Oregon Water Atlas: A Digital Collection and Visualization of Oregon's Water Data

by
Gareth Baldrica-Franklin

A THESIS

submitted to

Oregon State University

Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Earth Sciences
(Honors Scholar)

Presented May 25, 2017
Commencement June 2017

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Gareth Baldrica-Franklin for the degree of Honors Baccalaureate of Science in Earth Sciences presented on May 25, 2017. Title: Oregon Water Atlas: A Digital Collection and Visualization of Oregon's Water Data.

Abstract approved:____

Todd Jarvis

The Oregon Water Atlas is an aggregation and visualization of Oregon's water data. Multiple government agencies (state and federal) maintain geographic data related to Oregon's water, and they exist almost exclusively in GIS (geographic information system) formats. Using GIS processing software in conjunction with web design, a wide array of publicly available data is displayed in an accessible online location. The atlas is intended primarily for a public audience. Sub-topics of the atlas include groundwater, water infrastructure, water use, drinking water, flood history and more.

Key Words: Water, Maps, Cartography, Web Design

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I understand that my project will become part of the permanent collection of Oregon State University, Honors College. My signature below authorizes release of my project to any reader upon request.

Gareth Baldrica-Franklin, Author

Introduction

Few resources can match the significance of water in Oregon. From lush valleys to flowing aquifers, water is not only extensively utilized, but forms a key part of Oregonian identity. As climate change and shifting human populations threaten the stability of hydrologic systems, Oregon's water is in flux. There is a growing movement towards sustainability, however, overuse, pollution, and competing interests have resulted in vulnerable water regimes throughout the state.

State and federal agencies are aware of the importance of water to Oregon's ecological, economic, and aesthetic well-being. Several agencies and organizations collect and create data related to water, and many of these data are publically available. They are also georeferenced, meaning they can be manipulated and displayed in various geographic information systems (GIS). However, the geographic and dispersed nature of water data limits public accessibility. GIS knowledge is largely confined to specialists and GIS professionals, and the data itself is widespread and difficult to aggregate.

Applications exist for the exploration of geographic data in Oregon. The Oregon Spatial Data Library has a relatively extensive collection of Oregon's GIS data, but it is not comprehensive (Oregon Spatial, 2016). *Oregon Explorer*, an online mapping application, gives users the ability to display geographic data for various topics. The application includes several datasets related to water (Oregon Explorer, 2014). Visualizations of Oregon's water data also exist, but are widespread and often lack visual appeal. Mapping applications are hosted on various state agency websites, as well on the *Oregon Explorer* site (Oregon Explorer, 2014).

The Oregon Water Atlas is an aggregation and visualization of Oregon's dispersed water data, designed to communicate with a public audience. It exists online, broadening its accessibility, and is created entirely with open-source software and mapping applications. As an atlas, it attempts to present specific narratives about the topics it covers. While its online nature makes the user experience fundamentally different from that of a paper atlas, the Oregon Water Atlas presents a complete and curated product.

Given the large amount of data and widespread efforts to communicate these data, the Oregon Water Atlas fills a crucial role in providing a single location where users can improve their understanding of Oregon's water.

Waterfalls
Humanitarian/ Hydrophilanthropy
Water Markets
Fisheries
Recreation
- -Wind Surfing
- -Rafting

Invasive Species
Water Treatment
Special Places
- -AOCC = Metolius
- -State Heritage Area = Willamette Falls

Piplines
- -Hillsboro
- -Other Mega Projects
- -Proposed

Bulk Water Transfer
- -Columbia/Willamette

Drougts
- -Agriculture
- -Industrial

Water Usage
- -Ag
- -M&I
- -Map Permit Exempt Wells

Wetlands

Drinking Water
- -Sources
- -Surface
- -GW
- -Protection Areas
- -INR Report on Coastal Systems

Rivers
Water Myths
- -Wallowa Lake Monster
- -Dowsing

Dams
- -History
- -Dams that Leak
- -Dams that Never Held Water

Conflict
- -Klamath
- -Umatilla
- -Deschutes
- -Others
- -Basins at Risk (Oregon)

Lake - PSU
- -Reservoir
- -Drying
- -Algae

Groundwater
- -Arsenic
- -Nitrate (GWMAS)
- -CGWA
- -Aquiger Storage & Recovery
- -Flooding

Bottled Water

AOCC: Area of Critical Concern
M&I: Municipal and Industrial
CGWA: Critical Groundwater Area
GWMA: Groundwater Management Area

Figure 3: List of relevant water-related topics. The list was created at the beginning of the atlas project. Not all topics listed are included in the final atlas.

Background

The Digital Atlas

An atlas is a collection of data or information displayed in graphic form through maps. An atlas usually has a guiding theme, from regions to thematic topics (da Silva Ramos, C., & Cartwright, W., 2006). With the advent of computers and the Internet, the digital atlas emerged. Several definitions of digital atlases exist, reflecting both different interpretations and classifications. The first digital atlas was the 1981 Electronic Atlas of Canada (Jenny et. al., 2012). Other early digital atlases include the *La Francophonie nord-américaine à la carte* and *Mines et minéraux à la carte.* The *Mines et minéraux à la carte* was created as an educational tool in 1990, offering an early insight into the potential of digital atlases as learning tools (Raveneau et al., 1991). Many early digital atlases would be considered static or view-only digital atlases by today's standards, as their use of interactivity was limited (Kraak, 2001).

The expansion and development of the Internet brought digital atlases into a new era of user friendliness and graphics capability. Not only did the Internet allow digital atlases to reach users around the globe, but many creators of Internet-based atlases did so with open-standards, allowing their work to be shared and expanded (da Silva Ramos, C., & Cartwright, W., 2006). In recent years, eBooks for tablet computers have been explored as having potential for the production and publication of digital atlases (Jenny et. al., 2012). However, some eBook formats are limited by proprietary production standards and a lack of cross-platform usability.

Digital atlases are frequently compared to paper atlases. One key difference between the two mediums lies in the way maps are structured (da Silva Ramos, C., & Cartwright, W., 2006). In traditional paper atlases, the linearity of the book form guides users through specific narrative experiences. With digital atlases, users have the choice of viewing different maps in any order, introducing a degree of randomness to the atlas structure (da Silva Ramos, C., & Cartwright, W., 2006). However, Jenny et al. (2012) notes that a digital atlas is still distinct from a GIS-based atlas in the sense that maps in digital atlases are specifically related to one another regardless of viewing order. This means that each user of a digital atlas will have a different experience, but will receive a similar narrative. Another key difference between the two mediums is the function of the map itself. In a paper atlas, each map is a consumable final product, while in a digital atlas, each map is an interface for data exploration and manipulation (da Silva Ramos, C., & Cartwright, W., 2006).

Spatial Data Clearinghouses and the Oregon Spatial Data Library

Spatial Data Clearinghouses (SDCs) are online collections of spatial data, usually managed by a government agency. Benefits of SDCs are primarily in the realm of improving data accessibility and providing a framework for more informed policymaking (Crompvoets et al., 2007). SDCs can be used to address regional or topical goals, and have steadily increased in popularity since the early 2000s (Crompvoets et al., 2004). However, a study by Crompvoets et al. (2017) highlights that SDCs have little impact on environmental decision-making and policy formation.

Table 1. Federal agencies, Oregon state agencies, data clearinghouses and other sources that maintain geographic data used in the Oregon Water Atlas.

Source	**Data Topic(s)**
Oregon Spatial Data Library	flood extent, flood insurance zones, groundwater management areas, drinking water source zones (ground and surface), census blocks, dams, wetlands
Oregon Department of Environmental Quality	drinking water contaminant sources, surface water pollution
Oregon Department of Water Resources	water rights, critical groundwater areas, groundwater limited areas
United States Geological Survey	aquifer geology, Landsat imagery, water use, hydrography
US Army Corps of Engineers	dams
PRISM Climate Group - OSU	precipitation
Data.gov	groundwater recharge
Oregon Department of Fish and Wildlife	fish habitats, fish barriers, hatcheries

The Oregon Spatial Data Library was created in 2009 to meet Oregon's spatial data needs. The Oregon Spatial Data Library (2016) was compared to a series of other statewide SDCs, which provided models for the optimization of its user interface. The Oregon Spatial Data Library is an excellent resource for the acquisition of geographic data related to Oregon; however, it is incomplete, especially when it comes to water. The Oregon Water Resources Department (OWRD), as well as the Oregon Department of Environmental Quality (DEQ), both maintain geographic data that are absent from the Oregon Spatial Data Library (Oregon DEQ, OWRD 2017). It is unclear if these omissions are intentional. **Table 1** highlights data included in the Oregon Water Atlas that were obtained from the Oregon Spatial Data Library, as well as data obtained from other sources.

Current Water Visualizations

The *Oregon Explorer* application is the primary online visualization tool for Oregon's spatial data. The *Explorer* was created in collaboration between Oregon State University Libraries & Press and the Oregon Institute for Natural Resources (Oregon Explorer, 2014). The *Oregon Explorer* maintains a map viewer for various Oregon spatial datasets, and also lists other visualization efforts from state organizations. The *Oregon Explorer* Map Viewer allows users the freedom to examine and manipulate datasets using a variety of GIS tools (query, buffer, etc.) (Oregon Explorer, 2014). The Map Viewer does not provide any narrative context for the data it shows. Thus, it is more similar to an online GIS application than a digital atlas, sacrificing narrative for user freedom (Jenny et al. 2012). In terms of water, there are seven listed topics: Dams, Rivers and Streams, Lakes and Waterbodies, Glaciers, Watersheds, Water Quality, and the Historic

Willamette River Channel. For motivated users, the tools and data options on the Map Viewer allow freedom for overlays and analyses.

Table 2: Listing of online web visualizations related to Oregon's water and their host websites.

Online Visualization Portal	**Website Host**
Oregon Explorer Map Viewer	Oregon Explorer
Oregon Watershed Restoration Tool	Oregon Explorer
Oregon Watershed Restoration Reporter Tool	Oregon Explorer
Oregon Explorer ATLAS	Oregon Explorer
OWEB Investment Tracking Tool	Oregon Explorer
Oregon Rapid Wetland Assessment Protocol Map	Oregon Explorer
Oregon Stream Flow Maps	OR Department of Fish and Wildlife
Protected Areas	OR Department of Fish and Wildlife
Oregon Watershed Councils	OR Watershed Enhancement Board
Water Rights Mapping Tool	OR Water Resources Department
Oregon Water Map Library	OR Water Resources Department
Soil and Water Conservation Districts Interactive Map	OR Department of Agriculture
Oregon Drinking Water Protection Program Map	OR Department of Environmental Quality
National Inventory of Dams Map Viewer	U.S Army Corps of Engineers

For each water related topic, *Oregon Explorer* also provides users with links to other visualizations related to those topics. Some of these visualizations are hosted on other websites (such as the Soil and Water Conservation Districts Interactive Map, hosted by the Oregon Department of Agriculture), while others are hosted on different map portals across the *Oregon Explorer* website (Oregon Watershed Restoration Tool) (Oregon Explorer, 2014). Many of the other visualizations are single-topic web maps. A list of different Oregon water visualizations and their online locations can be found in **Table 2**.

Online mapping applications related to Oregon's water are commonly presented as tools for environmental and land use planning. Visualizations hosted on Oregon state agency websites are typically accompanied by GIS data download options. Many are displayed using GeoCortex (2017) partnered with Environmental Systems Research Institute (Esri) ArcGIS (2017), which can result in long load times. There appears to be little attention to the design and presentation of the data included. Instead, these web mapping applications serve as online GIS platforms that are limited to the data displayed by each site. It is unclear what the relationship is between users who utilize the data portals and those who download the GIS data itself (where available).

One interesting exception to the pattern of GeoCortex (2017) data viewers is the Oregon Water Resources Department Map Library. The library provides a list of various water-related maps, and allows users to download PDFs of these maps. They are all static maps, and cover a wide range of topics and dates. However, similar to the modern online presentations, many of the maps included in the library, especially recent ones, appear to be mere presentations of spatial data, with little attention to cartographic design and representation principles.

Existing Water Atlases

The *Willamette River Basin Atlas* (2002) is a comprehensive collection of maps and figures about the Willamette River Basin. It was conceived as a tool for land use planning (Willamette River Basin Atlas, 2002). The atlas uses its maps to compare different development scenarios within the Willamette Valley and their spatial implications. The print version of the atlas includes a multitude of accessible maps for readers. Most of the maps in the atlas are more functional than beautiful, but the topics and data are portrayed competently (Willamette River Basin Atlas, 2002). Every section of the *Willamette River Basin Atlas* (2002) can be viewed online and downloaded, making it a hybrid print-digital atlas.

The *Atlas of the Columbia River Basin* (2014) was created by Oregon State University students taught by Dr. Bernhard Jenny. The atlas was created as an iBook and is downloadable from the iBooks store (Jenny et al., 2013). Unlike the *Willamette River Basin Atlas*, the *Atlas of the Columbia River Basin* was created as a tool for exploring the potential of iBooks as atlases in a classroom setting (Jenny et al. 2014). As a result, the atlas has a much greater focus on cartographic design and general audiences.

The fully digital *Atlas of Oregon Lakes* (2017), maintained by Portland State University, is a visual catalog of Oregon lakes. There is a map viewer that allows users to select lakes throughout Oregon, and when they do, information about the selected lake displays on the right side of the screen (Oregon Lakes, 2017). Where detailed bathymetric information is available, a bathymetric view of the selected map is also shown. According to the framework provided by Jenny (2006), the *Atlas of Oregon Lakes* (2017) functions as an Atlas Information System, providing users with interactivity in conjunction with a theme or narrative.

Oregon Water Atlas

Atlas Format

The Oregon Water Atlas was initially conceived as a downloadable iBook atlas. Jenny et al. (2014) summarizes the benefits of iBooks as a platform for atlases: iBooks Author is a free program that allows user to easily create and publish iBook atlases to the Apple Store, iBooks run in an independent application, meaning their viewing performance is not dependent on Internet speed, and iBooks simulate many functions of print atlases, such as page turning and a chapter structure. However, the iBook is a proprietary eBook format created by Apple, and it is incompatible with other operating systems.

After some initial data collection and map creation, the Oregon Water Atlas was reconceived as a series of HTML maps, hosted online. HTML maps are an alternative format for digital atlases. Although coding is necessary to create HTML maps, the interactive possibilities are virtually unlimited. Additionally, there are fewer barriers to use. Any computer with Internet access and a web browser is able to view HTML maps. At the same time, the performance of HTML maps is dependent on the Internet speed of the client, which can be extremely variable.

The Oregon Water Atlas is divided into a series of chapters, which can be selected from the atlas. Each chapter represents a different water-related topic (surface water, groundwater, drinking water, water use, etc.), and presents a series of maps in story map format about that topic. Story maps allow users to scroll through a webpage to view different visualizations and narrative information. Maps are displayed on the right side of the screen, while accompanying text is displayed on the left. Despite the fact that users are able to select the chapters in any order, the display within the story map is designed to create a specific user experience for each individual chapter. An example of a story map seen in the atlas is shown in **Figure 2.**

Story maps for the atlas were created using a JavaScript library developed by Dr. Bo Zhao (2017) of Oregon State University in conjunction with Leaflet (Agafonkin, 2017), an open-source JavaScript library for web mapping. The atlas homepage was created using a Bootstrap (2017) template, and is designed to be responsive to changes in browser window size.

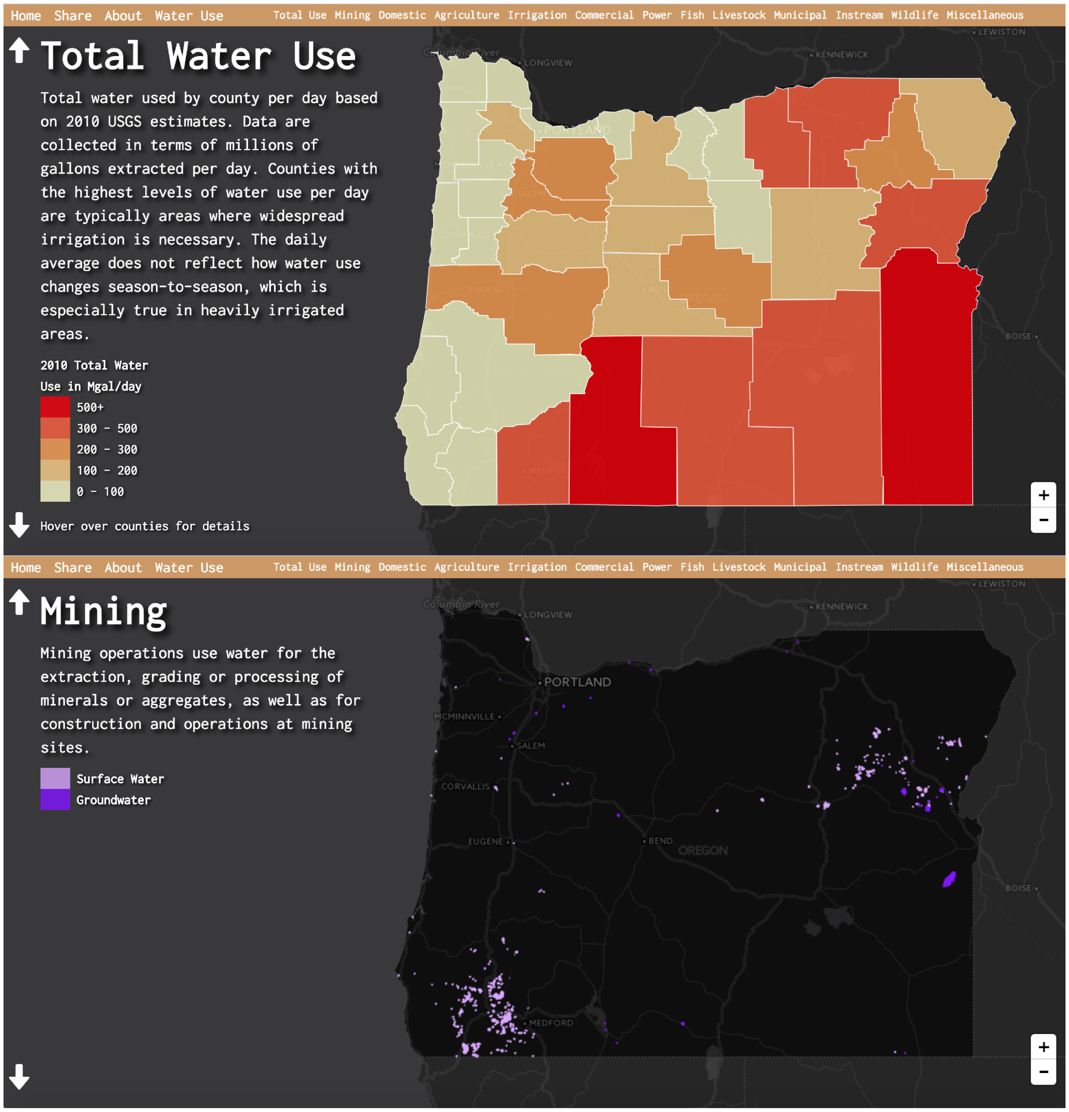

Figure 2: Story map structure. Users can either press the arrows on the left side or scroll up and down to move from one map to another. The column on the left side of each map displays narrative information and the map legend.

The geographic data are served via GeoServer, an online, open-source program (2013). GeoServer creates both Web Mapping Services (WMS) and Web Feature Services (WFS) for each uploaded dataset. WFS layers upload data directly to the client (user computer), and are visualized on the fly. WFS layers can be enabled with interactive, data-driven features. Due to their client-side nature, large WFS layers experience performance issues for users with slow Internet speeds. If interactivity is desired, geometries must be simplified in order to reduce file size. WMS layers upload visualized tiles directly from the server to the client. WMS tile layers have more limited interactivity, but are able to display large datasets faster than WFS layers. The difference between WFS and WMS layers is shown in **Figure 3**.

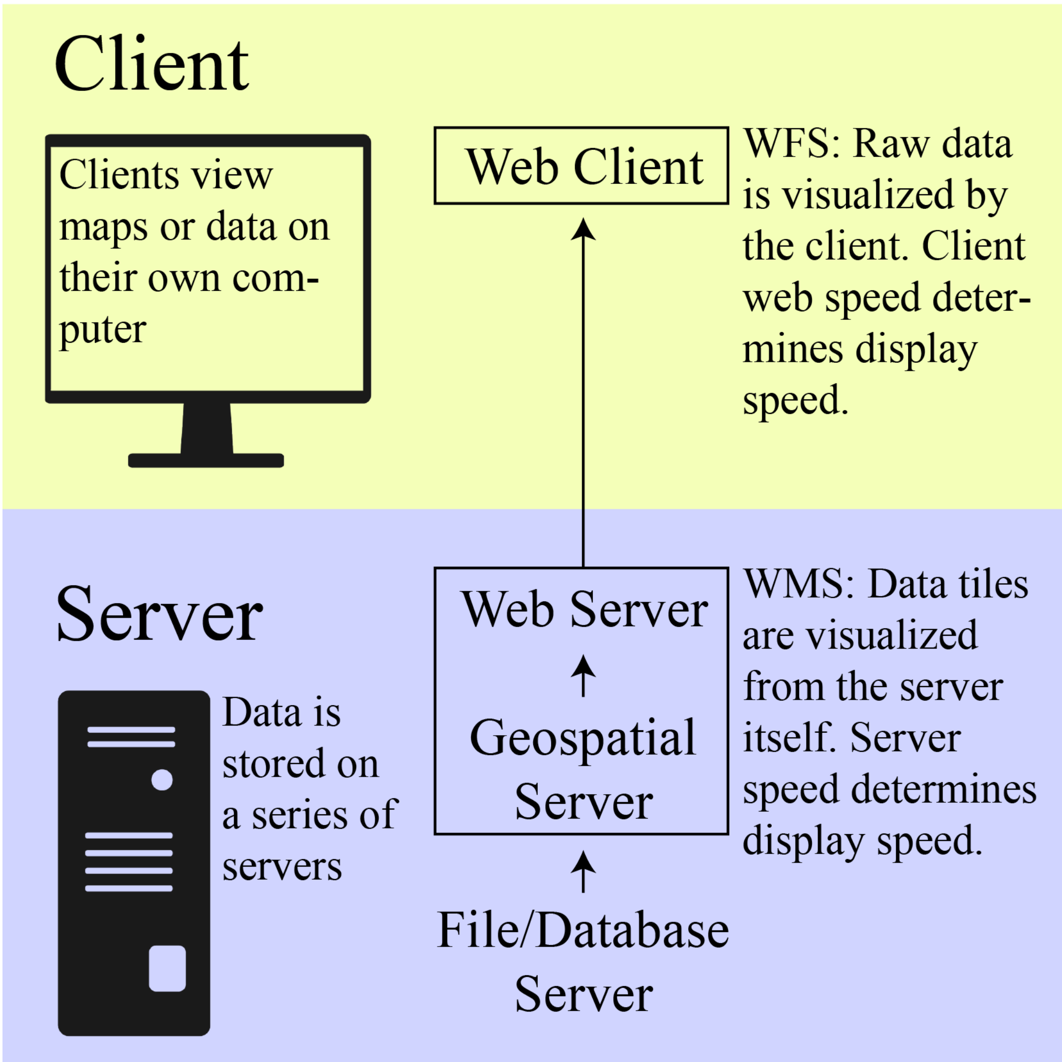

Figure 3: A flowchart of web-mapping architecture that highlights the distinction between WMS and WFS layers.

Sub-Topic Selection

Data about Oregon's water is dispersed but accessible (see **Table 1**). Choosing sub-topics to include in the atlas was based partially on data availability and partially on a list of relevant water-related topics (see **Figure 1**). Topics with available data became the subjects of both general chapters and individual maps. In many cases, multiple maps were created from one topic, and tailored to available data. For example, as a topic, groundwater is quite broad. Geographic datasets about aquifer rock-type and aquifer recharge are available, as well as groundwater use at the county level. These datasets were used to create a series of four maps in the groundwater chapter. For a complete list of chapters and sub-topics, see **Table 3**.

Data Collection and Processing

The workflow of the Oregon Water Atlas was similar to workflows used in the creation of print maps. Data was downloaded from the Internet, GIS software was used for processing, and the HTML map was created. Data were collected from a variety of online sources, and are summarized in **Table 1**.

Much of the data required reprojection into the WGS84 geographic coordinate system, which is used as a baseline for hosting maps on GeoServer (2013). Some datasets required clipping to the extent of Oregon. One goal when processing data for web mapping is limiting the size of datasets. Smaller datasets have faster loading speeds and greater interactive potential. Extraneous attributes were removed from the data, and retained attributes were pared down to essential information.

QGIS (2017), an open-source GIS program, was used for data display and processing. QGIS is workflow compatible with Leaflet and GeoServer (Agafonkin, 2017), and allows users to export Style Layer Definition (SLD) stylesheets, used for styling WMS tiles.

Cartographic Considerations

Individual map and chapter design in the Oregon Water Atlas are nested into multiple categories. Certain design elements, such as font and layout, are consistent across the entire atlas. However, other design elements vary from chapter to chapter, including basemaps, color schemes, and other visuals (pictures, graphs, etc.). The goal was to give each chapter a distinct and memorable visual appeal.

Table 3: Oregon Water Atlas outline, showing chapters, sub-topics in each chapter, basemaps, and color schemes.

Chapter	Sub-Topics/Maps	Basemap	Color Scheme(s)
Precipitation	none	CARTO Dark	Gold/Blue
Surface Water	rivers, watersheds, lakes, watershed councils, wetlands, surface pollution by county	Shaded Relief[1], Rivers & Counties[2]	Blue/Real, Yellow/Orange/Red
Groundwater	aquifers/aquifer recharge, groundwater use by country, Critical Groundwater Areas, Groundwater Management Areas	CARTO Dark	Green/Blue/Tan, Yellow/Orange/Red
Water Use	13 water right categories, total water use by county	CARTO Dark	None
Drinking Water	surface source areas, groundwater source areas, bottled water, contaminants	CARTO Dark	Light Blue/Dark Blue, Green/Yellow/Red
Infrastructure	dams (age, hazard rating), dam density, dam removals, hydropower, bridges	Esri Satellite, CARTO Light Labels, Rivers & Counties[2]	Black/Gray/Beige/Gold, Blue/Pink/Gold, Green/Red/Black
Flooding	1861 flood, Vanport flood, 1964 flood, 1996 flood (January & February), FEMA flood zones	CARTO Light	Maroon
Fish	fish passage barriers, 9 fish species habitats, fish hatcheries	Shaded Relief[1], CARTO Light Labels, Rivers & Counties[2]	Salmon Pink/Teal

[1]Shaded Relief basemap layer created using Pyramid Shader and served using WMS
[2]Rivers & county basemap layer created in Geoserver and served using WMS

There is an online library of basemaps compatible with Leaflet-created (Agafonkin, 2017) maps. For the Oregon Water Atlas, basemaps created by CARTO

(2017) are primarily used. CARTO provides both dark and light basemaps. Other basemaps include Esri satellite imagery and an Oregon shaded relief model created with Pyramid Shader (Jenny, Preppernau, Eynard, 2015). Each chapter has a specific basemap consistent with the surrounding visual elements of that chapter.

There may be one or multiple color schemes in each chapter. Typically, if there are multiple color schemes, two or more distinct sections within a chapter have been identified. Each color scheme is largely reflected in the visualization of the data itself. Some chapters lack a unified color scheme altogether. For example, in the Water Use chapter, each map shows a different water right category, and different colors are used to represent these different categories. **Table 3** shows the visual aspects of each chapter.

Interactivity

Where possible, interactive elements are incorporated into the maps. As mentioned earlier, only WFS layers can be enabled with interactive features. As a result, larger datasets are not interactive. Most of the interactivity is limited to selecting or hovering over map data to receive additional information, primarily feature names. These function as a replacement for labeling, which can easily clutter a web map displayed on a smaller screen. For example, in the Surface Water chapter of the atlas, a map of Oregon river systems enables users to hover over or select individual rivers to display the name of the river. This interactive element is included in many of the individual maps throughout the atlas, and is demonstrated in **Figure 4**. Hand-placed labeling can be costly and time-consuming. Using interactivity as a substitute for labeling can increase the efficiency of map creation.

Where relevant, other information is included when interacting with a feature. On a map showing dam hazard ratings, users can hover over points to reveal both the name of the dam and its height. For aquifer recharge, hovering over features displays the type of aquifer and the modeled amount of recharge it receives. Incorporating supplemental information into interactive features allows a greater density of data to be displayed on a single map.

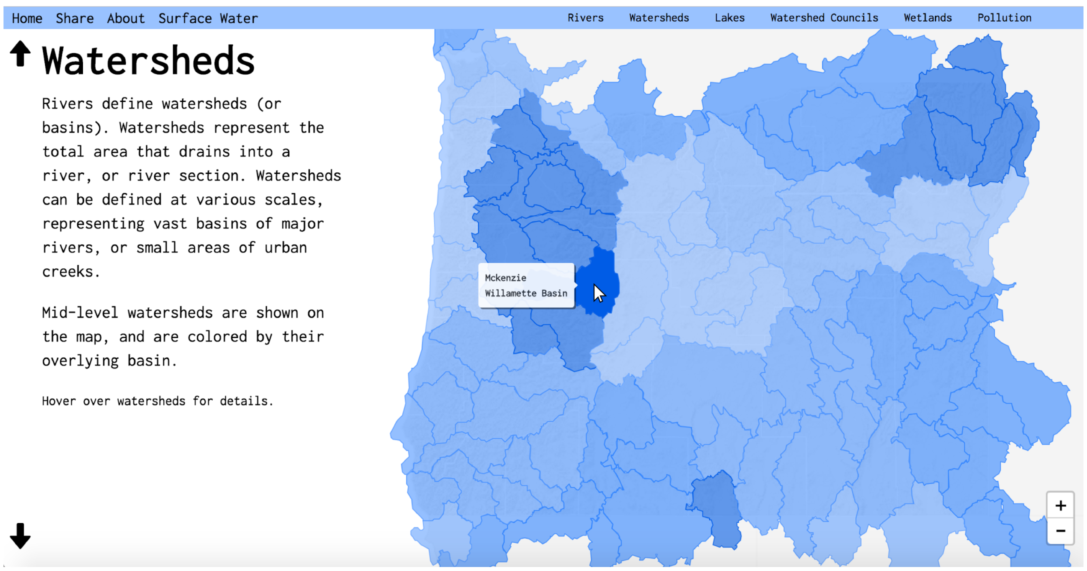

Figure 4: Example of interactivity as a replacement for labeling. The cursor is hovered over the highlighted watershed, which displays the name and nested location of that watershed.

Conclusion

Digital atlases are important media for the dissemination of geographic information. The Oregon Water Atlas is a tool to inform Oregonians about the nature of their water in one easily accessible location. The combination of linear chapters over a non-linear atlas creates a different experience for each user while presenting the same information. It is available for use by anyone with Internet access at oregonwater.info.

The Oregon Water Atlas was created entirely with open-source programs and software, and will continue to be updated. Only some of the relevant water-related topics listed in **Figure 1** were included in the initial version of the atlas, leaving much room for expansion. **Table 4** summarizes topics that could be added in future versions of the atlas. Real-time social media data could also be used to highlight public perceptions of water.

Table 4: Map topics for future versions of the Oregon Water Atlas.

Topic
Drought
Pipelines
Waterfalls
Water Recreation
Pollution
Permit Exempt Wells
Groundwater Pollution
Social Media Data

The workflows used in the creation of the Oregon Water Atlas are easily applicable to the creation of other maps and atlases. To improve the performance of the Oregon Water Atlas, investigating methods of reducing dataset size could be useful to display more complex, interactive, geographic information. Vector tiles offer the potential to display large datasets while retaining interactivity. Currently, the Oregon Water Atlas has limited mobile compatibility. Research is necessary to determine how story maps can be combined with mobile applications. Lastly, performing user studies on the ease-of-use and effectiveness of digital atlases and story maps could highlight areas for improvement in future projects.

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