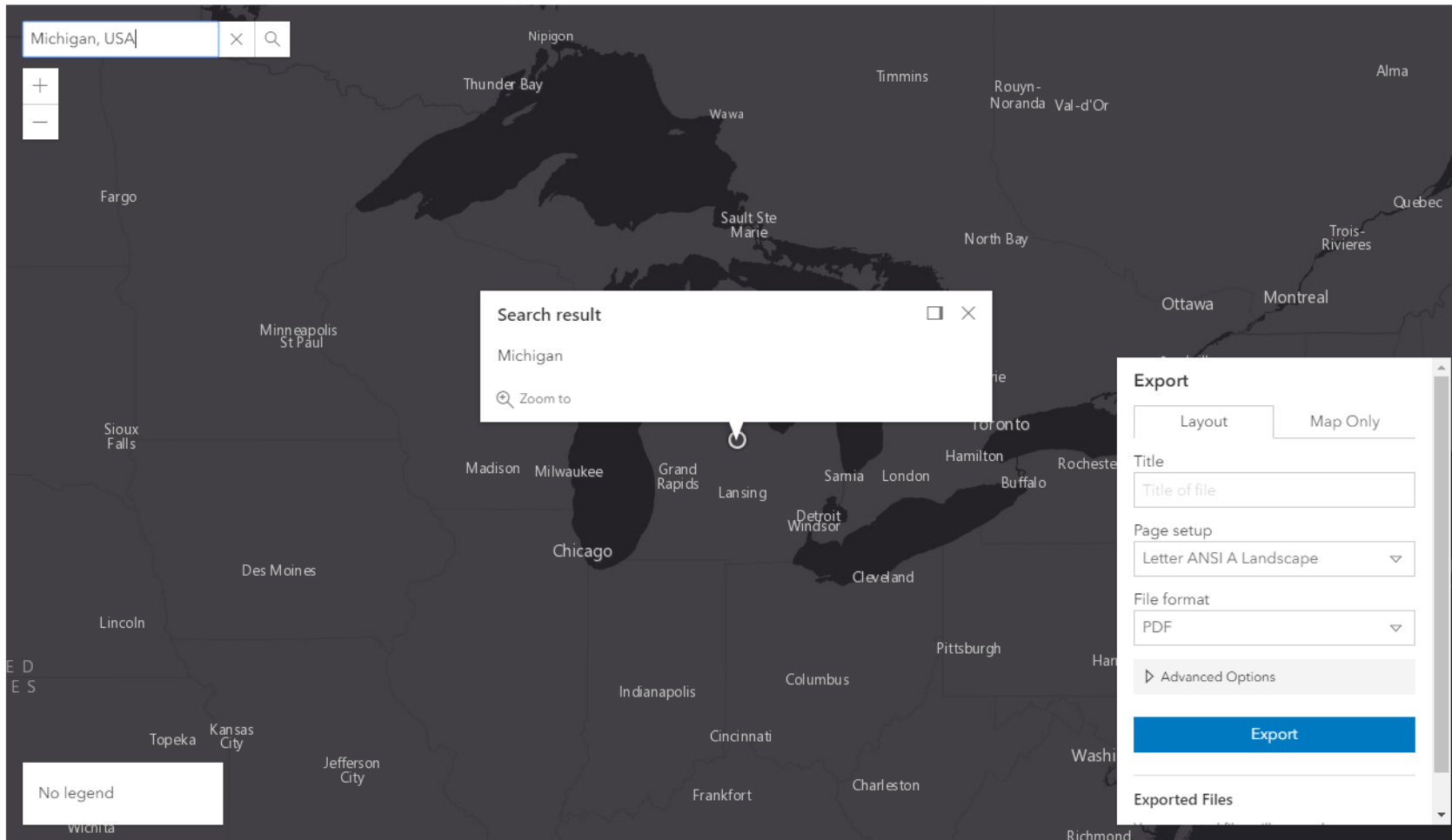


Figure 2.8. Search widget (Michigan, USA) (Interface of the application created by author).



44

Figure 2.9. Search widget (Michigan, USA) (Interface of the application created by author).

- **Legend**

Labels and symbols for layers can be displayed in a map by the Legend (ESRI, Developers ArcGIS, Legend Widget 2017). In Figure 2.10, when any data is unchecked, no legend is shown on the screen. When zooming out from the map, the layer is evaporated so no legend is shown on the screen again. As shown in Figure 2.11, one of the data added to the map and current zooming is enough to display the legend on the screen.

```
require([  
    "esri/widgets/Legend"  
], function(Legend) {  
    /* code goes here */  
}); (ESRI, Developers ArcGIS, Legend Widget 2017)
```



No legend

Figure 2.10. Legend (Interface of the application created by author).

46

**bedrock\_geo**

label

- ANTRIM SHALE
- ARCHEAN GRANITE & GNEISSIC
- ARCHEAN ULTRAMAFIC
- ARCHEAN VOLCANIC & SEDIMENTARY
- BADWATER GREENSTONE
- BASS ISLAND GROUP
- BAYPORT LIMESTONE
- BEDFORD SHALE
- BELL SHALE
- BEREA SANDSTONE & BEDFORD
- BIG HILL DOLOMITE

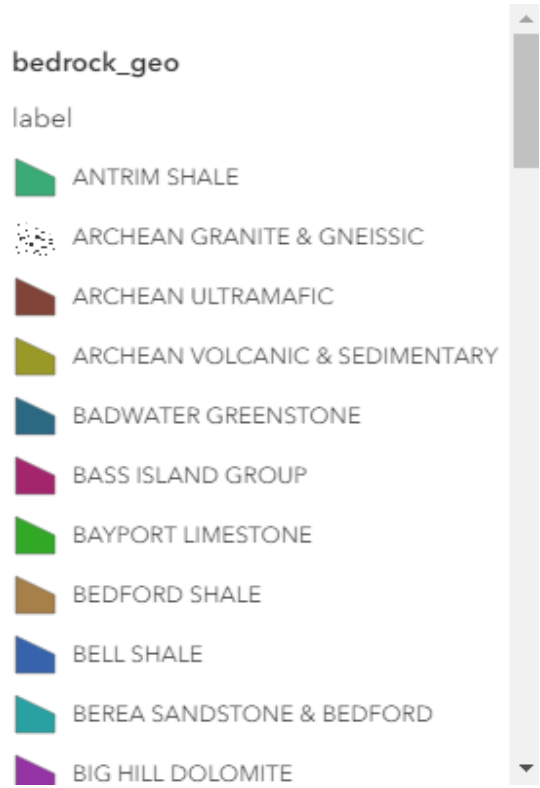


Figure 2.11. An example of legend (Interface of the application created by author).

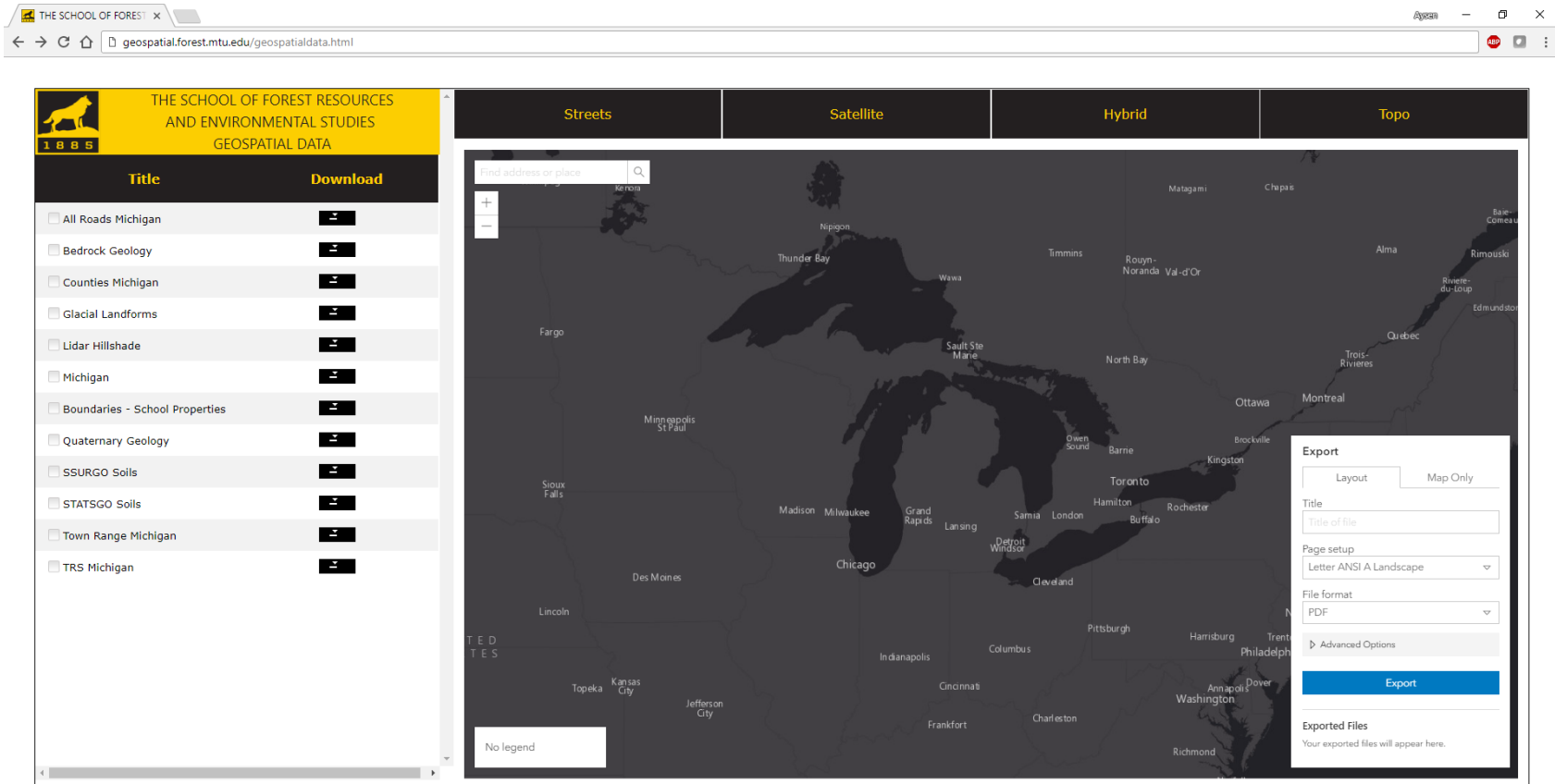
### 2.4.2. Dojo

The dojo toolkit is used because the application behaves the same in different browsers and it simplifies the development process. The application works with three different browsers, Google Chrome, Internet Explorer and Mozilla (Figure 2.12, Figure 2.13 and Figure 2.14) (ESRI, Developers ArcGIS, \_dojo 2017). Here are some common functions used for the application.

➤ **On**

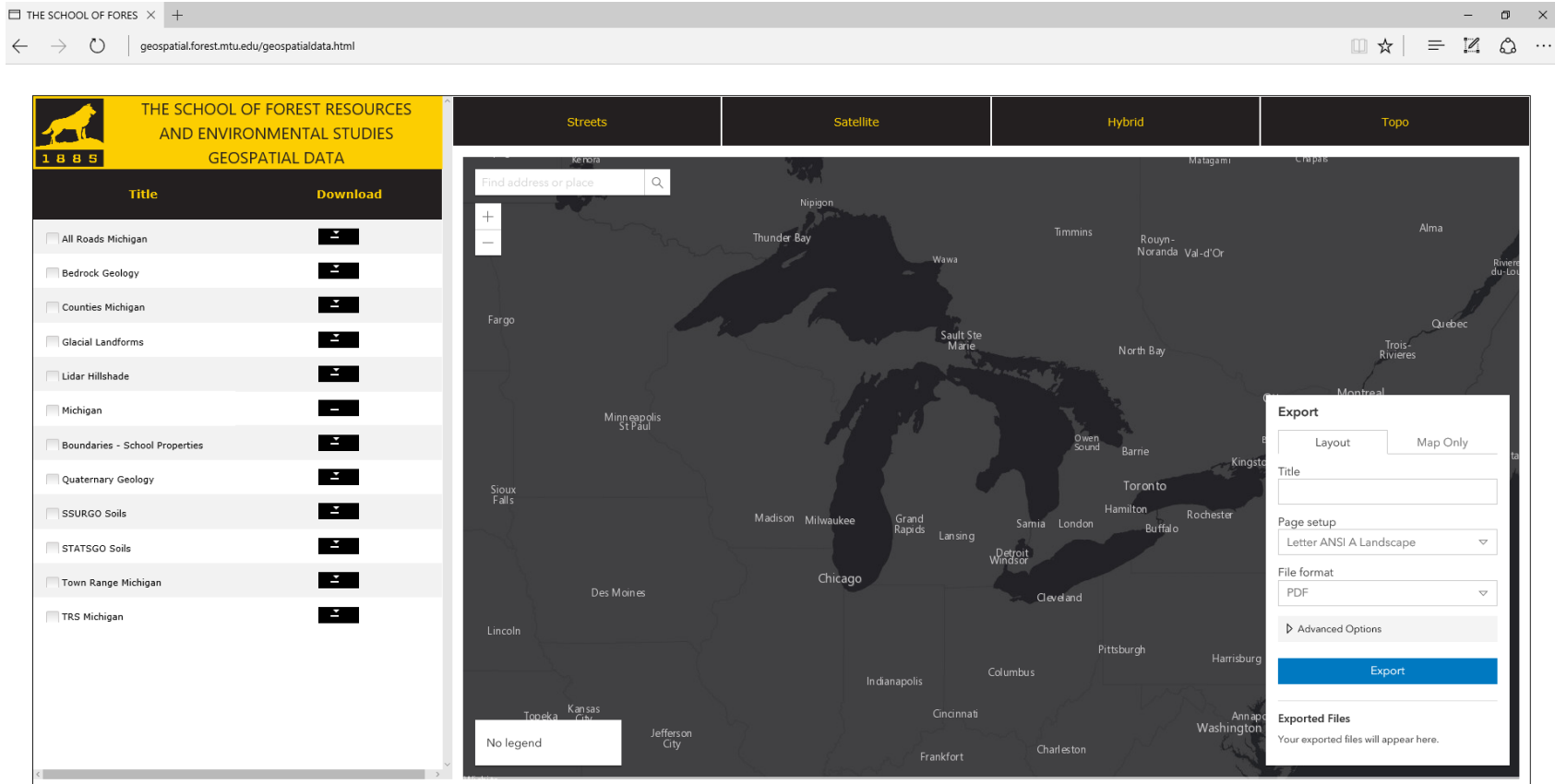
This method for registering an event handler.

```
require([  
    "dojo/on"],  
function( on ) {  
    view.on("click", function(event){  
        map.add(Layer);  
    }); (ESRI, Developers ArcGIS, _dojo 2017)
```



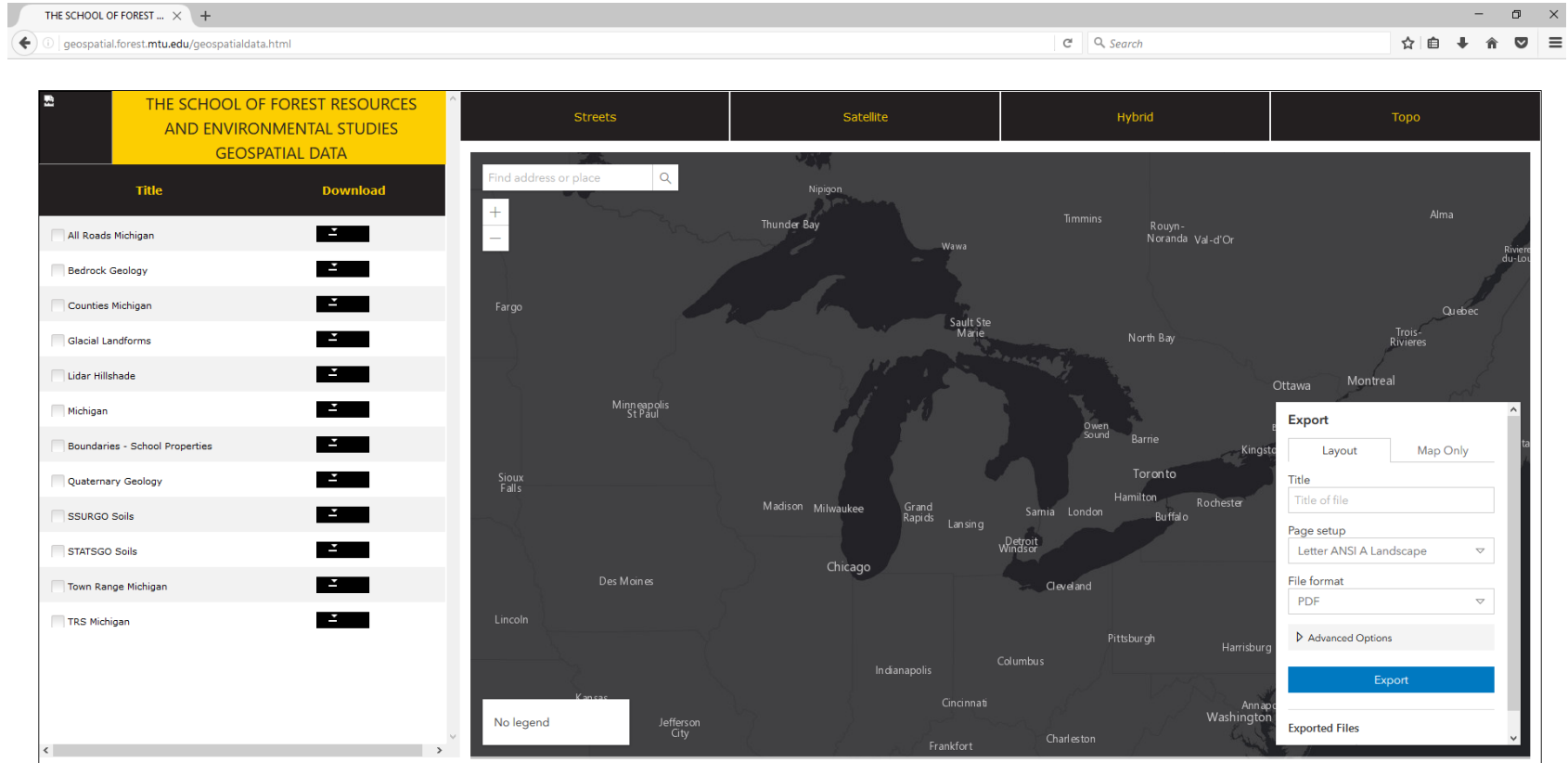
48

Figure 2.12. The application with Google Chrome (Interface of the application created by author).



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Figure 2.13. The application with Internet Explorer (Interface of the application created by author).



50

Figure 2.14. The application with Mozilla (Interface of the application created by author).

➤ **DOM**

DOM stands for Document Object Model and it describes the core Dojo DOM API.

```
require([  
    "dojo/dom"],  
function(dom) {  
    /* code goes here */  
}); (DojoToolkit 2017)
```

➤ **DOMReady**

DOMReady defers the function by DOM is ready (DojoToolkit 2017).

```
require([  
    "dojo/DomReady"],  
function() {  
    /* code goes here */  
}); (DojoToolkit 2017)
```

## **3. Chapter – Results and Discussion**

### **3.1. Introduction**

A diagram of the website sequence in a complex system is displayed in Figure 2.1. Data is presented as an ArcGIS REST service such as Map Server, and Feature Server services to make the data accessible to a web map. Then a website is created by using ArcGIS JavaScript API. This website enables downloading data that are feature classes, and/or raster data, such as slope and aspect. Furthermore, maps in 2D can be displayed and data-driven visualization created. The feature classes displayed on maps and legends are displayed via the legend widget. The scale bar is also shown in the window. The app is programmed to create cartographically correct maps which include a neat line, border, title, scale, legend, credits, place-name, inset, ground and figure.

### **3.2. Web Application**

The overall website displays (Figure 3.1) is separated into two components. The right side contains the map display, and the left side lists the available spatial data for creating the map.

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<input type="checkbox"/> Bedrock Geology	[Download Icon]
<input type="checkbox"/> Counties Michigan	[Download Icon]
<input type="checkbox"/> Glacial Landforms	[Download Icon]
<input type="checkbox"/> Lidar Hillshade	[Download Icon]
<input type="checkbox"/> Michigan	[Download Icon]
<input type="checkbox"/> Boundaries - School Properties	[Download Icon]
<input type="checkbox"/> Quaternary Geology	[Download Icon]
<input type="checkbox"/> SSURGO Soils	[Download Icon]
<input type="checkbox"/> STATSGO Soils	[Download Icon]
<input type="checkbox"/> Town Range Michigan	[Download Icon]
<input type="checkbox"/> TRS Michigan	[Download Icon]

Map Style: Streets | Satellite | Hybrid | Topo

Search: Find address or place

Map Legend: No legend

**Export**

Layout | Map Only

Title: [Title of file]

Page setup: Letter ANSI A Landscape

File format: PDF

Advanced Options

**Export**

Exported Files: Your exported files will appear here.

Figure 3.1. Website overall display (Interface of the application created by author).



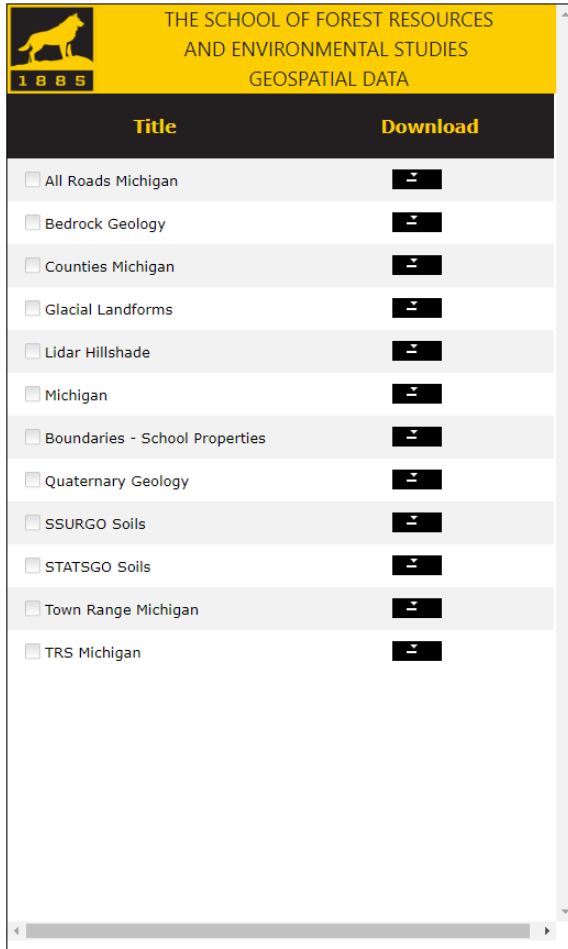


Figure 3.2. SFRES geospatial data tree (Interface of the application created by author).

On the left side of the application, (Figure 3.2), all publically accessible data from the online ArcGIS Server is displayed. When a checkbox is selected, the data displays in the map viewer on the right side of the display. When the download button is clicked (Figure 3.3) the selected data downloads from the server (Figure 3.4).













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Title	Download
<input checked="" type="checkbox"/> All Roads Michigan	
<input type="checkbox"/> Bedrock Geology	
<input type="checkbox"/> Counties Michigan	
<input type="checkbox"/> Glacial Landforms	
<input type="checkbox"/> Lidar Hillshade	
<input type="checkbox"/> Michigan	
<input type="checkbox"/> Boundaries - School Properties	
<input type="checkbox"/> Quaternary Geology	
<input type="checkbox"/> SSURGO Soils	
<input type="checkbox"/> STATSGO Soils	
<input type="checkbox"/> Town Range Michigan	
<input type="checkbox"/> TRS Michigan	

Figure 3.3. SFRES geospatial data tree (checked one) (Interface of the application created by author).

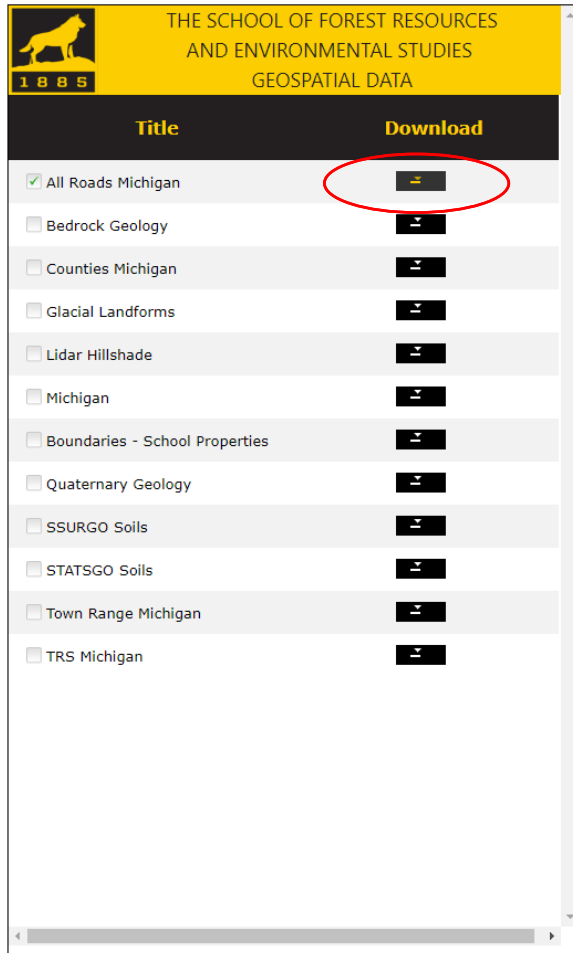


Figure 3.4. SFRES geospatial data tree (downloaded one) (Interface of the application created by author).

The map viewer is capable of displaying four basic map types- Street (Figure 3.5), Satellite (Figure 3.6), Hybrid (Figure 3.7), or Topo (Figure 3.8). The type of base-map is easily changed by clicking on any of the four buttons.

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<input type="checkbox"/> Counties Michigan	[Download]
<input type="checkbox"/> Glacial Landforms	[Download]
<input type="checkbox"/> Lidar Hillshade	[Download]
<input type="checkbox"/> Michigan	[Download]
<input type="checkbox"/> Boundaries - School Properties	[Download]
<input type="checkbox"/> Quaternary Geology	[Download]
<input type="checkbox"/> SSURGO Soils	[Download]
<input type="checkbox"/> STATSGO Soils	[Download]
<input type="checkbox"/> Town Range Michigan	[Download]
<input type="checkbox"/> TRS Michigan	[Download]

Streets | Satellite | Hybrid | Topo

Find address or place

Export

Layout | Map Only

Title

Title of file

Page setup

Letter ANSI A Landscape

File format

PDF

Advanced Options

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Exported Files

Your exported files will appear here.

No legend

Figure 3.5. Website overall display with street map (Interface of the application created by author).

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Streets Satellite Hybrid Topo

Search for place

Title	Download
<input type="checkbox"/> All Roads Michigan	[Download]
<input type="checkbox"/> Bedrock Geology	[Download]
<input type="checkbox"/> Counties Michigan	[Download]
<input type="checkbox"/> Glacial Landforms	[Download]
<input type="checkbox"/> Lidar Hillshade	[Download]
<input type="checkbox"/> Michigan	[Download]
<input type="checkbox"/> Boundaries - School Properties	[Download]
<input type="checkbox"/> Quaternary Geology	[Download]
<input type="checkbox"/> SSURGO Soils	[Download]
<input type="checkbox"/> STATSGO Soils	[Download]
<input type="checkbox"/> Town Range Michigan	[Download]
<input type="checkbox"/> TRS Michigan	[Download]

No legend

**Export**

Layout Map Only

Title  
Title of file

Page setup  
Letter ANSI A Landscape

File format  
PDF

Advanced Options

Export

Exported Files  
Your exported files will appear here.

Figure 3.6. Website overall display with satellite map (Interface of the application created by author).

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Streets Satellite Hybrid Topo

Search for a place

No legend

Title	Download
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<input type="checkbox"/> Bedrock Geology	[Download Icon]
<input type="checkbox"/> Counties Michigan	[Download Icon]
<input type="checkbox"/> Glacial Landforms	[Download Icon]
<input type="checkbox"/> Lidar Hillshade	[Download Icon]
<input type="checkbox"/> Michigan	[Download Icon]
<input type="checkbox"/> Boundaries - School Properties	[Download Icon]
<input type="checkbox"/> Quaternary Geology	[Download Icon]
<input type="checkbox"/> SSURGO Soils	[Download Icon]
<input type="checkbox"/> STATSGO Soils	[Download Icon]
<input type="checkbox"/> Town Range Michigan	[Download Icon]
<input type="checkbox"/> TRS Michigan	[Download Icon]

**Export**

Layout Map Only

Title  
Title of file

Page setup  
Letter ANSI A Landscape

File format  
PDF

Advanced Options

Export

Exported Files  
Your exported files will appear here.

Figure 3.7. Website overall display with hybrid map (Interface of the application created by author).

THE SCHOOL OF FOREST RESOURCES  
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1888 GEOSPATIAL DATA

Streets Satellite Hybrid **Topo**

Find address or place

All Roads Michigan  
 Bedrock Geology  
 Counties Michigan  
 Glacial Landforms  
 Lidar Hillshade  
 Michigan  
 Boundaries - School Properties  
 Quaternary Geology  
 SSURGO Soils  
 STATSGO Soils  
 Town Range Michigan  
 TRS Michigan

No legend

Export

Layout Map Only

Title

Title of file

Page setup

Letter ANSI A Landscape

File format

PDF

Advanced Options

Export

Exported Files

Your exported files will appear here.

Figure 3.8. Website overall display with topo map (Interface of the application created by author).

On Figure 3.9, focusing on the button of the basics maps, it is observed that button color is black and the font color is yellow. When one of the button of the basic maps is selected its' color is changing and it can be realized which one is selected (see Figure 3.10).



Figure 3.9. Basic map types (Interface of the application created by author).



Figure 3.10. Basic map types (chosen streets) (Interface of the application created by author).

There is a search button on left-top side (Figure 3.11), which runs locator service(s) and map/feature service feature layer(s). After selecting or typing a location, the area of interest is displayed.

Below the search button, are the zoom in and zoom out options.

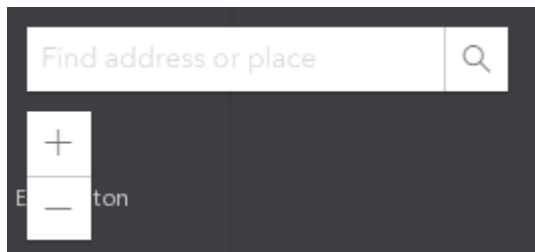


Figure 3.11. Search widget (top), and zoom in and zoom out button (Interface of the application created by author).

The legend widget is found at the left bottom side of the map viewer and it displays the legend information after the selected thematic layers, and downloaded and displayed on the map. The legend may be scrolled up and down if needed to see the information associated with the selected thematic layers.



One of the aims for this project was easily getting a cartographically correct map. As shown on the Figures 3.12, 3.13 and 3.14, the map layout is completed by filling in the desired information. If needed, the map can be easily printed.

**Export**

Layout      Map Only

Title

Title of file

Page setup

Letter ANSI A Landscape

File format

PDF

▶ Advanced Options

**Export**

---

**Exported Files**

Your exported files will appear here.

Figure 3.12. Export – Layout (Interface of the application created by author).

▼ Advanced Options

Set scale

18489297.737236

Author

Copyright

Include legend

**Export**

Figure 3.13. Export - Layout - Advanced Options (Interface of the application created by author).

The image shows a software interface for exporting a map. At the top, there are two tabs: 'Layout' and 'Map Only', with 'Map Only' selected and highlighted by a blue border. Below the tabs, there is a 'File Name' section with a text input field containing the placeholder 'File name'. Underneath is a 'File format' dropdown menu currently set to 'PDF'. The 'Width' is set to '800' and the 'Height' is set to '1100', with a swap icon between the two fields. A checkbox labeled 'Include attribution' is checked. A large blue button labeled 'Export' is positioned below these settings. At the bottom, there is a section titled 'Exported Files' with the text 'Your exported files will appear here.' A vertical scrollbar is visible on the right side of the interface.

Figure 3.14. Export - Map Only (Interface of the application created by author).

On the Export Layout page, a title textbox is available to create the map title. Page size uses the 8 different paper sizes recognized by ESRI.

- Letter ANSI A Landscape
- A3 Landscape
- A3 Portrait
- A4 Landscape
- A4 Portrait
- Letter ANSI A Portrait
- Tabloid ANSI B Landscape
- Tabloid ANSI B Portrait

There are also eight type of export file formats to select from.

- PDF
- PNG32
- PNG8
- JPG
- GIF
- EPS
- SVG
- SVGZ.

In the Advanced Options (Figure 3.13) an option is available to set the scale. There are also Author and Copyright text boxes, which are displayed in the bottom-right of the map view. If the legend checkbox is selected, the legend is included in the exported map.

Clicking the Export button will generate a file with the chosen file format (Figure 3.15).

## Glacial Landform

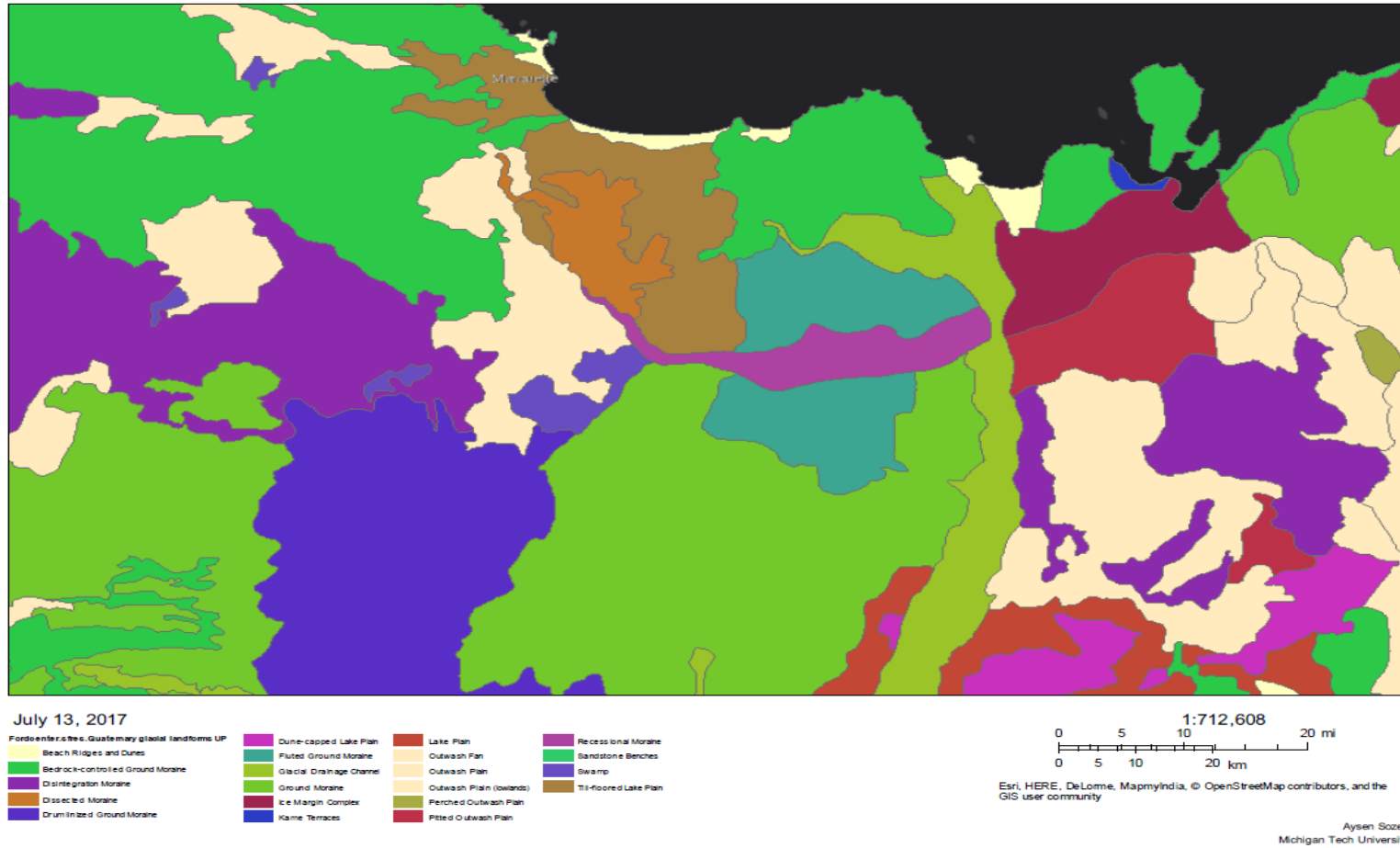


Figure 3.15. Example of a cartographic correct map layout ready to be exported and printed if desired (Displaying an exported map from the application created by author).

For simplicity and quick viewing there is a Map Only option (refer back to Figure 3.14). The file name can be written and there are same file formats used for the annotated map are available. The width and height of map may also be set. After giving a name to the file, choosing file format as a pdf document, setting width and height as default values and checking include attribution check box, the map is exported by clicking the export button (Figure 3.16).

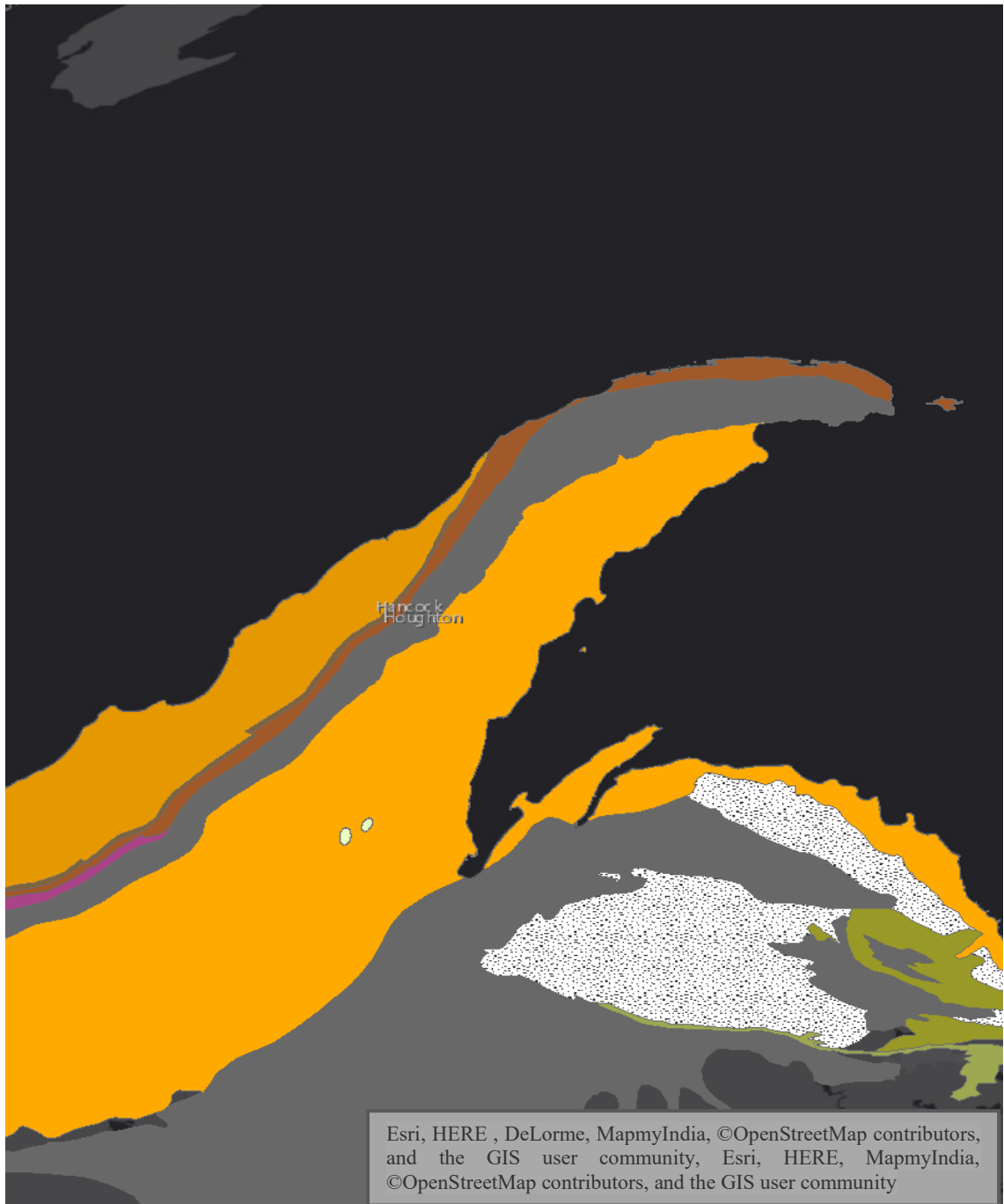


Figure 3.16. An example of map only display (Displaying an exported map from the application created by author).

## **Copyright Permission**

### **Figure 1.1. Architecture of a Single ArcGIS Server Machine & Figure 1.2. Architecture of Multiple ArcGIS Servers in Multiple-Machine**

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### **Figure 2.1. Producing maps with ArcGIS API for JavaScript**

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