EXPLORING CLIMATE CHANGE, ECOSYSTEMS AND WELL-BEING CONNECTIONS: LESSONS LEARNED FROM THE APPLICATION OF A GEOSPATIAL KNOWLEDGE EXCHANGE TOOL IN THE NECHAKO WATERSHED

by

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Abstract

The Nechako Watershed is a large system in northern BC that exemplifies the challenge of integrating information across climate, environment and well-being. This research responded to this need with the goal of enhancing how information about the Nechako Watershed is communicated and shared. Informed by the development of a geospatial ‘portal’ tool in northern BC, this research sought to establish the Integrated Watershed Research Group (IWRG) Portal, gain insight on establishing accessible knowledge exchange strategies, and identify its perceived benefits and limitations. The research had two phases. Phase I involved working with a development team to understand this tool, testing, establishing the IWRG Portal, finding and formatting content. Phase II brought members of the Portal User Research Group together to further refine the IWRG Portal and content through scoping discussions, workshops, and a focus group. Thematic analysis was used to code and analyze the transcribed focus group. The research identified benefits of the portal with how it dealt with complexity and its integrative features. Limitations were also found, including the need for intentional framing of data, a steep learning curve, and the need for an internet connection. Analysis also identified the need to tailor content for specific audiences. The research has shown that tools such as the IWRG Portal can create new pathways to understanding and finding information. The research has also identified paths for further refinement and development of the portal tool by expanding the user base and continuing to evaluate the effectiveness of this tool in various contexts.

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List of Acronyms

BC: British Columbia
CWB Index: Community Well-Being Index
GIS: Geospatial Information System
IWRG: Integrated Watershed Research Group
LEO Network: Local Environmental Observer Network
MEA: Millennium Ecosystem Assessment
NEWSS: Nechako Environment and Watershed Stewardship Society
PGIS: Participatory Geospatial Information System
PPGIS: Public Participatory Geospatial Information System
PURG: Portal User Research Group
REB: Research Ethics Board
WMS: Web Map Services

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Chapter One: Introduction

Understanding and being able to communicate the complexities and uncertainties of climate change is extremely difficult (Groot et al., 2015; Picketts et al., 2017; Tàbara et al., 2017). Climate change is a complex, global phenomenon that many organizations and researchers have devoted their time and energy to understanding and communicating. The Intergovernmental Panel on Climate Change (IPCC) has been working internationally since 1988 to guide the world's governments in mitigating, adapting, and planning for a future with a different climate than experienced in the past or present (Pachauri et al., 2015). The IPCC has been effective at synthesizing a large body of science to create reports that present the risks of a changing climate (Sterman, 2011; Tàbara et al., 2017). The IPCC's work exemplifies how communicating climate change information to policy makers, the media, and the global public remains challenging despite the Panel's extensive expertise and long history of synthesis on the topic (Sterman, 2011).

However, presenting the information in an accessible manner has proven to be difficult and dependent on identifying the targeted audience (Gislason et al., 2021). These communication challenges are further exacerbated by the impacts that climate change asserts on global and local ecosystems, and in turn, human well-being (Charron, 2012; Parkes et al., 2010; Watts et al., 2015). Whereas communicating information about climate change, ecosystems, and well-being recorded in the past or present is already difficult, additional challenges arise when discussing how the future may look. Furthermore, a growing body of literature argues for a need to discuss complex topics, such as climate change, in a more localized manner (Groot et al., 2015; Ring, 2015; Tàbara et al., 2017).

To address these converging communication challenges in a way that responds to local needs, this research is focused on the climate, ecosystem and well-being interactions in Nechako Watershed. In response to the increasingly uncertain future of the Nechako Watershed, researchers have been studying approaches to better understand what is occurring in the region, and how to respond to changes in the environment (Integrated Watershed Research Group, 2021). The Nechako Watershed, part of the Fraser River Basin, forms a large system in central British Columbia (BC) (Albers et al., 2016; French & Chambers, 1997; Hartman, 1996; Macdonald, 2007; Picketts et al., 2017). Amplified climate change in the Nechako Watershed, relative to more southern regions in the province, provides a unique research opportunity (Picketts et al., 2017).

Watershed scale approaches are an emerging means of framing ecosystems for research and planning purposes, in part due to the holistic scope that watershed scale and related watershed management provides (Jenkins et al., 2018). Watershed approaches often include considerations accounting for land use, human activity, non-human activity, and the combined impacts these have on land and water, as well as communities and health (Parkes et al., 2010). Informed by these potentials, this study focuses on the Nechako watershed as a context to address the complex challenge of communicating climate change, ecosystem and well-being connections.

1.1 Study Rationale

The University of Northern British Columbia's (UNBC) main campus in Prince George resides alongside the boundary of the Nechako Watershed. The university has a long history of collaborations and partnerships throughout the Nechako Watershed. Much of this research falls under the umbrella of the UNBC Integrated Watershed Research Group (IWRG). The range of interdisciplinary research focused on the Nechako is exemplified by the scope of publications by IWRG team members (e.g. Gateuille et al., 2019; Islam et al., 2019; Owens et al., 2019; Picketts et al., 2020; Sharma & Dery, 2015). The IWRG research in the Nechako comprises three main themes: 1) Climate Change and Water Security; 2) Sediment Sources and Dynamics; and 3) Tools for Integration in Watershed Management and Governance. This third theme explores tools that support management and governance to "create a web-based tool that can provide a single point of access to information that is relevant to the Nechako River Basin" (Integrated Watershed Research Group, 2021). A key component of this research theme is the use of the IWRG Portal, which is software developed as a web portal that has been created by Scott Emmons and his team, in partnership with the UNBC GIS lab and UNBC researchers. The current Portal is the result of over ten years of development of previous versions that have been used and guided by First Nations communities throughout British Columbia (BC). This Portal is a geospatially enabled database that allows users to upload and share a diverse range of data. The Portal can be thought of as a spatially enabled library that provides a unique web-GIS experience. Since 2014, the IWRG Theme 3 research team has partnered with the Nechako Environment and Watershed Stewardship Society (NEWSS), the Cheslatta Carrier Nation and more recently School District 91, to explore using the Portal to support their goals (Integrated Watershed Research Group, 2021).

Interactions across IWRG research themes in the Nechako have identified a need to improve knowledge exchange to reflect the nexus of climate, ecosystems, and well-being issues in the Nechako Watershed (e.g. Picketts et al., 2017). During the development of this study, participation in lectures, presentations, and informal conversations related to the Nechako and the IWRG research reinforced a willingness among different researchers and research partners working in the Nechako Watershed to exchange information about topics such as climate change. There was also a growing interest in making connections across various groups, organizations, and individuals spanning UNBC, the IWRG, School District 91, the Nechako Watershed Roundtable, the municipality of the District of Vanderhoof, and the Cheslatta Carrier Nation, among others. Some examples of this interest has been published (e.g. Picketts et al. 2017, 2020).

These converging interests have created the rationale for research that explores new opportunities for climate change communication strategies within the Nechako Watershed, with a particular focus on the role that the IWRG Portal can play as a tool to support the exchange of information. This research therefore combines a focus on climate change communication with a need for further research on the potential for web-platforms including web portals to facilitate knowledge exchange processes (Cvitanovic et al., 2015).

1.2 Research Questions and Specific Objectives

The goal of this study is to collaborate with researchers to develop a knowledge exchange approach that enhances discussions on the interrelationship of climate change, ecosystems, and well-being in the Nechako Watershed. This knowledge exchange approach will use the Portal as a geospatially enabled communication tool. The research explores the following three research questions:

> ***Research Question 1****: How can complex systems such as climate change, ecosystems and well-being be better understood through the use of a map centric web-portal that connects and aligns different sources of information (based on geospatial attributes)? (RQ1)*

Research Question 2*: What are the perceptions of knowledge 'users' about the utility of the web-portal as a tool to communicate the links between climate, ecosystems and well-being? (RQ2)*

Research Question 3*: How can existing data about climate change, ecosystems, and well-being be leveraged in a way that fuels conversation, new perspectives and awareness of connections? (RQ3)*

To answer these research questions, the specific objectives of the research are to:

1. develop a knowledge exchange approach that will enhance discussions and sharing of information about climate change, ecosystems, and well-being in the Nechako Watershed, through the use of a map centric web-portal.
2. apply this knowledge exchange approach within the context of the Portal to iteratively evaluate and refine strategies for presenting and sharing data within the Nechako Watershed.
3. critically examine the strengths and weaknesses of fostering discussions of climate change, ecosystems and well-being at the watershed scale.

These research questions will be answered and research objectives addressed through a qualitative research design focused in the Nechako watershed. This study context is introduced here, and the research design is described further in Chapter 3.

1.3 Study Context

The Nechako watershed is one of the largest in BC and, at approximately 47,200 km^2, which is the second most expansive tributary watershed draining to the Fraser River Basin (Déry et al., 2012). The size of the Nechako can be appreciated when considering that it is over 1.5 times the size of Vancouver Island (which has an area of 31,285 km^2). The headwaters of the watershed lie in the Coast Mountains and the main stem is the Nechako River, which flows into the Fraser River, within the boundaries of the City of Prince George (Picketts et al., 2017). The Nechako Watershed has approximately 100,000 residents (Fraser Basin Council, 2016), with 86,622 people living in the City of Prince George (Statistics Canada, 2017). There are many smaller communities dispersed throughout the watershed, including (listed in from largest to smallest population) population, as follows: Vanderhoof, Burns Lake, Fort St. James and Fraser Lake (Picketts et al., 2017). These communities are depicted in Figure 1.

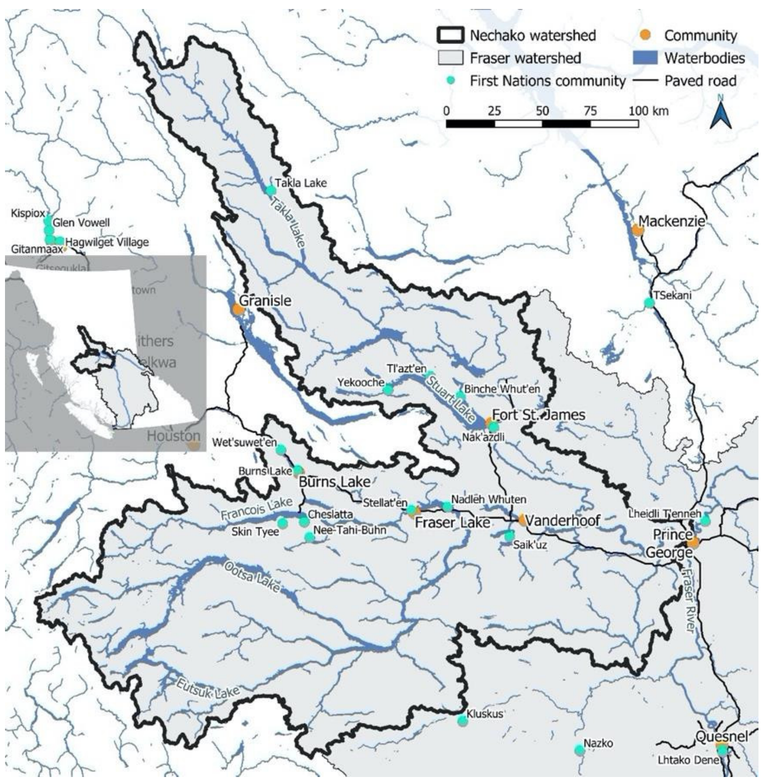

Figure 1. Map of the Nechako Watershed, showing human communities and main water bodies throughout the Stuart-Nechako system. Map created by Aita Bezzola.

The Nechako Watershed also overlaps with the traditional and unceded territories, Indian reserve-lands and Band Council office locations of 15 First Nations, including those around the Nechako mainstem (Cheslatta Carrier Nation, Lake Babine Nation, Wet'suwet'en First Nation, Nee-Tahi-Buhn Indian Band, Ts'il Kaz Koh [Burns Lake] Band, Stellat'en, Nadleh-Whut'en, Saik'uz, Lheidli T'enneh) and within the Stuart Takla system (Binche Whut'en, Nak'azdli Whut'en, Skin Tyee Band, Takla Lake, Tl'azt'en, and Yekooche First Nation) (Picketts et al., 2017).

The Nechako River has been regulated by the Kenney Dam and Skins Lake Spillway since 1952. This has impacted the annual streamflow rates (Déry et al., 2012). The development of the Kenney Dam also forced the Cheslatta Carrier Nation off of their traditional territory due to flooding (Hartman, 1996). The impacts of climate change, in conjunction with other human activity, such as damming, are clearly visible throughout the watershed. A notable example is the negative impacts on salmon populations, largely as a result of altered streamflow levels and increasing water temperatures (Déry et al., 2012; Islam et al., 2019). The watershed's forest and timber supply is being altered drastically by mountain pine beetle (*Dendroctonus ponderosae)* as well (Picketts et al., 2017).

Some initial studies on stakeholders' concerns for the future have been conducted throughout the Nechako Watershed, looking at integrating watershed framings of local environmental phenomena (Matthews et al., 2015; Picketts et al., 2020). Ongoing research in the Nechako Watershed identifies a need for "geospatial watershed portal tools capable of integrating diverse forms of spatially related data, documents, audio-visual materials across health, social and ecological realms within watersheds" (Parkes, 2016, p. 127). In response to these needs, the IWRG team, especially Theme 3 lead researcher Margot Parkes, has worked closely with Scott Emmons to establish an IWRG Portal. This IWRG Portal is designed to be a database that incorporates the aspects noted above by Parkes (2016), while also being a tool for stakeholders throughout the Nechako Watershed that can foster engagement and conversation (Tools for Integration in Watershed Management and Governance, 2021).

1.4 Positionality

Positionality is a reflective process of declaring “our own philosophical, theoretical, and political dispositions” (Hay, 2016, p. 127). This can be done by locating oneself in the context of the project, and explaining life experiences that have led to the research. While this can be difficult it is argued that acknowledging positionality can increase research rigour and objectivity (Hay, 2016). While potentially controversial in some disciplinary traditions, one way researchers can explicitly locate themselves in their research is to reject the common practice of writing in third person narrative, and to make use of personal pronouns (Hay, 2016). In this thesis I have chosen to introduce myself in this section and, where relevant, to use the first person in relation to my role and position as a researcher.

This section on my positionality therefore introduces the readers to some of my own background and relates them to my way of interpreting the world. I grew up in the Maritimes, and spent the vast majority of my life living in Nova Scotia, which is the unceded territory of the Mi’kmaq. I have two previous degrees, both of which are Bachelors of Arts. One degree is a double major in English and philosophy from the University of New Brunswick, and the most recent one is in environmental studies from Mount Allison University. The English aspect of my first degree had a strong focus on studying literature from Chaucer to the Victorian era, while the philosophy focus was split between the philosophy of science and environmental philosophy. A large portion of my environmental studies degree was dedicated to GIS and learning how to perform spatial analysis. It was during my time studying environmental studies that I became a proponent for experiential learning, thinking about my surroundings at a watershed scale, and truly began to realize the importance of people who could be classified as generalists, or as I like to say, 'a jack of all (or many) trades.' I began to see GIS work and analysis as a great position from which to draw from the array of experts around me and to respond to complex questions and challenges. UNBC drew my interest for three main reasons. The first reason being the interesting research being conducted by the IWRG team as a whole, and the challenge of taking on this particular project as it was presented to me by Dr. Margot Parkes and Dr. Stephen Déry. The second was the allure of a smaller campus at UNBC, similar in size to Mount Allison University, which had provided me with many positive experiences as a direct result. The third reason to come to UNBC was a previous visit to Western Canada for a field course. During this course, I realized it would be beneficial to spend some time away from home to hopefully gain new perspectives and exposure to new things and opportunities.

During my stay at UNBC I was fortunate to spend time and work within the traditional territories of many First Nations, including the Cheslatta Carrier Nation, Lake Babine Nation, Lheidli T'enneh, Nee-Tahi-Buhn Indian Band, Skin Tyee Band and Yekooche First Nation, and other nations in the wider Dakelh or Carrier speaking nations (Reconciliation, 2021). After having spent two years undertaking research based at the UNBC Prince George campus, I have moved back to Nova Scotia and am working full-time in New Brunswick as a GIS specialist.

1.5 Thesis Roadmap

This thesis is the outcome of the research conducted during my Master's degree. It commences in Chapter One with an introduction that presents the rationale for the research, guiding questions and objectives and also introduces BC's Nechako Watershed as the study context for this research. The literature review, Chapter Two, comprises two sections: concepts and applied processes. The big picture concepts and theories guiding this research are examined in relation to climate change communication, watershed scale approaches, and ecosystem services and well-being. The applied processes section of the literature review details the theories that focused on processes such as knowledge exchange, and the use of geospatial tools and web-based tools. Chapter Three describes the methodologies that influence this work, the two phased design of the research, the various methods used, and ethical considerations. Chapter Four is presented in two main sections that look at the findings for both phases. Chapter Five provides a discussion of the findings, how they relate or do not relate to the literature, and concludes this thesis.

Chapter Two: Literature Review

This literature review presents the main concept and processes that, in combination, provide the backdrop to and impetus for this research. The chapter commences with a focus on concepts and literature spanning climate change communication, watershed scale approaches, and ecosystem services and well-being, prior to a section focused on applied processes and practices relating to knowledge exchange, and the use of web-based geospatial tools. The knowledge exchange and climate change communication sections draw from academic literature and complementary sources are used to provide brief review of useful web-based geospatial tools relevant to this research. Since no academic papers and publications have been published on the web-based Portal tool used in this research, communication with the developers of the Portal have assisted in the section relating to the portal, making this thesis one of the first publications that describes the form and function of this Stewardship Portal. The literature review chapter does not focus specifically on methodological influences such as pragmatism and ecohealth, which are addressed in the methodology section of Chapter Three. This literature review was conducted from September 2016 to May of 2018, but some literature that has been found and published beyond the completion of this literature review is referred to in Chapters One and Five.

2.1 Concepts

This section explores key concepts that this research draws on. While the argument could be made that each of these fields (climate change communication, watershed scale approaches, and ecosystem services and well-being) has applied components, they are more closely aligned with the theory and concepts supporting this research. For example, watershed scale approaches to research can provide a context to anchor issues in a particular place and develop management practices that pertain to the specifics of that watershed (Parkes et al., 2010). There is an obvious applied nature to establishing and conducting management policies but the emphasis in this section is on the theory and reasoning determining when watershed scale approaches are beneficial and/or necessary.

2.1.1 Climate Change Communication

Climate change is the change in the climatic patterns and norms that can be measured over long periods of time. For example, thirty-year periods are a common timeframe used by the World Meteorological Organization when calculating climate (Bates et al., 2008). Climate change communication can be thought of as being both a theoretical concept and an applied process. The emphasis here is on the conceptual considerations relevant to climate change communication strategies that provide a series of steps to link watershed scale approaches and ecosystem services and well-being, while also complementing knowledge exchange processes. There are also obvious overlaps between climate change communication and knowledge exchange, recognising that communicating about climate change can be very unidirectional, and does not always focus on processes for knowledge exchange explored later. Even so, many of the researchers whose work is introduced in this section do mention the need for a true exchange or conversation between knowledge ‘producers’ and ‘users’ (Groot et al., 2015; Picketts et al., 2012, 2017; Tàbara et al., 2017), meaning that experience and advice from this literature also has direct relevance for knowledge exchange.

A starting point for this section on climate change communication is an examination of Ring’s (2015) approach for delivering in-person presentations. Ring developed an approach with four principles: 1) start by identifying a target audience; 2) balance the content and tone of the presented information; 3) focus on the present situation; and 4) attempt to tell or create narratives. While recommended for giving in-person presentations and talks, these general concepts can be applied to other types of presentations and approaches to climate change communication. The first step in Ring's (2015) approach is to identify the target audience, or the people you wish to communicate with. By identifying a target audience, it is then possible to better adapt materials for this audience's specific spheres of knowledge (Ring, 2015). Ring (2015) also suggests making a personal connection with the audience, in the form of an introduction, where you also make a point of stating common ground between yourself (the presenter), and the audience.

Ring's emphasis on a specific target audience also aligns with the value situating climate change issues in a specific place. Global and regional scales can be difficult to relate to in terms of what individuals experience in their daily lives, and also may not reflect the local situation (Tàbara et al., 2017). The impacts of climate change are not uniform, and some areas, such as the Nechako Watershed, are experiencing amplified rates of change than other regions (Picketts et al., 2017). Bringing climate change information to a scale that reflects the experience of the audience helps to create a connection between people, place, and the associated challenges and opportunities (Ring, 2015).

Another important benefit from establishing a specific audience is the opportunity to craft the wording or language of the content to better reflect the audience's language. If the audience is not a scientific one, the language of 'experts,' or scientific language, can depersonalize the content (Ring, 2015), and make it difficult for audiences to connect with and interpret the material. This is not about 'dumbing' down information; rather, it is about valuing and accounting for the diverse backgrounds of different people (Gislason et al., 2021). Technical reports and policy briefs, such as those coming from the IPCC, can be difficult to understand (Sterman, 2011; Tàbara et al., 2017), which has often limited their use to academics and policy makers (Tàbara et al., 2017). Even amongst academics, the language can be drastically different between disciplines, and potentially even more confusing when these different disciplines use the same terms to mean different things (Groot et al., 2015). It has also been established that there is a generally low degree of scientific literacy throughout the public of the United States and other nations (Sterman, 2011), which makes it even less appropriate to default to scientific communication styles. Targeting specific audiences in a place and time provides the opportunity to craft more accessible materials.

After establishing a target audience, Ring (2015) suggests balancing the content by focusing on solutions and not relying on just emotional or intellectual content. Ring (2015) provides three key approaches to balancing climate change information that can improve the communication strategy. The first consideration is to focus presentations on local solutions. The second is to highlight the most important risks that are posed by climate change and acknowledging different types of presentation bias. The final consideration is to appeal to both the intellectual and emotional aspects of climate change.

An important step in finding a balance to emotional and intellectual content is to acknowledge the emotions caused by discussing topics such as climate change, and to focus on positives such as solutions and specific actions the audience can take (Ring, 2015). This focus on solutions and producing action is reverberated throughout the literature. Tabara et al. (2017) also suggest that promoting knowledge at the local scale helps to focus on solution-based communication, and to avoid spending too much time highlighting the negatives. In addition to Tabara et al.'s balanced and solutions-focused approach, Sterman (2011) suggests communicating the most important risks as well as the different types of presentation bias that exist. Some of the biases Sterman (2011) emphasizes as important to be aware of include: violating the rules of probability, overconfidence, wishful thinking, illusion of control, framing, and anchoring (Sterman, 2011). Focusing on the most important or pressing risks may be a good approach to finding balance in how material is presented, as the important information can be presented and then potential solutions or action(s) can be addressed.

Ring (2015) suggests that there is a need for balancing material and whether it draws on emotional or intellectual perspectives because of how the human brain reacts to both emotional and intellectual stimuli. Emotional or experiential processing is "centered in the amygdala, is emotional, visual, rapid, intuitive, automatic, and based on past experiences" (Ring, 2015, p. 412). Analytic processing is located in the "anterior cingulate cortex, is intellectual, abstract, rational, and deliberative" (Ring, 2015, p. 412). Ring also points out that survival responses are often handled by experiential processing and explains why scientific content may fail to get public support and action (Ring, 2015). So how can information about climate change be presented in a balanced fashion? One approach is to focus on the current situation, while anchoring this to the place of the target audience (Ring, 2015). In the context of the Nechako Watershed, Picketts et al. (2017) found that participants in their study felt more comfortable discussing climate change implications situated in the present, and had more difficulty when looking to the future.

2.1.2 Watershed Scale

In a commentary on optimism versus hope, Knight (2017) proposes that "if watershed after watershed is made healthier, if the human communities living in these watersheds prosper, might not Earth itself over time be made healthier?" (p. 1398) As explored in the

Climate Change Communication section, there is a desire to downscale the way we address climate change to a more local scale. Using a watershed scale approach has the potential to link people living in a watershed to climate change, the ecosystem services they rely on, and their general health and well-being.

A common starting point to define a watershed is an area of land that is drained by a stream or river (Benke & Cushing, 2005). The term watershed is used often in North America, while other synonyms commonly used are drainage basin and catchment (Benke & Cushing, 2005). Another way to think about a watershed is, as areas where rain or water flows under the force gravity towards a watercourse (Ison et al., 2007). Moving beyond these standard definitions that pertain only to their hydrological aspects, watersheds provide a useful "geographical unit for where water concentrates along with solar energy, nutrients and soil, and where functions of water purification, nutrient recycling, waste decomposition and flood and drought resilience are performed" (Parkes & Horwitz, 2009, p. 96). By expanding on our understanding of what a watershed is beyond its hydrological definition, the complexity of watershed scales and the range of interactions becomes more important.

While the actual size and spatial extent of watersheds is highly variable, they are often considered to be small enough to be more manageable than a nation. Watersheds can be thought of as being a mesoscale feature (Parkes & Horwitz, 2009) that typically provides good examples of a geographic boundary that intersects and contains various other boundaries. For example, watershed boundaries can be used to delineate ecosystem boundaries (Parkes & Horwitz, 2009). Watersheds not only delineate geographic areas of drainage patterns, but also often intersect with jurisdictional boundaries created by society (Ison et al., 2007; Morrison et al., 2017; Parkes, 2016; Parkes & Horwitz, 2009), such as local municipal governments, health authorities, school districts, provincial governments, and even federal governments. In addition, watersheds do not exist in seclusion, and instead are impacted by upstream and downstream dynamics (Morrison et al., 2017).

There is a developing field of research and action that uses watersheds as spatial units within which to better understand the connection between land and water, but also ecosystems and human health (Jenkins et al., 2018). Jenkins et al. (2018) found that increases in upstream tree cover had effects similar to improved engineered sanitation infrastructure. Parkes et al. (2010) present a heuristic tool, 'The Watershed Governance Prism,' which aids the understanding of the relationships and interconnectedness between watersheds, ecosystems, social systems, and health and well-being (Parkes et al., 2010). They also state that "[w]atersheds provide an ideal context to design integrated governance that addresses health, environmental and socio-economic proprieties" (Parkes et al., 2010, p. 694). This is also in keeping with themes introduced in the Millennium Ecosystem Assessment that made connections between watersheds, ecosystems, and human well-being (Millennium Ecosystem Assessment, 2005). The Millennium Ecosystem Assessment's adaptive mosaic scenario is considered to be a more desirable future, in which watershed scale ecosystems are the focus of government and economics. This scenario may have potential to provide greater diversity of culture, health benefits, better development of networks among communities, regions, and entire nations, all based on a heightened sense of place (Morrison et al., 2017; Parkes & Horwitz, 2009).

Echoing back to the themes of Climate Change Communication (Section 2.1.1), is the common theme of locating research and action in a particular place. This place-based focus is also effective in public health initiatives (Morrison et al., 2017). Thinking about and acting on complicated topics such as climate change, ecosystems and well-being at the watershed scale is perceived as more manageable. Conservation students are challenged to solve global problems, but find some ease in solving problems for a single watershed at a time (Knight, 2007). The connections between watershed scale approaches in research and ecosystem services and well-being are a result of the complex and dynamic nature of watersheds.

2.1.3 Ecosystem Services and Well-being

Influenced by the impacts of climate change, and compounded by human actions, there is a need to think, plan and act at various scales. Watershed scales are one of the approaches being researched and implemented when trying to solve the complex issues resulting from climate change. This is due to the places people live, work, and play having an impact on their health (Horwitz & Parkes, 2016), or the environment and ecosystems that people are a part of are a contributing factor to their overall health and well-being. Ecosystems and ecosystem services, and their relation to health and well-being will be explored in this section, also acknowledging their complex relationship with climate change. This includes consideration of ecosystems and the services they provide, the links with human well-being, discussion about how ecosystem services are valued, and the implications for how research is conducted, as expressed by the emerging field of ecohealth.

While the Millennium Ecosystem Assessment (MEA, 2005) was not the first to define ecosystems, ecosystem services and health, the MEA definitions have guided how many researchers think about these concepts. This assessment document defines ecosystems as being "dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit" (Millennium Ecosystem Assessment, 2005, p. V). The same report explicitly states that humans are imbedded and important parts of ecosystems when discussing the connection between ecosystems and human well-being

(Millennium Ecosystem Assessment, 2005), which is a sentiment expressed by many others (Charron, 2012; Waltner-Toews et al., 2003).

While people may think of humans as being outside of ecosystems, or their surrounding ecosystems as being a part of nature that they are separate from, it is important to recognize that ecosystems provide services and goods that humans and other living creatures depend on. These goods and services are defined as ecosystem services, and have been subdivided as follows: provisioning services, regulating services, cultural services, and supporting services (Millennium Ecosystem Assessment, 2005; Oosterbroek et al., 2016).

Provisioning services are things like providing food, water, and timber (Millennium Ecosystem Assessment, 2005; Oosterbroek et al., 2016). Regulating services provide a comfortable and stable environment such as: air and water purification, climate stabilization, protection from natural hazards such as wildfires, floods, etc., and regulation of the spread of infectious diseases (Oosterbroek et al., 2016). Cultural services from ecosystems are recreational opportunities such as swimming in a lake or hiking through a forest, as well as the aesthetic benefits (Millennium Ecosystem Assessment, 2005). Much art depicts ‘natural beauty,’ and quite often good scenery is considered to be mountains, forests, fields, or water. These cultural services also include the spiritual benefits that form many religions and worldviews (Millennium Ecosystem Assessment, 2005). The last type of ecosystem service is supporting services, which often are less direct in providing an end product or service to humans and other living organisms, but include important processes such as photosynthesis, soil formation, and nutrient cycling, which provide many of the key cycles that are the foundation for life on Earth (Millennium Ecosystem Assessment, 2005). There is a growing understanding that ecosystem services have a direct impact on the health and well-being of people (Horwitz & Parkes, 2016), which makes it important to define what is meant by the terms health and well-being.

Oosterbroek et al. (2016) integrates the World Health Organization and Millennium Ecosystem Assessment definitions of health together as, "a state of complete physical, mental and social well-being not merely the absence of disease or infirmity… [t]he health of a whole community or population is reflected in measurements of disease incidence and prevalence, age-specific death rates, and life expectancy" (Oosterbroek et al., 2016, p. 238). Well-being includes health, but also extends to other important factors, such as the context in which health exists. This understanding of well-being moves beyond the mere absence of disease and instead is a more holistic state that includes "physical, psychological, and social aspects of wellness" (Ford et al., 2015, p. 661). It follows that if a person or community's well-being is based on physical, psychological, and social determinants, that one's surroundings have a role to play in their overall well-being.

The Millennium Ecosystem Assessment makes the connection between human well-being and the ecosystem services those humans depend on (Millennium Ecosystem Assessment, 2005; Parkes et al., 2010). These direct connections between place, ecosystem services and well-being have been explored throughout the literature (Horwitz & Parkes, 2016; Oosterbroek et al., 2016; Parkes et al., 2010; Parkes & Horwitz, 2009; Webb et al., 2010), and can be thought of as a foundation for exploring health (Parkes & Horwitz, 2009). Horwitz & Parkes (2016) outline nine areas in which ecosystem services determine health and well-being:

1. Contributors to hydration and safe water
2. Contributors to nutrition and microbiomes
3. Sites of exposure to infectious diseases

4. Sites of exposure to pollution or toxicants
5. Settings for mental health and psychosocial well-being
6. Sites of exposure to physical hazards
7. Places where people derive their livelihood
8. Places for lifestyles, personal behaviors and community engagement
9. Sites where medicinal and other products can be derived or accessed

These connections and pathways of influence are not new. Many aspects of these pathways have been explored by health researchers over the past decades, including a study that found that patients recovering from surgery recovered faster when they had a view of nature in comparison to those who had a view of a wall (Jackson et al., 2013). An additional concern, when considering the dependence of human well-being on ecosystem services is that many ecosystems - and their services - are being quickly degraded. The Millennium Ecosystem Assessment found that around 60% of these services, such as air and water purification, are degraded or being exploited at unsustainable rates (Oosterbroek et al., 2016). This is even more concerning when it has been found that 25% of diseases globally are directly related to environmental causes, and 80% of these global disease rates are indirectly related to the environment (Parkes et al., 2010). Making the connection between which ecosystem services have a specific impact on particular people is not a clear task.

While ecosystem services can be understood as foundational for health and well-being benefits for people, it is important to be aware of the degree of complexity that is at play when dealing with ecosystem services. Improving the health benefits one group of people receives from an ecosystem service may result in another group of people experiencing a worsening of their own well-being as a result (Horwitz & Parkes, 2016). Attempts to better understand the spatial scales in which certain ecosystem services operate have produced the concept of servicesheds (Mandle & Tallis, 2016). Servicesheds are the areas that specific ecosystem services provide benefits to a specific people, and have been found to have various scales depending on the particular ecosystem service being considered and the place it is being considered in (Mandle & Tallis, 2016). In addition to the complexity of finding the appropriate scale of influence from an ecosystem service, there are also complex challenges in dealing with: the multiple drivers of ecosystem change, long and complicated cause and effect chains, multiple health impacts, the role of socio-economic factors, and the site specifics of impacts. This small sample of the complexity of dealing with ecosystem services impacts on well-being is why it is necessary for health researchers and providers to interact and engage in transdisciplinary work (Parkes & Horwitz, 2009; Webb et al., 2010). This recognition of the need to find better ways to deal with complexity has led to the development of approaches such as ecohealth (Charron, 2012; Webb et al., 2010) that will be explored further for its methodological implications in Chapter Three.

2.2 Applied Processes

This section of the literature review focuses on content that pertains to knowledge exchange and geospatial tools (with a focus on web-based tools), as expressions of the applied fields and processes that have provided the background to the research. While there are significant theoretical elements to each of these topics, this research is interested in their application to address the questions and objectives introduced in Chapter One.

2.2.1 Knowledge Exchange

There are many different terms used interchangeably when it comes to knowledge exchange, including: knowledge generation, coproduction of knowledge, knowledge transfer, knowledge sharing, knowledge mobilization, knowledge translation, and knowledge to action. Knowledge exchange can be defined in many ways, and Fazey et al. (2013) provide a useful generalized definition as being a "process of generating, sharing, and/or using knowledge exchange through various methods appropriate to the context, purpose, and participants involved" (p. 20). This is the preferred term and definition used throughout the thesis, due to the emphasis and assumptions of an exchange of knowledge, as compared to a term such as 'knowledge translation' that focuses on simply modifying the content that is relayed to an audience (Fazey et al., 2013). Knowledge exchange as a process incorporates many of the best features of the other terms. The need for the knowledge exchange process to be appropriate for the specific situation is important, as one approach may be suitable for one situation, and not the next. There is not a universal approach that will always work, and new exchange processes will also often involve some degree of iterative refinement.

Reed et al. (2014) provide a robust structure for understanding the process of knowledge exchange by providing five principles for practicing knowledge exchange in environmental management. The five principles are: 1) design; 2) represent; 3) engage; 4) impact; and 5) reflect and sustain. The design principle begins the process by requiring that the desired outcomes of knowledge exchange be known from the start of any project. They suggest that goals are set, a communication strategy is developed, there are suitable resources to support the process, and there is built-in flexibility that can account for the potentially changing needs of knowledge exchange participants.

The second principle identified by Reed et al. (2014) is the need to represent the knowledge needs and priorities of the knowledge users. Projects must identify the potential users of the research, finding ways to include these people in the research, while remaining sensitive to ethical implications relating to the research and collaborations (Reed, Stringer, Fazey, Evely, & Kruijsen, 2014). Reed et al.'s (2014) third principle is engagement between the knowledge 'producers' and 'users,' to establish two-way conversations where both parties are equals. In the literature, there is agreement that knowledge exchange should be a multi-directional process (Cvitanovic et al., 2016; Fazey et al., 2013). The exchange is often generalized between knowledge 'producers' and 'users' (Cvitanovic et al., 2016), where researchers create knowledge and exchange it with the people who want to use it for some purpose. This is a more unidirectional process, which is accepted as being a less desirable form of knowledge exchange (Fazey et al., 2013).

The fourth knowledge exchange principle that Reed et al. (2014) propose is the need to focus on the impacts of the process. Among the many connections between knowledge exchange and some characteristics of ecohealth as an approach to research (see Chapter Three), the emphasis on impacts resonates strongly between the two. Potentially one of the best ways to keep participants and knowledge 'users' engaged is by having tangible results that address challenges they are experiencing (Reed et al. 2014). Ecohealth would refer to this as being a form of knowledge to action (Charron, 2012). The final principle Reed et al. (2014) explore is reflection and sustaining the project. This principle focuses on evaluating how the process you are involved in is progressing, and then refining as learning occurs. Fazey et al. (2014) refers to this process as formative evaluations. Some of the potential outcomes of knowledge exchange that can be evaluated are: a change in understanding, a change in practice or policy, and the resulting changes from changing practice or policy (Fazey et al., 2014). These features of knowledge exchange are all relevant to the design and evolution of geospatial tools.

2.2.2 Geospatial tools

The use of maps and geospatial tools is useful for aiding people in identifying and providing a visual aid to make the connection between the human environment relationship (McLain et al., 2013). This section of the literature review covers geospatial tools to provide context and understanding of the purpose of using the web-portal in this research (the Stewardship Portal, introduced in Chapter One). To accomplish this, a brief background on the development of geospatial tools that led to web-based geospatial tools is provided. An overview of these web-based tools is provided, and the web-portal being used for this research will be explained, relative to other geospatial tools.

The first operational GIS dates back to 1962 when Roger Tomlinson, who is considered to be the father of GIS, developed a GIS for the Canadian Federal Department of Forestry and Rural Development (Fu & Sun, 2011). As this technology continued to evolve throughout the following decade, it became apparent that spatial analysis would be a driving force in geography and many other fields (Dragićević, 2004). GIS are typically focused on: storing and accessing geospatial data, editing capabilities, analysis, and providing digital visualizations and maps (Songer, 2010). GIS started as a desktop-based software package, which is still a prevalent format used today in the field. Examples of current desktop versions of GIS are ESRI's ArcMap and an Open Source software package called Quantum or QGIS. While these desktop GIS have become powerful and efficient at processing geospatial data, they also have limitations and criticisms. A common issue for individuals or organizations who want to perform spatial analysis using GIS is the relatively high cost of computer hardware to accommodate processing, and the high cost of some software options (Songer, 2010), such as ArcMap, which is an industry standard in North America and much of the world. In addition to the cost of software, which can be avoided using freely distributed open source software such as QGIS, there is also a significant learning curve associated with GIS due to their complexity (Songer, 2010). This high entry cost of both time and money makes it difficult for many individuals, organizations, and even governments to make use of these powerful tools (Mukherjee, 2015). Thanks to the continuing development of the internet, in 1993 a new approach to GIS was developed, which is now known as web GIS (Fu & Sun, 2011).

In 1993, Xerox launched their PARC Map Viewer, a web-based tool that provided the ability to display maps, zoom in and out, select and deselect different data layers, and convert map projections, all without having to purchase or install resource intensive software on your computer (Fu & Sun, 2011). PARC Map Viewer provided a web mapping experience by generating and visualizing maps and other geospatial data through the web, but it also provided web GIS functionality through the conversion of data projections (Li et al., 2011). Web GIS are considered to provide online mapping services, but also provide additional functionality such as: spatial analysis, querying of data, collection of data, and the distribution of geospatial data (Fu & Sun, 2011; Li et al., 2011). Another defining feature of a web GIS is that they have, at a minimum, a server and a client, where the client is typically a web browser, desktop, or mobile application that requests data and services from a server through the internet (Fu & Sun, 2011). Web GIS have many advantages over desktop GIS, as they only require internet access and virtually any computer, and due to their less extensive suite of tools, they are significantly easier to learn how to use (Songer, 2010). As a result, people who would not have been able to invest the time and money required for a desktop GIS can make use of this technology. This more accessible use of GIS provides: access and sharing of spatial data, the exploration and visualization of data, and analysis and modeling all at greater rates than could be done using only desktop-based GIS (Dragićević, 2004). This increased access to GIS has also made it easier for new mapping approaches, such as: participatory mapping (Lowery & Morse, 2013), public participation GIS (Mukherjee, 2015), and volunteered geographic information (Ota & Plews, 2015), all of which have a common theme of collecting and/or sharing data from a bottom up approach.

Defining the various types of web GIS tools that are available is a difficult task, as the literature (both academic articles and textbooks) does not make distinctions beyond being a web GIS or not. A query of the UNBC library catalogue using the following searches all provide a plethora of products that cover a diverse range of fields and topics, but no specific typing beyond being a GIS or web GIS: types geospatial web, types geospatial web tools, web GIS types, and web GIS tools. The distinctions being made in the literature are related to the design and purpose of each web GIS. Due to this lack of specific categories of web GIS, this literature review will distinguish between different types of web-based geospatial tools by their range of features.

The evolution of web GIS has been marked with an increasing amount of functionality and processing capabilities that have been the staples of desktop GIS. While Figure 2 depicts a general outline of features that have become available, this is by no means an extensive feature list, but is instead meant to be a helpful heuristic tool for readers.

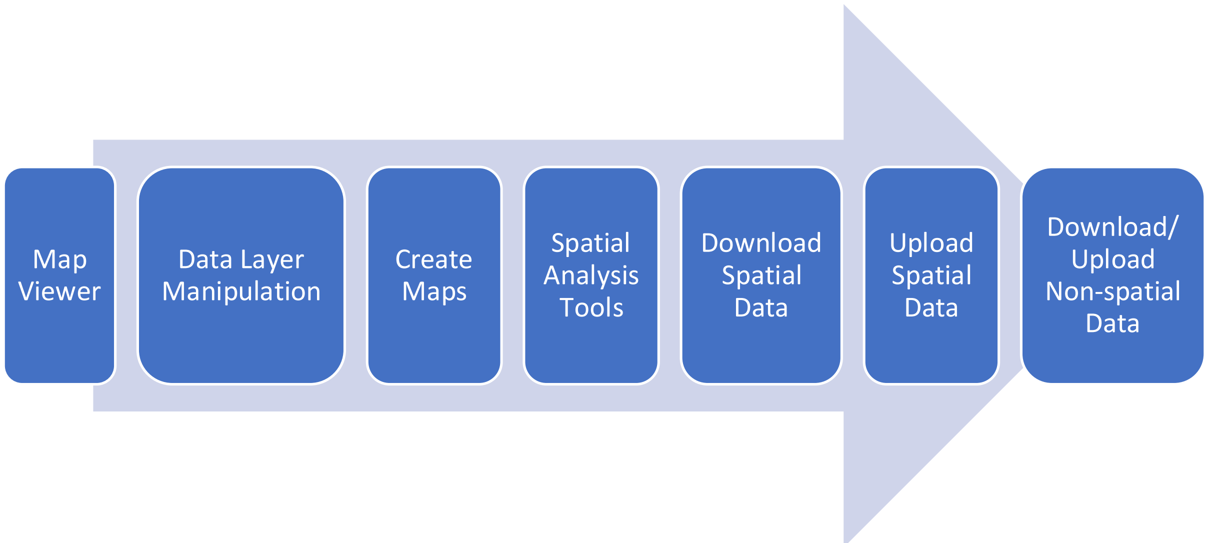

Figure 2: The Evolution of Web GIS Functionality

The tools covered in this section are: the Local Environmental Observer (LEO) Network, the Nechako Watershed Atlas, the Mid-Atlantic Watershed Atlas, EnviroAtlas, and the IWRG web-portal. This is not meant to be an extensive overview of all the features, design, and technical details of these tools. The purpose of discussing these tools is to provide some context for what kind of features they each make use of, which will also highlight the uniqueness of the combination of features available in the IWRG web-portal.

The Local Environmental Observer (LEO) Network (LEO Network, 2021) is a networking website and mobile application that connects people observing unusual phenomena occurring in their surrounding environment to a network of other interested observers and experts who can shed some light on what is being observed. The LEO Network is best described as falling on the 'Map Viewer' hierarchy of web GIS tools. The argument could be made that it is not actually a web GIS, but instead displays observations as points on a map to provide users with an easy way to see potentially interesting posts in areas that are relevant to them. The map centric viewing approach is secondary to the purpose of connecting a diverse range of people with observations about environmental change.

The Nechako Watershed Health Atlas was created by the Fraser Basin Council, Community Mapping Network, and other partners from throughout the Nechako Watershed (Fraser Basin Council, 2015). This atlas goes one step further in terms of web GIS functionality from the LEO Network. The atlas has the ability to enable and disable an array of predetermined spatial datasets, which can also have their attribute tables shown. There are built-in basic spatial analysis tools, such as measuring length and area, and buffering. The atlas also allows users to create and print or download maps produced with the provided data. This particular atlas does not provide the option to upload or download any data types.

The Mid-Atlantic Watershed Atlas (MAWA) was a tool that was developed to create a regionally focused community that provided access to a wide array of data pertaining to watersheds throughout the northeastern United States (Reed, Bills, Anderson, Ketchum, & Piasecki, 2010). MAWA is unfortunately no longer a functional tool, so the summary of the functionality is drawn from the associated paper from Reed et al. (2010). MAWA provided access to a wide range of imagery products, some of which were available for download directly from the tool. There were also some basic analysis tools, such as graphing functions, available. Similar to the LEO Network, MAWA also provided the ability for users to create points on the map, then type summaries and make direct URL links to websites.

EnviroAtlas is a web GIS tool developed for the United States Environmental Protection Agency (EPA), which uses ESRI systems to create the entire web GIS experience. The EnviroAtlas has a well-developed user interface and a vast array of functionality thanks to the use of ESRI products. This atlas is capable of uploading data from other online sources or a local hard drive, has basic mapping and analysis tools, and is also able to upload additional tools if they work with other ESRI web GIS products. Another aspect of this tool is the three pre-determined categories for data that are provided. These categories are: Ecosystem Services and Biodiversity, People and Built Spaces, and Boundaries and Natural Features. Spatial data are available for download through the EnviroAtlas website.

The final web GIS tool to be discussed in this literature review is the IWRG Portal. This Portal has all of the web GIS functionality mentioned in previous tools: map viewing and creation, analysis tools, reporting, and the ability to download data directly from the Portal. In addition to these features, the Portal also allows users to upload their own data. In fact, this tool provides base layers but the rest of the content relies on user contributions. The data that are hosted in this web-portal are more than just geospatial in nature; any digitally stored data can be included in the database. The linking of spatial and non-spatial data provides the opportunity to make spatial connections between forms of data where they may not have been considered before. For example, a person could contribute a study on the impacts of the Kenney Dam on the Nechako River, and their submission would contain a text file or link to the article. They could also attach pictures they had taken, a point on the map to show where the dam is, and a polygon feature that represents the Nechako River itself. Previous web GIS have provided the ability to link out to other websites, but none found in this literature review provided this range of data types in one single location. Another critical feature of this web-portal is the permissions-based system in which data are protected. Since users can download any data they have access to, it is important to provide a system in which users uploading data can indicate which users should have access. This allows sensitive material to be stored in the web-portal and preventing it from being obtained by an audience larger than what the uploader desires.

2.3 Synthesis: linking concepts and application through geospatial tools

The purpose of this section is to highlight both the connections and gaps that exist between health, ecosystems, climate, and the use of geospatial tools to further understand these relationships. This will be accomplished by outlining some of the general benefits, strengths, and weaknesses of geospatial tools for integrating and synthesizing data on complex topics such as climate, ecosystems and well-being. Some of the connections between climate change, ecosystems, and well-being will be highlighted. This section concludes by discussing the challenges with integrative research.

Using maps or spatial visualizations of data can be effective forms of presenting information pertaining to topics such as environment, natural resources, and demographics (WHO, 2017). Spatial representations can effectively combine complex sets of data (Burkhard et al., 2012), reducing the effort and time required to understand the presented information (Lieske, 2015). Spatial data are also helpful in providing the opportunity to discover patterns that may have been otherwise overlooked in other formats (Sopan et al., 2012; WHO, 2017). Exploring spatial data has been identified as an effective way to represent the connections between humans and the environment (McLain et al., 2013). Maps and spatial data also have limitations that are important to understand. Maps are never an objective model of reality; instead, they are the result of choices made about which data should or should not be included (McLain et al., 2013; Stocker et al., 2012). Not everyone finds that maps and spatial data are easily understood, and even choices about colour can be interpreted differently by different cultures (WHO, 2017).

Health and well-being research appears to be one field that has explicitly made the connection between climate change, ecosystems, and well-being. In this field, it is recognized that climate change is a significant issue for public health because it increases the risks of disease in many demographics. This increased risk is felt the most by vulnerable groups, such as the young, elderly, and individuals already suffering from chronic illness and that having ecosystems that are functional and productive are important contributors to the overall health and well-being of humans (Galway, Parkes, Corbett, et al., 2016). Galway et al. (2016) also note that climate change needs to be seen as exerting pressure on ecosystems, as well as the economic and social structures that support human civilization.

Developing research and/or geospatial tools to explore this incredibly complex relationship is not an easy task. One response to this challenge that is identified in the literature is the benefits of scoping a problem to make it more manageable. For example, geospatial tools that were found under climate change headings tended to have a focus on the increased vulnerability experienced as the climate changes (Bai et al., 2014; Lieske, 2015). Vulnerability for these tools is defined as a monetary factor, though both Bai et al.'s (2014) and Lieske's (2015) tools use demographic data to develop the monetary risks. Much of the literature and tools coming from ecosystem services work has a focus on bridging the gap between ecosystem services and humans by calculating the monetary value of these systems services (Burkhard et al., 2012; Crossman et al., 2013; Pickard et al., 2015). This type of ecosystem services literature creates the connection to humans by appealing to their economic well-being.

Tools like InVEST and ARIES attempt to spatially model the value of ecosystem services, which provides results that can be used in summaries, briefings, and maps (Pickard et al., 2015). Ecosystem services tools, such as the Social Values for Ecosystem services (SoIVES), move away from reducing ecosystem services to how much money they are worth to society, and focus on the inherent social value (non-monetary) of ecosystems (Sherrouse et al., 2011). SoIVES approaches ecosystem change as being a result of social changes, which are indirectly impacted by demographic and cultural factors (Sherrouse et al., 2011). EnviroAtlas is an open access ecosystem services mapping web tool that provides data on ecosystem services, as well as people and built spaces (Sherrouse et al., 2011). In terms of mapping health-related data, there are examples of presenting data spatially and presenting them in a map (Elliott et al., 2001), but there are also examples of including mapping tools as a core tool in public health and environmental justice research (Maclachlan et al., 2007).

Climate change is considered to be one of the greatest threats to human well-being, and is a complex problem (Galway, Parkes, Allen, et al., 2016). Galway et al. (2016) present five lessons for interdisciplinary research seeking to connect climate change, water (a product/service provided by ecosystems), and health: 1) the need for frameworks that facilitate integration, 2) emphasize learning-by-doing, 3) the benefit of examining issues at multiple scales, 4) making implicit knowledge explicit, and 5) the need for reflective practice. A gap in the literature related to this research is that it is not known if a geospatial tool (such as the IWRG Portal) can provide an opportunity to understand climate, ecosystems, and well-being data through the integration of spatial and non-spatial data. It also is not known if presenting climate, ecosystems, and well-being data using such tools is an effective means to leverage existing data to assist conversations and new perspectives of the interconnectedness of these data. Insights gained in relation to these gaps will be discussed further in Chapter Five.

Geospatial tools, such as the IWRG Portal, have the potential to accommodate learning-by-doing, looking at problems at multiple scales, and making implicit knowledge, such as values, spatially explicit. The subsequent chapters will present how this study has been designed to explore and provide insights into the strengths and limitations of the IWRG Portal as a contribution to addressing these challenges.

Chapter Three: Research Design

This thesis is the product of research that was designed to answer the research questions and objectives present in Chapter One, Section 1.2, and to address the gaps identified in Chapter Two. The research design presented in this chapter is, therefore, a response to a combined conceptual challenge of integrating and understanding the interactions of climate change, ecosystems and well-being in the Nechako, with a technical challenge of iteratively refining a map-centric portal tool to support this integrative understanding. To respond to this combined challenge the research was designed and conducted in two iterative phases. Phase I (IWRG Portal Research and Development) was, overall, concerned with learning about the relevant technical aspects of the Portal. Phase II (IWRG Portal Showcase) provided a chance to showcase and examine how the map-centric portal could leverage existing data about climate change, ecosystems and well-being.

A key aspect of developing a coherent two-phase research design was drawing on different methodological approaches that, together, accommodate the combination of conceptual and technical or applied aspects of my research questions and objectives. This chapter is structured in four parts to reflect these different considerations. Section 3.1 describes key methodological influences that supported research design focusing on both knowledge exchange about climate, ecosystems and well-being and also the technical development of the web-portal. Section 3.2 introduces the two iterative research phases that were combined to address the research questions and objectives. Section 3.3 introduces the specific research methods that were used to gather and analyse data to address the research questions and objectives. Section 3.4 addresses considerations of research ethics and rigour that were relevant to this research design.

3.1 Methodology

As introduced above, the research questions and objectives of this research combine an interest in both conceptual and technical/applied considerations. One response to this is a two-phase qualitative research design that will be introduced in Section 3.2. This type of research design also required careful consideration of both methodological approaches and specific methods. Methodology and methods are two different terms, which need to be distinguished and defined. Methods are the actual techniques used to collect data. Interviews, observations, field notes, and questionnaires are all examples of methods that can be applied in research (Roberts, 2014), and the relevant methods used in this research are presented in Section 3.3. This section focuses on methodology, which Roberts (2014) describes as the reasoning and structure that underpins how, and which, methods are applied in research.

Methodology has been described as being an aspect of different research paradigms. A paradigm can be understood as "the basic belief system or worldview that guides the investigator, not only in choices of method but in ontologically and epistemologically fundamental ways" (Guba & Lincoln, 1994, p. 105). Guba and Lincoln (1994) describe research paradigms as consisting of three fundamental questions that ask about: 1) ontology, 2) epistemology, and 3) methodology. Ontological questions seek to establish the nature of reality, and epistemological questions focus on understanding what can be known, as well as the relationships between the person who knows and one who wants to know (Guba & Lincoln, 1994). Guba & Lincoln also describe methodology as being how a researcher can approach the things they believe can be known, which is constrained by the researcher's own beliefs about epistemology and ontology.

In keeping with these descriptions by Roberts and Guba & Lincoln, this section introduces the methodological approach of pragmatism and the methodological influences from ecohealth and knowledge exchange, which have shaped the design of this two phased research. A pragmatic approach is especially appropriate for the applied place-based nature of this research that is influenced by more than one research paradigm (Patton, 2002), including the different types of past research within the Nechako Watershed, that have generated existing information on climate change, environment and community. In keeping with the emphasis of Research Question 1, and Objective 1, two other notable methodological influences are the fields of knowledge exchange, and ecohealth which both help to ground thinking about and discussing interactions about climate change, ecosystems, and well-being.

3.1.1 Pragmatism

Pragmatism is a social science paradigm that can be applied to qualitative, quantitative, or mixed methods research (Morgan, 2014). Pragmatism does not rely on establishing a metaphysical philosophy of knowledge (Morgan, 2014). Pragmatism as a paradigm relies on a process-based understanding of knowledge (Morgan, 2014). Pragmatism understands research as a human experience that differs according to both the beliefs and actions of researchers (Morgan, 2014). Beliefs and actions for pragmatists are the combined result of a person's lived experiences, which are inherently contextual and based on lived history, culture, social situation, and emotions (Morgan, 2014).

Pragmatism can be a flexible methodological approach (Patton, 2002), which provides the ability to explore the different ways of knowing and interacting with the real world (Wood & Smith, 2008). Pragmatism considers ideas to be a result of lived experiences and actions that are continually evolving, which leads to a definition of pragmatism as being, "a pluralist approach with an appreciation of the fallibism of all knowledge and every style of knowing" (Wood & Smith, 2008, p. 1527). To clarify, fallibism is "a theory that it is impossible to attain absolutely certain empirical knowledge because the statements constituting it cannot be ultimately and completely verified" (Merriam-Webster, n.d.). The scope of pragmatism can be reduced to concerning itself only with what works, which has been criticized throughout the literature (Morgan, 2014). The scope should not be this narrow; instead, a pragmatist approach is concerned with understanding what researchers do and why they do it, the choices that are made about research goals, and the means that are used to reach research goals (Morgan, 2014). The pragmatic approach could be considered the return to the linguistic roots of methodology, which is the study of methods (Morgan, 2014). A pragmatic paradigm accepts the value of research conducted under other paradigms and approaches, because it is recognized that different research communities have their own set of beliefs that lead to actions and research (Morgan, 2014). The pragmatic approach provides the flexibility to incorporate Ecohealth, Knowledge Exchange influences, while also allowing a two phase research design that were broken up into 1) a technical and practical phase, 2) a qualitative phase. Having an inclusive methodology is important to me because there are many different approaches to research and knowledge, and they all have value. Pragmatism also recognizes that people's own experiences can influence their understanding of the world and is continually evolving, just as this research evolved through its different phases. These ideas are also consistent with my evolving experience and positionality as a researcher, as outlined in Section 1.4.

3.1.2 EcoHealth

Ecohealth is an evolving field that is especially relevant to research that combines social and ecological influences on health, and that also seeks to both improve understanding of and develop responses to complex issues (Forget & Lebel, 2001). In keeping with Roberts' (2014) definition of methodology, the principles of ecohealth have impacted the design of this research by influencing my reasoning as a researcher, the structure of the research, as well as the methods applied. Forget and Lebel (2001) note that ecohealth adds value to this research design by placing people into nature, while attempting to frame this relationship between humans and nature in a systems manner that connects health, ecosystems and societal responses (Forget and Lebel, 2001; Charron 2012).

When describing ecohealth, Charron (2012, p. 7) notes "that health and well-being are the result of complex and dynamic interactions between determinants, and between people, social and economic conditions and ecosystems. The conditions of ecosystems are also affected by a dynamic process of interactions, often determined by the social and economic activities of people." Charron (2012) makes the direct connection between ecosystems, people, and their well-being, with an emphasis on six principals, among them 'systems thinking' and the benefits of moving 'knowledge to action.' Systems thinking sees the world as an array of interacting, nested hierarchies, with feedback loops that exist across the space-time continuum (Waltner-Toews et al., 2003). It is important to recognize the relationships that exist across and within these systems, and that these systems are truly complex (Charron, 2012; Waltner-Toews et al., 2003; Funtowicz & Ravetz, n.d.).

Watersheds, catchments and river basins (such as the Nechako Watershed) can be seen as a mid-scaled system, which are less complicated to apply systems thinking to than the entire country or globally, but still complex enough to have examples of intersecting boundaries of ecosystems and institutions (Parkes & Horwitz, 2009). The watershed scale is thought to be "an ideal context to design integrated governance that addresses health, environmental and socio-economic priorities" (Parkes et al., 2010, p. 694). While this research does not involve designing governance structures, Parkes et al. (2010) suggest that watersheds are complex systems that facilitate exploring the relationship between human health and ecosystems.

Charron (2021) identifies systems thinking as a principle of ecohealth that encourages consideration of interconnectedness, of impacts on health, spanning ecosystems, social systems, power dynamics and more. Knowledge to action is a related principle that focuses on the need to use information to enact real world change (Charron, 2012). These concepts and principles of ecohealth have influenced how research has been designed to address Research Question 1 and Objective 1. Knowledge to action is closely related to knowledge exchange, which is the methodological influence discussed in Section 3.2.3.

3.1.3 Knowledge Exchange

Knowledge exchange has been explored in some detail in the literature review, and has also been one of the important methodological influences on the design of this research. This research is concerned with understanding the role a geospatial web-portal tool can play in facilitating conversations throughout the Nechako Watershed relating to climate change, ecosystem services and well-being. Knowledge exchange recognizes the need to develop context-appropriate methods for facilitating exchange among different knowledges and knowledge-holders, and seeks to do so in an ethical manner (Fazey et al., 2013). Although being able to transfer or translate knowledge to other people is important, this research is interested in incorporating the knowledge others are willing to share. A unidirectional exchange approach could simplify this research by reducing the number of phases required, but would not actually consider the value of knowledge held by those who are referred to as knowledge 'users.' To have a true 'exchange,' one needs to engage in a conversation.

In the current global context, complex problems, such as climate change, require new approaches to thinking about and managing our actions within the environment. A key principle of knowledge exchange is the need to reflect throughout and after the process (Reed et al., 2014). This principle is reflected in the design of this project by building research phases that take the time to reflect and learn, so that the next phase benefits from the previous. This learning emphasis links to the challenges of evaluating the knowledge exchange process being developed, as well as the demand for new methods to be created for this (Cvitanovic et al., 2015). Although this research is interested in learning about the processes of knowledge exchange enabled using the IWRG Portal, the outcomes of the actual exchange of knowledge also need to be addressed. Fazey et al. (2014) suggest that some of the potential outcomes of knowledge exchange that can be evaluated are: a change in understanding, a change in practice or policy, and the resulting changes from changing practice or policy.

Knowledge exchange influenced the two phased design of this research by providing guidance on the importance of intentionally designing collaboration, reflection, and an understanding of the importance of all types of knowledge into this research.

3.2 A Phased Research Design

In response to the research questions, literature gaps and methodological influences above, this research was designed and conducted in two iterative phases. The first phase was concerned with learning about the relevant technical aspects of the Portal, developing an instance of the Portal for the IWRG, finding suitable secondary data for the IWRG Portal, and testing methods to integrate these data into the IWRG Portal. This first phase concluded with the creation of Portal-related training materials to assist new users, as well as I achieved an understanding of how the Portal works. The second phase focused on evaluating the perceived effectiveness of the integration of data into the IWRG Portal. This was accomplished by drawing on the combined experience and opinions of members of the portal user research group (described below in 3.2.1). It is important to note that while this research is divided into two phases, due to the iterative nature of this work, Phase II did not start when Phase I concluded. Instead, Phase II started when Phase I reached the point where it was ready to benefit from the portal user research group's input.

3.2.1 Phase I: IWRG Portal Research and Development

Phase I had three main goals. The first goal was focused on the technical aspects of the Portal that were relevant to this research, such as developing an understanding of how the Portal was designed and functioned, to assist in launching an instance of the Portal for the IWRG. The second goal was to acquire secondary data that related to climate change, ecosystems, or well-being within the context of the Nechako Watershed, and to integrate these data into the Portal. The final goal of this phase was to take the knowledge acquired through this phase and use it to provide the IWRG and members of the portal-user research group, with training materials that could be used to streamline the process of learning how to use the Portal for new users. The portal user research group (PURG) involved directly in this research consisted of: members of different themes of UNBC's Integrated Watershed Research Group team, the Nechako Environment and Water Stewardship Society (NEWSS), School District 91, and the 'Potential Portal User Group associated with the ECHO Network' mentioned in the Research Ethics associated with this research. Engagement of these participants is described in Section 3.4, the Portal User Research Group Consent can be found in **Appendix Three**, and the Workshop and Focus Group Invitation can be found in **Appendix Four**.

3.2.2 Phase II: IWRG Portal Showcase

Phase II of this research directly builds off the work in Phase I, and was designed to showcase and examine the data that had been entered into the Portal and had three main goals. The first goal was to draw on the experiences of the participating members of the PURG regarding possible communication strategies for presenting data related to climate, ecosystems, and well-being appropriate to the context of the Nechako Watershed. The second goal was to evaluate the perceived benefits of using the Portal as a tool to convey information. The final goal of this phase was to determine the perceived limitations of using the Portal within the context of the Nechako Watershed.

Phase II consisted of four scoping discussions that occurred in small groups, a workshop that acted to provide hands-on in-person training to members of the PURG, and a focus group that was held on the same day, immediately after the workshop. The focus group was recorded and transcribed. To analyze the transcript from the focus group, a thematic analysis approach was used. The specific methods used in this phase of research will be described in more detail in the next section.

3.2.3 Phased Research Design Summary

To summarise – this study utilized a pragmatic two-phased iterative research design, with a qualitative approach that supported an iterative research design that evolved as the research progressed (Gaudet & Robert, 2018). The research methods are presented separately for each phase of research. The methods sections for Phase I (Section 3.3) provides a high level overview of the work that went into developing a working IWRG instance of the Portal. In this context, an 'instance' is a different database and website that has been set up to run the Portal software. For example, while there are multiple groups using the Portal software, the IWRG Portal has its own database and web URL that are not shared with other instances of the Portal. The approach used to describe Phase I methods is not typical in many research projects, and yet is essential to describe and lay the foundation for the work that Phase II builds on. The Phase II methods section (Section 3.4) is more in line with a traditional qualitative research design, and will outline specific methods and related considerations.

3.3 Phase I Methods: Hands-on Learning with the Portal

The methods used for Phase I of this research involved a range of hands-on learning activities with the portal to develop a working IWRG 'instance' of the Portal. Creating an 'instance' of the portal required a series of steps:

- first, to develop an understanding of how the Portal is designed and operates;
- second, to acquire climate, ecosystem, and well-being data for the Nechako Watershed and integrate these data into the IWRG Portal; and
- third to provide direct training and training documents that can be used to help new users learn how to make use of the Portal (**Appendix Five**).

Phase I was, therefore, designed to inform Phase II, by providing an IWRG-themed Portal with an array of data related to the Nechako Watershed's climate, ecosystems, and well-being. The intent was that this would provide the foundation for Phase II, whereby the IWRG Portal tool was ready to be explored by members of the PURG, and data collected to address the research questions and objectives.

To gain a working understanding of exactly what the Portal was, and how it worked, it was necessary to spend time with the development team that was actively developing the third version of this map-centric web portal tool. This involved attending and participating in development progress meetings where the team discussed what features were being worked on, bugs that had been identified, and created plans on how to continue making progress. In these meetings the overall architecture of the Portal was also discussed among a team with diverse technical and GIS expertise, including: overall design and development, programming, research and UNBC GIS lab assistants.

Informed by work with the development team, it was also necessary to spend time using the Portal alone, learning how the various aspects of the Portal worked. While much of this solo hands on time with the Portal was self-directed, it was not unusual to have a specific focus that resulted directly from a development meeting. For example, when the development team was creating a tool that would allow bulk uploading of forms and information into the Portal, it became necessary to spend time testing this new feature to find bugs that may be present. Generally, this Portal exploration time was done systematically, which started with learning the basic functions that general users had access to. For example, adding spatial data to the map, uploading content, searching for content, and applying the available spatial tools. After these functions were understood the next step was to become acquainted with the Portal administrator features. These features included the ability to create custom forms for data entry, schemas to allow spatial data to have attributes, creating groups to organize users, creating user accounts, and changing the user interface schemes and banners.

The second focus of Phase 1 was to start acquiring data related to climate, ecosystems, and well-being in the Nechako Watershed. Data were collected in two ways. First, I contacted researchers doing work in the Nechako Watershed that was relevant to the scope of this research (especially those with links to climate, ecosystems, and well-being), and asked if they would be interested in having their research hosted in the Portal. The second data collection method involved searching through literature on the Nechako Watershed and querying databases to explore what kinds of data (spatial and non-spatial) existed that could potentially be incorporated into the Portal.

To upload data into the Portal, a few steps had to be completed. The first was to create a form that could be used to capture the relevant aspects of the data. For example, the forms created have fields to capture citation relevant information, links to the research if it was published online, abstracts, or where appropriate, the complete data, such as a paper. The next step was to determine how this information could be presented in a spatial manner. Often this was accomplished by identifying spatial data that captured where the work focused on or was undertaken. To provide attribute data within the spatial data, schemas had to be created. These schemas determined which fields would be displayed within the spatial data. It was also necessary to develop an IWRG theme for their instance of the Portal, which involved applying a suitable colour scheme as well as adding an IWRG banner image.

The final goal of Phase I was to provide training and training materials for the IWRG Portal. Throughout the course of this research dozens of demonstrations and training sessions were held in person and online. These demonstrations usually involved showing the various features of the Portal, and showcasing some of the datasets that had been uploaded. In addition, training documents were developed after the scoping discussions (Section 3.4.2) and workshop and focus group (Section 3.4.3) to guide new users on how to navigate and use the Portal. These training materials can be found in **Appendix Five**, and cover everything from the general layout and features of the Portal, to how to navigate spatial data, upload personal content, and search for existing content already in the Portal. The findings section for Phase I will present a detailed description of what the Portal is, and the subsequent discussion (Chapter Five) will compare the portal to the literature and other GIS based tools.

3.4 Phase II: Methods: Qualitative data collection with portal users

Phase II adopts a qualitative approach that, in keeping with Gaudet & Robert (2018), supports an iterative research design able to evolve and develop as the research progressed. Phase II activities included small group scoping discussions, a workshop that showcased the data within the Portal as well as training on how to use the Portal, and a focus group with workshop participants.

3.4.1 Phase II: Recruitment

Existing portal users (including those involved with Phase I) were called on to recruit participants. The selection criteria for these participants were: established PURG members, individuals who collaborated by providing data for the Portal, individuals with experience communicating their research to a diverse range of audiences, and individuals with specific expertise in: development of the Portal, climate change, ecosystem services, and health and wellness. Two phases of recruitment and participation occurred:

Through March and April of 2018, four small group scoping discussions were held with members of the Portal User Research Group (PURG) who had been actively providing data to be uploaded into the Portal, as well as other PURG members who had expressed a keen interest in being involved with this research and the IWRG Portal. In total, nine individuals participated in these four scoping discussions (see Section 3.4.2). In addition eleven members of the PURG were recruited to participate in a workshop that focused on showcasing data representing climate, ecosystems and well-being on May 22nd, 2018 (see Section 3.4.3). Five participants engaged in both the scoping discussions, as well as the Workshop and Focus group.

3.4.2 Phase II: Scoping discussion using semi-structured guide

A semi-structured guide was used in Phase II to gather background information and important 'scoping' details from collaborating researchers. The semi-structured guide for these scoping discussions provided a consistent but flexible way for both parties to have a discussion and build rapport. The semi-structured guide included discussion-points pertaining to:

- the research that is being shared and integrated into the portal
- the objectives of this research
- whether there was an audience that the collaborating researcher would ideally like to reach
- what, if any, copyright or use restrictions are in place on the data being shared?
- whether there were other formats of these data? For example, raw data, published papers, technical reports, interviews, news articles, etc.
- whether there were other researchers who conduct research relevant to the three key themes (climate change, ecosystem services and well-being) within the Nechako Watershed that should be contacted?

- whether the researcher would like to meet again to review and discuss how their data was formatted within the web-portal?

Field notes were a key form of data collection during these scoping discussions (see Section 3.4.4). Field notes were taken during the semi-structured scoping discussions, and reflective notes were taken after each interaction. Detailed analysis of these scoping discussions was not conducted. Rather, the discussions provided important opportunities to gather and discuss potential data, and provided the researchers who were sharing data an opportunity to approve and suggest improvements as to how their work was adapted to be part of the IWRG Portal. The findings for these scoping discussions can be found in section 4.2.1 (Group Scoping Discussion Findings).

3.4.3 Phase II: Portal Workshop and Focus Group Data collection

In addition to showcasing the data that had been formatted and uploaded into the IWRG Portal, the workshop and focus group on May 28th, 2018 provided hands on training to PURG members on how to use the Portal. For many, this was the first hands on, in depth training they received.

As introduced above, the IWRG Portal is a tool to store, share and present data. For participants to have the opportunity to discuss their understanding and perspectives on the data connected to climate change, ecosystems and well-being that are uploaded into the IWRG Portal, they first need to be able to have basic functional knowledge of how to navigate the IWRG Portal. To facilitate this functional knowledge and experience the necessary data within the IWRG Portal, a hybrid session that combined a workshop and focus group was designed. This hybrid approach was possible and feasible because workshops and focus groups have similar characteristics. For example, workshops can be effective at providing a learning experience for a small group, usually consisting of less than 12 people (Vidal, 2009). Focus groups allow a small group of six to ten people to have a discussion where they can express their thoughts and opinions and learn from the experience and fellow participants (Hay, 2016). As stated in Section 3.4.2, the goal of this session was to provide the foundation for participants to navigate the data held within the IWRG Portal to inform their opinions for the focus group discussion. The workshop directly preceded the focus group on May 22nd (see **Appendix Four**). Eleven individuals of varying backgrounds participated in the workshop focus group session; the eleventh person helped facilitate the session by note-taking, and was also encouraged to participate in questions and discussion.

The workshop part of the session was designed to walk the participants through a variety of tasks that would provide the skills required to explore data stored within the IWRG Portal. The workshop was held in the GIS Lab at UNBC, as this location was available, had the number of computers required, and had a projector. Each participant was provided with a printed version of the workshop, and confirmed and obtained consent forms from everyone participating. After an orientation to the research project, the participants were guided through the workshop stages and the connections with the focus group discussion to follow. This part of the session was not recorded, as the intention was to have a discussion during the focus group.

For the focus group segment, the group moved across the hall and sat at three round tables that were fitted end to end. The entirety of the focus group's audio was recorded for transcription and analysis purposes. The focus group was structured using a collective learning spiral P4D approach (Mitchell et al., 2014). This learning spiral approach uses four discussion point questions to structure learning processes: 1) What should be? 2) what is? 3) what could be? and, 4) what can be? With the exception of 'What should be?,' which was outlined in the orientation section before the workshop, these questions provided the structure for questions asked during the focus group.

The prepared question for 'What is?' focused on the current experience of participants in communicating their own research to people outside their field. This question was intended to draw from participants' experience to leverage existing data, and facilitate knowledge exchange that is specific to the Nechako Watershed context, and made a direct contribution to addressing Research Question 3. The 'What could be?' question focused on discussing the integration of data relating to climate, ecosystems, and well-being, perceptions of the effectiveness of this as seen in the IWRG Portal, and sought suggestions for specific examples that are integrative and improvements to be made. This question was followed up with a question on the participants' perceptions of the IWRG Portal as a tool for sharing and discussing topics of climate change, ecosystems, and well-being in an integrative way. Finally, exploring 'What can be?,' participants were asked to suggest concrete next steps to improve the exchange of information on the three topics mentioned above.

The focus group discussion was recorded and field notes were made during and after the discussion (see Section 3.4.4 Field Notes). I transcribed the recording verbatim. The transcription was done by transferring the recording to a portable hard drive as a .mp4 file. This allowed for listening and transcribing to occur through a computer. This single device setup provided an easy way to type up the transcription but also control the audio, so if a word was not clear, rewinding was quick. The transcription was completed in this manner, along with a second full listen of the audio while comparing to the text.

3.4.4. Field Notes

Keeping consistent and detailed field notes is a critical aspect of qualitative research. It is so important that some qualitative researchers believe there is little point in conducting any type of qualitative field work if field notes are not taken (Patton, 2002). Field notes allows researchers to document and remember details about what is observed as being important. These notes need to be descriptive and detailed (Patton, 2002). An example of a potential field note that is not descriptive enough could be, "the focus group was pleasant and the participants had a good discussion." This provides nothing of value when it comes to conducting analysis or writing a report. Instead, field notes need to contain details about: who, what, when, quotes, your own feelings and reactions to what is observed, the insights you have when conducting the field work or writing the field notes, and any other specific details that strike you as potentially being important (Patton, 2002). Writing field notes can be considered the start of the analysis process (Hay, 2016; Patton, 2002).

Field notes were taken throughout Phase I and II. During Phase I, notes were taken on a daily basis. This is quite common in the GIS field, and they tend to be quite detailed. These notes cover working with the Portal Development Team, my own exploration and learning process with the Portal, and any meetings that pertained to this project. In addition to the notes taken during the semi-structure scoping discussions, reflective notes were taken after each interaction. Hosting a workshop focus group session was an intensive task, making it difficult to take detailed notes during the session. However, reflective field notes were made after the session, and a GIS-lab member was also tasked with taking field notes during the focus group. Both types of notes were taken into account when analysing the transcript of the focus group audio recording. Detailed notes were also taken during the analysis of data, and writing up of results and discussion, making connections across different phases of research and reflecting on connections with literature in conjunction with technical insights. Field notes from all phases of research were also used as point of reference throughout the process of writing of Chapters Four and Five.

3.3.5 Thematic Analysis

The data collected for analysis are qualitative, which stems from the perspectives and opinions of the participants and interpreted through my own understanding. To give some voice to these participants, a flexible approach is required in analyzing these data.

The previous sections have outlined different phases of research leading to a range of data being collected spanning technical development, scoping conversations, workshop design, field notes and most specifically a transcript from a focus group discussion. Informed by the methodological emphasis on pragmatism and knowledge exchange, a flexible approach to qualitative data analysis was sought and thematic analysis was identified.

Thematic analysis is a qualitative method that is used to identify, analyze, and report on patterns found within data (Braun & Clarke, 2006). Thematic analysis was identified as an appropriate choice for this research because it is thought of as 'foundational' when dealing with qualitative data, while providing a high degree of flexibility that pairs well with a pragmatist methodological approach. Braun and Clarke (2014), note that thematic analysis is particularly helpful for applied research, as it can both reflect the reality of a situation and dig deeper into the context of situations (Braun & Clarke, 2006). While thematic analysis can pair nicely with pragmatist approaches, it is a method that can be applied independently of particular theories, paradigms, or epistemologies (Braun & Clarke, 2006). Since being developed in the 1970's, thematic analysis has been used to provide, "robust and even sophisticated analyses of qualitative data, but yet focus and present them in a way which is readily accessible to those who are not part of academic communities" (Braun & Clarke, 2014, p. 1). This aligns well with the previously discussed methodology guiding this research. A modified approach to Braun & Clarke's (2006) six phases for conducting thematic analysis was used in this research and the key steps involved are summarised in Table 1.

Table 1: Thematic Analysis adapted from Braun and Clarke (2006)

Phases of Thematic Analysis (adapted from Braun and Clarke, 2006)	**Summary of key steps taken in analysis of Qualitative data**
Phase One – Familiarizing yourself with your data	- Listened to the audio recording and made notes - Transcribed the audio recording through multiple iterations of listening to the recording - Reviewed field notes taken during the focus group - Made new field notes
Phase Two – Generating initial codes	- Continued reading through the transcription and noting possible codes - Over the span of months re-visiting this to determine and refine codes - Created field notes from every session working on this
Phase Three: Searching for themes	- Reviewed codes and field notes critically to determine if codes overlapped in meaning or not - Developed distinct themes - Used SocNetV 2.4 software to visualize codes and themes
Phase Four: Reviewing themes	- Reviewed notes from transcription, developing codes, and developing themes extensively - Went through dozens of iterative cycles of evaluating themes for distinctiveness and overlap.
Phase Five : Defining and naming themes	- Developed final theme names and created definitions for each theme - During this process made some final consolidating changes to themes
Phase Six – Producing the report	- Wrote Chapter Four: Findings and Chapter Five: Discussion and Conclusion

Braun & Clarke (2006) begin their description of the six phases by noting that thematic analysis requires a continual process of engaging and re-engaging with the data and analysis that you are providing to describe the data. They also mention that "writing is an integral part of analysis… writing should begin in phase one… and continue right through the entire coding/analysis process" (Braun & Clarke, 2006, p. 86).

3.5 Research Ethics and Research Rigour

To conduct a proper research project certain quality control measures have to be taken. Research ethics is an important and necessary process to understand, be considerate of, and be approved for. Another important concept to implement is research rigour, through transparency of how the research was conducted and what verification strategies have been implemented.

3.5.1 Ethical Considerations

To ensure this research is in line with the Tri-Council Policy Statement, UNBC Research Ethics Board (REB) clearance was obtained through UNBC prior to collecting data (E2015.0204.010.00; see also, **Appendix Three** and **Appendix Four** for Consent form and Information Letter). This research seeks to respect the need for human dignity, to do no harm, and to enshrine the three core principles of: 1) Respect for Persons; 2) Concern for Welfare; and 3) Justice (Government of Canada, 2016).

A potential ethical concern in this research is the role of power dynamics. The process of knowledge exchange and the implications of this process should not be considered benign by default. Fazey et al. (2013) explore power implications as important considerations in a knowledge exchange process. This reflects the fact that deciding who and what knowledge is included or excluded from the process is important. In this research, attention to and acknowledgment of the role power plays included: asking collaborating researchers to identify audiences they wish to enhance communication with, striving to have equal numbers of male and female participants, and seeking to be inclusive of a diverse range of participant perspectives, while acknowledging that there are more perspectives not yet being voiced.

In Phase I and II there is the possibility of a conflict of interest as well as psychological and social risks resulting from including members of the IWRG in data collection. This is especially due to the fact that Committee members and IWRG team members who were involved with oversight of the research, were participants in scoping discussions, workshop and focus group activities, creating a dual role situation. One way to address this was the fact that one member of my committee was not included in data collection methods. There was also the possibility that during discussions in the focus group that differences of opinions could lead to emotional turmoil. However, this possibility is no greater than would occur in daily interactions.

3.5.2 Research Rigour

Research rigour can be considered the trustworthiness of how research is conducted (Morse et al., 2002). To maintain research rigour, strategies need to be put in place early in the research process to establish the trustworthiness of the work (Hay, 2016). One method I used to maintain rigour is a verification process of checking, re-checking, and confirming (Morse et al., 2002) through participating in an on-going and iterative research process with the data, co-supervisors and the larger thesis committee. While this formalized research process is required by UNBC, it is still an important aspect of maintaining rigour. This research was approved and complies with the UNBC Research Ethics Board policies.

In addition to a verification strategy, this research also recognizes the importance of reflexivity and triangulation as methods to maintain rigour. Reflexivity is the "process of constant, self-conscious scrutiny of the self as researcher and of the research process" (Hay, 2016, p. 34). This concept is built into the research design by having iterative phases of research. At the end of each phase, analysis and reflection on what has been learned through the phase is used to refine the following phase. Triangulation or the use of multiple types of data and data sources to ensure rigour in research (Hay, 2016) is reinforced by having different sampling groups for the phases, and by conducting workshop focus group hybrid sessions, keeping field notes, and all the other methods used to collect or analyze data.

The two phased design of this research ingrained the requirement to regularly reflect, check how the progress was coming along, and adapt when changes were necessary. Both phases of research were informing the other phase. Phase I and Phase II had plenty of reflection points built into them. In Phase I, after every meeting or new feature learned or developed for the IWRG Portal, it was necessary to reflect on my process of discovery and learning, as well as to consider how this new information may impact future Portal users, and how data should be presented in Phase II. In Phase II, comments and findings from participants helped direct focus onto how features may need tweaking or require new features all together. The interaction between both phases only ended after the workshop and focus group (Section 3.4.3) was completed. The reflecting and taking an iterative approach did not end with the focus group though, as it continued right up to the conclusion of this thesis.

This chapter has outlined the two phased iterative design of this research. The methodology of pragmatism and methodological influences of ecohealth and knowledge exchange that guided this research were also discussed. The methods that were used were presented and explained along with consideration of research ethics and research rigour.

Positionality considerations which inform methodological considerations, were introduced in Section 1.4. Chapter Four will present the findings of this research.

Chapter Four: Findings

This research is divided into two distinct phases, and accordingly, the findings presented in this chapter are presented in two parts. The first section covering Phase I establishes some of the technical details of the Portal, while the second section is a more standardized section and discusses the findings from Phase II. The two sections of the findings section will be structured differently reflecting the disparate research design and methods introduced in the previous chapter.

4.1 Phase I Findings

As explained in Chapter Three, Phase I of this research was focused on establishing an 'instance' of the IWRG Portal and learning how to properly set it up, administrate, and establish content that is related to climate, ecosystems, and well-being within the Nechako Watershed. The findings shared here relate to the establishment of the IWRG Portal. Drawing on the work done throughout this research, the findings from the Phase I process are presented as a description of the characteristics of the IWRG Portal. To accomplish this, an overview of the IWRG Portal is provided detailing what the portal tool is, and also providing insight into the features and functions of the IWRG Portal. This section of the findings also describe the architecture that the IWRG Portal is built on and provides a summary of the data that were prepared and uploaded into the IWRG Portal during Phase I, and in preparation for Phase II. Training documents that were created during Phase I are provided as **Appendix Five.**

4.1.1 The Integrated Watershed Research Group Portal Tool

The IWRG Portal is a web-based tool that integrates non-spatial and spatial data in a map-centric context. There are multiple, different iterations of the Portal in existence. For example, the Tsilhqot'in National Government (TNG) has an iteration they have named the Tsilhqot'in National Government Stewardship Portal (Tsilhqot'in National Government, 2021). The TNG and IWRG Portals are both based on the same architecture. However, their purpose, use, and look are slightly different. From this point onwards, reference to the Portal refers to the tool itself, which is shared across multiple iterations, and reference to the IWRG Portal is referring to the specific instance of the Portal related to the IWRG.

The Portal is probably best understood as the combination of multiple, different tools and features. The Portal is a database, or digital file cabinet, that allows users to store data using forms that Portal administrators design and provide for users. These forms are customizable and can be made to suit virtually any purpose. In addition to the form-based data, the Portal allows users to attach digital files with each individual form submission. These digital files, whether they are photographs, videos, document files, audio, or any other digital file type, are linked directly to the submitted form. The attached files and the submitted form are related in the database. While relational databases are not new, the Portal goes a step further and relates the above-mentioned data to spatial data. Key features of the Portal are presented in Box a.

***Box a**: Key Features of the IWRG Portal, identified and described through Phase I research*

- *Map-centric*
- *A spatially referenced, web accessible database*
- *Uses form-base data*
- *Links spatial and non-spatial data in a relational way*
- *Allows for key-word searches*
- *Permanent and stable records system*
- *Secure sharing platform*

The Portal is map-centric, implying there is an obvious orientation towards maps and spatial data in general. Spatial data, like non-spatial data, require an organization structure to display the appropriate data. However, for spatial data schemas are used. Schemas allow the Portal to display the attribute data contained within the spatial data. With a blank schema the Portal will display the actual points, lines, or polygons of the spatial data. When an appropriately designed schema is applied, the user will be able to explore the full depth of the spatial data attributes.

In addition to being able to store both non-spatial and spatial data, the Portal goes another step further and links the two in a relational way. This means that the form-based non-spatial data and the spatial data are both directly associated with each other. The spatial data are uploaded directly to the form in a similar manner to non-spatial data. Due to this relational status, users are able to find and explore both the spatial and non-spatial data quite easily.

Like many online resources, the Portal allows for keyword searches, which on the default settings will search keywords throughout the entire form to make matches to the searched word(s). Seeking data using this method allows users to see the form and the details it contains, as well as to see if there are relevant spatial data associated with the form. The user can also download the spatial data directly from the form to their own computer if they desired. If the user explores the 'Add Layer' feature under map tools, they are able to search through the available data using Portal Schemas or the actual submissions previously made that have spatial data. In addition to being able to add spatial data to the map without searching through forms, when spatial data are displayed users can view the attribute data provided by the schema. Within every schema is a direct link back to the form associated with the spatial data, allowing users to quickly go directly to the form-based data from the spatial data.

The Portal was also developed to be a permanent and stable records system. This means that everything uploaded to the Portal is permanent and cannot be deleted or edited in any way by the original user who uploaded it, or any other users. Since every user has a unique username, Portal administrators and other users can easily attribute each form submission to the exact user who made it. This serves as a form of accountability, as no one is anonymous, and it also means that all uploaded data remain the same as they did upon being uploaded.

The Portal also provides a secure sharing platform. The administrators of each instance of a Portal are required to assign individual and group permissions to every user. When uploading a new submission, the uploading user is able to direct the Portal to share the submission with the appropriate groups and users, or if they so desire, to everyone on the Portal. This allows for multiple user groups to use a single instance of a Portal, while also controlling which data they share with other people.

4.1.2 Portal Architecture

The Portal comprises extensive, custom code in multiple programming languages, and since this tool is open source, this code is available from Scott Emmons and his team. Instead of getting into an in-depth and technical discussion about this custom code, this subsection briefly outlines the various systems that the Portal makes use of as core architecture. This provides context and understanding about the general structure of this tool, and a starting point for individuals interested in learning more. This section discusses the role of PostgreSQL, PostGIS, and Apache in making the Portal a functional web tool.

PostgreSQL is an Open Source object-relational database system that is a well known for being a reliable database for the past 30 years (PostgreSQL, 2021). This database system (and the data stored within) represents the data foundation of the Portal and is the software that stores all data uploaded. PostgresSQL works on all the major operating systems and is free and Open Source. At a philosophical level, it fits well into the Open Source approach that is at the core of the Portal. In addition to being Open Source, on its website the PostgresSQL database is described as follows:

> *"PostgreSQL tries to conform with the SQL standard where such conformance does not contradict traditional features or could lead to poor architectural decisions. Many of the features required by the SQL standard are supported, though sometimes with slightly differing syntax or function. Further moves towards conformance can be expected over time. As of the version 13 release in September 2020, PostgreSQL conforms to at least 170 of the 179 mandatory features for SQL:2016 Core conformance. As of this writing, no relational database meets full conformance with this standard".* (PostgreSQL, 2021).

PostgreSQL is a Relational Database Management System, which is most easily understood as being the software that stores, organizes, and provides access to data when properly queried (What Is a Relational Database Management System?, 2021). Another way to think about PostgreSQL is to imagine software that stores and organizes Excel tables. Data are stored in tables that are set up by administrators and developers to hold particular bits of data. In this example, think of the forms that currently exist in the IWRG Portal. Each form is essentially a table within PostgreSQL, with its own unique columns of data. The relational aspect of a database means that these tables of data are able to be queried by individual elements of the table, or in this case, a single cell or record from the table (What Is a Relational Database Management System?, 2021). Having a relational database then allows the Portal to be setup to have a keyword search system, because the search is looking through the various rows and columns of the database to find a match to the word being searched. When it finds matches, it will provide those as results of the search.

This section has outlined what PostgreSQL is and the role it plays within the Portal in terms of non-spatial data. Another reason this software was integrated into the portal is due to the availability of a geospatial database extension, PostGIS (PostgreSQL, 2021). PostGIS provides PostgreSQL databases with the ability to store spatial data and display them within a web map. As PostgreSQL is a relational database, and PostGIS integrates and extends the databases capabilities, the spatial data are also relational. To illustrate how PostGIS integrates into the Portal, consider the PostgreSQL database and the forms created within the Portal to input and display data. Much like this, with PostGIS the spatial data have schemas that are set up by Portal administrators that fulfill the same role as forms. These schemas are designed to match the attributes that are desirable to be visible within the Portal when uploading spatial data. While the PostGIS extension software does significantly more than what has been discussed here, the general concept of what this software does is sufficient to gain a deeper insight into the Portal. The last software that is going to be discussed is Apache HTTP Server, which is how the Portal is brought to life on the internet.

Apache HTTP Server (Apache), is an open source project that has been led with the same goal since it was first launched in 1995: to develop and maintain in Open Source a HTTP server that works on UNIX and Windows platforms (The Apache Software Foundation, 2021). As of April 2010, the developers of Apache recognized over 120 million servers running this software (The Apache Software Foundation, 2021). This software provides users the ability to take an offline webpage concept, and share it live with the internet. Apache allows a single machine to support multiple virtual hosts or machines, while recognizing that each virtual host requires a unique web address or IP. The ability to recognize virtual hosts allows multiple iterations of Portals on one computer, allows administrators to have testing and production versions on a single server. The most critical aspect to understand about the Apache software is that it is a tool that provides the mechanism to share the Portal through the internet.

4.1.3 Data used in the IWRG Portal for the Phase II Workshop

This section describes the data that were collected, formatted, and uploaded into the Portal, and used in the Phase II workshop. These data are maintained in a separate test database for the IWRG Portal, and have also been brought into the current or 'live' database that is being used for the IWRG Portal. The findings described in this section do not draw on the data that were worked with when planning and designing the Phase II workshop. Instead, workshop participants were provided with datasets enabling them to explore contributions relating to one or more of the categories of climate, ecosystems, and well-being. In cases where data had such use restrictions these data were omitted. A summary of the data used in the workshop is provided in Table 2.

The biggest determining factor if a particular dataset made it into the workshop was if the data were restricted in use in anyway or not. There were plenty of freely available data that were identified, however some had restrictions on use.

Table 2 Summary of data and information focused on climate, ecosystems, and well-being that were submitted to the Portal for Phase II workshop

Data category	**Description**	**Type**	**Link to Figure or Map**
Climate	Nechako Decadal Mean Air Temperature by Sub watershed. 1950 – 1960 and 2000-2010	Dataset available via ANUSPLIN	Figure 3a and 3b
Climate	Prof. Stephen Déry speaking about climate change	Audio file (.wav) file collected at Stuart Lake	File georeferenced where recoding was made
Ecosystems	Nechako Wildfires 1920's and between 2010-2017	Shapefile	Figure 4a and b
Ecosystems	Nechako anthropogenic disturbance	Raster	Figure 5
Well-being	"The Community Well-Being Index."	Excel table combined with shapefile	n/a
Ecosystems and well-being.	Identifying Youth Place-Based Values in School District 91	Manually digitized a photograph of the maps from the workshop	Figure 6.
Citation information can be found for each dataset in the text below			

The first dataset that falls within the category of climate is titled "Nechako Decadal Mean Air Temperature by Sub watershed." This submission made use of processed historical climate data for Canada from 1950 to 2015, which was provided by ANUSPLIN (McKenney et al., 2011). Aseem Sharma suggested using these data as they are available in a type of spatial data known as rasters. These rasters cover all of Canada and consist of two rasters per day. One raster is a daily minimum temperature and the other is a daily maximum temperature. To process this information into decadal mean air temperature rasters for the various sub watersheds of the Nechako, two Python scripts were written (see **Appendix One** and **Appendix Two**). These Python scripts used GDAL spatial processing tools and QGIS to process the raster data. In brief, this Python script completed the following steps:

1. The national dataset was clipped to the extent of the Nechako Watershed. This involved clipping two raster files (minimum and maximum air temperature) for every day between January 1st, 1950 and December 31st, 2015.
2. Daily values were organized by decade so that the mean values could be calculated. First, the decade's minimum mean temperature was calculated, followed by the maximum mean temperature for each decade.
3. After the minimum and maximum mean temperatures for each decade were known, the decade's mean temperature was calculated.
4. As a final step, the air temperature data were processed through a focal statistics tool within QGIS. This focal statistics tool used the Nechako's sub watersheds as boundaries, which provided the decadal mean air temperature by sub watershed within the Nechako.

As a result of these steps, the Portal contains a form that describes the data, their source, how they were processed, a spatial layer for each decade that can then be downloaded, the python scripts can be downloaded. Two examples of this depiction are provided in Figure 3.

Another climate related dataset that was prepared and selected for the workshop is an audio recording of Dr. Stephen Déry speaking about climate change. Dr. Déry participated in a field trip conducted as part of the UNBC Ecohealth course (HHSC760: Field School in Human Ecology) that took place in the summer of 2017, which involved travelling to Fort St. James for the day, and participating in the planned activities. One of these activities involved going to the banks of Stuart Lake, which is where Dr. Déry sat down for a moment to discuss what climate change would most likely mean for the local area and Nechako. This submission can be found in the IWRG Portal under the title, "Dr. Déry speaking about climate change in the Nechako Watershed." The submission itself has a brief introduction, an audio file (.wav), which can be downloaded. Within the shared layers, this submission also is linked to a shapefile of Stuart Lake, to geospatially represent where this discussion occurred.

Figure 3a: Nechako Decadal Mean Air Temperature 1950-1960

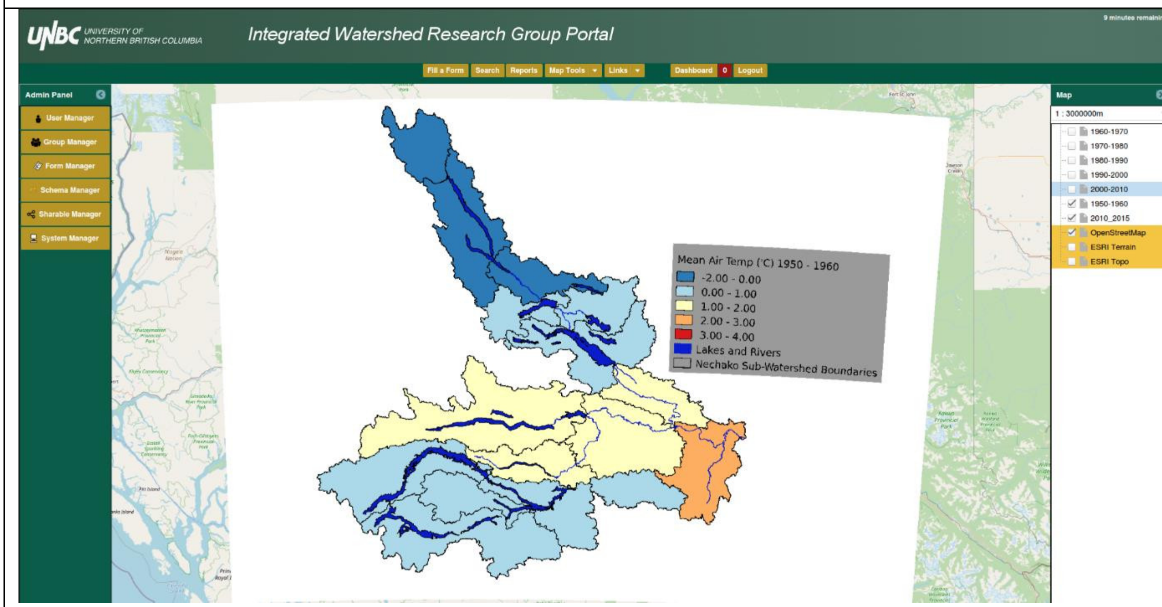

Figure 3b: Nechako Decadal Mean Air Temperature 2000-2010

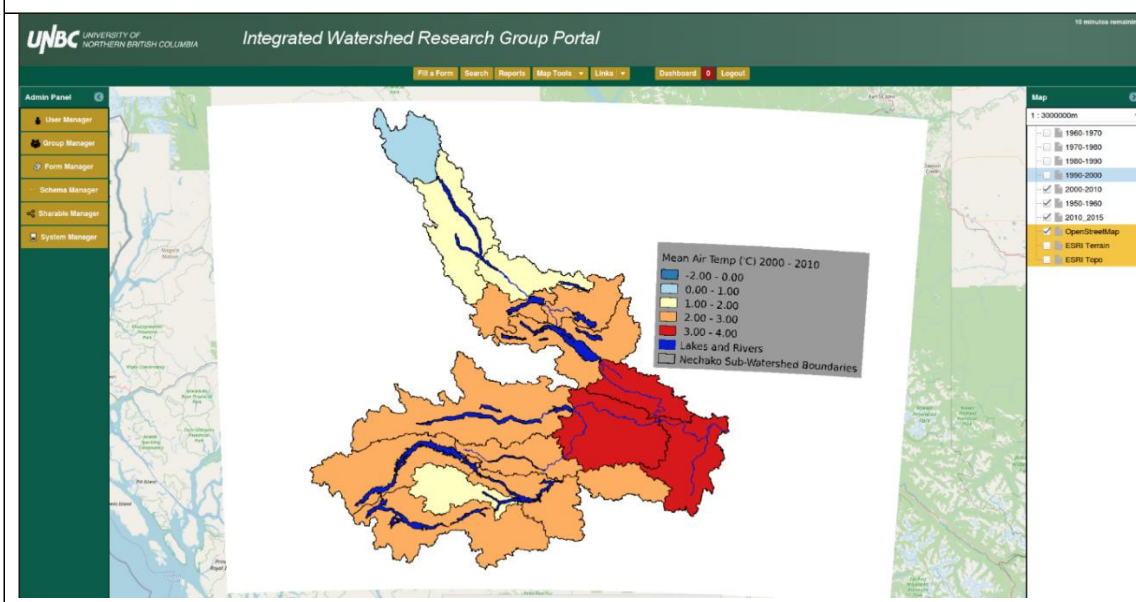

*Figure 3**:** Nechako Decadal Mean Air Temperature (3a: 1950 – 1960 and 3b: 2000-2010)*

An ecosystem related dataset that was formatted for the IWRG Portal for the purposes of discussion at the Workshop in Phase II, is titled "Nechako Wildfires 1920 – 2017," which showcases the size and number of wildfires within the Nechako Watershed per decade beginning in the 1920's. The original data were created by the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, and are updated on a yearly basis. These spatial data are available from the BC Data Catalogue under the title, "Fire Perimeters – Historical" (Fire Perimeters - Historical - Data Catalogue, 2021). Two examples of this depiction are provided in Figure 4.

For use within the IWRG Portal, the data were clipped to the Nechako Watershed boundary, then were divided into different shapefiles for each decade, and the size of each decade's total hectares burned was summarized in each shapefile. The IWRG Portal submission for these data is titled, "Nechako Wildfires 1920 – 2017," and has the shapefiles for each decade available for download or visualization in the IWRG Portal.

The air temperature dataset was developed first because of the need to acquire climate related data for the IWRG Portal. The requirement of having robust spatial data to accompany climate data led to the concept of providing a change over time spatial dataset to showcase how air temperature trends may have changed over time in the Nechako Watershed. This dataset was developed prior to the wildfire data, and whenever data in the IWRG Portal were shown, they seemed to be the dataset that people were the most interested in. Later, in the search for more ecosystem related data, it was suggested that mountain pine beetle data would be interesting since this species has had such a large impact on the region. However, finding appropriate spatial data that I was able to freely share with Portal users on mountain pine beetle proved difficult. In lieu of this, the idea of wildfire data was proposed, fuelled in part by the 2017 summer wildfires that had been a significant issue in British

Columbia. Prince George and UNBC had hosted people who had been displaced and evacuated from their homes due to the fires burning throughout the region. It turned out that the BC government hosted a shareable spatial dataset of historic wildfires throughout the province.

Figure 4a: Nechako Wildfires 1920s

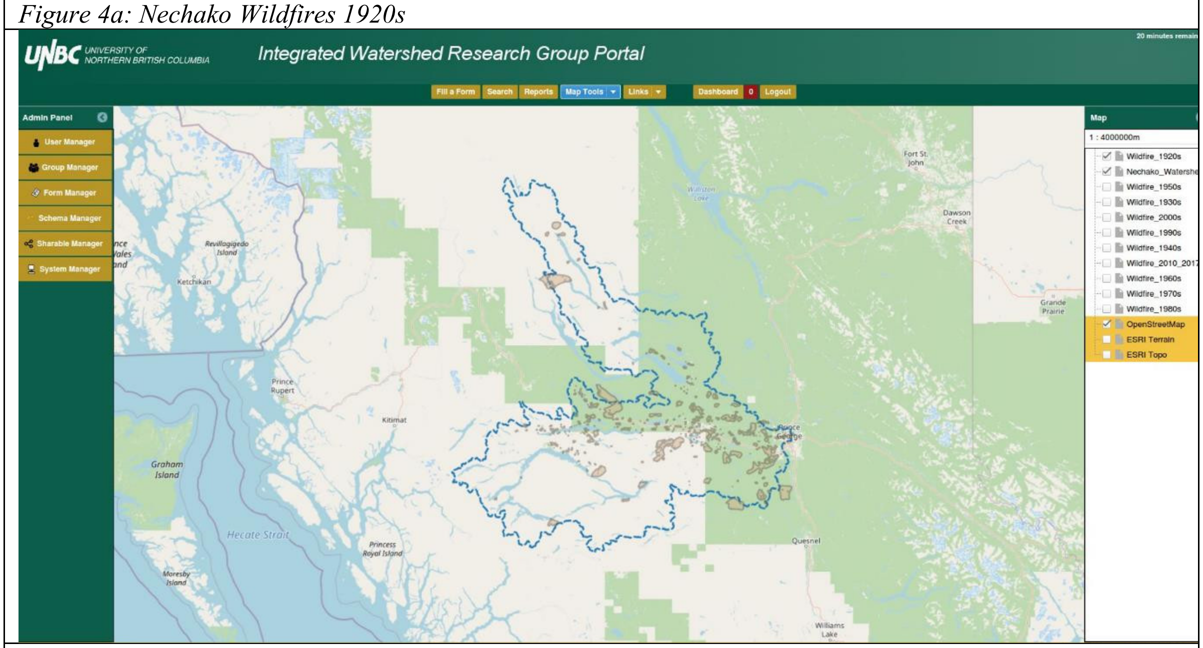

Figure 4b: Nechako Wildfires 2010 - 2017

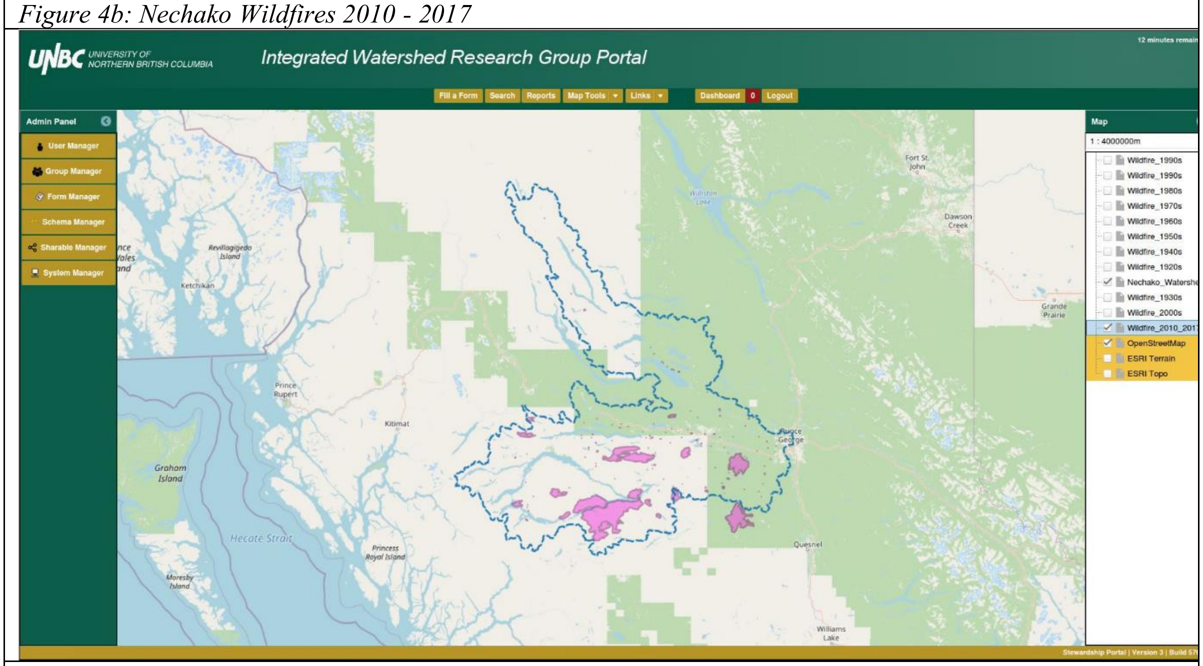

Figure 4 Nechako Wildfires 1920 – 2017. Showing 4a: 1920-1929 and 4b: between 2010-2017

The idea of creating a change over time spatial representation seemed reasonable, since the air temperature change over time was accepted so well. This seemed appropriate since wildfires were such a large issue the year prior and could be argued to touch on ecosystems and well-being since forestry is a major industry in the area. The only intended link between the air temperature and wildfire datasets was that they both were well suited to display change over time. Despite this, it is clear a connection was made for some participants.

Jordan Brubacher, in conjunction with members of the Environment, Community, and Health Observatory Network (ECHO) Network, developed an interesting way to visualize and map the impacts of humans on British Columbia. Jordan worked on and was an active participant in Phase I of this research. Working together, a portal submission titled 'An anthropogenic disturbance map of the Nechako Watershed' was developed from the larger province-wide spatial product (see Figure 5 below). This work represents an attempt to map the combined physical impacts of human activities on the landscape.

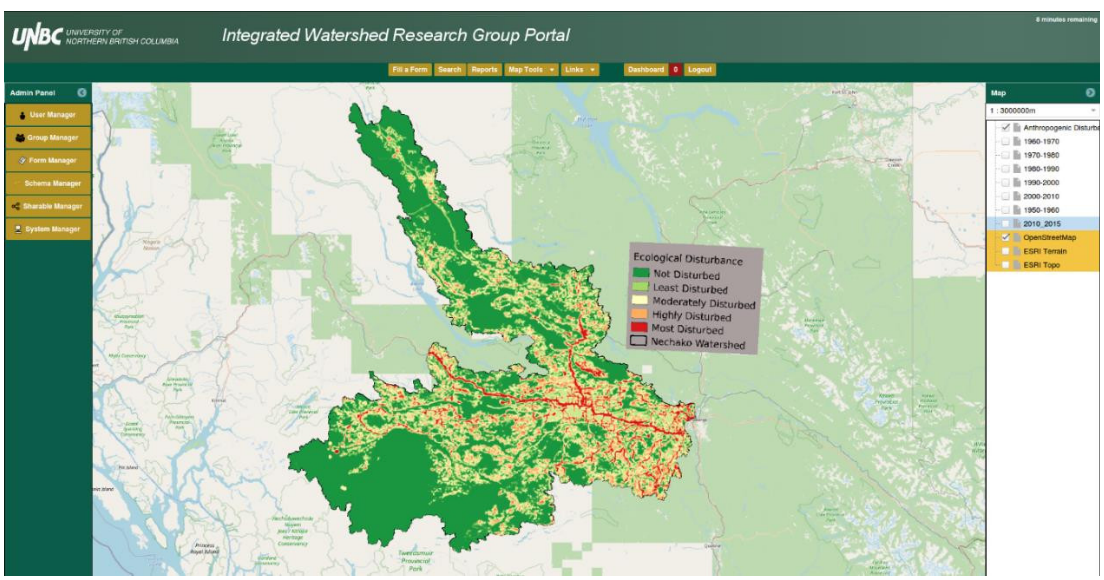

Figure 5: Map of anthropogenic disturbance in the Nechako (Map created by Jordan Brubacher)

An in-depth summary of this work can be found in the Portal submission, along with the original sources of all the data used, the detailed weighting scheme for how Jordan valued different impacts, a thoughtful limitations section, as well as a Web Map Service (WMS) layer that can be added to the map. Note that this work has continued to evolve since initially being submitted to the Portal in January 2018 (Brubacher et al., 2018).

One of the submissions that focused on well-being is derived from Indigenous Services: "The Community Well-Being Index." This index measures socio-economic well-being for communities across Canada using four components: education, labour force, income and housing (Canada, 2015).

To upload these data to the IWRG Portal, a summary, description of the data catalogue that was applied in the spatial data, and the metadata for all the original data and sources were input into a submission titled, "Nechako Watershed Community Well-Being Index 2011." To create the spatial data for this submission, a point-based shapefile was obtained from the BC Data Catalogue (BC Major Cities Points, 2019). Using these data, the various communities within the Nechako were clipped out. A schema was created to provide the details of how the Community Well-Being (CWB) index was created. After the schema was setup, the attributes for each community' income, education, housing, labour and overall CWB score was applied. In addition to the spatial data that were created for this submission, the form also contains the original BC Well-Being Map, the Community Well-Being Index Summary, and a comma separated value (csv) table of the values used for each community.

The last dataset that was entered into the Portal for the purposes of the Phase II workshop, can be categorized as falling into both ecosystems and well-being (see Table 2). In 2017, UNBC's Cumulative Impacts Research Consortium (CIRC) conducted a workshop in British Columbia's School District 91 (SD91), that sought to collect and map the perspectives of youth in the school district in relation to their environment, community, and health values. "The overall goal of this workshop was to learn about the kinds of environment, community and health values that are important to youth living in SD91 in relation to resource development" (CIRC, 2017). The workshop involved three classes of students. Each class was split up into three groups that rotated around three different tables. Each table had facilitators and a map of the school district on transparent plastic material that illustrated a large portion of the school district boundary, and some major features such as highways, lakes, etc. At each table, students would indicate with stickers, or text, the places of importance as it related to the theme of the table: environment, health, or community. The students also talked briefly about what that location was and how they valued it, which was recorded to better flush out their ideas in the final report.

The workshop report can be found at CIRC (2017), or within the IWRG Portal under the name, "Identifying Youth Place-Based Values in School District 91 – CIRC." Within the IWRG Portal, there is a summary of the workshop, and links to the report, CIRC, funders for the workshop, as well as the contact information for CIRC. This submission (Figure 6) in the Portal also has instructions on how to access WMS layers created from photographs of the mapping products the students created.

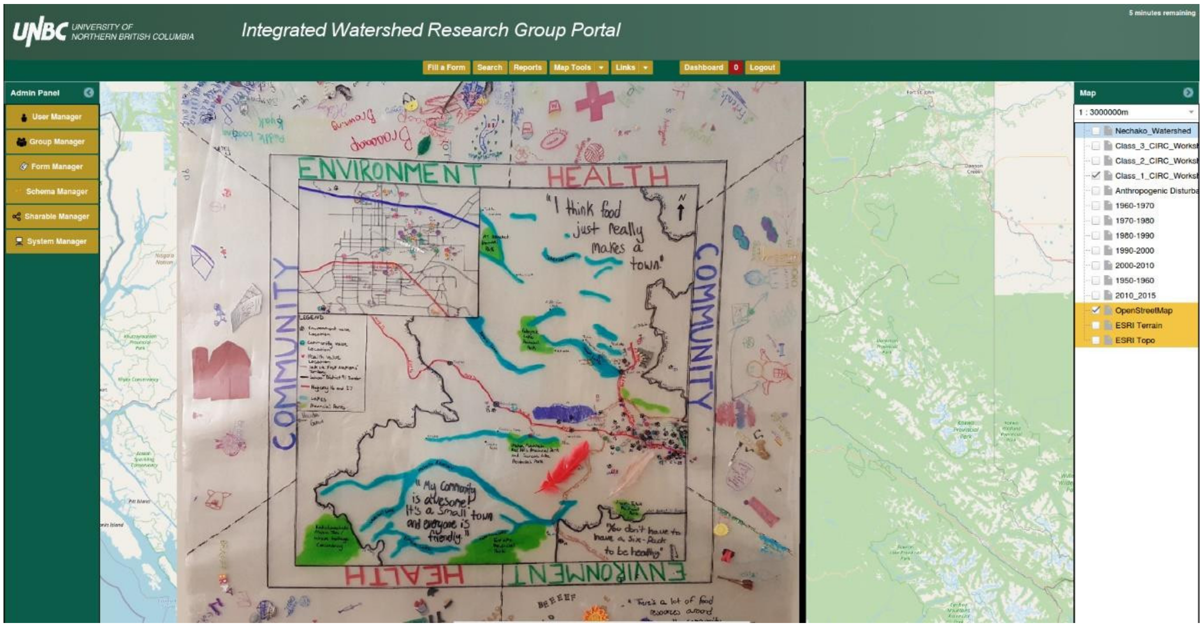

Figure 6: Identifying Youth Place-Based Values in School District 91 (from CIRC 2017)

4.2 Phase II Findings

This section examines the findings from Phase Two of this research. The group scoping discussions generated data and insights about Portal use, but these discussions were not recorded, nor was there any transcription. Instead, field notes were taken during the process and these were revisited prior to designing the focus group. The findings from the group scoping discussion are presented as suggestions and potential 'action items' that resulted from the four small group discussions. The focus group findings have been analyzed, using a thematic analysis approach (Braun & Clarke, 2006, 2014).

4.2.1 Group Scoping Discussion Findings

Four scoping discussions were held with PURG members to allow the opportunity to visualize data in the Portal, and to make comments and suggestions on possible next steps to consider for further developing the Portal and its content. Three main types of suggestions resulted from the scoping discussions: 1) new data for the Portal, 2) changes to the forms, and, 3) user interface changes.

The group scoping discussions resulted in suggestions for additional data that participants thought could be beneficial to have within the Portal. The perceived value of expanding the climate-related data was noted multiple times, and one suggestion was to include updated models of future climatic projections. Another climate-related data source suggested was to show how glaciers have spatially changed over time. One suggestion was to try and pair local historic knowledge with climate data to supplement and validate the climate data. Gaining access to weather stations, owned by the government and private parties, could also fill in data gaps and be displayed within the Portal.

Climate related data were not the only type of data suggested as being a good fit for the Portal. There was interest in having data on the mountain pine and spruce beetles, and historic paper maps scanned and georectified. Data and information overtly linked to First Nations such as place names, traditional territories, and even the grease trails, were other suggestions of relevant information that could be potentially uploaded into the Portal.

These scoping discussions also resulted in suggestions on how to improve the layout and content in the Portal's forms. One suggested improvement was to generalize the forms to make them more useful for other users or situations. Additional sections on the forms were suggested to better capture the limitations of the data, such as how the author(s) prefer to be cited, and to document where the data originated.

The final grouping of suggestions that resulted from the scoping discussions were to make some improvements in user-interface elements. There was interest in including a more diverse range of visualizations in the mapping window. This could include tables, graphs or graphics. There was also interest in adding legends, such as those that would scale accordingly as Web Map Service (WMS) layers were manipulated.

Overall, the Group Scoping Discussion Findings highlighted suggested improvement and action items for me to consider, arising from a series of conversations with PURG members. These can be summarized as potential new sources of data that would work well within the Portal, changes to the forms and how data are entered into the Portal, and user interface changes to improve the functionality of the Portal.

4.2.2 Focus Group Findings

The workshop and discussion was informed by the scoping group discussions as described in more detail in Chapter Three. Eleven people participated in the combined workshop that took place May 22, 2018. It involved a workshop of sixty minutes, and a focus group discussion of ninety minutes. I recorded and transcribed the focus group discussion. Field notes were taken before, during and after the process. Thematic analysis of the focus group transcriptions resulted in three themes: 1) tailoring content for the audience, 2) the perceived benefits of the Portal and, 3) the perceived limitations of the Portal. Each are described below in relation to themes and sub-themes (Table 3).

The three themes have evolved through the course of the thematic analysis process. Tailoring content for the audience is concerned with customizing presentations and presentation style to be as appropriate as possible for the intended audience. The perceived benefits of the Portal captures the focus group participant’s thoughts on the Portal as a tool, whereas the limitations explore the weaknesses of the Portal. In the sections to follow, each of the themes is described in relation to subthemes that emerged in keeping with Table 3.

These ideas are explored and demonstrated through quotations from the participants. Participant quotations are identified as (Participant four) etc.

Table 3: Summary of Themes and Sub-Themes

Theme	Sub-Theme
Tailoring content for the audience	• Making content relatable • Using accessible language • Developing effective visualizations of data
Perceived benefits of the Portal	• Tools that may help deal with aspects of complexity • Many different and potentially integrative aspects
Perceived limitations of the Portal	• Data require intentional and careful framing • Steep learning curve • Requires an active internet connection

4.2.3 Tailoring Content for the Audience

The theme of tailoring content for the audience emerged as a code during the thematic analysis. It eventually evolved into a theme because it had so many other codes, which eventually became sub-themes that contributed to it. The theme of tailoring content for the audience represents the idea that to effectively communicate to a particular audience, it is necessary to consider who the audience is, and how the information can be effectively presented to them. In the focus group, it was generally accepted that to communicate effectively it is necessary to mold communication strategies to particular audiences. Participants three, four, and eight all explicitly mentioned the need to know who the audience was, and to make changes that are appropriate to the content and presentation manner for that audience. Analysis of the focus group discussion also identified sub-themes and suggestions on how content can be tailored for specific audiences (see Table 4), which included: making content relatable, using accessible language, and developing effective visualizations of data.

The first sub-theme presented in Table 4 is making content relatable for the audience. This sub-theme is concerned with situating information in the context of the audience. For example, Participant three said this is about “trying to find ways to ground it in people’s everyday lived experience.” Participant two mentioned that when giving presentations on the Nechako Watershed, they start with a story detailing the history of the watershed.

The next sub-theme in Table 4 is the use of accessible language, which strives to use appropriate language that can be understood by the audience. Participant four provided concise advice for this sub-theme, “just try to avoid the jargon that we use in our day to day conversations for my field.” Participants in the focus group discussed the need to get away from jargon, recognizing it is helpful for people who share a field of study or expertise, but it also can be a barrier for anyone who is not part of that field. Participants also suggested that in addition to avoiding the use of jargon, people should try to use language that is concise and gets right to the key points of the subject.

Table 4: Focus Group Quotations relating to "Tailoring Content to Audience" theme

Quotes coded in relation to "Tailoring Content to Audience" (with participant)	Sub-theme
"trying to find ways to ground it in peoples everyday lived experience. If I'm talking about cumulative impacts or cumulative effects, you know coming with an understanding of the place and being able to populate the idea with a particular example that people might be familiar with. So the use of examples, the use of metaphors, use of stories, trying to find alternative ways to bring your message to life." (Participant three)	Making content relatable
"you start the discussion with a story about the Kenney dam. And you gotta back peddle you've got to put it into a geographic scope" (Participant two)	Making content relatable
"and it's a really cool way of telling a story because you need to have narrative but you also need, you can put slides up but to have a Google Earth kind of thing it brings the scope and scale that people need, there are times that I can, when people's jaws are dropping and they kind of go … and it did that and it did that" (Participant two)	Making content relatable
Umm so the inclusion of a lot of visuals right, just try to avoid the jargon that we use in our day to day conversations for my field, which is climate change and water resources" (Participant four)	Using accessible language
Participant four's point about getting away from walls of text, about using images and graphics really effectively, again this sort of speaks back to the audience. I'm not going to put up a really big complicated table with tons of numbers on it at a public workshop. It would be better to highlight you know in a single sentence what the one take away is from that wall of numbers that I want people to be engaged in" (Participant three)	Developing effective visualizations of data

Making effective use of visualizations to summarize and explain complex topics is another sub-theme of tailoring content for the audience. Understanding that everyone learns differently, visualizations can be a powerful way to increase the likelihood that your audience will be able to engage with the content. Participant four noted that they like to include a lot of visuals, while Participant three followed up on this point by adding that avoiding "walls of text" and "really big complicated tables with tons of numbers" is important. Participant three also said that, "using images and graphics really effectively" was an aspect of tailoring presentations for specific audiences. In addition to the normal suite of visualizations, such as photographs, models, charts, etc., the concept of spatial visualizations, such as maps and spatial data, was brought forth. Participant two provided a description of how they provide a history of the Nechako Watershed.

> "So I start off with a Power Point presentation which is fine and then I need to switch to Google Earth which is fine, then I switch back to Power Point, but it's an incredibly powerful tool because it does exactly what you are talking about. It brings, you start the discussion with a story about the Kenney Dam. And you gotta back peddle, you've got to put it into a geographic scope, you've gotta, you have to be able to show that one a map, you have to be able to show this is where the dam is, before the dam was there it looked like this and all I have is a paper map, but that is ok. A paper map on a Power Point presentation, and then they built the dam and this happened and to be able to demonstrate, they decided they were going to build the dam, then they dug these tunnels, so that's on Google Earth, that's a clickable thing, that's an attribute. Here's the dam, click, here's the tunnel, click, here's where they put the water in, click, here's the hydroelectric facility right of way they've built, click, and here's the smelter in Kitimat. It's had these implications for this, here's the spillway for Cheslatta, click, and it's a really cool way of telling a story because you need to have narrative but you also need, you can put slides up, but to have a Google Earth kind of thing it brings the scope and scale that people need, there are times that I can, when people's jaws are dropping and they kind of go … and it did that and it did that. Then I have pictures from Cheslatta of houses being burnt. You know when the people in Cheslatta were forced from their homes, the government actually burnt their homes and here are pictures of the homes being burnt." (Participant two)

This quote emphasizes how combining non-spatial and spatial visualizations can complement and add meaning to a presentation.

4.2.4 Perceived Benefits of the Portal

The perceived benefits of the Portal was a theme that connected across several sub-themes all describing benefits and strengths of the portal noted by focus group participants. This theme is described here in relation to two main sub-themes: first, the Portal has tools that deal with aspects of complexity, while the second was recognizing that the Portal has many different and potentially integrative aspects (Table 5).

> "[T]oday is the first time that I think I've saw some of the true potential of the Portal, being able to visualize these multiple layers and trace connections between temperature data, fire data, school district value data, seeing that all in one place to me the integrative potential is kind of limitless and really exciting" – Participant three

Table 5: Focus Group Quotations relating to "Perceived benefits of the Portal" theme

Quotes coded in relation to "Perceived benefits of the Portal" (with participant)	Sub-theme
"So there is something in there about trying to communicate change that I think is very interesting. And so change over time is, is always very powerful and interesting. And so you can imagine change over time on the landscape with a visual thing. Let's just take the wildfires or pine beetle, and so there's always how we communicate the change over time of a particular thing and then there's that messiness of how we might have a conversation about how change over time with climate might be related or not related to change over time with wildfires which may or may not be related to change over time in terms of forested landscapes you know areas, you know forested landscape." (Participant nine)	Complexity
"I couldn't help but think about that idea of resolution. You know really drill down on a particular thing, and looking at the attributes of a particular stream for example to use Participant ten's idea. Then I just scroll out and I see that this stream connects to another stream, you know what there's actually data over here that's connecting the two. I can scale out all the way to the watershed level, and say oh now there's actually dozens of observations just related to the stream and how might that relate back to some of Particiant four's really savvy climate model or climate observations back over time. So that idea of the resolution with which we are viewing things becomes a really powerful way to communicate how everything is connected." (Participant three)	Complexity
"So for me there is a total exercise here of focusing in on the singular element and recognizing they are part of a bigger much more complicated or complex whole. And in theory that's kind of the territory that the Portal's moving us towards. It's not just issues of scale, its issues of values, its issues of time if we wanna do the temporal dimension." (Participant three)	Complexity
"[s]patial really works… I think. To mix that with the non-spatial I think how the Portal is laid out right now can really work in that sense. Cuz I like how the portal, Portal 3 is map centric. We can get the spatial stuff in but then it links us to more stuff like documents, having not, if you are interested. It creates a picture like that, I think that's just how it works. Going from spatial first and then to non-spatial if you're interested. I think that's a good way to put it." (Participant eight)	Integrative

The sub-theme of tools beneficial for dealing with complexity reflects participants' descriptions of the Portal's ability to allow users to examine data at various geographical scales. This may be helpful to make connections in systems that otherwise may have been difficult to visualize. Participants two, three, and five all discussed how the ability to visualize and explore data at different scales enhances understanding of issues and systems that are difficult to explain. Participant five discussed how different types of maps and spatial data can "get people thinking about the multidimensional way things are connected." Participant five also described ways to spatialize data that are normally non-spatial using mind maps to aid in connecting ideas and larger concepts, and by allowing people to provide feedback. Participant three described the ability to adjust the spatial scale we look at data in the Portal to better understand a watershed starting with a single stream as an example of trying to find ways to ground information in people's everyday lived experience. Participant three also described how they imagine an individual may use the data within the Portal to better understand a watershed by manipulating the spatial scale in which they consume data. This also touches on the concept of approaching complex problems in a bottom up approach that may lead to an improved or more holistic understanding of the issue at hand. Participant three also noted, "[s]o for me there is a total exercise here of focusing on the singular element and recognizing they are part of a bigger, much more complicated or complex whole, and in theory that's kind of the territory the Portal's moving us towards. It's not just issues of scale, it's issues of values, it's issues of time."

Focus group participants also identified the change over time examples as being beneficial for showing long term changes within the Portal. In the workshop, there were two such examples provided. One showed the decadal change in mean annual air temperatures from the 1950's until 2015, and the second displayed wildfires that have occurred in the Nechako Watershed between 1920 and 2017, organized by decade. Many of the participants described these changes over time datasets as being effective. Participant nine mentioned, "change over time is always very powerful and interesting." They also discuss how change over time can lead to complex conversations about how different change over time examples, such as climate and wildfires, may or may not be related, which is a framing limitation that will be discussed in the following section on perceived limitations.

The participants also discussed how the Portal had many different integrative aspects that were potentially beneficial. They identified that the Portal was able to integrate different types or formats of data together in one place where they could be viewed. Participant eight mentioned that they liked how the Portal is map centric, but allows spatial data to link to other data types, such as documents. In addition to hosting various data types within the database of the Portal, it also has the ability to integrate with other databases. For example, participant five described how the Portal can be connected to government databases that serve up wildfire data daily, allowing the Portal to provide users with the ability to see daily updates on wildfires throughout the province. There was also discussion about how a single instance of the Portal, such as the IWRG Portal, could be used across multiple different organizations to share data in a controlled manner.

4.2.5 Perceived Limitations of the Portal

The theme of perceived limitations of the Portal was developed to organize the limitations that participants perceived during the workshop and discussed during the focus group. These limitations are summarized as the following sub-themes: data within the Portal likely require the intentional and careful framing of data, the Portal has a recognized steep learning curve, and also requires an active internet connection to access them, which can be an issue for many parts of the Nechako Watershed (Table 6).

Table 6: Focus Group Quotations relating to "Perceived limitations of the Portal" theme

Quotes coded in relation to "Perceived limitations of the Portal" (with participant)	Sub-theme
"So bringing our own portal back to the community and making sure that everything is ok, is kind of tough. My own challenges I'm faced with you know, there is no wifi in the community, what do I have to there. I have to make screenshots, different presentations, visuals are important. I can't just be just ranting on and on about something, when the jargon that I know they aren't ever going to know right away right? So it has to be a really learning curve and just starting very grassroots, slow, and those are the challenges I've faced so far, but yeah." (Participant eight)	Requires active internet connection
"And I think one of the things that is going to always be really tricky with the portal is like any kind of research, you're not necessarily saying just because they have the same pattern there is actually a cause and effect relationship between these things" (Participant nine)	Intentional and careful framing
"If I put this tool in front of my grade 8 students, they'd be incredibly lost at this point and time. And that's one perspective where a guide or a walkthrough specially with the 80s perspective, that would defiantly resonate with them. But we're dealing with a generation coming up that is very virtual with a very short attention span." (Participant seven)	Steep learning curve
"I think it is still clunky and it will difficult for our younger students to access. But I think you've got the footings in there to build in the interactivity that they're going to need." (Participant seven)	Steep learning curve

Stemming from the focus group discussion about the effectiveness of datasets that show change over time, was a related discussion about how it is important to frame data to avoid situations where different datasets may be mistaken as showing cause and effect relationships. These datasets showed the change in mean annual temperatures, and the number, location and size of forest fires. As described in the perceived benefits sub-theme in Table 5, Participant nine described change over time as being a powerful tool. However, they also point out that there can be a "messiness of how we might have a conversation about how change over time with climate might be related or not related to change over time with wildfires, which may or may not be related to change over time in terms of forested landscapes… [a]nd I think one of the things that is going to always be really tricky in the Portal is like any kind of research, you're not necessarily saying just because they have the same pattern there is actually a cause and effect relationship between these things." Participant nine also describes this situation as being dangerous if there is not any framing to guide users in understanding what the data are intended to describe. Participants one and three both add to the conversation about framing information, acknowledging that having an effective framing system or adding prompts to the data in the Portal could help facilitate people in making connections and even potentially starting new conversations.

Some participants noted that learning to use the Portal was difficult, and that this could make it less accessible to certain people. For example, it was mentioned that younger students would likely have a difficult time. It was suggested that in an attempt to make the learning process easier, that there should be training or tutorial documentation available. Training documents were created to address this concern.

An obvious limitation of the Portal is that it required an active internet connection to access. Participant eight mentioned that "there is no wi-fi in the community" that they work for, and it is necessary to use screenshots and other presentation formats to bring information from the Portal to that community.

This chapter has presented the findings from the study design described in Chapter Three. Phase I findings share my understanding of what the IWRG Portal is as a tool, a high level overview of the major components that power the Portal, and the data that were uploaded and used in Phase II. Phase II findings present the direction and thoughts of participants from the scoping discussions, and then delve into the findings from the workshop and focus group. The findings from the focus group underscore the need to tailor content for the audience, as well as the perceived benefits and limitations of the Portal. Chapter Five discusses these findings in relation to the literature.

Chapter Five: Discussion and Conclusion

The chapter begins with a discussion of the findings in relation to each research question, and also explores other insights in relation to the literature. Later sections discuss implications for future research, recommendations for geospatial development and proposed for practices moving forward, prior to providing concluding remarks.

5.1 Discussion of findings

This section of the chapter consists of four subsections. The first three subsections discuss the findings as they relate to each of the three research questions, and also how these findings resonate with the literature introduced Chapter Two. The final subsection discusses other insights from the literature that are not directly addressed in relation to the research question findings.

5.1.1. Discussion Findings in relation to Research Question 1

This subsection discusses how the findings from this research address the first research question:

RQ1: "How can complex systems such as climate change, ecosystem and well-being be better understood through the use of a map centric web-portal that connects and aligns different sources of information (based on geospatial attributes)?"

A particular theme emerging from the findings that resonates with RQ1 is the perceived benefits of the Portal. Two sub-themes that emerged from the research and which are especially relevant to addressing RQ1, relate to the ways the portal dealt with complexity and was able to incorporate integrative features relevant to climate change, ecosystems, and well-being.

The Portal features that may deal with complexity were emphasised in focus group discussions in ways that directly relate to RQ1. For example, focus group participants emphasized the ways the portal created opportunities to view spatial data and change the scale at which the data were seen. It was noted that this was potentially helpful for individuals to achieve a better understanding of how complex systems such as watersheds are connected from the smallest stream to the whole area it encompasses. This potential to increase understanding of complex systems via geographic representations at various scales may be a result of being able to see connections between the data and the larger environment that the data represent. The focus group participants discussed the importance of creating effective visuals to explain difficult concepts to audiences and also highlighted the importance of being able to support text and verbal dialogue with both spatial and non-spatial visualizations.

The decadal mean air temperature and decadal forest fire datasets that were presented during the workshop (depicted as Figures 3 and 4) were of particular interest to focus group participants, and were noted to be especially effective at representing trends over time. Comparing and contrasting spatial data from different decades, and overlaying these data, allowing participants to better understand how air temperature and wildfires have changed throughout the Nechako Watershed. This finding offers an interesting contrast with Ring's suggestion that it is important to focus on the present state of things to avoid a dilution effect that happens as time passes (Ring, 2015). Picketts et al. (2017) note a similar tendency, stating that they found individuals within the Nechako Watershed were less comfortable discussing implications of climate change as they pertain to the future than they were about the implications currently being faced in the present. Although neither Ring (2015) nor Picketts et al. (2017) specifically examine how information from the past is perceived, this study shows that focus group participants reacted positively to the way the portal presented historic data via spatial visualizations. This could indicate that using past and present data could be an effective way to represent the changes in climate data. It would be interesting to explore if there is a specific timeline people are less likely to relate to, e.g. their lifetime, their parents' lifetime, their grandparents' lifetime, etc.

The decadal change spatial datasets also brought forth a challenge. Having both the decadal mean air temperature and decadal forest fire datasets could potentially give the impression that there is a cause and effect relationship between the trends in air temperature and the amount of forest fires occurring in each decade. However, this was not the intent of having both these datasets in the Portal. Recognising that there may or may not be a relationship between the trends in the datasets, the combination of air temperature and decadal forest fires provided a good discussion point during the focus group about the necessity of providing thoughtful framing to data when they exist in databases such as the Portal. This finding underscores the need to further understand how to frame and present data in geospatial tools such as the Portal. The challenge of users interpreting cause and effect relationships and the discussion about framing data is further explored in Section 5.1.2 which discusses the perceptions of the utility of the Portal.

Other integrative features of the Portal were also found to be potentially helpful in dealing with complex topics such as climate, ecosystems and well-being. Being able to include spatial data, text-based information, hyperlinks to outside content, and virtually any digital content in a single form submission provided users with a system that can integrate almost any type of data. This integration of multiple data types (see section 4.2.4) provides the opportunity to give more supplementary data than a traditional paper, presentation, or map could. Another integrative Portal feature with potential benefits for those seeking to understand complex topics is the ability to link into other webpages, databases, and systems. For example, in the workshop there was forest fire data provided; however, they were all historic data. It is simple to link into the British Columbia government website or any other website that provides the proper services to feed daily data about wildfires (BC Wildfire Service, 2022) or anything else they update frequently, and have these data input directly into the Portal for consumption. This flexibility in terms of data, data sources, and map centric design could make complex topics more accessible for individuals when they are trained on the use of the Portal.

Having a map centric tool such as the Portal provided the focus group participants with another way to explore the data, and this was seen as a positive way to enhance awareness of complex interrelated processes occurring within watersheds. The ability to highlight connections between spatial data and non spatial data was identified as another helpful aspect of the IWRG Portal. Discussion of participant insights about the use of visualization in the Portal, will also be addressed in Section 5.1.3 in relation to Research Question 3.

5.1.2. Findings in relation to Research Question 2

The second research question that this research was designed to address was introduced in Chapter One as follows:

RQ2: "What are the perceptions of knowledge users about the utility of the web-portal as a tool to communicate the links between climate, ecosystems and well-being?"

Knowledge user perceptions on perceived benefits of the Portal noted in relation to RQ1, also have some relevance to RQ2. Since perceived benefits were discussed in Section 5.1.1, this section focuses mainly on perceived limitations of the Portal. Perceptions of focus group 'knowledge users' in relation to portal limitations are discussed here in relation to: 1) the need to carefully frame data, 2) the steep learning curve, and 3) the challenge of needing active internet connection to access the portal; and where possible potential solutions are suggested.

Directly after the workshop designed to showcase the data prepared and uploaded to the IWRG Portal, the Focus Group discussion identified a need to carefully frame data to avoid implying cause and effect linkages between datasets, especially in relation to the two temporal datasets focused on annual air temperature by decade and the Nechako Wildfire data (Figures 3 and 4), both of which were intended to visualize change over time in the watershed. This limitation was also identified as a benefit of this tool (Section 5.1.1).

The discussion about the necessity to carefully frame data being entered into the IWRG Portal started quite early in this research. An early step in preparing data for submission is the requirement of a text-based form to associate with the submission. These forms could be created to be generic and used for a plethora of situations and data types, or they could be very specific and intended for a particular purpose or type of data. Discussions about forms were ongoing among Portal development staff, myself, and Dr. Margot Parkes. These conversations continued between myself and members of the PURG throughout the research. In the end, we decided to move towards more generalized forms that would provide more flexibility than highly specialized forms would allow. Within these generalized forms there is an opportunity to provide all the citation information, as well as room for abstracts and other information that could be used to frame the data. Although it is possible to provide framing information for all data being submitted into the IWRG Portal, there is no mechanism to force users to consult the forms for framing information, and if a person is viewing the spatial data in isolation from their context (form), there clearly can be some confusion.

Focus group participants identified a clear concern with the necessity of framing data to avoid misleading users into thinking the existence of any datasets within the IWRG Portal were connected, and to not misrepresent the data. Although not exclusively identified in relation to the datasets of mean annual air temperature per decade and Nechako Watershed Wildfire, these two datasets exemplified this challenge most clearly. This is because it is easy to relate the changing trends in temperature over the decades to be potentially causing the increasing number and size of wildfires occurring within the Nechako Watershed. While it is possible, even likely, that the changing temperature trend over the decades has had an impact on wildfire occurrence, there are a plethora of other factors that could be contributing to this, and extensive research would be required to make any assertions about the relationship between the two trends. This challenge is recognized in the literature, and there have been suggestions for governments that provide open data to also provide training and educational documents for the public that guide people on how to access, use, and interpret data from open sources (Johnson et al., 2017). While I developed training documents on how to use the IWRG Portal (**Appendix Five**), a next potential step could be to provide training resources for people to better understand the process of finding data, transforming them into a product that is visualized, and understanding this new version of the data (Johnson et al., 2017).

This challenge of framing data is particularly interesting because while this particular example was framed as being a challenge or issue, it was also established that participants considered the ability to explore data spatially, to be able to see patterns, and to identify connections that would otherwise not have been as easy to discover as a benefit of the Portal. The making of a potential link, or cause and effect connection between temperature changes and wildfires could be considered to be another example of this 'benefit,' though this is not how participants generally saw it. Framing data is important, but it needs to be noted again there was no framing made to influence people into thinking there was a connection between these datasets, at least beyond the themes of this research and the area of interest being the Nechako Watershed.

The second important limitation identified by the thematic analysis is the steep learning curve required to learning how the Portal works. Tools that communicate complex information should be as simple as possible while still being effective. It is worth noting that even a relatively simple visualization tool such as Google Earth is even too complicated for some individuals (Johnson et al., 2017). Songer (2010) notes that Geographic Information Systems, generally have a significant learning curve due to their complexities (Songer, 2010). While web-GIS services have historically been easier to learn, this is partly because these online services offered less functionality and tools that reduced the barrier to entry (Songer, 2010). With the evolution of web-GIS services, there has been a consistent trend to increase the functions available, making some web-GIS services more like the desktop GIS programs, which also increases their complexity and the learning curve necessary to use them. As Johnson et al. (2017) note, geospatial visualization and analysis tools will not be beneficial to all people, but it remains an important goal to make these tools as user friendly and accessible as possible.

Compared to many other web-GIS services (LEO Network, 2021; Pickard et al., 2015; Reed et al., 2010) the IWRG Portal offers more functionality, tools, and features including the features outlined in Box a, many of which are also associated with the strengths and limitations being discussed here. While the Portal provides users with additional functionality (see Section 2.2.2 and Figure 2), it also creates the need to have a greater understanding of how more traditional GIS operate, which means there is a steeper learning curve and a larger barrier to entry with the service. When it comes to web-GIS services, there appears to be a fine line between additional tools and functionality. This challenge relates back to the theme of tailoring content for the audience, knowing who the intended audience is, and developing tools that are the best suited for that audience. The Portal User Guide (**Appendix Five**) is one attempt to address the challenge of a steep learning curve, and to teach new users how the navigate and use the IWRG Portal. This guide provides an explanation of what tools and features are available, where to find them, and how to use them. While it does not eradicate the steep learning curve, it does provide a degree of improved accessibility to the IWRG Portal. This guide has also provided a foundation for further training materials and approaches, including a series of YouTube videos and tutorials that have been created by researchers with the ECHO Network to introduce and orient Portal Users (ECHO, 2021).

A further important limitation of the IWRG Portal is the fact that users require the internet to access it. Internet connectivity is a problem in 60% of rural BC communities, and 62% of BC Indigenous communities do not have access to high speed internet. High speed internet is classified as being at least a download speed of 50 Mbps (Ministry of Citizens' Services, 2019). This issue of internet equity has been and continues to be addressed by the BC Government since the focus group was held. As well, Portal development has made progress on being more easily accessible on mobile devices such as smart phones and tablets, and has even established methods to collect data in the field when there is no internet access. Examples of mobile devices and tools creating ways to import data into the Portal (using tools such as Geopaparazzi), are also profiled on the training videos and tutorials on the ECHO Network YouTube channel (ECHO, 2021).

5.1.3. Findings in relation to Research Question 3

The third and final research question that this research sought to address is:

RQ3: "How can existing data about climate change, ecosystems, and well-being be leveraged in a way that fuels conversation, new perspectives and awareness of connections?"

This research question was most notably addressed by the findings relating to the theme of "tailoring content for the audience" in Section 4.2.3. The theme of tailoring content for the audience focuses on the importance of customizing materials with the intention of making the information more accessible for that particular audience. The three sub-themes presented in Section 4.2.3 offered suggestions on the types of considerations that should be made when considering the intended audience and in this section these themes are going to be discussed in relation to the relevant literature.

As outlined in Section 4.2.3, the focus group participants emphasised a close connection between tailoring content for the intended audience and the need to make content in the portal relatable, also underscoring the connection between the presented information and the audience's own experiences. Ring (2015) notes that targeting and identifying the audience is a critical element in this process. While this approach is not infallible, if one has a good idea of what kind of audience will be attending you can more easily aim to provide audience specific material. One way to make content more relatable for the intended audience is to provide examples that are localised within the region the audience lives in. This can make the data more meaningful and also easier to understand than national or global examples. This supports the suggestion by Tabara et al. (2017) who state that data presented at global and regional scales make it difficult for people to relate those data to their everyday experiences. Applying a watershed scale approach when thinking about ecosystems has the potential benefit of making connections across health benefits, networking across communities, and a heightened sense of place (Morrison et al., 2017; Parkes & Horwitz, 2009), but this may depend on the size of the watershed in question. This underscores the potential value of reducing the scale to one that people can relate to, in keeping with the findings presented in Sections 4.2.3 and 4.2.4. While there is support for using watershed scale approaches in the literature, is this an effective approach for the Nechako Watershed?

The Nechako Watershed covers an expansive area of approximately 47,200 km^2, which makes it larger than Switzerland (Albers et al., 2016), and 1.5 times the size of Vancouver Island (Figure 1). This is certainly not an area that should be classified as being 'local,' and highlights the challenge people may experience when considering a location that is a substantial distance from their everyday travels. A range of proposals have been made to 'localise' watershed approaches by reducing the area being considered, such as dividing the watershed into sub-watersheds (Ison et al., 2007; Jenkins et al., 2018; Morrison et al., 2017; Parkes, 2016; Parkes & Horwitz, 2009). There is also no reason one cannot reduce size again to an individual stream and brook level. This is common in research and conservation work including in the Nechako. For example, the Murray Creek which flows through the town of Vanderhoof is the site of many restoration and conservation matters. In fact, the IWRG is working with the school district to collect water quality data from the Murray Creek. Using geospatial tools, such as the IWRG Portal, this can quite easily be accomplished by allowing users to zoom in and out at any point through the map interface, while also providing the spatial data for the entire watershed and the sub-watersheds for further guidance.

In the focus group, a participant described their efforts used to convey some of the history of the Nechako Watershed, in an effort to make the content relatable to newcomers to the watershed. Having personally experienced a version of this onboarding presentation, I appreciated the use of historic and current photographs, Google Earth, and cross-references to a map on the wall of their office. Using narrative and metaphors to convey information is recognized in the literature as an effective method (Gislason et al., 2021; Ring, 2015). Using multiple mediums along with telling a story about the history of the Nechako Watershed not only makes content relatable, but also resonates with all the sub-themes of tailoring content for the audience, and underscores the idea that having different approaches to presenting data can lead to new conversations and perspectives on existing data.

Making effective use of language is a critical component of any type of communication, whether it be a conversation, a presentation, or writing a paper or article. Findings about accessible language were presented in Section 4.2.3 with participants noting the need to avoid the use of jargon and to be as concise as possible. Numerous authors emphasize the importance of identifying the audience to adapt both the material and language for a specific audience (Chryst et al., 2018; Gislason et al., 2021; Ring, 2015). While technical jargon has uses, it can also be a significant barrier for individuals that are not a part of the discipline that creates the specific jargon to explain phenomena being studied. Technical language or jargon can also differ between disciplines, further creating a language divide even amongst academics and scientists.

The second finding regarding making effective use of language is the need to present information in a concise manner, and resonates with themes raised by Kreslake (2016) who notes that presenting information regarding climate change is no easy task, but can be enhanced by providing the important information in a concise manner (Kreslake et al., 2016). Depending on the audience, some may be more receptive to a very concise summary, which again further emphasizes the importance of figuring out who the audience is, and adapting the materials to their specific needs (Chryst et al., 2018; Gislason et al., 2021). Importantly, making use of accessible language is not about dumbing down content; instead it is about finding a common language with audiences who are not experts on a particular topic but are still intelligent human beings (Fazey et al., 2014; Reed et al., 2014).

Analysis of the focus group also underscored the importance of effective visualizations as part of tailoring content for the audience, which can be supported by providing additional media formats to convey the ideas being presented. Visualizations offer powerful tools that provide additional perspective to topics (Gislason et al., 2021; Lieske, 2015; Picketts et al., 2017). As presented in Section 4.2.3, it can be helpful in some circumstances to be as concise as possible when presenting complicated material. Effective visualizations can be thought of as being the critical information that has been distilled down to its most crucial elements. Providing a tool that includes spatial and non-spatial visualizations in one place may provide the opportunity for an increased understanding of data.

Although the Portal was initially developed for use by First Nations, the initial 'intended audience' of the IWRG Portal was mostly focused on academic users from UNBC, that spanned a range of disciplines. From this base the network of users has expanded to include individuals from communities throughout the Nechako Watershed who are actively engaged in topics of climate change, ecosystems, well-being and conservation in general. By 2021 the IWRG Portal has also expanded to include students and teachers from School District 91. It is fair to say that it is not going to be possible to present one version of academic literature or datasets that will be accessible and relevant to such a diverse user group. This challenge has expanded further since I stopped having an active role in the IWRG Portal, as indicated by the development of an additional version of the Portal for the

ECHO Network. Even while portal users expand, it will remain important to try to identify the intended audience and provide appropriate and useful content for that audience.

5.1.4 Other insights in relation to the literature

This research was designed in part around the concept of knowledge exchange. Knowledge exchange can be defined in many ways. However, this research focused on the definition given by Fazey et al. (2013), which is a "process of generating, sharing, and/or using knowledge exchange through various methods appropriate to the context, purpose, and participants involved" (p. 20). Reed et al. (2014) provide five principles for effective knowledge exchange: 1) design, 2) represent, 3) engage, 4) impact, and 5) reflect and sustain. For a more thorough explanation of these five principles, refer back to the literature review chapter, Section 2.2.1. The research was designed to allow for an exploration of how knowledge exchange may be facilitated in the Nechako Watershed through use of the IWRG Portal. While this research was specifically interested in knowledge exchange around the topics of climate change, ecosystems and well-being, the insights gained could be applicable to guiding knowledge exchange activities in the watershed on a wide range of topics, for example riparian management.

This research sought to achieve a level of knowledge exchange, which the literature describes as establishing multi-directional exchanges (Cvitanovic et al., 2016; Fazey et al., 2013). These type of exchanges occurred between myself and the development team of the Portal, as I was a set of fresh eyes coming into the project. The development team taught me about the technical aspects of the Portal, while I gave them new perspectives to be considered. A degree of knowledge exchange occurred during the scoping discussions, workshop, and focus group. Many participants in these events were either experiencing the

Portal for the first time, or had only previously seen small aspects of it. There is a considerable challenge in trying to bring together a complex geospatial tool such as this Portal and a group of people who all have different levels of both geospatial and technical literacy. While this work did not evaluate the degree of learning that participants experienced regarding the IWRG Portal, there was interest in continuing to explore how this tool could benefit various groups throughout the Nechako Watershed and beyond. Currently, the IWRG Portal and the work being done with it has expanded beyond this research, and is actively being used by other researchers as well as School District 91, and the ECHO Network as exemplified by the YouTube channel mentioned above (ECHO, 2021).

Participatory GIS (PGIS) is another area of literature that could be seen as relevant to the framing and approaches used in this research alongside the emphasis of knowledge exchange. PGIS has been used by academics who are interested in broadening access to GIS (Sieber, 2006). Many aspects of PGIS fit well within this research, such as drawing on the knowledge and expertise of various stakeholders and members of the public, viewing all data as being important, the importance of people and place, making the technology and data more accessible, and trying to determine processes and evaluate outcomes (Dunn, 2007; Mukherjee, 2015; Sieber, 2006). PGIS also explores ideas that have relevance to some knowledge exchange principles. Dunn (2007) notes that PGIS works to integrate local and indigenous knowledge with data from 'experts.' The theme of tailoring content for the audience is also seen in PGIS literature, and it has even been suggested that different PGIS interfaces should be developed for different public groups to limit the barrier of entry to these tools and approaches (Sieber, 2006). While not the emphasis in this research PGIS and Public Participatory GIS (PPGIS) could provide some useful avenues to consider when undertaking future research in relation to the Portal.

5.2 Implications and Recommendations

In addition to discussing findings in relation to the literature, it is also important to consider implications, potential recommendations and next steps from this research including ways to build on key insights and strengths, as well as to address limitations and constraints arising in the course of this Master's thesis research. Section 5.2.1 provides an overview of these implications regarding the IWRG Portal and some of the work being progressed in the Nechako Watershed and beyond. Section 5.2.2 discusses the trends in geospatial tools that have been developing since this research started.

5.2.1 Implications for future research

This research has contributed to early steps in establishing an IWRG Portal, while recognizing that there is considerable work to be completed for full potential of this tool. A key limitation with the IWRG Portal during this research was the need for a more active user base. As such, this research was only able to provide a starting point for understanding which types of data visualizations, form design, and general perceptions of how a small group of knowledge users from various backgrounds experience the benefits and limitations of the IWRG Portal. There is a need to further understand the optimal method to present data within the IWRG Portal. To get a better understanding of how to improve the data presentation, additional research needs to be conducted. Building on ideas proposed by Chryst et al. (2018), on audience segmentation could be interesting to consider applying within the Nechako Watershed (Chryst et al., 2018). Expanding the active user base and checking in with new and existing users over time could further refine the approaches used within the IWRG Portal. In addition, there are always improvements that can be made directly to the Portal, as part of ongoing iterative development. Further consultation on both the IWRG Portal as a tool and how content is uploaded is needed. This task of iteratively developing the Portal has continued, with new tools being introduced that provide additional spatial and reporting functionality, with training materials to introduce and orient users to some of these new approaches becoming available on the ECHO Portal YouTube channel (ECHO, 2021). There is also development work underway that addresses bringing new visualizations to supplement spatial data being shown on the map. For example, the ability to better incorporate legends, raster data, and even showcase live data from weather stations.

The work of expanding a larger user base is already underway, through the various research projects and networks that are linked in with and informed by the work undertaken with the IWRG Portal. With this introduction of new projects and users to the IWRG Portal, consideration should be given to study how knowledge exchange could be better facilitated throughout the Nechako with tools such as the IWRG Portal. Beyond the research goals of this research, additional outcomes have resulted from the work in this project. The IWRG Portal has expanded in its use; UNBC graduate student Ella Parker has been working with BC School District 91 to store stream monitoring data that is being collected by School District 91 students also linked to the wider 'Koh-learning in our watersheds' Project (Koh-Learning in Our Watersheds, 2021). In addition, another instance of the Portal has been established for the Environment Community Health Observatory (ECHO) Network. While both these developments are not part of this research and I have not been an active part in either, they are examples of the potential future uses of the Portal and underscores the importance of ongoing research into the strengths and weaknesses of the Portal going forward. With this introduction of new projects and users, consideration should be given to study how knowledge exchange could be better facilitated throughout the Nechako and beyond, to optimize the benefits of tools such as the IWRG Portal.

Considerations for future research should also be informed by insights from and limitations of the research design used for this study. In particular the limitations of using the two-phased iterative approach warrant reflection. This type of research is time intensive, which limits the scope of work that can be completed, especially within the scope of a Master's degree. Originally, I had hoped there would be a third phase where I would work with individuals from School District 91 and other groups to bring the IWRG Portal to a more diverse audience, and to test and explore the benefits and weaknesses of the Portal in ways that create wider participation – not unrelated to some of the aspirations of PGIS (Dunn, 2007; Mukherjee, 2015; Sieber, 2006). Working with my co-supervisors and committee, we determined this further iteration of my research was not feasible within the time and scope of the intended Master's research, noting also that the initial two phases had already generated a range of new insights. Fortunately, as mentioned, a lot of the ideas developed for this third phase of work have been factored into the future development of the Portal and applied by other researchers, through the use of the Portal with other user groups.

As noted above, wider participation in future research could be informed by the literatures on PGIS and PPGIS (Dunn, 2007; Mukherjee, 2015; Sieber, 2006). These future research opportunities underscore the ways that my current research stands as a first step in establishing the IWRG Portal, determining if this tool could be effective in the Nechako Watershed context, and identifying some of the benefits and limitations of the Portal. As well as identifying opportunities for future research, this study has also informed recommendations for how to further develop and refine geospatial tools such as the Portal, which I touch on in the next section.

5.2.2 Recommendations for geospatial development and practice

This section explores recommendations for the developing and refining the Portal as a specific geospatial tool, as well as for wider implications for geospatial development and practice. Being able to track and evaluate is important to the process of knowledge exchange (Fazey et al., 2014). Incorporating the ability to track how Portal users influence the development and changes within the Portal is one recommendation that could be seen as a way to benefit from greater knowledge exchange between users and administrators. This is how the Portal has been developed from the start. It has iteratively evolved through the suggestions and needs of various users. A precedent for this kind of feedback and refinement is already in place within the Portal design, with the purpose of identifying, reporting, and solving bugs, e.g. coding errors and unintended impacts from code changes. This system currently provides developers with the information from the individual who has found an issue or bug, a description of the problem, and maintains this information in one location so it is easy to find and organize priorities. At the same time, users can also use this tool to track when specific issues have been addressed. I would recommend a similar system be put in place long term, to track user suggestions from all iterations of the Portal. This will result in new features or changes to the Portal. This could also show some detail regarding the degree of knowledge exchange going on between developers and users. This kind of iteration and refinement is characteristic of many areas of technical research and development (Lieske, 2015), and is an extension of what has already made the Portal successful to date.

It may also be beneficial to consider a process for Portal users to provide feedback or comment on what they have learned through their use of the Portal. This could be accomplished in many different ways. Possibilities to document and benefit from this kind of feedback could include: implementing a system similar to bug tracking (as above); creating forms within the Portal for the purpose of users to document their learning and feedback; and/or creating a Portal forum within or across Portal user groups. A Portal forum would be particularly interesting if it was developed to include all users from all versions of the Portal, creating a larger Portal user community. This would allow for the exchange of ideas between users, developers, and administrators, and potentially provide greater opportunity for learning and innovation (Lieske, 2015).

Now turning to some wider implications, there has been a general trend in geospatial development since this research was initiated, which has moved towards creating more web accessible geospatial tools (Johnson et al., 2017). These new tools often focus on providing non-GIS specialists with easy to use templates, often with a large catalog of pre-configured data, such as ESRI's ArcGIS Living Atlas of the World available through their online services (ESRI, 2021b). Often the intention of these tools is to reduce the barrier of entry to GIS tools, while still providing products that can look good and perform well. There are examples of geospatially enabled dashboards and story maps that have recently become hot topic tools. Dashboards link maps and spatial data to widgets that are setup to display information and statistics drawn directly from the spatial data (ESRI, 2021a). These dashboards can be setup to change the displayed numbers and statistics as the user changes the perspective of the map. Zooming in and out, or panning around the map will cause the dashboard to update the numbers being displayed for the user. Story maps take another approach by mixing text based information, or stories, and maps together (ESRI, 2021c). Think of a PowerPoint presentation with a map and text on a single slide. In a story map this can be done, but the map can be interactive and there are a slew of features to merge the text and map elements together in a cohesive way.

The development of the Portal has also highlighted there needs to be a continued effort to decrease the barrier of entry for GIS tools (Kong et al., 2015; Songer, 2010). Research should continue to look into methods that can make GIS tools more accessible. In keeping with the discussion above about the intended audience, my suggestion is to determine who the intended audience of the tool is and to cater the software to suit the needs of this audience. This probably means providing only the tools that are necessary for their intended purpose, to minimize the complexity and learning curve.

Applications for the Portal and other GIS providers have also made strides in providing mobile data collection options such as Geopaparazzi (OSGeo, 2021), making the production of spatial data more accessible than previously possible (ECHO, 2021). It is now possible to collect and view spatial data with mobile devices such as smartphones and tablets, which can be seen in YouTube videos created to provide additional training resources (ECHO, 2021). These improvements make it easier for people to collect and share spatial data, as they can do so with the devices they carry with them on a regular basis.

In Section 2.2.2, Figure 2 was introduced as a heuristic tool to provide guidance on how web-GIS tools can have varying degrees of GIS functionality. This figure showed how the Portal was expanding the range of services being provided in these web tools. This research has underscored a challenge with the progression depicted in Figure 2, since with each new feature or service these tools provide there is added complexity to learning how to operate these tools.

There has been a trend of making GIS tools more accessible to an audience much more diverse than just GIS experts (Zhu et al., 2021). There has also been improvements in integrating more qualitative data such as text based stories into spatial tools and data (Lowery & Morse, 2013). This trend needs to continue, and it would be very interesting to have research conducted to evaluate how effective these more accessible tools are when conveying their message to audiences.

5.3 Conclusion

This research was designed to assist in establishing the IWRG Portal in multiple ways and respond to my three Research Questions. The research gained new insights about the Portal as a tool for knowledge exchange in the Nechako Watershed, as well as expanding opportunities for Portal users to share perspectives about the benefits and limitations of the Portal. Using thematic analysis on the transcription of the workshop, it was determined that the Portal was beneficial by providing additional ways to deal with complex topics and provided interesting ways to integrate and showcase data. The analysis also drew out the perceived limitations of the Portal. These limitations were: the need for intentional framing of data, a steep learning curve, and the necessity of having an active internet connection. Amongst participants, a degree of knowledge exchange also occurred. Research participants learned about the IWRG Portal and the datasets showcased. The input from participants also provided direction and insight into how this tool could be further developed, and these insights have already contributed to ongoing refinement of the Portal tool. The research has shown that tools such as the IWRG Portal can create new pathways to understanding information, and an ongoing need to evaluate the effectiveness of these tools in ways that match the contexts they are used in.

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Appendices

Appendix One: Python Code to Clip ANUSPLIN Data

```
import fnmatch
import os

inFolder = '/home/gothreau/Data/ANUSPLIN_1950_2015/Min Temp 2010s/'
outFolder = '/home/gothreau/Data/ANUSPLIN_1950_2015/Clipped/MinTemp10s/'
aoi = '/home/gothreau/Data/ANUSPLIN_1950_2015/Test/Nechako_4326.shp'
os.chdir(inFolder)

def findRasters(path, filter):
    for root, dirs, files in os.walk(path, filter):
        for file in fnmatch.filter(files, filter):
            yield os.path.join(root, file)

for raster in findRasters(inFolder, '*.asc'):
    (infilepath, infilename)= os.path.split(raster)
    print infilename
    outRaster = outFolder+ 'Nechako_'+ infilename[:-4]+ '.tif'
    print outRaster


#processing.runalg("gdalogr:cliprasterbymasklayer",raster,"/home/gothreau/Data/ANUSPLI
N_1950_2015/Test/Nechako_4326.shp","",False,False,False,5,4,75,6,1,False,0,False,"",outR
aster)
    cmd = "gdalwarp -q -cutline \'%s\' \'%s\' \'%s\'" % (aoi, raster, outRaster)
    os.system(cmd)

   # A special thanks to Matthew McLean for his assistance with this code
```

Appendix Two: Python Code to find Mean Temperature

```
import gdal
import ogr
from osgeo import osr
import os
import argparse
import subprocess
from itertools import cycle
import sys
import numpy as np
#Used for parsing boolean arguments
def str2bool(v):
    if v.lower() in ('yes', 'true', 't', 'y', '1'):
        return True
    elif v.lower() in ('no', 'false', 'f', 'n', '0'):
        return False
    else:
        raise argparse.ArgumentTypeError('Boolean value expected.')

#List of hex colours used for syling vector data
colours = cycle(["#FF0000", "#00FFFF", "#00FF00", "#0000FF", "#FF00FF"]);
num_images = 0
out_image = ""
sum_array = np.zeros((510, 1068))
tiffs = ""
#Inputs to program
parser = argparse.ArgumentParser()
parser.add_argument("-i", "--directory", help="Directory to traverse")
parser.add_argument("-o", "--output", help="Where mapfile will be saved")
parser.add_argument("-u", "--url", help="What is the URL of your mapserver")
parser.add_argument('-s', "--srs", nargs='?', default=3857, type=int, help="Coordinatae
system of mapfile")
parser.add_argument('-v', "--vectors", nargs='?', default=True, type=str2bool, help="Process
Vector files (True or False)")
parser.add_argument('-r', "--rasters", nargs='?', default=True, type=str2bool, help="Process
Vector files (True or False)")
parser.add_argument('-c', "--colour", nargs="?", default='random', type=str, help="Color for
imported vector layers, defaults to random")

#List of supported raster formats
rasters = ['.tif', '.TIF', '.TIFF', '.tiff']


#list of directorys to exclude from search
exclude = set(['.snapshot', 'files_external', 'files_trashbin', 'files_fersions', 'gpxedit'])
```

```
args = parser.parse_args()
print "Searching: " + args.directory
out_srs = osr.SpatialReference()
in_srs = osr.SpatialReference()
out_srs.ImportFromEPSG(4326)

#Walk the file system, and search for files to add
print 1
for root, dirs, files in os.walk(args.directory, topdown=True):
    print 2
    dirs[:] = [d for d in dirs if d not in exclude]
    if args.rasters is True:
        print 3
        for extension in rasters:
            for file in files:
                if file.endswith(extension):
                    current_image = gdal.Open(os.path.join(root, file))
                    if num_images is 0:
                        #sum_array = np.ma.asarray(sum_array)
                        driver = current_image.GetDriver()
                        out_image = driver.Create(args.output, 1068, 510, 1, gdal.GDT_Float32)
                        out_image.SetGeoTransform(current_image.GetGeoTransform())
                        out_image.SetProjection(out_srs.ExportToWkt())
                        if out_image is None:
                            print 'Could not create results.tif'
                            sys.exit(1)
                    current_array = np.array(current_image.GetRasterBand(1).ReadAsArray())
                    #nodata = current_image.GetRasterBand(1).GetNoDataValue()
                    nodata = -999.0
                    #masked_array = np.ma.masked_equal(current_array, nodata)
                    sum_array = np.add(sum_array, current_array)
                    num_images+=1
                    print num_images

sum_array /= num_images
print sum_array.min()

out_image.GetRasterBand(1).WriteArray(sum_array.astype(float))
out_image.GetRasterBand(1).FlushCache()
out_image.GetRasterBand(1).SetNoDataValue(-999.0)
out_image.FlushCache()
current_array = np.array(out_image.GetRasterBand(1).ReadAsArray())
#print current_array.max()

np.set_printoptions(threshold=np.nan)
#print sum_array
  # A special thanks to Matthew McLean for his assistance with this code
```

Appendix Three: Portal User Research Group Consent

The Nechako Watershed Portal: A web-based, geospatial tool to foster information exchange and guide land and water decision-making in the Nechako River Basin

Consent to become a member of a Portal User Research Group

Dear **[Name to be hand-written],**

You are invited to participate in a research project being conducted by researchers from the University of Northern British Columbia, focused on developing and piloting a community-oriented watershed portal to inform land and water decision-making in the Nechako Watershed. The lead researcher for this project is: Dr. Margot Parkes (University of Northern British Columbia) whose contact details are provided below. Details about Dr. Parkes' research can be found at http://www.unbc.ca/parkes/home.html. Initial funding for this project has been provided by the BC Real Estate Foundation. Additional funding support has been provided in 2017 from the ECHO Network (Environment, Community, Health Observatory) which is funded through the Canadian Institutes for Health Research (CIHR). This research will continue to be supported by Dr. Margot Parkes's research funds until the project is completed.

The purpose of the proposed portal is to develop and refine a web-accessible interface that builds upon existing web-based data management interfaces being used by other land use planning groups in British Columbia. The goal is to create a next generation of "community watershed library" that is available to community, research and other watershed partners who may access, profile and share information in new ways to guide decision-making related to the land and water resources in ways that will foster resilient, healthy communities and natural environments. The project will be an action research project in which different participants will contribute to design and development of the watershed portal and related research, as part of a Portal User Research Group.

You have been selected to be a member of this Portal User Research Group due to your expertise in land and water resources, and/or the development of web-based geospatial tools. Your input into this project would be highly valued as a member of the Portal User Research Group along with other knowledge users, specific portal user groups and research collaborators.

Study Procedures

Your consent to participate in this study provides us with the ability to collect and analyze meeting minutes and/or discussions that take place in the development and progression of the research associated with the Portal User Research Group. Further to your contributions to this study, we may invite you to participate in additional research collection through mediums such as interviews, focus group, and/or survey questionnaire. There will be a separate consent form for you to sign if you are interested in participating in an interview, focus group, and/or survey questionnaire. Further, if you consent to become a member of the Portal User Research Group for this project, **you may decline to participate in the additional research mediums of the interviews, focus groups and/or survey questionnaires without any consequence**. In addition, you may also withdraw as a member of Portal User Research Group at any time without any consequence. Should you withdraw completely from the research community, your contributions will be withdrawn automatically and destroyed unless you indicate otherwise.

All research data arising from the Portal User Research Group meeting minutes, discussions among portal user groups interviews, focus group, as well as survey questionnaire will be aggregated and anonymized. No preparation is needed for the interviews, focus groups, only a motivation to be engaged in discussions is required.

Time and Data Requirements
Your involvement in Portal User Research Group meetings will include an average of one 60 minute meeting or discussion every 2-3 months. Should you choose to participate in additional research (e.g. interviews or surveys) we would need to seek your permission again, and additional consent forms will be required. We anticipate that any interviews would last approximately 60 minutes, focus groups would last approximately 90 minutes and survey questionnaires would take approximately 30 minutes to complete.

Potential Risks of Participating in the Study:
There are no known risks associated with participating in the study. All data collection will take place only after you are made fully aware of the study, and after informed consent is obtained.

Potential Benefits of Participating in the Study:
As a participant in the Nechako Watershed Portal project you will receive regular updates about the development of the project and will also be provided summaries of research findings. The results of this study will lead to a platform that enables the sharing, exchange, and synthesis of research among knowledge users, communities and research with an interest in land and water decision-making in the Nechako Watershed, and will contribute to an overall increase in understanding and awareness of community health and wellbeing related to land and water stewardship projects.

Confidentiality
If you consent to be a member of this Portal User Research Group, anonymity within the research group cannot be guaranteed since you will be interacting with individuals from other portal user groups. The organizations who are involved as portal user groups may be listed in relevant communications (portal website, funding reports) but unless you ask to be named, individual participation within the Portal User Research Group will be kept confidential from the outside community as a whole. In regards to the research community, the completed consent form will be kept separate from data collected to protect your identity. All data from the meeting minutes, interviews, focus group sessions, and survey questionnaires will be kept in a locked filing cabinet. Only members of the study team will have access. **Your name or any other identifying information will not appear in any reports on the completed study**.

Please note that only limited confidentiality can be offered for individuals who choose to participate in the focus group sessions and discussions. At the outset of the focus group sessions and launch of meetings we will encourage all participants to refrain from disclosing the content of the discussions outside of the study; however, we cannot control what other participants do with the information afterward.

Due to the long-term nature of portal development, any data collected with Portal User Research Groups, including notes and consent forms, will be continue to be kept secure (using password protected computers, and locked filing cabinet in the research office of Dr. Parkes), until which point the research project is deemed complete by the project lead (Dr. Parkes). If you withdraw from the study, the information you have provided will be withdrawn automatically and destroyed unless you indicate otherwise. If you consent, the information gathered in this study may be kept and may be used in this and other related studies.

Remuneration/Compensation

Study participants will not be paid for the time spent in meetings, survey questionnaires, interviews, or focus groups. Expenses such as travel, accommodation, and meals may be covered; however, this will subject to available grant funding. Please note that this means **you may be required to cover your own expenses** related to your participation in this study.

Contact Information about the Study

If you have any questions or desire further information about this study, or would like to request an update about the project you may contact Dr. Margot Parkes (250-960-6813).

Contact for Concerns about the Rights of Research Participants

Please be aware that you are not waiving any legal rights in signing this consent form. If you have any concerns about your treatment or rights as a research participant or would like to register a complaint, you may contact the UNBC Office of Research (Research Ethics Board) at 250-960-6735 (reb@unbc.ca).

Consent

Your consent is required before you may become a member of the Portal User Research Group and participate in this study; however, your participation in this study is entirely voluntary. You may refuse to participate or withdraw from the study at any time without any consequences. Your consent to participate is not required immediately. Your signature below indicates you have received a copy of this consent form for your own records. By signing below you are consenting to participate in this study.

If you choose to participate in this study, we ask that you keep a copy of this consent form for your records and FAX the other signed copy to Margot Parkes, at 250-960-5744, or email a scanned, signed copy to margot.parkes@unbc.ca.

______________________ Participant Name	______________________ Participant Signature	______________________ Date

Sincerely,

Margot Parkes, **MBChB, MAS, PhD**
Canada Research Chair in Health, Ecosystems and Society,
Associate Professor, Health Sciences Programs,
University of Northern British Columbia,
margot.parkes@unbc.ca, (250)-960-6813

Appendix Four: Workshop and Focus Group Invitation Letter

<u>**Workshop Invitation**</u>

Climate implications for ecosystems and well-being:
developing effective geospatial knowledge exchange tools in the Nechako Watershed

Hello

As a member of a Portal User Research Group associated with the Nechako Watershed Portal, we are pleased to invite you to a portal workshop focused on climate change, ecosystems and well-being. *More information about this workshop is provided in the Information Letter and Consent form attached to this invitation.*

Who is involved?

The workshop is being conducted by Joseph Gothreau as part of his graduate studies in Masters of Natural Resources and Environmental Studies at UNBC. Joseph's research is as part of a wider project conducted by Dr. Margot Parkes, that seeks to refine and develop the portal for use by other groups, titled: "Nechako Watershed Portal: A web-based, geospatial tool to foster information exchange and guide land and water decision-making in the Nechako River Basin". Workshop participants will include other Portal Research User Group members, including researchers UNBC, Nechako Watershed partners and others interested in integrative geospatial tools.

What is the workshop about?

The workshop is part of a research project is designed to trial and refine interdisciplinary knowledge exchange approaches, with a particular focus on data, information and knowledge relating to climate change, ecosystems, and well-being. The study uses a web-based geospatially enabled tool (the Nechako Watershed Portal) to store, manage and share both spatial and non-spatial data.

<u>**What will happen at the workshop:**</u>

This interactive workshop and focus group session has three Stages.

1. **Overview of project**, orientation to session and consent forms.
2. **An interactive workshop exercise** that seeks to guide participants through examples of the data in Integrated Watershed Research Group's Portal and orient them to the basics of navigating the portal.
3. **A focus group discussion**, where participants will discuss how climate, ecosystems, and well-being data has been shared and presented within the Portal. Discussion will also cover the perceptions of the Portal as a tool to assist in making connections between climate, ecosystems, and well-being data through spatial visualizations. The focus group session will conclude with a discussion revolving about the experiences of participants in communicating their own research with diverse audiences.

<u>**Consent**</u>

Since this workshop is being conducted as part of a research project, your consent is required in order to participate. However, your participation is entirely voluntary. You may refuse to participate or withdraw from the study at any time without any consequences. Information required to provide your consent is attached to this invitation, and you will be asked to provide your consent to participate prior to the start of the workshop.

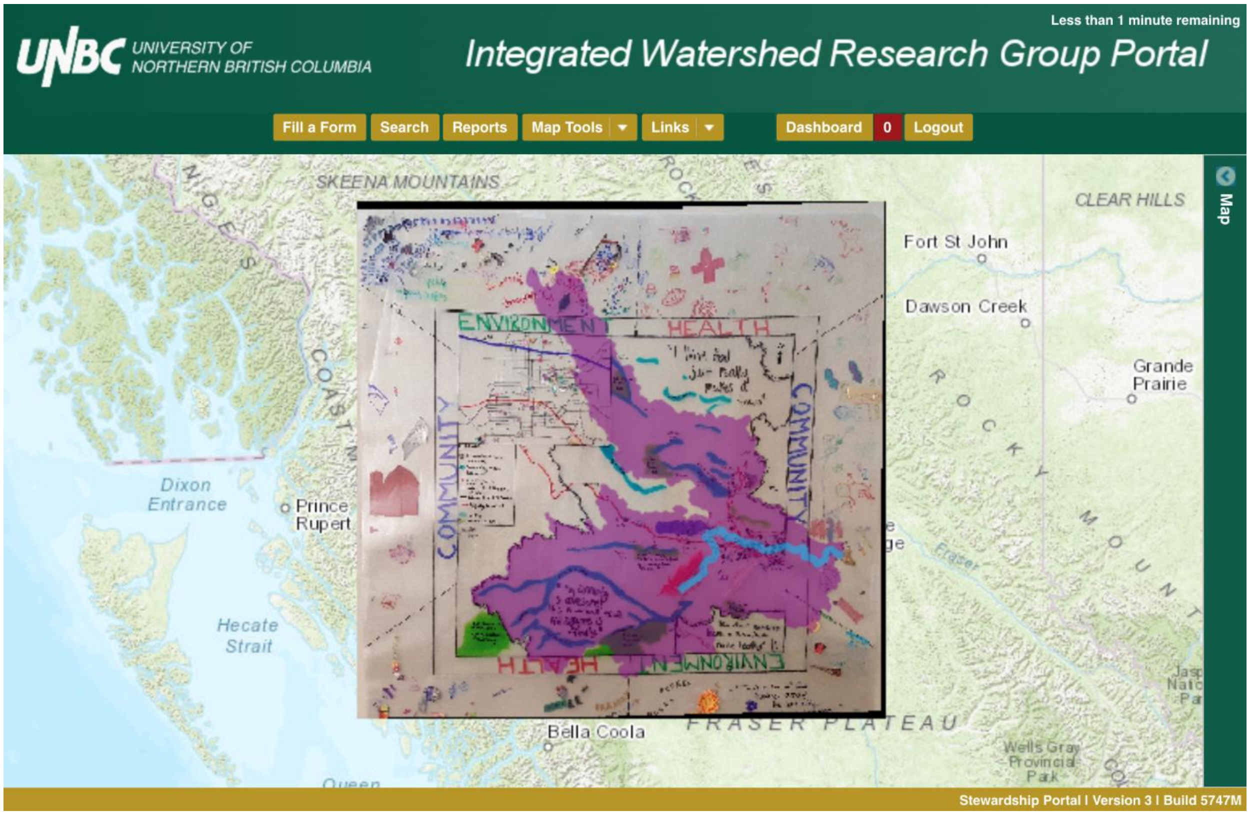
Timing and Location
When: May 22nd, 2018 from 4:00 pm until 6:30 pm (an optional dinner will be hosted by Margot Parkes and the Integrated Watershed Research Group after the workshop).
Where: University of Northern British Columbia Campus, GIS Lab (8-125)

Faculty Researcher:
Dr. Margot Parkes, School of Health Sciences
Phone: 250-960-6813
Email: margot.parkes@unbc.ca

Student Researcher:
Joseph Gothreau, Masters of Natural Resources and Environmental Studies Candidate
Supervisors: Dr. Margot Parkes and Dr. Stephen Déry UNBC
Phone: 250-960-5193, Email: stephen.dery@unbc.ca.

Appendix Five: Portal User Guide

Portal User Guide



Developed by Joseph Gothreau, MNRES
Integrated Watershed Research Group, University of Northern British Columbia
December 2018

Table of Contents

1. Portal Definition

Our Portal is a map-centric web based tool that was originally designed by Scott Emmons (and team) in conjunction with First Nations communities in British Columbia. This tool is designed to be a next generation web geographic information system (GIS) that is able to store, display, manage, and share spatial and non-spatial data within its database. As a map-centric tool, it has basic GIS features, such as but not limited to: identifying features, creating new spatial layers on the fly, editing, buffering, clipping, querying attribute tables, and creating simple maps that can be downloaded. In addition to these GIS features it also provides the ability to search submissions and data, store and share any digital file format, and develop customized forms to display information.

As a total records system this tool also documents and permanently stores all information that is submitted into the database, protecting the integrity of the data. Unlike many other systems, such as Google Earth, this Portal allows users to be in complete control of their data. This is done by allowing users to determine who will have permission to access the data they are uploading, through a system of user and group permissions.

This Portal has been developed as a user driven tool, as such users determine the development path and provide all relevant data that is being uploaded. It should be mentioned that while this tool developed out of collaboration with First Nation groups, it has evolved to include a diversified user group portfolio which still includes various First Nations, the Integrated Watershed Research Group at the University of Northern British Columbia, British Columbia's School District 91, and many others across British Columbia, Canada, and even internationally.

Importantly this tool is open source in nature, the code and all API's and tools are freely available, however hardware and more importantly having the capacity to manage have inherent costs for groups wanting to start their own instance of this tool. While there are multiple distinct and separate instances of this tool being used, they all share a single development path. This means that as one user group invests in new feature and functionality all the other groups benefit from this investment by gaining access to the new code.

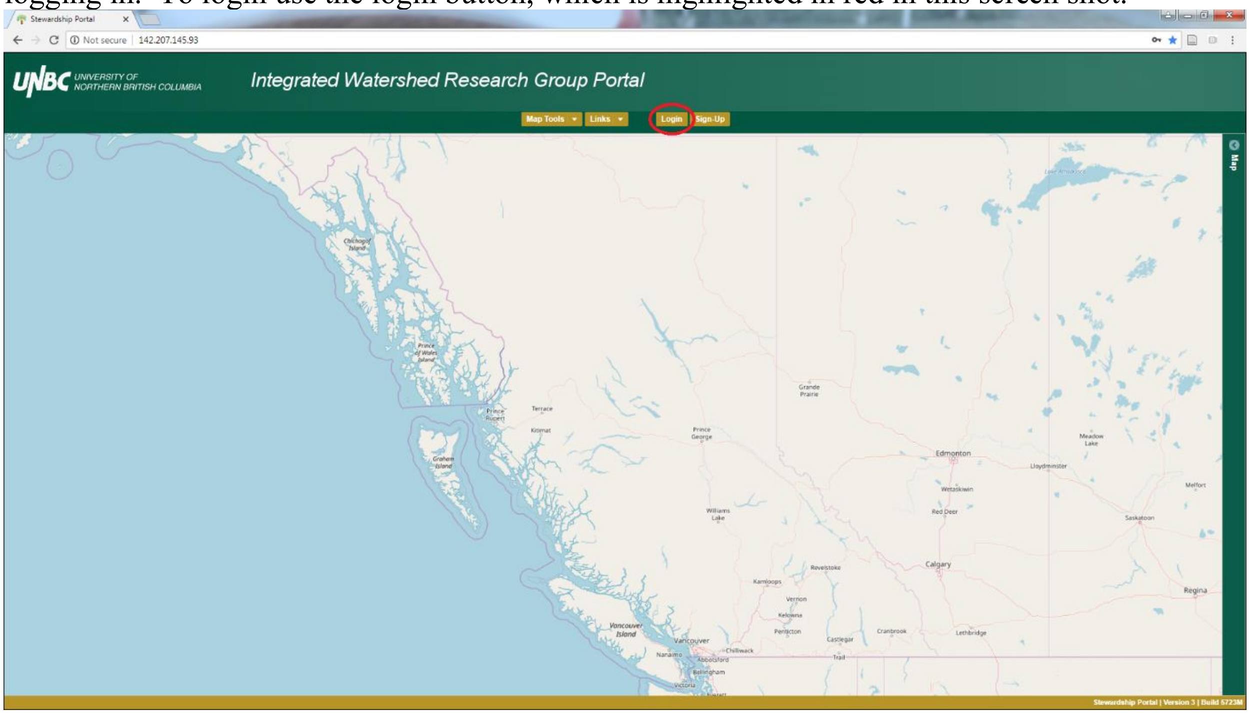
2. Finding your way around the portal

What to showcase in the demonstration session:

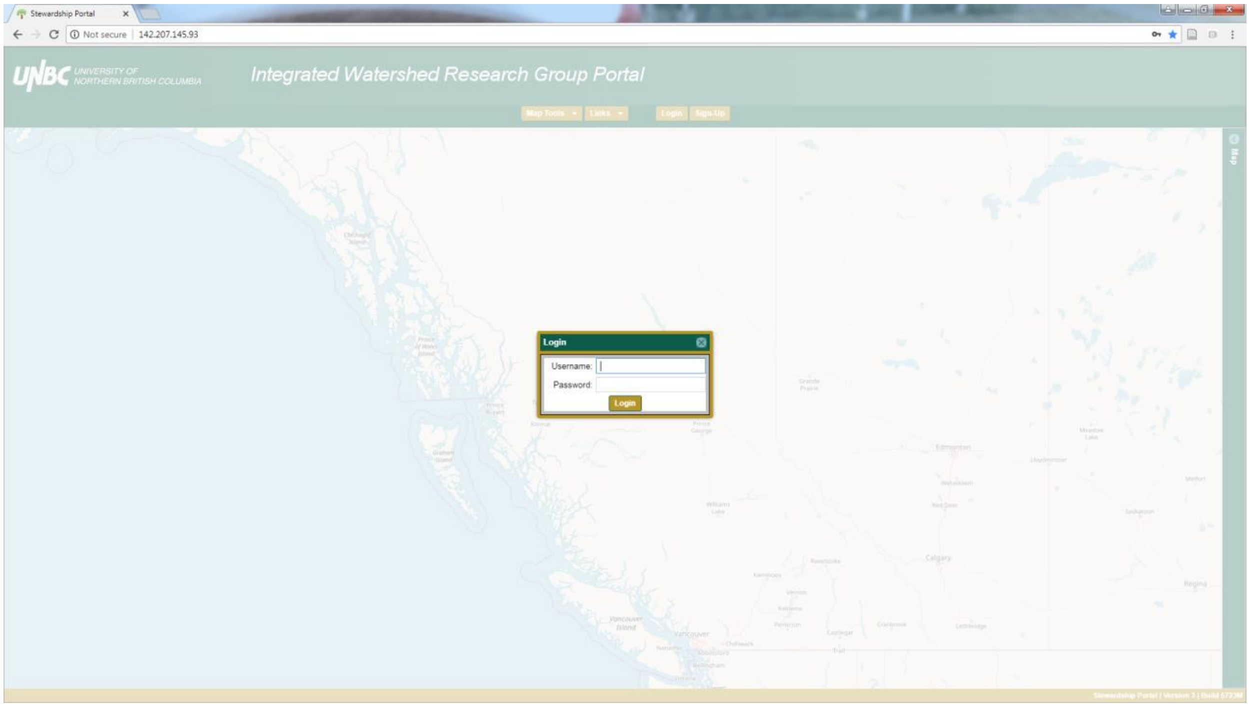
- Intro? Showing all the buttons and what they do.
- Query data with search
- Spatial visualization
- Map tools
- Forms
- Permissions

Home Screen of the Portal:

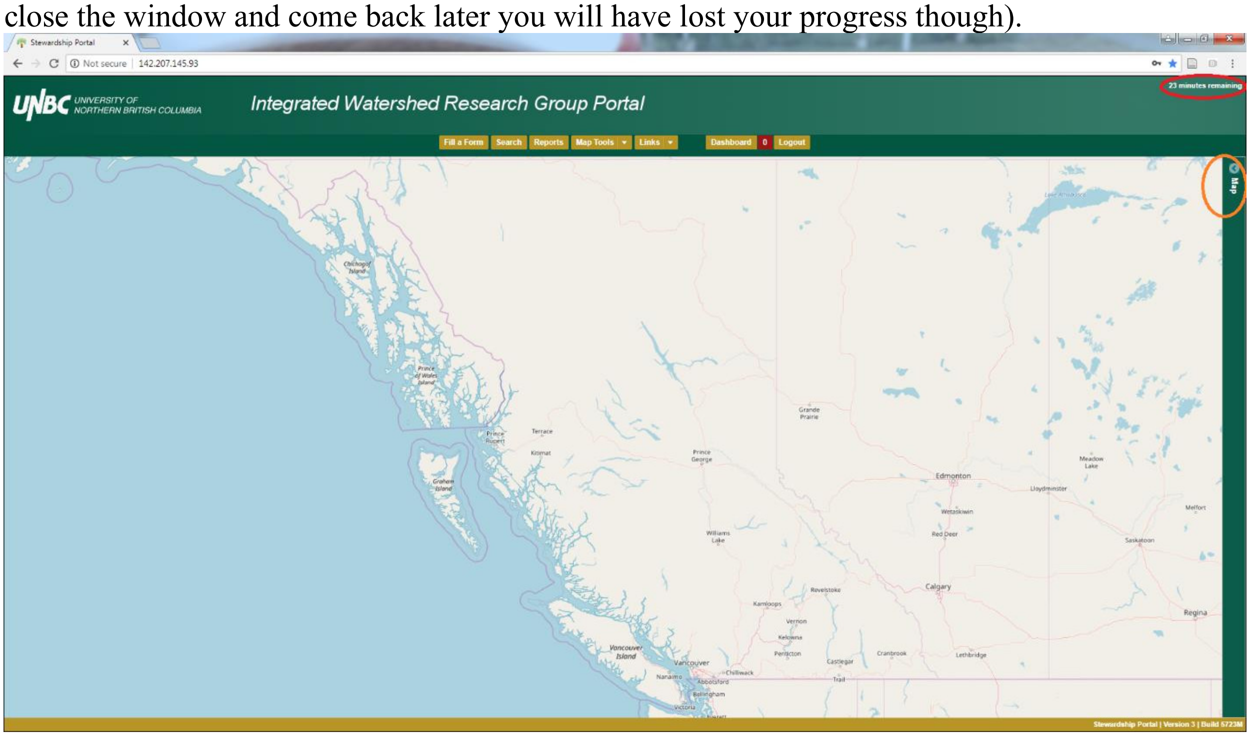
The landing screen of the Portal is map-centric, there isn't much you are able to do before logging in. To login use the login button, which is highlighted in red in this screen shot.



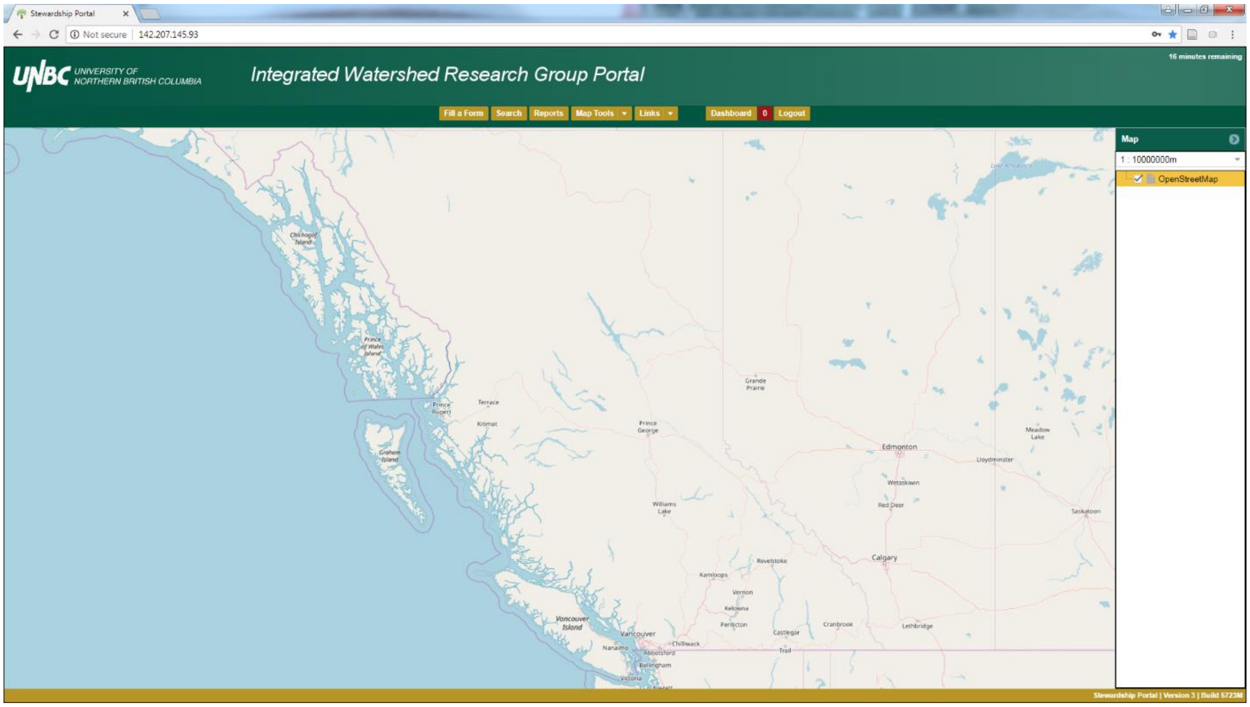
Doing so will open the login window where you use your Portal account details to gain access.



Now you have some new buttons available.
In the top right hand corner (highlighted in red here) you have a countdown showing. When this countdown ends you will have to enter your credentials again. You don't lose anything you were working on when it logs you out, as long as you log back in when prompted (if you close the window and come back later you will have lost your progress though).



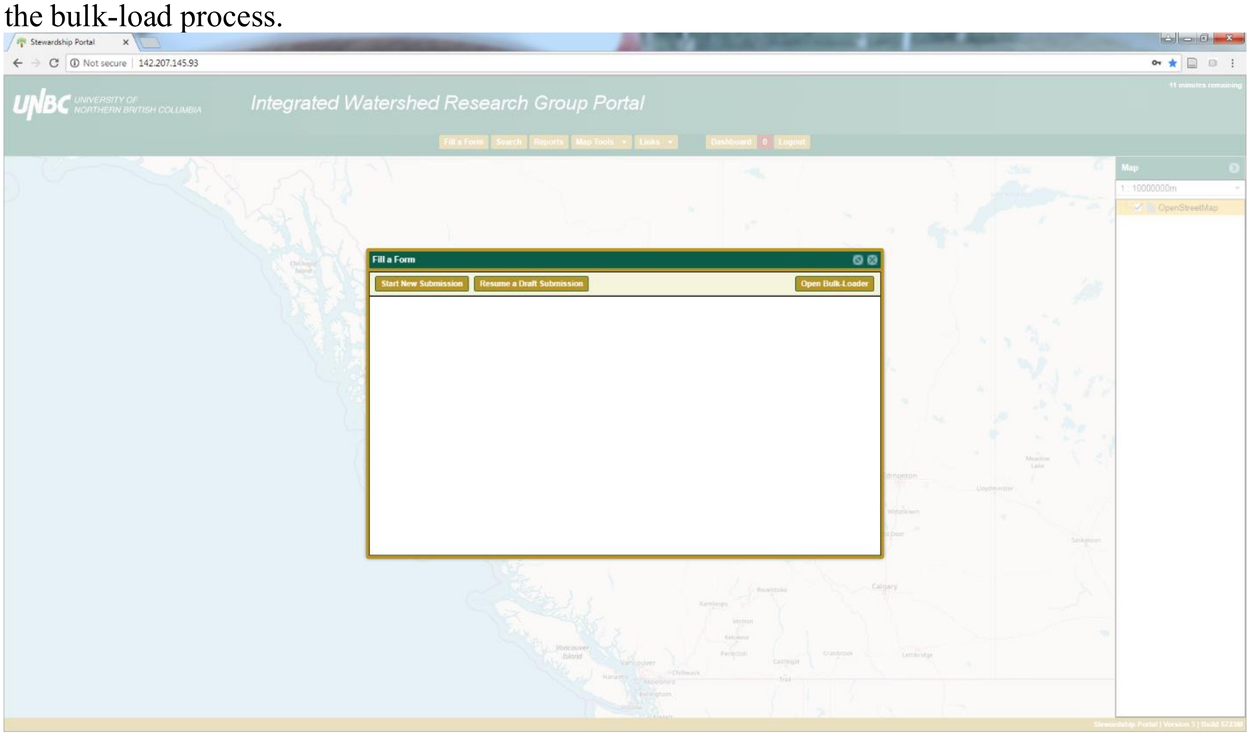
There is also a Map bar on the right of the screen (highlighted in orange), you can click on this bar and expand the spatial data content list as shown below.



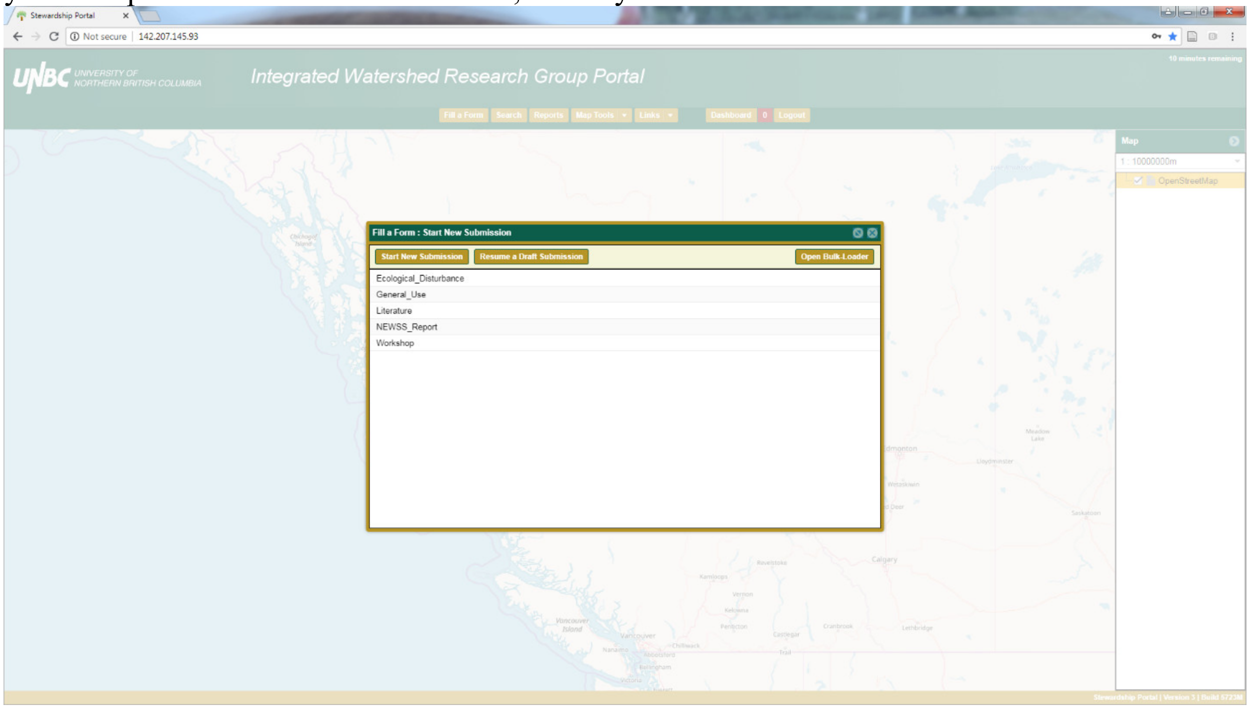
This opened Map bar will list all spatial data that is displayed on the map. You are able to change the order, check attributes, change symbology, among other features using the right click functions which we will explore in detail later.

In order from left to right we will quickly look at each button across the top of the screen.

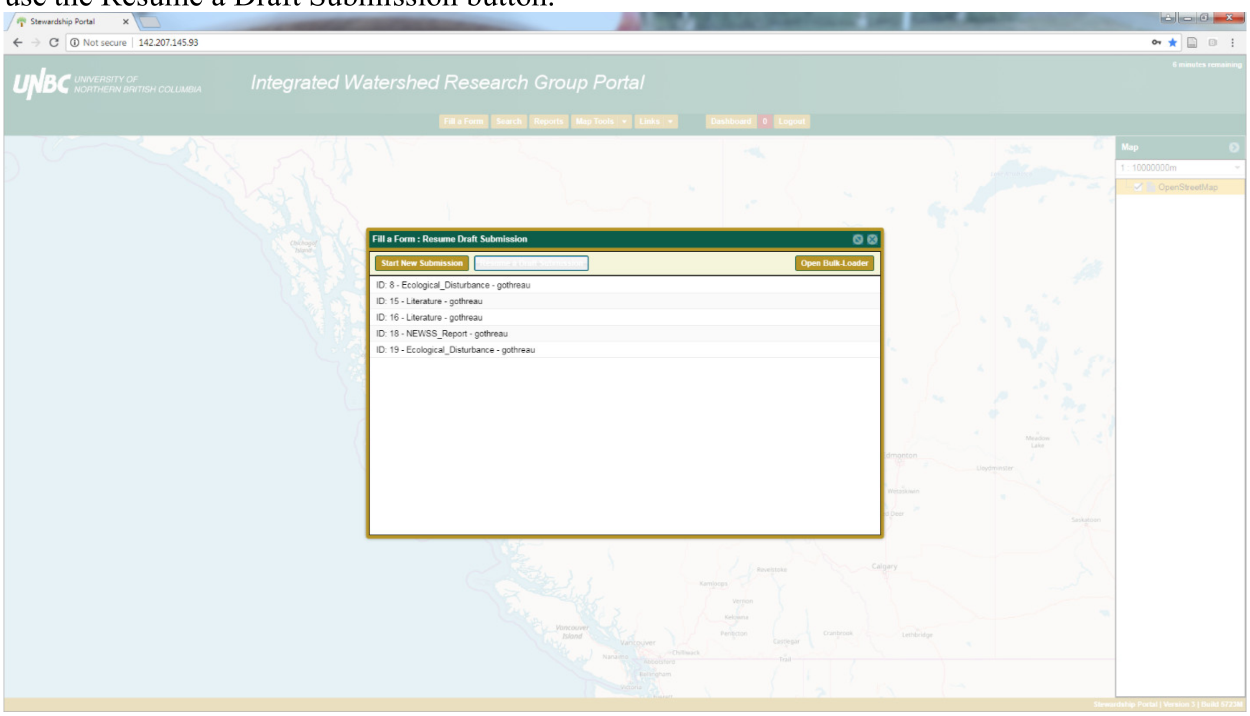
Fill a Form: This is used to start making a submission, continue a draft submission, and start the bulk-load process.



If you're starting a submission you will click Start New Submission and a list of forms that you have permission to access are listed, which you can fill out.

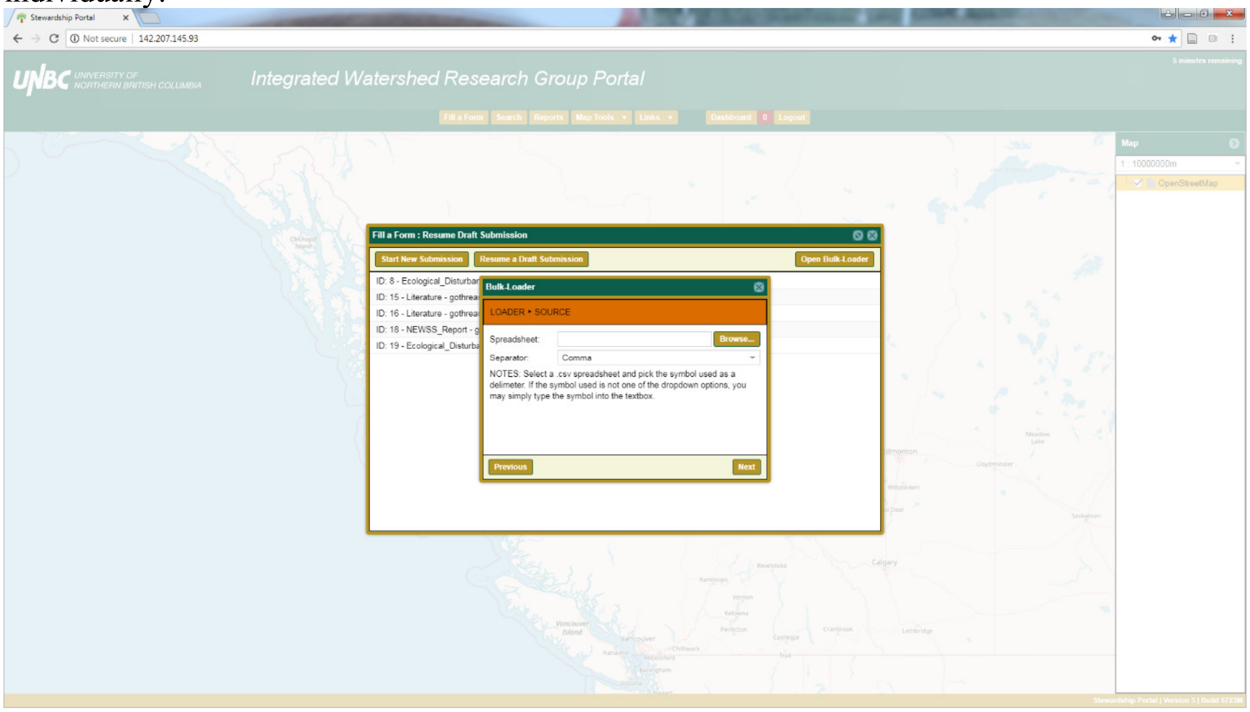


If you saved a draft submission, or have been asked to resume someone else's draft, you will use the Resume a Draft Submission button.

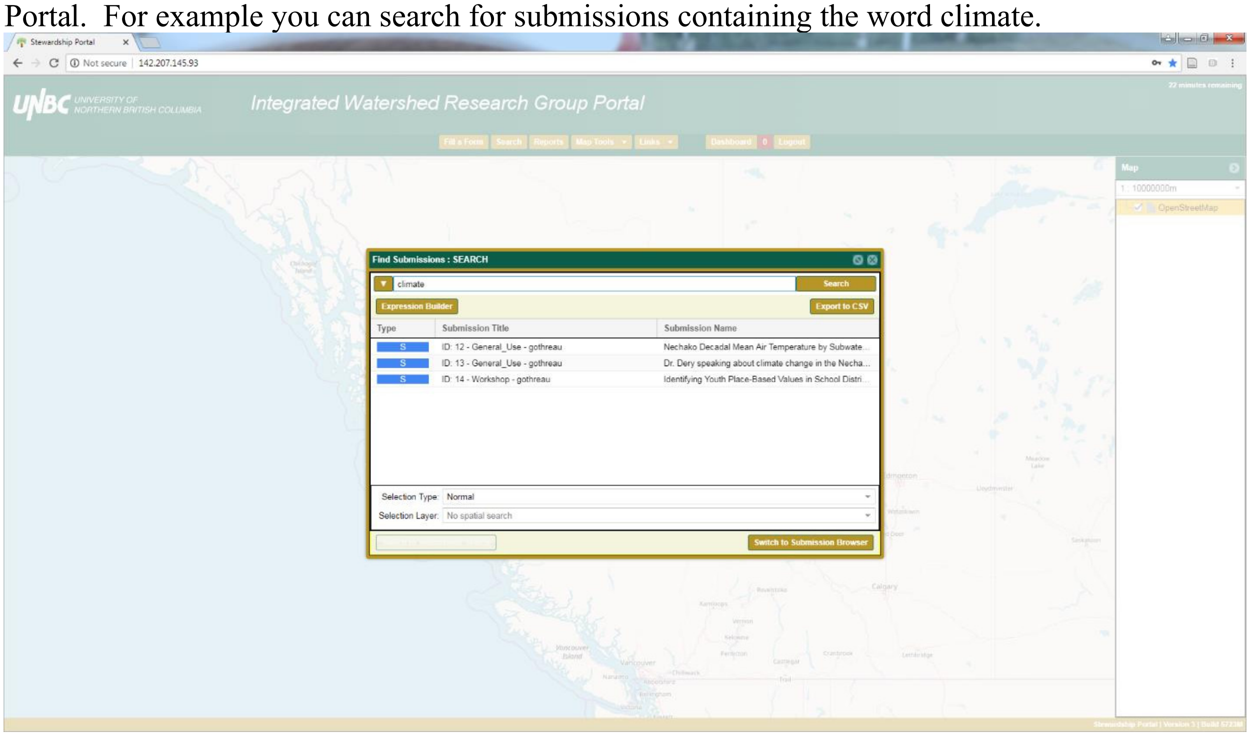


Double click on the Draft you want to continue and continue working on it.
The Open Bulk-Loader will allow you to start a bulk-loading session, for those times you have a large number of submissions to create. There is a fine line of when you are going to want to make use of this feature, as there is a lot of work that is required to prepare the data

for bulk-loading. For example we have a literature review with over four hundred articles to be submitted, we are going to use the bulk-loader to complete this task. However, if this literature review had twenty articles it would probably be more efficient to load them in individually.

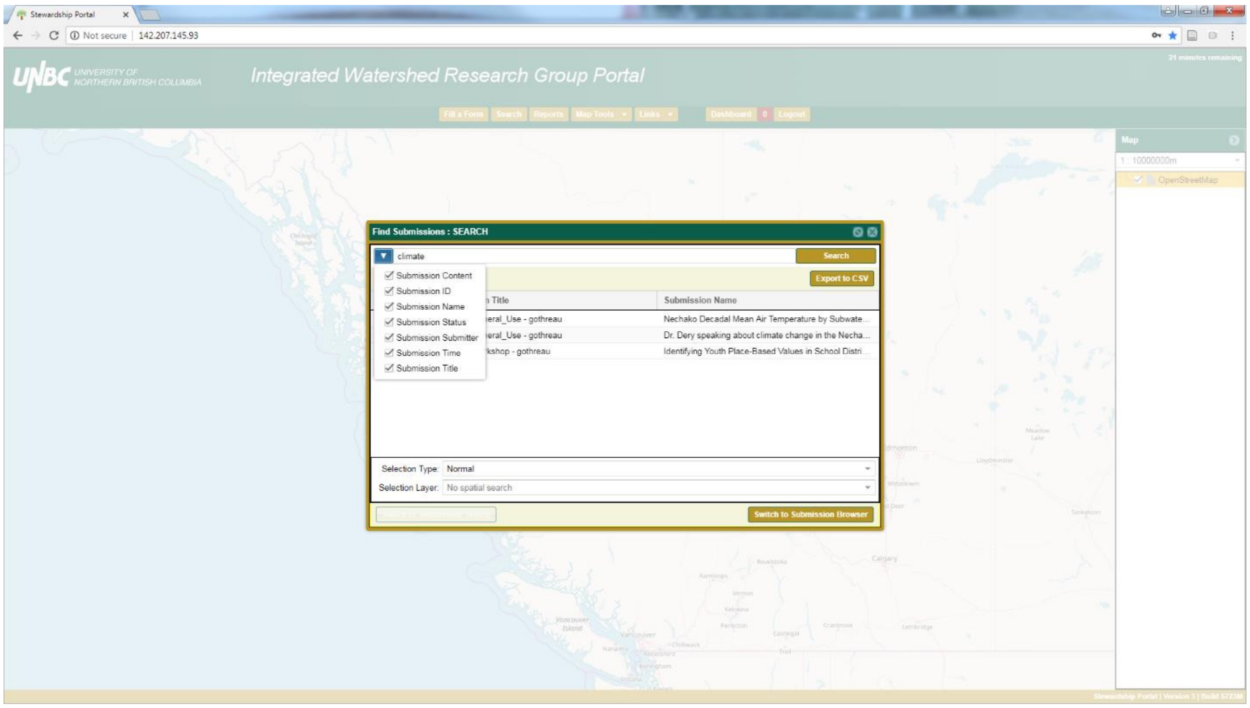


Next is the Search button, this is used to use words to search through data submitted to the Portal. For example you can search for submissions containing the word climate.

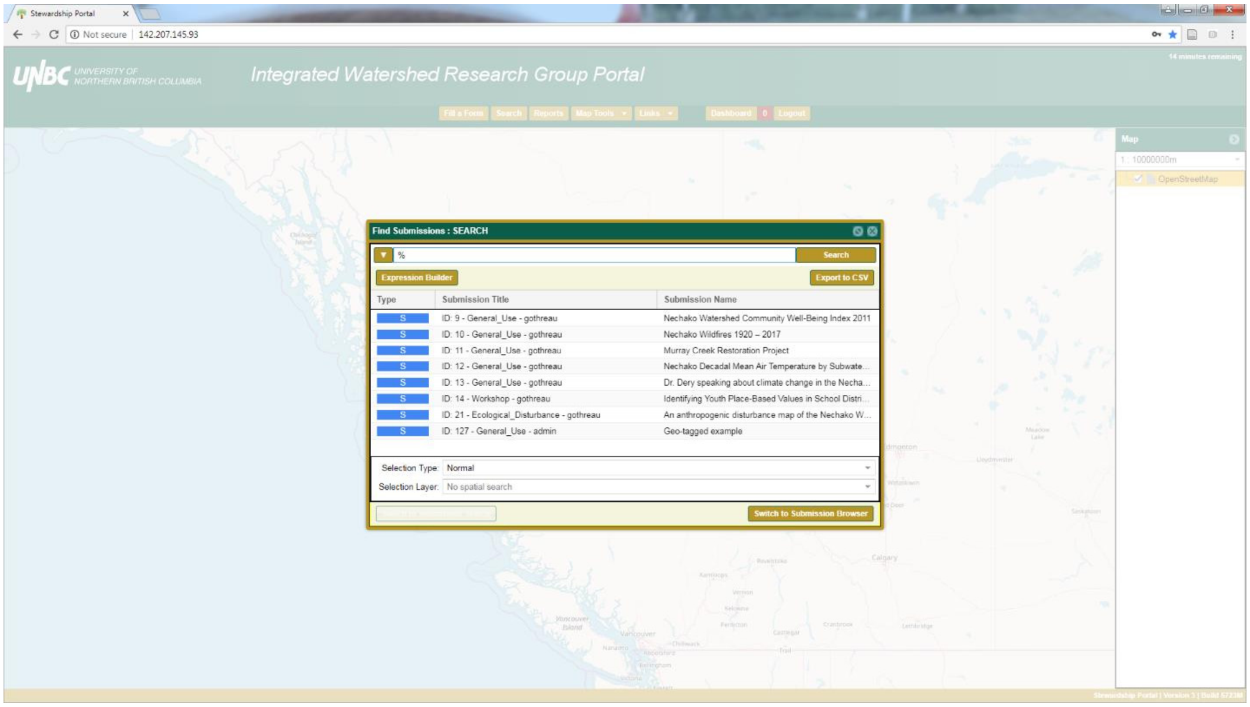


Clicking on the down arrow beside the search field allows you to select which fields you want to search through.

Submission Content: searches by content within the submission itself.
Submission ID: searches by the unique identifying number given to each submission.
Submission Name: The name given to a submission.
Submission Status: Is the submission submitted or in a draft?
Submission Submitter: The user who created the submission.
Submission Time: The date and time that the submission was created (submitted or started?)
Submission Title: These are automatically created by the Portal and are in the following format. ID: XX – Form Name – User who created the submission

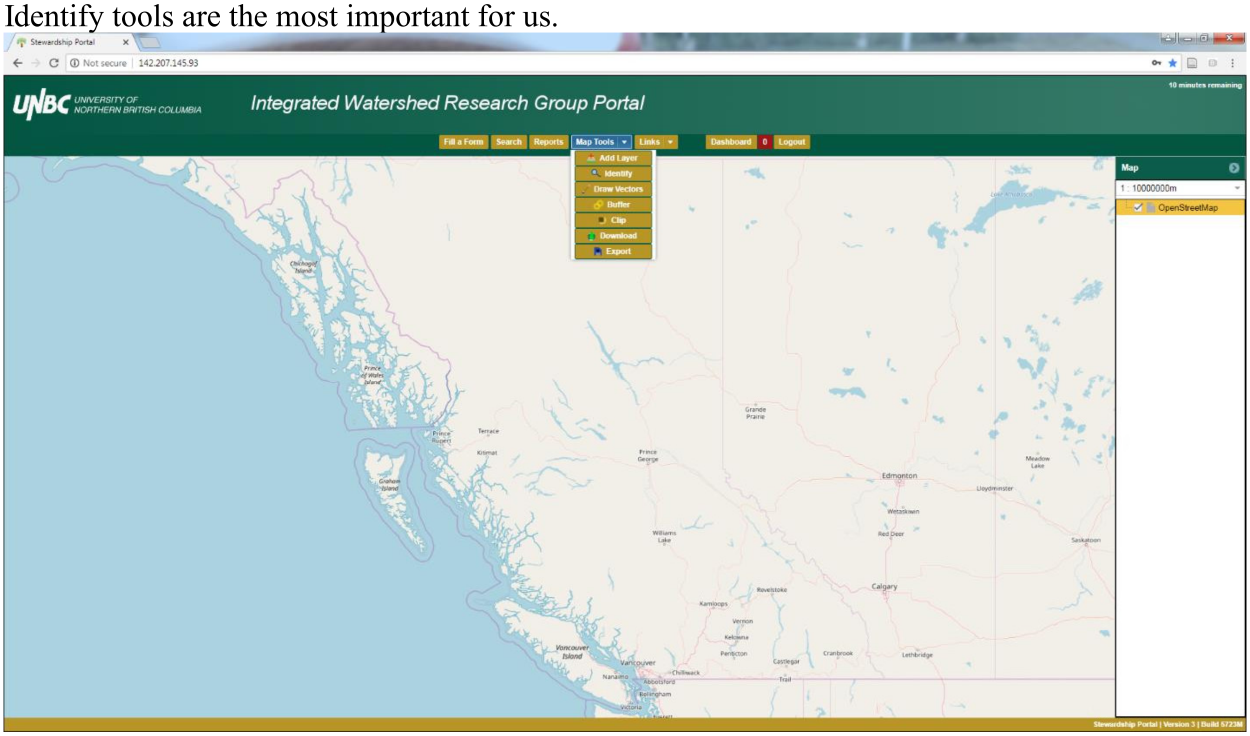


You can also search for everything by using the % character.



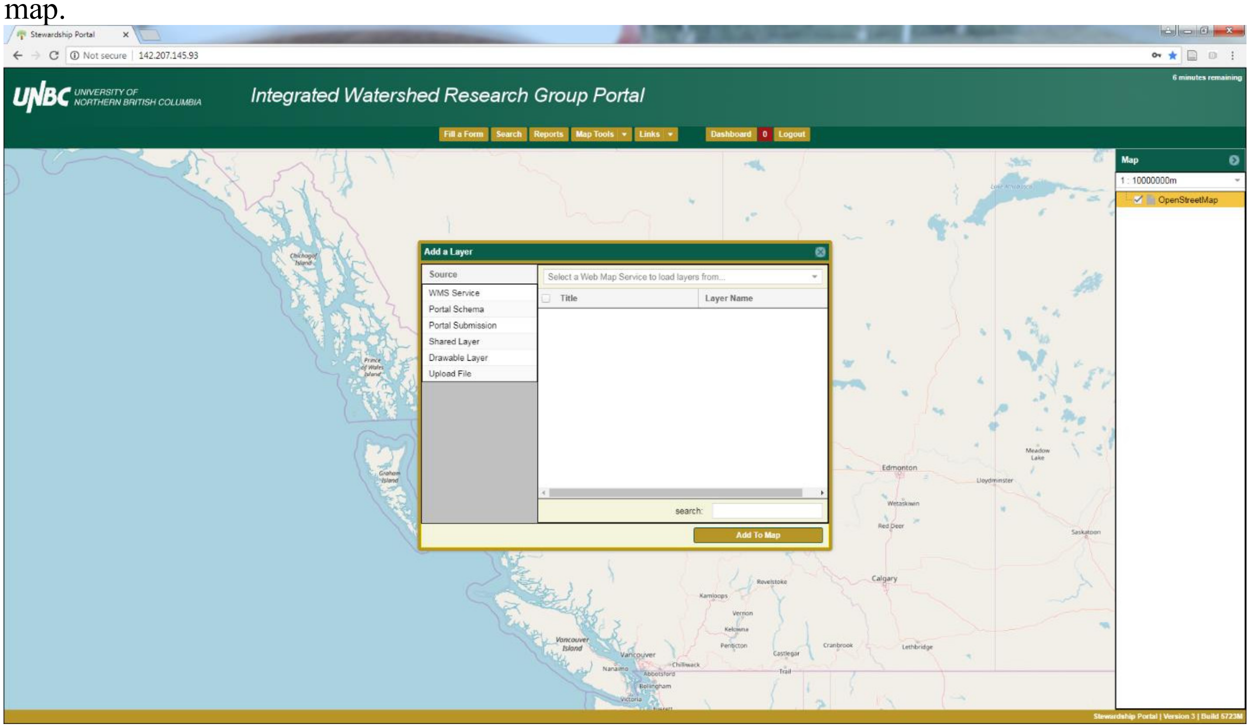
Next there is a Reports button, which we are going to ignore for now. This is under development, but currently you could also bulk-download data from the Portal using this tool.

Map Tools is next, and is used to load spatial data to the map and the various tools provided for working with spatial data. For the purposes of this demonstration the Add Layer and Identify tools are the most important for us.

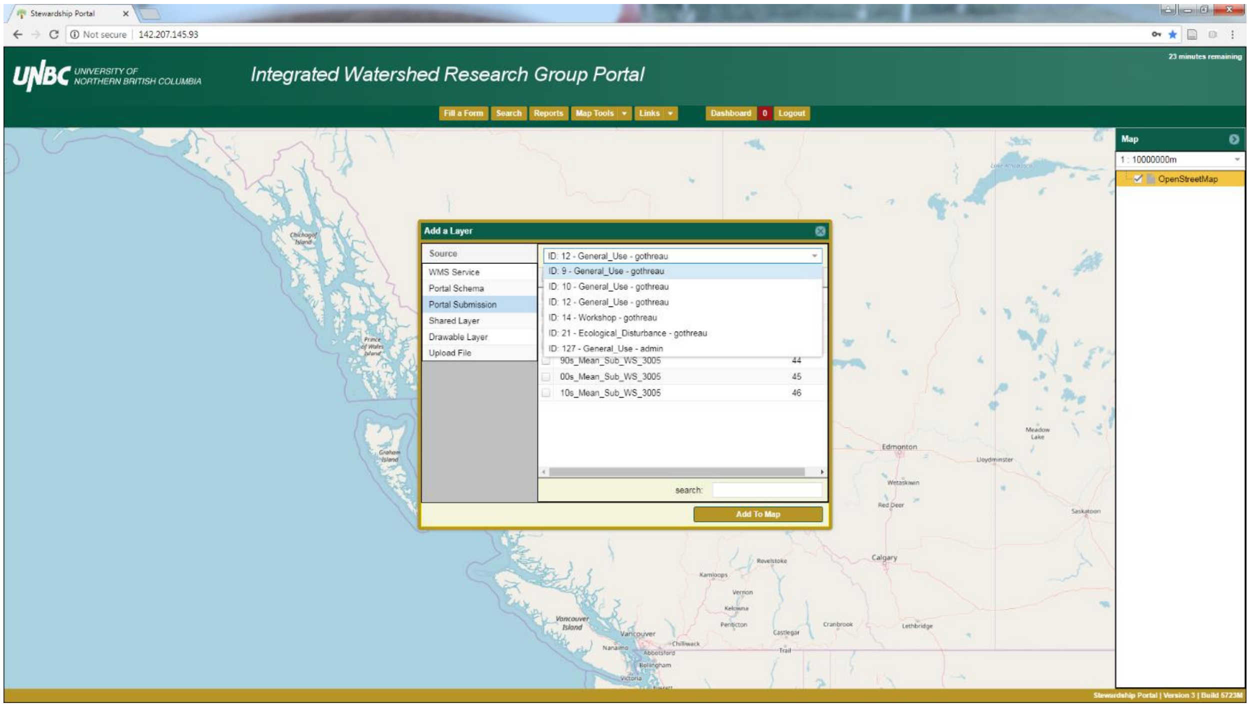


Add a Layer brings us to a window that allows us to find spatial data which has been organized by:

WMS Service: These are Web Maps
Portal Schema: You can find all spatial data that is associated with a specific schema.
Portal Submission: Find the spatial data associated with individual submissions
Shared Layers: These are spatial layers that are available to all Portal users.
Drawable Layer: Allows you to create a new spatial layer that you can draw on the map.
Upload File: This allows you to upload spatial data you have on your hard drive onto the map.

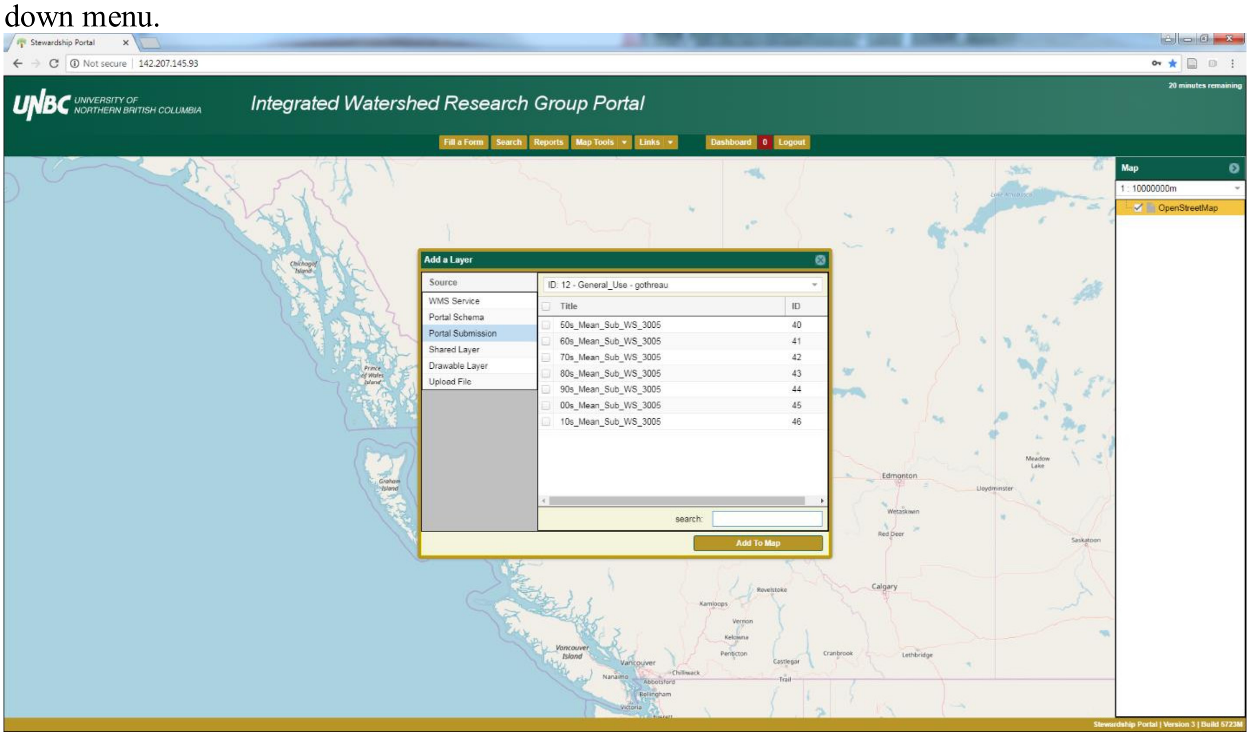


Unlike the search feature, you have to use a drop down menu to sort through spatial data after you have selected the Source category.

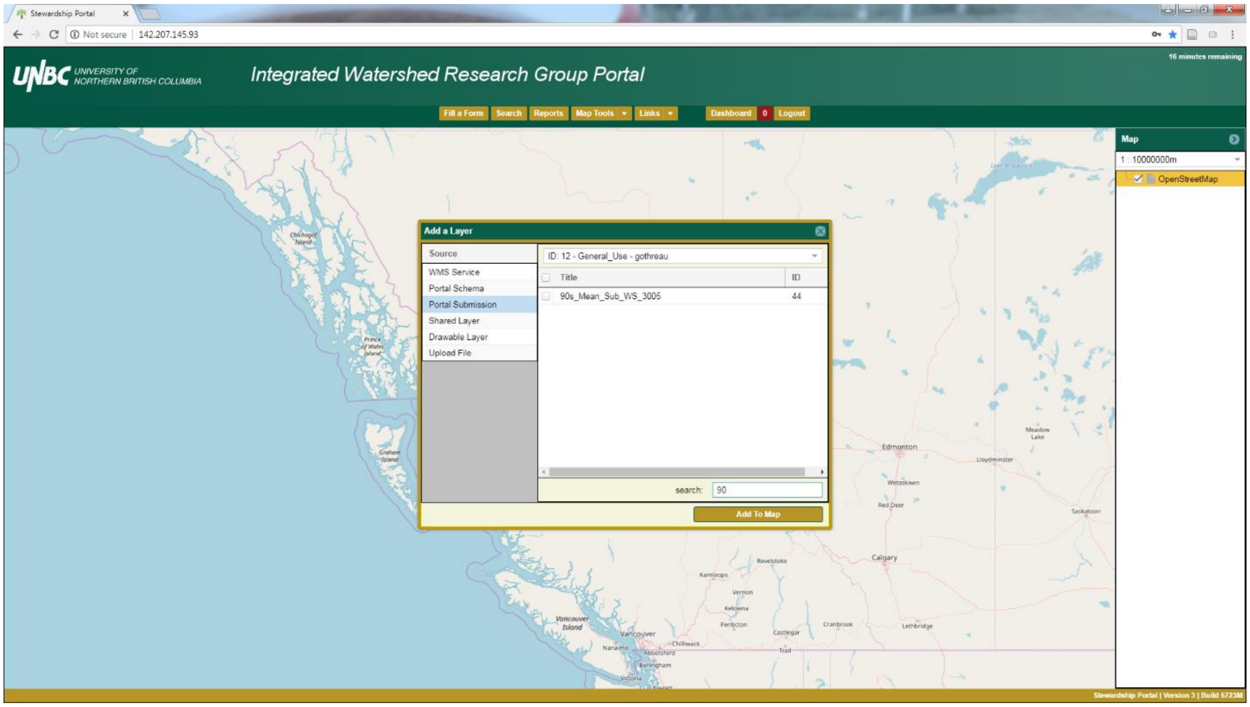


These windows have a search field, however, this only sorts through data that has already been selected using the drop down menu.

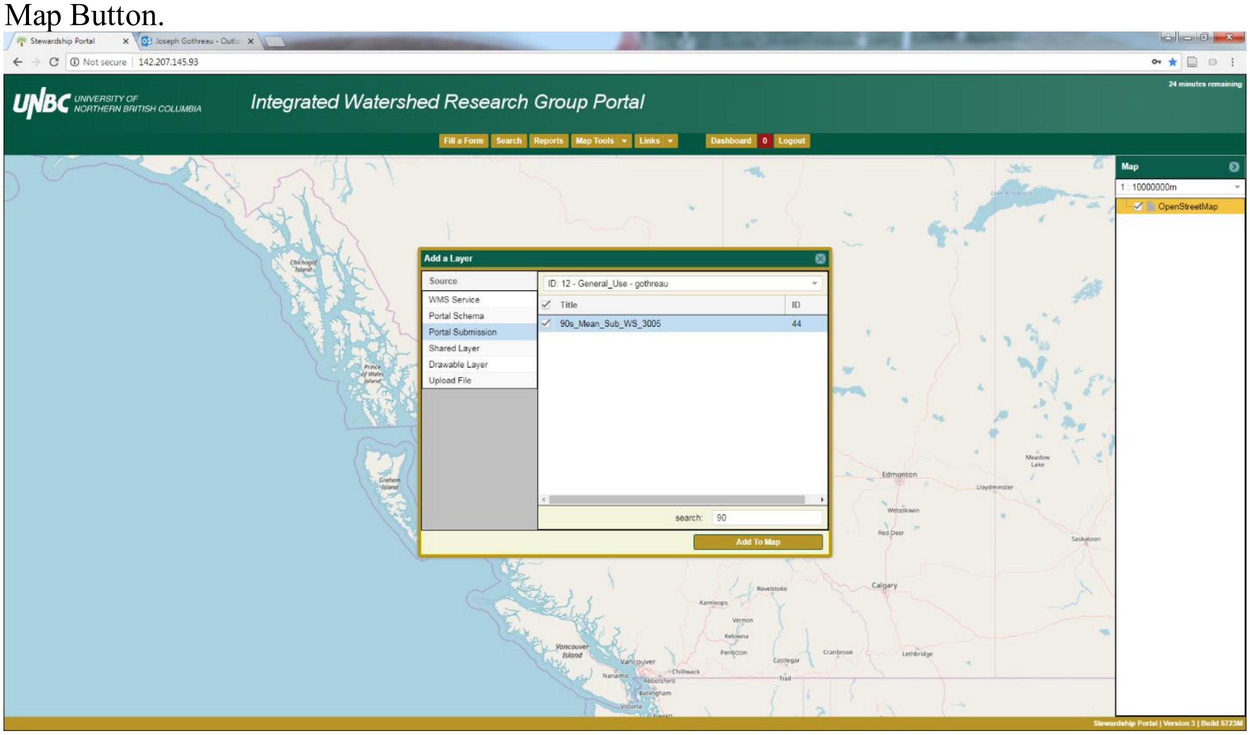
Here is an example of me selecting Submission (ID) 12 from the Portal Submission Drop down menu.

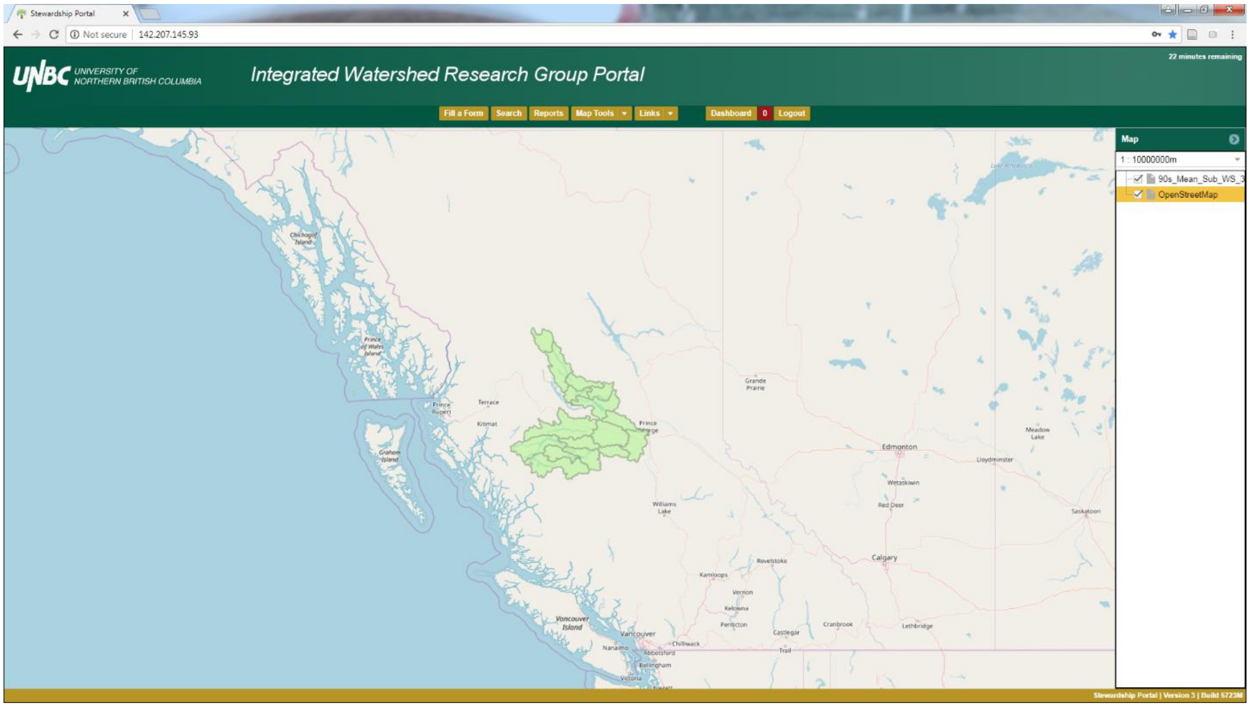


Note the search field is empty and we are shown all the spatial data contained within this submission. Now if we type 90 in the search field we are left with only the features that contain 90.



To actually add the spatial data to the map you need to click the checkbox and hit the Add to Map Button.

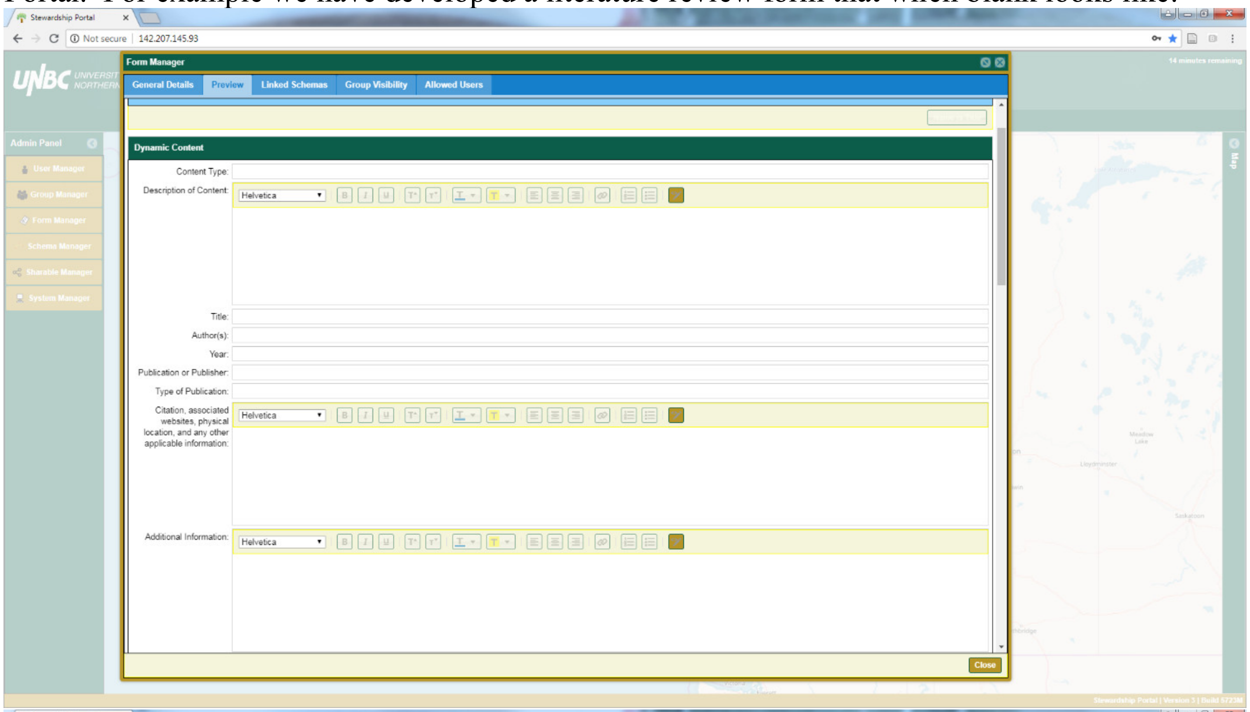


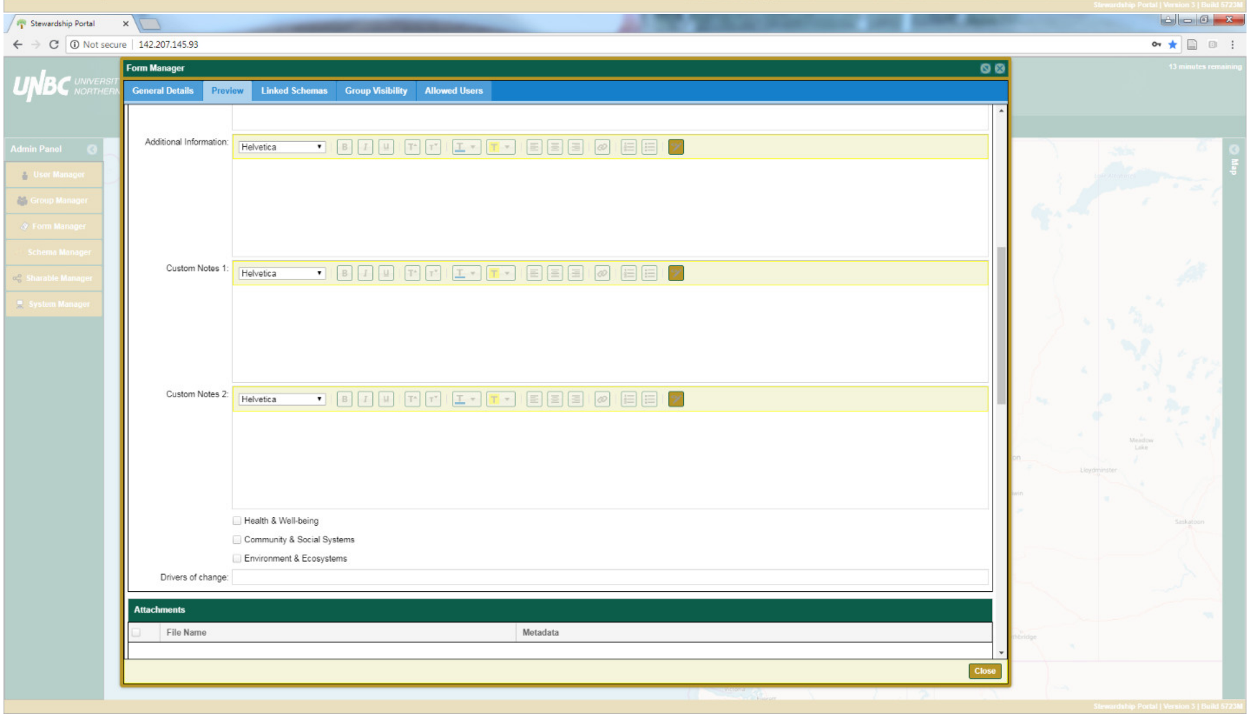


Stewardship Portal
Not secure | 142.207.145.93
UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA
Integrated Watershed Research Group Portal
22 minutes remaining
Fill a Form
Search
Reports
Map Tools
Links
Dashboard
0
Logout
Map
1 : 10000000m
90s_Mean_Sub_WS_3
OpenStreetMap
Edmonton
Calgary
Vancouver
Stewardship Portal | Version 3 | Build 5723M

3. Filling out a form and making a completed submission

To add content to the Portal, we are required to fill out forms and submit these forms to the database. Forms are used to provide information about the data we are uploading into the Portal. For example we have developed a literature review form that when blank looks like:



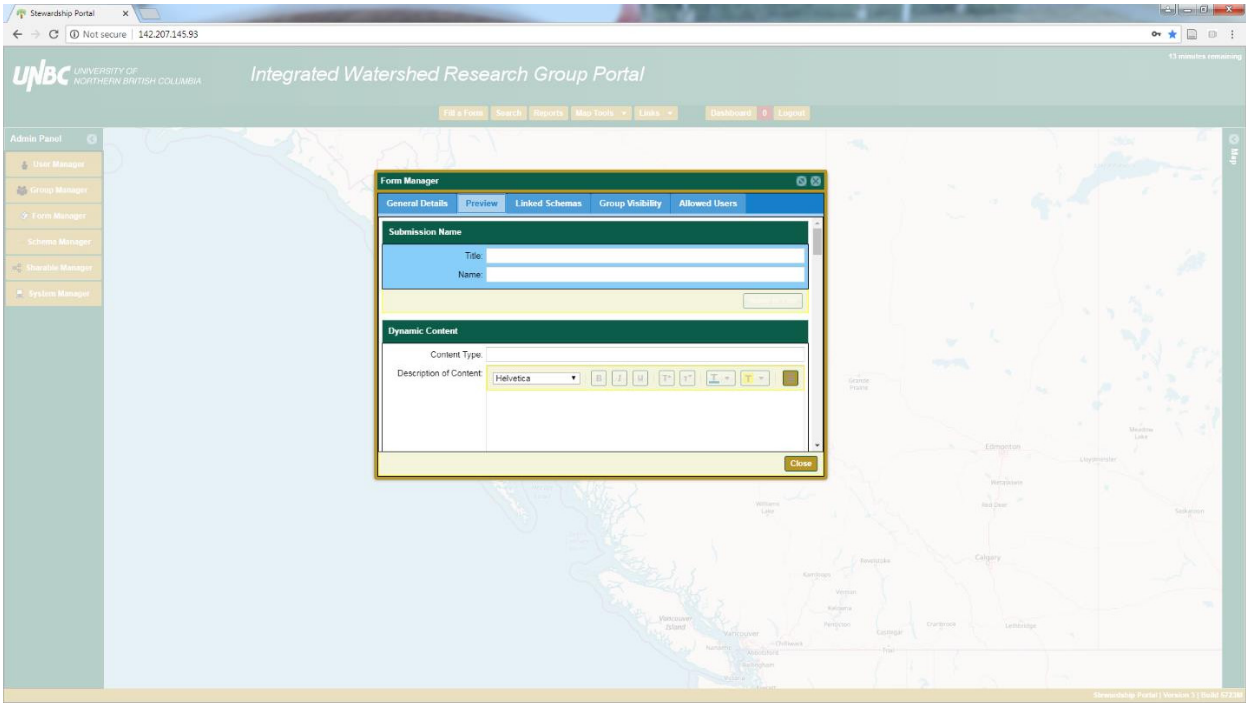


All forms have a Title and a Name section, the title is automatically filled out upon submission by the Portal, and the name can be created by the person filling out the form. It is recommended that the name field is filled out and is informative, otherwise the Portal will

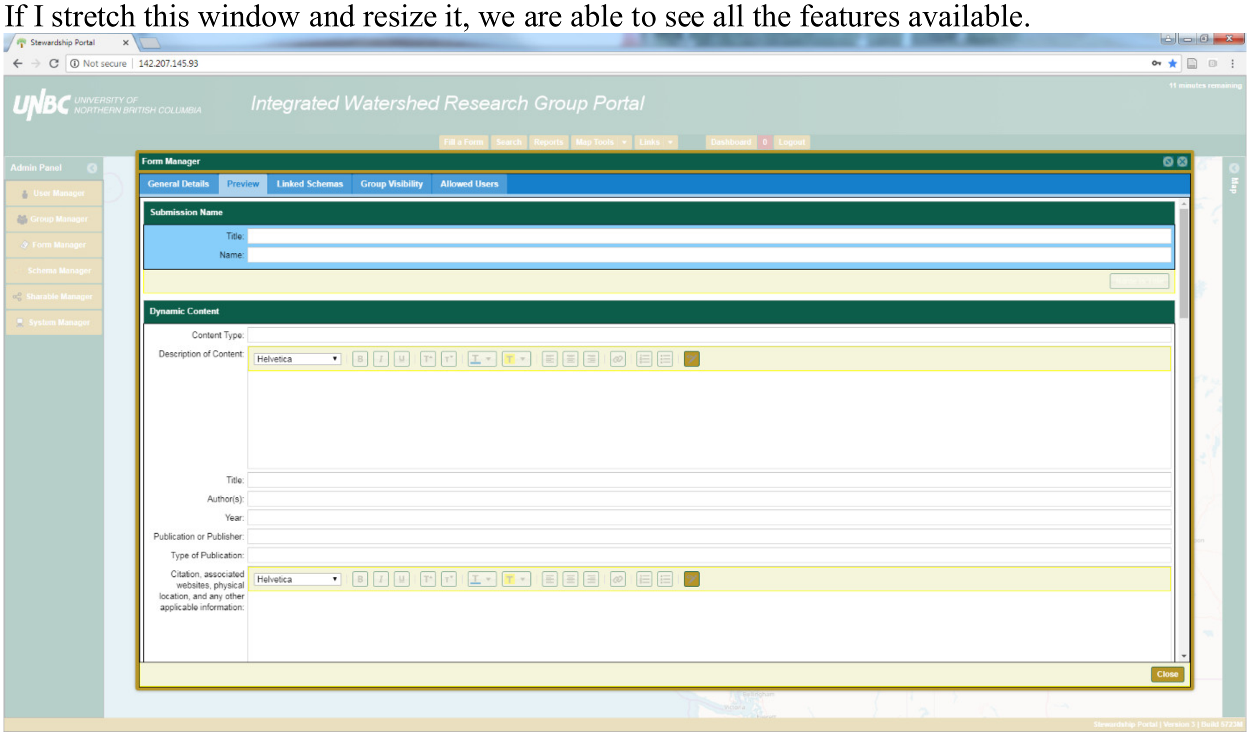
duplicate the title and it is not very human readable. In the case of a literature review the actual name of the article is the perfect information to be placed in the name field.
The various fields and features that fall within the Dynamic Content box are the majority of the content within the form. This is also where forms can be customized by the Portal Administrator for users. We will explore this literature form to learn about some of the features that can be customized.
The Content Type, Title, Author(s), Year, Publication or Publisher, Type of Publication, and Drivers of change fields are all text fields. These text fields are useful for short lines of text or numbers.
The Description of Content is our first example of a HTML editor box, which is essentially a text box with a few additional features. A text box is similar to the text field, but as the name indicates it gives you a box, which allows for larger amounts of text to be easily displayed. The HTML editor box used here gives us that larger area for more text, but it also provides additional features such as:

- Choosing different fonts
- Adding a bold effect to text
- Adding italics to text
- Underlining text
- Changing the font size
- Changing font colour
- Highlighting
- Aligning to the left, right, or center
- Creating hyperlinks to outside websites
- Creating lists
- It is also possible to paste excel sheets into the HTML editor box, which can be helpful with tables of information

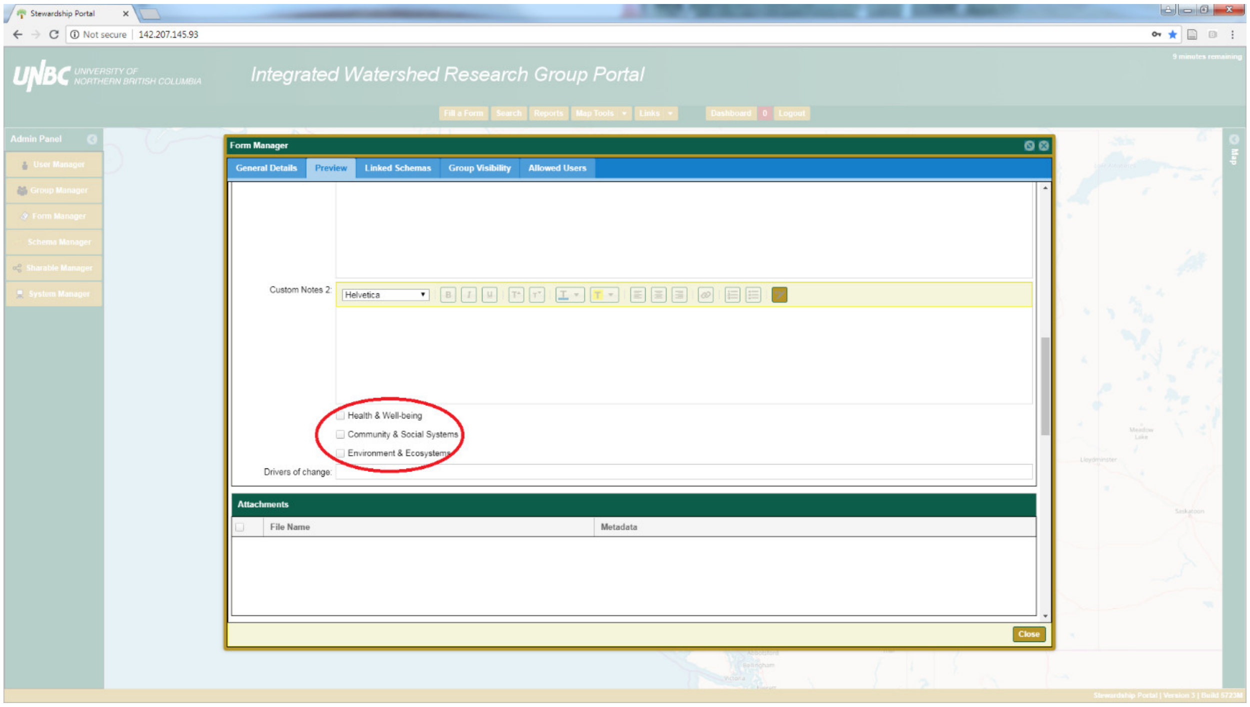
It needs to be noted that depending on the resolution of your screen, you will likely have to stretch the form window to be able to see all these features. For example on my screen this is what the form window looks like before being stretched:



If I stretch this window and resize it, we are able to see all the features available.

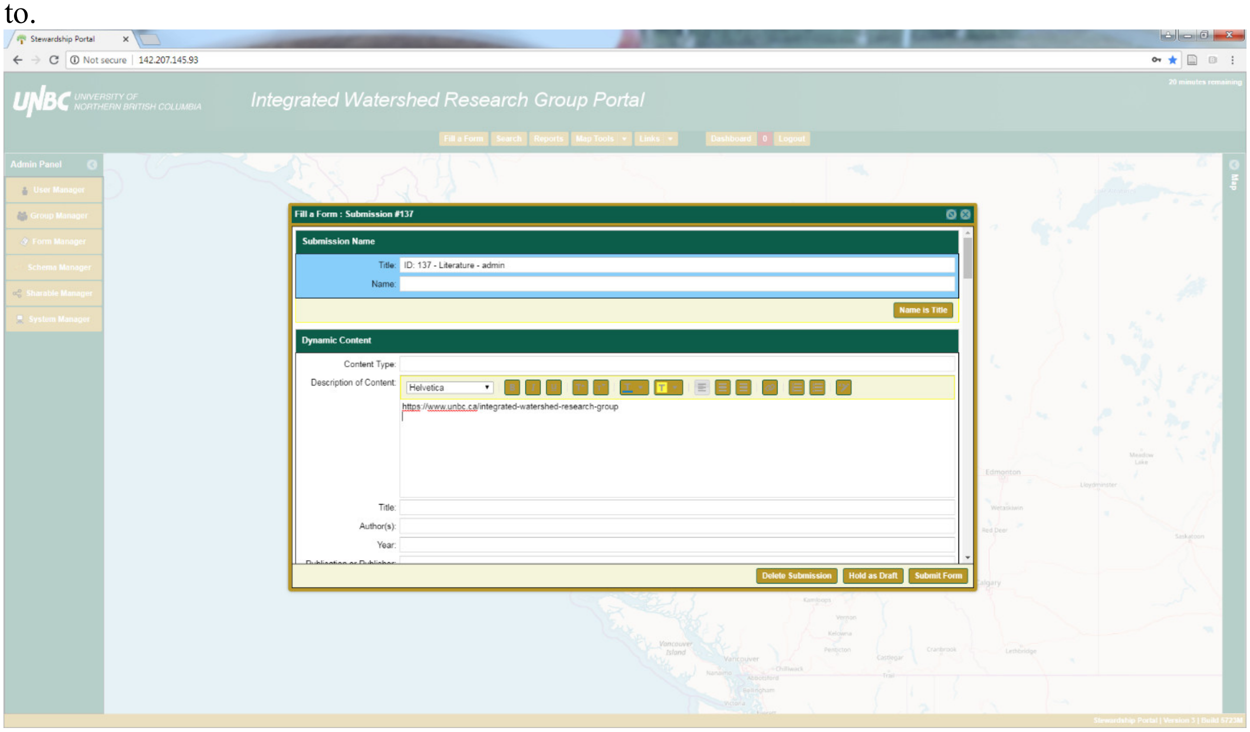


This literature form also makes use of Check boxes to indicate some of the themes that were of interest to us.

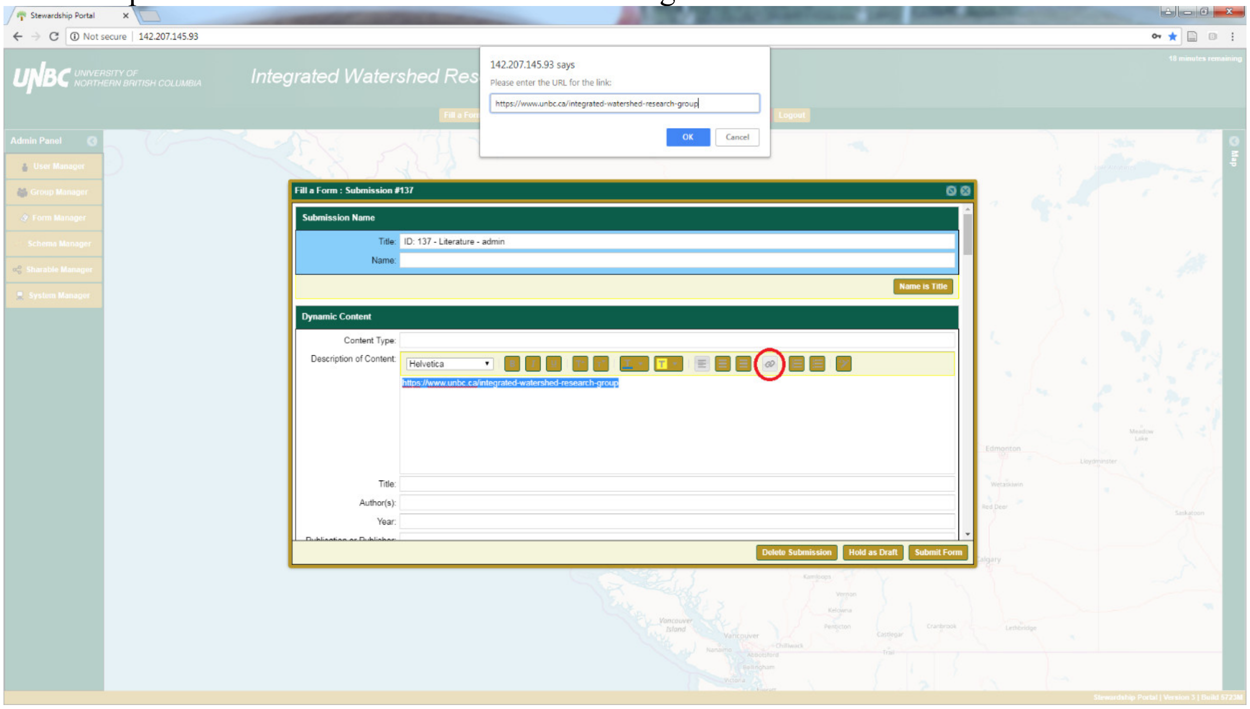


Most of filling out a form is straightforward, simply type or paste the necessary information into the appropriate section. However, creating a hyperlink has proven to be less obvious so we will cover how to do this.

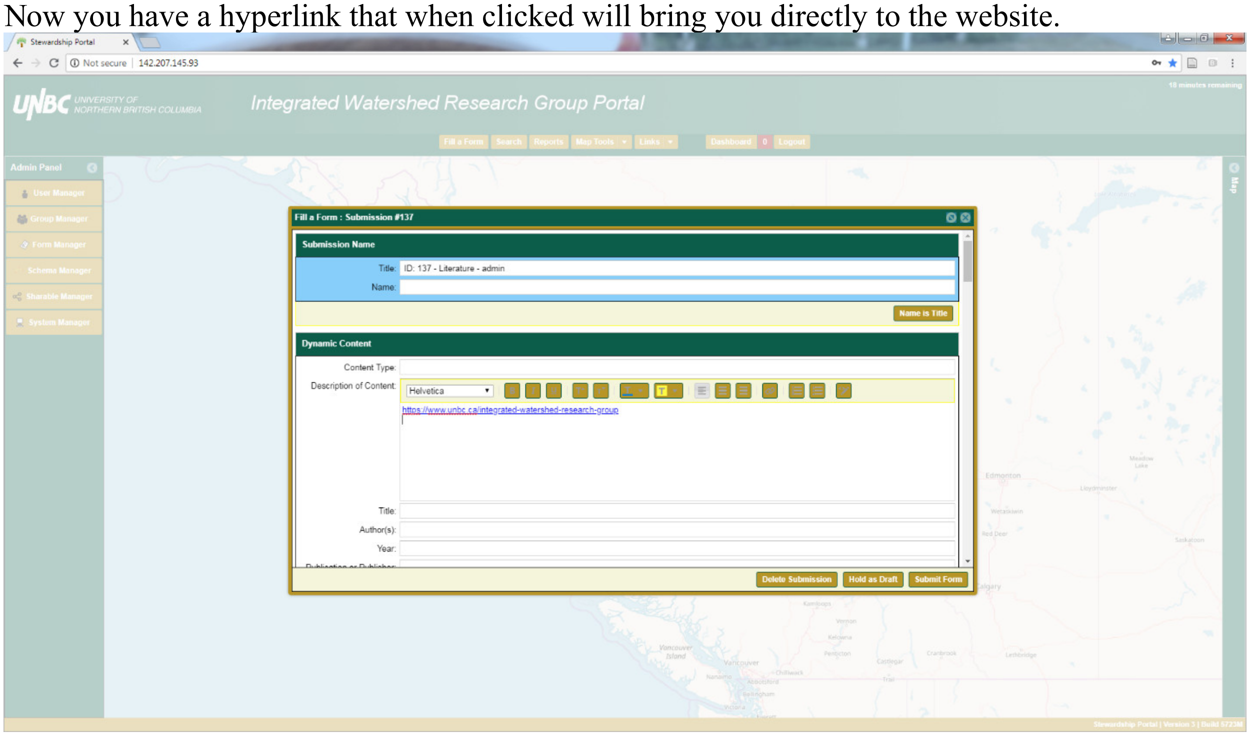
Within a HTML editor box you can copy and paste the URL of the site you would like to link to.



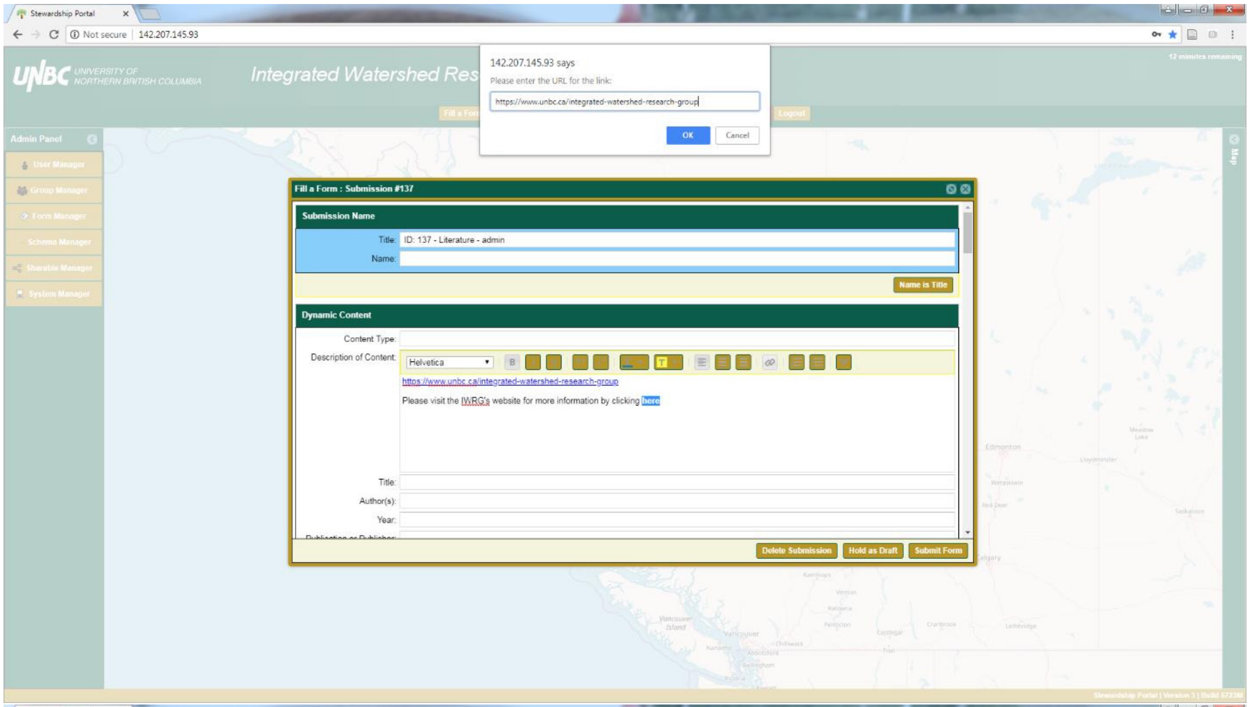
Note that this is just the text, which could be copied and pasted into a browser. However, we want to be able to click on it and have it take us to the website. So with the url highlighted we will click on the hyperlink button (two chain links) which is highlighted in red below. You then paste the url into the window that is asking for the url and hit the OK button.

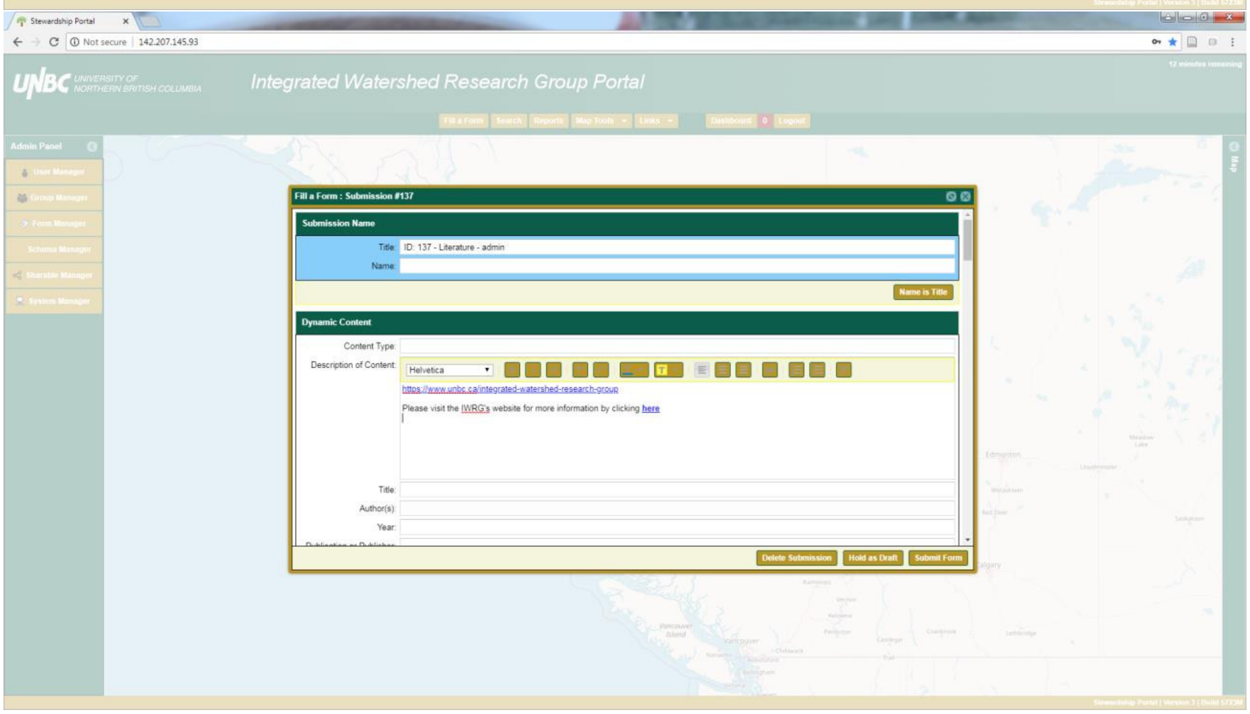


Now you have a hyperlink that when clicked will bring you directly to the website.



If we want to get really fancy we can actually make the hyperlink a word or series of words that when clicked will bring us to the desired website. To do this we simply type out some text, in this example we'll use the line "Please visit the IWRG's website for more information by clicking **here**. Here is the word we'll make into the hyperlink. Highlight here and paste the url into the box that appears.

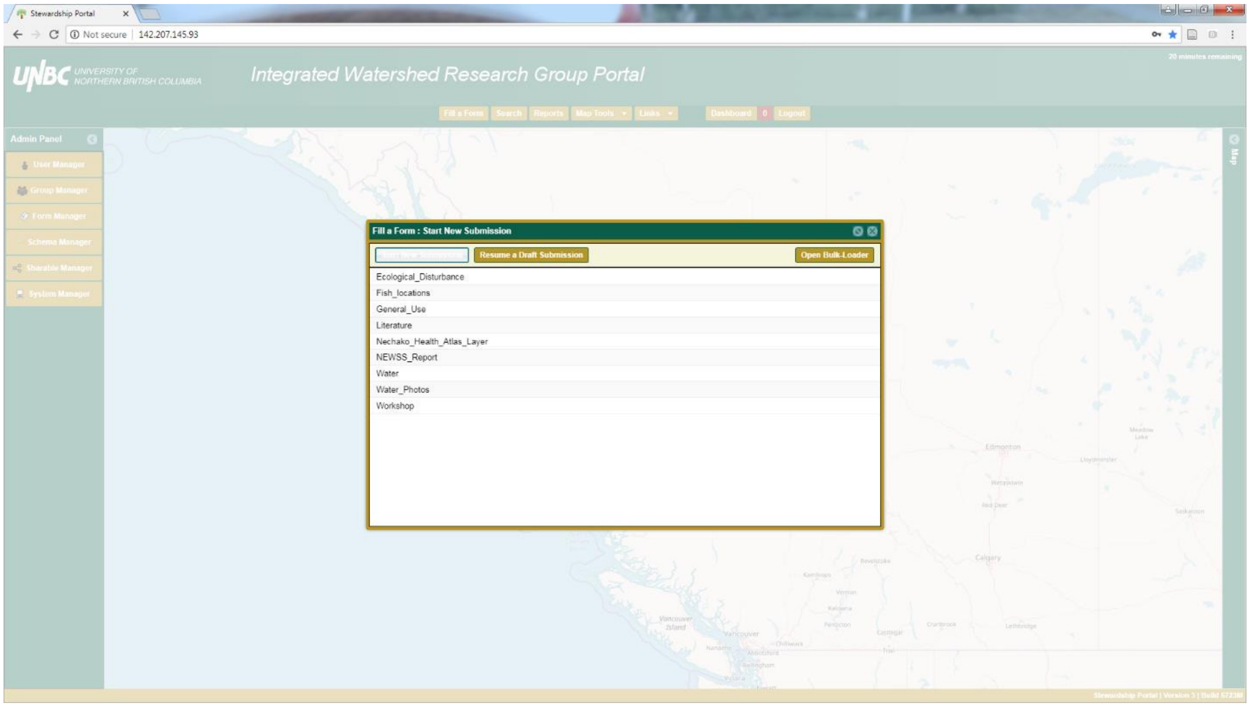




To start making a submission you will have to login and click the Fill a Form bottom. You are then prompted with three options:

1. Start New Submission
2. Resume a Draft Submission
3. Open Bulk-Loader

Click on Start New Submission and you will be prompted with all of the forms that are available to you.



Double clicking on the form you want will open a blank version of that form. Note that the Title is automatically created for you, don't forget to give the submission a more readable name!

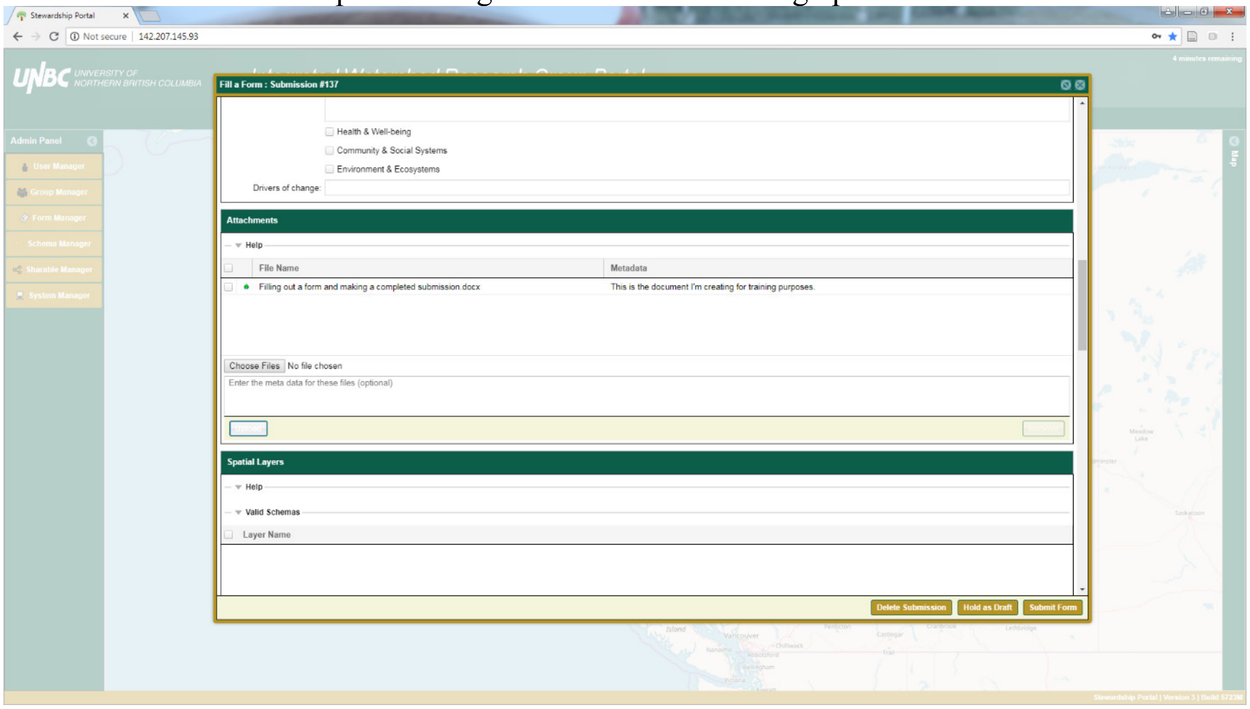
Fill out the sections of the Dynamic Content that are appropriate, while ideally every section would be completed the Portal will allow you to submit forms that have blank sections. We've made use of this particular feature with the Custom Notes sections of the Literature form. We can make use of additional sections if need be, while not limiting our ability to submit the form.

After finishing with the Dynamic Content section there are a few more sections that we can make use of. Of particular interest to us currently are the following sections:

- Attachments
- Spatial Layers
- Parent Submission
- Permissions
- Notifications
- Linked Layers

Attachments:

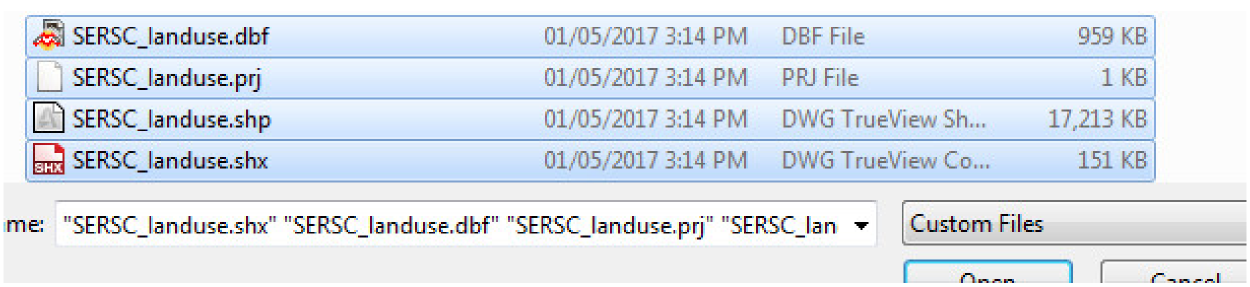
The attachments section is used to attach non-spatial data to the submission. This can be any type of digital file, e.g. documents, PDFs, pictures, video, and audio files to name a few possibilities. To attach a document simply click on the Choose Files button and browse to the location of the desired file and click the open button when you have the file. Beside the Choose Files button there should be the condensed name of the file you just selected. You can also add meta data directly below, where you may want to indicate where this file came from, or any other pertinent information that hasn't already been described in the form. You can upload multiple documents, simply repeat this process. If the files are large you may get an error, in which case you will want to contact the Portal Administrator and inquire about having the file size limit increased. When you have the attachments you want, hit the upload button. Below is an example of a single Word document being uploaded.



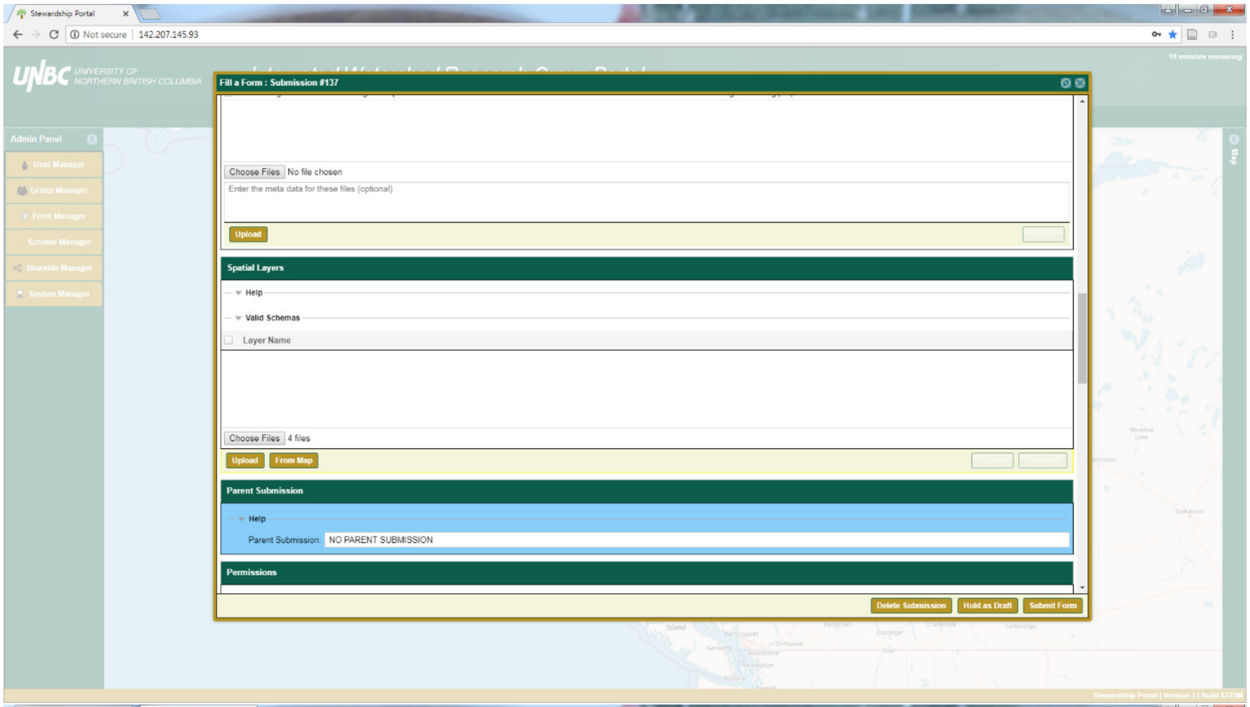
Spatial Layers:

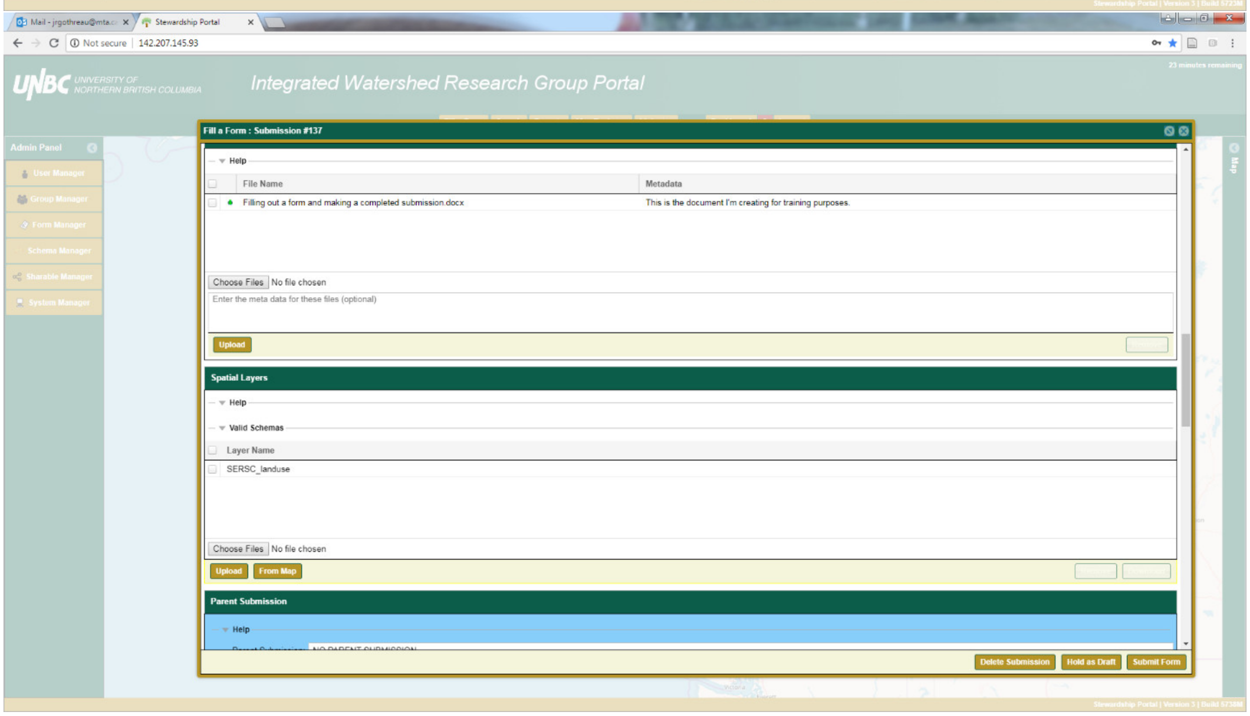
This is very similar to the attachment section, except it is designed exclusively for non-raster spatial data (points, lines, and polygons). The only significant difference with spatial layers is when you are dealing with shapefiles. To upload a shapefile you need to select four different files that make up the shapefiles, which are:

- .dbf
- .prj
- .shp
- .shx



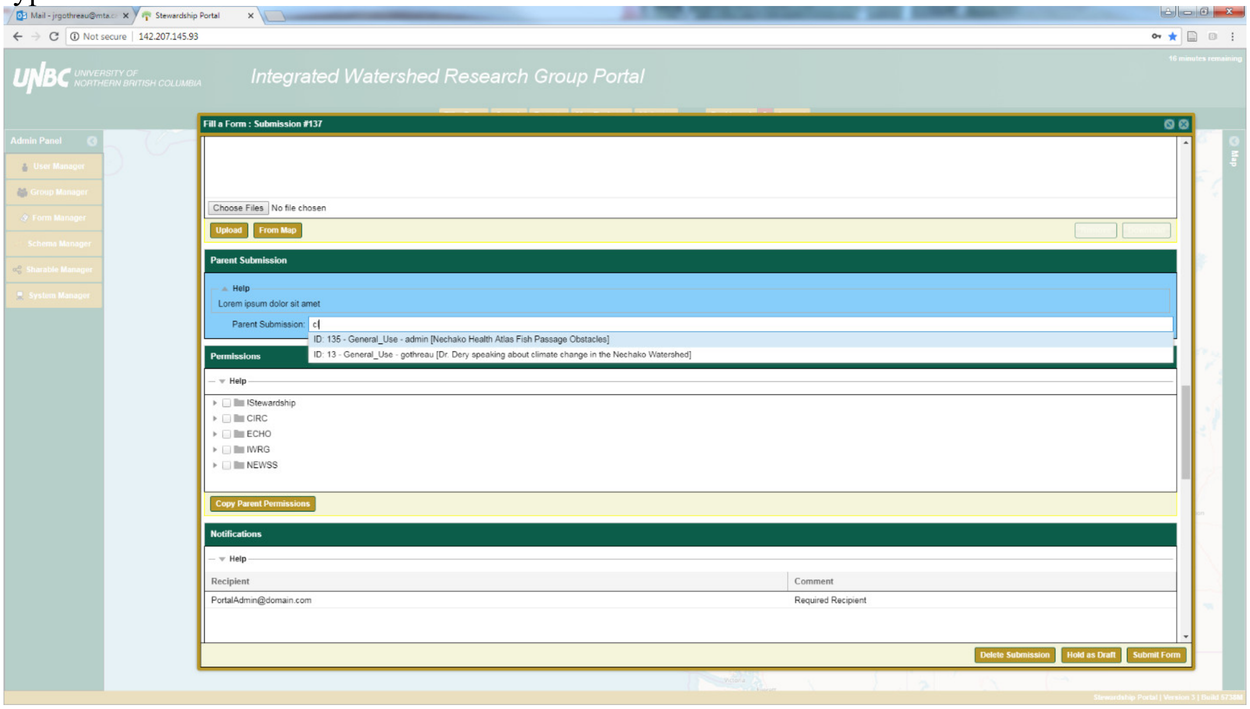
When you've selected all four files and hit open you'll see that there are 4 files ready to be uploaded.



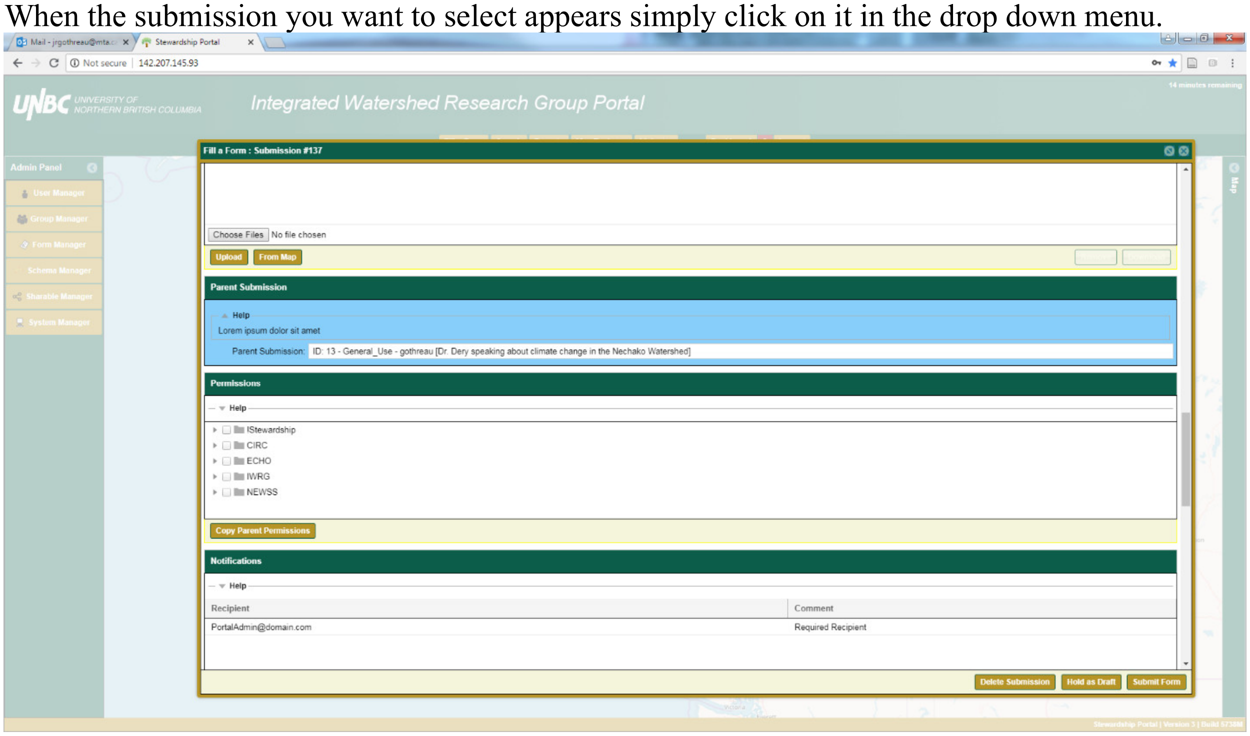


In this case we don't have any reason to make use of the Parent Submission option, but we will walk through it for the sake of being comprehensive. Parent Submissions are meant to make a connection between two or more submissions. We may want to make use of a Parent and Child submission relationship if we are trying to update a submission that is already in the database. Since this is a total records system, we are unable to edit a submission after it has been completed, so the only way to update information would be to make a child submission which has the updates. This isn't the only situation where we might want to make use of the Parent/Child relationship.

To create this relationship use the text field within the Parent Submission box by starting to type in a submissions name or submission ID.



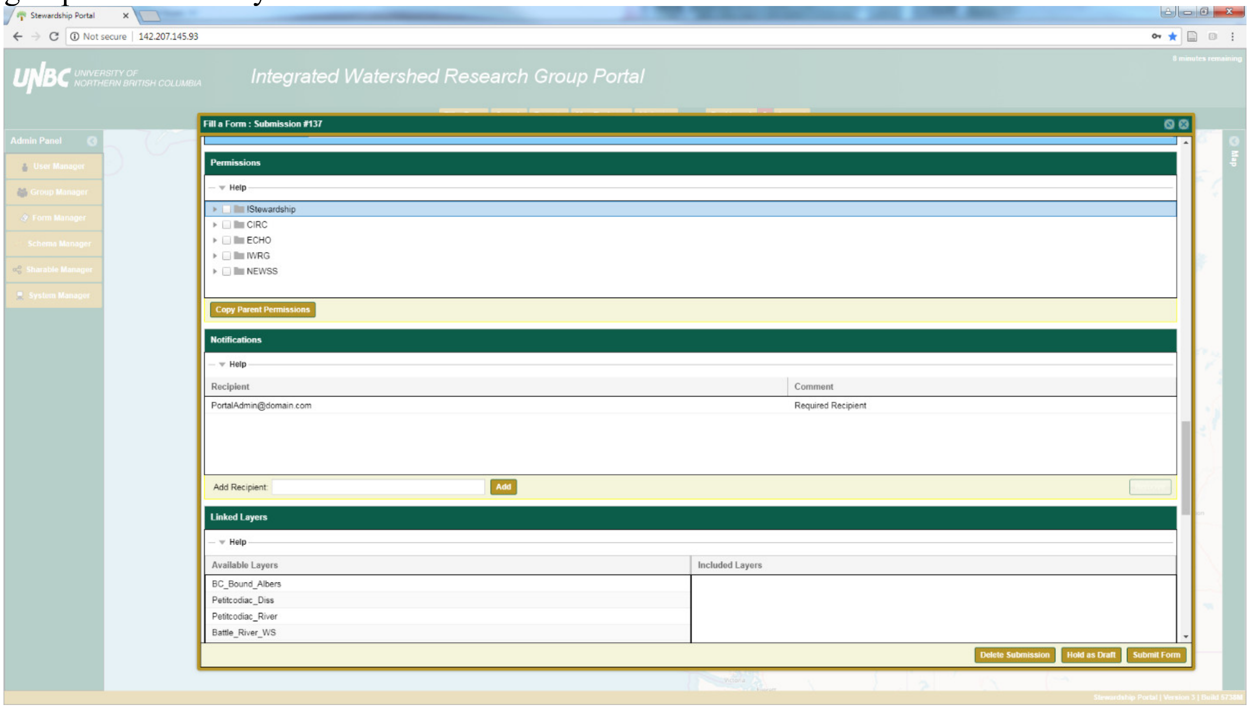
When the submission you want to select appears simply click on it in the drop down menu.



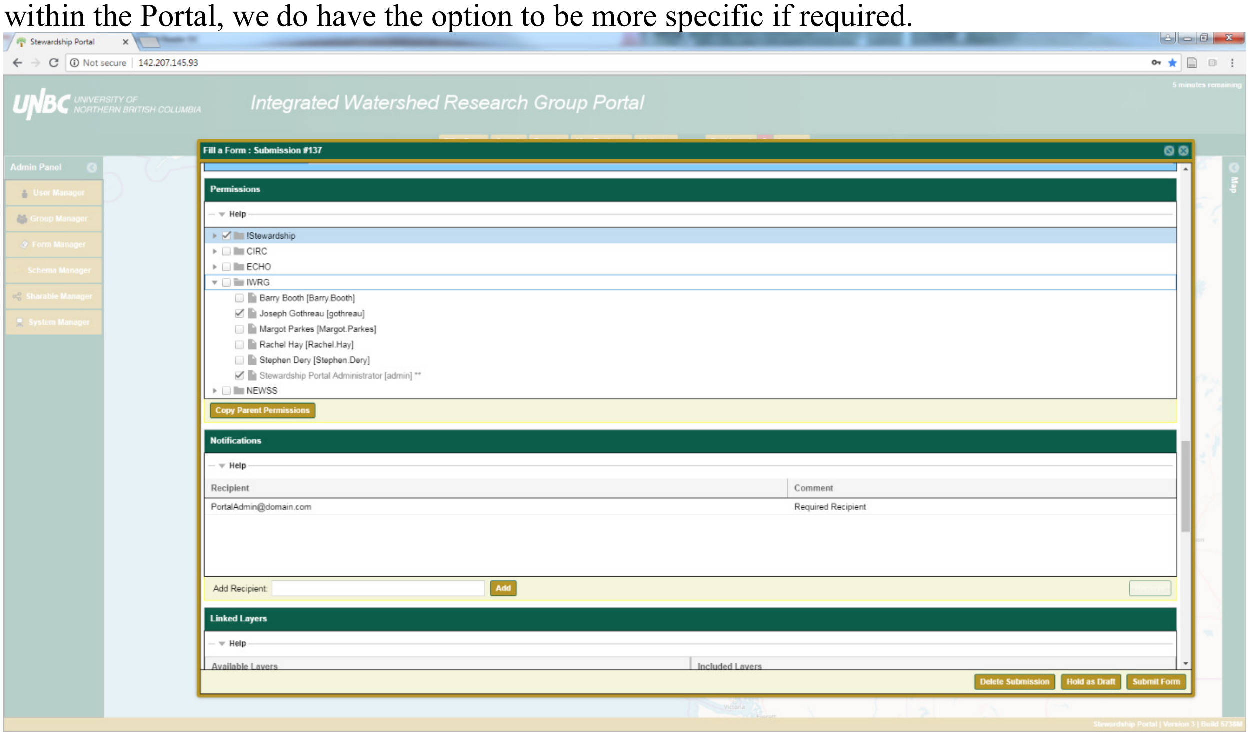
We have now successfully made this new submission a child of submission ID 13.

Permissions:

Next we need to determine which permissions are appropriate for the submission. If we were to leave the permissions all unchecked, only the administrator account will be able to see the submission. Since we want to be able to share our submissions we will start determining who should have access to the submission. The Permissions box will show the various groups that currently exist within the Portal.



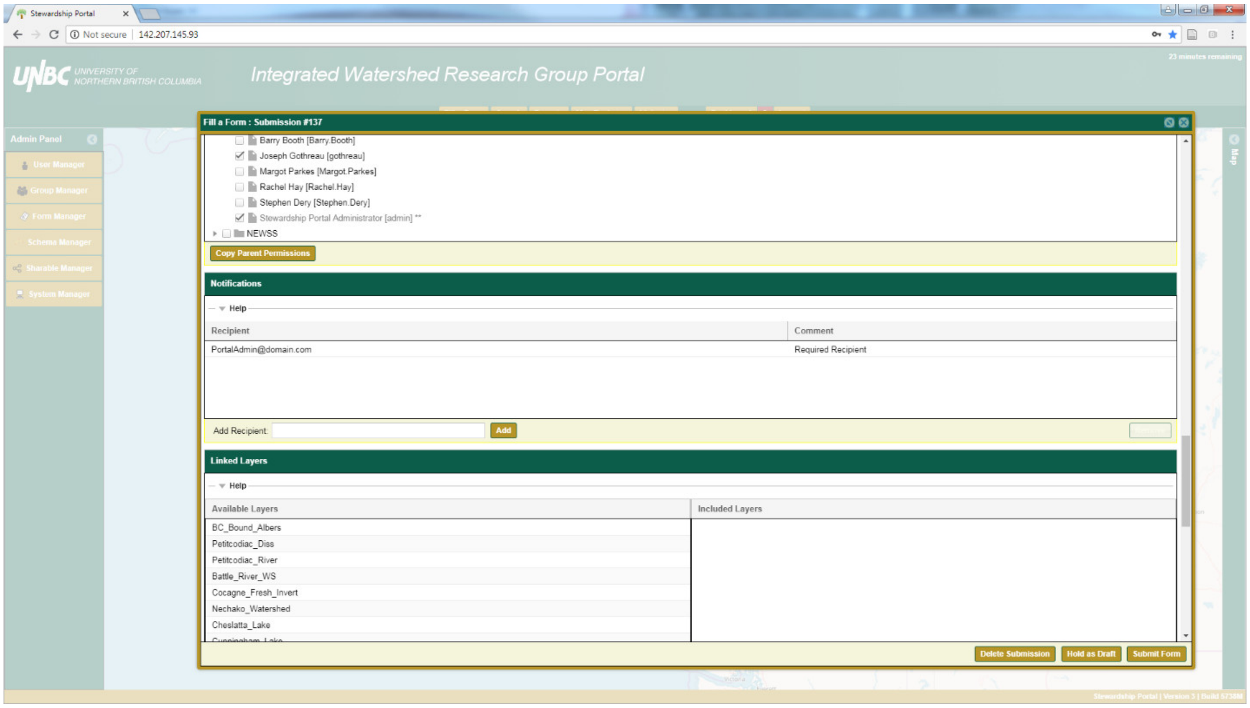
We can click the empty box beside a group to give everyone who is part of that group access, or we can click the triangle beside a group name to show a complete list of everyone who is a member of that group. This allows us to pick and choose who within a group can have permission. While it is unlikely we will have many reasons to not share across the network within the Portal, we do have the option to be more specific if required.



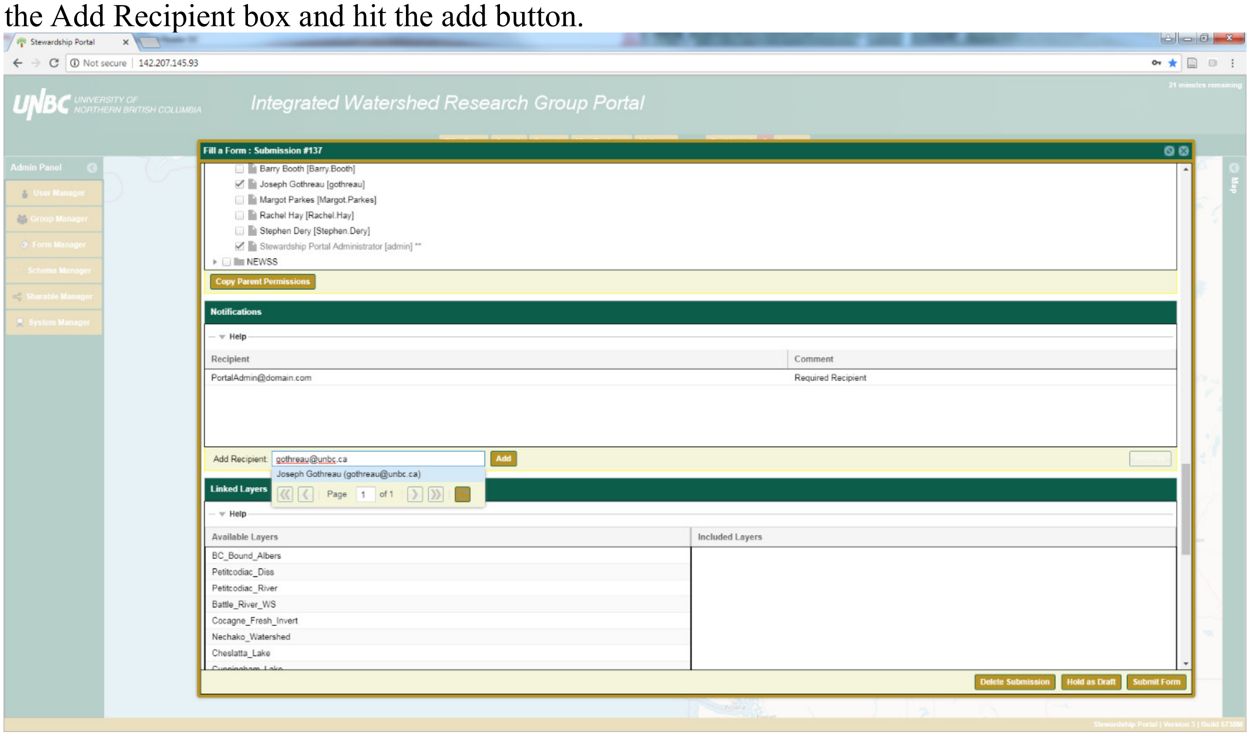
If we are making use of the Parent Submission relationship we are also able to simply copy the Parent's permissions.

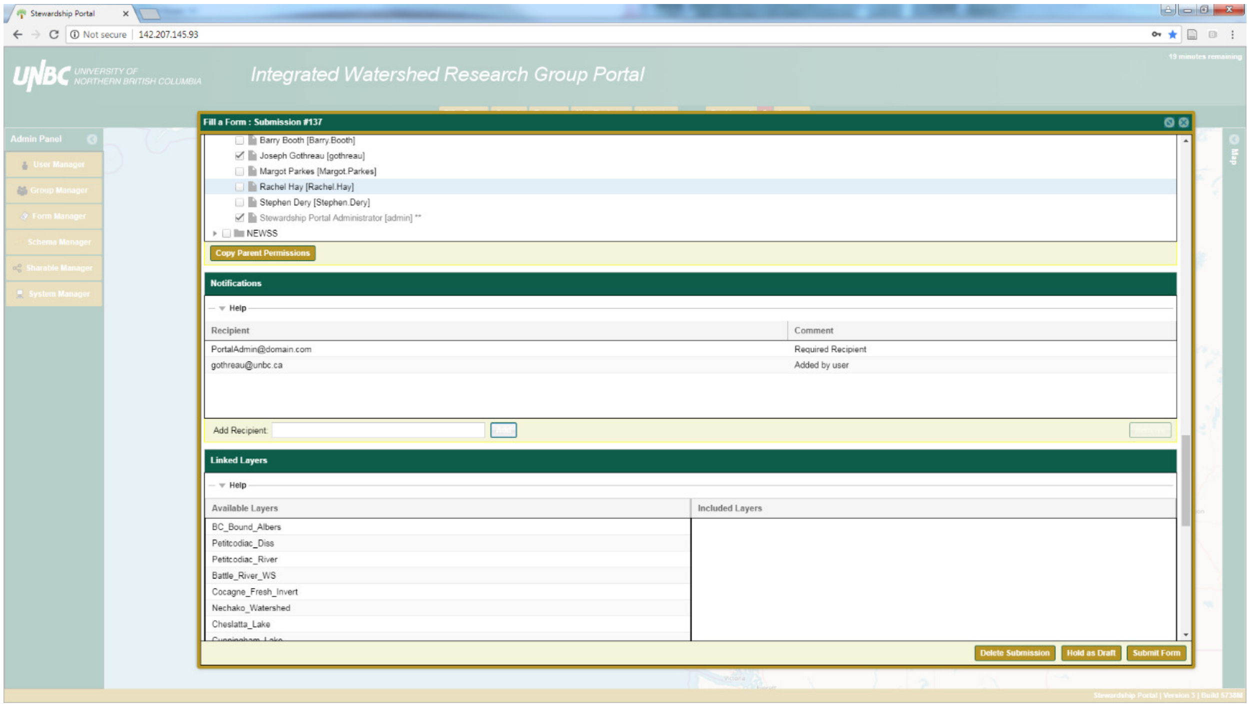
Notifications:

The notifications box allows us to send an email out to users when we submit new content. The default is set to send the Portal Administrator an email.



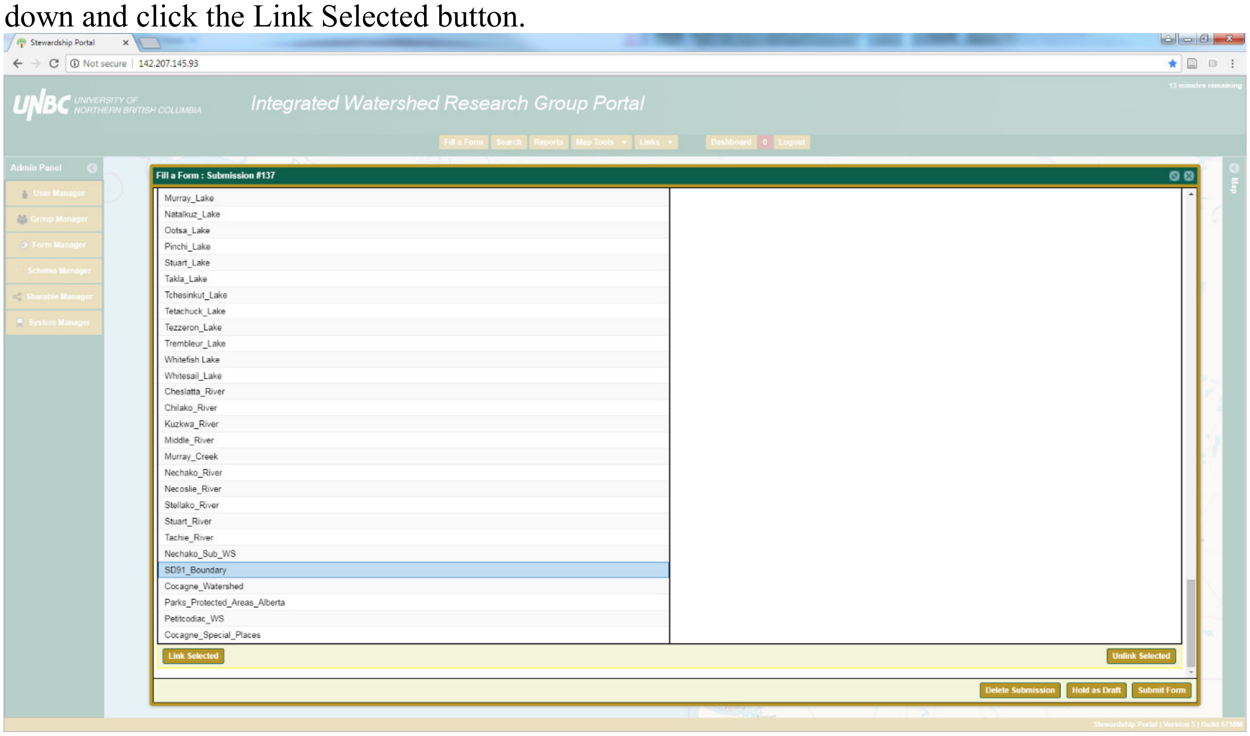
If the submission was of particular importance to someone we would type in their email in the Add Recipient box and hit the add button.

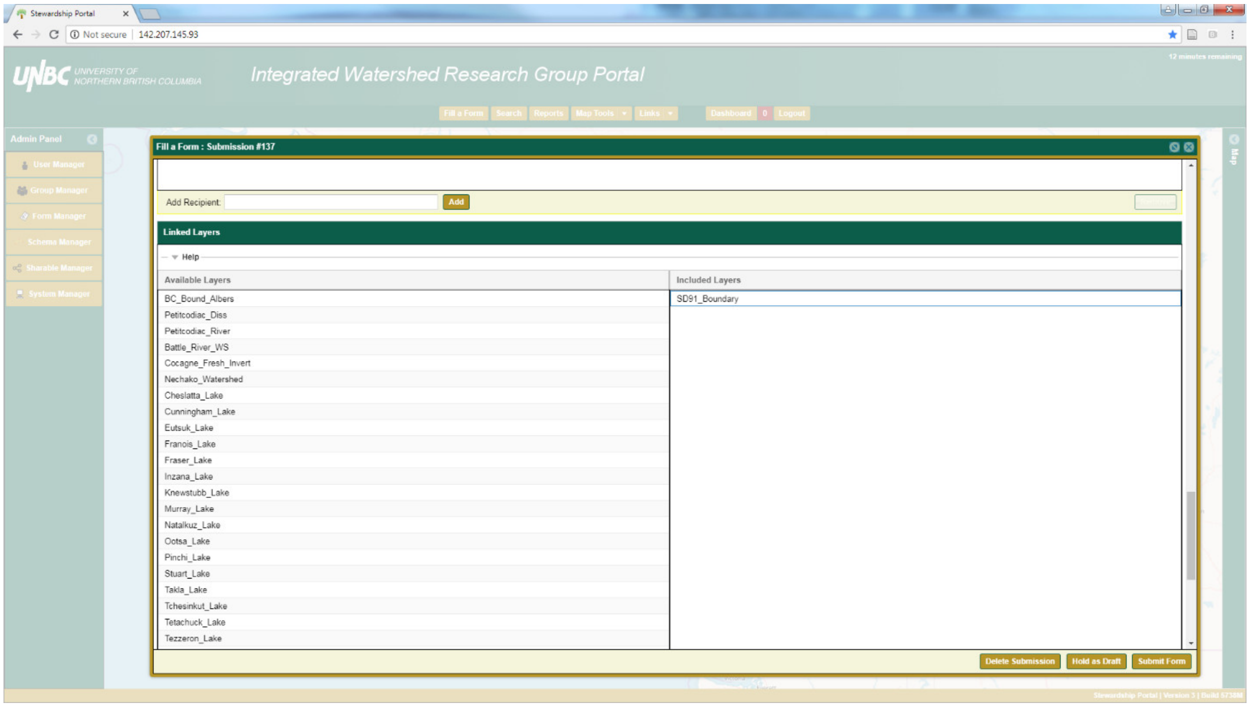




Linked Layers:

The last section of making a submission is the Linked Layers section. This may be a little confusing since elsewhere in the Portal it is referred to as Shared Layers. These are the spatial layers that have been shared by other Portal users with the intent of saving others the hassle of going out and finding/creating these layers. To link one or more of these layers simply click on them to highlight the name (in the case of multiple selection you'll have to complete this step multiple times), and when you have the selection you are looking for scroll down and click the Link Selected button.



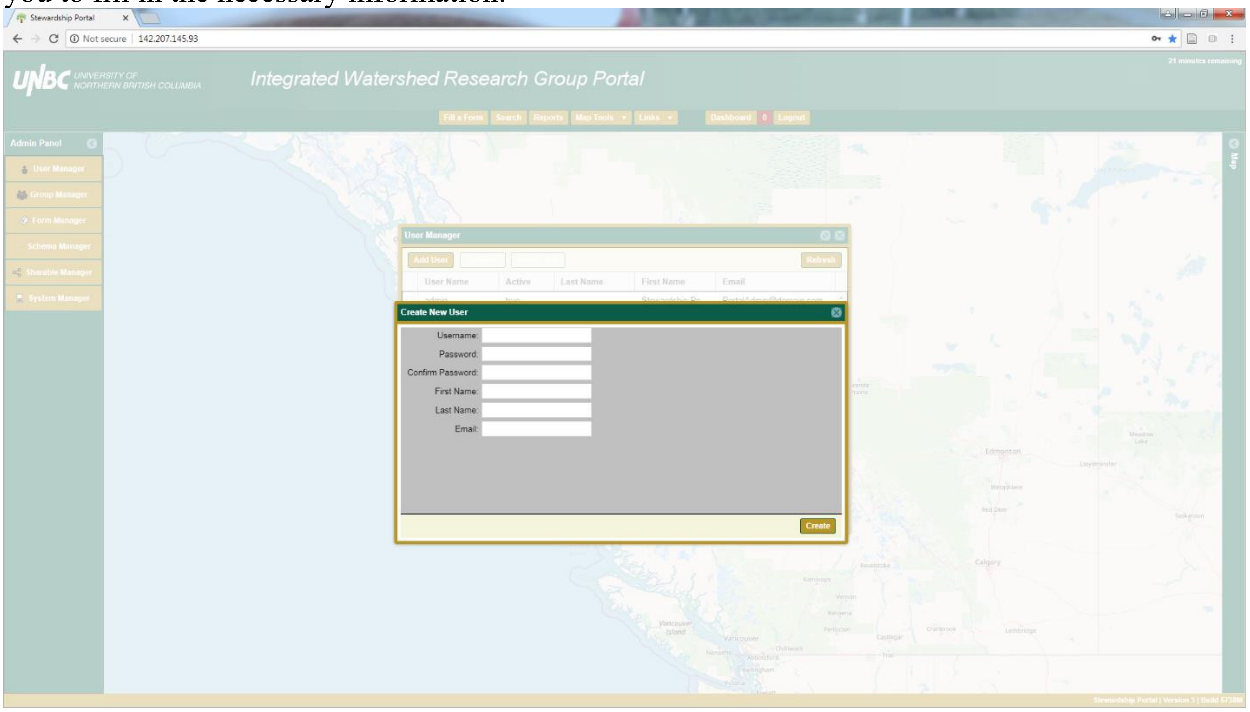


Finishing Steps:

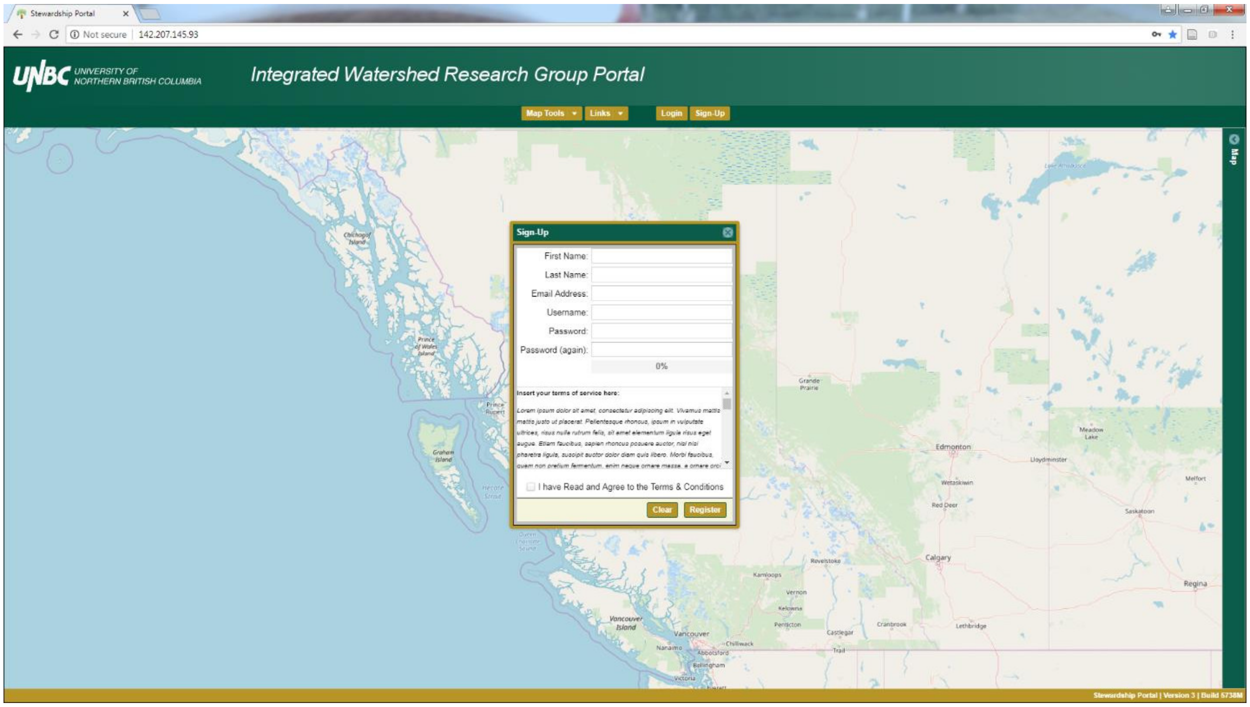
Now all we really have left to do is review the content to make sure everything is how we want it before submitting the form.

4. Setting Users Up:
Two ways:
1. Administrator setup
2. Self-Registration

Administrator Setup:
Using the User Manager button on the Admin Panel go in and hit Add User, it will prompt you to fill in the necessary information.



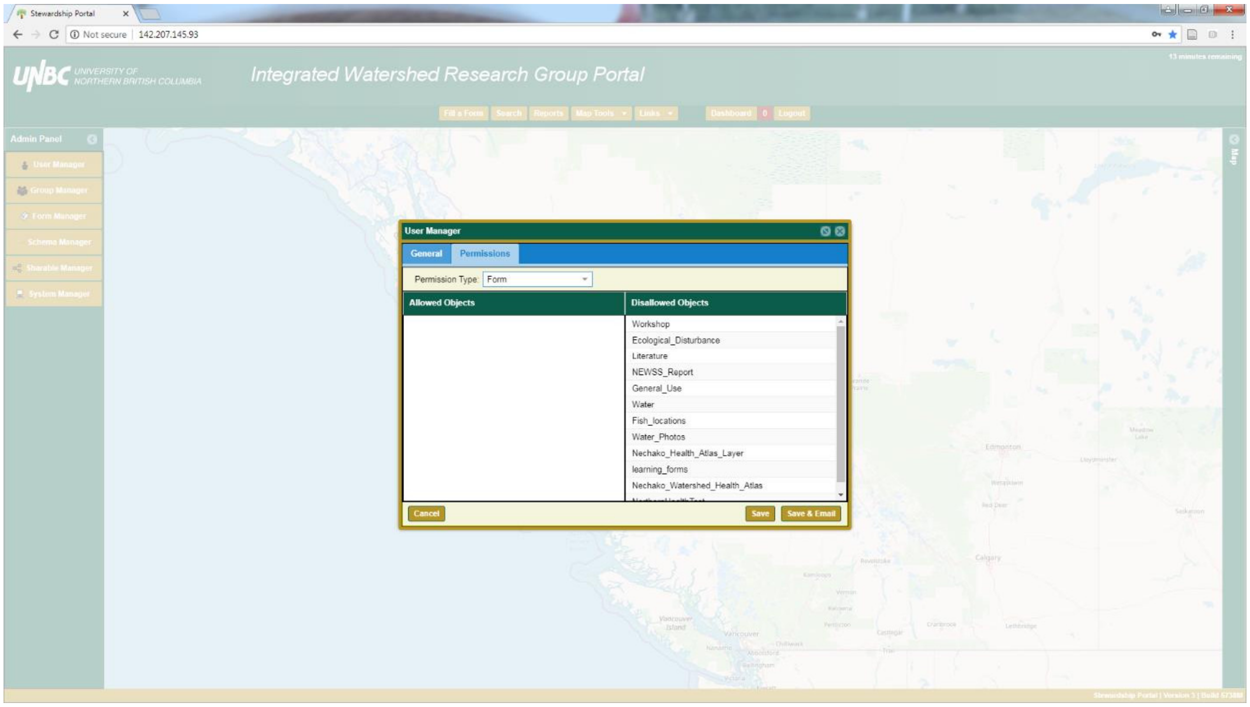
Self-Registration:
Simply go to the Portal (142.207.145.93) and use the Sign-Up button, it will prompt the person to put their information in.



Either of these registration processes brings us to the same spot, where an administrator needs to finish setting up the account.

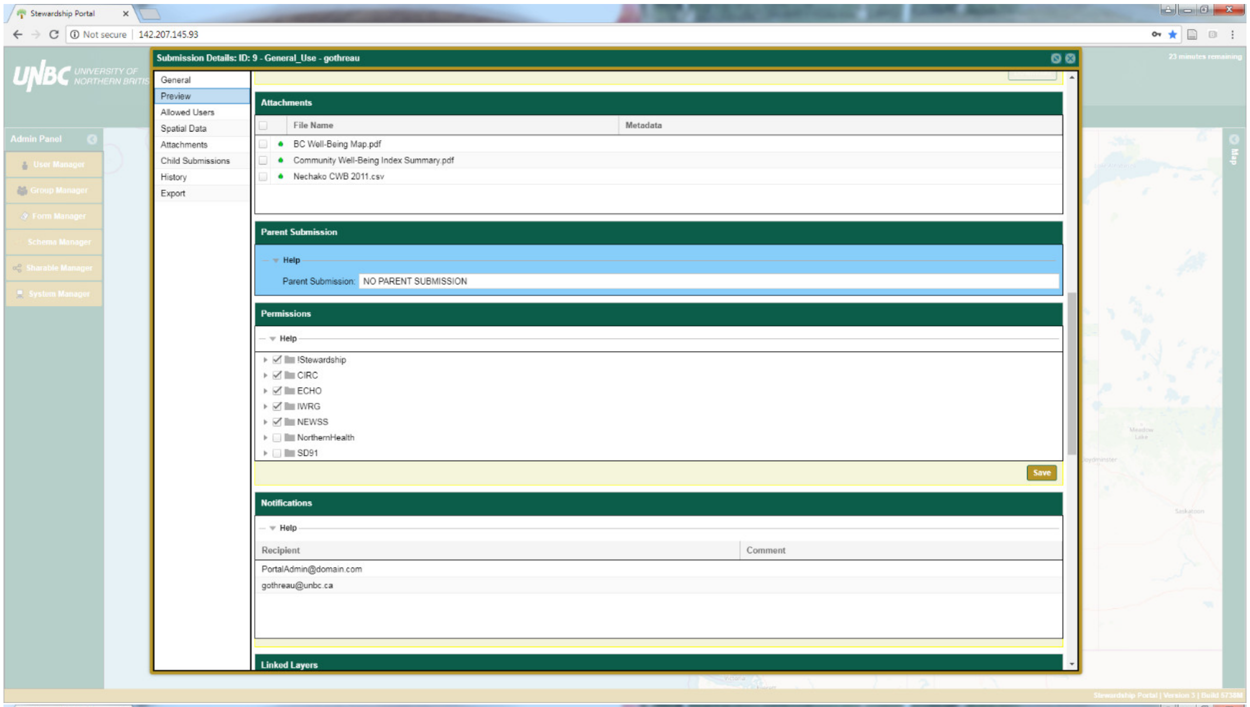
Now the administrator can use the User Manager to finish this process. Locate the new user and use the Edit User button to bring the profile up. The user needs at a bare minimum to have their "Is Active" button checked on. Depending on what each user is required to do you can setup notifications, the ability to assign or be assigned submissions, and a few other less important details.

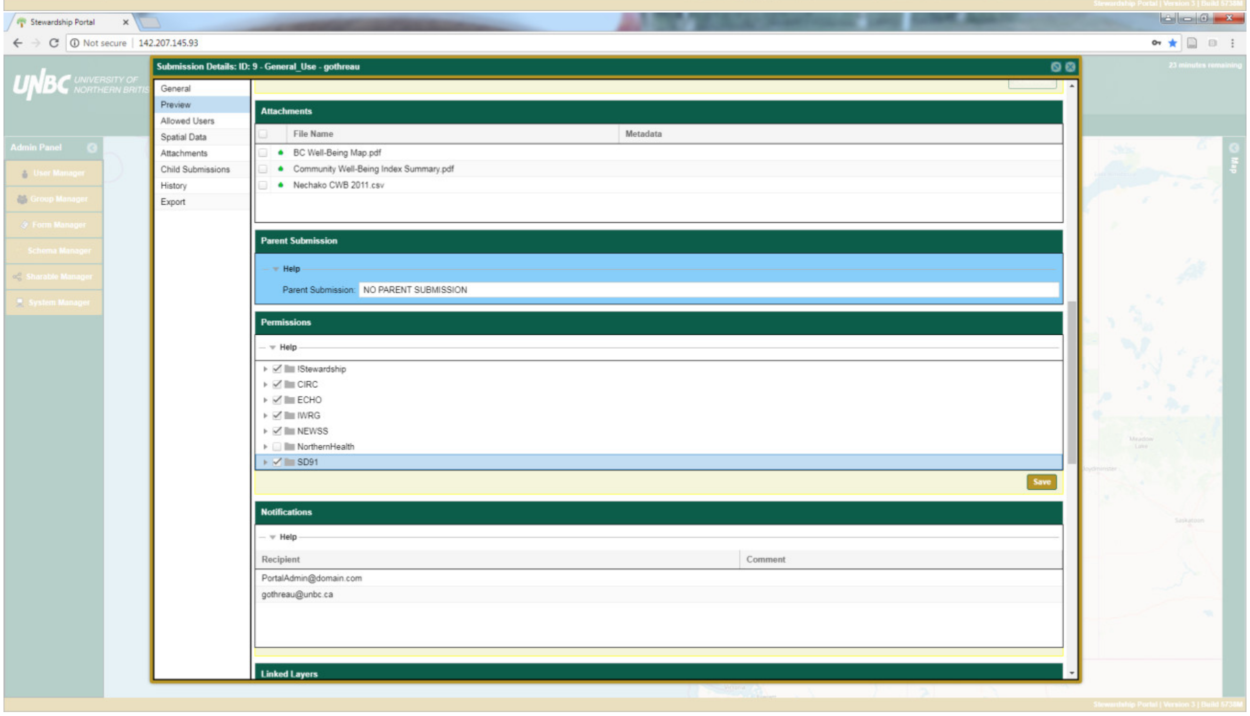
Using the Permissions tab we will need to provide access to the forms the user will be able to fill out. We can also use the Permission Type to change from forms to submission, which may be helpful if only one new user is being setup. Please note that this list includes draft submissions as well. It is also possible to setup a single user or a batch of users using Group functionality.



After the account has been setup we need to place the user into a group. The Group Manager button is under the User Manager button, and this is where groups can be created or edited. To add people into a group use the edit group button and you can drag and drop people into the group.

It needs to be noted that when you put new users into the Group, they will not automatically be given access to submissions that pre-date the user, this needs to be completed manually. Using the admin account use the search menu and search for everything (%), go into the submissions the new users should have access to and click their group back on in the Permissions node.





This should allow them to gain access to the same content everyone else in their group has. I always verify that this has worked (if I've setup the account I log in and check).

5. Bulk-Loading

Bulk-loading can be helpful for uploading a large number of submissions into the Portal, as it can save a lot of time. There is however, some work that needs to be completed in order for this tool to work properly.

In order to complete a bulk-load you will need:

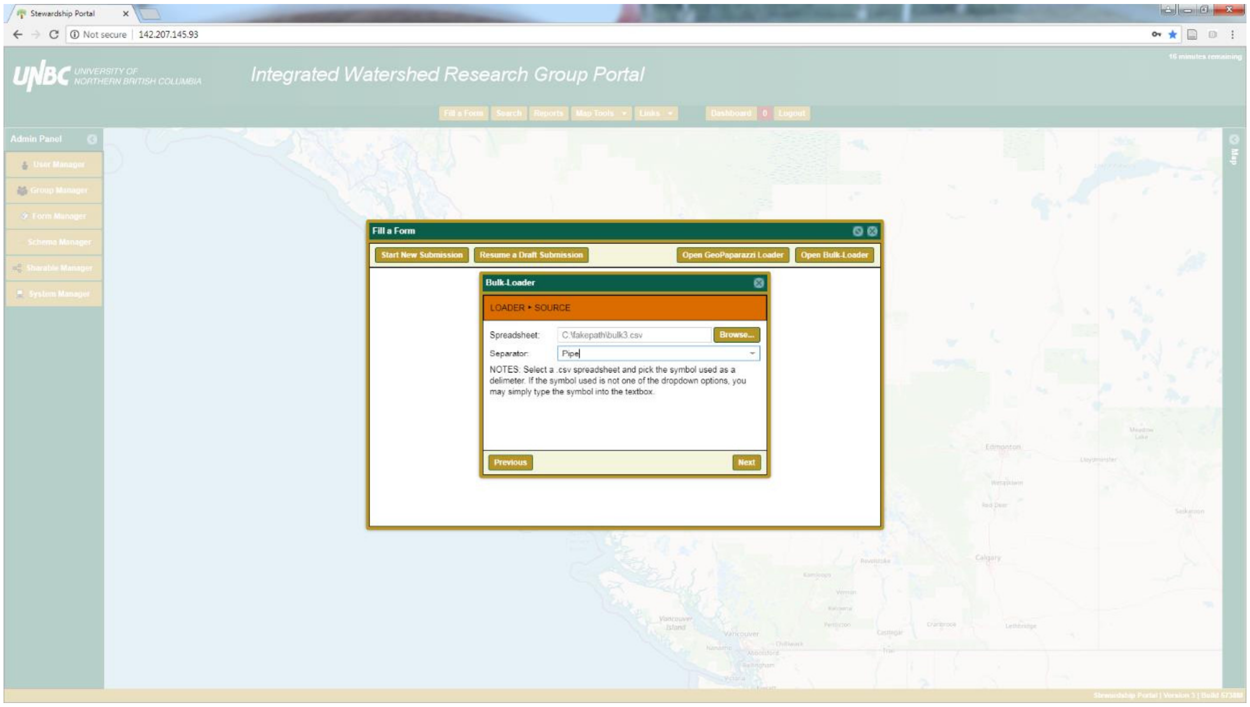
- A suitable form to match up with your data
- A spread sheet with your data
- Notepad ++ (free software) or some other software that will allow you to edit the spread sheet.

You will want to setup the spreadsheet so that each column corresponds to a section of the form you are using in the Portal.

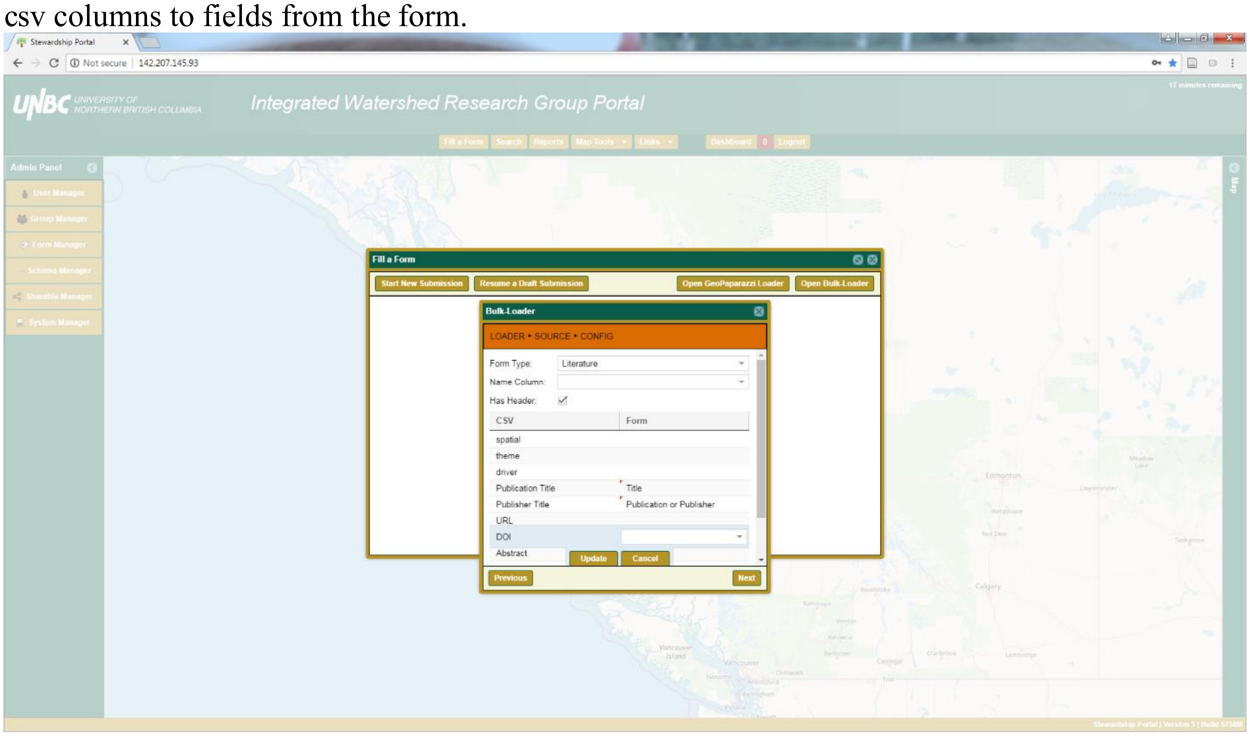
Please note that attachments (spatial and non-spatial) currently have to be added after the bulk-loader tool has been used.

The first real step is down in excel, and involves cleaning characters that will prove problematic during the bulk-loading process.

- Remove and/or replace all commas that are within the spread sheet. This is necessary because we are going to be converting the spread sheet to a .csv (comma separated value) format. If there are commas within any cells it will split that cell at each comma messing everything up. If you are replacing the commas use a character that doesn't appear in any of the data, as we will be converting this character with commas before the bulk-upload.
- Save the spread sheet (as it is possible you may have to come back to this multiple times to remove odd characters)
- Now use the save as feature to save the file as a .csv
- Open the .csv version of the file using Notepad++
- In Notepad++ complete a find and replace on the commas. We will be replacing these with the 'pipe' (|).
- It is critically important that 'odd' characters are removed from the excel sheet, which can be completed in Notepad ++. Under Encoding use the 'Convert to UTF-8' option.
- Now we should be good to go into the Portal and begin the bulk-loading process.



On the next screen select the appropriate form for the data. Click the Has Header checkbox on, and you will be able to see the column names from the csv file. Now we must match the csv columns to fields from the form.



After matching the fields you are given a preview screen to verify the bulk-load and matching process has worked properly. Next you are asked if you want to start a draft submission for each row. You will have to go through the draft submissions finalize everything

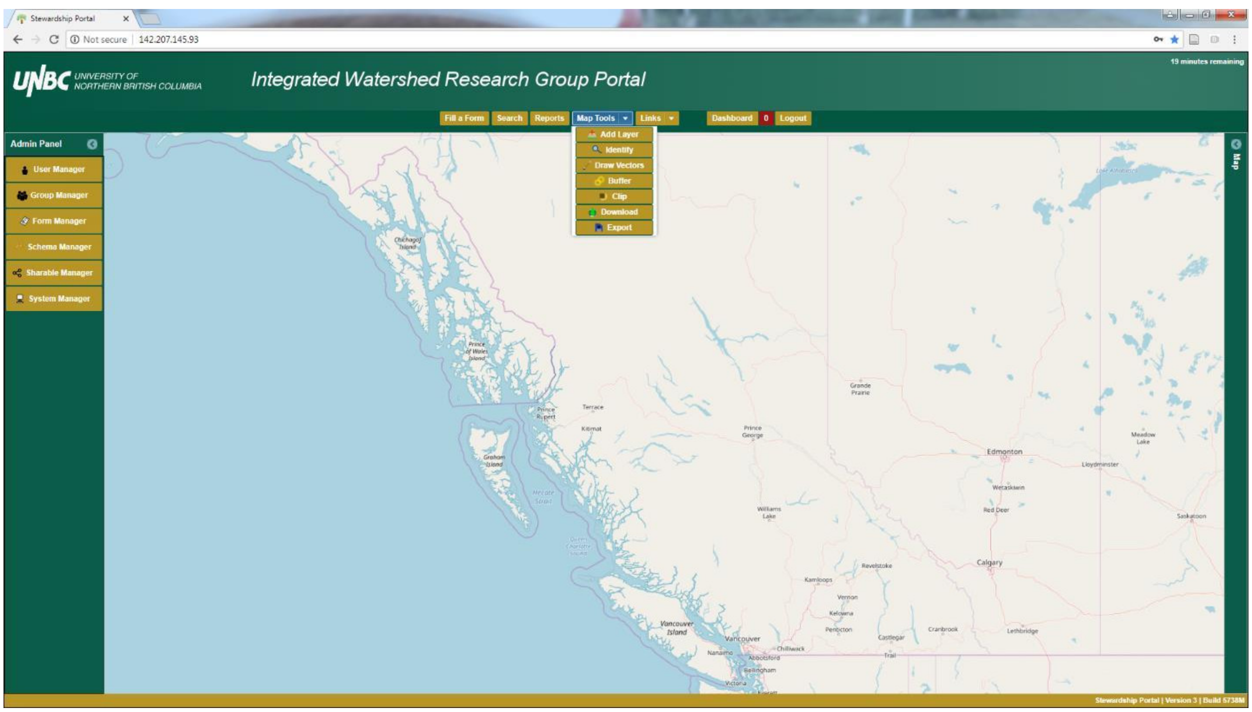
6. Spatial Visualization and Mapping Tools

This document focuses on spatial data within the Portal, and details all of the features found within the Map Tools button. We will follow the features in the order they are listed:

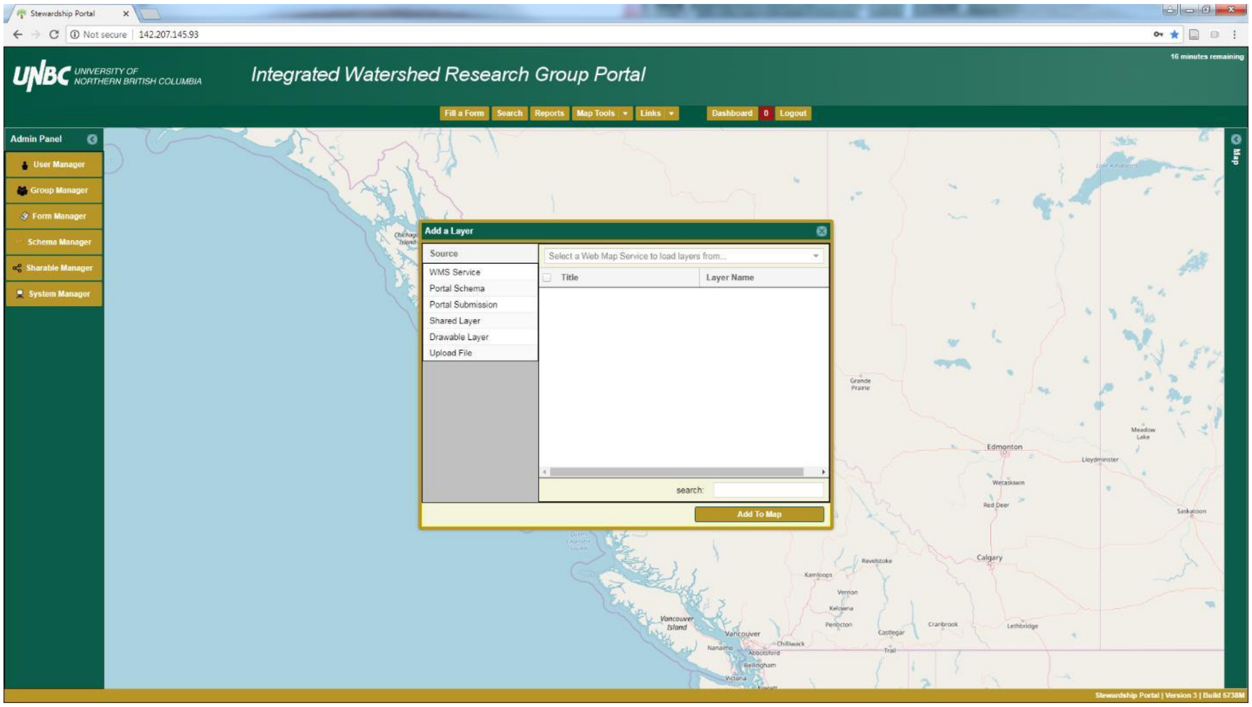
- Add Layer: WMS Service

o Portal Schema Portal Submission o Shared Layer Drawable Layer UploadFile

- Identify
- Draw Vectors
- Buffer
- Clip
- Download (currently broken)
- Export (currently broken)



Add a Layer:There are six ways to add spatial data to our map view which we will explore now.



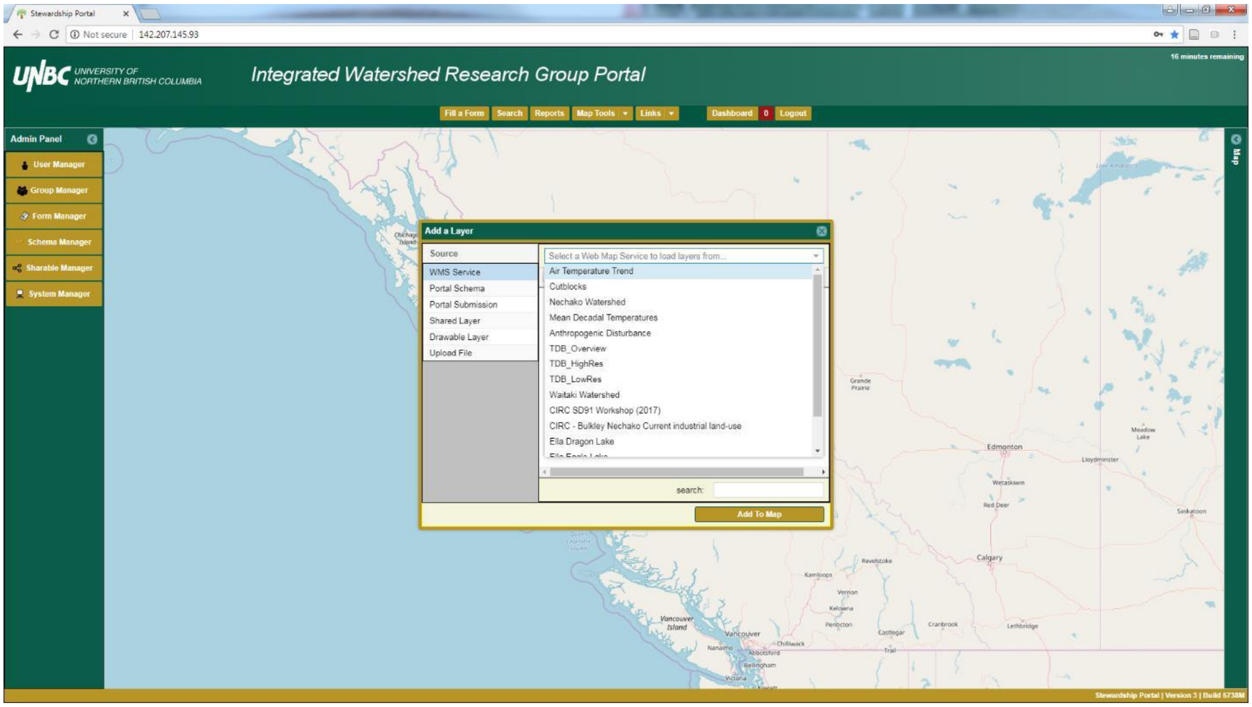
WMS Service:

WMS stands for Web Map Service, which can be used to share spatial data or complete maps through the internet. A fairly easy example of this is the base map we see within the Portal, this is an Open Street Map WMS layer.

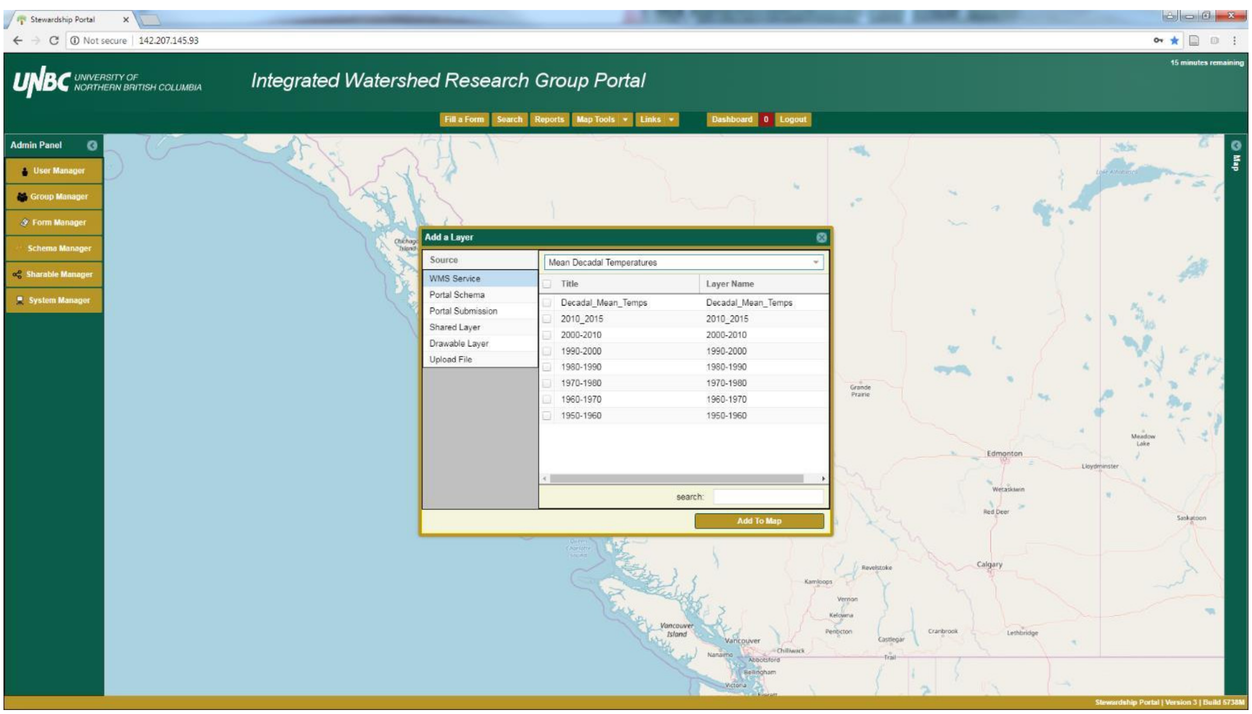
WMS layers can provide a consistent symbology and provide features such as a legend that currently aren't dealt with effectively within the Portal. This requires a little explanation. Currently if you use any of the other options to add spatial data to the map the symbology is randomly generated. However, the symbology of a WMS layer is defined within the layer itself, so it will appear the same way every time it is called.

A disadvantage of WMS layers is that they are only images being provided. This means they have no attributes, they look good but we are unable to view any specific information contained within the layer. Whereas, the other spatial data options available can all contain attributes which can be queried. We can think about a spatial layers attributes as an excel sheet, containing specific information about the layer.

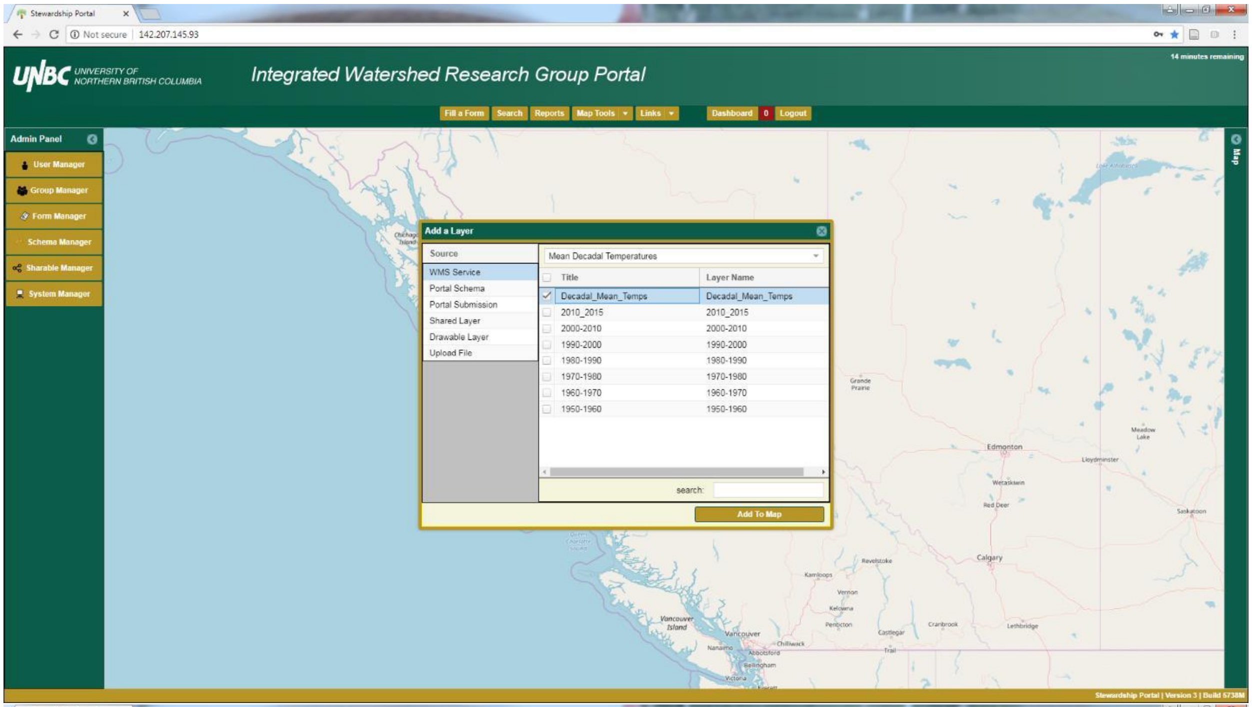
The WMS Service layer is brought up by default when accessing the Add a Layer option, however, if we've clicked something else we simply need to click under Source where it says WMS Service. There is a drop down menu labeled "Select a Web Map Service to load layers from...", we simply click this and select the WMS desired.

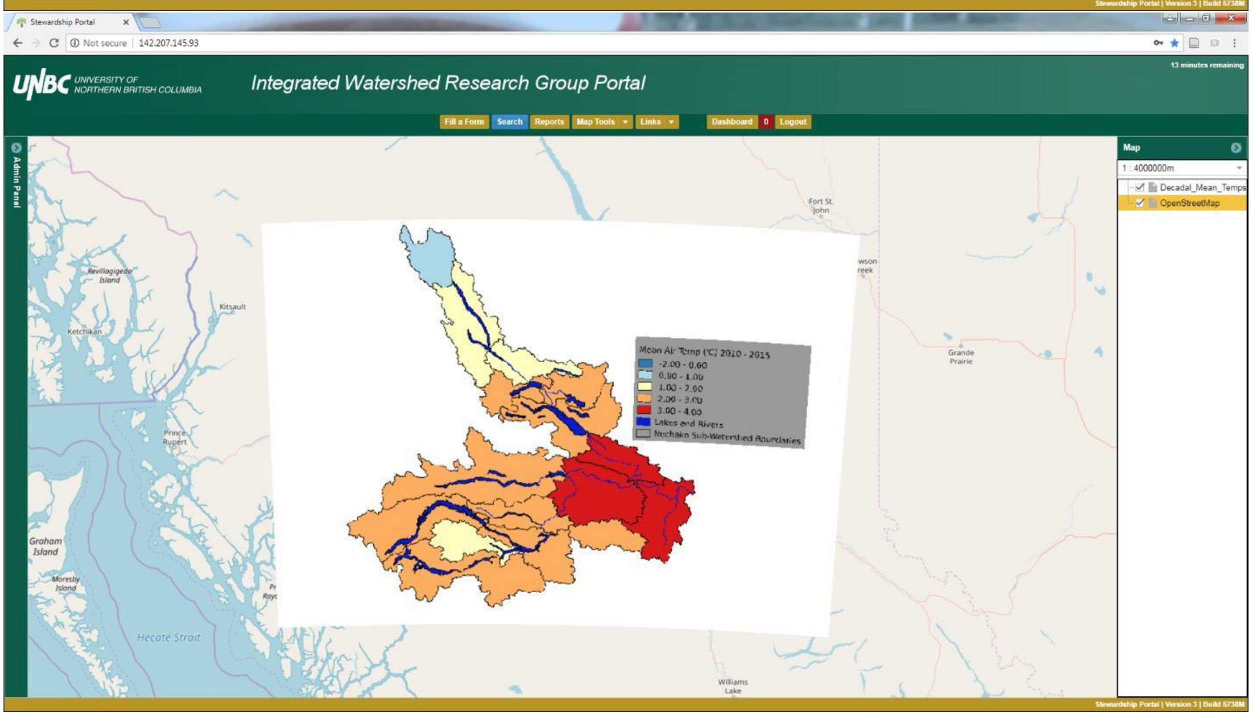


In this example we've selected Mean Decadal Temperatures, which brings us the following options to pick from.



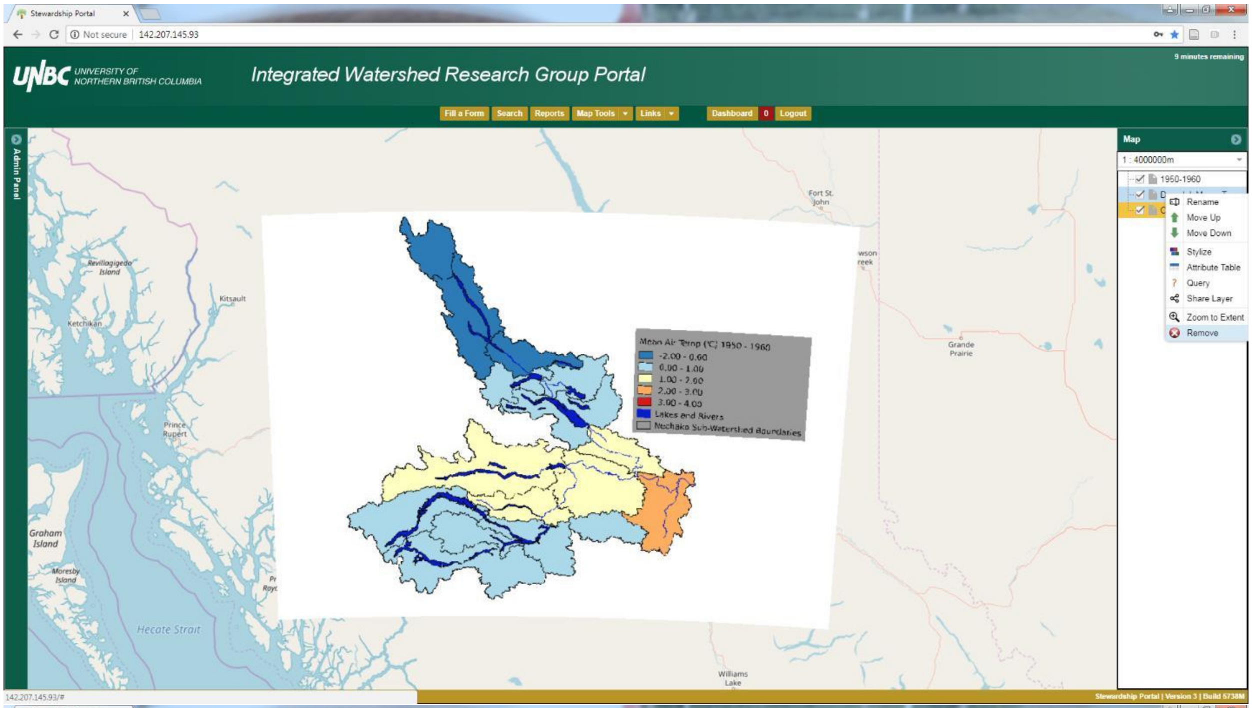
If we pick the first available layer named Decadal_Mean_Temperatures and click add to map we get the following:

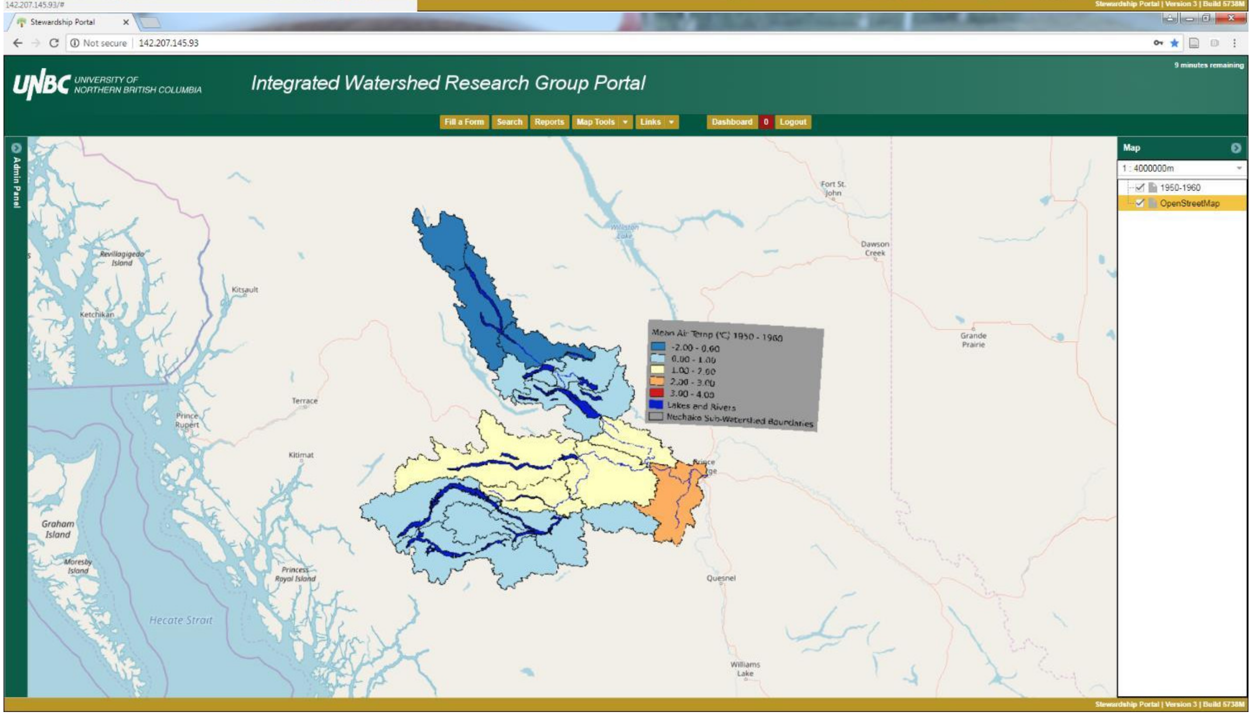




This first option is actually all of the layers that are listed below it, this is an artifact of how we are using QGIS to serve up these WMS. This will be the case for all of our own WMS layers that we are hosting. To get around this we simply ignore the first layer and select the layer that is of interest to us.

We will pick the layer 1950-1960 and add it to our map. We've added this layer right on top of the previous stack, so we will open our map tab, right click on Decadal_Mean_Temps and remove it from the map.





We will explore a way to combine WMS layers and shapefiles uploaded into the Portal by making use of stacking layers and using the Identify tool later.

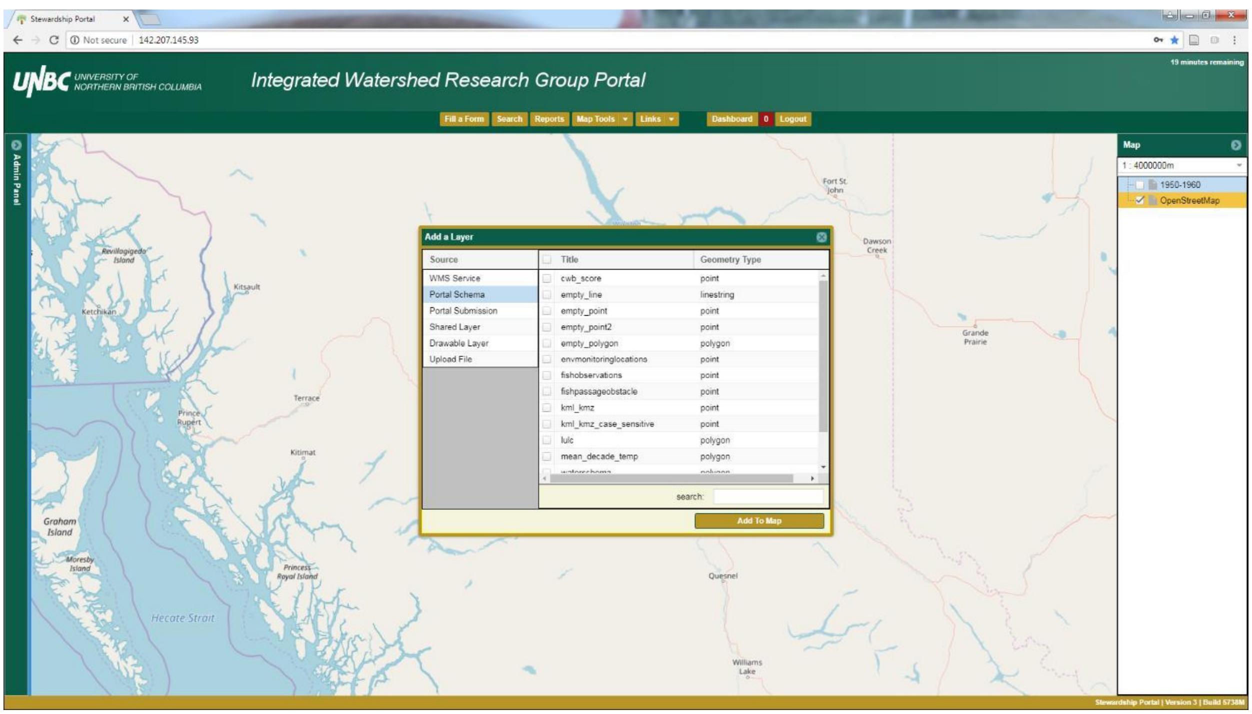
Portal Schema:

Adding layers by Portal Schema is probably the most difficult option available to us to understand. This stems from the fact that many people who aren't regular GIS and web-GIS users won't have had much

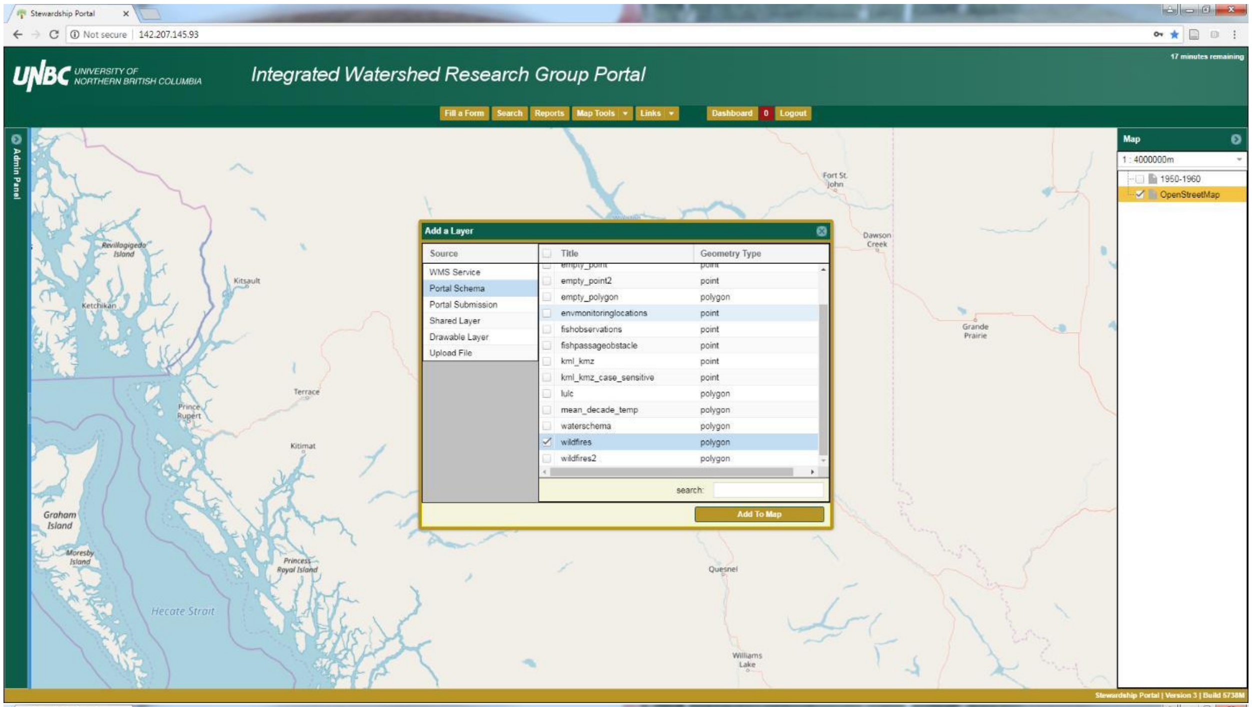
(or any) interaction with a spatial schema. Essentially a schema is a set of rules that the Portal uses to determine which attributes from a spatial file get shown within the Portal. All forms require at least a single schema to be linked to it for spatial files to be attached to a submission. This is a process the average user will never need to understand, and in situations where a schema needs developed the Portal Administrator will be crucial in assisting.

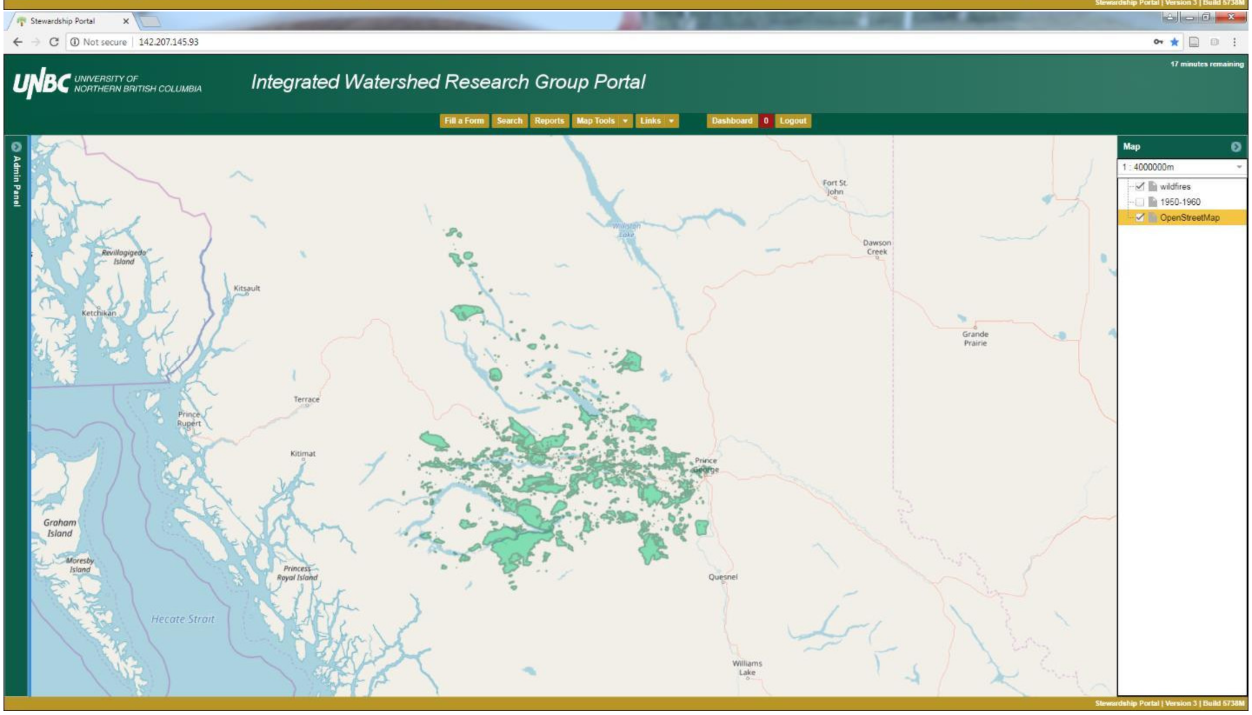
For our purposes today we simply need to understand that this option in our Add a Layer tool will allow us to grab all spatial layers that share a common schema and load them into the map. This could be helpful if we know there are multiple submissions that have a similar format of spatial data, and we want to add those all to the map without having to individually add them from their separate submissions.

When we select the Portal Schema option we are provided with a list of all the current schemas.



If we select wildfires and add this to our map we get





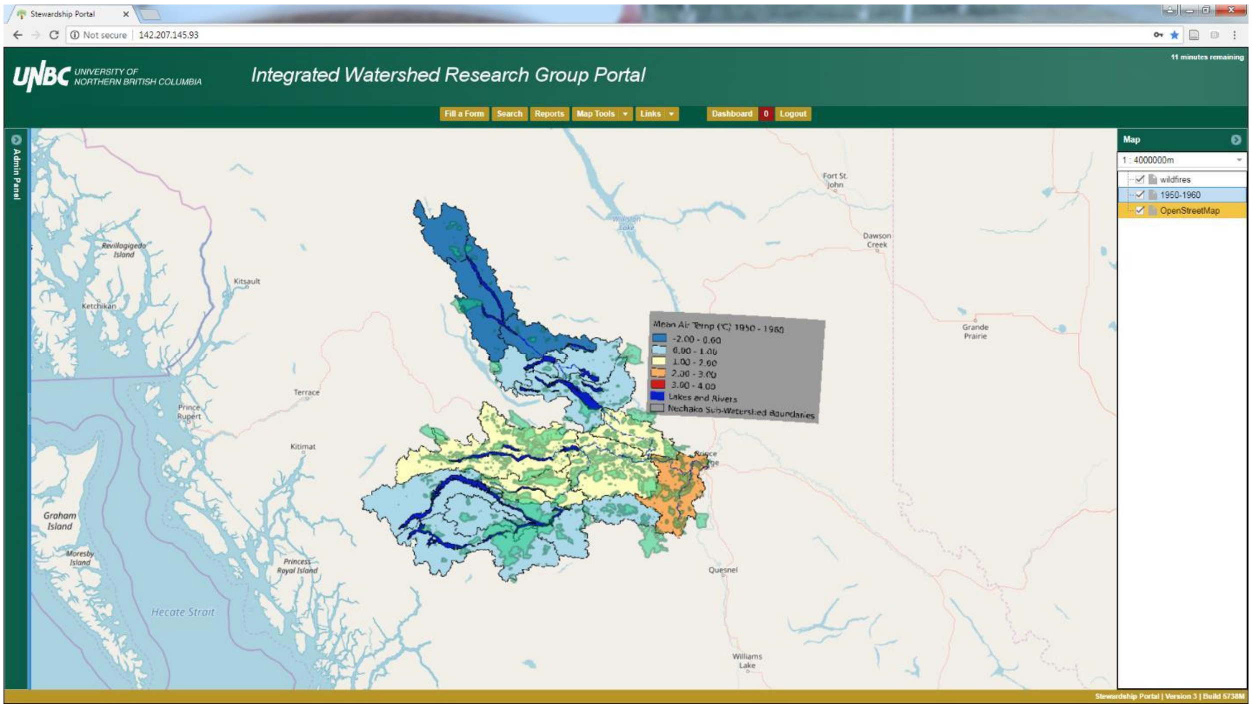
Please note that all of the separate spatial layers that use this schema are combined into this one layer, which can make it a bit more difficult to sort through data or symbolize.

Right Click Options:

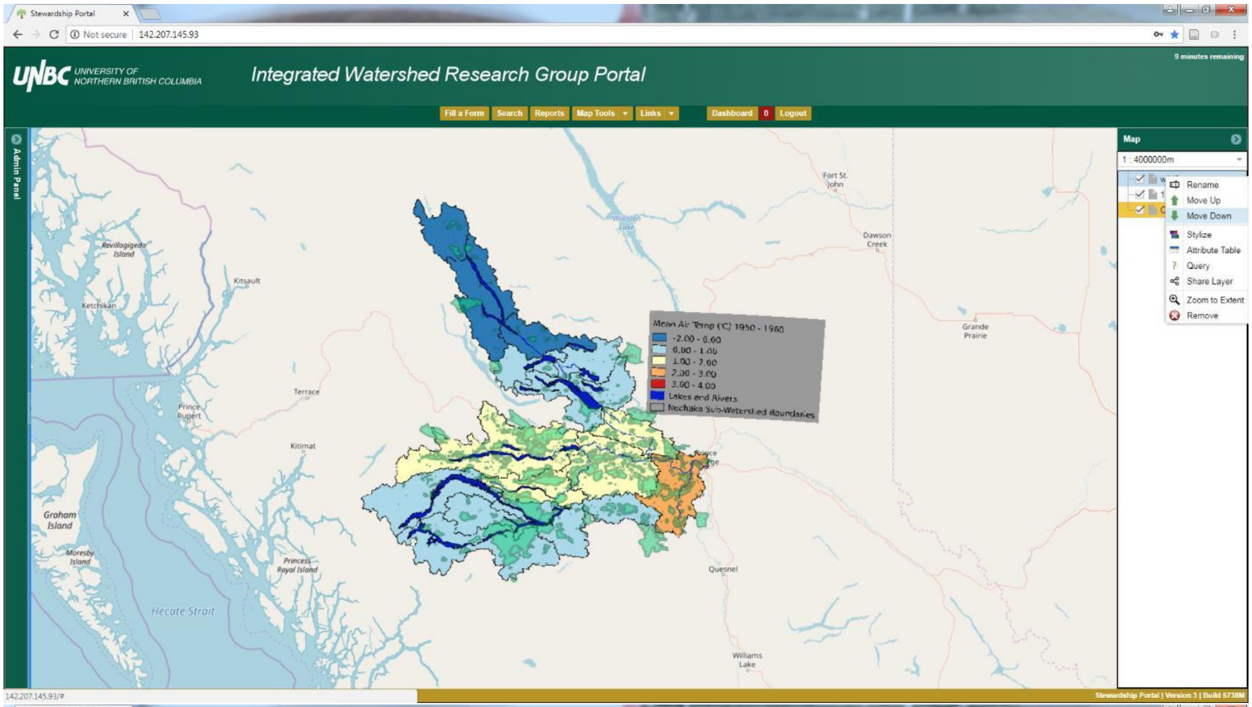
Now that we have a couple of spatial layers on our map we are going to look at the right click options within the Map tab.

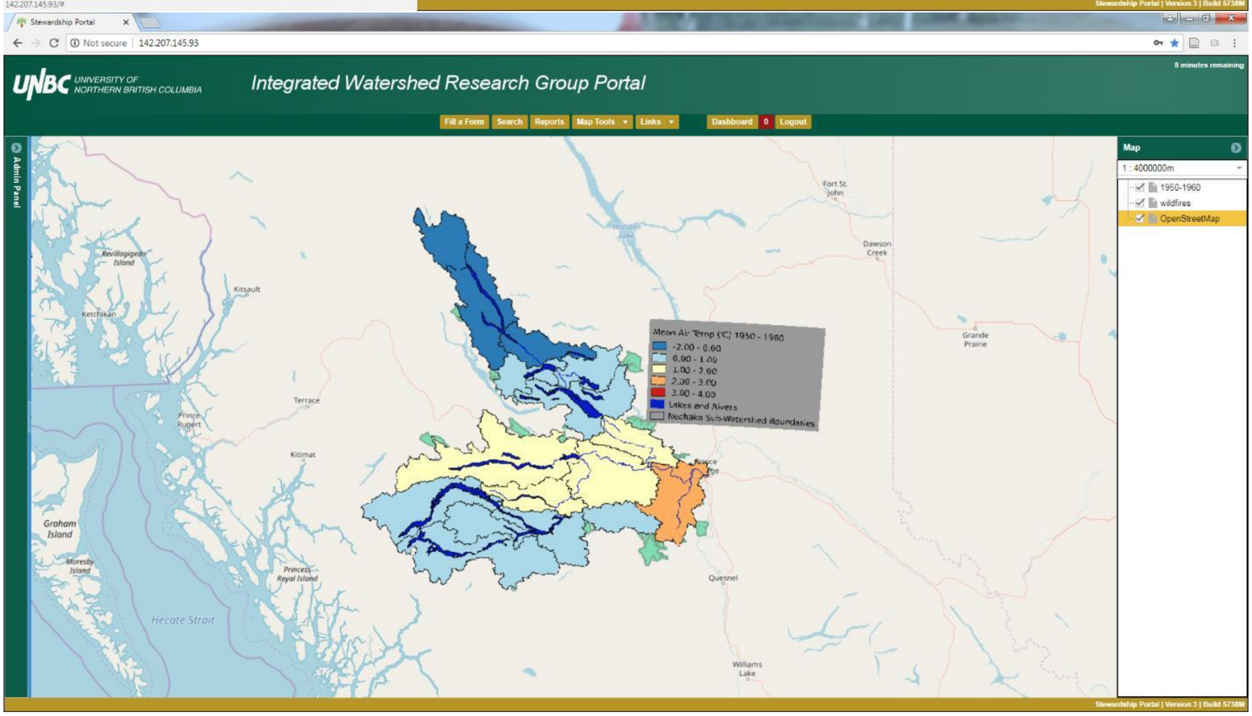
Rename: this allows us to temporarily rename a spatial feature

Move up and move down: this allows us to change the order in which layers appear in the map list. This also impacts the order which they are drawn, or stacked. The top most layer will appear on top of the layers below (if there is a spatial overlap). Note that the green from wildfires is above the climate layer, as wildfires is on the top of the map list.



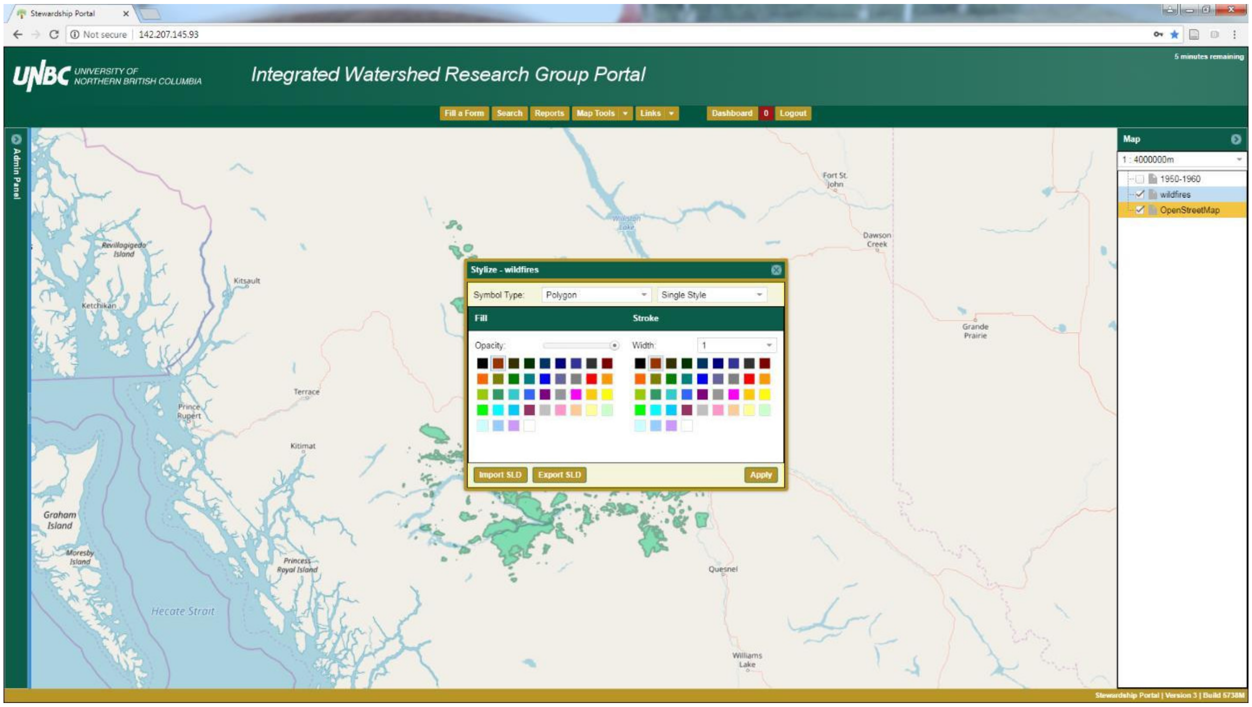
If we move wildfires down we get the following product:



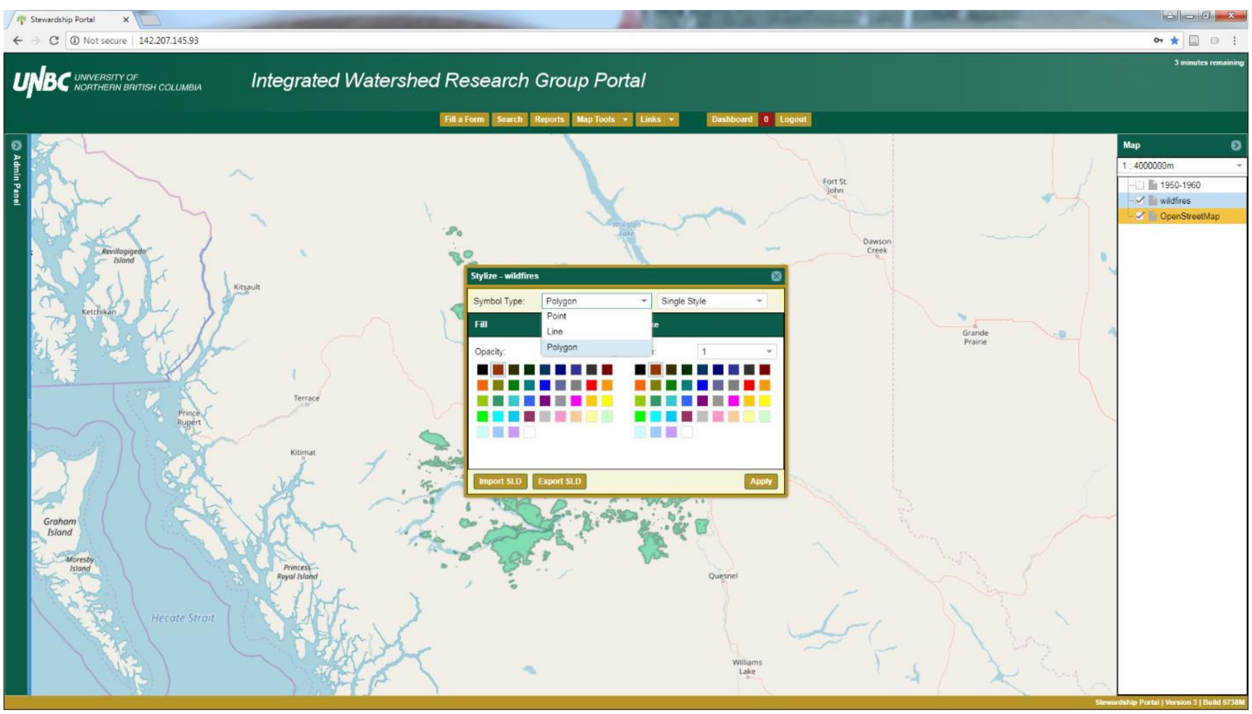


Note that we can no longer see the wildfire polygons that were overlapping with the climate layer. They are below 1950 – 1960 (climate layer) which has no transparency applied, which blocks the view of the wildfires below.

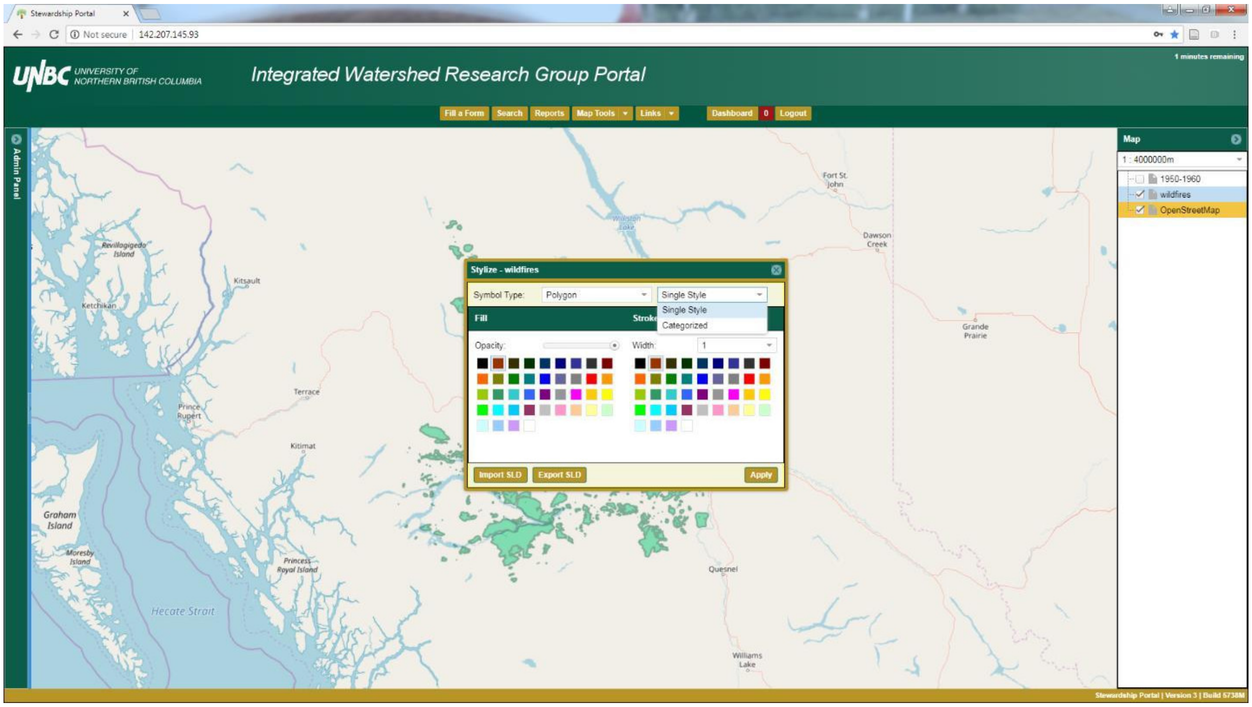
Stylize: For this example we've turned off the 1950 – 1960 layer by clicking the check mark off beside it. Now we can right click the wildfires layer and pick Stylize.



Here we are required to verify the Symbol Type matches our spatial data. In this case we are dealing with polygons so we are good. There are three options available: polygon, line, and point.



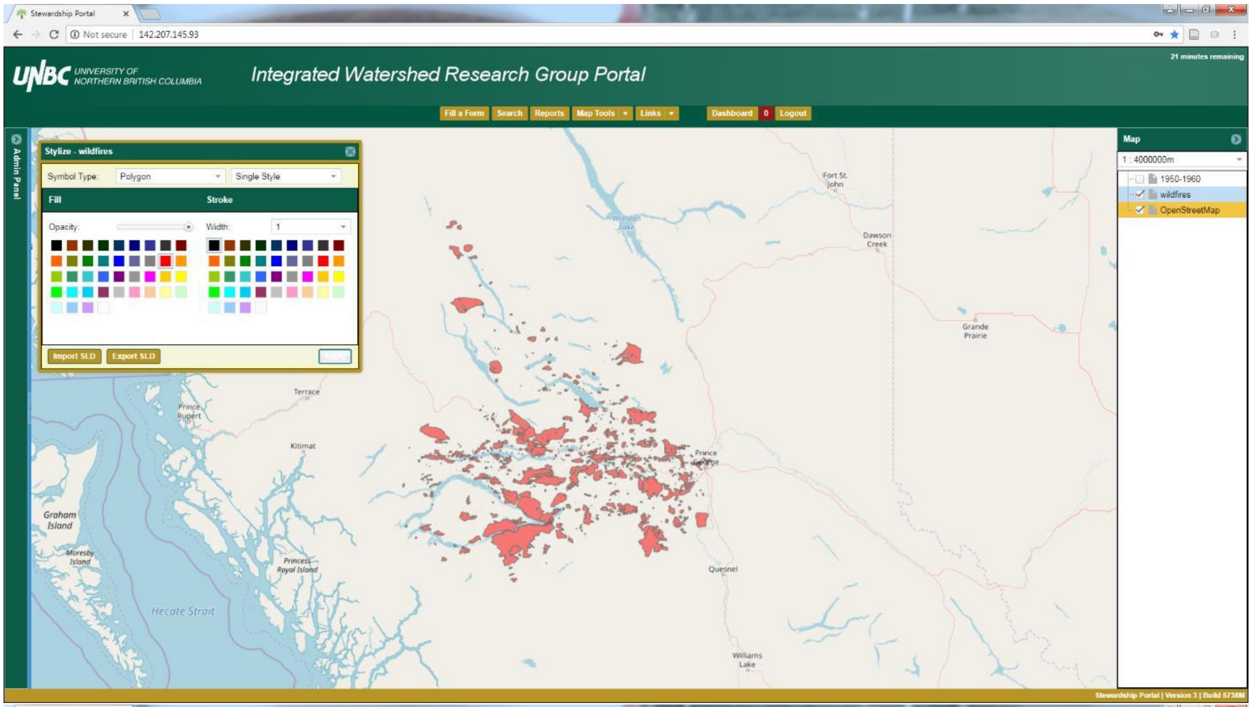
Next we must determine if we want to use a Single Style or Categorized style. Single Style will make all the features a uniform style, whereas Categorized can be used to style according to attributes to give an array of colours.

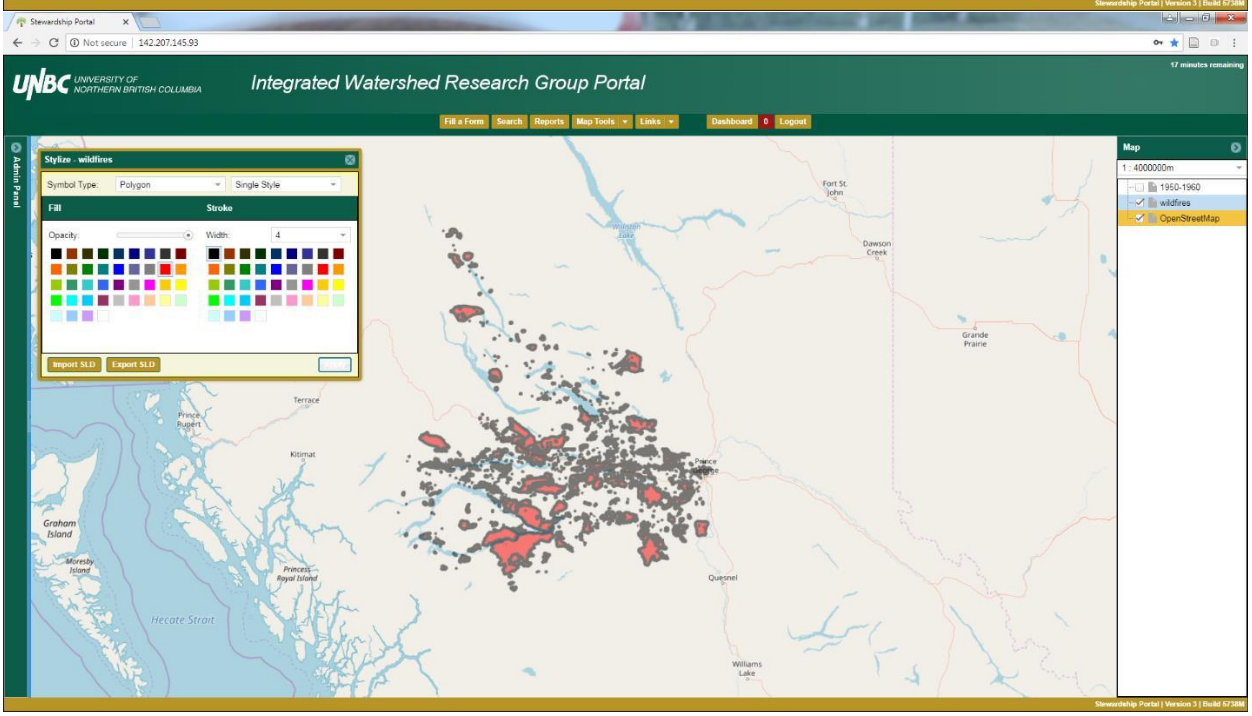


We are going to start with the Single Style.

We'll pick a bright red for the Fill colour (the inside of the polygon) and black for the Stroke (the outline). Hitting apply and moving the Stylize window to the side will produce the following:

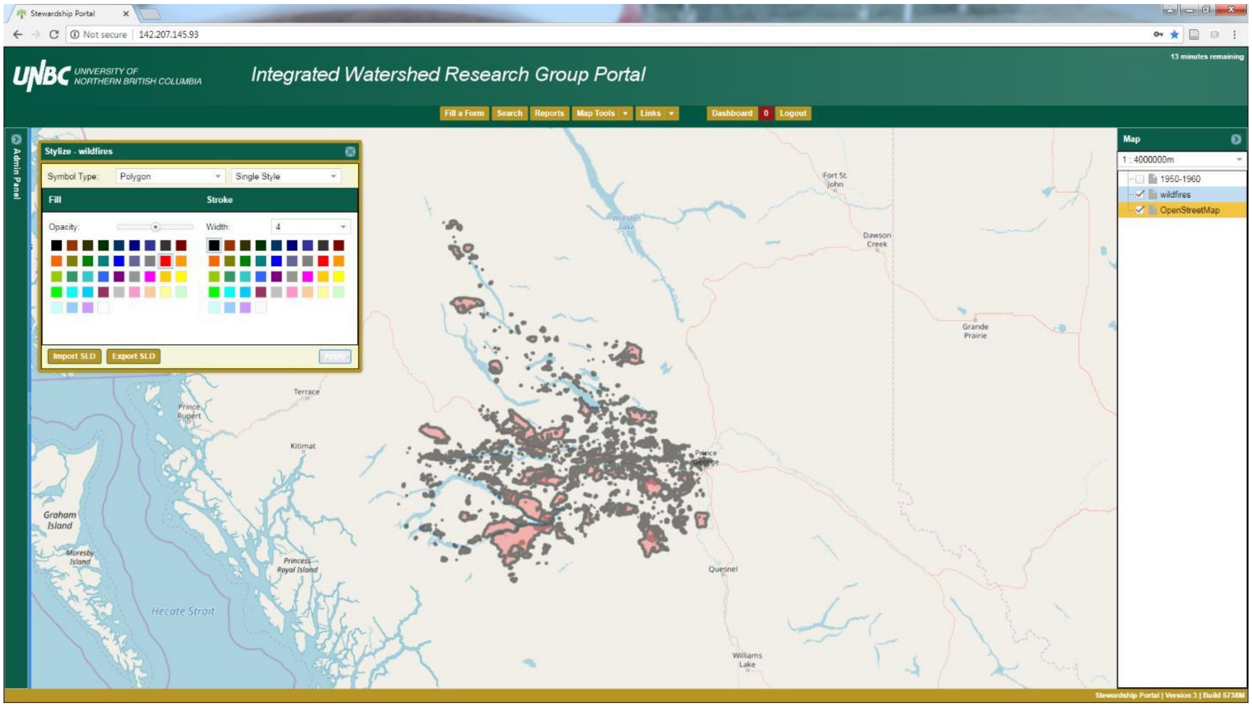
Now maybe we don't think the outlines stand out enough here, so we can adjust the Width number. We can use the drop down bar or simply type in a number, we'll try 4.



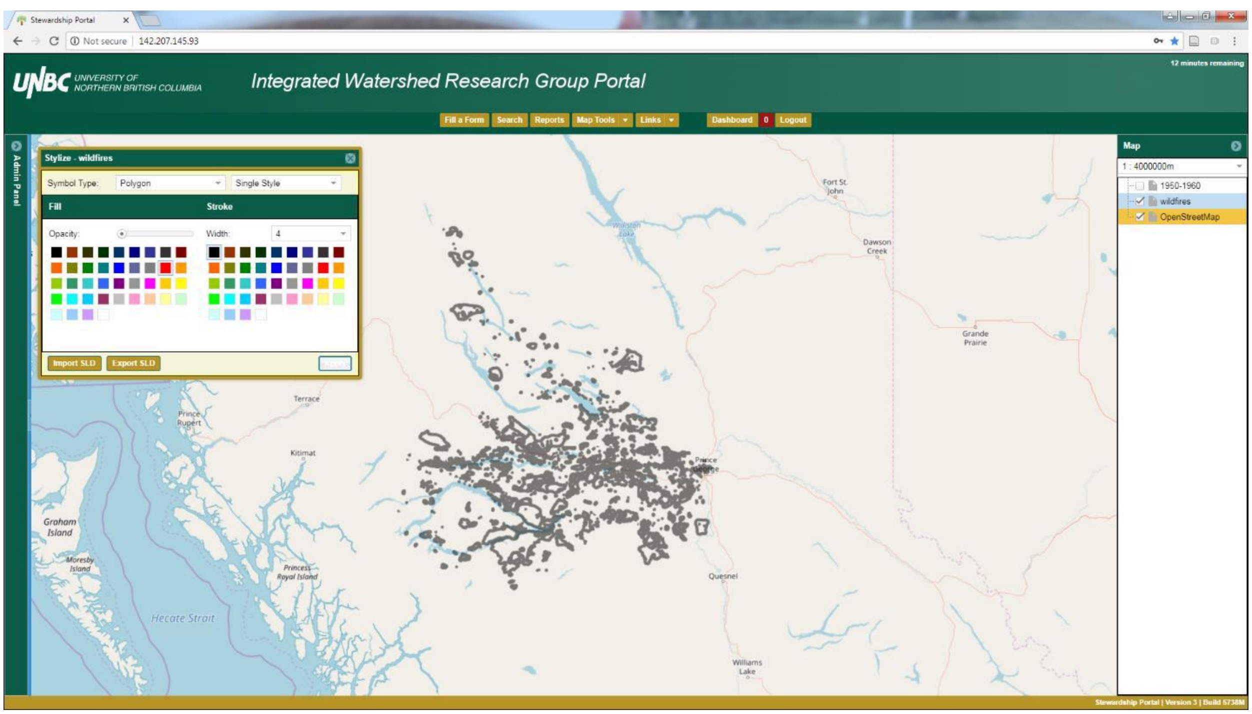


Now a 4 width was probably too much, but as we have now seen this is adjustable until we are satisfied.

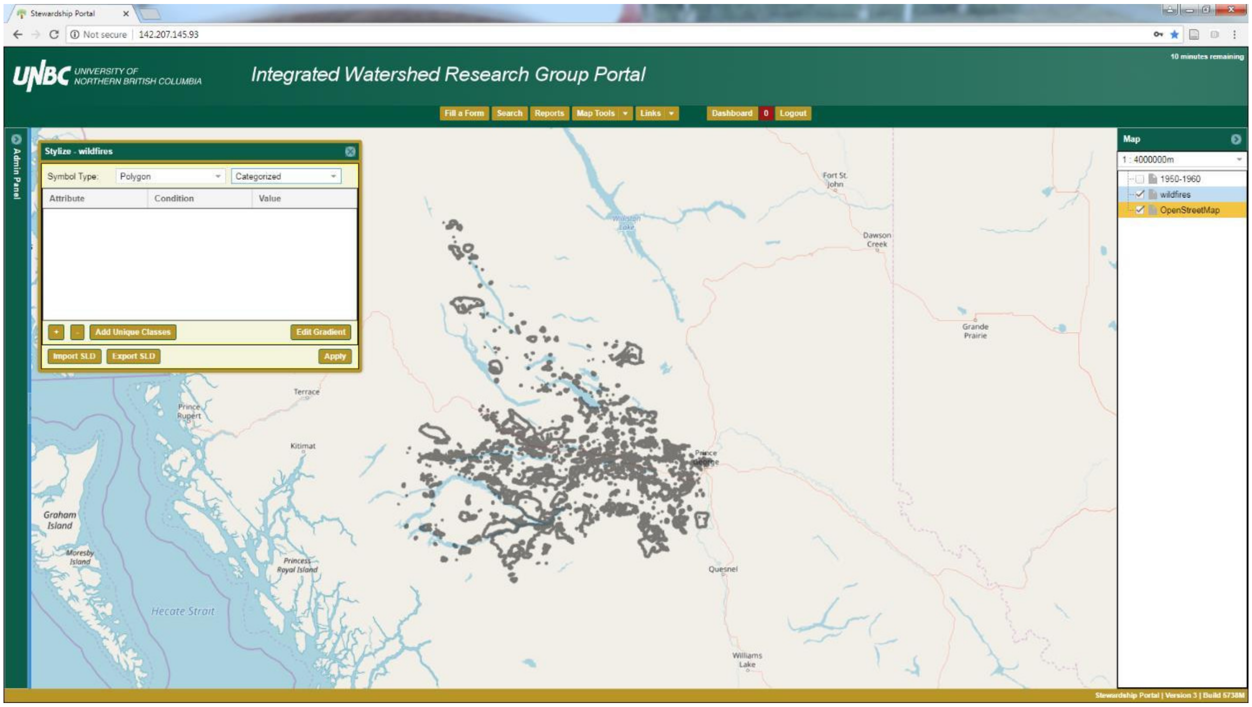
There is also an Opacity scale so that we can adjust the transparency of the fill of a spatial layer. This scale seems to be backwards though, the default here is 100 which allows for the least transparency. If we turn it down to 50 we get the following.



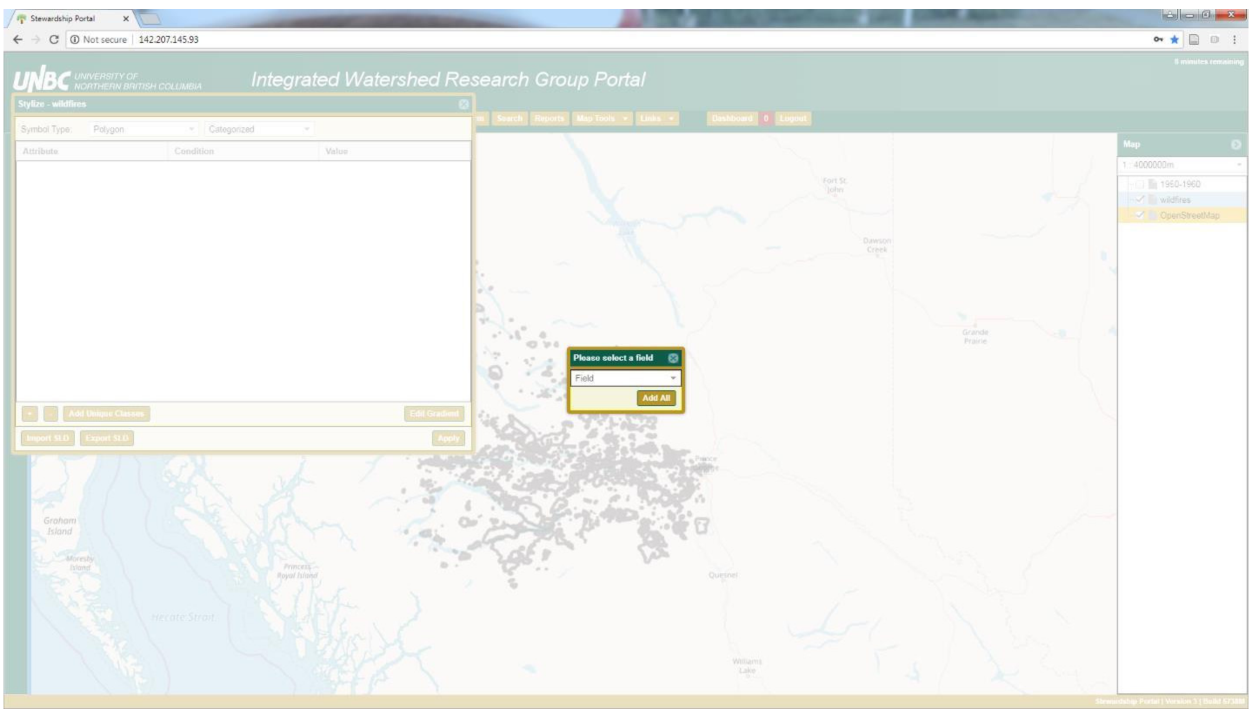
With an Opacity of 0 we get no fill colour.



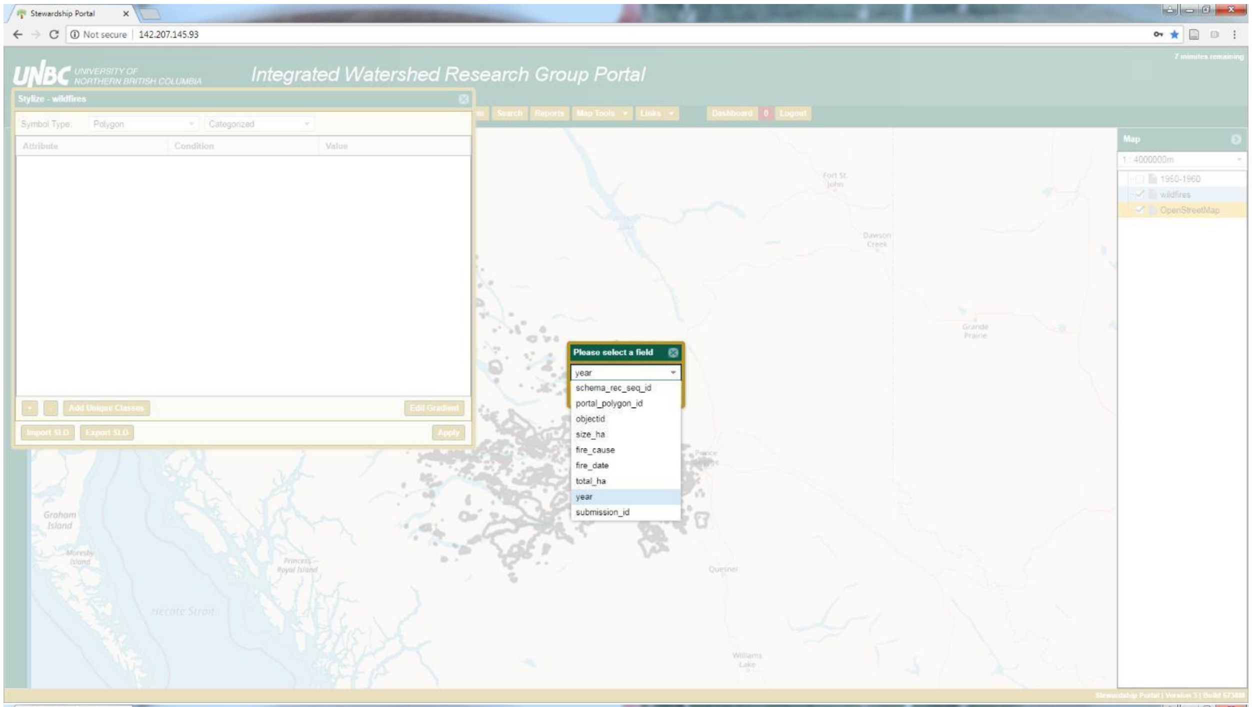
Now if we want to create a symbology according to categories, we can select the Categorized option.

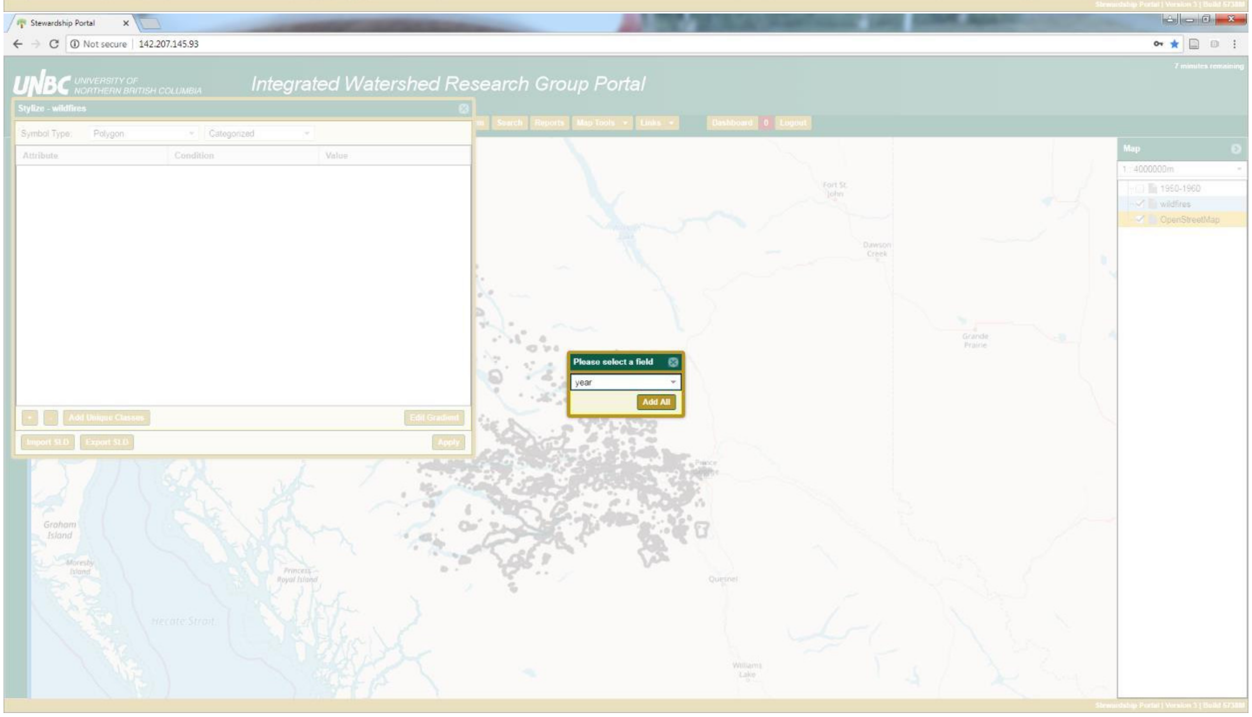


Here we need to determine which attribute we want to use to differentiate colours by. We'll do this by using the Add Unique Classes button.

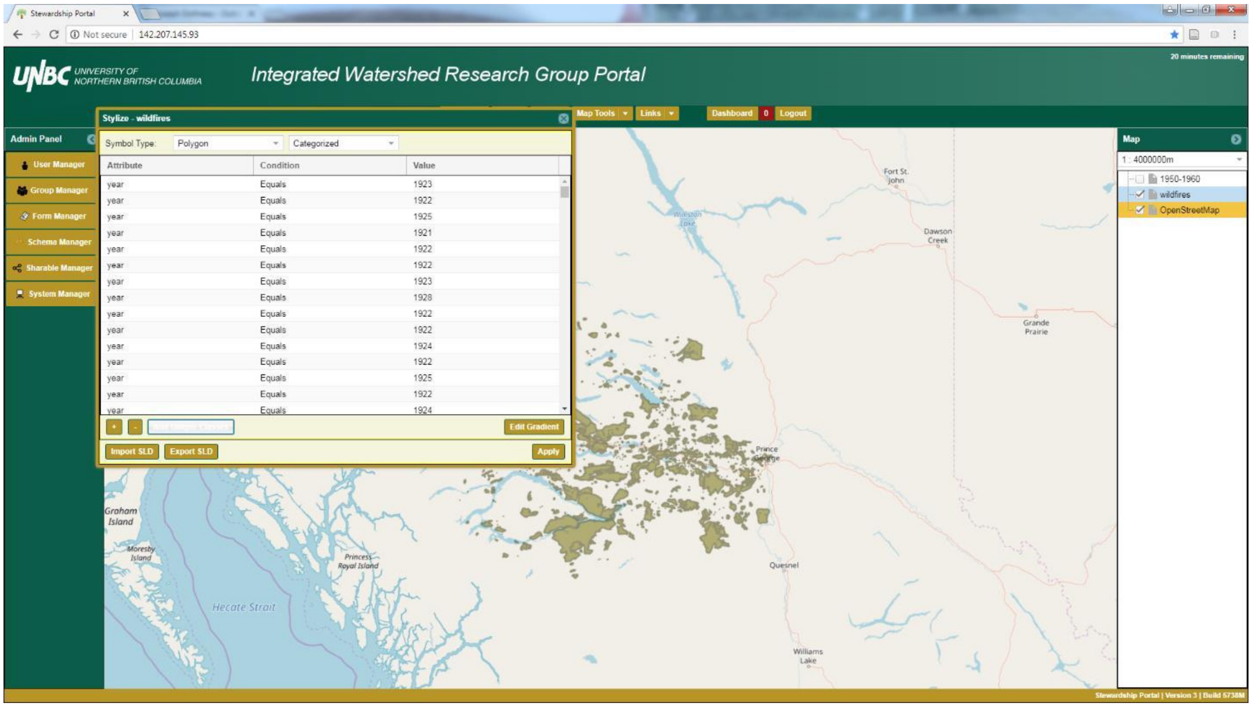


We'll use year here.

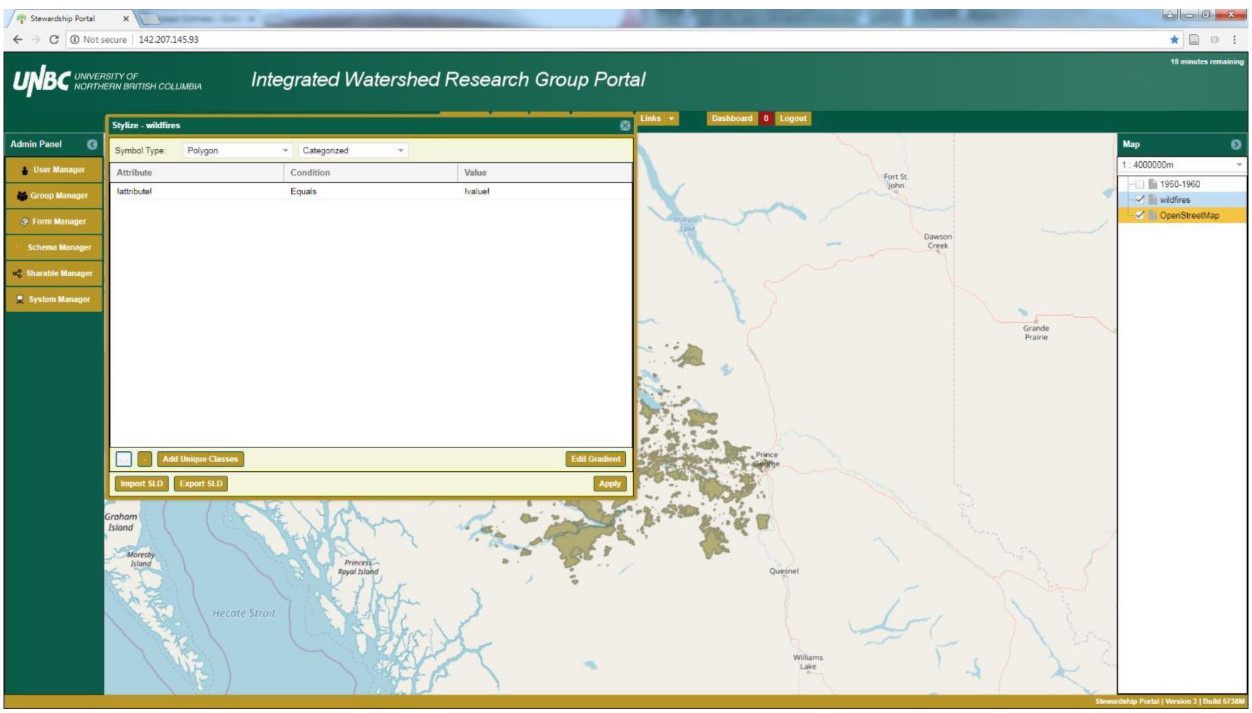




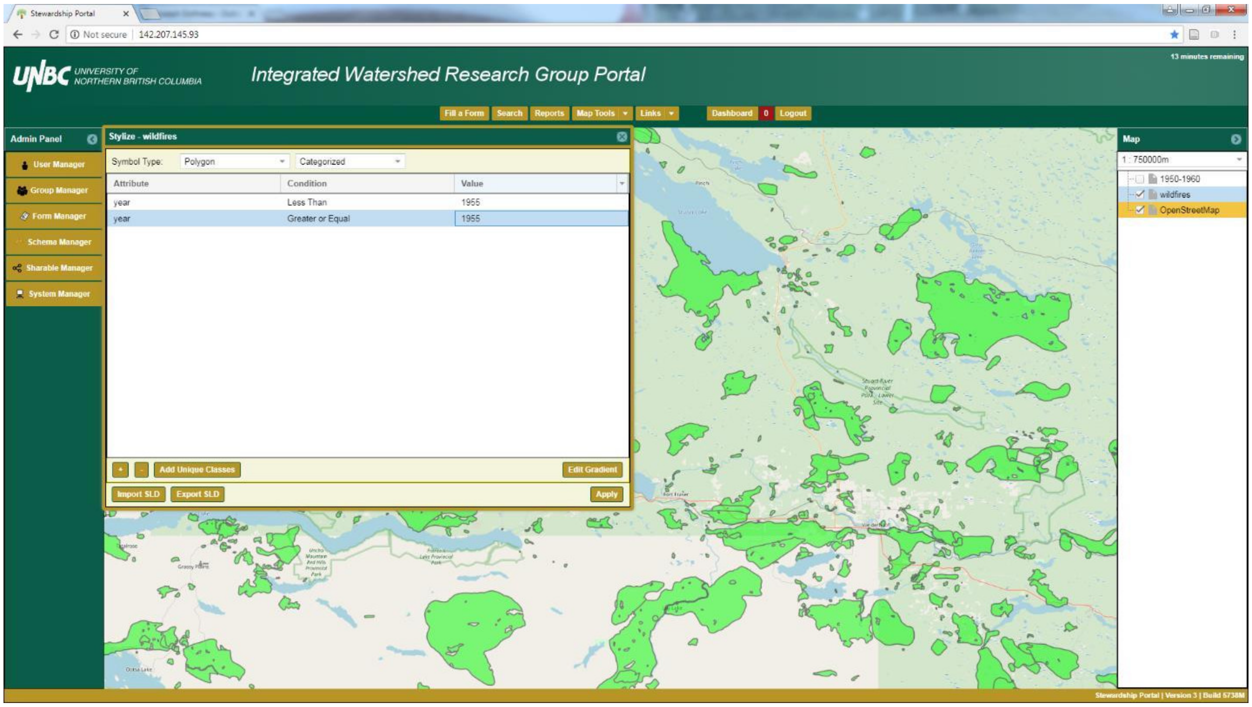
This leaves us with a huge array of unique classes, probably too many to make use of in this case.



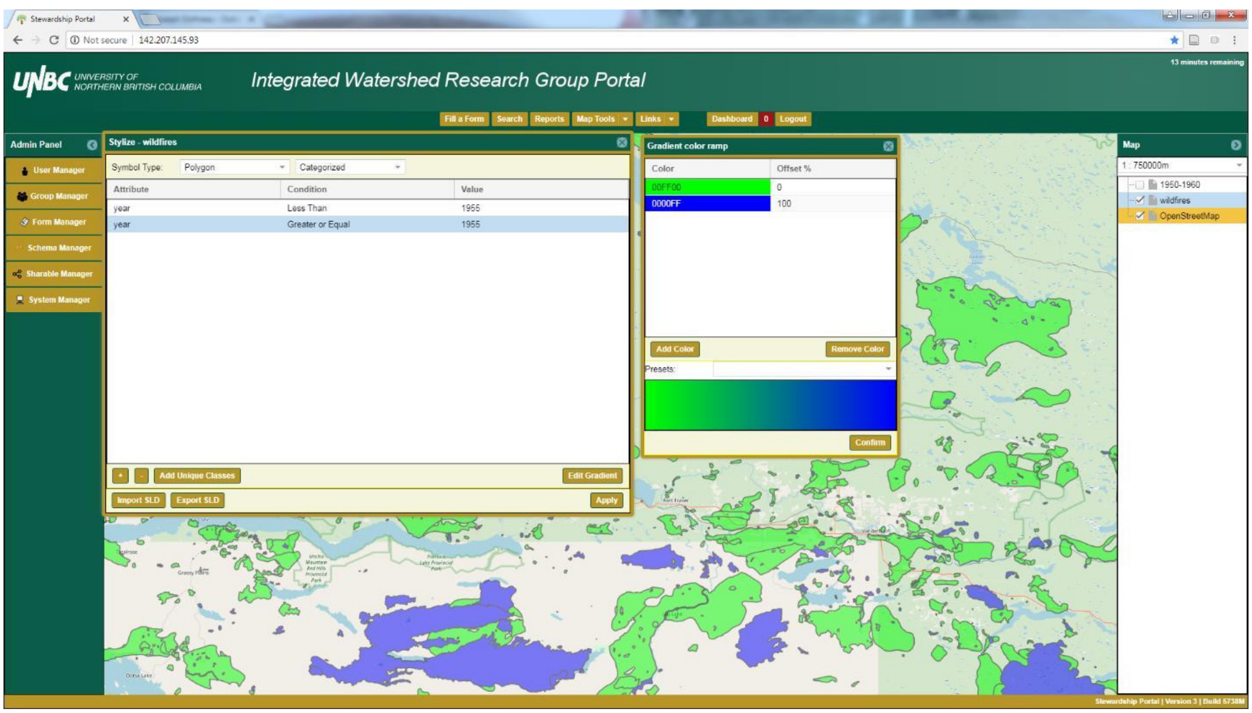
Instead we'll develop our own class to sort and symbolize this data. We'll close our Stylize window and re-open a new one. Back in the Categorized option we'll press the + button.



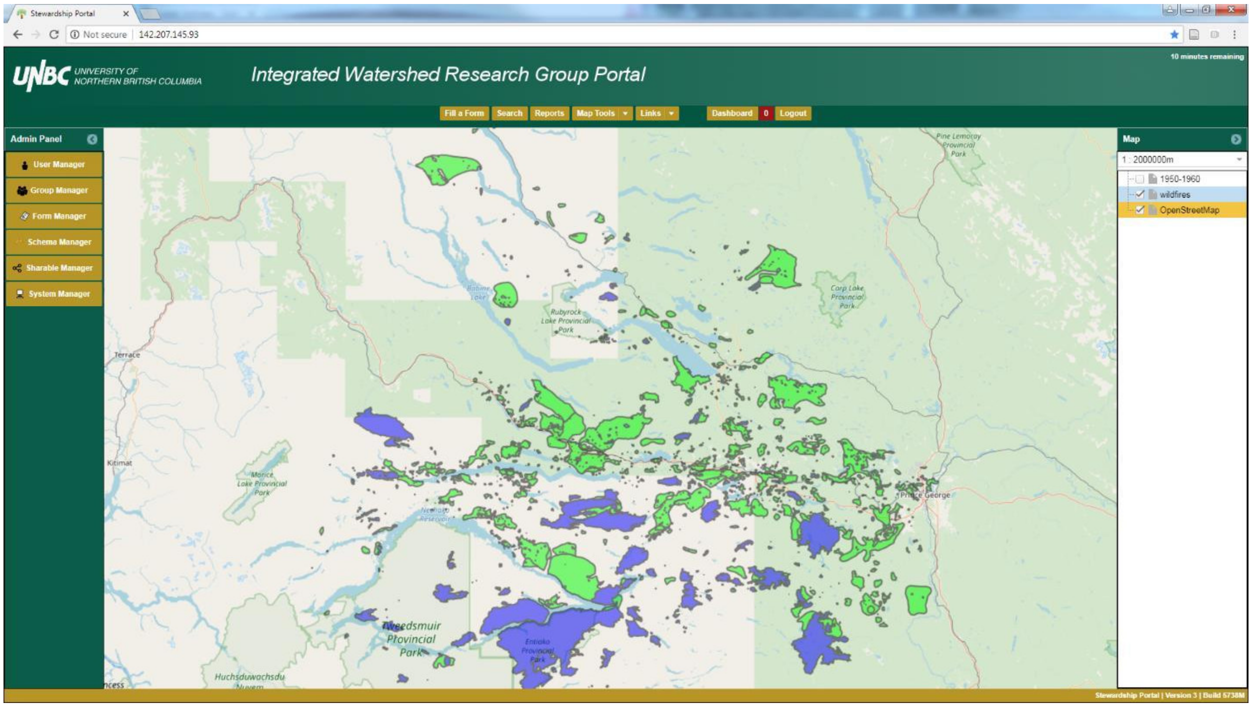
Now we will type in the year as the Attribute we want to sort by. Our condition will be less than, and the value will be 1955. So we are setting up a category to give us the first half of the decade and the second half.



Now by using the Edit Gradient button we get a new color ramp option.

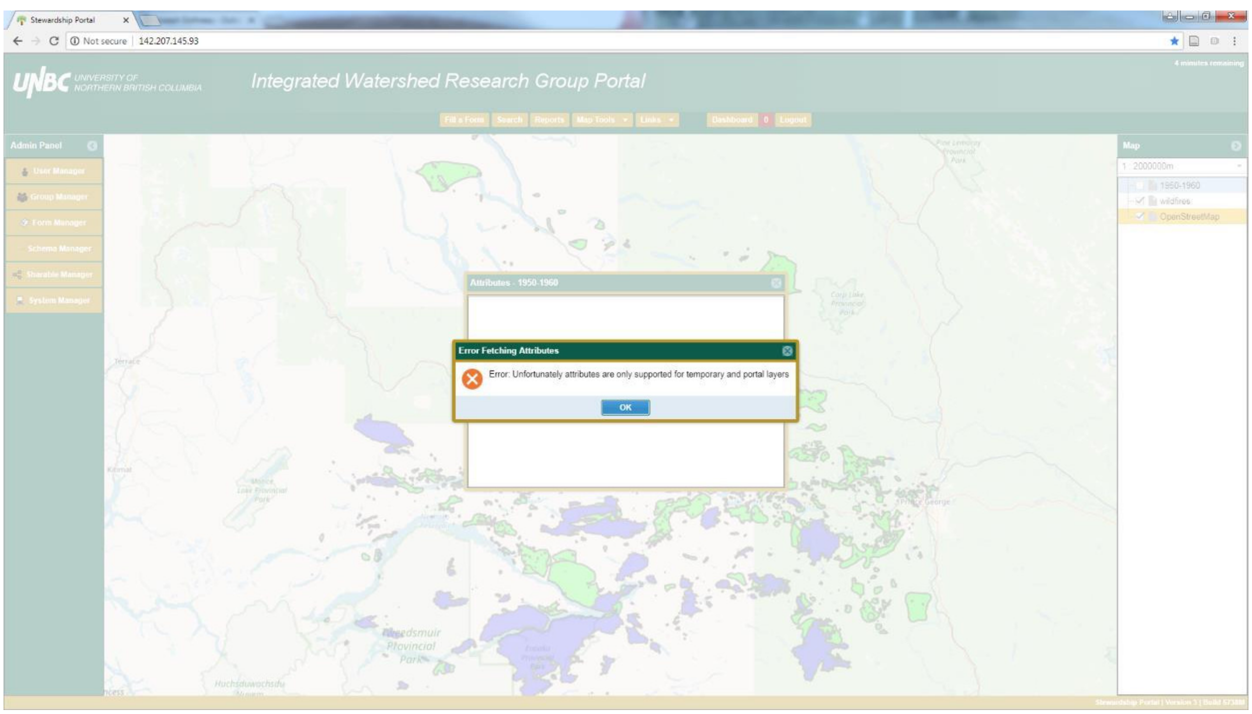


We hit confirm and we have create a style (or symbology) that has any fires that occurred from 1950 – 1954 in green and all the fires that occurred during or after 1955 in blue.



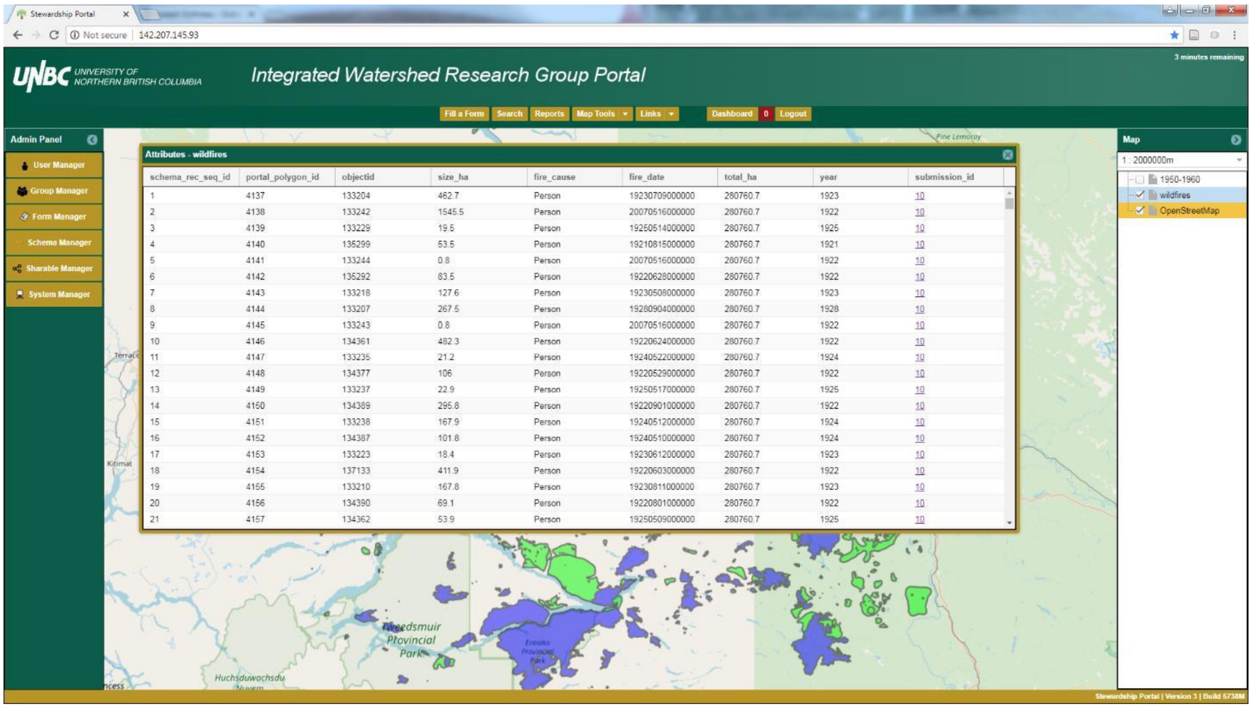
Attribute Tables:

Another right click function available on spatial layers within the Map tab is being able to read the attribute table. We’ll open the attribute table on the 1950 – 1960 layer.

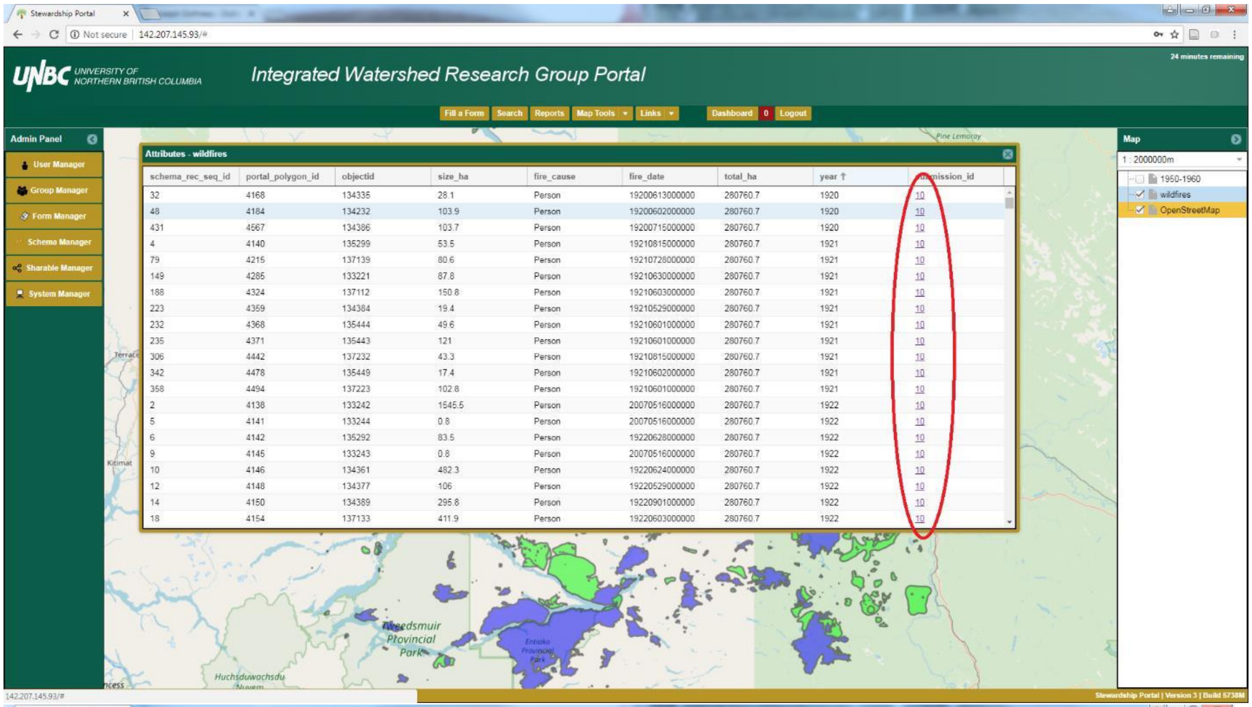


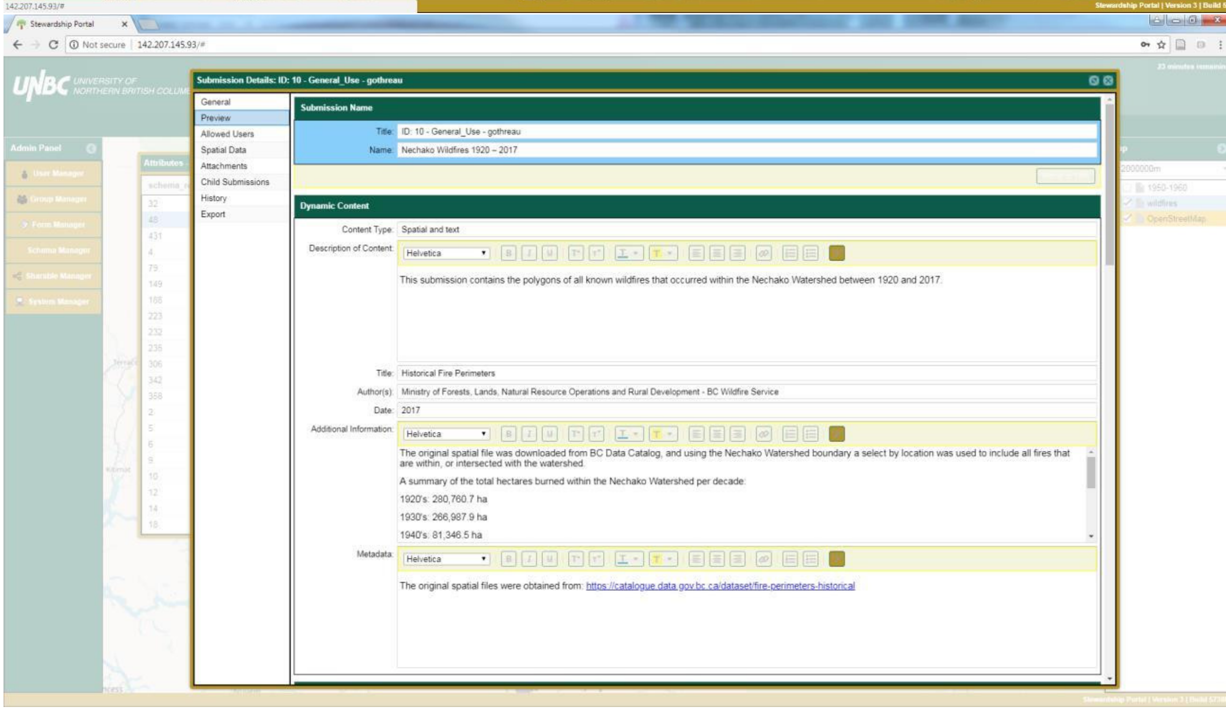
This result is due to us trying to read the attribute table of a WMS layer, which of course doesn’t actually have an attribute table. Now we will try on our wildfires layer, and after resizing the window we get:

We are able to sort by descending or ascending order as well, which we will do by year by clicking the down arrow on the header when we are hovering on it, and choosing ascending. Now the 1920s are on the top and we can scroll down through the years in chronological order.



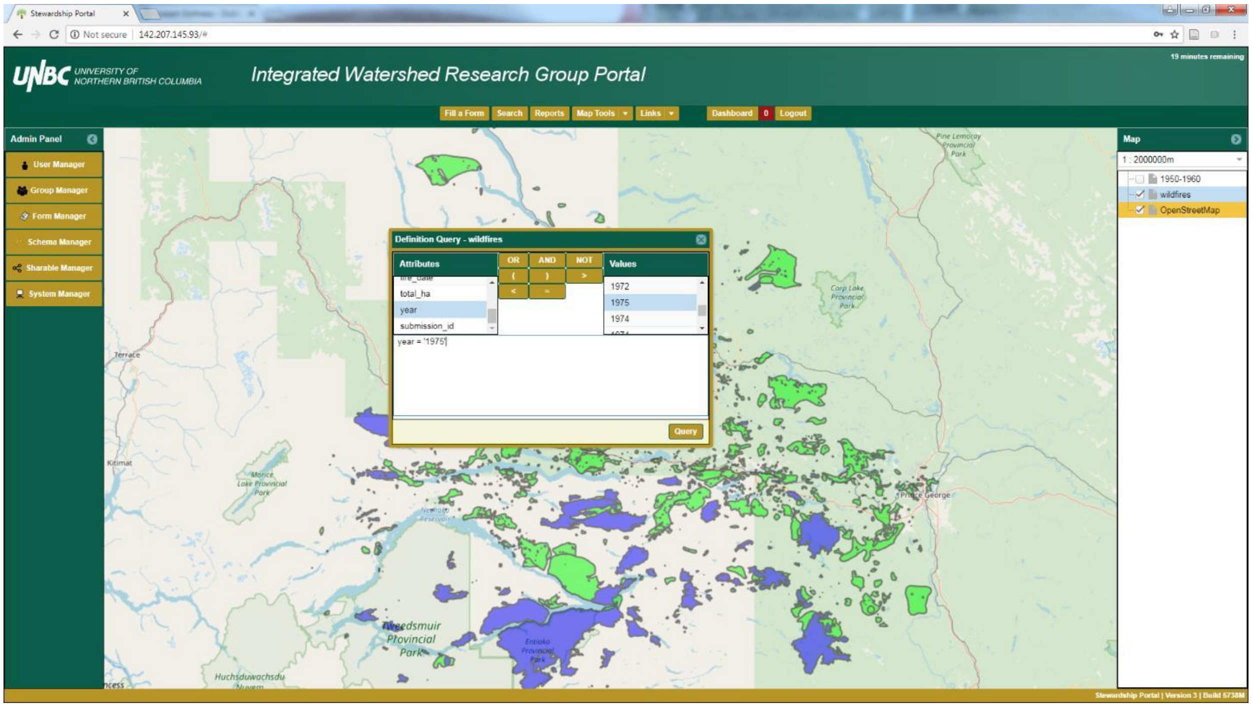
We can also click on the submission_id hyperlink and be sent directly to the submission for this data.





Query:

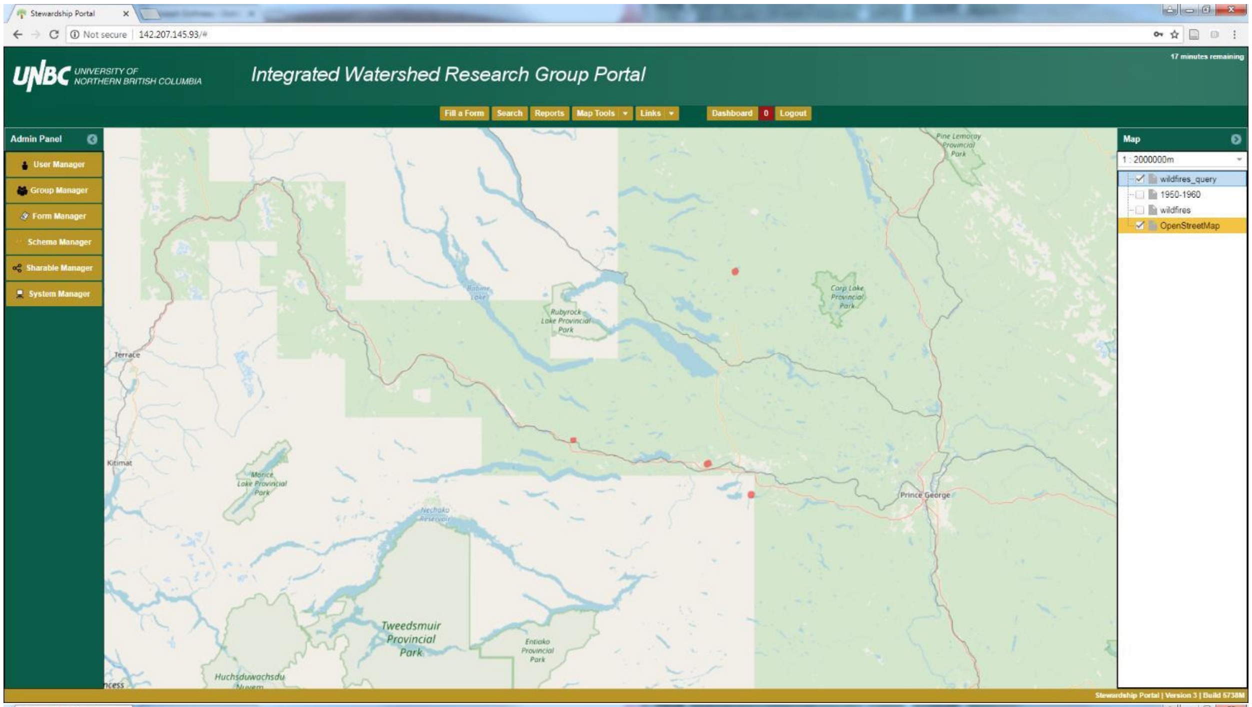
Next we are going to explore another right click function, Query. Let's perform a query on the wildfires layer. In this example we've asked for all wildfires that occurred in 1975 (year = 1975).

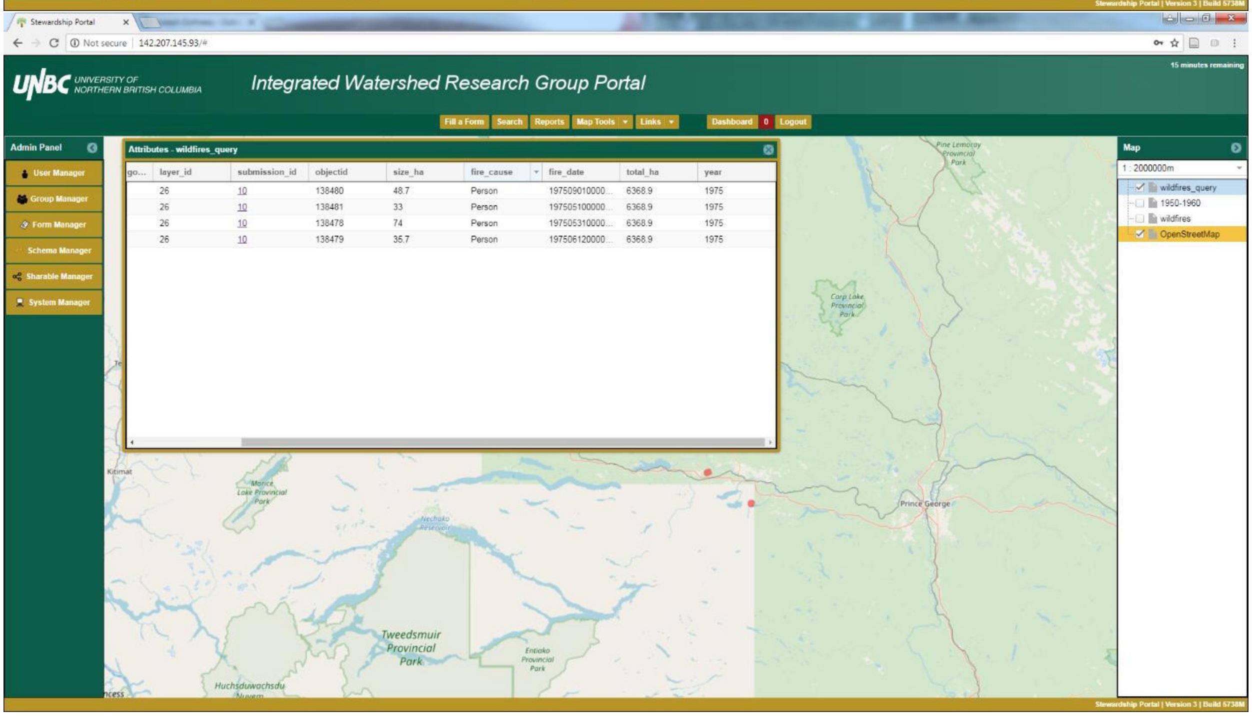


Hit the Query button and a new layer appears named wildfires_query. Close the query window and turn off wildfires. We are left with:

It needs to be noted that I've actually increased the stroke size on this example so it is more visible, if you picked this year the fires will be much smaller and difficult to see.

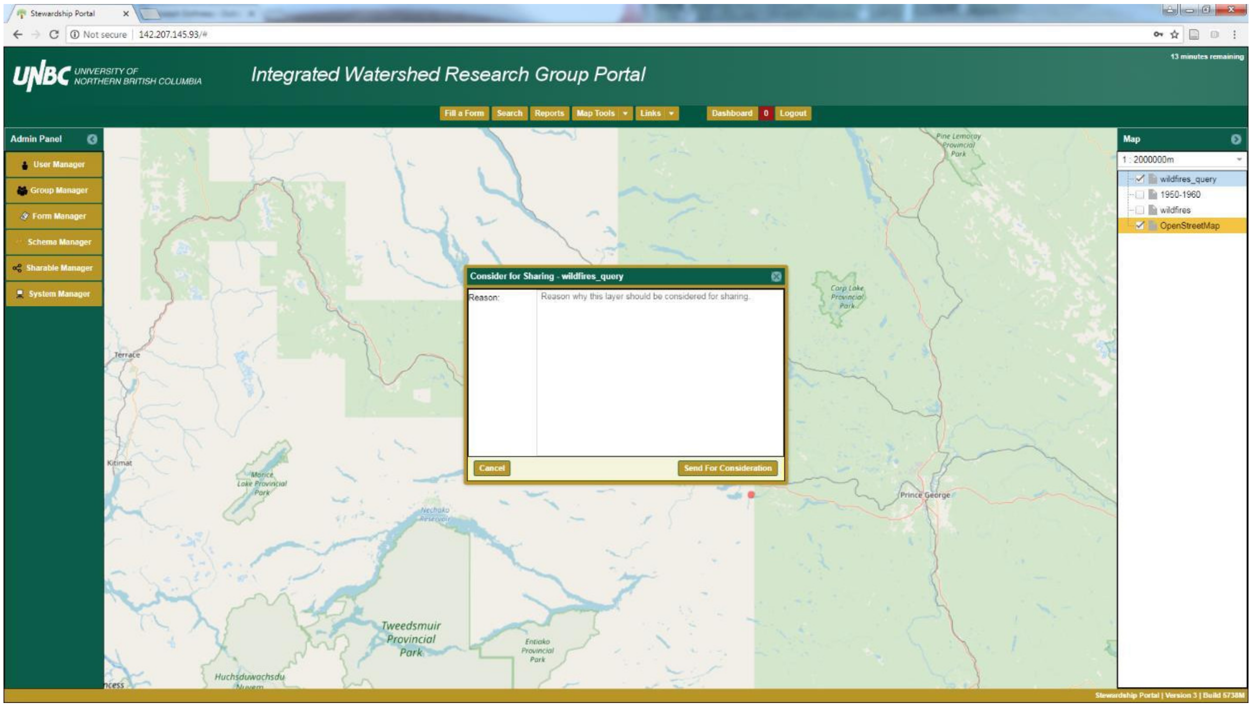
We can verify in the attribute table that we are left with only fires from 1975.





Share Layer:

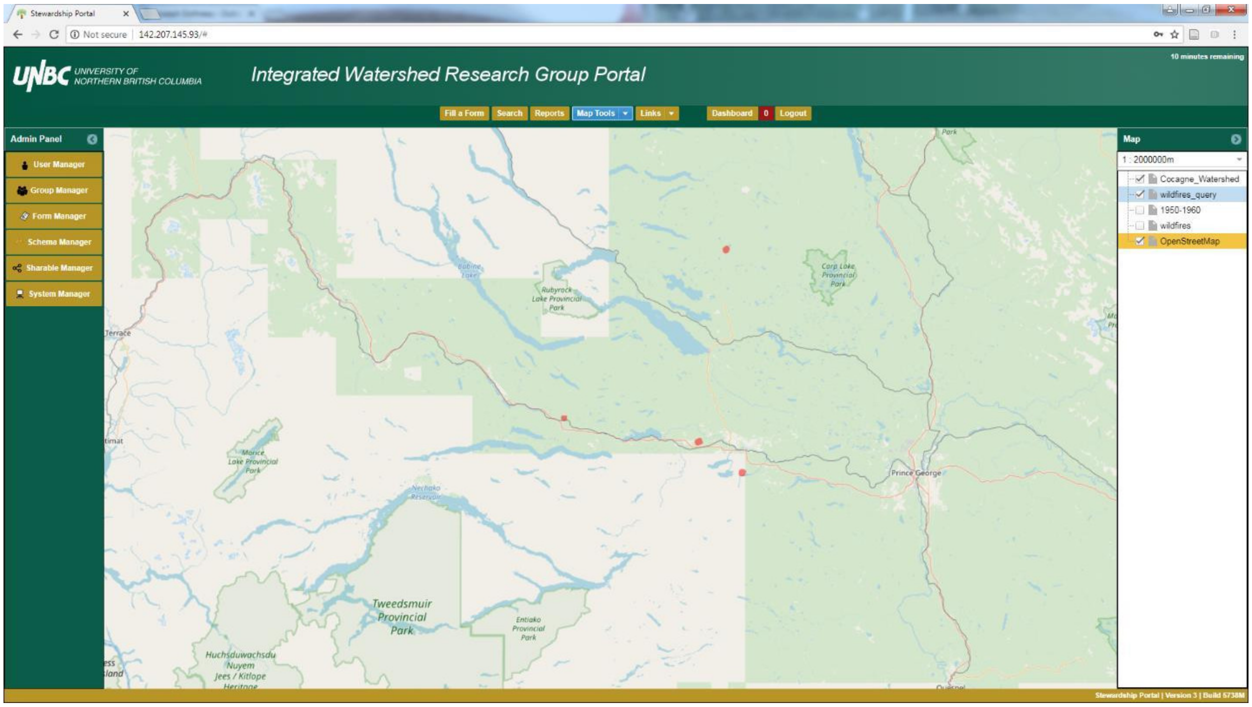
Another right click option is Share Layer. Share Layer allows us to request that the administrator makes this layer sharable across the Portal, and will appear in the Linked Layers section when filling out a form.



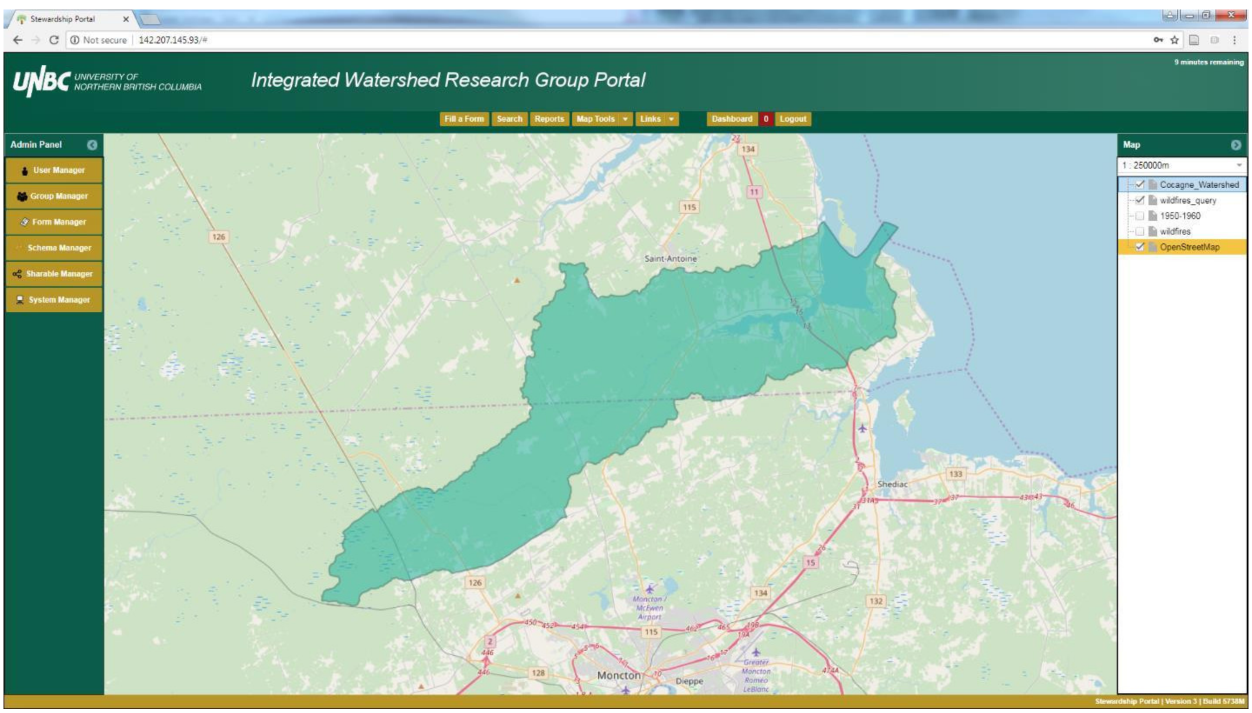
We simply type in a reason why this layer should be shared and hit the Send For Consideration button, the Portal Administrator takes care of the rest of the process.

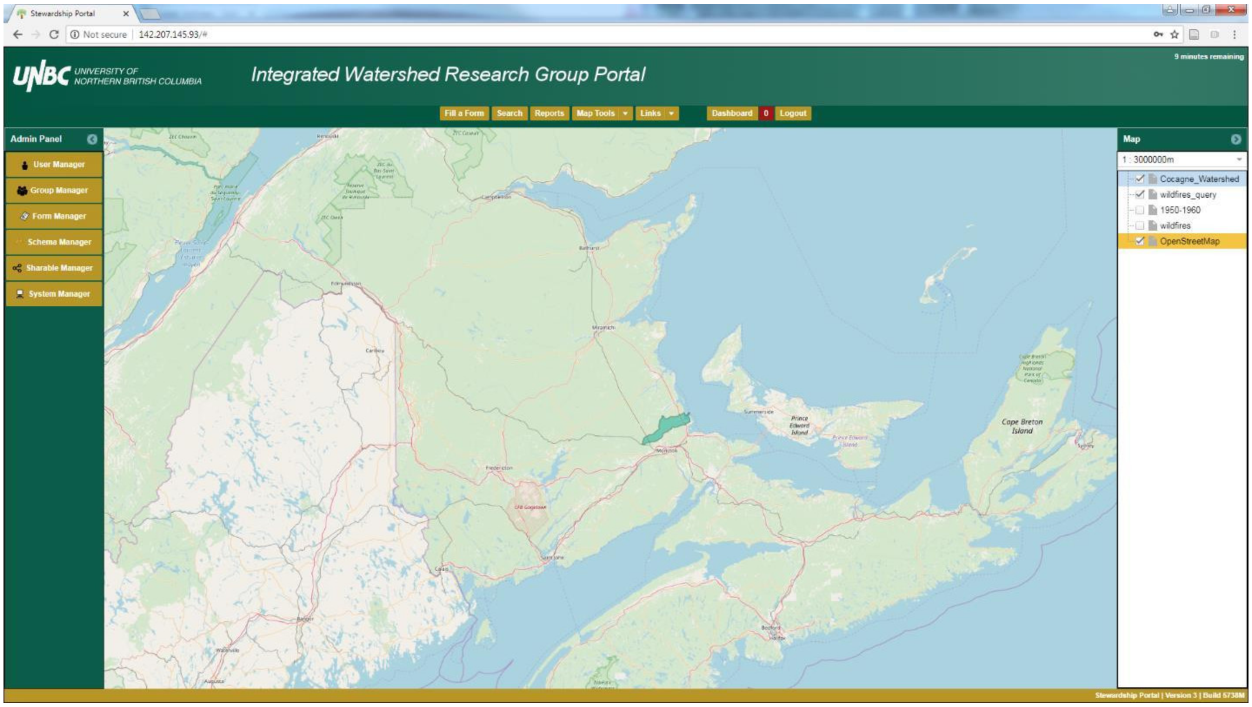
Zoom to Extent:

Being able to zoome to a layer can be very helpful, and we can do so using the Zoom to Extent feature. I’ve added a layer from New Brunswick named Cocagne_Watershed.



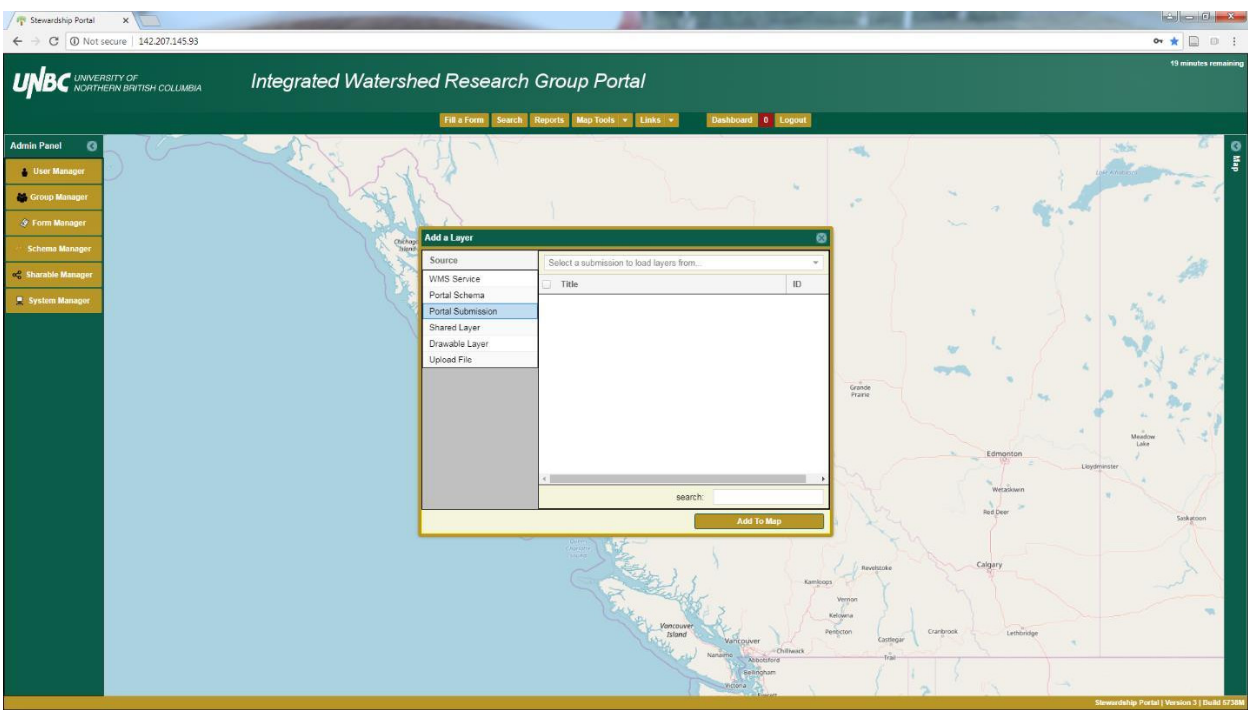
After zooming to the extent of Cocagne_Watershed our map is in New Brunswick.





Add a Layer by Portal Submission:

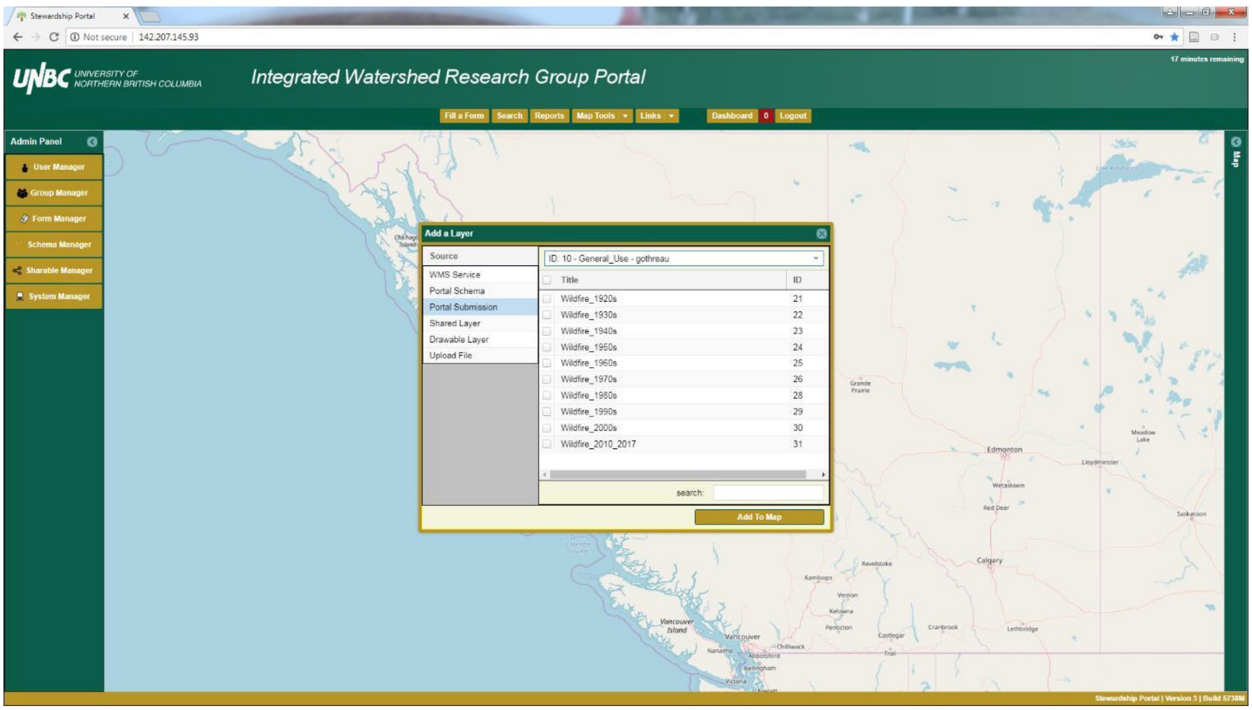
Going back to adding spatial layers to our map, we have already looked at adding WMS Service and Portal Schema, next we discuss adding by Portal Submission.

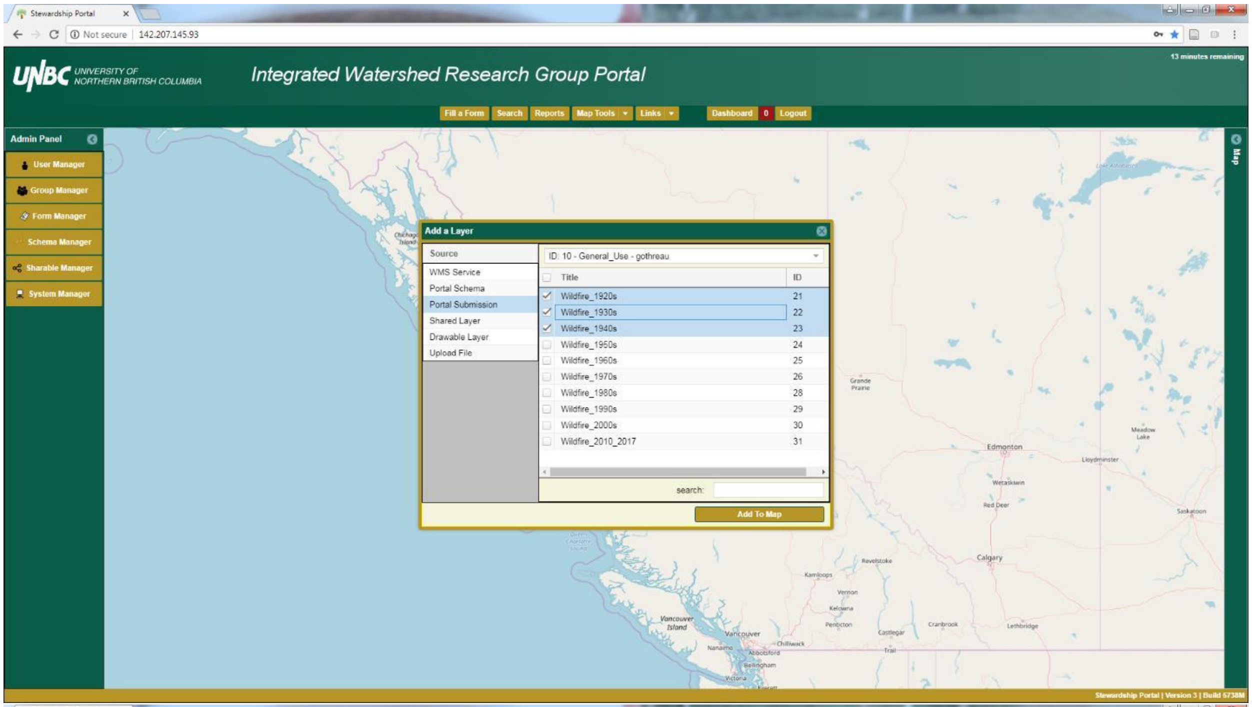


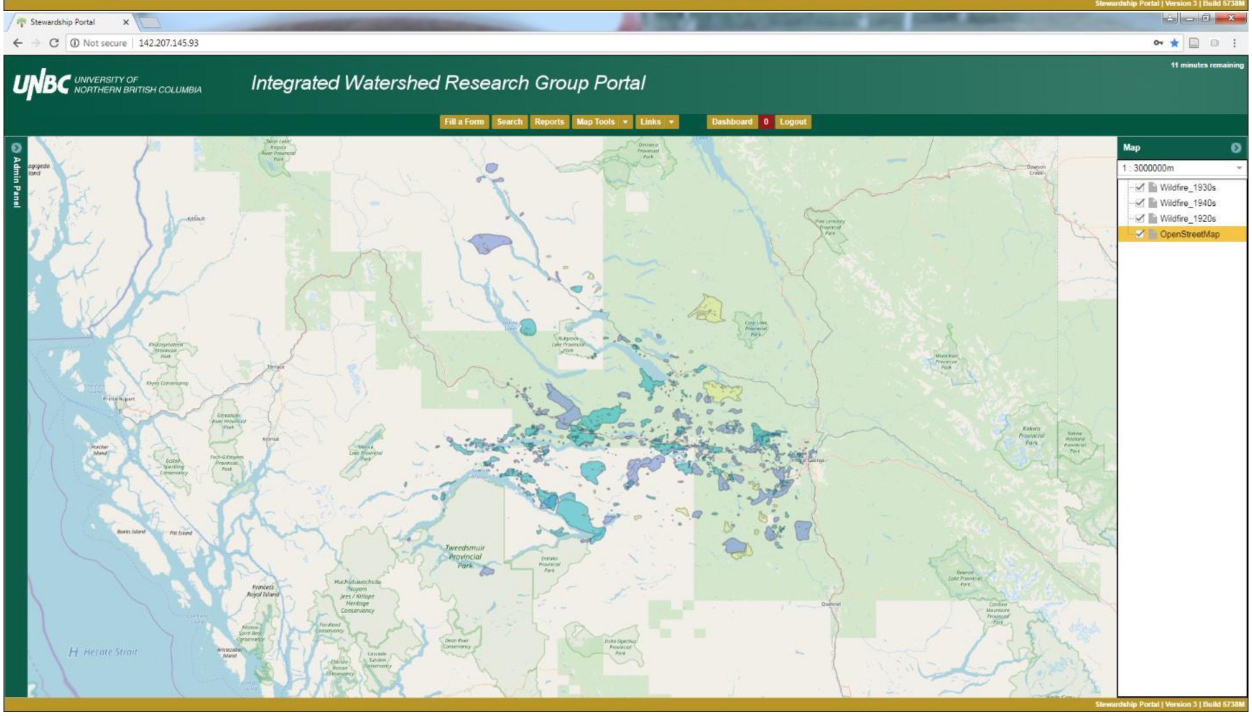
Using the drop down menu we have to select the submission that has the spatial data we wish to display on the map. This selection option only provides the title of the submission, which includes the submission ID, form name, and submitter but not the human readable name. This requires either an intimate knowledge of the submission ID's or a little bit of trial and error to find the right submission. As an alternative you could also perform a key word search and find the submission, note the ID number and then use this method to display it on the map.

After finding the submission of interest the spatial layers attached will appear in a list.

Now we just need to select the desired layers and add them to the map.

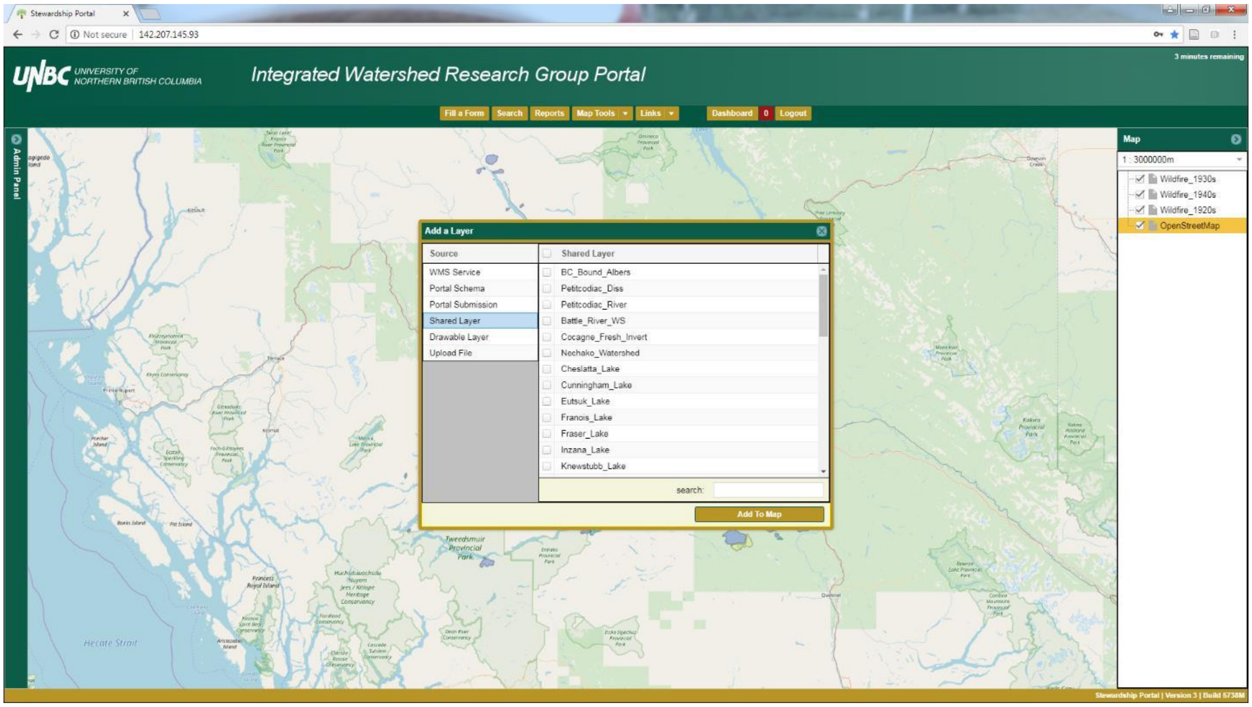






Shared Layer:

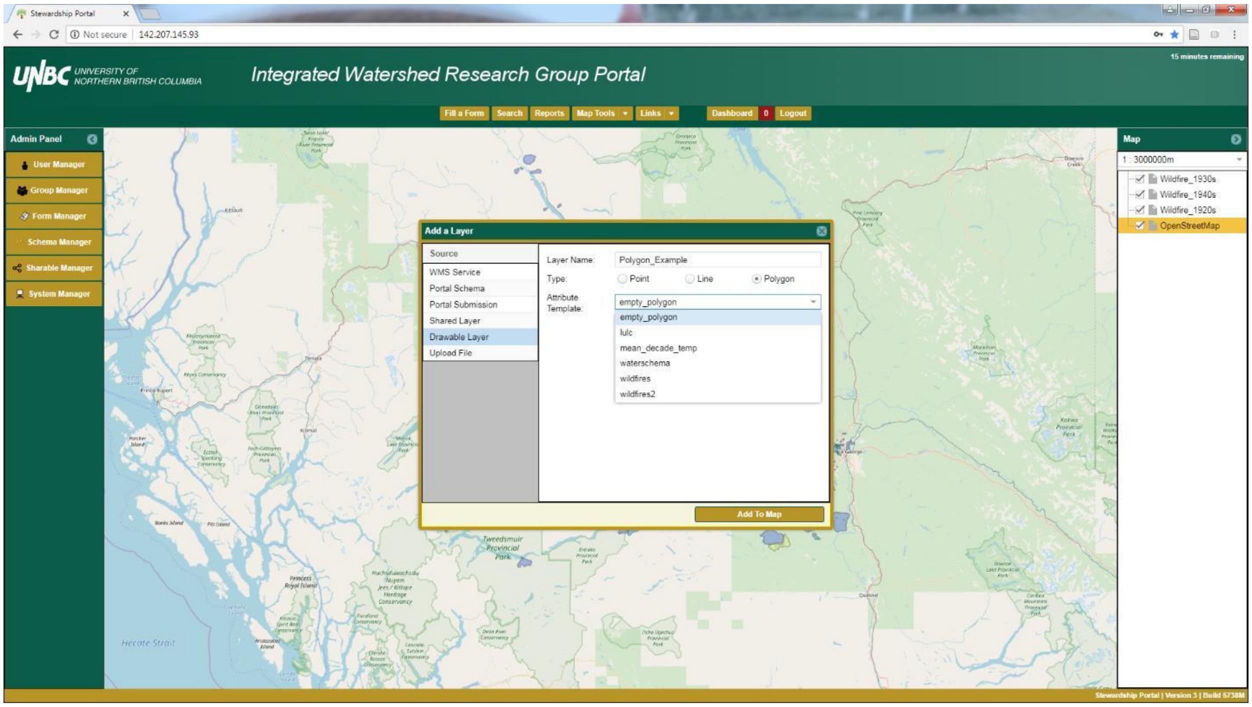
We are also able to make use of Shared Layers, which are spatial layers that have been shared by other Portal users. These are available for anyone to use, and if some of these are basic geographical features they can make it easier for individuals who don't have a spatial database or GIS experience to draw on.



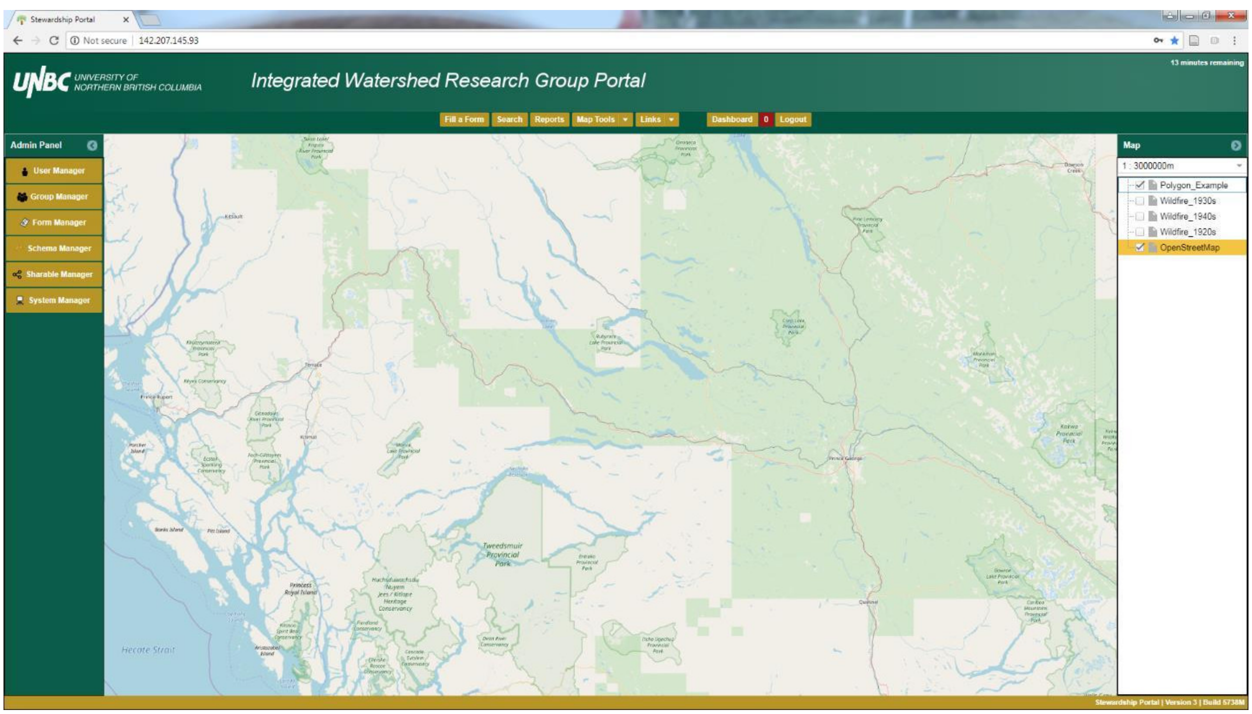
Drawable Layer:

Drawable Layers are used to create/draw new layers directly on the map within the Portal. This functionality will be covered later in this document, but for now we will cover how to create the blank layer required to draw on the map.

To create the layer give it a name, select the feature type (point, line, or polygon), and select an attribute template. Attribute templates are another term for schema, so if we intended on giving this attributes later it will be important to select an appropriate schema (attribute template). For this example we'll use an empty polygon schema.



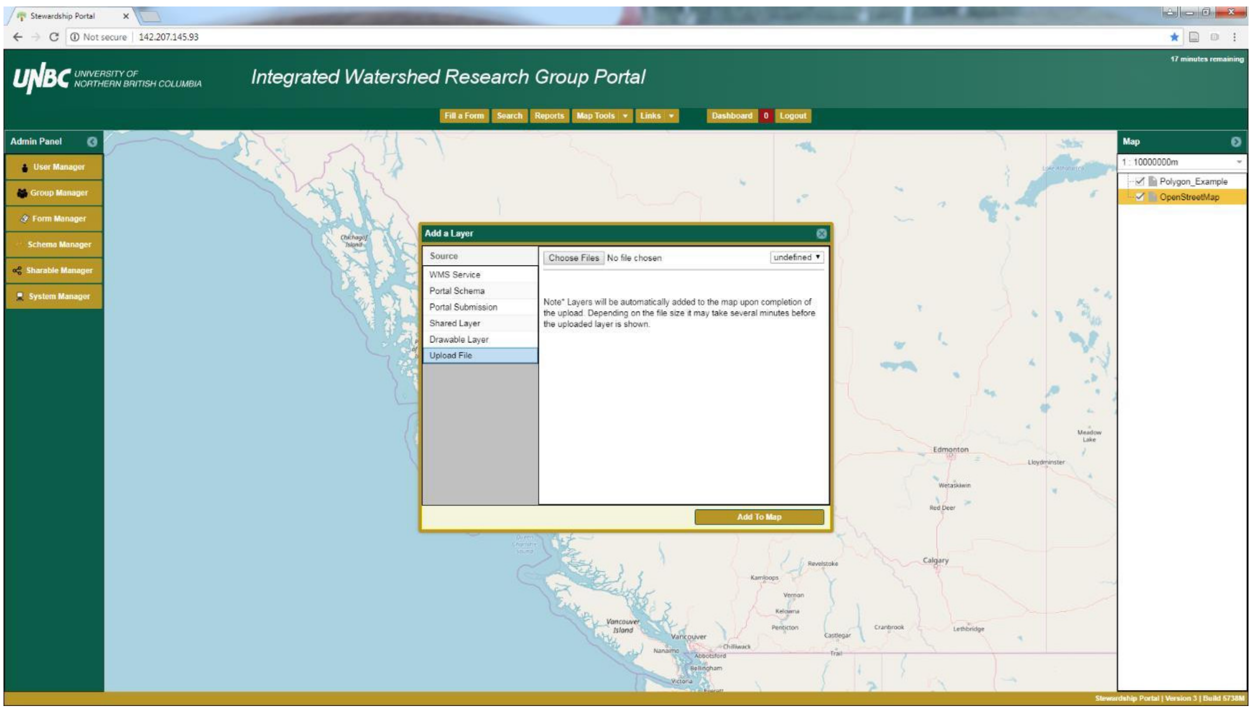
Now we add this to our map. Since this is a blank layer that we will later draw on the map, it currently won't show anywhere but in the Map Contents tab.



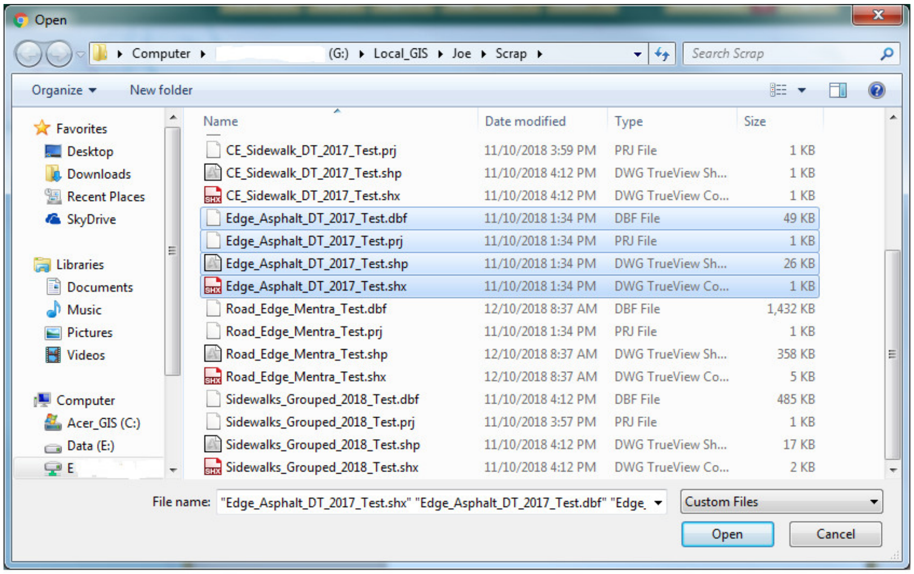
Upload File: Finally our last option for adding layers to our map, uploading a file from a hard drive. *note at the time of writing this the spatial data formats were glitched and only reading undefined* *note: also cannot download layers from the map due to the same circumstances, there is no format you can pick*

We will discuss how to upload shapefiles from a computer into the map. Shapefiles have been chosen because they are the most complicated spatial file to upload, while other formats such as KML, KMZ, etc. require only one file.

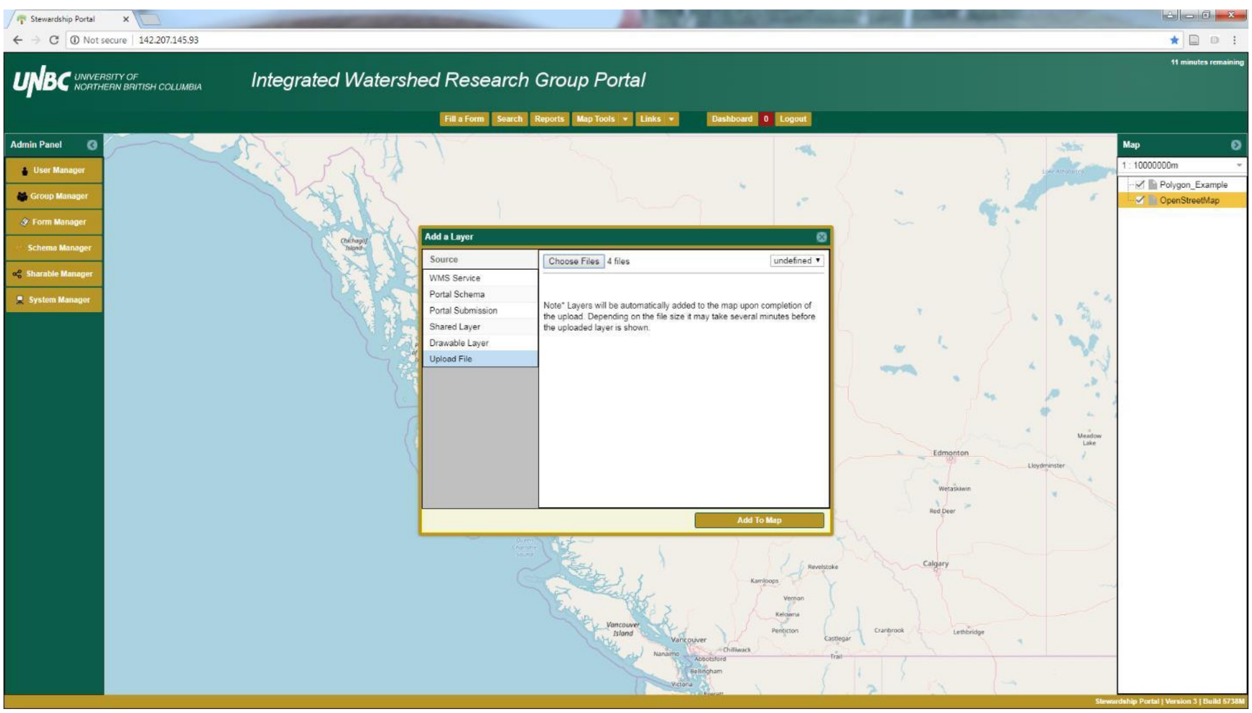
To upload a shape file we click on the Choose Files button in the Upload File window.



Navigate to the spatial file of interest, and select the necessary files. Since we are uploading a shapefile here we need to select the .dbf, .prj, .shp, and .shx files.



Now that all four files have been selected and 'opened' we are ready to add them to the map.



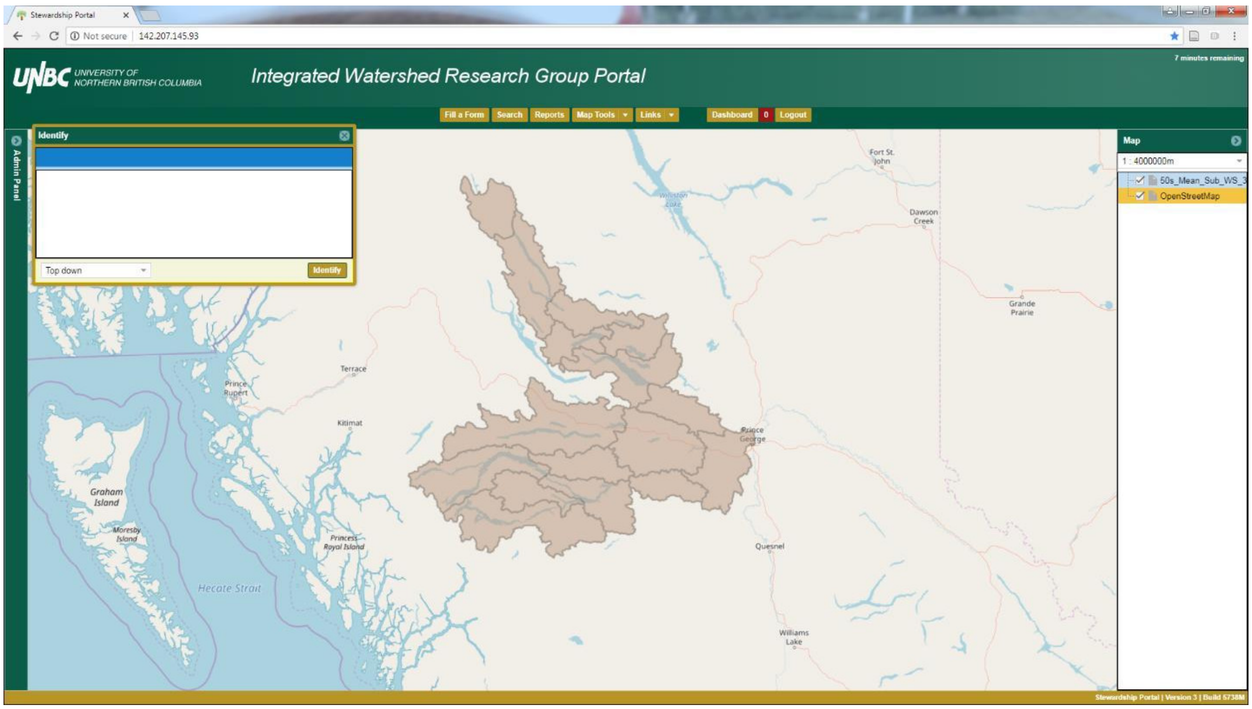
Identify:

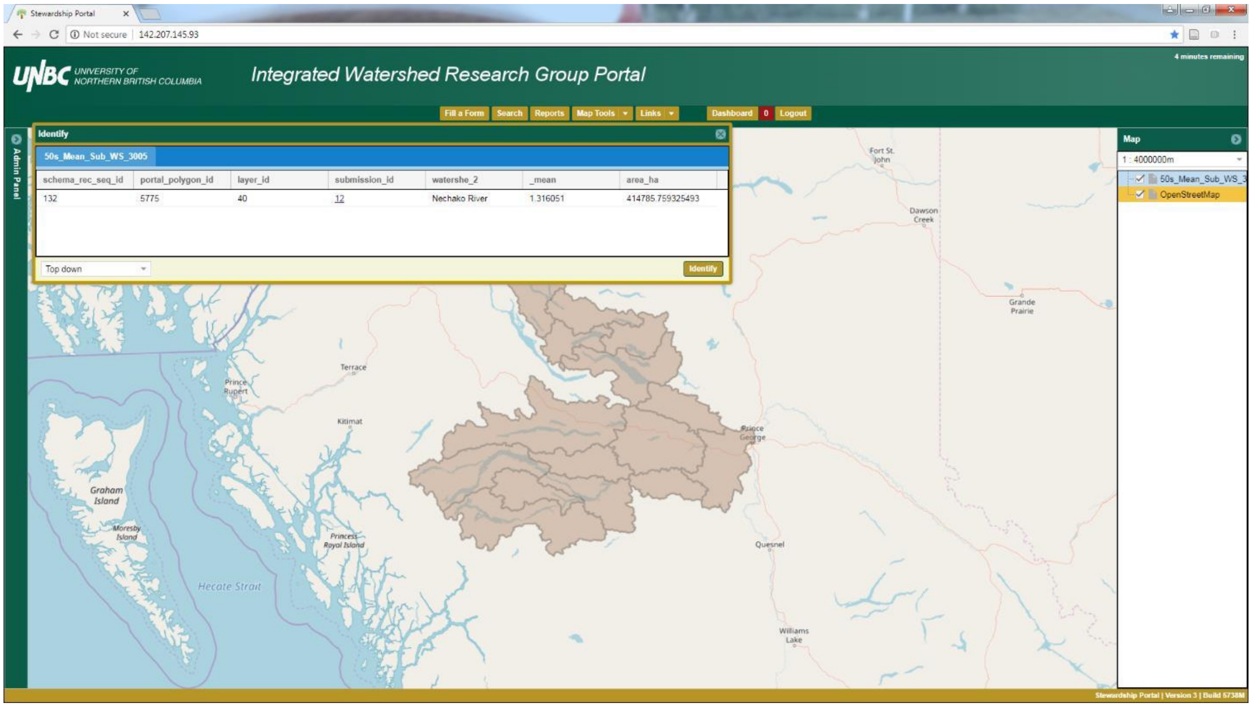
Using the identify tool we are able to investigate the attributes of spatial layers. We looked at how to view the complete record of attributes using the attribute table earlier, this tool allows us to view the attributes of a single point, line, or polygon within a spatial layer.

After opening the Identify window, we will move it out of the way.

Now by clicking on the Identify button, and clicking on a part of the spatial file we will obtain the attributes for that individual polygon.

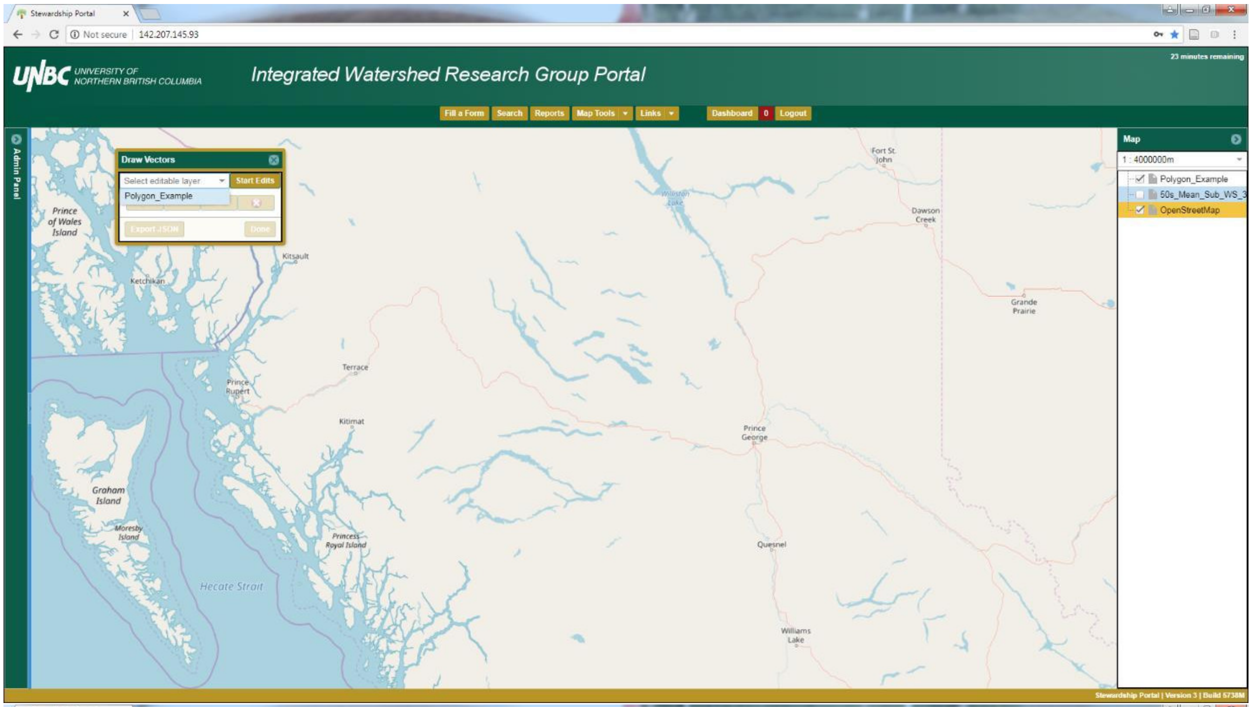
Please note that you cannot successfully identify a WMS layer, as they do not provide any attribute data.

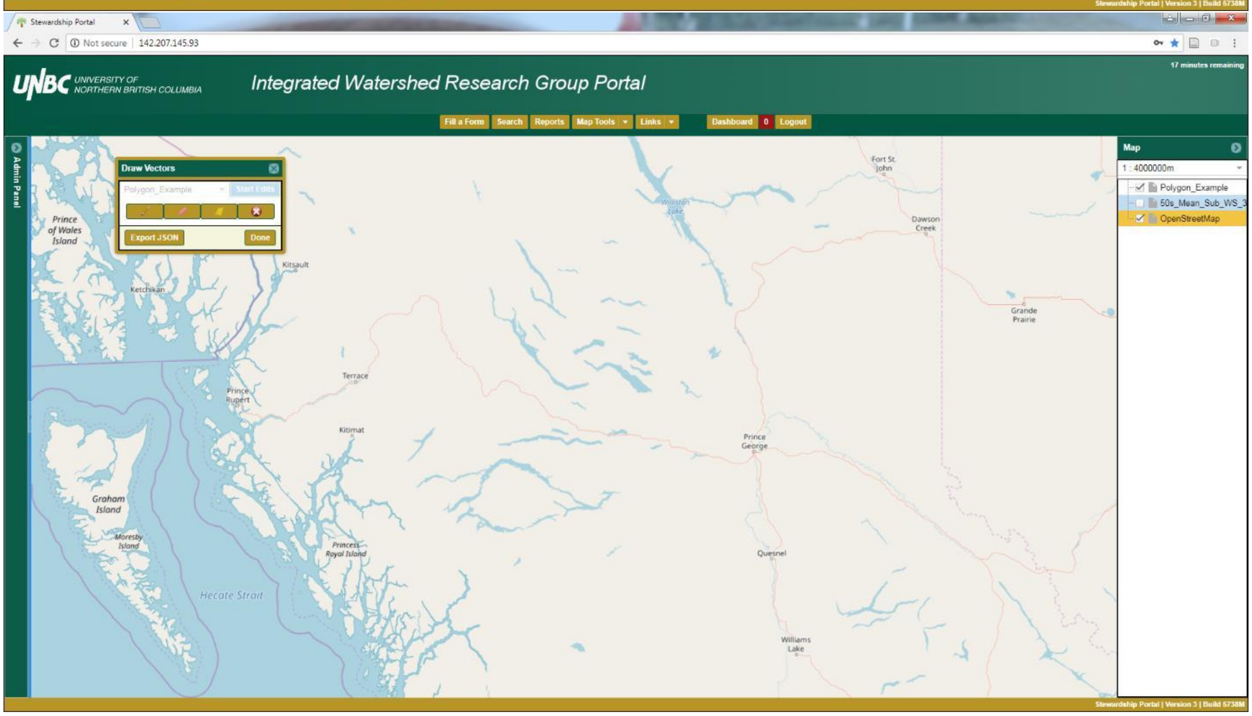




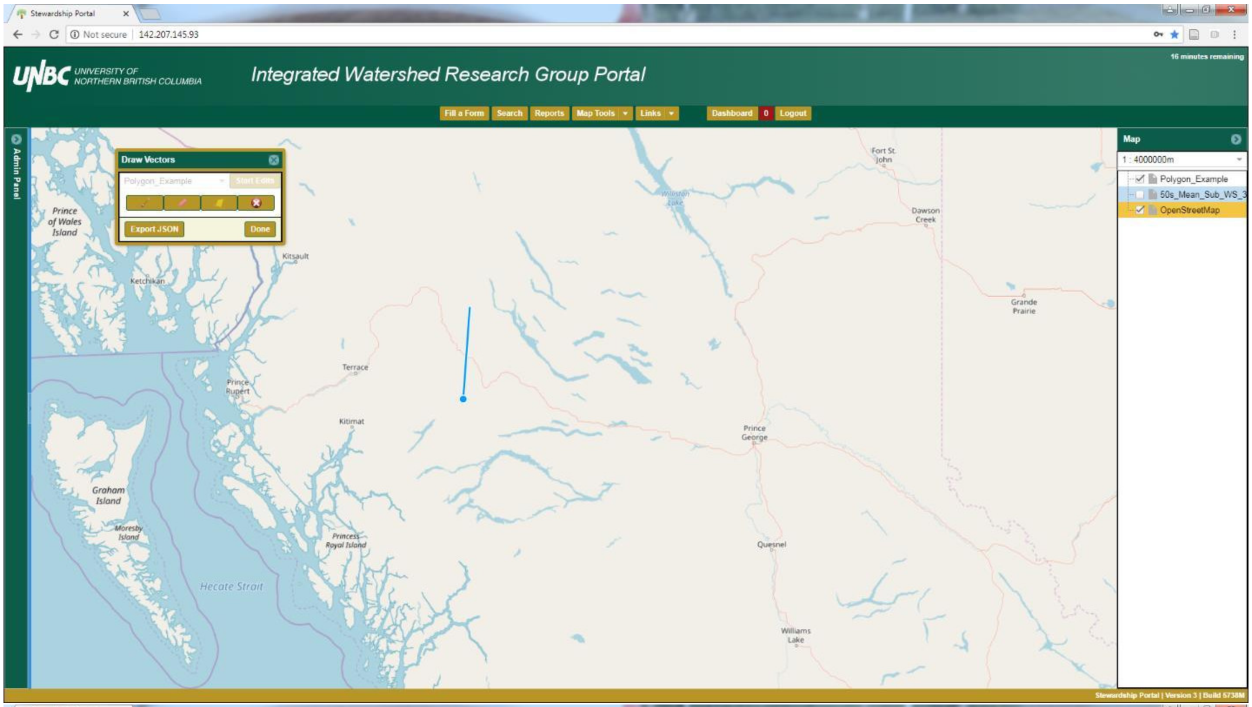
Draw Vectors:

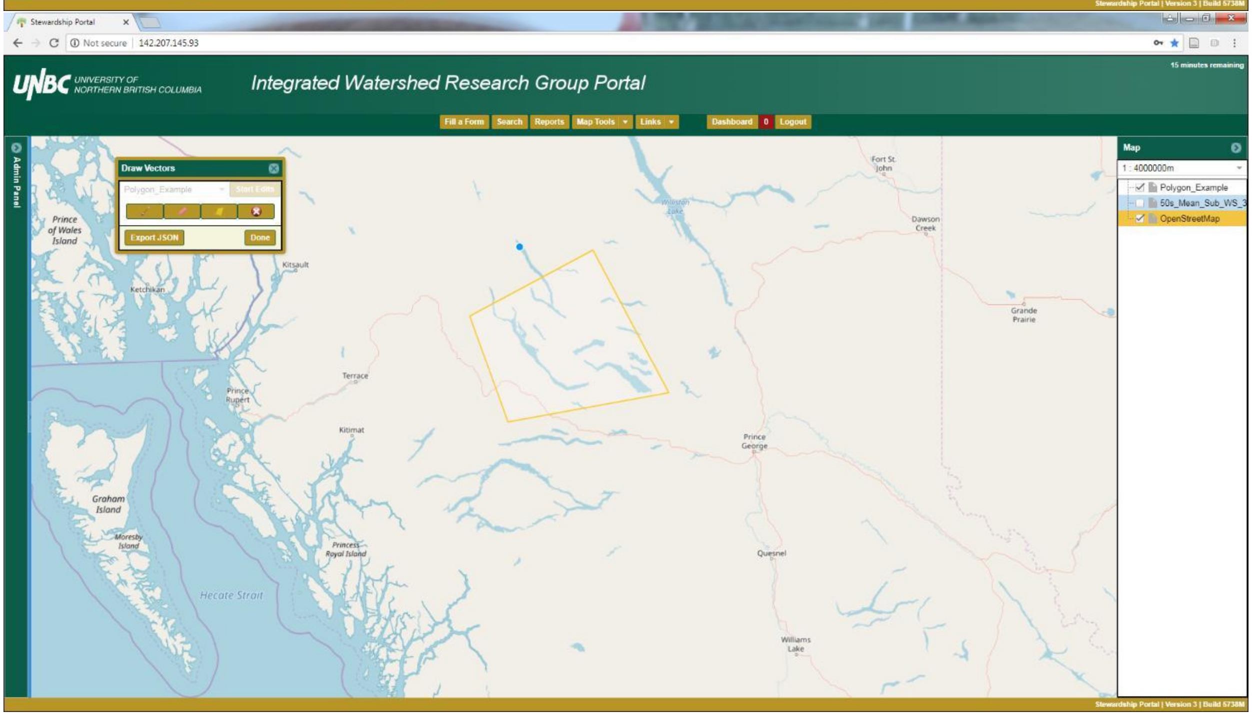
Earlier we looked at how to create a drawable layer, now we will use that empty layer to draw on the map. After selecting the empty layer from the drop down menu we hit the Start Edits button, which allows us to pick from four options: draw new features (pencil icon), erase (eraser icon), reposition misplaced points (four points in a rectangle), and erase all features (white x in red circle).





We will select the draw new features tool, which allows us to start creating our polygon. By clicking the blue dot we create lines, and eventually we connect them to make a polygon feature.

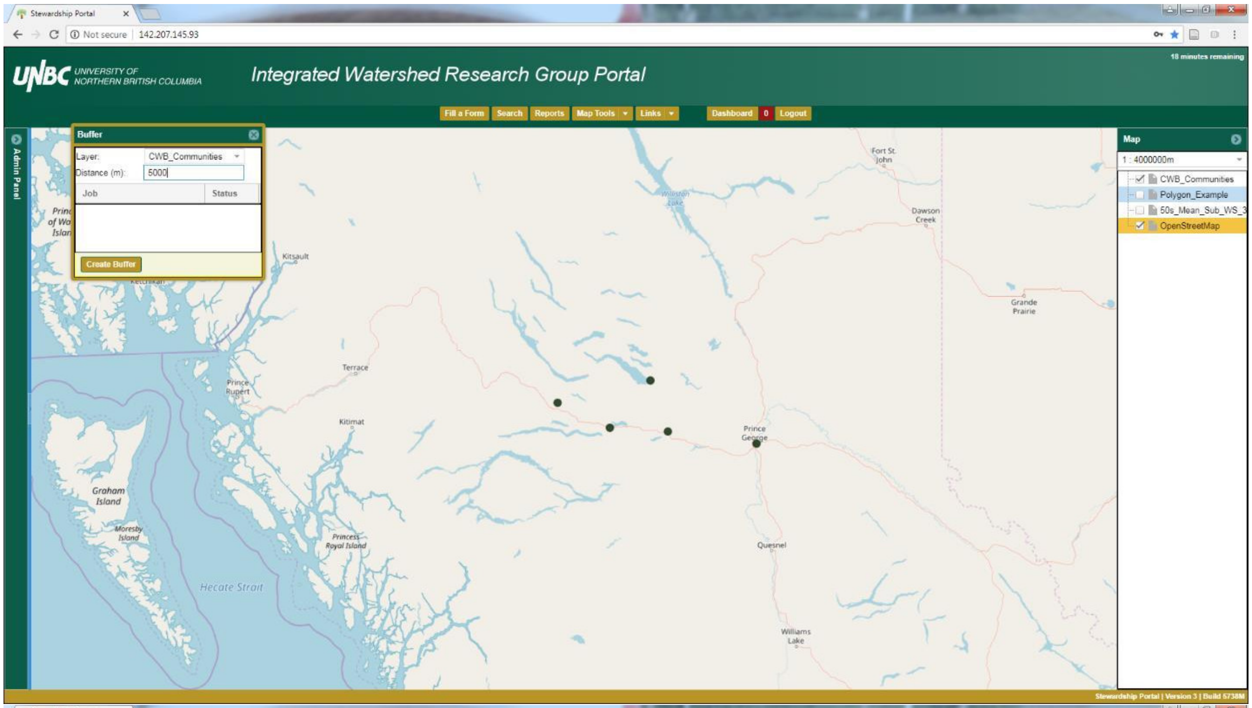


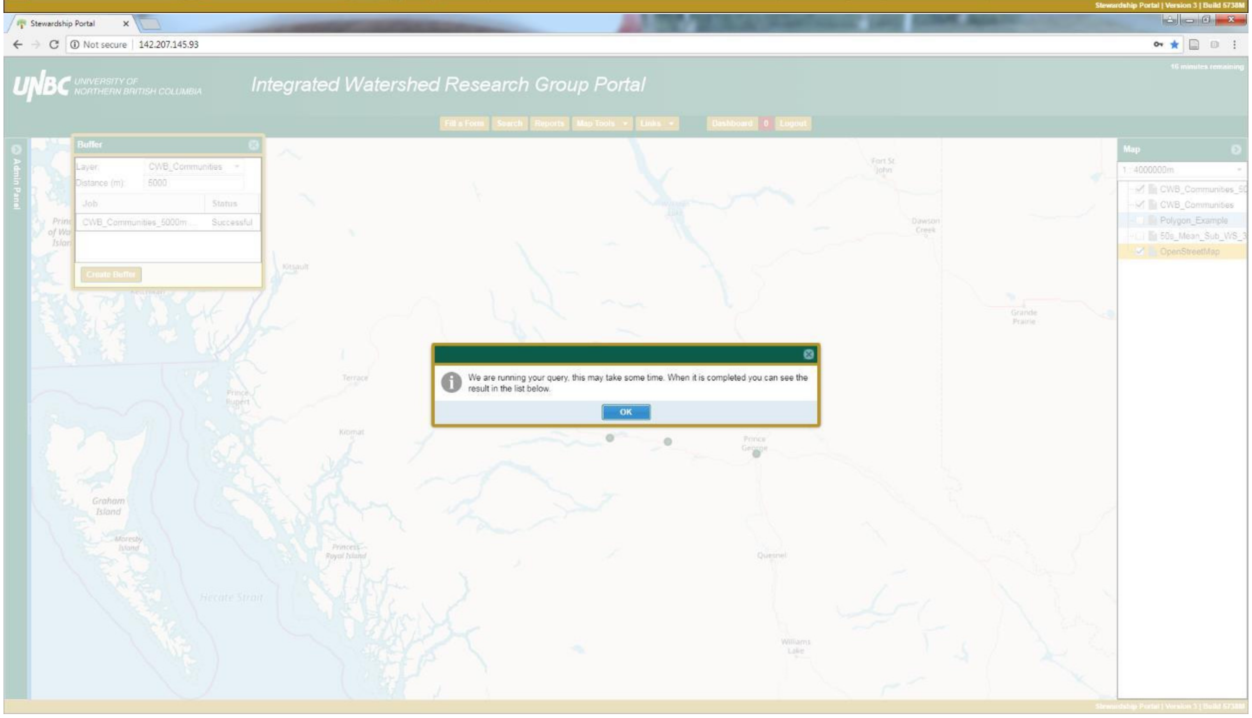


By clicking the done button we have a temporary polygon feature on the map. It is possible to create complicated features using this tool, but it can also be used to create simple features.

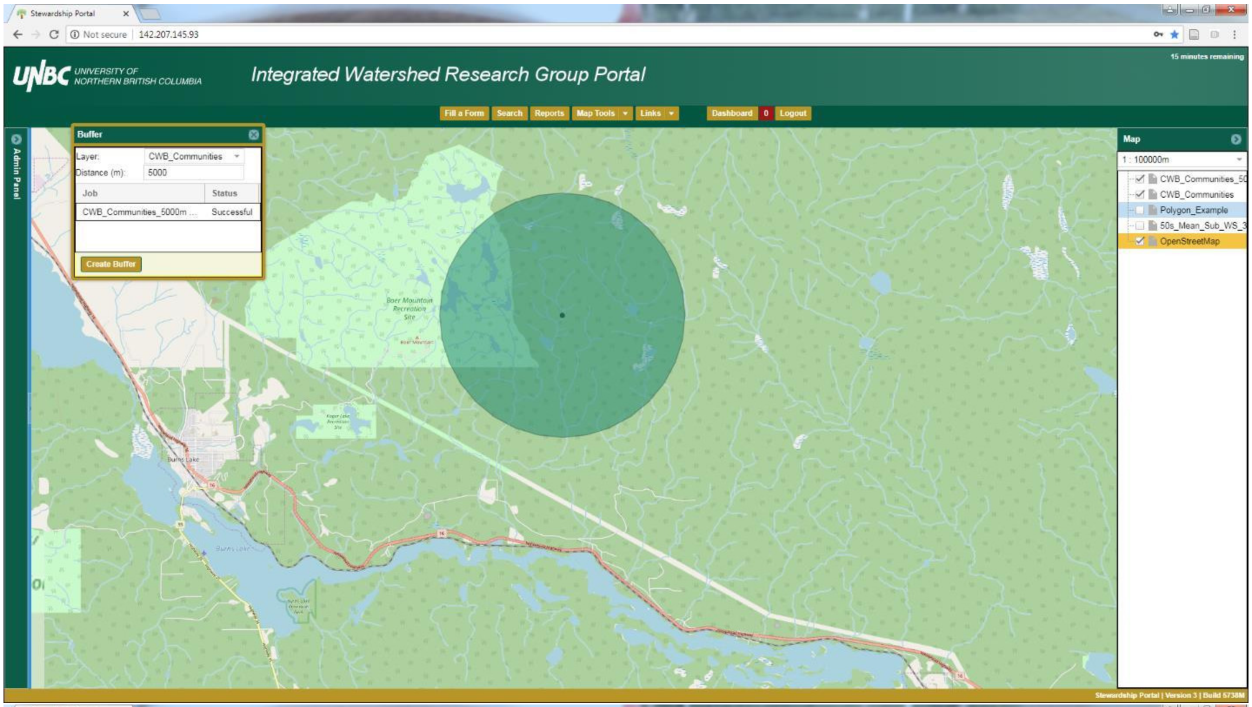
Buffer:

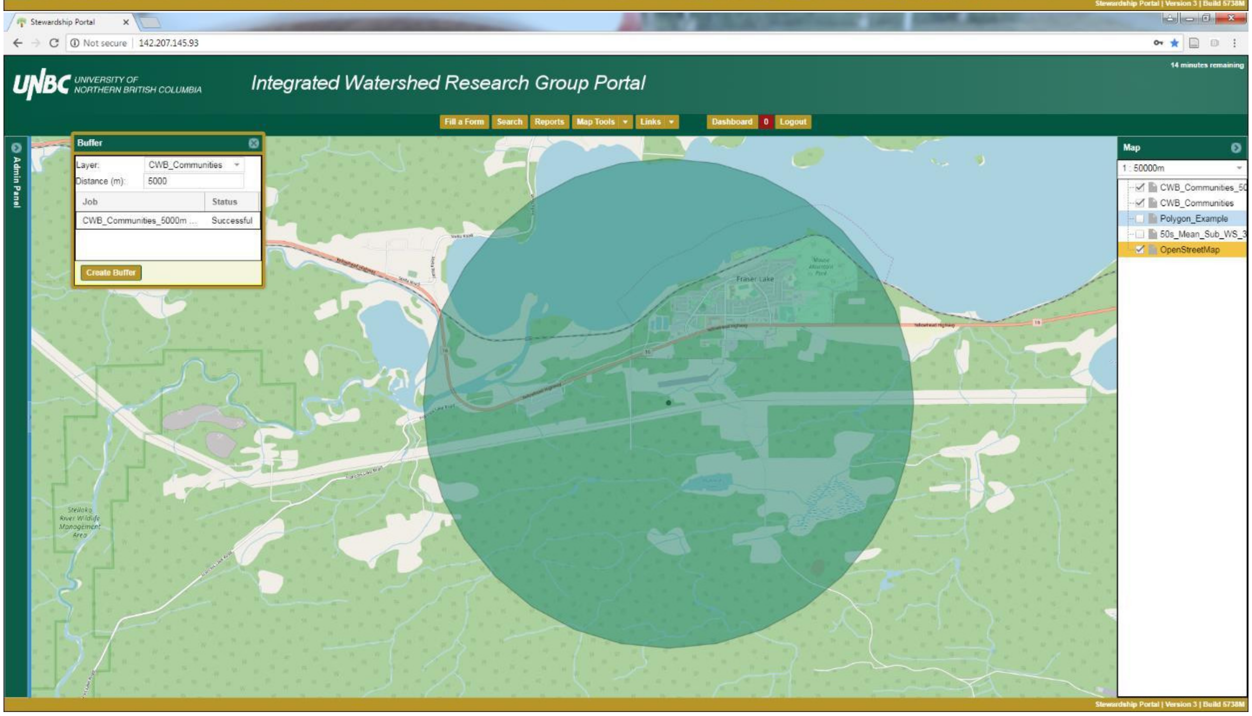
We can use the buffer tool to create buffers around points, lines, and polygons all within the Portal. All we do is pick the layer we want to buffer (it has to be one that has been submitted with a form into the Portal), put in the distance of the buffer we want, and click the create buffer button.





Now we can see the result of our buffer.

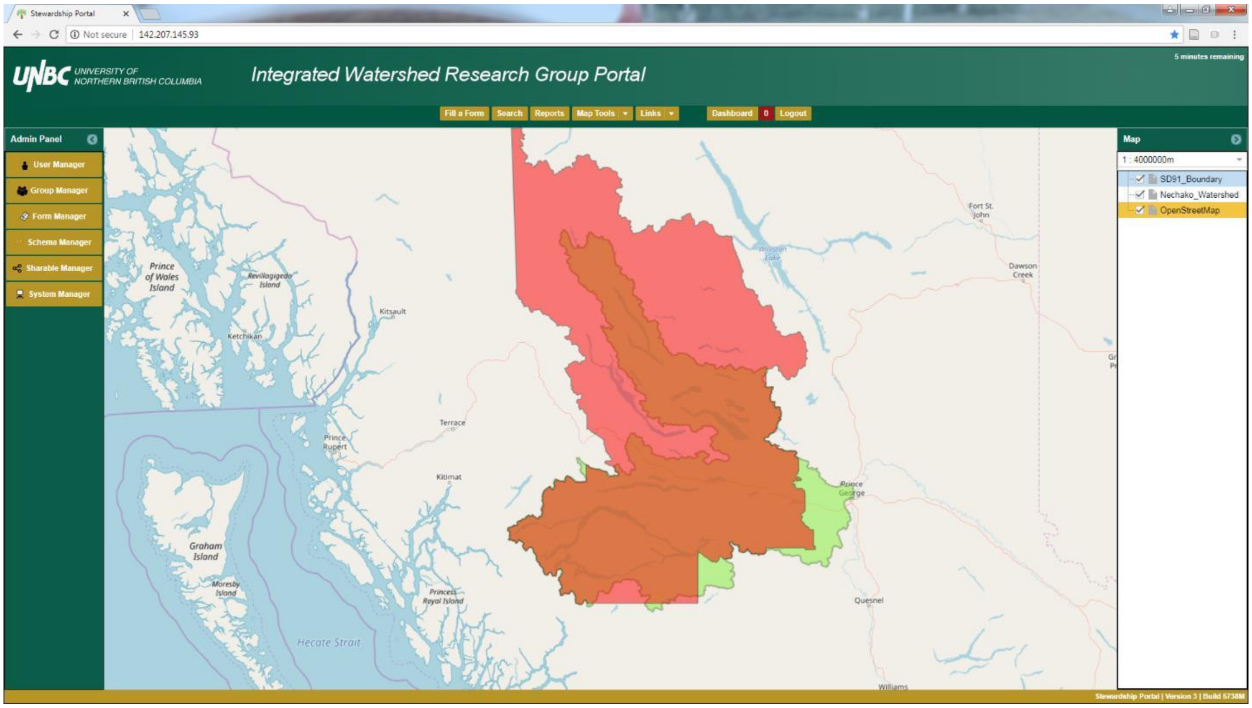




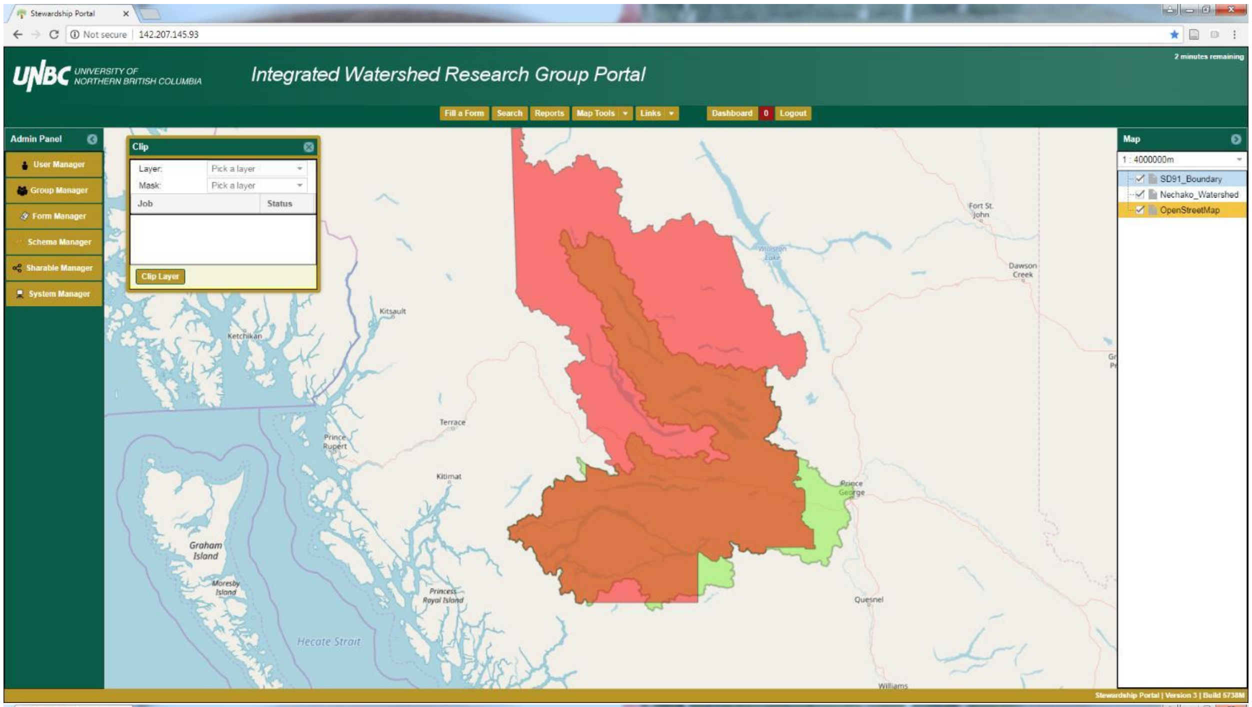
The buffer tool can be used on points, as we have done in this example, but also on lines and polygons.

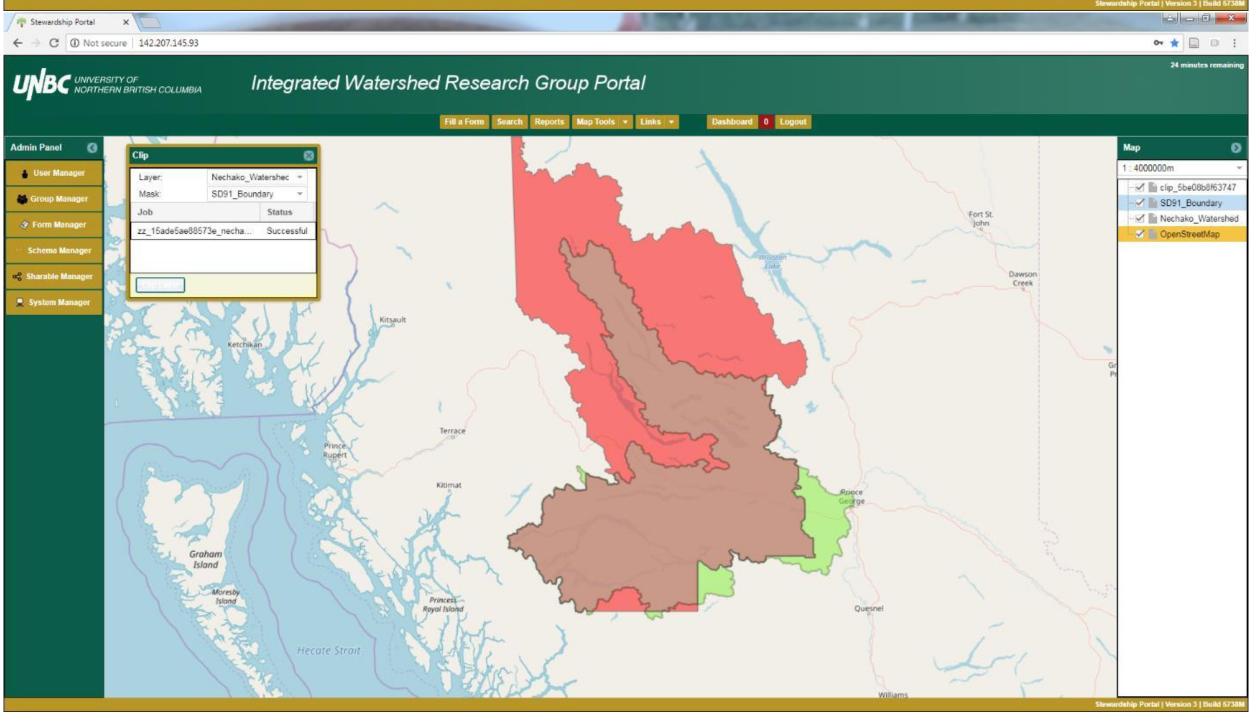
Clip: The clip tool takes two spatial layers and uses one layer to cut an area out of the other layer. We'll use an example to flush this concept out.

In this image we have the School District 91 boundary in the red colour, and the Nechako watershed in green. The areas that overlap are all that we would be left with if we clipped the Nechako watershed using the School District boundary.



In the clip tool we have a Layer and a Mask, in this example we are going to use the Nechako watershed as the layer, and the School District boundary will be the mask. The layer is the feature that we want to retain, after being cut down by the other layer. The mask is the layer being used to cut the layers extent.





After performing the clipping action, we are left only with the area of the Nechako watershed that fell within the School Districts boundary.